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Geoscientific Model Development Discussions

Interactive comment on "Modelling the mid-Pliocene Warm Period climate with the IPSL coupled model and its atmospheric component LMDZ4" *by* C. Contoux et al.

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We thank the reviewer for his useful comments, which have improved the quality of this manuscript. We answer to the Comments/clarification and minor changes/technical corrections below.

COMMENTS/CLARIFICATION

Introduction, page 517, lines 10-19

Various proxy data, e.g. delta 18O data from marine cores, do not indicate a record of continuous, sustained warmth for the period suggested, in fact providing us with ev-

idence of high (global) climate variability. How can you justify the modeling for such a (climatologically) long time period, which additionally seems to be quite heterogeneous?

The question of the reviewer is highly relevant, and the further step in the PlioMIP project is to focus on a shorter time period, a time slice, possibly around 3.2 Ma, which would be related to a precise orbital configuration. Oxygen isotopes in foraminifera depict some climate variability from 3.3 to 3 Ma. This variability is partly driven by orbital forcing with a dumped effect due to a weaker polar amplification. The mid Pliocene warm Period is a period of warm climate on the global and the major reasons for targeting this period are further developed in Haywood et al., 2010. In particular, it is important for modellers to have a substantial amount of data, and it is more difficult as you go back in time. The PlioMIP time slab phase has allowed the gathering of a substantial amount of data, in particular for SSTs. Climate simulations with different orbital configurations into the PlioMIP time slab have been tested (Dolan et al., 2011). Now, the project will move to a better definition of the forcings for more realistic simulations, choosing the period which will allow us to keep the more data possible. Since the mid Pliocene period is globally warmer than any interglacial, and occurred just before the onset of Northern Hemisphere Glaciation and the glacial-interglacial driven climates, it is certainly an interesting target for paleoclimate modellers. We added this last sentence into the text of the introduction.

Model description, page 519, lines 5-7

The description of land ice included in ORCHIDEE is not used when coupled to the atmosphere. What are the consequences given the fact that LMDZ accounts for the land ice instead? The mid-Pliocene ice sheets drastically differ to modern configurations (e.g. Hill et al. 2007). How do you treat the two different ice configurations in the Pliocene vs. modern scenarios? How does this impact the results of this study?

This sentence will be removed, because it is confusing. In each of our simulations, the land ice is treated by the atmospheric component. Land ice is treated by ORCHIDEE only when it is used offline, like a dynamic vegetation model forced with climatic outputs. Hence, there are no consequences of LMDZ treating the land ice, it is always treated like that in a coupled simulation. In LMDZ there are 4 types of surfaces: land, land ice, ocean, or sea ice. In our simulations, ice sheet extent is prescribed, and cannot vary during the simulation. LMDZ then calculates the radiative forcing and hydrology cycle above the land ice. As the reviewer said, mid-Pliocene and modern ice sheets are different. For the modern scenarios, in AGCM and in AOGCM, modern ice sheets are imposed. For the Pliocene scenarios, AGCM and AOGCM, PRISM3 ice sheets are imposed (see Haywood et al., 2010, 2011). For the Pliocene scenarios, regions where ice sheets are removed are replaced by the corresponding plant functional types from the PRISM3 vegetation reconstruction (Salzmann et al., 2008). This is included in the Pliocene scenario boundary condition for vegetation. Climate in the regions where ice sheets are removed compared to the modern is modified due to the changes in albedo (from ice sheet to the replacing vegetation or bare soil) associated to the topographic changes due to the removal of ice sheet, which is included in the PRISM3 paleotopographic reconstruction from Sohl et al., 2009. Both effects modify the temperature and hydrological cycle in these areas. We added the sentences “For the modern scenarios, in AGCM and in AOGCM, modern ice sheets are imposed. For the Pliocene scenarios, AGCM and AOGCM, PRISM3 ice sheets are imposed (Hill et al., 2007; Salzmann et al., 2008; Hill, 2009). For the Pliocene scenarios, regions where ice sheets are removed are replaced by the corresponding plant functional types from the PRISM3 vegetation reconstruction (Salzmann et al., 2008)” in the Boundary conditions section, page 521, line 27, for better understanding.

Experimental design, page 520-522

For the AGCM experiment the authors prescribe SSTs. How are SSTs handled by the atmospheric component of the model? Fixed or slab-ocean component? Comment on the consequences of choosing one or another? How does this compare to other

models in the PlioMIP framework and comply with the guidelines of PlioMIP? Please clarify.

