The role of history and strength of the oceanic forcing in sea-level projections from Antarctica with the Parallel Ice Sheet Model

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The Cryosphere Discussions

The role of history and strength of the oceanic forcing in sea-level projections from Antarctica with the Parallel Ice Sheet Model

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Abstract. Mass loss from the Antarctic Ice Sheet constitutes the largest uncertainty in projections of future sea-level rise. Ocean-driven melting underneath the floating ice shelves and subsequent acceleration of the inland ice streams is the major reason for currently observed mass loss from Antarctica and is expected to become more important in the future. Here we show that for projections of future mass loss from the Antarctic Ice Sheet, it is essential (1) to better constrain the sensitivity of sub-shelf melt rates to ocean warming, and (2) to include the historic trajectory of the ice sheet. In particular, we find that while the ice-sheet response in simulations using the Parallel Ice Sheet Model is comparable to the median response of models in three Antarctic Ice Sheet Intercomparison projects – initMIP, LARMIP-2 and ISMIP6 – conducted with a range of ice-sheet

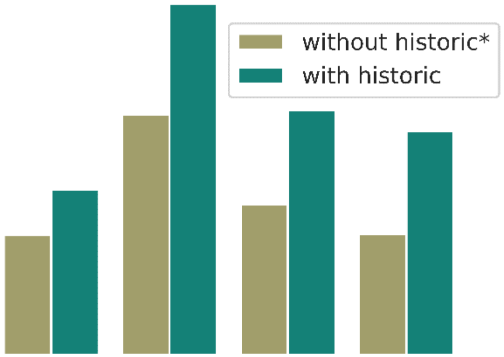
What?
We analyse projection of Antarctica's future sea
– ISMIP6 and LARMIP-2 - with all simulations
initial configurations.

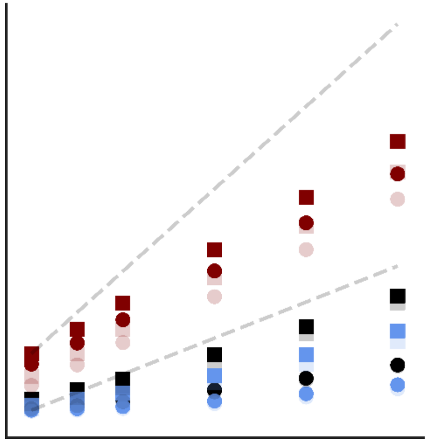
Main finding 1
Sea-level projections for the highest emission sc

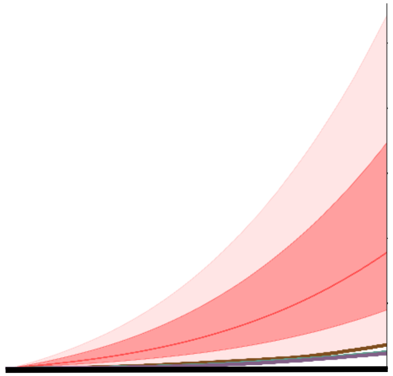
Why?
Main difference is how the basal-melt rates cha
in the ISMIP6 projections is used.

Main finding 2
Starting the experiments after a preceding histo
5 and 50% in comparison to a 'cold-start'.

Implications
To better constrain Antarctic sea-level projectio
rates and (2) make 'hindcasting' experiments.







Go to TCD manuscript

Very short summary

Read about the role of the history

Read about the oceanic forcing

Go to the outlook

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References & Acknowledgements

1 Very short summary

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What?

We analyse projection of Antarctica's future sea-level contribution following two recent Model Intercomparison Projects – ISMIP6 and LARMIP-2 - with all simulations done with the Parallel Ice Sheet Model and started from the same initial configurations (using only ocean forcing; using PICO in ISMIP6, model response comparable to median in both MIPs).

