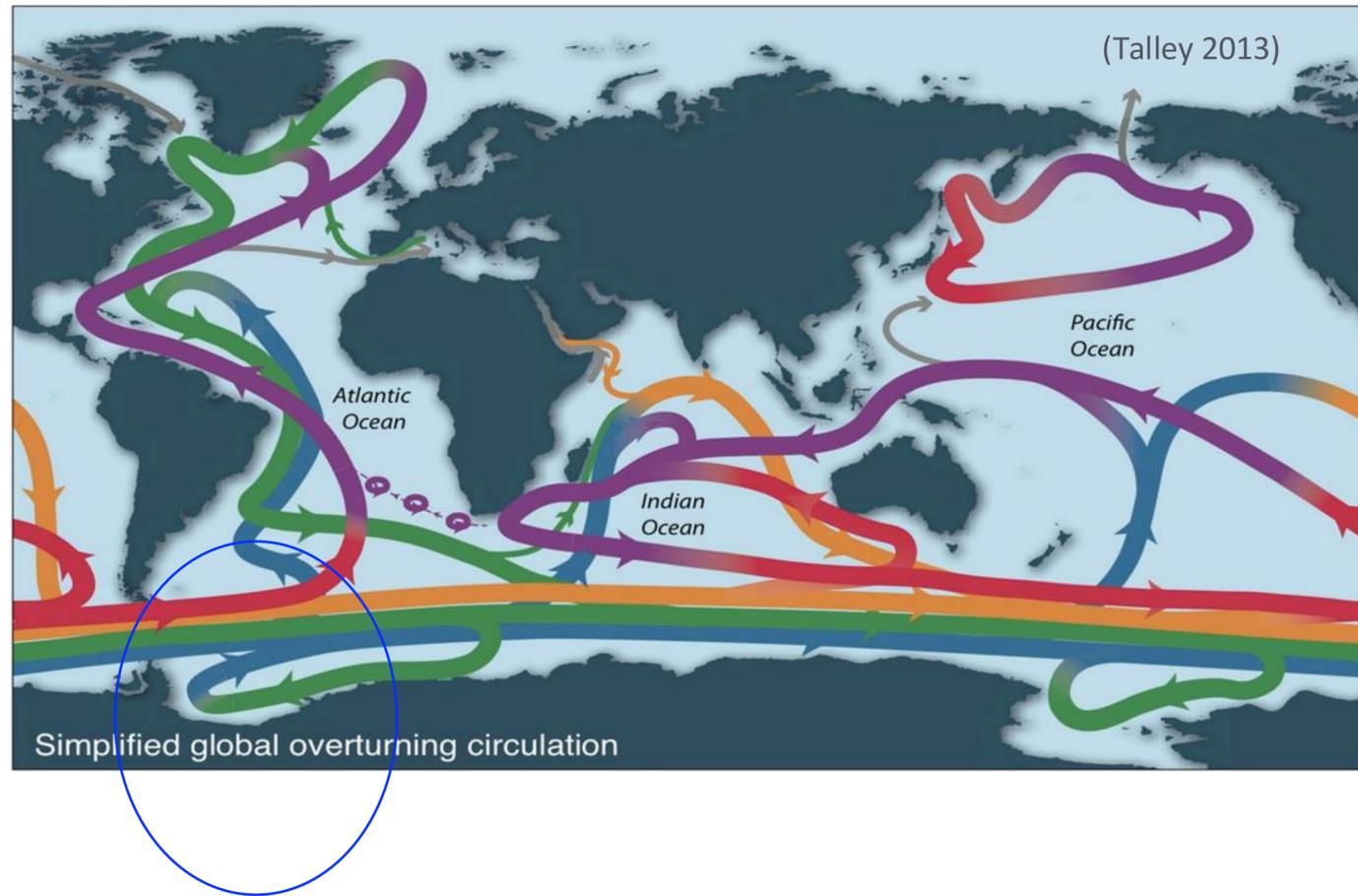


On the role of the Antarctic Bottom Water in the Atlantic Meridional Overturning Circulation

Marina Noro, Ilana Wainer, Tiago S. Dotto



**National
Oceanography
Centre**



The Weddell Sea produces up to 50% of AABW as part of the global overturning circulation.

(Meredith, MP; 2013 Nat Geosc)

Goal: Understand how changes in Antarctic Bottom Water (AABW) impact the AMOC.

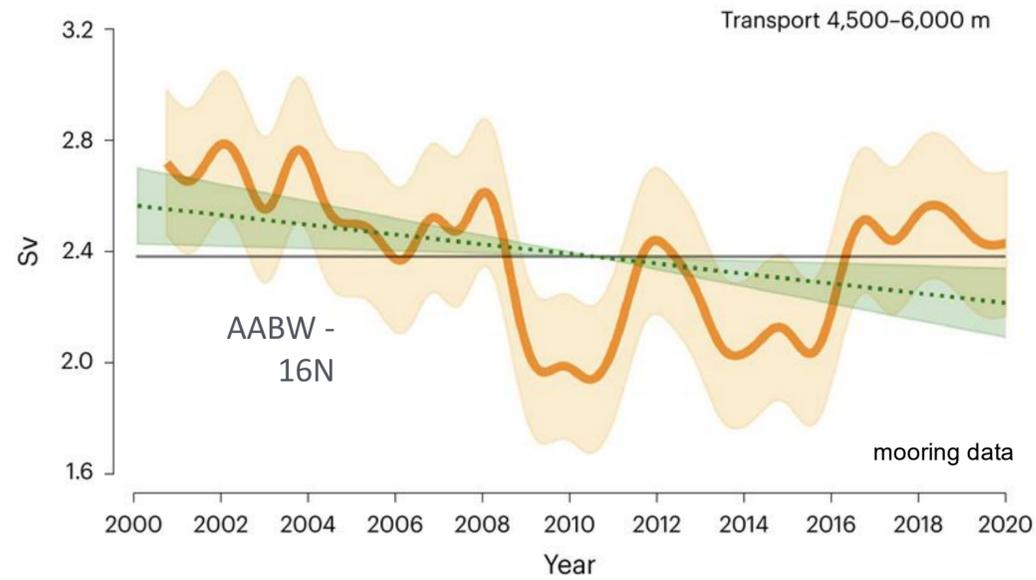
AABW represents 30-40% of the global ocean volume (Johnson, GC; 2008 JGR).

Important because it regulates Earth's climate by storing and transporting heat and carbon throughout the ocean as part of the global overturning.

What is happening with AABW?

