# What can Hydrography between New York and Bermuda tell us about the strength of the AMOC over the last century?

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Outline:

A little background (our 2019 paper)

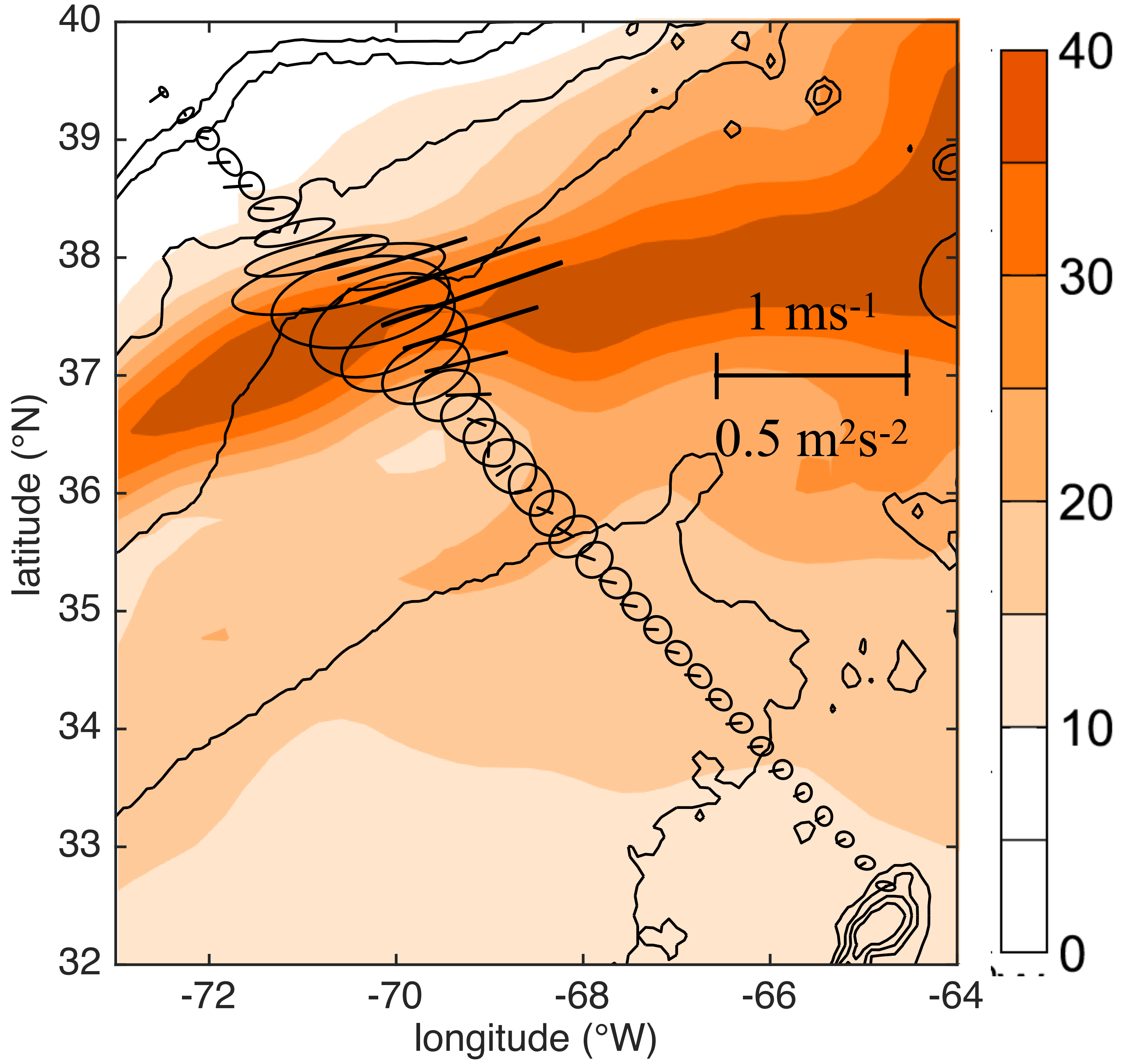
