

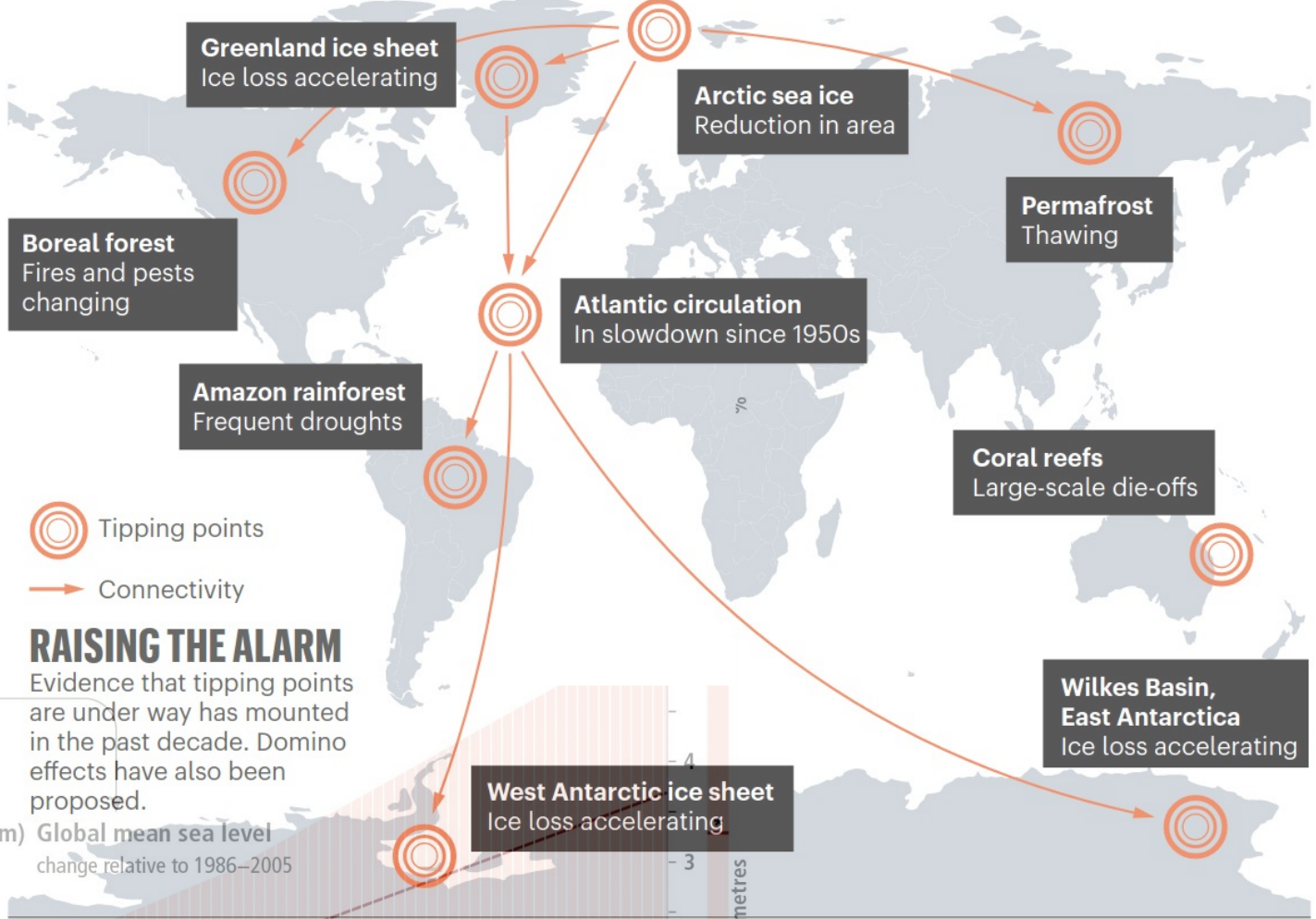
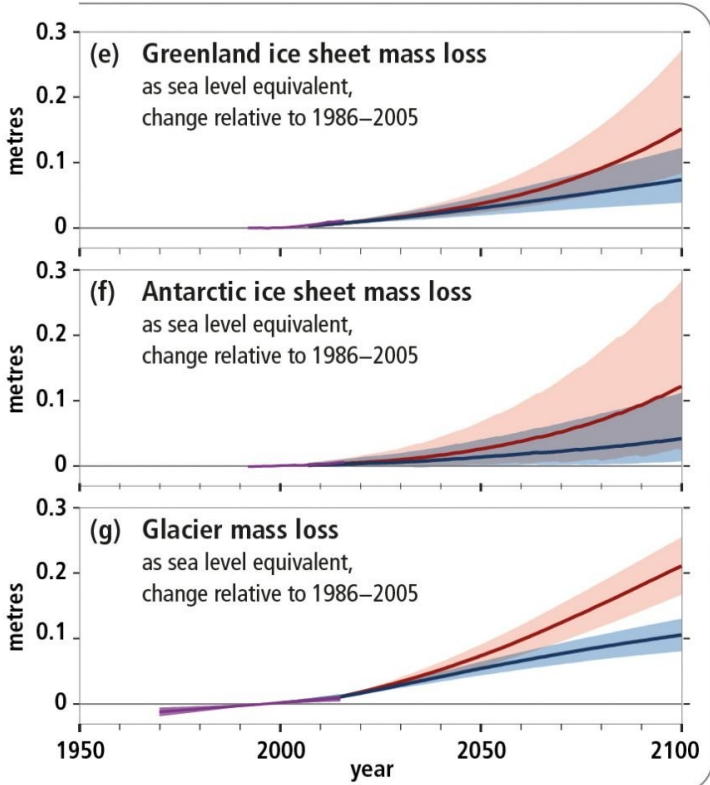
Coupling the U.K. Earth System Model to a Dynamic Model of the Antarctic Ice Sheet

Robin S. Smith, Antony Siahahan, Pierre Mathiot, Victoria Lee, Stephen Cornford, Tony Payne, Adrian Jenkins, Paul Holland, Jonathan Gregory and the UKESM team

Smith et al., *J. Adv. Modeling Earth Systems*, 2021 doi.org/10.1029/2021MS002520

Siahahan et al., *The Cryosphere*, 2022 doi.org/10.5194/tc-2021-371

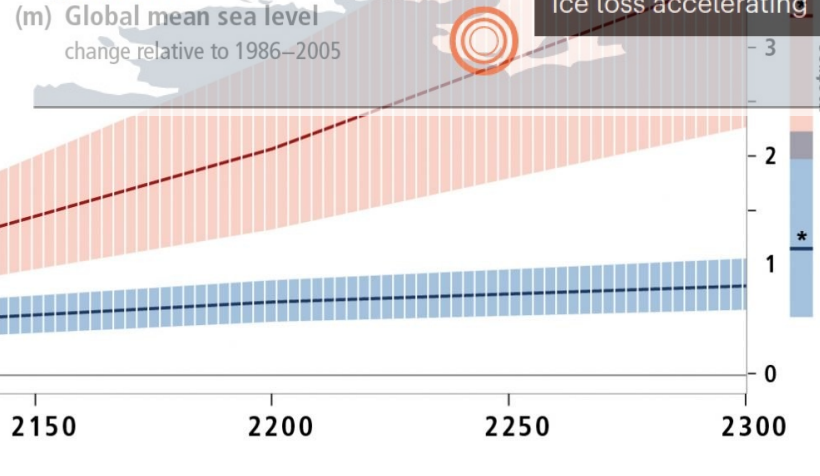
Why would you want to model icesheets in an ESM?



