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esm 2025
Earth System Models for the future

Greenland: the importance of marine terminating glaciers

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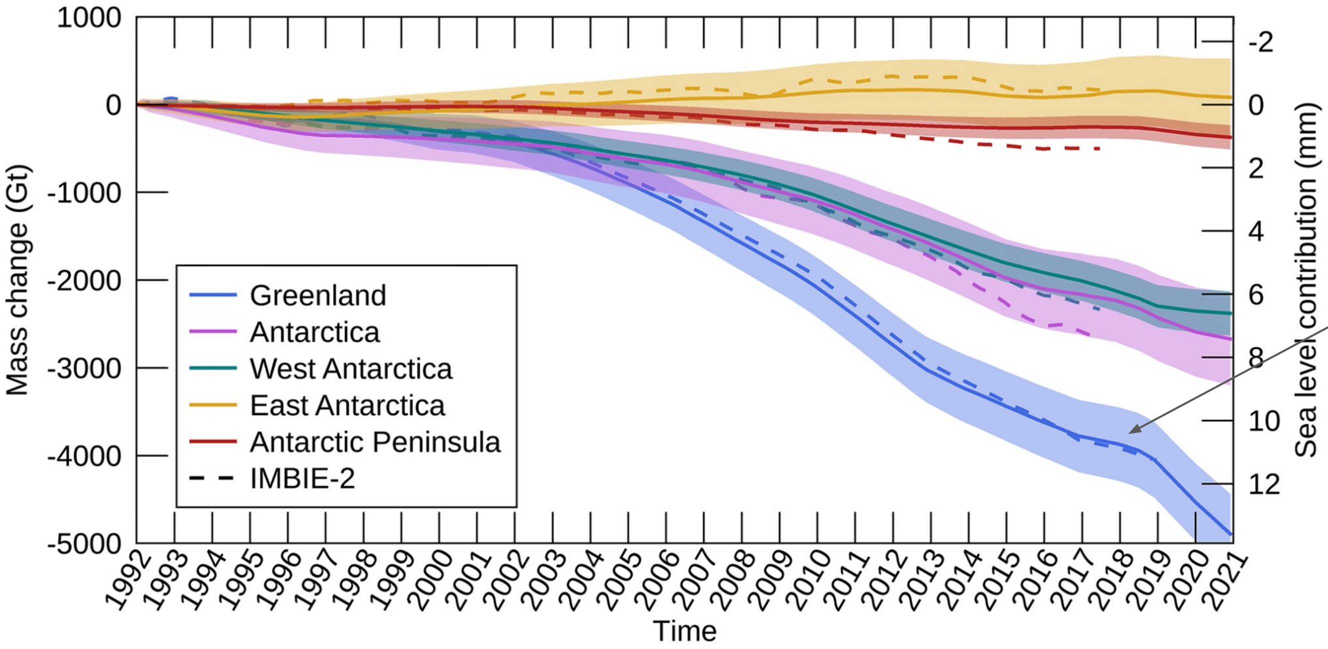
Robin Smith

Why? Observed Mass Change



Otosaka *et al* (2023)

Combination of:

