Reducing uncertainties in projections of global sea level rise

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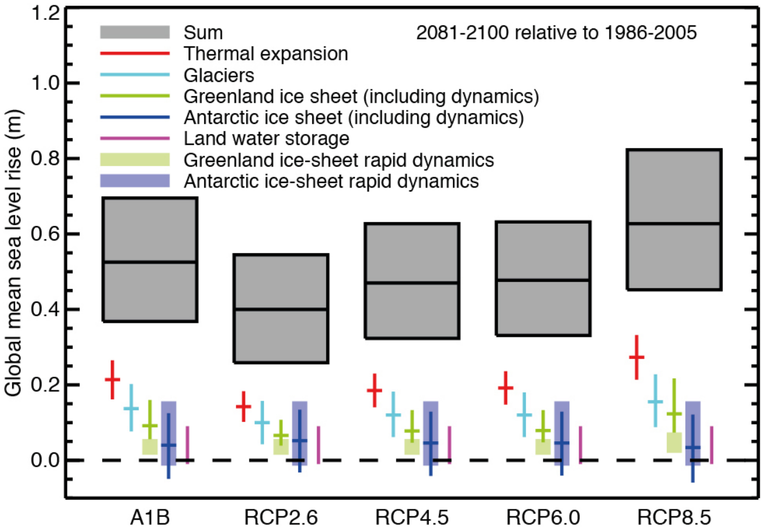
Likely changes in global sea level by 2081–2100

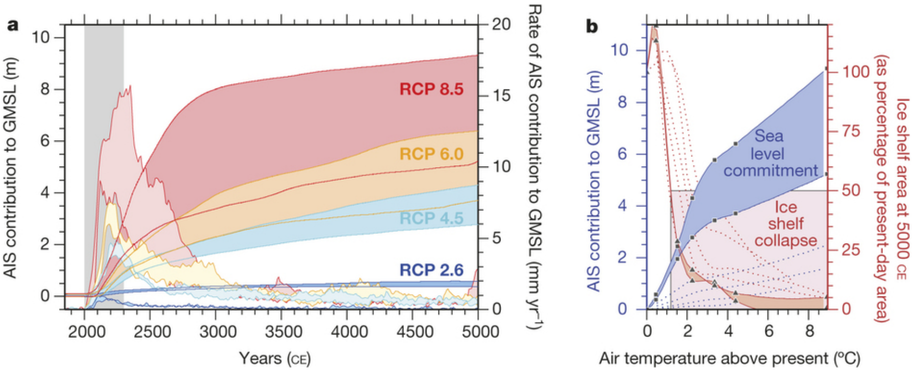


IPCC AR5 WG1 report (2013)

