Bjerknes Centre for Climate Research

iC3 Centre for ice, Cryosphere, Carbon and Climate

Norwegian Centre of Excellence

NORCE

Land ice component in the Norwegian Earth System Model: towards CMIP7 and beyond

M. Petrini, M. Vertenstein, H. Goelzer, W. Lipscomb, G. Leguy, B. Sacks, K. Thayer-Calder, D. Chandler, P. Langebroek

2025 CESM workshop - Land Ice Working Group session

Outline

- Ice sheet coupling in ESMs: what is the goal?

- What’s new in NorESM3: overview and preliminary results

- Focus: ocean forcing around & under Antarctic ice shelves:

- Roadmap towards CMIP7 and (coupled ESM-ISM) ISMIP7;

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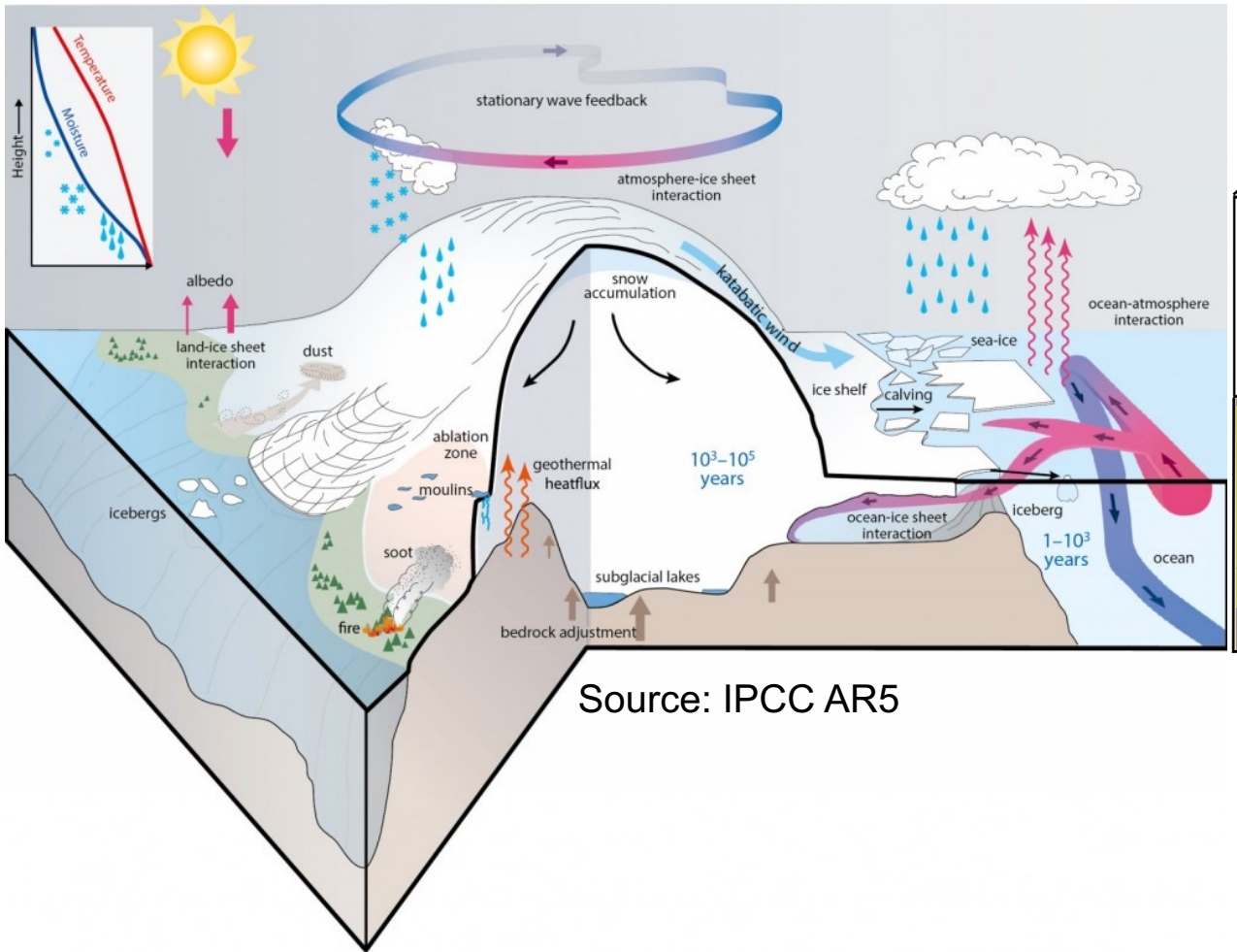
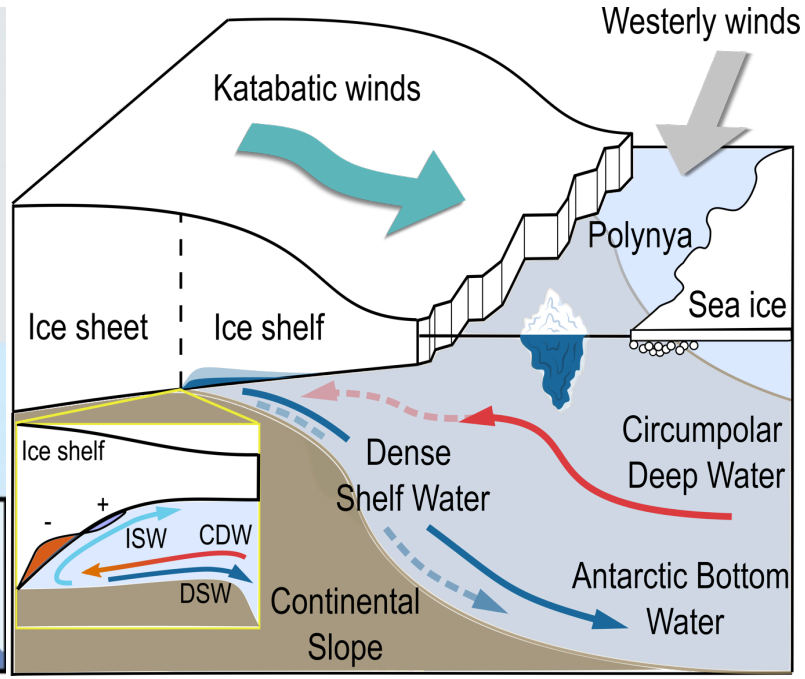
Coupling ice sheets in global ESMs: why and how?

- Assess impact of ice sheet changes on large-scale atmosphere and ocean circulation, evaluate feedbacks important for ice sheet loss (melt elevation, ice albedo, ocean-driven melt,…);
- Present & future distribution of glacial meltwater always consistent with climate & modelled ice physics;





