Ventilating the Deep: What ocean observations tell us about deep ocean ventilation and circulation

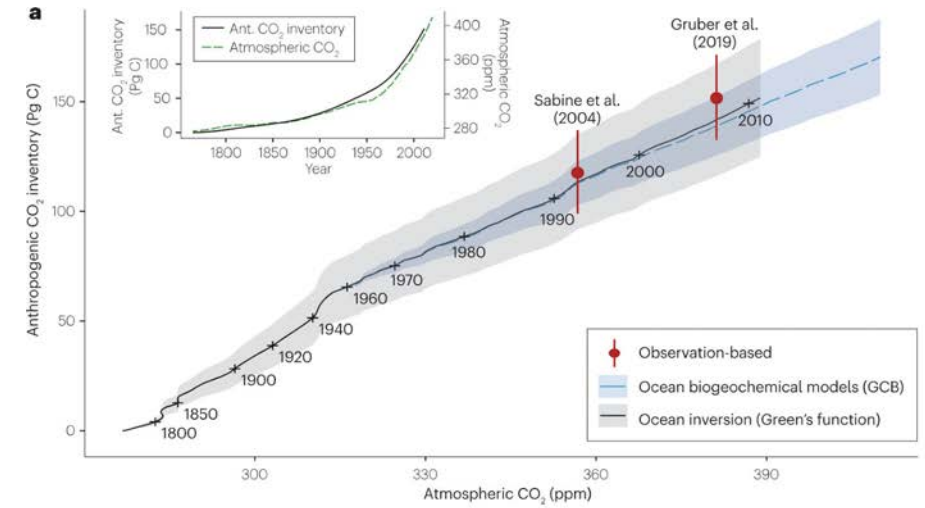
Sarah Purkey

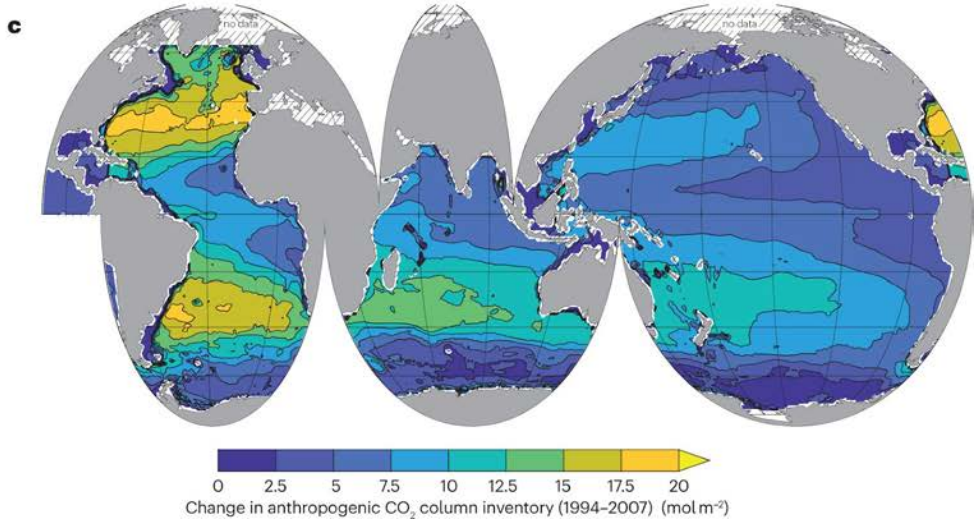
April 23rd, 2024

CLIVAR/OCB

Ocean Ventilation Matters for Carbon and Heat Uptake

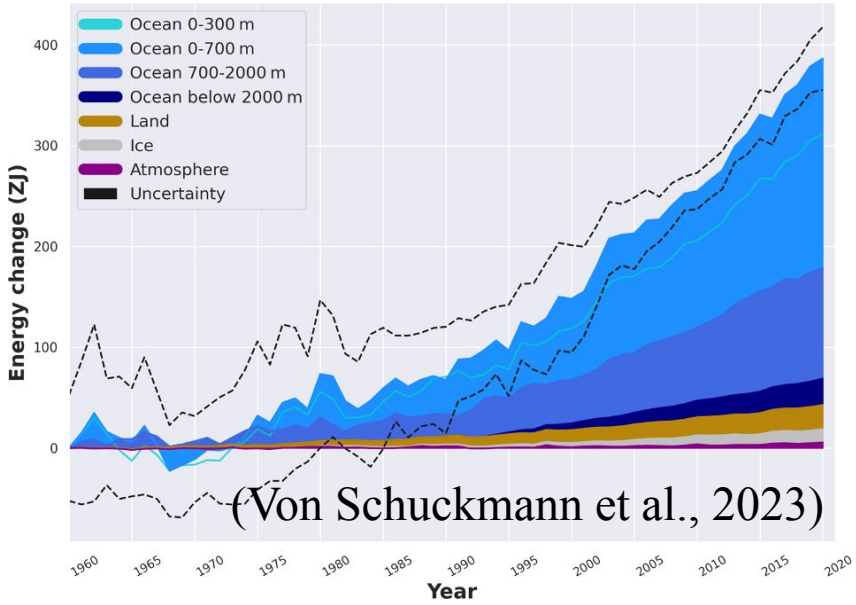
Anthropogenic Carbon



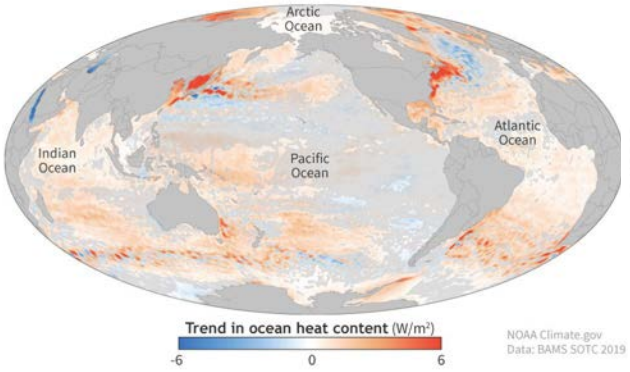


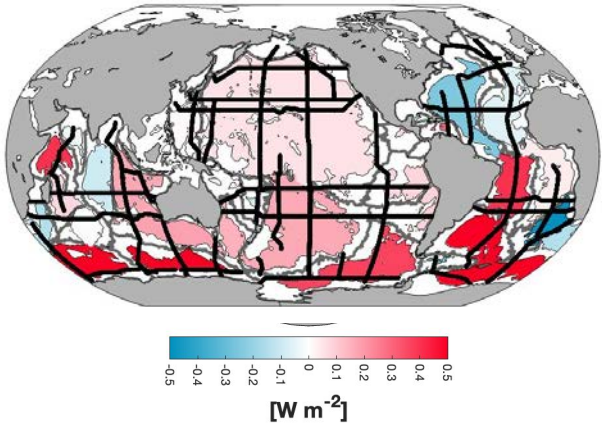
(Gruber et al., 2023)

Anthropogenic Heat



(Von Schuckmann et al., 2023)





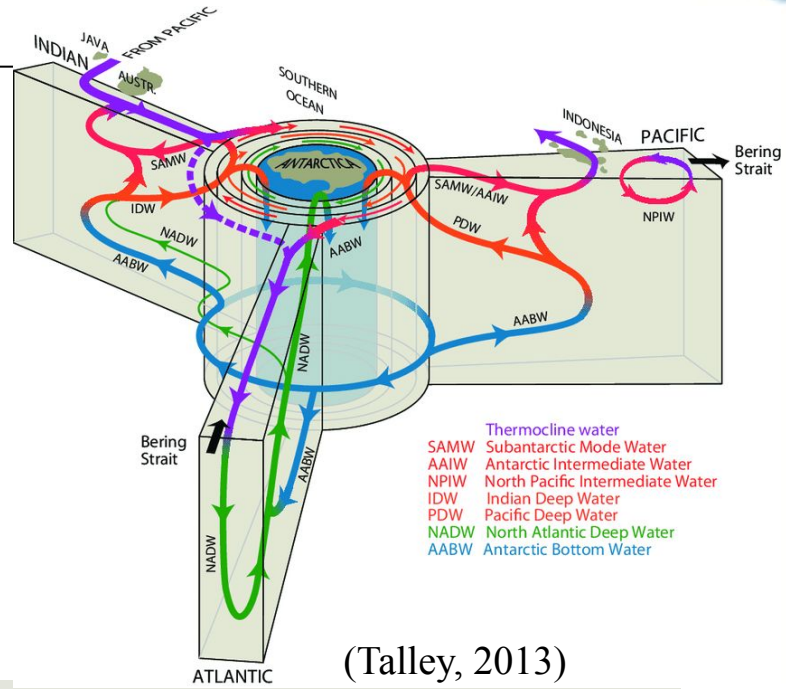
(Johnson, OHC state of the climate)

(Updated from Purkey & Johnson 2010)

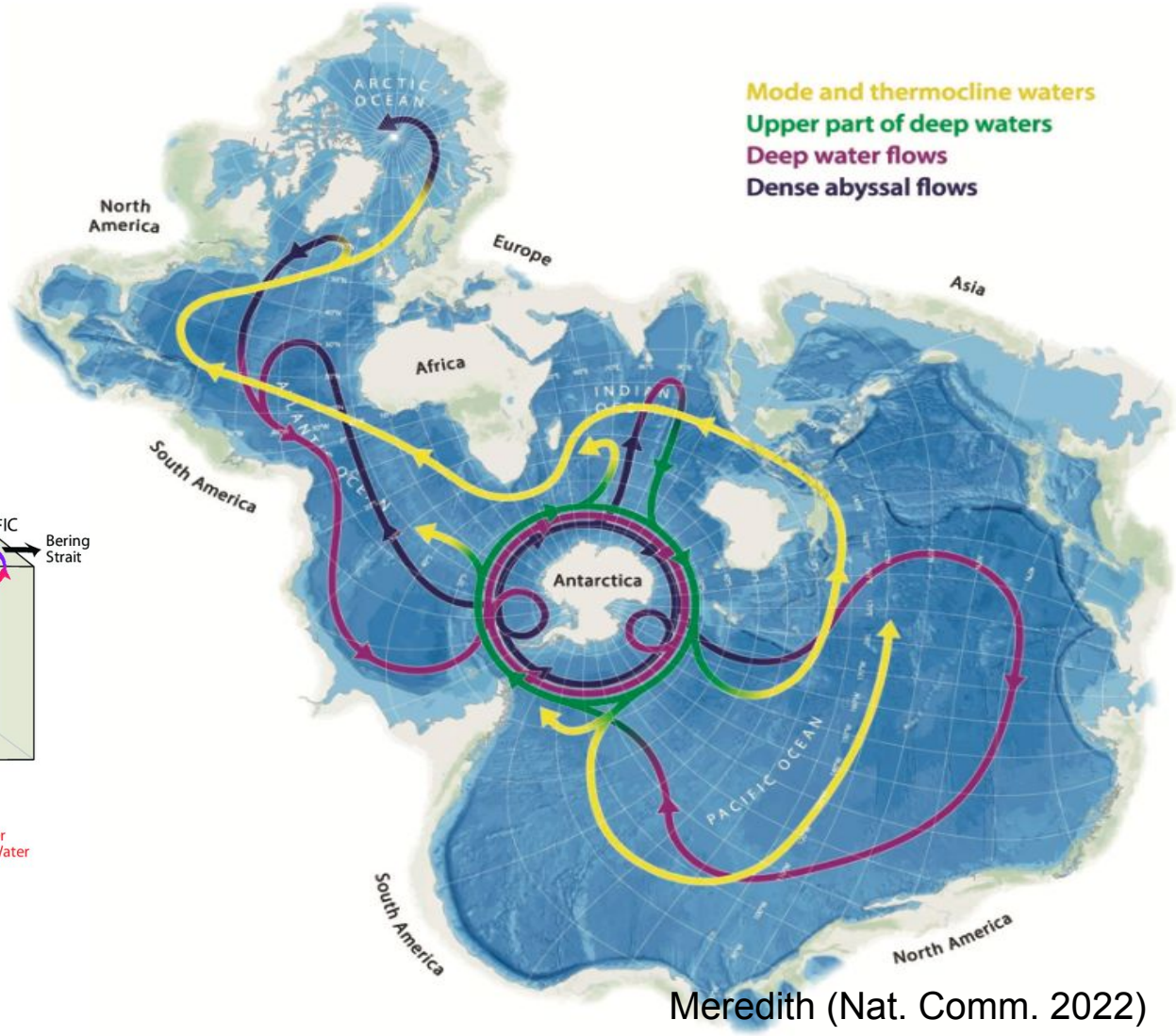
Bottom and Deep Limbs of the Meridional Overturning Circulation (MOC)

Outline

- Antarctic Bottom Water (AABW)
- North Atlantic Deep Water (NADW)
- Observed variability in the deep ocean

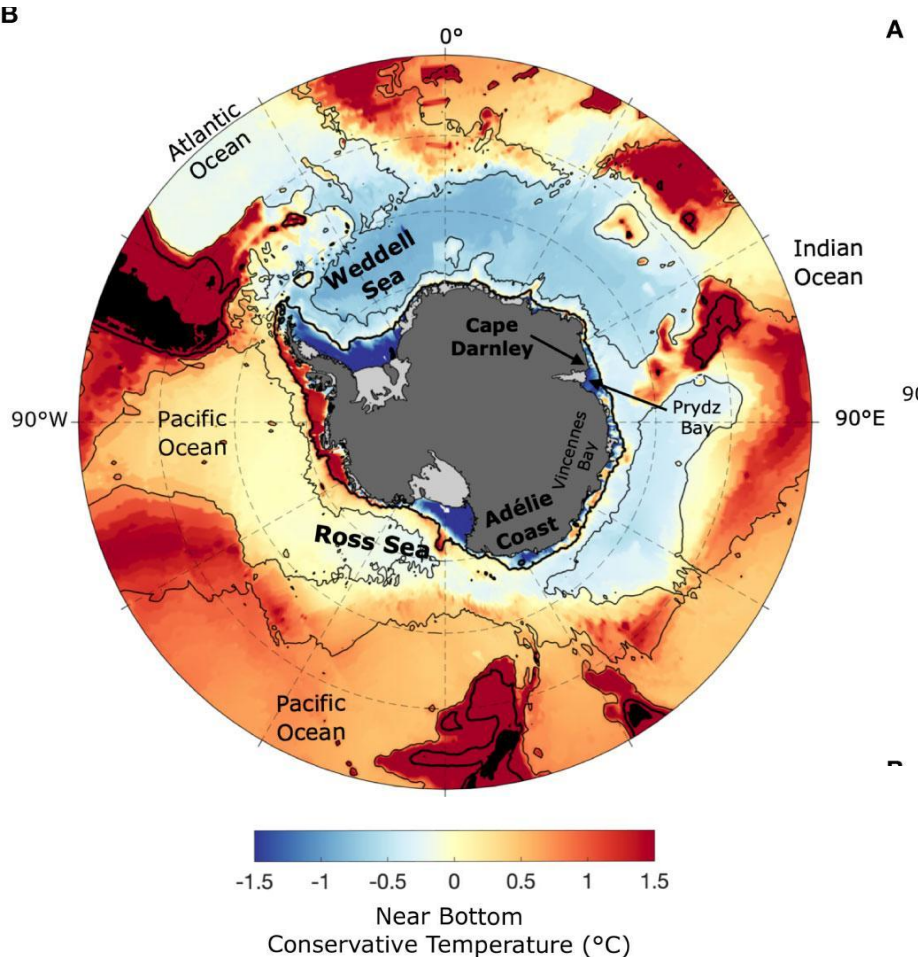


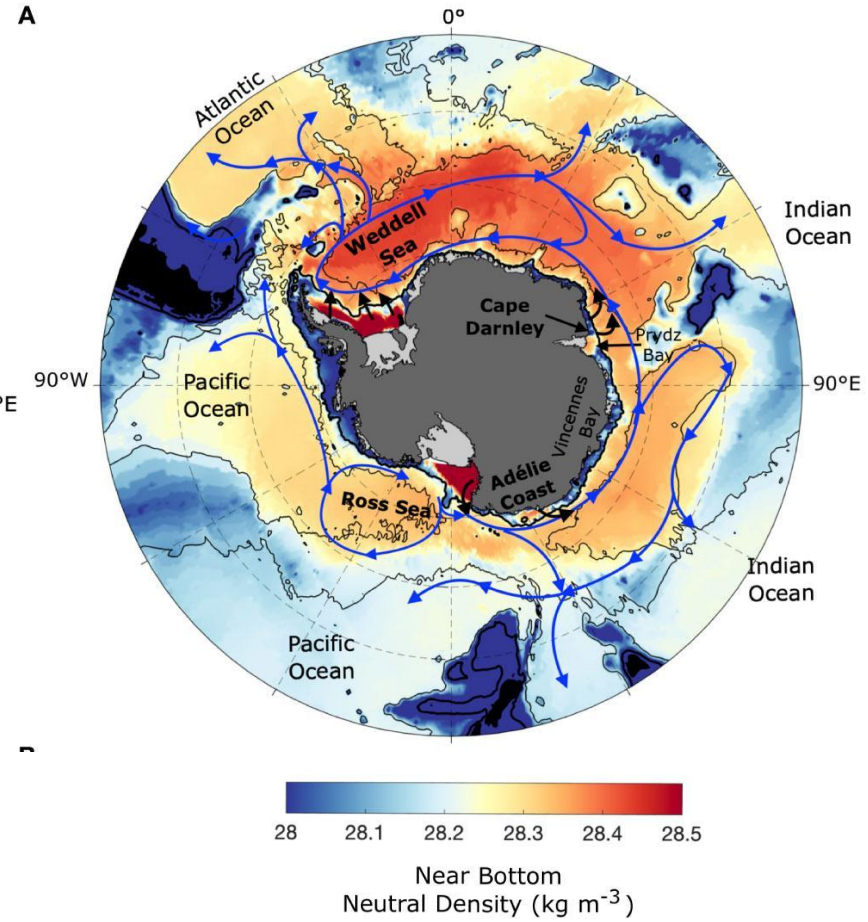
(Talley, 2013)