Future Antarctic contribution to global sea level

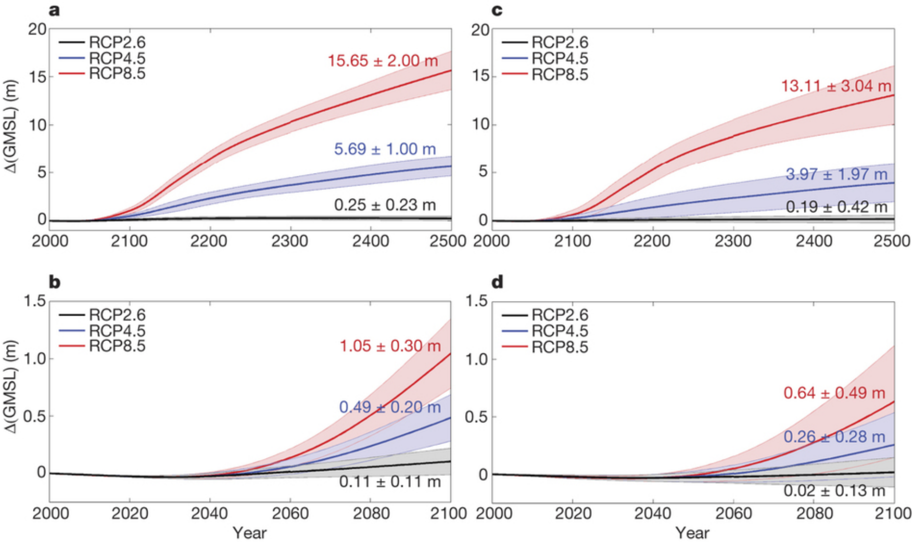
Golledge et al. (2015), *Nature*

Future Antarctic contribution to global sea level



Golledge et al. (2015), *Nature*

Future Antarctic contribution to global sea level

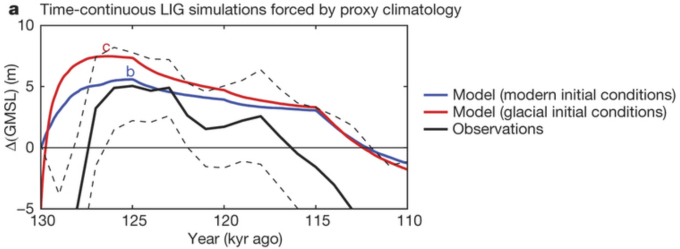


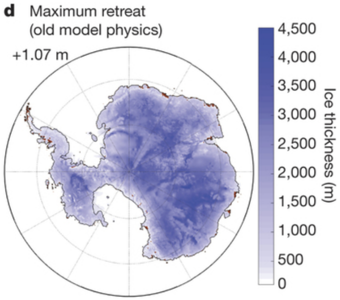
DeConto and Pollard (2016), *Nature*

Challenge 1

Missing physics

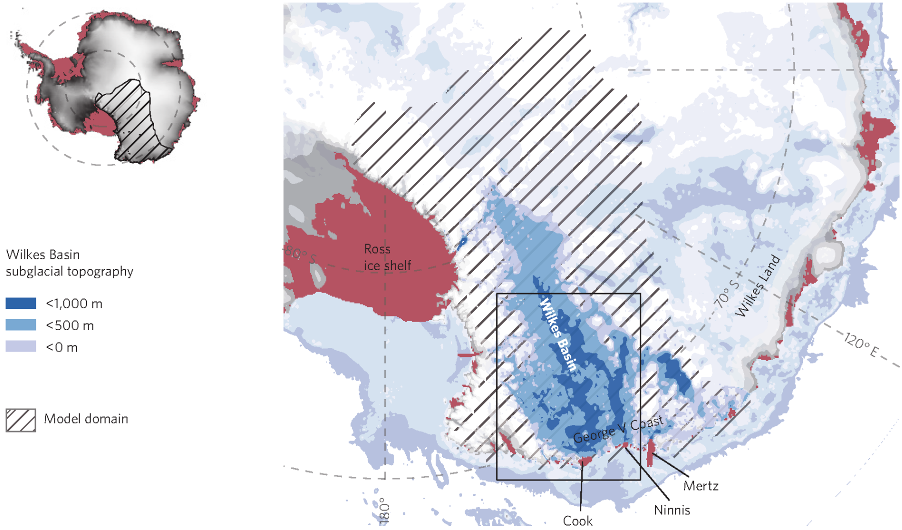
Challenge 1: The case of the ice that won't melt



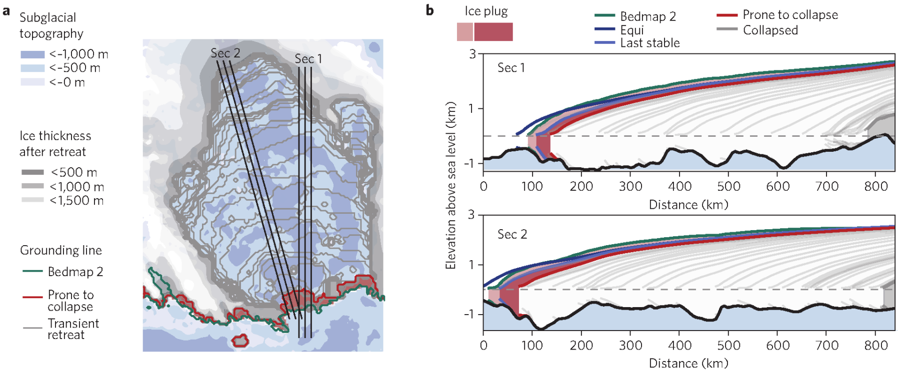


DeConto and Pollard (2016), *Nature*

Marine ice sheet instability (MISI)

