**Climate
of the Past
Discussions**

Interactive comment on "Influence of dynamic vegetation on climate change and terrestrial carbon storage in the Last Glacial Maximum" by R. O'ishi and A. Abe-Ouchi

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Received and published: 15 March 2013

Dear anonymous referee

We would like to thank the reviewer for instructive comments and suggestions on our manuscript. We revised our manuscript for the purpose of better for understanding.

LPJ is a widely used model, also in paleo applications. In this respect, it would be important to emphasize in more detail how the present study and its setup are different from earlier works using LPJ. This could be done in the abstract, but it should be definitely included in the Introduction section.

-> In the present study, the new point is an introduction of bias-correction into the inside of coupled AOVGCM. We noted this point in the abstract and introduction. In the model description (2.2), we explained the method in detail and explained the benefit of the introduction of bias correction.

The last sentence of the Abstract should be rephrased, it is not straightforward to understand. -> This sentence was rephrased so as to be simple.

As the study covers several different aspects and uses different model setups and model components, it would be helpful to more clearly state the main goals and approaches of this study at the end of the Introduction section.

-> The most important aspect is climate and carbon reproduction by bias correcting AOVGCM. We made it clear in the Introduction.

Section 1 should mention that the "working horse" of this study is an AGCM with a slab-ocean component. This becomes only clear from the last sentence of section 2.1. From reading section 1, people might think of the "typical" PMIP setups using fully coupled AOGCMs with the ocean being represented by a comprehensive GCM as well. I am fine with the slab-ocean setup, but it should be stated much more clearly, maybe also together with a motivation why choosing this setup.

-> In section 2 (Model description), we explained why we choose the slab-ocean.

For readers who are no MIROC experts, it can be confusing whether MIROC is the coupled model or the AGCM only. This should be written in a clear and consistent way, in particular in section 2.1.

-> In section 2.1, we made it clear that MIROC is composed of AGCM and OGCM. We also explained that we use a slab-ocean instead of OGCM in our MIROC-LPJ.

The authors use the expression "separated DGVM experiments". I think such experiments are more commonly referred to as "offline" simulations. So I suggest to use this term throughout the paper.

-> We defined these experiments as "offline DGVM experiment" throughout the manuscript.

p. 5789 l. 8: I would add the MARGO paper (Nat. Geosci. 2009) to the Reference list.

-> Waelbroeck et al. 2009 is referred in the introduction.

p. 5789 l. 27 - p. 5790 l. 3: This should be rephrased for improvement. Also, mentioning published AOVGCM studies for the LGM requires a statement what is special about your new study.

-> These sentences are modified. We also added the speciality of this manuscript in the last paragraph of the Introduction

p. 5790 l. 25: "so that we could assume" - What do you mean by that? Please rephrase, e.g. into "we apply an AOVGCM to simulate the climate of the LGM, but in contrast to earlier studies, the vegetation feedback onto climate is included".

-> This sentence is rephrased to explain the introduction of bias-correction to the running AOVGCM is new to earlier studies.

Section 2.1 and 2.2: Since there is a section on its own ("Bias correction") in the paper, I would only mention the bias-correction procedure there and not yet in section 2.1 (line 11/12). What do you mean by "the GCM bias"?

-> We defined GCM bias as difference between GCM result and specific observation datasets. We also added detailed explanation of bias correction in section 2.2

p. 5791 l. 26 - p. 5792 l. 3: This is a bit hard to read. I would first describe how the model with fixed vegetation works and then describe what is different when coupling the model with the DGVM.

-> In section 2.1 we explained what the actually does in the "coupling" process and what is the difference with fixed experiments.

p. 5792 section 2.2: What do you mean by "control and present day"? Is "control" pre-industrial? "false response" could also be misleading as it should be consistent within in the model. Is the bias correction exactly the same for modern and paleo simulations, i.e. with the underlying assumption that the model bias is independent of the respective climate? As details on the bias correction are given in O'ishi and Abe-Ouchi (2011), it would be interesting to list two examples of regions most concerned by the bias in this section.

-> We added a figure without bias-correction in the Appendix. We also discussed about the validity and limitation of the introduction of bias-correction.

section 2.3: One could add the whole carbon model description to section 2.1 where LPJ and PFTs are already introduced. At least, all important elements of the model which will be discussed later (litter in Fig. 4) should be introduced here. Since quite some part of the discussion is on the separation of carbon storage (as outlined on p. 5791 l. 2-3), it would be important to introduce everything needed for this in the context of the model description.

-> We described detailed explanation of carbon balance and carbon storage in section 2.3 which is used for analysis.

p. 5793 l. 12: I would mention here which ice sheet version is used (ICE-5G?) and whether all the boundary conditions are following PMIP2/PMIP3 guidelines. It would be worth mentioning and interesting for all people aware of PMIP activities.

-> The setting in the present manuscript is not exactly same as that of PMIP. We described ice sheet, sea level, orbit and GHGs.

p. 5793 l. 16: Do you mean the vegetation map fixed in terms of PFT? Is the AOV equilibrium state a multi-year mean annual cycle (e.g. monthly means)?