- Accumulation
- Melt (air/sea)
- Dynamics

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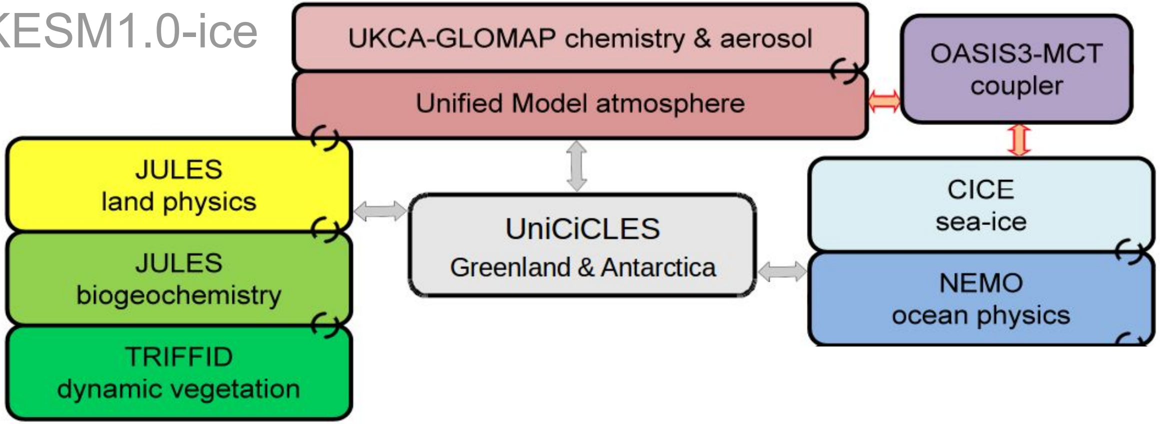
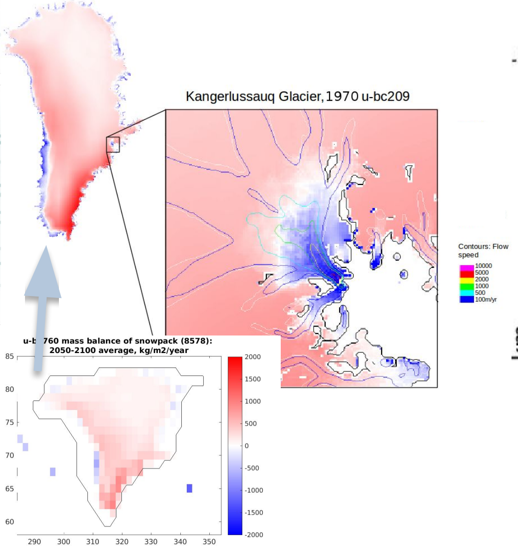
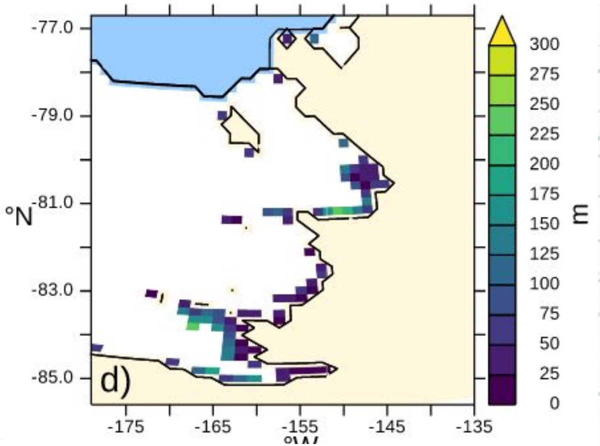
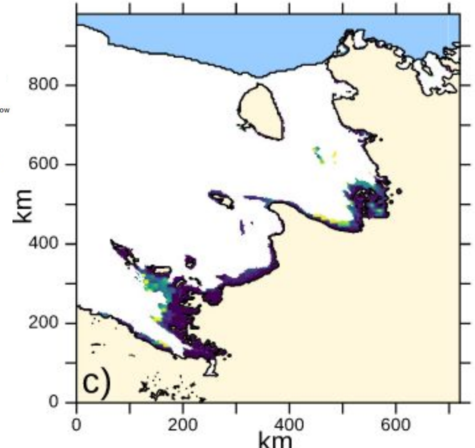
UKESM1.0-ice



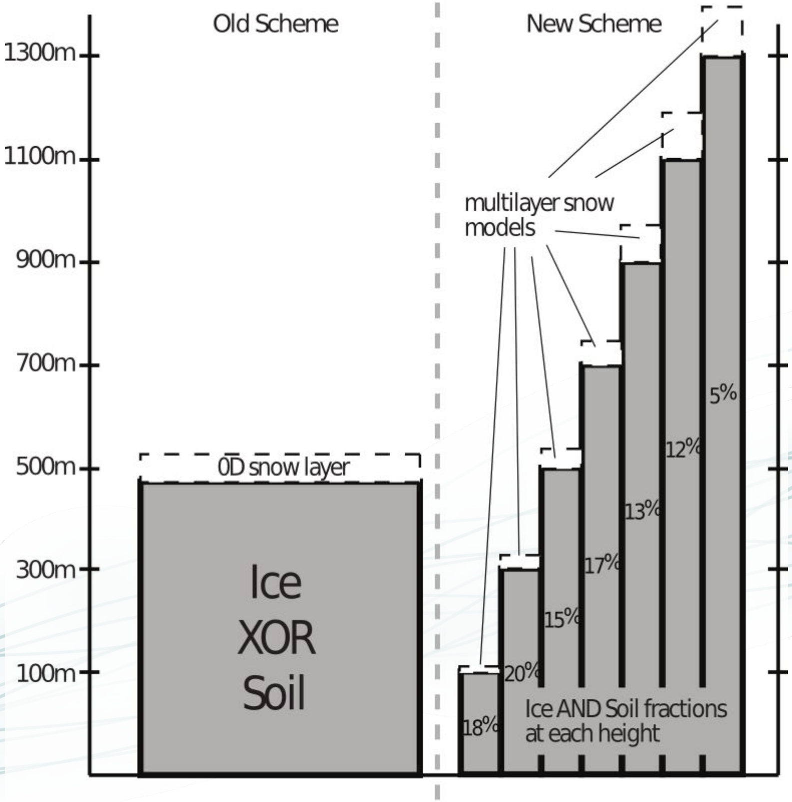
- ~100km resolution, 85 level atmosphere
- Multilayer snow scheme with melt percolation and refreezing
- Greenland dynamics with up to 1.2km resolution, Antarctica at 2km
- Explicit Lagrangian icebergs
- Ocean underneath floating Antarctic ice shelves
- Surface Antarctic shelf calving front is fixed, but grounding line can retreat
- **No marine forcing of Greenland outlet glaciers**



