ANTARCTIC GATEWAY PARTNERSHIP

Reducing uncertainties in projections of global sea level rise

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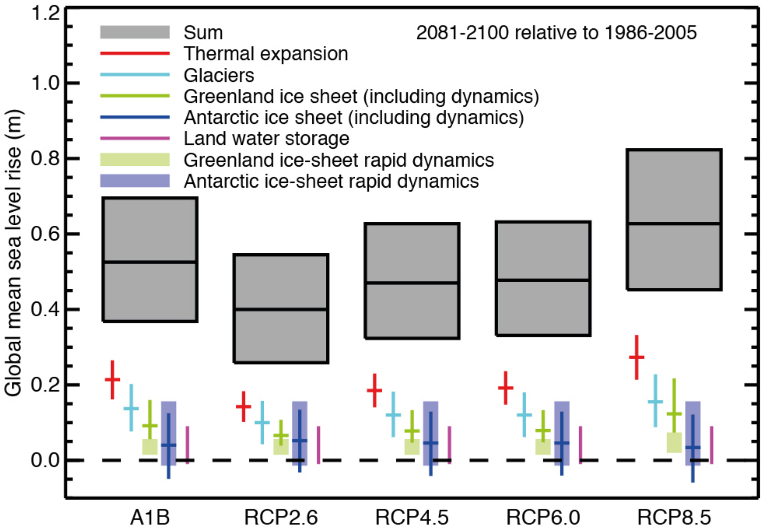
Australian Government
Australian Research Council
UNIVERSITY of TASMANIA AUSTRALIA
CSIRO
Australian Government
Department of the Environment
Australian Antarctic Division
A Special Research Initiative of the Australian Research Council

Context

Likely changes in global sea level by 2081–2100

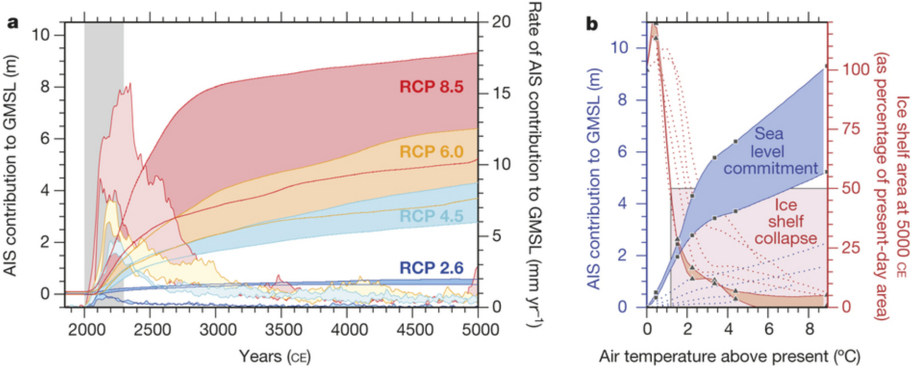


IPCC AR5 WG1 report (2013)

Future Antarctic contribution to global sea level

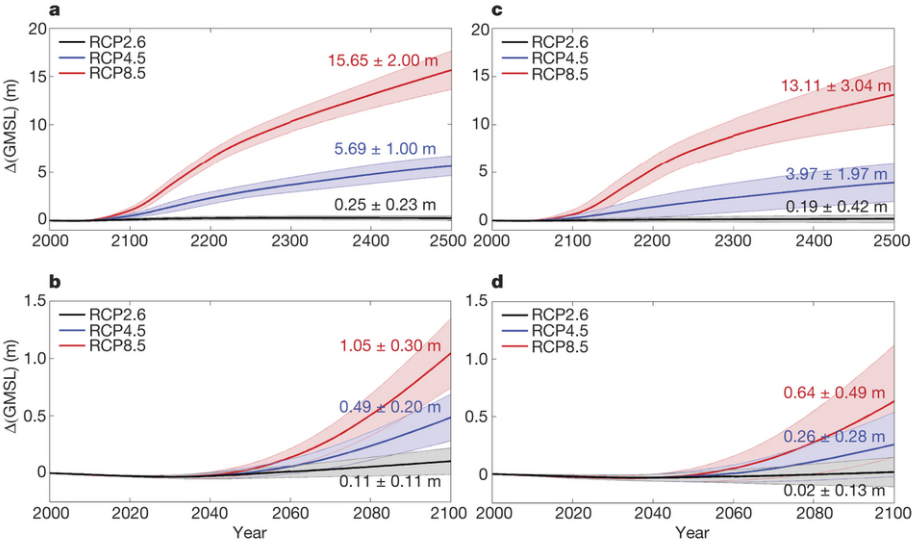
Golledge et al. (2015), *Nature*

Future Antarctic contribution to global sea level



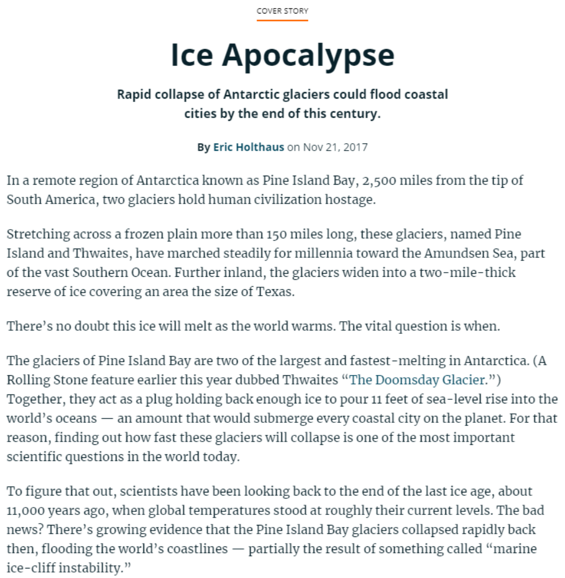
Golledge et al. (2015), *Nature*

Future Antarctic contribution to global sea level



DeConto and Pollard (2016), *Nature*

Are we facing an ice apocalypse?