Source: IPCC AR5

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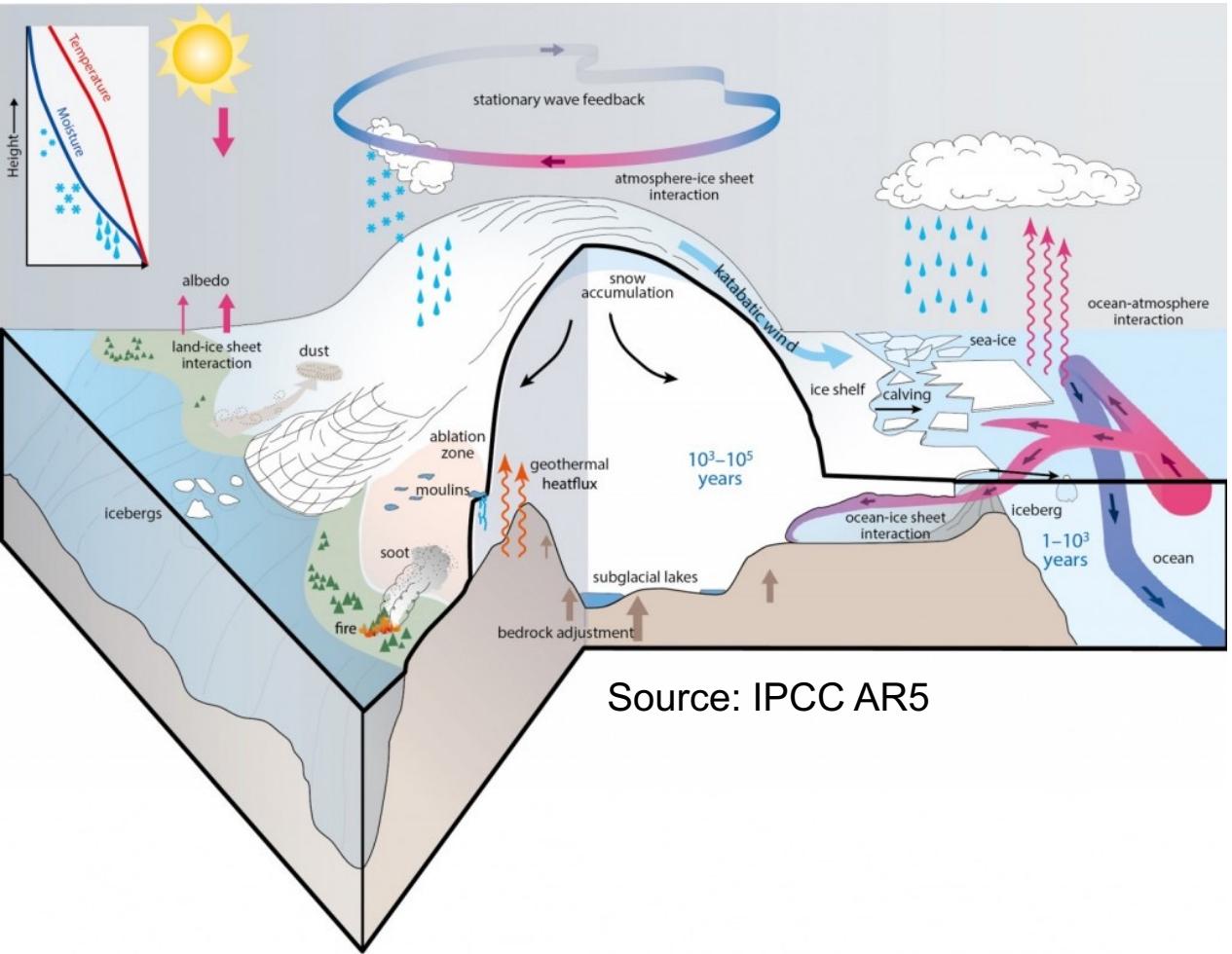

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- Ideal, unbiased ESM: two-way ice sheet coupling gives you both more realistic and useful model;
- CMIP ESMs: compromise between useful (evaluate coupled system, free-evolving) and realistic (matching present-day climate and ice sheets as baseline for projections, tuned);
- Ice sheets in fully coupled ESM-ISM context:
  - free-evolving vs masked present-day extent?
  - paleo-spinup vs inverting basal friction coeffs?
  - tuning ocean melt params vs plume models?
- Impact of choices on ESM-ISM ensembles?

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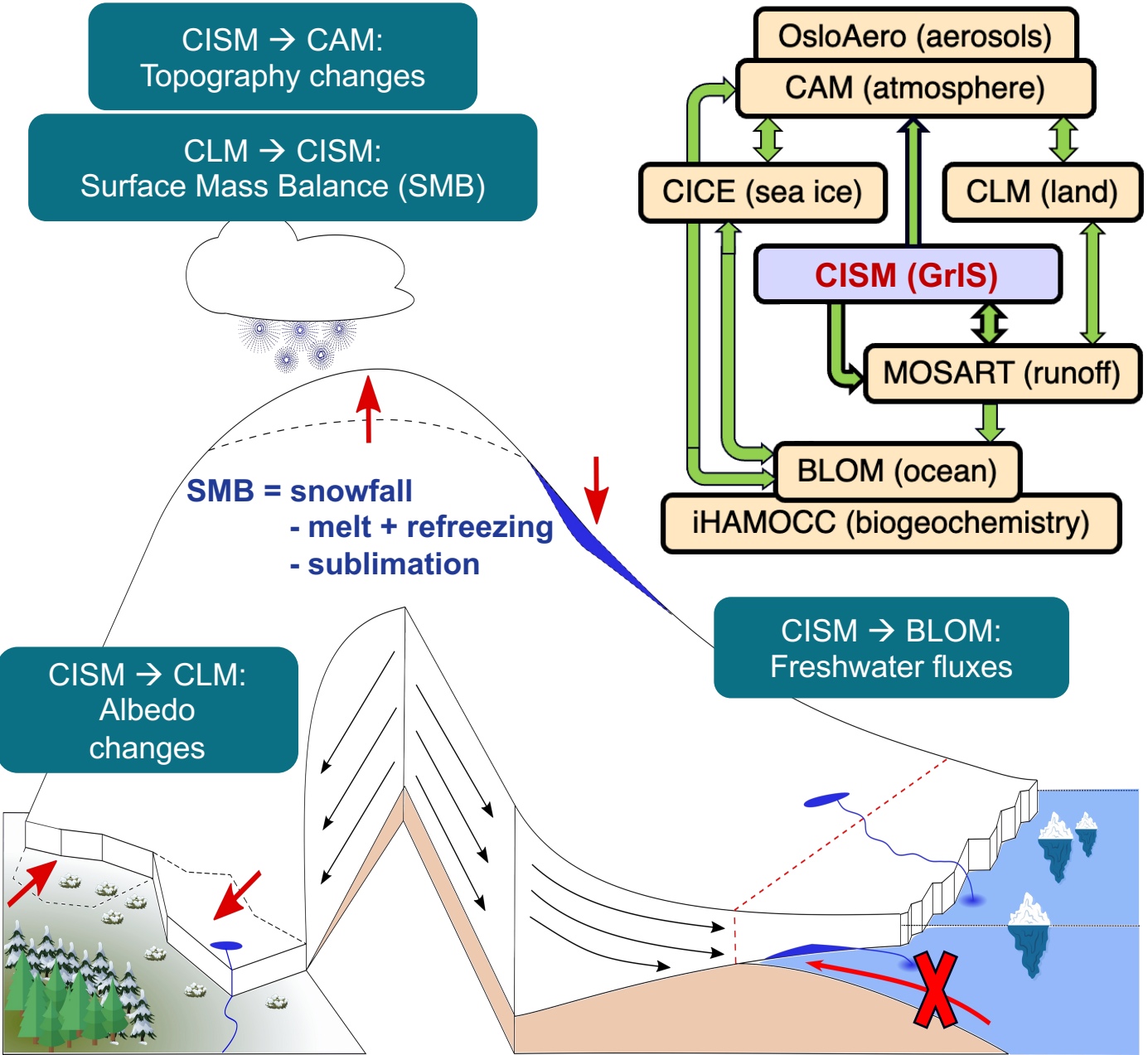
Land ice from NorESM2 to NorESM3: an overview



- Norwegian Earth System Model (NorESM): CMIP-type model for atmosphere, land, ocean (incl. biogeochemistry) and sea ice;
- NorESM2: interactive Greenland ice sheet component (CISM), SMB (no ocean forcing), ice cover/extent, freshwater fluxes;

Interactive coupling of a Greenland ice sheet model in NorESM2

Heiko Goelzer[1], Petra M. Langebroek[1], Andreas Born[2], Stefan Hofer[3,4], Konstanze Haubner[2], Michele Petrini[1], Gunter Leguy[5], William H. Lipscomb[5], Katherine Thayer-Calder[5]

Limited global effect of climate-Greenland ice sheet coupling in NorESM2 under a high-emission scenario

Konstanze Haubner[1], Heiko Goelzer[2], and Andreas Born[1]

Goelzer et al., 2025 (GMD, *in review*)
Haubner et al., 2025 (TC, *in review*)

