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Climate of the Past Discussions

Interactive comment on "Modelling ocean circulation, climate and oxygen isotopes in the ocean over the last 120 000 years" *by* R. Marsh et al.

R. Marsh et al.

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We thank reviewer 2 for a thorough review, and we look forward to improving the paper accordingly. Below we outline our response to each group of comments. We agree with most of the comments. In order to thoroughly revise the manuscript, we will need to largely re-run model experiments. Although regrettable in terms of required effort, no other course of action is appropriate.

1. Model Setup In terms of glacial-interglacial cycles, the most important boundary conditions that determine the mean climate state are the atmospheric pCO2 concentration and the ice-sheet distribution and elevation (Hansen et al, 1984; Rind, 1987). We include both of these first-order forcings. The reviewer is correct that the winds and

vegetation are also likely to be important, but they are certainly second-order effects. Not varying the vegetation also allows direct comparison with PMIP-1 models which also used the Peltier ICE-4G ice sheet reconstructions for the LGM. Other changes like the land-sea mask and ocean bathymetry are probably third-order effects. We include the orbital changes, as these are simple to implement, but these are also likely to be third-order, certainly in terms of global annual means. Again, this also allows a direct comparison with PMIP-1 models.

In the revised version, we will include a clarification of the way in which vegetation and ice-sheets interact as the ice-sheet waxes and wanes. In fact, an expanding ice sheet simply overlays any vegetation present, which then re-appears, unchanged, as the ice sheet retreats. This allows, as the reviewer imagines, both trees and icesheets within a single gridbox. The gridboxes in the model are relatively large, so this is not as unlikely as in higher-resolution models. However, allowing the vegetation to alter in response to the evolving ice sheet is again a second-order effect.

In the revised manuscript we will more thoroughly explain the reasons for our choices of boundary conditions, with reference to the implications. We will no longer include results obtained with the alternative (traceable) parameter set, but we will supplement this with an alternative run in which one crucial parameter (Atlantic-Pacific moisture flux adjustment) is tuned to render the THC less stable, which should control the timescale of THC weakening/collapse under MWP forcing and lead to more DO-type variability (see response to Reviewer 1). Finally, our model set-up and boundary conditions in the period 0kA - 30kA is identical to that of Lunt et al (CotP, this issue), and we wish to retain this correspondence for clean comparison with their work.

2. Control Climate In a companion paper submitted to the same Special Issue of Climate of the Past (Lunt et al. 2006), the realism of LGM climate simulated with GENIE-1 (using the same parameters) is more thoroughly investigated. Instead of repeating this evaluation, we will reference their work in a revised version. In the revised manuscript we will consider showing the Atlantic MOC for glacial time-slices, and evaluate LGM

climate more critically and with reference to available reconstructions. We will pay particular attention to the presence of absence of AABW in the model. The 10°C cooling in Antarctica is mainly an orographic effect as the ice sheet is nearly 1 km thicker in some places at the LGM (see Fig. 4d), and the environmental lapse rate (-6.5°C/km) dictates that surface air temperature is accordingly lower. This will be explained in the revised manuscript.

3. d18O forcing Reviewer 1 raises similar concerns. We reiterate our response in brief here. To account for changes in surface ?18O, we will consider additional relaxation of surface delta towards values consistent with local surface salinity, according to the established delta O-18 - Salinity relationship, ensuring that the global-mean effect of this relaxation (on delta O-18 in surface waters) is zero. Whether this approach proves successful remains to be determined. If we are unable to "simply" include the effect on oceanic delta O-18 of changes in E-P+R (linked to changes in salinity), we will discuss the implications for our results and conclusions.

4. Sea-level & d18O forcing We will endeavour to carry out new experiments in which the ice sheet forcing and delta O-18 forcing are consistent. This will not be straightforward, but we agree with the reviewer that it is necessary. We will also reduce the magnitude of MWPs, especially hypothesized to be of Antarctic origin (see also response to comment of Reviewer 1)

5. Statistical relationship between oceanic cores and model Once we modify the ice sheet boundary conditions, guided primarily by the Siddall et al. (2003) sea-level reconstruction, we expect an even better agreement between simulated and measured delta O-18 of calcite at the three selected core sites. In particular, we expect better agreement in the first 20 ky, based on the large reconstructed fall in mean sea level over this period. We will furthermore run an experiment with a less stable THC, which may feature multi-millennial variability in response to episodic MWP forcing (albeit weaker in the proposed new scenarios). We agree with the reviewer that our correlations are misleadingly strong due to the dominance of the glaciation-deglaciation, and we will try

CPD

2, S616–S619, 2006

Interactive Comment

removing this to evaluate correlations between simulations and core measurements at timescales corresponding to MWP forcing.

Minor Concerns We will omit Figure 2. We will filter the Siddall et al. (2003) reconstruction and add to this changes in sea level implied by our hypothesized MWPs. This sea level curve will be consistent with the revised glacial/evaporative delta O-18 forcing and will be superimposed in Fig. 3b. We will investigate use of the NGRIP record. We will show LGM streamfunctions. We will scale MOC time series plots for clarity.

References Lunt, D. J., Williamson, M. S., Valdes, P. J., Lenton, T. M., and R. Marsh (2006) Comparing transient, accelerated, and equilibrium simulations of the last 30 000 years with the GENIE-1 model. Submitted to Climate of the Past.

Interactive comment on Clim. Past Discuss., 2, 657, 2006.