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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Conditions for super-adiabatic droplet growth after entrainment mixing" *by* F. Yang et al.

Anonymous Referee #1

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This paper investigates if cloud parcels that go through a mixing event can produce larger droplets than undisturbed parcels (this is called super-adiabatic growth by the authors). Mixed parcels contain less water and fewer droplets than undisturbed parcels, and therefore droplets there grow faster after a mixing event, although starting from a smaller radius. From thermodynamical considerations, the authors show that super-adiabatic growth is expected for a pristine environment when mixed parcels rise to a given height. This height mostly depends on the thermodynamical properties of the cloud and of the environment, and it is independent of the updraft velocity and of the mixing fraction. This result is tested with a parcel model for different updrafts velocities, different polluted environments and for a polydisperse droplet population.

It has been argued in the past that super-adiabatic droplet growth can help to explain rain formation in warm clouds. The authors are able to quantify this effect in idealized

conditions, and I think that their results can be used to estimate the relevance of the mechanism in future studies. For these reasons, I think that the work can be a worthy publication for ACP if the authors answer the next questions.

1) One of the inherent assumptions for the parcel model and for the thermodynamical calculations is that the parcel only mixes once with the cloud-free environment, which means that it never mixes with cloudy air. I would like that the authors discuss this assumption more in detail. Clouds are turbulent and continuously mix (see for example Margaritz et al. 2014), which homogenizes the droplet number concentration. In the example from Figure 1, the parcel has to rise for $\sim$3000 seconds without mixing with other cloud parcels in order to become super adiabatic. It seems unlikely for me to find such a parcel in a real cloud.

2) It would be interesting to know the authors conclusions about the role of super adiabatic droplets for large droplets production and rain formation, from the results presented in the paper. Do they think that the mechanism is relevant for all warm clouds or only in a few particular cases (very wet and very clean environment)? Do they think that the mechanism is relevant for stratocumulus (which are usually thin ($\sim$300 m), with a dry capping free atmosphere and with mixing only on the top)? Can they estimate how does the droplet size distribution broaden due to this mechanism (is it sufficient for rain formation)?

Technical corrections:

1) Line 120. Equation (4) can be directly obtained from Eq. (1) in the quasi-stationary limit. No need to refer to Eqs. (2) and (3).

2) Line 135. There is a prefactor missing in the definition of the liquid potential temperature, which accounts for the pressure dependence. With the current definition, liquid potential temperature is only conserved for adiabatic and isobaric processes. Also, I do not see why \epsilon appears in the definition (it does not appear in Gerber et al. 2008).

3) Line 141. Equation number missing.

4) Line 151. I would not discuss the state im (after mixing but before phase changes). It is not very useful for the discussion, and it adds more symbols.

5) Line 156 and 192. Equation 2.1 does not exist.

6) Line 246. Explain better why ql,fm /ql,f = \chi is the condition for the critical height. Remind the condition of completely clean environment.

7) Line 316. Provide the number of CCN in the polluted environment.

References: Magaritz-Ronen, L., Pinsky, M., and Khain, A.: Effects of Turbulent Mixing on the Structure and Macroscopic Properties of Stratocumulus Clouds Demonstrated by a Lagrangian Trajectory Model, J. Atmos. Sci., 71,1843–1862, 2014.

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