Learn more about ISIMIP6 (paper)

Learn more about LARMIP-2 (paper)

Main finding 1

Sea-level projections for the highest emission scenario RCP8.5 vary by an order of magnitude.

Why?

Main difference is how the basal-melt rates change: in the LARMIP-2 projections a sensitivity three times as large as in our ISMIP6 experiments is used.

Read about the oceanic forcing

Main finding 2

Starting the experiments after a preceding historic simulation from 1850 to 2015, the sea-level contribution increases between 5 and 50% in comparison to starting from equilibrium.

Read about the role of the history

So what?

To better constrain Antarctic sea-level projections, it is important to (1) improve the sensitivity of sub-shelf melt rates and (2) make 'hindcasting' experiments.

Go to the outlook

2 The role of history

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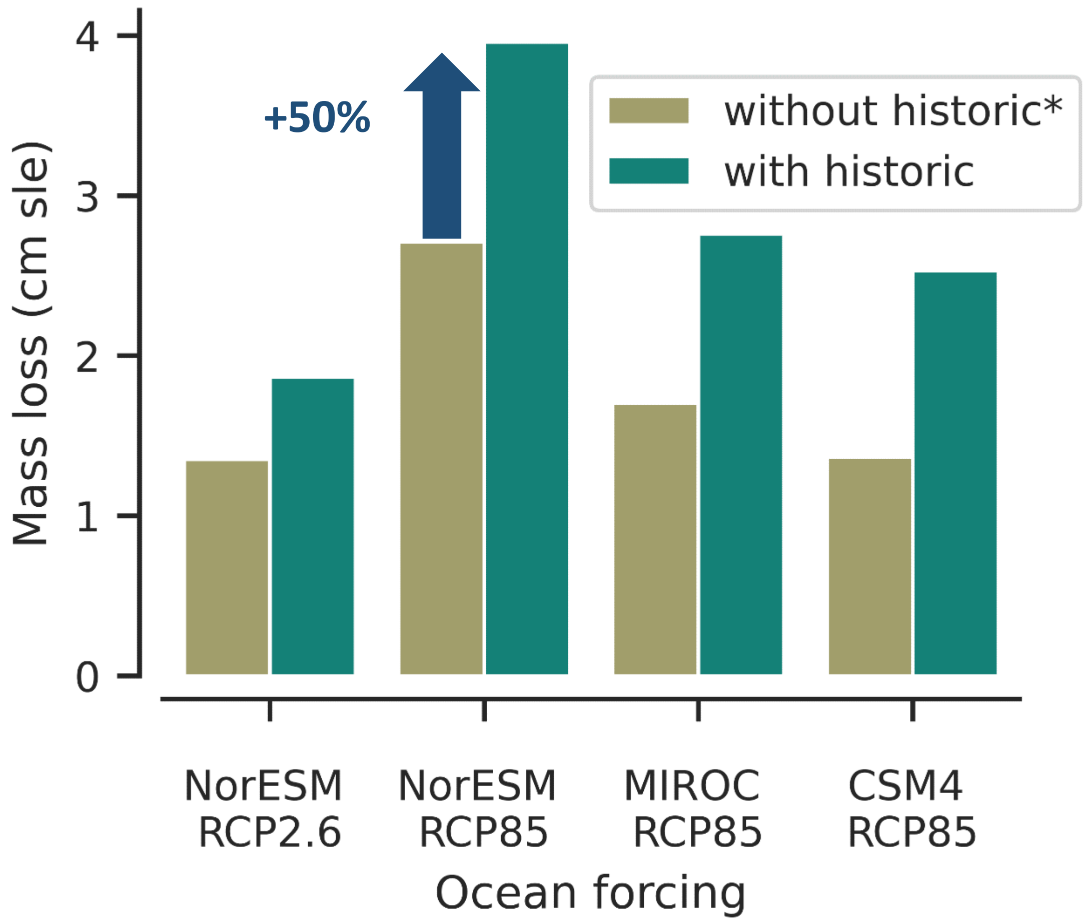

The historic simulation increases mass loss in future projections by up to 50%.

