The Challenge of Modelling Antarctic Shelf Dynamics

Andy Hogg

with thanks to Adele Morrison, Angus Gibson, Andrew Kiss, Paul Spence & Matthew England

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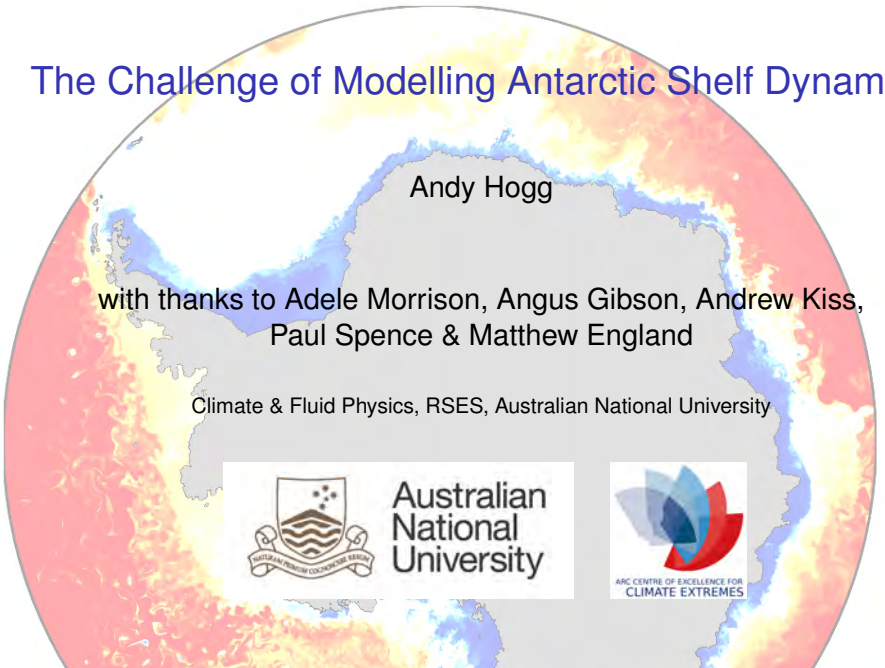
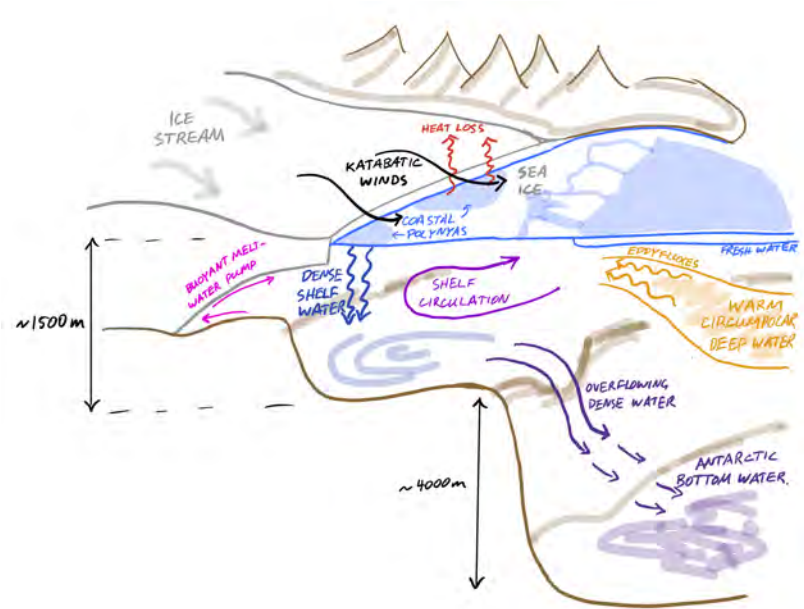
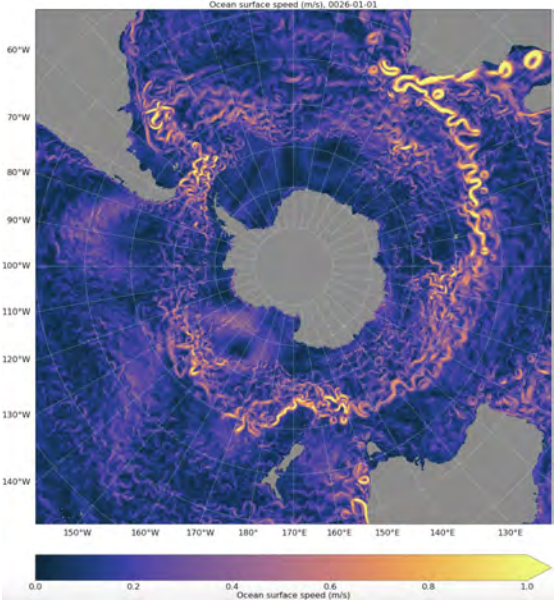
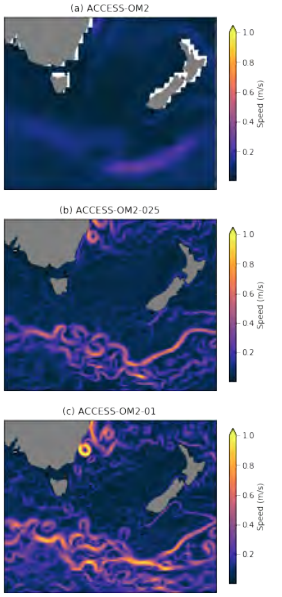


