Coupled ice sheet model in HadGEM3

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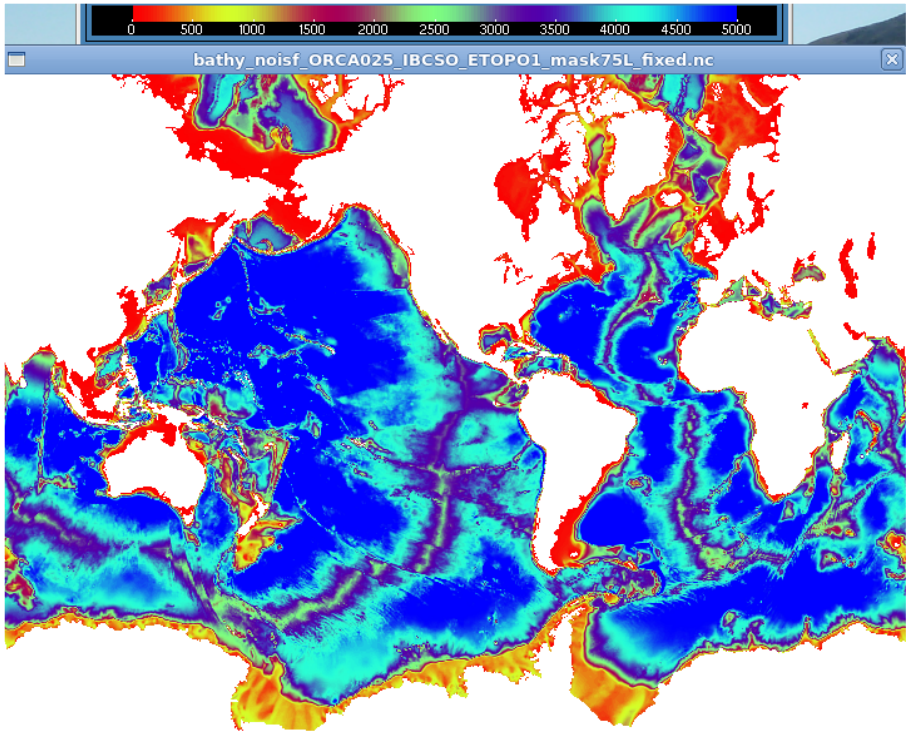
- What do we have working – ice sheet-ocean (BISICLES-NEMO)
- Issues encountered
- Issues to be resolved

