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aerosol effects on marine stratocumulus cloud development under different thermodynamic conditions - an LES model study

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The marine stratocumulus topped boundary layer (STBL), which prevails in the subtropical oceanic regions (30% of global ocean) 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. One of the major challenges in studying the STBL is how the marine stratocumulus clouds evolve with various environmental conditions, e.g., aerosol, radiation and thermodynamic conditions. We studied the overall evolution and diurnal contrasts of the marine stratocumulus clouds using the CIMMS (Cooperative Institute for Mesoscale Meteorological Studies) 3D LES model, which explicitly resolve clouds and turbulent eddies and therefore can show detailed evolution of the STBL. Examined are the microphysical and dynamical evolution of the STBL under three different initial CCN loadings (maritime, continental and polluted; the concentrations at 1% supersaturation were 163, 1023, and 5292 cm-3, respectively) for four different thermodynamic conditions (the key differences are in moist condition and inversion layer height). The model uses bin microphysics and 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 = 5×10-6 s-1 is assumed.

Results show that, regardless of inversion layer heights, under the moist condition, cloud depth is thicker in the polluted cloud, because heavy drizzling in the maritime cloud leads to the dissipation of the cloud. To the contrary, in the dry condition there is no drizzle and the cloud depth is shallower in the polluted cloud, because the cloud droplets are smaller and therefore being evaporated more effectively near the cloud base. However, cloud optical depth and albedo are higher in the polluted cloud regardless of moisture condition, mainly due to the much smaller cloud droplet effective radii of the polluted cloud. The anthropogenic cloud radiative forcing (polluted – maritime) is the highest for the moist and high inversion layer height condition.

The cloud layer and subcloud layer are often decoupled during the daytime. In the moist and low inversion layer height condition, clouds are most strongly decoupled. The ratio (I) of the sum of buoyancy flux in the cloud layer to that in the subcloud layer serves as an index of decoupling strength [Nicholls, 1984] and this value is -0.66 and -0.64 for polluted and maritime clouds that form in this condition, which are much lower than the threshold value of decoupling, -0.4. For the moist and high inversion layer height condition, |I| is smaller than those for low inversion height cases, mainly because LWC is much larger and therefore stronger cloud top long wave radiative cooling compensates more effectively for shortwave warming. The |I| for the dry condition are somewhat smaller than those for the moist condition. Much more detail will be discussed in the conference.