Extending the range and reach of physically-based Greenland ice sheet sea-level projections

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LIWG winter meeting, Mesa Lab and online 11.02.2026

Introduction

How this work fits into the ISMIP cycle

ISMIP6/7: The Ice Sheet Model Intercomparison Project's core activity is the design and delivery of projections of the sea level contribution of the ice sheets using Coupled Model Intercomparison Project (CMIP) forcing.

ISMIP6 (2014 - 2020)
Core activity mostly ended with providing input for IPCC AR6

Protect CRYOSPHERE & SEA LEVEL

European project (2020-2025)
Projecting Sea-Level Rise: from Ice Sheets to Local Implications

https://protect-slr.eu/

ISMIP7 (2025 -)
Is now actively working towards the IPCC AR7 fast track delivery

Experimental setup

Global forcing
Climate change over and surrounding the ice sheets

Selected CMIP climate models

Regional downscaling
and parameterisations

Regional Climate Models

Retreat parameterisation

Projections
Ice sheet evolution, along with associated uncertainty

Standalone ice sheet models

ISMIP6

Nowicki et al. (2016; 2020)

Experimental setup for Greenland

CMIP6 models

- selected based on availability
- quality check over historical period

CMIP5 models

- performance over historical period
- to maximise spread in projections

Surface mass balance forcing

- RCMs forced by CMIP models
- SMB anomalies relative to 1960-1989
- SMB elevation feedback parameterized based on d(Runoff)/dz

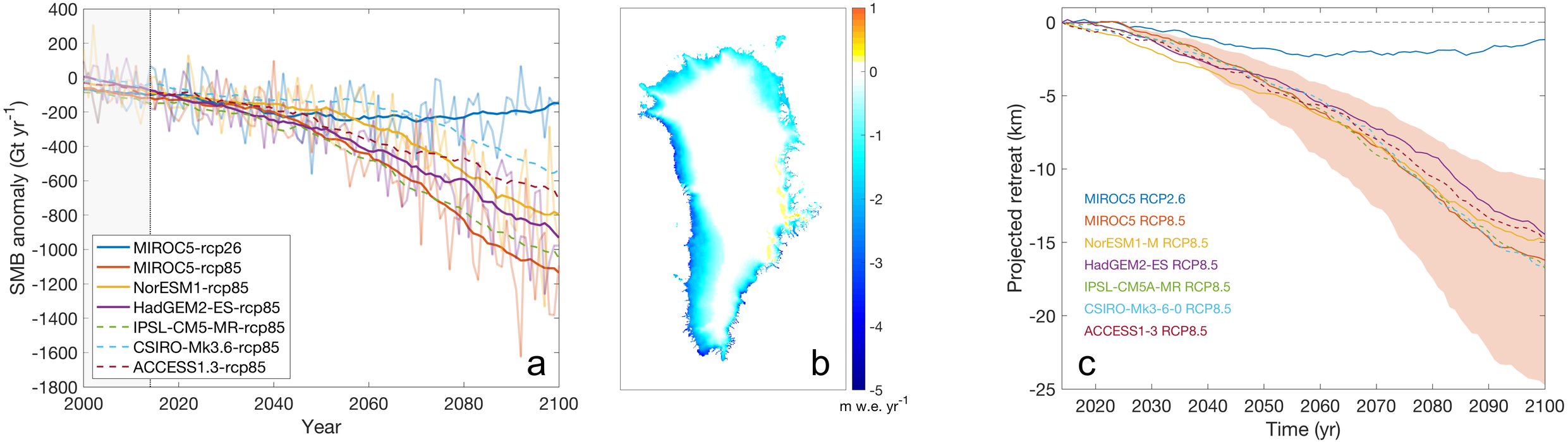
Outlet glacier forcing

- Prescribed outlet glacier retreat
- Empirically derived based on historical glacier retreat, ocean temperature and runoff
- κ parameter for sensitivity

Ice sheet models

- From PROTECT project partners

Forcing for the ice sheet models



- Projections out to year 2100 for the CMIP5 subset of global models
- SMB anomaly (a, b) and projected retreat (c)

Goelzer et al. 2020 https://doi.org/10.5194/tc-14-3071-2020.