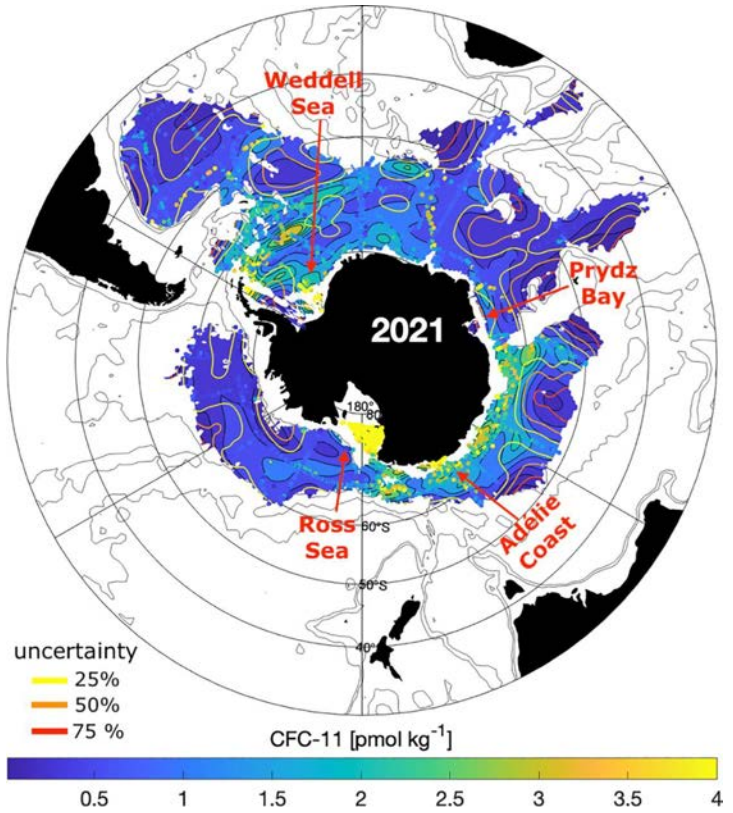


Meredith (Nat. Comm. 2022)

AABW Formation



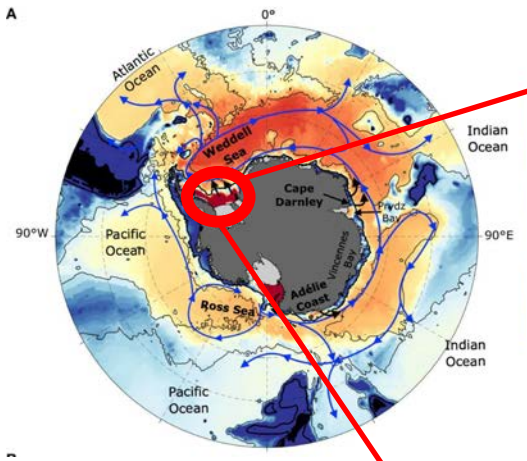


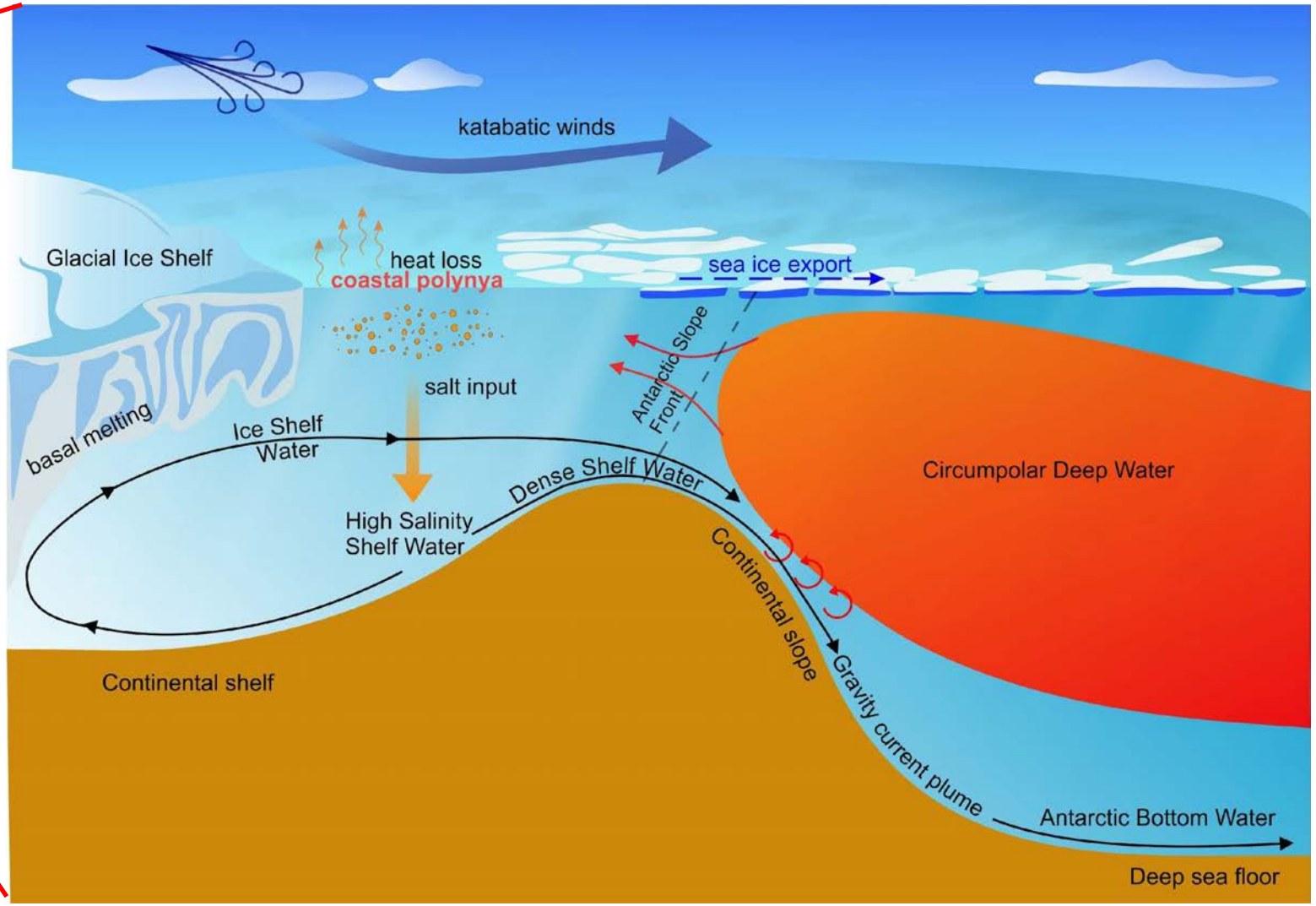


(Silvano et al. 2023)

- AABW is formed in 4 locations around the Antarctic coast

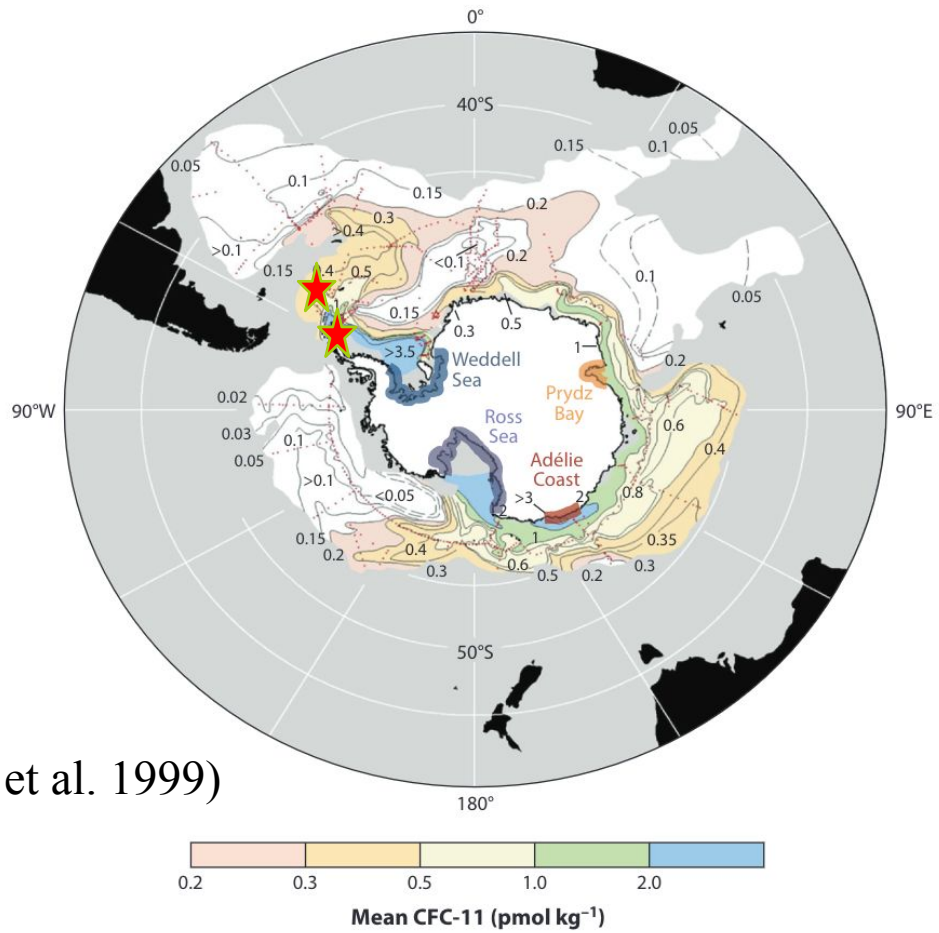
AABW Formation



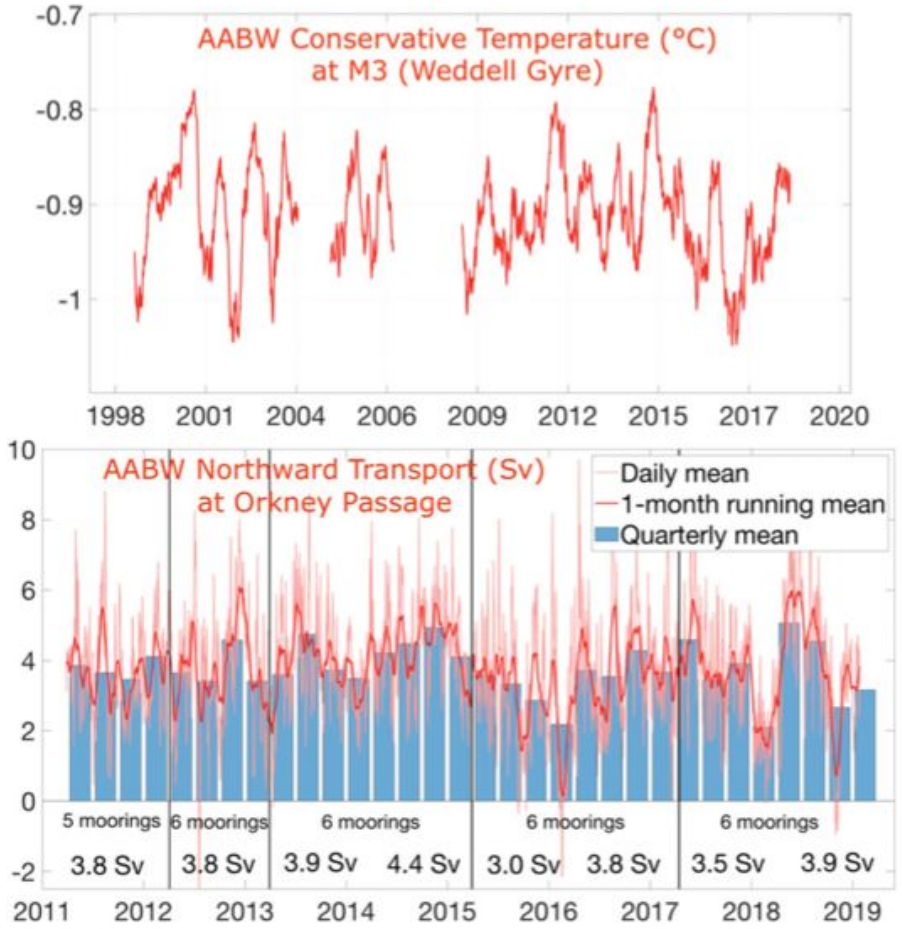


(Silvano et al. 2023)

AABW Formation



(Orsi et al. 1999)

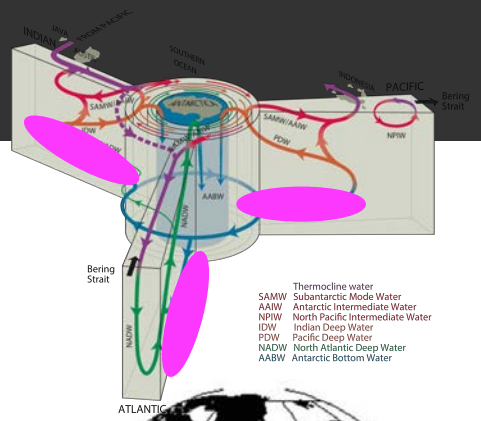


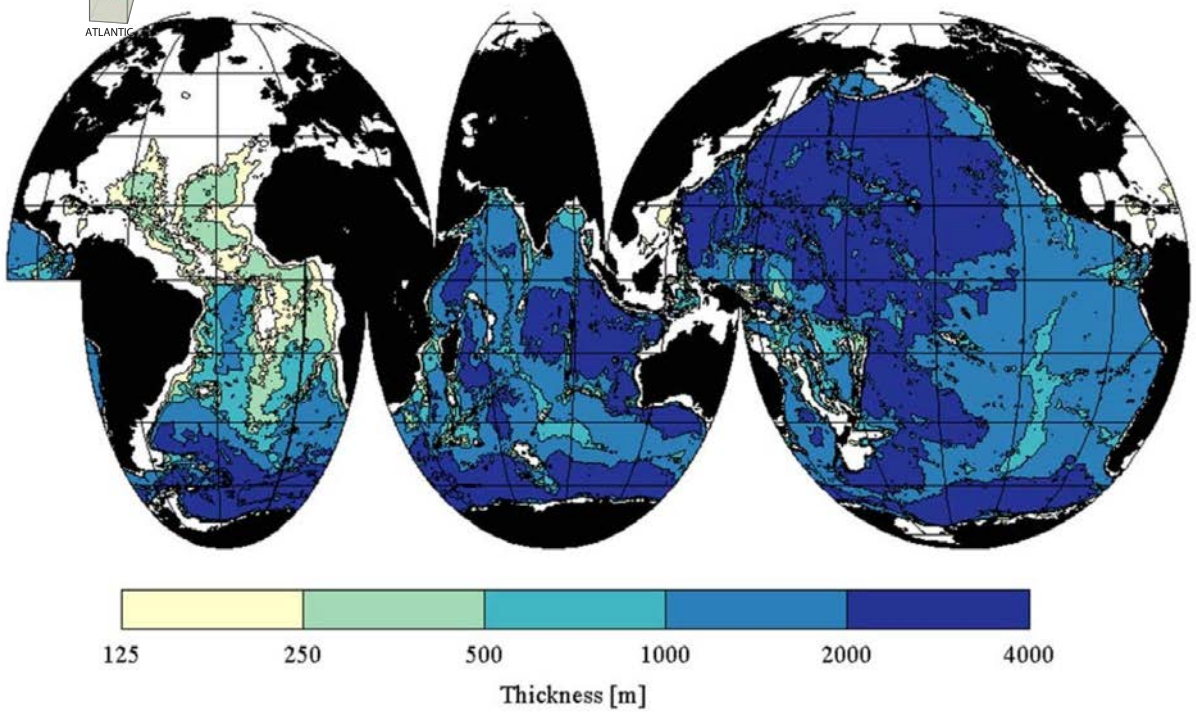
- AABW formation rates have been mostly estimated from ocean properties and tracers

- Limited direct observations of AABW formation show variability in properties and volume

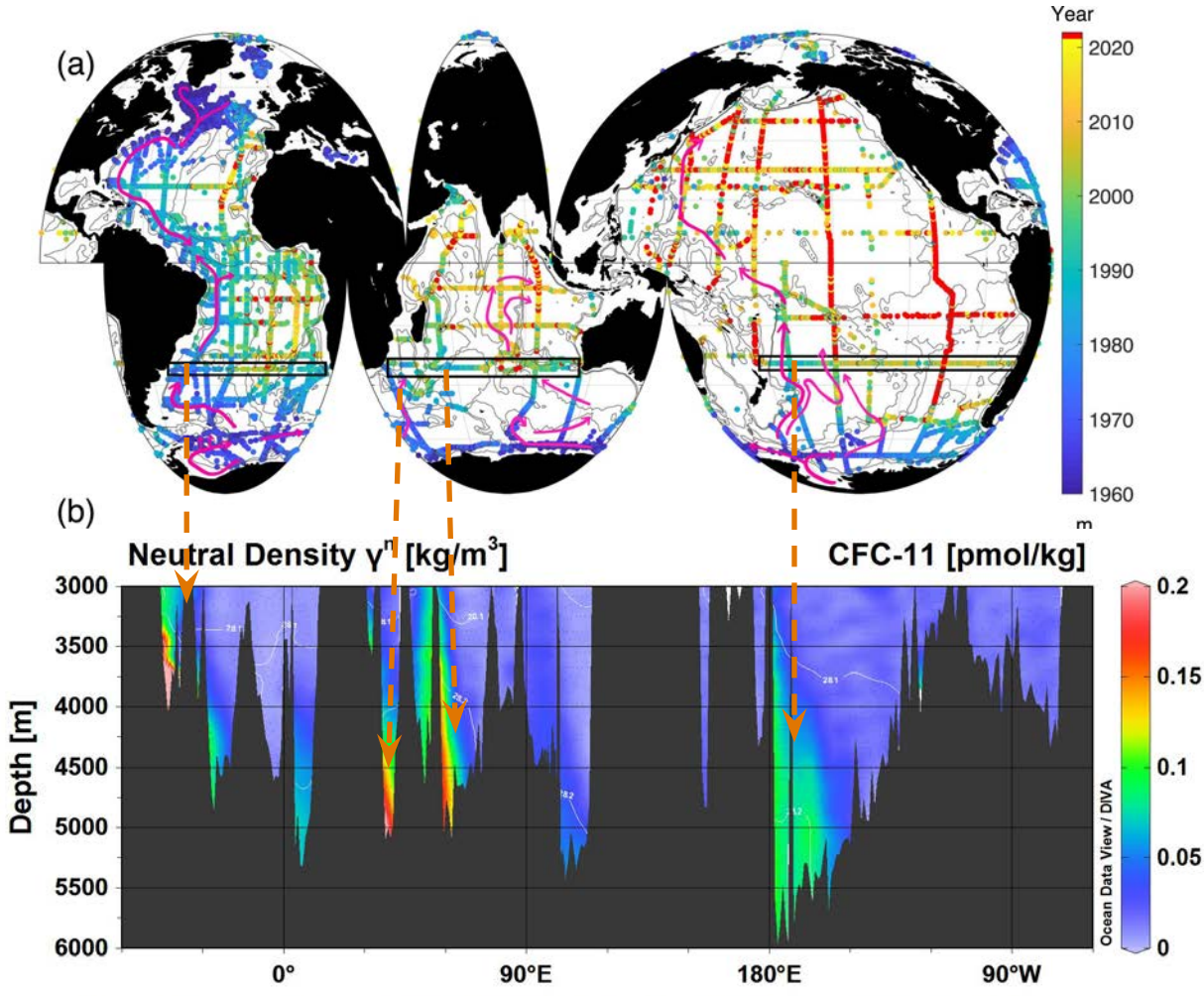
(Silvano et al. 2023)

