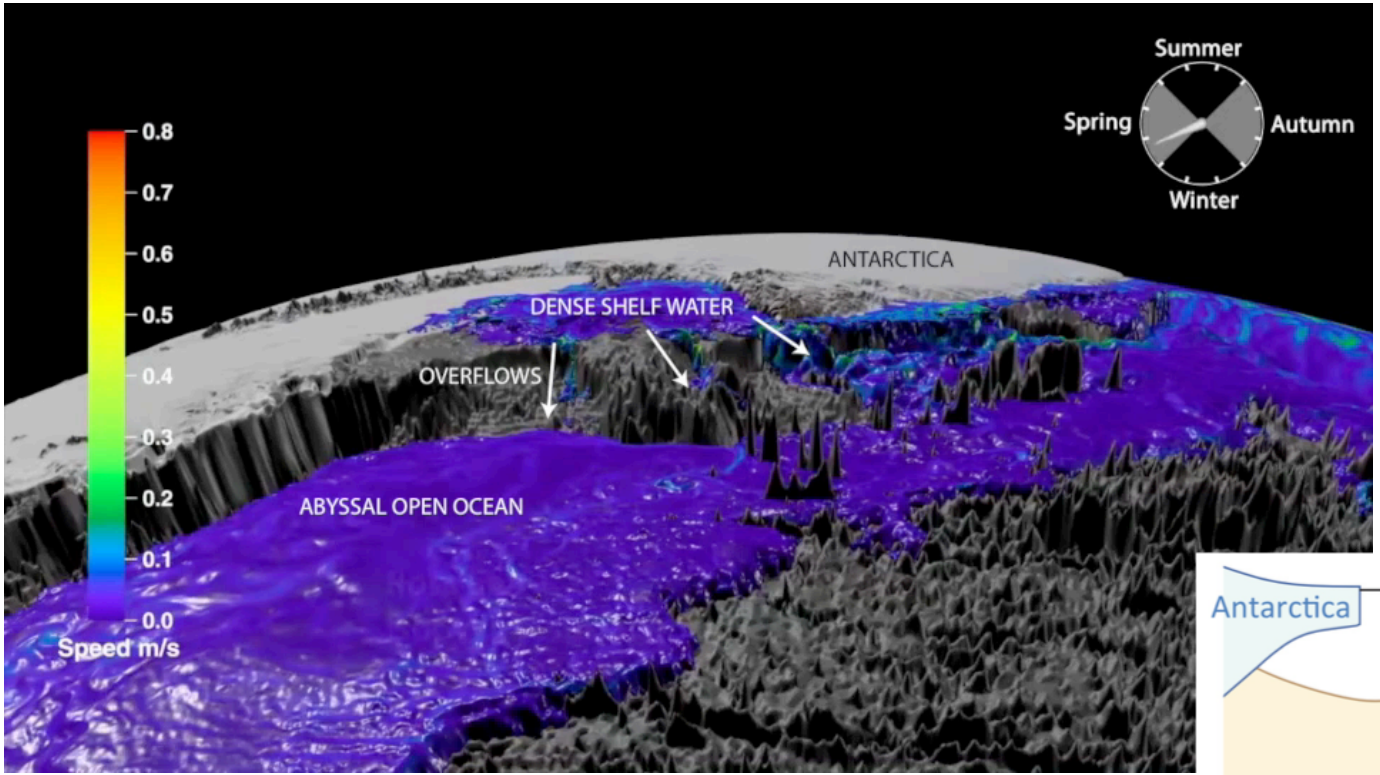
Circumpolar Deep Water transport towards Antarctica driven by dense water export

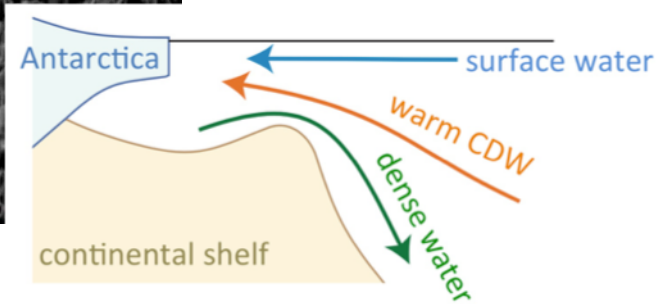


Visualisation by Stuart Ramsden, NCI Vizlab

Adele Morrison (ANU),
Andy Hogg,
Matthew England,
Paul Spence

Australian National University

UNSW SYDNEY



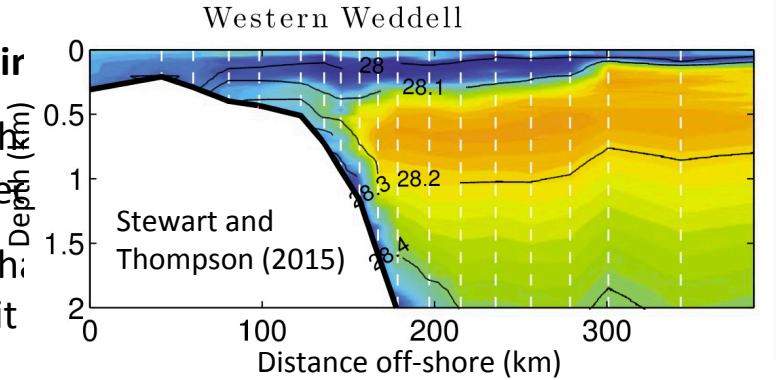
What controls the warm CDW transport onto the shelf?

