

# ***Interactive comment on “Projecting Antarctica’s contribution to future sea level rise from basal ice-shelf melt using linear response functions of 16 ice sheet models (LARMIP-2)” by Anders Levermann et al.***

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This study uses a linear response function method to estimate the basal melting of 16 ice sheet models in response to a range of external forcing from anthropogenic emissions. The study is relatively novel using a recently published methodology (Levermann et al. 2014) to explore basal melt across the many state-of-the-art ice sheet models, and is a natural follow up on that work. The authors succinctly describe their methods and results, and promisingly find relatively good agreement between models and with observations. I have only a few substantive comments which I hope the authors will

consider. They relate to the motivational and concluding discussions, and the need for more detailed statistical analyses of the linear assumption; my other comments concern methodological clarity or are grammatical. In my estimation this study will be a valuable addition to the literature.

#### General Comments:

1. The abstract and conclusions provide new information to the reader that are not discussed throughout the rest of the paper, which detracts from the study. In the case of the abstract, the Paris agreement is mentioned without being discussed in the main text, and the method's structural uncertainty limitation isn't discussed anywhere except in the abstract. It would be helpful discuss these somewhere in the paper itself, or removed from the abstract. It is also confusing that a new methodology is specifically introduced in the discussion section (pg. 10, line 15). I would suggest introducing it earlier in the paper (section 3) where the model is compared against observational trends, and then simply noting the method (without the equation) in the concluding section.

2. One of the more compelling sentences in the abstract discussed how this study will be used to explore the range of responses to the external climate system forcing. But that motivation/wording isn't found in the introduction, which is a missed opportunity. The paper would be improved if a paragraph which more strongly motivated this work was written, becoming the second paragraph of section 1.

3. Section 2.3 and pg. 5, lines 22-34: While the criteria for choosing 8 m/yr was explained here, the way this section is currently written doesn't provide a clear explanation of what the 8 m/yr value is trying to accomplish and why a specific melt rate was selected in the first place. This makes the method sections on the response function difficult to follow. A few sentences are needed to clarify and describe how the 8 m/yr value is used to derive the response function, and then connected to how those functions are used along with the range of melting rates in Figure 3 to derive sea level

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contributions. It will be helpful to methodically explain what the "switch-on" experiments are, and how they relate to the timeseries of melt rates found.

4. In pg. 7, lines 11-14: Is there any way to discuss and quantify how close "generally close" is, maybe with some statistical test? It seems that as alpha approaches 0 or 1, you are off by a factor of 2 or more, which probably does not constitute linearity. How was the range -1 to 2 chosen? A theoretically supported statistical test for linearity would be helpful for making sense of the results.

5. Section 3 and Figures 6-7: How do these observations compare with the modeled changes over individual regions?

6. A concluding paragraph noting the importance and novelty of this work—for understanding the uncertainties in ice-sheet response to uncertainties in external forcing—would improve the manuscript. Moreover, the importance of human decisions (i.e. their role in driving external forcing and its uncertainties) should be emphasized.

Line-by-line comments:

Pg. 2, Line 4: This sentence reads a bit odd, can it be rewritten for clarity?

Lines 5-6: This sentence might be better suited towards the end of the abstract, or just in main text of the paper. Noting the limitations here in the abstract disrupts the flow of what it is trying to highlight and the study goals. In contrast, the limitations discussed in the following sentences seem more pertinent to the study goals.

Line 23: To my knowledge, the total contributions from the Paris Agreement could put the world on track to  $\sim 3$  degrees of warming or more, although ratcheting down emissions and could reduce this. In contrast the stated goal of the Paris agreement is "well below 2 degrees". I suggest either adding this language of "goal", or removing this from the abstract. Moreover, the Paris agreement is not mentioned anywhere else in the manuscript, so it may be appropriate to either cut it altogether or add more details to the main text.

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Line 26: Remove “the” before “five Antarctic regions”. The reader doesn’t yet have familiarity with which 5 regions are being referred to; this is good opportunity to let them know that you are using five regions.

Line 26-27: “rate” should be “rates”, “is” should be “are”

Pg. 3, line 17: remove “a”

Line 18: “will be” should be “is”

Line 20: I suggest removing the line about repeating the method. This comment could be left to section 2, and “try not” reads rather casual and should be rewritten.

Line 29: I suggest removing this casual line about the contribution the paper is “trying to make”.