RAISING THE ALARM

Evidence that tipping points are under way has mounted in the past decade. Domino effects have also been proposed.

primary drivers



Challenges

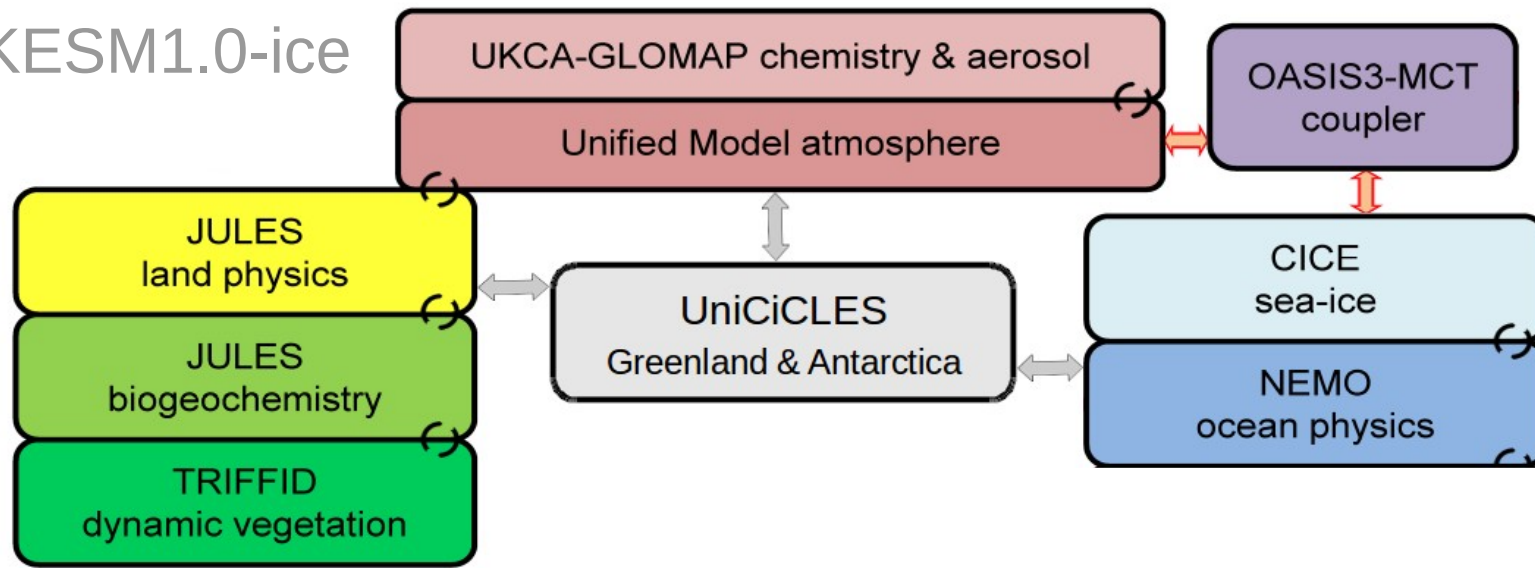


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- There's a significant lack of observations around climate – ice sheet interactions
- We have difficulty making projections with the specialised ocean .OR. ice sheet models we do have
- Global ESMs:
 - insufficient resolution to explicitly model key processes in ocean and ice (and land/atmosphere)
 - significant computational expense => cannot be integrated over some timescales of interest
 - structurally ill-suited to moving solid domain boundaries
 - haven't really been developed with a strong focus on polar climate
- We have approaches to *mitigate* all of these problems, but...
- ...a global ESM with interactive ice sheets is not the best tool for projecting ice loss, sea-level rise or global warming. Yet. However:
 - They are complimentary to other approaches, and may be the only way of getting a mechanistic understanding of how some regional process interactions can produce global effects and vice-versa
 - This area of Earth System modelling is immature, but it's really important, and it's not going to improve unless we work on it.

UKESM1.0-ice



~100km resolution, 85 level atmosphere

Multilayer snow scheme with melt percolation and refreezing

Greenland dynamics with up to 1.2km resolution, Antarctica at 2km

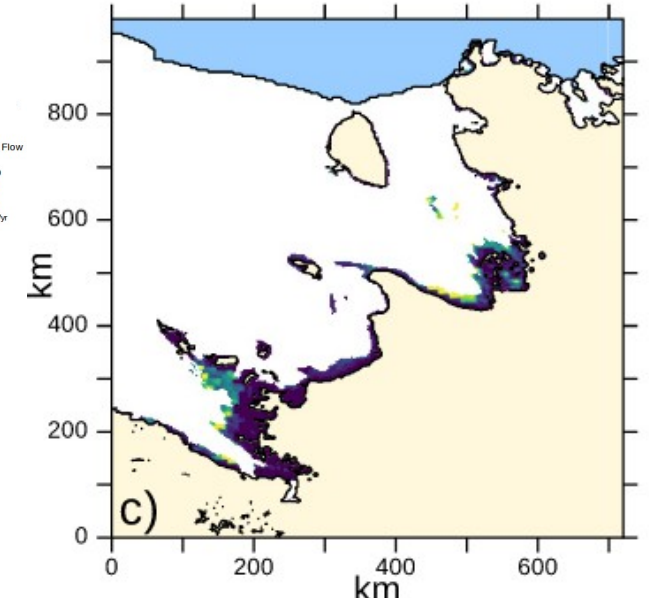
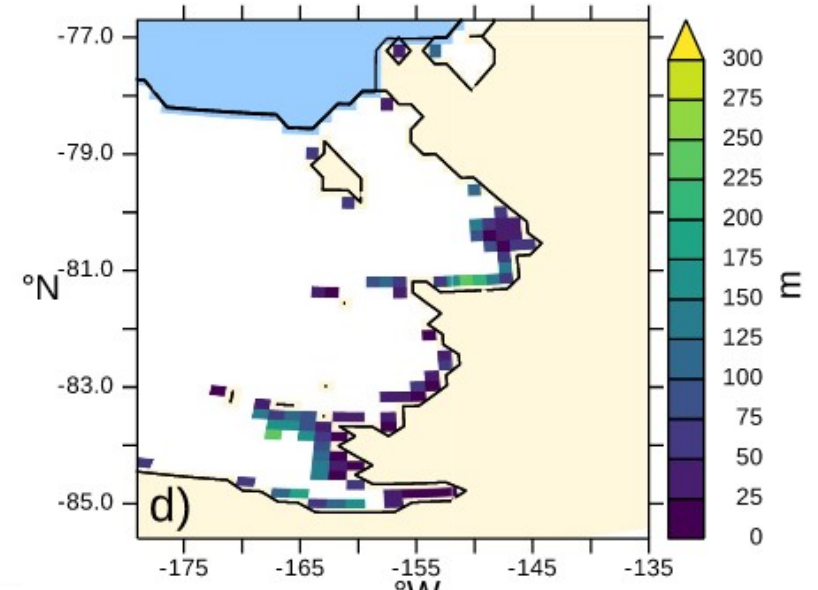
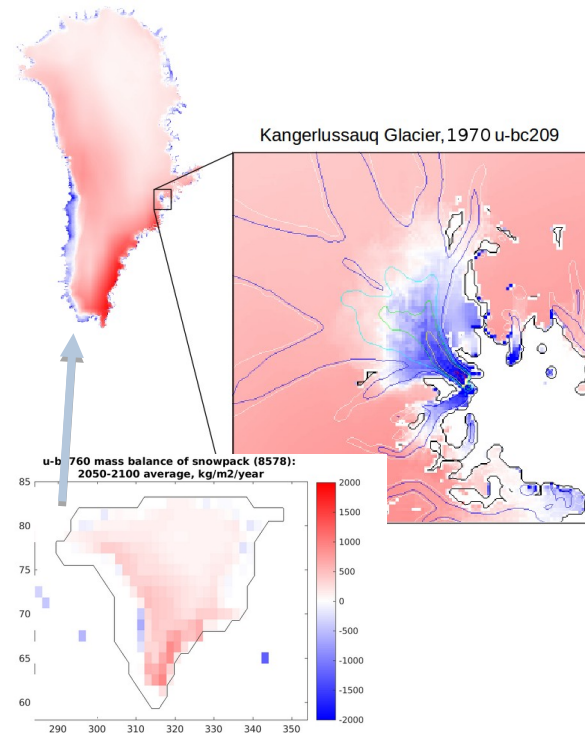
Explicit Lagrangian icebergs