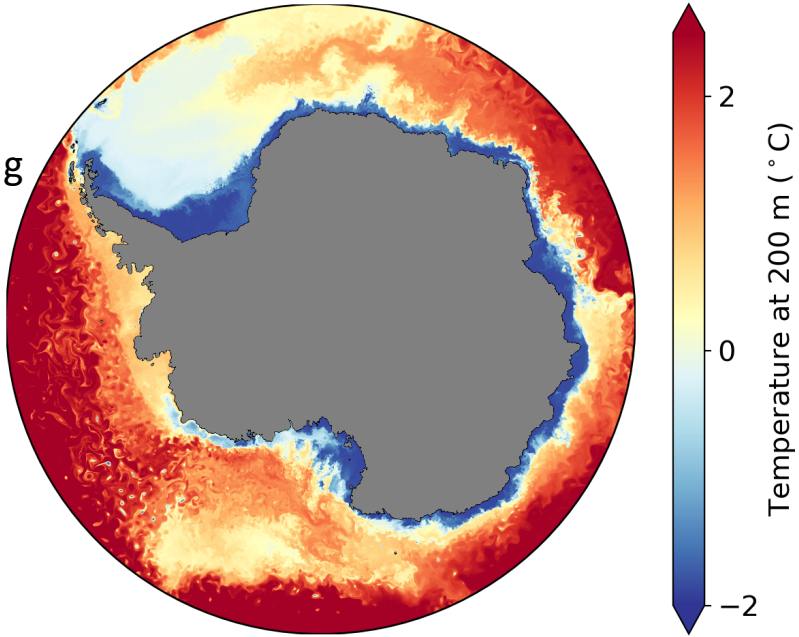
Many proposed theories, including:

- Mesoscale eddy transfer along sloping isopycnals (e.g. Stewart and Thompson, 2015)
- Tidal fluctuations (e.g. Wang et al. 2013)
- Interactions between the slope current or topographic waves and canyon features (e.g. St-Laurent et al., 2013)
- Bottom Ekman layer transport (Wahlin et al. 2012)
- Upward transfer of westward momentum from descending dense water (Stewart and Thompson, 2016)

Remair

- Wh
  me
- Wh
  is it

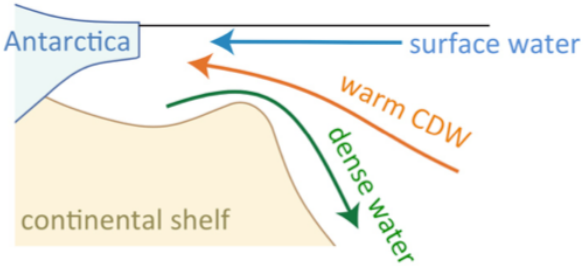




What controls the warm CDW transport onto the shelf?

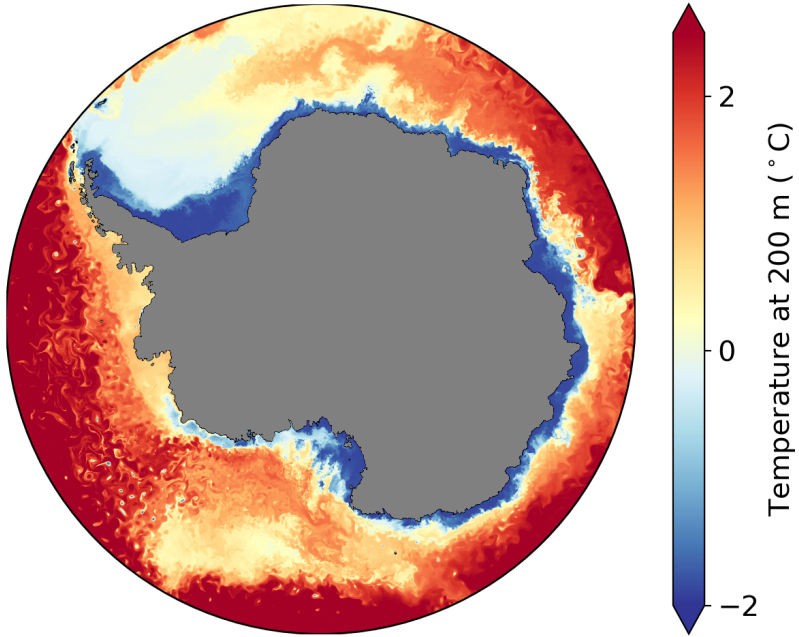
Aim of this study:

- Quantify the spatial distribution of cross-slope CDW transport around Antarctica using a global, eddying ocean-sea ice model.
- Explore to what extent the dynamics of overflowing dense water and onshore CDW transport are connected.



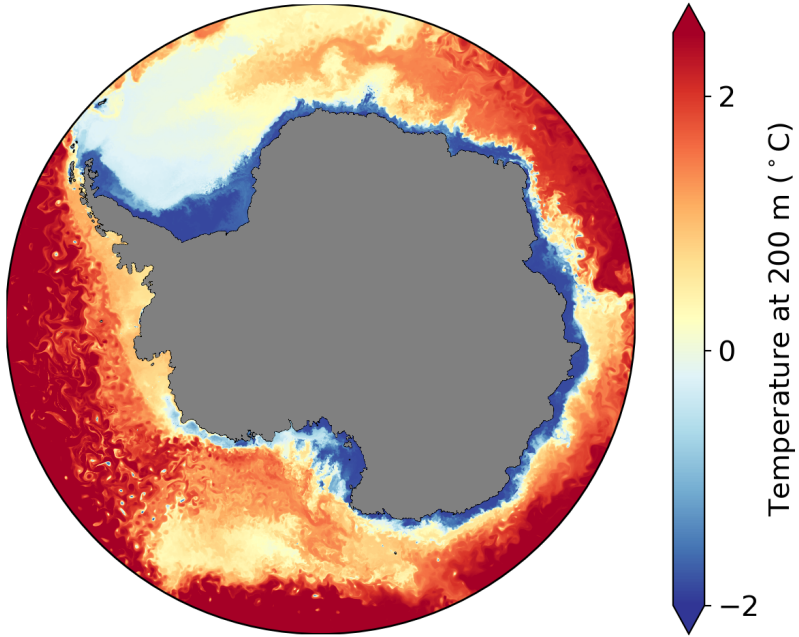
Remaining questions:

- What is the relative importance of each of these mechanisms?
- What is the spatial distribution of CDW transport – is it uniform or dominated by certain regions?

