Clim. Past Discuss., 9, C2857–C2863, 2013
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Climate of the Past Discussions

# *Interactive comment on* "Uncertainties in the modelled $CO_2$ threshold for Antarctic glaciation" *by* E. Gasson et al.

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Received and published: 10 December 2013

This study focuses on the important topic of the uncertainties in the CO2 threshold for Antarctic glaciation. The approach of testing different climates simulated by Eocene-based GCMs on an ice sheet model is appealing, the research is timely and the results should be published. However, I do have some comments that I would like to see discussed before publication of the final CP paper.

General comments

1) How well do the modern climates of the same GCMs represent a realistic modern Antarctic ice sheet? Preferably by forcing Glimmer, and using the same set-up as for the Eocene simulations.



2) How do the ice-free conditions in the GCMs affect the threshold results? How different would the GCM climates be if there was an intermediate or large ice sheet considered? Please discuss.

3) Orbital parameters:

- For the GCMs ran with different orbital parameters: which orbital setting is used in your equilibrium and transient simulations?

- HadCM3L does not simulate a different ice volume due to different orbital settings, but this is because it has too warm temperatures in general in order to grow an ice sheet. How large are the variations in ice volume, due to insolation changes, as simulated by GENESIS?

- Or the other way around: how uncertain are the CO2 thresholds of Fig. 11, due to different orbital settings, and resulting different ice volumes?

4) The CO2 thresholds can possible be better defined if we know which model represents the Eocene best. Which of the GCM simulated climates fits best to Eocene proxy data? I know there is not much data available, and you do not need to repeat Lunt's EoMIP paper (Lunt et al., 2012), but some discussion is needed.

5) I find the order in the paper confusing. This will be largely improved when the GCM climates (temperature, precipitation/snow fall, and seasonality) - the input for the ISM - are discussed before the equilibrium and transient simulations, and not afterwards.

Specific and technical comments

Title should acknowledge the fact that the results are based on GCMs with Eocene boundary conditions.

(page.line) 5702.3: name the ice sheet model used

5703.5: "... ice-sheet and climate modelling studies..."

5703.8: "... glaciation of 2.8 x pre-industrial CO2 concentration (PIC) (∼780 ppmv)..."

5703.13-15: mention glaciation threshold values of references

5704.9: "ISM model description"

5704.10: "... in this paper. The mechanics ..."

5704.12, 17: what do you mean with "whole ice sheet ISMs"?

5705:1: why is there no basal sliding? Not prescribed or not occurring? Is there no bottom melting either?

5705.1-2: "... 20 km, and all simulations..."

5705.5: vertical lapse rate is not a feedback, but a correction

5705.7-8: not only due to spatial discrepancy, but also for (vertical) topography differences between ISM and GCMs, or?

5705.19: Emphasize that only the climate forcing and the GCM topographies are different. All other boundary conditions (also PDD factors and lapse rate adjustment) are the same in all simulations, right?

5705.27: "... by e.g. DeConto and Pollard..."

5705.28: delete one "we"

5706.4: "thermal subsidence and plate movements": how did they account for those? Or mention/quantify how they changed TOPO1 to TOPO3/TOPO4 due to thermal subsidence and plate movements.

5706. 5-6: skip sentence, as it repeats sentence before

5706.16: what is area of TOPO2?

5707.2-8: move to a new section "Simulation set-up" or to end of 2.3.



5708.20: not all paleo-climate are so uncertain as the Eocene/Oligocene. Rewrite.

5708.21-22: "100 member" – which parameters are perturbed? Make clear that the one selected out of this 100 is the one that shows the best agreement to the proxy data.

5709.1: All sections 3 include discussion, so call this "Results and discussion" and change 4.1 to 3.6.

5709.10-13: And where does ice nucleate for CESM1.0 forcing?

5709.15-20: That sounds plausible, but GENESIS has even lower climate sensitivity and in contrast has an even larger ice difference between 2 and 4xPIC. Please explain.

5710.3-5: Change sentence. 4xPIC HadCM3L has no ice.

5710.21: Change "To" to "The"

5711.13-19: Rewrite scaling explanation, is not clear. You linearly scale between 2 and 4xPIC, and extrapolate beyond that range, right?

Include info from Supplement in paper. You can show the table and discuss the other info. The table would be clearer is you just show the extrapolated values, and in brackets the difference to the "control" values.

