

Interactive comment on “BVOC-aerosol-climate interactions in the global aerosol-climate model ECHAM5.5-HAM2” by R. Makkonen et al.

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We thank referee #1 for insightful comments and suggestions, which have improved the manuscript. Below are point-to-point answers, with review-comments in bold.

The study calculates the first aerosol indirect effect from pre-industrial to present day, and present day to 2100, under a number of different BVOC and future anthropogenic emission scenarios. As such, I feel that the abstract requires some rephrasing, as the contribution of BVOC emission is included and the climatic response to its uncertainty is explored, but is not explicitly determined.

The paper includes extensive detailed discussions on the differences between various scenarios, mechanisms and locations but a more concise drawing to-

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gether of the overall results and implications would be beneficial. The paper is certainly within the scope of ACP and of interest to its audience; I would recommend its publication, following clarification of the below issues.

Specific Comments: Is there any potential for discrepancy in using two different SRES emission scenarios (A1 and A2) to generate the BVOC emissions, and then actually running the model in the future with the three different RCP scenarios? This may be worth mentioning sooner in the discussion on p9203; how much of the behaviour described in lines 8-15 could be explained by the fact that the models have been driven by two quite different future emission scenarios (i.e. not a diverse response to climate change but a different amount of climate change to respond to?). Also need to specify, on p9203 line 18, which A1 scenario is used (i.e. A1B, A1T, A1FI), as they are quite different. I appreciate that the difference between the future emissions generated by the two models is not the point of the paper, but I think it's worth being clear about the potential causes for it.

We agree the possible confusion in the use of different emission (and climate) scenarios for the BVOCs and anthropogenic emissions. We have added the following paragraphs to the revised manuscript:

Currently, most global aerosol-climate models prescribe BVOC emissions rather than calculating them interactively. Also, even the current online schemes for BVOC emission calculations do not usually allow for changes in the underlying assumptions on vegetation or VOC emission strength. One aspect of this paper was to analyze the effect of using two mechanistically different BVOC emission parameterizations on aerosol number concentrations. Since we did not constrain the BVOC emission models with the same meteorology or vegetation, the results shown can also arise from differences in e.g. temperatures, radiation or precipitation. However, this is usually the case when using prescribed emissions in a global aerosol-climate model. In fact, most often models use the BVOC emissions compiled in Guenther et al. (1995), even though the modeled meteorology could be significantly different.

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The inconsistencies between the year 2100 climates in MEGAN2, LPJ-GUESS and ECHAM deserve some discussion. MEGAN2 and LPJ-GUESS models are forced with SRES A1 and SRES A2 scenarios, respectively, while ECHAM5.5-HAM2 uses the RCP-scenarios to simulate future aerosol concentrations. The differences in the simulated future BVOC emissions are both due to mechanistic differences in the BVOC emission parameterization and the differences in the applied climate scenarios. In this paper, the LPJ-GUESS model was chosen to represent a scenario with rather similar global BVOC emissions in years 2000 and 2100, due to assumed CO₂ inhibition. The MEGAN2 model was chosen to represent a scenario with increasing BVOC emissions until the year 2100. Without the implemented CO₂ inhibition mechanism, LPJ-GUESS would also show increase in BVOC emissions until the year 2100. Exploring the effects of various climate scenarios on BVOC emission and CCN is beyond the scope of this paper. The emphasis of this paper is not on the scenarios per se, but rather having emission patterns that differ. It should be noted that the climate in ECHAM5.5-HAM2 is constrained with fixed sea-surface temperatures in all simulations.

- Page 9200, line 8: how is LCF value obtained? and how is the change in short-wave cloud forcing calculated? More details would be beneficial here

The low-cloud fraction is a standard diagnostic output of ECHAM, following the ECMWF definition of low clouds with model level: $1.0 > \sigma > 0.8$. The cloud forcing is defined in chapter 2.1:

“Cloud forcing is calculated as the difference between all-sky and clear-sky top-of-atmosphere shortwave radiative fluxes.”