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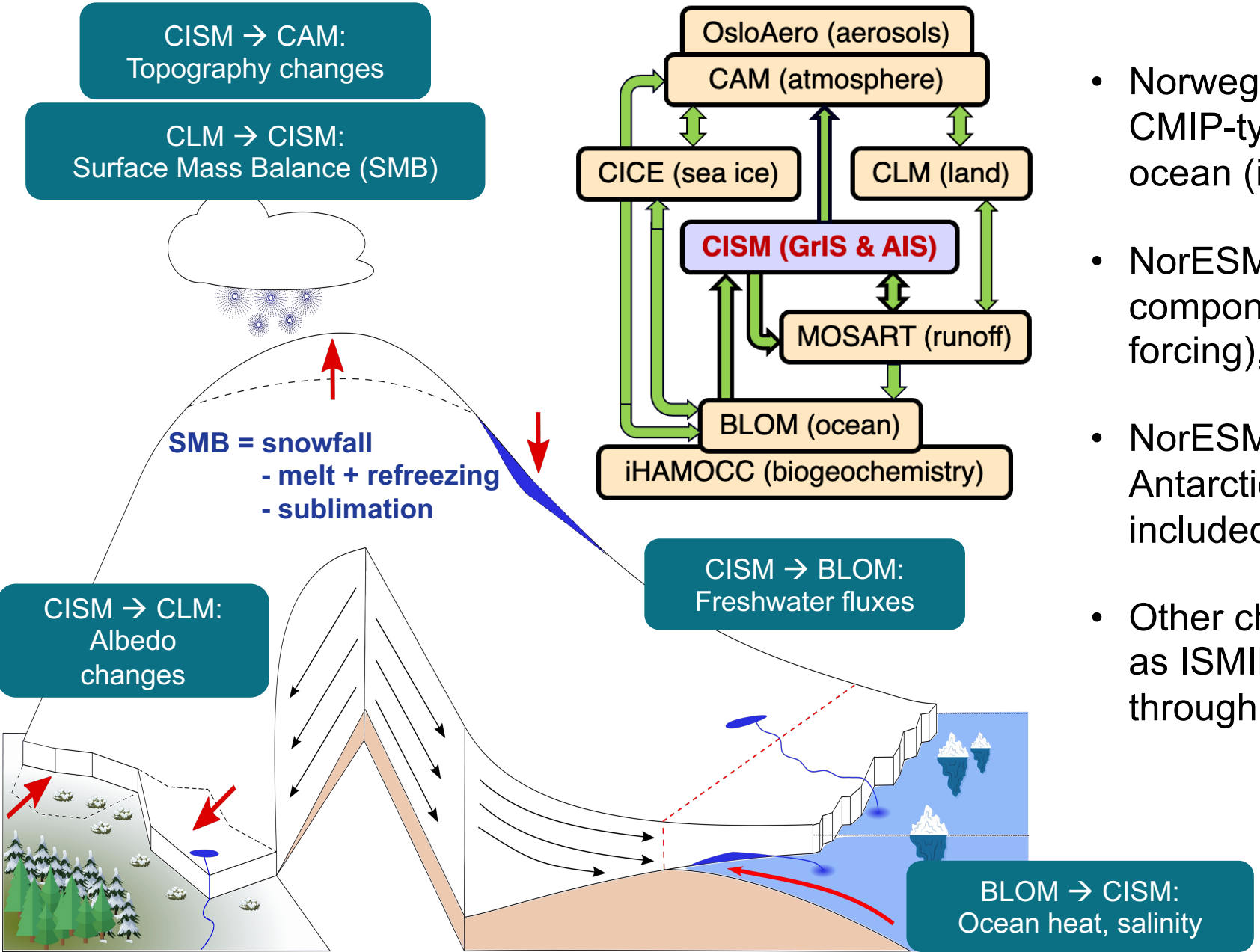

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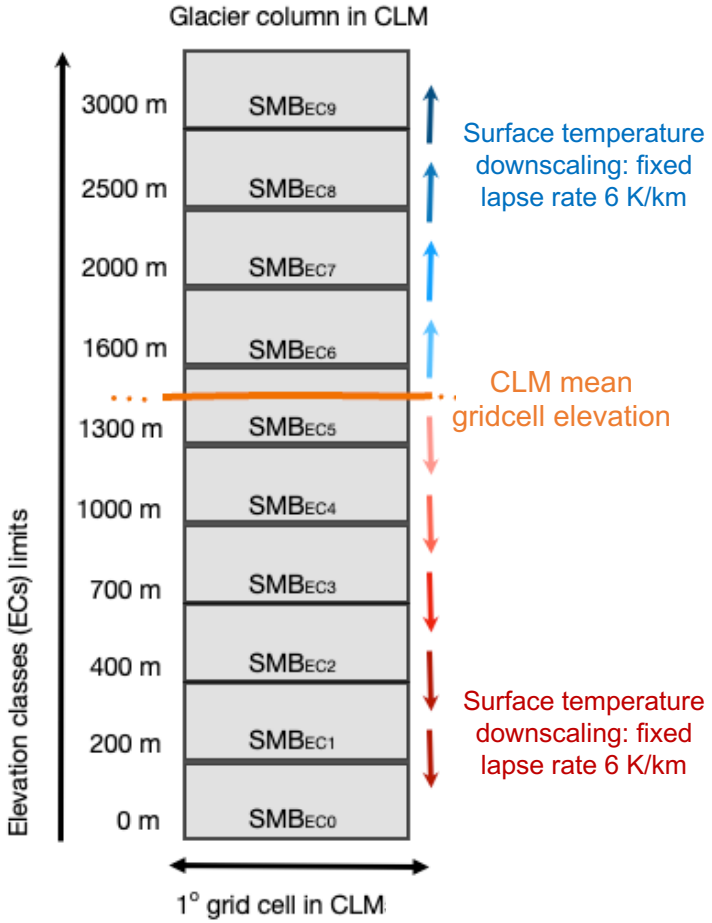
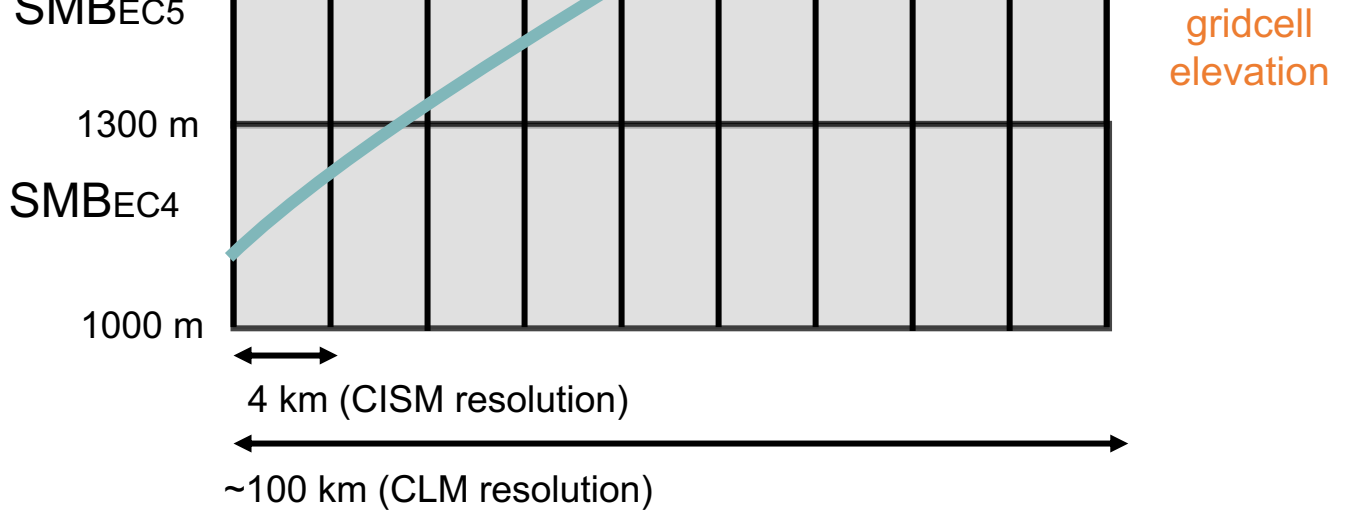
- NorESM2: interactive Greenland ice sheet component (CISM), SMB (no ocean forcing), ice cover/extent, freshwater fluxes;
- NorESM3: interactive Greenland & Antarctic ice sheet components (CISM), included ocean --> ice sheet coupling;
- Other changes: new ice sheet grids (same as ISMIP), glacial meltwater routing through MOSART (more efficient);