Recent OBS show decline in AABW transport

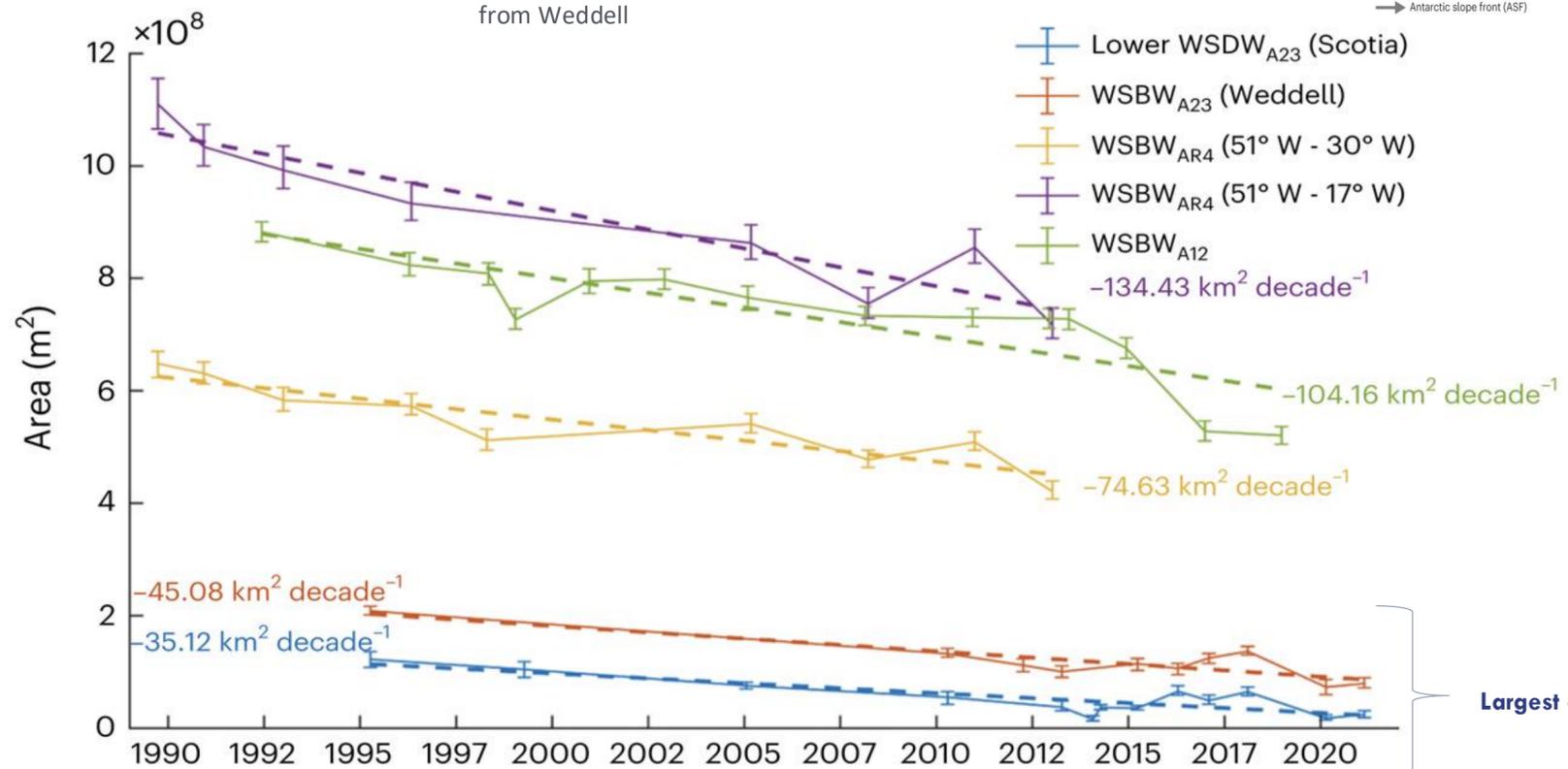
↓ $12 \pm 5\%$



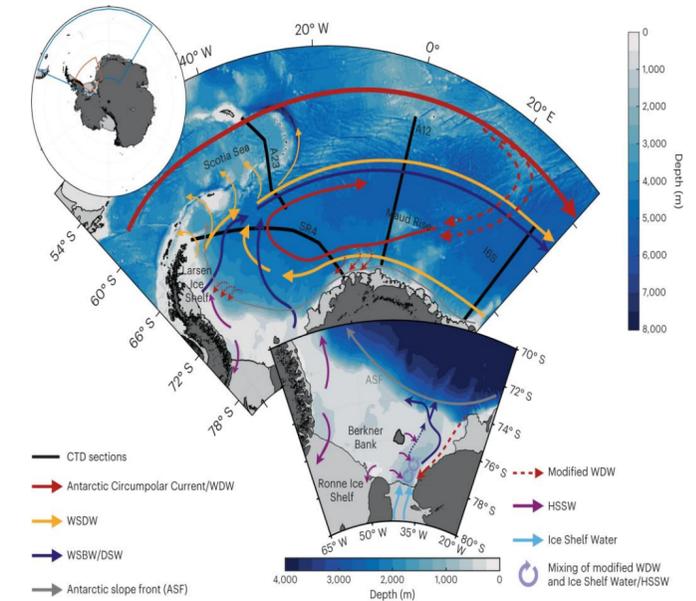
(Biló et al. 2024)

↓ 30%

Reduction of AABW exported from Weddell



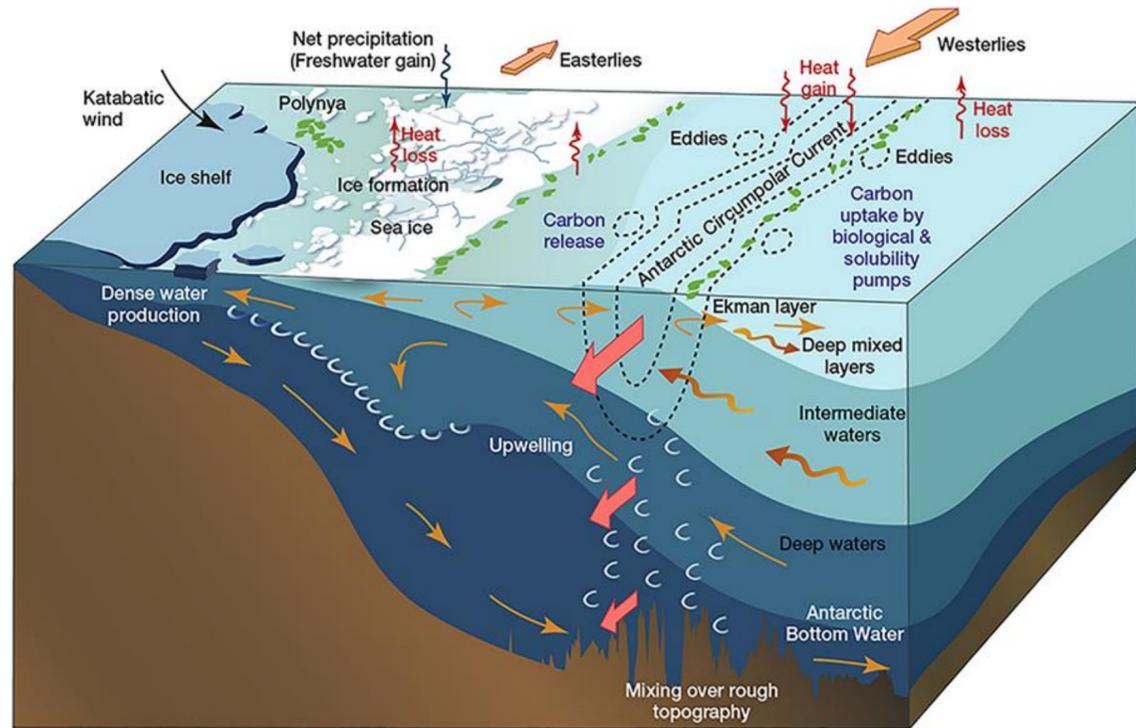
(Zhou et al. 2023)



Largest decrease in the densest water classes

Surface Water Mass Transformation (WMT):

Surface WMT analysis helps understanding surface drivers of ocean density-space overturning



We want to identify anomalous periods of **WMT** for the SO and examine how it relates to

- AABW properties;
- AMOC isopycnal;
- Wind stress and
- SIC.

simplified view of processes to illustrate complexity of the SO
(Kennicutt et al. 2019)

$$\text{WMT} \quad \Omega(\sigma, y, t) = \frac{1}{\Delta\sigma} \iint_A -\frac{\alpha}{C_p} Q - \beta \frac{1}{1-S} F_w dA$$

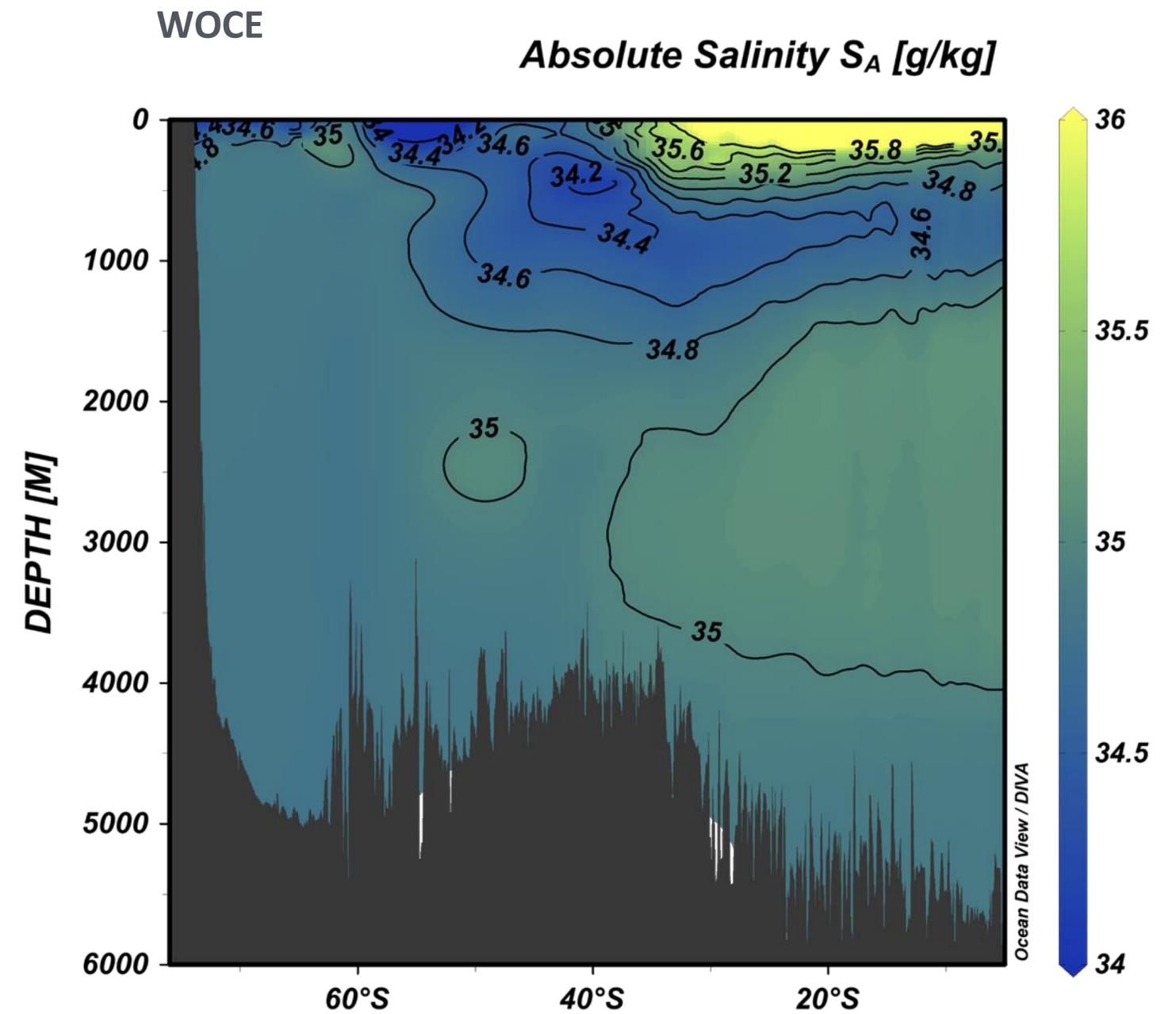
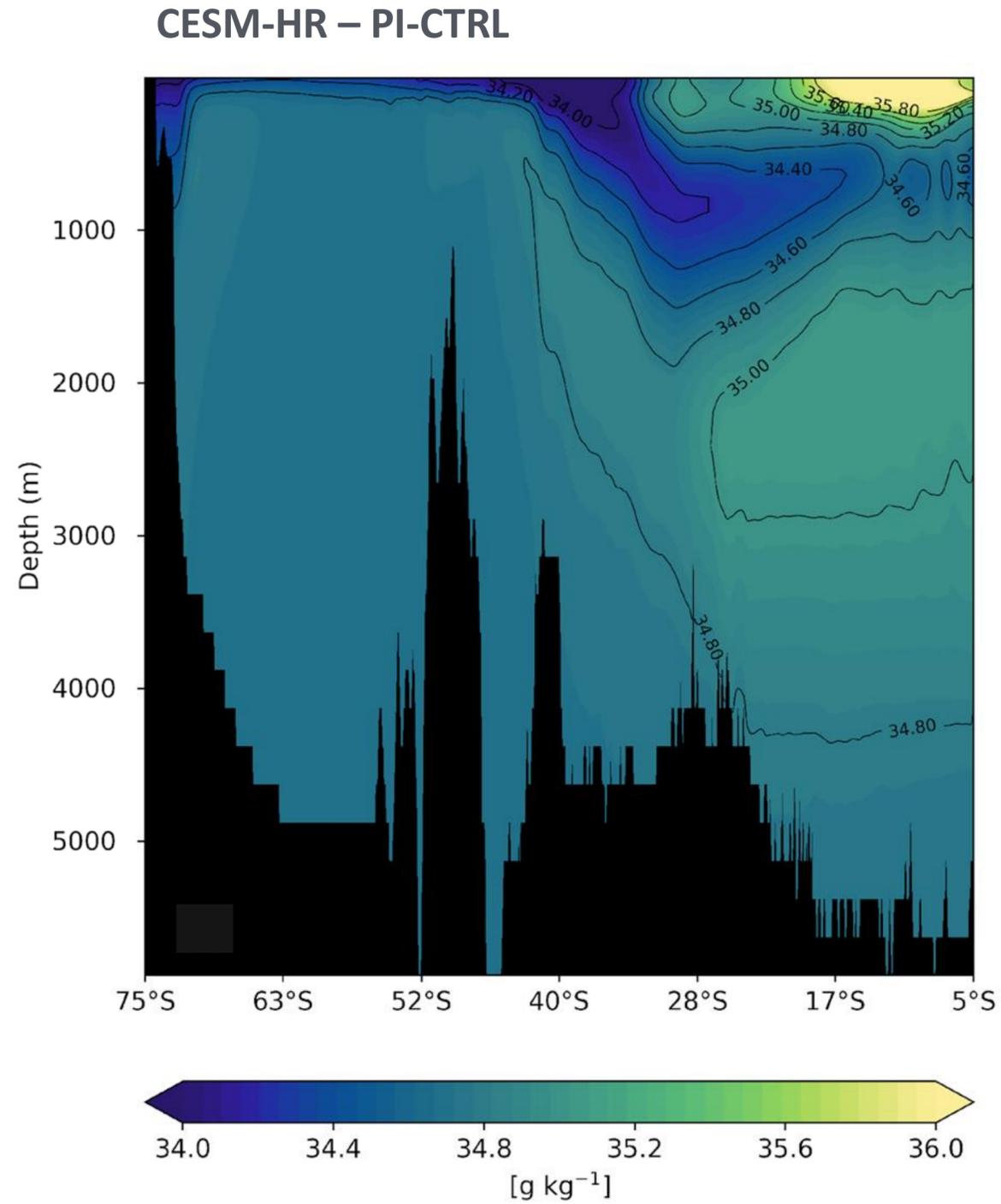
Data: MESoscale Atmosphere-Ocean Interactions
in Seasonal-to-Decadal CLimate Prediction
(MESACLIP)