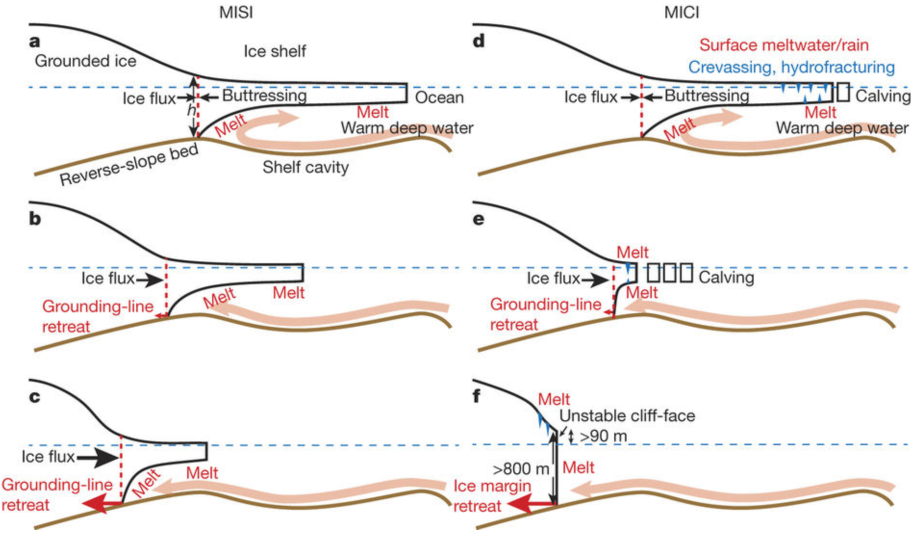


Mengel and Levermann (2014), *Nature Climate Change*

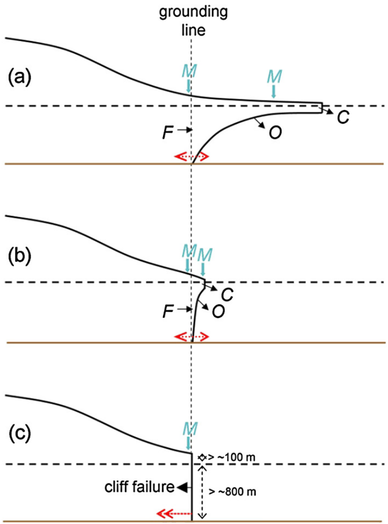


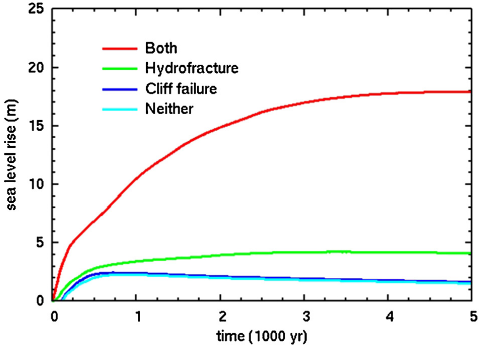
Mengel and Levermann (2014), *Nature Climate Change*

Mechanisms of ice sheet instability



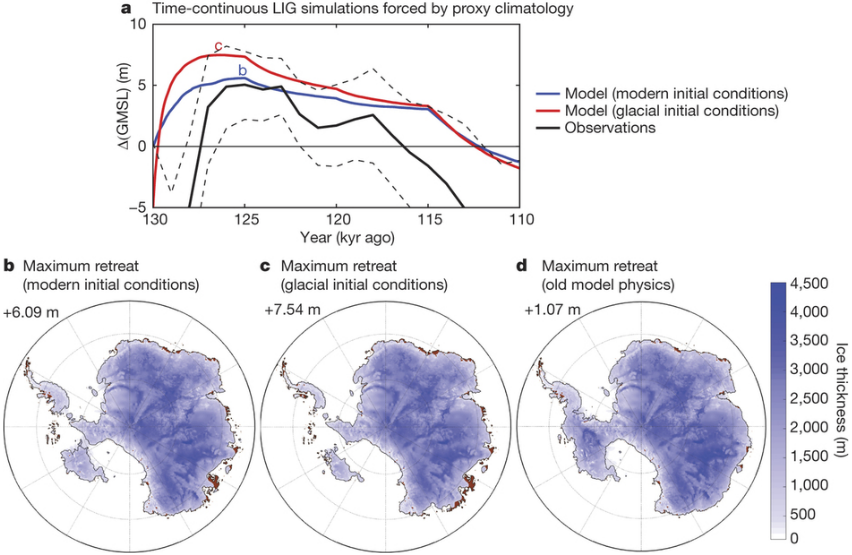
DeConto and Pollard (2016), *Nature*





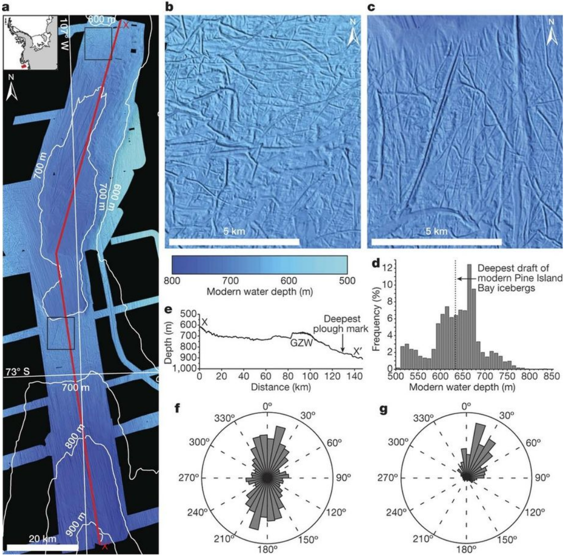
Pollard et al. (2015), *Earth and Planetary Science Letters*

Marine ice cliff instability (MICI)