Global Circulation of AABW





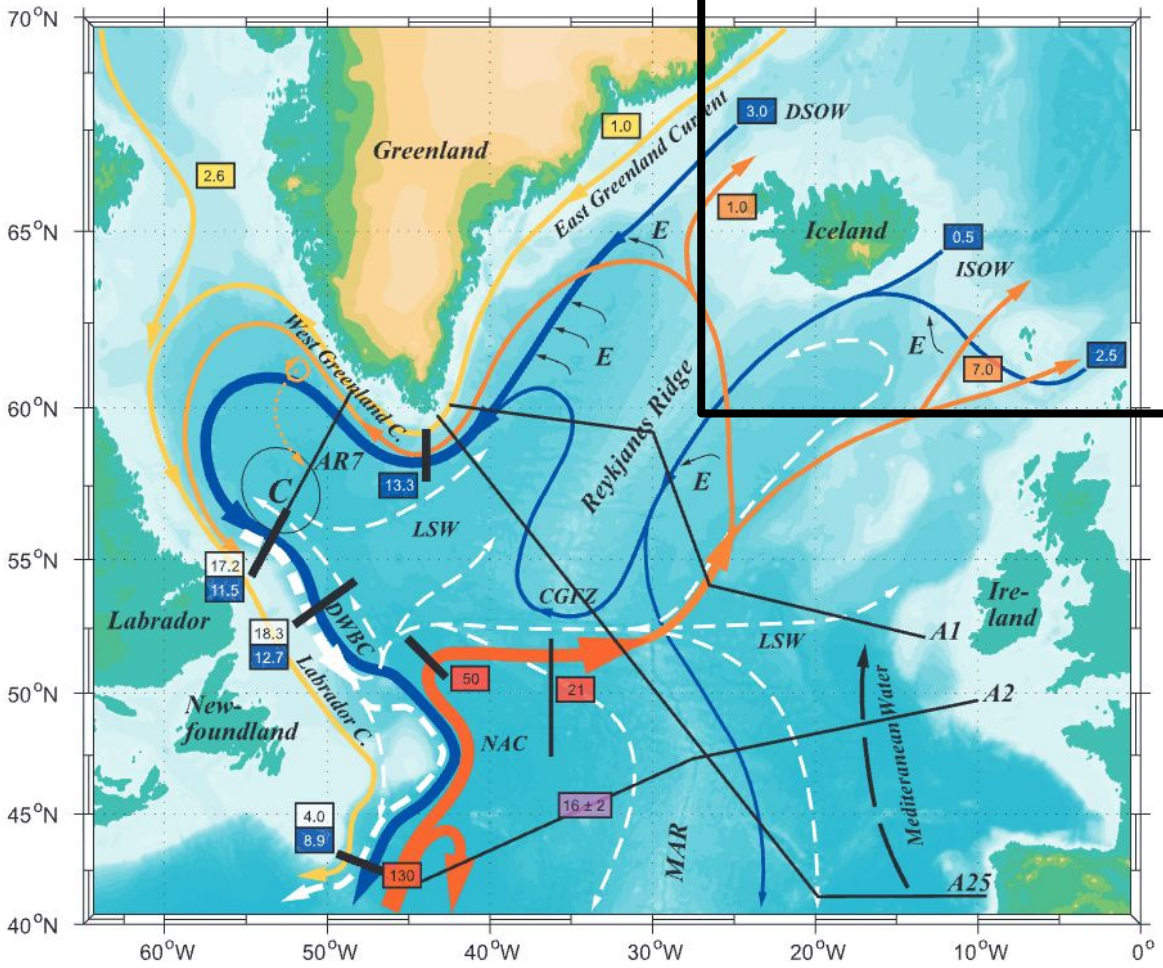
(Johnson 2008)



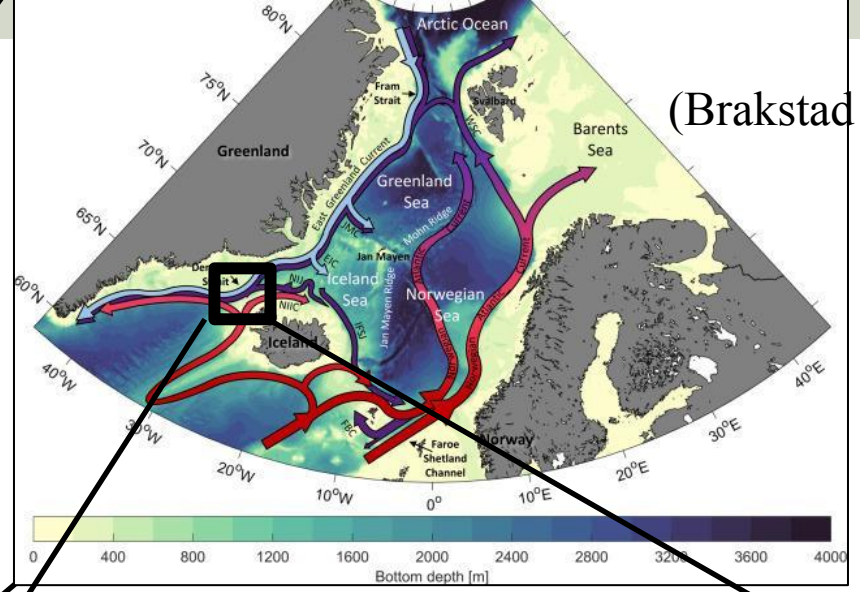
(Purkey et al., 2018)

(Cimoli et al., 2023)

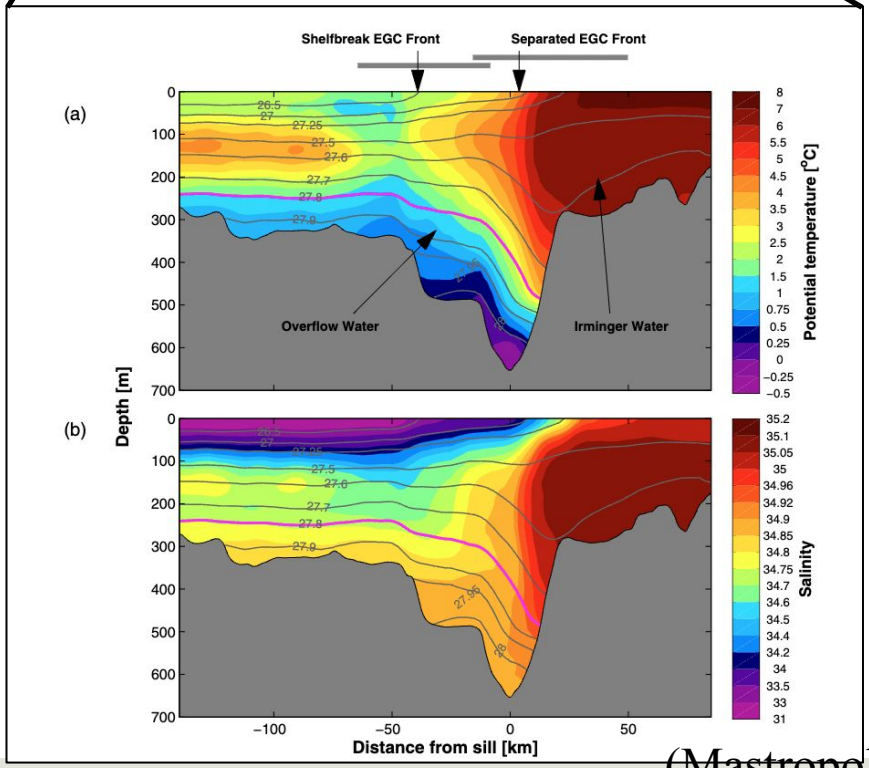
NADW Formation



(Schott and Brandt, 2007)

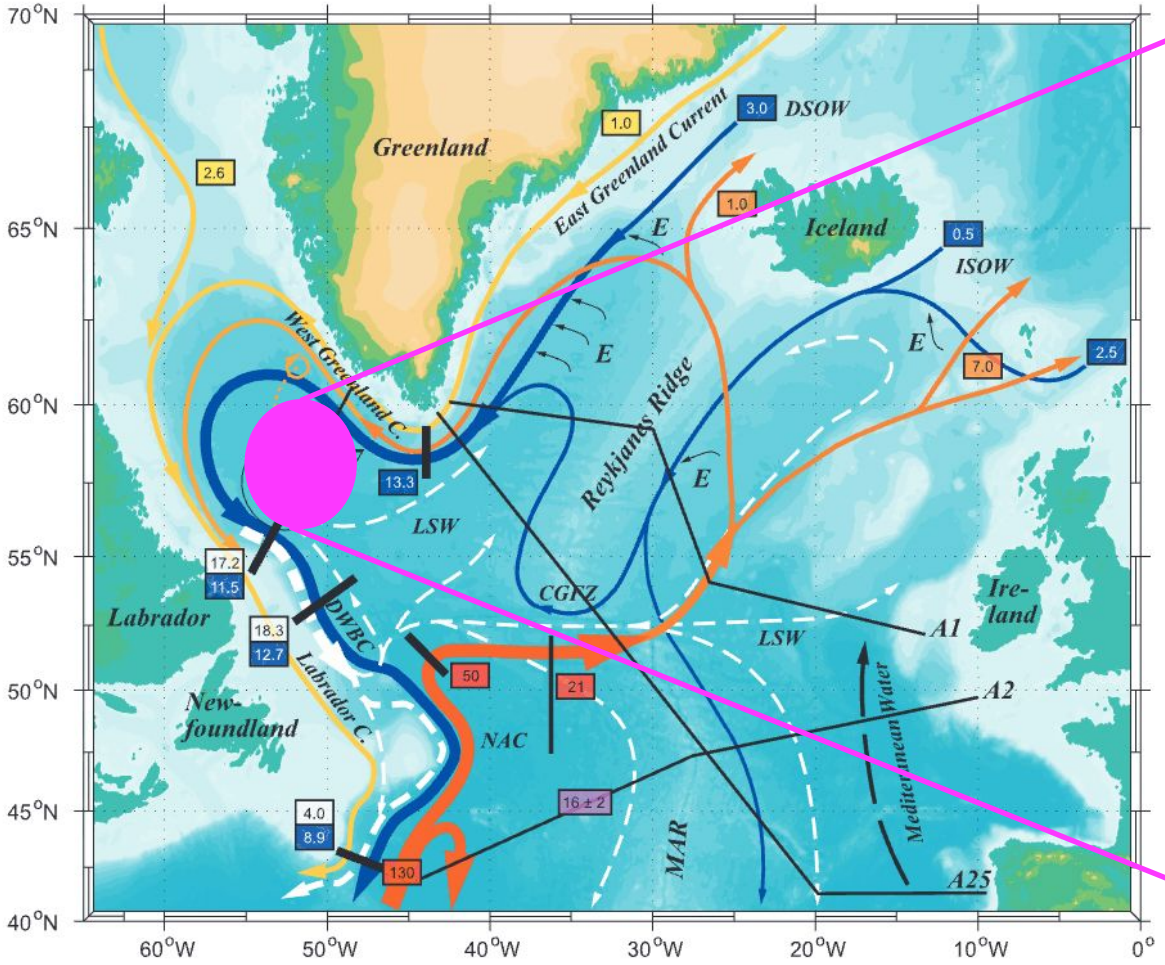


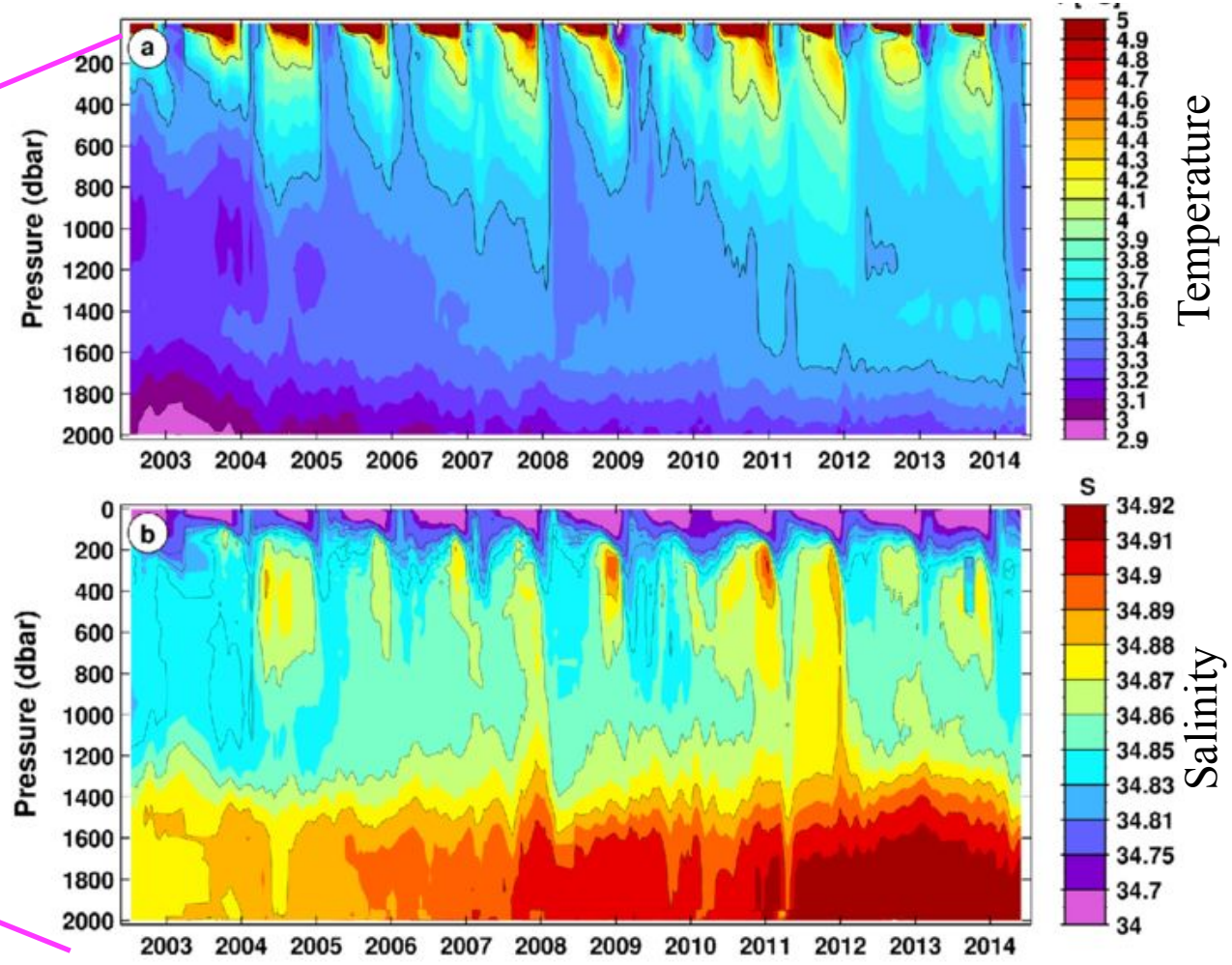
(Brakstad et al. 2023)



(Mastropole et al 2017)

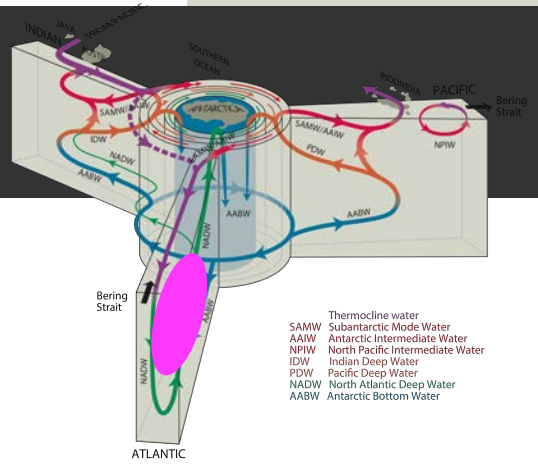
NADW Formation

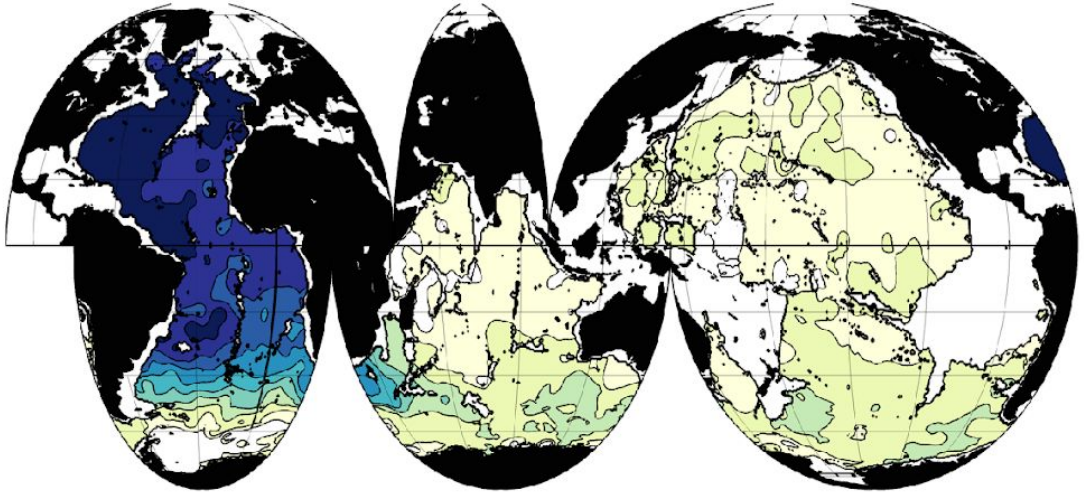




(Kieke and Yashayaev et al 2014)

