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Interactive comment on "Modelling the evolution of the Antarctic Ice Sheet since the last interglacial" *by* M. N. A. Maris et al.

Anonymous Referee #1

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General comments:

This paper contains a description of relevant aspects of the ANICE ice sheet model, and sensitivity studies of model parameters through the last glacial cycle for Antarctica. Only a few model parameters are varied, but they are carefully selected to include those with relatively unconstrained values and the potential to substantially impact results. The paper is generally clear and well written, the model description is detailed and pertinent, and the results are of significant interest. Although the paper does not attempt large-ensemble suites or optimization involving many parameters as in some recent studies, the results are useful, and illustrate some dependencies of interest to the modeling community.

Specific comments:

1. The method of climate weighting between PD and LGM climate solutions (pg. 91-92) seems unusual, with a linear-in-time (sawtooth) interpolation for relative spatial patterns, but with an ice-core-based interpolation of the means. The rationale for choosing the method should be explained. For instance, why not use the simpler method of simply interpolating between PD and LGM climate quantities, in proportion to the ice-core time series? i.e.,

T(t) = T(LGM)*alpha + T(PD)*(1-alpha) where alpha = DeltaT(t) / DeltaT(LGM)

and DeltaT(t) is the temperature anomaly from modern in the EDC ice core. And similarly for SMB, or perhaps:

SMB(t) = SMB(LGM)ˆalpha * SMB(PD)ˆ(1-alpha)

This is probably not a shortcoming, but some explanation of the choices would be helpful. Similarly, an alternate (and standard) normalization could be: Tnorm = (T - Tmean)/ s.d.(T), where Tmean is the mean temperature and s.d.(T) is the standard deviation.

Incidentally, it could be noted that: - The procedure in steps 1 to 3 is done for each spatial point independently. - T is in deg. K (pg. 91, line 26). - Means are taken over the Antarctic continent (or the whole RACMO domain?).

2. It is not completely clear in section 3 whether the runs used in the selection of best-fit parameters, and also the final reference run, are equilibrated modern simulations with perpetual present-day climate, or the end results of full glacial-cycle runs over the last 120 kyr, or some combination. Lines 18-20 on pg. 98 can be interpreted as the former, but Fig. 7 of course implies the latter.

3. Fig. 7 shows grounding lines for WAIS, but another important test of the model is the smaller grounding-line retreat from LGM to present on the other side of EAIS. An additional panel should be added to show that (or lack of it) in the model. Presumably "grounding line has moved very little along the EAIS" (pg. 99, line 7) refers to LGM vs.

modern, but there should be some retreat in places such as Prydz Bay.

4. In. Fig. 7, the model's grounding line retreat across the Ross embayment is nearly complete by 12 ka. Thus the major retreat occurs considerably earlier than found by data (Conway et al., Science, 1999; McKay et al., Palaeo3, 2008), which should be mentioned. Also (pg. 99, line 13), the timing of retreat onset in the Weddell embayment ($\sim$13 ka) may agree with Anderson et al., 2002, but more recent work (Weber et al., Science, 2011) suggests the onset was considerably earlier, $\sim$19 ka (?).

5. In Fig. 9, D (lithospheric rigidity) and tau (bedrock relaxation time) are varied together. However, aren't they basically independent, with tau depending mainly on upper-asthenospheric properties? If so, it would be instructive to show results where each is varied independently. That would also aid in comparing results with analogous sensitivity studies using more complex Earth models (Whitehouse et al., GJI, 2012). Also, it would be more consistent with previous studies such as the cited Stern and ten Brink (JGR, 1989) to try a two-valued D, with a lower value over West Antarctica vs. a higher one over East Antarctica (10ˆ22 to 23 vs. 10ˆ24 N m respectively in that paper).

6. Has the ANICE model participated in or run any MISMIP or MISMIP3D-like tests? The resolution is 20 km, and there is no special treatment or adaptive fine-grid around the grounding line, so in light of previous experience with other coarse-grid models in those intercomparisons, it is surprising that there is no spurious "sticking" (failure to move) of grounding lines in these experiments. Any discussion of previous tests, and/or the absence of this problem in ANICE, would be of interest.

