

Interactive comment on “Distributions and climate effects of atmospheric aerosols from the preindustrial era to 2100 along Representative Concentration Pathways (RCPs) simulated using a global aerosol model SPRINTARS” by T. Takemura

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Dear Reviewer,

Thank you very much for taking your time to review our paper. Your comments are very helpful to making our manuscript better. We tried to revise our manuscript so as to answer to your comments. We wish this revised manuscript deserves to publication.

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1. [Comment] Page: 20521 Lines: 7-9 “A decrease in the cloud droplet size due to an increase in CCN results in an extension of cloud lifetime and then to an inhibition of precipitation (e.g. Albrecht, 1989).” The aerosol second indirect effect for warm clouds is introduced as straightforward concept while the effect of ice nuclei is reported to have both positive and negative effect on mixed phase clouds. Lebsock et al. (2008) show that increasing aerosol concentration may lead to a decrease in LWP in warm non-precipitating clouds. The sentence should be modified to reflect that uncertainty.

[Answer] Thank you for your suggestion for modifying the sentence. The following sentence has been added: “On the other hand, Lebsock et al. (2008) suggested from satellite observations that the higher aerosol concentration may lead to reduced liquid water path in nonprecipitating mixed-phase clouds.”

2. [Comment] The introduction cites several model studies on transient historical simulations, but none of the studies simulating future aerosol effects are mentioned. For example, Leibensberger et al. (2012) simulated effects of US anthropogenic sources for period 1950-2050 and Horowitz (2006) simulated aerosol concentrations from 1860 to 2100. Also the results section would be greatly improved if some comparison between this study and previous studies on future aerosol scenarios was provided. Please, include some references to other works that have simulated future aerosols and their radiative effects, compare your results to previous studies and discuss possible reasons for differences.

[Answer] The following sentence has been added to the revised manuscript in the introduction section: “On projecting future global aerosol distributions, Horowitz (2006) calculated them with the Special Report on Emissions Scenarios (SRES) which was used in the Third and Fourth Assessment Reports of IPCC. There are, however, no studies with the latest emission scenarios for estimating future aerosol radiative forcings.” The other sentence has been also added in discussion of Figure 4: “Horowitz (2006) using the SRES estimated that atmospheric BC and OC monotonically increase toward the end of the 21st century except in the scenario which has the smallest emission

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amounts (SRES B1) although burdens of sulfate aerosols have peaks in the mid-21st century in all scenarios. The future projections of atmospheric burdens and consequent radiative forcings and climate effects of aerosols are greatly different between applied emission scenarios.”

3. [Comment] How do the model's simulation of clouds and aerosol indirect effect compare with observations or other model simulations? This is discussed briefly in the results section, but some kind of summary in the model description part would be good. Are there large differences caused by treating only aerosol mass instead mass and number concentrations?

[Answer] In the original manuscript there is a sentence in the second paragraph of Section 6: “Changes in the liquid water path with changes in AOT are quantitatively similar to satellite retrievals in SPRINTARS (Quaas et al., 2009).” The following sentence has been also added to the first paragraph of this section in the revised manuscript: “A sensitivity of a change in the cloud droplet number concentration which is a basic parameter to estimate its radius to a change in AOT in the SPRINTARS are close to that from the satellite retrieval (Quaas et al., 2009).”

4. [Comment] Author could add an explicit description /summary of the simulations made. Was the simulation with pre-industrial emissions run for years 1860-2100 also?

[Answer] Thank you for your advice for the important information. The following paragraph has been added at the end of Section 2: “The past transient simulation from 1850 to 2005 and the future transient simulations with four RCPs from 2006 to 2100 are carried out in this study, which are the standard experiments (STD). The other experiments with continuous preindustrial emissions for aerosols and transient changes in other conditions along RCPs (AEROPI) are also done to analyse effects of changes in aerosol emissions on radiation and clouds by calculating differences with STD. The AF for the aerosol direct effect is calculated as a comparison of a difference in net radiation fluxes with and without aerosols by a double call of the radiation code between

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STD and AEROPI, i.e., ((STD with aerosols) – (STD without aerosols)) – ((AEROPI with aerosols) – (AEROPI without aerosols)). It is under the all-sky condition in this study. The AF for the aerosol indirect effect is defined as a difference in the cloud radiative forcing between STD and AEROPI.”

5. [Comment] Is adjusted forcing for a single simulation calculated by a double call of the radiation code with and without aerosols? If that is the case, then it should not be labeled adjusted forcing for a single simulation, because tropospheric state is not allowed to adjust. I understand that the term should be used for the difference between two simulations as the tropospheric state is different in eg., pre-industrial and RCP-simulations. In the text, “adjusted forcing” is used interchangeably with “\Delta adjusted forcing” which is a bit confusing. See for example, Figure 8 and page 20530 lines 7-8. The author should clarify how adjusted forcing from aerosol direct effect is defined and use the term consistently.

[Answer] The forcing in this study is an adjusted forcing as replying to the above comment. As you indicate, the expression “\Delta adjusted forcing” is confusing. The reference state (preindustrial experiment) is clearly described in each figure caption. Then it has changed to simply “adjusted forcing” in the revised manuscript.

6. [Comment] Is “adjusted forcing” calculated for all-sky radiation values?

[Answer] Yes. It has been described at the end of Section 2 as shown in the Answer 4.

7. [Comment] How is adjusted forcing from indirect effects calculated? This should be explained somewhere in the text.

[Answer] It has been also described at the end of Section 2 as shown in the Answer 4.

8. [Comment] Page 20529: lines 2-7 Can't there be some contribution of changes in the natural emissions to the AF even though sea surface temperature and sea ice extent are fixed? Are the wind speeds fixed also or are the changes in natural emissions negligible when sea surface temperature and ice cover are fixed?

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[Answer] The AF of the aerosol direct effect calculated by the method as shown in the Answer 4 does not include the influence of natural aerosols. A difference in the natural aerosols between STD and AEROPI in the estimation of the indirect effect can be negligible in comparison with a difference in anthropogenic aerosols. A phrase of the final sentence of the fourth paragraph in Section 4 has changed to "Note that these changes in natural aerosol emissions can be negligible for estimates of adjusted forcing (AF) provided in the following sections".

9. [Comment] Page 20532: lines 7-8 Being able to divide aerosol direct effects into contributions from different substances is a feature with bulk aerosol model. In internally and externally mixed aerosol population (in the real atmosphere) it would be impossible to make that kind of neat distinction. I think, that this should be briefly mentioned.

[Answer] The following sentence has been added: "These separations are expedient because many aerosol components interact each other in the real atmosphere."

10. [Comment] Page 20533-20534 AF from indirect aerosol effects is sometimes called just AF. It would be clearer if the distinction between direct and indirect effects is made every time term AF is used. For example lines 28-89 on page 20533-20534 say: "The year-to-year variations are, however, much larger than the variations due to the direct effect because the AF includes rapid responses from all aerosol effects, which affects the hydrological cycle."

[Answer] Basically discussion of the direct and indirect effects are separated into Sections 5 and 6, respectively. Therefore "AF due to the aerosol direct effect" and "AF due to the aerosol indirect effect" are omitted if not confused. However, they have been added in a few places including where you indicate.

Thank you very much for reviewing our manuscript.

Sincerely yours,

Toshihiko Takemura, Dr.

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