FANSSIE

Framework for Antarctic System Science in E3SM

Los Alamos NATIONAL LABORATORY

Investigating the impact of ice shelf cavities on Antarctic sea level rise projections

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DOE CSGF Annual Program Review

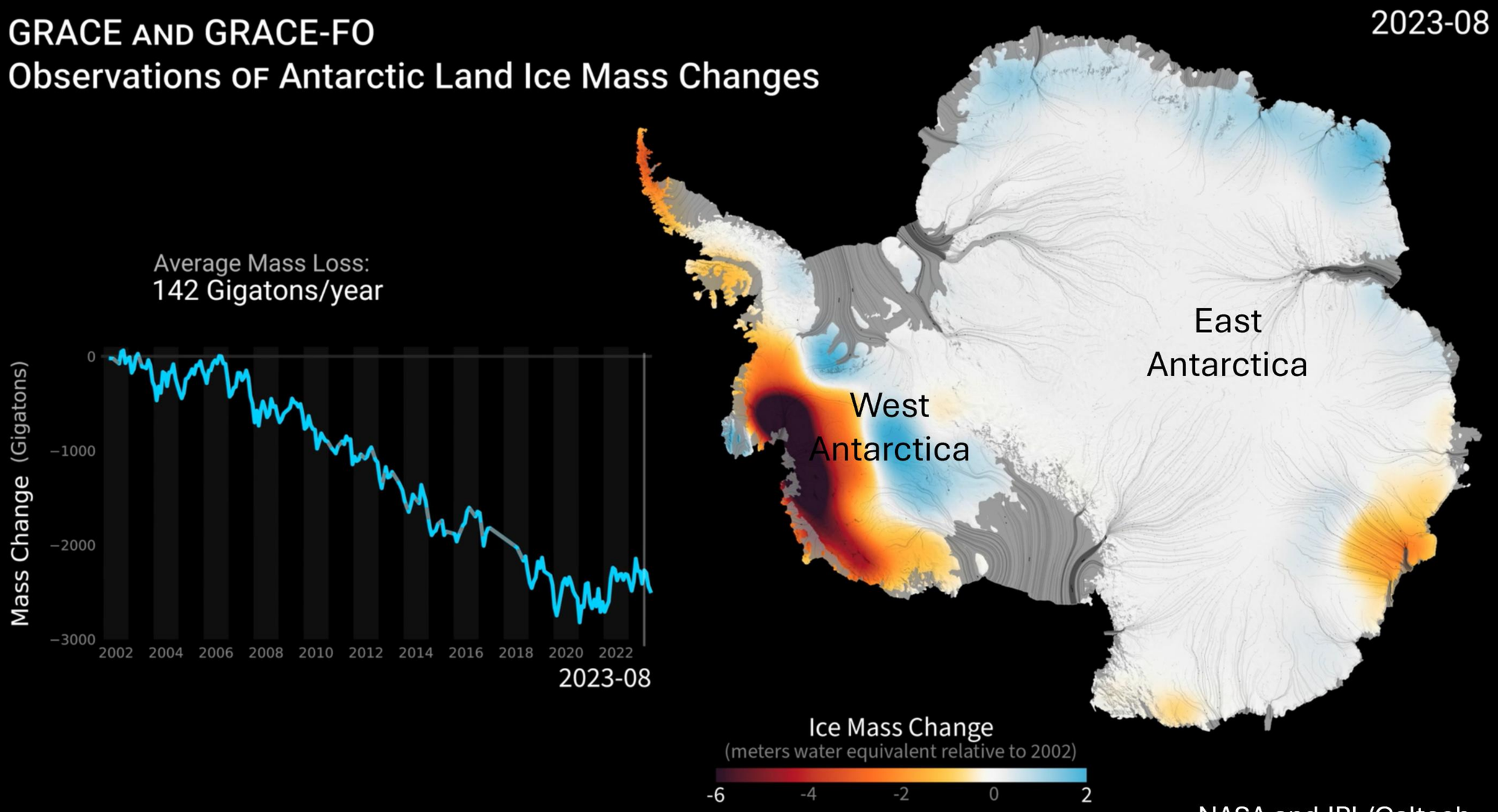
July 15th, 2025

University at Buffalo
The State University of New York

DOE CSGF

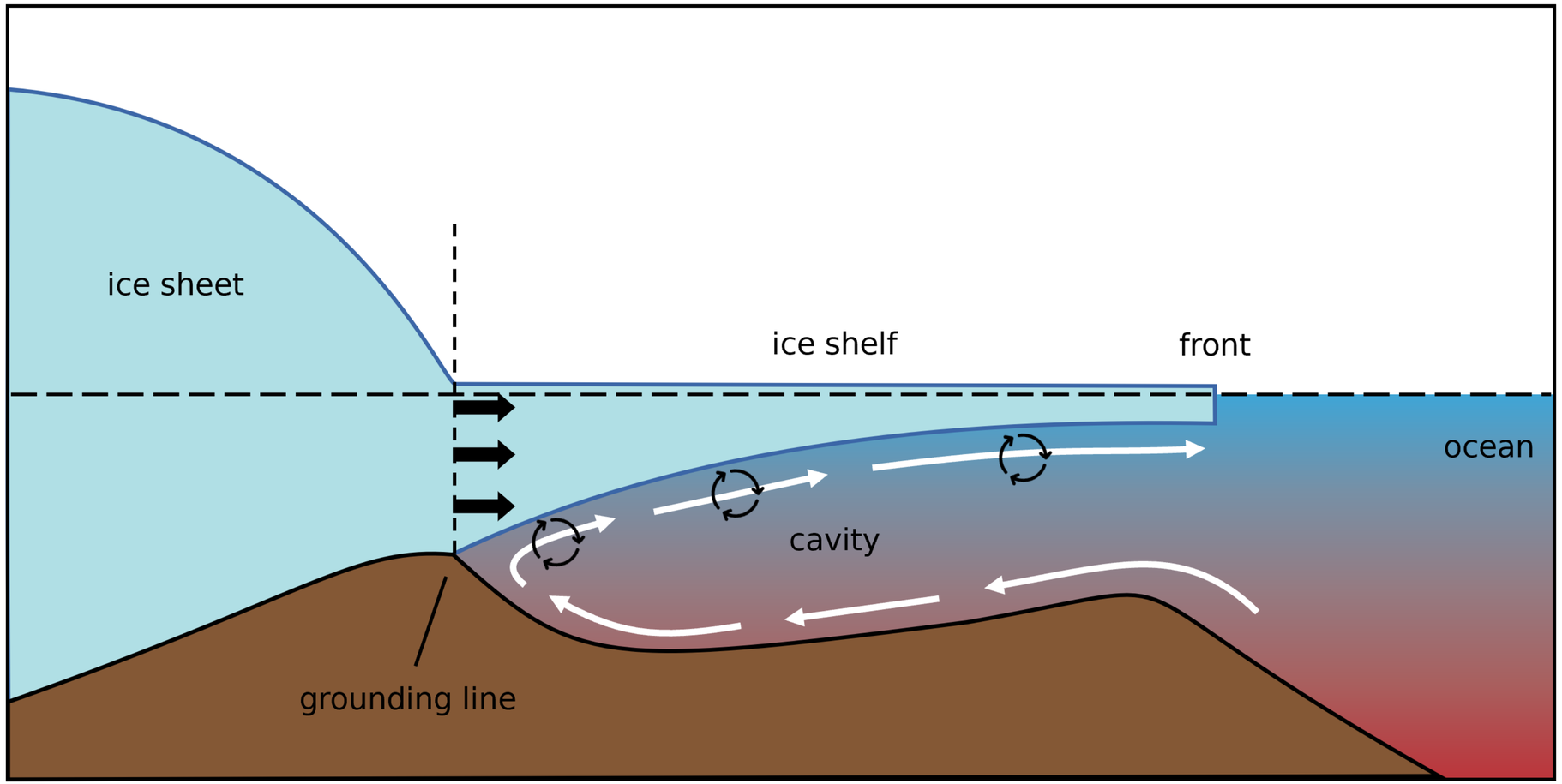
E3SM
Energy Exascale Earth System Model

