Using palaeoclimate data to improve models of the Antarctic Ice Sheet

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1. Introduction

- Ice sheet models are the most descriptive tools available to simulate the future evolution of the Antarctic Ice Sheet (AIS).
- However, ice sheet modelling is an inherently uncertain exercise:
  - our knowledge of ice sheet dynamics is limited, and
  - to build models that can be run for multiple millennia, it is necessary to use simplified parameterisations.
- The past evolution of the AIS provides an opportunity to constrain the description of physical processes within ice sheet models.

2. Designing an ensemble

- We use the Parallel Ice Sheet Model (PISM; Winkelmann et al., 2011) to construct a perturbed-physics ensemble.
- The ensemble spans uncertainty in the parameterisations of six key physical processes (Table 1). We generate a 50-member ensemble, with a Latin hypercube approach used to sample the range of uncertainty in the parameter values.

Parameter	Description	Min.	Max.	BEST
`-sia_e`	Shallow ice enhancement factor	1.0	4.5	3.44
`-ssa_e`	Shallow shelf enhancement factor	0.5	1.6	1.26
`-pseudo_plastic_q`	Exponent of basal resistance model	0.15	1.00	0.670
`-till_effective_fraction_overburden`	Effective till pressure scaling factor	0.01	0.04	0.0115
`-eigen_calving_K`	Calving rate scaling factor	3.0e16	1.0e19	7.84e18
`-thickness_calving_threshold`	Min. thickness of floating ice shelves	150.0	300.0	170.2

Table 1. The six parameters varied in the perturbed-physics ensemble, including the minimum value, the maximum value and the value used in ensemble member BEST.

- The ensemble is integrated for 100,000 years under present-day boundary conditions, allowing each member to reach equilibrium.
- Figure 1 shows the simulated ice surface elevations. Based on the RMS error relative to Bedmap2, two ensemble members are identified as BEST and WORST respectively.