COVER STORY

Ice Apocalypse

Rapid collapse of Antarctic glaciers could flood coastal cities by the end of this century.

By Eric Holthaus on Nov 21, 2017

In a remote region of Antarctica known as Pine Island Bay, 2,500 miles from the tip of South America, two glaciers hold human civilization hostage.

Stretching across a frozen plain more than 150 miles long, these glaciers, named Pine Island and Thwaites, have marched steadily for millennia toward the Amundsen Sea, part of the vast Southern Ocean. Further inland, the glaciers widen into a two-mile-thick reserve of ice covering an area the size of Texas.

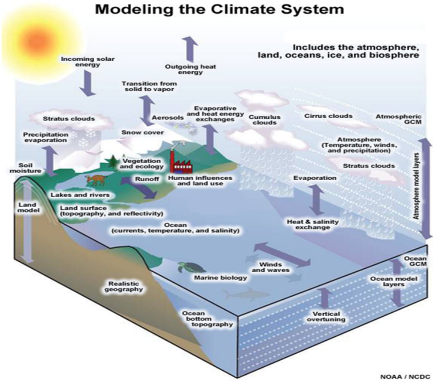
There's no doubt this ice will melt as the world warms. The vital question is when.

The glaciers of Pine Island Bay are two of the largest and fastest-melting in Antarctica. (A Rolling Stone feature earlier this year dubbed Thwaites "The Doomsday Glacier.") Together, they act as a plug holding back enough ice to pour 11 feet of sea-level rise into the world's oceans — an amount that would submerge every coastal city on the planet. For that reason, finding out how fast these glaciers will collapse is one of the most important scientific questions in the world today.

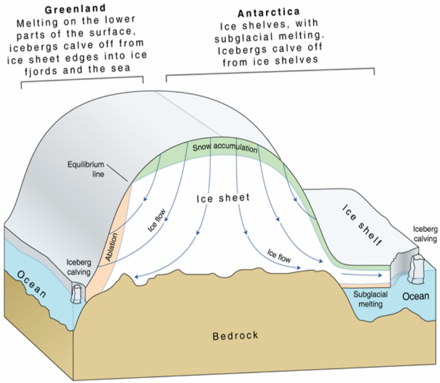
To figure that out, scientists have been looking back to the end of the last ice age, about 11,000 years ago, when global temperatures stood at roughly their current levels. The bad news? There's growing evidence that the Pine Island Bay glaciers collapsed rapidly back then, flooding the world's coastlines — partially the result of something called "marine ice-cliff instability."

Climate and ice sheet modelling

Climate model

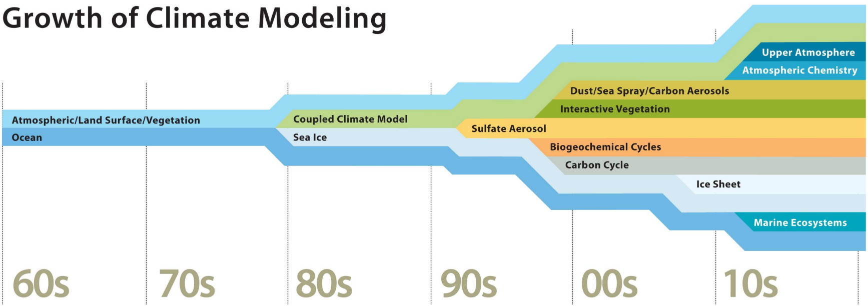


Ice sheet model



Images courtesy of NOAA/NCDC and NSIDC

The development of coupled climate system models



Challenge 1

Ice sheet models are under-constrained

Challenge 1: Ice sheet models are under-constrained

PISM
Parallel Ice Sheet Model

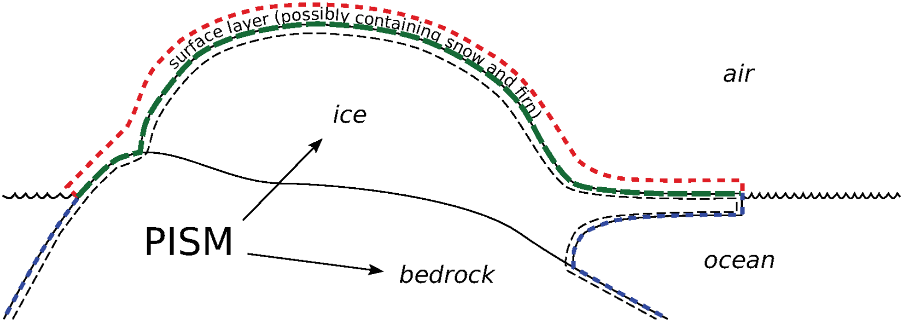


Figure 15: PISM's view of interfaces between an ice sheet and the outside world

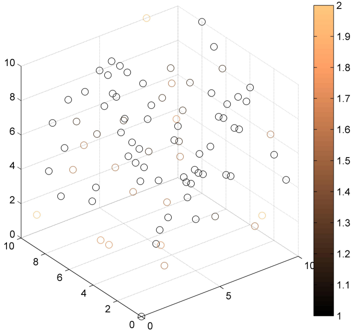
Challenge 1: Ice sheet models are under-constrained