Antarctic mass loss is accelerating



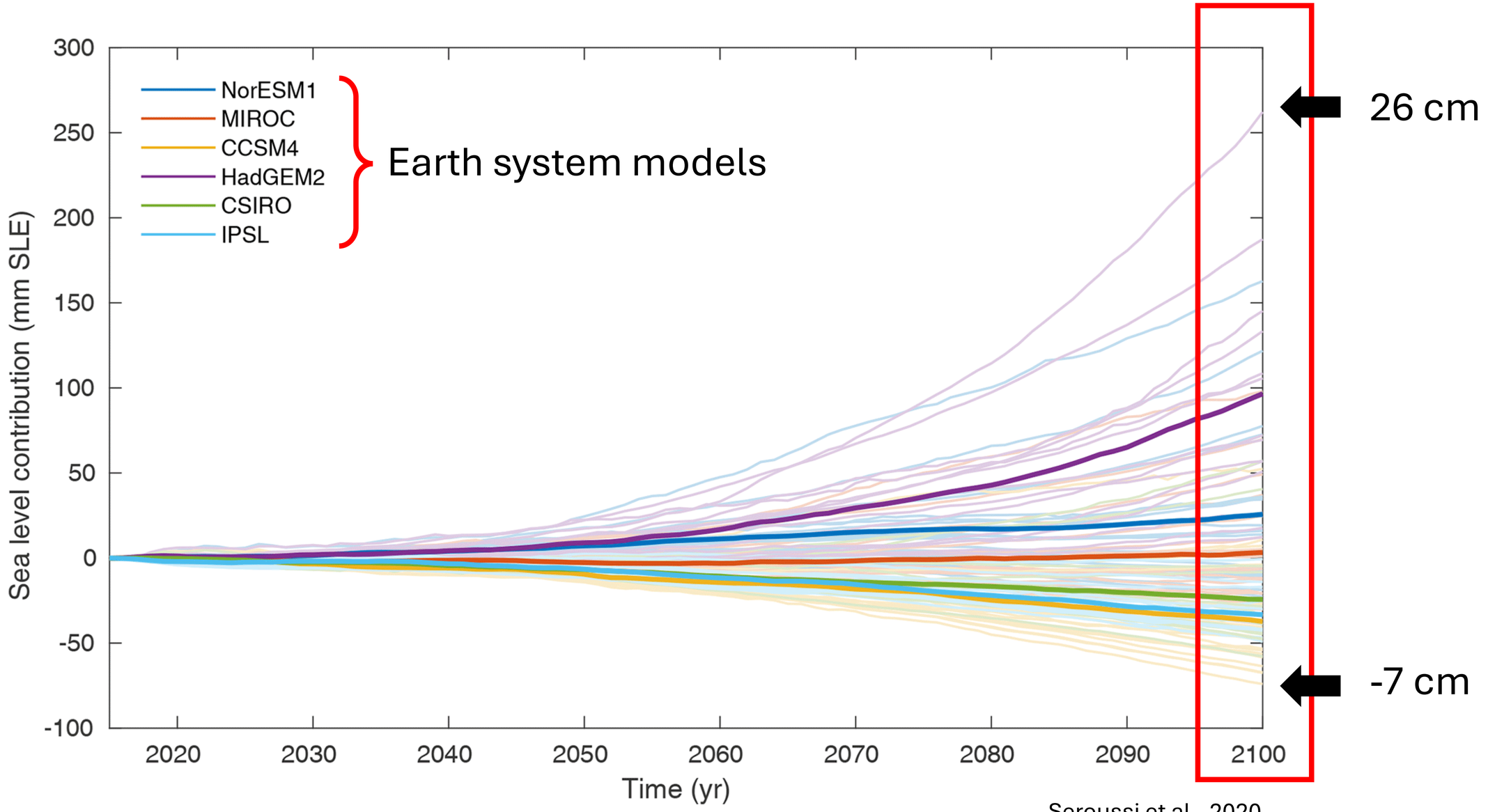
Will Salter, *Getty Images*

Sub-shelf melting is driven by warm ocean circulation



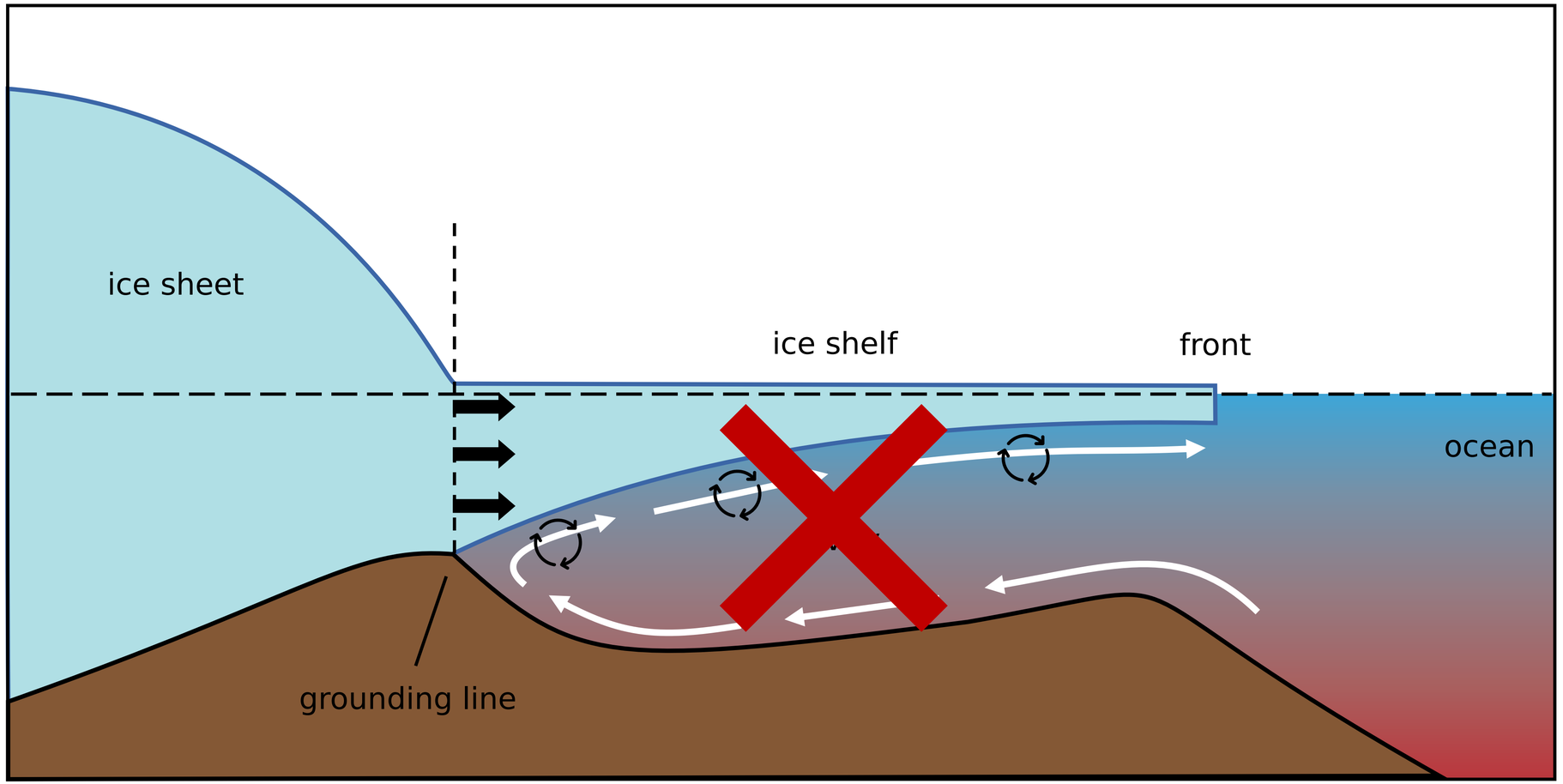
adapted from Gassan and Kiesling, 2020

Future contribution to sea level rise is uncertain

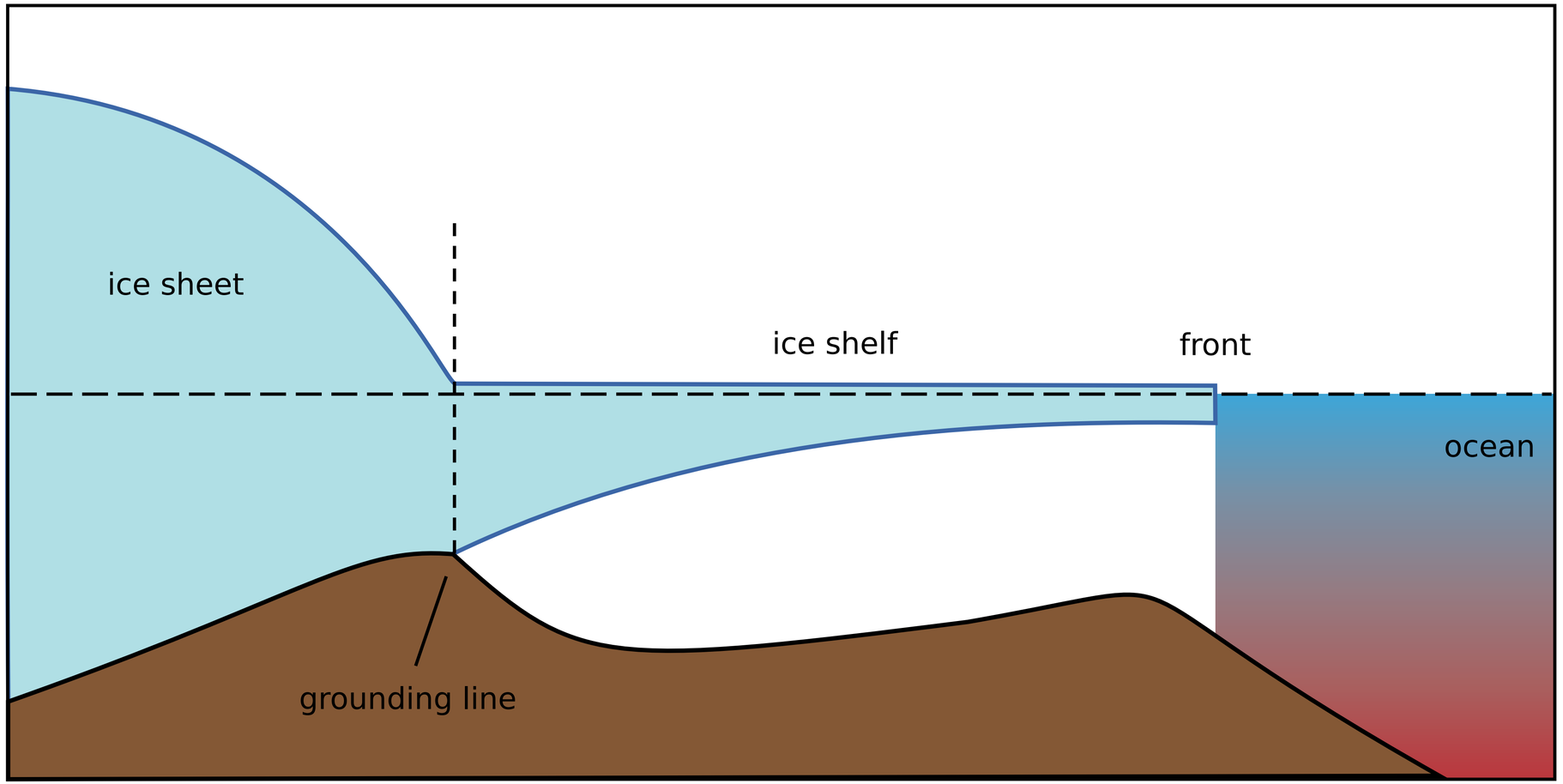


Seroussi et al., 2020

Most Earth system models DON’T resolve cavities!



Most Earth system models DON’T resolve cavities!

