Using paleoclimate data to improve models of the Antarctic Ice Sheet (C41B-0663)

Steven J. Phipps[1,*], Matt A. King[2], Jason L. Roberts[3,4] and Duanne A. White[5]

[1]Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania, Australia. [2]School of Land and Food, University of Tasmania, Hobart, Tasmania, Australia.
[3]Australian Antarctic Division, Kingston, Tasmania, Australia. [4]Antarctic Climate & Ecosystems Cooperative Research Centre, University of Tasmania, Hobart, Tasmania, Australia.
[5]University of Canberra, Canberra, Australia. *Email: Steven.Phipps@utas.edu.au

ANTARCTIC GATEWAY PARTNERSHIP
A Special Research Initiative of the Australian Research Council

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 modeling is an 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 parameterizations.
- 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 parameterizations 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	Minimum	Maximum
-sia_e	Shallow ice enhancement factor	1.0	4.5
-ssa_e	Shallow shelf enhancement factor	0.5	1.6
-pseudo_plastic_q	Exponent of basal resistance model	0.15	1.00
-till_effective_fraction_overburden	Effective till pressure scaling factor	0.01	0.04
-eigen_calving_K	Calving rate scaling factor	3.0e16	1.0e19
-thickness_calving_threshold	Minimum thickness of floating ice shelves	150.0	300.0

Table 1. The six parameters varied in the perturbed-physics ensemble.

- 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 in the simulated elevation, two ensemble members are identified as BEST and WORST respectively.

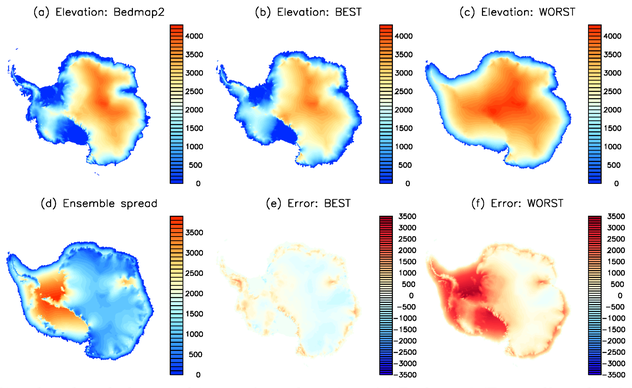

Figure 1. Simulated and observed ice surface elevation: (a) Bedmap2 (Fretwell et al., 2013), (b)–(c) members BEST and WORST, (d) the ensemble spread, and (e)–(f) the error for BEST and WORST.

3. Transient simulations of the last deglaciation

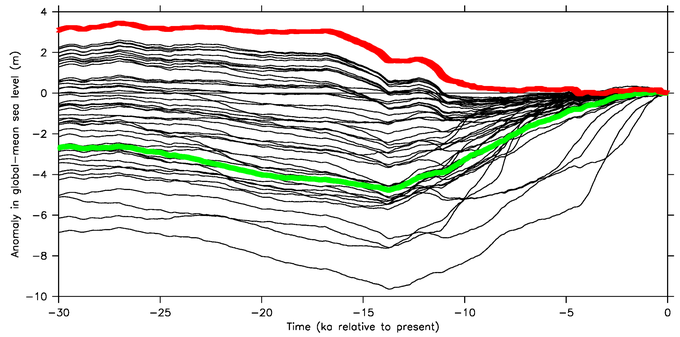

Figure 2. The simulated contribution of the AIS towards changes in global-mean sea level, relative to present. Ensemble members BEST (green) and WORST (red) are highlighted.

- 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 paleoclimate 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 paleoclimate 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 paleoclimate 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.

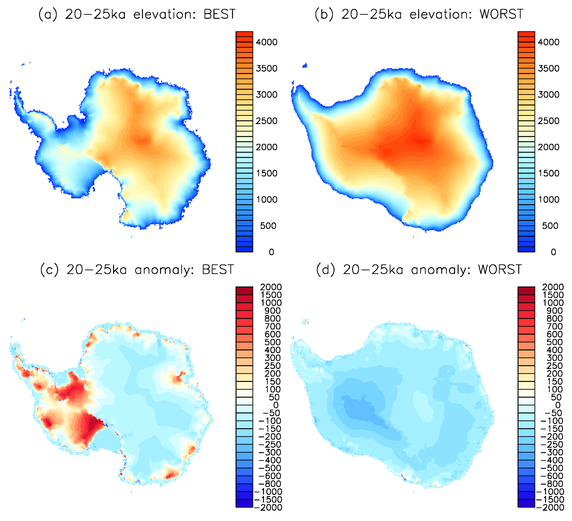

Figure 3. The mean simulated ice elevation during the period 20–25 ka BP, and the anomaly relative to present, for ensemble members BEST AND WORST.

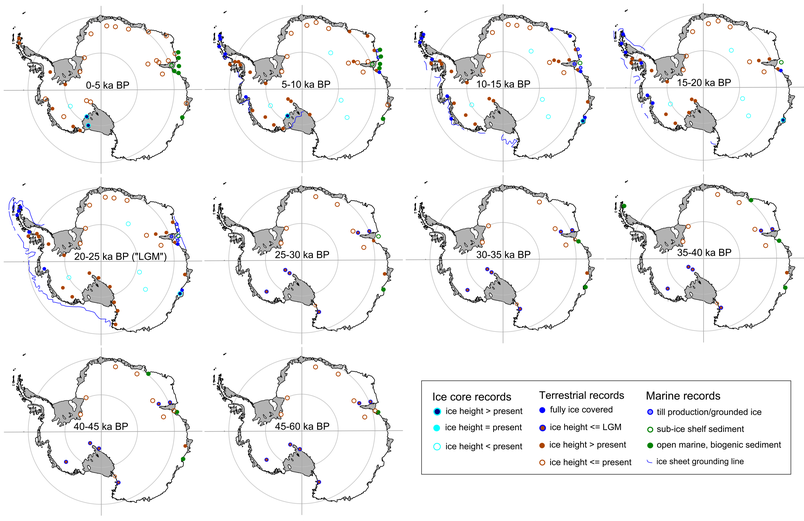

Figure 4. Evidence from paleoclimate data for past changes in the AIS (figure supplied by Duanne White, based in part on Bentley et al., 2014).

References

- Bentley et al. (2014), A community-based geological reconstruction of Antarctic Ice Sheet deglaciation since the Last Glacial Maximum, *Quaternary Science Reviews*, 100, 1–9, doi:10.1016/j.quascirev.2014.06.025.
- Fretwell et al. (2013), Bedmap2: improved ice bed, surface and thickness datasets for Antarctica, *The Cryosphere*, 7, 375–393, doi:10.5194/tc-7-375-2013.
- Imbrie and McIntyre (2006): SPECMAP time scale developed by Imbrie et al., 1984 based on normalized planktonic records (normalized O-18 vs time, specmap.017), doi:10.1594/PANGAEA.441706.
- Petit et al. (2001), IGBP PAGES/World Data Center for Paleoclimatology Data, Contribution Series #2001-076.
- Winkelmann et al. (2011), The Potsdam Parallel Ice Sheet Model (PISM-PIK) – Part 1: Model description, *The Cryosphere*, 5, 715–726, doi:10.5194/tc-5-715-2011.