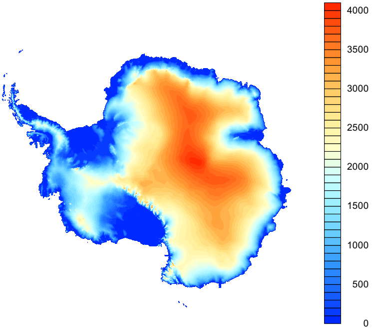
```
mpiexec -n 4 pismr -skip -skip_max 10 -i nomass_20km.nc
-sia_e 3.0 -atmosphere given -atmosphere_given_file
pism_Antarctica_5km.nc -surface simple -ocean pik
-meltfactor_pik 5e-3 -ssa_method fd -ssa_e 0.6 -pik -calving
eigen_calving,thickness_calving -eigen_calving_K 2.0e18
-thickness_calving_threshold 200.0 -stress_balance ssa+sia
-hydrology null -pseudo_plastic -pseudo_plastic_q 0.25
-till_effective_fraction_overburden 0.02
-tauc_slippery_grounding_lines -topg_to_phi 15.0,40.0,
-300.0,700.0 -ys 0 -y 100000 -ts_file ts_run_20km.nc
-ts_times 0:1:100000 -extra_file extra_run_20km.nc
-extra_times 0:1000:100000 -extra_vars thk,usurf,
velbase_mag,velbar_mag,mask,diffusivity,tauc,bmelt,
tillwat,temppabase,hardav,Href,gl_mask -o run_20km.nc
-o_size big
```

Challenge 1: Ice sheet models are under-constrained

Constraining ice sheet model parameterisations

- Use PISM to simulate the past evolution of the Antarctic Ice Sheet.
- Run the model many times. Perturb the model physics each time, sampling as many different parameter combinations as possible.
- Identify the model configurations where the simulated evolution of the ice sheet agrees best with the known history.

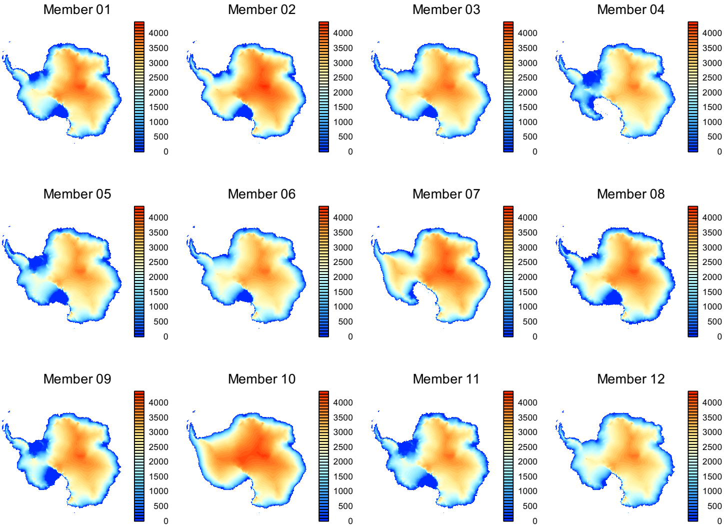




“Tuning” an ice sheet model: Parameters

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

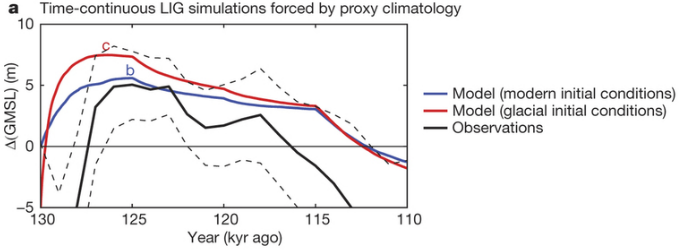
Constraining ice sheet model parameterisations

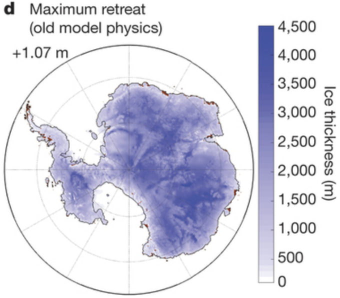


Challenge 2

Missing physics

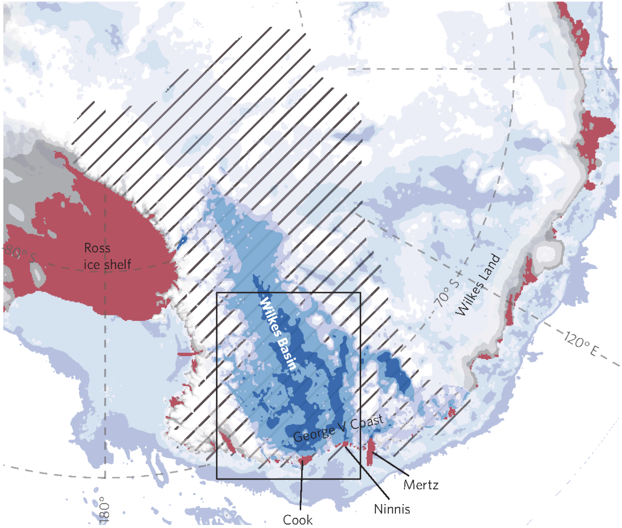
Challenge 2: The case of the ice that won't melt