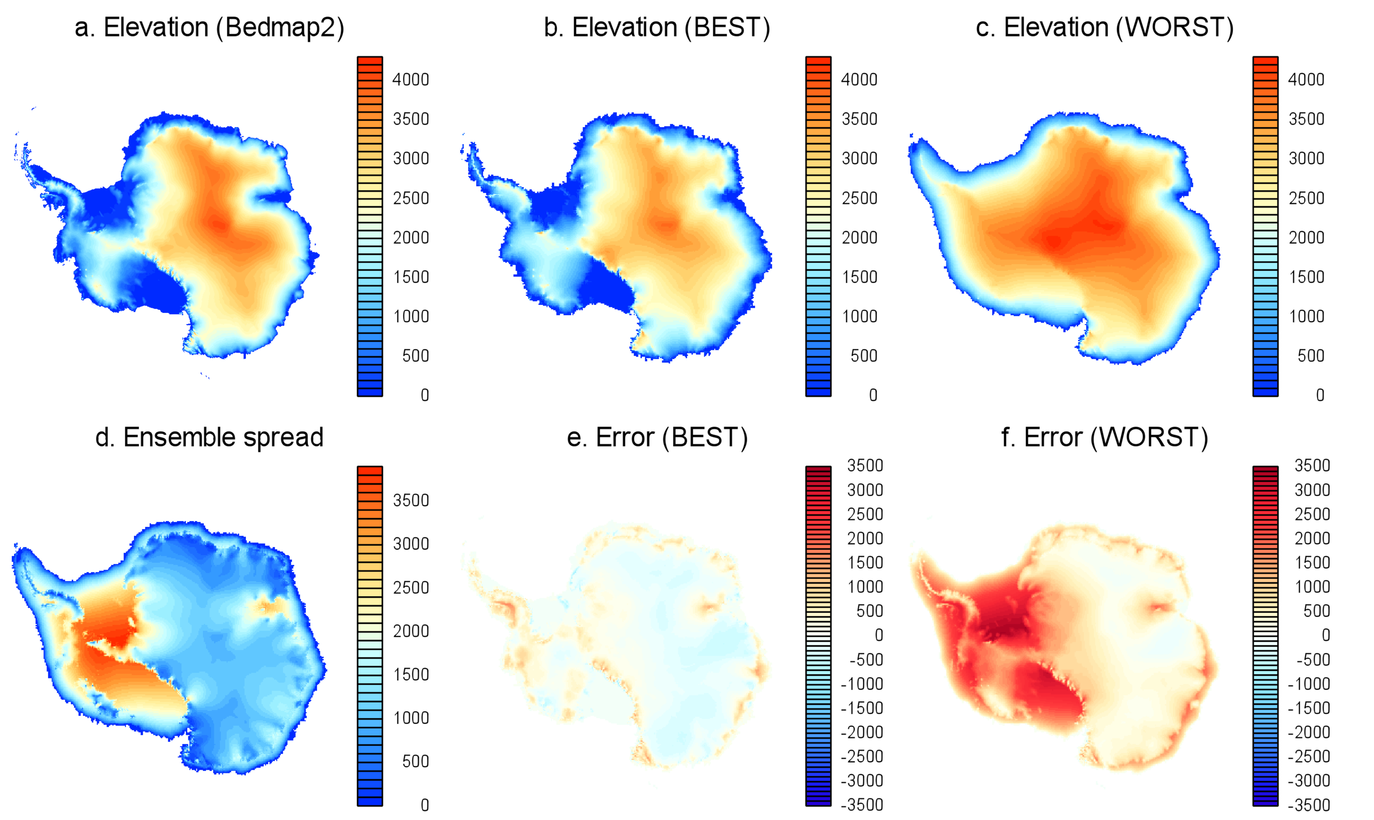

Figure 1. Simulated and observed ice surface elevation (m): (a) Bedmap2 (Fretwell et al., 2013), (b)–(c) members BEST and WORST, (d) ensemble spread, and (e)–(f) error for BEST and WORST.

3. Transient simulations of the last deglaciation

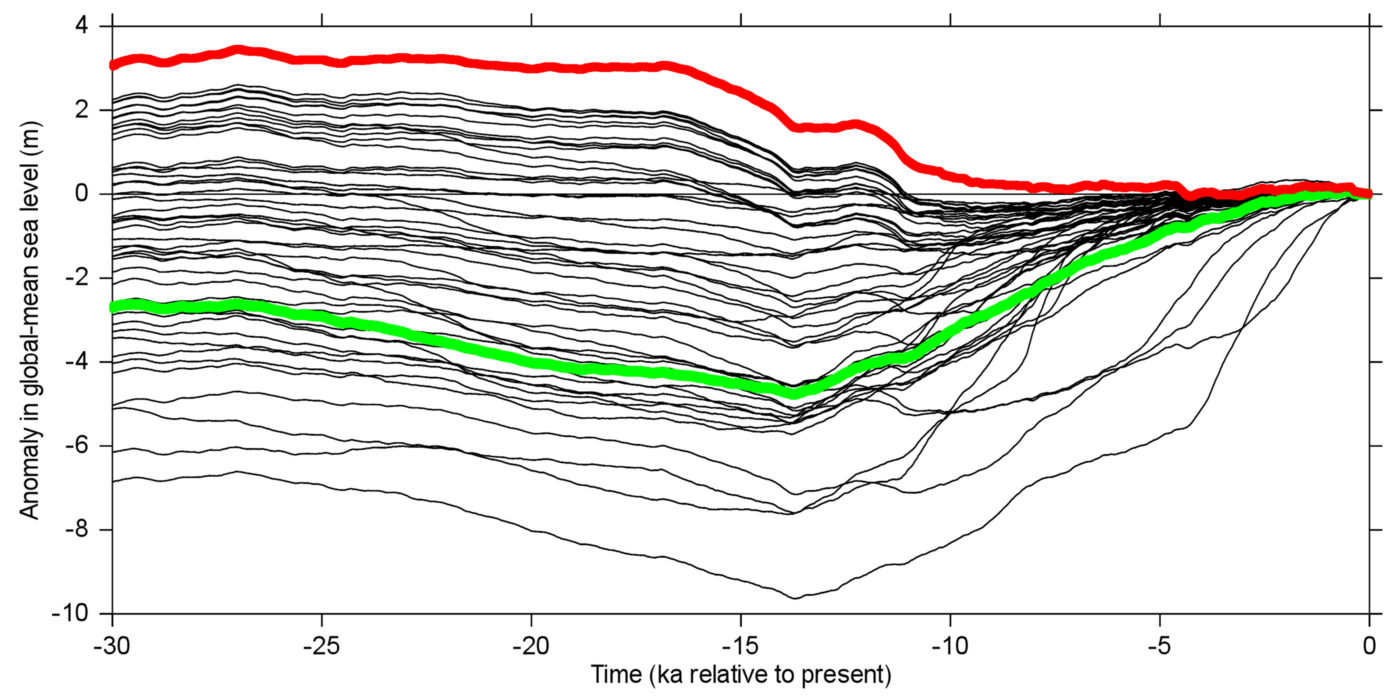

Figure 2. Simulated contribution of the AIS towards changes in global-mean sea level, relative to present (m). Ensemble members BEST (green) and WORST (red) are highlighted.