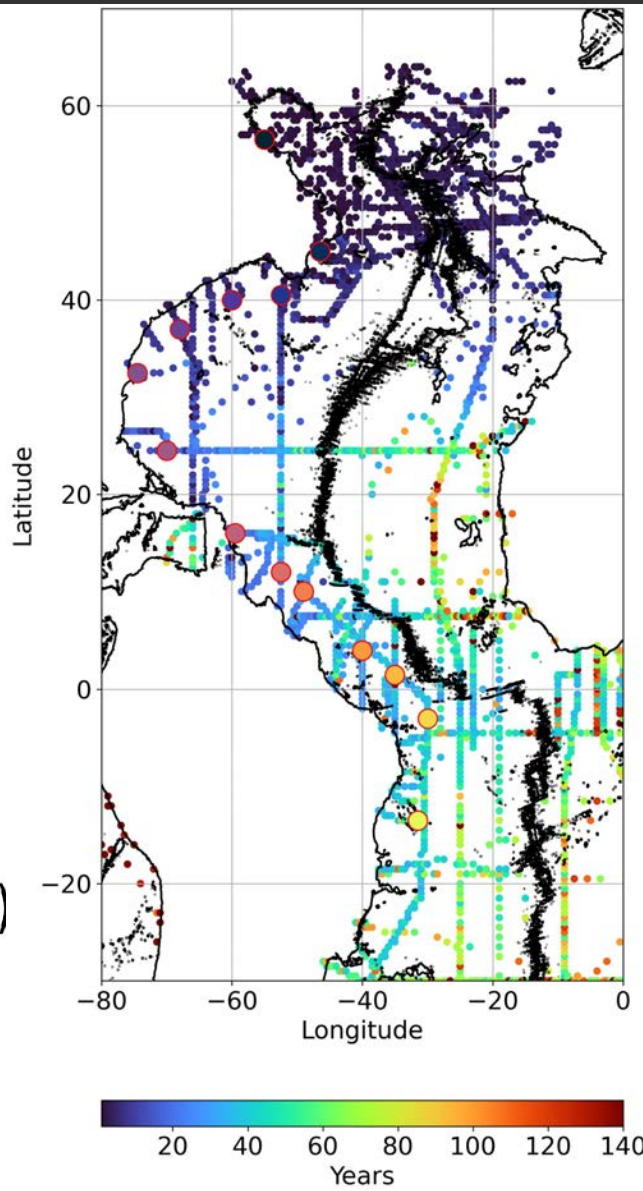
NADW Circulation

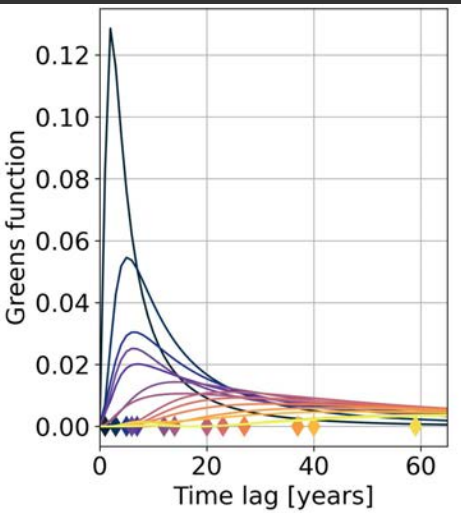


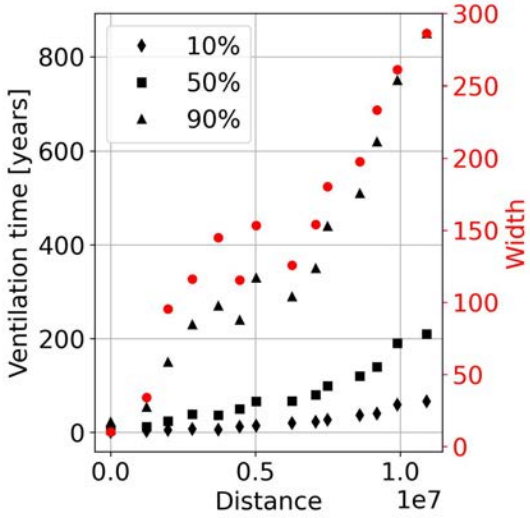


(a) Fraction of NADW at γ^N=28.06 kg/m^3 (2500-3000 m)

(Johnson 2008)

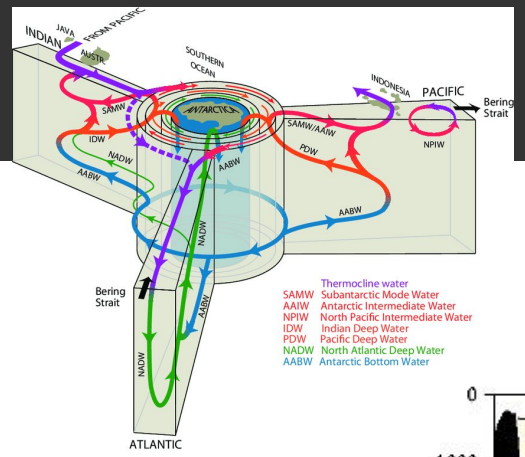






(Cimoli et al, 2023)