Estimating transport and AMOC trend

Connection to the Subpolar gyre

Intermediate versus Deep water

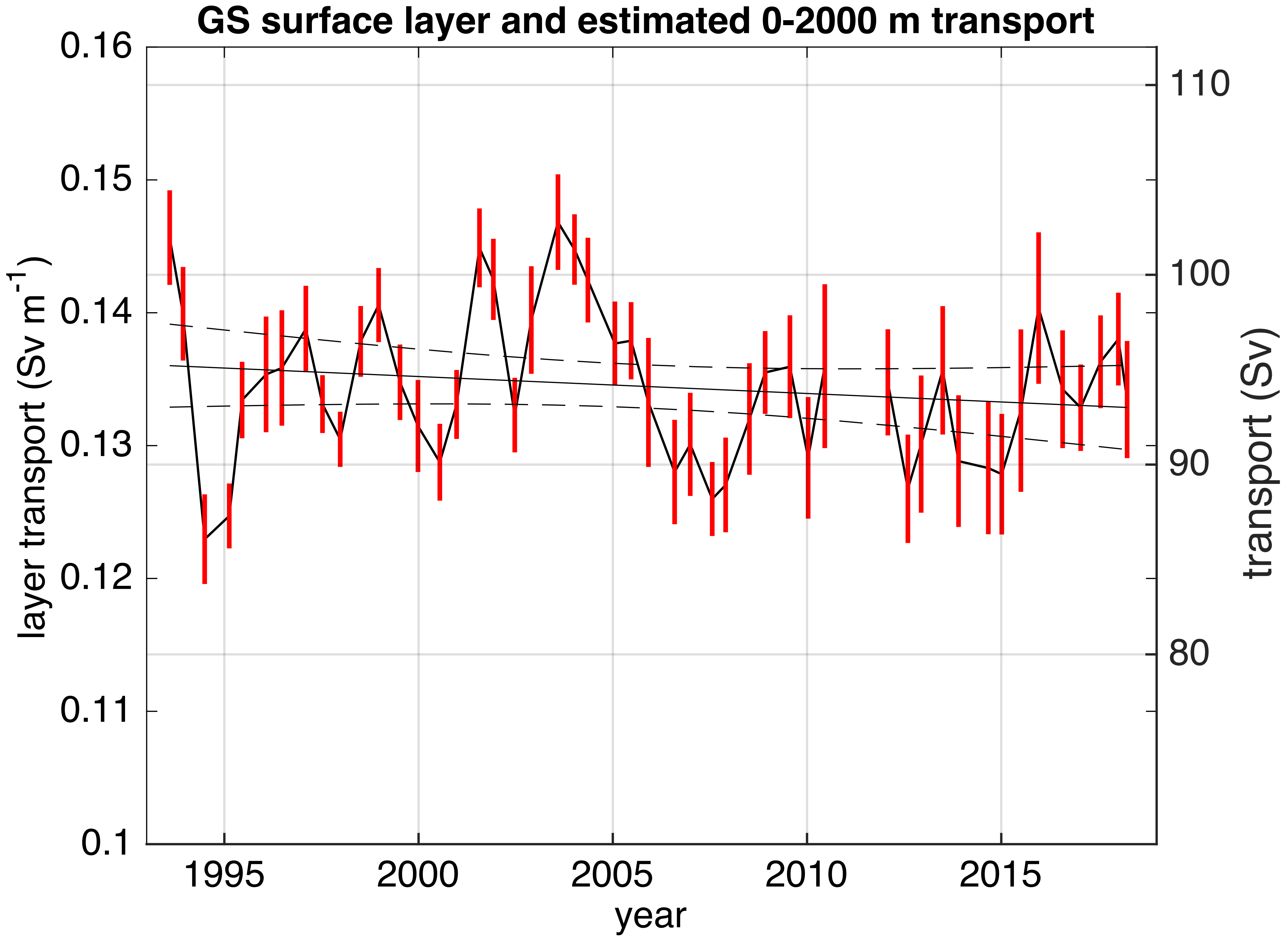
# Oleander 150 and 75 kHz

## Mean flow and EKE



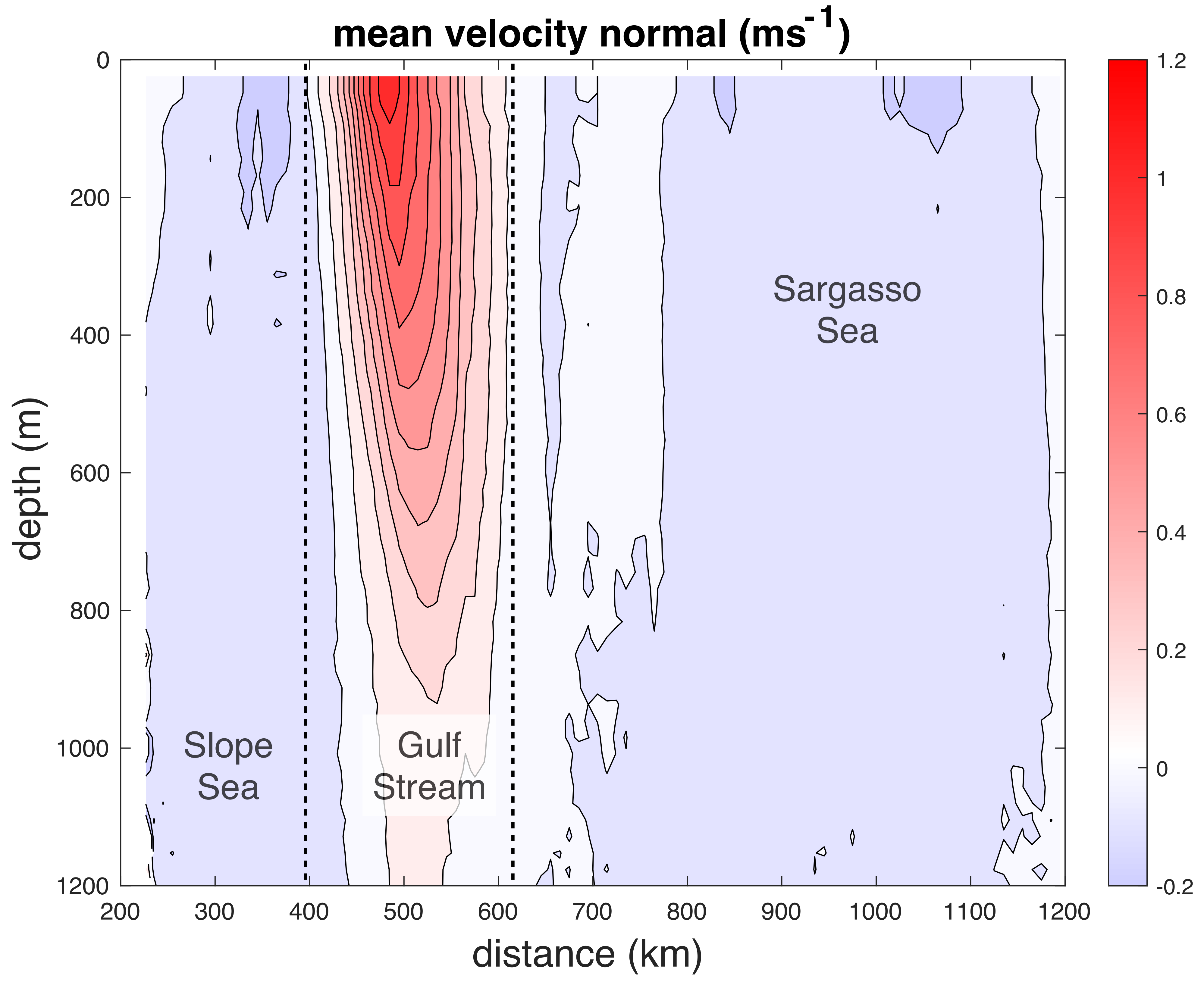

Mean velocity and variance ellipses from continental shelf edge to Bermuda between 1992-2018. Horizontal bar = 1 $ms^{-1}$ and 0.5 $m^2s^{-2}$. Color field indicates the standard deviation of the SSH (unit: cm) for the same 1992-2018 period.

