Review of ACP-2017-508

In this manuscript the authors made theoretical assessment of how mixing of cloudy air with unsaturated clear air affects the evolution of cloud microphysical parameters in the mixed volume, using a one dimensional diffusion-evaporation model. Entrainment and mixing in clouds have been known to be an important but not well understood problem in cloud physics for several decades even though their effects on cloud microphysics critically affect further cloud development. In that sense, this type of study is highly needed for advancement of our understanding of the problem. The authors calculated droplet spectral evolution in a one dimensional horizontal column of 40 m length during the turbulent mixing of cloudy air and unsaturated clear air of different proportions. Mixing starts at the interface between cloudy and clear air and proceeds gradually throughout the whole length by turbulent diffusion. Cloud droplet spectrum in the mixed volume changes due to droplet evaporation until saturation is restored. All these processes are expected to occur during the entrainment and mixing and with the model they employed, the authors seem to have calculated these processes well. But the critical question is if indeed they occur in real clouds under the conditions provided in this manuscript. If not, it would be inappropriate to give so much credit to the arguments the authors made in this manuscript. Nevertheless, I think that this manuscript is worth the publication if the authors clearly specify the limitation and applicability of their results. English is definitely not up to the standard of ACP publication and therefore requires great improvement. Some specific comments are followed.

Major comments

According to the model description, turbulent diffusion and evaporation of the droplets in the mixed volume occur simultaneously. The authors call this process inhomogeneous mixing because the degree of mixing is not uniform throughout the whole volume during the mixing. I am not sure if inhomogeneous mixing is the right term for this process. But I will stick to this definition for this review. In a one dimensional column, mixing may proceed only this way no matter what Damkohler number (Da) is. It seems that the model is capable of simulating homogeneous mixing as a special case for very small Da. How about the case of extremely inhomogeneous mixing, which is likely to occur when Da is very large? In a 3-D space overturning of turbulent eddies during the mixing of cloudy air with clear air may create some

portion of cloud volume remaining unaffected and some other portion of cloud volume losing all droplets due to complete evaporation. Is the model capable of simulating something similar to this 3-D reality when Da is very large? Or setting a different Da value just changes the speed of mixing and evaporation that occur in an invariably simultaneous fashion in the mixed volume? If so, this model does have intrinsic limitation. Another important point is that it takes nearly 5 min to arrive at the equilibrium state in the model simulations. In reality the mixed volume of 40 m length would not remain as an adiabatic entity for that long time as is pointed out by the authors themselves in the Discussion and Conclusion section. Therefore, I am hesitant to give too much credit for the arguments based on the results obtained at the equilibrium state.

Narrow and wide DSDs are used as input to the model. It is shown that mixing and evaporation actually result in increase of r_e in the mixed volume when DSD is wide. However, assuming a wide DSD does not reflect the reality. In the argument of entrainment and mixing, we start with an adiabatic cloud parcel and see how entrain and mixing of clear air would affect cloud microphysics in this parcel. Importantly, droplet distributions in adiabatic parcels are intrinsically narrow. The wide DSD the authors used is therefore unrealistic. If a wide DSD is observed in a cloud parcel, it would indicate that this parcel has already been through severe entrainment and mixing and/or coalescence process but certainly not a parcel that will start entrainment and mixing just now.

RH of 60% is the lowest in the model calculation of this manuscript. What about the mixing of air with RH of \sim 20%, which is a proper RH value for the air above the stratocumulus cloud top in the subtropics? Mixing will be more likely to be extremely inhomogeneous when this very dry air is entrained. Can this be simulated in the model?

The authors claim that mixing diagrams are not capable of distinguishing between mixing types. Moreover, results are not distinguishably different for different RH values of entrained clear air (Fig. 11). However, distinction between inhomogeneous and homogeneous mixing seems so obvious in Fig. 9a. It is not so in Fig. 9b as the authors claim but here unrealistically wide DSD is used for the calculation and therefore giving too much credit is unjustifiable. Even in the traditional mixing diagram that uses normalized concentration (N/N₁) as in Fig. 11, distinction should be obvious between inhomogeneous and homogeneous mixing and also

among different RH values for homogeneous mixing. The authors do not put the lines for homogeneous mixing in Fig. 11. If they do, I expect that the results would be distinctively different from those for inhomogeneous mixing. Their argument is based only on the results for inhomogeneous mixing. However, RH dependence of inhomogeneous mixing is not known to be significant anyway and has never been discussed in mixing diagram analysis (e.g., Burnet and Brenguier, 2007). Another thing to note is that in the traditional mixing diagram, y-axis is the cube of normalized mean volume radius (representing mean volume of the droplets), not the cube of normalized effective radius as is used in this manuscript. With the obvious relationship of L = NV, where L is the liquid water content, N is the number concentration and V is the mean volume of the droplets, L/L_a (i.e., normalized L, where L_a is the adiabatic value of L) = const lines can be drawn with rectangular hyperbolic lines in the mixing diagram, making the diagram somewhat like a 3 D field of N, V and L (Burnet and Brenguier, 2007). So I recommend the authors to use mean volume radius instead of effective radius.

Minor comments

L28: It is not right to say that droplet concentration remains unchanged when mixing is homogeneous. It does reduce because of simple dilution of cloud volume by clear air. The total number of droplets in the whole mixing volume remains unchanged but not the concentration, which is the number of droplets in a unit volume.

In several Figure captions, it is stated that p = 8288 mb. Shouldn't it be 828.8 mb?

Figures 9, 10 and 11: How are r_e/r_{e0} values obtained? Are they averages for the whole mixed volume at the time when equilibrium is achieved? How about N/N₁? Explain clearly.

Inappropriate English expressions are found in many places in this manuscript. They need to be corrected.