Ensemble setup

Ensemble overview

CMIP5 global models

- ACCESS1.3, CSIRO-Mk3.6, HadGEM2-ES, IPSL-CM5-MR, NorESM1, MIROC5

CMIP6 global models

- CESM2, CNRM-CM6, CNRM-ESM2, MPI-ESM1, UKESM1, NorESM2, EC-Earth3, IPSL-CM6A-LR

Scenarios

- RCP/SSP5**85**, RCP/SSP2**45**, RCP/SSP1**26**

Regional climate models

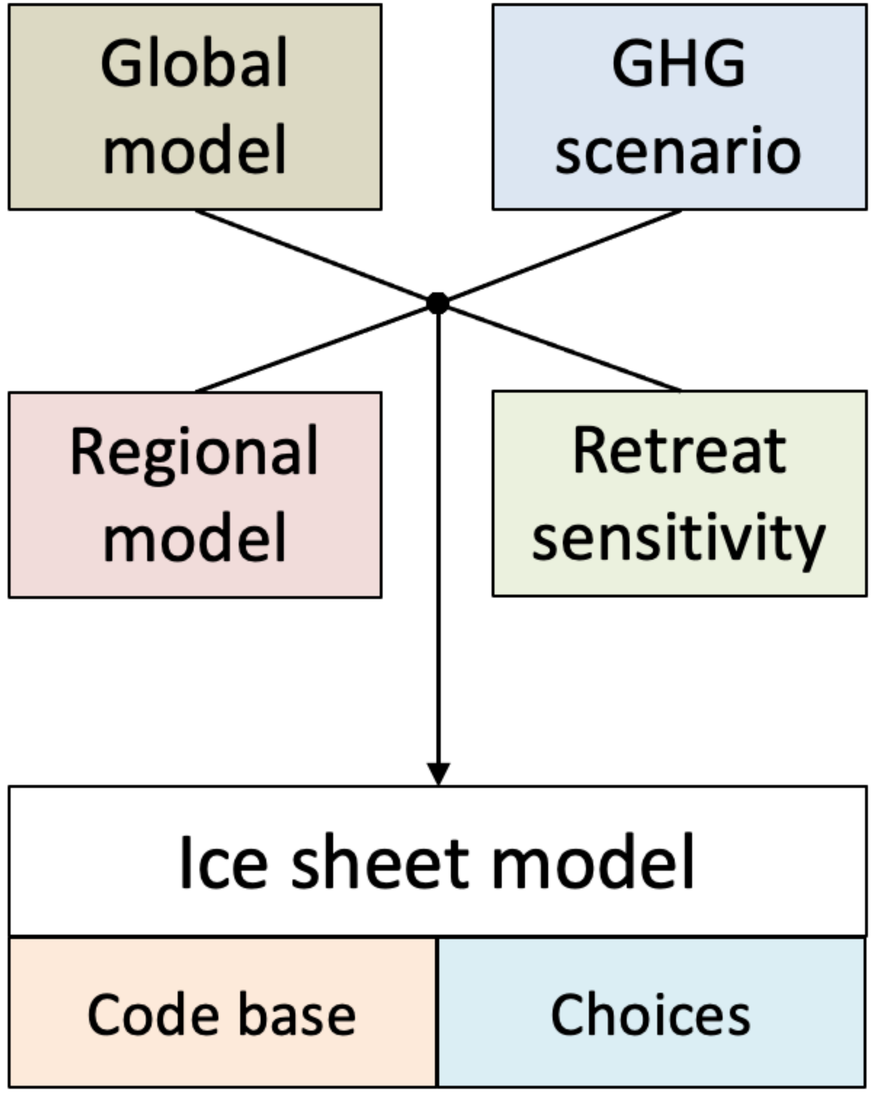
- MARv3.9/v3.12, RACMO2.3p2, HIRHAM5, SDBN1

Retreat sensitivity

- medium (p50), high (p25), low (p75), [p05, p95]

Ice sheet models

- VUB-GISM, NORCE-CISM, IMAU-IMAUICE, IGE-ELMER



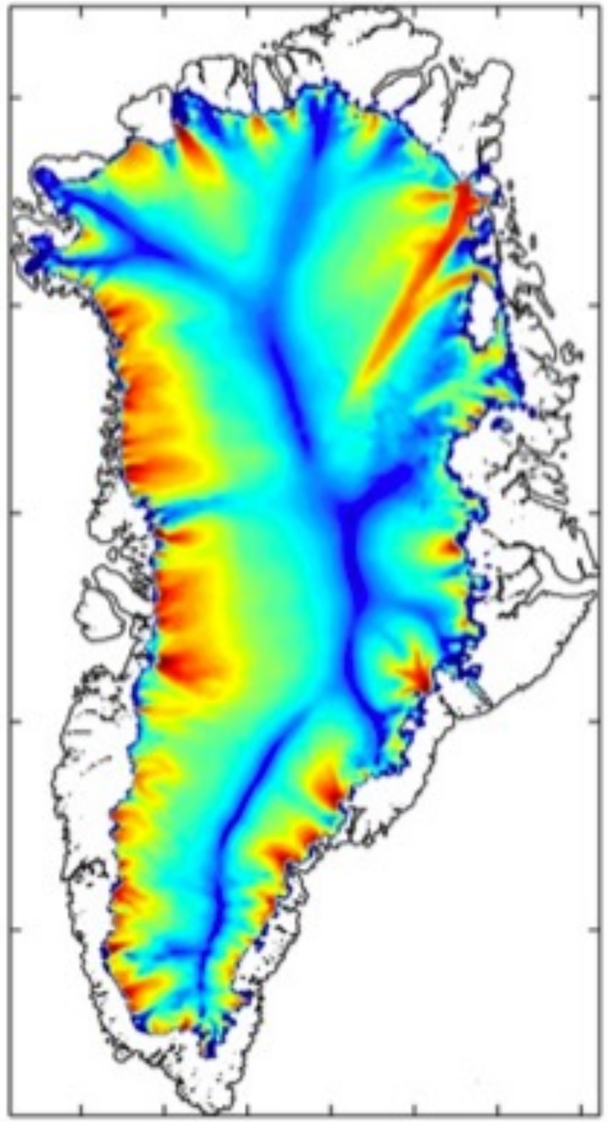
Ice sheet models

IMAU-IMAUICE
Resolution: 10km, 16km, 20km, 30km, 40km
Variants: Different sliding laws and spinup

NORCE-CISM
Resolution: 2km, 4km, 8km, 16km
Variants: Different initial and historical SMB