Processes on the Antarctic shelf



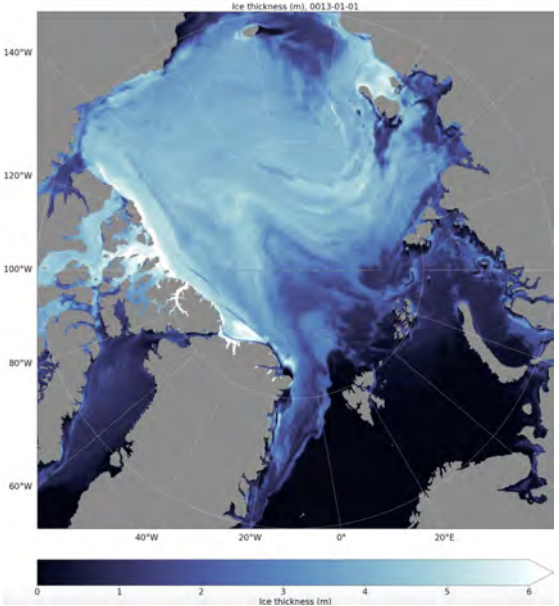
Ocean Model Resolution





Andrew Kiss & COSIMA

Ice Model Resolution



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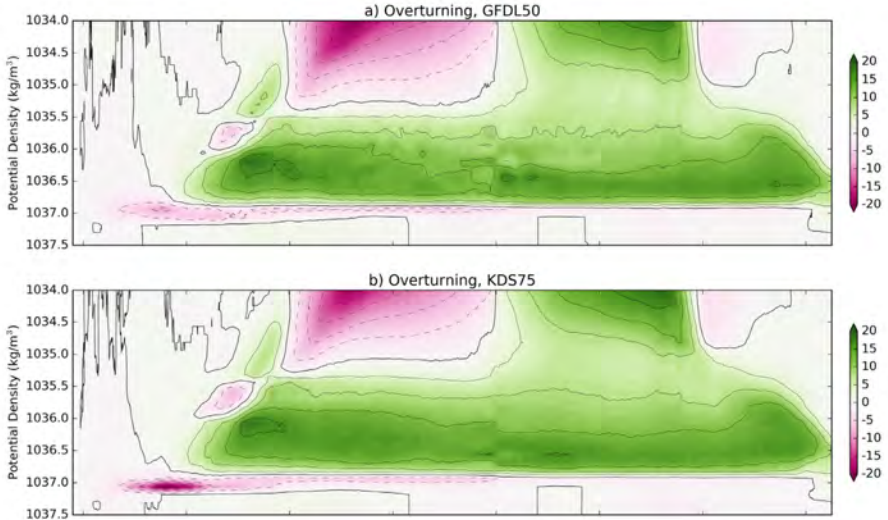
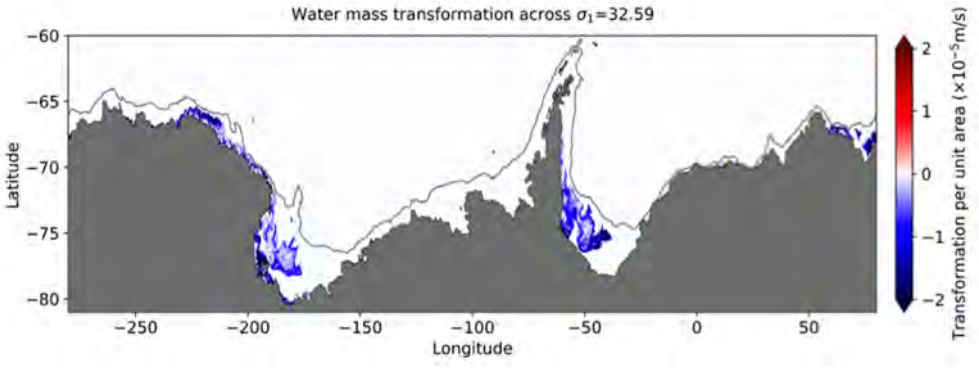
Vertical Resolution



