Southern Ocean freshwater hosing experiments:
Preliminary results from NorESM simulations with a coupled Greenland Ice Sheet

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What is a hosing experiment?

- Fresh water from melting ice sheets is added to the ocean directly, as a forcing in an ocean model or Earth system model.

- Represents increasing ice sheet melt, without having to model the ice sheet itself.

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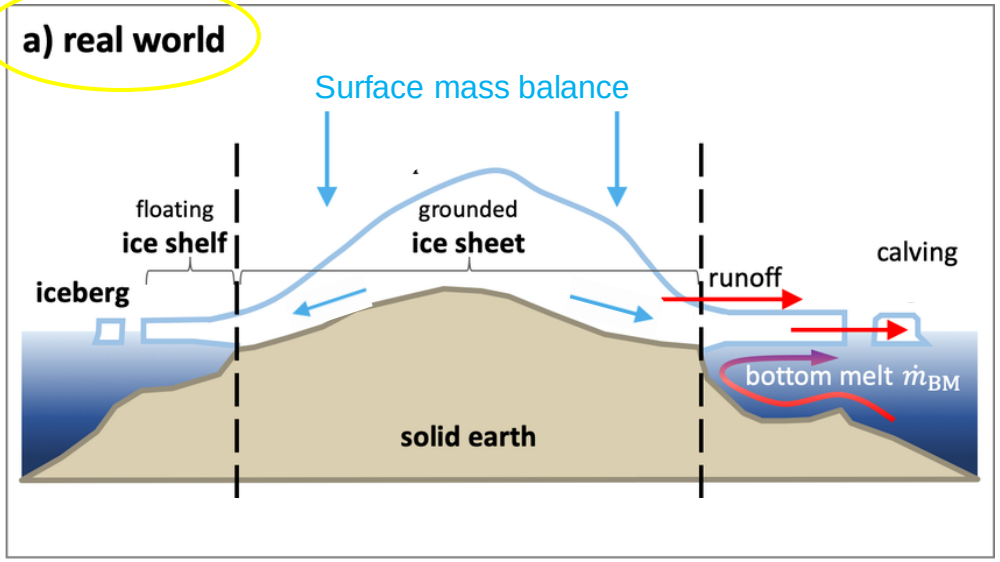
Real-world and ESM-world ice sheets



Snow accumulates where mass balance is positive

Ice flows towards margin - time scale is many millennia

Freshwater flux driven by both atmosphere and ocean

Modified from Martin et al. 2023 (10.5194/gmd-16-7289-2023)

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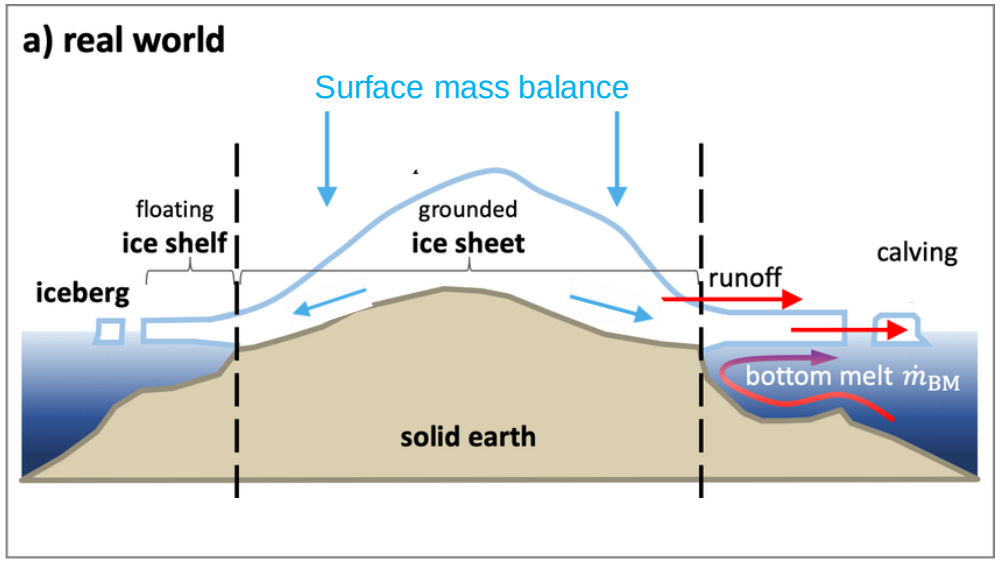

