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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Global distribution and radiative forcing of soil dust aerosols in the Last Glacial Maximum simulated by the aerosol climate model" *by* T. Takemura et al.

T. Takemura et al.

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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.

[Major comments and answers]

1. [Comment] There are a lot of English mistakes throughout the text. Even if this does not generally prevent the text from being clear, these should be corrected before the text is finally published. Not being a native English speaker myself, I would suggest the

authors or the editors to have this manuscript carefully proof-read by a native English speaker (and scientist). I have listed suggestions of corrections in a special section at the end of this review. The abstract summarizes the content of the manuscript very well. It will read better once the language is corrected.

[Answer] Thank you very much for your polite English corrections. The manuscript was checked by a native speaker after revisions according to your corrections, then he told us that there are basically no problems in English.

2. [Comment] The introduction is, in my opinion, the least satisfactory section. It gives the impression of being imprecise, perhaps because of an uneasiness in the language. Expressions such as "assumed", "is thought to be" should be avoided. The review of previous work is generally good, but the work of some citations is sometimes not summarized. For instance, on page 20466, the work of Claquin et al. (2003) is acknowledged but not described. Also, to emphasize what is new in their study, the authors should clearly state that all the studies mentioned in the 1st paragraph of page 20466 only concern the dust distribution and not its radiative impact.

[Answer] The expressions "It is assumed that" and "though to be" have been deleted according to your comment. A sentence "They estimated its global and annual mean values to be about $-2.0\ \mathrm{W\,m^{-2}}$ at the top of the atmosphere without the indirect effect." has been added for the review of Claquin et al. (2003) in the revised manuscript. Also a following sentence has been added at the end of the 3rd paragraph of Introduction: "The past studies with simulations mentioned above concerned the dust distribution at the LGM, not its radiative impact."

3. [Comment] Model description: This section is fine, except that it includes, within the pure model description, a discussion of the vegetation simulated for the LGM. It would be better to reorganize the section with a description of the model first, and then a description of the boundary conditions for each experiment. These are not precisely given in the current manuscript. In particular, the authors do not precise if they use a

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perturbative method (imposing the LGM - pre-industrial anomalies onto the HadISST ocean surface conditions used in their CTRL) or if they directly use the LGM AOGCM output to force their atmosphere GCM. They should also comment on the length of the simulations (6 years) which appears to be quite short.

[Answer] The description on the vegetation has moved to the last second paragraph in Section 2. In this study, the AOGCM SST and HadISST are used for the LGM and control runs, respectively. We recognize that a bias of the LGM SST from AOGCM should be actually revised with the control SST from AOGCM and observed SST (HadISST). However, SST at the LGM is much different from that at the present climate, so that we think that the revision of the bias scarcely affect results in this study. One more reference, Otto-Bliesner et al. (2009) has been added for validating the PMIP2 SST within a range of an uncertainty of reconstructed data. The length of the simulation (6 years) is not generally short if SST and sea ice are prescribed.

4. [Comment] Aerosol emission, distribution, and deposition in the LGM: page 20470: the sensitivity experiment LGMfv, with all LGM conditions except for the vegetation which is set up at its present distribution is very interesting. If the authors really want to be complete, though, they should also run the complementary experiment, with LGM vegetation/land surface but present conditions for the meteorological factors. Indeed, there could be non-linearities in the combinations of the impacts of these two sets of factors!

[Answer] We tried the PRE simulation but with LGM vegetation, and obtained that about 40% of the increase in the dust emission is due to a difference in vegetation. This is almost the same result as LGMfv.

5. [Comment] Page 20472, end of 1st paragraph: could the bias in Antarctic deposition be related to the fact that the altitude of the Peltier ICE-5G 2004 ice-sheet reconstruction is probably over-estimated for Antarctica (cf. Masson-Delmotte et al, 2005)?

[Answer] We cannot suggest the relationship between the overestimation of the Peltier

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ICE-5G 2004 altitude and accuracy of the dust deposition flux. Our impression is that it is much difficult to simulate one order-of-magnitude larger dust deposition estimated from the reconstruction of the ice core in Antarctica at the LGM than in the present climate condition.

6. [Comment] Dust radiative forcing in the LGM: In this section, there is one missing element which could be of importance and is not discussed: does the dust deposition computed by SPRINTARS have an impact on the atmospheric model snow albedo? This is important for the surface radiative balance (e.g. Krinner et al, Climate Dynamics, 2006) and should be clarified.

[Answer] A following sentence has been added at the end of the 2nd paragraph of Section 2: "An effect of dust deposition on the snow albedo change is not included in this study."

7. [Comment] The authors should also better explain how (technically) they separate between the direct and indirect effects. Are there separate calculations in the model? To me the differences between the LGM and PRE indirect radiative forcing at the surface shown on Fig. 7 are not so obvious. It could help if the authors give more details on the regions for which they find the largest differences, or to show the difference in could cover?

