

Interactive comment on “Comparing transient, accelerated, and equilibrium simulations of the last 30 000 years with the GENIE-1 model” by D. J. Lunt et al.

Anonymous Referee #1

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Summary

The submitted manuscript briefly describes results of different simulations with an earth system model of intermediate complexity (EMIC). The results are the model's equilibrium response to constant boundary conditions as well as the transient simulation of the climate of the last 30,000 years, where the varying boundary conditions are prescribed with different time acceleration factors of 1 (no acceleration) to 10. Using an effective EMIC, the paper enlightens strengths and limitations of the novel (and yet sparsely applied) method of accelerating the boundary conditions in long paleoclimate

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modelling studies. The conclusions, in case these are applicable for similar EMICS — and moreover for higher resolution coupled circulation models (AOGCMs) — are of substantial relevance for paleoclimate modellers. The paper is clearly outlined and well written. It is of interest for a broad audience of paleoclimatologists and thus well within the scope of CP. Nevertheless, the arguments as well as the presented results are not yet mature enough to be published in the current form. I suggest to publish the manuscript after major revisions.

Major Comments

In general, the presented results in the paper are not sufficient to convince the reader that the conclusions are reasonably justified. Particularly, it is not evident to what extent the results are relevant for other models, apart from the specific coarse-resolution EMIC that is used for the experiments described in the paper. Comparing hypothesised accelerated AOGCM simulations with paleodata it is concluded that "the Northern Hemisphere is likely to be more robust than the Southern Hemisphere". In the current form of the paper it could not be ruled out that this result may be related to:

- a somehow linear response of the model to the changing boundary conditions;
- a misleading behaviour of a subcomponent of the model, like sea ice;
- the usage of a specific set of tuning parameters of the model;
- the specific resolution of the model.

Non-linearity: There is a lack of information about the transient behaviour of the ocean dynamics. Is there any change in the meridional overturning circulation

(MOC) during the transient simulations by GENIE? The response of the global mean deep ocean temperature to the boundary conditions seems to be at first order linear (Fig. 3). Do North Atlantic deep water and Antarctic Bottom water production rates react to the changing atmospheric temperature and P-E forcing fields as these are changing in response to the varying ice sheet and CO₂ boundary conditions? Or are these rates nearly constant?

Sea ice, particularly in the Southern Hemisphere: see no. 11. of specific comments.

Tuning: Why is the model that is used for the experiments considered as "untuned"? Why is the "tuning of the model to the modern climate underway" and not yet done? Is this the reason, why results of the preindustrial run are neither shown, nor precisely cited. There is no comprehensible reason that a (moderate) tuning exercise in order to improve the simulated preindustrial climate could not be done before publishing this paper.

More arguments are necessary to assess the transient performance of the GENIE model in comparison with state-of-the-art coupled AOGCMs, like the HadCM3. In this context, some more results of the preindustrial run of this efficient model would be very interesting. Specifically a few key variables from the subsystems, such as P-E, sea ice thickness, MOC, could be shown and compared to those of the HadSM3 as well as HadCM3 models.

Specific Comments

1. page 269, line 24 (p269l24): The model contains more information than global mean temperatures, which are worth to be examined. As long as large-scale areas are considered (e.g. tropical Pacific, extratropical North Atlantic, central