7. Like many previous studies, the parameters for the reference simulation (pg. 98, lines 17-20) are presumably the product of a manual tuning process qualitatively seeking the "best" subjective agreement with the present-day state. Other recent studies (Whitehouse et al., QSR 2012 and Geophys. J. Int. 2012; Briggs and Tarasov, QSR, 2013; Briggs et al., TCD, 2013) have started to use large-ensemble techniques in this area, which yield more objective sets of quantitatively optimum parameters. Also, those

studies compare not only to modern ice geometry and grounding-line history as here, but also to Relative Sea Level curves, GPS uplift rates, and cosmogenic age-elevation data. These issues and prospects for further work could be acknowledged briefly.

Technical comments:

a. p. 88, line 21-22: Just a comment: This minimum-thickness calving criterion may prevent any regrowth of marine WAIS ice after a complete West Antarctic collapse, because the initial small coastal ice shelves may all be < 250 m.

b. pg. 91, line 14-15: This text says the feedback of ice-sheet geometry on regional climate and SMB is strong. Thus there is strong motivation to somehow couple the evolving ANICE with RACMO. Lines 17-18 say this is not computationally feasible, but why? The authors were able to input ICE-5G geometry into RACMO (lines 7-8), so why not ANICE's? Perhaps "not computationally feasible" on line 17 means not that it is infeasible in the code, but that it would be too computationally expensive to run RACMO multiple times through the glacial cycle (?)

c. pg. 93, line 10: If observational datasets of 3-D modern ocean temperatures are available (Orsi and Whitworth as cited; also e.g. World Ocean Atlas, 2009) why use a model at all for this field? Similarly, on pg. 94, line 1, why not use a data-based sea level record (e.g., Siddall et al., Nature, 2003) for the last 125 kyr instead of a model? It would be of interest to mention the reasons briefly.

d. On pg. 94, the sub-header "2.4 Sensitivity experiments" is exactly the same as "4 Sensitivity experiments" on pg. 100. One of them could be changed to avoid confusion.

e. pg. 98, line 11: In Eq. (16) for dh/dt, the first group of terms within the parentheses on the right-hand side seems to represent the loading from just one point load, and should probably be summed over all (nearby) points, as mentioned on pg. 97, line 15.

f. It would be of interest to add a 3rd panel to Fig. 5 showing the difference in surface elevation (model minus observed). This is shown in several previous papers of this type, and would be useful for comparison.

g. pg. 99, line 17-18: At first sight, it is a bit surprising in Fig. 8 that ice discharge over the grounding line dominates loss from grounding-line motion, especially during the last deglacial period (say 15 to 10 ka). The ratio of the former to the latter is roughly the ratio of ice velocity at the grounding line to the average grounding-line retreat rate between ∼15 to 10 ka. For the Siple Coast at least, these are ∼100 m/yr and ∼500 km/5 kyr, i.e., about equal. Perhaps the result in Fig. 8 is due to the other marginal sectors of the AIS where deglacial grounding-line retreat is much less. But on the other hand, the other sectors do not contribute as much to total loss (per unit circumferential distance). These considerations could be mentioned and explained briefly.

h. pg. 100, lines 19-21: The last sentence of this paragraph is opaque to me, and more explanation would help.

i. pg. 100, line 22-23: It would be of interest to describe where around Antarctica does most of the Holocene re-advance occur in the model? Is it pronounced at the Siple Coast (Ross) and/or Filchner-Ronne grounding lines? This would help in comparisons with other models.

j. pg. 101, line 21-22. It would help to explain the process mentioned in this sentence a little more, as follows (I think): bedrock rebound causes shallower grounding-line depths, which reduces ice flux across the grounding line (as many dynamical studies have shown), and thus slows down upstream thinning and grounding-line retreat. A similar sentence is on pg. 104, line 9.

k. pg. 102, lines 5-7 state that the model's AIS total modern grounded ice volume is 24.8 x 10ˆ6 km3, and this is a significant overestimate. But Bedmap2's total grounded ice volume is 26.54 x 10ˆ6 km3, and Bedmap1's was 25.34 (Fretwell et al., TC, 2013). I did not find a total volume figure in ALBMAP papers (the dataset used here), but it would be surprising if it is far enough below Bedmap2 to make the model's value an overestimate.

l. pg. 102, lines 11-13: In addition to these recent model estimates of LGM-to-modern Antarctic sea-level contribution, the paper could mention those in Briggs and Tarasov (QSR, 2013) and Gomez et al. (EPSL, 2013).

m. In Table 1 and the relevant model equations, the symbol "q" is used for two different quantities; one could be changed.

Interactive comment on The Cryosphere Discuss., 8, 85, 2014.