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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Effect of aerosol sub-grid variability on aerosol optical depth and cloud condensation nuclei: Implications for global aerosol modelling" *by* N. Weigum et al.

Anonymous Referee #3

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In this study, the authors describe a new method that isolates the impact on simulated aerosol and chemistry distributions of changing horizontal resolution of the aerosol and chemistry components. Compared to previous studies looking at resolution impacts, the method guarantees that no other changes, i.e. to the structure of the model or the resolution of other model components, contribute. The causes for the changes can then be fully understood.

Applying their method to WRF-Chem, the authors find that modelled AOD decreases with decreasing resolution because of underestimation of water uptake, itself traced back to the non-linearities of the nitrate equilibrium between gas and aerosol phases, and to convective transport. The authors also find that modelled CCN increases with

decreasing resolution because of non-linearity in nucleation rates, itself traced back, via OH, to ozone production and again convective transport.

The paper is interesting to the aerosol and chemistry modelling communities because it is an in-depth analysis that seeks to understand the roots of differences caused by resolution, and because it convincingly demonstrates that neglecting sub-grid variability has sizeable consequences on weather- and climate-relevant variables like aerosol optical depth and cloud condensation nuclei. The paper is also well written, with well-chosen and good quality figures. For those reasons, I recommend publication.

I would however like to see minor revisions that improve the description of the analysis and discussion in places. I also think that the authors should elaborate on their conclusion that aerosol model development should account for the effects of sub-grid variability.

1 Main comments

- The paper's message that sub-grid variability is important and should be accounted for in aerosol model development is well-taken, but also easier to say than do. With their experience of looking into those aspects, the authors must have interesting views on the following questions. Is high resolution required? Line 223 gives an interesting statement in that respect. Do the authors have references or experiences to back up that statement that 10 km is a length scale characteristic of aerosol and CCN distributions? If high resolution is required, does that mean that low resolution simulations should not be trusted? Can low resolution be made to behave like high resolution by imposing subgrid distributions or stochastic parameterisations?

2 Other comments

- Lines 134-137 and Figure 2b: it is unfortunate to have chosen to illustrate the effect of inner domain averaging with a variable (ammonia emissions) which does not get averaged in the method. Ammonia surface concentrations would have been a better choice. Having said that, lines 115-120 in the previous section could be interpreted as saying that emissions have also been averaged – but we are now told it is not the case. I guess variables that get passed from module to module are averaged while variables that are only used within one particular module are not. It would be helpful to clearly list in a Table in section 2.1 which variables are averaged in the AA setup.
- Lines 156: How was the length of the spin-up period chosen? Typically spin-up should be long enough for tracer mass budgets to balance for given boundary conditions. 2 days is probably too short, and I am unclear whether both real and averaged aerosol mass budgets should balance, or only the real one.
- Lines 177-181: According to previous sections, averaged variables also include "gases". What are the gases represented in MADE/SORGAM?
- Lines 207-208: So which aerosol types/modes are PM10 emissions emitted into?
- Line 228: Could we have more details on this coarse-graining procedure?
- Lines 236-241: For the sake of completeness, a Table summarising the correlations studied, and the resulting correlation coefficients, would be good.
- Section 3.1.1: The causes for the lack of water uptake in AA80 are well investigated, but there a disconnect between the paragraph discussing ammonia (lines 325-340) and the paragraph discussing vertical profiles (lines 341-354). Should the sentences beginning lines 351 and 359 say that the causal chain begins with

underestimated ammonia in the HRHA regime? That conclusion seems partly confirmed by the discussion in section 3.1.2.

- Table 3: It would be useful to state in the caption that the LRHA regime is not shown.
- Figure 7: What is the unit of x axis?
- Line 459: From this point, the word "mixing" is used to mean averaging or dilution over a grid-box. I am not sure that it is the best use of the word, because of the risk of confusion with vertical mixing. I recommend using averaging instead.
- Line 516: Again, a Table showing the list of variables tested and the resulting correlations would be useful.
- Figures 14 and 15: Figure 15 is only used to make a small point, so its contents could be merged into Figure 14.

3 Technical comments

- Line 207: Typo: components
- Line 325: There is a full stop missing somewhere in this sentence.
- Line 449: Extra word: in some
- Caption of Figure 13: Something has gone wrong with square brackets.
- Captions of Figures 14 and 15: Why the plural in "FRA10 simulations"? There is only one FRA10 simulation according to Table 1.
- Line 559: Remove closing bracket.

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