AMOC
isopycnal

$$\psi^\sigma(y, t) = - \int_{\sigma_b}^{\sigma} d\sigma \int_{X_W}^{X_E} v(\sigma, x, y, t) dx$$

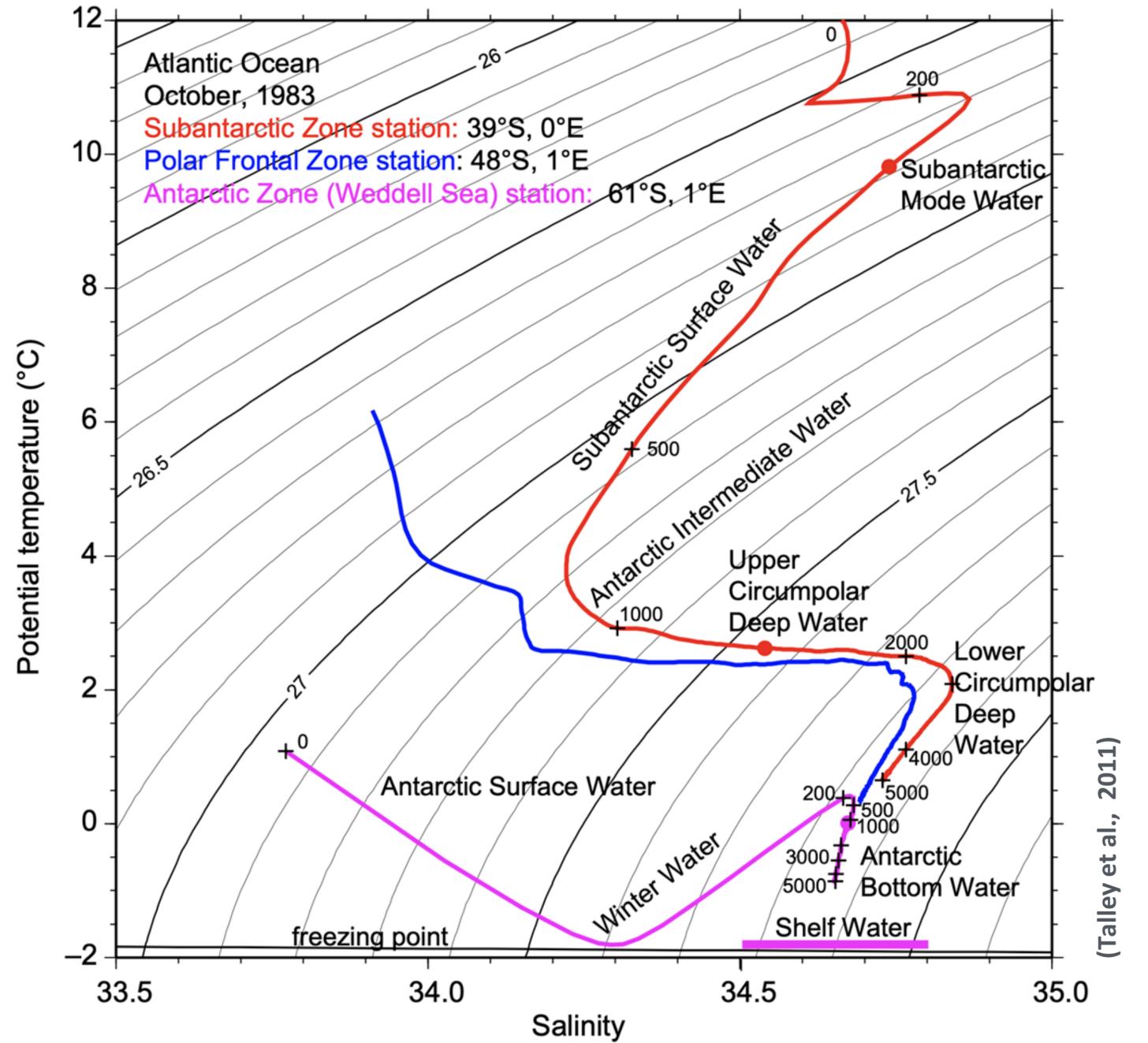
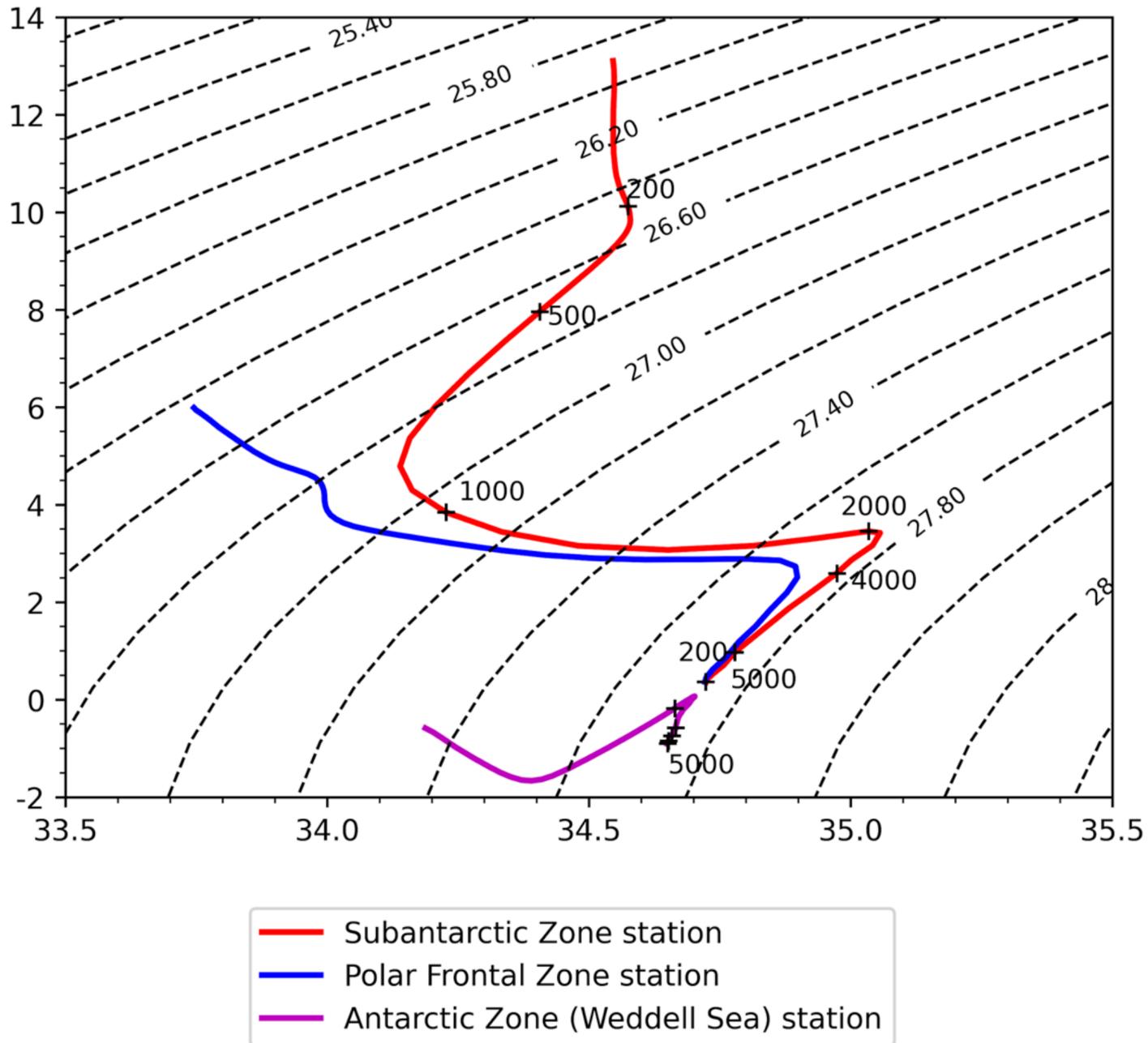
Validation