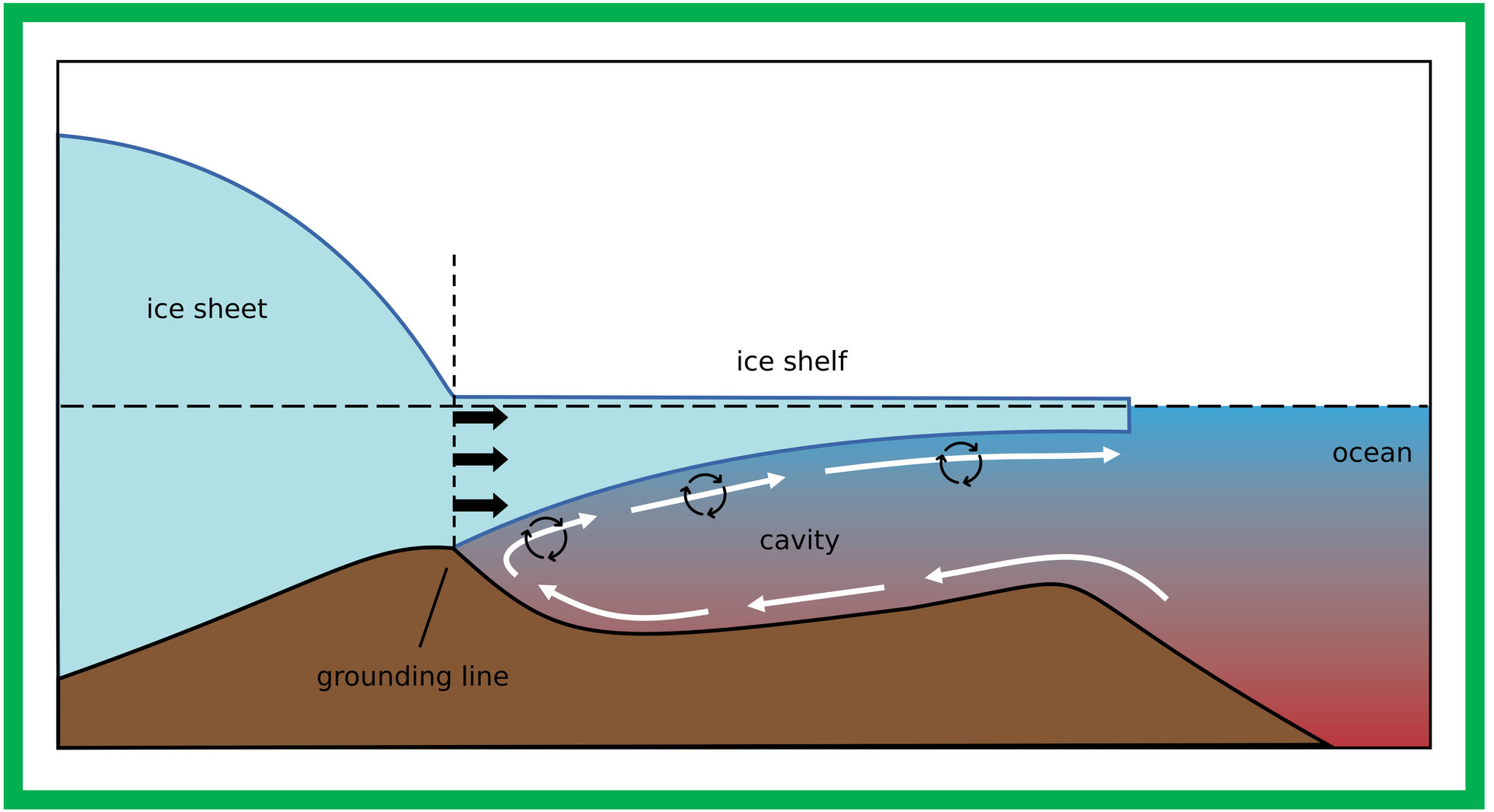


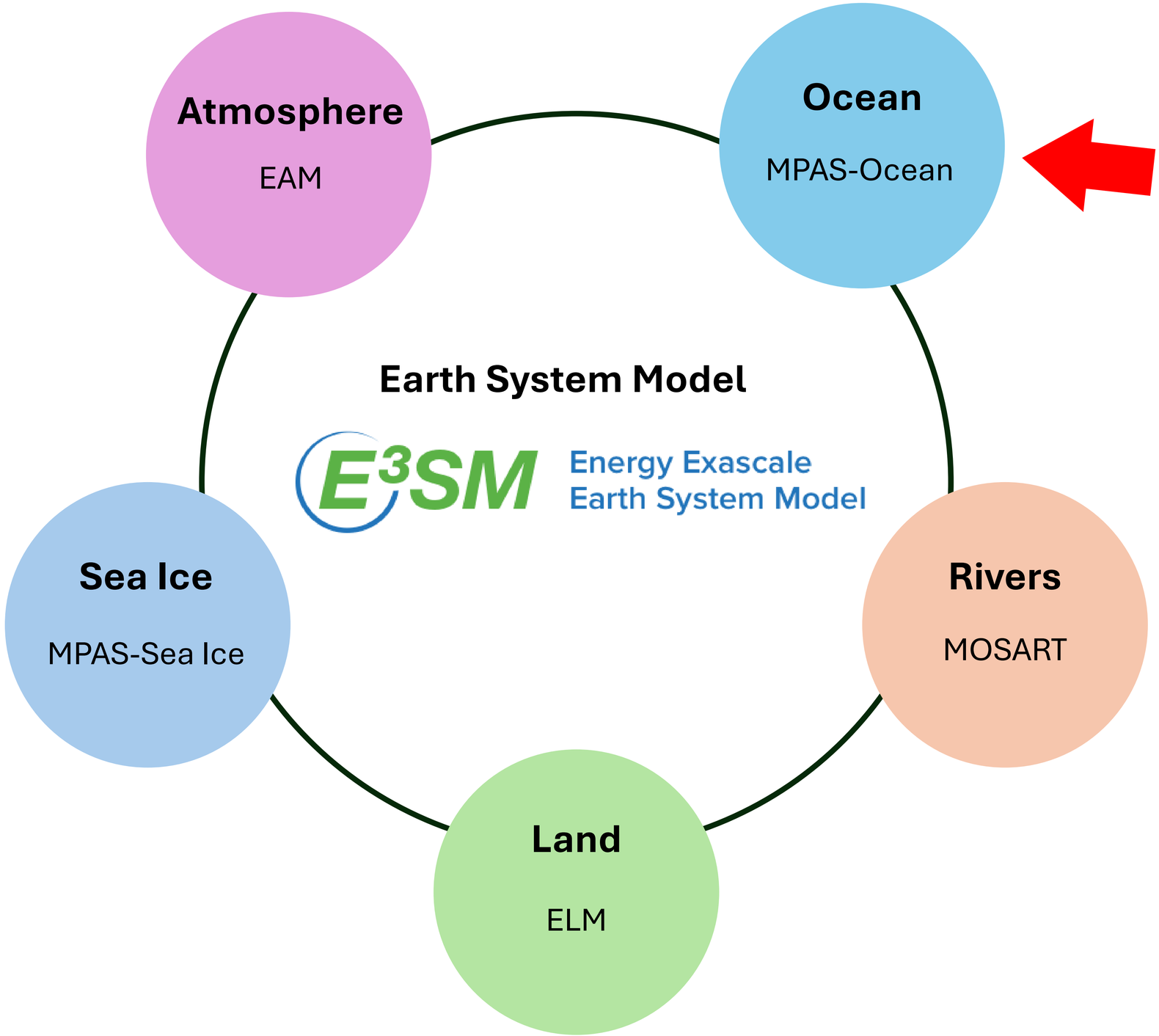
ESMs without cavities are missing this circulation mechanism

What is the error introduced on Antarctic projections of sea level rise when models exclude ice-shelf cavities?

In other words, how well do most Earth system models perform?

We need an Earth system model that resolves cavities





Ocean domain was updated to include cavities!

(Comeau et al., 2022)

Atmosphere

EAM

Ocean

MPAS-Ocean

Earth System Model

E3SM Energy Exascale Earth System Model

Sea Ice

MPAS-Sea Ice

Rivers

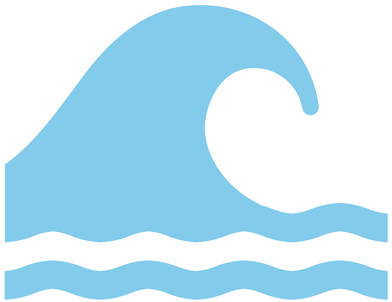
MOSART

Land

ELM

Cavity-Included

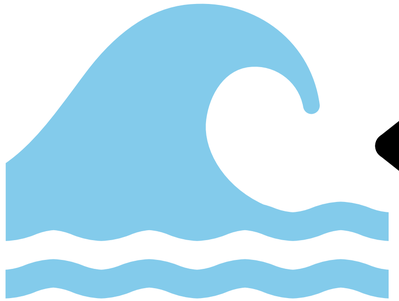
Ocean Outputs



100 years

Run ice sheet model out to 2100 for our two configurations

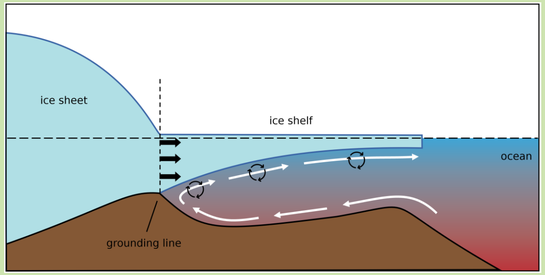
Cavity-Included
Ocean Outputs



100 years

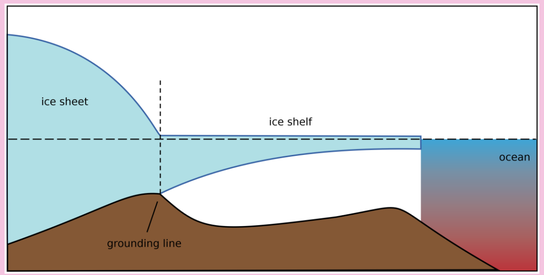
Experimental Configurations

With Cavities



Parameterized Melt Rates

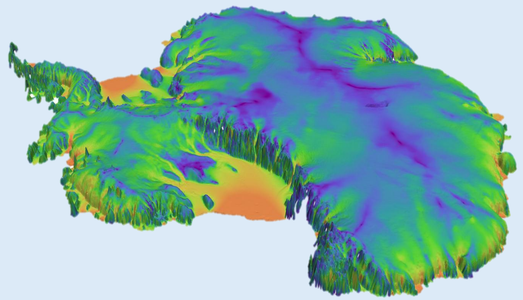
No Cavities



Parameterized Melt Rates

Ice Sheet Model

MPAS-Land Ice (MALI)
(Hoffman et al., 2018)