The change in cloud forcing refers to a difference in cloud forcing between two experiments. We have improved chapter 2.1 to clarify these issues in the revised manuscript.

- Page 9211, line 3-6: true, but CN number is not just a reflection of nucleation rate

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True. We added an additional sentence to clarify:

“... smaller sulphuric acid activation coefficient in ORGSULACT. This can be seen as an increase in CN concentration over all marine areas, especially in the tropics.”

- Page 9214, Section 3.3: there is a lot of discussion on the past, present and future emissions in each location; I'm not sure that so much detail is required here.

We agree with the referee that the discussion in 3.3. might be a bit extensive at certain points. However, since neither the model setup (ECHAM5.5-HAM2) or the applied emissions (RCPs) have been extensively reviewed, we feel that the analysis provides a necessary background for the study.

- Page 9217, line 1: see previous comment about use of different emission scenarios to generate BVOC emissions for 2100

Please see our answer on the first comment.

- Page 9217, line 24 onwards: are you talking about a particular time period? These trends don't appear to hold across the whole table (Table 3) i.e. MEGAN2 emissions do not always give higher CN concentration

Thank you for pointing out, there is clearly a mistake in the text. We have corrected the text accordingly in the revised manuscript.

- Page 9218, line 14-18: see previous comment about use of different emission scenarios to generate BVOC emissions for 2100

Again, please see our answer on the first comment.

- Page 9221, line 21-24: I'm not sure it is possible to conclude this from Figure 10

Considering the uncertainties, we have removed the conclusion on anti-correlation on

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present-day, but we have left the sentence:

"In the year 2100, the changes in cloud albedo forcing and cloud forcing are correlating."

- Page 9220, line 13 onwards: can you include any Figures to support this?

We decided not to include a figure, as there are already rather many, and the discussed issue of Ract can be rather easily seen from Table 3.

Technical Suggestions:

- Page 9198, line 19: perhaps rephrase "made experiments"
- Page 9198, line 29: change "a location" to "one location"
- Page 9199, line 5: change "the other model" to "one model" (or even specify which model)
- Page 9204, line 21: remove "are also accounted for by MEGAN2" as this was said at the beginning of the sentence
- Page 9208, line 8: specify which "additional boundary layer nucleation scheme" i.e. SULACT?
- Page 9208, line 12: remove one "of"
- Page 9209, line 11: rephrase "seems to work best", be more specific
- Page 9213, line 17: change "panelss" to "panels"
- Page 9213, line 21: change "separeted" to "separated"
- Page 9214, line 9: change "red dashed line" to "red dotted line", if that it is correct (or remove this sentence as it is explained in the caption)
- Page 9214, line 26: perhaps insert "In the future scenarios used here, wildfire emis- sions will either....."

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- Page 9218, line 11: change "produce always" to "always produce"
- Page 9220, line 18: rearrange to give "the MEGAN2 BVOC emissions"
- Page 9222, line 24: remove "only"
- Page 9222, line 25: perhaps change to "gave the best agreement to observations"
- Page 9223, line 6: the highest value (least negative) is -1.53 W/m² in Table 4
- Page 9223, line 7: perhaps replace "reduction in cloud forcing" with "change in cloud forcing"
- Page 9224, line 3: insert "to the" between "sensitive" and "treatment"
- Page 9234, Table 1: state whether these are global averages and include units some- where
- Page 9236, Figure 1: state which year these emissions are from
- Page 9238, Figure 3: are these annual means? Would help visually if numbering intervals were consistent either side of zero
- Pages 9239-9240, Figure 4 and 5: missing "-" sign from 5 on colour bar
- Page 9241, Figure 6: state which simulation (nucleation scheme) these plots are from in the caption
- Page 9243, Figure 8: state which simulation these plots are from (nucleation scheme) in the caption and define which lines are for LPJ-GUESS emissions (dashed?). Add note to highlight different y-axis scales.

We thank the reviewer for the extensive list of technical corrections, which have been implemented in the revised manuscript.