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Atmospheric Chemistry and Physics Discussions

Interactive comment on "The relationship between aerosol and cloud drop number concentrations in a global aerosol microphysics model" *by* K. J. Pringle et al.

K. J. Pringle et al.

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We thank the referee for the helpful comments. The issues raised are well taken and we have responded to every comment made by the referee.

1. *The lack of other aerosols but seasalt and sulfates leads to a problem when diagnosing reasons as to why biases in cloud droplet number may be great, or not, especially in regions where aerosols may contain more than one species. How do you plan to address this? Maybe only analyze those regions where sulfates or sea-salt are expected to dominate.*

We agree that by neglecting other species we have chosen to study a simplified scenario but it is, to an extent, an idealised experiment to see if the explanatory power of an empirical relationship is sufficient to describe the distribution of CDN throughout the globe. I think this is explained in the text. In addition, we choose to focus on marine regions, which are better described by this scenario than continental regions.

To clarify, we have re-worded part of the model description section (P3212 L19-20).

"The model treats sulfate and sea-salt aerosol only. The lack of other aerosol components such as elemental and organic carbon means that the model will underestimate aerosol number in many polluted regions. However, a comparison with observations (Spracklen et al., 2007) showed that the model simulates realistic distributions of aerosol number and size in most remote marine regions (where this paper will focus), with only a small improvement in the comparison when emissions of carbonaceous particles were included."

2. *The concept presented in Figure 6 is good but could the figure be improved? It looked a bit blurry.*

   I will contact the production office on this issue.

3. *When Figure 7 is first described on page 3220, please state why those regions were considered.*

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Added the text:

These geographical regions were chosen as; (i) they give reasonable coverage of marine regions, and (ii) they showed a range of different probabilities of producing high / low CDN concentrations (for a given aerosol number concentration, Figure 6.)

Intuitively one expects to see results presented, so what would be more useful is to compare to observations if any could be found. Regions considered should have been based on regions where some field campaigns were conducted so you could support evidence of bias of empirical vs. mechanistic treatments more robustly. Also, you could have considered results from Bennartz (2007, JGR) that shows the global distribution of cloud droplet number and there have been several field campaigns which have measured cloud droplets and aerosols. This would greatly strengthen the paper.

We agree with the reviewer that comparing the results of the model to observations is also an important step, but it is also a non trivial one; CDN concentrations are also affected by the in-cloud updraft velocity, which is poorly parameterised in global models and can vary systematically between regions. We cannot do a comprehensive comparison of our findings to observations without first addressing the issue of updraft in some detail, as without this one can not know if changes in CDN between regions are from the changes aerosol size distribution or from updraft effects. This will be the subject of a future study, but is beyond the scope of this paper.

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4. *Point 5 on page 3224 suggests Arctic cloud droplet number is predicted to be low if one uses the correlation relation. This is important. How well can you support that point based on your modeling exercise? Once again, having some observations would have been useful.*

   We have expanded our explanation of the Arctic findings (pg 3224).

5. *Table 1 should report cloud droplet number without significant digits as is done in the text on page 3224.*

   Done.

6. *Why do all regions have the same cloud droplet number in Tabe 1 for the mechanistic treatment?*

   The CDN concentrations presented in the table are global mean CDN concentrations, not regional mean. Thus the title “region” in column one refers to the region from which the correlation relation was derived, thus has no effect on the global mean CDN calculated using NS03.

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Interactive Comment

We have adapted the description of the table to clarify this:

"Table 1 shows the global mean CDN concentration calculated with the mechanistic and regionally derived correlation relationships. Note this is a global mean CDN, thus for the NS03 case just two values are given (corresponding to the two updrafts considered). The fourth column shows the global mean CDN concentration calculated using the various regionally-derived correlation relations. The fifth column gives the absolute global mean change in CDN between the NS03 and the correlation scenarios, weighted by the monthly mean low cloud fraction and grid-box area."

We have changed the order of the table columns and the table caption has been changed to:

"Summary of global mean CDN concentrations calculated using the two methods. "Updraft": Updraft velocity used for NS03; "CDN NS03": Global average CDN concentration for the two updraft velocities, calculated using NS03; "Region": Region used to derive the regionally-derived correlation relations; "CDN Corr": Global average CDN calculated using the regionally-derived correlation relations; "Abs Diff" (or $\%$ Diff): The global mean absolute (or $\%$) difference in CDN between the two calculations of CDN (weighted by gridbox area and low cloud cover from ISCCP). All CDN concentrations are in cm^{-3}, regions defined in Figure 10."

Do you not consider variations in aerosol properties at all? I thought that Figure 10 was a good example of showing how the bias may change across regions but it would have been more useful if aerosols changed as well. Does GLOMAP not calculate aerosol properties?, and if it does as shown, I could not quite follow why only updraft velocities change when using the mechanistic

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treatment. That is a bit limiting.

We apologize if this is not clear from the text, but this is a misunderstanding that needs to be clarified: GLOMAP does indeed calculate aerosol properties for each grid box, thus the aerosol size distribution changes throughout the globe (controlled my the microphysical processes simulated in the model). This means that the aerosol DOES change between regions - indeed it is this change in aerosol that drives the pattern of change shown in Figure 10 (the updraft velocity does not change).

We have made this clearer by adding the line (pg 3222, line 5):

"Thus because the aerosol size distribution varies throughout the globe, aerosols may be more or less able to activate in particular regions. The use of a single (regionally derived) relationship applied throughout the globe cannot capture this detail, thus it leads to biases compared to a calculation of CDN which takes the aerosol size distribution in each individual grid box into account (i.e. NS03)."

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