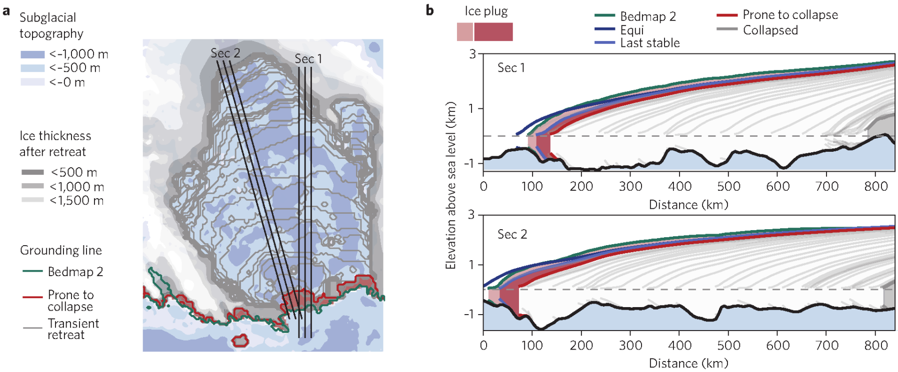
DeConto and Pollard (2016), *Nature*

Marine ice sheet instability (MISI)



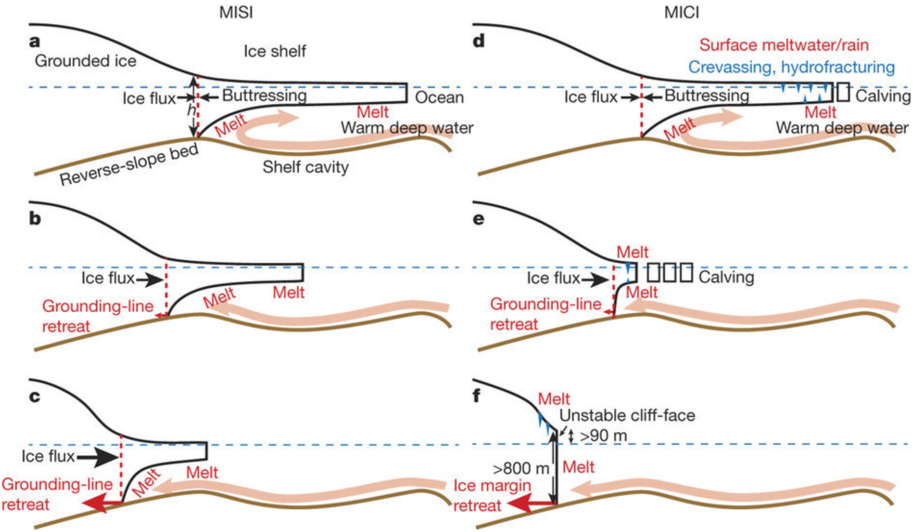
Mengel and Levermann (2014), *Nature Climate Change*

Marine ice sheet instability (MISI)



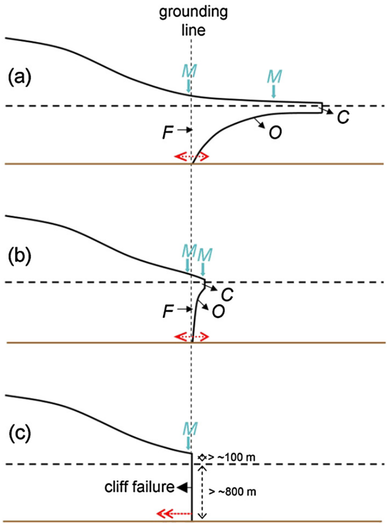
Mengel and Levermann (2014), *Nature Climate Change*

