θ-S structure of the North Atlantic circulation and the associated heat/freshwater transports

Xiaobiao Xu[1], Peter Rhines[2], and Eric Chassignet[1]

[1]Florida State University;
[2]University of Washington

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Motivations

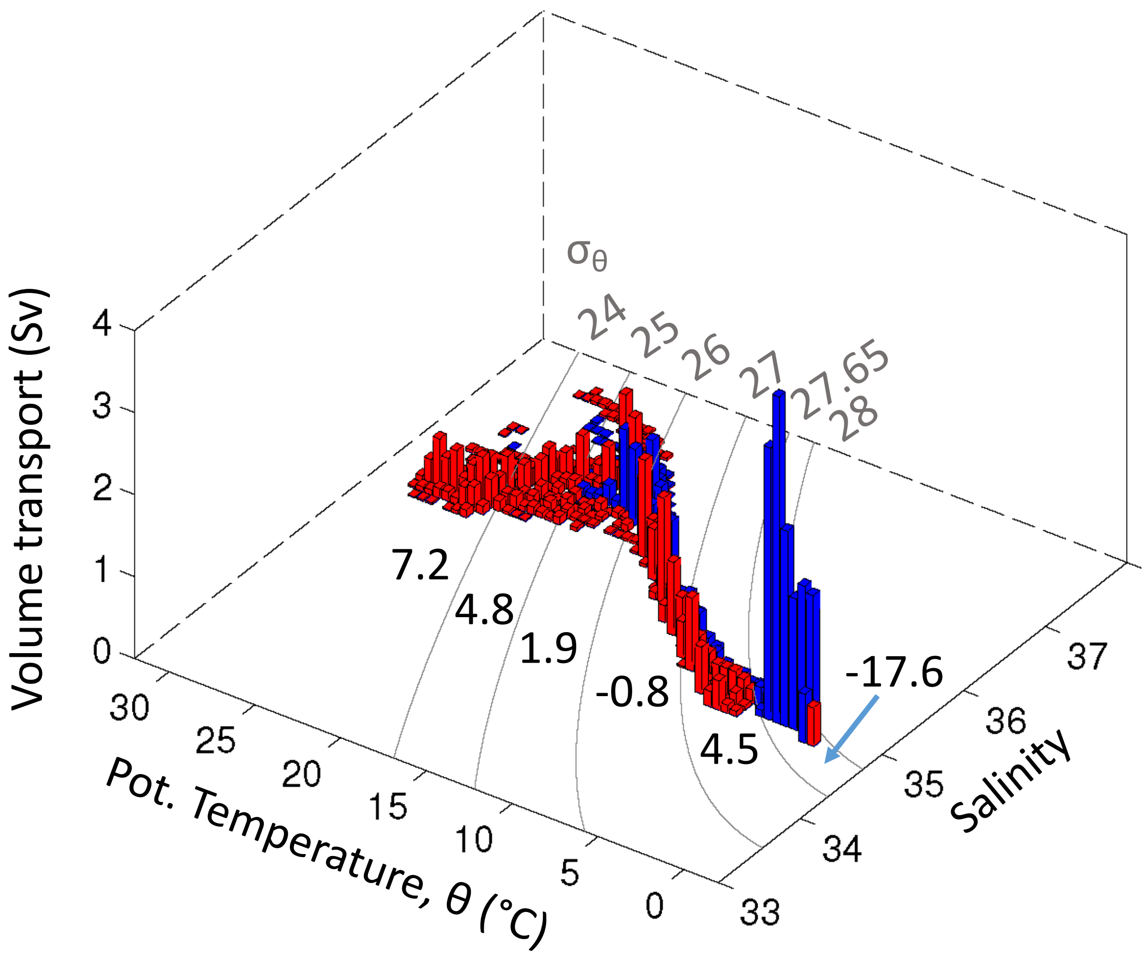
We know the North Atlantic circulation well: basin scale AMOC that is mostly vertical/diapycnal and sub-basin scale gyres that are mostly horizontal/ isopycnic. Yet, there are uncertainties regarding the partition of the meridional heat transport (MHT) between the AMOC and gyres. For example, at 25°N,

- *Classical vertical-horizontal decomposition suggests that 90% MHT is due to the AMOC and the remaining 10% is due to the subtropical gyre (e.g., Bryden and Imawaki 2001; Johns et al., 2011; McCarthy et al., 2015)*
- *0.1-0.4 PW (10-30%) by the subtropical gyre (Talley, 2003)*
- *40% by the subtropical gyre (Ferrari and Ferreira, 2011)*

The meridional freshwater transport (MFWT) is less well-known, so are the AMOC and gyre contributions:

- *Vertical-horizontal decomposition of the RAPID data based transports suggests that -0.78 Sv MFWT is due to the AMOC, 0.35 Sv due to the subtropical gyre (McDonagh et al. 2015)*