UKESM

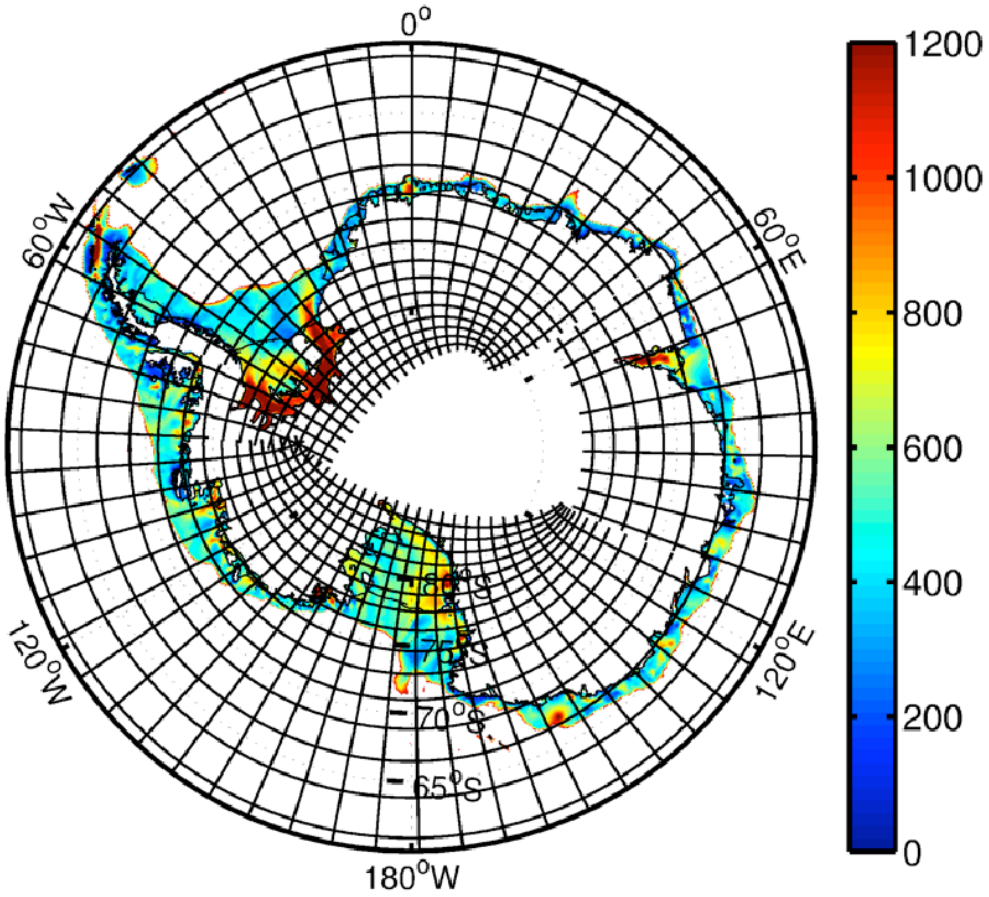
Met Office Hadley Centre

NEMO

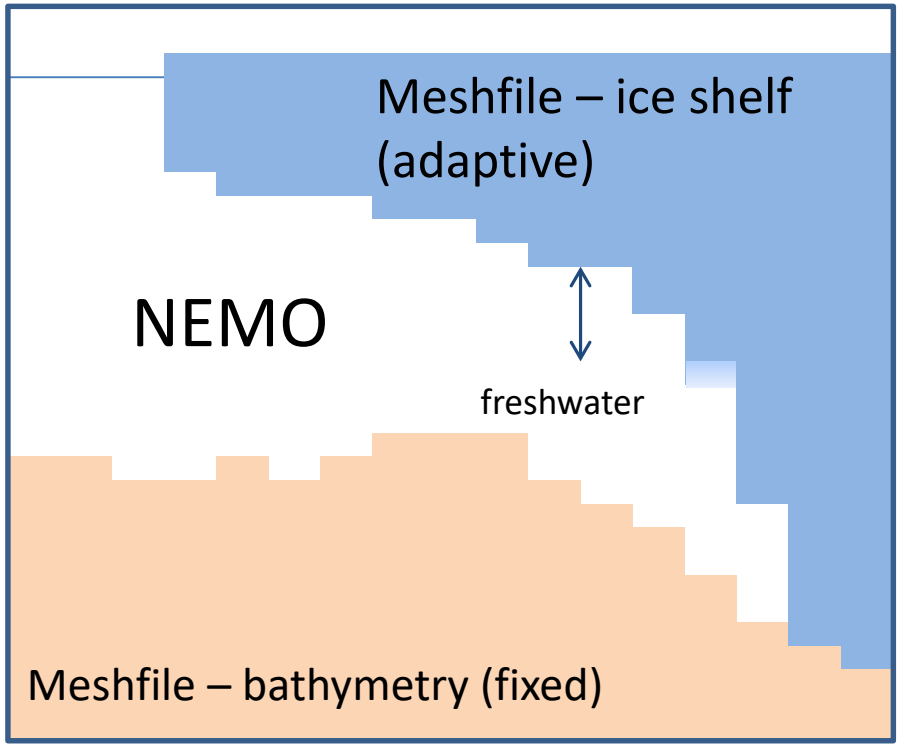
- European ocean model (C-grid)
- Resolutions used 1, 1/4 & 1/12^{o}
- 75 vertical levels 1m (top 10) and 60m at 1000m depth.
- Lagrangian icebergs drift, breakup and melt
- Extended grid to cover ice shelf cavities and regions of potential ice shelf retreat.
- Presently bathymetry not defined under grounded ice.