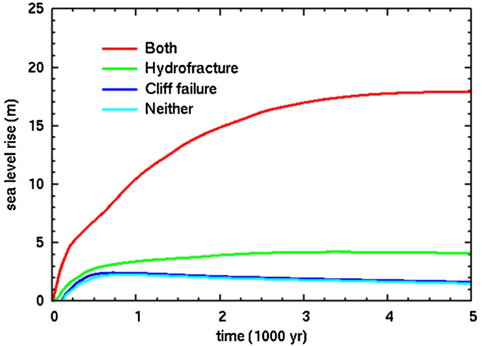
Mechanisms of ice sheet instability



DeConto and Pollard (2016), *Nature*

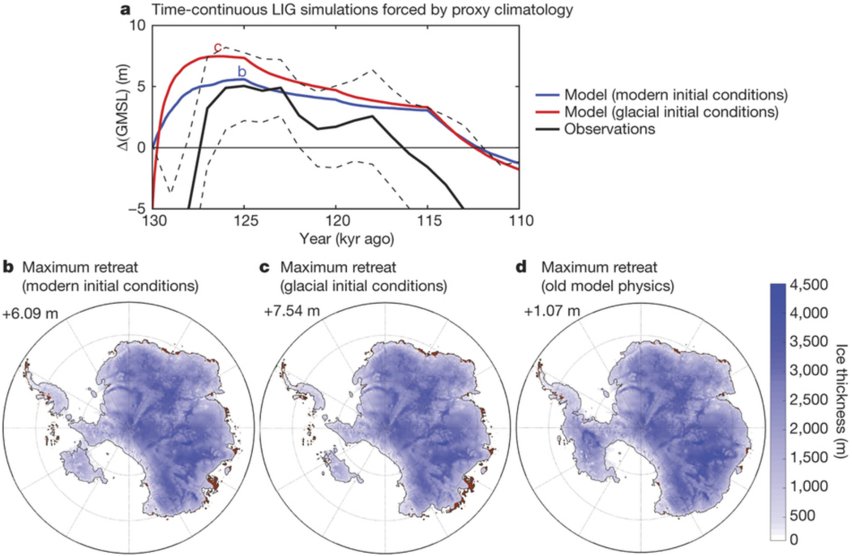
Hydrofracturing and ice cliff failure





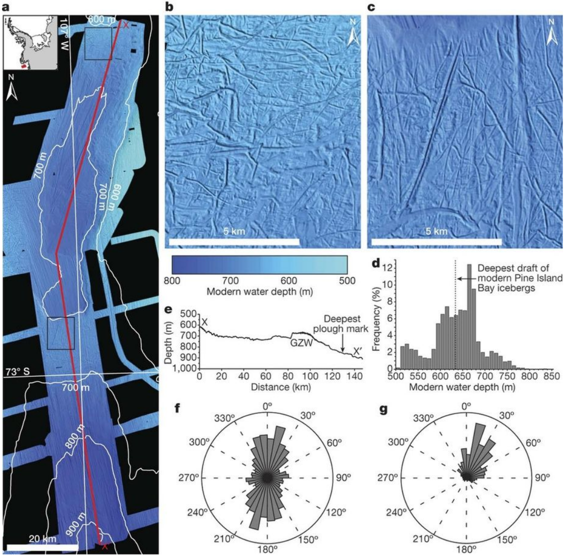
Pollard et al. (2015), *Earth and Planetary Science Letters*

Marine ice cliff instability (MICI)



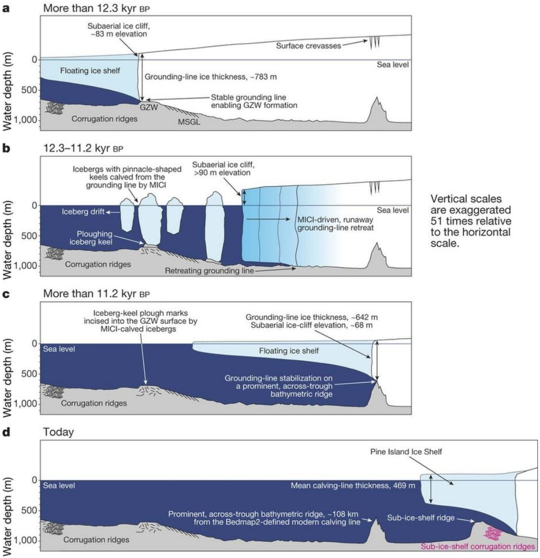
DeConto and Pollard (2016), *Nature*

Marine ice cliff instability: observational evidence



Wise et al. (2017), *Nature*

Marine ice cliff instability: observational evidence



Wise et al. (2017), *Nature*

Challenge 3

Boundary conditions

Challenge 3: Boundary conditions

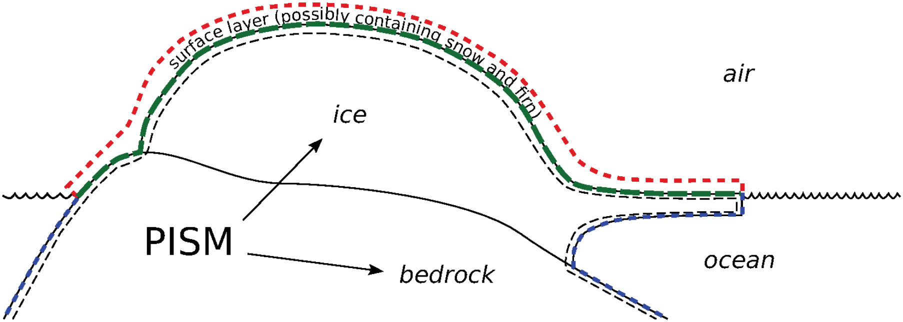
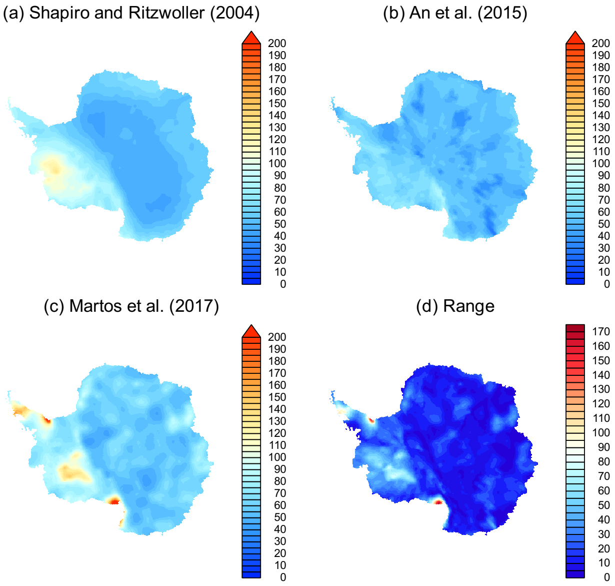
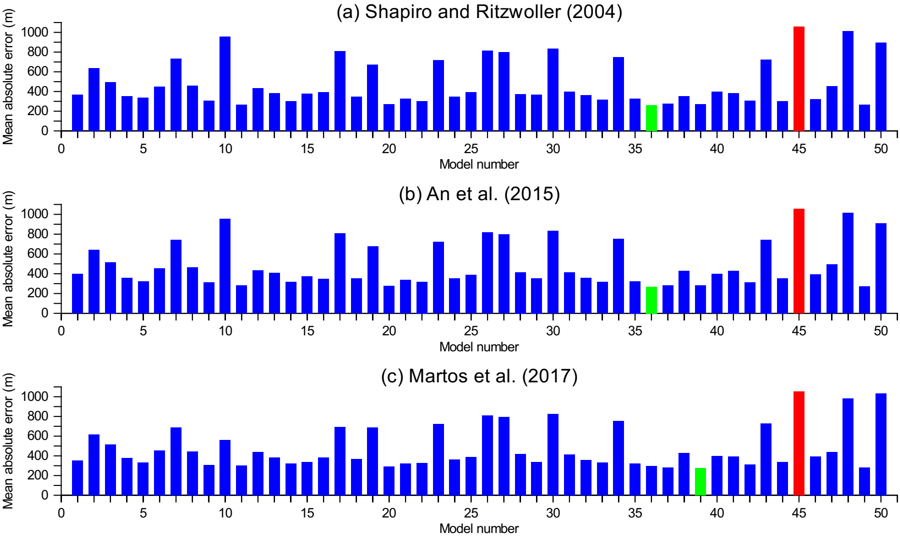


