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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Explicit simulation of aerosol physics in a cloud-resolving model" *by* A. M. L. Ekman et al.

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Using a cloud-resolving model coupled with a modal-approach aerosol module, this paper describes the interactions between aerosols and deep convection based upon a series of sensitivity simulations. The sensitivity simulations are conducted to evaluate the dependencies of the results on the assumptions used in constructing the aerosol module. This paper does well in investigating the aerosol physics formulation and the importance of various processes on the results. Questions still remain on a few of the assumptions and on why such sensitivities occur.

General Comments:

1. One aspect of the work that surprised me was how sensitive the storm characteristics (e.g., updraft speed and precipitation amount) are to the aerosol formulation. Could

the authors state whether they think observed deep convection contains these same sensitivities? For example, the initial concentration of aerosols affected precipitation amount by 30-70% in some of the sensitivity simulations.

A follow-up question on this topic is whether the storm characteristics will show the same dependencies if the spatial resolution were much finer (on the order of 100s of meters).

2. Are results at t = 3 h similar to what occurred throughout the simulation?

3. One set of sensitivity simulations explored the dependence of precipitation scavenging of aerosols on aerosol, cloud, and transport properties. An interesting result from these tests showed a 40-50% increase (decrease) in precipitation amount at the surface due to an increase (decrease) in the collision efficiency of aerosols onto precipitation (rain, snow, or graupel/hail). How does precipitation depend on impact scavenging of aerosols?

4. What is the importance of the boundary conditions to these results? One of the major conclusions of the paper is that the supply of CCN must be continuous to maintain vigorous convection. The authors point to the importance of aerosol condensation and coagulation to sustain the CCN supply, but couldn't the transport of CCN from outside the domain also maintain the CCN supply? The authors impose no flux of aerosols or chemical species into the model domain (section 4 introduction), yet in reality these tracers do flow into the domain from other regions.

Similarly, could the authors speculate whether the emission of any of the aerosols or chemical species could influence aerosol, cloud or transport properties?

5. One of the many results shown was the average ice particle radius near cloud top for each of the simulations. Although the average value between simulations did not differ greatly, I found it interesting that out of the 35 cases (11 cases shown in plot) only 3 simulations (D1, E3, H3) revealed a relatively large variability during the 3 hour

integration. Could the authors speculate as to what causes the ice particle radius to vary so much for these 3 cases, but not for the other cases? Is this a result of the storm development (intensity and structure) on cloud physics because of variations in aerosol representation?

6. Andreae *et al.* (2004) *Science*, **303**, 1337-1342 (www.sciencemag.org) recently published an article showing that rain is suppressed from deep convection when smoke is abundant in the atmosphere. One reason is because cloud drops activate on many, smaller CCN (there is no tail in the cloud drop distribution going to large drop sizes at cloud base), which cannot coalesce to form rain. In any of the simulations presented in this paper, or any subsequent simulations, have the authors seen a similar result to that presented by Andreae et al.?

II) Specific Comments

1. On pages 766-768, I found the text to be inconsistent with what was shown in Figure 6. Because it is stated in the Section 4.1 that the reference simulation was within 20% of the observations, I would consider effects of sensitivity simulations that are greater than 20% to be substantial, while those less than 20% to be small and may not be important. In particular, I found these inconsistencies:

- Page 766, line 24. Case A1 of Fig 6b shows only about a 10% decrease (a *small* change).

- Page 767, line 16-17. Fig 6a shows about a 5% decrease for case F1 (not substantial).

- Page 767, line 20. Case F2 in Fig 6a shows a 20% decrease in Aitken MNC (not 40%).

- Page 767, line 28-29. Case F3 in Fig 6d shows 10-20% decrease in precipitation, which I interpret as a somewhat less intense storm (not more intense). However other

ACPD

4, S156–S160, 2004

Interactive Comment

factors, such as updraft speeds, contribute to storm intensity, so this could lead to an incorrect interpretation on my part.

• Page 768, line 1. Case F3 in Fig 6a shows a 10% change in the Aitken MNC in the upper troposphere (and not a considerable change).

2. Page 768, lines 11-13. It states that with fewer CCN (resulting from higher dry deposition rate) precipitation increases by 40%. Is this because the conversion from cloud to rain, snow, or hail is greater when fewer CCN are available?

3. Page 771, line 17. Case G2 in Fig. 6a shows about a 5% decrease in Aitken MNC at 10.4 km. The text states that the transport of Aitken mode particles is weaker, but I would argue that the transport of these particles was about the same for the two cases.

4. Page 772, lines 19-20. When it is stated "negative correlation between aerosol amounts and ice crystal radius", does that mean aerosol mass or aerosol number concentration?

5. Page 774, lines 14-20. It would be nice to see these remarks about aerosol nucleation extended to the uncertainties in the current model parameterization.

6. Page 786, Fig 4. Why is the average precipitation intensity greater than the maximum precipitation intensity?

III) Minor Corrections:

1. Page 773, lines 21-22. I suggest being clear about aerosol processes versus cloud processes. Thus, on line 21, state “coagulation of aerosols" and “H_2SO_4 condensation". Check for this clarity in the subsequent paragraphs.

2. Page 775, line 8. I suggest using the word, predict, instead of, give, at the end of the line.

3. Page 775, line 11. “...than on the by the aerosol module calculated aerosol concentration" should be “... than on the aerosol concentration".

4. Page 782, Case E2. I suggest changing the word, old, to empirical.

5. Page 797, Fig 6 caption. Part c should state that it is for the concentration at 4 km (not 10.4 km).

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ACPD

4, S156–S160, 2004

Interactive Comment