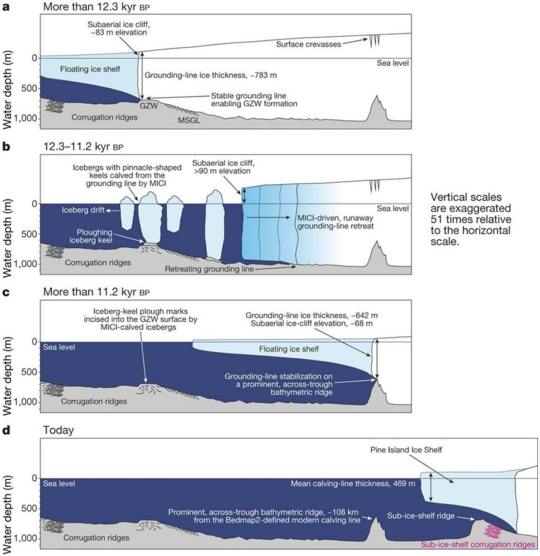
DeConto and Pollard (2016), *Nature*

Marine ice cliff instability: observational evidence



Wise et al. (2017), *Nature*

Marine ice cliff instability: observational evidence



Wise et al. (2017), *Nature*

Challenge 2

Ice sheet models are under-constrained

Challenge 2: Ice sheet models are under-constrained

PISM
Parallel Ice Sheet Model

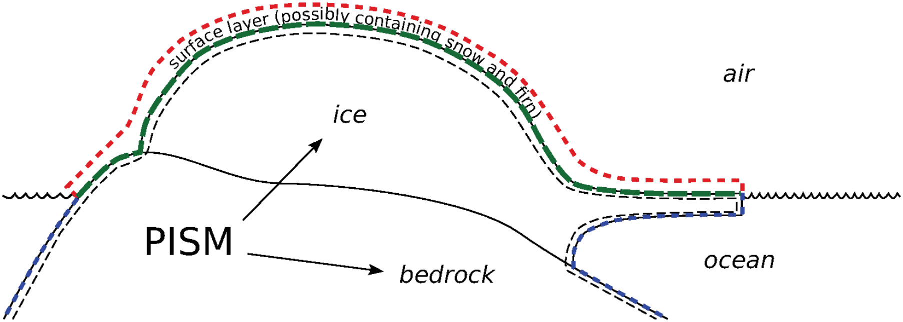
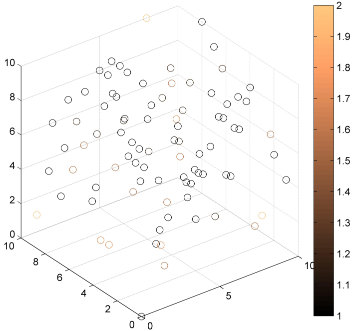


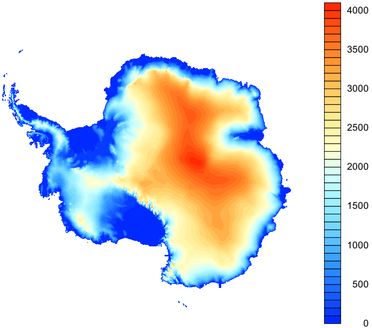
Figure 15: PISM's view of interfaces between an ice sheet and the outside world