Figure 15: PISM's view of interfaces between an ice sheet and the outside world

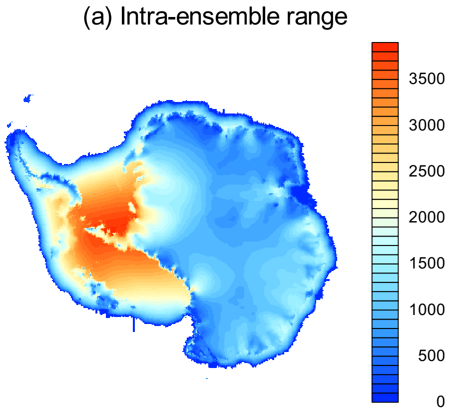
Uncertainty in boundary conditions



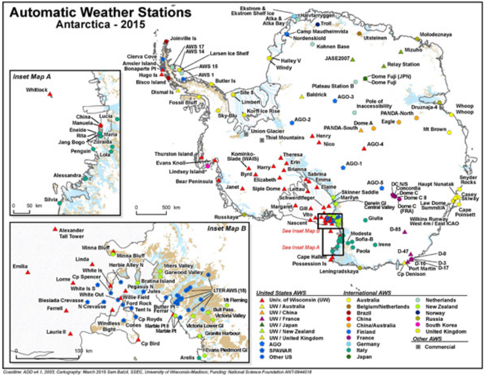
Impact on “tuning” an ice sheet model



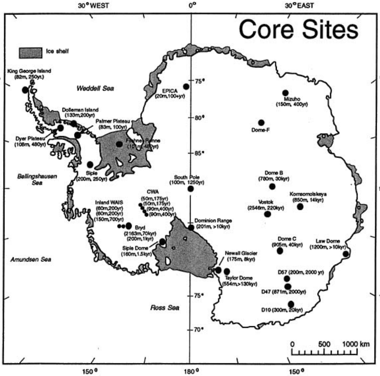
"Tuning" an ice sheet model: Roles of physics and GHF