- All simulations were done with the Parallel Ice Sheet Model

Learn more about PISM (website)

- Sea-level contribution between 2015 and 2100 for different simulations driven by CMIP5 ocean forcing as provided by ISMIP6 (Seroussi et al., under review). The simulations start from two different initial states, one with and one without a preceding historic simulation from 1850 to 2014.

Why could this be the case? Some ideas:

- After the historic simulations, the configuration is losing mass and shows thinning in many regions
- Small changes in geometry over the historic simulation might have made the state more vulnerable to ocean changes
- Non-linearities, e.g., in temperature field or buttressing
- Historic state is closer to an instability

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3 The role of the oceanic forcing

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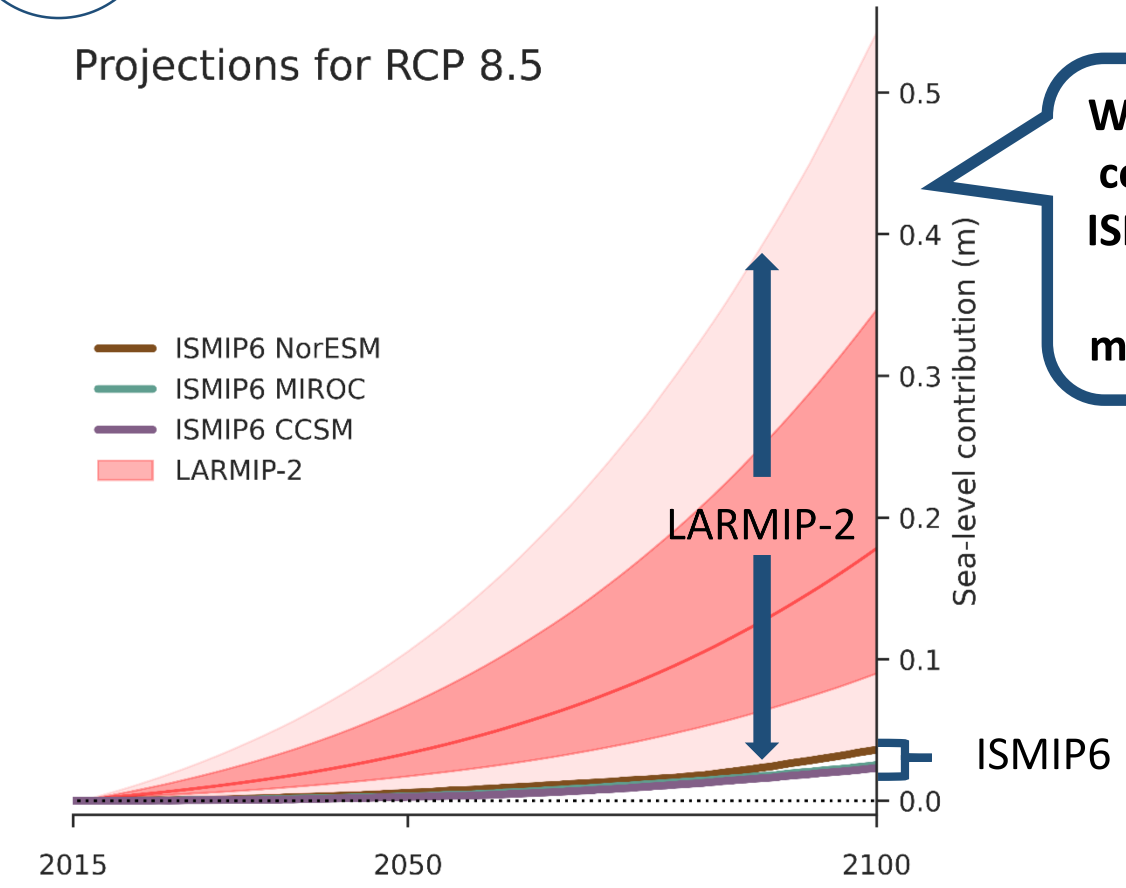
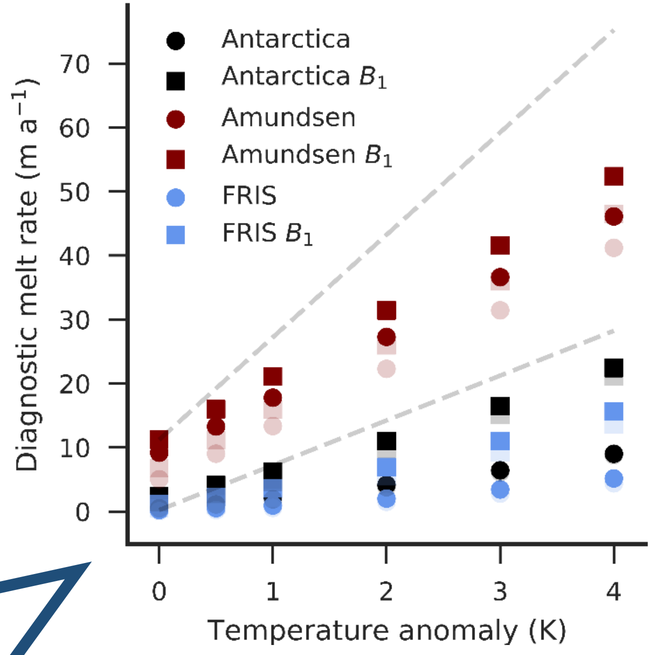