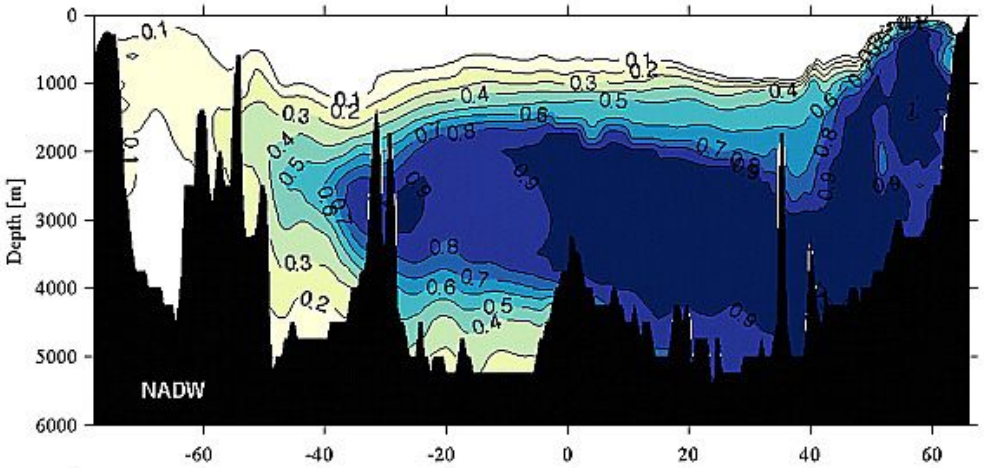
AABW and NADW in the MOC

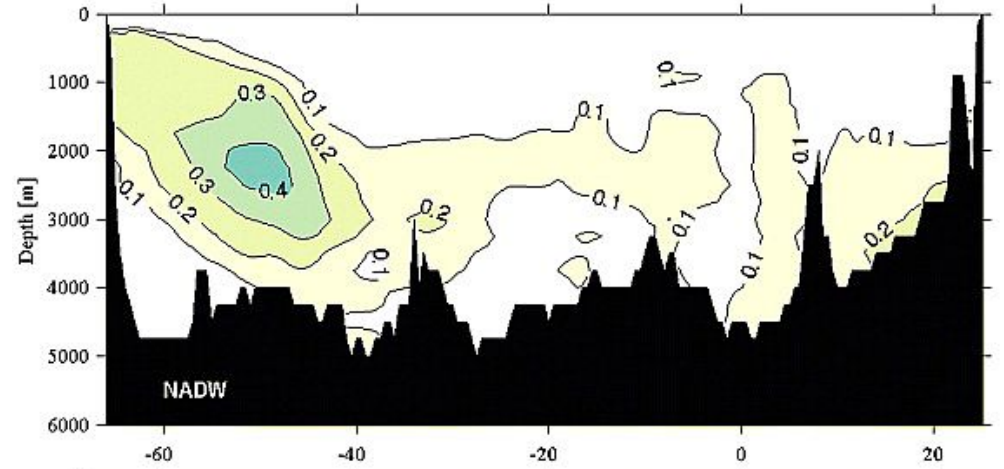


Atlantic

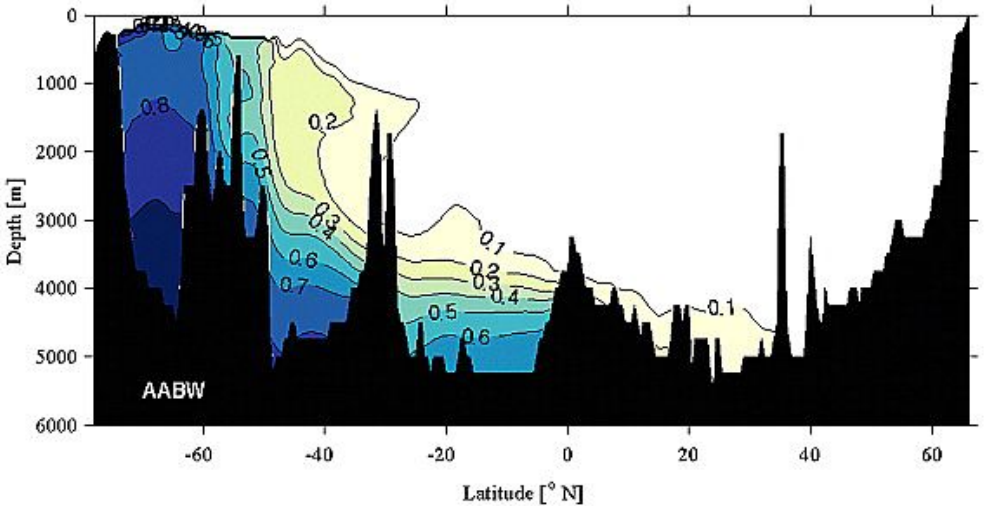
Pacific

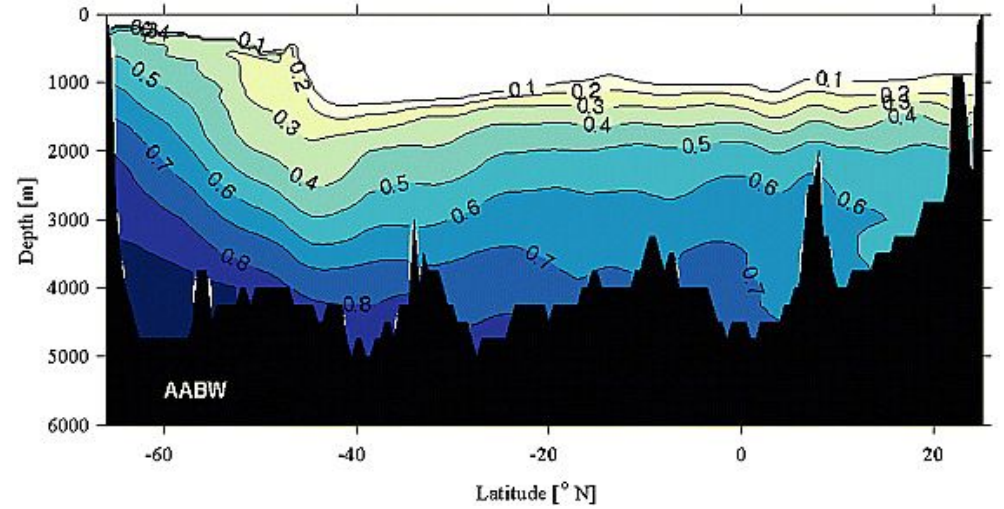
NADW



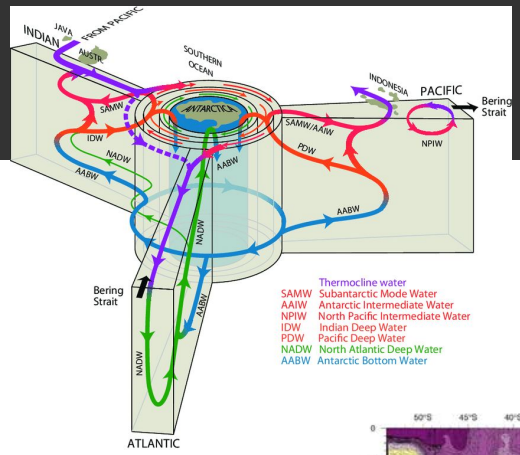


AABW





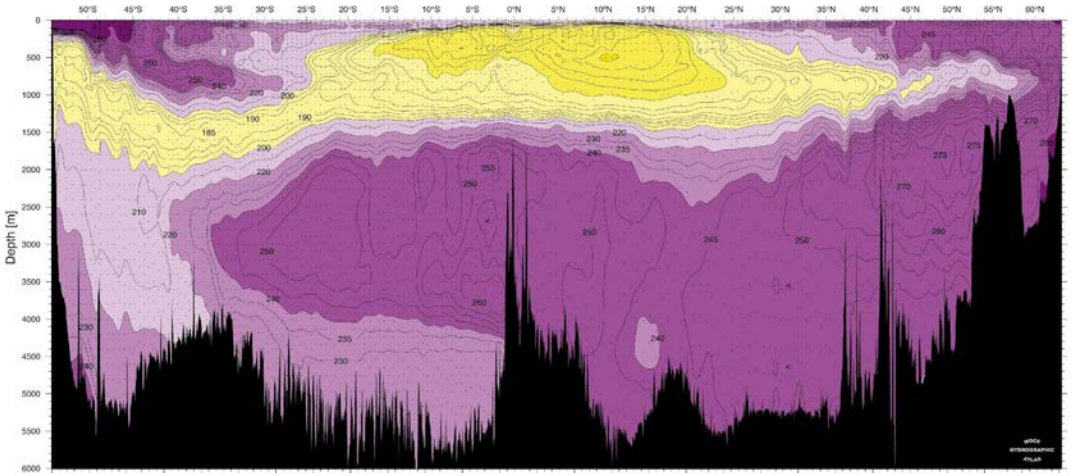
AABW and NADW in the MOC

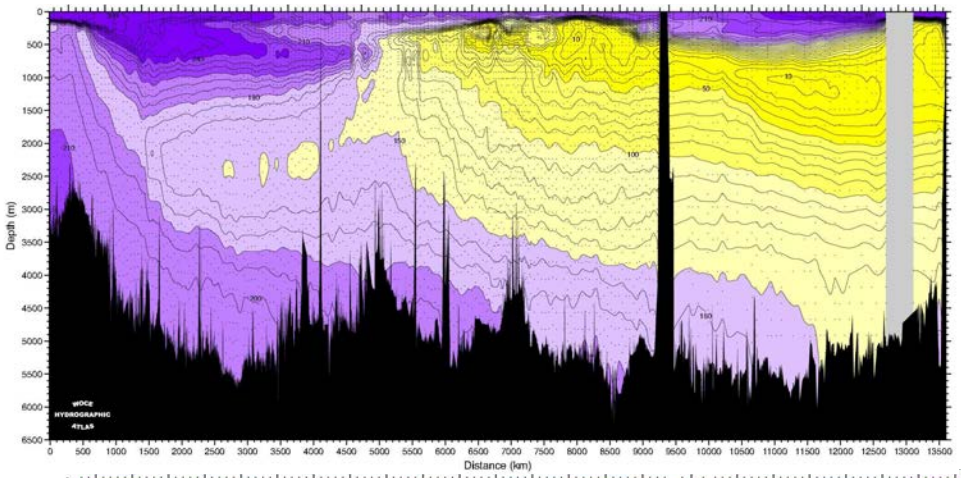


Atlantic

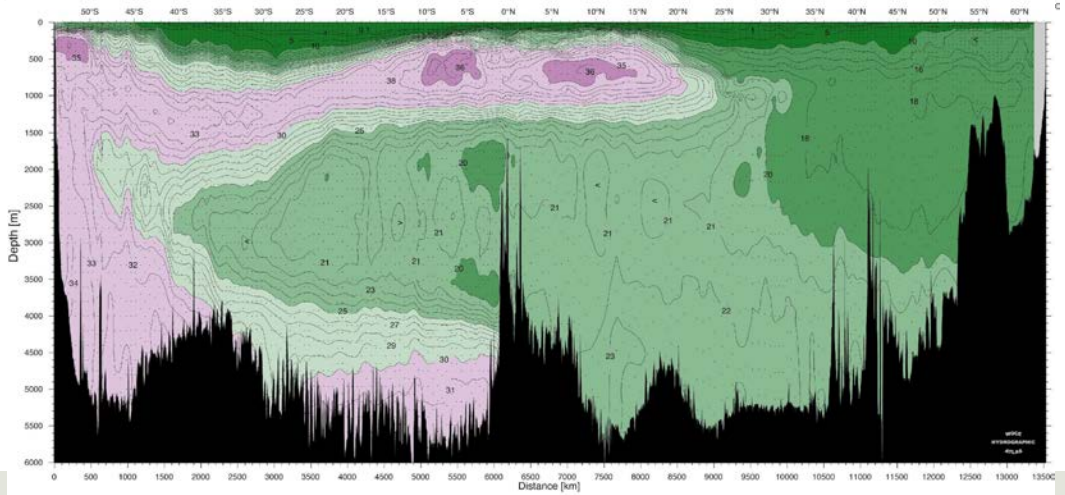
Pacific

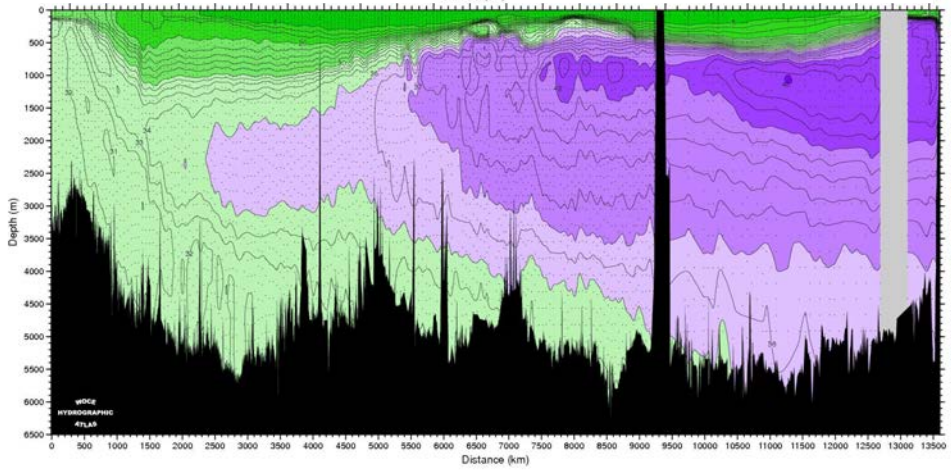
Oxygen





Nitrate

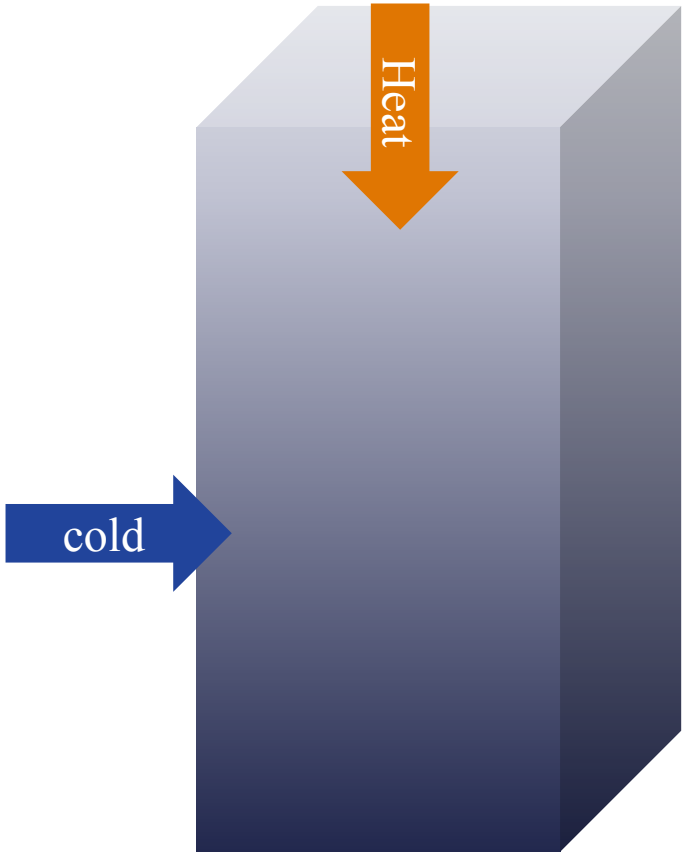


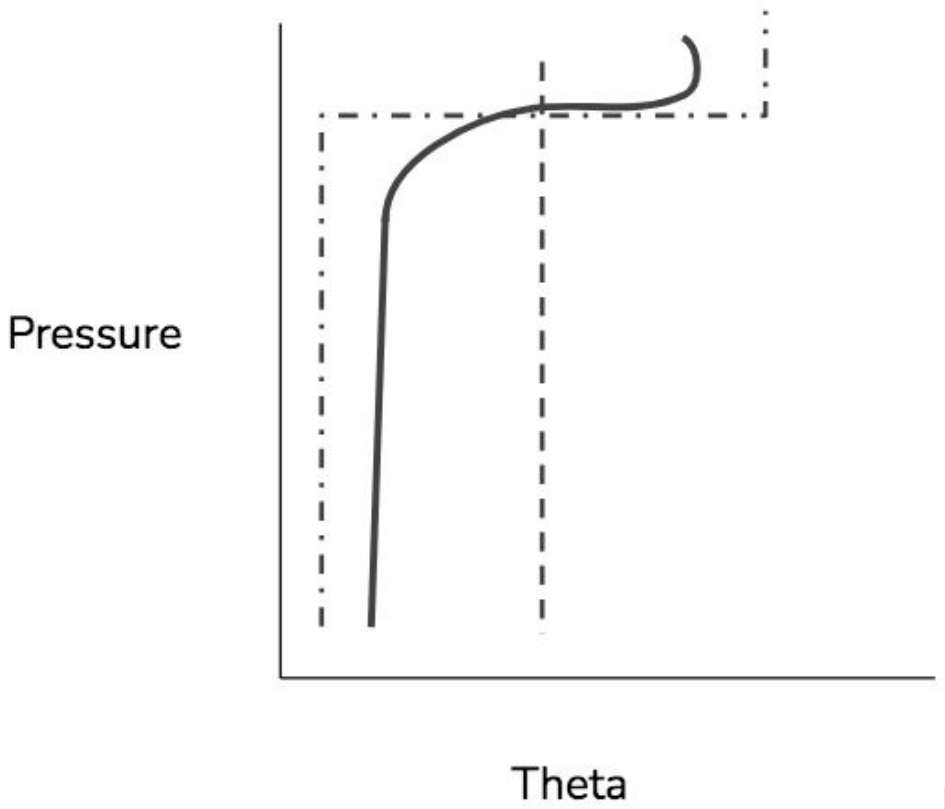


The Global Meridional Overturning Circulation (MOC)

Bottom water properties are set by the balance between the renewal of deepwater formed around Antarctica and the rate of mixing with overlying water

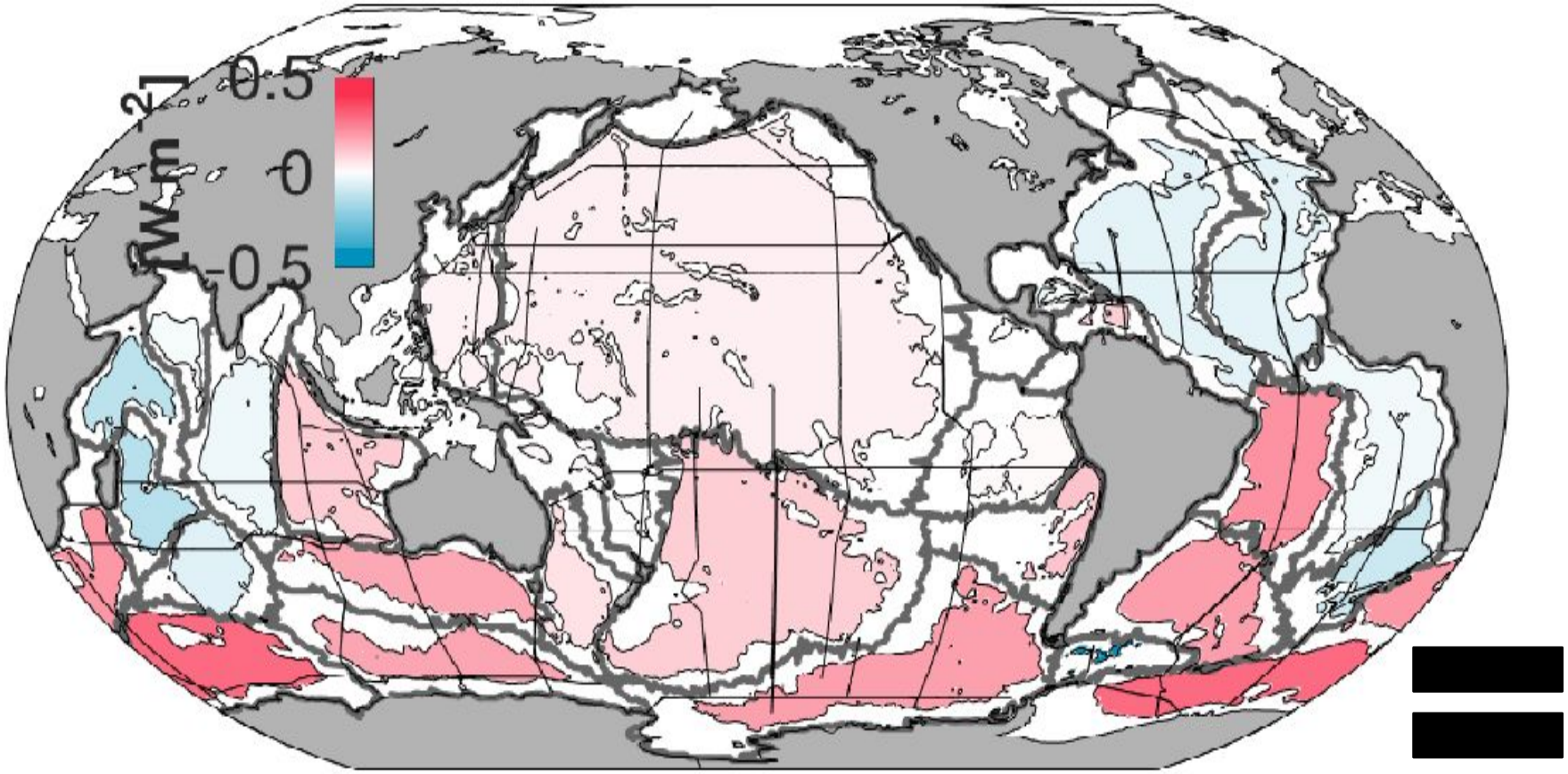
Advection + Mixing = 0





- In steady state, these two processes are equal and bottom temperature is constant in time

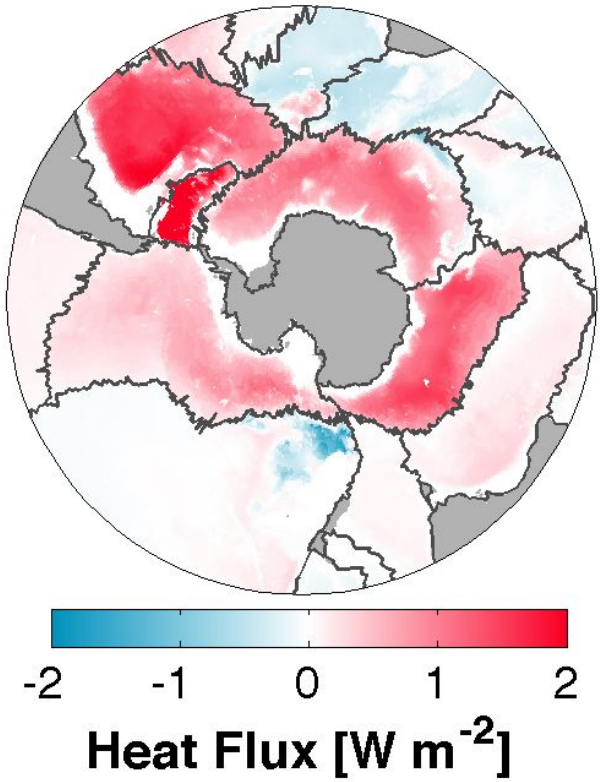
Accumulation of heat below 4000m

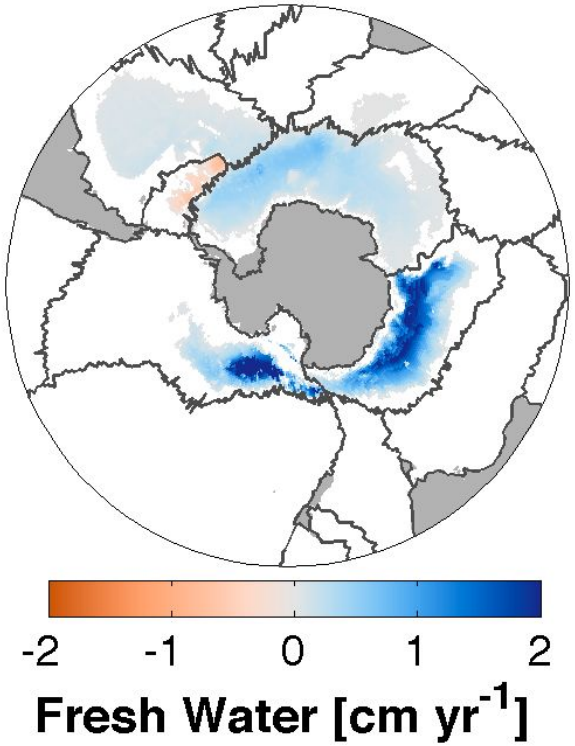


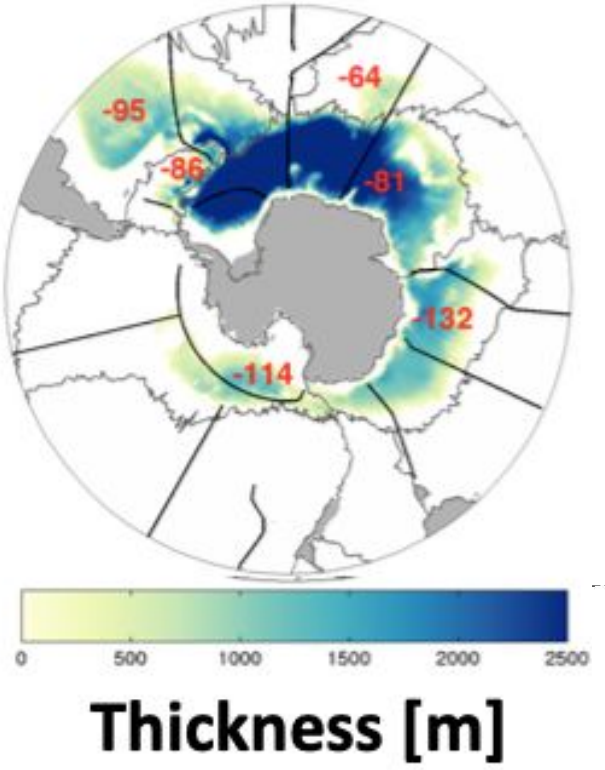
(Updated from Purkey and Johnson, 2010)