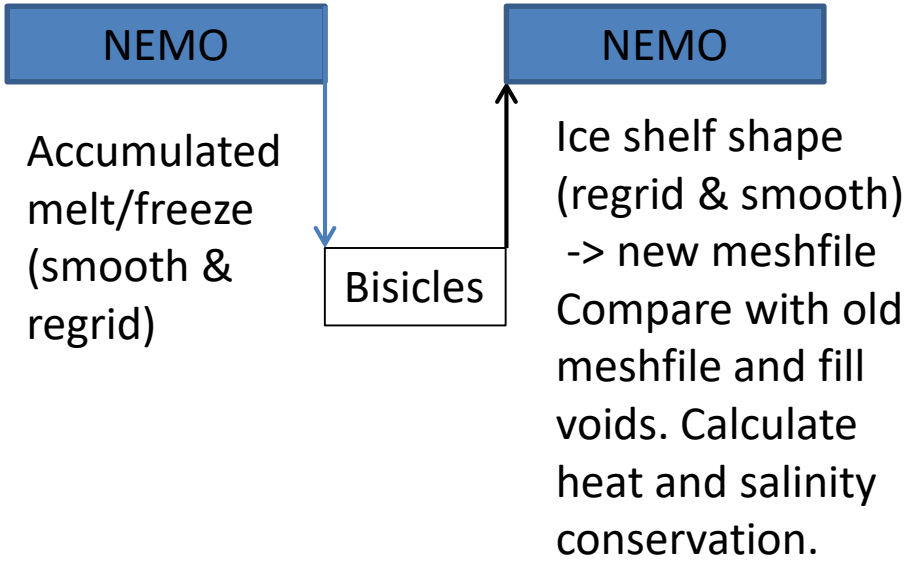


extended grid for ice shelves + modified Antarctic bathymetry



Maximum grid resolution same as that near Northern poles (blocks of 25x25 grid-cells shown).

