

Interactive comment on “On the mechanisms of warming the mid-Pliocene and the inference of a hierarchy of climate sensitivities with relevance to the understanding of climate futures” by Deepak Chandan and W. Richard Peltier

Anonymous Referee #2

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Major comments

Although this paper presents valid results, I must say that the paper left me at times very confused. I find the paper verbose, unnecessarily long while at the same time unprecise and messy (in particular in the introduction). As a consequence the potentially interesting results do not strike out. The contribution of Pliocene climate models to estimations of long term climate sensitivity have already been explored by Lunt et al. and Haywood et al. The authors here investigate these concepts with different boundary conditions, in particular a closed Bering Strait, and add new concepts of climate sen-

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sitivity over different time scales. Additionnally they explore the mechanisms leading to a warming in the UofT model in response to PRISM4 boundary conditions. These mechanisms are similar to previous studies on this topic, which makes sense.

I recommend a thorough rewriting with a focus on being concise and precise, removing all repetitions and unnecessary considerations. In particular, the introduction needs a complete re-writing in order to give the reader some perspective on what has already been done in previous studies on the mechanisms of warming in climate models (e.g. Hill et al Clim Past 2014) and the estimations of climate sensitivity/earth system sensitivity (e.g. Lunt et al., Nature Geoscience 2009 ; Haywood et al., Clim Past 2013). Then you can eventually say in which ways and with which method your study is going to fill in the gaps. The discussion as well needs rewriting, to avoid repetitions and put their results in better perspective compared to previous studies. Also, describe the results in the results section, not in the discussion (e.g. page 31, lines 1-8)

Remove the part around reversing climate in the introduction, which is very confusing and unnecessary.

About the fact that ice sheet is considered in a part of the results as a factor which has "evolved independently" from CO₂ and topography changes... Well, this is completely unconceivable... The precise cause of the absence of Greenland ice sheet before the late Miocene is due to low topography, with several phases of uplift during the late Miocene and Pliocene (Solgaard et al., PPP 2013) after which some ice starts to appear, also seen in IRD records (Jansen et al 2000, Kleiven et al 2002) Then an important inception of Greenland ice sheet occurs due to decline in pCO₂ at the end of the Pliocene (Lunt et al., Nature 2008), which probably took several tens of millenia according to variations in insolation (Contoux et al., 2015). Nothing mysterious there... Please remove that part, or rephrase accordingly.

The great absence in this paper is the changes to the land surface. If I understand correctly, you have imposed Pliocene vegetation and Pliocene lakes in your model, for

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all experiments which includes "orography" changes. Although it is clearly visible that the PRISM4 great African lakes (MegaChad, Okavango) have an impact, locally, on air temperature (figure 5c, 5d, 7c), you never mention this in the text. Vegetation is never mentioned either, it is not even clear if it is imposed or coupled. Please say a few words about the impact of these boundary conditions as far as you can, because you can't separate them from topography changes if I understand well. This last point should also be mentioned ; your analysis of orography changes includes in fact vegetation and lakes (maybe you mentioned it and I missed it) ; so if you want to state that the changes are due to topography only, you first have to demonstrate that the changes due to vegetation&lakes are of second order.

Specific comments

1/ Abstract, 1rst sentence : the authors state that the Pliocene climate has "supported the same magnitude of global warmth as that which has been projected for the climate at the end of the 21rst century when pCO₂". This sentence gives the impression that the Pliocene was a period during which temperatures have risen, which is not true, as the authors explain later in the introduction. Please rephrase accordingly, stating something like "during which temperatures were 2° to 3°C higher than the preindustrial, which is of the same magnitude as the warmth expected for the end of the 21st century"
2nd sentence : "these mechanisms explore changes to the ..." ? This formulation is not understandable. You can explore the mechanisms of change ; but can the mechanisms explore the changes ? Did you mean "these mechanisms explain changes" ? In which case, explain what mechanisms you're talking about, otherwise it's really mysterious.