-> In section 3.1, we described how we "fix" vegetation distribution. We just give a most frequent vegetation type of MIROC's land surface submodel.

p. 5793 l. 19: This confuses me, especially "using the LGM land cover". Do you mean the LGM distribution of ocean and land points? You should also add why you didn't take the mean LGM vegetation from the AOV (LGM) experiment.

-> We rephrased this sentence to " an offline LPJ-DGVM experiment is performed using the LGM coastline with the AOV(PI) result as input".

p. 5793 l. 23: what is meant by "after two AOV experiments"?

-> This sentence is rephrased. We just intended that both AOV experiments are well equilibriated.

p. 5794 section 3.2.1: You should definitely mention here which setup you are using here, e.g. "We performed three sensitivity experiments using the LPJDGVM in an offline mode. In order to compare the impact of...., in each of these experiments, one factor is set to the PI value..."

-> In section 3.2.1, we rephrased the sentence as your suggestion. We also added three new offline experiments as the other reviewer's recommendation.

p. 5794 section 3.2.1: It would be interesting to add the length of the sensitivity experiments to Table 2 and to the text of this section as well. Are you also showing results from the last 50 years of these experiments as stated at the end of section 3.1?

-> We added the integration time in Table 2. These results are shown in Figure 2 and Figure 3. We have shown these results from last 100 years result, because all output variables are well equilibriated at the end of 1000 years integration.

p. 5794 l. 11: With 400 years, are you referring to the length of the AOV (LGM) in Tab. 1?

-> We added "approximately" because we mention both AOV(PI) and AOV(LGM).

p. 5794 section 3.2.2: I am a bit confused by this experiment description. Did you actually perform several experiments with AO (LGM) input (line 19/20)? And what is

C3548

meant by using the last 50 years from the AOV GCM experiments and running the DGVM for the equivalent of 1000 years? Do you prescribe a climatological average or do you repeat 50 years forcing for 1000 years in total? Some reference for the "traditional offline diagnosis" (l. 21) also would be nice.

-> In section 3.2.1 and 3.2.2, we described that we used 20 times repetition of 50 years timescale as input of offline experiments. We have done an offline experiment by using AO(LGM)'s result. AO(LGM)'s offline result is shown in Table3 and Figure 7.

p. 5795 section 4.1: Are you referring to 2m air temperature as stated in the titles of Fig. 1?

-> We specified 2m temperature in both text and Figure 4 (the order of subsection in 4. Result and thus order of Figures are modified according to the other reviewer's suggestion)

p. 5795 ll. 14-15: Where do you derive from that 30% of the total cooling is vegetation-induced?

-> We just divided the contribution of vegetation by total cooling. This explanation is added in the text (section 4.2)

p. 5795 l. 23: If you didn't perform a statistical test, the word "significant" should be replaced.

-> We redraw Figures 4b and 4d with 95% significance. We omitted to show the significance in Figures 4a and 4c since it covers almost all area.

p. 5795 section 4.1: Please be careful with the description of your results. You want to distinguish pure LGM changes (such as Fig. 1a,c) from the effects of vegetation. The same is true for section 4.2 where you want to distinguish between the description of the general LGM changes and the changes due to a certain forcing factor on PFTs and NPP. Sometimes this seems a bit mixed and would benefit from organizing the discussion more along the figures.

C3549

-> We have redrawn most of our figures so as to focus on the effect of vegetation change in GCM results and effect of three factors in offline sensitivity experiments.

Section 4.2: Please be consistent in the wording. Fig. 2 caption says "potential vegetation", the legend lists the different PFTs, and in the text (e.g. p. 5796) you are using expressions like "tropical forest", "temperate forest".

-> Actually, the older classification is based on the land surface submodel. We renamed the classification in caption of Figure2 to more common terms.

p. 5796: discussion of NPP: If you are looking at global averages of NPP (l.16), shouldn't it have the same unit as shown in Fig. 3? Or are you showing an integral over the globe? Furthermore, I don't understand the "reduction of NPP" in the PI experiment (l. 19).

-> We mention a global total NPP (PgC/year) in the text and distribution of NPP (kgC/m**2) in Figures. They are described in the text and figure captions, respectively. "reduction of NPP" was a mistake. It is modified to "in AOV(LGM), ... reduction of NPP is seen ... compared to AOV(PI)"

p. 5796 l. 21: rephrase to "additional sensitivity experiments for the LGM using the offline LPJ-DGVM, but setting one of the forcing parameters to preindustrial values." This will provide the link to the experiment description.

-> This sentence was rephrased as your recommendation, but explains 6 settings.

p. 5797 l. 15: From Fig. 2e, it seems as if CO2 has a strong influence on Southeast Asia and Australia.

-> We added the influence of CO2 in the LGM based on 6 offline sensitivity experiments.

p. 5797 l. 20 and 24: I think it should be "additive" or "combined" instead of "nonlinear". Replace "these three variables" by "the three different forcing factors".

-> We chose the word "synergy" instead of "nonlinear". The latter sentence has been removed due to reconstruction of section 4.1 (4.2 in previous manuscript)

p. 5798 l. 1: rephrase into "Output from two AOV...were chosen as input for the offline LPJ model (see Table 1 last column)." I don't understand the sentence in ll. 2-4 and the expression "after the AOGCM result" in l. 4.

