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The effects of meteorological conditions, aerosol concentrations and microphysics on shallow marine clouds

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Typical marine boundary layer clouds are dependent on sensible and latent heat fluxes, turbulent updrafts and radiative cooling from the cloud top. In addition, clouds are dependent on aerosol that can act as a cloud condensation nuclei (CCN). Large eddy simulation (LES) models that are coupled with a radiative transfer solver and a cloud microphysics package are excellent tools for examining such clouds. Here we compare predictions from a LES model that is coupled with two very different cloud microphysics packages. The LES model is UCLALES (e.g., Stevens et al., Mon. Wea. Rev., 133, 1443-1462, 2005), which has a built-in bulk microphysics package where cloud droplet number concentration is constant and cloud water is diagnosed from total water. The same LES core was coupled with a highly detailed bin microphysics package and this setup is called UCLALES-SALSA (Tonttila et al., Geosci. Model Dev., 10, 169-188, 2017). In this setup water vapor condensation and cloud activation are modelled using several aerosol and cloud droplet size bins. Both bulk and bin schemes also include precipitation and ice microphysics, but here the focus is on non-precipitating liquid clouds.

The model intercomparison is based on 130 cases with different initial atmospheric temperature and humidity profiles and CCN concentrations, which were sampled from ECHAM6 simulations. Both bulk and bin microphysics LES models were run for 3.5 hours and statistics were sampled from the last simulation hour. These simulations show that the final cloud state depends mostly on meteorological conditions. However, there is a range of meteorological conditions, which represent the intermediate region between steady and unsteady cloud conditions, where CCN concentration and microphysics scheme become important for the cloud development. Examination of different cloud stability parameters showed that these regions and the final cloud state can be predicted based on the initial inversion strength (e.g., Lock, Q. J. R. Meteorol. Soc., 135, 941-952, 2009). Even if the effects of CCN concentration and microphysics are relatively small in these simulations, their effects become larger with longer simulation time and with increasing complexity such as when accounting for precipitation and ice microphysics.