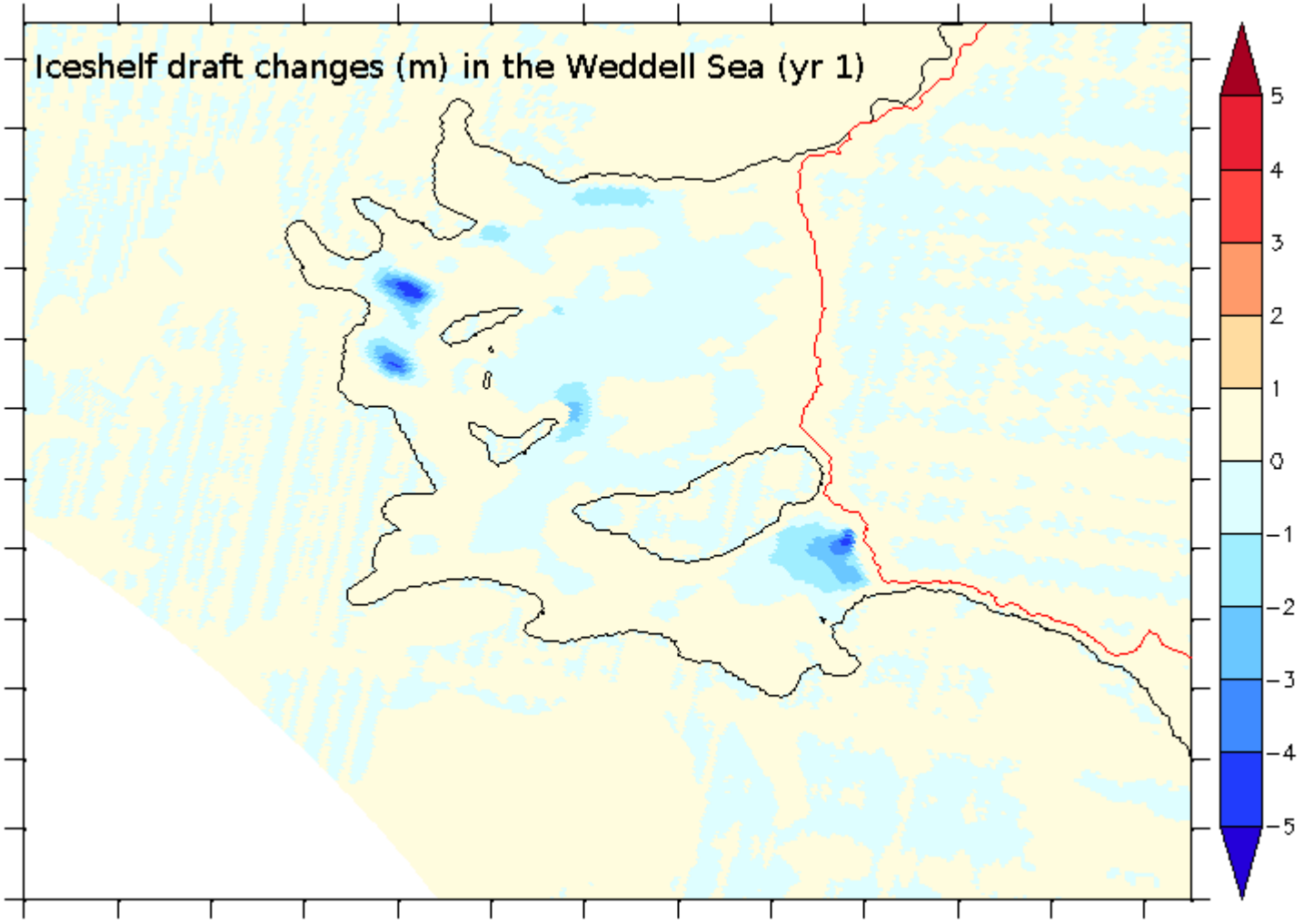




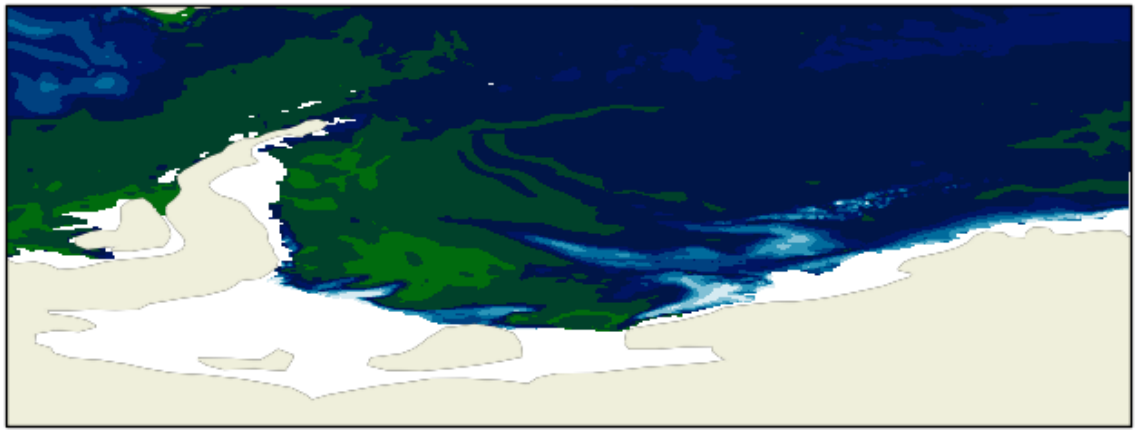
- Smoothing required for stability
- However smoothing reduces ice shelf feedback
- Solution is more frequent coupling (monthly)

- Coupling requires halting ocean model
- Increases total model runtime 2% each coupling per year

Annual update example (spin-up)

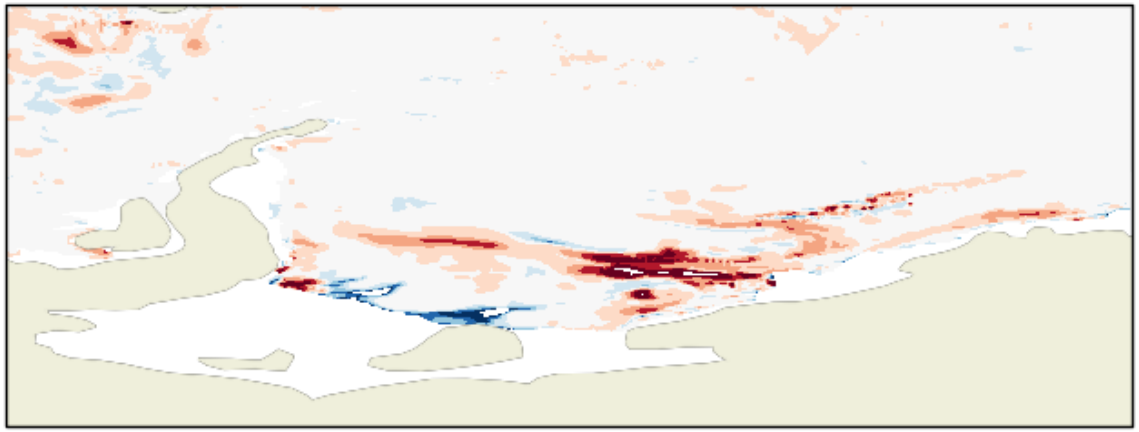


Ocean and ice sheet stable



Turbocline depth (m)