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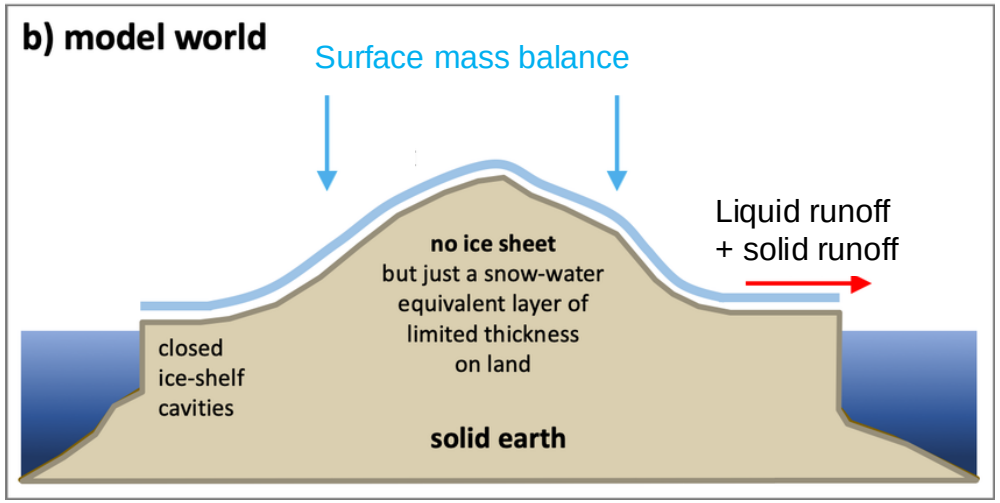

Ice sheet is a “snow-covered mountain”.

Excess snow transferred directly to ocean anywhere that snow height exceeds threshold (e.g. 10 m).

Forced equilibrium.

Freshwater flux driven only by atmosphere.

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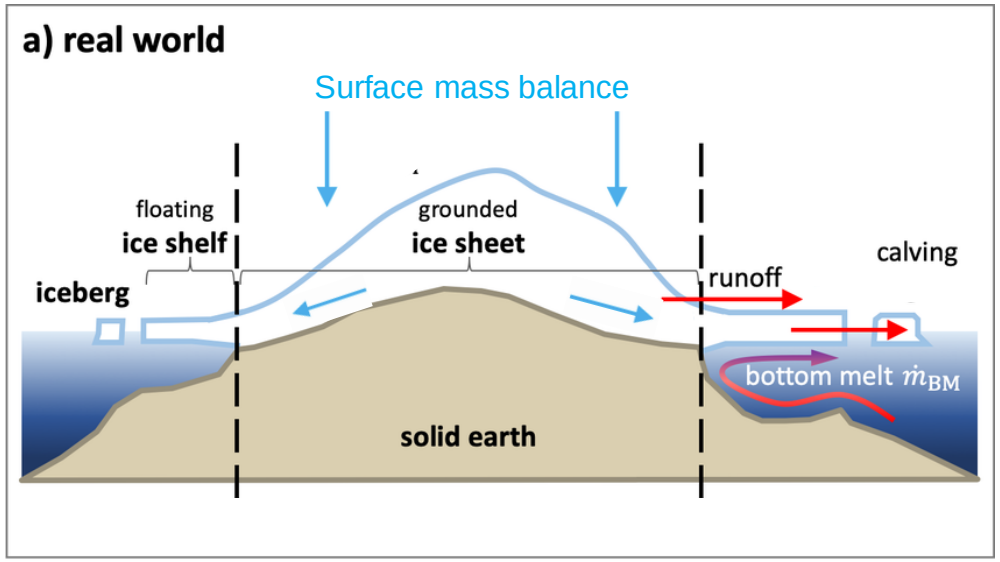
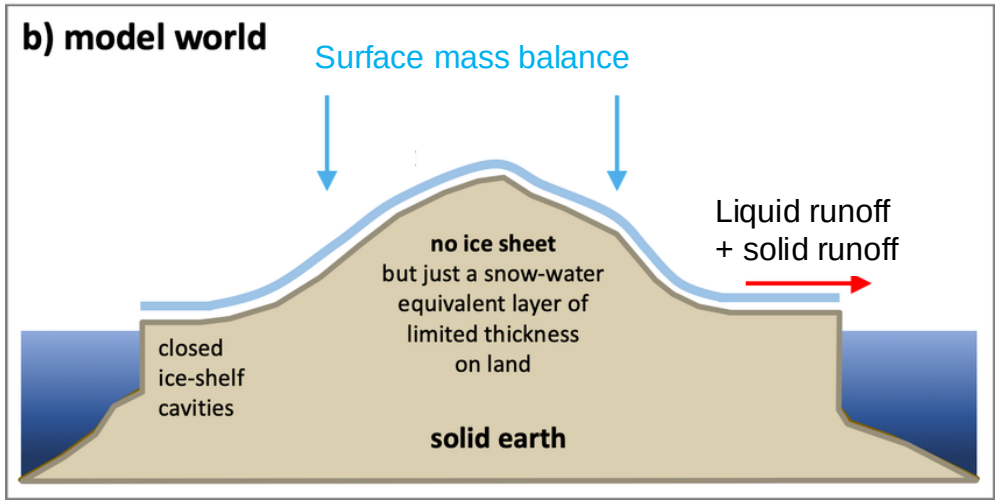


