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Atmospheric Chemistry and Physics Discussions

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

The most important point is for the authors to be more careful with statistical signficance of their numbers. Sometimes they show 3 significant digits of % change! That seems unlikely to be statistically significant. Because they are running a climate model, interannual variability can be large: are the changes outside interannual variability? Please do not show or discuss changes that are not outside one standard deviation as a minimum (including on horizontal plots). I can't really find how many years were run: please describe that.

We agree with the reviewer on the issue of statistics, and we have gone through the manuscript keeping this in mind. Although we did check the statistical significances of the results, some reported values were of too high accuracy. We have reduced the accuracy of certain values shown, however, we have not removed all data outside of statistical significance, for example from map-plots. The length of simulations is mentioned in chapter 2.1.: all experiments are integrated for five years.

Concerning aerosol concentrations, averaging for five years and taking a global average reduces the model noise significantly, and rather accurate results can be shown. Annual global average CN and CCN(0.2%) concentrations have a standard deviation of 6 cm^{-3} and 0.5 cm^{-3}, respectively. Generally, one would expect more variation in the cloud-related variables. For global average cloud droplet number concentration (CDNC) and low-cloud fraction, the standard deviations were found to be 0.5 cm^{-3} and 0.05%. Considering the signals from the different experiments conducted, the standard deviation in the global average short-wave cloud forcing is rather large, about 0.1 Wm^{-2}.

1. "where the change in cloud albedo from the year 1850 to the year 2000 was found to be +3.97% and +3.85% without and with boundary layer nucleation, respectively." This is a tiny difference? Is it really statistically significant? Are you really discussing this?

We can not fully address the statistical significancy of the above numbers, since no details are included in Merikanto et al. (2009). Considering the methods and the offline simulation setup in Merikanto et al. (2009), the difference can be statistically significant, although very small.

2. "Considering only the main experiments SULACT and ORGSULACT, the decrease in the cloud albedo from the year 2000 to the year 2100 is 4.1 %, 3.8 % and 3.4 % with emission pathways RCP-2.6, RCP-4.5 and RCP-8.5, respectively. Averaged over all future pathways, MEGAN2 and LPJ-GUESS emissions lead to

a similar change in cloud albedo (−3.8%)." Are any of these differences statistically significant? Are they statistically significant from each other?

The change in cloud albedo is derived from change in global average CDNC. The above numbers are statistically significant, and also the difference is statistically significant.

3. "Averaged over all 10 future pathways, MEGAN2 and LPJ-GUESS emissions lead to a decrease in the low- cloud cover of −1.3% and −1.0%, respectively." Again, are these statistically significant?

As mentioned above, the standard deviation in global average low-cloud cover is only 0.05%. We have checked that the above values are statistically significant.

4. "While binary nucleation simulations show a large change in cloud albedo since the pre-industrial period, 6.06–6.20%, the increase in low-cloud cover (ranging from +1.22 to +1.44%) is more modest than with boundary layer nucleation included (from +1.43 to +1.84%). All SULACT and ORGSULACT experiments show a similar change in cloud albedo, 4.45–4.49 %, and the highest (lowest) increase in low-cloud cover corresponds to the highest (lowest) change in shortwave cloud forc- ing." Do you really think you should show 3 significant digits in % in this case? Are these values statistically significant or just a result of interannual variability?

The above numbers are barely statistically significant. We have decreased the number of significant digits in the above text to "6.1-6.2%", "1.2-1.4%", "+1.4% to +1.8%" and "4.5%", respectively.

5. "The change in short-wave cloud forcing from pre-industrial to present-day, calculated with several boundary layer nucleation schemes and the two BVOC emission models, ranged from −1.54 to −1.75Wm−2. The reduction in cloud forcing from present-day until year 2100 var- ied from +0.99 to +1.53Wm−2, when

boundary layer nucleation was included in the model." Given the uncertainties, should you really show 3 significiant digits?

The three digits are indeed too accurate here. We have changed the above values to -1.5, -1.8, 1.0 and +1.5, respectively.