- The model ensemble is now used to simulate the evolution of the AIS over the past 30,000 years.
- Changes are applied to three boundary conditions: (i) surface temperature, using data from the Vostok ice core (Petit et al., 2001); (ii) precipitation, which is scaled using the Clausius-Clapeyron equation; and (iii) global-mean sea level (Imbrie and McIntyre, 2006). Each ensemble member is integrated from 130 ka BP (before present) to today, with the first 100 ka being a spin-up period.
- The simulated contribution of the AIS towards changes in global sea level is shown in Figure 2. A wide variety of behavior is apparent, including both positive and negative changes.

4. Using palaeoclimate data to constrain the model

- The ice surface elevation during the period 20–25 ka BP, for ensemble members BEST and WORST, is shown in Figure 3.
- Ensemble member BEST simulates thinner ice over inland domes in East Antarctica, but generally thicker ice elsewhere. This agrees well with evidence from palaeoclimate data (Figure 4). In contrast, WORST simulates thinner ice everywhere and is not realistic.
- Future work will focus on quantitative comparisons between the model simulations and palaeoclimate data. This will allow us to use data from past climates to directly constrain our understanding of the past contribution of the AIS towards changes in global sea level.

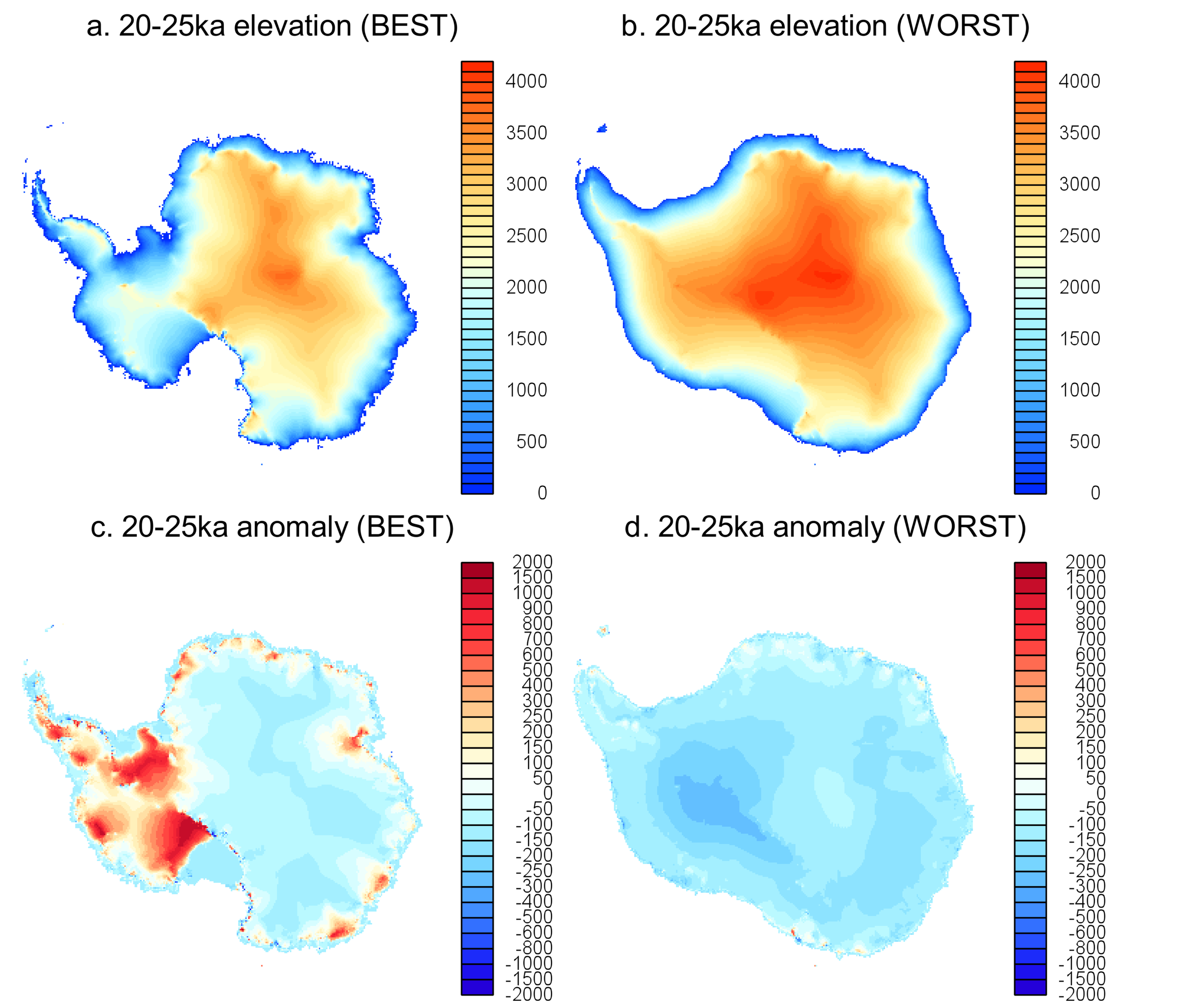

Figure 3. (a)–(b) Mean ice elevation (m) during the period 20–25 ka BP, and (c)–(d) anomaly relative to present (m), for ensemble members BEST AND WORST.