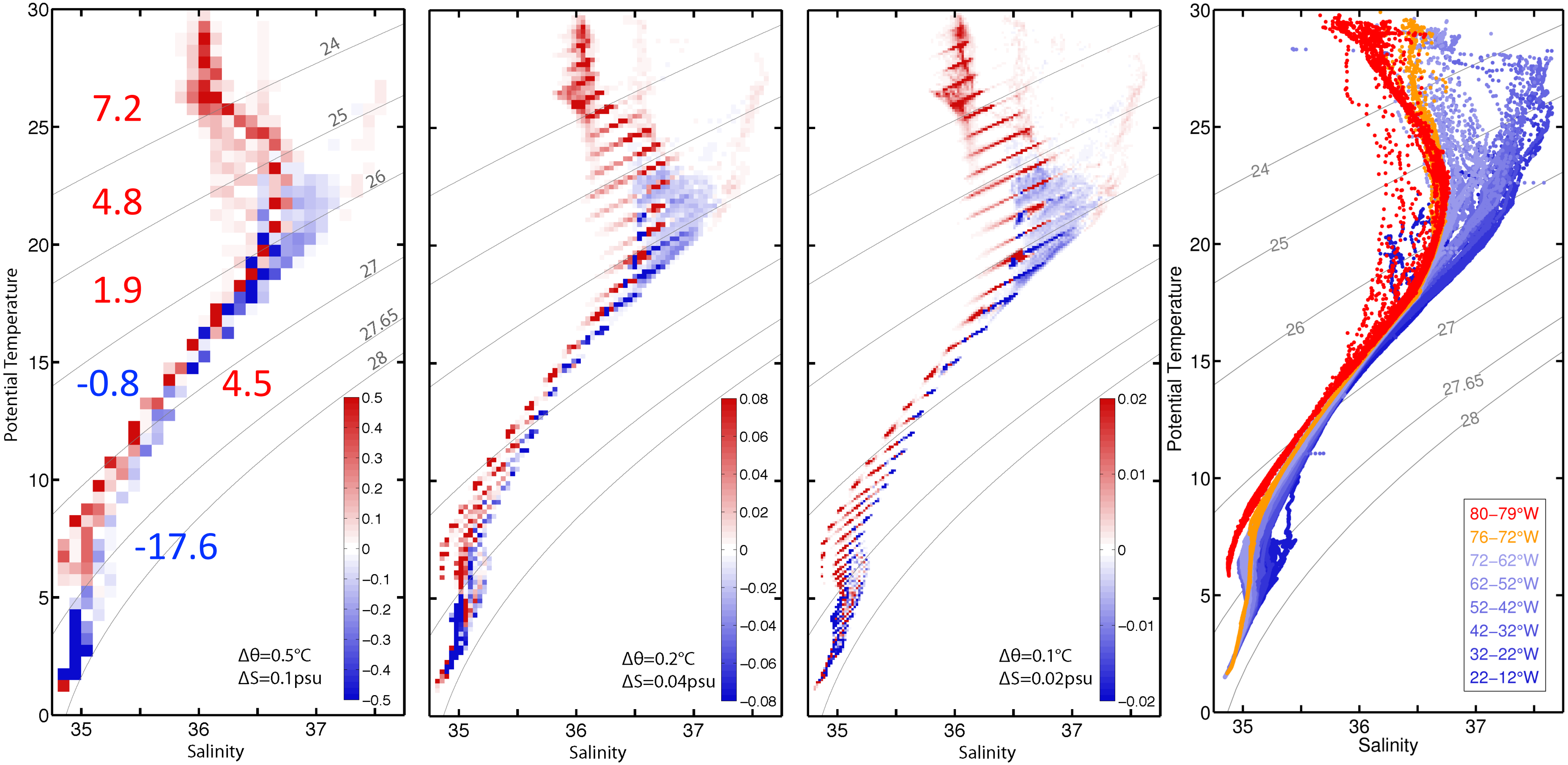
The purpose here is to examine the circulation structure to clarify the differences, using high-resolution model results. A simple (natural) approach of summarizing the essential of the meridional flows (of different water masses) across a zonal section is to project the meridional transports on a θ-S plane. For example, the Northward and Southward transports across 26°N



From a different angle …

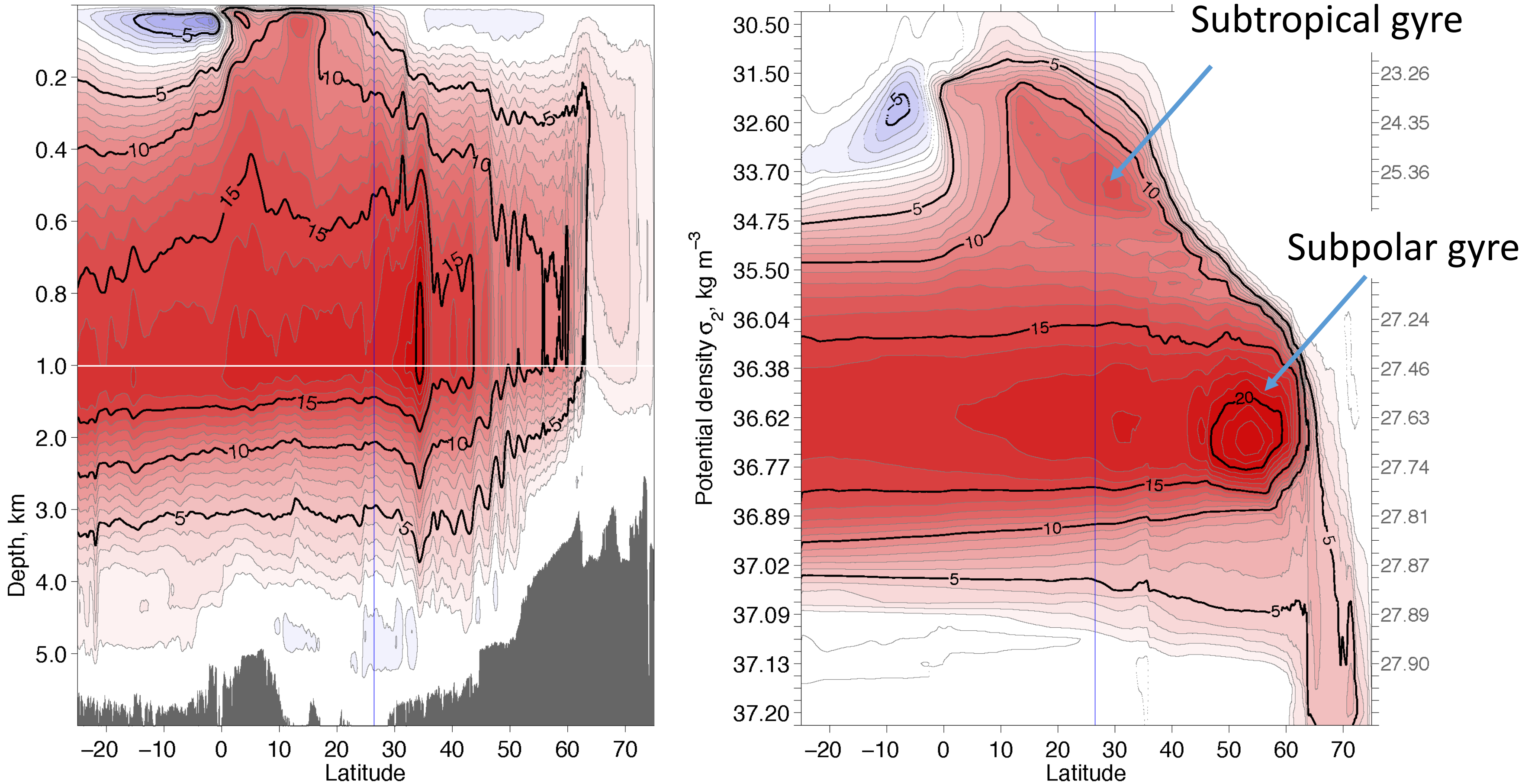
Model meridional transport on θ-S plane for three ΔθxΔS

