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Interactive comment on "A technique for generating consistent ice sheet initial conditions for coupled ice-sheet/climate models" *by* J. G. Fyke et al.

J. G. Fyke et al.

fyke@lanl.gov

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Reply to reviewer 1 comments

General comments and responses

We thank the reviewer for their comments. We agree that showing that a transient spin-up results in an improvement is not a new result (and we now note this explicitly in the paper). We also realize that the reader might be interested in maps of the actual SMB and temperature (SMB/T) fields used - we now include these. However, along with these figures, we emphasize that this development-oriented manuscript is meant to present and evaluate the transient spin-up procedure and not an evaluate of the

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coupled climate model itself (which is implied by evaluation of the SMB/T fields). Furthermore, the climate model CESM is currently undergoing rapid development, such that current CESM-derived SMB/T fields have already changed significantly from those shown here. It is for this reason (to avoid a full analysis of the CESM, and focus on an evaluation of the implemented spin-up procedure) that we chose the inter model comparison between the transient and equilibrium spin-up simulations as the main focus for evaluation. This solely evaluates the impact of including the transient spin-up technique on the preindustrial ice sheet, the difference of which would (to first order) persist despite changes to the absolute SMB/T input due to the evolving CESM simulated climate. Finally, we note that while an evaluation of a spin-up simulation without the mid-Holocene climate included would be quite interesting, we felt that inclusion of such an exercise would be just one of many such interesting sensitivity experiments involving tweaking the spin-up procedure, that would detract from a basic description of the main 'all-in' spin-up simulation (and how it was produced). As such, with the reviewer's permission, we chose to leave this experiment out.

Specific comments and responses

REVIEWER: Not necessary to emphasize that a transient approach is better - this has already been demonstrated. Rather, for a reader trying to understand the coupling approach, it would be more interesting to see information about SMB/T fields for various time slices

We agree with the reviewer, in that the fundamental utility of a transient spin up is certainly not a new finding on our part. We have included the following paragraph in the section "Comparison of transient spin-up to equilibrium spin-up at 1850" to highlight that the transient simulation is performing as expected (e.g. similarly to previous transient spin up procedures).

"A comparison of the final preindustrial state of the transient spin-up simulation to the final state of the equilibrium spin-up simulation clearly highlights the impact of integrating a realistic climate history into the ice sheet spin-up procedure. Importantly, we note that the fundamental utility of a transient spin-up in improving preindustrial ice sheet states has been well-demonstrated previously (e.g. Huybrechts, 1994). Here, we identify improvements of the transient spin up relative to the equilibrium spin up simply to show that the particular transient spin-up method we have developed is performing as expected (e.g., by improving the final state of the preindustrial ice sheet relative to the equilibrium spin-up simulation), despite the novel nature of the forcing technique which allows for consistency within a coupled climate model framework. ."

REVIEWER: Surprised that authors used parameters from an optimized equilibrium simulation

We have expanded the paragraph in the text describing why we used parameters derived from an optimization exercise using equilibrium simulations in the following manner:

"The ice sheet model had previously undergone a perturbed-physics analysis to determine a set of ice sheet parameters that corresponded to an optimal steady-state GIS geometry under constant preindustrial climate (Lipscomb et al., 2013). We adopted these parameters for the present study, as they provided the best estimate of an optimal parameter combination despite their generation using an ensemble of equilibrium simulations. A full implementation of the spin-up technique (demonstrated here with one simulation) will involve a large computationally intensive ensemble of transient spin-up simulations and subsequent selection of optimal ensemble members(e.g. Applegate et al., 2012). We chose not to undertake this effort for the present study, which is meant primarily as a test of the feasibility of the transient spin up procedure, and not a full optimization exercise to identify optimal preindustrial parameter combinations."

REVIEWER: Replace 1850 with 'preindustrial', so that the specific year is not important

Done, we agree with the overly specific nature of year 1850. We could have stopped the simulation at any time.

REVIEWER: Clarify "end-member" terminology

We have attempted to clarify what we mean by 'end-member climatologies' in all occurrences, especially early on in the manuscript when the terminology is introduced.

REVIEWER: add sentence or two to justify approach to initialization, since it is quite specific

We have added verbiage in the Introduction and Conclusion that further justifies the effort to make a new initialization method.

In the Introduction:

"These issues point to a requirement for alternate methods for generating spun-up ice sheets driven by conditions generated with integrated energy balance calculations from within coupled models that have deep internal memories of the past glacial climate state, yet grade at shallower depths to states that are fully consistent with the warmer climate of the recent past. Such a method will be required for dynamically/thermodynamically consistent initial conditions in coupled ice-sheet/climate model predictions of future ice sheet and sea level response to climate change. To address these specific requirements, we have developed and evaluated one such approach with the Community Earth System Model (CESM).

A summary of this paper is as follows: we first detail important aspects of the SMB and ice sheet models, the general procedure for generating transient SMB forcing for the last glacial period and how this forcing drives an ice sheet model. We then we demonstrate the ability of this method to simulate a transiently spun-up preindustrial ice sheet that exhibits: a) dynamic and thermodynamic memory of past climate, yet: b) is consistent with simulated preindustrial CESM climate model state and shows notable improvement relative to an equivalent equilibrium spin up simulation. Finally, we discuss potential future ice sheet and climate model developments that could further improve the transiently spun-up preindustrial ice sheet state and briefly contrast spin-

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up of ice sheet models against inversion-based initialization methods in the context of coupled ice-sheet/climate modeling."

In the Conclusion:

"We have described and demonstrated a new procedure for generating a preindustrial preindustrial ice sheet state for use in fully coupled ice-sheet/climate models. The procedure generates an ice sheet state that is consistent with simulated preindustrial climate forcing but also contains a consistent thermodynamic memory of climate-model-simulated paleoclimatic conditions. As a result, the effect of past climate on future ice sheet evolution is captured while non-physical trends in the ice sheet component of future ice-sheet/climate simulations are avoided. This capability allows for creation of consistent ice-sheet/climate conditions that can be used to initialize coupled model simulations of future ice sheet and sea level change. "

REVIEWER: 'Climate-derived bias' is too specific - SIA models well-known to produce too much volume

We agree with the reviewer that the SIA model used here could also be responsible for some of the excess ice volume. We should be able to test this shortly with higher-order ice sheet models under development. We have explicitly noted this possibility in the text. However, in a previous analysis (in Lipscomb et al., 2013) we showed fairly convincingly that SMB biases are mainly responsible for excess ice - for example, the coupled model gets positive in-situ SMB in much of the presently ice-free marginal coastal areas of Greenland. So even with a 'perfect' ice sheet model, it is almost certain we would still get excess ice growth.

REVIEWER: Consider plotting the temperature difference with GRIP to better highlight reduction in mismatch

We tried plotting the difference as the reviewer suggested, and decided to retain the original figure, despite the fact it doesn't do as well at highlighting the improvement

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between modeled and observed profiles. This is because retaining the absolute temperature profiles allows the reader to better see the absolute shape of the profiles, including the cooling at mid-depths for the transient and observed profiles.

Interactive comment on Geosci. Model Dev. Discuss., 6, 2491, 2013.