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Overlap statistics of shallow boundary layer clouds: comparing ground-based observations with large-eddy simulations

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As large-scale models for weather and climate have coarse spatial resolutions, they cannot resolve clouds within a vertical grid column and thus rely on parameterizations, leading to uncertainty in the representation of clouds and the way they overlap in the vertical. The uncertainty in the cloud overlap parameterizations remains a significant source of error in the Earth's radiation budget in general circulation models (GCMs).

Most studies concerning cloud overlap mainly focused on either large ensemble of cloud types or deep convective cloud fields. Cumuliform boundary layer cloud fields have been less researched despite the fact that their irregularity in shape and in spatial distribution at subgrid scales can impact the cloud overlap significantly.

In this study, high-resolution ground-based measurements are used to assess the realism of fine-scale numerical simulations of shallow cumulus cloud fields. The overlap statistics of cumuli as produced by i) local large-eddy simulations (LES) as well as ii) the big-domain ICON at cloud resolving resolutions are confronted with CloudNet datasets at the Jülich ObservatorY for Cloud Evolution (JOYCE). Cloud fraction masks are derived for five different cases during the April-August 2013 period, using gridded time-height datasets at various temporal and vertical resolutions.

The overlap ratio (R), i.e. the ratio between cloud fraction by volume and by area, is studied as a function of the vertical resolution. Good agreement is found between R derived from observations and simulations. Simulated and observed decorrelation lengths are smaller (< 300 m) than previously reported (> 1 km). A similar diurnal variation in the overlap efficiency is found in observations and simulations.

The inefficient overlap we found at sub-grid vertical scales has the potential of significantly affecting the vertical transfer of radiation, yet few GCMs take such overlap at small, unresolved scales into account. A better understanding of the unresolved cloud overlap now opens the door for parameterizations where cloud overlap is better grounded in physics.