Ice apocalypse? Using the history of Antarctica to improve projections of global sea level rise

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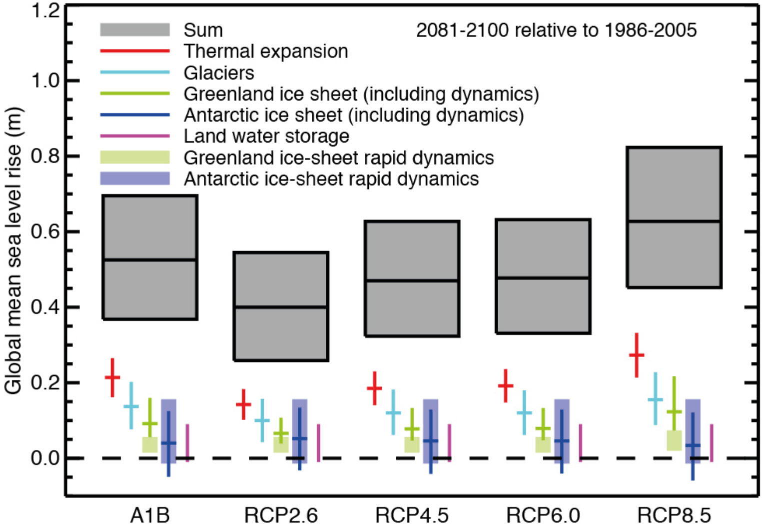
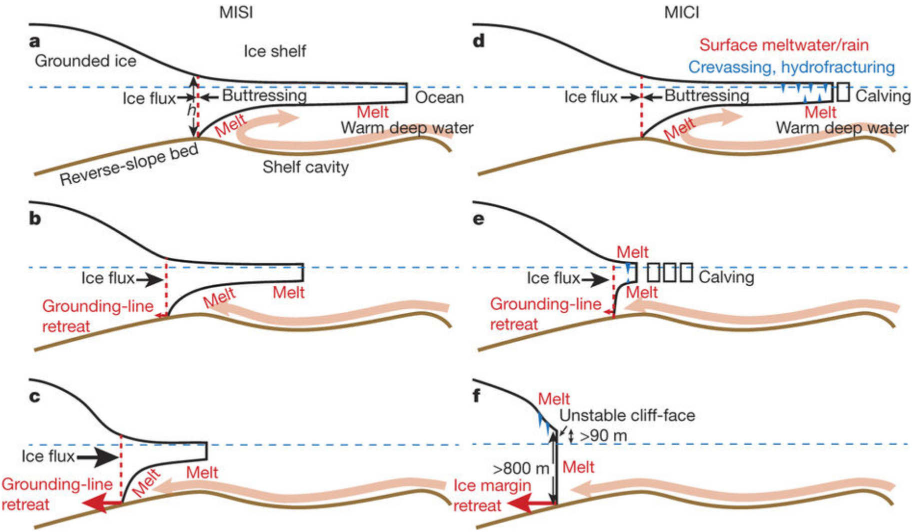
CSIRO
Australian Government Department of the Environment Australian Antarctic Division

Likely changes in global sea level by 2081–2100



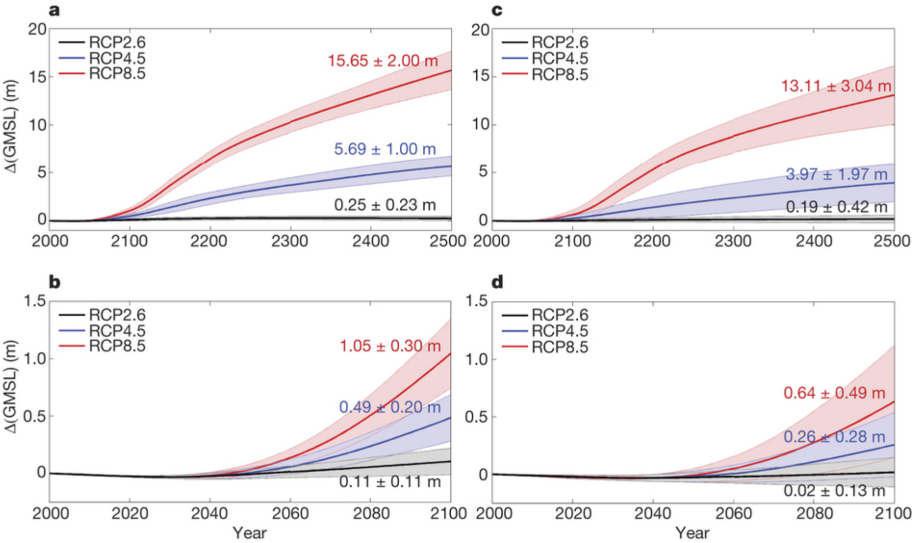
IPCC AR5 WG1 report (2013)

Mechanisms of ice sheet instability



DeConto and Pollard (2016), *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."