KDS75 case has 25 more layers – upper cell 2 m deep!

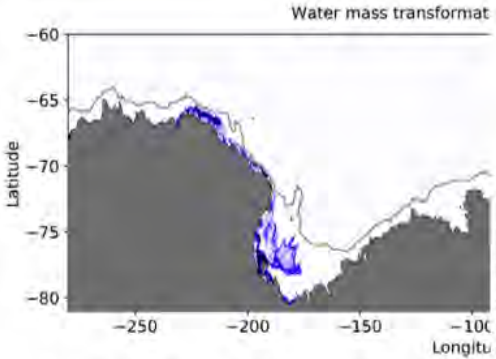
Stewart et al. (2017)

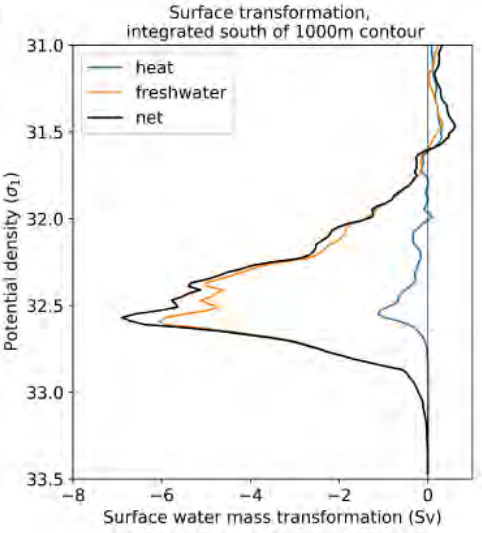
Vertical & Horizontal Resolution: Dense water formation



Morrison et al. (under review)

