Review for: “Spatial and temporal CCN variations in convection-permitting aerosol microphysics simulations in an idealised marine tropical domain”

Summary and recommendation:

This article employs a convection-permitting resolution model to assess the contribution of spatial and temporal variations in aerosol properties for the case of a convective tropical marine boundary layer to CCN variability across a domain the size of a GCM grid box. The model is setup in a simplified idealised configuration in which the radiation scheme was turned off and CCN concentrations do not feed through to the cloud microphysics. Subsequently, the current setup ignores feedbacks associated with aerosol-radiative and aerosol-cloud microphysical interactions that may impact the simulated aerosol field in the model. The authors find that the simulated CCN concentrations can vary significantly over the domain, more than a factor of 8 during strongly convective conditions. They assess the contribution of dynamical, chemical and microphysical processes to this high variability in CCN and attribute it to increased sea salt/DMS emissions when spatial and temporal wind speed fluctuations become resolved at this convection-permitting resolution, increasing peak wind-speeds. This is an interesting finding as current GCMs cannot explicitly resolve sub-grid scale variability in wind speeds. Such modelling frameworks are required to elicit the impact of spatial/temporal resolution in GCMs on the representation of aerosol-cloud interactions. Therefore, I recommend publication of this article ACP once the following revisions have been addressed:

General comments:

- The modelling framework developed is described as ground-breaking. One of the key advantages of the model is in the use of a unified modelling (UM) framework to investigate the dependence of parameters involved in aerosol-cloud interactions on model resolution. However, this strength has not been captivated upon in this study. There is a lack of evaluation of the impact of the increased resolution in the model on the parameters of interest. A comparison of the domain averaged parameter values presented in the study to the same parameters simulated by the GCM would be highly beneficial and greatly strengthen the conclusions presented. Does the observed sub-grid scale variability in CCN impact the average CCN concentration across the domain compared to a GCM? This comparison should be provided before publication in ACP.

- CCN represent the aerosol particles that can form cloud droplets under reasonable atmospheric supersaturations. Accordingly, CCN concentrations always refer to a specific supersaturation, for example, CCN (0.1%) or CCN (0.5%) and one should be careful when comparing CCN concentrations measured or simulated at different supersaturations. What supersaturation was used throughout the article for the CCN concentrations presented?

The variability in CCN concentrations reported in this idealised configuration has been shown to be strongly dependant on variability in wind speed across the domain. This is unsurprising considering the strong wind-speed dependence of the sea spray emission parameterisation employed. Accordingly more discussion is required as to the sensitivity of the results presented on the choice of sea spray emission parameterisation with regard to the following:

- As the findings presented are strongly linked to the simulated wind speed field across the domain some discussion is required as to how accurate the simulated wind field and convective perturbation is compared to the real world. Also, is the aerosol, thus, CCN variability simulated expected compared to observations? Please discuss in relation to the footprint of flux measurements performed to measure sea-salt emissions in the marine environment and associated variability observed from these measurement campaigns.

- Numerous sea-salt emission parameterisations exist, derived from a variety of in-situ measurement campaigns and laboratory experiments. How does the chosen parameterisations wind-speed dependence compare to the range of parameterisations in the literature, e.g. Fig. 5 Salter et al., 2015? How might a different parameterisation alter the high variability in CCN across the domain found?

- The onset of wave breaking is important for sea spray aerosol formation. It is generally recognized that the whitecap fraction and therefore sea spray aerosol production is zero for wind speeds less than ~ 3 m s^{-1} (Blanchard, 1963; Monahan, 1971). The implication of this with respect to the findings requires discussion, for example, what is the contribution of the total CCN variability simulated between 0-3 ms^{-1}? At what wind speeds does the CCN concentration begin to increase sharply, is there a threshold value?

- Discussion is required on the applicability of the chosen parameterisation of the resolution of the model (1Km) and time-step. Typically sea salt emission parameterisations are applicable to certain footprints, and parameterisations developed from in-situ observations are dependent on the memory of the wave field (a rising sea will result in a different emission profile than a falling sea). In addition parameterisations are developed using longer time windows for averaging for flux measurements compared to the model time-step employed. Is the sea spray source function being applied in the model at this temporal/spatial resolution in the way it was designed?

Minor comments:

- Section 2: A figure of the modified sea-spray source function used in the study would be beneficial here, especially for experimentalists.
- Section 2: For a modelling framework described as ground-breaking the model description is relatively sparse, for instance, how is hygroscopic growth parameterised in the model? This will affect the evolution of the aerosol field across the domain. Please provide a more detailed description of the aerosol microphysics scheme.
- Section 2.2: It is widely known 1-moment cloud microphysics schemes introduce errors compared to 2 or3 moment schemes. Some justification of this choice is required, was it due to computational restraints?
- Section 3.2, line 8: “Aitken mode are almost exclusively secondary in nature”: Please reword, this is two strong, studies exist which show emission of sea spray in this size regime, e.g. Salter et al., 2015.
- Section 4, line 25. “comprising two elements”: reword
- Fig.4: Why do the error bars in DMS & SO2/H2SO4 not correspond? Some discussion on expected oxidation timescales required, why is there no offset between H2SO4 & DMS observed?
- Recent studies have probed the dependence of aerosol processes on model resolution, for instance Weigum et al., 2016. This should be referenced.

Blanchard, D. C.: The electrification of the atmosphere by particles from bubbles in the sea, Prog. Oceanogr., 1, 171–202, 1963.

Monahan, E. C.: Oceanic whitecaps, J. Phys. Oceanogr., 1, 139– 144, 1971.
Salter, M. E., Zieger, P., Acosta Navarro, J. C., Grythe, H., Kirkevåg, A., Rosati, B., Riipinen, I., and Nilsson, E. D.: An empirically derived inorganic sea spray source function incorporating sea surface temperature, Atmos. Chem. Phys., 15, 11047-11066, doi:10.5194/acp-15-11047-2015, 2015.
Weigum et al.: Effect of aerosol subgrid variability on aerosol optical depth and cloud condensation nuclei: implications for global aerosol modelling, ACP doi:10.5194/acp-16-13619-2016.