

Sensitivity of Antarctic sea level contribution to bed friction inversion choices in the BISICLES ice sheet model

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Abstract. Antarctica is the largest potential contributor to future sea level but is also the most uncertain. The ice sheet initial state is known to be a significant source of uncertainty, but this uncertainty is rarely explored outside of large-scale model intercomparison projects.

Century-scale projections of the Antarctic ice sheet typically generate an initial state by solving an inverse problem for basal friction – and sometimes other fields – such that modelled ice velocities closely match observations. While this yields realistic short-term behaviour, it may also overfit by masking deficiencies elsewhere in the model.

Few modelling studies explicitly treat the inverse problem itself as a source of uncertainty. There is some evidence that regularisation choices within the inversion can produce uncertainty comparable to other commonly perturbed ice sheet model parameters, though this is limited to select experimental setups. It is unknown whether these results translate to other ice sheet models or domains.

Here, we use the BISICLES ice sheet model to explore inverse problems as a source of uncertainty in Antarctica's future sea level contribution. We generate an ensemble of initial states and project them forward to 2300 under a high-emission scenario. We assess the sensitivity of sea level projections to regularisation parameters within the inversion and compare it against other commonly perturbed parameters. We find that the sensitivity to regularisation in BISICLES is generally lower than other parameters and that this gap widens on longer timescales.

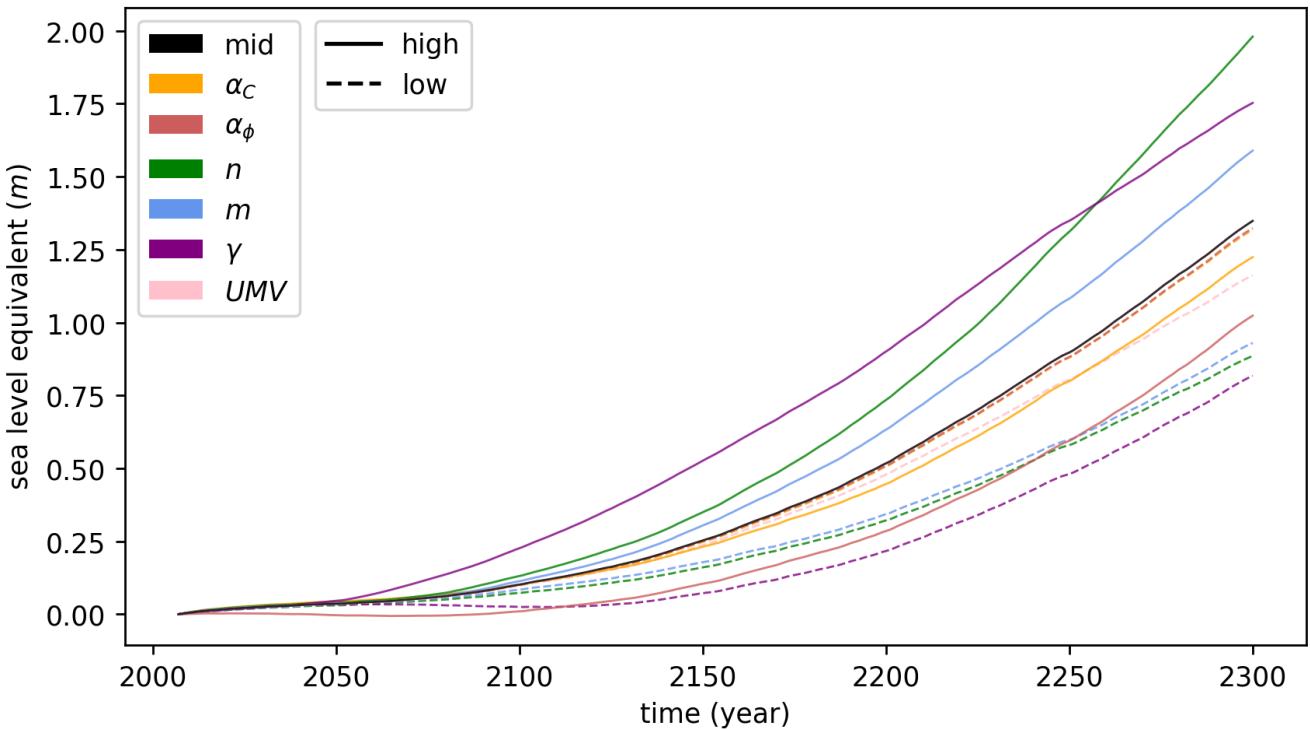


Figure 1. Timeseries of Antarctic sea level contribution for high and low values of each perturbed parameter.