Vertical & Horizontal Resolution: Dense water formation

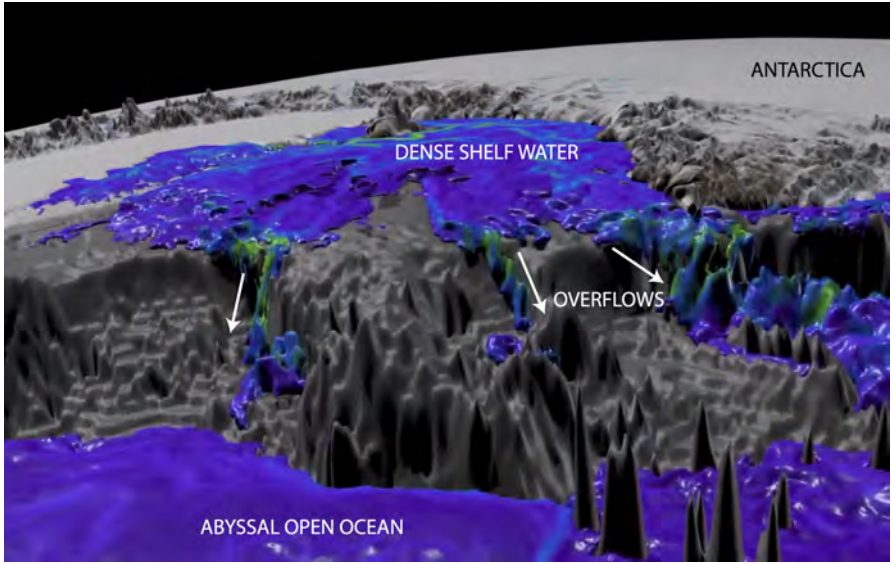




Excellent simulation of dense water production (compared with other models).

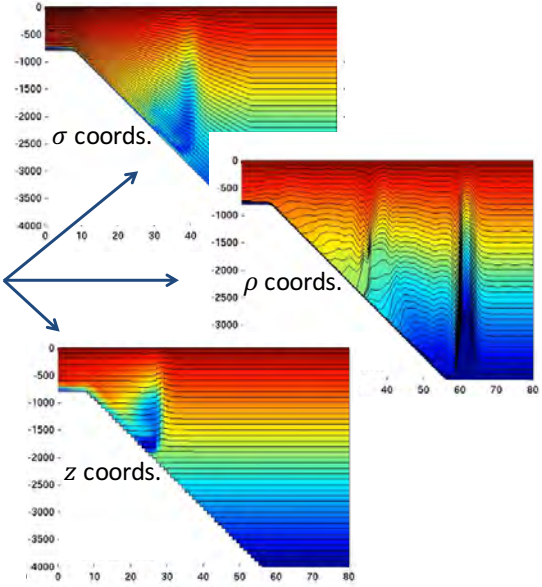
Morrison et al. (under review)

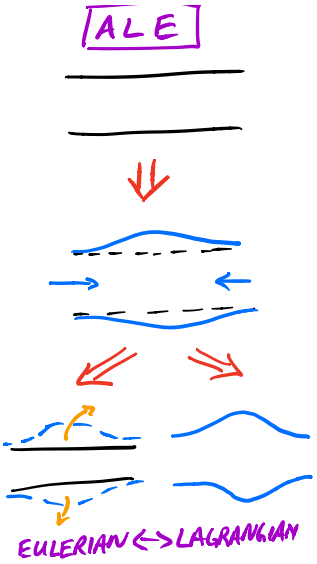
Vertical & Horizontal Resolution: Dense water formation



https://youtu.be/8VMSF28J9H4

Vertical Coordinate: ALE





Alistair Adcroft, Bob Hallberg

An Adaptive Vertical Coordinate

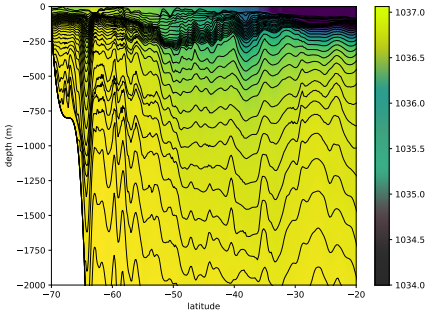
$$\partial_t z_k = -\nabla_H \cdot \Bigg(\underbrace{\omega_\sigma \frac{\kappa \nabla_H \sigma}{\sqrt{\sigma_z^2 + (\nabla_H \sigma)^2}}}_{\text{density adaptivity}} + \underbrace{\omega_z \kappa \nabla_H z_k}_{\substack{\text{lateral} \\ \text{smoothing}}} \Bigg) + \underbrace{\tau_r^{-1} \left(z_k^* - z_k \right)}_{\text{vertical restoring}} + \underbrace{F_{\text{con}}}_{\substack{\text{grid} \\ \text{adjustment}}}$$