5712.18: Change to "Sensitivity to lapse rate adjustment and topography"

5713.17: - Mention default value at the start of the section.

- You repeat the simulations with CCSM3_H and GENESIS forcing, not the GCM simulations itself, right? Clarify.

5713.29-5714.4: Did they allow for changes in (land) albedo?

5714.26: "... topography (Fig. 7)..."

Section 3.4: Please rewrite this section; it is too vague & long

5715.13-14: Change to “It is not immediately clear why there is such variation in ice volume caused by the different climate forcing”

5716.24-25: move explanation temperature half range up to 5715.20

5715.27-28: Change to “The lack of ice in the simulations using HadCM3L (and FAMOUS) is a result of ablation exceeding precipitation.”

5716.1: Mention variables

5716.22-23: Change to: “simulations which cause the main restriction in ice growth.”

5717.1-2: Change to “lowest annual mean air temperature, but at the same time also the lowest precipitation and the highest annual air temperature half range.”

5717: You mention that you’ll determine whether the low precipitation or high seasonality causes the HadCM3L results, but then you continue with comparing annual mean vs half range temperatures. Bit confusing, please rewrite.

Fig. 8: Would be much clearer if you do not just show snowmelt, but the difference between snowmelt and snow accumulation, so that it is directly clear is ice can be sustained or not.

5718.15-17: rewrite to “. . . other simulations, and nucleates on Victoria and Wilkes Land instead of Queen Maud Land and the Gamburtsev Mountains.”

5718: “variability from this mean”. Please explain.

5718: last section. Can you redo Fig. 8, taking into account elevation lapse rate adjustment?

Section 3.5: - This section could fit better in the beginning of the Results section, or even in 2.3.

- Also, clarify that this is the global picture, not just Antarctica.

2719.6: What do you mean with “annual temperature range”? The seasonal cycle,



max/min temperatures, monthly mean or daily? Or transient annual mean temperature variations (guess not)?

5720.14: “significant”: how did you define this as significant?

Fig. 9&10: You can reduce the number of panels by plotting the North and South views in one map.

5720.14-15: FAMOUS has a different seasonality over Antarctica.

5720.16-20: What is so different in the HadCM3L boundary conditions, compared to the other EoMIP models?

5722.1-5: “replacing the East Antarctic ice sheet”? I thought there was no Antarctic ice sheet included in these GCM simulations?

Change 4.1 to 3.6

5721.15: Change to “. . . glacial CO2 threshold is . . .“

5731.18: Mention also the model results plotted in Fig. 11.

5722.10-11: Delete

5722.11: Change “coupled” to “compared”

5724.11-26: The isotopic composition of the Antarctic ice sheet is not constant, but depends on the size and climate (maybe Fig.7 in Langebroek et al. (2010) is useful). How does that change your computation?

5725.6: “less than 1xPIC”, be more precise

5725.27: add “. . . are correct.”

5726.5: Change “recent” to “previous”

Table 2: Maybe you can include the number of PDD for each model. I guess HadCM3L has many.

Fig. 1B: Why not show the higher resolution bedrock that is actually used?

Fig. 2: - Include total ice volume values.

- “Bedrock/bathymetry scale as in Fig. 1”

Fig. 3: Include total ice volume values.

Fig. 4: Colour the symbols same colour as the corresponding lines.

Fig. 6: Enlarge legend. Change titles to “HadCM3L – ISM” etc.

Fig. 11: - Change time direction for paleo scientists. - Check colours (is PD2005 brown and pink?) - Include (if possible, at least for GENESIS), uncertainties due to different orbital settings.

References

Langebroek, P. M., A. Paul, and M. Schulz (2010), Simulating the sea level imprint on marine oxygen isotope records during the middle Miocene using an ice sheet–climate model, Paleoceanography, 25, PA4203, doi:10.1029/2008PA001704.

Lunt, D. J., Dunkley Jones, T., Heinemann, M., Huber, M., LeGrande, A., Winguth, A., Loptson, C., Marotzke, J., Roberts, C. D., Tindall, J., Valdes, P., and Winguth, C.: A model–data comparison for a multi-model ensemble of early Eocene atmosphere–ocean simulations: EoMIP, Clim. Past, 8, 1717–1736.

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Interactive comment on Clim. Past Discuss., 9, 5701, 2013.