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

Anonymous Referee #2

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Review of ACP-2016-94

In this manuscript the authors tried to tackle the problem of super-adiabatic droplet growth, which has been a subject of great interest in cloud physics community for the last several decades. For without such growth, warm rain initiation within a realistic time scale seems very difficult, if not impossible. The authors considered entrainment and mixing processes as a key to the super-adiabatic droplet growth and derived equations that could calculate analytically the variation of temperature and liquid water mixing ratio and thus droplet radius after entrainment and mixing and during the further ascent of the mixed cloud parcel. Then the authors demonstrated that this theoretical formulation was consistent with the results of cloud parcel model simulations of such processes. Moreover, the authors suggested some proper environmental conditions for super-adiabatic droplet growth. This manuscript does add some new insights on super-adiabatic droplet growth and could be worth publication in ACP if the following issues are handled properly.

In Eq. (7), epsilon appears in the denominator of the second term in each side, which is not right. Likewise, epsilon in Eq. (15) should be removed. A critical mistake is made in Eq. (12): pf in the denominator of the right hand side should be removed. Meanwhile, in Eq. (14), pf should appear in the denominator of the second term on the right hand side. I doubt that these wrong formulations were actually used in theoretical calculations. If that was the case, the results might have been very different from those shown in the manuscript. The authors should clear this problem.

The authors used a cloud parcel model to calculate the evolution of cloud droplet size distribution during the ascent of a cloud parcel after entrainment and mixing. Very similar but much more sophisticated calculations were already made by Wang et al. (2009). Using a cloud parcel model that incorporates a full CCN spectrum, they calculated the evolution of cloud droplet distribution in an ascending cloud parcel that was mixed with just saturated air in several different proportions. Because the mixed air was just saturated, classification of homogeneous or inhomogeneous mixing was irrelevant. However, during the ascent after mixing, supersaturation of the mixed cloud parcel was readjusted and droplet number concentration and size distribution responded accordingly. Right after mixing, mean droplet diameter was reduced due to the newly activated small droplets from the portion of the just saturated air, but because of reduced droplet number concentration, droplet growth was faster and eventually at some altitude above the mean diameter of the mixed cloud parcel became larger than that of the unmixed cloud parcel. Here the key to the faster droplet growth was due to reduced droplet number concentration and increased supersaturation in the mixed cloud parcel after just saturated air was mixed. Such behavior cannot be resolved when a monodisperse CCN distribution is used as was done in Figs. 1 and 2. But for Fig. 3, a polydisperse CCN distribution was used and the evolution of individual size classes was calculated. Similarly to Wang et al. (2009), I urge the authors to show the variation of supersaturation and activated droplet number concentration and to include them in the discussion of faster growth in the mixed cloud parcel.

Obviously the mixing scenario presented in this manuscript is not likely to occur in exactly the same manner in real clouds. As pointed out by the authors, inhomogeneous mixing may occur instead of homogeneous mixing. Cloud parcels may undergo multiple mixing events not only with entrained environmental air but also with neighboring in-cloud parcels as exemplified in Wang et al. (2009). Some discussion should be made in this perspective.

Line 47: one of 'that' should be removed.

Line 192: Equation 2.1 does not exist. Apparently it is meant to be Equation 7.

Line 320: The fact that more aerosols lead to smaller cloud droplets is simply a fundamental aspect of cloud physics. This does not indicate aerosol indirect effect. The key factor of aerosol indirect effect is the anthropogenic increase of aerosol concentration that leads to increased concentration of smaller cloud droplets. So linking the fact that more aerosols lead to smaller cloud droplets to aerosol indirect effect is not appropriate.

Where is Table 1? I only see Table 2.

Reference Wang et al.: Observations of marine stratocumulus microphysics and implications for processes controlling droplet spectra: Results from the Marine Stratus/Stratocumulus Experiment, Journal of Geophysical Research, 114, D18210, doi: 1029/2008JD011035, 2009.

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