Vertical Sections — South Atlantic (25W)



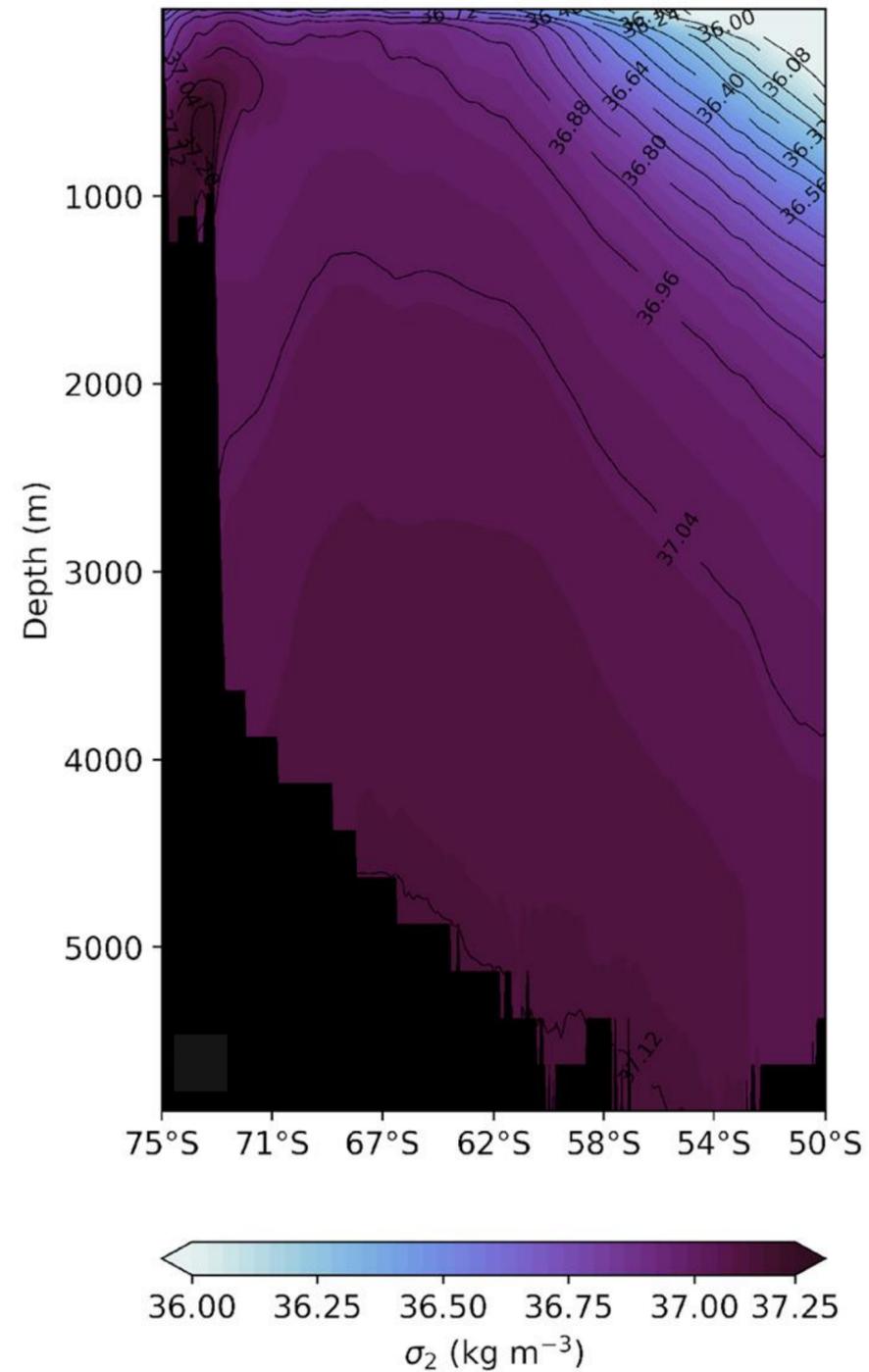
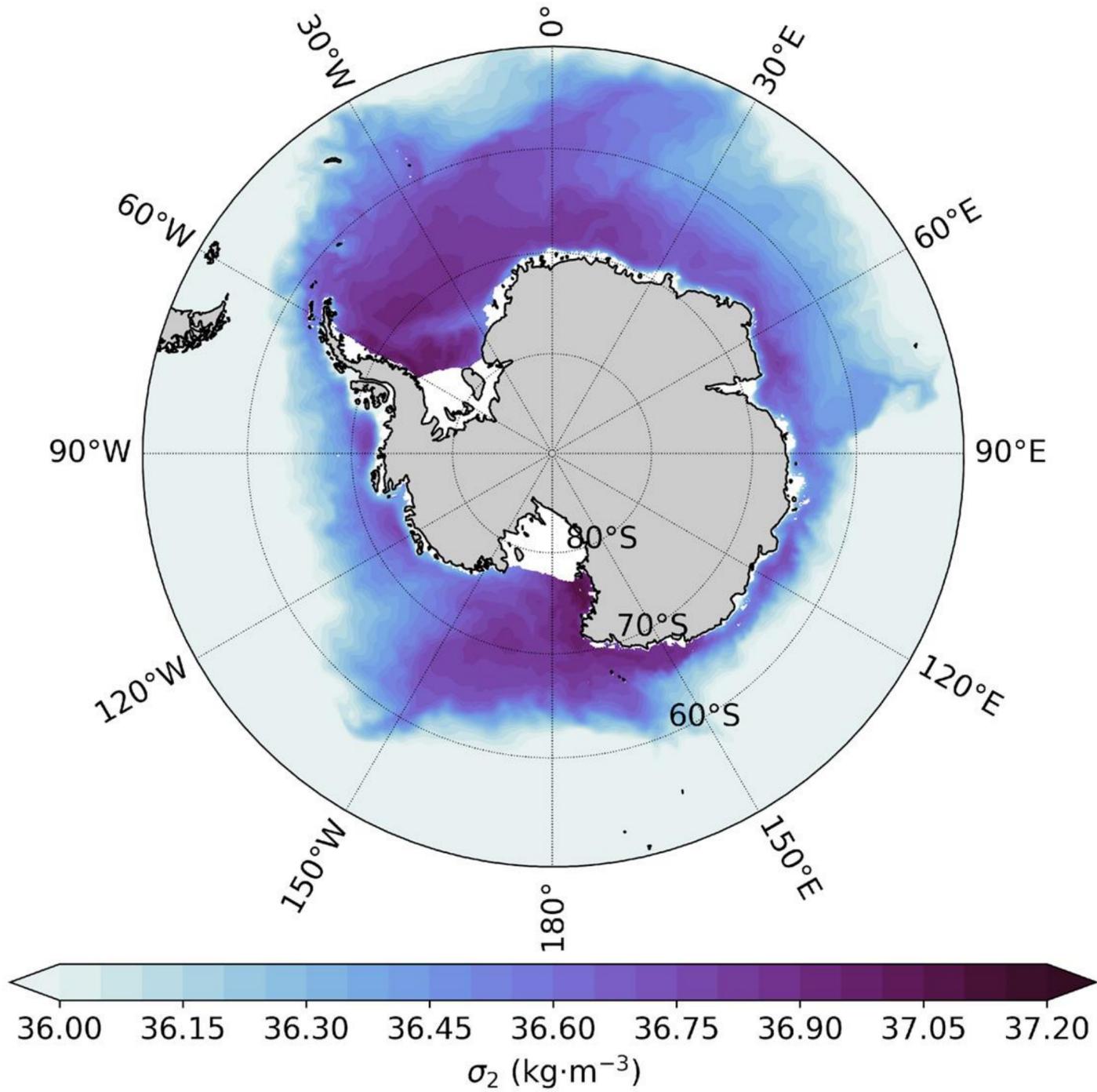
Validation (2)

T/S — South Atlantic Sector



Dense Water analysis

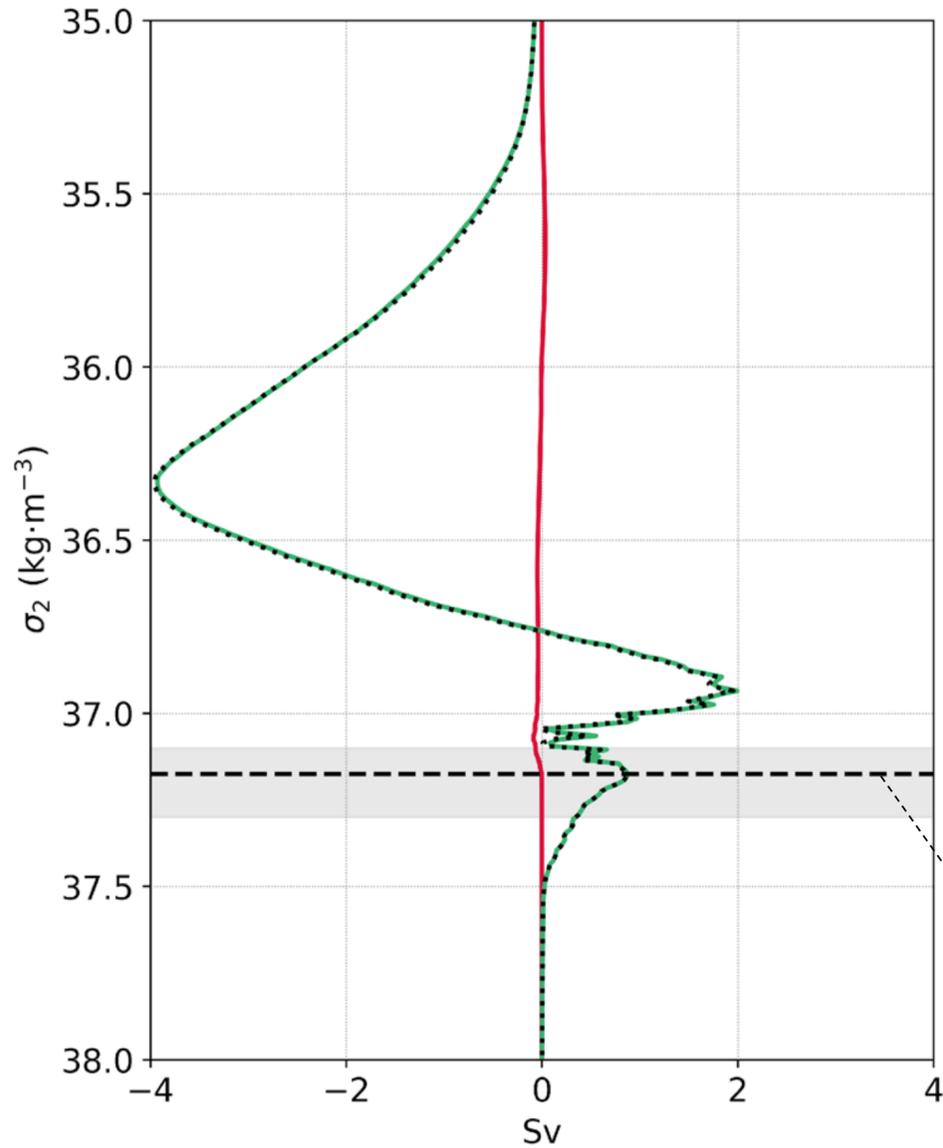
Potential Density (referenced to 2000m - σ_2) — Southern Ocean



we define the range from 35 to 38 $\text{kg}\cdot\text{m}^{-3}$, with increments of 0.01 $\text{kg}\cdot\text{m}^{-3}$, to define the isopycnal bins required for the calculation of the SWMT.