Observed θ-S



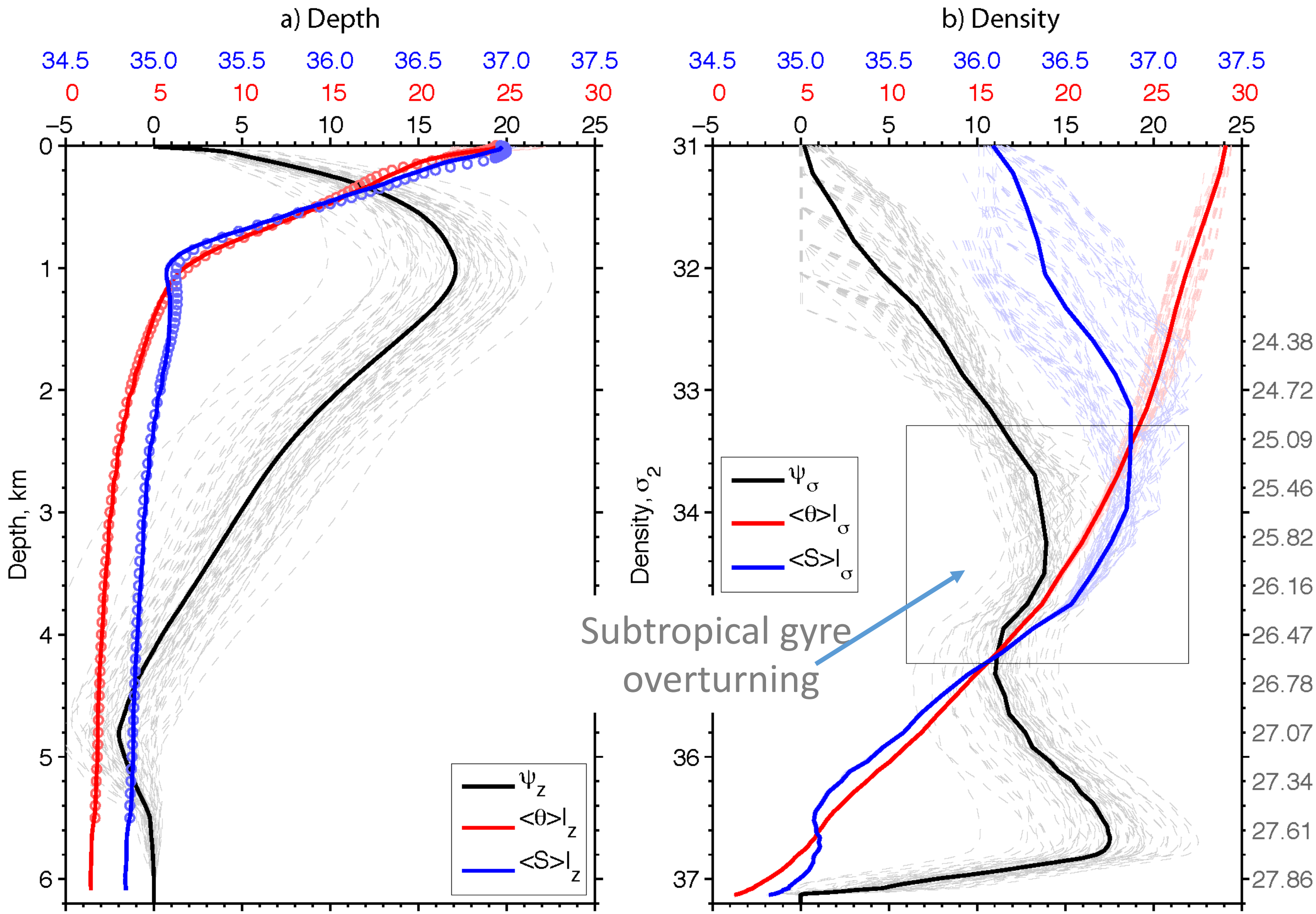
- diapycnal AMOC (warmer, saltier water northward)
- diapycnal subtropical gyre (warmer, saltier water northward)
- isopycnic subtropical gyre (colder, fresher water northward)

In the basin-scale perspective



- Different meridional overturning circulation projected on depth and density spaces: the later shows sub-basin scale diapycnal overturning cells (in both the subtropical and subpolar NA), which are not part of the basin-scale AMOC. How does this difference impact the MHT/MFWT?

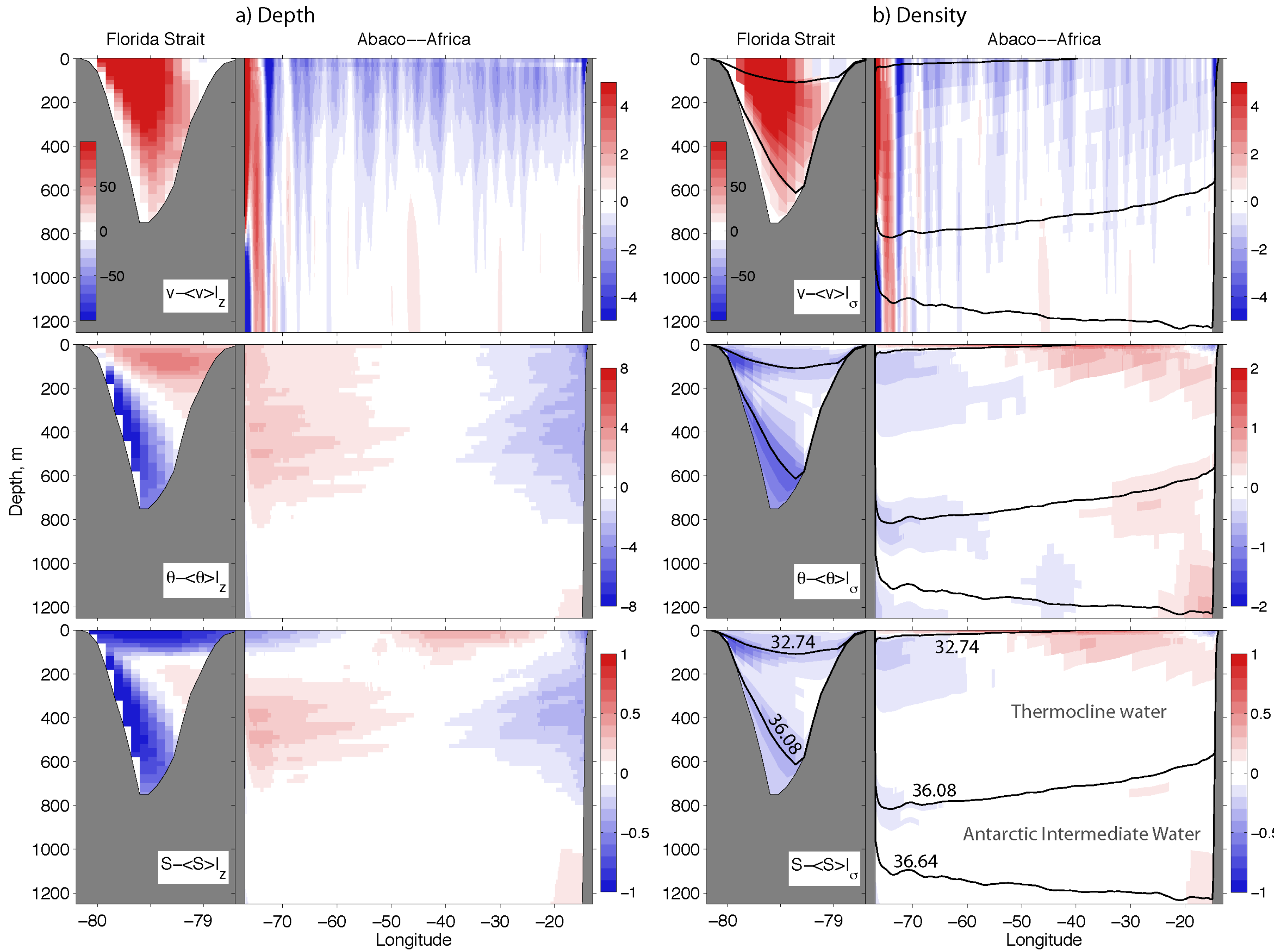
Overturning (vertical vs. diapycnal)