Ocean underneath floating Antarctic ice shelves

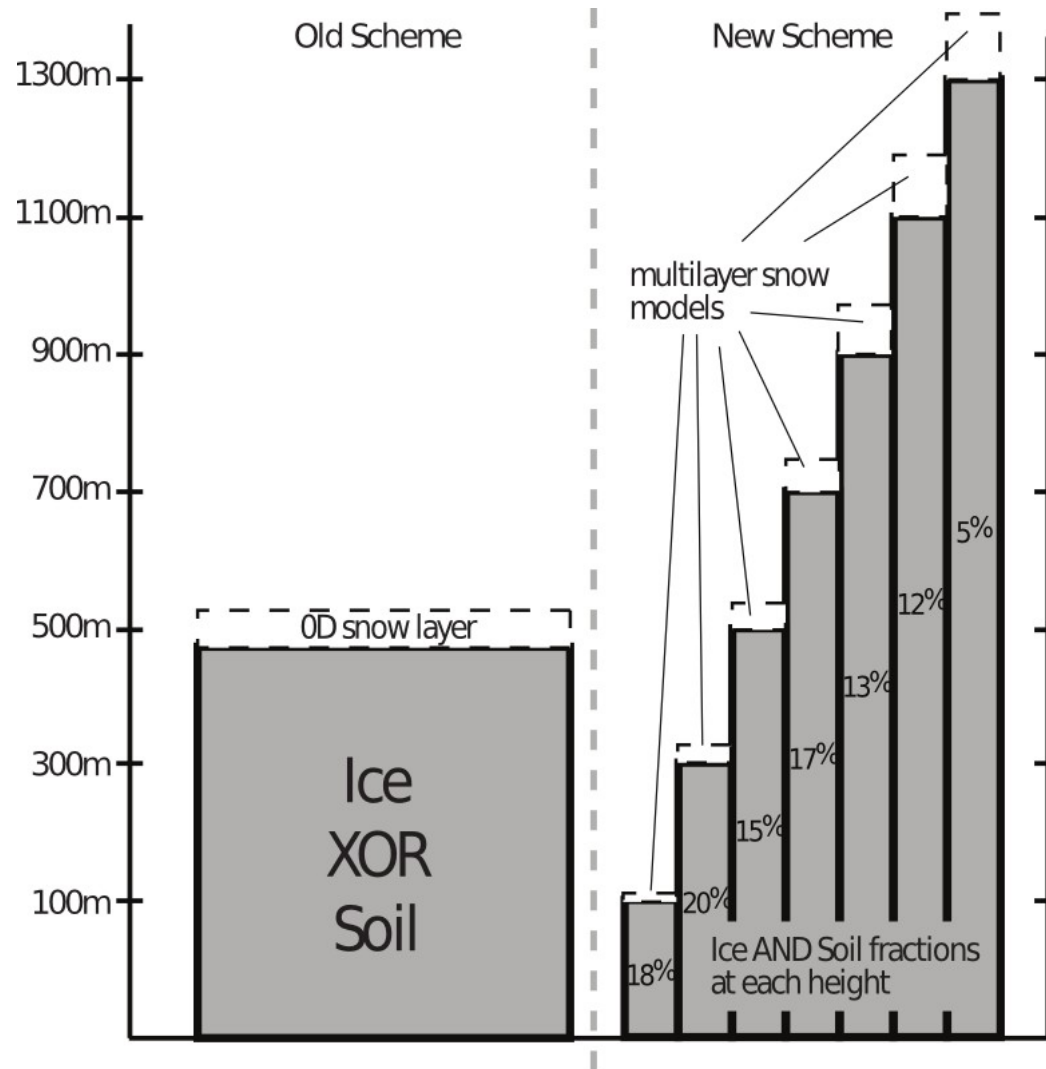
Surface Antarctic shelf calving front is fixed, but grounding line can retreat