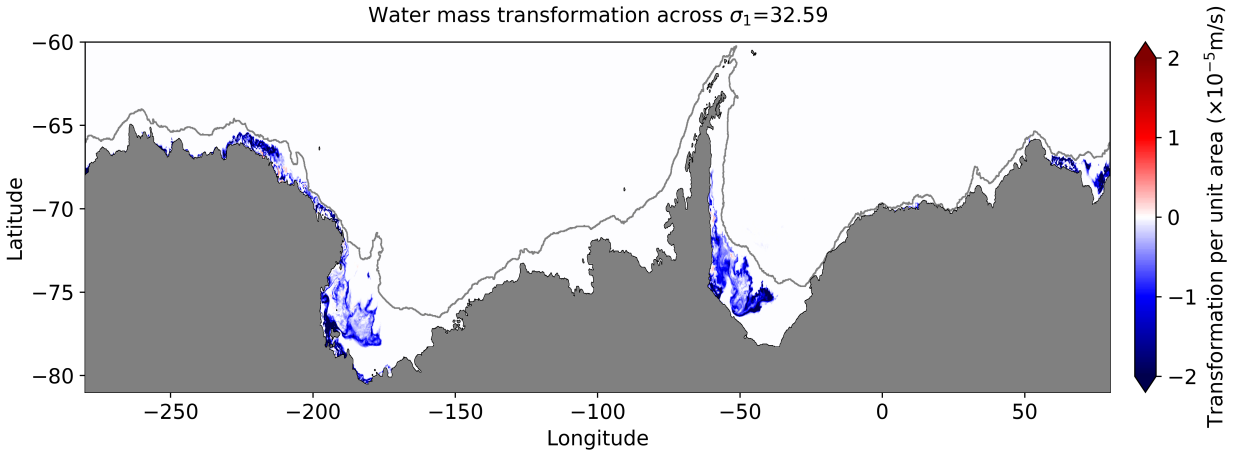


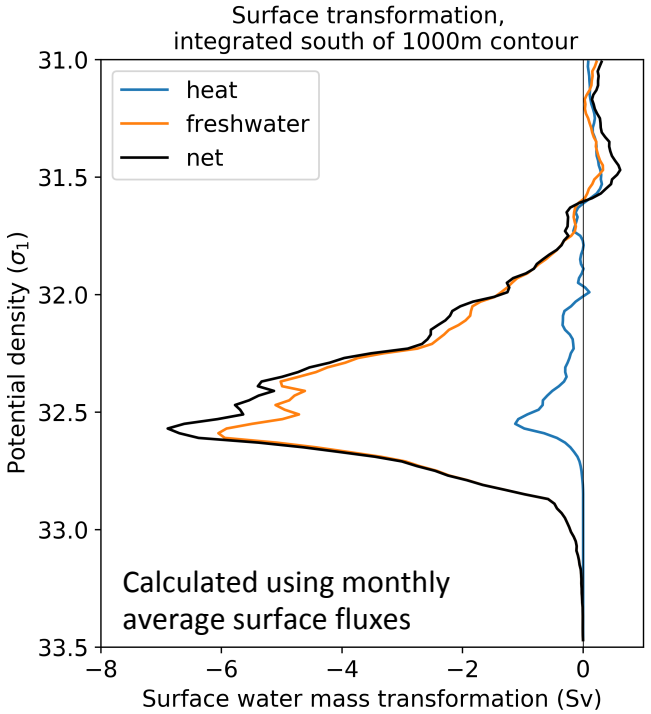
Model

- Global eddy-permitting 0.1° ocean (MOM5) − sea ice (SIS) model
  [known as MOM01 − as described in Spence et al. 2017, Stewart et al. 2017].
- Model resolution varies from 2.6 − 5.5 km around Antarctica,
  compared with a Rossby radius of 1.8 − 5.5 km.
  Only partially resolving the mesoscale field.
- 75 vertical levels
- Forced by COREv2 NYF.
- Spun up for 80 years.
  Most analysis uses a 10 year averaging period.



Dense water formation in MOM01





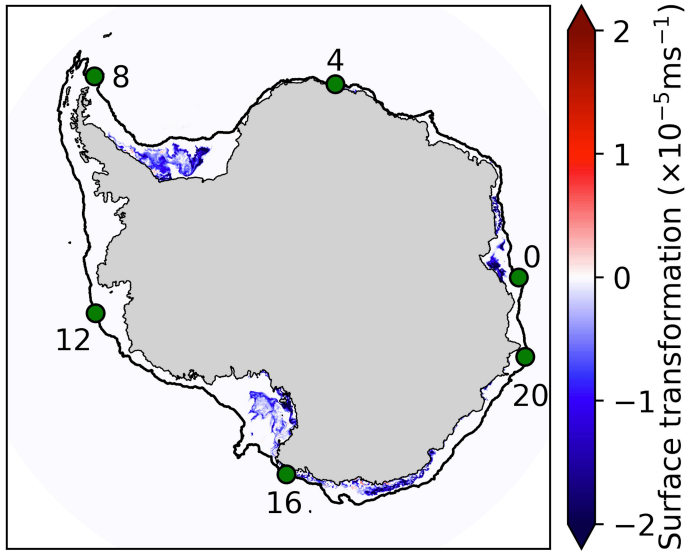
- Excellent simulation of dense water production compared with other models.
- Locations and formation rate are reasonable − surprising given coarse resolution forcing.

[New JRA55-forced ACCESS-OM2 model looks very similar, except with 11 Sv of surface transformation.]