1 Introduction

2 Methods

2.1 Ice sheet model

2.2 Inversion method

20 2.3 Experimental design

2.4 Climate forcing

3 Results

We project our initial states forward with the CESM2 climate forcing up to 2300 and calculate total Antarctic sea level contribution for each ensemble member (Figure 1). The ensemble range at 2100 is ??–?? m, which compares well with the IPCC AR6 range of 0.03–0.28 m under SSP5–8.5 (cite IPCC). In the 22nd and 23rd centuries, all ensemble members accelerate their mass loss and the range widens to ??–?? m by 2300.

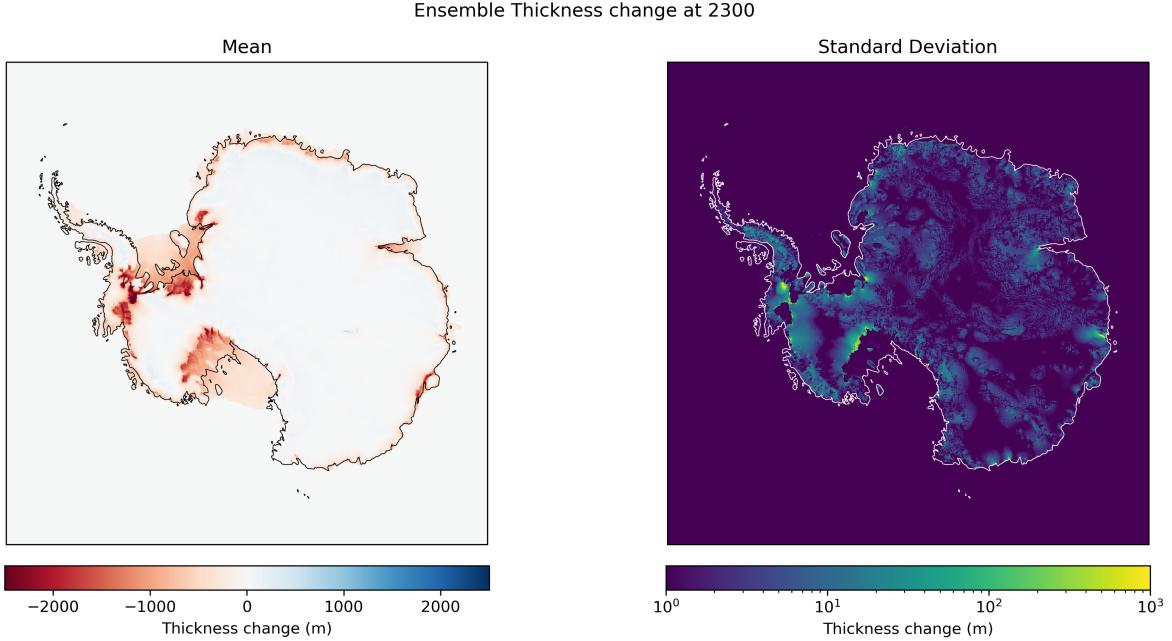


Figure 2. Timeseries of Antarctic sea level contribution for high and low values of each perturbed parameter.

The spatial patterns of ice thickness change are broadly similar across the ensemble, with most mass loss occurring in regions of West Antarctica: the Amundsen Sea sector, the Siple coast, and the Weddell sea sector. However, the extent of mass loss in these regions depends on parameter choices, with high variance along Thwaites, Foundations, and Denman glaciers (Figure 2).

Some areas of low variance also show regions that retreat in all ensemble members, including the collapse of Pine Island Glacier and the Ross and Filchner-Ronne ice shelves.

For each parameter, we calculate the range in sea level contribution between ensemble members with minimal and maximal values of that parameter. This provides a rudimentary measure of sensitivity, which we can compare across parameters. Figure 3 highlights the timescale-dependance of this sensitivity, with different relative importance of parameters at 2100 and 2300.

