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Climate
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Discussions

Interactive comment on "Simulation of the last glacial cycle with a coupled climate ice-sheet model of intermediate complexity" *by* A. Ganopolski et al.

Anonymous Referee #1

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This paper applies the coupled CLIMBER-SICOPOLIS climate-ice sheet model to the global climate and Northern Hemispheric ice sheets of the last 125 kyr glacial cycle. It extends previous applications of earlier model versions to the last glacial inception, and adds several new features, mainly glaciogenic dust and radiative dust forcing. In the absence of a carbon-cycle component, greenhouse gas variations are prescribed in terms of equivalent CO2 amounts. Reasonably realistic ice-sheet variations are achieved with the nominal model, including ice volume time series, and individual ice extents at LGM (and modern), comparable in quality to previous results using simplified climate models.

1. The addition of a simple model for glaciogenic dust is significant, following Mahowald et al. (2006a)'s finding that it was a major source of the LGM dust load. The formulation in Appendix A would benefit from more discussion, addressing: a. In Eq. (A1), this dust source is proportional to M, the annual surface ice melt. Does this mean that the source is literally englacial debris that melts out on the ice surface? Or more reasonably, is M a proxy for basal outwash, with the main dust source being basal debris and sediment flushed out by merging basal streams? As it is, the formulation seems circular, with dust both being deposited onto the ice-sheet surface by Q/tau in (A2), and simultaneously being released (from the ice surface?) proportional to M in (A1). b. The formulation in Appendix A does not include deposition and long-term accumulation of dust on ice-free land (Q/tau term in (A2) for such points). Significant amounts could accumulate, which could then be redistributed by winds onto the ice. This is presumably the equivalent of loess, and if added to the model, could be validated against today's observed glaciogenic loess distributions. c. Alongside Fig. 8, it would be interesting to show the relative amounts of glaciogenic vs. non-glaciogenic dust sources, in oder to give an idea of the relative importance of the two.

2. On pg. 2281, it is suggested that PDD vs. SEMI is the reason that previous models with PDD produced only small precessional ice-volume variations. But this could instead be due to many other competing or canceling factors (as discussed in pt. 1 above). It would be more convincing to try PDD in the current model, combined with other compensating allowable parameter variations to see what ice-age results can and cannot be achieved.

3. In the discussion on pg. 2290, it is perhaps misleading to deal with total ablation (which increases with ice sheet area) in relation to phasing with orbital variations. The local melting rate on the ice-sheet southern flanks (m/yr) probably has little phase shift from summer insolation.

4. As described here and in earlier Calov et al. papers, the model produces interesting internal fluctuations in the ice sheet and AMOC related to D-O and Heinrich Events.

But beyond that, it is unclear here whether they are more closely related to HE's or D-O's or both. For instance, does the model produce the observed sequences of increasing D-O's culminating in an HE? Are all the modeled fluctuations associated with a surge in the Norther Laurentide ice sheet? Some more discussion would help. #Incidentally, the paper emphasizes the stochastic nature of the #fluctuations, but some recent papers suggest the deterministic timing #(relative to SH) may be important for terminations (Barker et al.,Nature,2009; #Wolff et al.,Nature Geosci.,2009; Cheng et al.,Science,2009).

5. Several figures could show more useful information; a. In Fig. 4c, show the fraction of total basal area at melt point, for all, NA and EU. (As in Fig. 4b, but for the fraction).

b. In Fig. 5, in addition to total amounts (Sv), show the averages over ice surfaces (m/yr), for all, NA and EU. (Related to point # 3 above).

c. In Fig. 6, add more interesting times: a few small early ice sheets from Stage 5, and during the deglaciation ∼15 and 10 ka.

d. In Fig. 8, add something to indicate relative strengths of glaciogenic and non-glaciogenic sources (point # 1c above).

e. In Fig. 10c, show information for the probably more important and variable deep North Atlantic, as well as for the Pacific.

Minor points:

A. pg. 2274 (section 2.1): the description of surface melting routing for ice melt is unclear. How does river routing differ from modern over ice sheets? If it is constant in time, how does it work for interglacials?

B. pg. 2279: The method for converting other greenhouse gas amounts to equivalent CO2, although simple (involving radiative equivalent effects?), might be of general interest and could be added as another Appendix.

C. pg. 2280: It would help to emphasize from the start that the ice-sheet model does not include Antarctica (I think this is the first place it is mentioned).

D. pg. 2289 (section 5.4): It would be interesting to give here the rough CPU amounts used by CLIMBER, SEMI and SICOPOLIS, in non-accelerated runs.

Background- no suggested changes:

A number of sensitivity tests are described in section 5, mostly concerning changes that significantly affect ice-sheet surface mass balance. The results are somewhat predictable, with large changes in the ice volume time series. As shown in many previous climate-ice sheet modeling studies, NH ice sheet variations are sensitive to relatively small changes in climate, equivalent to only a few degrees C in summer temperatures and associated melt. This is comparable to or smaller that errors in the model's modern climate and the uncertainty cannot be eliminated simply by tuning to modern climatology. This means that coupled climate-ice sheet models need to validate their results not just for a single ice-sheet state such as LGM, but against whole glacial cycles, inception, etc., as here. But it also means that the various tests adding and removing climate features (Fig. 9b,c) cannot conclusively identify which features are vital and which are not - tt is likely that the degradation of ice-age results when one feature is removed can be counteracted by other combined adjustments in the model (not performed in the paper), all within the uncertainty of fit to the modern climate.

Interactive comment on Clim. Past Discuss., 5, 2269, 2009.