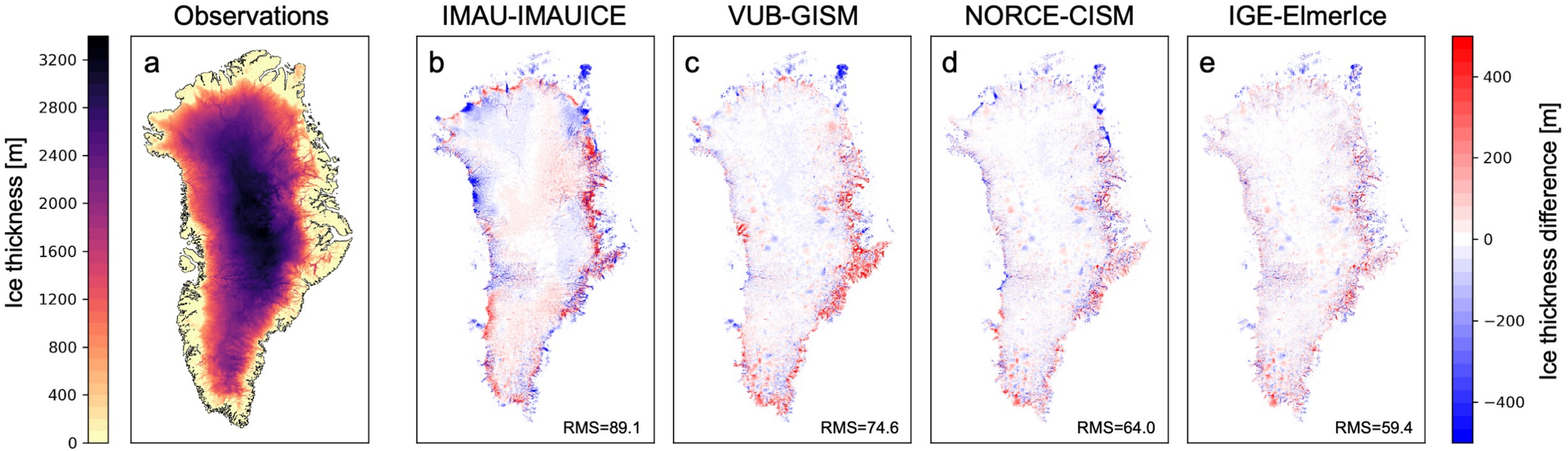
VUB-GISM
Resolution: 5km
Variants: SIA, HOM

IGE-ELMER
Resolution: adaptive <1km – 10km



Ice sheet model initialisation

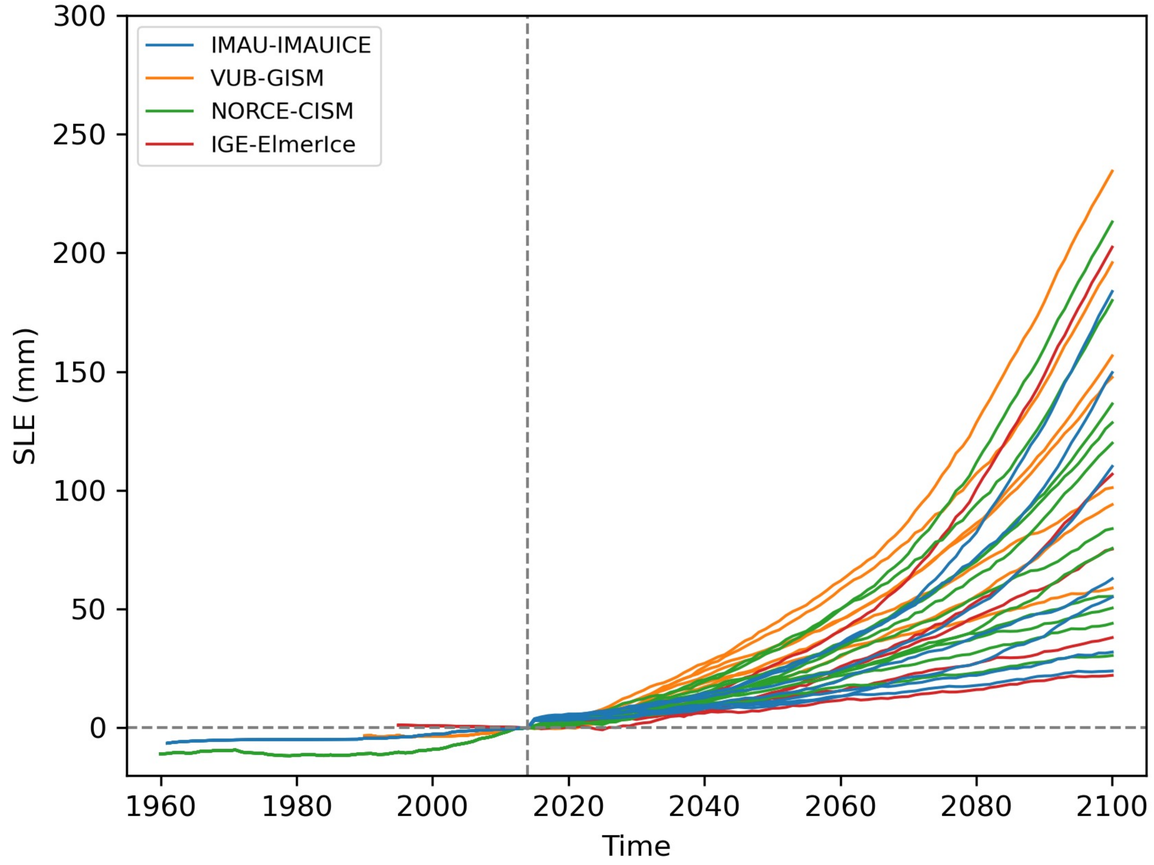
- IMAUICE uses a paleoclimate spin-up
- The other ISMs all calibrate the basal friction coefficient
- The figure shows the resulting differences with observed ice thickness



Projections

Ice sheet projections

- Showing results for one ice sheet model per group
- Forcings produced specifically for PROTECT