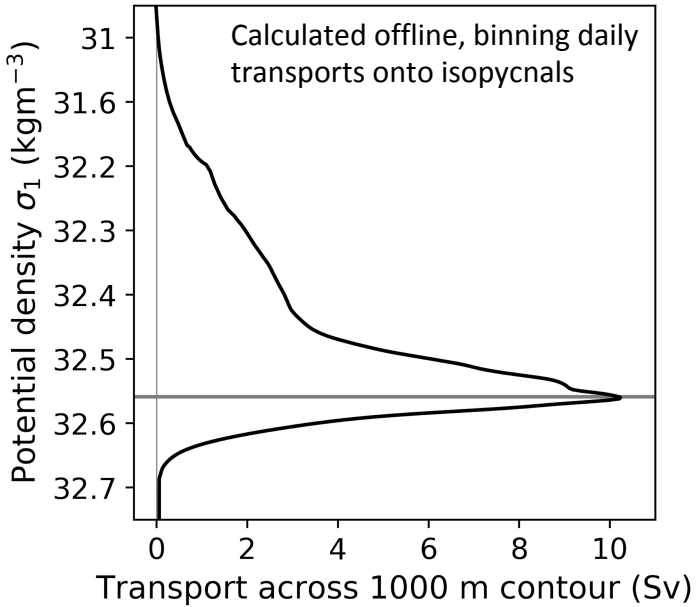
Circumpolar integrated cross-slope transport

- The 6.9 Sv of dense water formed at the surface increases to 10.2 Sv flowing northwards across the 1000 m contour (due to entrainment / thermobaricity).
- Compares well with observations at upper slope: 8.1 ± 2.6 Sv (Orsi et al. 2002).