<u>In our NorESM experiments:</u>

- **Greenland is a "real-world" ice sheet.**
- CISM ice sheet model coupled within NorESM.



- **Antarctica is still an "ESM-world " ice sheet.**
- Freshwater fluxes can be modified by applying additional forcing to the ocean model (BLOM).
- ***Modified fluxes can represent ice mass imbalance.***

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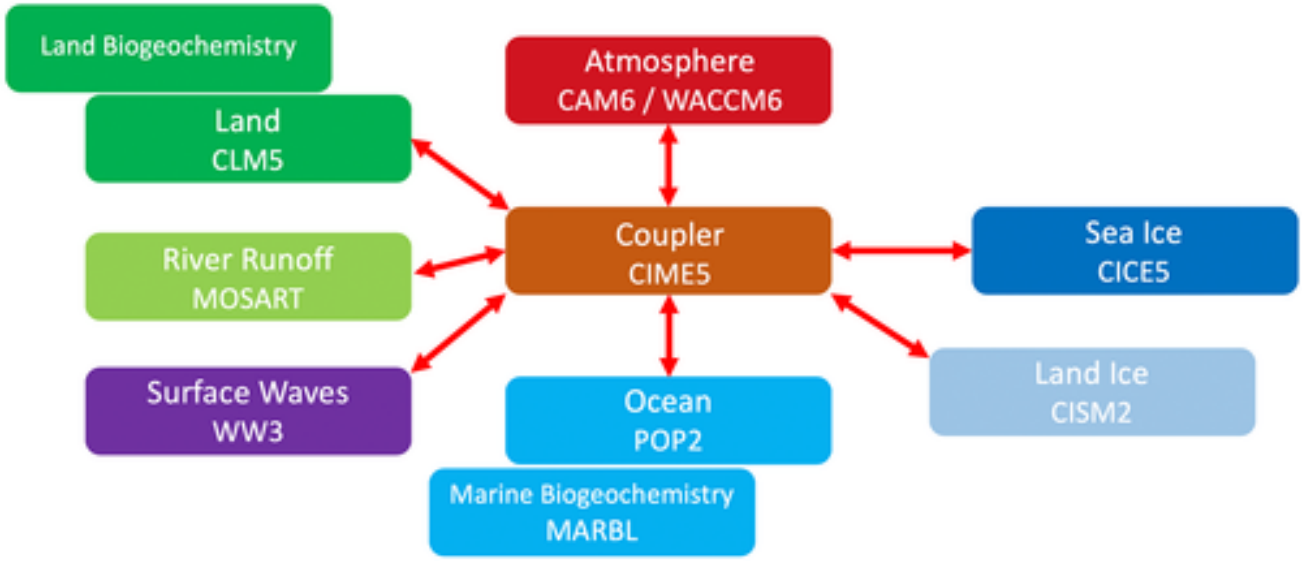
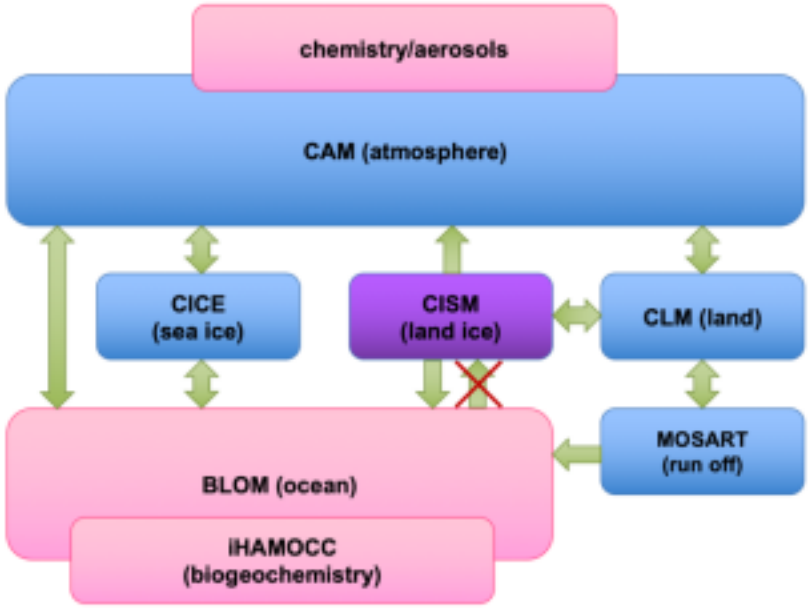
NorESM Southern Ocean hosing experiments