How do we project changes in global sea level?

PISM
Parallel Ice Sheet Model

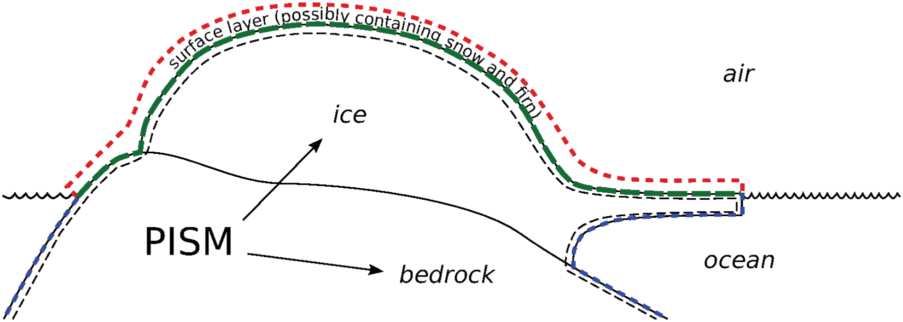
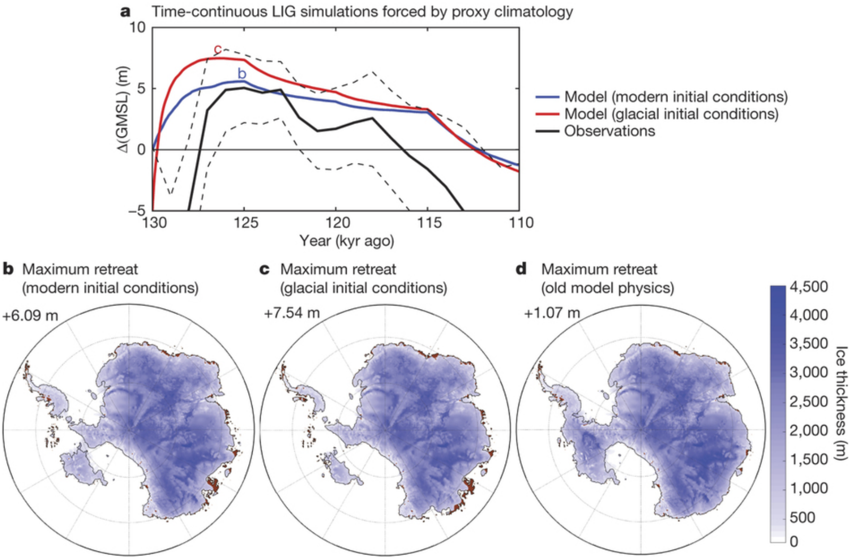