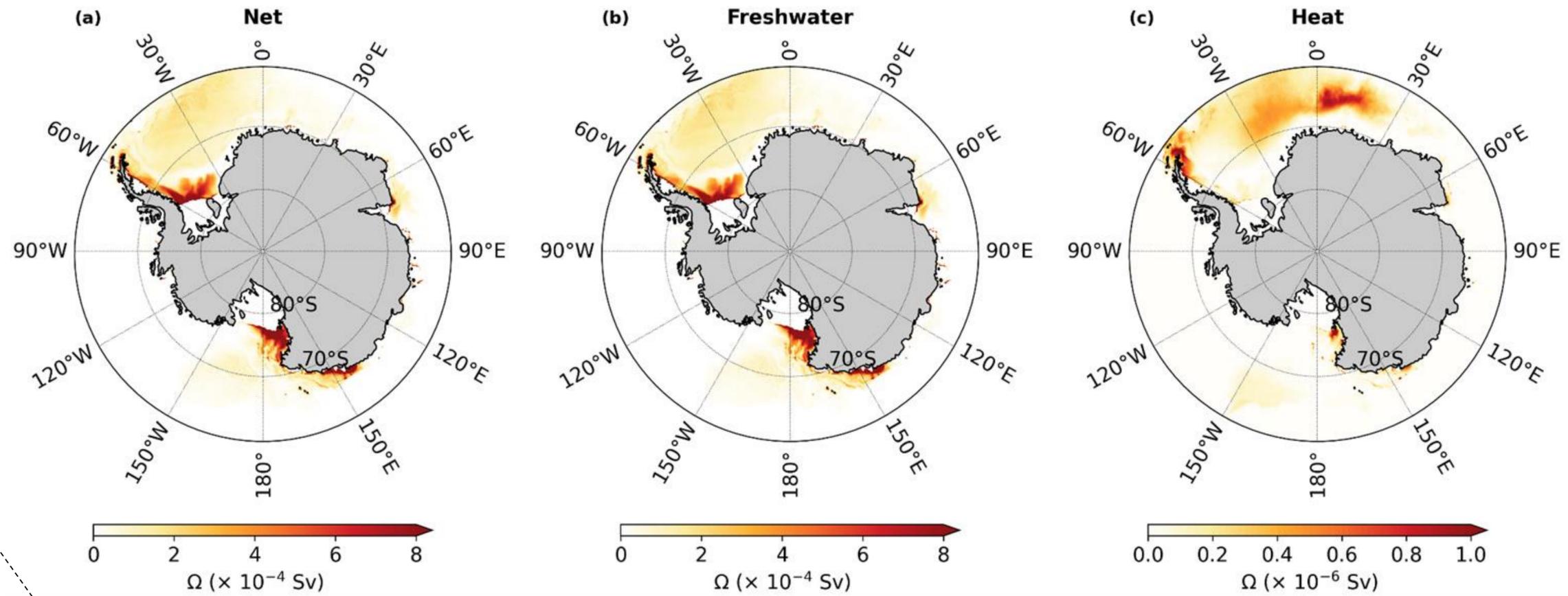
$$\Delta\sigma_2 = 35 \text{ to } 38 \text{ kg m}^{-3}$$

Water Mass Transformation PI-CTRL — Southern Ocean



- Total Heat Driven Transformation
- Total Freshwater Driven Transformation
- ⋯ Total Surface Transformation

Maps of max WMT rate for the layer below 37.0 kg m⁻³ avg for each yr



(2 orders of mag. Lower)

-- Maximum transformation rate associated with Dense Shelf Waters formation.

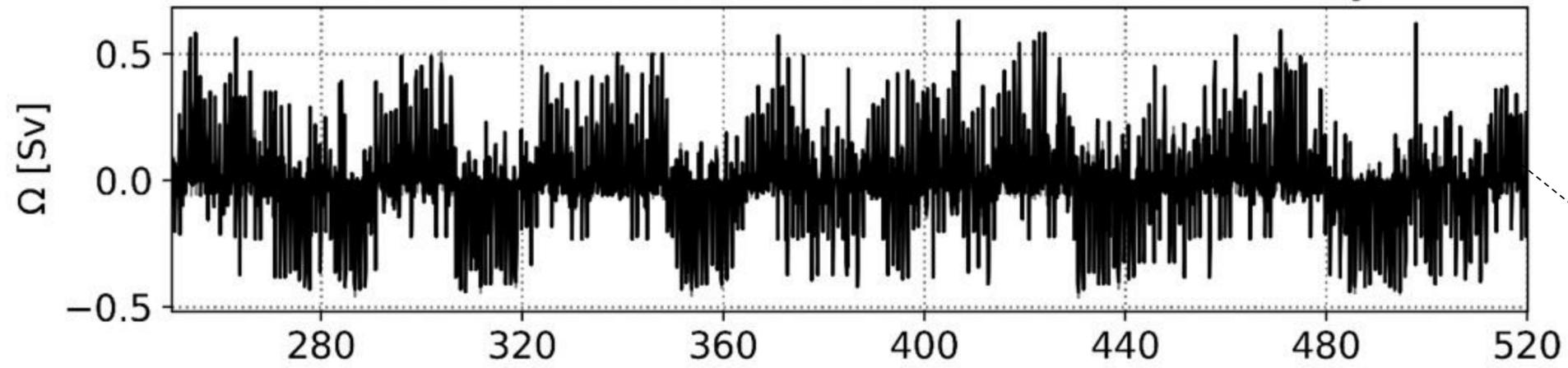
Freshwater fluxes dominates (buoyance loss)

$$\Omega(\sigma, y, t) = \frac{1}{\Delta\sigma} \iint_A -\frac{\alpha}{C_p} Q - \beta \frac{1}{1-S} F_w dA$$

Time Series

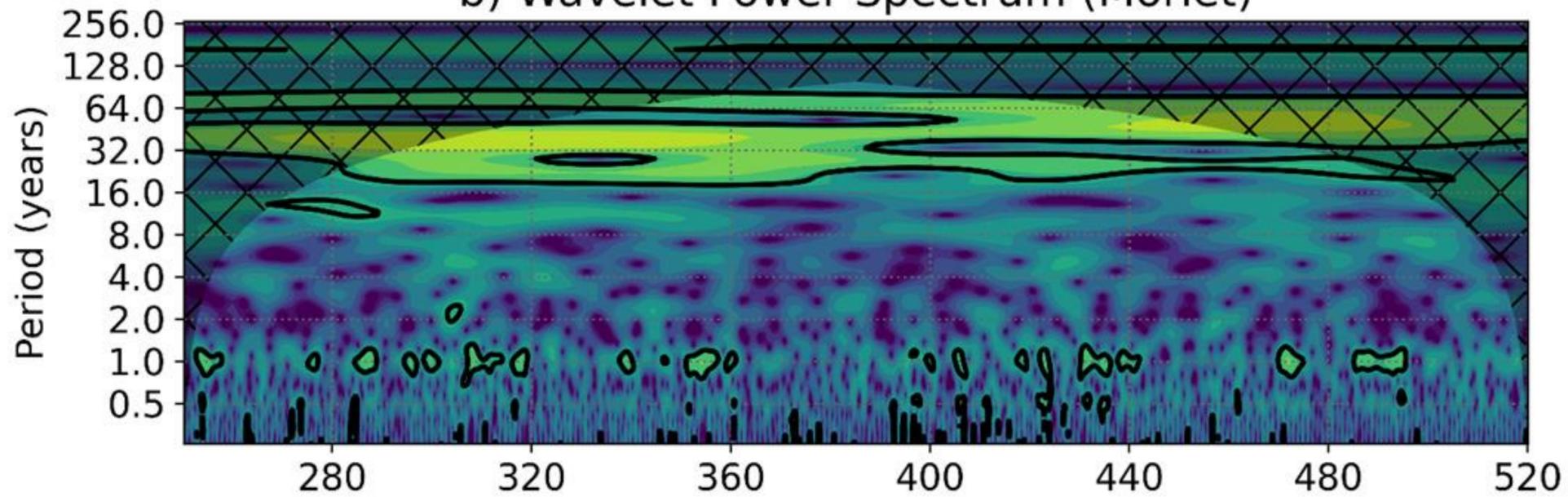
Max WMT for the layer below 37kgm^{-3} (area averaged) SO

a) Surface Water Mass Transformation Anomaly

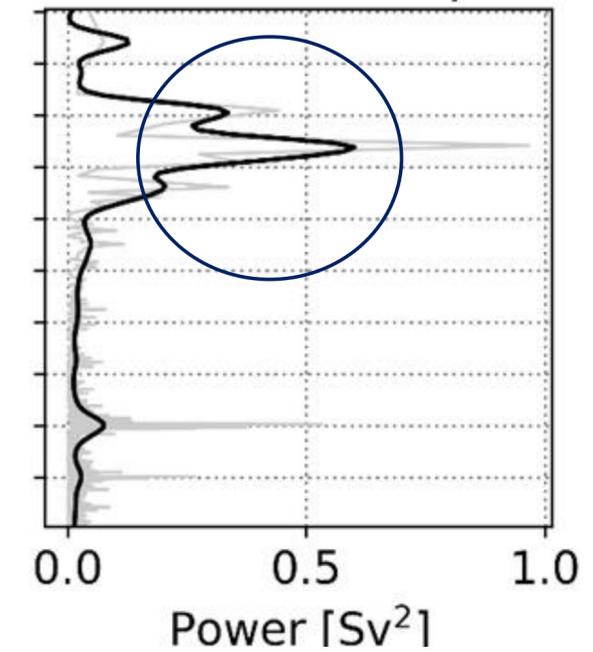


Maximum transformation rate associated with Dense Shelf Waters formation.