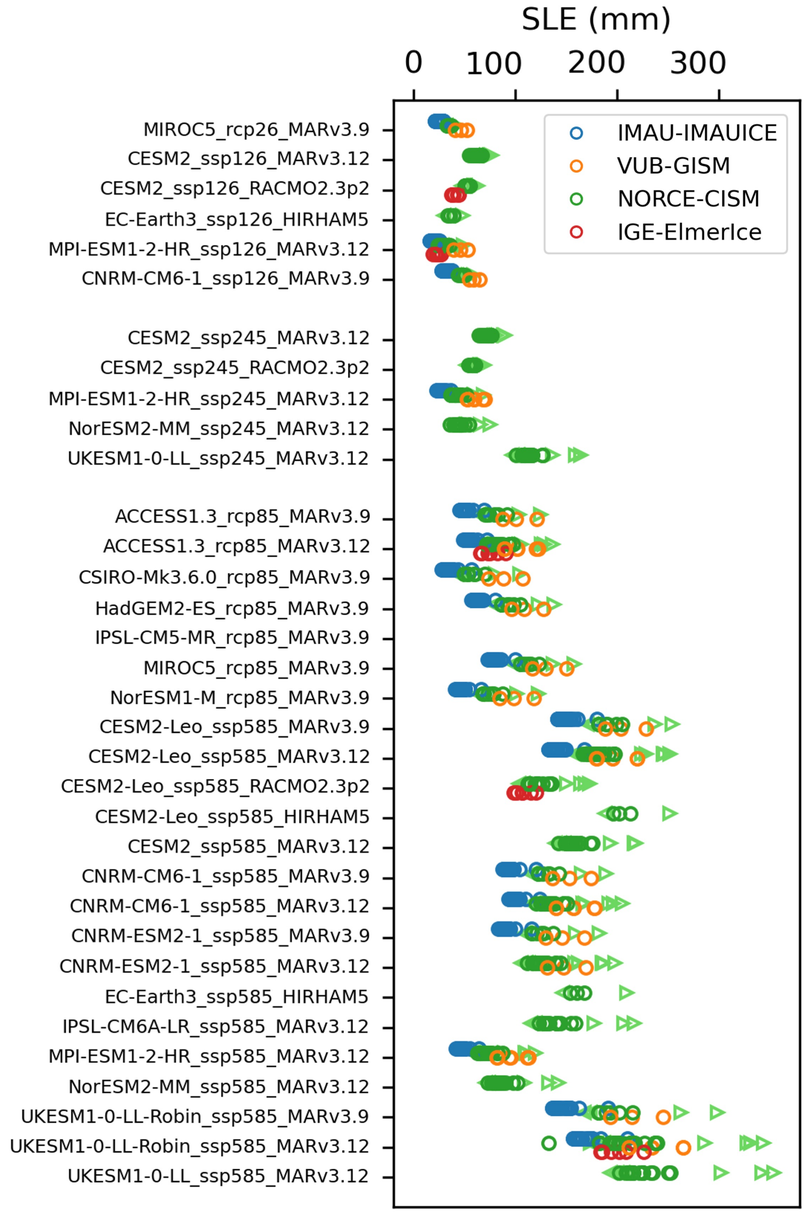


- 3 ISMs forced with historical retreat
- Less models, more model versions

Overview

- All GrIS sea-level projections for the year 2100

- Addional RCMs RACMO2.3p2 and HIRHAM5
- New scenario SSP2-4.5
- Larger number of CMIP6 models
- Larger range of retreat parameter