Figure 15: PISM's view of interfaces between an ice sheet and the outside world

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
```

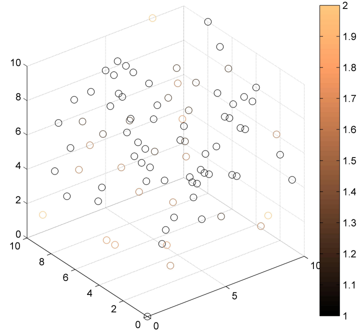
Challenge 1: Ice sheet models are under-constrained



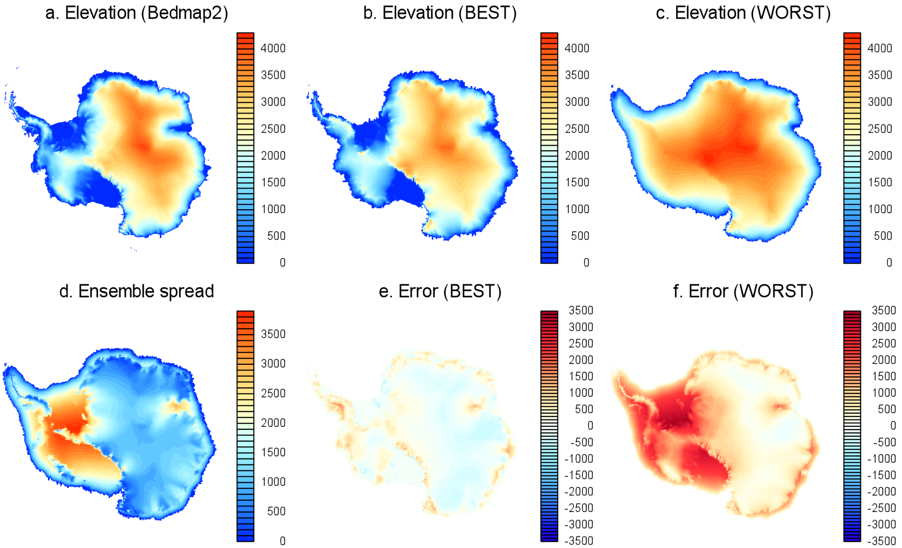
DeConto and Pollard (2016), *Nature*

Constraining ice sheet model parameterisations

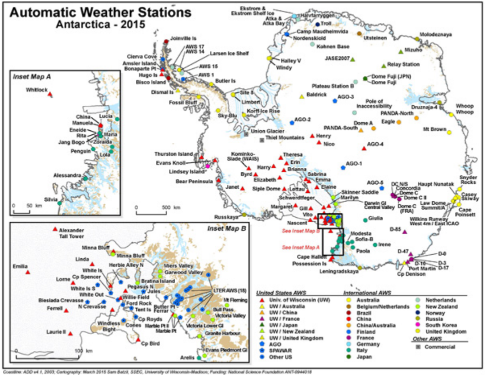
- Use PISM to simulate the past evolution of the Antarctic Ice Sheet.
- Run the model many times. Perturb the model physics each time, sampling as many different parameter combinations as possible.
- Identify the model configurations where the simulated evolution of the ice sheet agrees best with the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



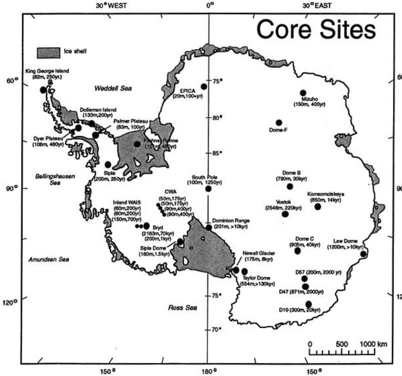
Constraining ice sheet model parameterisations