No marine forcing of Greenland outlet glaciers

This was *not* used for CMIP6



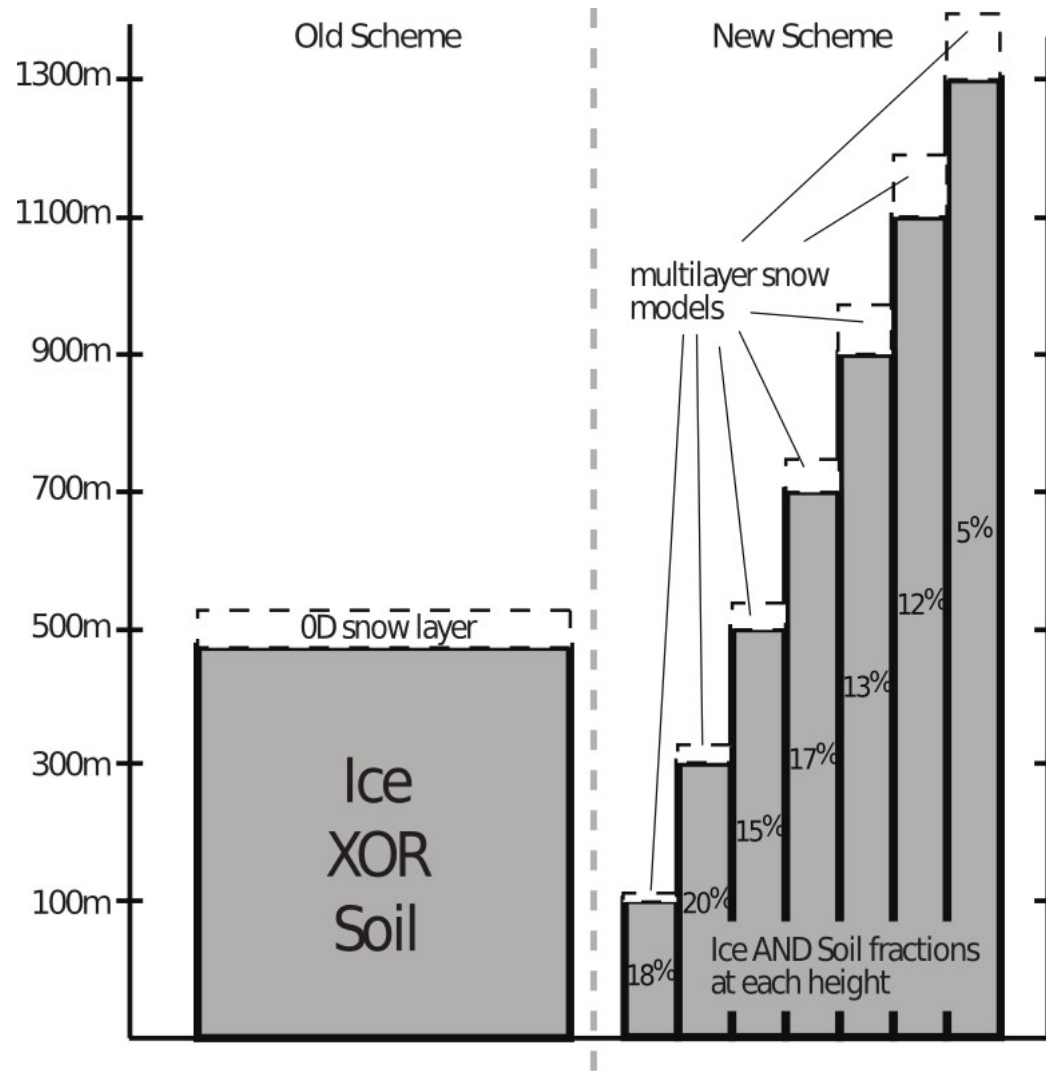
Dealing with spatial resolution



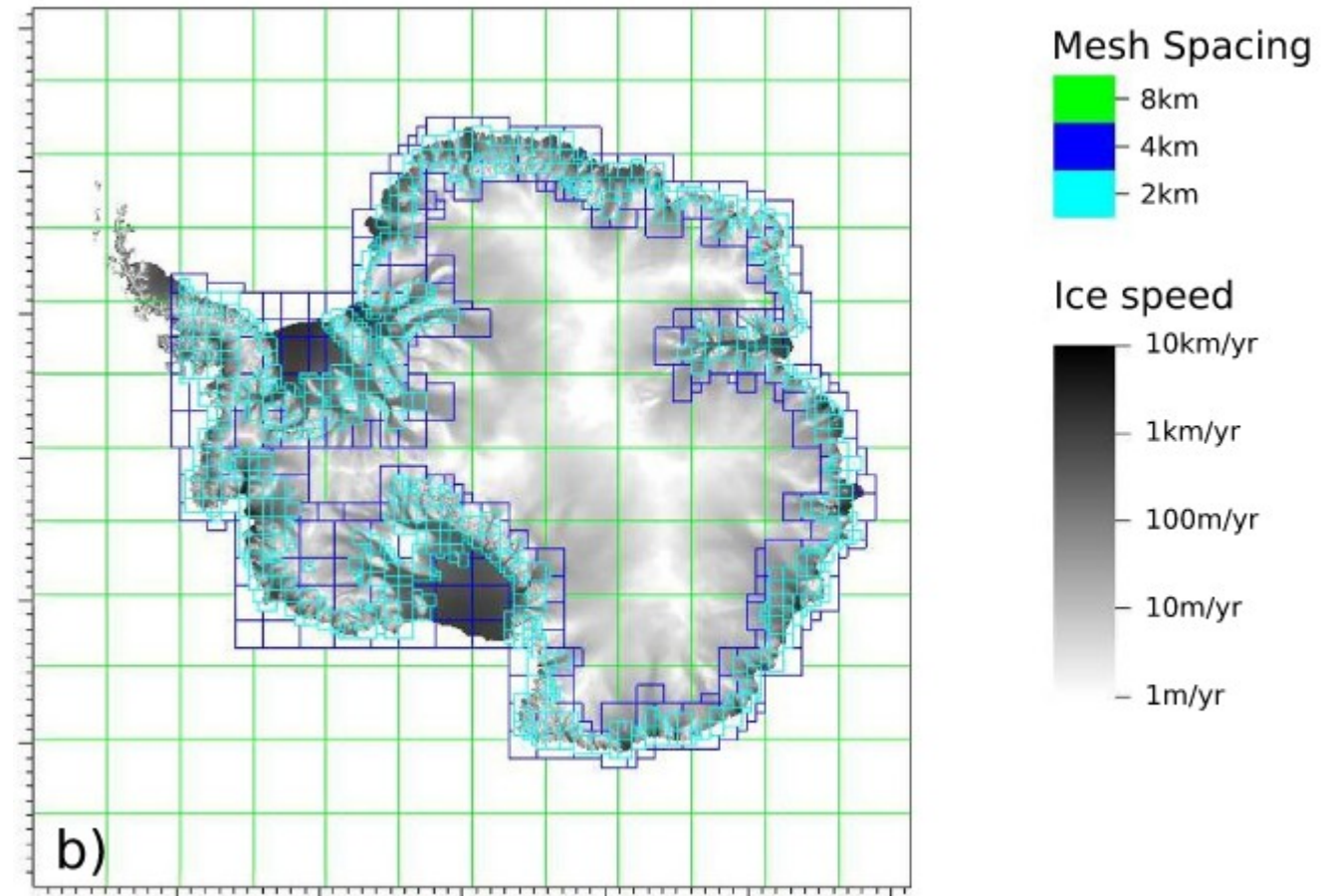
Icesheet surface modelling:

- Introduce a multi-layer snow/firn model for icesheet SMB
- Use subgrid-scale surface tiles to represent detail of icesheet height and extent
- Use in-model downscaling of atmospheric conditions and surface exchange
- Tune representation of polar climate