Challenge 2: 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
```

- 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.



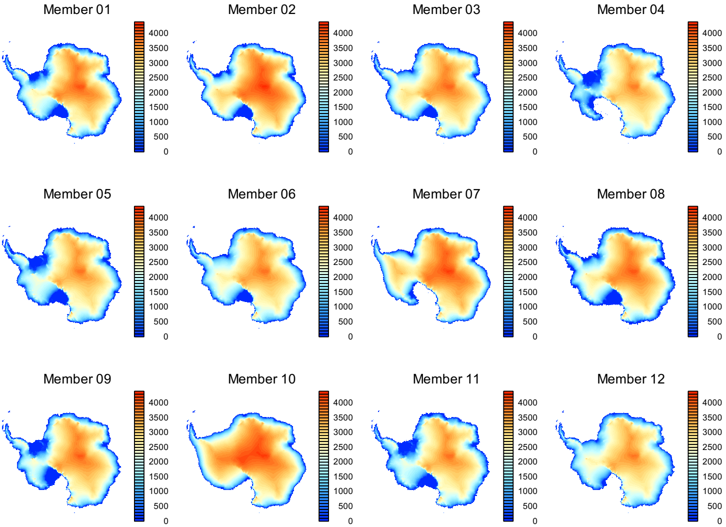


Constraining ice sheet model parameterisations

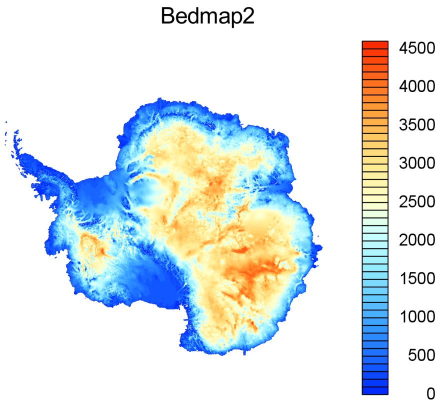
- 100-member ensemble, perturbing 10 parameters

Parameter	Description	Minimum	Maximum
-sia_e	Shallow ice enhancement factor	1.2	4.5
-ssa_e	Shallow shelf enhancement factor	0.7	1.6
-pseudo_plastic_q	Exponent of basal resistance model	0.50	1.00
-till_effective_fraction_overburden	Effective till pressure scaling factor	0.01	0.02
-eigen_calving_K	Calving rate scaling factor	1.0e16	1.0e19
-thickness_calving_threshold	Minimum thickness of floating ice shelves	100.0	200.0