b) Wavelet Power Spectrum (Morlet)



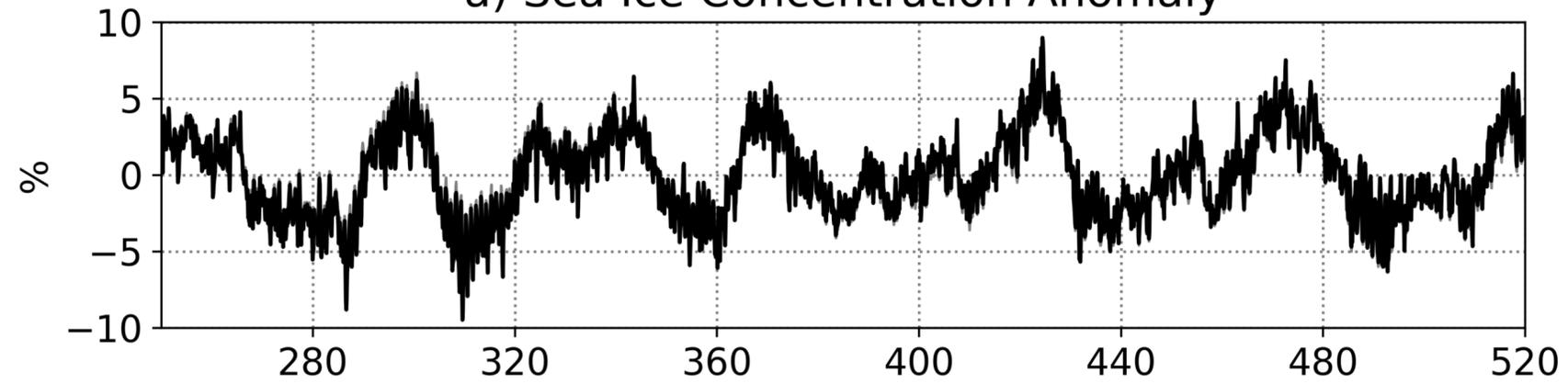
c) Global Wavelet Spectrum



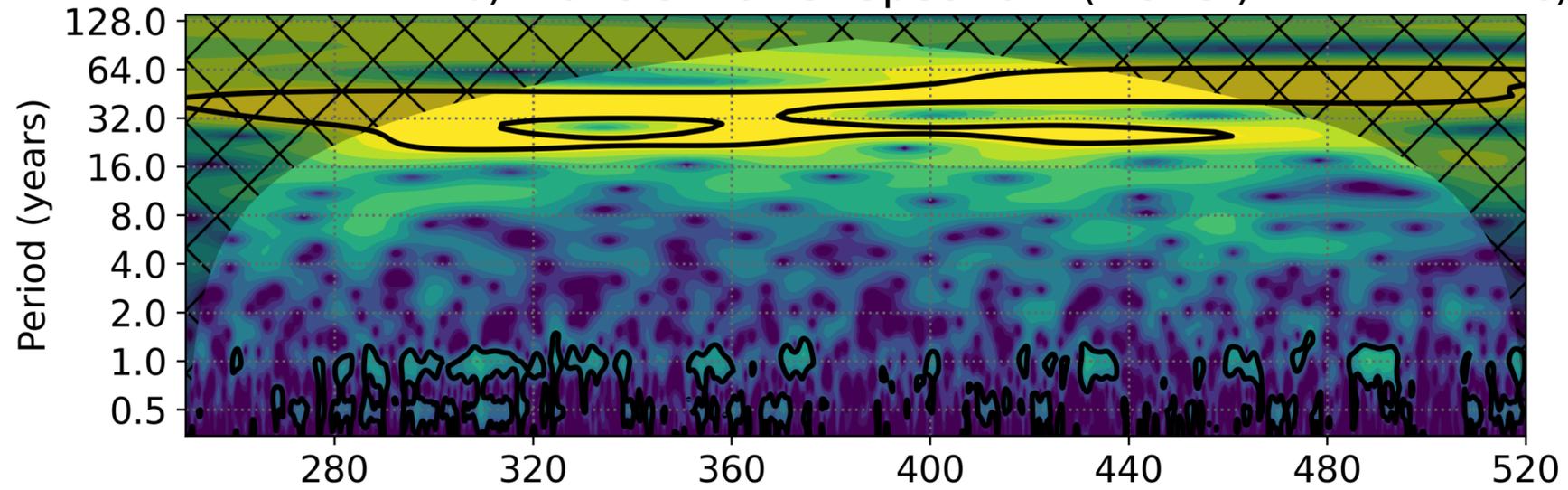
max ~48yrs

Sea Ice

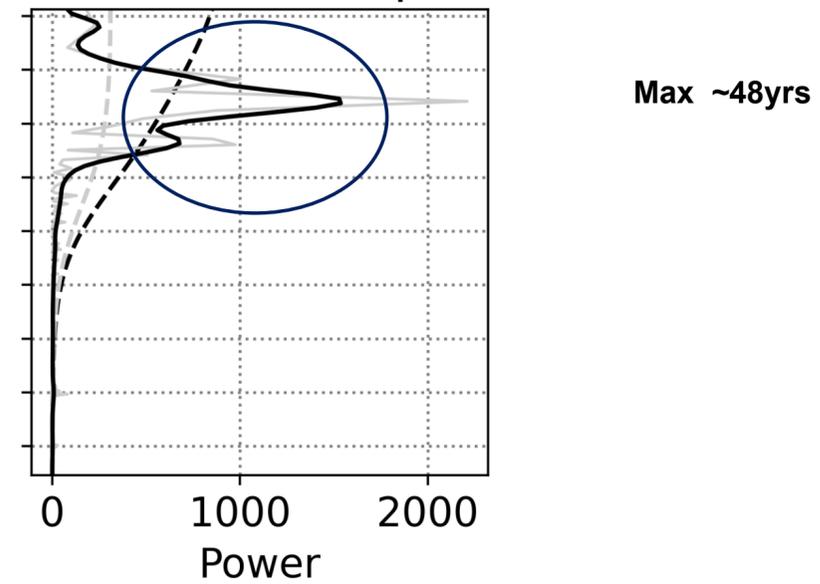
a) Sea Ice Concentration Anomaly



b) Wavelet Power Spectrum (Morlet)



c) Global Wavelet Spectrum



SIE linked to the multidecadal WMT variability.