NorESM2 : many similarities with CESM2



CESM2 Danabasoglu et al. 2020



NorESM2 Goelzer et al. 2025 in rev.
Blue boxes same as CESM2

NorESM Southern Ocean hosing experiments

- Conceptualised experiments adding freshwater to Antarctic coastal grid cells
- Follows SOFIA protocol for now (*Southern Ocean Freshwater Input from Antarctica*)
- Total 0.1 Sv distributed evenly to surface of coastal grid cells (0.1 Sv = 3150 Gt/yr)

For comparison: current fw flux from Antarctica is approx 2000 Gt/yr

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SOFIA protocol : Martin et al. 2023 (10.5194/gmd-16-7289-2023)

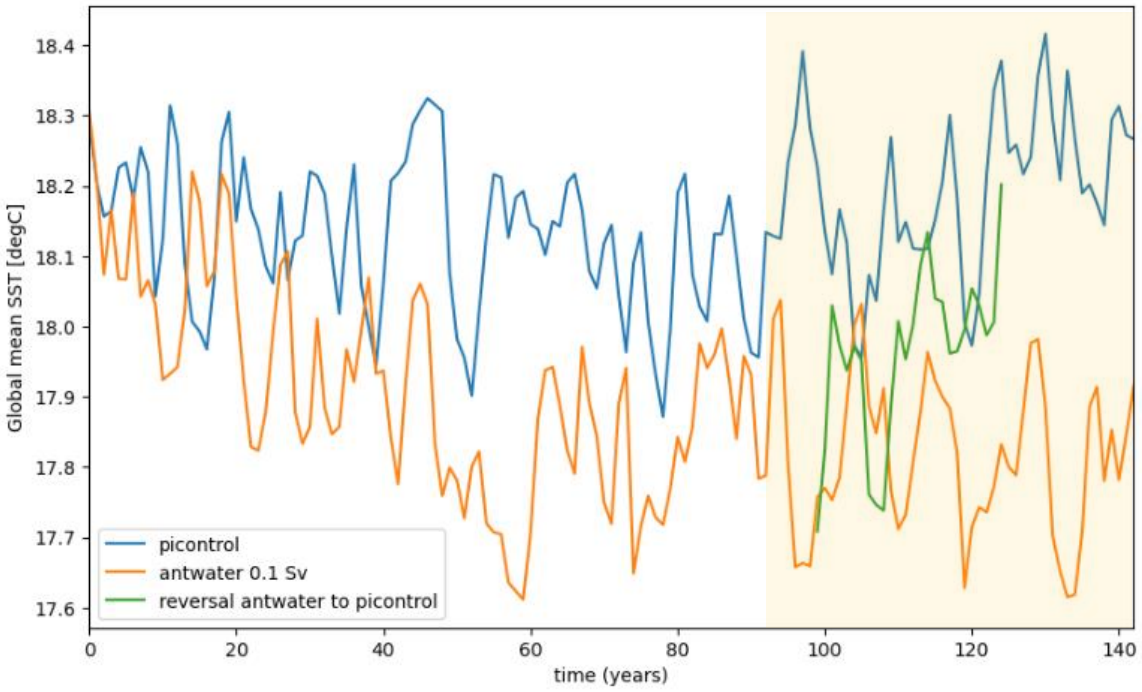
Name	FW perturbation (Sv)	Branch year	Time span (year)	Other forcing
Tier 1				
piControl	None	N/A	≥ 100	Fixed pre-industrial
antwater	Fixed 0.1	Model year	≥ 100	Fixed pre-industrial
Tier 2				
hist-antwater-70-01	Increasing by 0.1 ($\times 10^{-3}$ Sv yr^{-1})	1970	1970–2020	Historical
hist-antwater-70-03	Increasing by 0.3 ($\times 10^{-3}$ Sv yr^{-1})	1970	1970–2020	Historical
hist-antwater-70-05	Increasing by 0.5 ($\times 10^{-3}$ Sv yr^{-1})	1970	1970–2020	Historical
hist-antwater-92-11	Increasing by 1.1 ($\times 10^{-3}$ Sv yr^{-1})	1992	1992–2020	Historical
ssp126-ismip6-water	Fixed 0.015	2015	2015–2100	SSP126 scenario
ssp585-ismip6-water	Increasing nonlinearly; maximum 0.196	2015	2015–2100	SSP585 scenario

