Sensitivity of the Antarctic ice sheet to marine climate variability and change

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Climate and ice sheet modelling

Climate model

Ice sheet model

Images courtesy of NOAA/NCDC and NSIDC
Differing degrees of complexity

Fig. 1. Pictorial definition of EMICs. Adapted from Claussen (2000)

Claussen et al. (2002), *Climate Dynamics*

Fig. 2. The climate modeling pyramid. Adapted from Henderson-Sellers and McGuffie (1987)
The development of coupled climate system models

Growth of Climate Modeling

60s  70s  80s  90s  00s  10s

Atmospheric/Land Surface/Vegetation
Ocean
Coupled Climate Model
Sea Ice
Sulfate Aerosol
Interactive Vegetation
Dust/Sea Spray/Carbon Aerosols
Biogeochemical Cycles
Carbon Cycle
Ice Sheet
Marine Ecosystems
Ice sheet modelling: The case of the ice that won’t melt

DeConto and Pollard (2016), *Nature*
Ocean forcing: Changes in ocean circulation

Figure 2. Proxy records of: (A) normalized stacked ice-rafted debris (IRD) profiles from the Weddell Sea (black line), and the Campbell Plateau (blue line). These composite records are based on datasets that were normalized to between zero and 1 (x-axis) by division of the maximum IRD concentration (Carter et al., 2002). (B) Biogenic particle flux, reconstructed by $^{230}$Th normalization for biogenic opal flux, a proxy for Southern Ocean upwelling triggered by SHW southward migration (Jaccard et al., 2013), plotted against Marine Isotope Stages (MIS) over the past 150 ka. This figure is available in colour online at wileyonlinelibrary.com.

Fogwill et al. (2014), Journal of Quaternary Science
Ocean forcing: Changes in ocean circulation

Fogwill et al. (2014), *Journal of Quaternary Science*

Fogwill et al. (2014), *Journal of Quaternary Science*
Ocean forcing: Marine ice sheet instability

Wilkes Basin subglacial topography

- Blue: <1,000 m
- Light blue: <500 m
- Light purple: <0 m

Model domain

Mengel and Levermann (2014), *Nature Climate Change*
Mengel and Levermann (2014), *Nature Climate Change*
Ocean forcing: Marine ice cliff instability

DeConto and Pollard (2016), *Nature*
Ocean forcing: Millennial-scale variability

Weber et al. (2014), Nature
Ocean forcing: Millennial-scale variability

Weber et al. (2014), *Nature*
Ice sheet forcing: ice sheet–ocean feedback loops

Hattermann and Levermann (2010), *Climate Dynamics*
Ice sheet forcing: freshwater fluxes into the ocean

(a) AMUN

(b) WAIS\textsubscript{MAX}

(c) WAIS\textsubscript{MIN}

(d) AMUN

(e) WAIS\textsubscript{MAX}

(f) WAIS\textsubscript{MIN}

Fogwill et al. (2015), 	extit{Earth’s Future}
Ice sheet forcing: freshwater fluxes into the ocean

Phipps et al. (2016), *The Cryosphere*
Consequences for global sea level

Golledge et al. (2015), Nature
Consequences for global sea level

Golledge et al. (2015), *Nature*
Consequences for global sea level

DeConto and Pollard (2016), *Nature*
Conclusions

- Ice sheet models can be used to explore the mechanisms that have driven past changes in the Antarctic ice sheet.
- Ice sheet models are the *only* physically-based tool that we have to predict future changes in the Antarctic ice sheet.
- Comparison with palaeoclimate data can be used to refine the models and identify potential missing physics.

Future research priorities:

- Continue to use palaeoclimate data to identify missing processes and incorporate them into ice sheet models.
- Couple, couple, couple...