SIC, Wind-stress

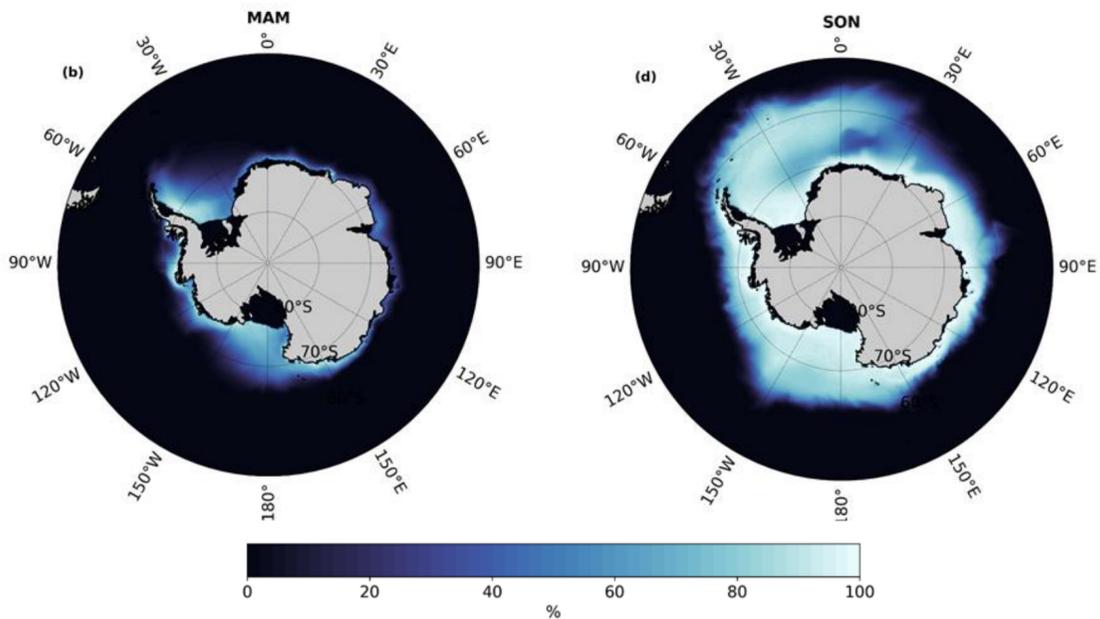
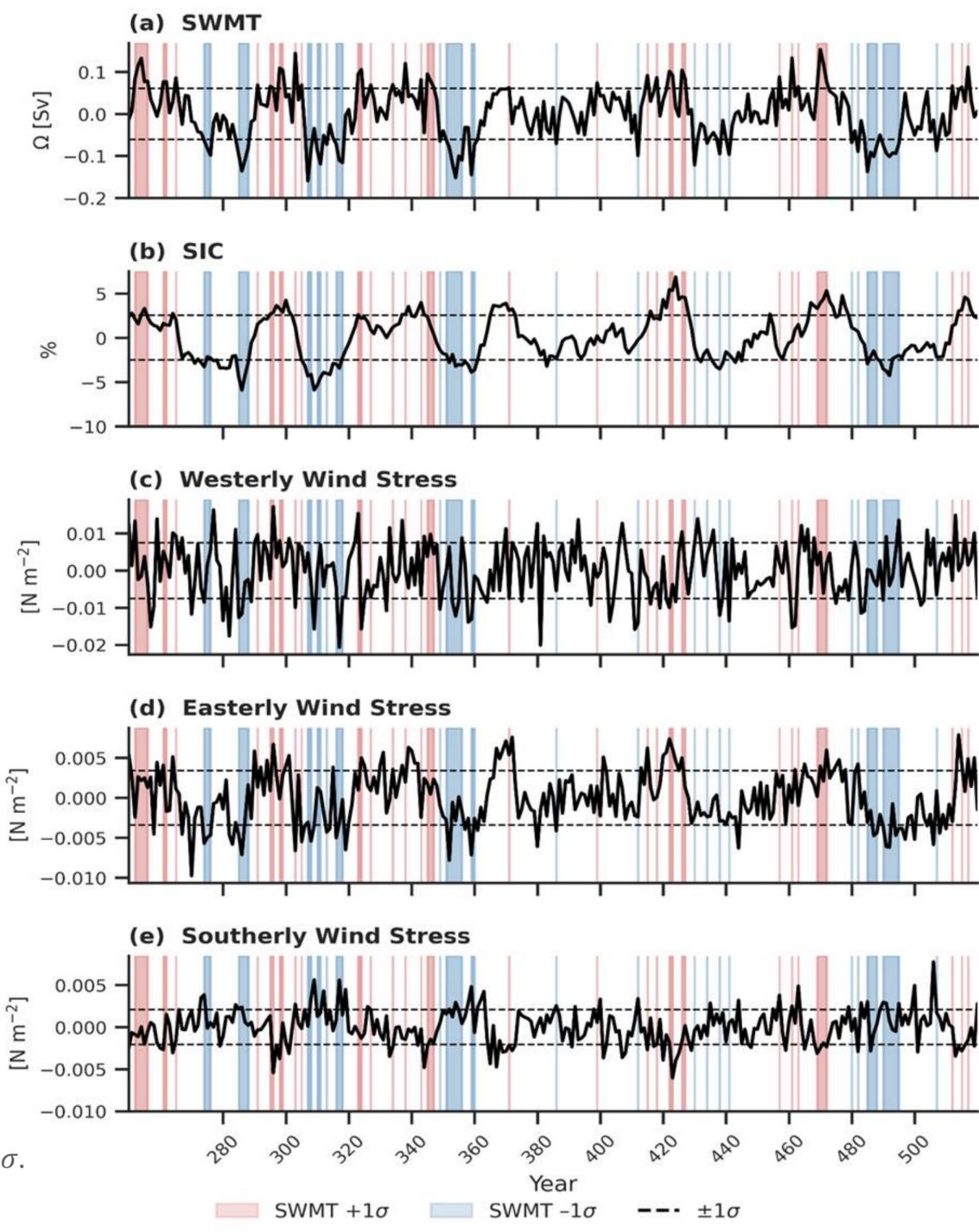
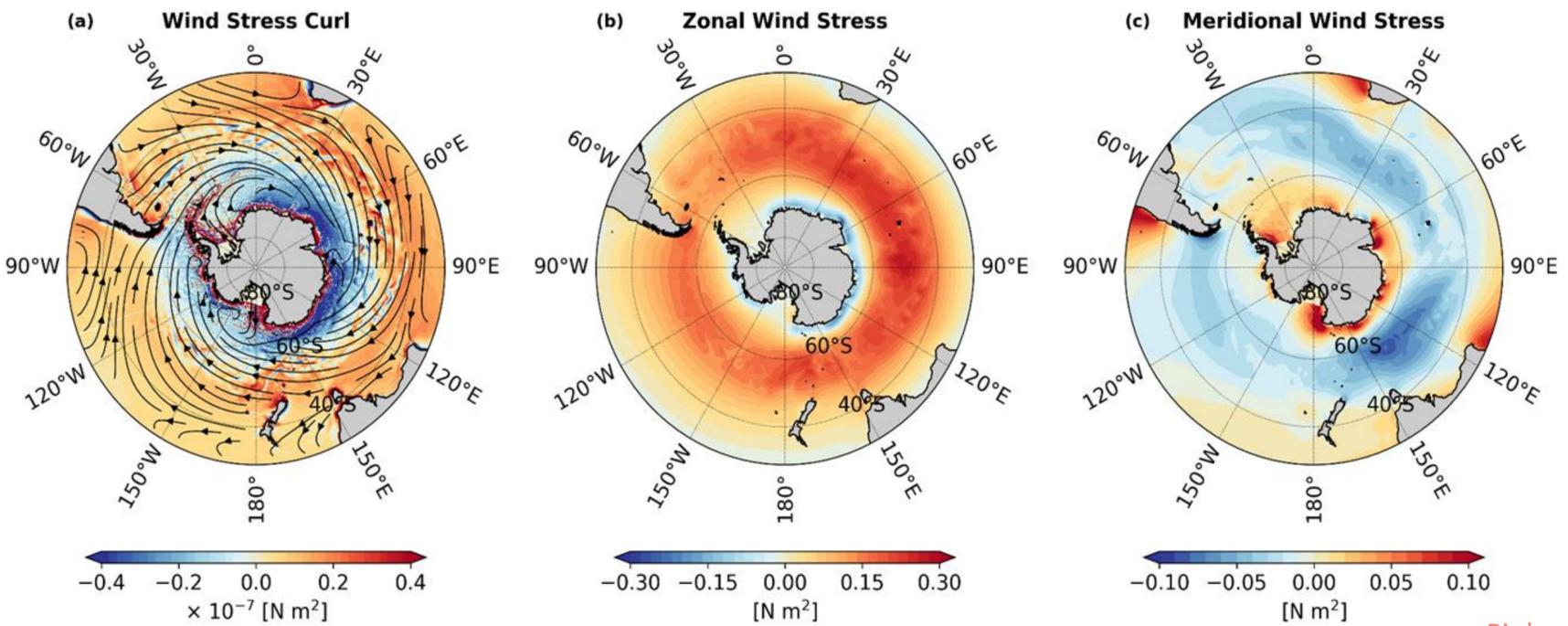


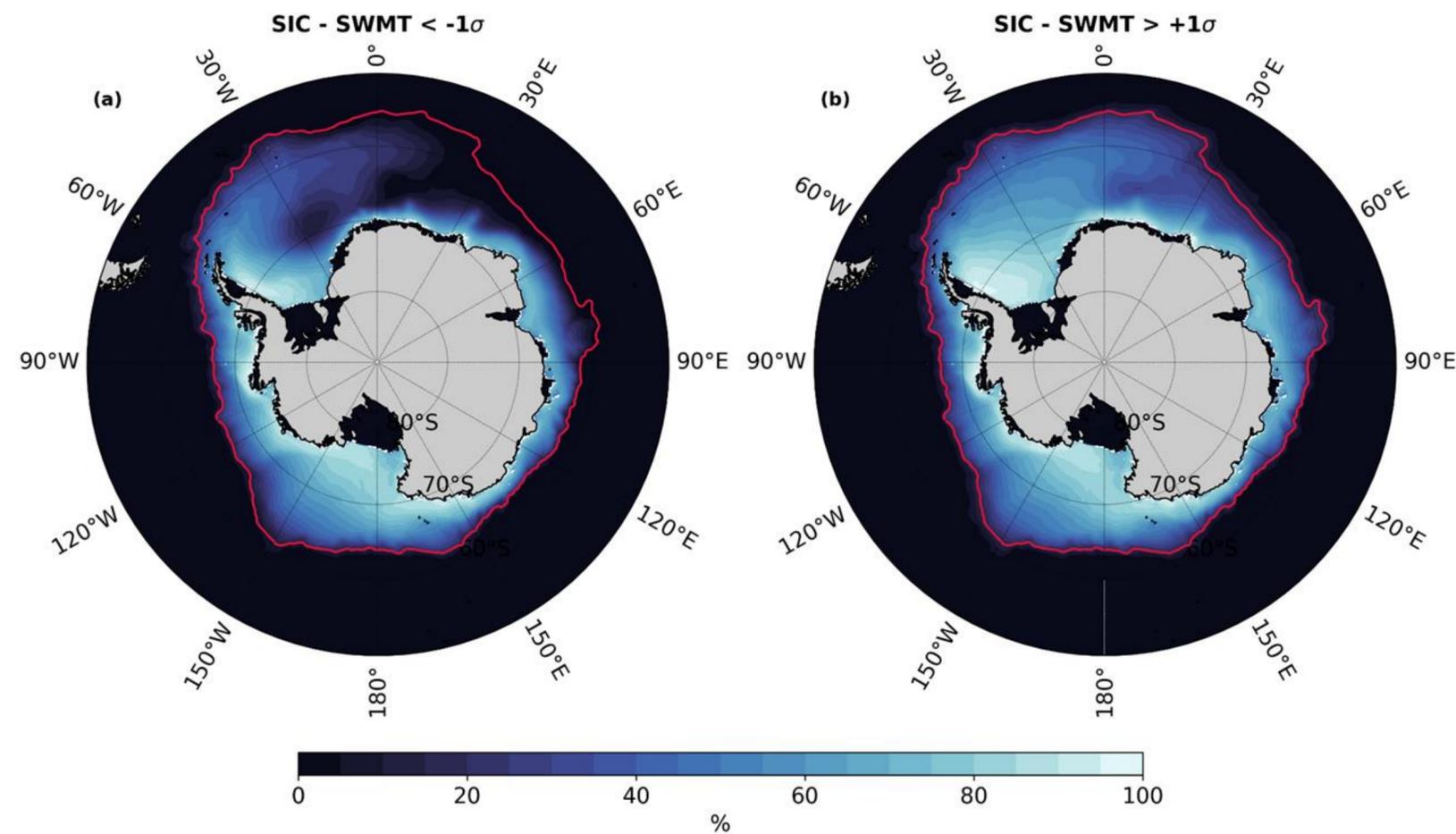
Table 1: Pearson correlation ($p < 0.05$)

Variable 1	Variable 2	r
SIC	SWMT	0.71
SIC	Westerlies	0.15
SIC	Easterlies	0.66
SIC	Southerly wind stress	-0.52
SWMT	Westerlies	0.14
SWMT	Easterlies	0.48
SWMT	Southerly wind stress	-0.37



Pink = years WMT above 1σ .
 Blue = yrs WMT below 1σ .