MHT: 1.10 PW [total 1.24 PW]
MFWT: -0.71 Sv [total -0.37 Sv]

1.29 PW (0.06 PW)
-0.53 Sv (-0.03 Sv)

Gyre (horizontal vs. isopycnal)



0.14 PW [total 1.24 PW]
0.34 Sv [total -0.37 Sv]

-0.05 PW
0.16 Sv

Gyre vs. AMOC in the MHT/MFWT

- The subtropical gyre (including a large isopycnic circulation and a small diapycnal overturning) contributes near 0 PW MHT and about 0.13 Sv MFWT northward;
- The zero gyre MHT is even lower than the 10% contribution based on the classical vertical-horizontal decomposition, let alone the higher gyre contributions in by Talley (2003) and Ferrari and Ferreria (2011);
- The northward gyre MFWT, also lower than the contribution based on vertical-horizontal decomposition, is opposite of that by the diapycnal AMOC: one corresponds to the positive E-P within the subtropical gyre, the other to the overall negative E-P in the northern North Atlantic that forms the NADW.

Why not higher gyre MHT?

- 0.4 PW gyre contribution in Talley (2003) comes from using the upper part of the Florida Current (and Ekman) transports to balance the returning component of the subtropical gyre

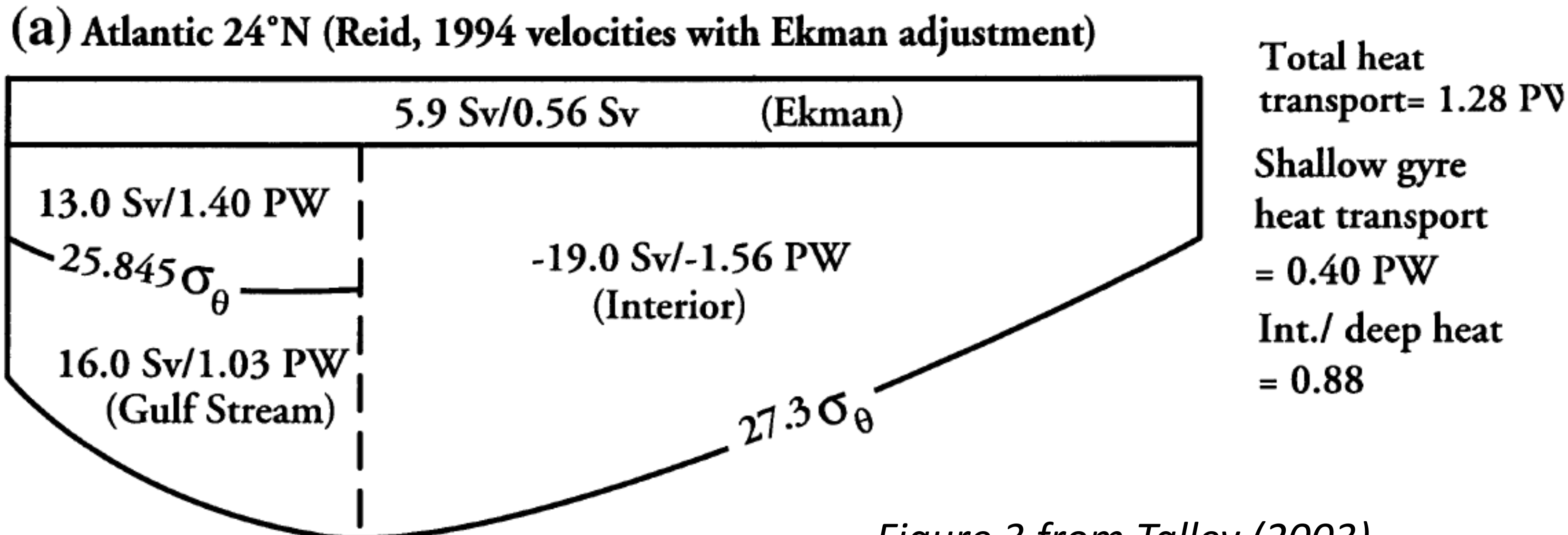
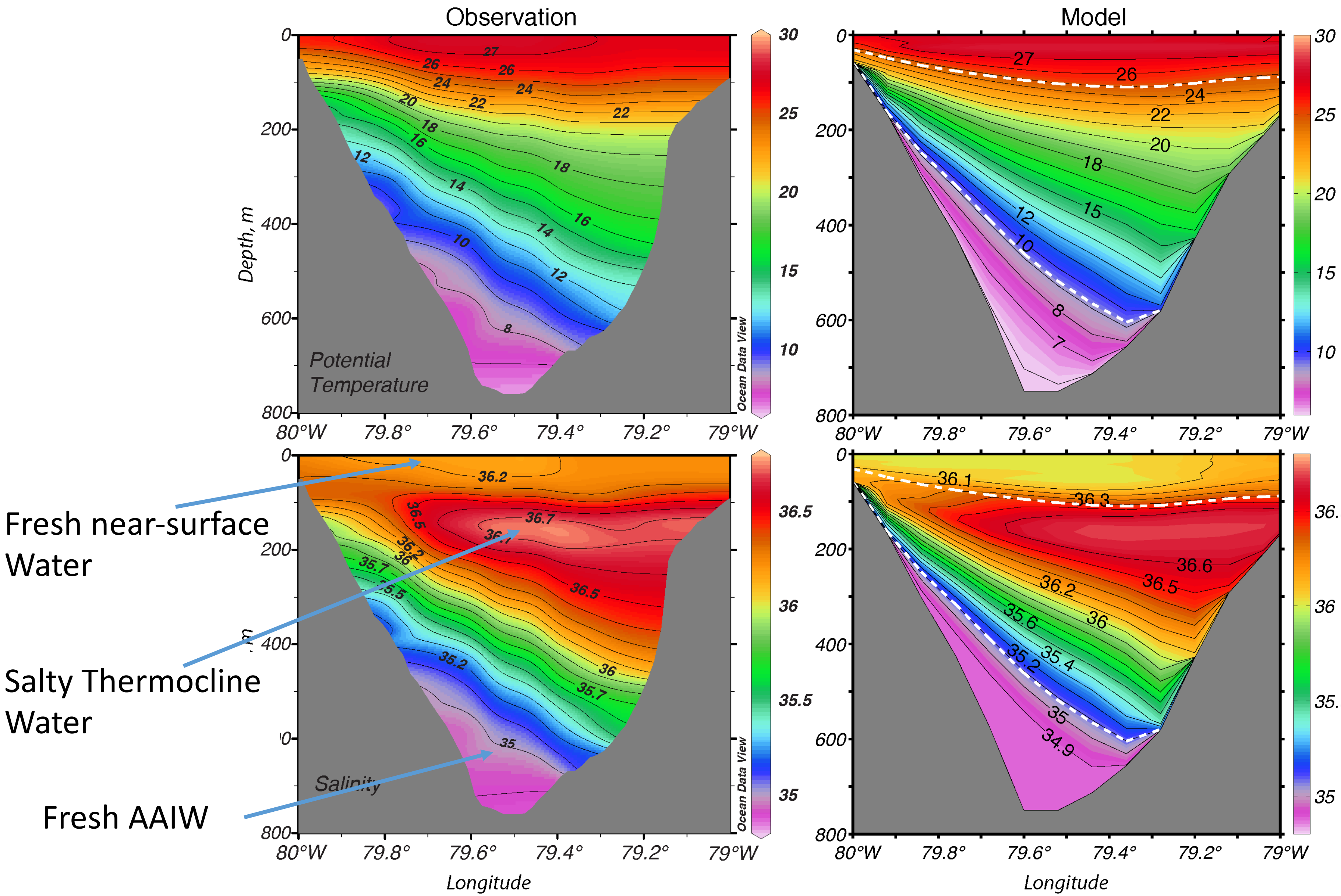
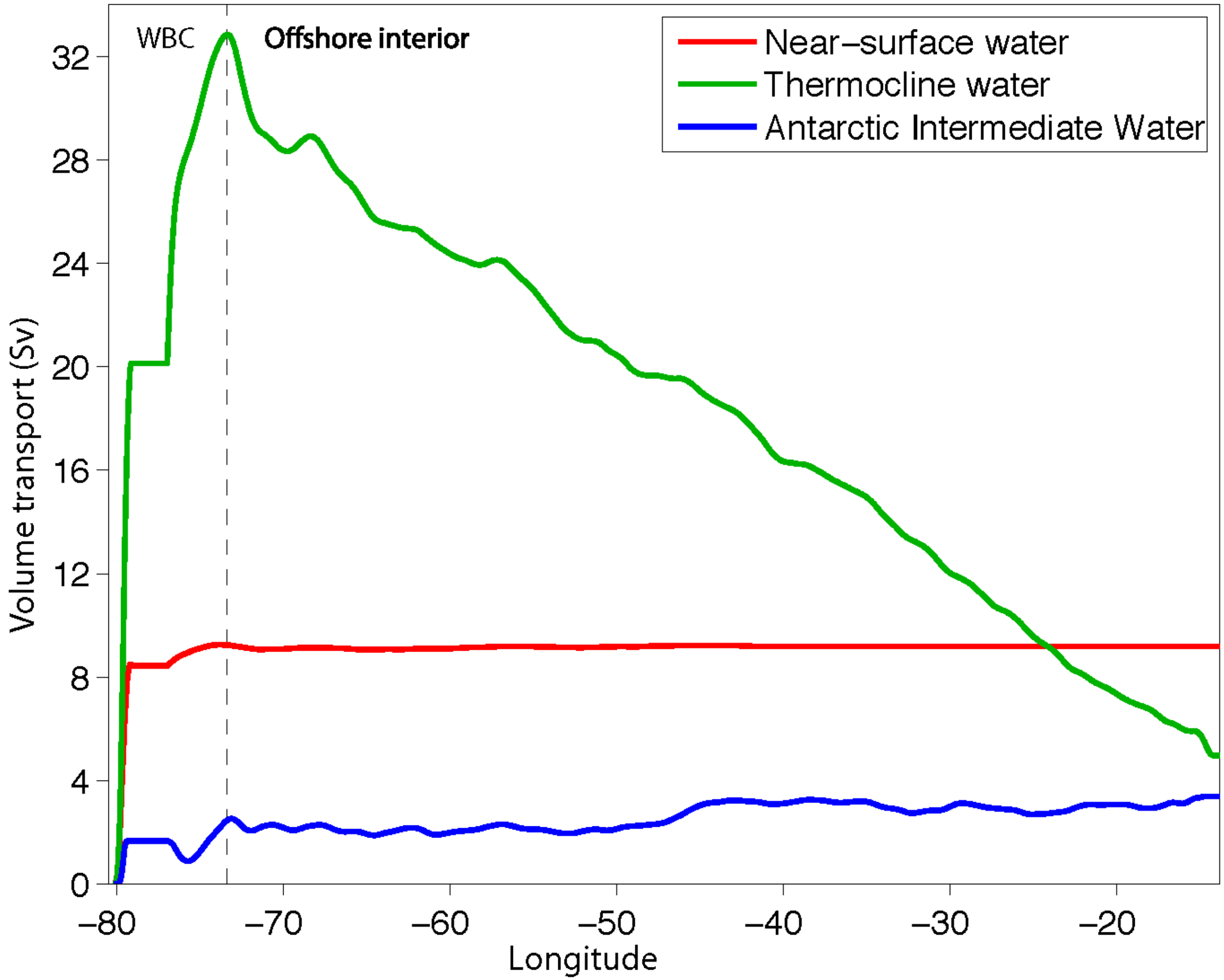


Figure 3 from Talley (2003)

However, T/S in the WBC (FC)