Have run 2 ensemble members for Tier 1

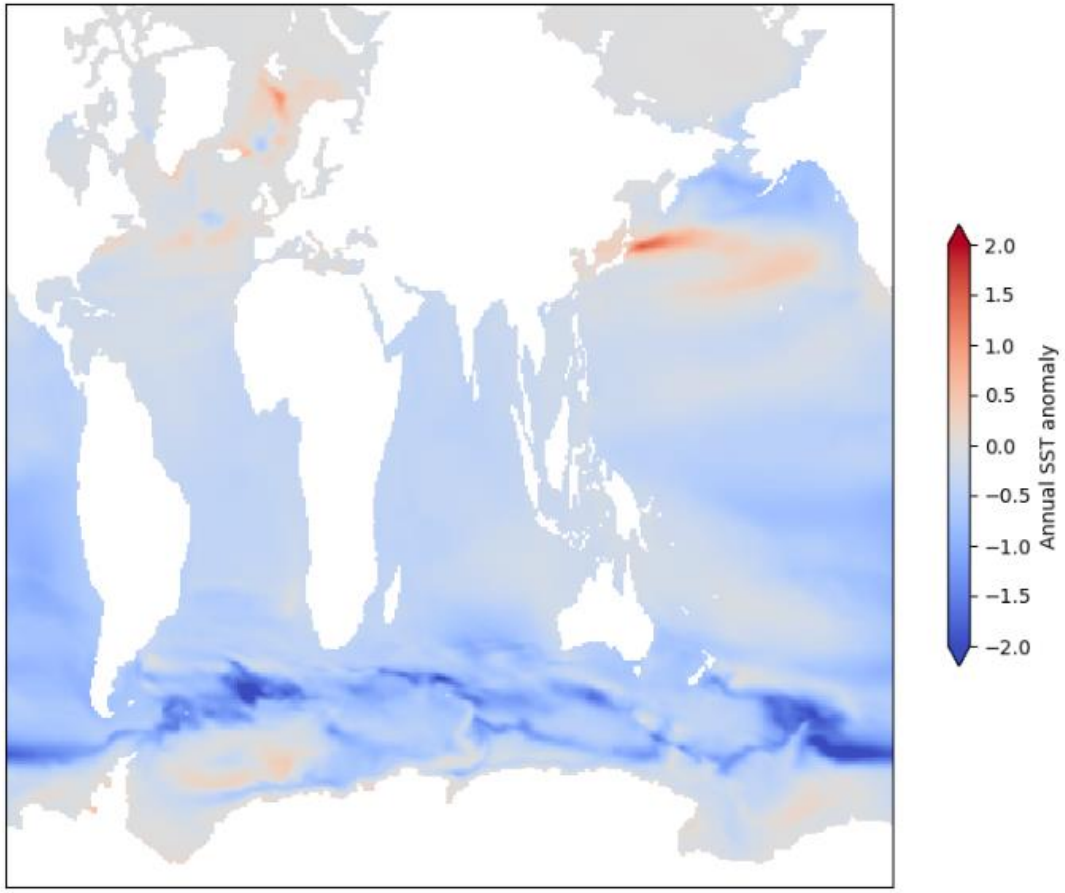
So far just historical for Tier 2

NorESM Southern Ocean hosing experiments

- Global mean SST shows weak negative anomaly in antwater experiment
- Appears to be reversible, if hosing turned off after 100 years.



