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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 #1

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The objective of the study is testing the hypothesis that CCN aerosols invigorate convective clouds and its sensitivity to different kinds of aerosols and their model representation.

The study uses a crude bulk microphysics two moments scheme, which is able to slow the autoconversion in response to enhanced concentrations of CCN aerosols, but inherently unable to simulate correctly the cloud and hydrometeor particle size distributions. This is critically important, because most processes, and with particular importance here scavenging and evaporation, depend strongly on these distributions. The model is also run in the rather crude horizontal resolution of 2 km and vertical resolution of 400 m, which cannot resolve but the largest convective elements. Therefore, such a model would fit to test very broadly the hypothesis that adding aerosols invigorates convective clouds due to delaying the autoconversion. It does so successfully by showing generally more invigoration with greater number of aerosol concentrations. This has been shown already by many previous similar studies. However, when convolving the crude processes of the cloud microphysics with the fine processes of the aerosols the inevitable outcome must be crude results, which render almost meaningless the admirable attempts of the authors to investigate the impacts of the aerosol properties and processes. This level of refinement with the aerosols has to be done with a spectral bin microphysics model, or not at all.

For example, one of the major "findings" where the simulation results deviate from the conceptual model of Rosenfeld et al. (2008) is the decreasing rain in greater amount of aerosols in some of the variants, explained by enhanced evaporation (e.g., first paragraph of page 6355). Evaporation rate of rain is critically dependent on its drop size distribution. It has been documented that rain drops are much larger in more microphysically continental (i.e., with more cloud drop number concentration) clouds (Rosenfeld and Ulbrich, 2003). Because the shape of the rain drop size distribution is prescribed, this effect cannot be taken into account in the 2-moment scheme, and hence all processes that depend on evaporation rate are very dubious, and respectively the conclusions that are based on them.

The authors state that they test the conceptual model of Rosenfeld et al. (2008) in the sensitivity study by varying CCN concentrations between a maximum of about 700 to a minimum of 700/4 cm-3 (see Fig. 1). However, the conceptual model of Rosenfeld et al. (2008) and the observational studies referenced there show that much larger range of concentrations should be used for capturing the range of sensitivity.

There are also issues with the glaciation:

P6343 L21-23 The text reads: "smaller cloud droplets also imply a shift of the homogeneous freezing level to colder temperatures". The authors misinterpret here Rosenfeld et al. (2008), according which smaller drops causes heterogeneous ice nucleation to occur at colder temperatures, and in the extreme case that is caused by cold cloud base temperature and high aerosols can be delayed to the homogeneous ice nucleation temperature of -38C.

P6344 L23-26: The text reads: "we constrain our study and do not include the effect of droplet size on homogeneous Freezing". The statement here is problematic for the same reason as for the previous comment. The authors probably mean that the droplet size does not affect the temperature or rate of heterogeneous freezing. With this respect, the model should still have implied dependence of heterogeneous freezing on drop size for the following reasons: The autoconversion rate depends strongly on cloud drop size. I suppose that warm rain is allowed to be formed in the model in supercooled temperatures. If so supercooled rain should freezes heterogeneously when colliding with ice crystals, snow or graupel. Hence, heterogeneous freezing occurs faster with larger drop size even in this model. If so, the conclusions that are based on the assumption that it is not so should be changed.

P3646 L18-19: See previous comment.

In summary, studying the sensitivity to differences in the treatment of aerosols and their interactions with clouds requires equally detailed cloud microphysical scheme, which is not used in this study.

Reference:

Rosenfeld D. and C. W. Ulbrich, 2003: Cloud microphysical properties, processes, and rainfall estimation opportunities. Chapter 10 of " Radar and Atmospheric Science: A Collection of Essays in Honor of David Atlas". Edited by Roger M. Wakimoto and Ramesh Srivastava. Meteorological Monographs 52, 237-258, AMS.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 6341, 2010.