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The Cryosphere
Discussions

Interactive comment on “Uncertainty quantification of the multi-centennial response of the Antarctic Ice Sheet to climate change” *by* Kevin Bulthuis et al.

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This manuscript uses a framework comprising an ice sheet model, an emulator, and uncertainty quantification methods to assess the response of the Antarctic Ice Sheet to climate change. The paper is generally well written and boasts beautiful figures. Its strength lies in the comprehensive probabilistic approach, with a thoughtful use various uncertainty quantification methods. While I remain suspicious of the applicability of emulators, as they could miss discontinuities and strong non-linearities, I must also admit that I am not sufficiently familiar with the topic to have an informed opinion.

Best wishes,

Andy Aschwanden

Major Comments:

I am a bit puzzled by the model setup. With reported computational costs of 16 CPU hours per simulation, one wonders if an emulator is indeed need as on the order of thousands simulations are computationally tractable? As discussed in the manuscript, the horizontal resolution of the ice sheet model is coarse, and topographic details will be missed. A demonstration of convergence under grid refinement would provide some confidence that the ice sheet model simulations are indeed robust. Nonetheless, one should not hold this too much against the manuscript, because, as I wrote above, the strength is clearly in the uncertainty quantification. Main-effect Sobel indices could become a standard tool in ice sheet modeling. Aschwanden et al (under review) use a similar approach for Greenland.

Why this confusing setup? P 10, l 26-26: "All results to follow have been obtained with the SGL parameterisation for the grounding-line migration, except in a discussion at the end of the section, where we discuss the impact of using the TGL parameterisation." Wouldn't it be easier to discuss the experimental design and results if the choice of grounding line parameterization were an additional parameters in the uncertainty quantification (i.e. by prescribing a uniform probability density function).

Minor Comments:

I find the introduction, discussion and use of "Uncertainty Community" somewhat awkward. While I think I understand what the authors try to express (and I like this approach), some clarification is warranted. What is the "recently formed uncertainty quantification community"? Maybe there is a white paper or similar that could be cited? UQ has been an integral part in numerical modeling outside glaciology but is only now making its way in ice sheet modeling (well, better late than never).

Detailed Comments:

everywhere: say "the contribution to sea-level is..." instead of "the contribution to sea-level rise". "Rise" is not needed here.

P 1

l 2-3: ...remain challenging due to...

l 10: sources of uncertainty, except bedrock relaxation time, contribute...

l 12: "as the scenario gets warmer" sounds awkward. Maybe "as temperatures rise"?

P 2

l 10-11: ..., with differences and uncertainty ranges of several meters of eustatic sea level.

l 24: ...initial state, climate forcing, and parameters...

P 3

l 2: ...based on probability theory,...

P 6

Table 1 and parameters. Rephrase "Uncertain parameters". Maybe "List of parameters and parameter ranges used in the uncertainty analysis" or similar. Also, it is not clear what distributions are used. Maybe the use of a "nominal" parameter suggests a Gaussian distribution. Or do all values in the parameter interval have equal probability? Note: I found that is is later explained on page 8, lines 24–31. Please add to the table legend that all parameters are drawn with equal probability. I am not sure that this is a good assumption though. Do you have any prior information that supports this?

P 7

l 15: Please explain what F_{calv} is. It appears to be a scalar multiplier of something (a calving rate, a stress condition)?

P 8

l 29: "We limit the probabilistic characterisation to assuming uniform probability density functions and we do not address how this probabilistic characterisation could be refined by using expert assessment, data and statistical methods such as Bayesian inference." OK, that's fine. For the exponent of the sliding law, one could perform a calibration and compare simulated and observed surface speeds to assess how well a certain exponent is able to explain the observations. See Aschwanden, Fahnestock, and Truffer (2016). This then be used as a prior for describing a PDF (done in Aschwanden et al, under review).

P 9

l 32ff: I'm afraid I do not follow here. Please detail how many (and for which parameter configurations) the ice sheet model was run, and how the emulator was used to fill in the space (is 500 the number of ice sheet model or emulator runs)?

P 11

l 3-6. Change "Under nominal conditions, we find (Table 2) in RCP 2.6 a nominal AIS contribution to sea-level rise of 0.02 m by 2100, 0.07 m by 2300 and 0.20 m by 3000 and in RCP 8.5 a nominal AIS contribution to sea-level rise of 0.05 m by 2100, 0.59 m by 2300 and 3.9 m by 3000." to "Under nominal conditions, we find (Table 2) for RCP 2.6 an AIS contribution to sea-level rise of 0.02 m by 2100, 0.07 m by 2300 and 0.20 m by 3000 and for RCP 8.5 an AIS contribution to sea-level rise of 0.05 m by 2100, 0.59 m by 2300 and 3.9 m by 3000."

l 19 (and elsewhere): I'm not a native English speaker, but I think "Figure 4a–c shows that in RCP 2.6" should read "Figure 4a–c shows that for RCP 2.6" or "Figure 4a–c shows that under RCP 2.6".

l 23: "This quadratic dependence can be explained by the influence of E_shelf on two competing processes: a higher value of E_shelf softens the ice, thus leading to faster ice flow in the ice shelves; but a higher value of E_shelf also leads to ice-shelf thinning, thus reducing grounding line ice flux."

P 12

l 18ff: you use "median" but provide a range. Please clarify. Do the ranges represent the 16/84th percentiles, for example?

l 22-23: "...except for certain cases..."

l 26-27: "...and starts to increase around 2100..."

l 29: maybe reference Fig. 6 here?

l 31: "...which contributes 3–3.5 metres to sea-level, followed by a slower retreat of the East Antarctic ice sheet."

l 33: "by the year 3000"

P 13

l 1: "For RCP 2.6, we find (Table 3) 5–95% probability intervals..."

l 4: "...an increase in sea-level, though a decrease cannot be ruled out for a viscous sliding law and cooler atmospheric conditions."

P 14

l 6: It is interesting that for RCP 2.6 rheology contributes a similar amount 40-60

P 15

l 23: "ice is certain to..." I would refrain from using strong words like "certain".

P 17

l 4-10: Rather than writing down numbers (which are listed in Table 4 anyway), I suggest to tell the reader how the plastic sliding law compares to the intermediate case

since this is what one cares about.

l 18: "..., which could explain the smaller ice loss in our results under m = 5 than m = 3." That's interesting, I would not have guessed.

P 19

l 11: "the pivotal role played by atmospheric forcing". I think you mean the role of the emission scenario.

l 26: Moreover, the lower sensitivity of the Amundsen Sea sector in our simulations may arise...

P 20

l 6-10: Very long sentence, maybe split into two. Figures

l 23-29: I understand what you are trying to say but I'm not sure the formulation "does (not) question the nominal projections". Maybe "in agreement with" or similar? The probabilistic framework expands upon the nominal projections, and your results provide good evidence that a thorough risk assessment must include UQ.

P 21

l 20: We found that all investigated sources...

3 b-e: Show outline of present-day grounded area for better visual comparison.

9: What does the m in the lower left corners of the plot mean?

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