a) Dense water formation, and 1000 m isobath contour

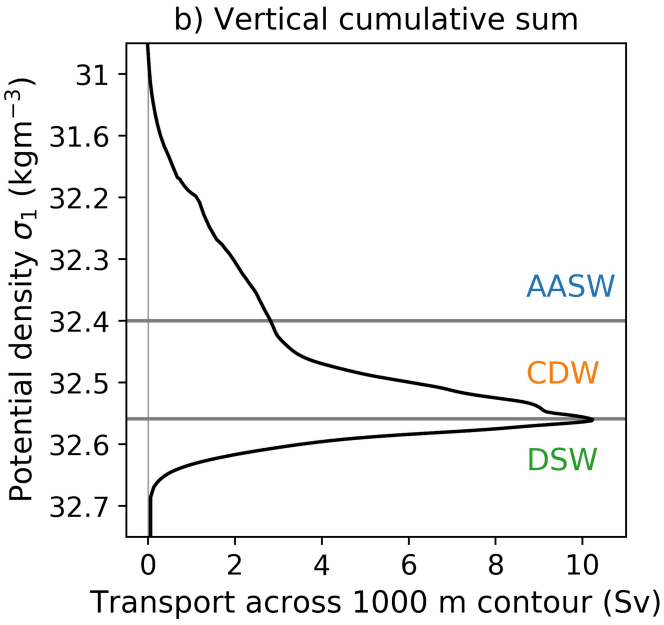


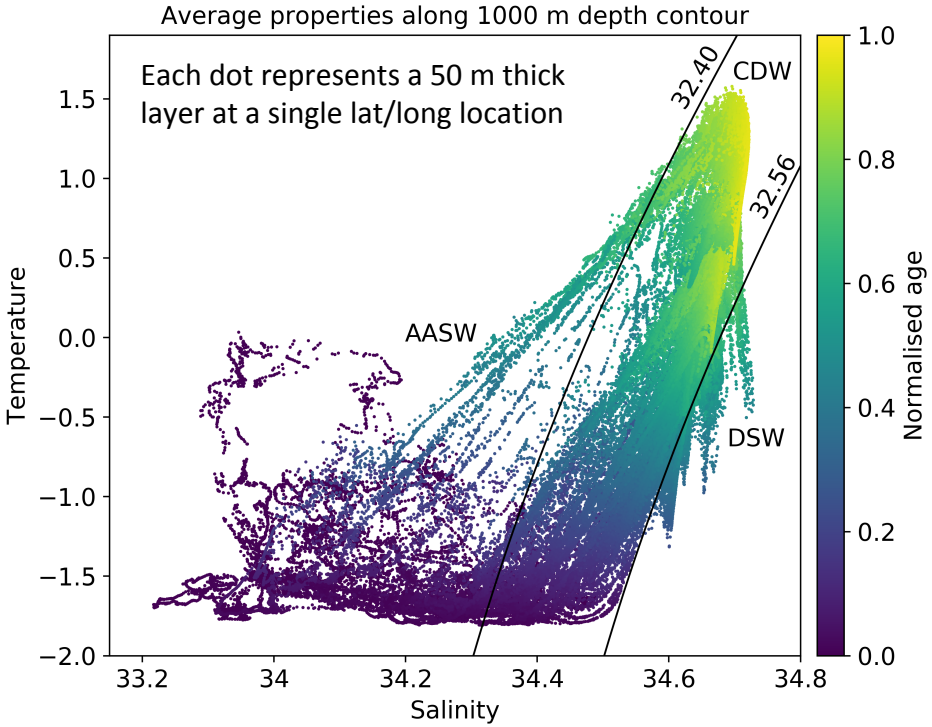
b) Vertical cumulative sum



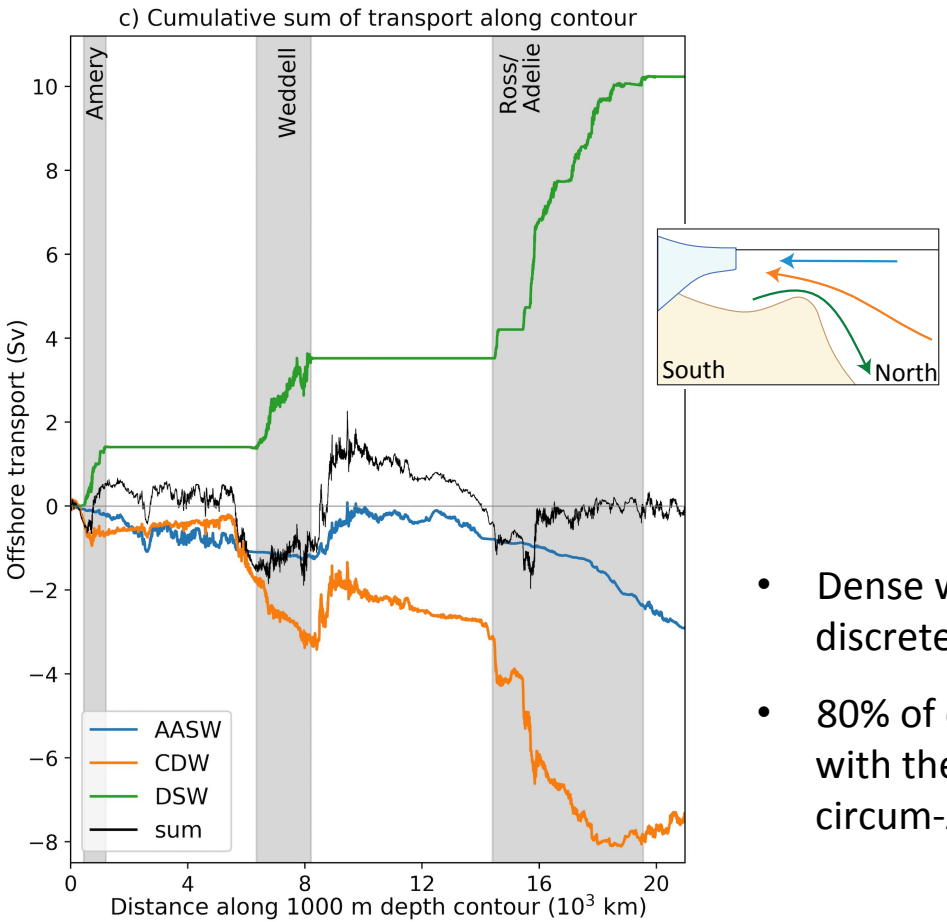
Water mass definitions

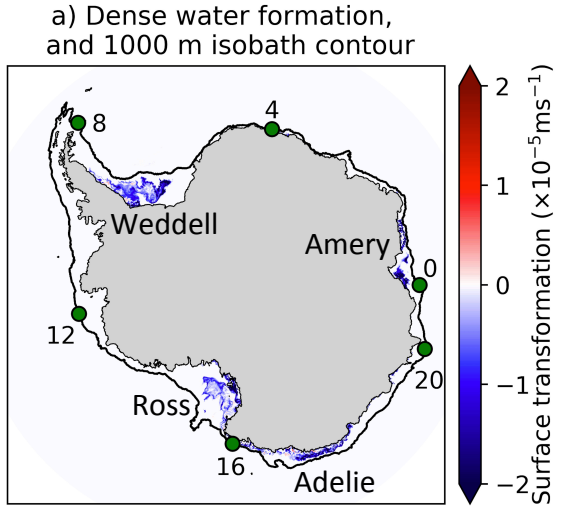
- Circumpolar definitions are difficult, because the temperature, salinity and density of water masses can vary around Antarctica.
- Therefore we choose simple, density threshold based definitions.