100 years

2000-2100

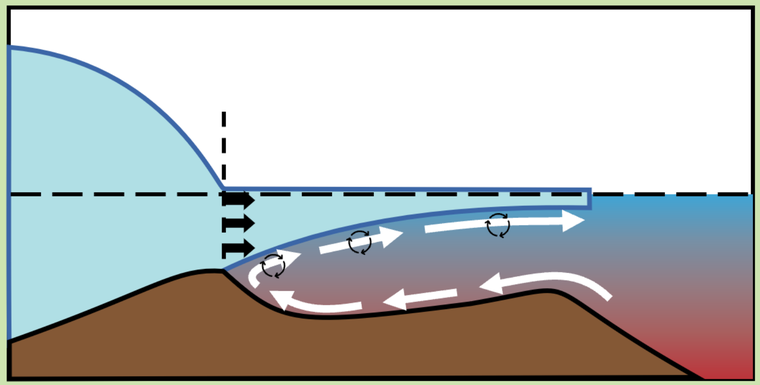
Parameterizing Ice Shelf Basal Melt

E3SM Energy Exascale Earth System Model

Use ocean information generated by E3SM

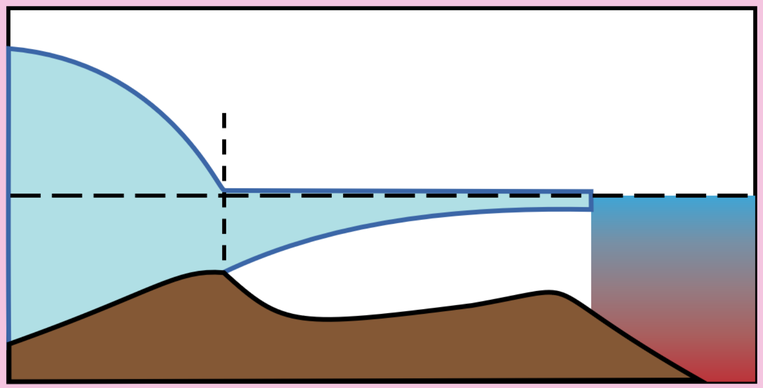
Configuration #1

Keep cavities



Configuration #2

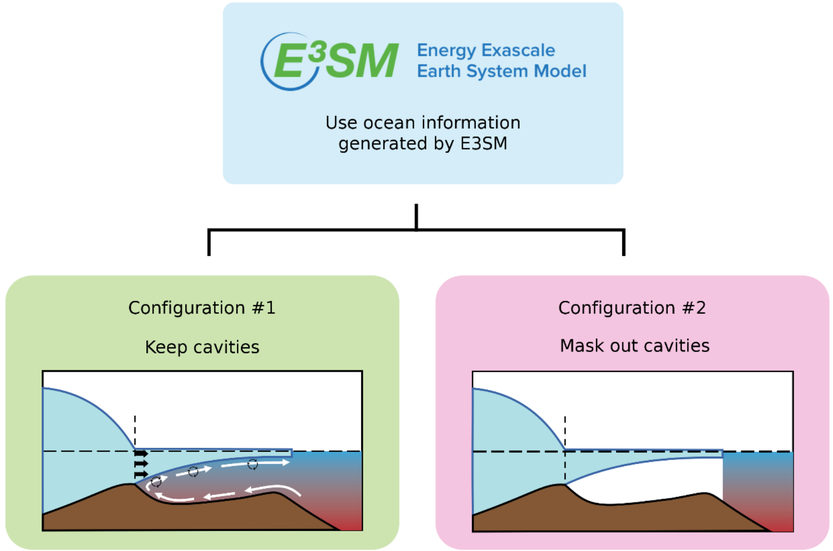
Mask out cavities



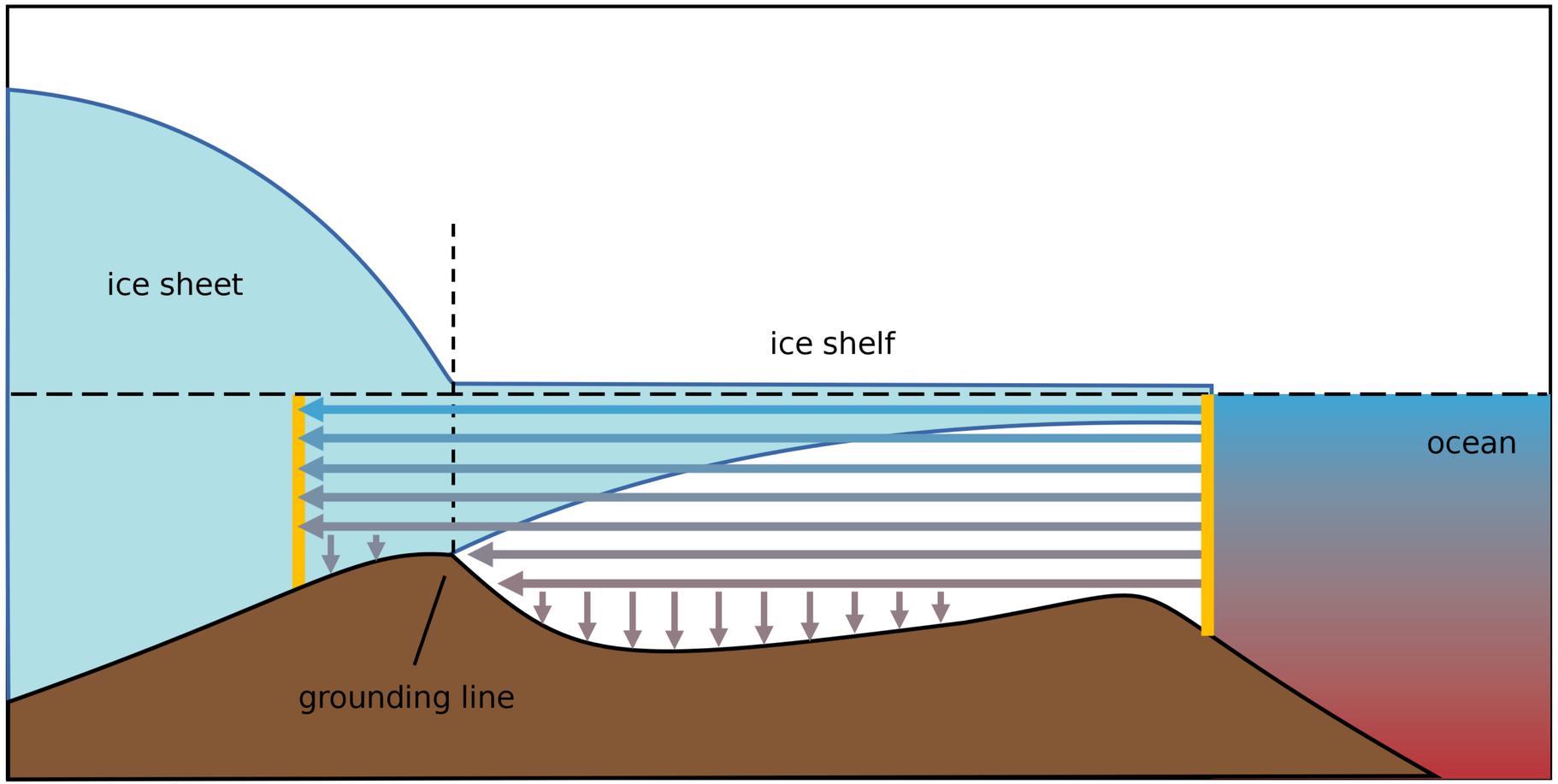
① Get ocean information from E3SM

② Split into two configurations

③ Extrapolate

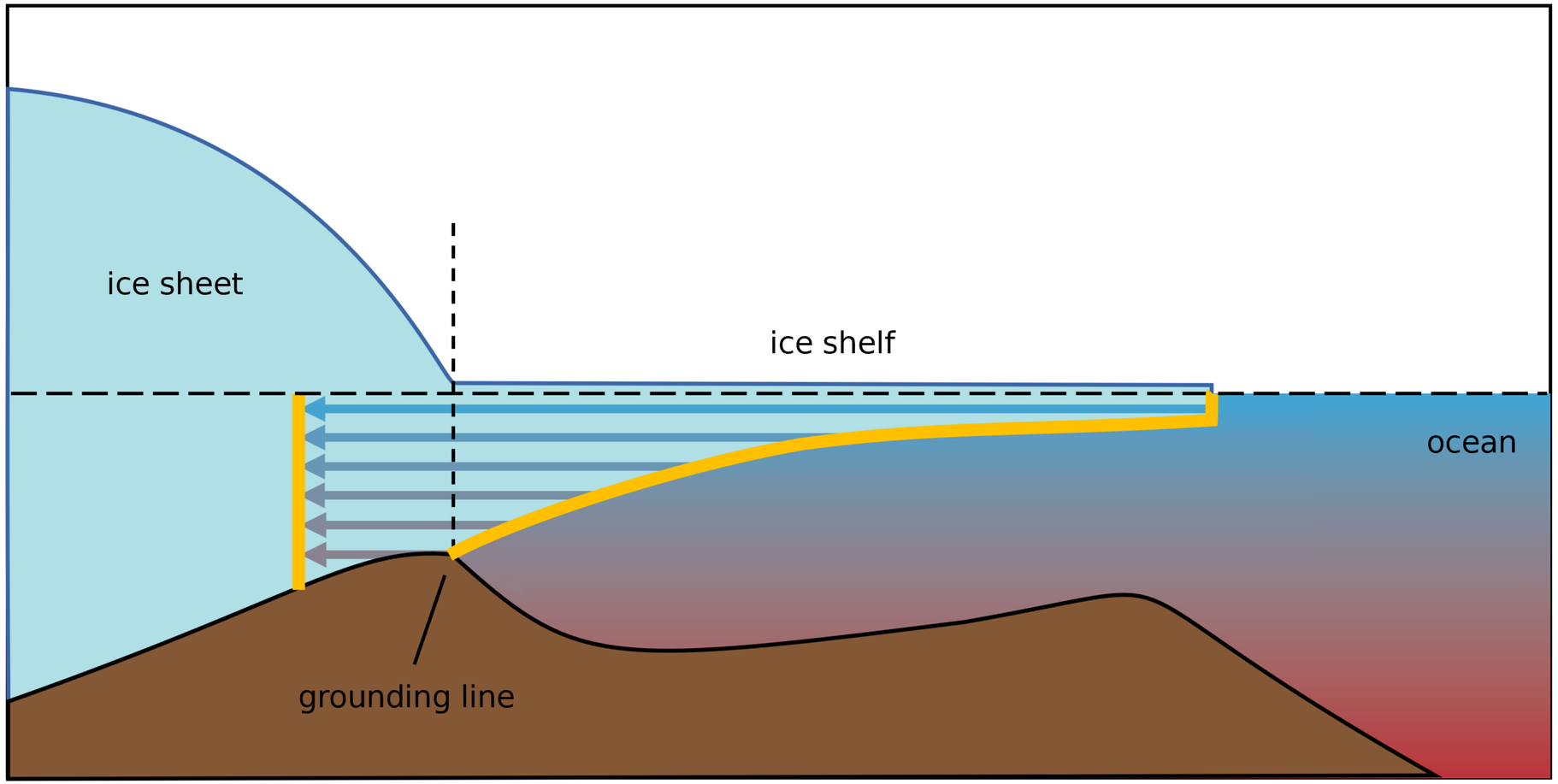


Extrapolation for the case with no cavities



We fill the cavity and extrapolate past the grounding line to account for ice sheet retreat