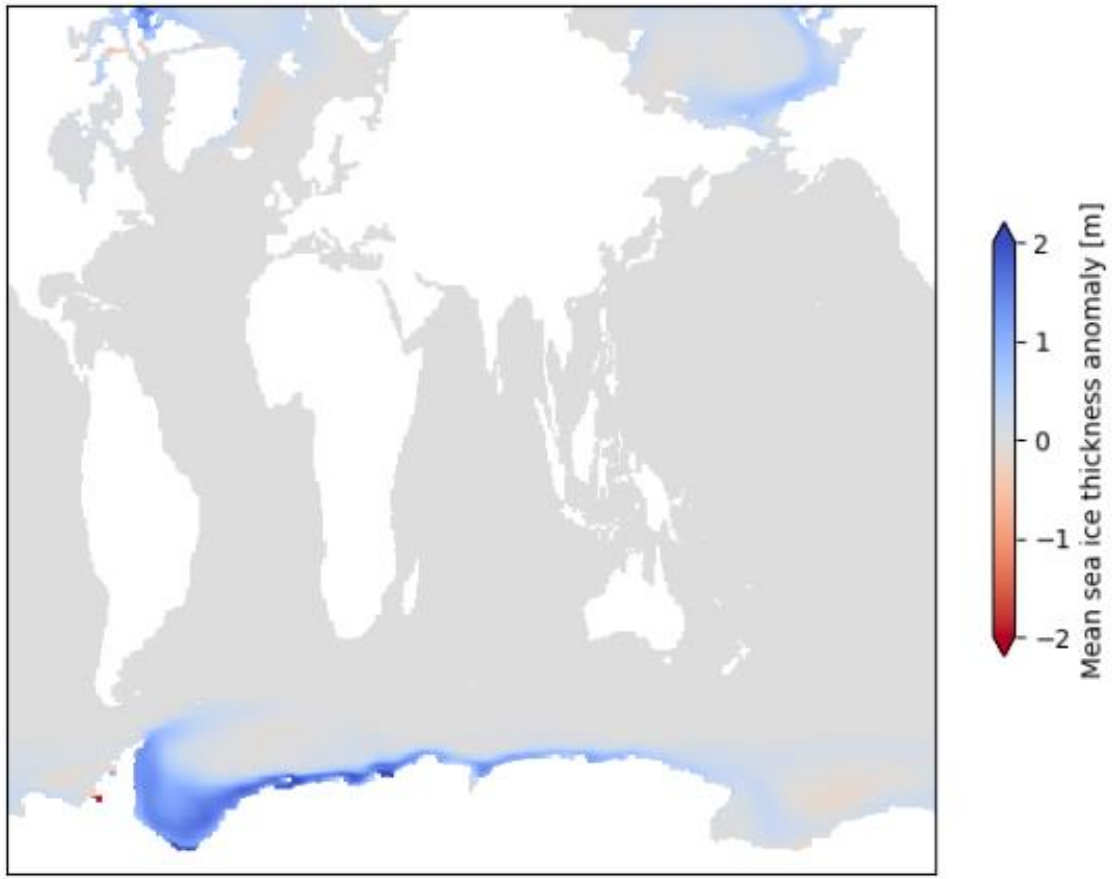
antwater mean SST anomaly



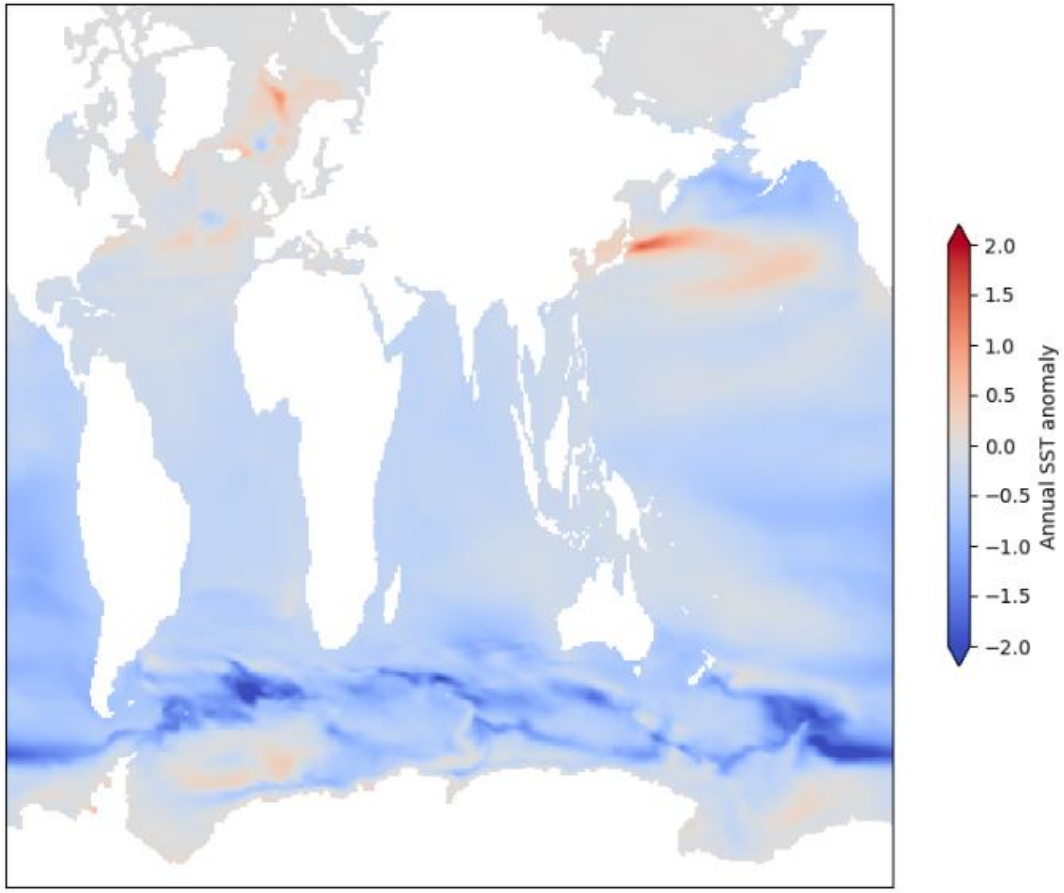
NorESM Southern Ocean hosing experiments

- Several regions with thicker sea-ice, including in Arctic.

antwater mean sea-ice thickness anomaly



