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

DeConato and Pollard (2016), Nature

DeConato 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

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

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,temp,temppabase,hardav,Href,gl_mask -o run_20km.nc -o_size big
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.
100-member ensemble, perturbing 10 parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Minimum</th>
<th>Maximum</th>
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<tbody>
<tr>
<td>-sia</td>
<td>Shallow ice enhancement factor</td>
<td>1.2</td>
<td>4.5</td>
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<tr>
<td>-ssa</td>
<td>Shallow shelf enhancement factor</td>
<td>0.7</td>
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<tr>
<td>-pseudo_plastic_q</td>
<td>Exponent of basal resistance model</td>
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<tr>
<td>-till.effective_fraction_overburden</td>
<td>Effective till pressure scaling factor</td>
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<td>-eigen_calving_K</td>
<td>Calving rate scaling factor</td>
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<td>-thickness_calving_threshold</td>
<td>Minimum thickness of floating ice shelves</td>
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<td>200.0</td>
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<tr>
<td>-topg_to_phi phimin</td>
<td>Till friction angle (marine history)</td>
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<td>25.0</td>
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<tr>
<td>-topg_to_phi phimax</td>
<td>Till friction angle (no marine history)</td>
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<tr>
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<td>Bed elevation (bottom of transition zone)</td>
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<tr>
<td>-topg_to_phi bmax</td>
<td>Bed elevation (top of transition zone)</td>
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<td>1000.0</td>
</tr>
</tbody>
</table>
Simulated ice thickness (m)
Simulated ice velocity (logarithm of velocity in m year$^{-1}$)
Challenge 3

Boundary conditions
Challenge 3: Boundary conditions

Figure 15: PISM’s view of interfaces between an ice sheet and the outside world
Lack of observational data

Present

Past

Automatic Weather Stations
Antarctica - 2015

Core Sites
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

Surface air temperature anomaly (°C)

Precipitation anomaly (%)

Surface air temperature (°C)

Annual precipitation (mm)
Bringing it all together

Using the past to constrain the future
Past and future changes in global-mean sea level

Anomaly in global-mean sea level (m) vs. Time (ka relative to present)

- Steven J. Phipps, IMAS, UTAS

Uncertainties in global sea level rise
Past and future changes in global-mean sea level

Anomaly in global-mean sea level (m)

Time (ka relative to present)

Air temperature

Steven J. Phipps, IMAS, UTAS

Uncertainties in global sea level rise

AORI, UTokyo, 6 Nov 2018
Past and future changes in global-mean sea level

![Graph showing anomalies in global-mean sea level over time, with lines representing air temperature and precipitation.](image-url)
Past and future changes in global-mean sea level

![Graph showing past and future changes in global-mean sea level. The x-axis represents time (ka relative to present), and the y-axis represents anomaly in global-mean sea level (m). The graph includes lines for air temperature, precipitation, ocean, and sea level, with different colors for each.](image-url)
Past and future changes in global-mean sea level

Anomaly in global-mean sea level (m)

Time (ka relative to present)

Air temperature
Precipitation
Ocean
Sea level
GIA

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Uncertainties in global sea level rise
AORI, UTokyo, 6 Nov 2018
Simulated change in ice thickness (m)

LGM (20-25 ka BP)

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

Duanne White/University of Canberra

Ice core records
- ice height > present
- ice height = present
- ice height <= LGM
- ice height < present

Terrestrial records
- fully ice covered
- ice height <= LGM
- ice height > present
- ice height <= present

Marine records
- till production/grounded ice
- sub-ice shelf sediment
- open marine, biogenic sediment
- ice sheet grounding line

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