We thank the reviewer for this comment, we indeed did not precise which components of the IPSL model were used in the atmospheric simulation. For the AGCM experiment, SSTs are fixed. There is no slab-ocean. We followed the PlioMIP guidelines described in Haywood et al., 2010. A majority of PlioMIP groups used AGCMs with fixed SSTs (see Kamae et al., 2012; Chan et al., 2011, Yan et al., 2012, all in this special issue). Our AGCM results are comparable to their results. Another publication will provide an intercomparison of all mid-Pliocene simulations within the PlioMIP framework. Most models provide a global warming with large sensitivity from model to model, even with prescribed SSTs. In the Model description section, page 518, line 2, we added the sentence “For the atmosphere-only simulations (AGCM), the ocean and sea-ice components are not used, SSTs and sea-ice are imposed.”

Experimental design, page 522, lines 1-3

BIOME4 data set consists of 28 data types, which are converted using 11 plant functional types. Explain potential consequences for the interpretation of simulated temperatures and other variables associated with an information loss of vegetation types?

Imposing a vegetation set to different modeling groups is challenging because each might use different ways to implement vegetation in their model. Some of them use the Biome classification, other use the Plant Functional Type (PFT) classification. For Biomes, there is only 1 Biome present in a grid cell of the model. For PFTs, several PFTs can coexist on one grid cell (for example Temperate Broadleaf Raingreen trees and Natural C4 grass). If you examine Table 1, each Biome corresponds to a unique combination of PFTs on one grid cell. By this way, we aim to preserve the more information possible. For this reason, we provide a lot of information on the change from 28 Biomes to 28 combinations of 11 PFTs. Changing vegetation from Control to Pliocene impacts particularly surface albedo. In order to better compare the differences between each modeling group's vegetation, we decided, thanks to the reviewer's comment, to add a figure of the surface albedo for the Control and the Pliocene. We also changed "11 PFTs" to "28 combinations of 11 PFTs" in the Boundary Conditions section.

Experimental design, page 522, lines 14-15

For the AOGCM experiment, the integration time is set to 50 years. By consulting Figure 5, the last 50 years show high variability. How do the results (e.g. mean annual surface temperatures, precipitation) change when the results are based on a longer (>150 year) time period?

The comment of the reviewer on the length of the simulation is appropriate. Unfortunately, when the deadline occurred for submitting this paper (February 1st), we could not provide a longer climatological integration period than 50 years, because the previous years were part of the spin-up (400 years, as stated in Haywood et al., 2011). We had compared 30 year means to 50 year means, and no significant changes were noticeable. Now, we have a 650 years simulation, and we provide a more realistic time integration and new figures for the AOGCM. Climatological means are still performed over a period of 50 years, because the model still seems to be slowly warming. Climatological means can only be performed if the model is in equilibrium or close to equilibrium. For this reason, even with our new 650 years simulation, we cannot perform longer than 50 year means. Climate between this new integration (years 600 to 650) and the old one (years 400 to 450) is a little warmer (+0.3°C in surface temperature). The same global and regional patterns can be noticed. About variability, for information, we provide here some key variables and their mean values over the last 50 years (600 to 650) compared to the last 100 years (550 to 650) of the simulation: Variable 50 year mean 100 year mean

Surface temperature °C 15.19 15.16

Total precipitation mm/day 2.785 2.782

Sea surface temperature °C 18.03 17.99

Sea surface salinity psu 34.35 34.35

TOA net down radiative flux W/m^2 0.69 0.715

Results, page 522, 526

Some figures do include significance testing (as indicated by dotted areas). Add notion to those performed tests and the consequences for the stated results into the text section.

Figures do not include any statistics, they are the direct results of the climate model. You may refer to the color bar below the figures.

Results, page 523-524

The authors are discussing the potential causes and mechanisms behind simulated precipitation results. This discussion could be included in a separate (new) discussion section. While I appreciate the detailed dynamical discussion of simulated precipitation patterns, it should be included in a new section, together with (at this point) missing discussion of temperature mechanisms and causes (section 4.1.).

Yes, it is very pertinent to suggest a discussion section. We added this section and move in the discussion about precipitation patterns, and added a discussion about temperature mechanisms and causes.

Results, pages 522-526

The authors had the advantage of running AGCM and coupled AOGCM experiments for the Pliocene and preindustrial scenarios. The authors should also include and discuss a direct comparison of the atmosphere-only vs. coupled model results. Use the results in Table 2 where significant differences are apparent between AGCM and AOGCM results.

We added discussion of the difference between AGCM and AOGCM in the new discussion section.

Results, page 525, lines 21 to page 526, line 2.

Additional sensitivity tests are performed by the authors and are very valuable. In the abstract the authors highlight those tests. Nevertheless, this section falls short later in the results section.