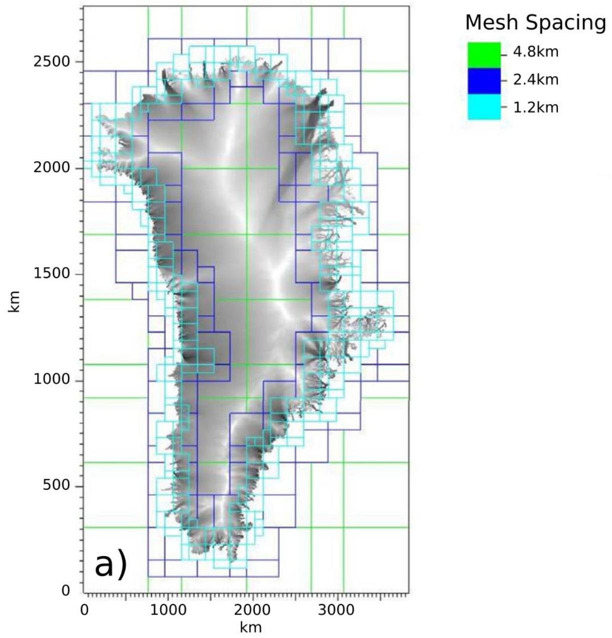




Dealing with spatial resolution



BISICLES adaptive mesh refinement



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

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“No marine forcing of Greenland Outlet Glaciers”

Calving:

$U_c = U_T - dL/dt$

Solve for U_c (or invert and solve for terminus position).

For fixed fronts easy: $U_c = U_T$ or 0 (**this is what happens in UKESM1.0-ice**)

Would like ice fronts to advance/retreat along fjords under both dynamic and air/sea melt forcing.

MAGRATHEA LABORATORIES CREATORS OF NEW WORLDS

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“No marine forcing of Greenland Outlet Glaciers”

Calving:

Greenland glaciers can flow at up to 5 md^{-1}.

Retreat and acceleration occurring since 2000 … leading to dynamic thinning.

Possible instability feedback leading to continued glacier loss with impacts on mass of internal ice sheet.

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New parameterisation for UKESM-ice

Building on previous uncoupled ISMIP methods.

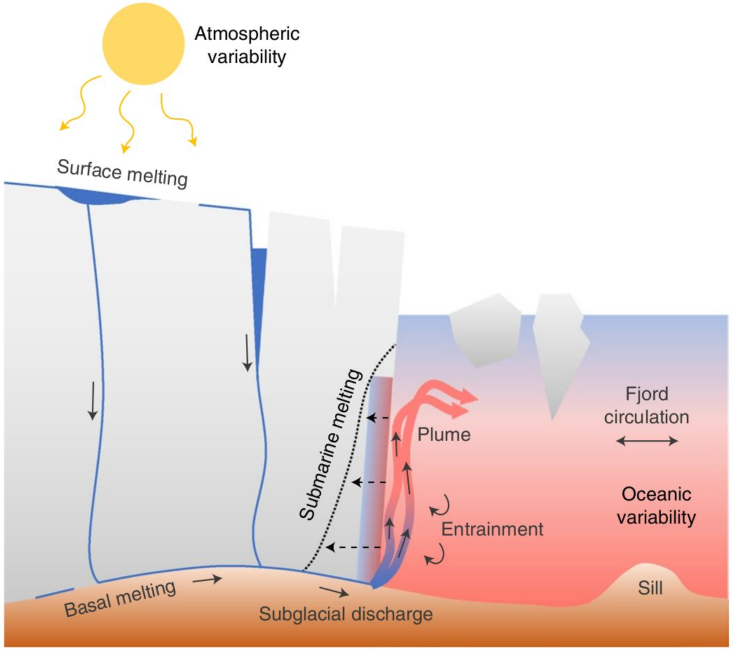
Enhanced submarine melt a combination of ocean heat anomalies and turbulent upwelling due to freshwater subglacial discharge.