0 44 89 133 178 222 267 311 356 40



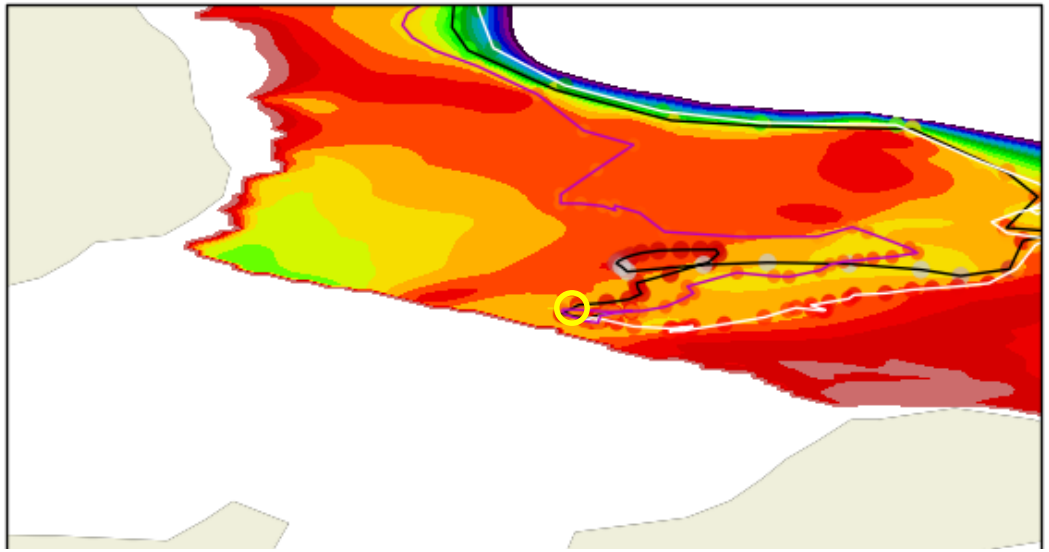
Difference in turbocline depth with cavities (m)

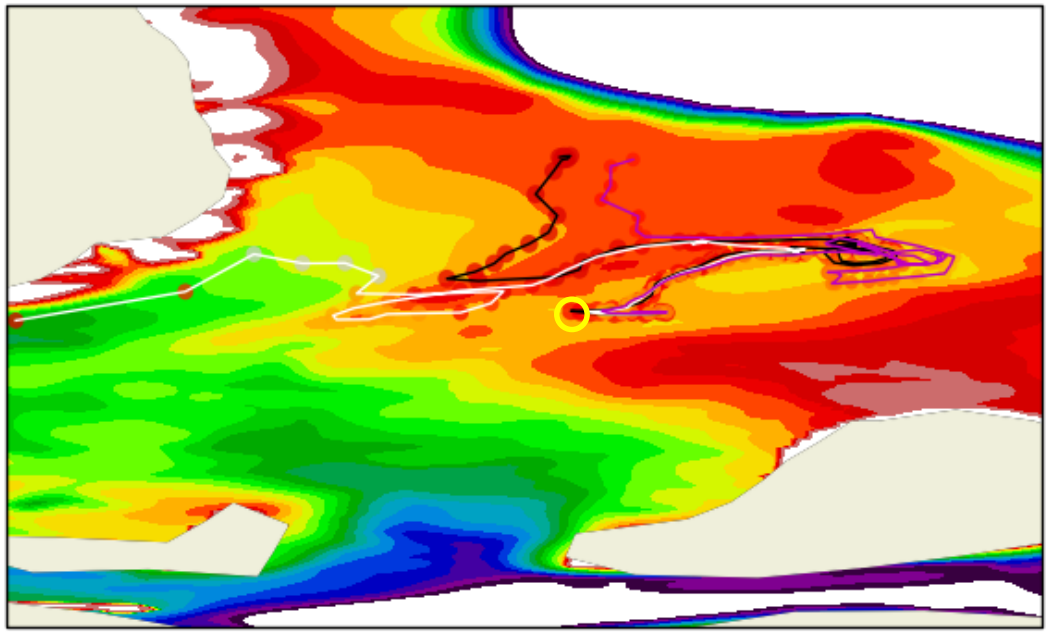
-200 -156 -111 -67 -22 22 67 111 156 200