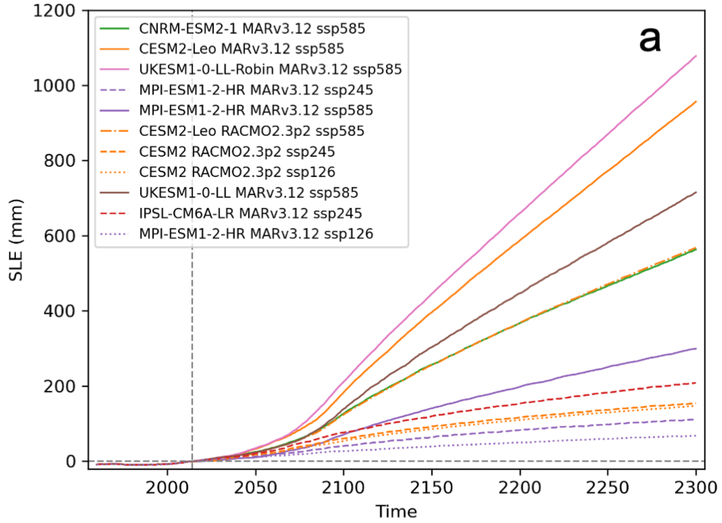


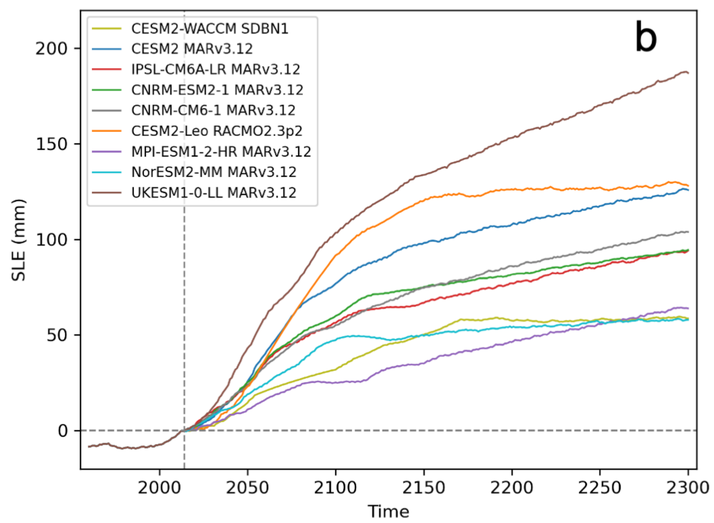
Extensions to 2300

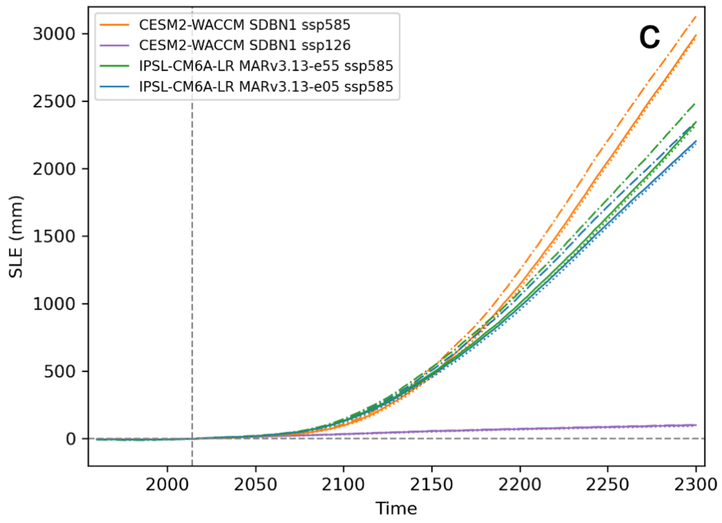
(a) Schematic repeat forcing

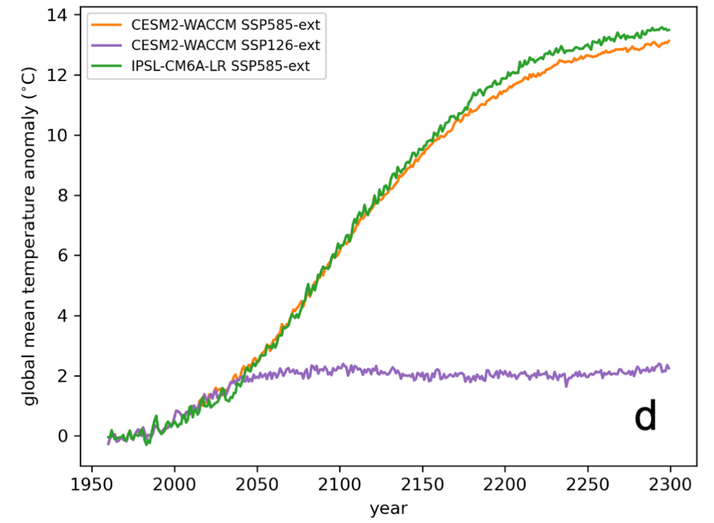
(b) Constructed overshot forcing mimicking SSP5-3.4-OS

(c) Natural ScenarioMIP extensions









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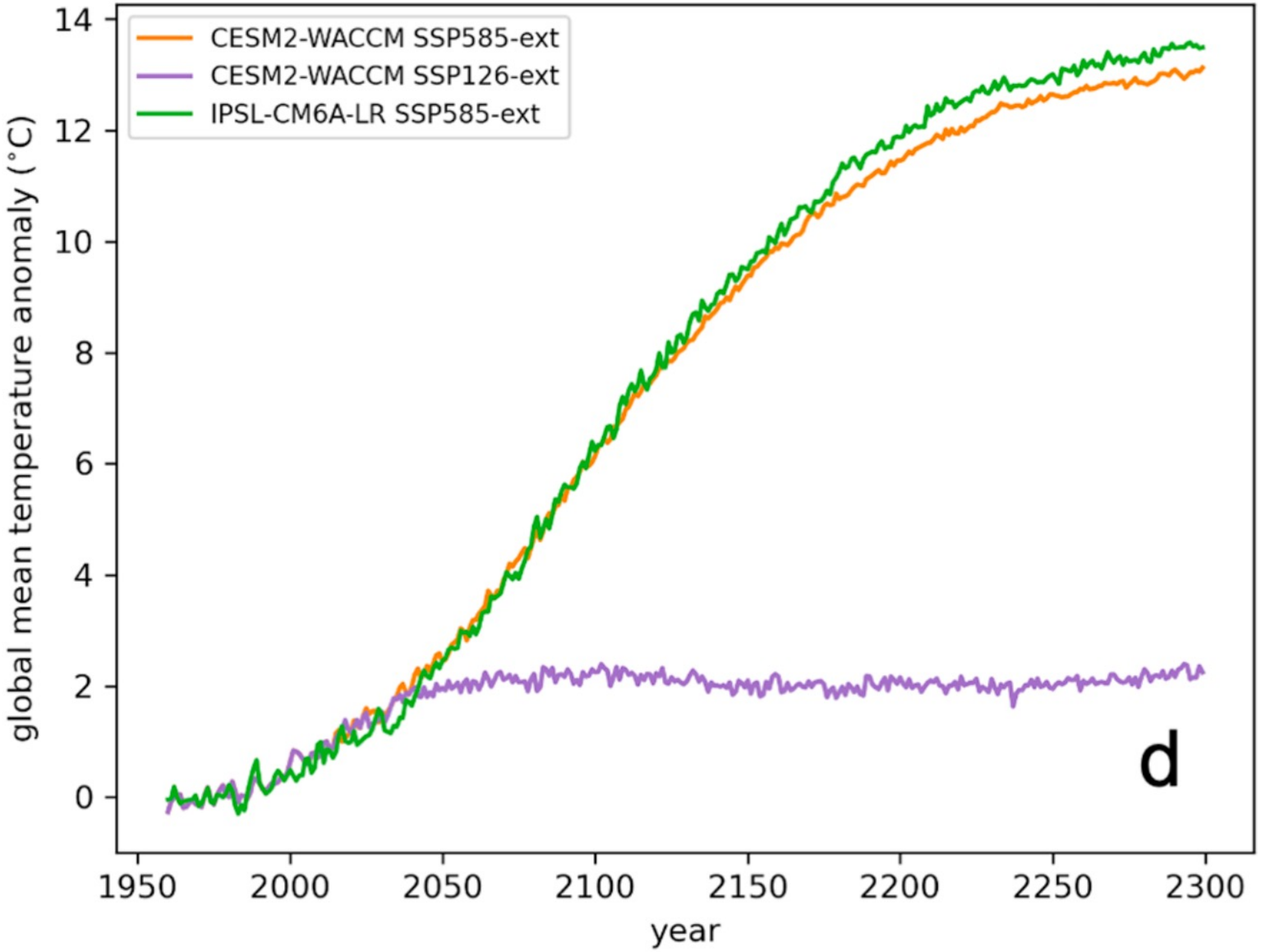