Ice sheet/land interaction: SMB forcing

- Same method as in CESM2/NorESM2: SMB calculated at multiple Elevation Classes, using surface energy balance scheme (radiative, turbulent, ground heat fluxes) & accounting snow/firn processes;
- Downscaling from CLM (~100 km) to CISM (4 km): using Elevation Classes to better represent surface melt at steep ice sheet margins (*precipitation is not downscaled*);





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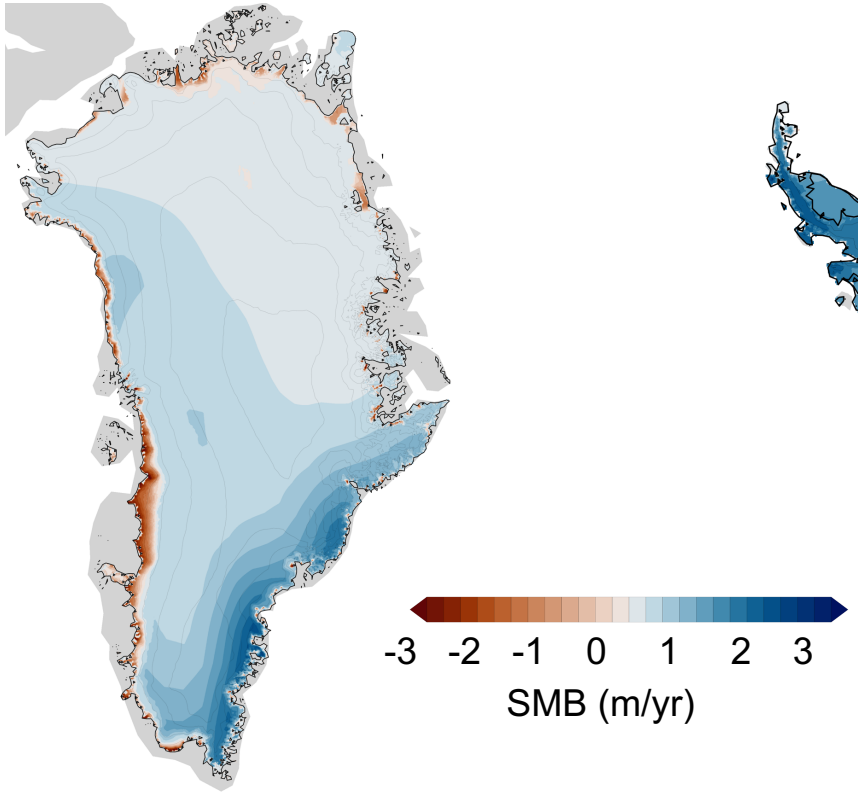
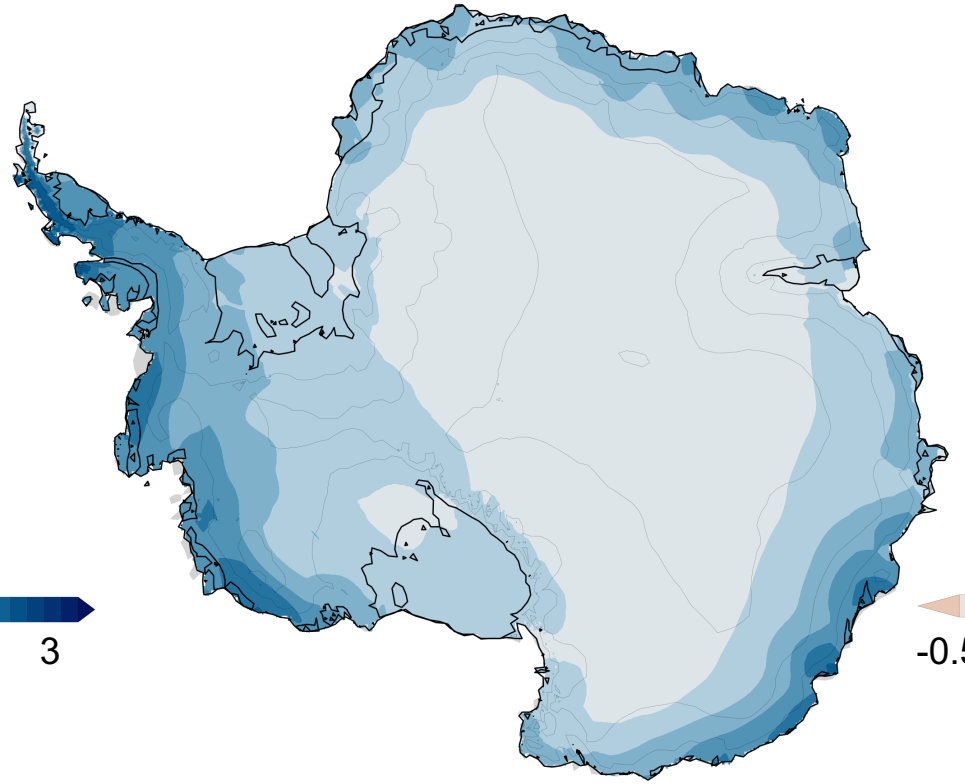
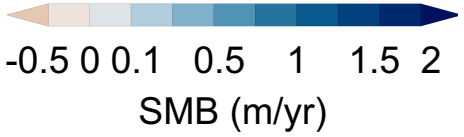
- First results from NorESM3-CISM coupled tests: GrIS similar pattern as in NorESM2, AIS more challenging due to coarse precipitation pattern;







Ice sheet/ocean interaction: ocean forcing

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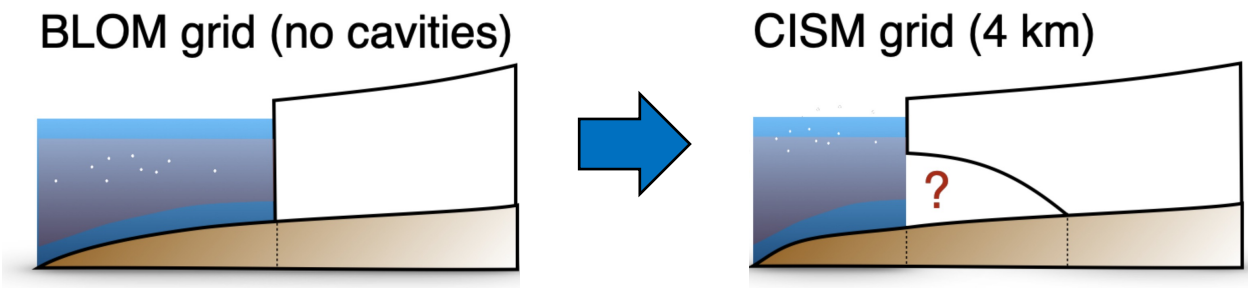

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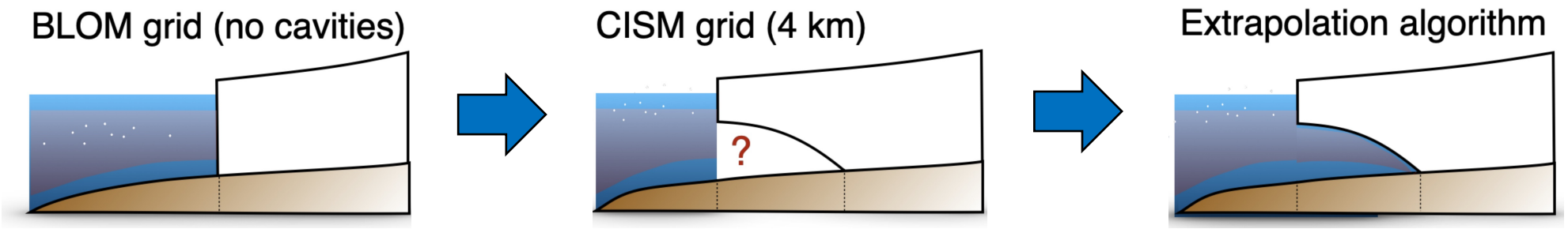