Dealing with spatial resolution



BISICLES adaptive mesh refinement

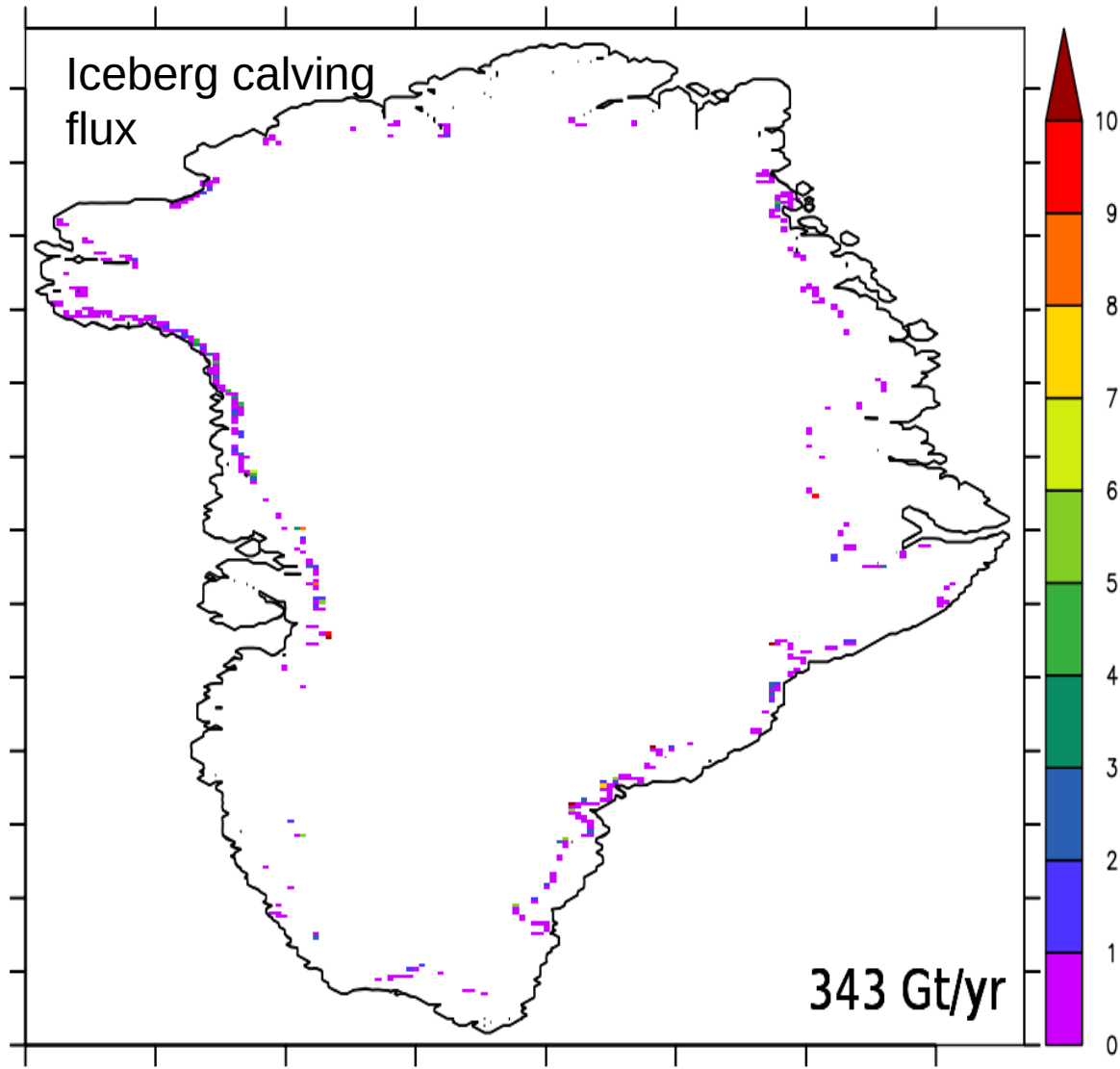


Ocean coupling in the ESM

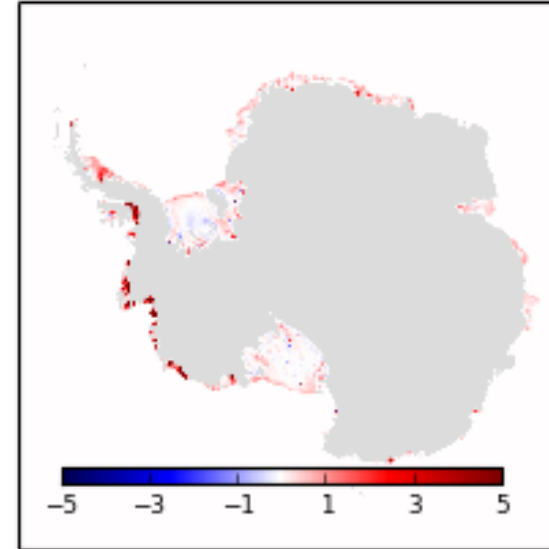


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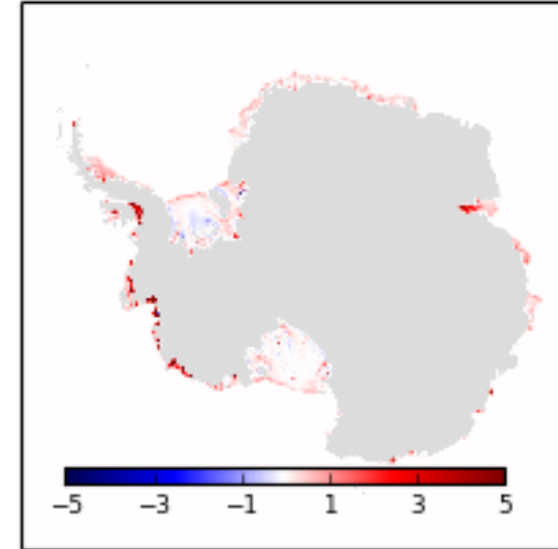
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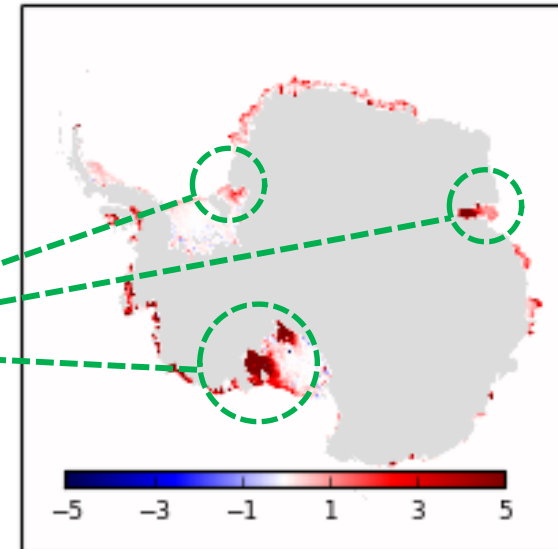
(a) 2020-2030 ALL-EM melt rate (m/yr)



(b) 2090-2100 SSP1-EM melt rate (m/yr)



(d) 2095-2100 SSP5-EM melt rate (m/yr)