- LARMIP: red curve shows median, red shaded region likely and very likely ranges.
ISMIP6: three different CMIP5 forcing experiments.

Why is the sea-level contribution in our ISMIP6 experiments an order of magnitude smaller?

Central reason: Higher melt rate sensitivity to ocean warming in LARMIP experiments…



- Melt rates increase differently for similar ocean warming: changes in LARMIP (grey lines) are based on ocean modelling studies, those in our ISMIP6 experiments calculated with PICO.

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4 Outlook

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Future sea-level projections: a comparison of two Model Intercomparison Projects (ISMIP6 and LARMIP)

- In line with LARMIP-2, only ocean-forcing from ISMIP6 is applied, basal melting in ISMIP6 experiments is calculated with PICO
- Model response shown here is comparable to the median found in both MIPs (also true for initMIP)
- Sea-level contributions in our ISMIP6 experiments are an order of magnitude smaller than estimates from LARMIP based on the same initial setup, both modelled with the Parallel Ice Sheet Model
- This can be explained by the different sensitivity of melt rates to ocean changes: the changes in LARMIP-2 range from 9 to 16 m/a/K, based on oceanographic estimates (Jenkins 1991, et al. Payne 2007)
- We find that this sensitivity is consistent with a coupled ice-ocean modelling study of Thwaites glacier (Seroussi et al., 2017)
- Changes in ISMIP6 were simulated with PICO which – for the current choice of parameters that were tuned to fit present-day melt rates – yields smaller sensitivities of 2.2 m/a/K over the entire ice shelves and 5.3 m/a/K close to the grounding lines
- Similar findings on role of the basal melt rate parameterization’s sensitivity were reported in Jourdain et al. (under review)

Future sea-level projections: role of history

- Mass loss estimates increase by up to 50% when started after a historic simulation in contrast to a cold start simulation based on the same initial setup
- Increases are smaller for the LARMIP-2 estimates (5-7%) where the ocean forcing is stronger and induces larger overall mass loss

Outlook

- Improve sub-shelf melt parameterizations such as PICO by re-tuning with melt sensitivities derived from observations and modelling
- Use hindcasting of observed changes over the past decades to better constrain ice sheet model projections

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References & Acknowledgements

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References & further reading

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