$$Q_m = 0.142\, Q^{0.31}\, TF^{1.39}$$

Maximum melt rate

Q - catchment runoff

TF - thermal forcing (in situ above freezing)



Slater (2022)

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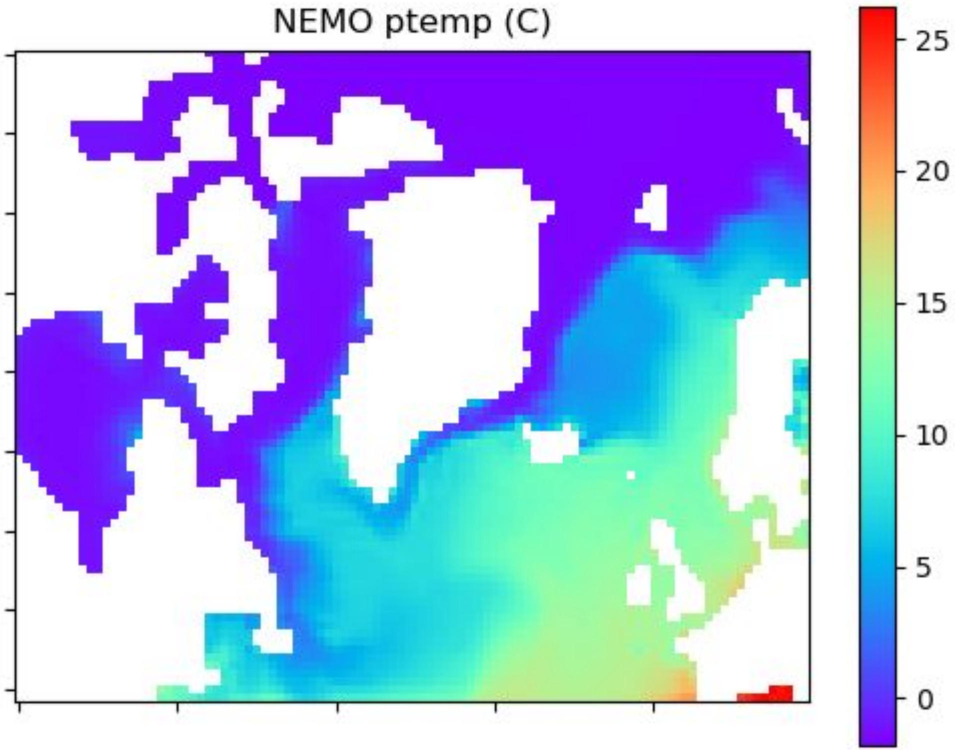
Model vs. Real World



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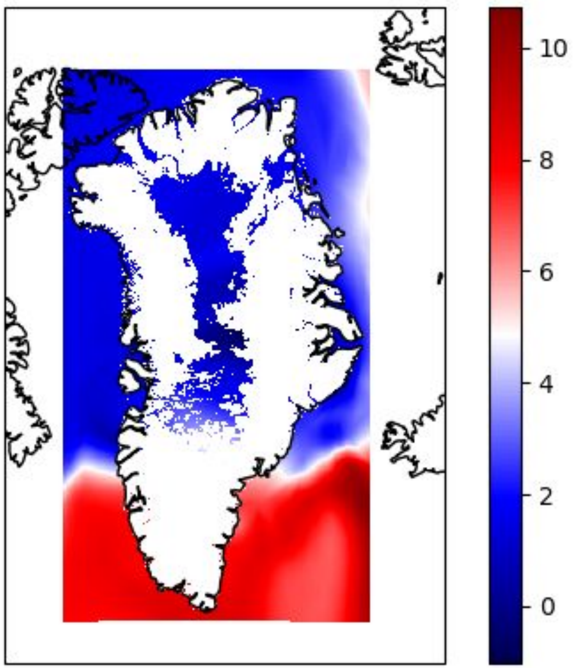
Ocean Thermal Forcing

$$Q_m = 0.142\ Q^{0.31}\ \mathbf{TF^{1.39}}$$

TF: Potential temp - local freezing temperature (200-500m)

