

## ***Interactive comment on “Large difference in aerosol radiative effects from BVOC-SOA treatment in three ESMs” by Moa K. Sporre et al.***

### **Anonymous Referee #1**

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This is a nice modeling study that provides key insights about how three different global climate models respond differently in terms of aerosol-cloud-radiation interactions with changes in VOC emissions, NPF etc. I have following suggestions for clarifications and discussions that will further improve the interpretability and take-home messages. One of the key points to be discussed is how different model responses to perturbations in VOC emissions, NPF etc. in different regions can be evaluated with observations. These observations could be a combination of surface-, aircraft and satellite observations. Comparison to observed responses of SOA, CCN, CDNC etc. to perturbations are critical for reducing model uncertainties.

Line 360: Why does increase in accumulation mode particles over remote regions cause a decrease in smaller (20-60 nm) particles in this model? If SOA gas precur-

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sors are transported to remote regions they should be effective in growing 20-60 nm particles to CCN sizes. This should increase CCN, CDNC and CRE. But it seems the opposing effects on accumulation and Aitken particles is related to transport of already formed accumulation mode SOA (upstream of the remote regions) that decreases smaller (20-60 nm) particles due to coagulation?

Conceptually, if in EC-Earth the timescale for SOA formation could increase by reducing oxidants over remote regions (due to changes in gas-phase chemistry), this should increase CCN?

Line 395: The strong reduction in nucleation rates in EC\_Earth over large anthropogenic regions (due to shutting off ELVOCs) seems less realistic. BL nucleation rates should not be shut off when ELVOCs are zero. Observational evidence suggests that presence of H<sub>2</sub>SO<sub>4</sub> will nucleate particles while low volatility organics grow these particles to CCN sizes (e.g. Riipinen et al. 2011 cited in this paper). Please comment on how realistic the nucleation rates are in EC\_Earth based on observational evidence.

Line 425: Why does increase in OH in EC\_Earth (in no isoprene) cause reduction in O<sub>3</sub>?

Line 425: Why does increase in oxidants not affect amount of SOA formed? If more SOA is formed close to sources it can undergo wet removal. Also dry deposition of SOA precursors would reduce available precursors. This could also change if SOA precursors L/SVOCs and their multigenerational chemistry are represented by a volatility basis set framework. For example see: <https://agupubs.onlinelibrary.wiley.com/doi/10.1002/2014JD022563>

Line 495-505: It is clear that the three global models would produce different results if used to investigate climate impacts of BVOCs. But observations could provide insights about changes in model behavior with respect to changes in VOC emissions, NPF, presence/absence of ELVOCs and H<sub>2</sub>SO<sub>4</sub>. Also one of the key insights from this work is importance of interactive oxidants. Future model measurement comparisons could

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focus on evaluating model responses to perturbations in VOC emissions, NPF, SO<sub>2</sub>, NO<sub>x</sub> emissions etc. with respect to observations for e.g. in cleaner locations such as over the Amazon: <https://www.nature.com/articles/s41467-019-08909-4>

Minor clarification comments: Page 2: Shrivastava et al. 2015 predicted biomass burning to be the largest SOA source followed by biogenic SOA. Fossil-fuel SOA burden was the smallest and contributed less than one-third of biogenic SOA (see their Figure 5). Please rephrase.

Sum of isoprene, monoterpene and sesquiterpene emissions to BVOCs should sum to 100%. Right now 50+15+3 is 68%. Am I missing something here?

Line 270-275: Why does ECHAM have more particles in nucleation mode than EC-Earth? Does EC\_Earth treat nucleation mode? I would expect since NorESM has no nucleation mode, it would have the lowest particle numbers since the SOA mass goes to larger particles, but seems EC\_Earth has the lowest numbers. Why?

Line 285: I would think if aerosols are located above bright/reflective surfaces, they will absorb more sunlight and contribute more strongly to DRE. But it seems in NOrESM when there is higher AOD above bright surfaces it results in lower DRE forcing. Above deserts, dust particles should also be light absorbing. So this statement is confusing. Please explain.

Also how do the various models determine fraction going to soluble versus insoluble modes?

Is hygroscopicity of insoluble mode assumed to be zero?

What is assumed hygroscopicity of SOA in soluble/insoluble modes and in different models? I would expect hygroscopicity of SOA to play a stronger role in SOA dominated regions like the Amazon. Please comment on the role of hygroscopicity and water uptake on aerosol-cloud-radiation interactions.

Why does EC-Earth experience particle number changes farther downstream related

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to other models? Is it related to interactive oxidants in this model that reduce SOA formation close to sources but increase it downwind relative to a model with prescribed oxidants?

Line 335: It says “smaller” CWP due to higher CCN, CDNC and smaller effective radius. I think the authors meant “larger” CWP?

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