2/ Page 2, line 1 : "the mid-Pliocene warm period (~3.3 Mya)". The mid-Pliocene warm period is not centered around 3.3 Ma which is precisely the date of the MIS M2 glaciation. The mid-Pliocene warm period has been defined in PlioMIP1 and 2 as lasting from roughly 3.3 to 3 Ma. The specific "time slice" of PlioMIP2 is the warm MIS KM5c interval at 3.205 Ma, not the glacial MIS M2 at 3.3 Ma.

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3/ Page 2, line 24 : "the onset of Pleistocene glacial-interglacial cycles $\sim 1\text{Ma}$ ". The onset of glacial-interglacial cycles is the beginning of the Pleistocene at 2.6 Ma. The transition from 40-kyr glacial-interglacial cycles to 100-kyr glacial interglacial cycles occurs at roughly 1 Ma.

4/ Page 2, last paragraph : from then on the introduction was difficult to understand, feeling more like the authors are listening to themselves, while lacking to explain in brief words the different concepts of climate sensitivity (among others). I have rarely seen an introduction with so few references. I have read about 10 times this last paragraph on page 2 and beginning of page 3 until line 10, but it can't seem to make sense to me given that the climate system, and in particular ice sheets have hysteresis trajectories and multiple equilibria (see eg Abe-Ouchi et al Nature 2013).

5/Page 3, line 33 : "what are the mechanisms through which the Pliocene warms ?" You cannot say that because the Pliocene doesn't warm. Replace by : "What are the mechanisms through which the UofT model warms in response the mid-Pliocene boundary conditions ?" (replace also accordingly in the discussion or, better, avoid the repetition of the questions...)

6/Page 4, first paragraph : this can be fixed in one sentence : mid-Pliocene climate is considered to be in equilibrium with its forcings. Second paragraph : please remove. This paragraph is unnecessary, it just repeats that your Pliocene simulation fits with the data, but you have already said that page 3, line 21.

7/ Page 4, model description ; The resolution of the model (atmosphere and ocean) should be mentioned in the model description. Is vegetation imposed or fully coupled ? Although you say here that all components are fully coupled, in your previous paper your state that the dynamical vegetation as turned off. Please precise, this is very important. Has the model been validated for the preindustrial ? There should be some reference for the validation of the UofT version of the model for the modern climates (and eventually other climates ? LGM, Mid-Holocene...)

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8/ Page 7, lines 25 to 30 : these two very long sentences can be removed, or replaced by "to save computer resource" in the next sentence.

9/Page 9, lines 18-19 "due to power dependence... would require eight additional simulations, 24 additional simulations". You already said that page 8 line 21, and earlier by stating you need 2^N simulations.

10/Page 15, lines 10-19 : this is unnecessary to my opinion.

11/Page 18, line 6 "sum to 3.87°C" I wonder where you take that number from, as I have not managed to calculate this from numbers in Table 5. Lines 19-20 "the other 46% comes from the increase in atmospheric water vapour as a result of changes in topography and ice sheet" This is the result of your EBM and is certainly true. However, I really wonder how changes in topography and ice sheet can lead to an increase in atmospheric water vapor, except via the fact that they cause a warming and thus lead to more evaporation ? Am I right ? Can you explain in the discussion please ? Also, the changes in sea level (included in topography) and ice sheet were ultimately caused by CO2 increase, so even if water vapor effect is important following ice sheet and topography changes, some of these changes were initially caused by CO2 increase. I think it is important to be very precise here because a lot of people read our papers even outside the scientific community.

12/ Page 23, line 31. Here the authors cite Pagani et al 2010 as a reference for "observationally-derived ESS estimates". Pagani et al do not have "observations" of Pliocene temperatures, they have proxies. Please replace by "proxy-derived ESS estimates" or another formulation

Good luck.

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