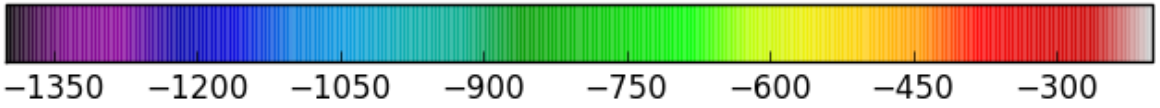
Oceanographic changes

Add ice-shelf cavities keeping same freshwater flux (referenced to open cavities).

- Stratification in latent heat polynyas
- Increase in mixing depth at continental shelf-break
- No significant far field effects (but only 10 year run).







Lagrangian tracers

Particle tracers starting from bottom three model levels (at yellow circle). Dot on tracks every 10 days and total 3 years (colour for depth as bathymetry)

No cavity

- All tracks follow shelf-break

Cavity

- Dwell time on shelf increased
- One track follows western cavity boundary to grounding line

Other start points show no tracks proceed under shelf

Missing processes?
Tides?

Processes-1

- Freshwater input from shelf melt treated identically in NEMO as are river outflows
  - Freshwater input causes local divergence flow
- Conservation of heat and freshwater in NEMO
  - Infill of ice shelf voids and extension (melt and refreeze) leads to latent heat and salinity conservation issues.
  - Infill of voids uses mean ocean properties of neighbour cells
  - heat and salinity adjustment applied globally spread over subsequent coupling period.

Processes-2

- Ice shelf floating seaward boundary fixed to avoid reconfiguring land/atmosphere scheme and associated conservation issues.
  - Fixed calving front means no calving law required with ice mass crossing front becomes source of Lagrangian icebergs.
  - Sea ice mask (CICE) need not be updated
  - However, on ice shelf retreat in BISICLES, the GCM ‘ice shelf’ is negligibly thin, with no ocean-atmosphere heat flux through it and no basal melt.
  - Locations of water mass formation do not change - possible missing ocean-climate feedback.

Issues to be resolved-1

- Ice shelves in shallow shelf seas
  - Underlying ocean depth 2 model levels but shallow model levels are thin (1-2m)
  - Freshwater and heat fluxes from ice shelf causes local ocean instability (transport/convection).
- Solution - treat as grounded ice
  - With no basal melt, ice in BISICLES gets thicker
  - Retain original calving front
- Long term solution – wetting/drying scheme

Issues to be resolved-2

- Ocean (NEMO) grid/bathymetry is amply defined for regions of potential grounding line retreat.
  - Grid configuration such that resolution does not continue to increase polewards (avoiding associated model time-step reduction).
  - Result is that configuration does not allow a sea passage to open between Weddell and Bellingshausen seas.
  - Remaining task - input bedrock into bathymetry mesh (Isostatic rebound not in GCM model but in BISICLES)
- Solution – a new double pole grid?

Issues to be resolved-3

- Coupled model spin-up (untested)
  - Fixed grounding line, basal friction inversion
  - Free grounding line, fixed basal melt, friction inversion
  - Iterate to free grounding line, free basal melt -> fixed bedrock friction field
  - Bayesian friction solutions preferred but impracticable

Summary

- Atmospheric 2-way coupled ice sheet completed (evaluation ongoing)
- Functional ocean-ice sheet coupling (Antarctica)
- Yet to be integrated into the HadGEM3-GC3 (CMIP6) infrastructure
- Completion + testing + evaluation by Dec 2017
- Coupled spin-up strategy (Pre-industrial)?