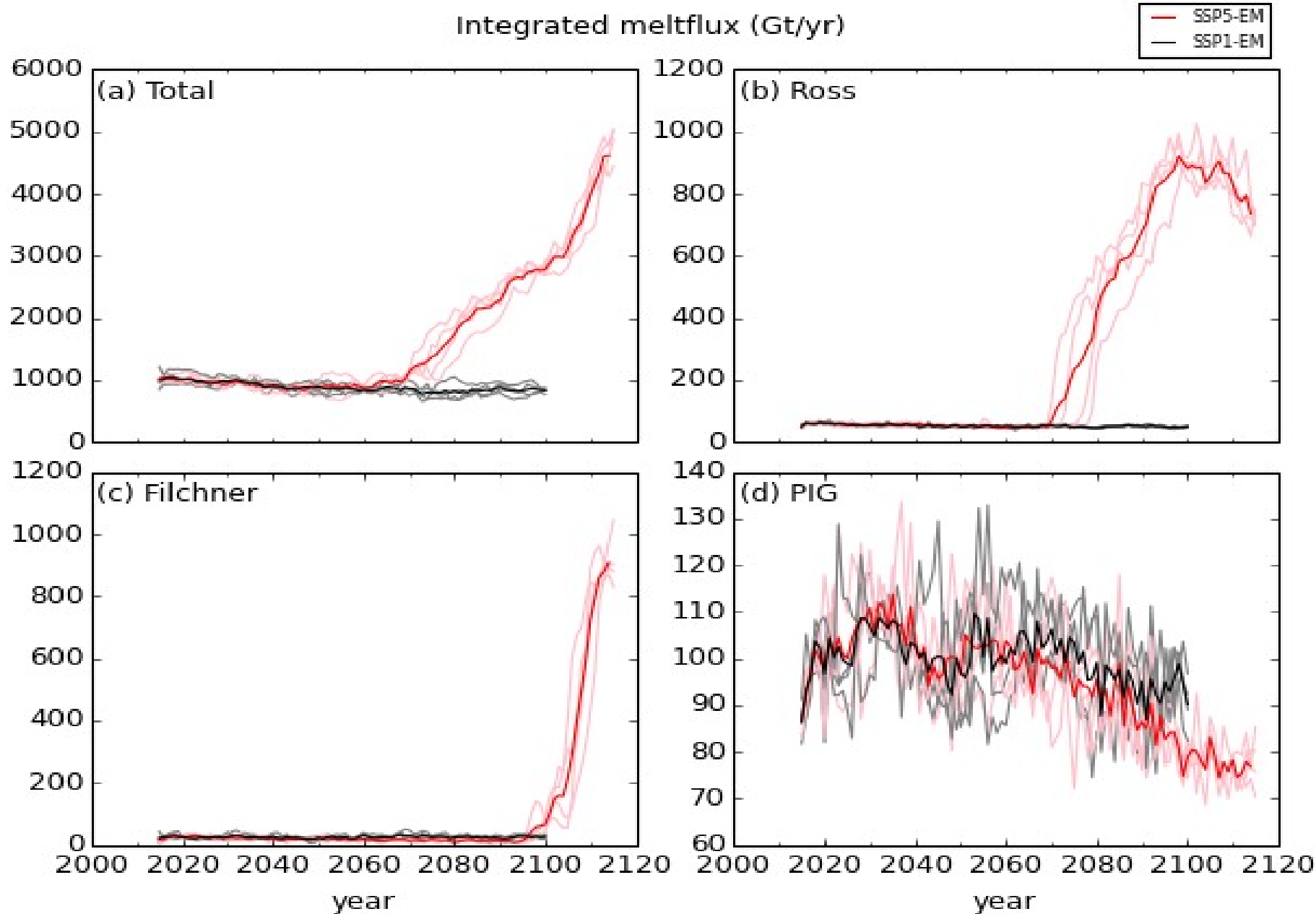


Melt under resolved ice shelves

Incursions of warm water

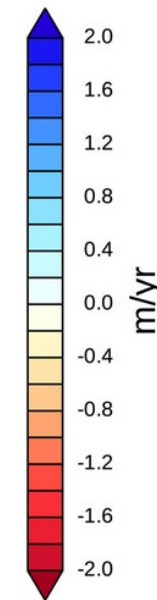
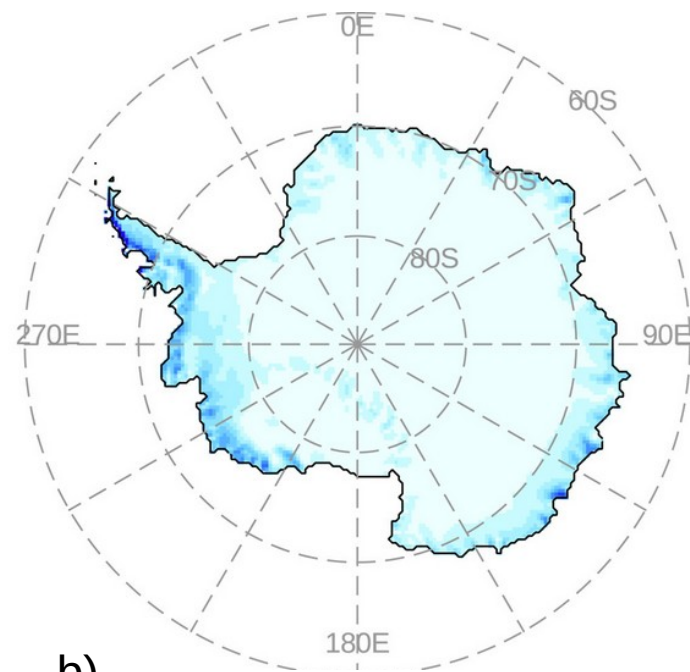
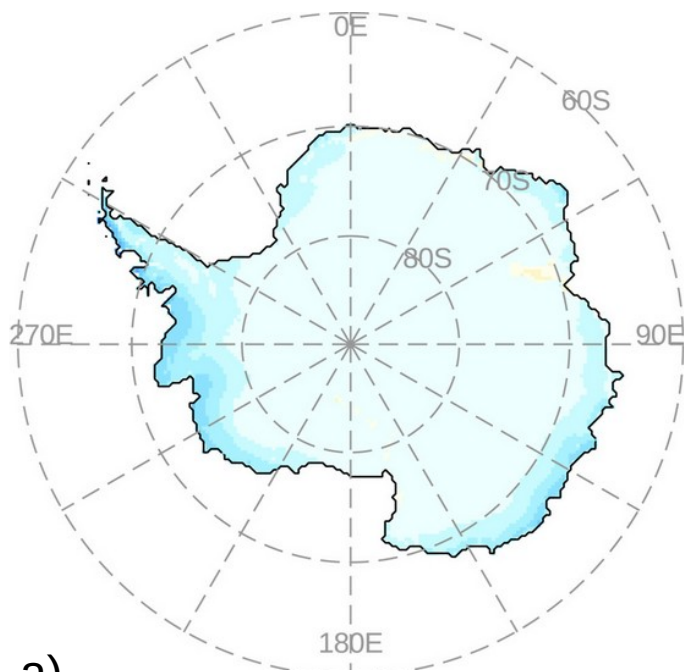
Siahaan et al., *The Cryosphere*, 2022
doi.org/10.5194/tc-2021-371