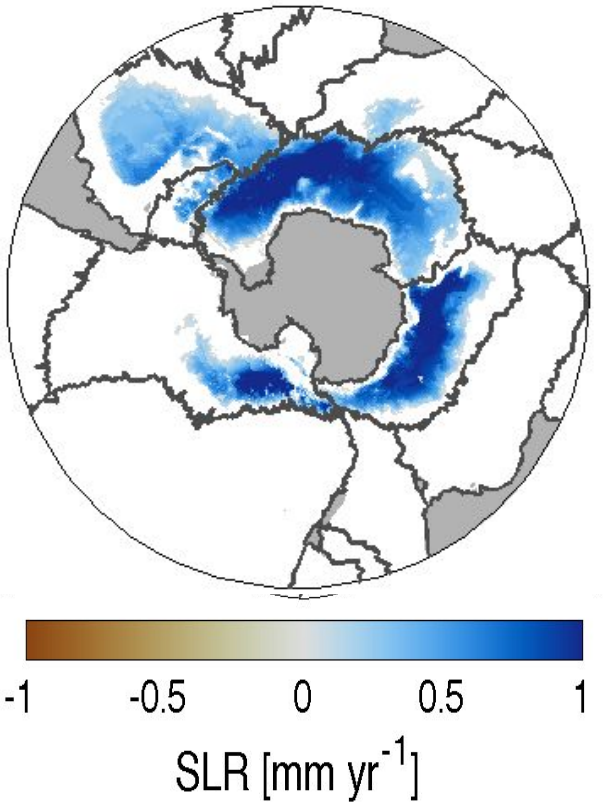
0.7 ZJ/yr

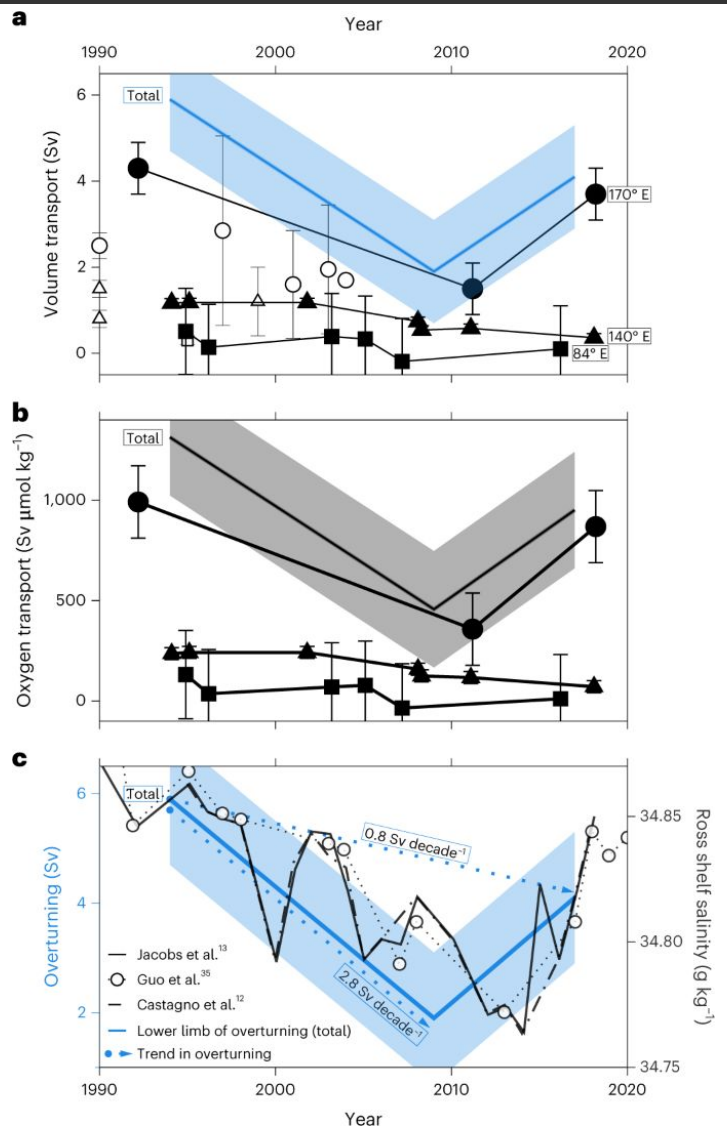
Accumulation of heat below 4000m



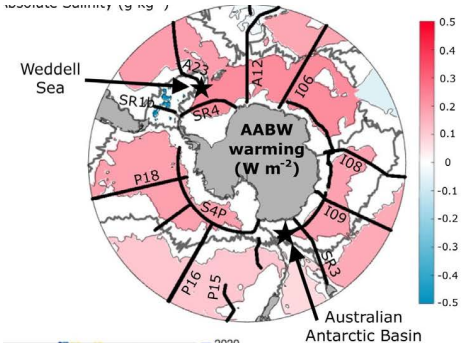


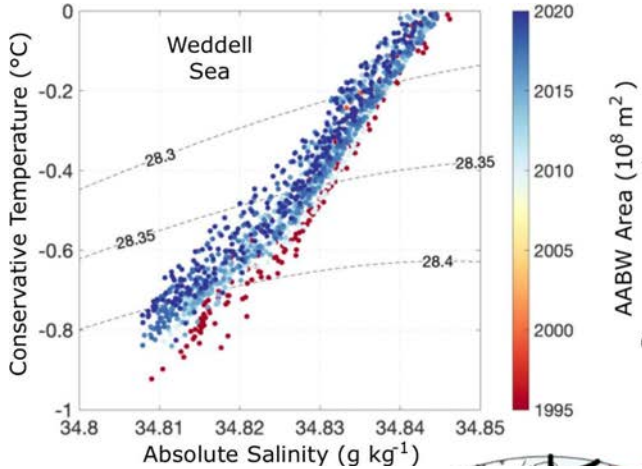


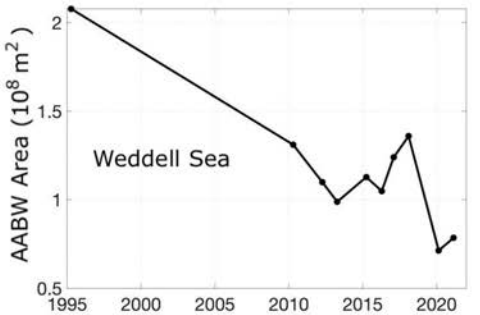


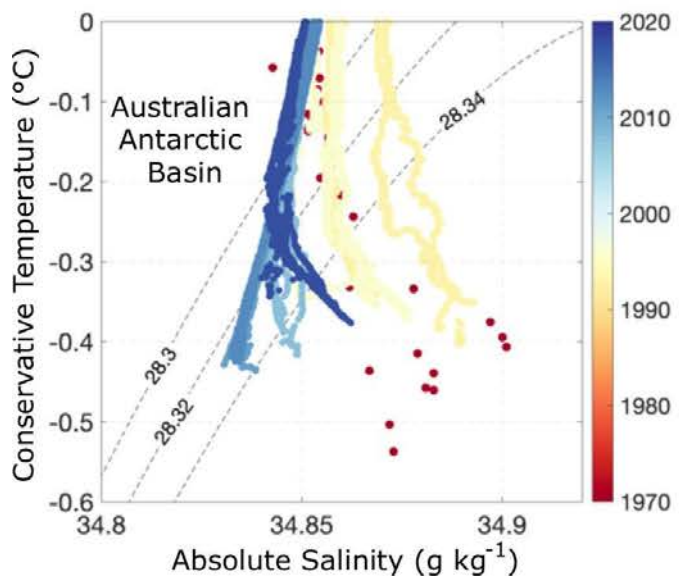


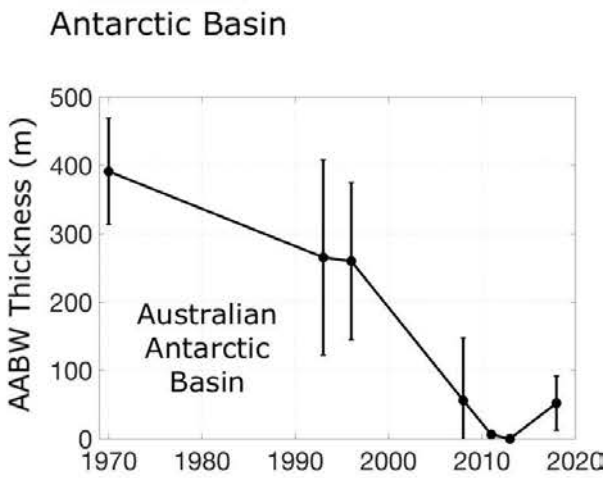
(Gunn et al. 2023)





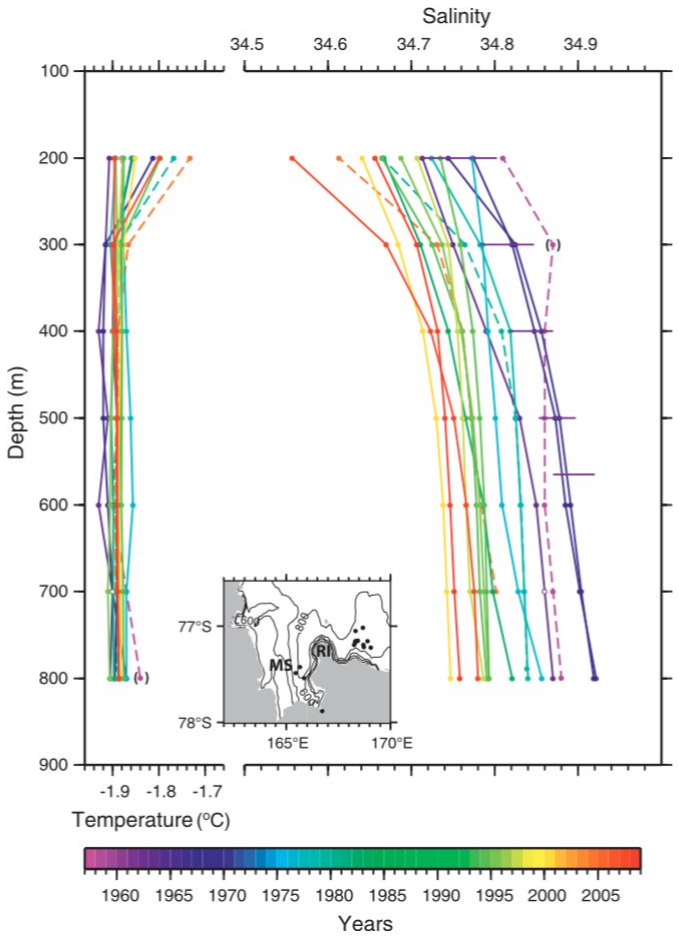




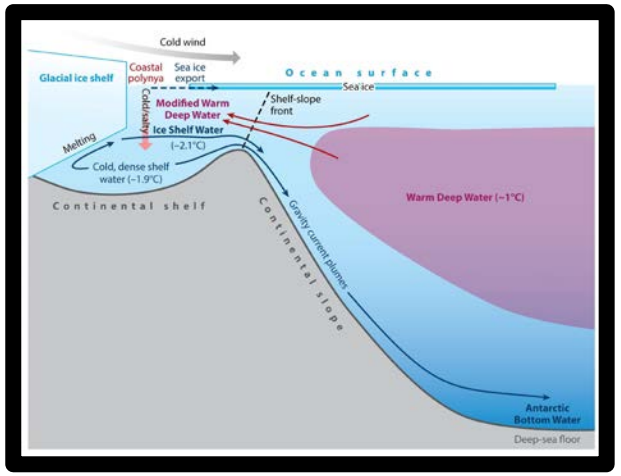


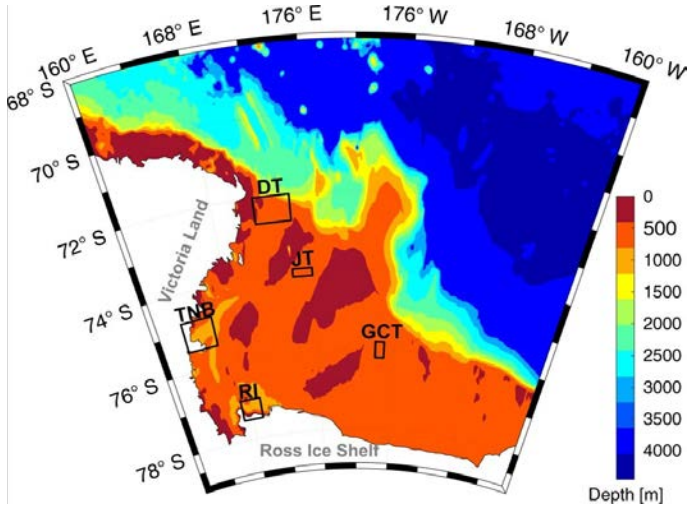
Silvano et al. 2023

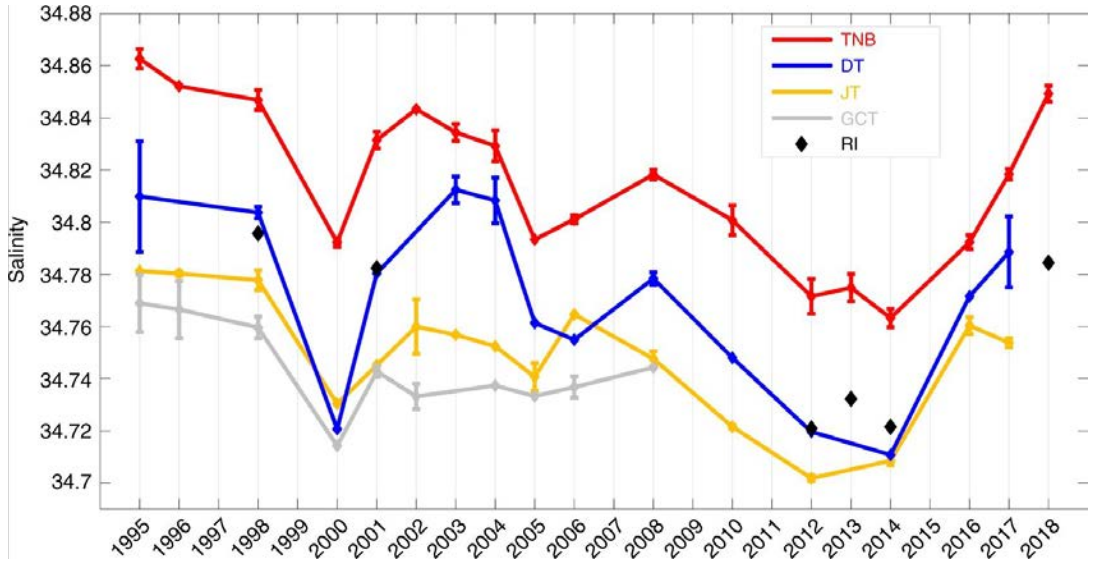
Ross Sea shelf water salinity variability



(Jacob and Giulivi, 2010)

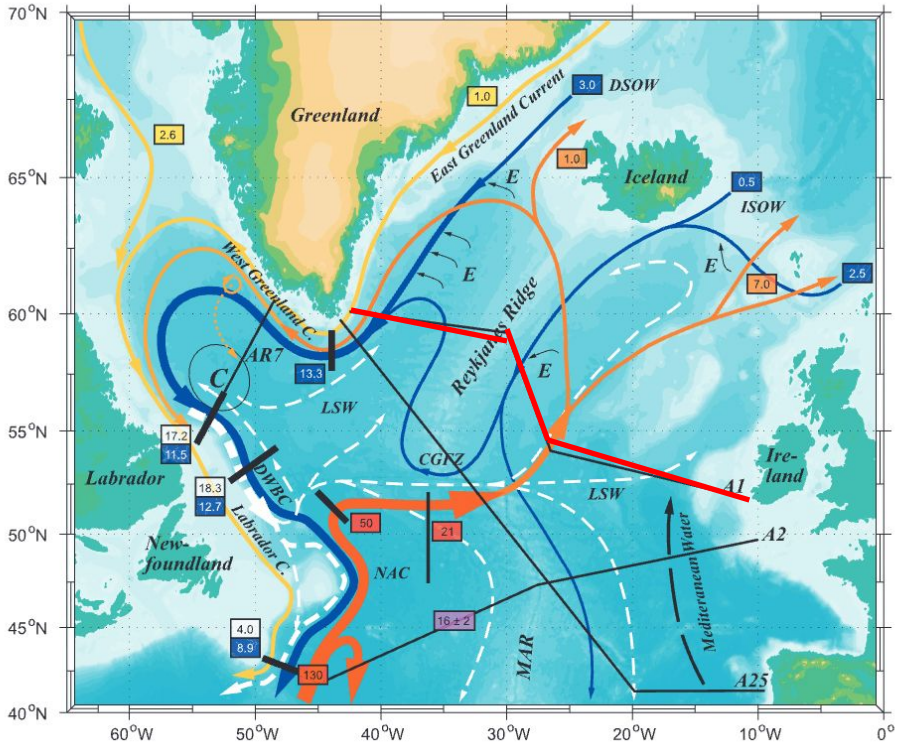


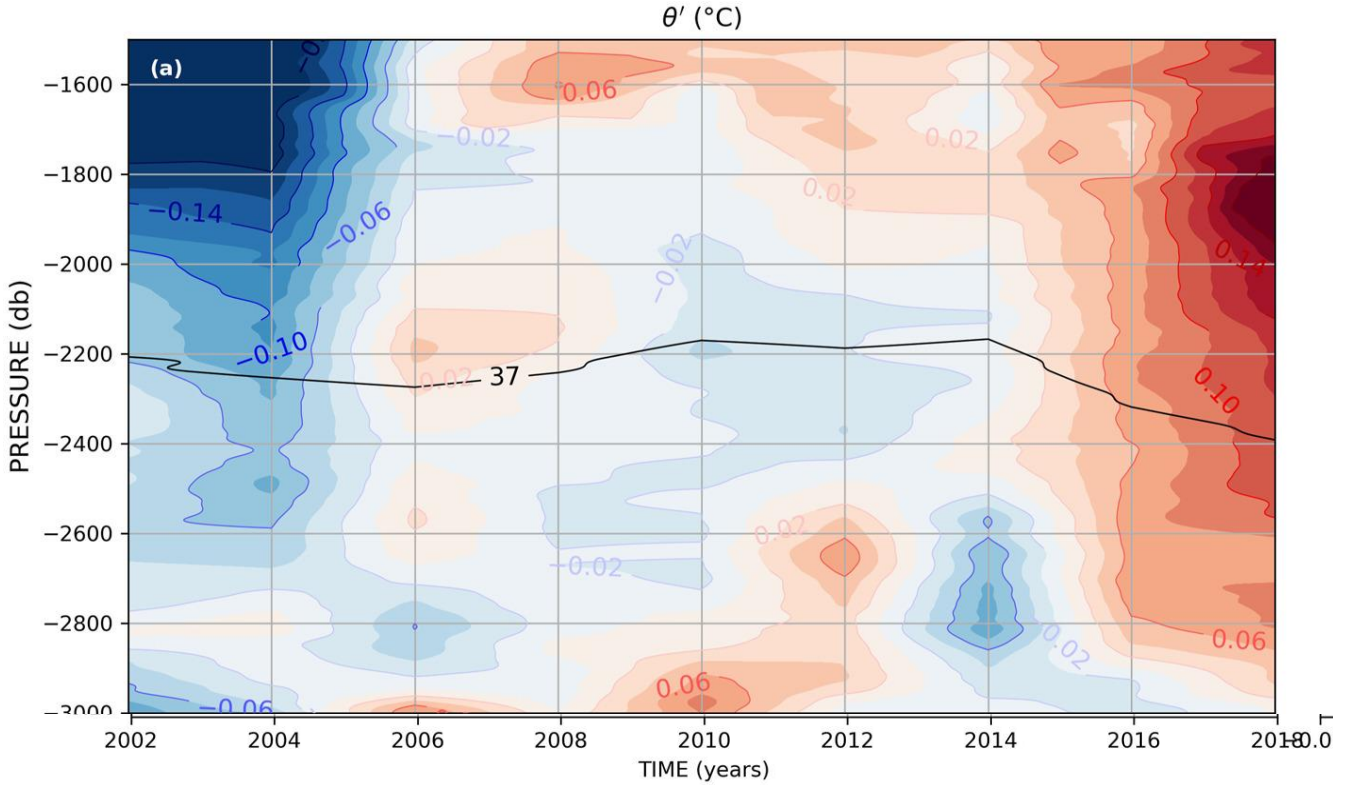




(Castagno et al. 2019)

