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Large eddy simulation of the influence of CCN and thermodynamic conditions on marine stratocumulus cloud development

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The marine stratocumulus topped boundary layer, which prevails in the subtropical oceanic regions where the subsidence inversion associated with the descending branch of the Hadley-Walker cell dominates, is thought to be an important component of the climate system. High albedo (30-40%) of stratocumulus clouds compared to the ocean background (10%) gives rise to large deficits in the absorbed solar radiation flux. Since cloud radiative properties are highly dependent on cloud microphysical properties, which are in turn dependent on the cloud condensation nuclei (CCN) distribution, understanding the influence of anthropogenic CCN on cloud microphysics and dynamics is a key to accurately assess the climatic impact of marine stratocumulus clouds. A large eddy simulation (LES) model is good for studying stratocumulus clouds in the boundary layer because it explicitly resolves turbulent scale eddies and can provide information on detailed microphysical structure that is difficult to be measured over the ocean. We employ the CIMMS (Cooperative Institute for Mesoscale Meteorological Studies, University of Oklahoma) 3D LES model with explicit bin microphysics. We examine the microphysical and dynamical evolution of stratocumulus clouds under different CCN loadings for four different thermodynamic conditions (the key differences are in moisture content and temperature inversion height). Contrasting results of daytime and nocturnal simulations are also examined. Three different measured CCN spectra that represent maritime, continental, and polluted air masses are used as input CCN spectra for the model; the concentrations at 1% supersaturation are 163, 1023, and 5292 cm-3, respectively. The grid spacing is 75 m in the horizontal and 25 m in the vertical, to make the total domain size of $3\times3\times1.25$ km. Total simulation time is 6 hrs. The large-scale subsidence is prescribed by w= –Dz, where the large-scale divergence D = $5\times$10-6 s-1 is assumed.

For the clouds formed under moist condition, the depths of the continental and polluted clouds are larger than that for the maritime cloud because heavy precipitation in the maritime cloud leads to the dissipation of the cloud, eventually reducing cloud depth. In the simulations with drier condition that showed no precipitation for all three air mass designation, the cloud depth is the largest for the maritime cloud; the cloud droplets near the cloud boundary evaporate more effectively in the continental and polluted clouds since they are smaller than those in the maritime cloud. Nevertheless, cloud reflectivity is larger in the continental and polluted clouds than in the maritime cloud. Much more detail will be discussed in the conference.