-> These sentences are totally rephrased and simplified.

p. 5798 section 4.3: I would suggest to present the difference numbers in a modified Table 3, so that it becomes immediately obvious which differences between experiments you are talking about.

-> We modified Table 3 as your suggestion. The absolute value is only shown in AOV(PI) result.

p. 5798 l. 12: At some points, you mention the equivalence of terrestrial carbon reduction to CO2 emissions to the atmosphere. A reference for the conversion between the two numbers would be helpful. Zickfeld et al. (2011), for instance, use 0.48 for the conversion between PgC and ppm.

-> We used 0.47 from Enting 1992. We also referred Zickfeld et al. (2011).

In section 2.3, the types of carbon storage and carbon pools are mentioned (p. 5792) but seem a bit decoupled from the discussion in section 4.3 and Fig. 4 (where different expressions in the Figure titles and captions are used, e.g. litter). Please use consistent terms to present your arguments.

-> We added the definition of biomass and soil carbon in section 4.3.

p. 5800 ll. 11-12: Is it really possible from your set of experiments to draw this conclusion (albedo most important factor)? This also refers to p. 5803 l. 3.

-> YES, albedo is the most important. We added vegetation contribution to surface energy balance in Figure 6 to explanation this result in section 5.1

p. 5800 ll. 14-16: I find this sentence confusing.

->This sentence is rephrased and a new figure (snow cover) is added in Figure 5.

p. 5800-5801: You announce three reasons for the overestimation of boreal forest (l. 21), but I only find two.

-> In this case, "three" is correct. We added the third reason in the text.

p. 5800 l. 28-29: This is an important information for the section of model description, since it also helps to correctly interpret Fig. 2.

-> We explained this limitation of MIROC-LPJ in the model description (section 2.1).

p. 5801 l.1: Please be more precise, "using variables" is very general. This is also true for p. 5803 l. 10 ("using separate dynamical vegetation modules with GCM variables").

-> These sentences are revised to more precise expression.

p. 5801 ll. 8-9: How do you estimate the 1-2 C change with a change in the fractional land-surface scheme? This would require additional experiments. Also

-> We just estimated by interpolation between cooling over forest and cooling over tundra in the LGM. This is explained in the manuscript.

p. 5802 l. 15: Did you perform additional experiments with a moderate (howmuch?) sea-level change?

-> No, we just estimated proportionally to the moderate extended shelf area. This is explained in the manuscript.

Please be consistent in using acronyms (e.g. AOV, AOVGCM and AOV GCM) and LGM throughout the paper. Sometimes, it is not completely clear what you are referring to by either using "LGM" for the climate state or instead of the experiment name AOV (LGM). This holds for the text, but also for the caption of Fig. 1. Another example would be p. 5801 l. 3. Please revise the manuscript with respect to adding figure references in the

text. This would point the reader directly to the figure being discussed.

-> We revised the name of experiment such as AOV(LGM) with different font throughout the manuscript. We just use "LGM" and "AO(V)GCM" as an acronym.

Fig. 1: What happens in the white areas of Fig. 1a? Furthermore, I am not completely sure about what is shown in Fig. 1f.

-> We have redrawn Figure 1a with 2K contour. We removed Figure 1f.

Fig. 1c: Why is there an impact of vegetation on the albedo response in regions covered by the continental ice sheets?

-> It is due to reduction of precipitation which reflects weakening of global water cycle due to cooling induced by vegetation change. This explanation is added in the manuscript.

Technical corrections and other minor suggestions -> These following points are revised as your suggestion.

- Abstract l. 6: replace the 2nd "level" by "concentration" - Abstract l. 11: "The result shows..". "that" is missing here. - p. 5789 l. 10: replace "than it is in the present-day" by "than at present-day" - p. 5789 l. 25: replace by "using vegetation models with GCM results as input" - p. 5789 l. 25/26: consistent with what? - p. 5791 l. 14: The AGCM acronym has already been introduced earlier. - p. 5792 l. 6: delete "points"; l. 10: delete "problem of" - p. 5792 l. 23: Do you mean "in the coupled MIROC-LPJ"? - p. 5793 l. 2-3: should read "integration years" and "in a coupled MIROC-LPJ setup" - p. 5793 l. 8: "In the pre-industrial control experiment...." - p. 5793 l. 9 and 11: I would prefer "orbital parameters" to "orbital elements" - p. 5793 ll. 17-20: I would split this long sentence. "Land cover ...present day. Thus, in order to...." - p. 5793 l. 21: I guess you mean "land grid cells". - p. 5795 l. 8: I would write "The global distribution of temperature..." - Section 6: This section could be slightly shortened, as it repeats some parts (e.g. around p. 5803 l. 15 and p. 5804 l. 6) - Fig. 4: For the caption,

I suggest "....obtained from LPJ forced by a)..." In general, the manuscript contains a number of typos and minor language errors. The manuscript should be improved in this respect. Interactive comment on Clim. Past Discuss., 8, 5787, 2012.