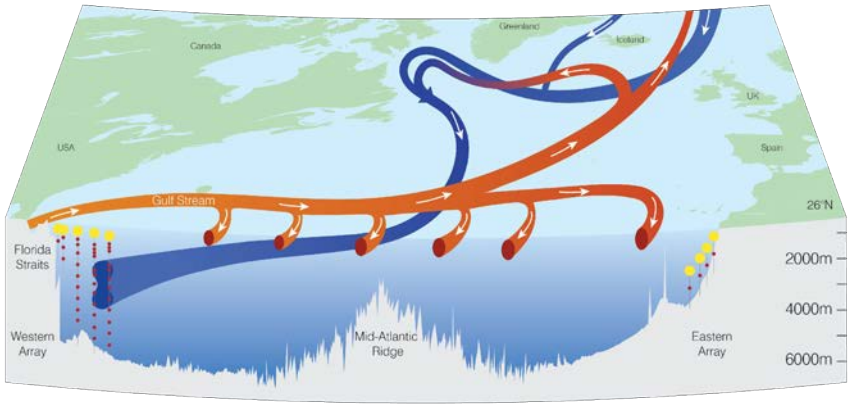
NADW Variability

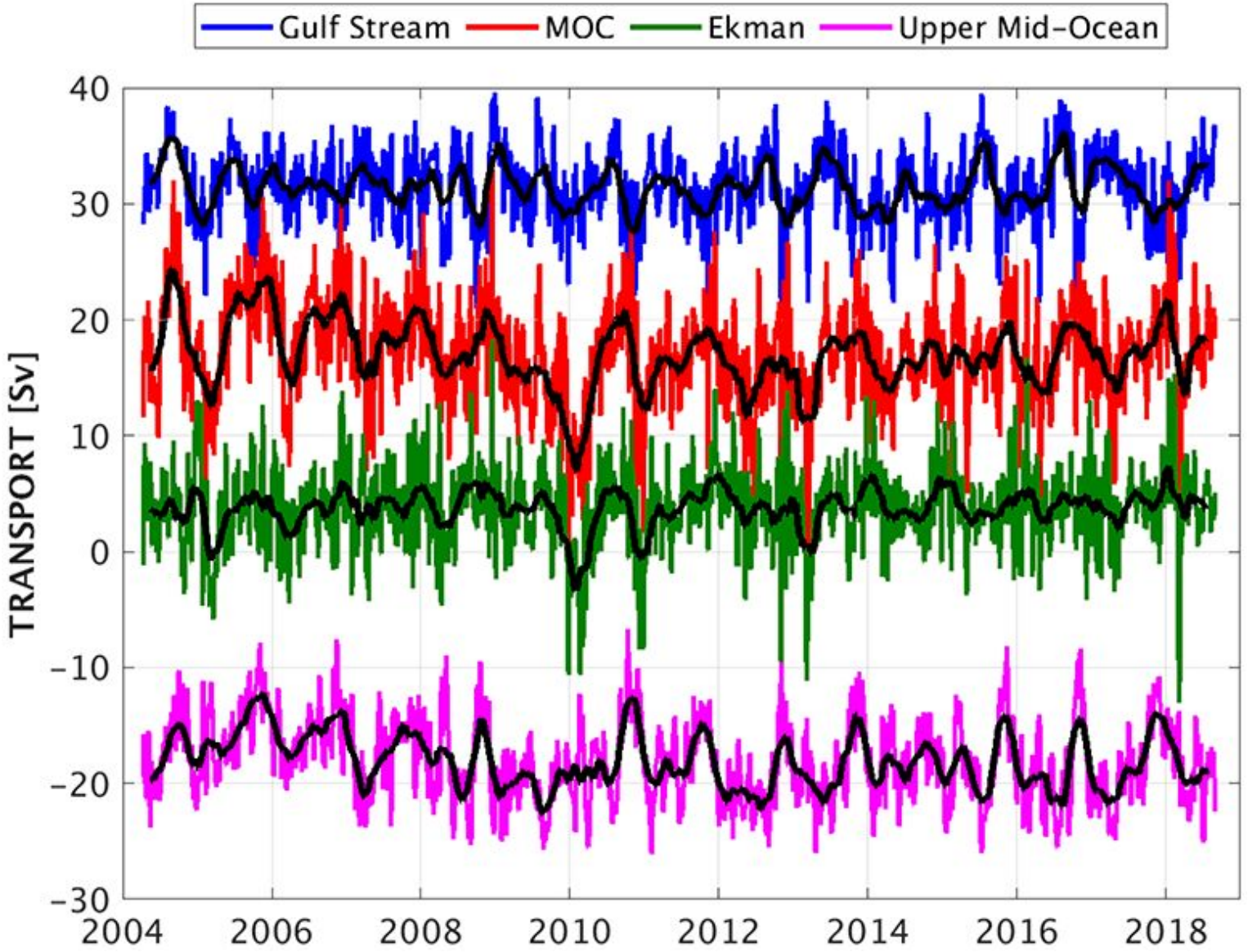




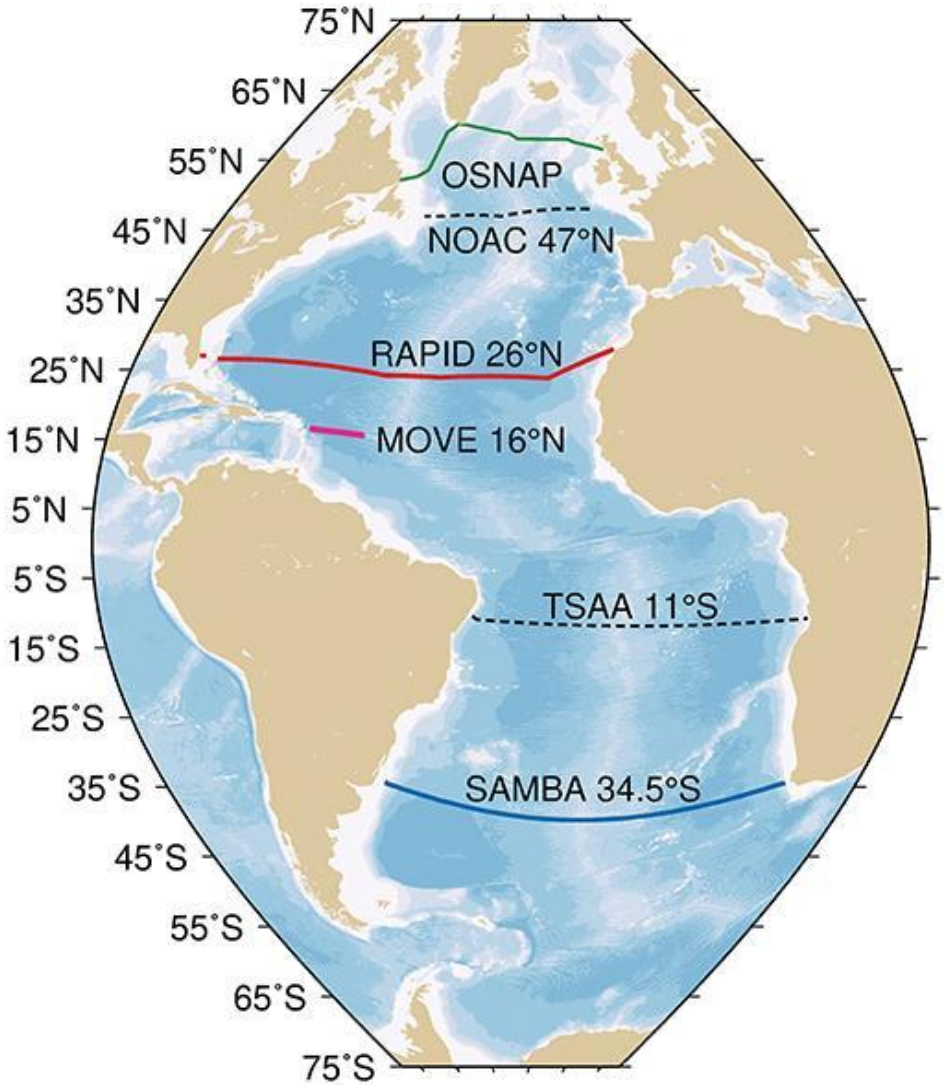
(Desbruyeres et al. 2022)

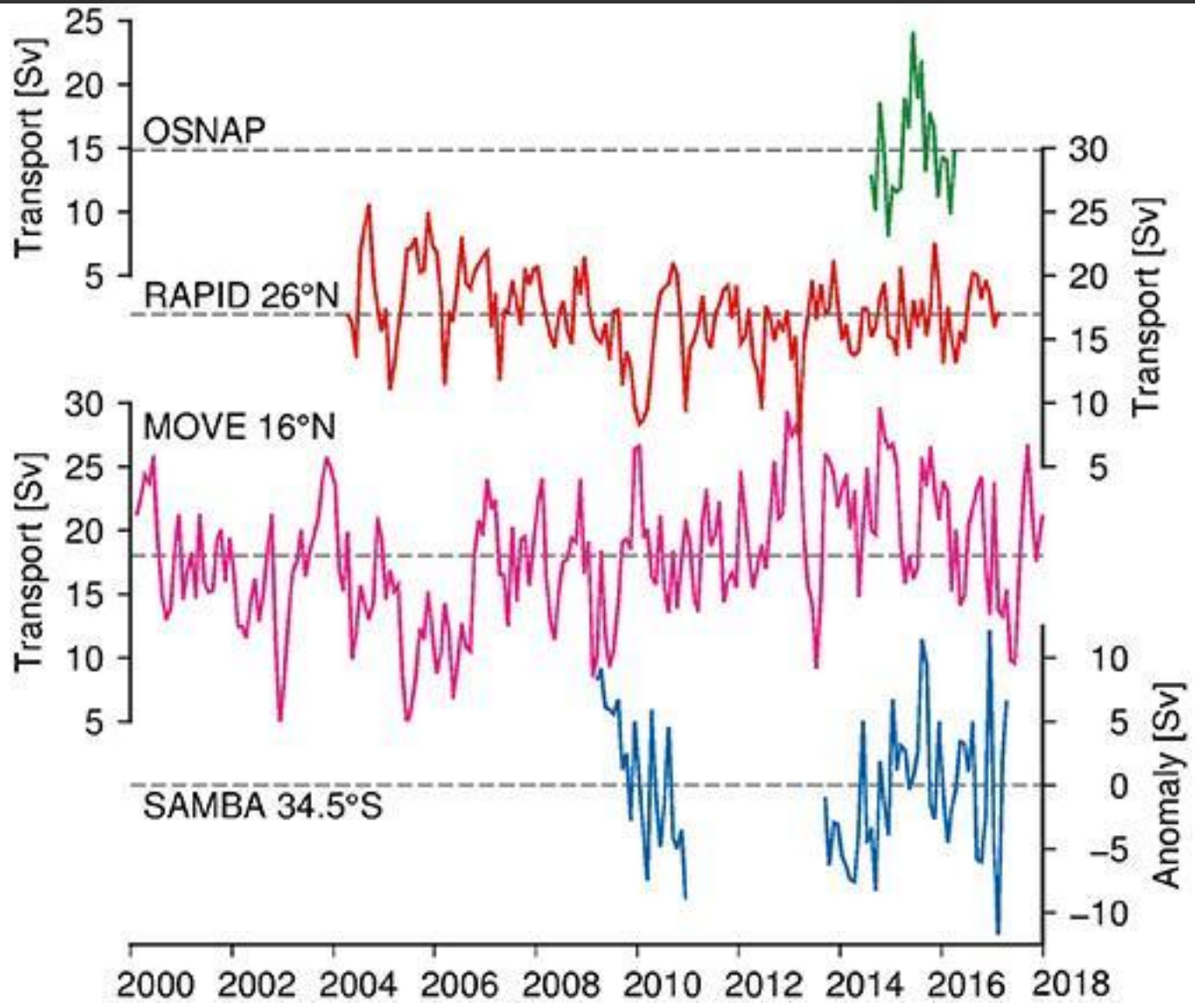
Long-term monitoring of the MOC





Long-term monitoring of the MOC

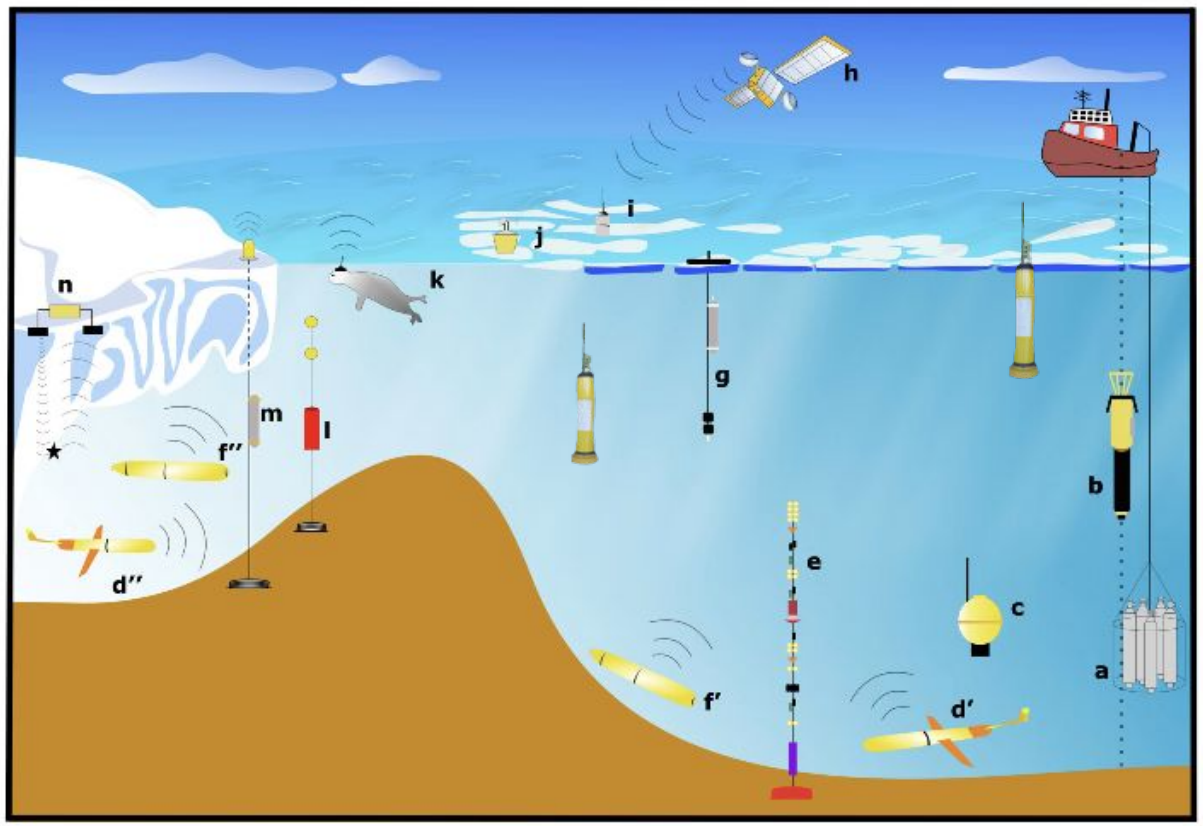




(Frajka-Williams et al. 2019)

Summary

- Antarctic Bottom Water (AABW) and North Atlantic Deep Water (NADW) fill the global deep and abyssal oceans
- Rates of AABW and NADW are set by surface buoyancy forcings that are vulnerable to climate change
- Over the past 4 decades, we have already seen remarkable changes in the properties and formation rates of both water masses
- Monitoring the deep ocean in coming decades will be critical to understanding climate.



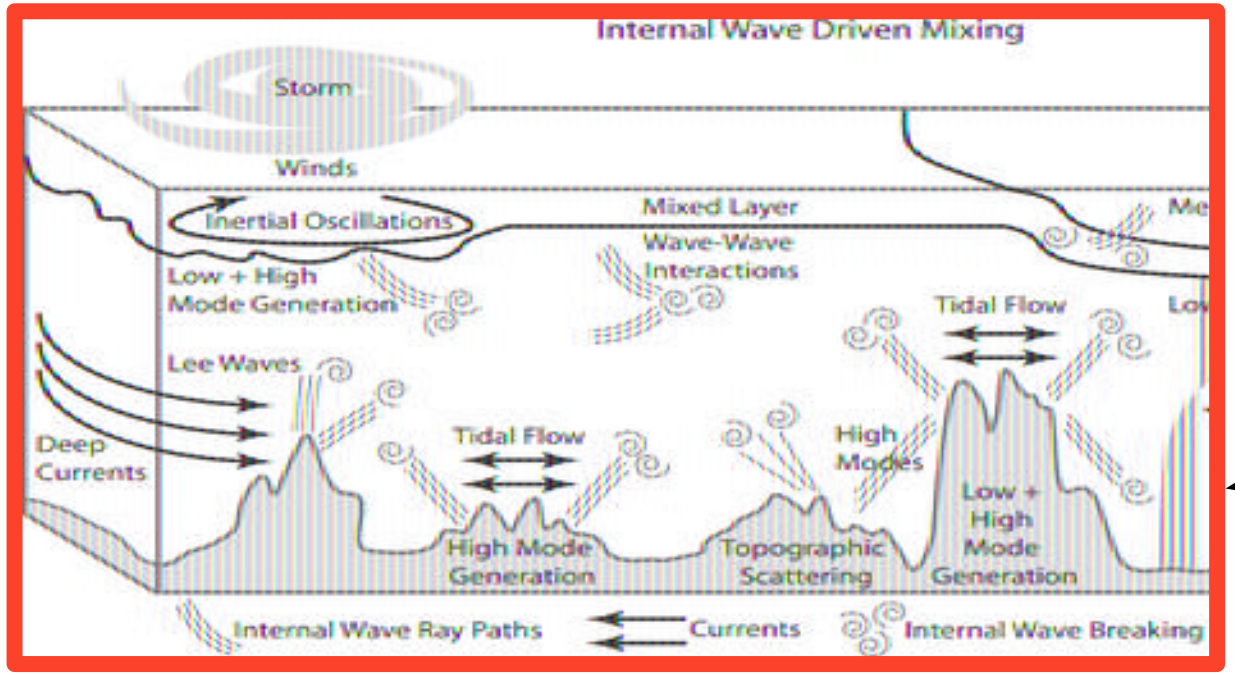
(Silvano et al. 2023) + floats from Talley

- 20 mins: 8:30-8:50am (5:30-5:50).

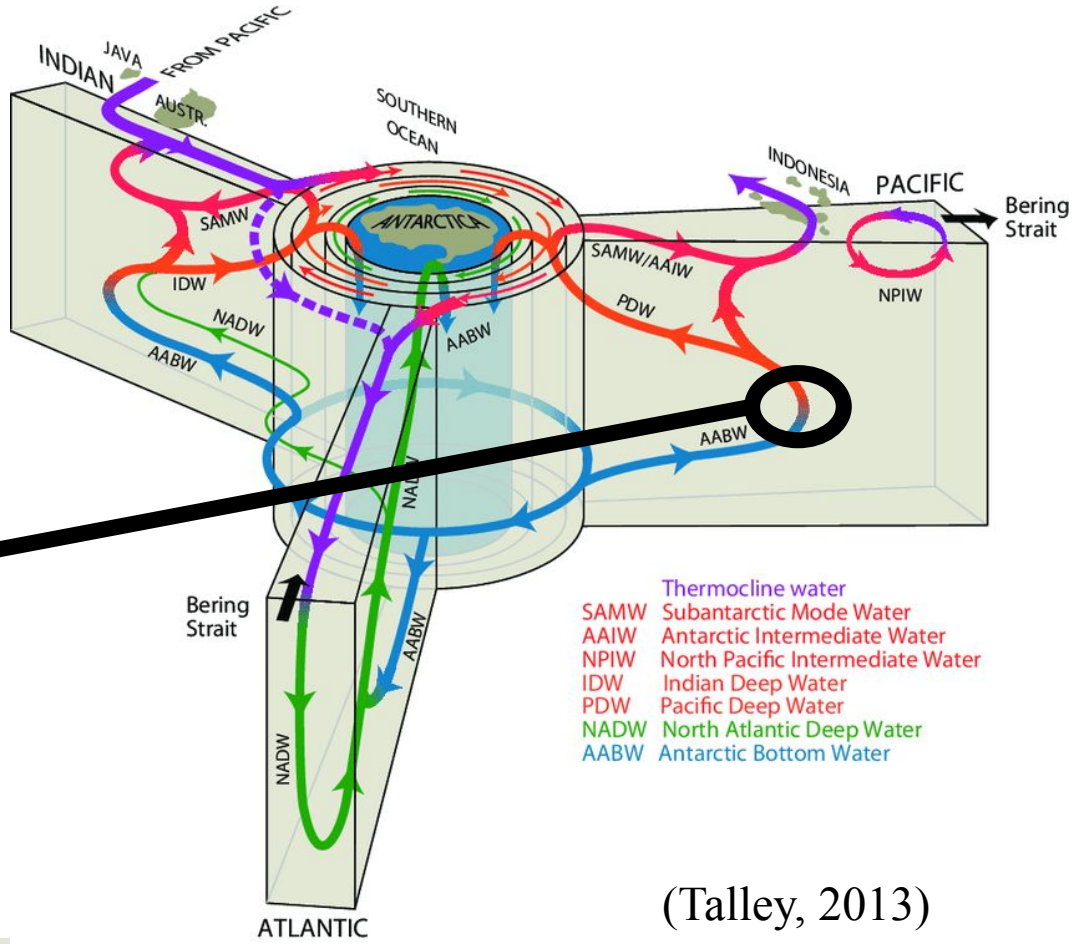
- Deep ocean ventilation is controlled by the physical processes at high latitudes that allow for the formation and export of dense water masses. Here we review the observational evidence of the volume and pathways of deep water from the North Atlantic and Antarctic Seas, including inferred estimates from deep ocean properties and tracers as well as direct observations from limited moorings and process studies. In addition, any observational evidence of temporal variability over the last four decades from observations will be summarized.