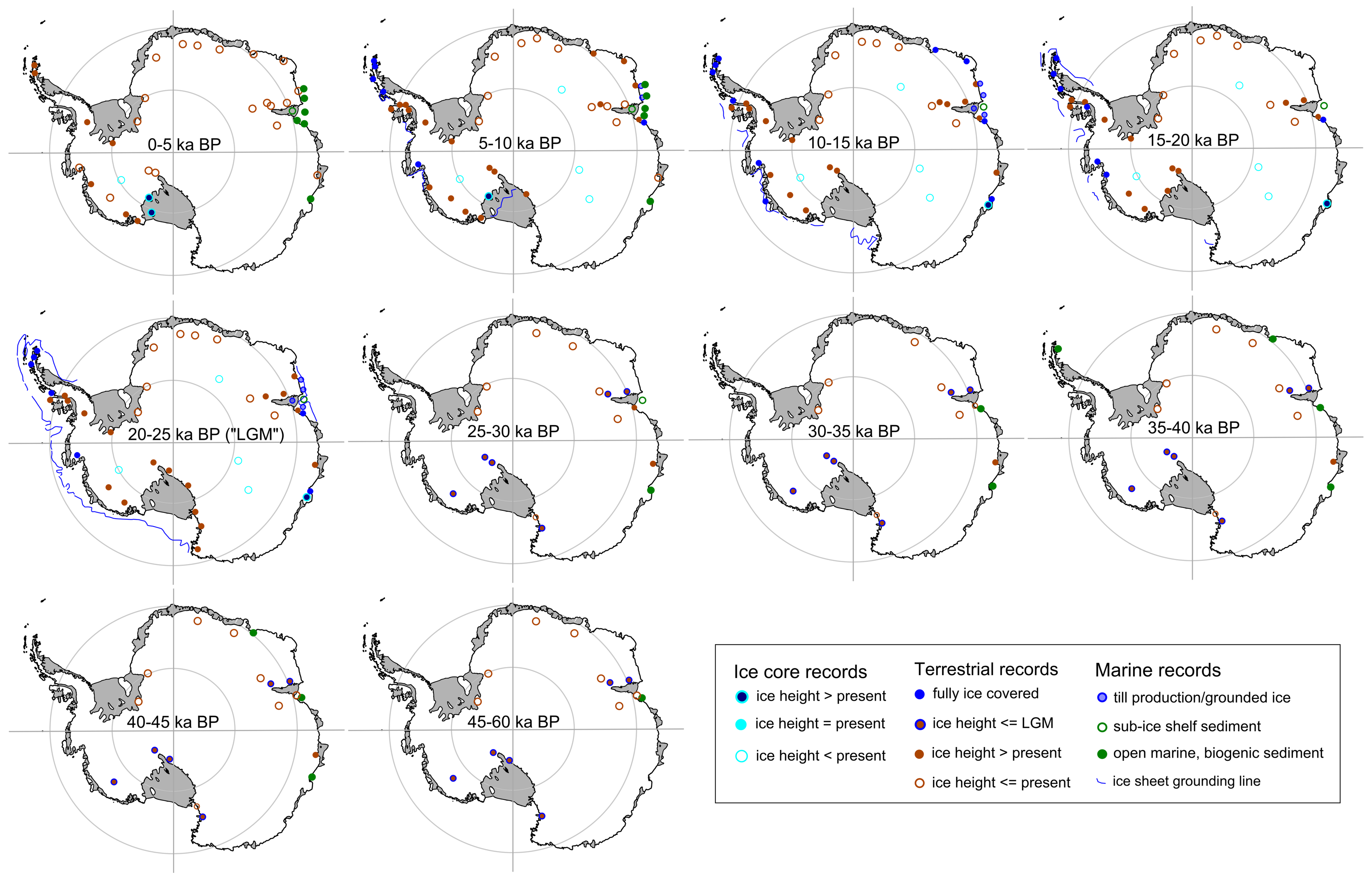

Figure 4. Evidence from palaeoclimate data for past changes in the AIS (based in part on the compilation of RAISED Consortium, 2014).

References

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