Radiative-Dynamical Feedbacks in Thin Stratiform Clouds

Research Highlight

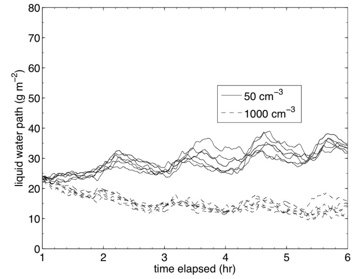
For low liquid water path (LWP) stratiform clouds, cloud integrated radiative heating can be sensitive to changes in LWP and droplet concentration. Because this radiative heating plays an important role in the evolution of such cloud layers, feedbacks between changes in LWP, droplet concentration, and radiative heating can exist. We investigated the potential importance of these feedbacks using large-eddy simulations of idealized low LWP stratiform clouds.

We found that changes in droplet concentration can substantially modify low LWP stratiform cloud evolution. In nocturnal simulations, more rapid initial evaporation of the cloud layer occurs when droplet concentrations are high. This rapid evaporation leads to more cloud breaks and lower LWP values, both resulting in less total longwave cooling. Weakened circulations result from this reduced longwave cooling, and entrainment drying is able to counteract cloud growth. On the other hand, when droplet concentration is low, the cloud layer is better maintained because longwave cooling is still relatively strong.

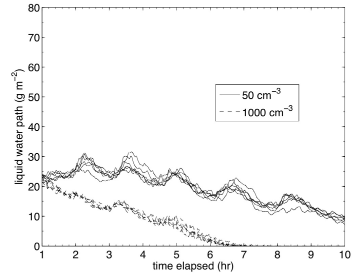
Daytime simulations revealed even larger changes in cloud evolution with increased droplet concentration. The addition of shortwave warming leads to reduced LWP for all droplet concentrations, consequently resulting in further reduced longwave cooling and weakened circulations. For high droplet concentrations, these reductions are such that the cloud layer cannot be maintained. For lower droplet concentrations the reductions are smaller, and the cloud layer thins but does not dissipate.

For our simulations, the initial model atmospheric profile is representative of stratiform clouds in the sub-tropics (well-mixed). Garrett et al. (Geophysical Research Letters 2009) investigated the impact of changes in droplet concentration on thin Arctic stratiform clouds using large-eddy simulation. In their study, LWP increased with an increase in droplet concentration, contrary to our findings. Their initial model atmospheric profile is of a stable boundary layer, and thus entrainment did not play an important role in their simulations. Instead, because radiative cooling increases with droplet concentration for thin stratiform clouds, they found that LWP increases faster when droplet concentration is high.

Lee et al. (Journal of Geophysical Research 2009) also investigated the impact of changes in droplet concentration on thin stratiform clouds using 2D eddy-resolving simulations. They found a response more in line with ours (cloud layer thins when droplet concentration increases) but implicate altogether different physical mechanisms for this response. Taken together, our results and the results in Garrett et al. and Lee et al. suggest that thin stratiform clouds are particularly sensitive to initial thermodynamic profiles, as well to choices in model configuration.



Large-eddy simulation time series output of nocturnal thin stratiform LWP for low (50 per cm^-3) and high (1000 per cm^-3) droplet concentrations. Six realizations are shown for each droplet concentration.



Large-eddy simulation time series output of daytime thin stratiform LWP for low (50 per cm^-3) and high (1000 per cm^-3) droplet concentrations. Six realizations are shown for each droplet concentration.

Reference(s)

Petters JL, JY Harrington, and EE Clothiaux. 2012. "Radiative–dynamical feedbacks in low liquid water path stratiform clouds." Journal of the Atmospheric Sciences, 69(5), 10.1175/JAS-D-11-0169.1.

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Cloud-Aerosol-Precipitation Interactions