Bottom limb of the MOC

- The bottom limb of the Meridional Overturning Circulation (MOC) = the Antarctic Bottom Water (AABW) limb
- Bottom water properties are set by the balance between the renewal of deepwater formed around Antarctica and the rate of mixing with overlying water



(MacKinnon et al. 2017)



(Talley, 2013)

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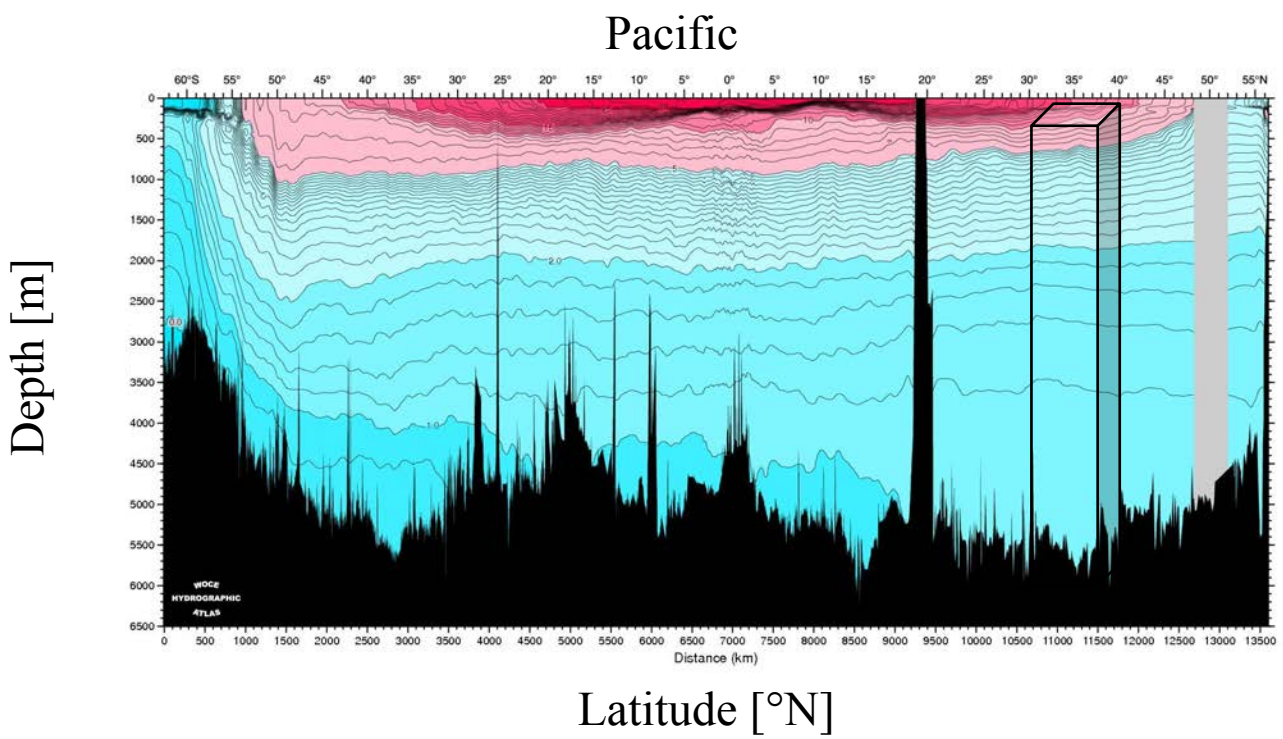

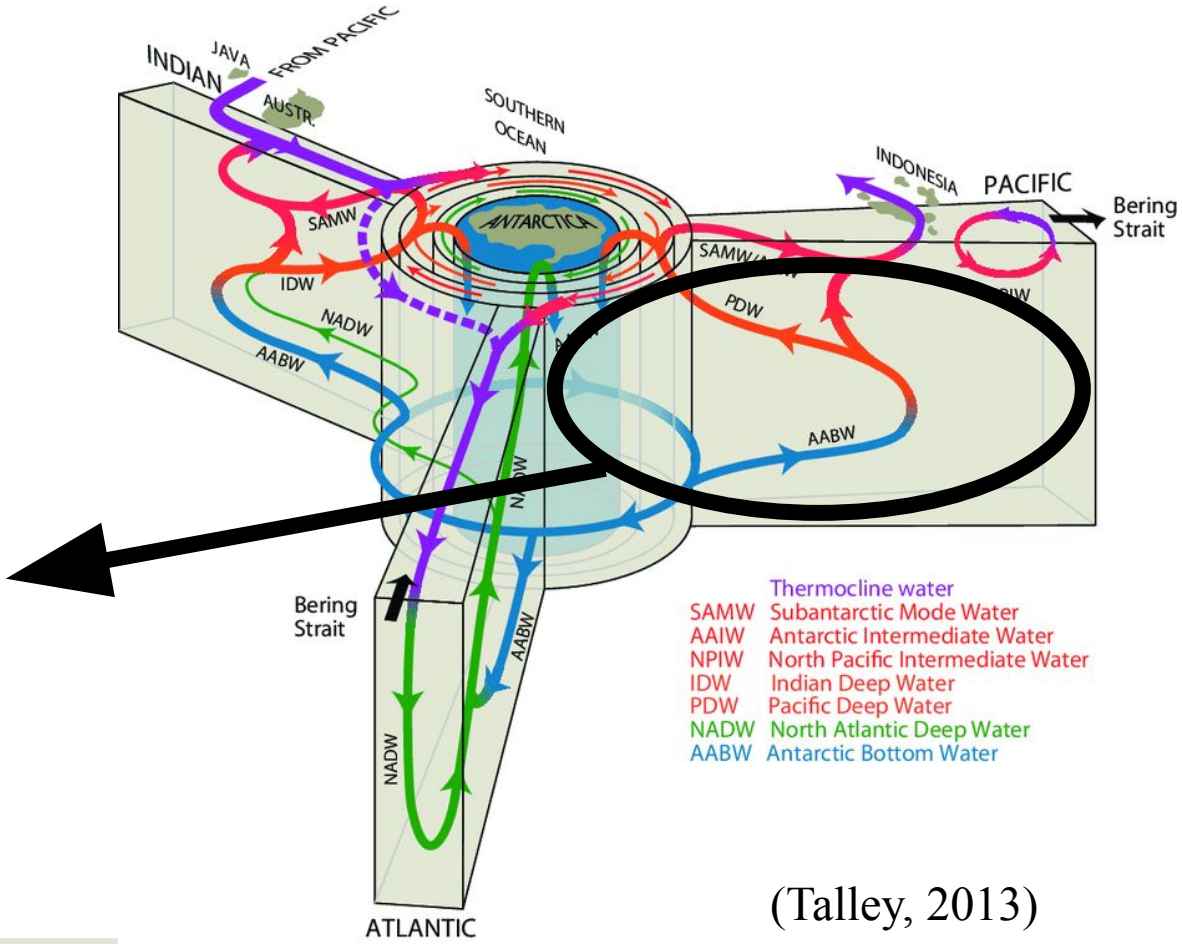

(Talley, 2013)

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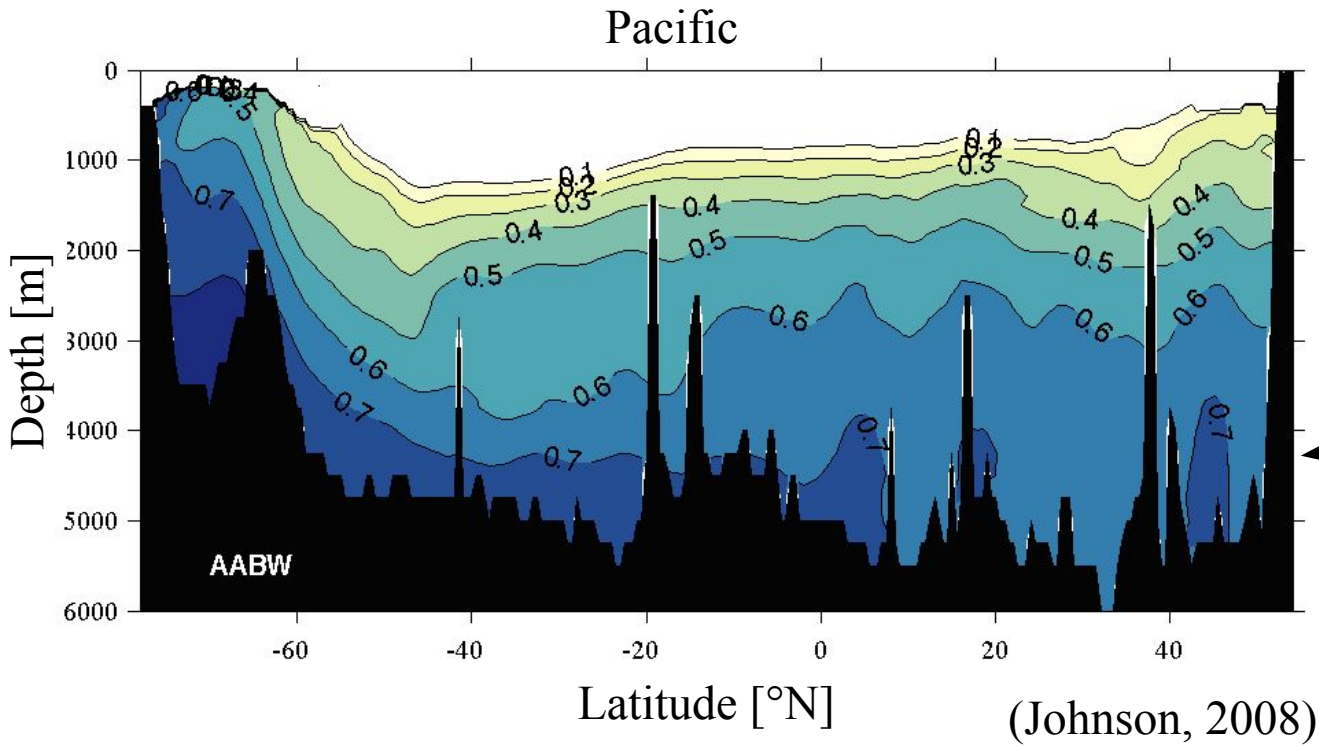
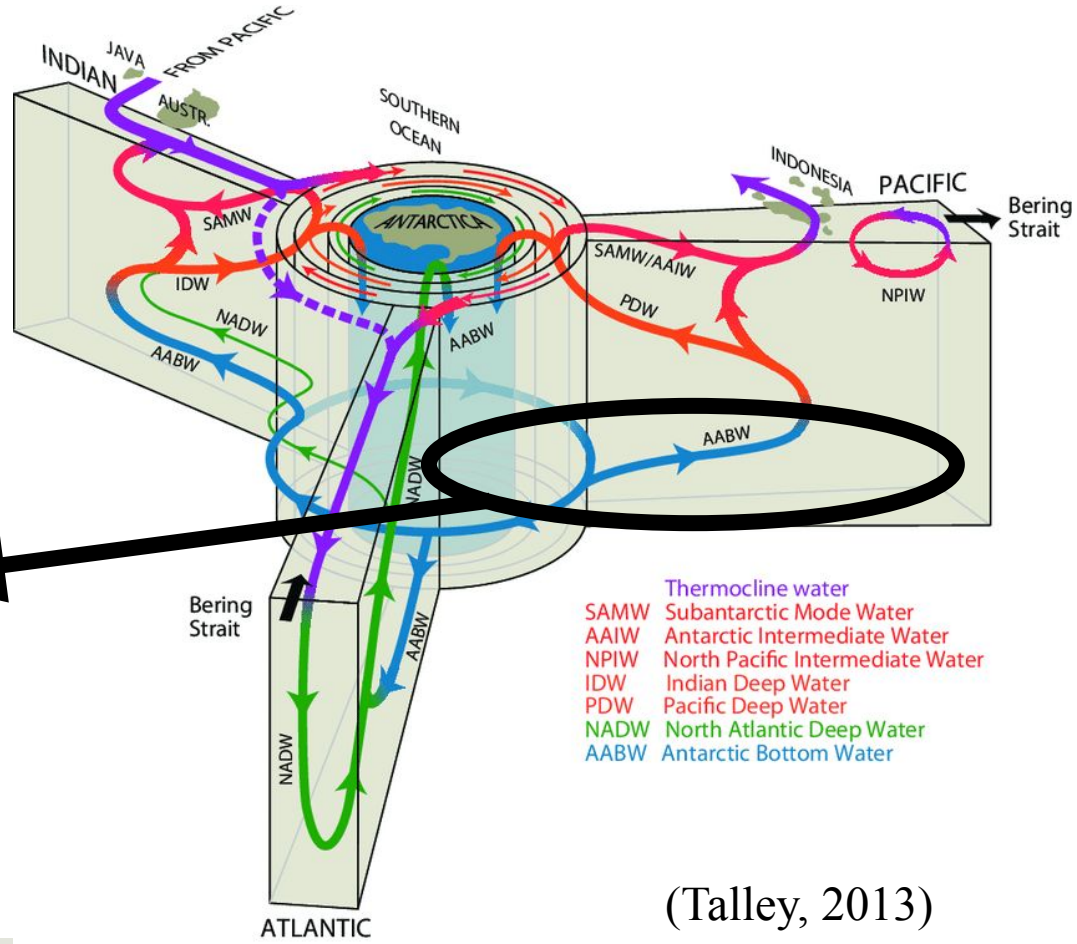


(Johnson, 2008)



(Talley, 2013)

Deep Ocean Properties

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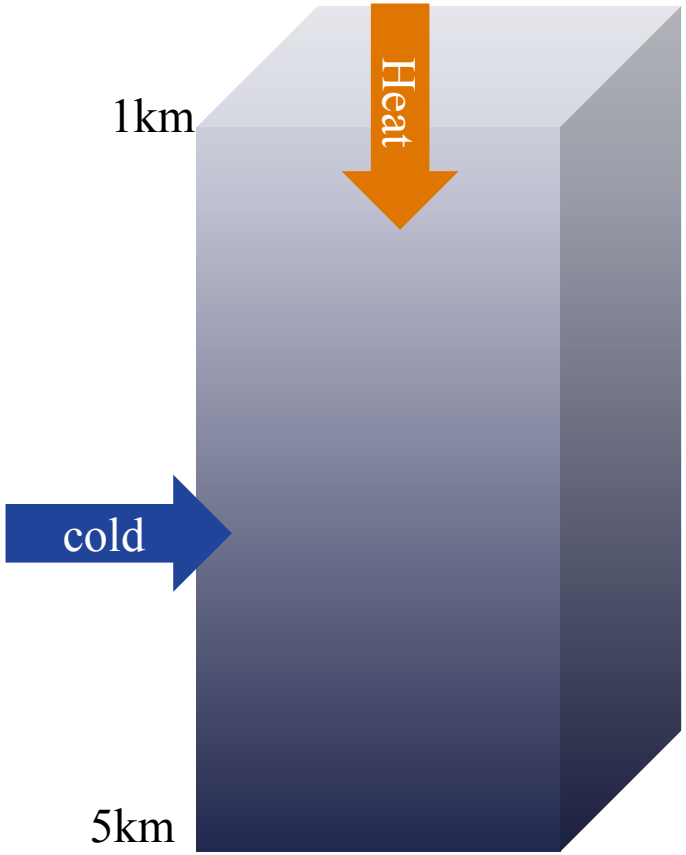
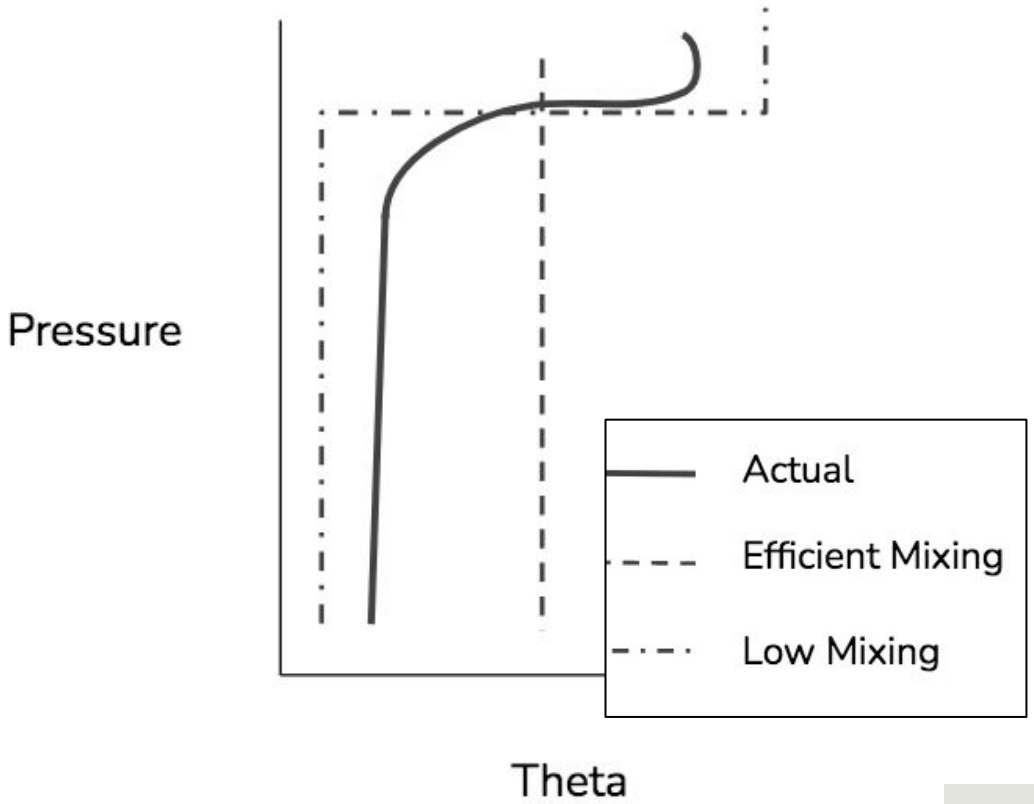
Advection + Mixing = 0





- In steady state, these two processes are equal and bottom temperature is constant in time