## Transport time series

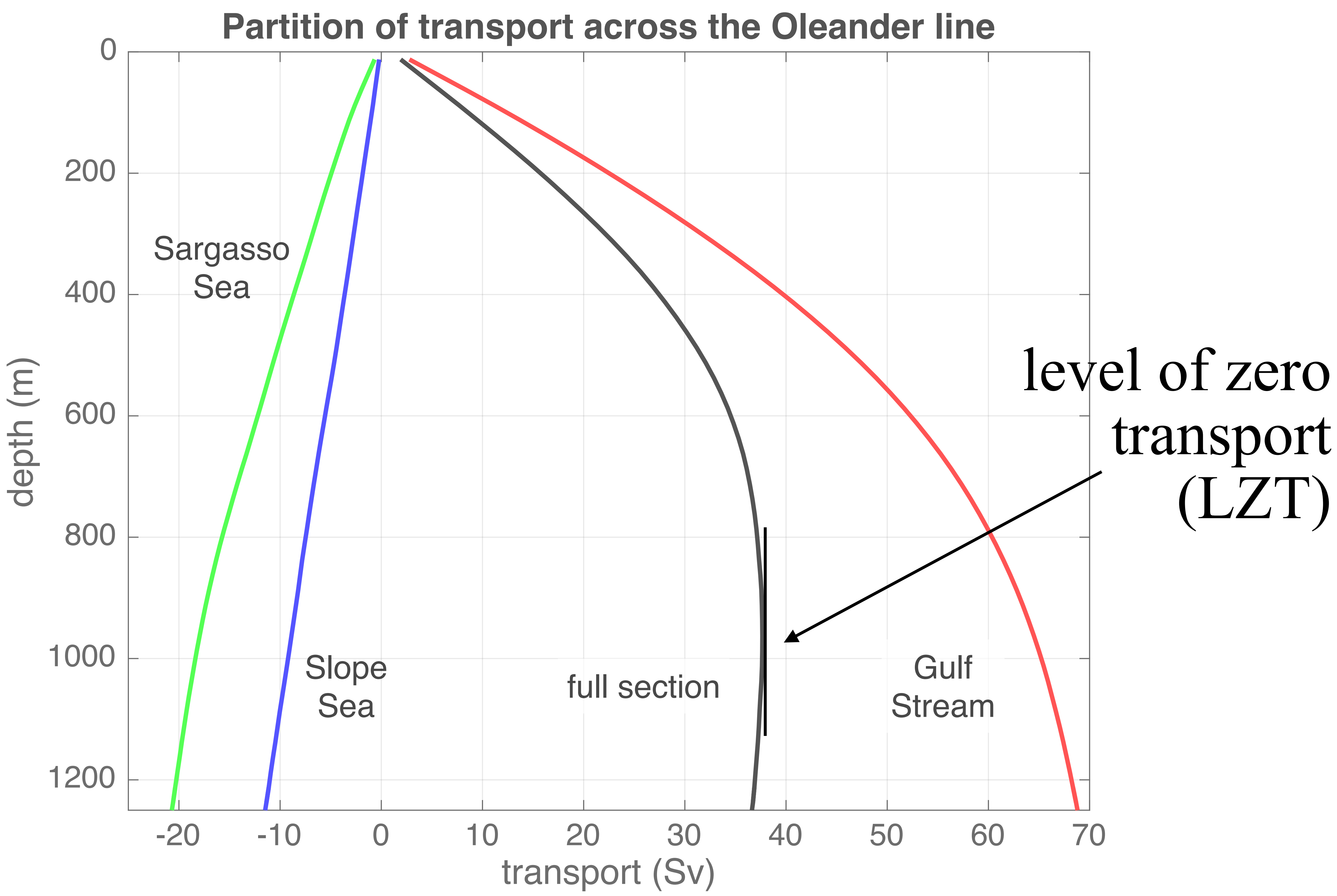



Annually averaged Gulf Stream layer transport and stdev for the entire record in 1/2 year steps. Solid and dashed lines represent a linear fit and the 95% confidence limits. The right axis shows the 0-2000 m transport assuming a scale factor of 700.

# Explorer of the Seas 38 kHz




Mean velocity perpendicular to the Oleander route based on 57 ADCP sections from primarily 2007 and 2008 (with rest from 2006 and 2010). The vertical dashed lines in the left panels delineate the Gulf Stream from the Slope and Sargasso Seas (right panel).




Integrals of transport from the surface down for the Slope Sea (blue), the Gulf Stream (red) and the Sargasso Sea (green) and the sum of all three (black). The 38 Sv maximum at ~1000 m = AMOC + wind-driven circulation.