Regional variation in cross-slope transports

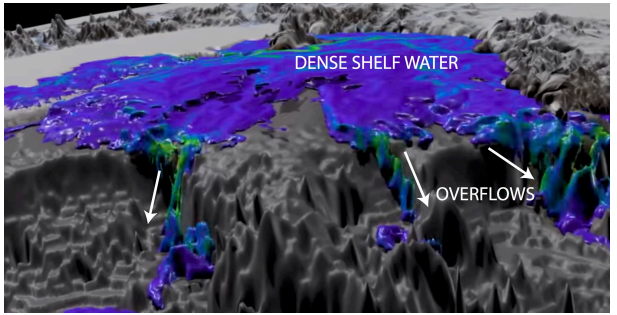


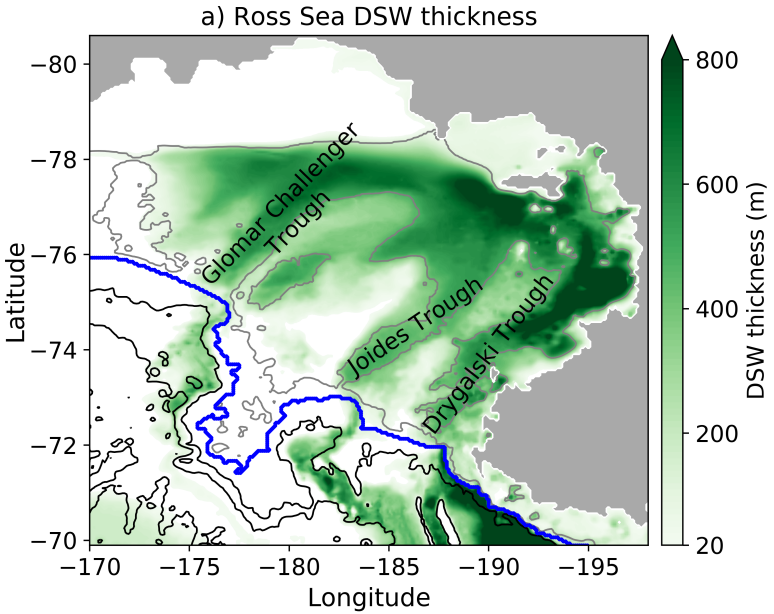


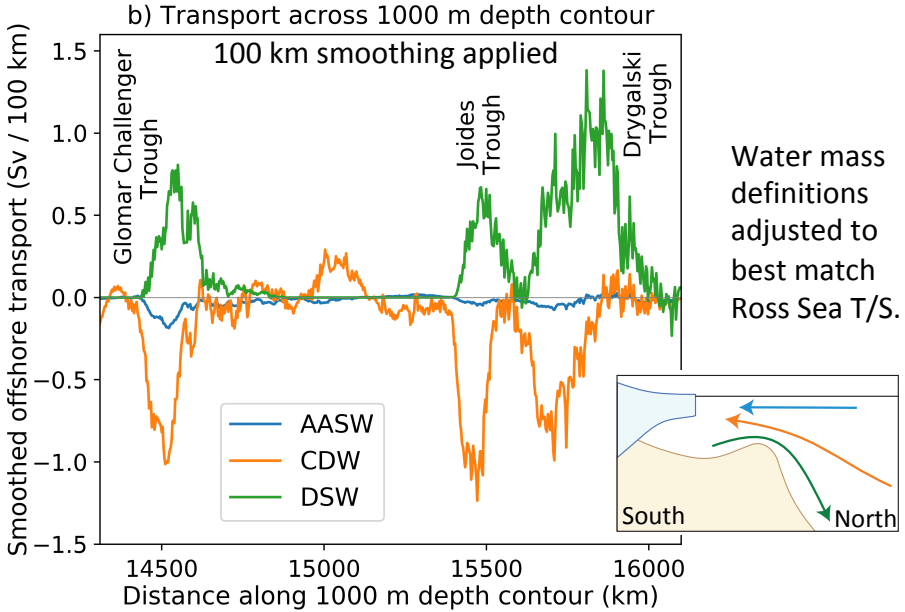
- Dense water (DSW) forms and overflows the shelf in discrete locations.
- 80% of on-shore warm CDW transport is collocated with the dense overflows (representing only 32% of circum-Antarctic contour).

Ross Sea cross-slope transports

- Localised spatial correlations between on- and off-shore flow.
- Cross-slope transports are focused in canyons.
- CDW on-shore flow is enhanced and offset ~20 km upstream of overflows.



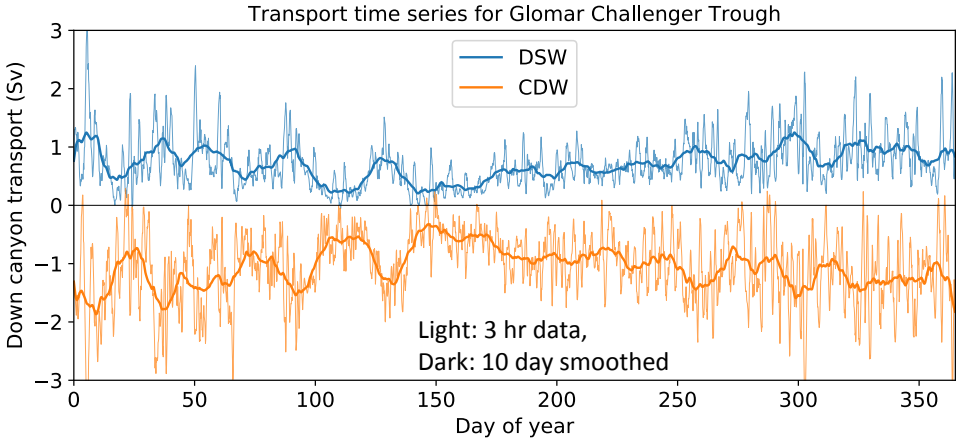




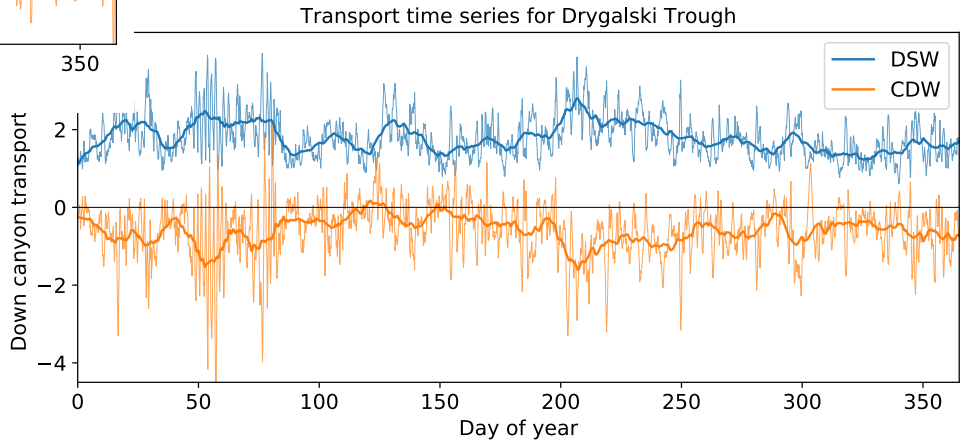
Water mass definitions adjusted to best match Ross Sea T/S.

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.



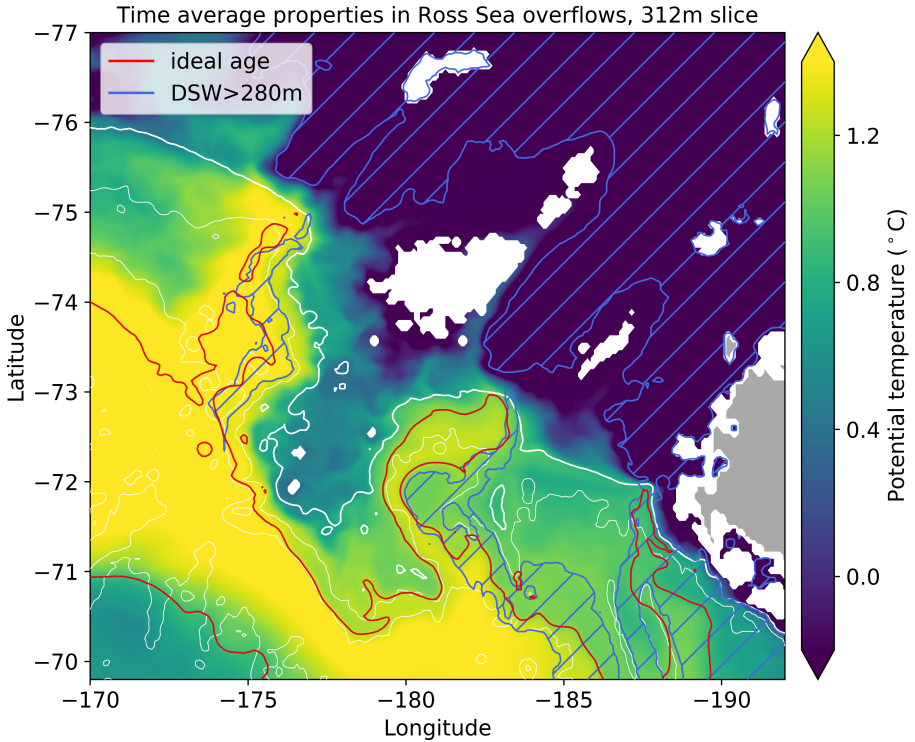
Canyon	Correlation coefficient (r)
Glomar Challenger	-0.71
Joides	-0.74
Drygalski	-0.71