At 2100, the largest sensitivity is to ice shelf basal melt, γ , but this reduces in relative terms by 2300 as other parameters become more important. Sensitivity to the flow law exponent, n , and the basal sliding exponent, m , both increase over time and are comparable to γ by 2300. Sensitivities to glacial isostatic adjustment (UMV) and bed friction regularisation (a_C) are negligible at 2100 and remain small by 2300. Sensitivity to regularisation of the viscosity coefficient, a_ϕ , is the second largest of all parameters by 2100 but becomes less significant relative to other parameters by 2300.

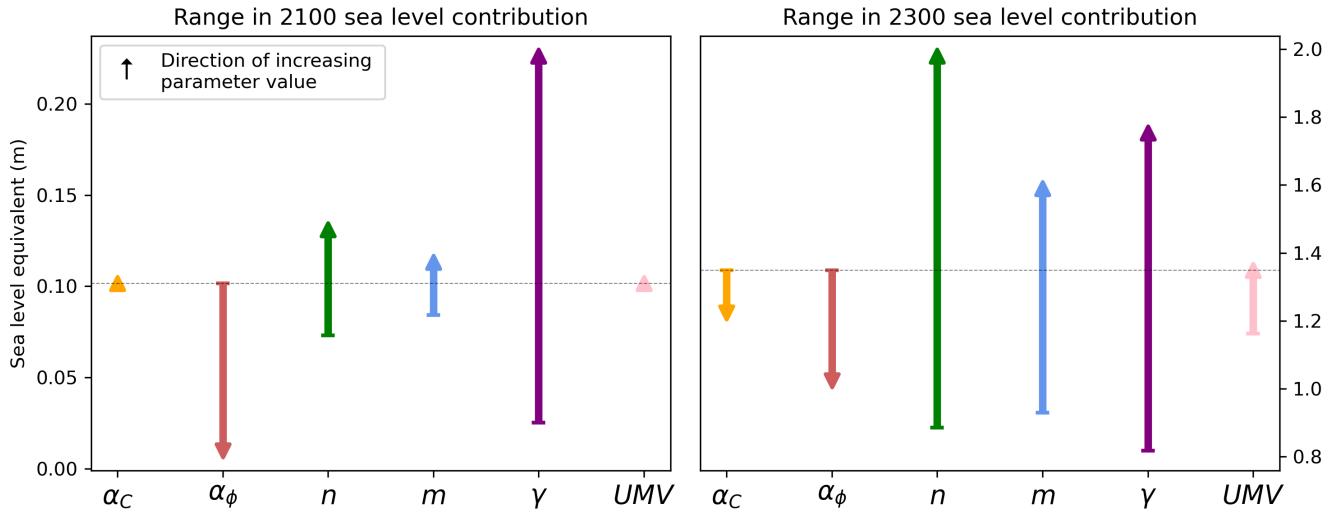


Figure 3. Sensitivity of Antarctic sea level contribution to each perturbed parameter at (a) 2100 and (b) 2300. Arrows denote the range in sea level contribution between ensemble members with minimal and maximal values of that parameter, pointing from minimal to maximal. Arrows pointing upwards/downwards therefore indicate a parameter that increases/decreases sea level contribution with higher values. The dashed horizontal line indicates the sea level contribution in a simulation with all parameters held at their default value (see Table ??).

40 4 Discussion

Although the sensitivity to one of the inversion parameters is high at 2100, the overall sensitivity to inversion choices is otherwise lower than other commonly perturbed parameters, particularly on longer timescales.

- The sensitivity of Antarctic SLC to parameters is a time-dependant question. Gamma starts our big very early on, but other parameters such as n and m catch up by 2300. • Glacial isostatic adjustment has negligible effect on SLC by 2100 and only a small effect by 2300. • Sensitivity to bed friction regularisation is negligible at 2100 and still small 15cm by 2300. • Sensitivity to viscosity coefficient regularisation is the second largest of all parameters by 2100 10cm, second only to gamma. By 2300, the parameter also plays a role in the stability of Pine Island. However, the SLC sensitivity still becomes less significant relative to other parameters.

5 Conclusions

50 *Code availability.* TEXT

Data availability. TEXT

Code and data availability. TEXT

Sample availability. TEXT

Video supplement. TEXT

55 Appendix A

A1

Author contributions. TEXT

Competing interests. TEXT

Disclaimer. TEXT

60 Acknowledgements. TEXT

References

REFERENCE 1

REFERENCE 2