Extrapolation for the case with cavities



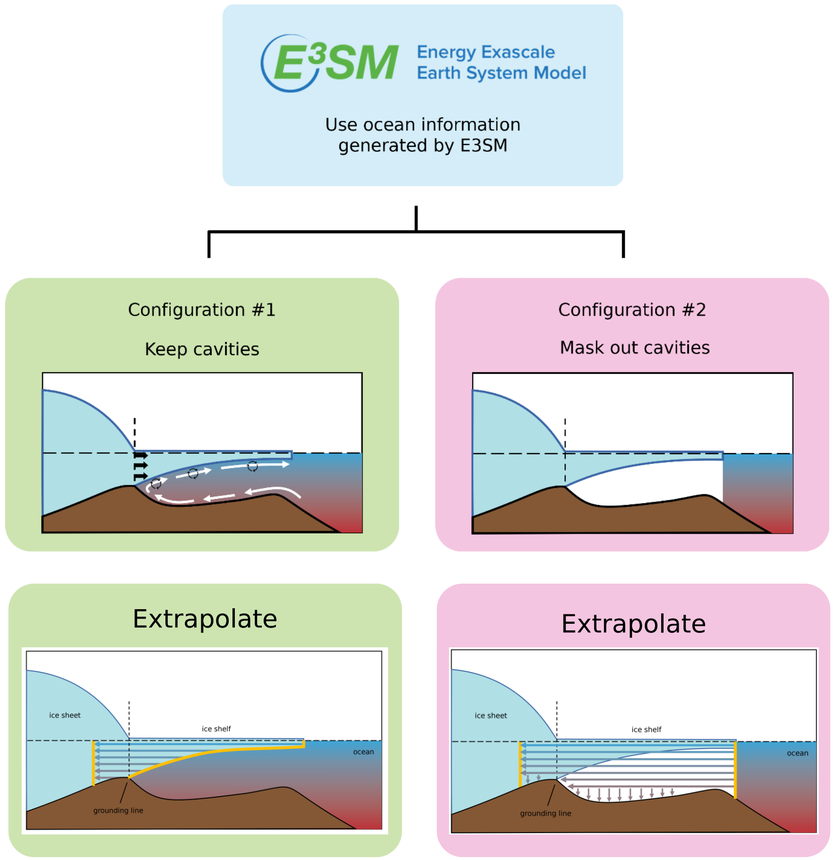
Extrapolate from the ice shelf base

① Get ocean information from E3SM

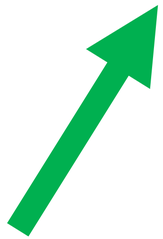
② Split into two configurations

③ Extrapolate

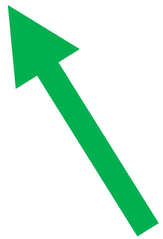
④ Parameterize basal melting



$$m(x,y) = f\left((T_{ocean} - T_{freezing})^2 \right)$$



Parameterized Melt



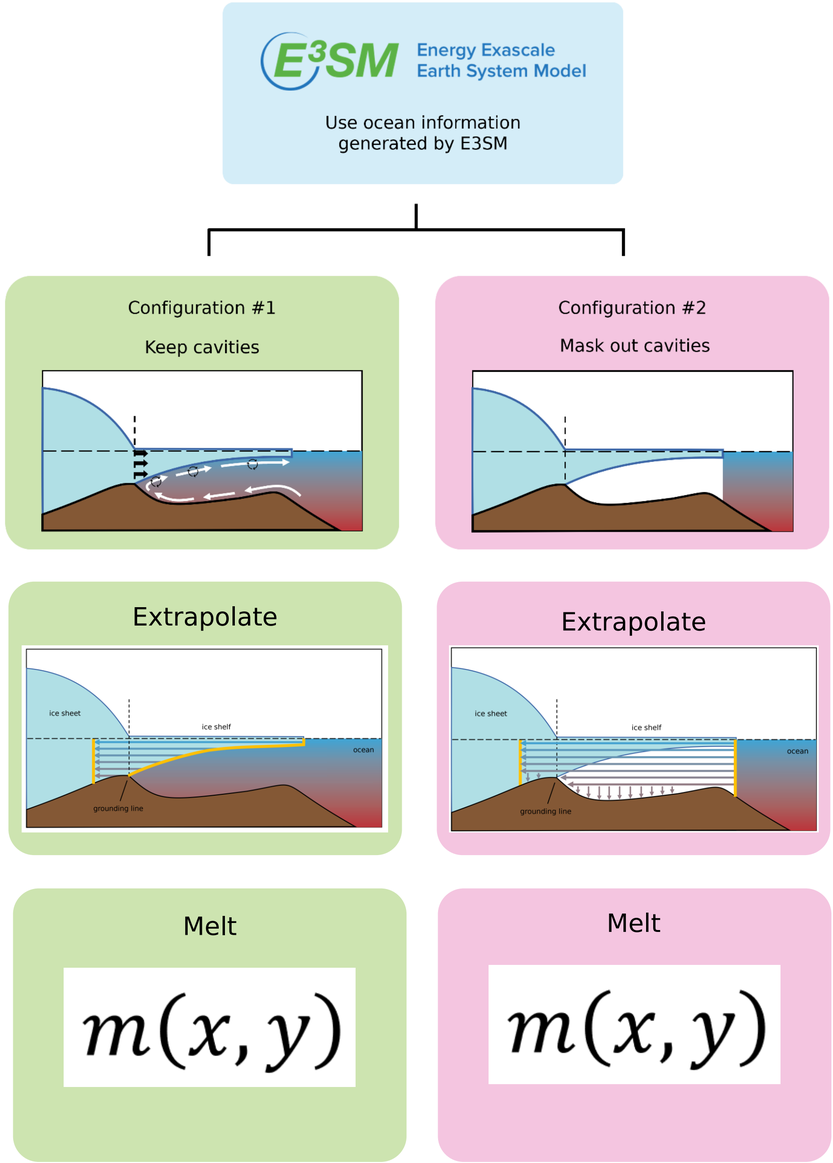