Other comments: "We show that the change in shortwave cloud forcing from the year 2000 to 2100 ranges from 1.0 to 1.5Wm−2. Although increasing future BVOC emissions provide 3–5% additional CCN,the effect on the cloud albedo change is modest. Due to simulated decreases in future cloud cover, the increased CCN concentrations from BVOCs can not provide significant additional cooling in the future." 1 W/m2 does not sound insignificant: it is offset somewhere else. Please be more clear about the relationship between short wave cloud forcing and climate RF.

The range 1.0 to 1.5 W m^{-2} refers to the total change in short-wave cloud forcing between years 2000 and 2100, including the change in anthropogenic perturbation. The insignificancy of BVOCs was related to the perturbations in short-wave cloud forcing due to BVOC-CCN coupling. We have added a clarification to the above sentence:

"We show that the change in shortwave cloud forcing from the year 2000 to 2100 ranges from 1.0 to 1.5W^{-2}, when considering changes in both anthropogenic and natural emissions."

"The anthropogenic influence on wildfire emissions is taken into account. Wildfire emissions are modeled according to AeroCom for pre-industrial and present-day (Den- tener et al., 2006), and according to each RCP pathway for the future." Do the RCPs include fire emissions? I didnÊijt think so? Please be more explicit.

The RCPs include emissions of savannah/grassland burning and forest fires due to land-use change (deforestation). The fire emissions are implemented according to

AeroCom A2 for the year 2100. The above sentence has been modified to:

"The anthropogenic influence on wildland fire emissions is taken into account. Wildfire emissions are modeled according to AeroCom for pre-industrial and present-day (Dentener et al., 2006). The fire emissions for the year 2100 are implemented according to AeroCom A2, taking into account the savannah burning and deforestation emissions in each RCP."

Section 2.3: "We will focus on experiments SULACT and ORGSULACT, which are simulated with each anthropogenic emission scenario and both BVOC emission datasets. The ORGSULHET and SULACT TER simulations are only done using MEGAN2 emissions,5 to address the increase in future BVOCs. To further reduce the number of simulations, ORGSULHET and SULACT TER are only simulated with the RCP-2.6 emission scenario (lowest SO2 emission in the year 2100)." IÊijm afraid I am confused. Please make a table which describes the experiments. The suffixes also donÊijt make much sense? Why HET and TER?

The ORGSULHET and SULACT_TER were chosen for "HETerogenous nucleation of ORGanics and SULphuric acid" and "ACTivation-type SULphuric acid nucleation over TERrestrial areas". We have included a table of experiments in the revised manuscript.

"This implies that although the BVOC-aerosol-climate feed- back would be negative with regard to CCN concentration (increased temperatures → increased BVOC emissions → increased CCN concentration), the indirect effects beyond the cloud albedo effect can have a large contribution on the resulting climate effect." This sentence is important and confusing: negative feedbacks on climate or CCN number???? Should be only on climate, right as warming would lead to increase in BVOCs, which lead to a positive forcing on climate??? Please be clear.

We agree that the sentence needed revising, and we have removed the word feedback in this context:

"This implies that although the increasing BVOC concentrations would act to increase the CCN concentrations, the indirect effects beyond the cloud albedo effect can have a large contribution on the resulting climate effect. "

Figure 1,3, 4 and 5: I found these hard to read. Another approach that might be easier to see differences, it to show the distribution for one model, but then show the differences between that model and the other models: otherwise we canÊijt really see anything but blobs.

Considering the number of experiments, the amount of map-figures has to be constrained. In the manuscript, we decided to locate the average distributions of each experiment in the Supplementary Material, and include only differences between experiments in the actual manuscript. We feel that moving the some of the average distributions from the Supplementary Material to the manuscript would increase the manuscript figure amount too much. We reviewed the current figure panels in the manuscript, and did not see that any of them would be unnecessary.

Figure 9: which ones are megan2 and which are lpj-guess?

The figure caption and axis labels were not very clear in Fig. 9. What is shown in the figure is the ratio of CDNC with MEGAN2 and LPJ-GUESS, as in CDNC(MEGAN2)/CDNC(LPJ-GUESS). We have rephrased the caption and figure labels in the revised manuscript.

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