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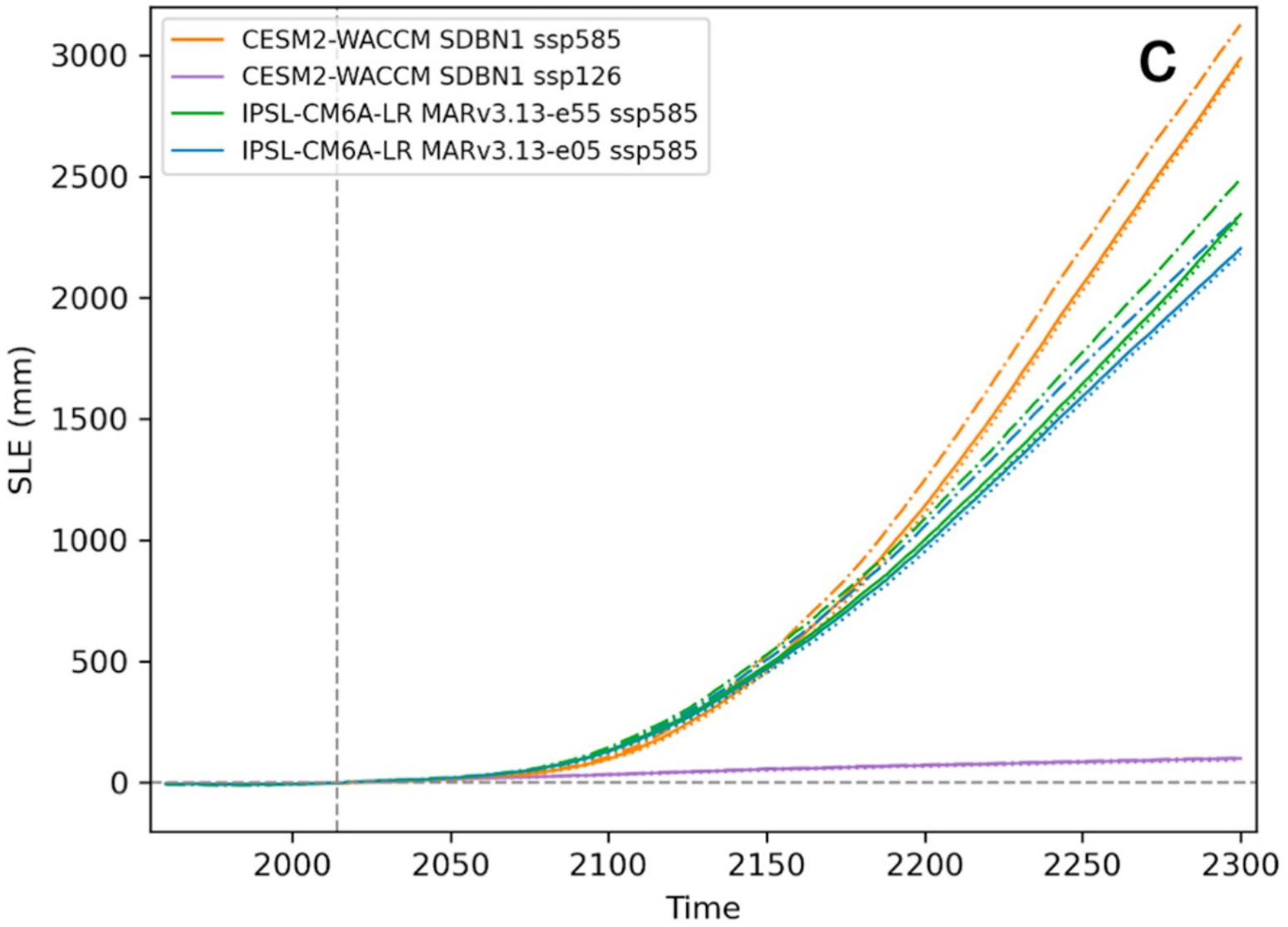