Quadratic thermal forcing

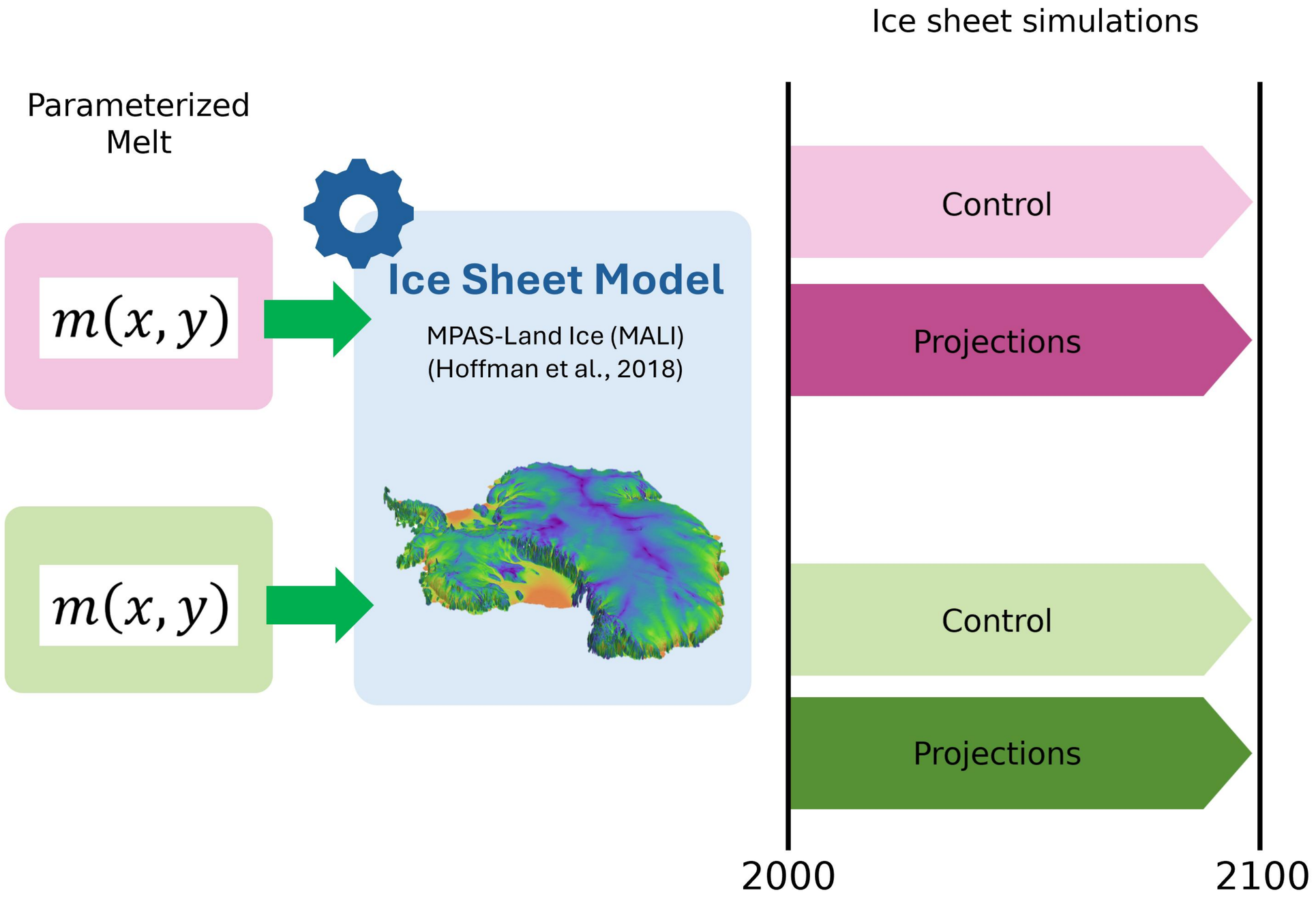
① Get ocean information from E3SM

② Split into two configurations

③ Extrapolate

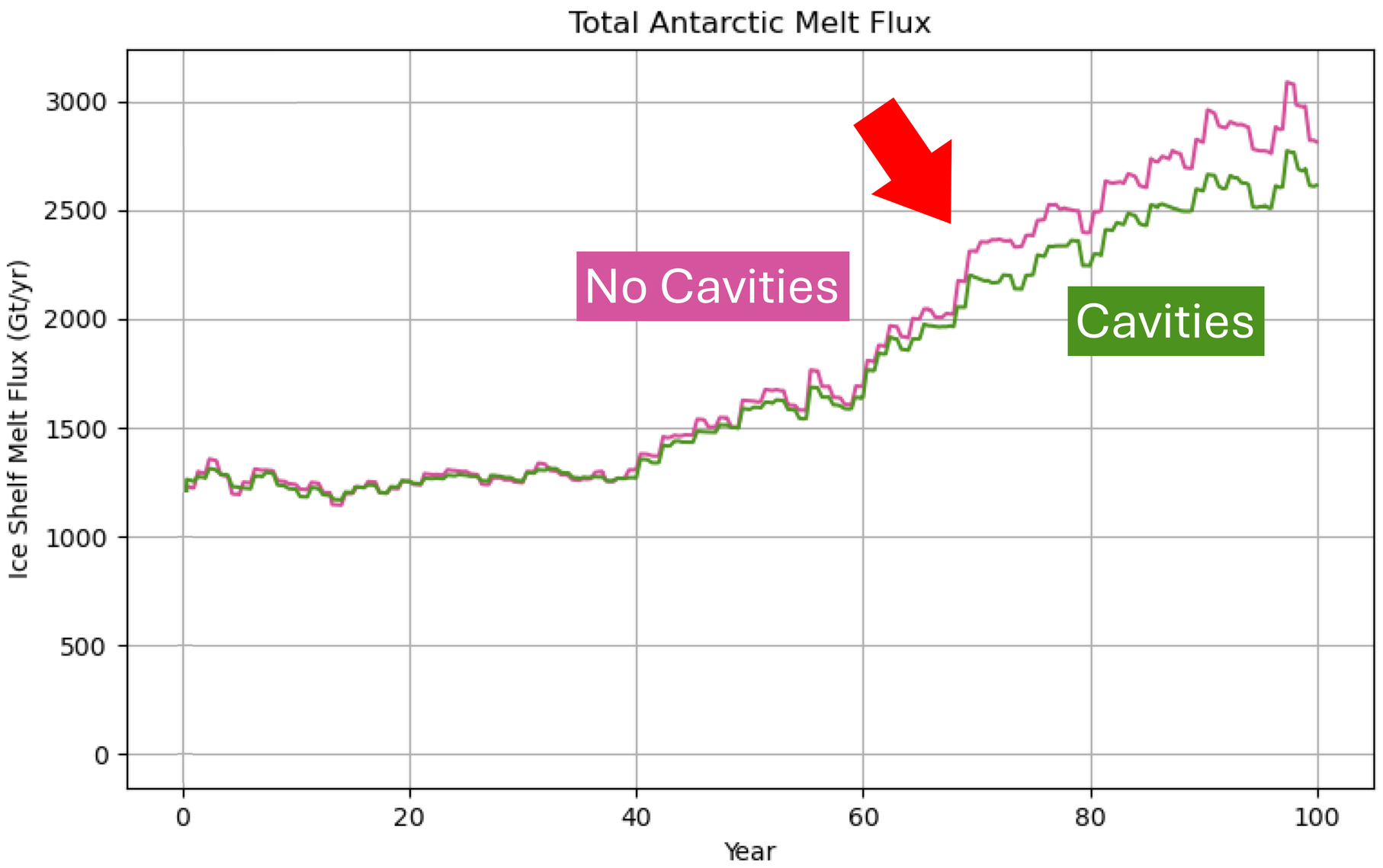
④ Parameterize basal melting



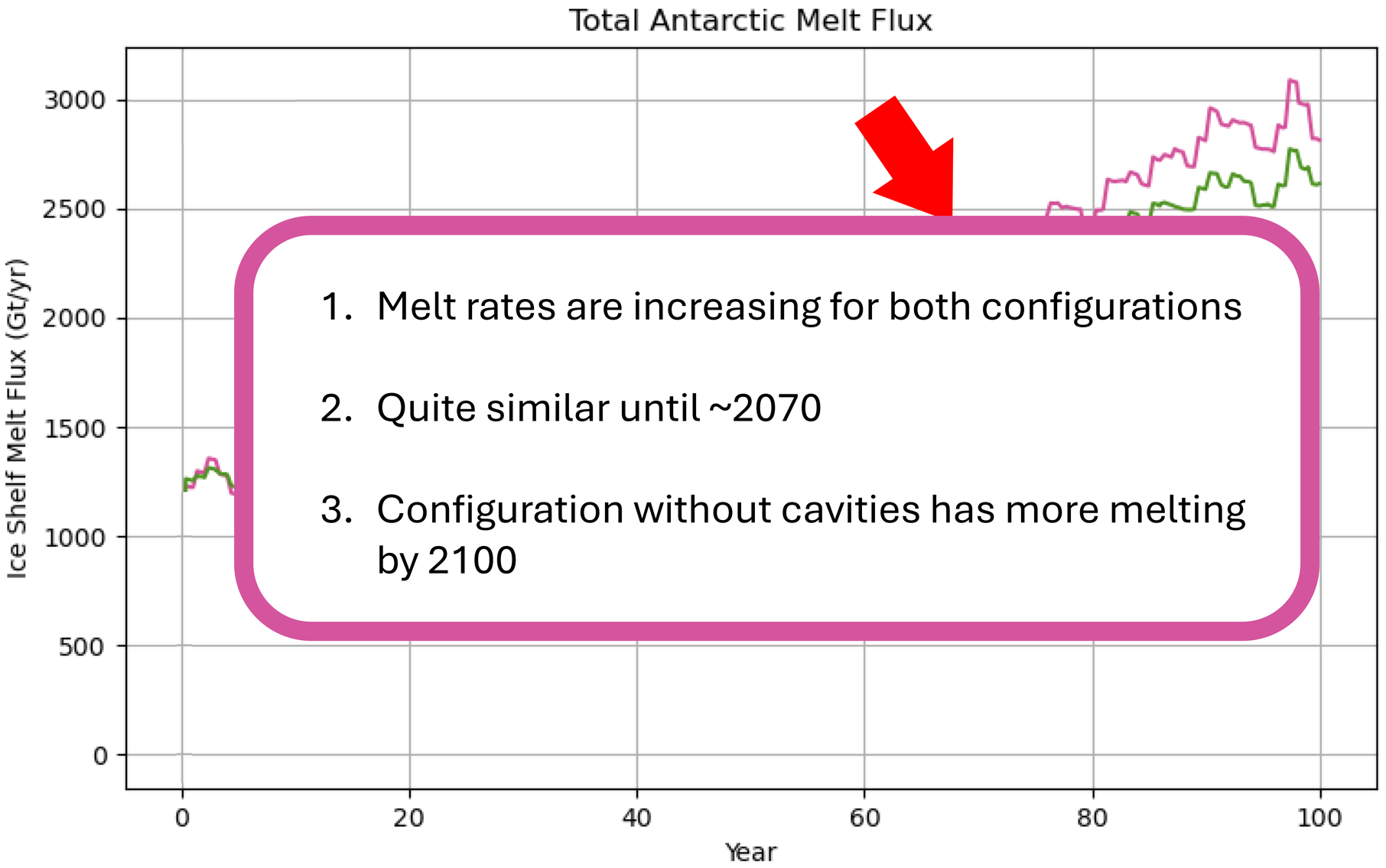

Ice sheet simulations
Parameterized Melt
$m(x, y)$
$m(x, y)$
Ice Sheet Model
MPAS-Land Ice (MALI)
(Hoffman et al., 2018)
Control
Projections
Control
Projections
2000
2100