Line 35: “This will be pointed out. . .” should be removed.

Line 36: This sentence is helpful! A useful detail which sets up the next section nicely.

Lines 38 and 39: “precisely” probably isn’t necessary here.

Line 40: This sentence about “the only thing that changed” is casual and not very descriptive. I suggest rewriting as: “The only difference between our study and the previous one are the ice sheet models used to project ice-sheet changes and sea level rise contributions.”

Pg. 4, line 1: Please replace “carbon dioxide concentration” with something like “emission pathways”. My understanding is that RCP scenarios are in carbon dioxide equivalent, including not only CO<sub>2</sub> but also other GHGs and constituents (and their forcings), which differ not only in concentrations but substance between each pathway.

Line 4: remove “the”

Line 10: Are the samples in this bulk approach approximately equally distributed among all ice-sheet models? This could affect the results of Figure 7, for instance, because

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the weighting towards some models might bias the results (cf. Figure 6 where there are clear differences between different models).

Line 13: “different”. . . is each timeseries drawn “without replacement”? Are any random selections repeated in your 20,000 samples?

Line 23: replace “now given” with “given below”.

Line 25: This introduction to RCPs is probably unnecessary, as they were introduced above in lines 1-2.

Pg. 5, lines 33-34: This sentence reads very awkwardly. I recommend rewriting this sentence for clarity as, “This is the most balanced choice to span the range of simulations, with 4 m/yr being too low for most of the RCP-8.5 scenario and 16 m/yr being too high for the majority of scenarios and ensemble samples.”

Line 37: can you add “(described in appendix A)” after “ice sheet models.”?

Line 37 and section 2.5: This paragraph seems out of place as its own section, being relatively short and quite necessary for the discussion at the beginning of section 2.4 I recommend removing section 2.5 altogether, and moving its context/text to wrap into and support the first few sentences of section 2.4.

Line 37: There are switches between past and present tense throughout. Can you choose one and be consistent in the manuscript?

Pg. 6, line 3: The start of this sentence could be rewritten for clarity as, “Although these simulations are highly interesting, a full discussion of their results...”

Line 6: remove the redundant “the uncertainty in.”

Line 22: please add “,  $A_{\mu}(t)$ ,” after “the observed response” to note the equation terms.

Line 24: This section is a bit difficult to follow. I suggest removing “the response func-

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tion is obtained” and adding a sentence like, “Following this procedure and using the fixed Heavyside forcing  $\mu=8\text{m/yr}$  chosen above, we obtain the response functions for each of the ice-sheet models.”

Line 38: I suggest rewriting “for the 200 years of the forcing period” as “which is held constant over 200 years.”

Pg. 7, line 25-26: “but not that far off in most cases” is rather general. A short but descriptive finish to this sentence would improve and contextualize this paragraph. I suggest rewriting as: “but in most cases the assumption is a reasonable approximation of how basal melting is responding to external forcing.”

Pg. 8, line 7: “and” should be “with”

Line 24: Increases in the ice-sheet associated with precipitation changes cannot be explicitly or implicitly accounted for in your linear response (this is apparent in the figures, as no changes are below 0). But observed ice-sheet changes over this period in the EAIS are increasing in mass. If they are not accounted for, could that also lead to differences between the estimates here and the observations? You mention this in the conclusions, but can you discuss this drawback and its implications in more detail in this section?

Line 31: By “largest” do you refer to the median values?

Lines 35-36: This sentence is difficult to follow.

Line 38: How are uncertainties distributed across the different regions, and why?

Pg. 9, line 1: Is there a way to decompose equation 5 at each timestep to determine the relative importance of each component at each timestep?

Line 6: “However” is redundant with your previous statement and I do not think is what you mean. Can you use something like “In any case. . .”

Pg. 11: Are the codes and data used to produce these analyses publicly avail-

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able? Please provide to the extent possible, in accordance with the ESD data policy:  
[https://www.earth-system-dynamics.net/about/data\\_policy.html](https://www.earth-system-dynamics.net/about/data_policy.html)

Figure 1 caption: It would be helpful to add the bold symbols for the basal melt rate and sensitivity, as was done for the other terms.

Figure 4b-e captions: “Figure 3a” should be “Figure 4a”.

Figure 5a: Please note that the response function are the grey lines.

Tables 2-5: Are these coefficients the  $\alpha_r$  values? It would be helpful label them in the table with their symbol and describe them in words in the caption.

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