-topg_to_phi phimin	Till friction angle (marine history)	12.5	25.0
-topg_to_phi phimax	Till friction angle (no marine history)	25.0	40.0
-topg_to_phi bmin	Bed elevation (bottom of transition zone)	-1500.0	0.0
-topg_to_phi bmax	Bed elevation (top of transition zone)	0.0	1000.0

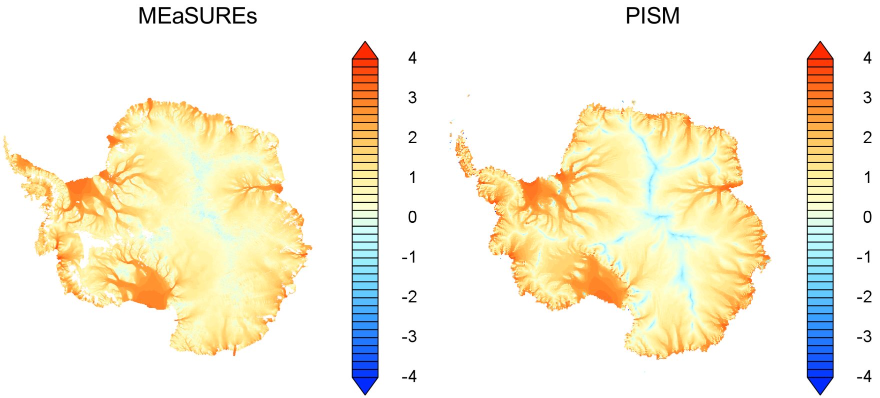
Constraining ice sheet model parameterisations

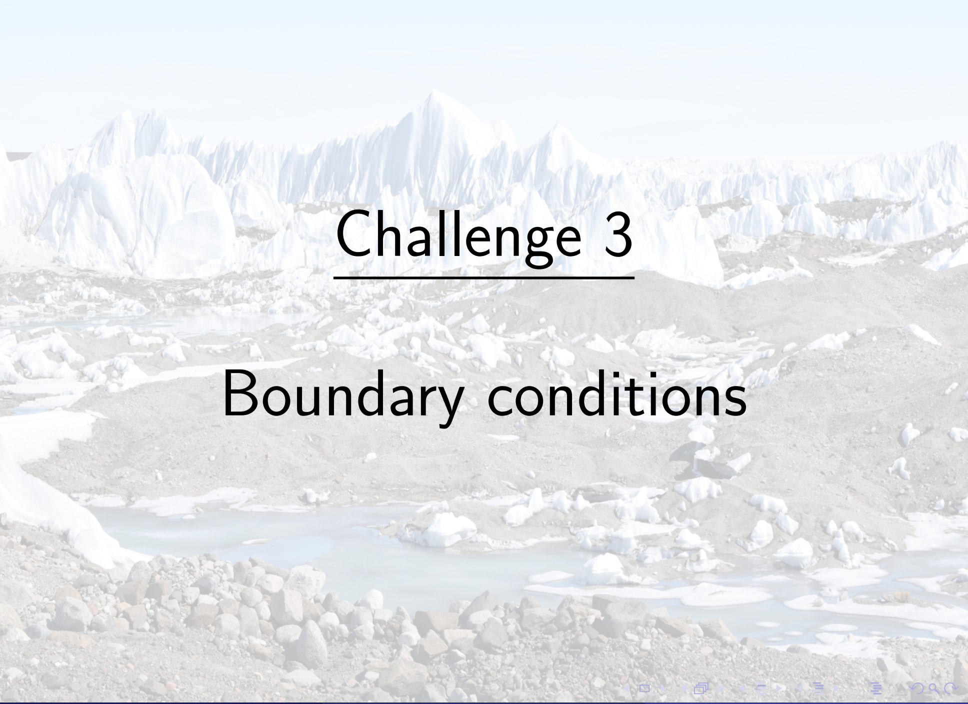


Simulated ice thickness (m)



Simulated ice velocity (logarithm of velocity in m year^{-1})





Challenge 3

Boundary conditions

Challenge 3: Boundary conditions

PISM
Parallel Ice Sheet Model

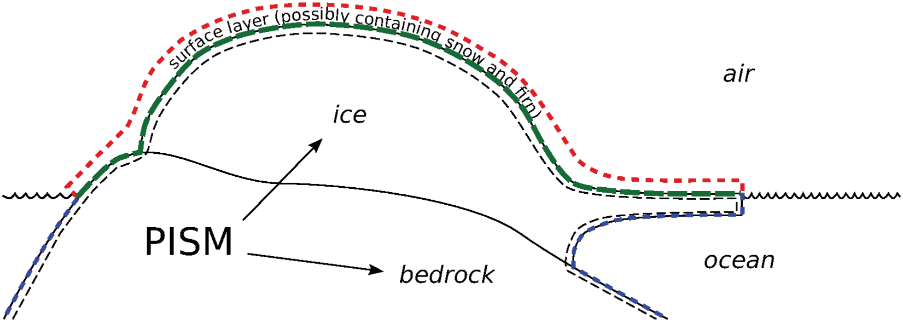