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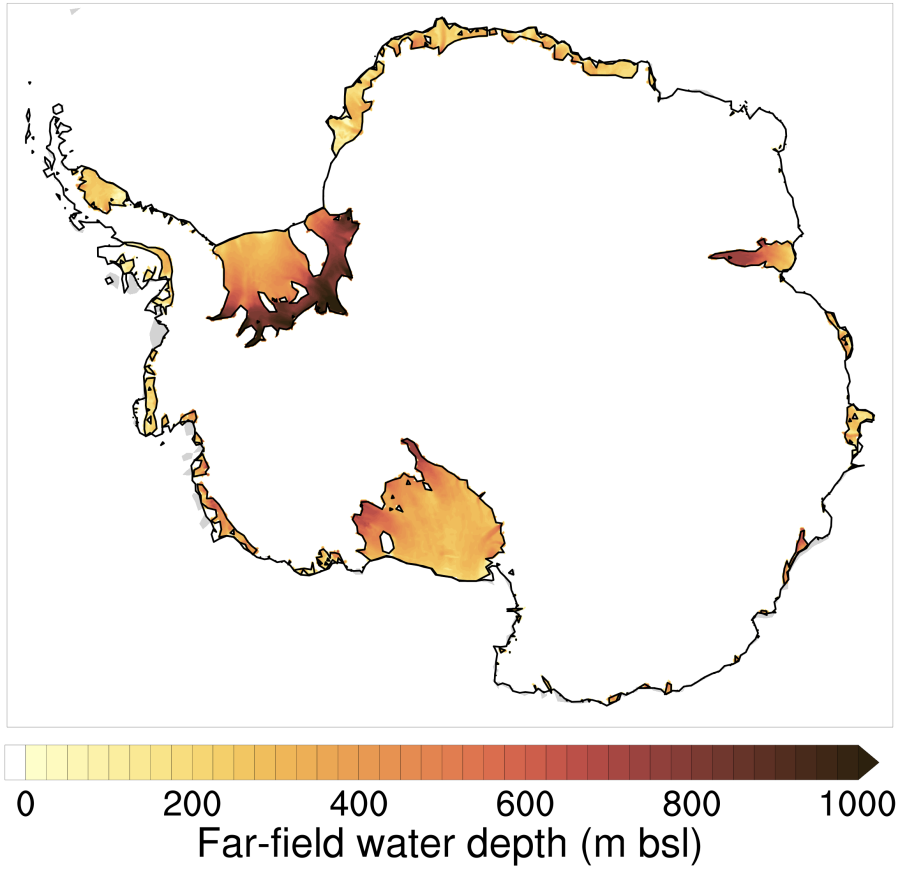