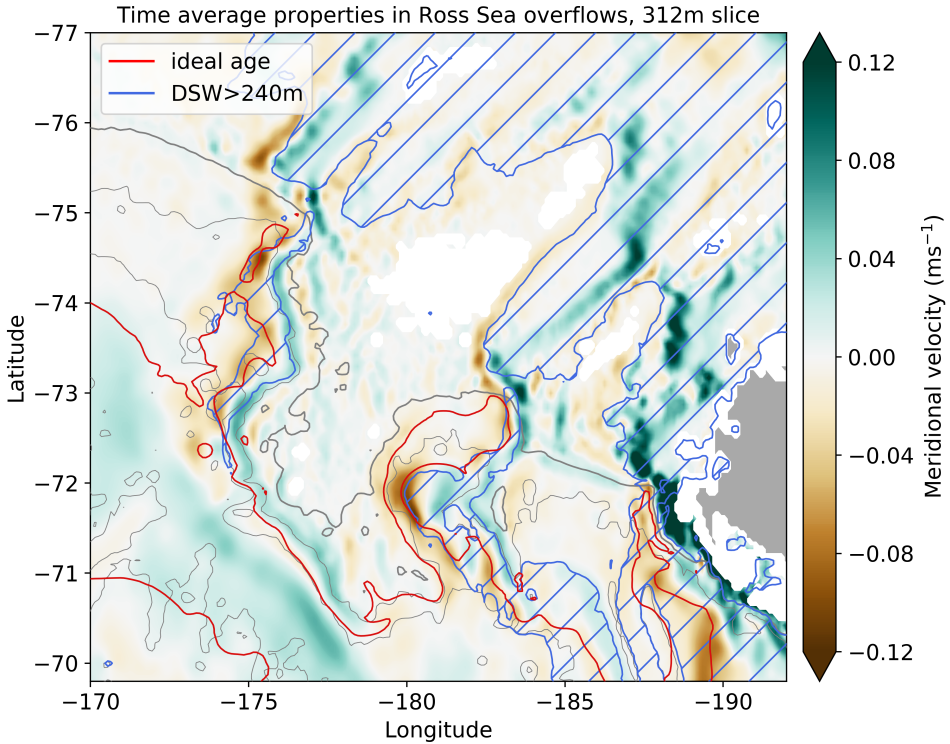


Water mass definitions adjusted to best match individual canyons.

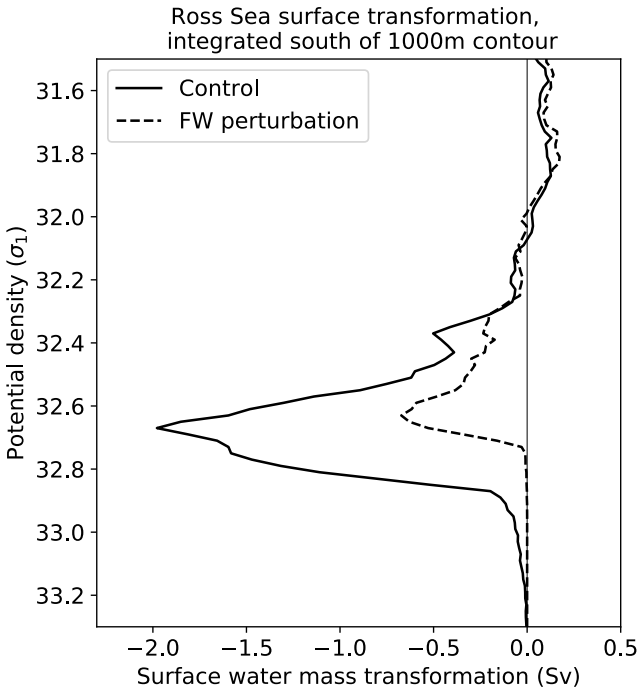
Spatial correlations of Ross Sea cross-slope transports

- CDW flows onshore following pathway of overflowing DSW.