Total Antarctic Basal Melting

Configuration with no cavities has more melting by 2100

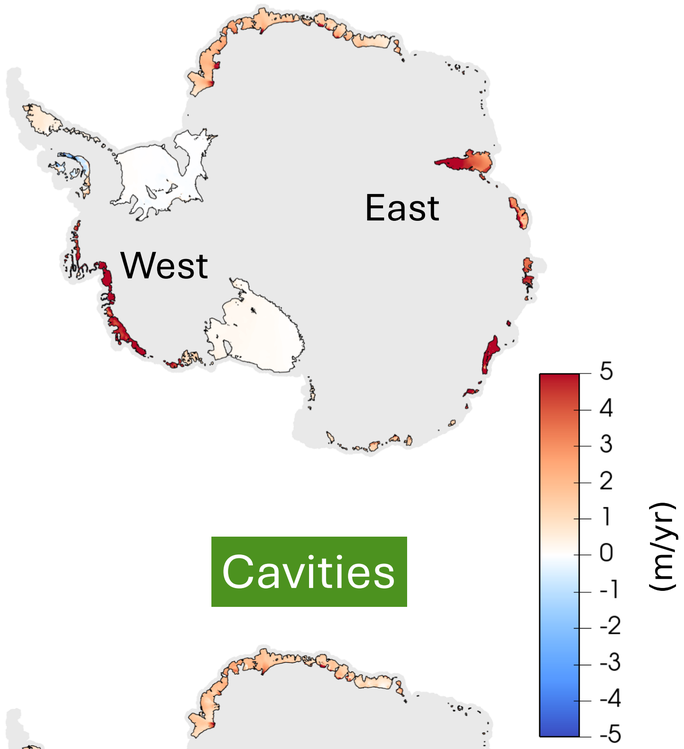


Configuration with no cavities has more melting by 2100

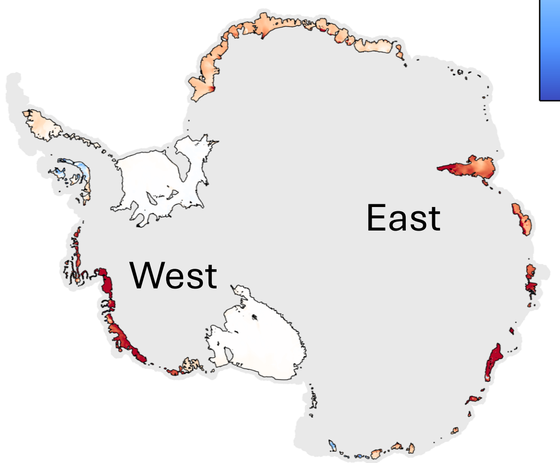


Change in Melt Rates between 2000 to 2100

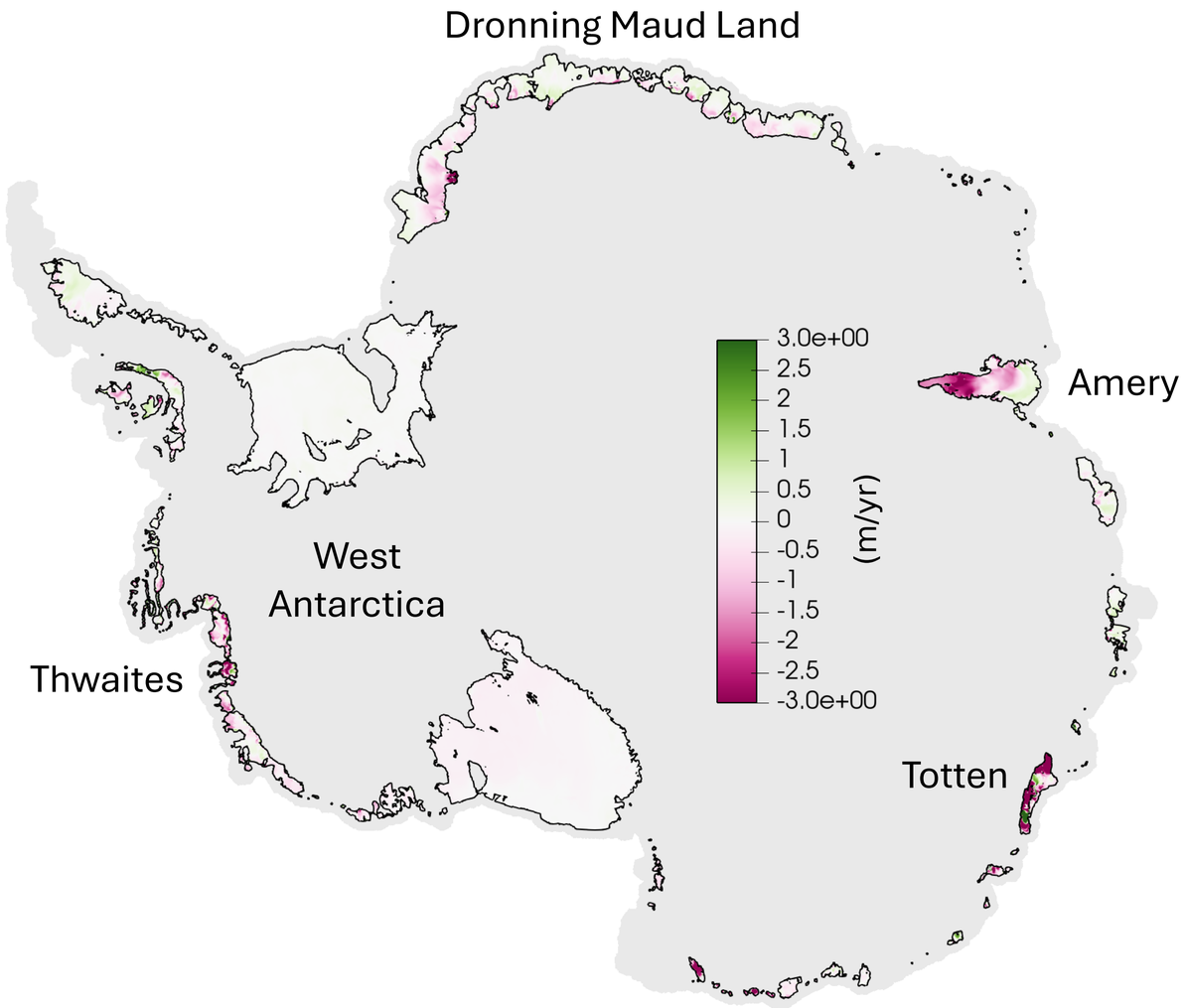
No Cavities



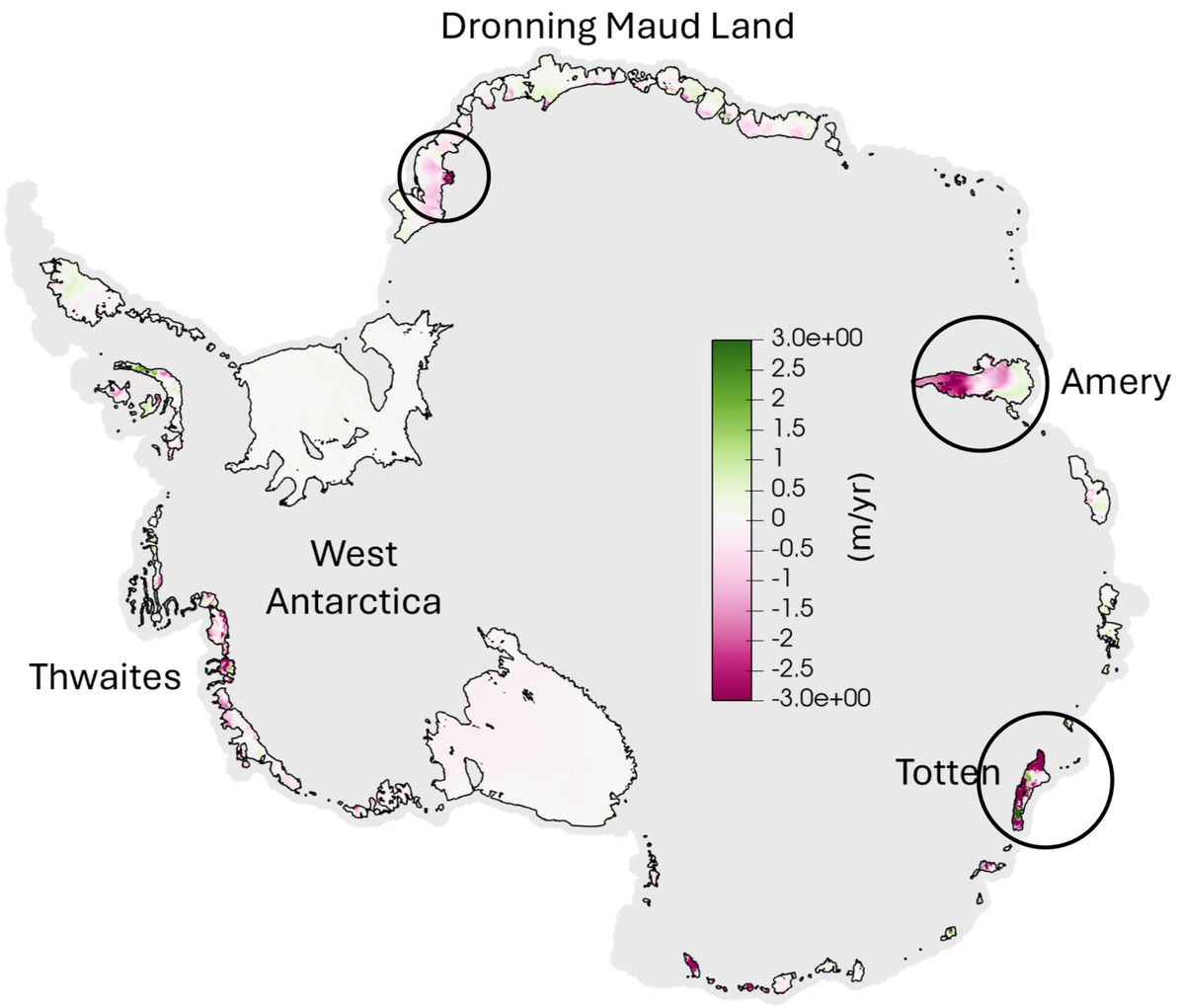
Cavities



Difference between configurations



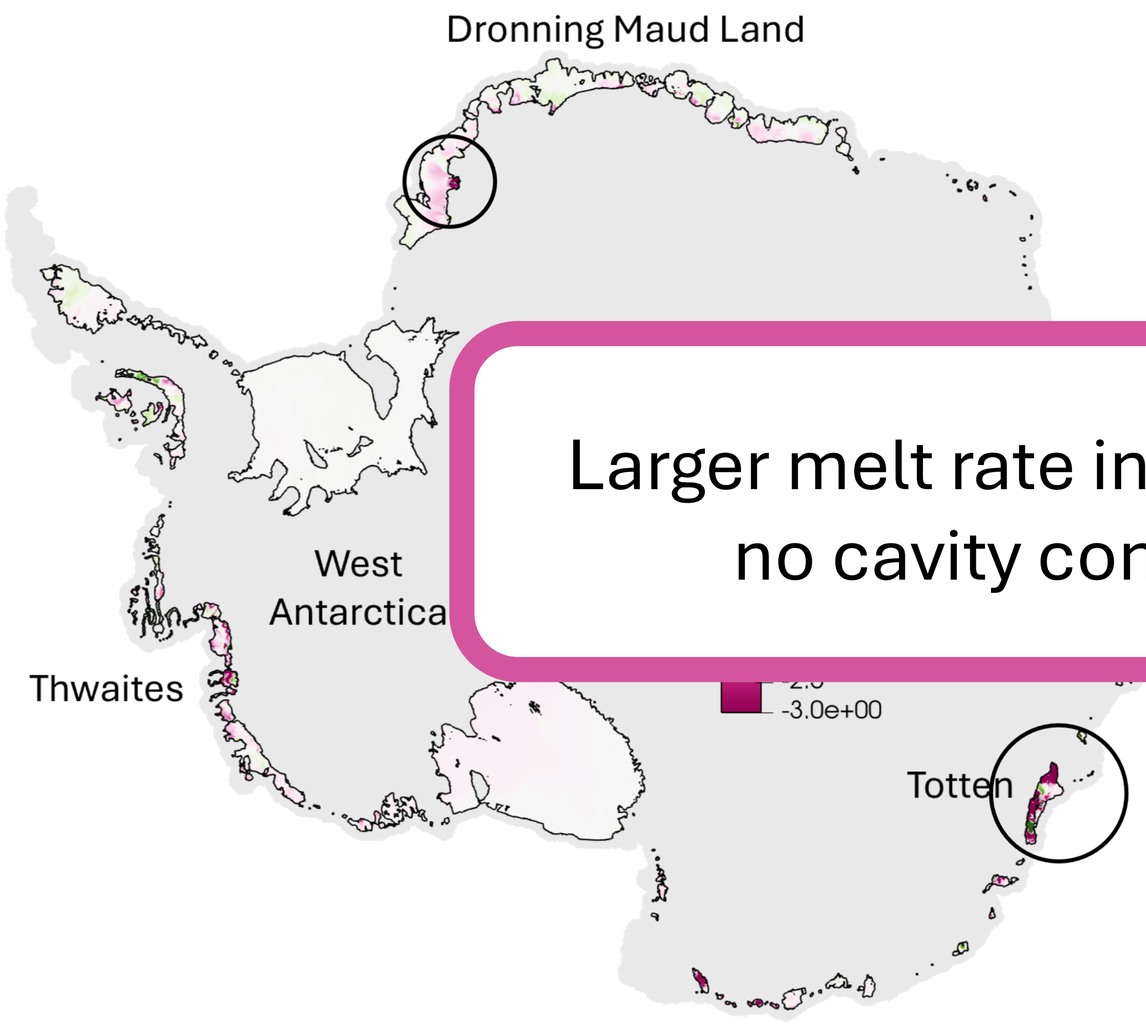
Difference between configurations



Larger increase in melting
Cavity Configuration

Larger increase in melting
No Cavity
Configuration

Difference between configurations



Larger increase in melting Cavity Configuration

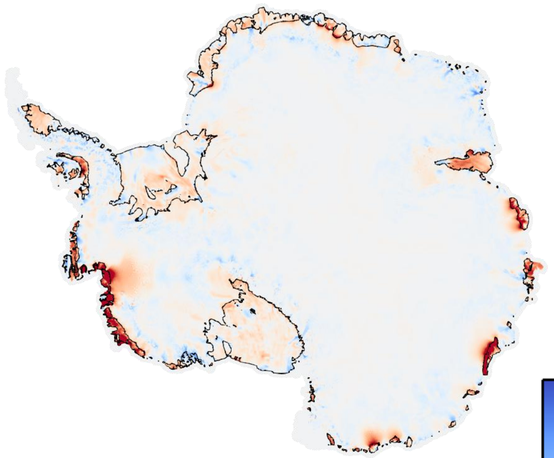
Larger melt rate increases for the no cavity configuration

Larger increase in melting No Cavity Configuration

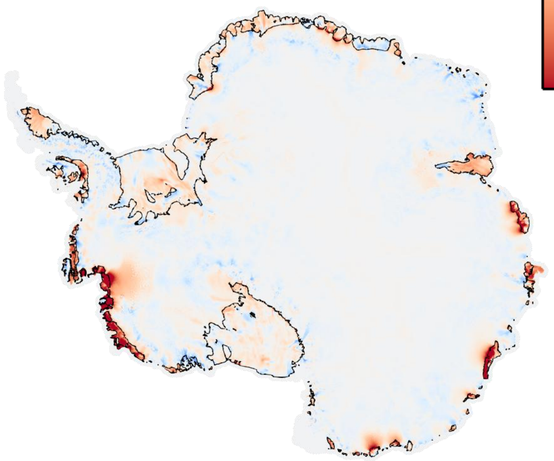
Ice Sheet Thickness change between 2000 to 2100

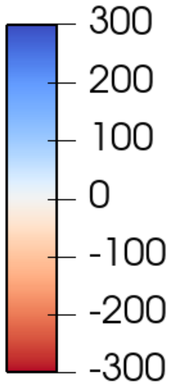
Change in Thickness between 2000 to 2100

