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Climate of the Past Discussions

Interactive comment on "Interhemispheric coupling and warm Antarctic interglacials" *by* P. B. Holden et al.

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We thank the referee for these detailed comments and agree that the manuscript will be greatly improved by addressing them. The referee's principal concern is with respect to the experimental design. We believe that all three experiments contribute usefully to the argument. In summary:

i) the 800 kyr simulation provides a transient validation of the model over a wide range of forcing scenarios, clearly illustrating the difficulties of simulating warmer-that-present Antarctic Interglacials but nevertheless demonstrating significant meltwater-forced Antarctic warming (up to $\sim$1.5°C) at times which coincide closely with observed transient warming,

ii) the TII ensembles provide an evaluation of the uncertainty that arises from structural, parametric and boundary condition sources. We believe that results from an Intermediate Complexity model which do not provide an error analysis of this sort should be treated with caution.

ii) HadCM3 simulations are required to test the robustness with respect to structural shortcomings of GENIE, in particular the lack of a dynamical atmosphere and the use of a simplified snow scheme. The HadCM3 simulations also suggest the potential importance of a bias to the ice core isotope signal that would arise in the (possible) absence of WAIS, resulting from increased summer precipitation.

We now address the specific concerns in more detail. The referee is not convinced of the merit of including the long transient simulation. We believe that this simulation adds greatly to the manuscript. Firstly, it demonstrates that GENIE-1 (together with the imposed transient boundary conditions) is sufficient (in general) to reproduce g-ig temperature change at the diverse locations of the Antarctic and the North Atlantic over 800,000 years, effectively providing 800 time-slice validations of the model in different climate states. Critically, this simulation demonstrates that the model fails to reproduce Antarctic warmth that is significantly greater than present at any point in time. This failure takes on a far greater significance in view of the success of the model elsewhere in the record. Although similar conclusions have been reached from simple energy balance considerations, and are suggested by the high correlation between Antarctic temperature and CO2, the corroboration with a complex model is useful (and has not, to our knowledge, been performed before). Secondly, and arguably more importantly for our specific purposes, the long simulation demonstrates that the timing of meltwater forcing, as inferred from the benthic δ18O stack, is highly consistent with the Antarctic transient warming observed during recent interglacials and interstadials. The magnitude of the bipolar warming in this single simulation, although insufficient to fully reconcile model with observations, is certainly not insignificant. It is worth noting that this warming mechanism can only be robustly simulated with a 3D ocean model. GENIE-1

is ideal for this purpose, providing the computational efficiency that is necessary for both this long simulation and for the ensembles of simulations.

Although, as noted above, the referee is correct that the magnitude of the observed warmth in this single simulation is insufficient to explain the ice core record, an important aspect of this work (which the revised manuscript will discuss in more detail) revolves around the fact that all models, irrespective of their complexity, contain both structural and parametric errors so that the detail of a single simulation cannot be regarded as robust. As such, we disagree with the referee's statement "...proving that the mechanism suggested by the authors in the abstract do not enable to achieve the required warmth." Rather, the application of an ensemble (which has been explicitly designed to address parametric and structural error, Holden et al 2009) is performed in order to better address the issue of "proof".

Ensemble EFW does not invoke WAIS retreat. This ensemble demonstrates a large uncertainty in the meltwater forced Antarctic warming ($1.6\pm1.0^{\circ}$C, 1σ). Within the ensemble, Antarctica warms by as much as 2.6°C above pre-industrial, leading us to conclude that "the possibility that WPTs could be explained without a substantial WAIS retreat feedback appears unlikely but cannot be ruled out". The "no WAIS" ensemble was performed to investigate uncertainties associated with potential WAIS retreat. WAIS retreat at terminations has been simulated in ice-sheet models (even in the absence of the bipolar forcing). The likelihood of WAIS retreat during at least the Last Interglacial is well known and is supported by several lines of independent evidence. The purpose of the EWAIS ensemble is to provide some quantification of the uncertainty associated with this feedback.

As requested, we will provide a more thorough description of the degree of reconciliation and uncertainty associated with each of these mechanisms.

Other points:

We agree that the manuscript would benefit from a more thorough coverage of the

existing literature. We note that the manuscript does not claim that the idea of bipolar warming during interglacials is a new one as the referee states: i.e. p2558 (5-8) "A recent climate model simulation...implicating the bipolar seesaw as a possible driver of transient warmth in MIS5.5 (Masson-Delmotte 2009)" and p2558 (3-5) "abrupt shift in Chinese speleothem...further suggesting a role for the bipolar see-saw at terminations (Kelly et al 2006)". However, we agree that more detail would be useful and will provide this.

We agree that more detail on the models would improve the paper and will address this in detail in the revised manuscript.

The North Atlantic core was included to demonstrate that i) millennial variability in the North Atlantic is simulated, essential to demonstrate a degree of robustness, and ii) the issue of absent warmth is confined to the Southern Hemisphere. As the manuscript is focussed on g-ig changes arising from changes in Atlantic circulation, we feel that a discussion of e.g other ocean basins or terrestrial proxies is beyond the scope required for our arguments.

We will address the more detailed comments and include the additional citations that have been suggested.

Interactive comment on Clim. Past Discuss., 5, 2555, 2009.