

# 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.

## 1 Introduction

## 2 Methods

### 2.1 Ice sheet model

### 2.2 Inversion method

### 20 2.3 Experimental design

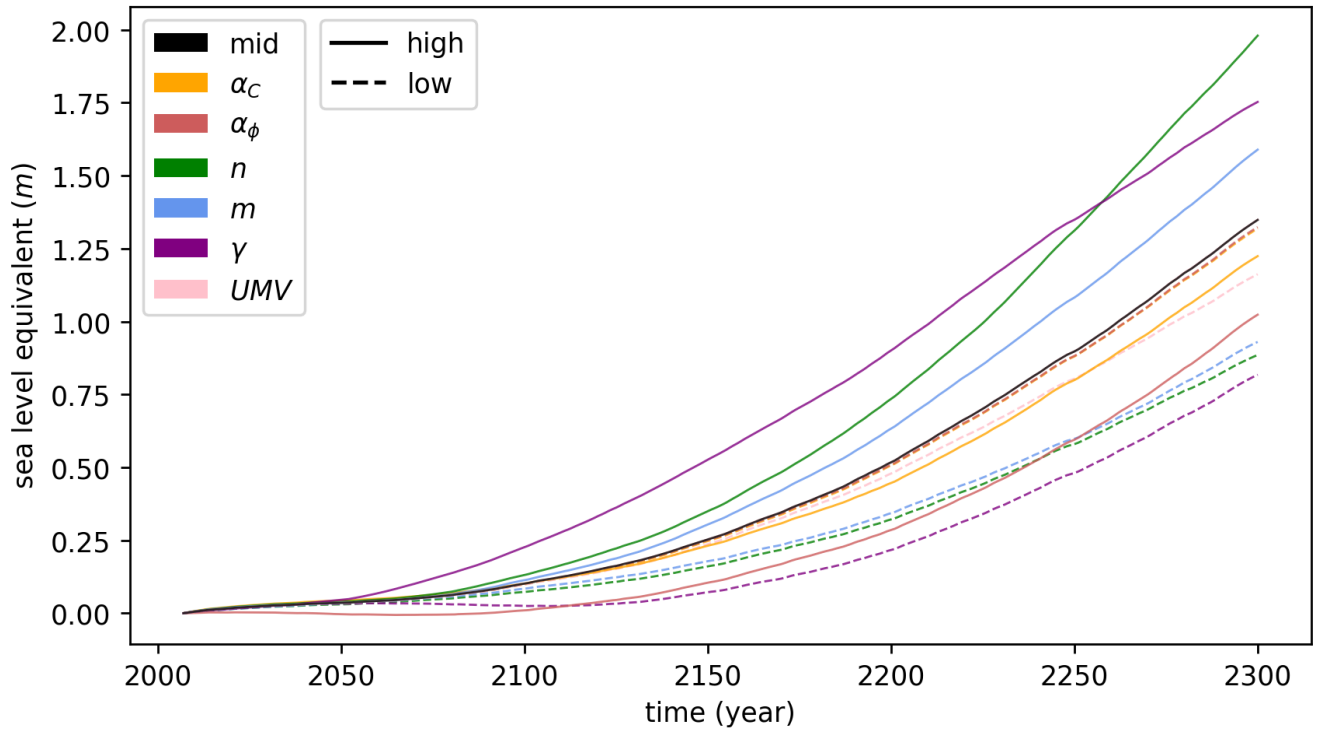
### 2.4 Climate forcing

## 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  
25 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.

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 glacier, Foundations glacier, Denman glacier,  
30 and the Siple coast (Figure 2).

- This sea level mostly comes from West Antarctica: Amundsen Sea sector, the Siple coast, and Weddell sea sector. • The major ice shelves collapse in all simulations by 2300, but their stability at 2100 is parameter dependent.
- Pine island glacier is mostly stable by 2100 but some parameter combinations trigger a collapse by 2300, contributing greatly to sea level rise. • Grounding line retreat in Thwaites and the Siple coast also contribute to sea level rise in some  
35 simulations. • 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  
40 significant relative to other parameters.



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

#### 4 Discussion

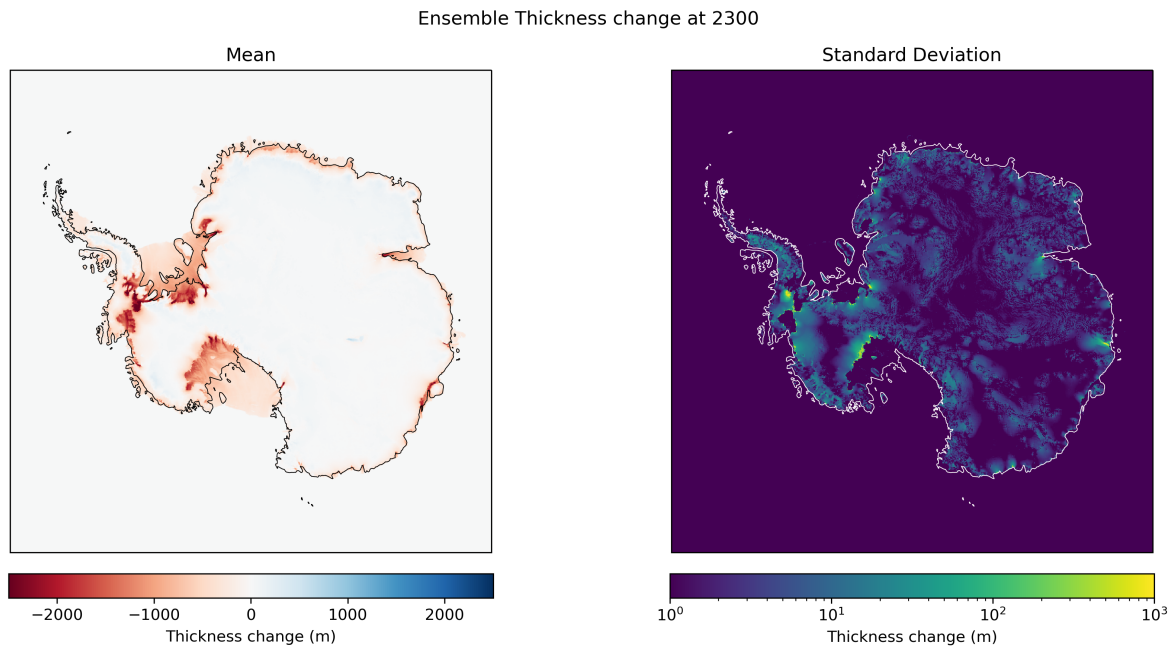
#### 5 Conclusions

*Code availability.* TEXT

*Data availability.* TEXT

45 *Code and data availability.* TEXT

*Sample availability.* TEXT



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

*Video supplement.* TEXT

## Appendix A

### A1

50 *Author contributions.* TEXT

*Competing interests.* TEXT

*Disclaimer.* TEXT

*Acknowledgements.* TEXT

**References**

55   REFERENCE 1  
      REFERENCE 2