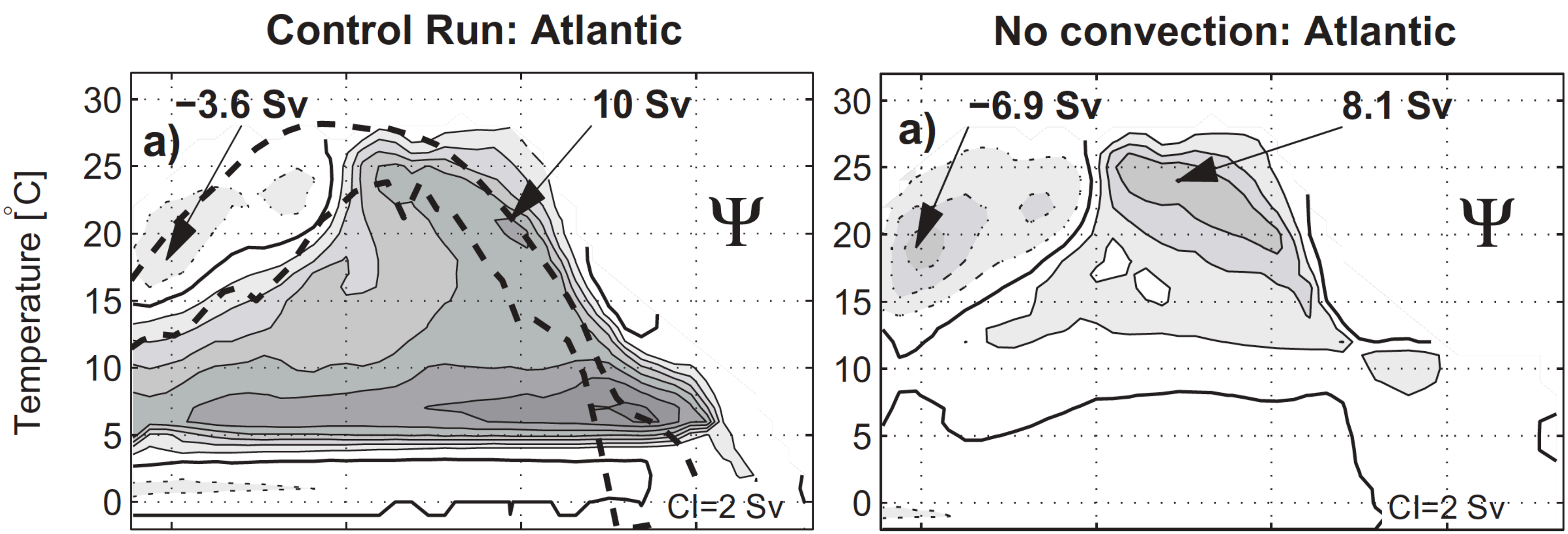


- It is thermocline water that constitutes the subtropical gyre, and the near-surface water and AAIW are the (basin-scale) AMOC components. If we refine the Talley (2003) calculation (using the thermocline water only), we obtain ~0 PW MHT and 0.13 Sv MFWT, consistent with the results of diapycnal-isopcynic decomposition.



Why not higher gyre MHT?

- 40% gyre contribution in Ferrari and Ferreira (2011) is based on two experiments: One with AMOC (0.8 PW); the other without AMOC (0.3 PW). However, subtropical gyre differs significantly between these two models: 0.3 PW represents the gyre MHT in the experiment without AMOC, not the one with AMOC.



Figures 6a, 12a in Ferrari and Ferreira (2011)

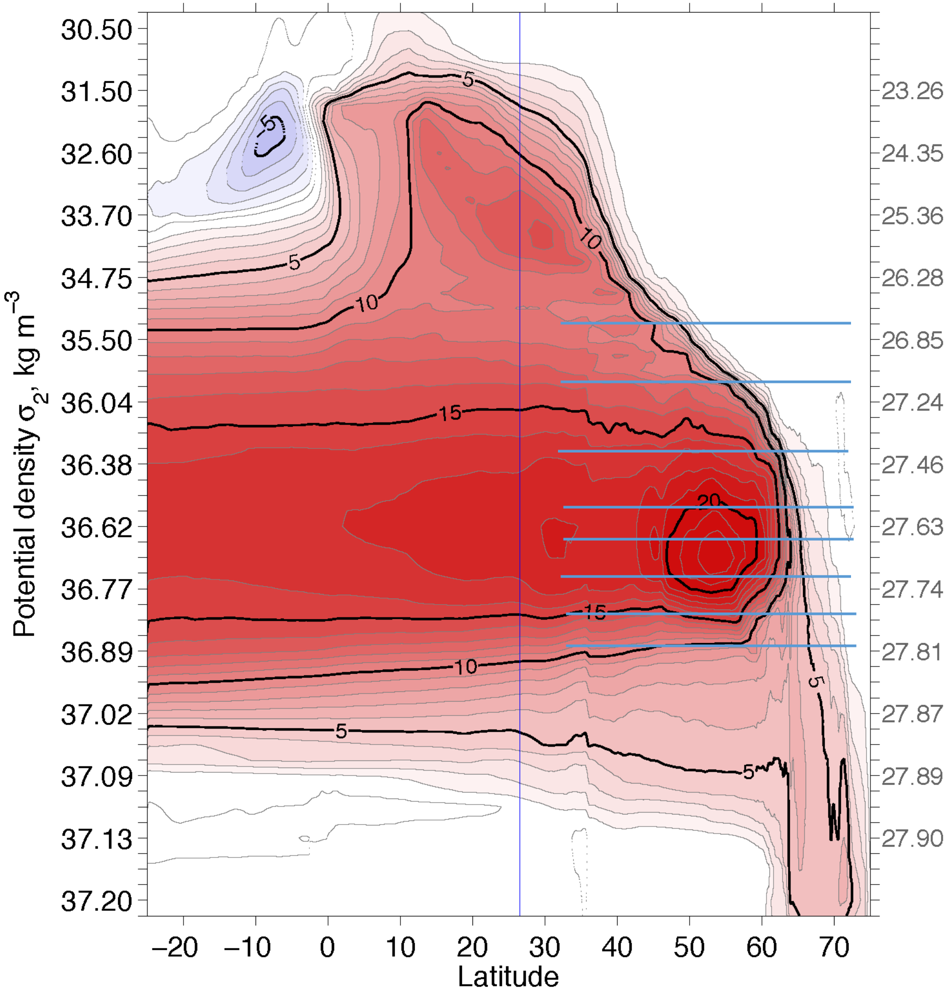
Summary

- The (basin-scale) AMOC is responsible for virtually all the MHT across the subtropical North Atlantic at 26°N;
- The subtropical gyre contributes quite significantly to the MFWT (0.13 Sv, northward), opposite to that contributed by the AMOC (-0.50 Sv, southward).