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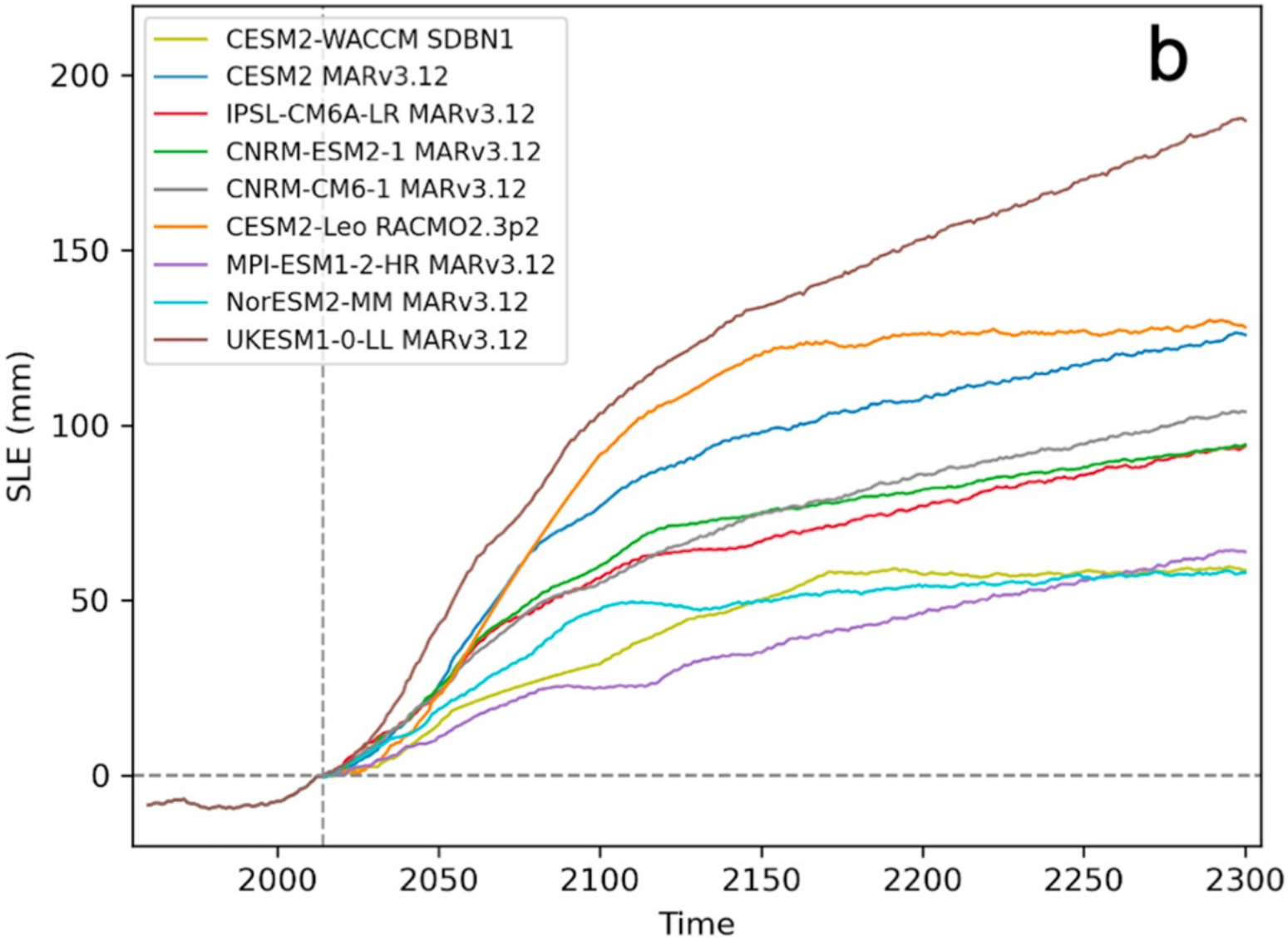