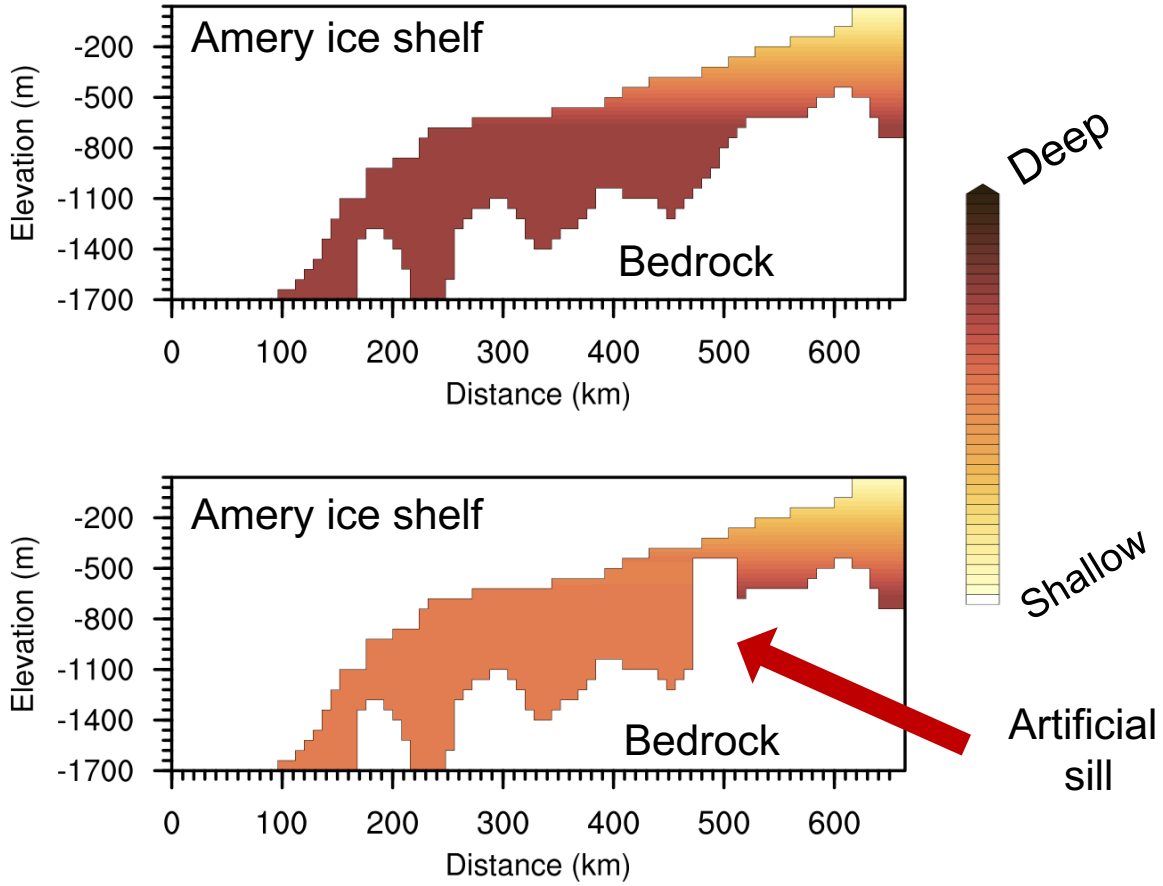

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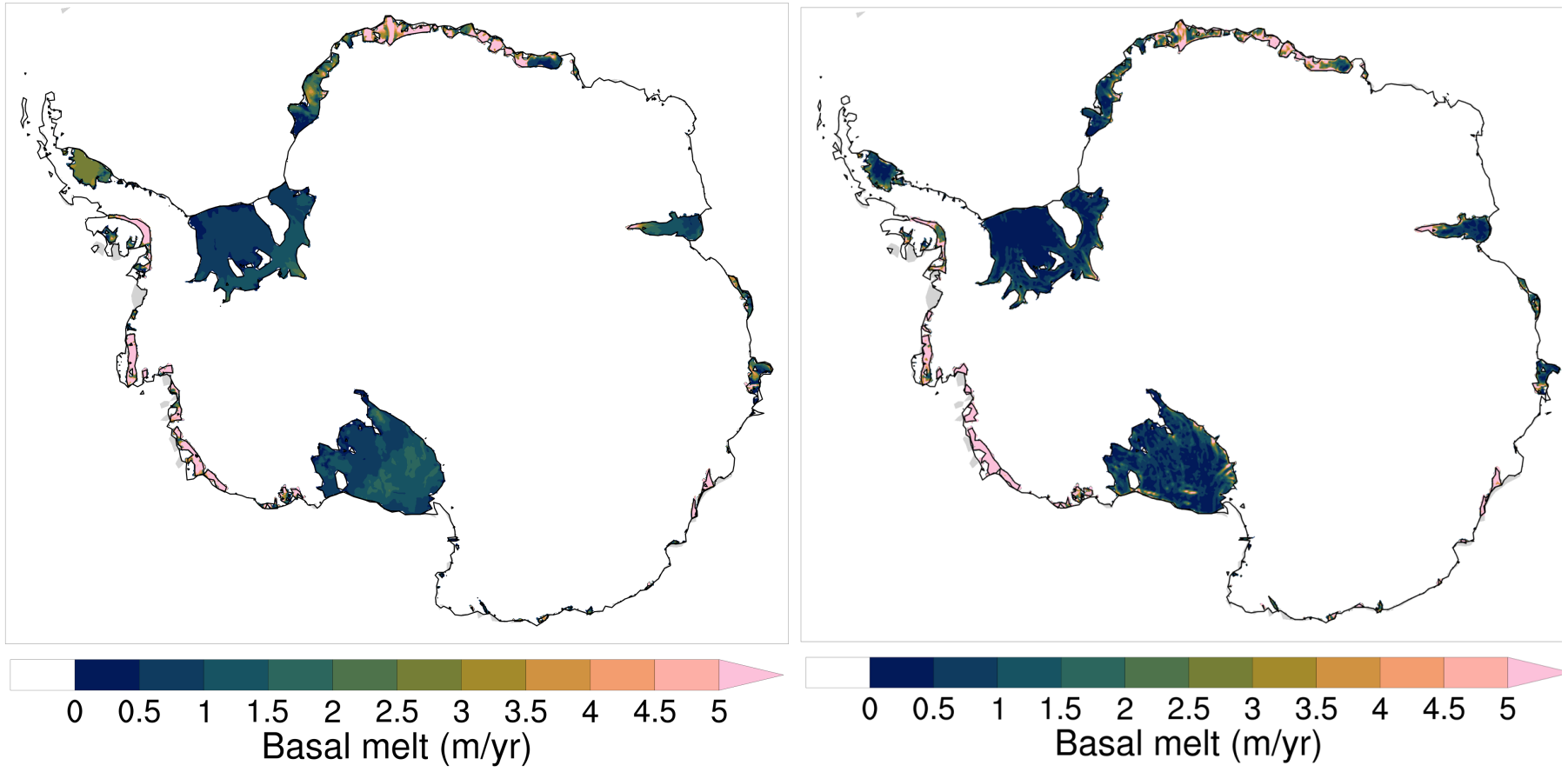
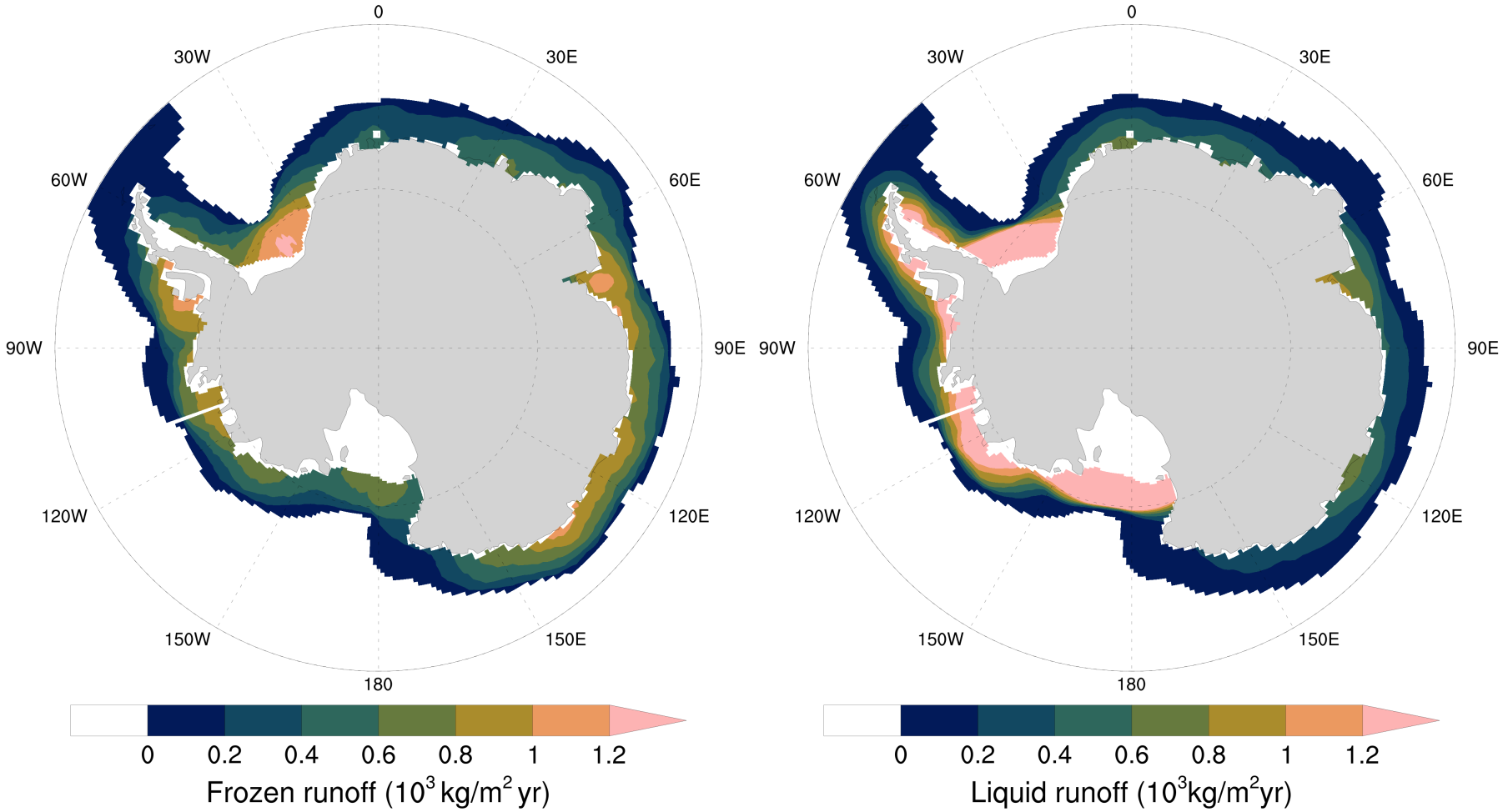
- Ocean forcing used to calculate sub-shelf melting (AIS: ISMIP6 parametrizations, GrIS: work-in-progress)



Ice sheet/ocean interaction: freshwater fluxes

- FWFs from surface runoff, ocean-driven melt and iceberg calving spread horizontally at surface;
- New logic in NorESM3 to separate how these fluxes enter the ocean: will test adding FWFs at depth;
- Below, distribution of frozen (iceberg calving) and liquid (ocean-driven melt) runoff in coupled test;



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- NorESM2 output to assess if/where warm water enter the ice shelf cavities using new algorithm;
- Ocean model in data mode, ice sheet not evolving: **purely diagnostic**!
- We look at picontrol & high warming scenario (equivalent to SSP5-8.5 for cumulative emissions);

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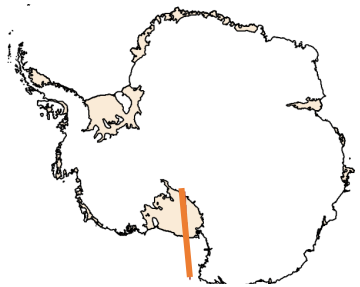