Regridded NEMO -> BISICLES



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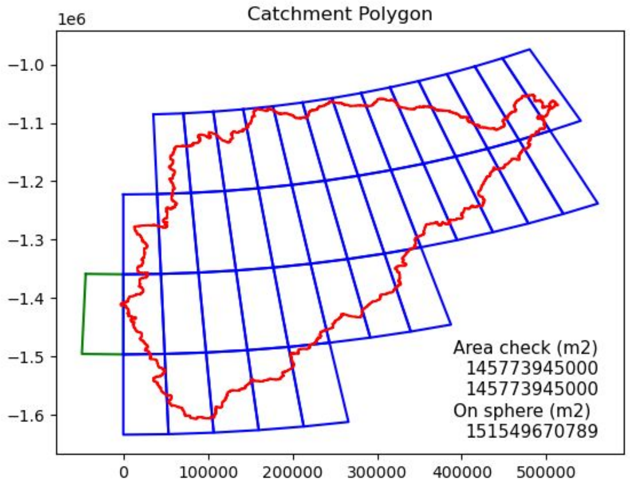
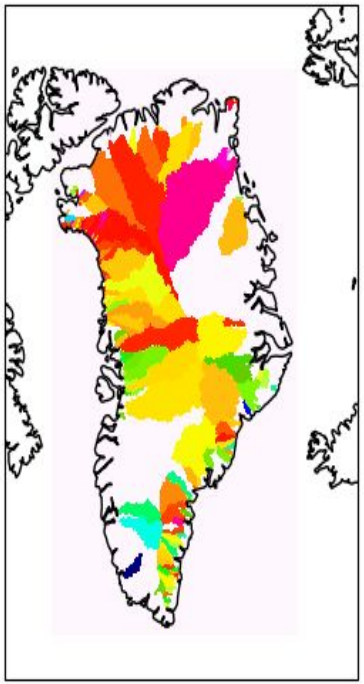
Surface Melt/Subglacial flux

$$Q_m = 0.142\ \mathbf{Q^{0.31}}\ TF^{1.39}$$

Meltwater from atmosphere model mapped onto drainage basins.





Implementation

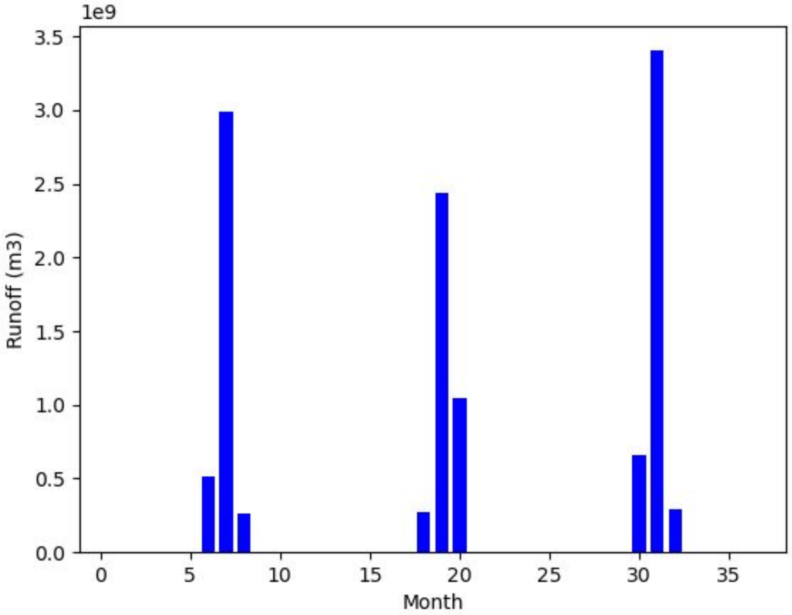
Ice is coupled to the atmosphere/ocean once a year.