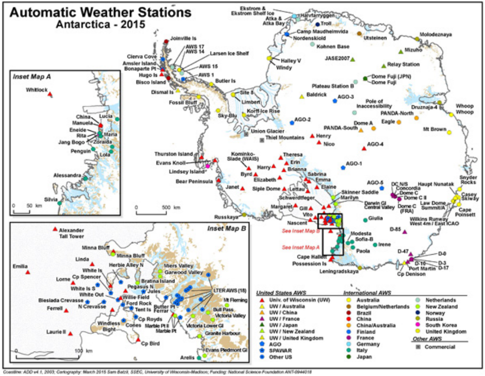
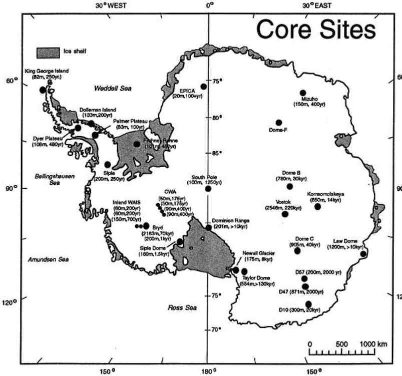


Figure 15: PISM's view of interfaces between an ice sheet and the outside world

Lack of observational data

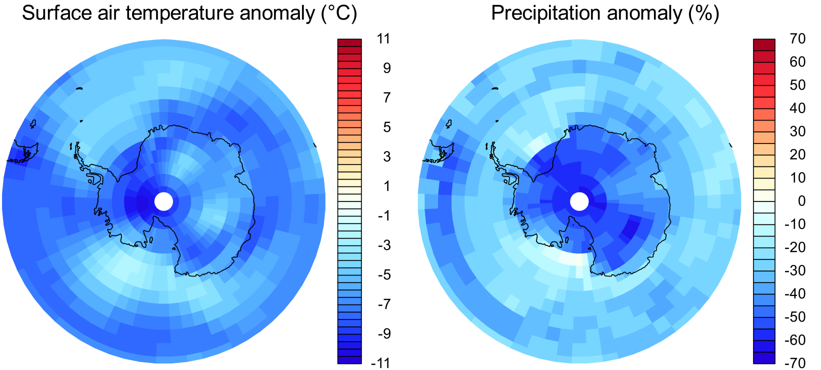


Present



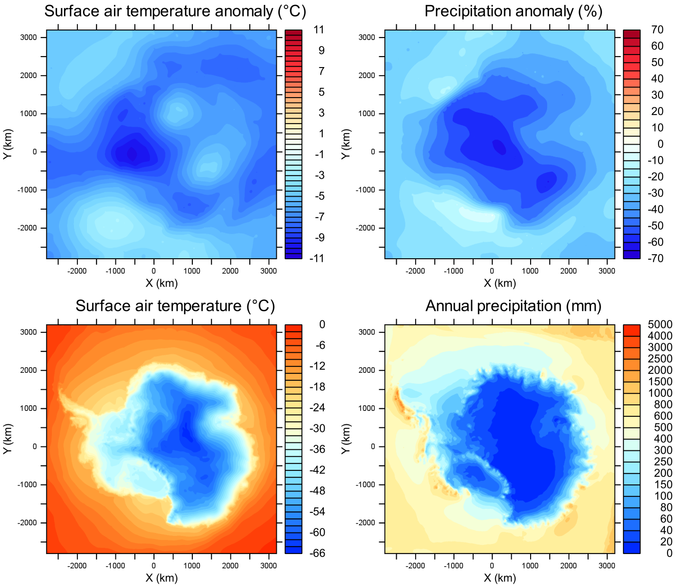
Past

Using climate modelling to generate boundary conditions



- Use the CSIRO Mk3L climate system model to simulate the period 41–0 ka, then 5,000 years into the future under the RCP8.5 scenario

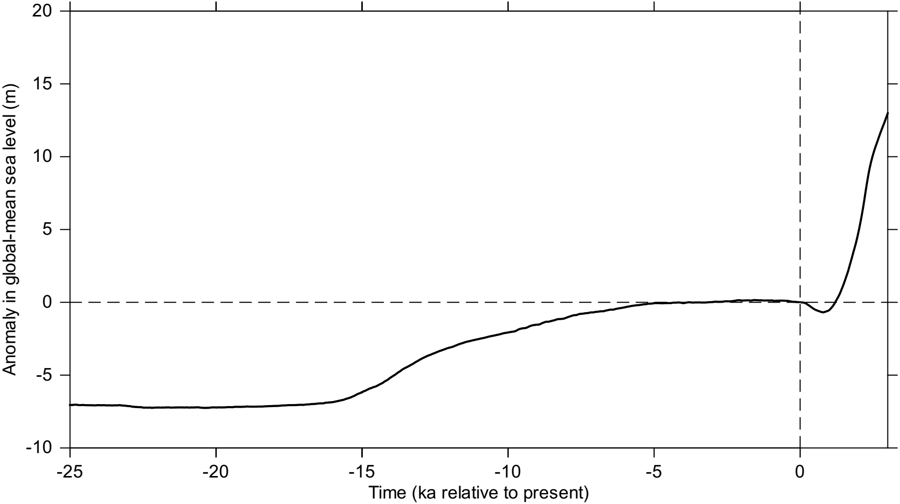
Using climate modelling to generate boundary conditions



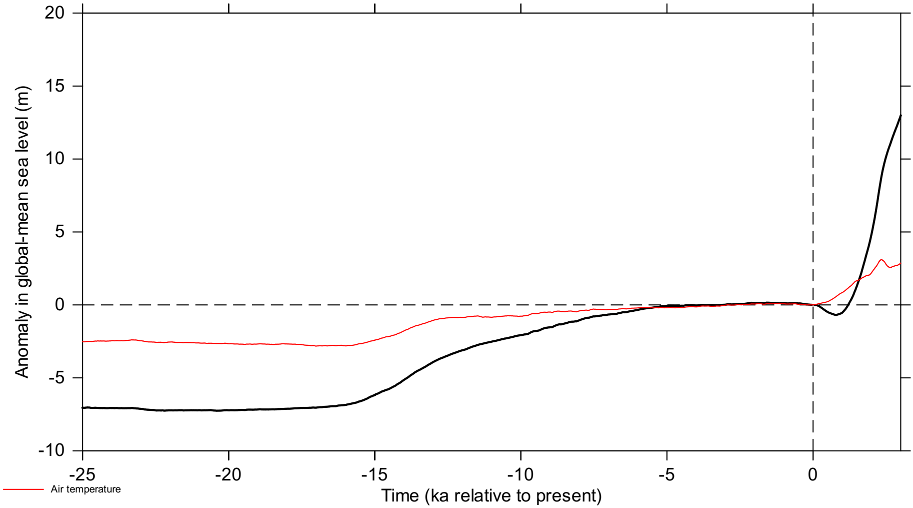
Bringing it all together

Using the past to constrain the future