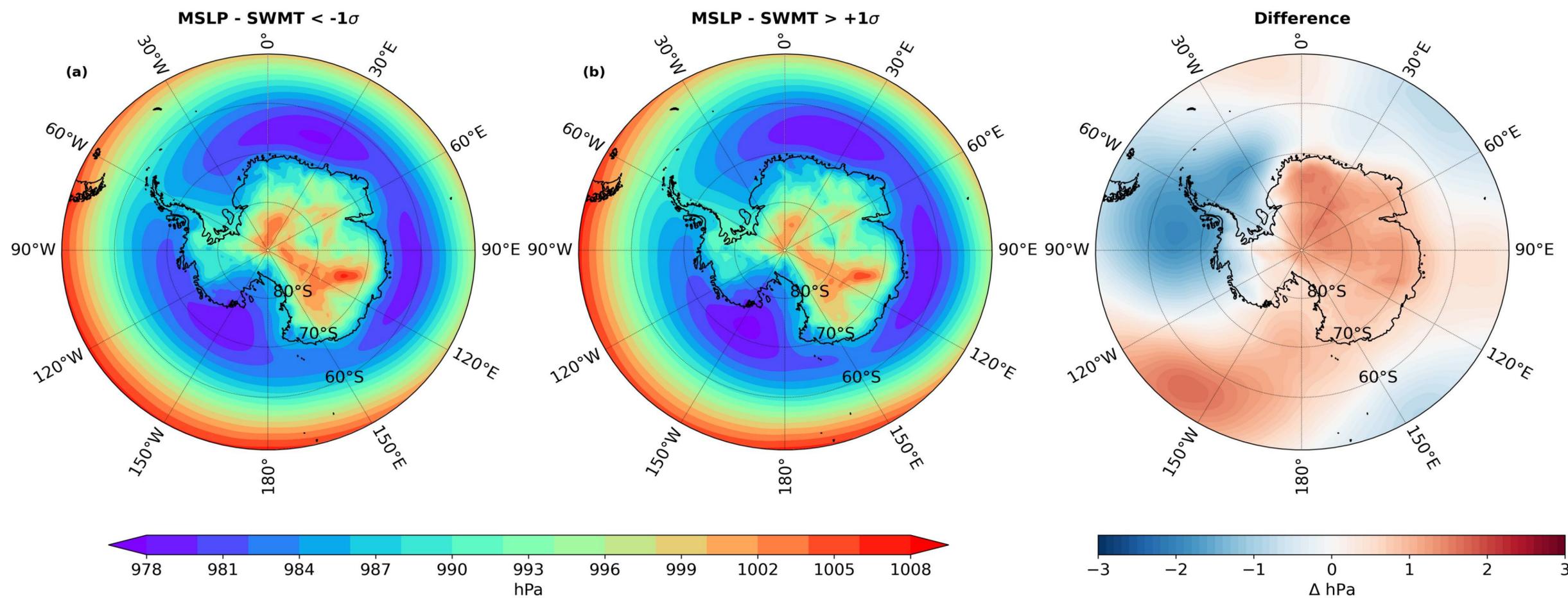
SWMT x SIC

Composites of SIC (SWMT +/- 1 σ)

- Changes in sea-ice concentration and formation, impact the production of HSSW/DSW (shelf waters) that feed the WSBW (bottom water).
- Global overturning circulation is driven by density differences. Brine rejection during sea-ice formation is a main source of dense water,

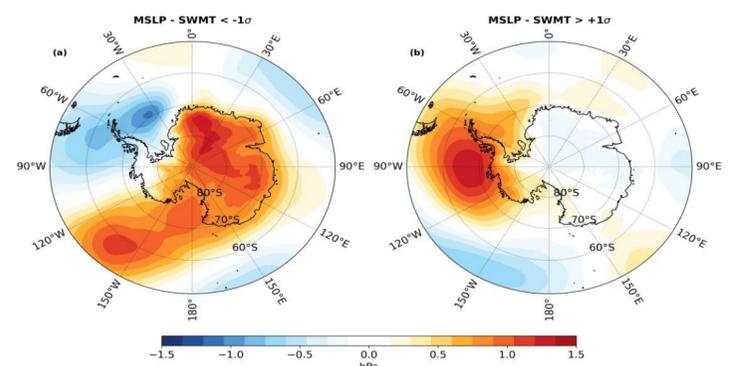
Weakend WMT associated with less SIC mostly in Weddell

Composites (SWMT +/- 1σ)

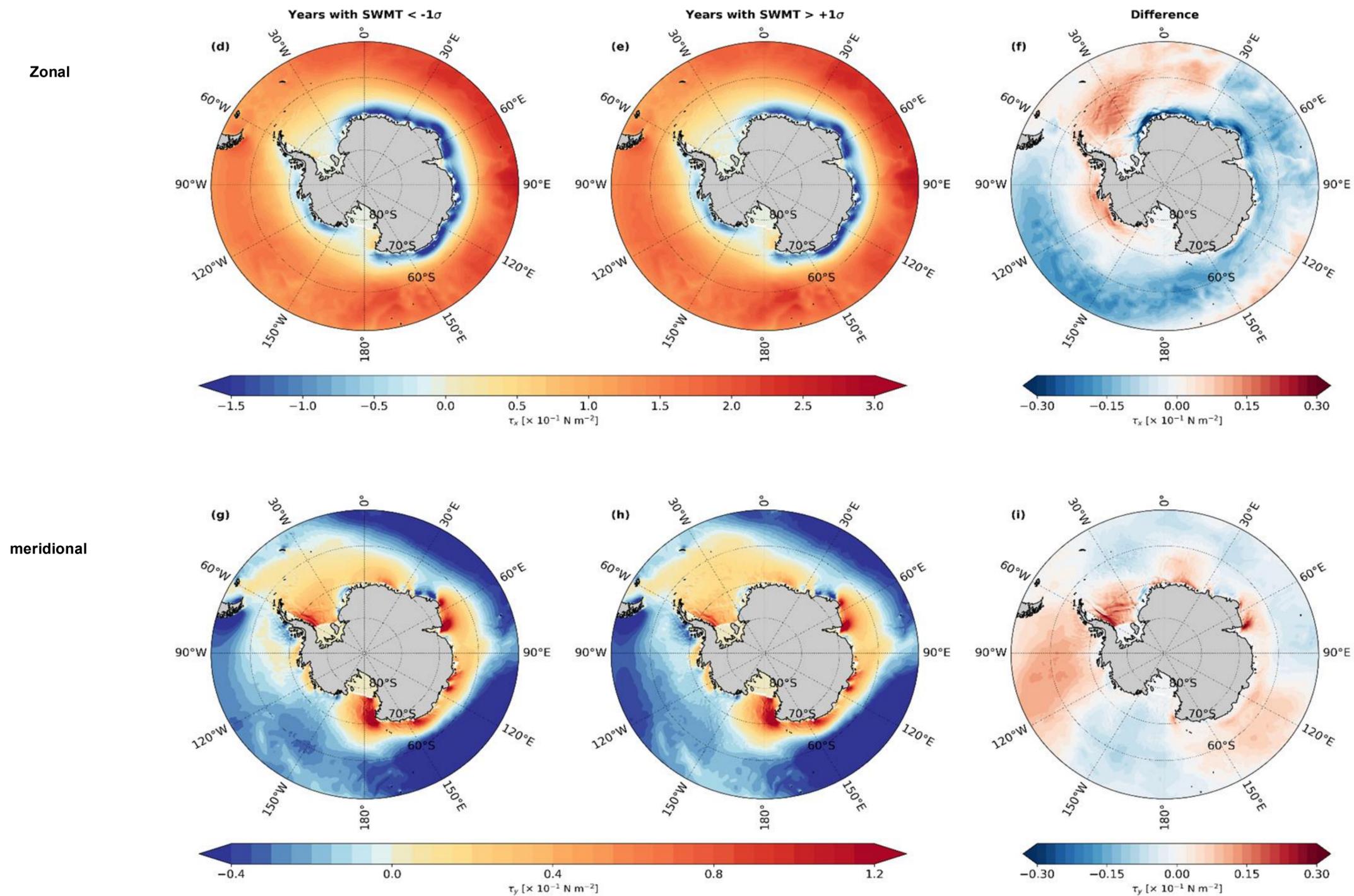


ASL deepens in Weddell and Peninsula.

Consistent with intensified Northerly winds.



Composites (SWMT +/- 1 σ)



- **weaker Easterlies: less sea-ice divergence/sea-ice formation less dense water production.**

- **Intensified Northerly winds associated with less sea-ice**

in fact Zhou et al., 2023 discuss northerly wind obs trend related to reduced sea-ice

1. Model shows good agreement with WOCE observations for South Atlantic water mass properties
2. AABW formation exhibits significant multidecadal variability in CESM-HR simulations
3. Water Mass Transformation is strongly coupled with SIC variations in the SO
4. Wind stress patterns and SIC primary drivers of AABW transformation variability

In progress/future:

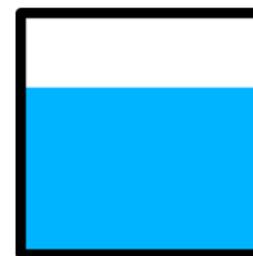
- 10-member ensembles (HIST and RCP8.5)
- Start looking for connections with IPO or other climate indices.
- Investigate the implications for AABW properties and their further impacts on the AMOC.

Key finding: In CESM-HR we can see (multidecadal) changes/reduction in dense water production related with decline in the sea-ice formation rate, most likely driven by northerly wind trends. In fact, Wang, S et al, 2022; *Env. Res. Let.* show the record-low SIE in February 2022 and intensified ASL produced anomalously warm northerly winds → promoting sea-ice loss

Could this process be related to a phase transition of the IPO + ASL variability?

Thank You!

wainer@usp.br



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