Lack of observational data

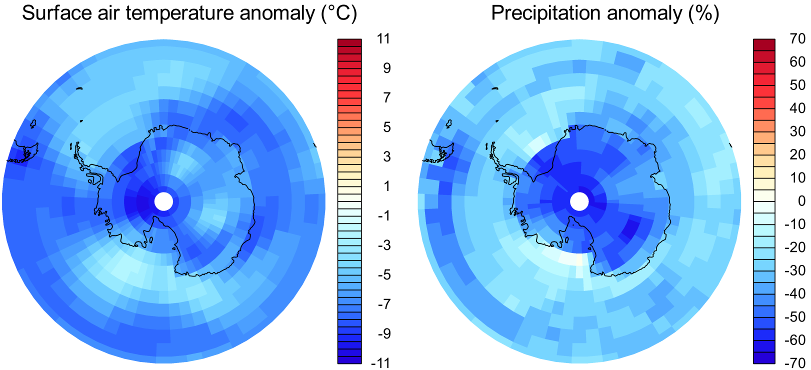


Present



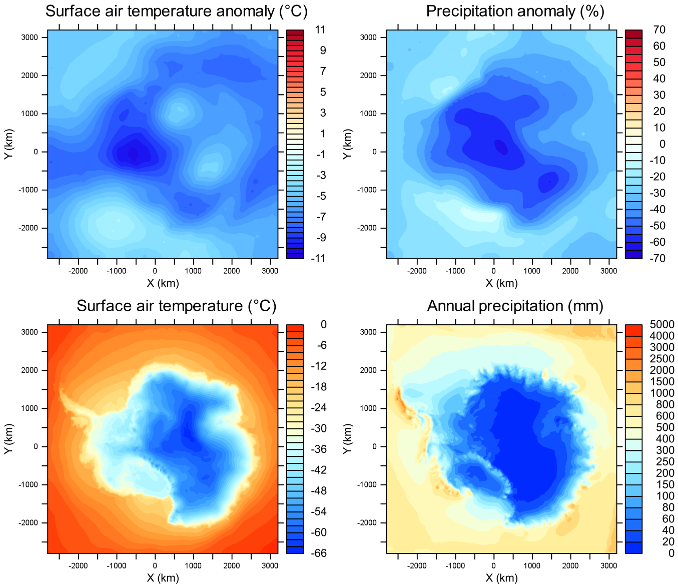
Past

Using climate modelling to generate boundary conditions

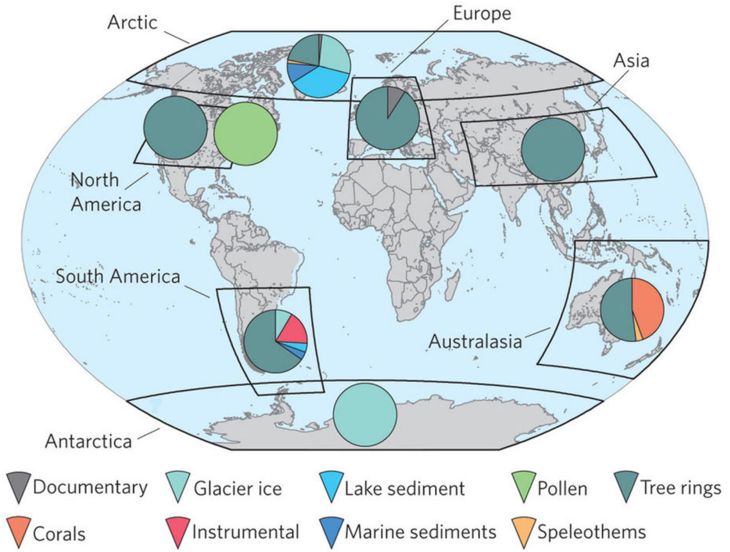


- Use the CSIRO Mk3L climate system model to simulate the period 56–0 ka, then 5,000 years into the future under the RCP8.5 scenario

Using climate modelling to generate boundary conditions

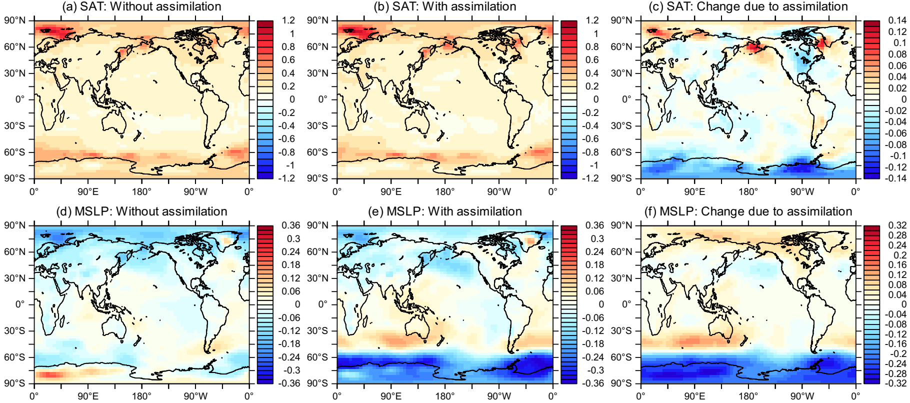


Using data assimilation to incorporate proxy information



PAGES 2k Consortium (2013), *Nature Geoscience*

Using data assimilation to incorporate proxy information



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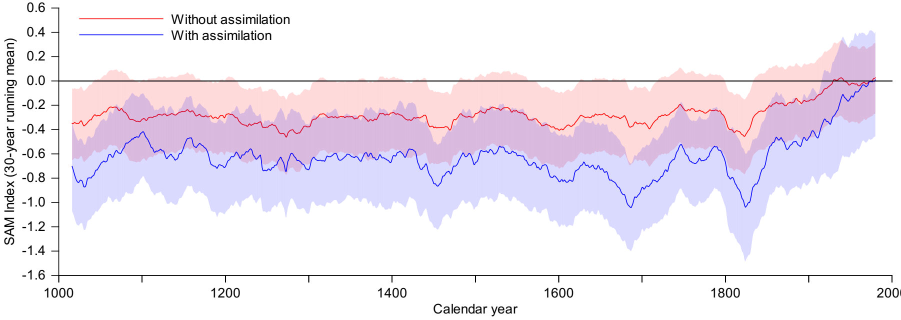
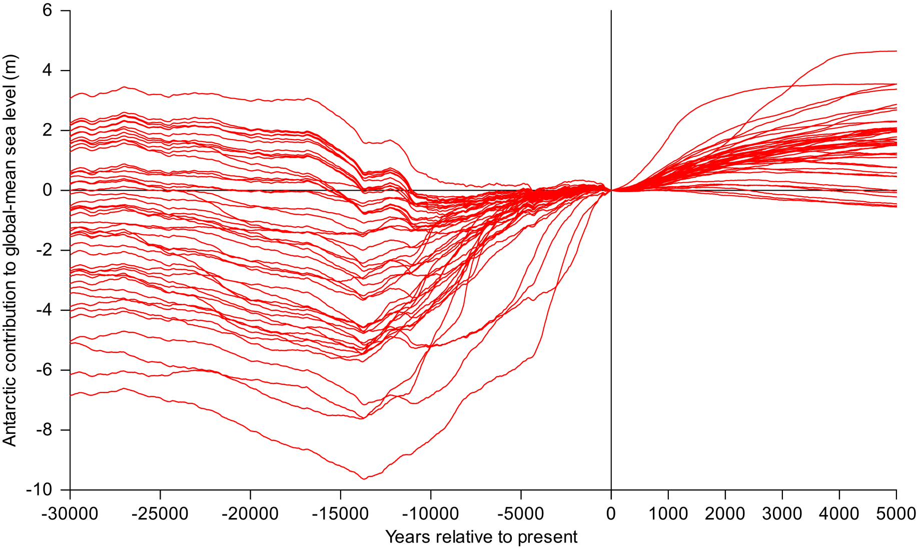