Challenge 2: Boundary conditions

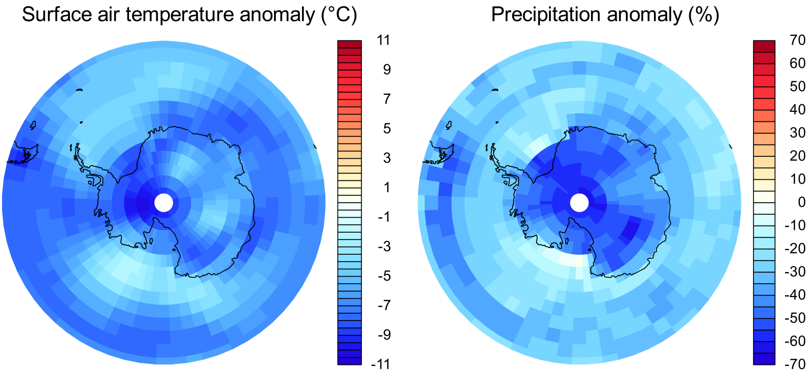


Present



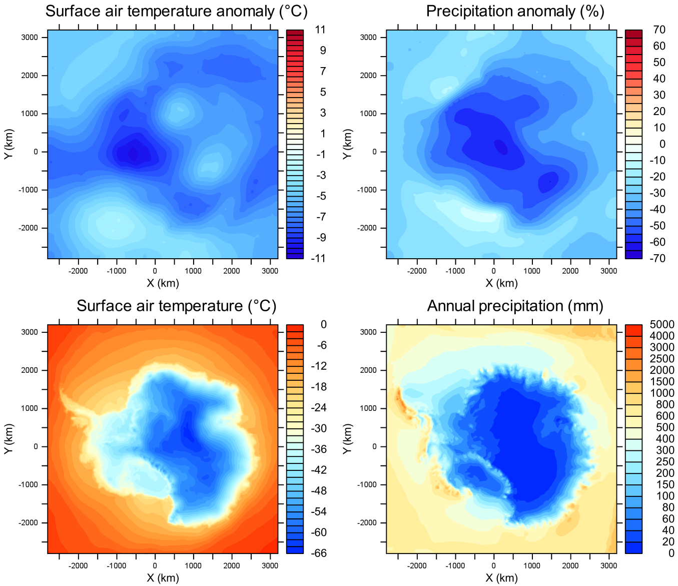
Past

Using climate modelling to generate boundary conditions

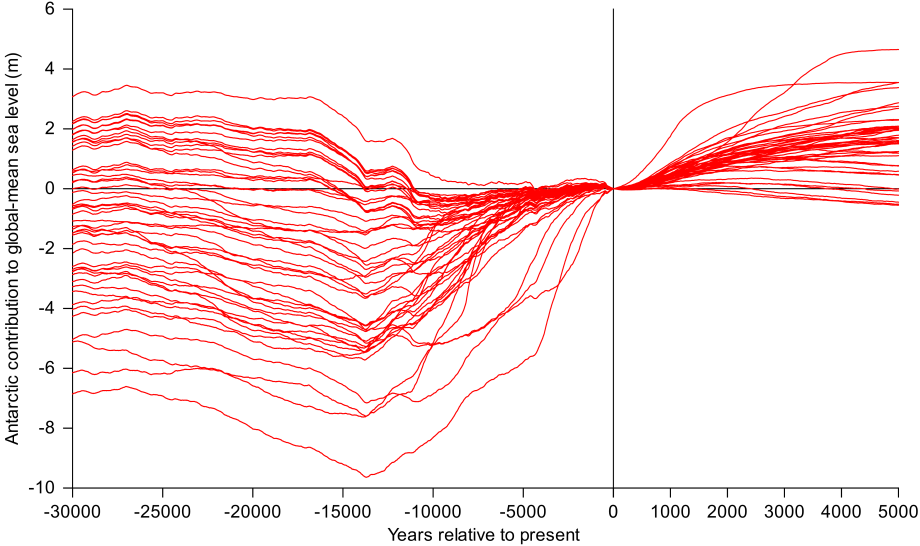


- Using the CSIRO Mk3L climate system model to simulate:
  - 26–0 ka, then 5,000 years into the future
  - 70–0 ka, then 5,000 years into the future
  - 120–0 ka, then 5,000 years into the future
- Next step: data assimilation

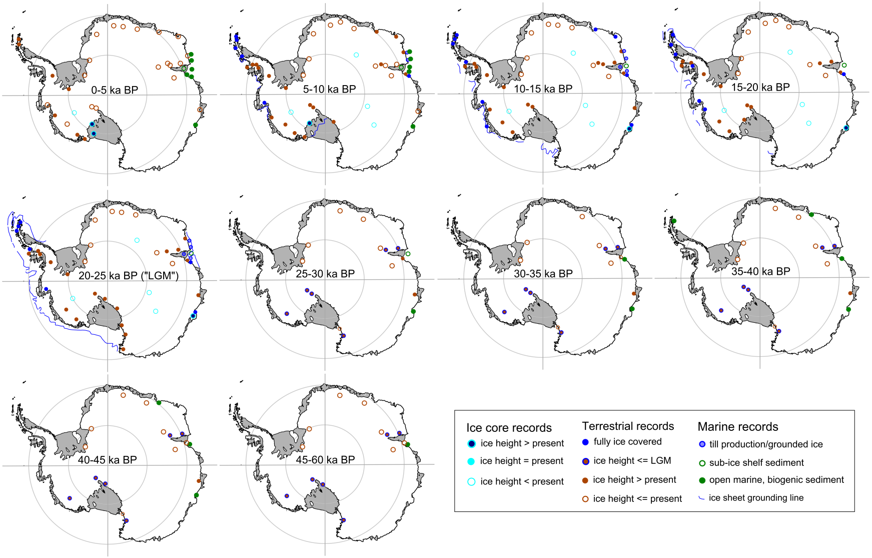
Using climate modelling to generate boundary conditions



Challenge 3: Evaluating ice sheet model simulations



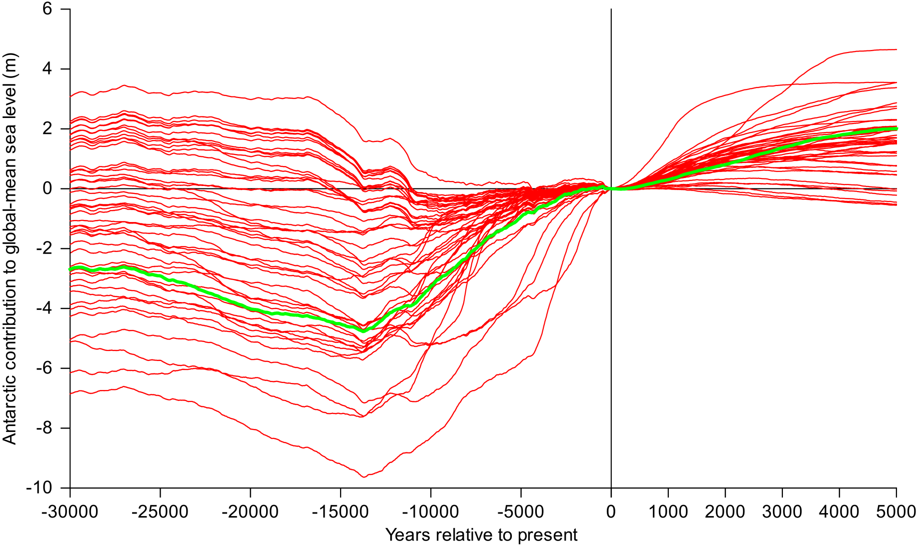
The history of the Antarctic ice sheet (60–0 ka)



Duanne White/University of Canberra

We need more data!

Constraining ice sheet model parameterisations



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