[Answer] The direct radiative forcing is calculated through the aerosol scattering/absorption process twice at every time step in one simulation. Dust is excluded at the first and included at the second, then a difference in the radiative fluxes between them is the direct radiative forcing of dust. The indirect radiative forcing is, on the other hand, calculated by a difference in the cloud radiative forcing between two simulations with and without dust. Therefore the direct and indirect radiative forcings can be separated. These are standard methods for calculating the aerosol radiative forcing. The largest difference between Figs. 7c and d is the larger negative forcing in LGM than PRE, especially over the tropics, as described in the text. A change in cloud cover

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is included in the indirect radiative forcing because a change in cloud lifetime is the aerosol second indirect effect.

8. [Comment] Comment on tables 2-5: the results would be easier to grasp at a glance with histograms instead of tables. One summarizing figure using all the results from the different tables would be really good.

[Answer] Your comment is understandable. It is, however, difficult to show them with graphs because values are different in orders of magnitude among regions/latitudes but not so different between LGM and PRE in each regions/latitudes.

[Minor comments and answers]

9. [Comment] Page 20464, line 26: to reinforce the message of this sentence, the authors should state that the LGM top-of-the-atmosphere solar incoming radiation is very similar to the present incoming solar radiation.

[Answer] We think that the original expression is sufficient.

10. [Comment] Page 20465, sentence ending line 12: references?

[Answer] Petit et al. (1999) has been added as a reference of this sentence.

11. [Comment] Page 20466, line 4: a weak increase of what?

[Answer] "in the dust emission" has been added.

12. [Comment] Page 20466, line 16-18: this sentence is not clear and should be expanded.

[Answer] This sentence has been revised as follows: "Mahowald et al. (2006) indicated that low CO_2 concentration at the LGM resulted in expanding dust sources due to less fertilization of vegetation.

13. [Comment] Page 20466: which ocean-atmosphere coupled model?

[Answer] MIROC (CCSR/NIES/FRCGC AOGCM). This description is in Section 2.

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14. [Comment] Page 20468, lines 2-12: the description of the vegetation distribution should not be part of the model description. Rather, there should be a separate paragraph with the description of the boundary conditions used for the present and LGM experiments.

[Answer] The description on the vegetation has moved to the last second paragraph in Section 2.

15. [Comment] Page 20468, line 10-12: what is shown on Fig. 2 is the annual mean LAI, but aren't the emissions computed every day or even more frequently? This is not described in the model description or in Appendix A but is very important, given the large non-linearities of processes such as dust emissions.

[Answer] "The dust emission flux is calculated at every model time step." has been added as the last sentence in Appendix A. The standard time step is 20 minutes as described in Section 2.

16. [Comment] Page 20468, lines 19-20: would it be possible to compute the BC and OC natural emissions given the changes in vegetation/climate? Maybe this should be stated as a perspective to this work?

[Answer] A following sentence has been added: "Differences in BC and OC emissions from natural sources between glacial and interglacial periods should be considered in future studies."

17. [Comment] Page 20470, line 16: here it could be useful to remind the reader that a lower sea level results in more extensive exposed continental shelves.

[Answer] It has been revised from "because of the sea level falling" to "because of the more extensive exposed continental shelves resulting from the sea level falling".

18. [Comment] Page 20471, line 12: insert "mean" between "annual" and "dust column".

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[Answer] It has been revised according to your comment.

19. [Comment] Page 20474, line 6. add the PRE values for comparison.

[Answer] ", compared with close to zero at the tropopause and -0.2 W m^{-2} at the surface in PRE" has been added.

20. [Comment] Page 20475, line 18: include a quantitative estimate of the cooling induced by the dust cycle.

[Answer] A following sentence has been added: "The global and annual mean radiative forcing of the direct plus indirect effects due to dust is -0.9 W m^{-2} at the tropopause in LGM relative to PRE."

21. [Comment] Page 20475, final sentence: reformulate last sentence, it is not understandable in its present state!

[Answer] This sentence has been deleted in order to avoid confusion.

22. [Comment] Appendix A: The frequency at which the emissions are computed should be added here.

[Answer] "The dust/sea salt emission flux is calculated at every model time step." has been added as the last sentence in Appendix A/B.

23. [Comment] Title: to be replaced by "A simulation of the global distribution and radiative forcing of soil dust aerosols at the Last Glacial Maximum" or "Global distribution and radiative forcing of soil dust aerosols simulated by the SPRINTARS models for the Last Glacial Maximum period".

[Answer] We will ask an editor whether the title can change to "A simulation of the global distribution and radiative forcing of soil dust aerosols at the Last Glacial Maximum".

