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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Aerosol effects on deep convective clouds: impact of changes in aerosol size distribution and aerosol activation parameterization" *by* A. M. L. Ekman et al.

Anonymous Referee #2

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The manuscript addresses a very important question within the cloud modeling community: How does the aerosol effect on clouds (namely, deep convective clouds in the current work) change among various aerosol activation parameterizations and size distributions. The authors outline six sensitivity cases in an effort to determine what the community should focus its attention on. They conclude that we must better understand the effects of graupel impaction scavenging of aerosols (as addressed in an additional sensitivity run contained within Section 3) as well as aerosol recycling from cloud droplet evaporation. However, there are some very important points that need to be addressed.

Major Comments:

A) Model

In regard to the model used in the study, it is stated in Section 2 that the ice nuclei (IN) concentration is fixed. What value is used for the simulations and why is this chosen? I am assuming that a fixed value is used so as to totally isolate the effect of increases in the aerosol concentration on activation, however, would it not make more sense to include some simple parameterization of IN as a function of temperature? Moreover, it is also stated in section 2 that all rain drops formed are assumed to have a radius $40\ \mu$m. It is unclear as to whether the size is fixed for all times or if this is just the size that newly formed raindrops take on during the timestep in which they are formed. How sensitive are the results to the choice of 40 μm? From *Rosenfeld et al.* (2008), convective invigoration should depend strongly on the autoconversion process.

B) Aerosols

From Figure 1, it seems as if the total aerosol concentration in the lowest 2 km is about 750 cm^{-3} and above 2 km it drops to 100 to 200 cm^{-3}. Also, from Section 2.2 we can conclude that these values are reduced to about 375 cm^{-3} and 50-100 cm^{-3} for the medium pollution case and 187.5 cm^{-3} and 25-50 cm^{-3} for the low pollution scenario. At first glance, the values reported for the domain- and time-averaged cloud droplet number concentration in Figure 3 seem very low. However, it is unclear where activation occurs predominantly from the text and figures. From what is provided, it appears as though cloud base is above 2 km and so most of the activation is occurring where the aerosol concentration is lowest within the column. Since the aerosol concentrations are low here, i.e., $<$200 cm^{-3} for all scenarios, one would expect most particles to activate. Figure 3 corroborates this statement. However, the study of *Rosenfeld et al.* (2008) showed that convective invigoration due to an increase in the aerosol number concentration is expected to peak when the aerosol number concentration is around 1200 cm^{-3}. Additionally, *Rosenfeld et al.* (2008) show that as the aerosol number concentration approaches 100 cm^{-3}, the invigoration becomes negligible. This might explain why there are "relatively small differences in convective strength obtained for all sensitivity simulations . . . " in this study. This should be addressed in the manuscript by either providing additional details in Section 2.2 and the conclusions, or by performing an additional set of simulations with higher aerosol concentration (e.g., 200% of the high case.

C) Figures

In general, the quantity and quality of the figures is lacking in the manuscript. In particular, I found that the second paragraph of Section 3.1 would be more understandable if it were accompanied by a figure of the cloud droplet number concentration and the liquid water content as a function of height. Moreover, a figure portraying the graupel mixing ratio and mean updraft velocity as a function of time would clearly show the results discussed in Section 3.4. As alluded to above, the paper lacks information regarding the vertical structure of the environment (e.g., initial temperature and moisture profiles, mean profiles of the condensed mixing ratios, etc.) The only vertical information that we are provided by the authors is that of a domain averaged temperature increase/decrease in Figures 5 and 6. It is not clear however from the captions if these changes in temperature are due to latent heating, advection, shortwave warming, etc. Lastly, these figures show a decrease in temperature above 8 to 10 km in many simulations. Is this in any way related to changes in cloud top height and thus changes in condensed water mass?

Minor Comments:

A) Lines 14 to 16 on page 6343: There are no references listed for the studies performed that show a decrease in precipitation with an increase in the aerosol number concentration.

B) Last paragraph: It is stated in the introduction that *Fan et al.* (2009) show that under weak vertical wind shear, aerosol effects on deep convective clouds are larger than for strong vertical wind shear. The last sentence states the opposite.

C) Throughout the manuscript: Köhler is used first on line 17 of page 6345 and is then used throughout the remainder of the paper in a different form, namely "Koehler". These should be changed for consistency. Moreover, the names of the simulations are defined in Section 2.2, but from there on many of the names are given backwards, e.g., aero-koehler becomes koehler-aero. These should also be changed so that the names are consistent throughout the manuscript.

Summary:
The submitted manuscript provides a look at various aerosol activation parameterizations in a cloud resolving model and provide focal points for future work in the realm of aerosol-cloud interactions, namely, aerosol recycling and graupel impaction. However, the aforementioned significant points need to be addressed.

References

Fan, J., T. Yuan, J. M. Comstock, S. Ghan, A. . Khain, L. R. Leung, Z. Li, V. J. Martins, and M. Ovchinnikov (2009), Dominant role by vertical wind shear in regulating aerosol effects on deep convective clouds, J. Geophys. Res., 114(D22206), doi: 10.1029/2009JD012352.

Rosenfeld, D., U. Lohmann, G. B. Raga, C. D. O'Dowd, M. Kulmala, S. Fuzzi, A. Reissell, and M. O. Andreae (2008), Flood or drought: How do aerosols affect precipitation?, Science, 321, 1309-1313.

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