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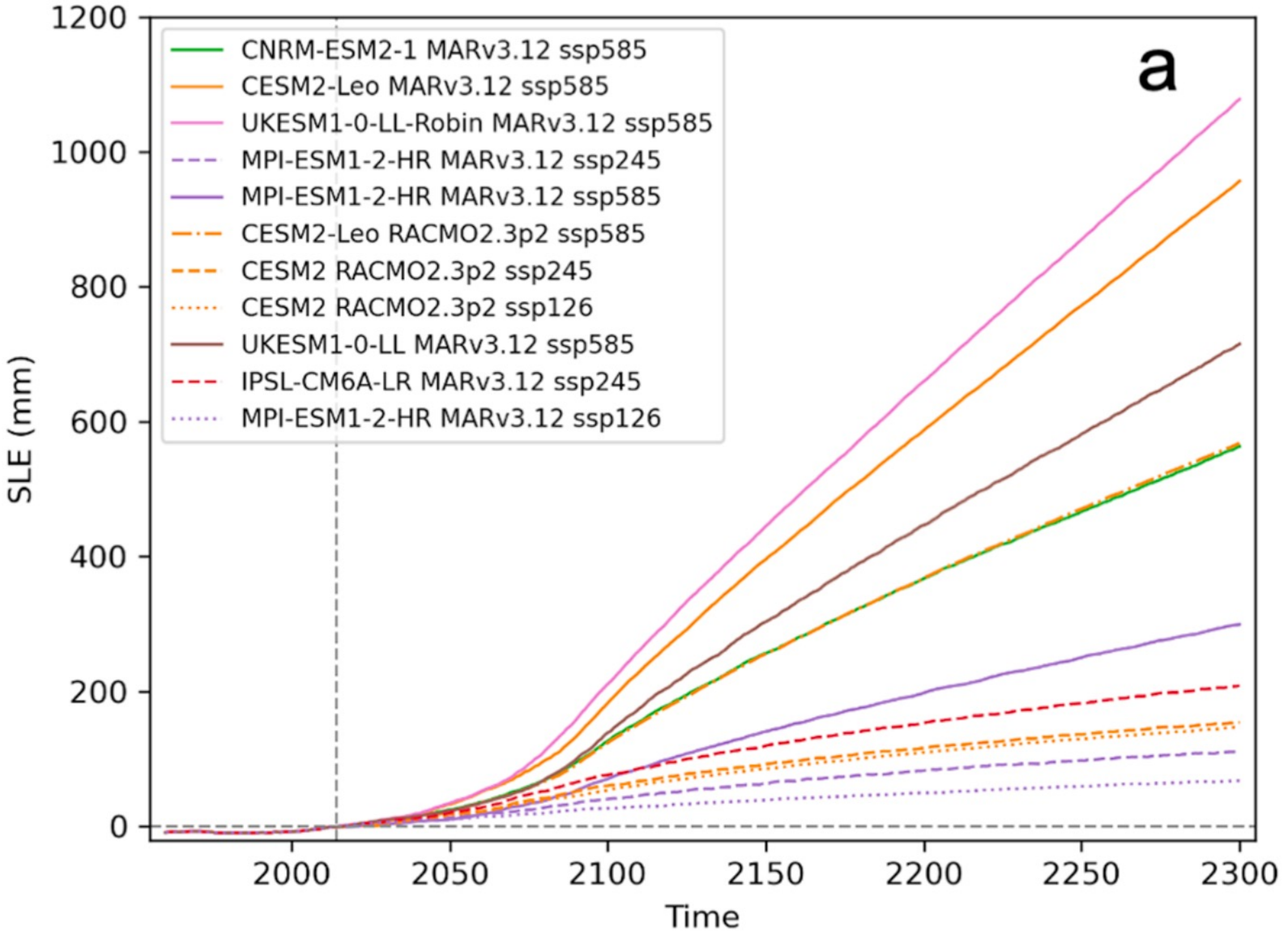
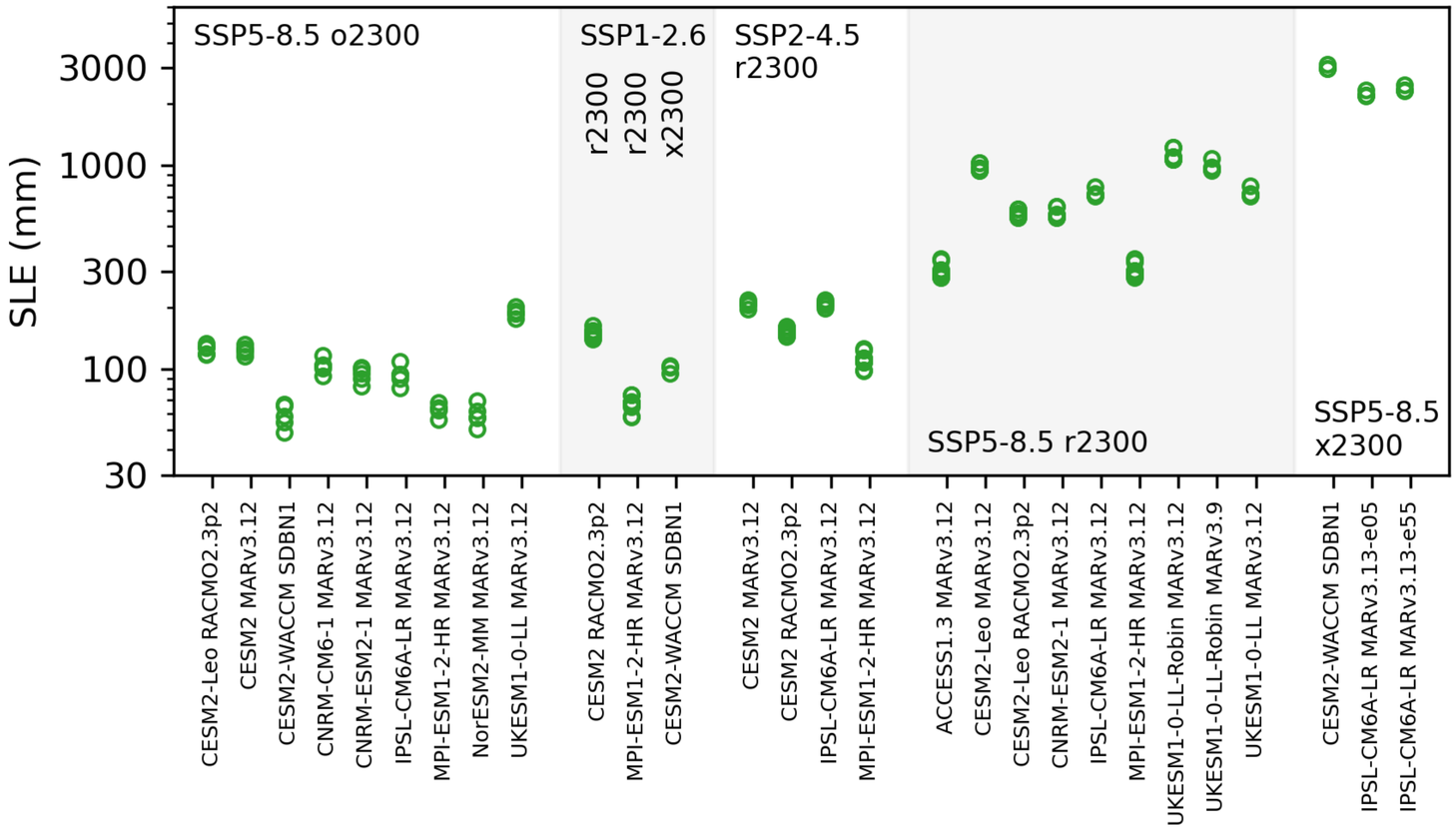


Extensions to 2300 summary

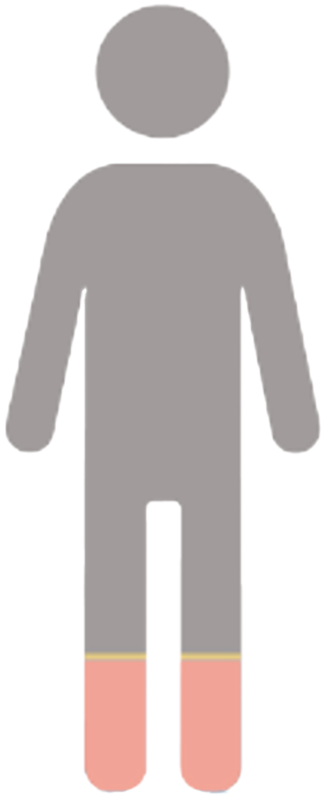
- Largest contributions by year 2300 for extreme extension SSP5-8.5
- Ice sheet may be stabilised for some of the overshoot scenarios
- Repeated forcing from 2100 shows large dependence on scenario and climate model choice



The end

The discussed paper is available here:

Goelzer, H., Berends, C. J., Boberg, F., Durand, G., Edwards, T. L., Fettweis, X., Gillet-Chaulet, F., Glaude, Q., Huybrechts, P., Le clec'h, S., Mottram, R., Noël, B., Olesen, M., Rahlves, C., Rohmer, J., van den Broeke, M., and van de Wal, R. S. W.: Extending the range and reach of physically-based Greenland ice sheet sea-level projections, The Cryosphere, 19, 6887–6906, https://doi.org/10.5194/tc-19-6887-2025, 2025.



Thank you for your attention