Melt only significant in summer season

Enhanced melt implemented as a scaling factor to an existing fixed-front control.

$$Q_{TOT} = Q_m * U_{REF}/Q_{REF}$$

U_{REF} - ice velocity/calving rate in control



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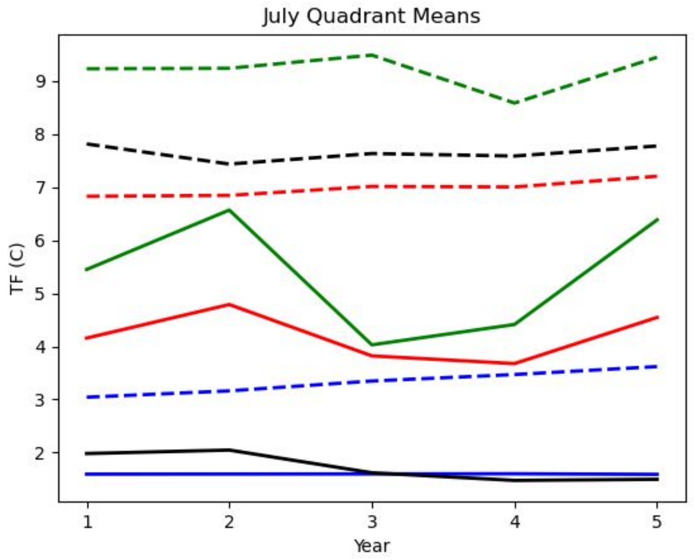
Model Implementation

Offline testing using existing UKESM-ice runs:

be760: ISMIP6 UKESM1-is control, w/ice

bh111: ISMIP6 UKESM1-is abrupt4xCO2, w/ice

Significant increase in thermal forcing in all quadrants.



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Model Implementation

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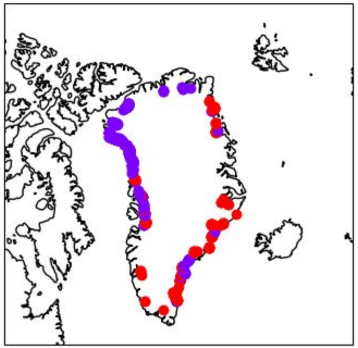
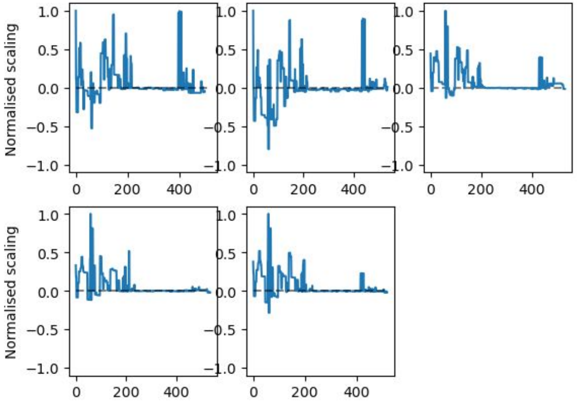
Significant increase in thermal forcing in all quadrants.

$$Q_m = 0.142\, Q^{0.31}\, TF^{1.39}$$

$$Q_{diff} = Q_{pert} - Q_{ctl}$$

Showing enhanced (strong signal) and reduced (small signal) calving.





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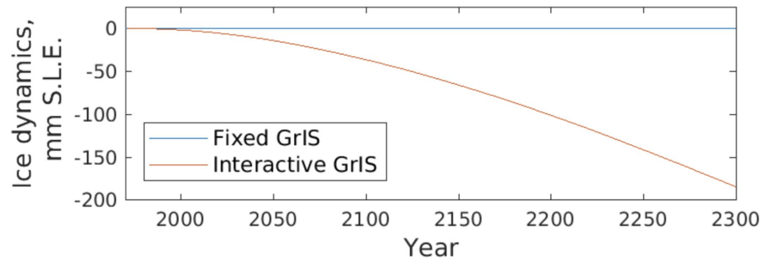
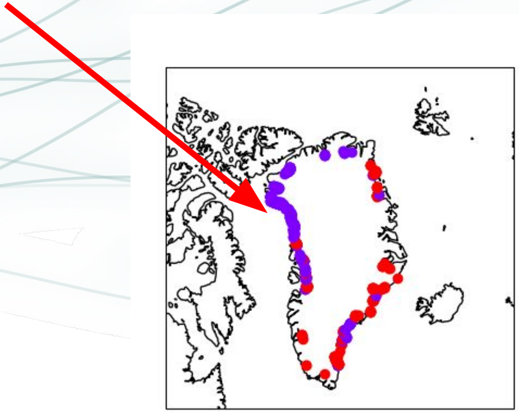
Interim Conclusions

Atmosphere (freshwater)/ocean (thermal forcing) parameterisation is working. Now in the process of plumbing it into the coupled system.

TF is enhanced in all quadrants. Any reduction in calving due to changes in runoff.

- Patterns of runoff changed in the atmosphere model.
- This associated with change in ice topography
- Thus drainage basin flow reduced in 4xCO2





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