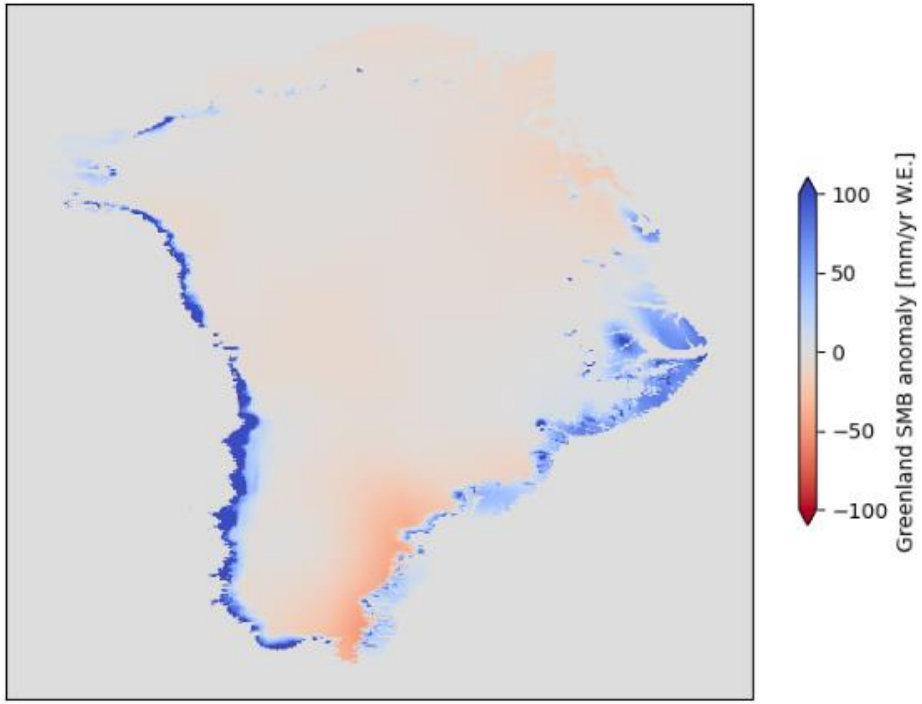
antwater mean SST anomaly



NorESM Southern Ocean hosing experiments

Greenland Ice Sheet surface mass balance
- negative anomaly in interior (precip-driven?)
- positive anomaly around margins
- Overall, slightly less runoff into North Atlantic.