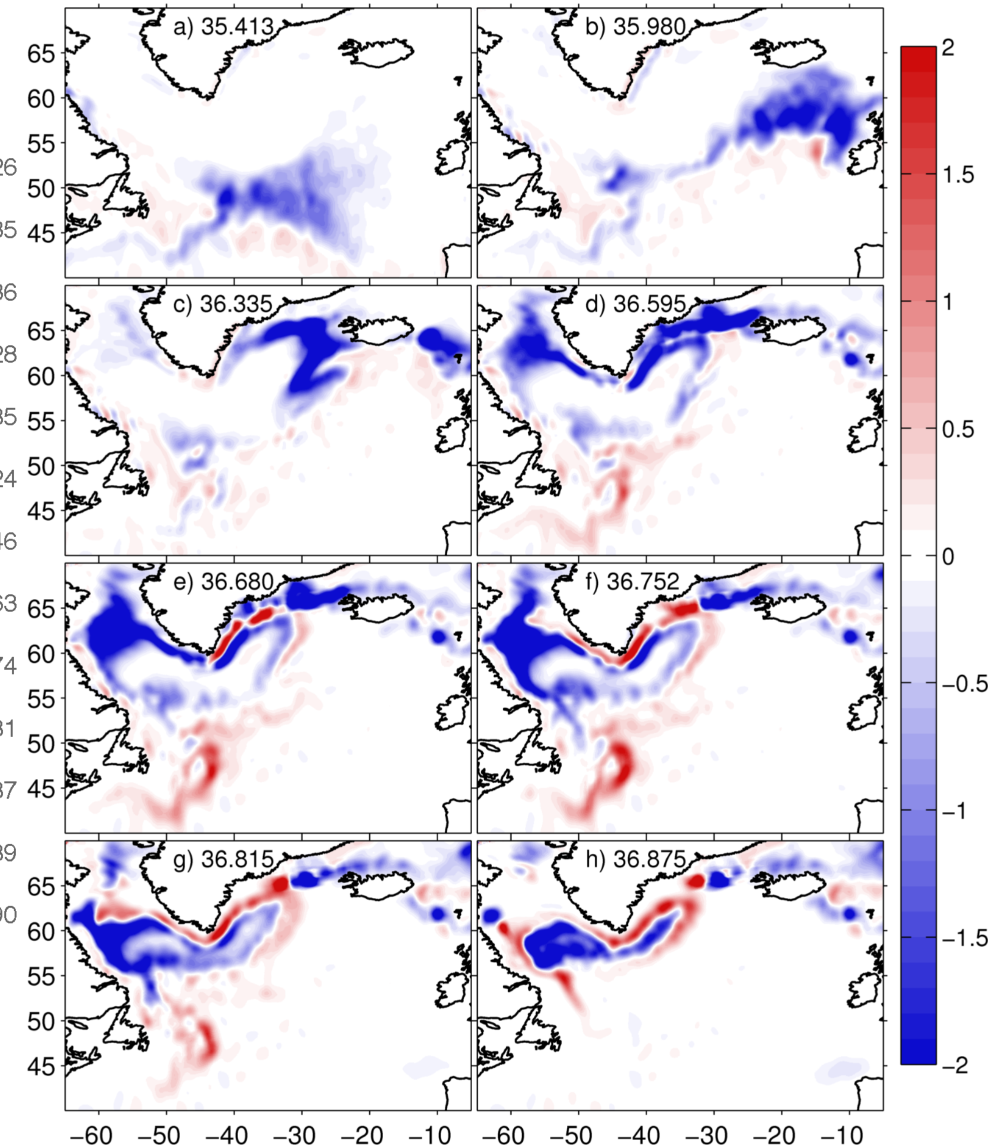
For more details of this work, see *J. Climate*; 2016 (DOI: 10.1175/JCLI-D-15-0798.1)