“Projected” NEMO shelf melting



Siahaan et al., *The Cryosphere*, 2022
doi.org/10.5194/tc-2021-371

AIS SMB 1970-1999

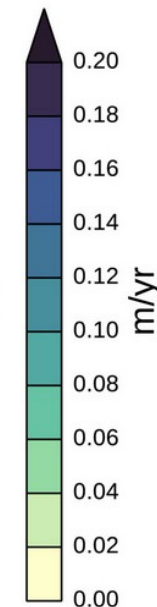
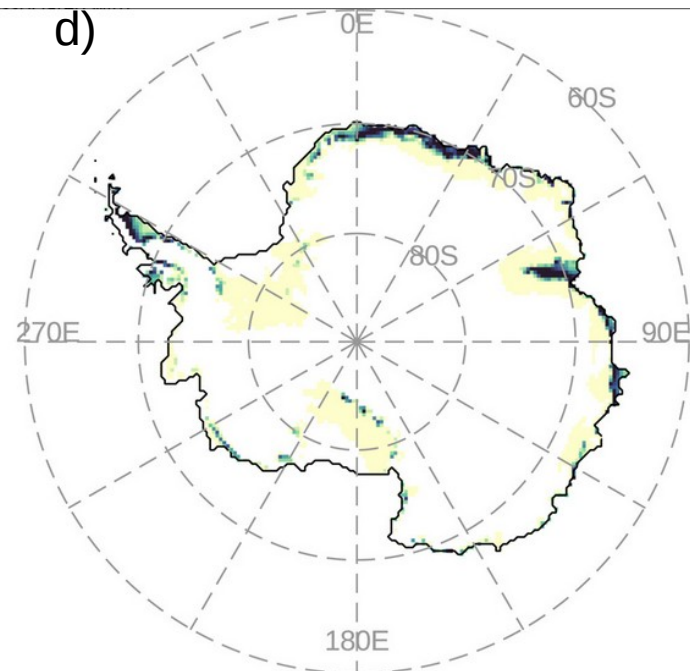
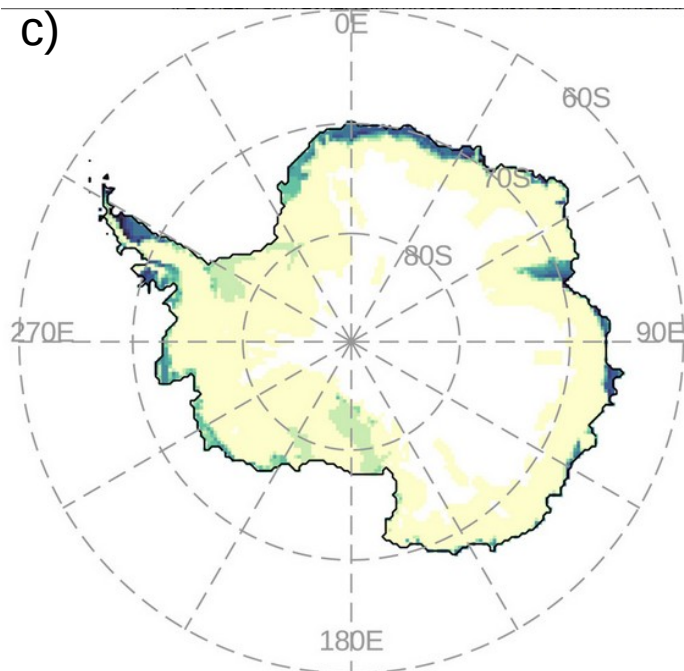


a)

b)

c)

d)



a) UKESM

b) MAR_ERA-I (2011)