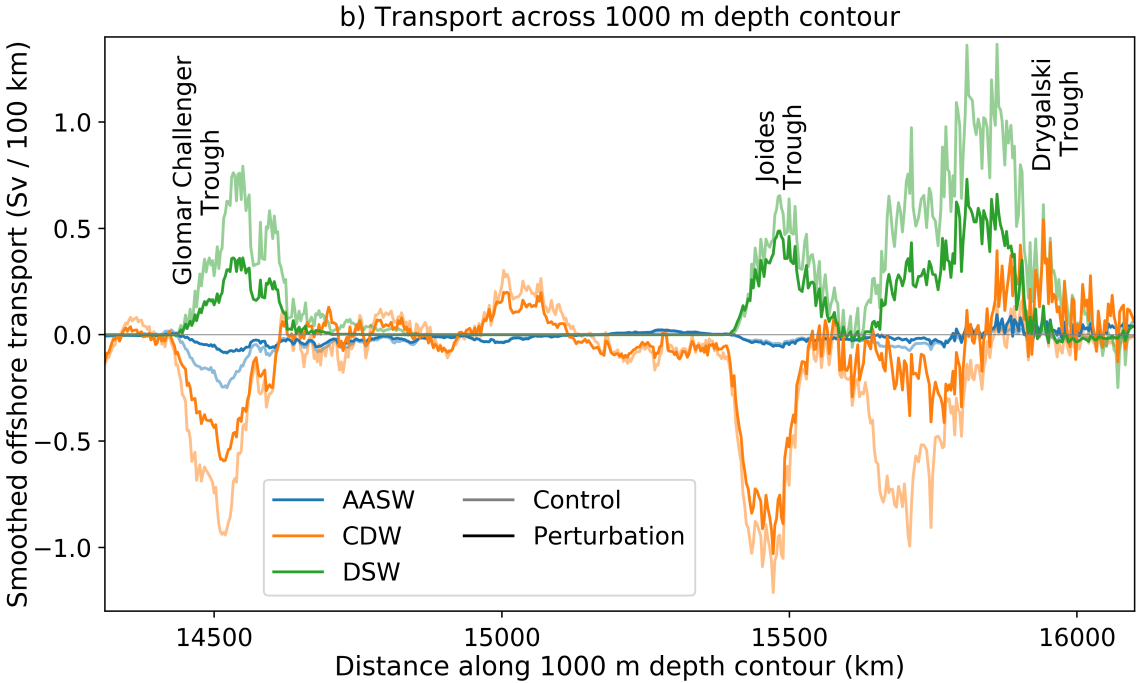




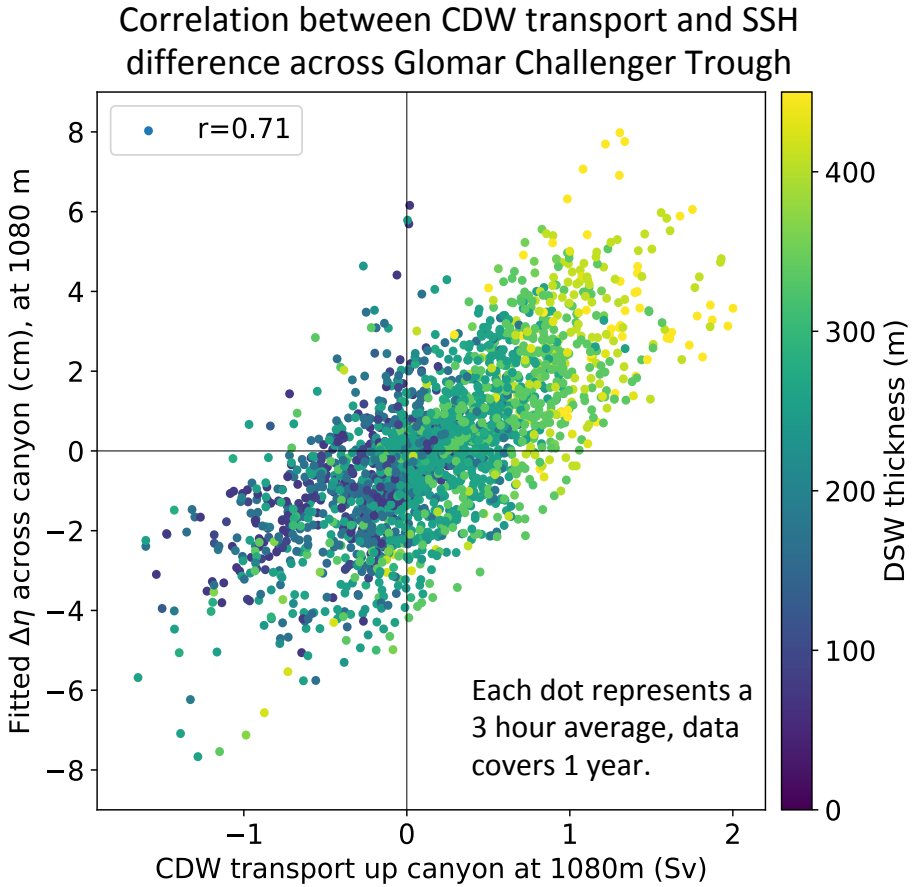
Is there a dynamical connection between DSW and CDW?



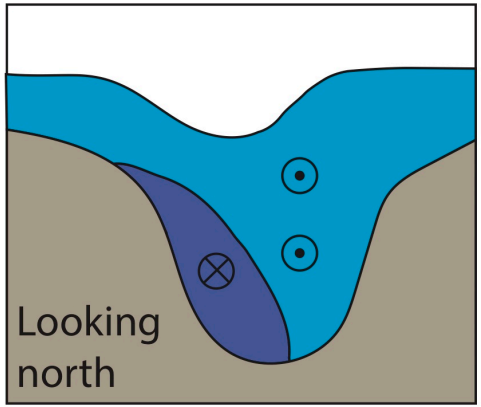
- Additional fresh water added to Ross Sea for 4 years.
- Response analysed for final 2 years.
- Both on-shore CDW and AASW transport decrease.



Proposed mechanism driving CDW transport



- Dense water pulses modify across-canyon SSH gradients, leading to barotropic on-shore flow in lighter layers (Kampf 2005).



- We hypothesise that westward momentum is fluxed upwards from DSW to CDW via horizontal pressure gradients (form stress).
  (Stewart and Thompson 2016)

Conclusions

- In a global 0.1° ocean − sea ice model, cross-slope CDW transport is strongly localised and co-located with overflowing dense water.
- This is a possible mechanism to investigate in future observations.
- Could overturn our current view of the CDW transport distribution.
- Caveats: no tides or ice shelf cavities, limited resolution.