Density adaptivity -
Near-isopycnal interior

Lateral smoothing -
Weakly stratified regions

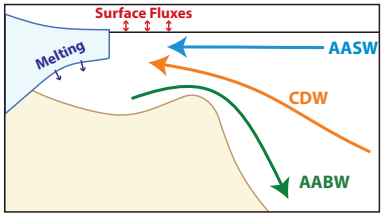
Vertical restoring -
Overall structure

Grid adjustment -
Lower boundary

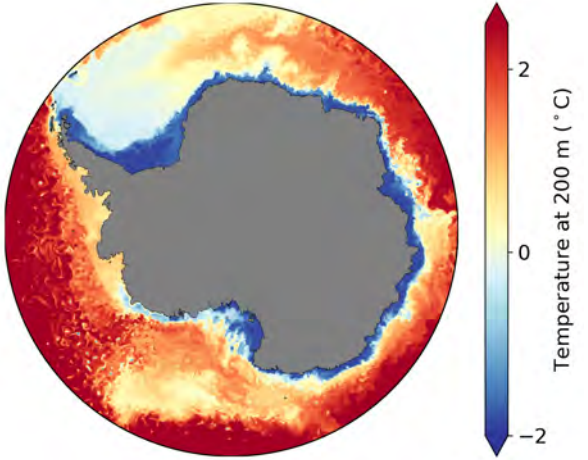


Angus Gibson, Alistair Adcroft, Bob Hallberg

What sets the temperature of water on the Antarctic shelf?



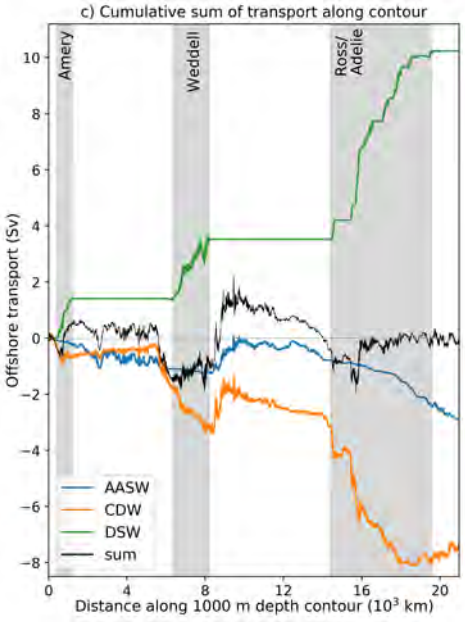
- Surface fluxes (including sea ice)
- Exchange with Southern Ocean (CDW)
- Glacial melt

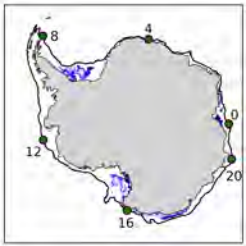


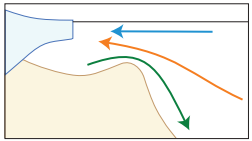
Temperature snapshot (200m depth)

Key Question: What controls the warm CDW transport onto the shelf?
Another Key Question: Where does on-shelf transport happen?

Dense water formation in ACCESS-OM2-01

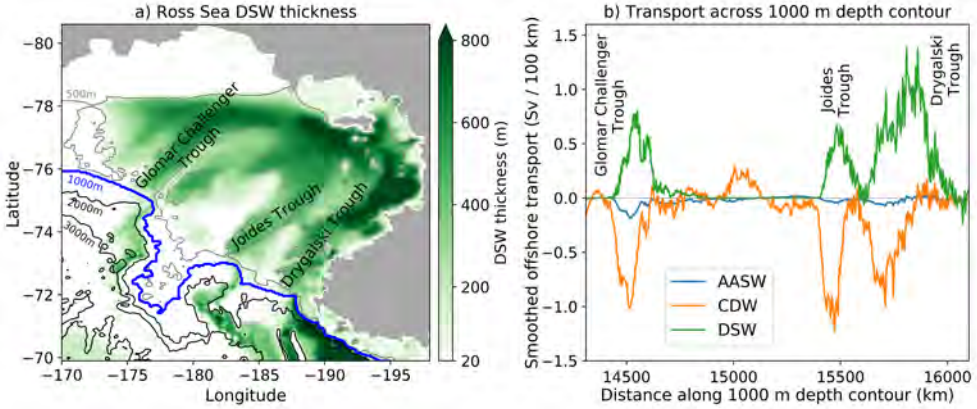




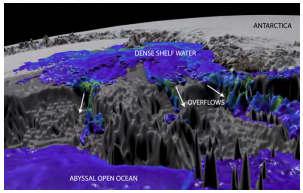


- Dense water (DSW) forms and overflows the shelf in discrete locations.
- 80% of on-shore warm CDW transport is collocated with the dense overflows (representing only 32% of circum-Antarctic contour).