Past and future changes in global-mean sea level



Past and future changes in global-mean sea level



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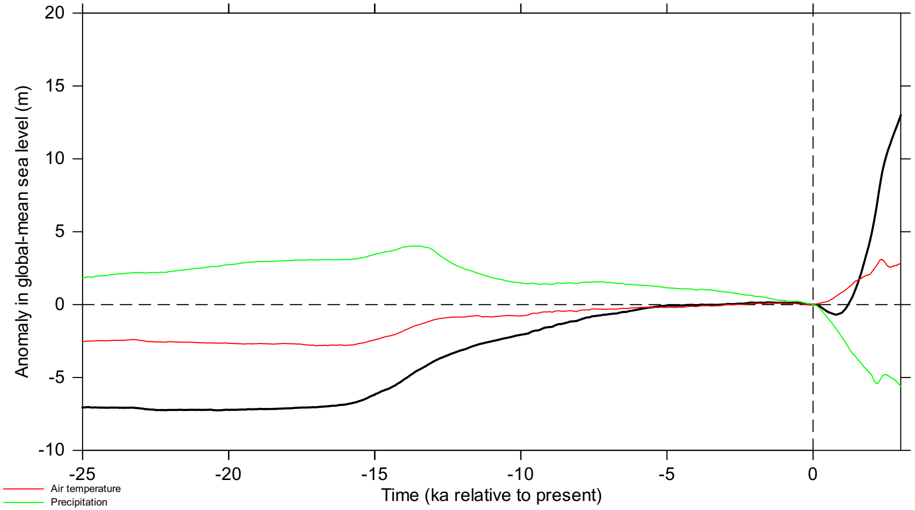

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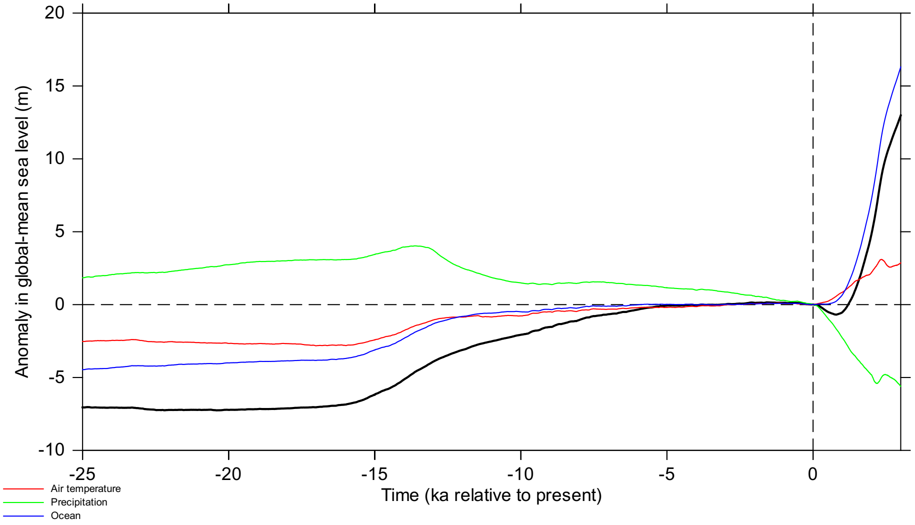

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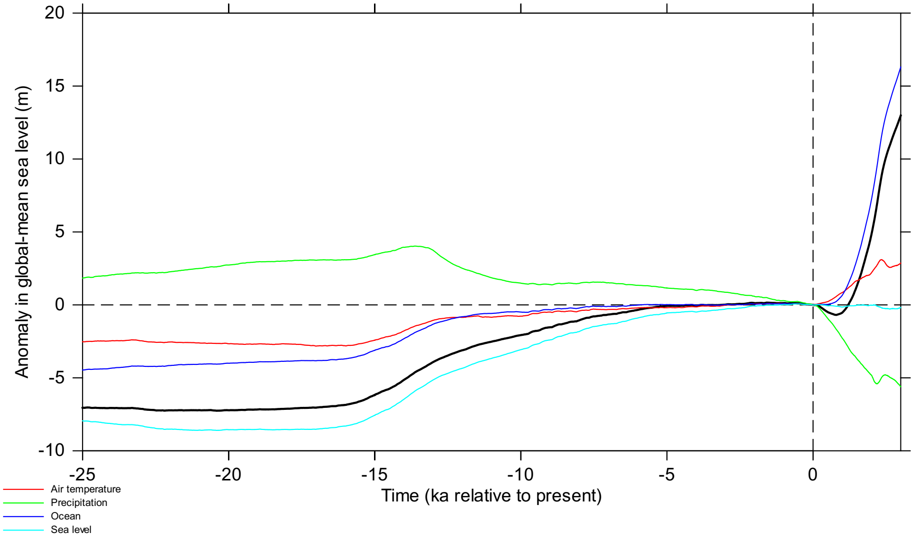
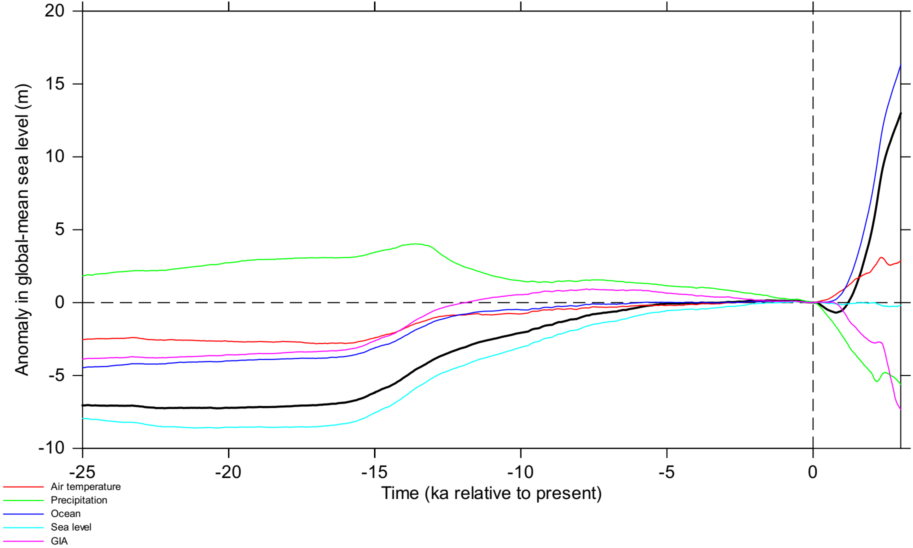
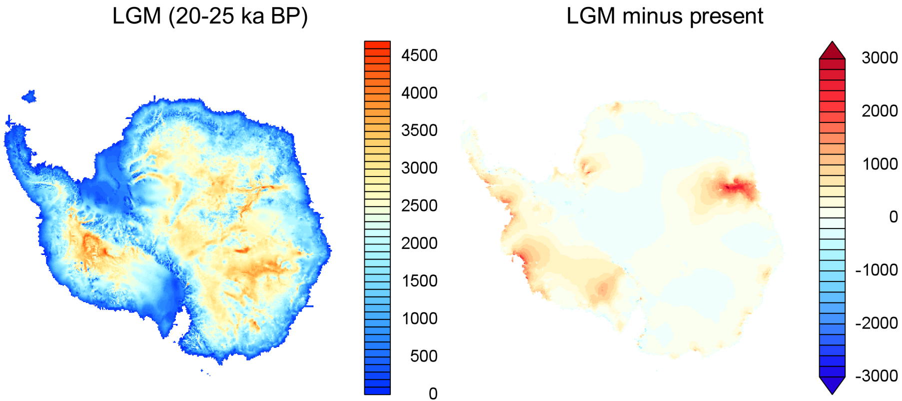


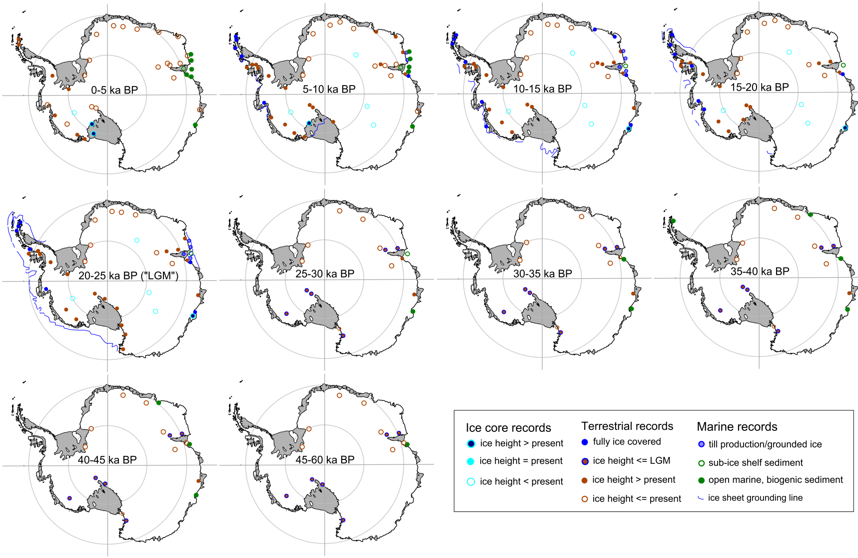
Past and future changes in global-mean sea level



Simulated change in ice thickness (m)



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



Duanne White/University of Canberra