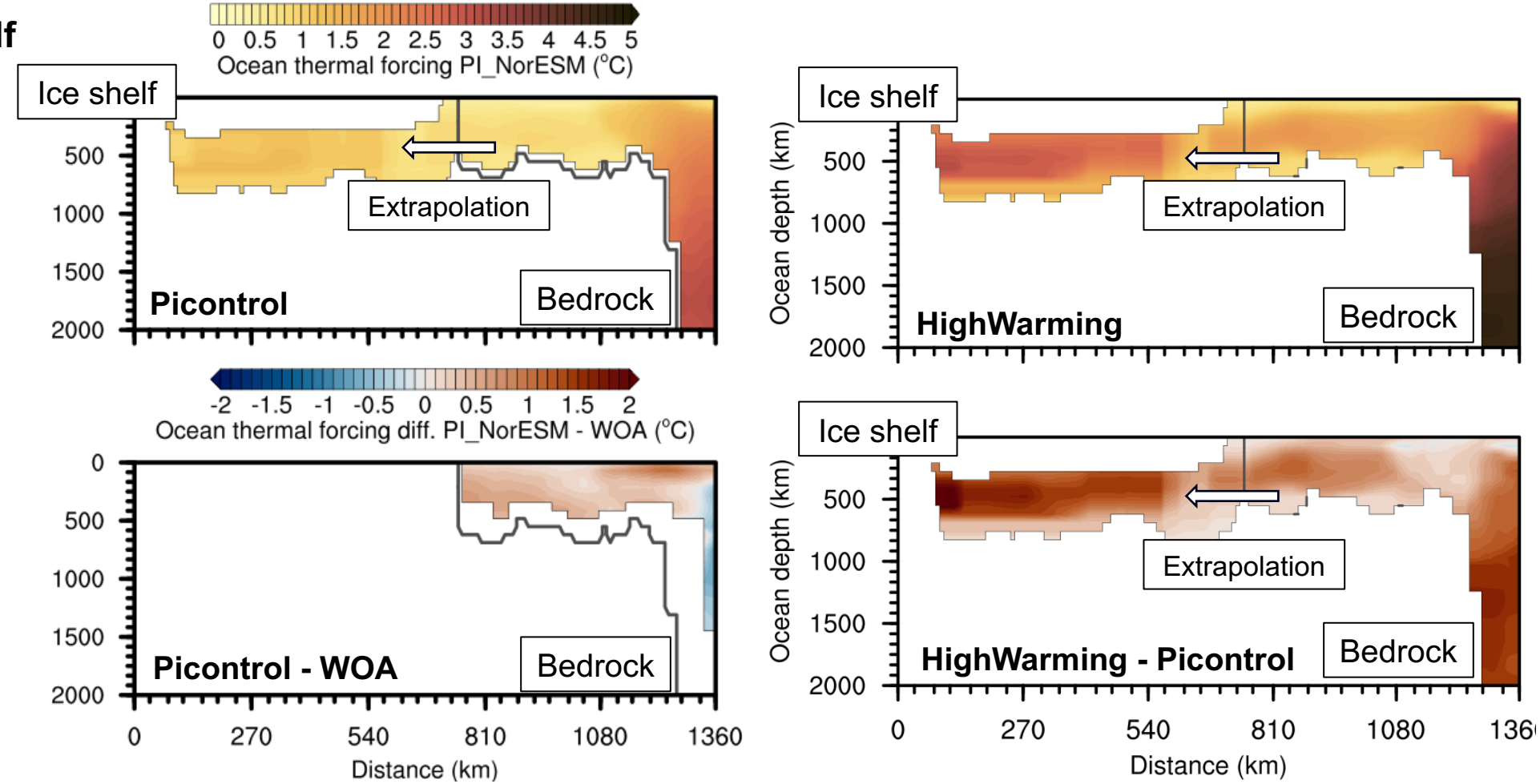

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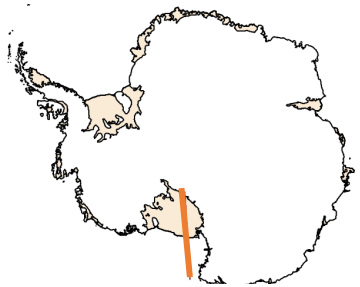

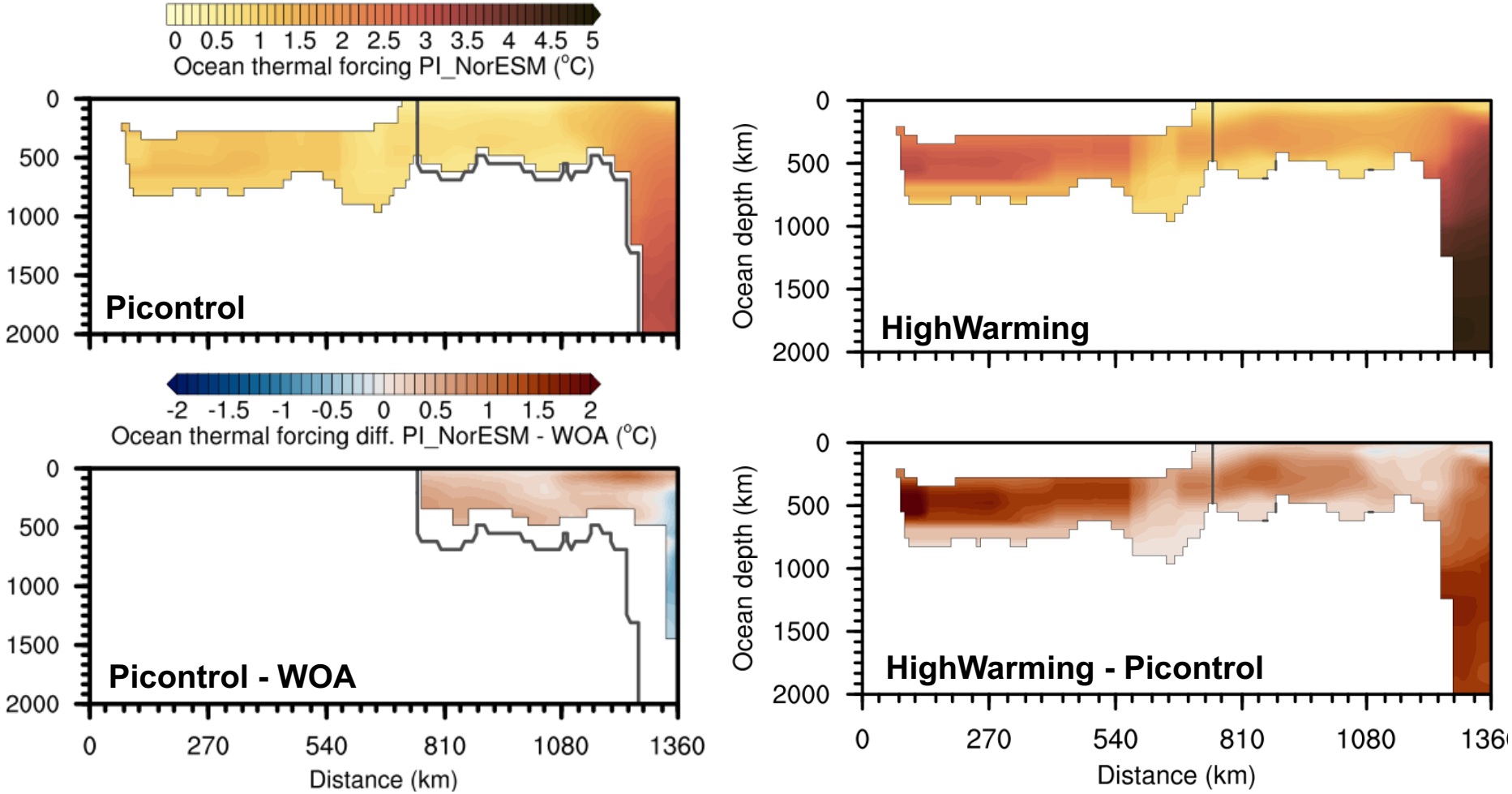

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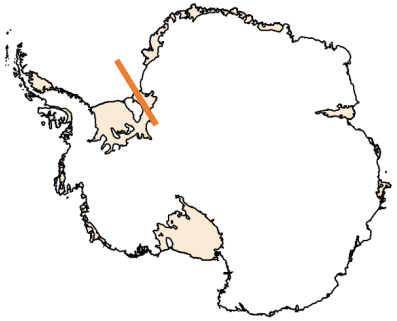