c) surface melt

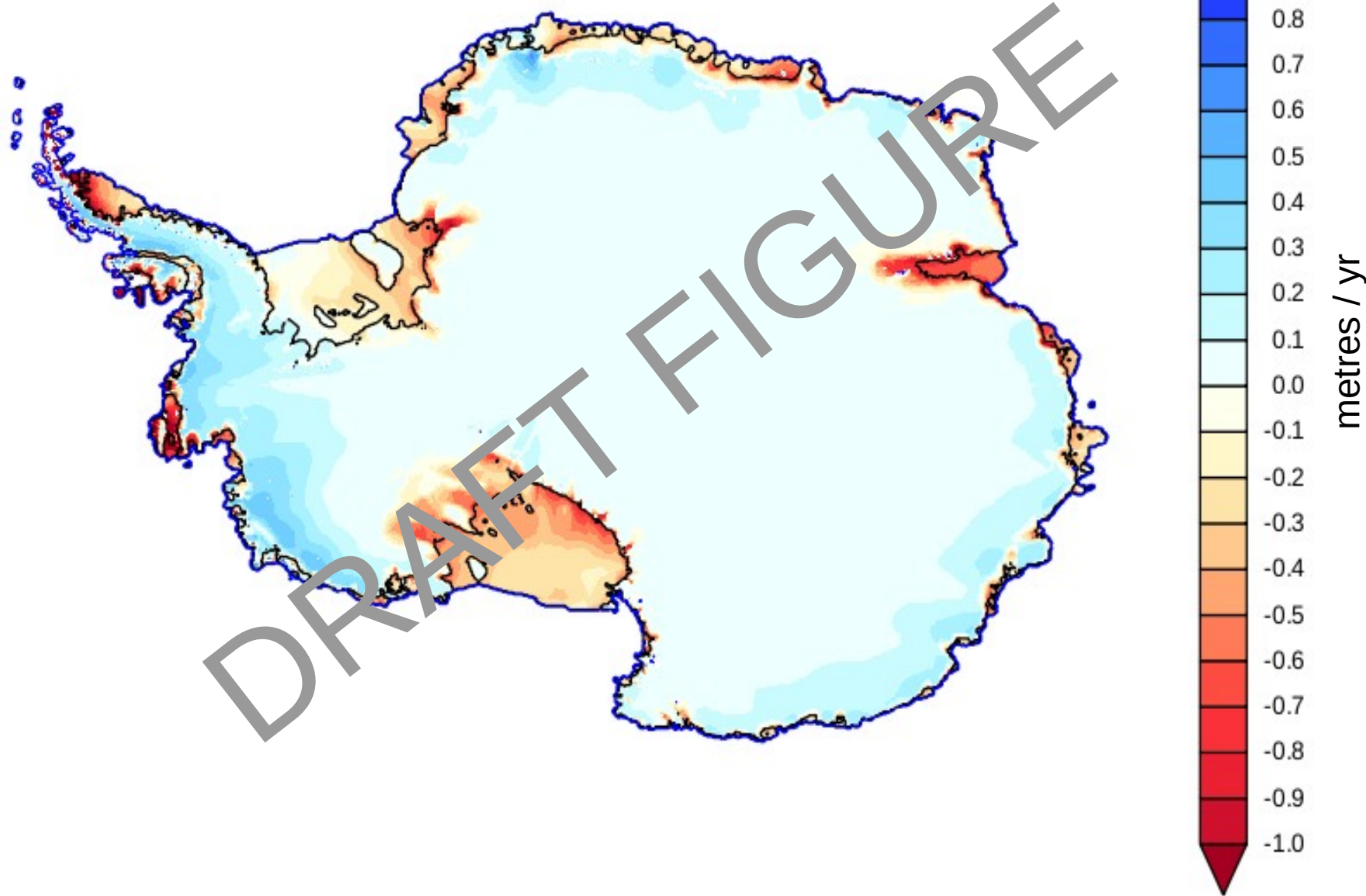
d) runoff

Change in AIS SMB 2100-2015 SSP5-85



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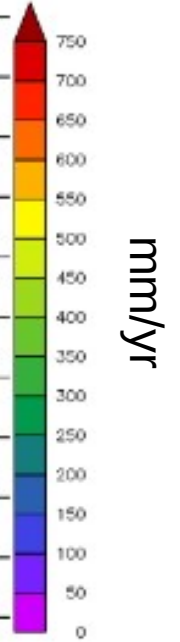
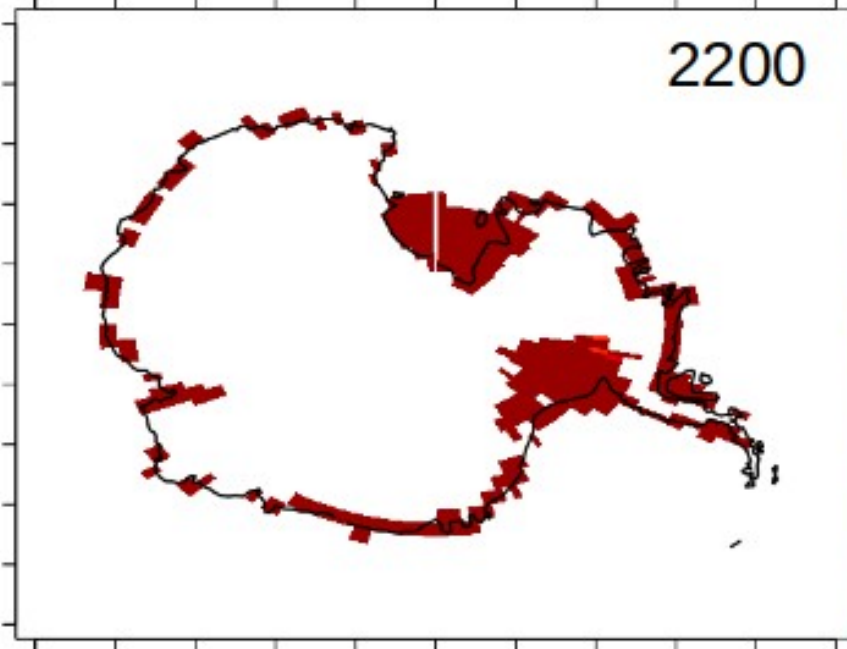
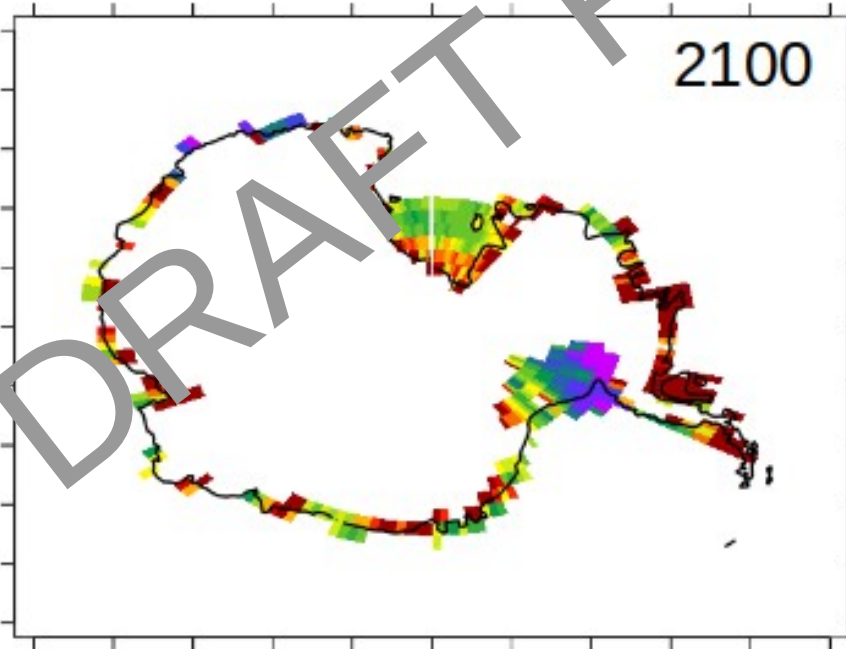
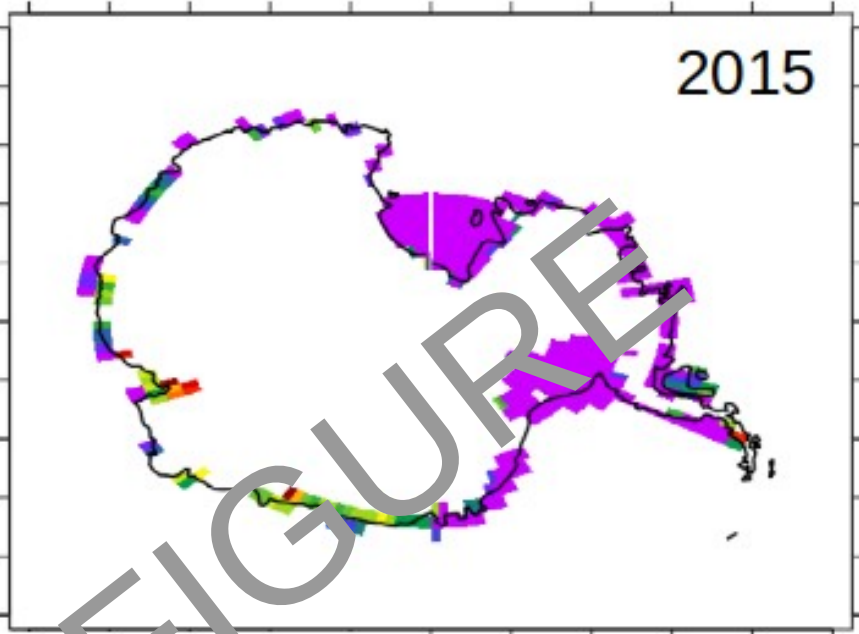
DRAFT FIGURE

Surface melt as a proxy for hydrofracture potential in SSP5-85



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DRAFT FIGURE

Future directions



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Long-term work to improve confidence in coupled ice modelling in global ESMs

- work with higher resolution regional models and observations
- convince the main (atmos) model developers to care about this and improve their polar climates/surfaces

Experimental protocols

- coupled spin-up and initialisation
- tipping points, overshoot scenarios, longer-term commitments
- useful protocols for High Impact, Low Probability events..or chains of them
- operational projections vs tools for understanding
- working as part of a multi-pronged approach