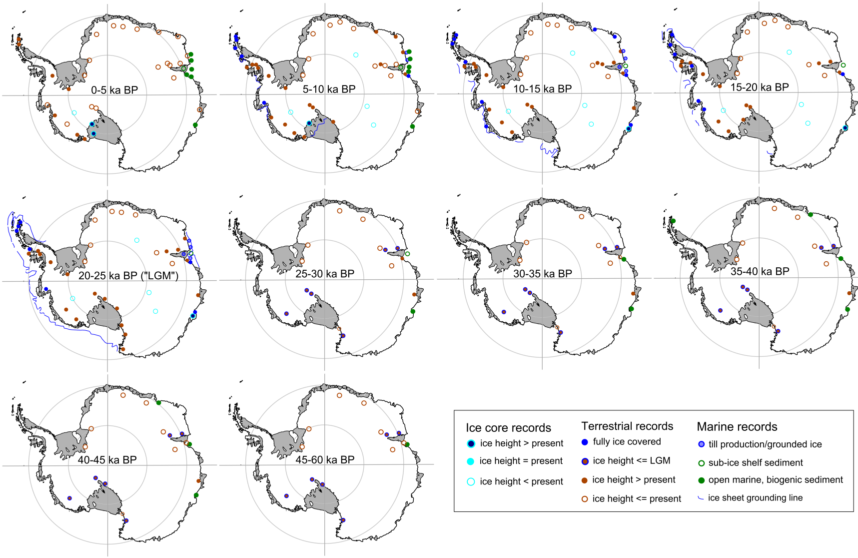
Challenge 4

Evaluating ice sheet model simulations

Challenge 4: Evaluating ice sheet model simulations

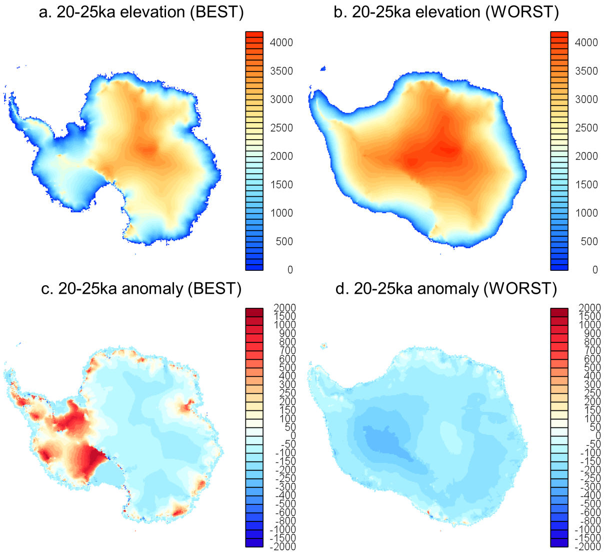


The history of the Antarctic ice sheet (60–0 ka)



Duanne White/University of Canberra

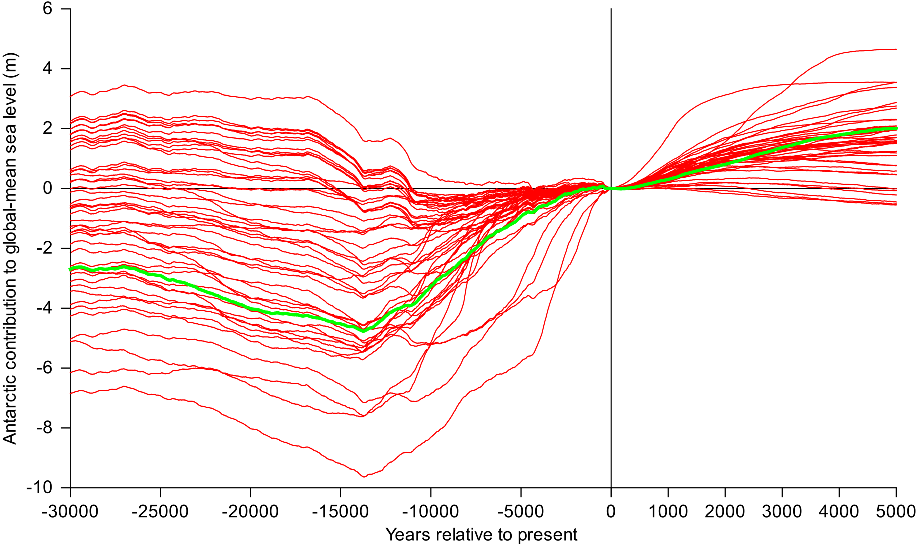
Constraining parameterisations: Using the past



We need more data!

Bringing it all together

Using the past to inform the future



Potential areas for collaboration

- Constraining ice sheet model parameterisations
  - Improving representations of known physical processes
  - Incorporation of hypothetical physical processes
- Simulating past and future changes in the atmosphere and ocean
  - Ensemble simulations using coupled atmosphere–sea ice–ocean general circulation models
  - Assimilation of Southern Hemisphere proxy data
  - Ice sheet–ocean coupling?
- Reconstructing past changes in the Antarctic ice sheet
  - Reconstructing past changes in ice thickness and extent
  - Using reconstructions to evaluate ice sheet model simulations