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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Theoretical basis for convective invigoration due to increased aerosol concentration" *by* Z. J. Lebo and J. H. Seinfeld

Anonymous Referee #2

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In this work the authors address the important issue of the effect of aerosol emissions on convective generation of precipitation via CCN and IN activation. The authors compare the results of bin and bulk representations of cloud microphysics in clean, polluted, high RH and low RH scenarios. They conclude that the competition between the timescales of sedimentation and latent heat release determines whether an increase in CCN and IN number concentration would lead to reduction/increase in precipitation. While I find the subject of this work highly relevant for the scientific community, I think the methods used need to be evaluated and better explained. The paper's presentation, particularly regarding the Figures, also needs to be improved.

1 General Comments

-The authors should look for a way to validate their results. The amount of precipitation between the bin the bulk and bin schemes differs by almost an order of magnitude. I understand that it is not the purpose of this study to predict with high precision the evolution of a given convective system, however the difference between the bin and bulk models is too high to overlook. Clearly one of the models is strongly biased. My concern is that conclusions obtained with a biased model may as well be biased. The authors conclude that a bulk model would not be able to capture the effect of IN and CCN increase on precipitation. However this conclusion is based on a bulk model that may not predict correctly the evolution of the unperturbed system.

-The authors suggest the bin model is more accurate. I think this is not necessarily true; both the bin and bulk models rely heavily on empirical/semi-empirical parameterizations of growth and evaporation, and on simplified treatments of CCN and IN activation.

- Why does the large difference in precipitation between the bulk and bin models not show up in any of the condensate profiles of Figure 5? The vertical profiles of rain, liquid, and ice look fairly similar. If the cause is stronger autoconversion in the bulk model I would expect that the rain and suspended liquid profiles would largely differ from the bin model. Strong autoconversion would deplete liquid water and increase rain. Eventually, rain would sediment and become surface precipitation. Thus the bulk model would eventually dry up or at least show large depletion of liquid water, otherwise where is all that water at the surface coming from?

- High vs. low RH cases. I don't see a significant change in the amount of precipitation between Figures 10 and 3, while between 15 and 9 is quite noticeable.

ACPD
11, C1093–C1096, 2011

Interactive Comment

- Bulk ice nucleation scheme: The Barahona and Nenes (2008, 2009) parameterization is a cirrus scheme. How is this scheme adapted to mixed phase/convective clouds? Is the predicted/specified IN concentration in the bulk model the same as in the bin scheme?

-I would suggest pairing all the low RH Figures along with the high RH ones. For example, pair Figs 3 and 10, 9 and 15, 6 and 12, 7 and 13, 8 and 14, and so on. This would reduce the number of figures by half and facilitate comparison. Also, please split Figure 5 into separate figures for ice, rain and ice for clarity. Finally please correct the labels of Figure 4 and make sure that the explanantion in the text is consistent with the labeling of the figures.

-How is the aerosol treated in the model? Is the aerosol size distribution adjusted after IN and CCN activation, at least in the bin model? Is the total aerosol depleted during the simulation or assumed constant?

- It would be helpful to see plots of mean rain, ice, and droplet size and number concentration to verify that the models are internally consistent. Also the role of autoconversion is just barely discussed, however it may be quite significant as droplet size, hence autoconversion, is highly affected by CCN concentration.

2 Specific comments

- Page 2784, lines 15-16. This procedure would result in an overestimation of N_{act} unless CCN is depleted as well.

- Page 2786, line 6. In the way it is written it seems that the new frozen droplets are

ACPD
11, C1093–C1096, 2011

distributed evenly over all bins of the ice size distribution. This would be a mistake as the maximum diameter of droplets is typically 20-30 μm whereas the ice crystals can be as large as 300 μm. Please clarify.

- Page 2794, line 23. Please provide support for this statement, i.e, compare the autoconversion rate predicted by the two models.

- Page 2796, line 13. The word discrepancy is misspelled.

- Page 2798, line 7. To carry out this sensitivity analysis I would argue that the model should be working well to start with. I don't think the conclusions made referring to the bulk model results are meaningful (assuming it is the bulk not the bin model which has the bias).

- Page 2798, line 18. This statement is confusing.

- Page 2810, lines 17-18. I would argue that not only the sedimentation but also the autoconversion time scale is reduced. Which one ultimately determines the evolution of the system?

ACPD

11, C1093–C1096, 2011