

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

Paper summary and recommendation:

This paper disentangles the contribution of different processes to the overall CCN variability detected over a domain the size of a conventional general circulation model (GCM) grid box for the case of a convective tropical marine boundary layer. The study is performed in a simplified idealised setup. Feedback pathways between aerosol concentrations and the environment via radiative or cloud microphyiscal interactions are ignored. Thereby, an attribution of different processes to CCN variability due to spatial and temporal variability of size and number of the 3 mixed-modes contributing to the CCN budget (Aitken, accumulation and coarse mode) is obtained. The authors show that CCN concentrations may vary up to a factor 3-8 throughout the simulation domain. Understanding the origins of this variability is an important step towards estimating the potential biases of aerosol-cloud interaction estimates obtained by GCMs, which do not resolve this variability. I therefore recommend this article for publication in *Atmos. Chem. Phys.* following minor revisions.

Minor Comments – general:

- I believe that your aerosol concentrations are spun up from an entirely clean (i.e. $Naero=0.0 \text{ cm}^{-3}$) atmosphere. Please state this explicitly in the manuscript. I agree with the authors that this gives you the opportunity to disentangle the individual processes. However, this may be at least partially responsible for the high variability in CCN (800%) obtained after 12h of simulation following the period of intensive updrafts. If that is the case, context should be provided for the interpretation of this estimate. If you initialised a homogeneous profile of e.g. accumulation mode aerosol, would you still obtain such a high degree of variability of CCN following the intense updraft period? Please comment.
- The phrase “strongly convective” period (or conditions) seems to refer to different things throughout the manuscript. Sometimes the phrase seems to be used to refer to the time period of intensive updrafts and strong horizontal winds and sometimes to periods of intense rain fall. Please define this term and use it consistently throughout the manuscript.
- It has been shown (e.g. Textor et al, 2006: “Analysis and quantification of the diversities of aerosol life cycles within AeroCom”) that different assumptions made in modeling the sea salt flux may yield vastly different estimates of sea salt emission fluxes. How sensitive do the authors think their results are to their implemented SS emission parameterisation? Please comment.

Minor Comments – specific:

- P3L10: Please include reference Zubler et al (2011):”Simulation of dimming and brightening in Europe from 1958 to 2001 using a regional climate model”, JGR, doi:10.1029/2010JD015396.
- P3L10-L12: Two recent studies have investigated the impact of resolution on aerosol variability and aerosol-cloud interactions in regional climate models down to the kilometre scale for boundary layer clouds. These references should be added:
 - Possner et al (2016): “The resolution dependence of cloud effects and ship-induced aerosol-cloud interactions in marine stratocumulus”, JGR, doi:10.1002/2015JD024685.

- Weigum et al (2016): “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.
- P3L18: Please clarify complexity of aerosol treatment here, as there have been numerous studies investigating the sensitivity of marine deep and shallow convection to simplified aerosol treatments.
- P3L23: Please rephrase “to well characterize”.
- P3L25: How do the authors determine the “realistic” level of variability? Please add references here.
- P4L30: Please rephrase “only a short demonstration simulation is here carried out”.
- P4L31: Please rephrase “carried on”.
- P5L11: Please rephrase “becomes precipitating”, “becoming more intense”.
- P5L22: Please rephrase “associated cold pooling”
- P6L24: By which criterion do you define your simulation to have fully spun up? Please clarify.
- P7L20: The correspondence between patterns in highest particle concentrations and smaller particle sizes in Fig. 3 is not obvious to me in this particular figure. Please elaborate, or remove comment.
- P7L31ff: The second half of the day is not only characterised by calmer wind conditions, but also by intense precipitation between 12 – 18 h. I believe that it should be mentioned here.
- P8L31: “adjusts to the very strong sea-salt emission and wet removal”. However precipitation only really intensifies much later than 8h after initialisation. Please comment on the role of wet removal during this period.
- P9L31 – P10L1: Remove sentence “The relative decrease in ...”. You already stated that it is linear.
- P10L30: “... sea-salt aerosol are transported vertically by turbulent diffusion”, I would have thought that the convective updrafts would also contribute? Please comment, or adapt text.
- P11L9: Please rephrase “wind speeds condition”.
- P11L21ff: The authors state that CCN variations can be as large as factor 8. This number is obtained 12h after the simulation (Fig. 8). At this time the winds subside and precipitation builds up. So, how well does it characterise the CCN variability obtained during the period of intense updrafts? It may be helpful to include a box diagram for 6h after initialisation in Fig. 8. Furthermore the authors state that the CCN variability is large whilst the accumulation mode variability is smaller. This is confusing as I would assume most CCN to stem from the accumulation mode (see Fig 7.). Please clarify.
- Fig 1: For illustrative purposes the authors may consider adding a line of adiabatic parcel ascent.
- Fig 2: Please rephrase “mean total top cloud height” to “mean cloud top height”. Please rephrase “rain accumulation” to “accumulated rain” or “accumulated precipitation”.
- Fig 4: For clarification it may help adding day and night markers for the sulfate chemistry.
- Fig6 and Fig7: Does your aerosol scheme specify modal boundaries for the Aitken, accumulation and coarse mode? If so what are these? These could be added in the model description section.
- Fig 7: What causes the large variability in radius for the accumulation mode particles up to 8h after initialisation? This is discussed in the text on P8L30ff, but I would have thought that the SS emission radius would be tighter constrained and that wet removal processes play a larger role later during the simulation (after 12h) as the RR peaks. Please clarify.