On-going work

2-D Diapycnal transformation

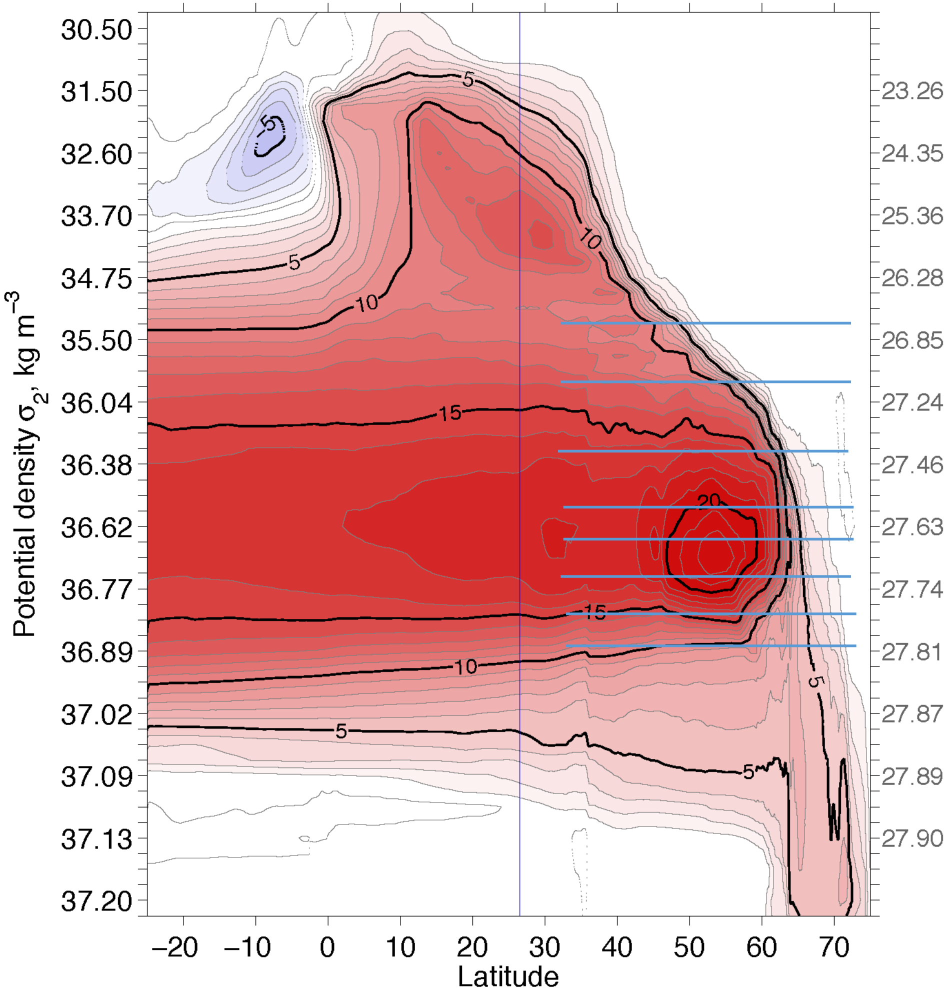


3-D maps of WMT

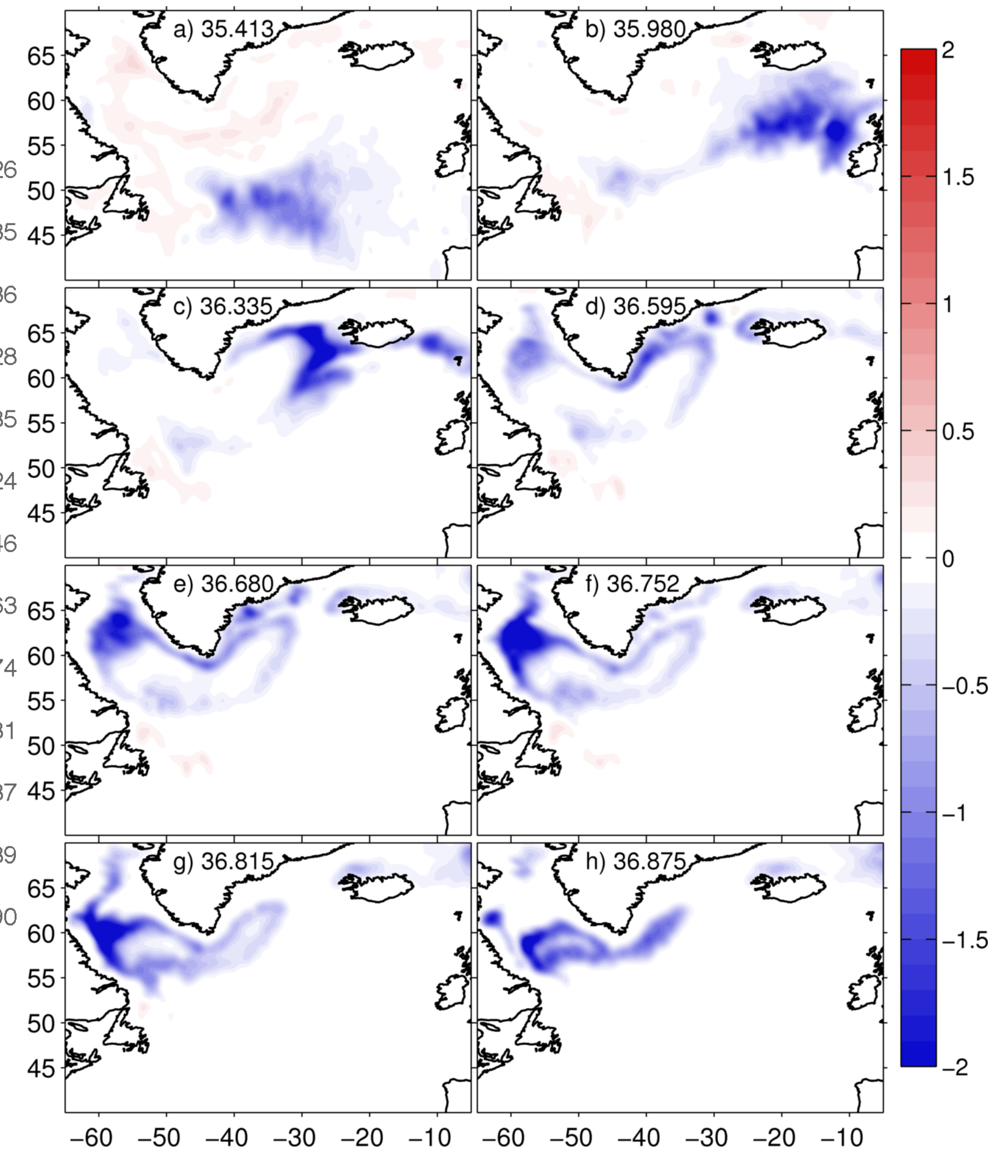


On-going work

2-D Diapycnal transformation

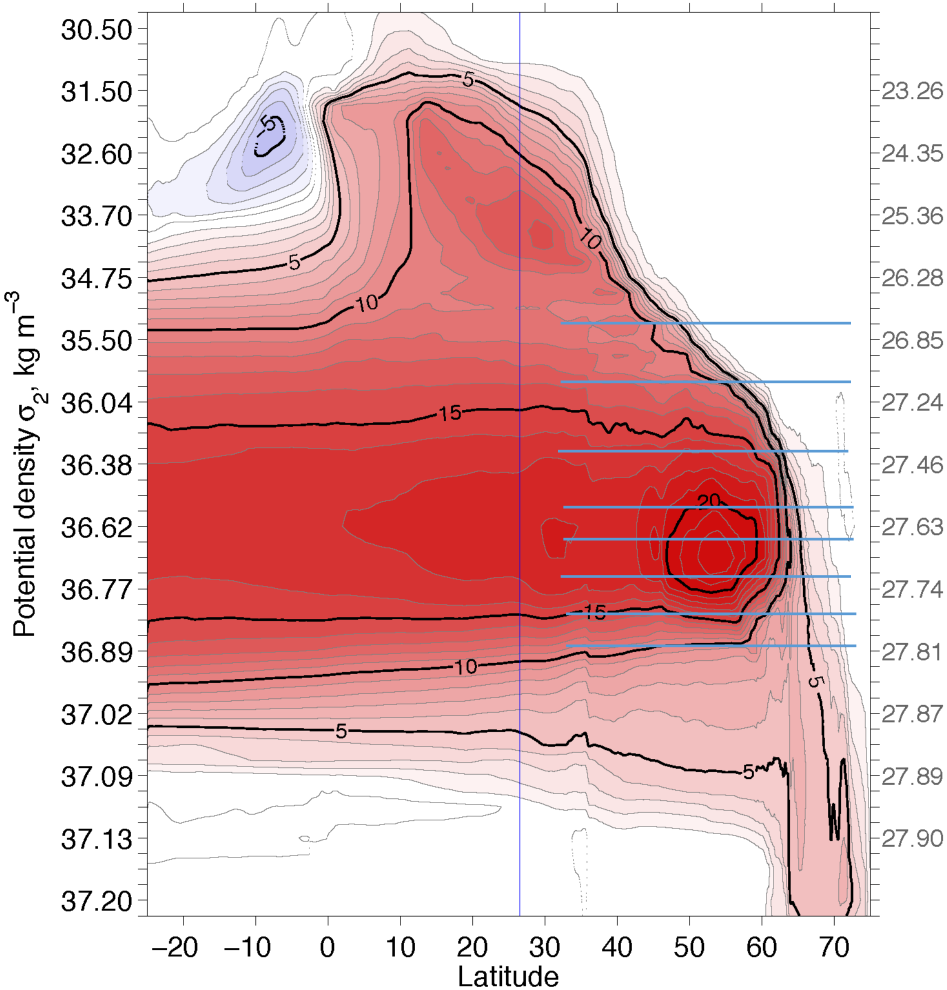


Surface buoyancy forcing



On-going work

2-D Diapycnal transformation



(difference: interior mixing)