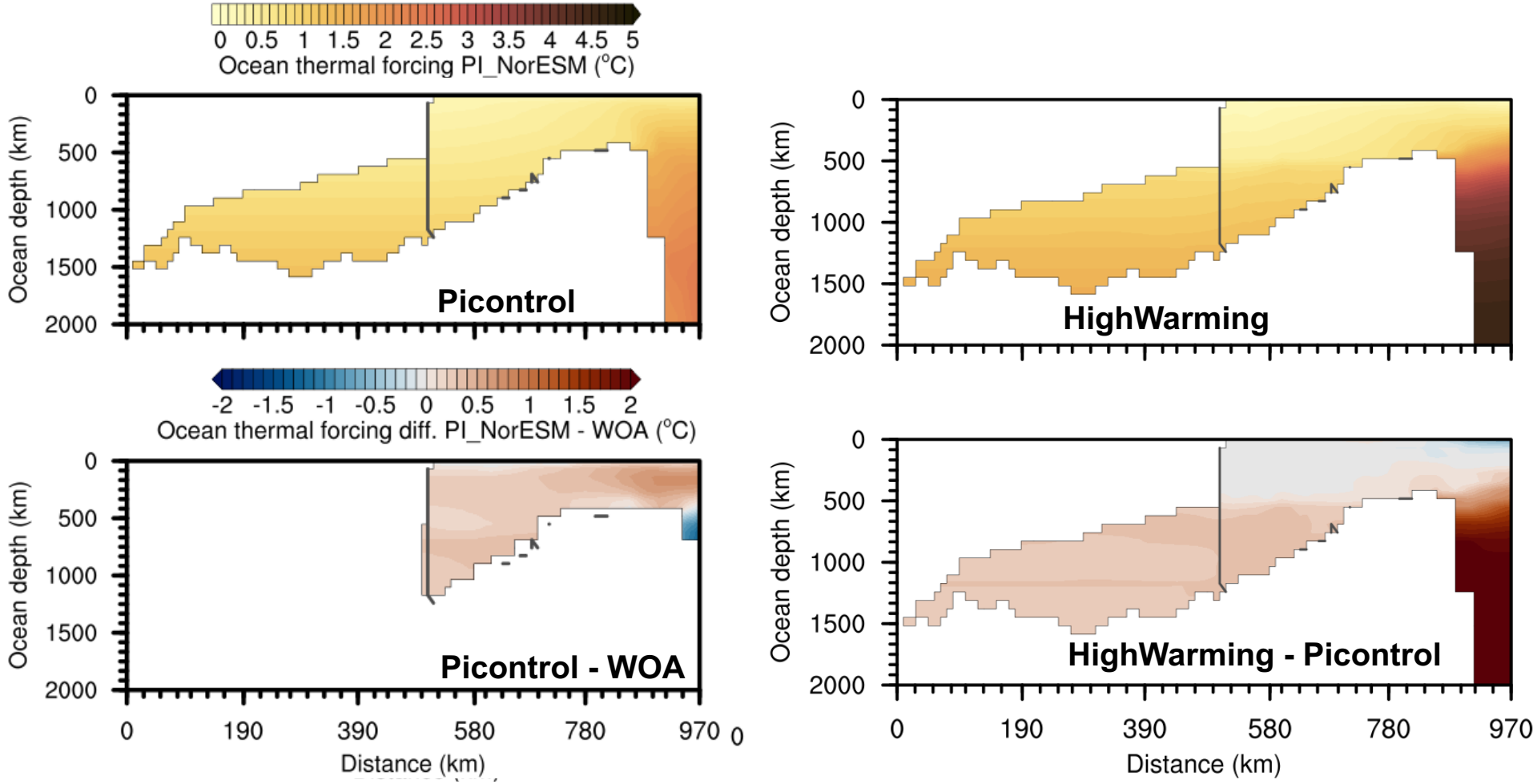

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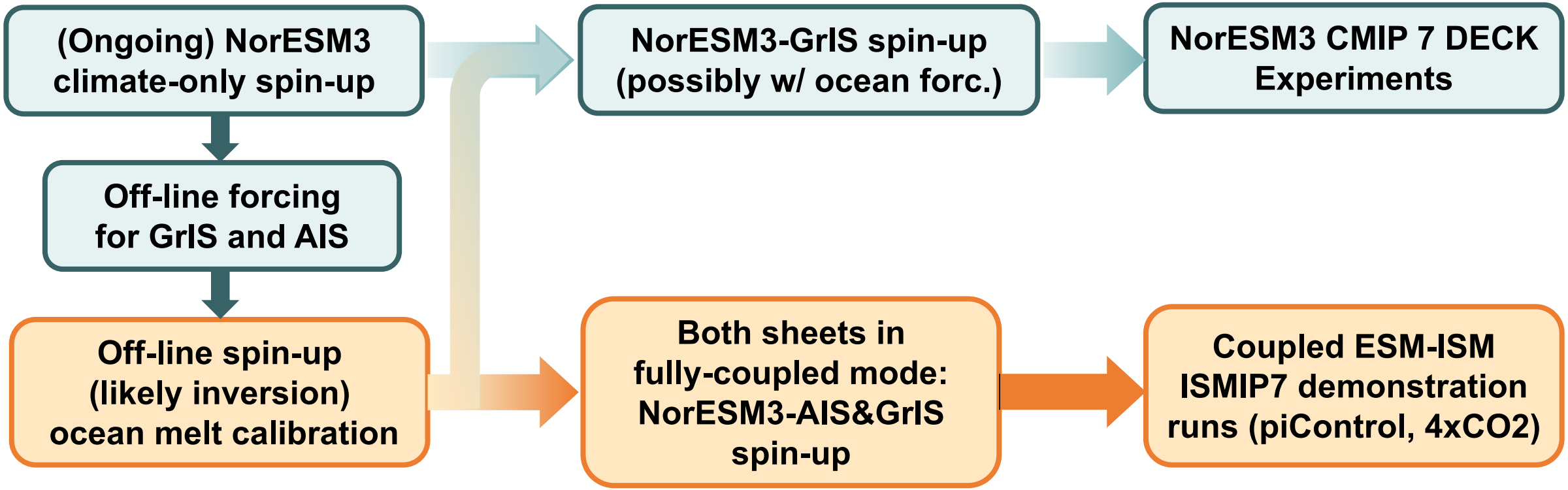

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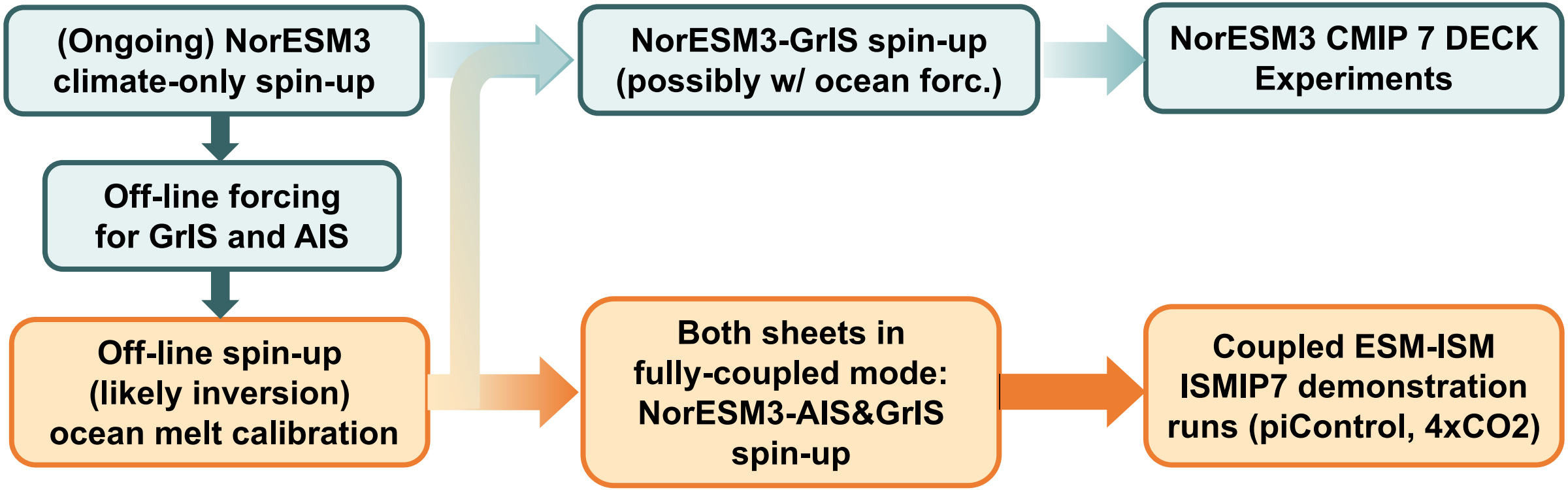

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