No Cavities

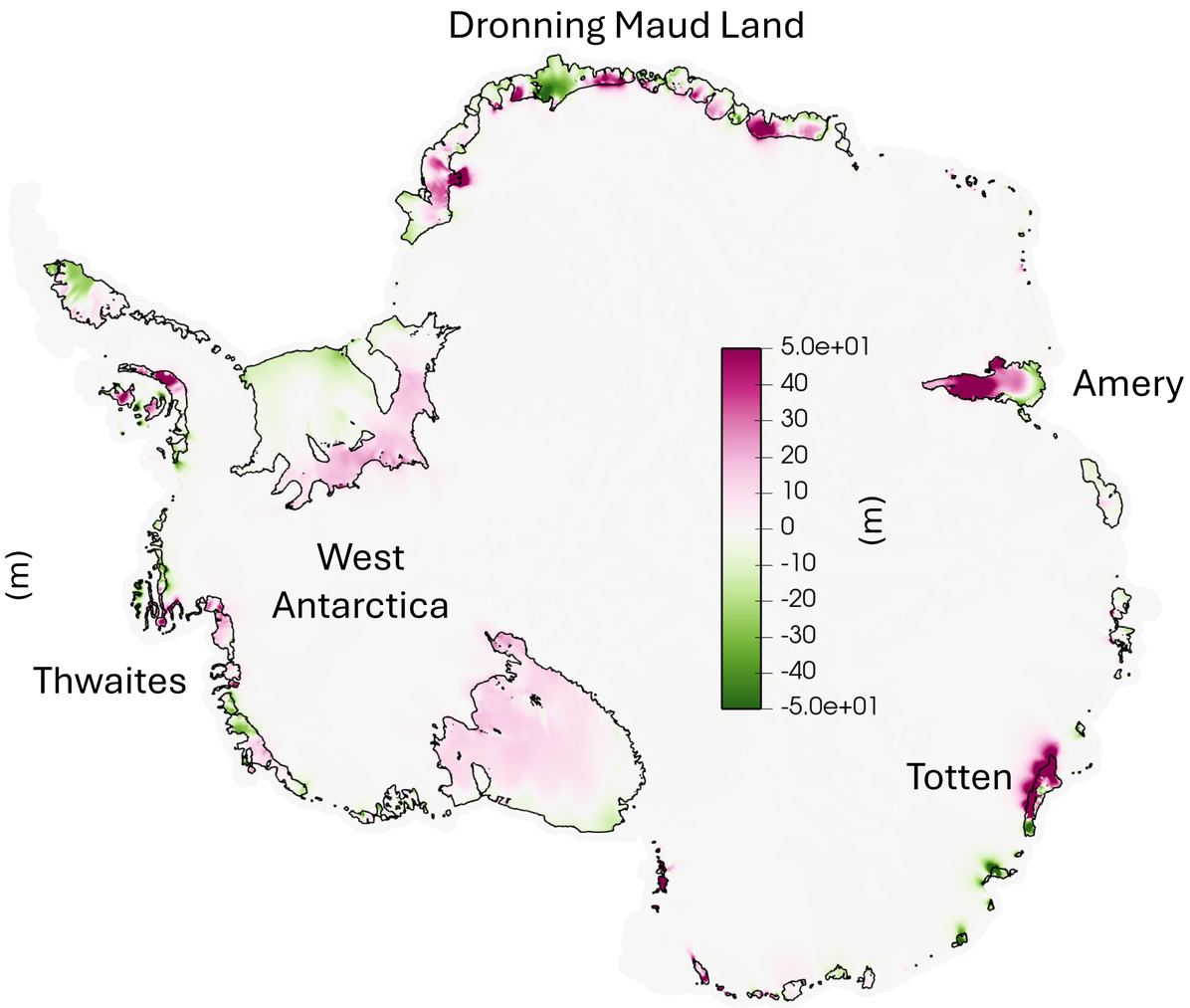


Cavities

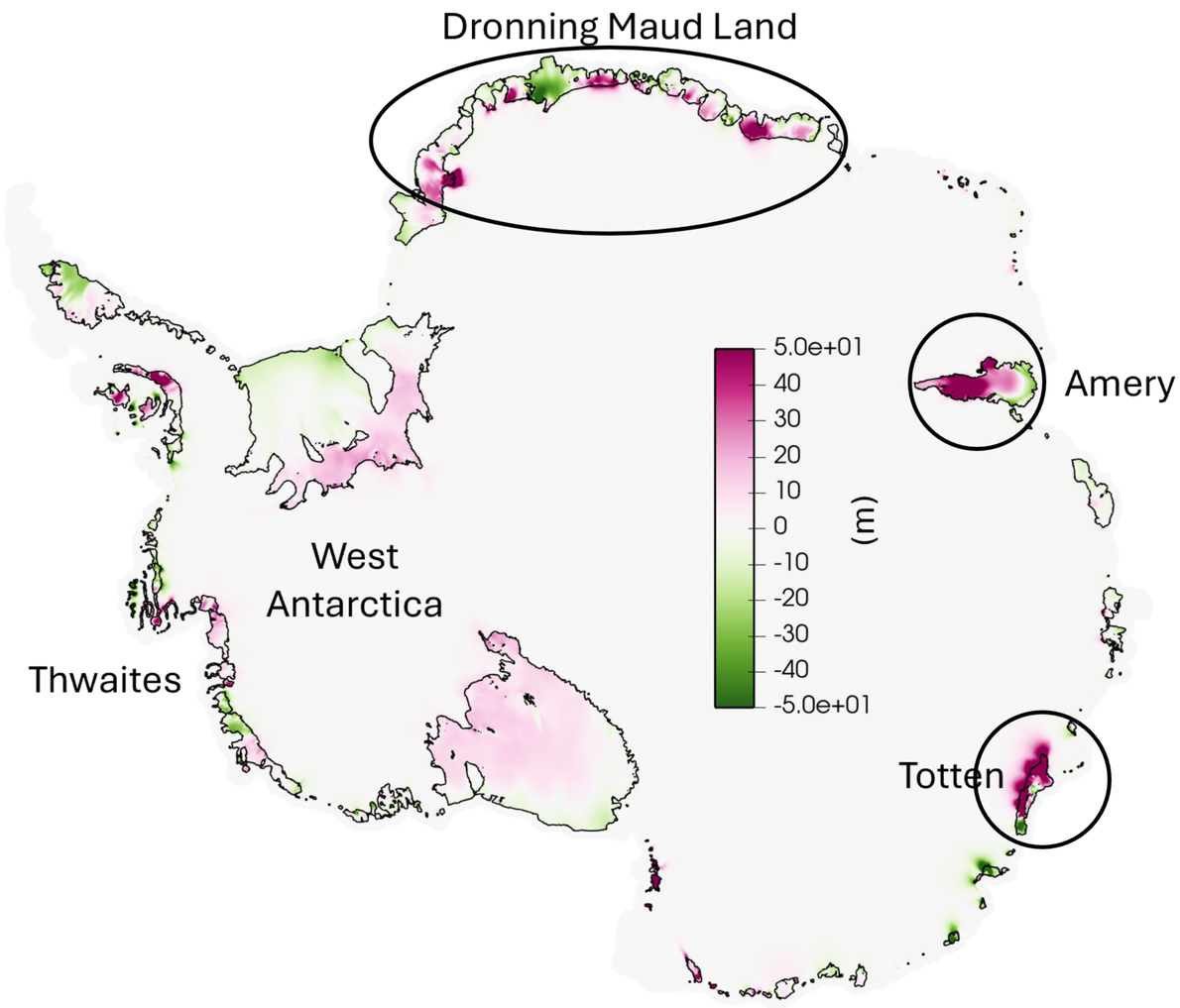




Difference between configurations



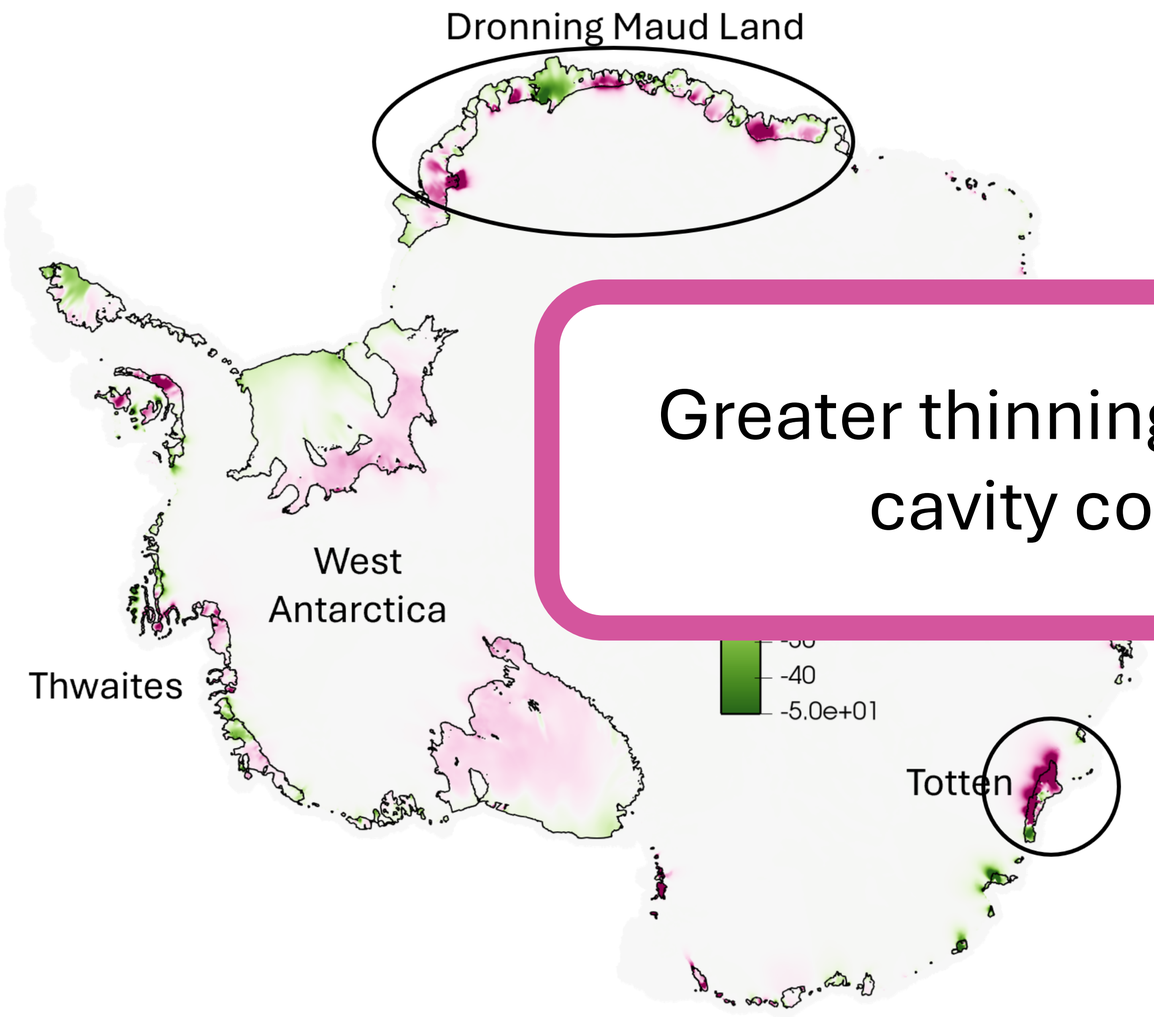
Difference between configurations



More thinning in No Cavity Configuration

More thinning in Cavity Configuration

Difference between configurations



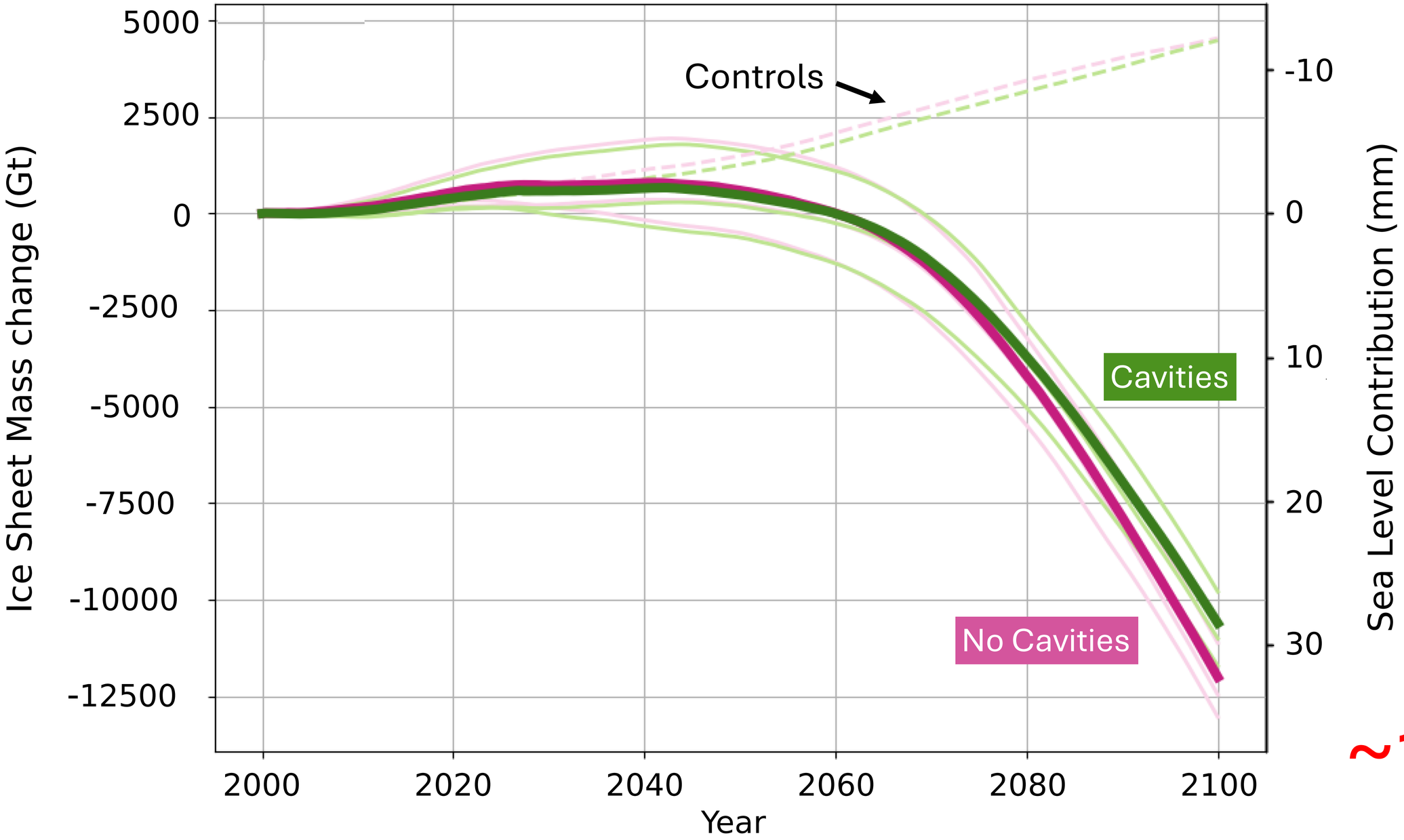
More thinning in No Cavity Configuration

Greater thinning signal for the no cavity configuration

More thinning in Cavity Configuration

Antarctica’s contribution to sea level rise for both experiments

Sea level contribution is slightly larger when ice shelf cavities are not resolved



~14%

What is the error introduced on Antarctic projections of sea level rise when models exclude ice-shelf cavities?

~14%

In other words, how well do most Earth system models perform?

Pretty well! … if your geometry doesn’t evolve drastically

Summary and Takeaways

1. Ice shelf basal melting is a critical control on Antarctic mass loss, but ocean conditions within cavities are not typically resolved in most Earth system models.

2. Our comparison experiment shows a slight overestimation in sea level contribution by 2100 when cavities aren't resolved, but not by much!

3. This is reassuring – Earth system models w/o cavities can still participate in large, collaborative modeling efforts when making projections to 2100

4. Beyond 2100, you would need an Earth system model with a fully-coupled, two-way interacting ice sheet model component to be able to feedbacks between the ice and larger climate system

Thank you!!!

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