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Interactive comment on "Modelling the Antarctic Ice Sheet across the Mid Pleistocene Transition – Implications for Oldest Ice" *by* Johannes Sutter et al.

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The paper by Sutter et al., describes a thorough study of simulations of the Antarctic ice sheets (AIS) through the past 2 million years. A clear goal is provided in terms of the search for the oldest ice location on the AIS. This paper provides additional insight on which locations on the AIS ice divide might be most suitable for drilling, discussed in conjunction with other recent studies. I think the paper address a relevant scientific question within the scope of TC, and touches upon several topics that have been in the Cryospheric community for many years, such as how the AIS changed through the Mid Pleistocene Transition, it's contribution during past interglacial sea-level high

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stands (specifically the LIG) and the possibility of the existence of 1.5 Myr old ice.

I think this is a well written paper, that provides a thorough analysis using the proper concept with a suitable range of different climate forcings, boundary conditions and model parameter choices. The title is clear and concise, although the term 'Oldest Ice' might be too conceptual at first, but does becomes clear after reading the abstract. The paper answers its own main question well, in terms of providing additional grounds for specific drill sites on the AIS in the search for the 'Oldest Ice'. Moreover, the discussion provides a good overview of general ideas in the literature and a comparison of findings in this paper with the literature. The methods used are in general well suited for the conclusions reached, although several other methodologies have been used to provide details of the proper drill sites, this is also clearly written in the discussion and conclusions. As said in one of the comments in the attached pdf, you should clearly highlight (on several occasions) that model results do depend on the imposed glacial index and boundary conditions. Overall this is done well, but it is an important aspect of an ensemble study such as this.

Overall I think the paper is well structured, and the language is good. Below I have raised several main remarks, mostly required additional clarification of methodology and the figures. I have marked comments in the attached pdf. Some sentences are written a bit too long, I have not marked all of them, so perhaps give the manuscript another good read in terms of the flow of reading and shorten (too) long sentences. References are appropriate and well discussed in the introduction and conclusions/discussion.

In summary, I accept the paper under minor revisions, several parts need some clarification as noted below under main remarks and in the attached pdf.

Main remarks

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1. Transfer function

As pointed out on line 15, page 5, you have used a transfer function to describe 2 Myr of climate variability, combining the EDC ice core record and LR04 benthic oxygen isotope stack. Please use a couple of sentences to describe this function in the main text.

2. Description of temperature forcing (eqns. 1 and 2)

The description of the temperature forcing in equations (1) and (2) should be expanded a bit more and made clearer. For example, since you use the temperatures at the LIG, LGM and Pliocene as anomalies, use a ΔT in the equations and description of the variables in the text below. Also describe all three anomalies below the equation for both surface and ocean temperatures as (for example):
"The ESM anomalies ΔT_{s-ig}, ΔT_{s-g}, and ΔT_{s-p}, represent the LIG, LGM and Pliocene, respectively. Ocean temperatures (eqn. (2)) are defined in the same way."

Secondly, when describing the calculation of the weighting factor w, using the glacial indices, it is unclear how you distinguish between the three states (w_g, w_{ig} and w_p). Also, it would be good to have a Figure 2 close by to refer to the GI values over time (instead of places in Figure 5 only). Also, what are the values of GI_{PD} and GI_{max}? Do these vary between the two GI records? Also, why did you not shifted the index to have GI_{PD} = 1 or 0 for example? (since it is an index and can be shifted any way you want, as long as you coherently adapt equations 3-5). I do understand that since you have two GI records, based on Snyder and ice-core/δ^{18}O records, the differences between the two need to stay intact.

3. Comparison with PD09 and dB14

As mentioned on line 3, page 10, you shortly explain the type of forcing used in the two other studies. For a good comparison I do think you have to add a bit more explanation on how these two studies derived a transient climate forcing, and use

this later on in your discussion as well. Both studies derive their long-term forcing in temperature and sea level from the LR04 benthic δ^{18}O record, although applied in different ways. Also, they both use a weighting index (eqn 6 in PD09, equation 7 in dB14) to prescribe the variation in sub-oceanic melting. This weighting index includes solar variations (through an anomaly at 80S) which mainly controls the waxing and waning of the WAIS (see dB14 supplement figure S4). The large peaks towards lower ice volume are caused by including this insolation anomaly, so take this into account in your comparison/discussion. For more description of the methods, please see Methods section at the end of both papers.

Some more thoughts: It is a bit hard to distinguish individual simulations in Figure 5, but I guess your simulations of the B1-ensemble should be, in terms of timing, compare rather well to both PD09 and dB14 (depending on the sea-level forcing used). As you noted on line 6, page 10.

4. Structure of the ensemble

Based on the variables in Tables 1 and 2 you have a possible ensemble of 12 x 92 members. Please clarify in Section 2.3 how the two ensemble branches are built up. How many members does each have, and which specific experiments did you perform. All possible combinations? Or only a set?

Also, in Table 2 the variable cE has only 1 value, so not a variable that you vary within the ensemble? If so, please remove form the table. What are the other settings of the model? Do you intend to include a parameter table? Or are these settings similar to previous simulations with PISM (please refer)?

5. Revise Figure 6

In general, I think your figures look really good. I do suggest you add panel labels to all figures (a,b,c, etc.) and use these in the captions. However, the left panel of figure

6 is unclear, and I cannot distinguish between the dots or triangles at all. I suggest you create a separate figure from the left panel and the two other panels (the maps). In the new figure 6, make the symbols much bigger and perhaps put the time frames next to each other (LGM, LIG and you could also add the simulated PreInd or PD ice volumes in the middle perhaps?). Please also mention the total number of simulations shown in the plot. Nice to add the values, that should be included again.

In the two panels with the map, please indicate which specific simulations you have used here. Is this a minimum/maximum within the ensemble, or a (sort of) reference simulation that represents the middle/median of the ensemble? Are the lines of LGM, PD and LIG shown in both panels?

6. Revise Figure 9

Also, figure 9 is not really clear for me, took quite some time to get the full picture right. Please indicate for each panel what it shows, i.e. write type of experiment above the labels or ordered in a 4x4 grid. Make the lines of the ice divides thicker. Since you have so many panels, I don't think panel labels are useful here. What is the purpose of the big central panel, just as an overview? It takes away the attention so if it is less important, position it more on the side. Also, make a clearer division between the different sensitivity experiments with using names on top of the figures and put the colour bars at the bottom of the figure. Something like a 4x4 panel, with the x-axis (on top) the four different regions and the y-axis (on the left) the four different GHF datasets used. And then the big panel on the left.

7. Reference list

I have added some minor comments in the reference list, seems to have some issues with the copy from Bibtex (in case you have used latex). Please carefully check your list of references on errors in mainly page numbers and hyperlinks via doi.

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Please also note the supplement to this comment:
https://www.the-cryosphere-discuss.net/tc-2019-24/tc-2019-24-RC1-supplement.pdf

Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194/tc-2019-24, 2019.