24. [Comment] Page 20464, line 20: I would not use "assumed". The authors can base their argument both on the available reconstructions (e.g. the recently published

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MARGO compilation) and on global climate simulations (e.g. PMIP simulations, Braconnot et al, Climate of the Past, 2007). This second sentence of the paragraph contains a lot of information (definition of the LGM, annual mean global cooling, regional cooling) and should be split up in separate, clearer, sentences.

[Answer] "It is assumed that" has been deleted. This sentence has been revised as follows: "The annual mean surface air temperature is 3 to 6 K lower on the global mean at the Last Glacial Maximum (LGM), which is about twenty-one thousands years ago, than in the present climate (Jouzel et al., 1993; Kucera et al., 2005; Masson-Delmotte et al., 2005; Wu et al., 2007; Otto-Bliesner et al., 2009). It is regionally about 3 and 10 K lower over the tropics and southern Europe, respectively."

25. [Comment] Page 20466, line 21: replace "compound" by "have an impact on"? The following sentence is difficult to understand and should be reformulated. The PMIP-2 experiments indeed never included dust potential impacts, concentrating on the atmosphere-ocean(-vegetation) response to the LGM boundary conditions. For more details, the PMIP2 web site (http://pmip2.lsce.ipsl.fr) and associated publication (Braconnot et al, 2007) should be given.

[Answer] I have replaced "compound" by "have an impact on". We just would like to state that the PMIP2 does not include dust potential impacts, so that "as well as the coupled ocean-atmosphere system" has been removed in order to avoid confusion.

26. [Comment] Page 20473, lines 12-15: reformulate the sentence. In particular, I don't understand "multiply absorb scattered solar radiation enhanced by the lower cloud layer than the aerosol layer". It might be useful to split this sentence into several sentences.

[Answer] It has been revised as follows: "because soil dust aerosols absorb the solar radiation scattered by the lower cloud layer than the dust layer as well as the direct solar radiation".

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27. [Comment] Suggestions of English language corrections.

Page 20464, move the "In this study" at the end of 1st sentence at the beginning of the sentence, replace initial "The" by "An" and "done by" by "performed with".

Page 20464, line 3: "simulation in the present..." to be replaced by "simulation for the present...".

Page 20464, line 8: "it might be" to be replaced by "it is" or "it appears to be".

Page 20464, line 10: replace "which are" by "which is".

Page 20464, line 13: replace "the indirect forcing" by "this indirect forcing".

Page 20464, line 19: replace "analyzed" by "reconstructed".

Page 20464, line 24: the expression "it is thought" should be avoided. Citation is adequate references would be more appropriate.

Page 20465, line 3, comma to be inserted after "reported".

Page 20465, line 4, comma to be inserted before "that".

Page 20465, line 17: insert "its" before "hydrophobicity".

Page 20465, line 19: remove "is also discussed" and replace by "is related to the absorption of solar and/or infrared radiation...".

Page 20465, line 24: insert "one" before "order of magnitude".

Page 20465, line 25: replace "data of" by "data from".

Page 20465, line 26: remove the "the" before "dust fluxes".

Page 20465, lines 28-29: replace "may assign the less precipitation" by "may be assigned to less precipitation".

Page 20465, line 29: add an "s" to "wind".

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Page 20466, 1st sentence to be replaced by "Several modeling studies have simulated and analyzed the soil dust...".

Page 20466, line 2: replace "demonstrated" by "investigated".

Page 20466, line 6: replace "considering variation" by "mostly due to variations".

Page 20466, line 8: insert "Indeed" before "Mahowald".

Page 20466, line 11: replace "a difference in vegetation..." by "a more realistic vegetation for the LGM" and "suggest" by "show".

Page 20466, line 13: polar regions (plural) and "suggested" after "Werner et al" for consistency of tenses in the paragraph. The present tense could also be used throughout the section.

Page 20466, line 18-19: move "mentioned above" after "previous studies". It "reproductivity" correct? Here it could be replaced, I think, by "understanding". Replace "by the simulations" by "by numerical simulations".

Page 20467, line 7: replace "understand reproductivity" by "evaluate the performance"?

Page 20468, line 7 and throughout the text: replace "sea level falling" by "the lower sea level".

Page 20468, line 29 and page 20469, line 11: replace "kind of aerosol" by "type of aerosol"?

Page 20469, lines 11-12: replace "ice crystal number concentration" by "ice crystals" and remove the "the" before "homogeneous".

Page 20469, line 17: remove the "the" before "Berry" and give the reference for Berry8217;s parameterization.

Page 20469, line 23: replace "prescribed with the simulated result by the CCSR..." by

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"prescribed from the results of the LGM simulation using the CCSR...".

Page 20469, line 25: replace "is based on PMIP-2" by "took part in the PMIP2 project" and give the references for the project as well as for the simulation.