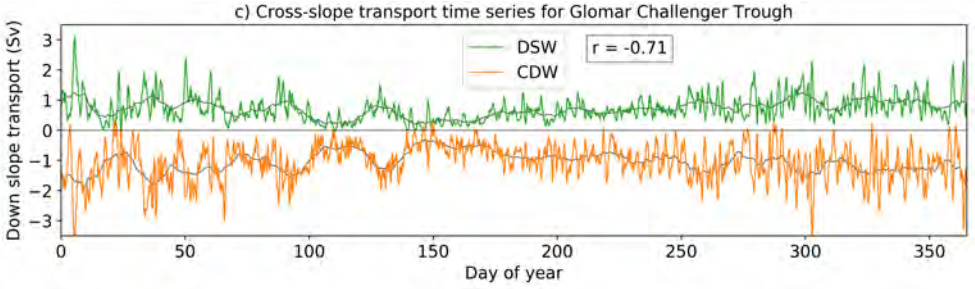
Ross Sea cross-slope transport



- Spatial correlations between on/off-shore flow.
- Cross-slope transport focused in canyons.
- CDW on-shore flow is enhanced and offset 20 km upstream of overflows.



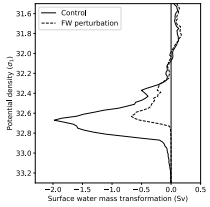
Temporal correlations of Ross Sea cross-slope transports

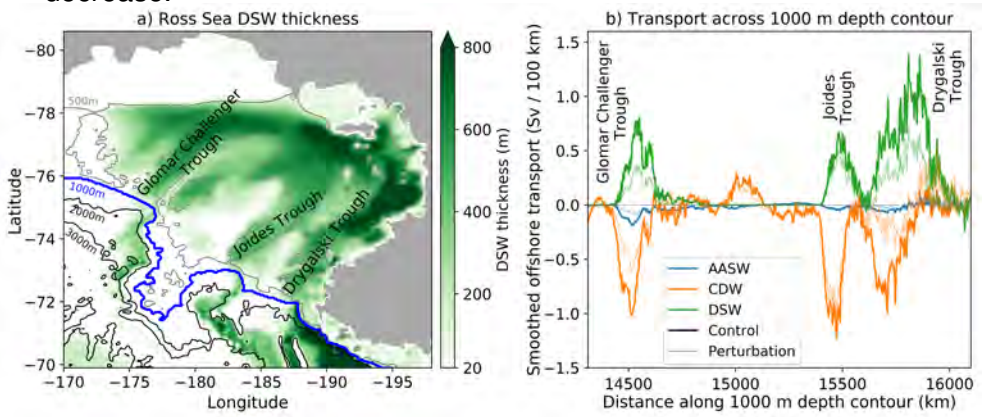


- Periodic down-canyon overflow events drive lighter water up-canyon.
- Correlations not perfect, due to other factors affecting CDW transport variability.

Is there a dynamical connection between DSW and CDW?

- Additional fresh water added to Ross Sea for 4 years.
- Response analysed for final 2 years.
- Both on-shore CDW and AASW transport decrease.





Summary

- **How should we design a climate model to obtain better predictions of polar climates on timescales of decades?**
  - Still finding new mechanisms of heat transport onto the Antarctic shelf . . .
  - **Resolution is key**
- **How can we integrate observations better with models?**
  - Subsurface data is very sparse in this region
  - Models can lead observations!
- **What additional observations would help improving models?**
  - We have no direct observations of the process shown here.
  - Moorings in troughs
  - Any measurements on shelf/slope (especially through the winter)
  - Surface buoyancy fluxes!!