We thank the reviewer for this relevant comment. We added at the beginning of the section “The change in sea-level is likely to be changing climate in coastal areas. Notably, we are interested in its impact on Antarctica, because it is the region most impacted by the sea-level rise (Fig. 1).” We also added at the end of the section “It seems that, at least as simulated with LMDZ5A, the 25 meter sea-level rise could have an impact on the ice sheet melting, because some areas are subject to an increase in temperature. However, there is no precipitation change over the polar regions, a small sea-level rise might not affect the growth of the ice sheet. Meanwhile, precipitation patterns are impacted in the tropics, namely, it increases over the Caribbeans and in Indonesia, precipitation increases in the Southern part while it decreases in the Northern part, probably because of the land-sea distribution change (Fig. 1). This issue could be further investigated using a coupled AOGCM which would calculate the SST and sea-ice change correlated with a 25-meter sea-level rise.”

MINOR CHANGE/TECHNICAL CORRECTION

Abstract, page 516, line 13

The authors are presenting annual temperature anomalies relative to control runs. However, this is not explicitly stated in the “Abstract”. Add for clarification.

We changed the sentence to “The simulated warming relative to the Control simulations is 1.94°C in the atmospheric and 2.07 °C in the coupled model experiments”.

Abstract, page 516, line 15

The authors state that “precipitation has a different behavior in the coupled ...”. The wording needs to be more specific here.

We changed the sentence to “Mechanisms governing the simulated precipitation patterns are different in the coupled model than in the atmospheric model alone.”

Introduction, page 517, line 16

“ . . . more and more interested . . . ”. Please rephrase (style).

We changed the sentence to “On their side, modellers show increased interest in simulating the mPWP.”

Introduction, page 517, line 17

Add comma after “. . . Chandler et al. (1994)”

Done.

Model description, page 518, line 2

Remove the word “together”

Done.

Model description, page 518, line 9

Replace “is” by “are”

Done.

Model description and experimental design, page 517-522

Introduce PlioMIP guidelines and definitions of “preferred” and “alternate” files for atmosphere-only and coupled runs right at the beginning of the methods section. This would help the reader to understand the tests performed for this intercomparison and puts the model description into context.

I understand what the reviewer's feeling is about this. The change of land-sea mask is already introduced in the abstract, and we added two sentences at the end of the introduction "We present simulations of the mid-Pliocene climate carried out with the atmosphere-ocean general circulation model (AOGCM) of the Institut Pierre Simon Laplace (IPSL), and with its atmospheric component alone (AGCM). The boundary conditions used are the ones used in the PlioMIP framework (Haywood et al., 2010, 2011). We also present a sensitivity test to the change of the land-sea mask in the atmospheric model, representing a 25 meter sea-level rise." The change you suggest would imply that a part of the "boundary conditions" section would go before or into the "model description" section. I think it might affect the structure of the paper and the reader comprehension.

Experimental design, page 521, line 15

". . . anomaly method. . ." Detail or at least reference to Haywood et al. 2010, 2011.

The anomaly method is detailed in the sentences afterwards, line 17-25 Âń For topography, the difference between the mid-Pliocene topographic reconstruction (. . .) was added to the IPSL model SSTs". We changed the sentence line 17 to "Both experiments use the anomaly method for implementation of topography and SSTs, as stated in Haywood et al., 2010, 2011."

Results, page 523, line 3

Change "Himalaya" to "Himalayas"

Done.

Results, page 525, line 10.

". . .are a very interesting feature. . ." Rephrase. Be more specific.

We removed this sentence. The discussion about this topic was also moved to the discussion section and rephrased differently.

Results, page 526, lines 5-6

". . ., and so does model results." change to ". . ., and so do model results."

Done.

Table 1

What is the basis for creating the percentiles?

Basis for creating the percentiles is a conversion made by Gerhard Krinner, also used in Krinner, G., A.M. Lézine, P. Braconnot, P. Sepulchre, G. Ramstein, C. Grenier, and I. Gouttevin (2012), A reassessment of lake and wetland feedbacks on the North African Holocene climate, Geophys. Res. Lett., 39, L07701, doi:10.1029/2012GL050992. We added this reference in the legend of table 1.

Figure 3

Anomalies are more telling than absolute values. Add spatial differences anomalous to modern.

With the anomaly method, the imposed anomaly of SSTs is the same for each PlioMIP group. However, the absolute SSTs implemented are different for each group because we might have different modern SSTs (reminder: imposed SST = (Pliocene_PRISM – Present_PRISM) + Present_local). This is why we decided not to present the anomaly but the absolute temperature, the anomaly being shown in Haywood et al., 2010.

Figure 5

Label all x- and y- axes appropriately.

Done.

Figure 7

The figure depicts regions of significant results (dotted). Please indicate method of calculating the significance in caption. Also add to discussion in text (section results).

There are no statistics included on the figures. Refer to the color bar.

Figures 11 and 12

Combine?

Combined. We also changed the prior figure 12. It is now the difference between the SST warming simulated with the AOGCM and the imposed AGCM SST anomaly.

Interactive comment on Geosci. Model Dev. Discuss., 5, 515, 2012.