- Asia), the development of a climate variable in such an area is of interest in order to compare the model's result to more complex models, predominantly with coupled GCMs comprising the atmosphere, the ocean as well as sea ice, like the HadCM3 (or other models participating in PMIP2).
2. p271109: The $\delta^{18}O$ record of Petit et al. (1999) from the Vostok ice core is interpreted as a temperature proxy, not as a proxy for ice volume. The relevant record that was used to prescribe the ice volume time series could be reproduced in the paper. Otherwise it must be explained precisely which data record of the Petit et al. paper is used for the forcing.
 3. p272115: Why is the preindustrial simulation not shown? Here, a figure from a control (preindustrial) run of GENIE and a rough comparison with actual data (Levitus, reanalysis) is necessary to assess the model's performance. Relatively large departures from present (industrial) data are tolerable for such efficient models, but the major shortcomings should be reported in more detail. Furthermore, the relation to former papers is not clear. Which set of parameters of Edwards and Marsh (2005) is used in this paper? Is the deviation of SST from the Levitus et al. (1998) data set, shown in Fig. 5 of Edwards and Marsh (2005), similar to that of the GENIE-model? This should be clarified.
 4. p272117: Please, explain the ENTS land-surface scheme (acronym is not described). Does this mean that the climatology of this model version is preliminary and worse than the one with a more simplistic vegetation-scheme? How is vegetation represented in the model? In p270110 is stated "that the land model is run with prescribed vegetation", what does that mean exactly? Apart from the ice sheets (which albedo is used there?), does any prescribed value for vegetation characteristics, such as albedo, roughness length, or soil water capacity, change in time for the 30 kyr run? Values for ocean diffusivity and the factor for the windstress-scaling used in the model simulations should be specified.

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5. p273l01: Why was the sea-land-mask not changed in the model, at least where the glacial ice sheets were present? In such a relatively simple model this could be done without extreme efforts. Considering Fig. 2, this could improve the model response substantially with respect to the HadSM3 model.
6. p272l07: The sea ice distribution for the two time slices should be shown and discussed here!
7. p273l18: Specify all four RMS values!
8. p273l20: Caution, I am not convinced that the "model does a good job" (perhaps reasonably well-done). Furthermore, low- and medium-resolution GCMs are generally not able to simulate well "local" effects. Interpretation of their response should be limited to more or less 'large-scale' response.
9. p273l26: The arbitrarily considered global mean temperature is not an adequate value to be used for the length of the spin-up integration, because large erroneously warmer and colder regions (e.g. on both hemispheres) could eliminate each other. A similarly simple but better-chosen parameter could be the RMS temperature deviation.
10. p275l04: Why is the response of the deep ocean temperature so similar to the ocean surface (in the global mean)? Here, more regional analysis or some snapshots of temperature profiles would be very interesting. See also major comments.
11. p275l18: Is it really the deep mixed-layer in the Southern Ocean simulated by the GENIE-model which produces the damping in the system. From Fig. 4a it could be assumed that the largest warming occurs with respect to changing sea ice, perhaps in response to erroneously thin or lacking sea ice around Antarctica. A figure illustrating the difference in sea ice distribution could clarify this

point. Additionally, Southern Ocean temperatures at intermediate depths as well as convection depth could be displayed.

12. p276l10-17: Here, a discussion of the influence of changing MOC when using different acceleration factors is missing. A possible rearranging deep ocean circulation during the period from the last glacial to the Holocene implicating strong climate change is reasonable and evident in models and proxy data (e.g. Duplessy et al. 1988, Grootes et al., 1993, McManus et al. 2004). This can cause completely different water masses in the global ocean which are affected by the acceleration due to the relatively short time of a potential reorganisation of the circulation and the very long time-scale of the mixing processes. A few sentences on this topic are necessary.
13. p277l09: "tuning of the model to the modern climate" is underway: how does this fact bias the model results of this paper? What is the difference of this model to the tuned version that is described in Hargreaves et al. (2004).
14. p280 Fig.1: axes labelling larger and more accurately (" 3×10^4 ")
15. p281 Fig.2: enlarge this figure as well as Fig 4; revise colour coding! It is very difficult to detect the different colours. The usage of a smaller number of but more distinct colours and isolines (e.g. $+50/22/18/14/10/6/2$ degrees for Fig 2a,b) would greatly clarify the temperature anomalies of the figures.

Minor Corrections

- a) p270l02: GENIE — write out acronym.
- b) p270l07: "(Williamson et al., 2006)" or "(Williamson et al., in press)" should work.

- c) p270l09: "has 8 equal log(z) vertical levels" — spaces are missing.
- d) p273l11: "The reason for ... is an intensification of ... monsoons, which results in" singular s for reason or intensification.
- e) p276l24: "(Heinrich, 1988)" not 1998.
- f) p278l26: Specify reference: Clim. Dyn. 26, 687-711.

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