Page 20469, lines 27-28: replace "reconstructed data of different proxies" by "climate reconstructions from different proxies", insert "to the" between "comparable" and "performance" and replace "to" by "of" after "performance".

Page 20469, line 19: remove "experiments".

Page 20470, line 3: insert "conditions" or "data set" after HadISST.

Page 20470, line 4-7: add "for the pre-industrial and LGM time slices" in each of these sentences, otherwise one could think that these parameters are set up in the same way in both experiments.

Aerosol emission, distribution, and deposition in the LGM: in this section title, either add "experiment" after "LGM" or replace "in the LGM" by "at the LGM". In the following sections, the article "the" should be removed when the authors refer to the numerical experiments ("In LGM" or "In PRE") or the words experiment/run should be added after "LGM" or "PRE": "In the LGM experiment/run", "In the PRE experiment". The article should be used when referring to the period: "At the LGM" for instance.

Page 20470, line 10: add an s at the end of Figure and remove the s at the end of shows.

Page 20470, line 11, remove the "the" before LGM or add "experiments" after the first "PRE". Same for the following occurrence of "PRE".

Page 20470, line 12: replace ";" by ":", add "over" before "the Sahara", add "the" before "Middle East" and before "Kalahari".

Page 20470, line 13: replace "into south" by "southward" and "into north" by "northward".

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Page 20470, line 14: remove the "the" before "Eastern Europe", remove "The" at the end of the line.

Page 20470, line 15: remove the "the" before "northern Siberia".

Page 20470, line 19: inset "a" between "estimated" and "2.2-fold".

Page 20470, line 26: replace "are assumed to be mainly due" by "could be due".

Page 20470, line 27: replace "strong wind" by "stronger winds".

Page 20471, line 2: replace "done" by "performed" or "carried out".

Page 20471, line 4: replace "others" by "other factors".

Page 20471, line 8: add an s at the end of condition and wind.

Page 20471, line 9: replace "The rations of contributing" by "These contributions".

Page 20471, line 10: replace "those in Werner" by "he computed by Werner".

Page 20471, line 11: add an s after "Figure" and replace "shows" by "show the".

Page 20471, line 14: insert "the" before "west", "those" before "from Asia" and "the" before "east". East and West should be capitalized.

Page 20471, line 15: larger in LGM than in PRE...

Page 20471, line 19: move "respectively" before "about".

Page 20471, line 22: remove "with being".

Page 20471, line 26: atmospheric conditions (plural).

Page 20471, line 27: add "the" at the end of the line.

Page 20471, line 29: replace ") which is estimated" by "), which estimates are".

Page 20472, line 1: replace "it is best database for understand the simulated results"

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by "it is the best database to compare the simulated results with".

Page 20472, line 2: replace "some uncertainty factors, for example," by "some uncertainties related to, for example, the fact".

Page 20472, line 10: replace "Also in the LGM, the simulation" by "Also, the LGM simulation".

Page 20472, lines 11-12: replace "except the Antarctic region" by "although it underestimates the fluxes over Antarctica".

Page 20472, line 12: replace "The isotopic measurement has" by "Isotopic measurements have".

Page 20472, line 20: replace "in spite of vice versa" by "contrasting with the behavior".

Page 20472, line 21: choose between "other" and "additional", add "the" before "underestimation".

Page 20472, line 23: replace "half of that in the present" by "half that in PRE".

Page 20473, line 2: replace "the stronger wind" by "stronger winds".

Dust radiative forcing in the LGM: title: same remark as for section 3.

Page 20473, line 10: replace "the all-sky condition" by "all-sky conditions".

Page 20473, line 15: remove "It has been known that" and insert "known to be" on line 16 between "is" and "much sensitive".

Page 20473, line 19: remove the "the" before "northern Europe" and add "the" in front of "Arctic ocean".

Page 20473, line 21: add "all" before "over the globe".

Page 20474, line 10: replace "shows" by "gives details on".

Page 20475, 1st sentence of concluding section. Move "In this study" at the beginning

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of the sentence, replace "were" by "are".

Page 20475, line 8: replace "present" by "pre-industrial".

Page 20475, line 9: replace "was" by "is".

Page 20475, line 11: insert "the" before "underestimation".

Page 20475, line 15: replace "was" by "is".

Page 20745, line 17: replace "suggested" by "suggest".

Page 20478, line 20: replace "The Berry's parameterization (Berry, 1967)" by "Berry (1967)'s parameterization"

Page 20479, line 7: replace "by the NIES computer" by "on the NIES computer"

[Answer] Thank you very much for revising our poor English. We have revised all of them.

Thank you very much for reviewing our manuscript.

Sincerely yours,

Toshihiko Takemura, Dr.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 20463, 2008.

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