antwater GrIS surface mass balance anomaly



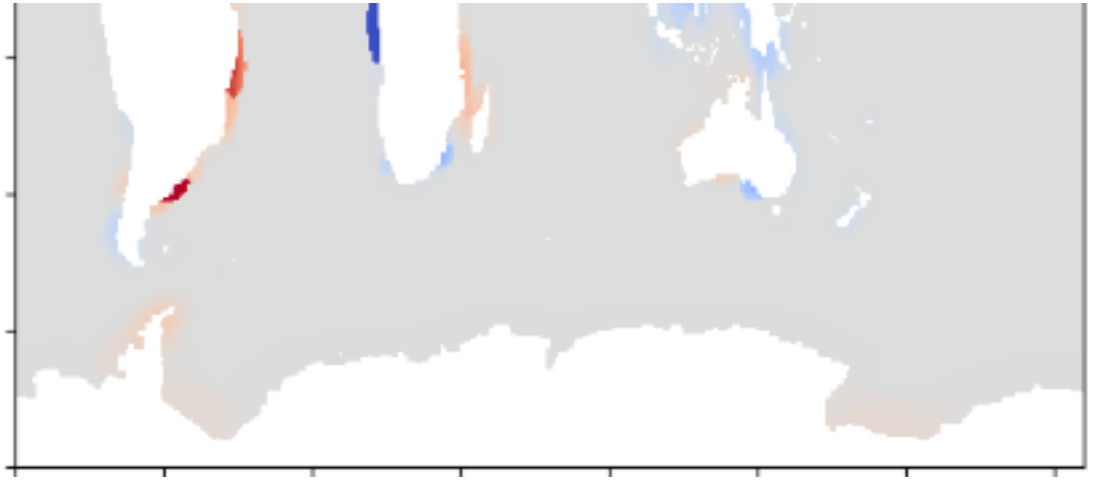
NorESM Southern Ocean hosing experiments

Antarctic Ice Sheet:

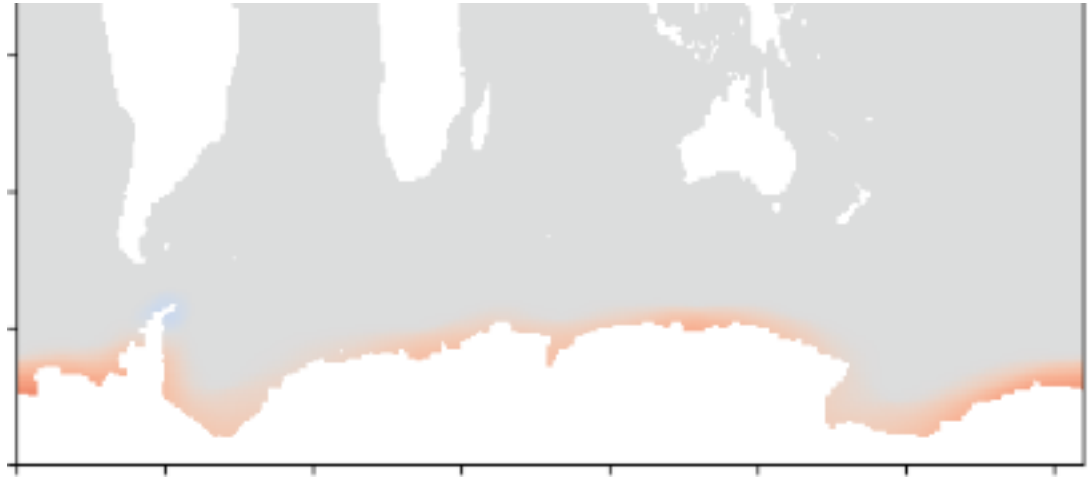
- Less precip over Antarctica
- Smaller liquid & solid freshwater fluxes into Southern Ocean

- Reduction in liquid runoff AIS →S.Ocean 0.001 Sv
- Reduction in solid ice discharge AIS → S.Ocean 0.007 Sv

Compare with 0.1 Sv freshwater forcing



Liquid runoff received by ocean (anomaly)
Red-blue scale +/- 1e-5 kg/m^2/s



Solid runoff received by ocean (anomaly)

NorESM Southern Ocean hosing experiments

Next steps / future plans

- Further analysis of *antwater* runs, significance testing, mechanistic understanding, …
- Comparison with standard NorESM2 SOFIA experiments (Morven /Tore – Tromsø Uni)
- Realistic freshwater scenario (probably Coulon et al. 2024)
- If possible some tier 2 SOFIA experiments.

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