We can also use mean surface velocity and dynamic height to estimate LZT.

# Estimating transport:

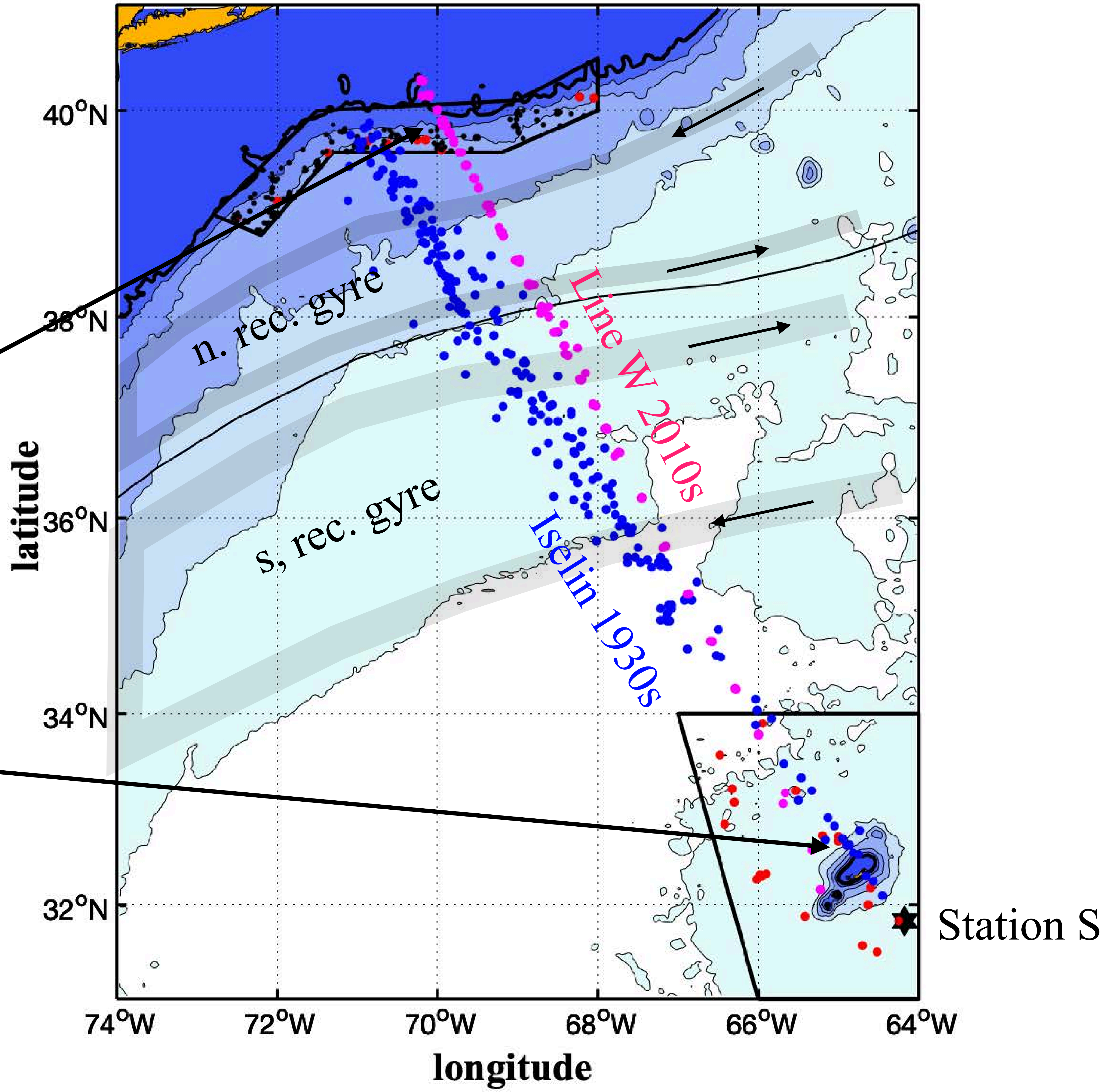
Geostrophic mass transport *M* from the surface to the LZT between two points is readily estimated from the difference in potential energy χ defined as:

$$\chi = 1/g \int_{p_0}^{p} \delta p \, dp$$

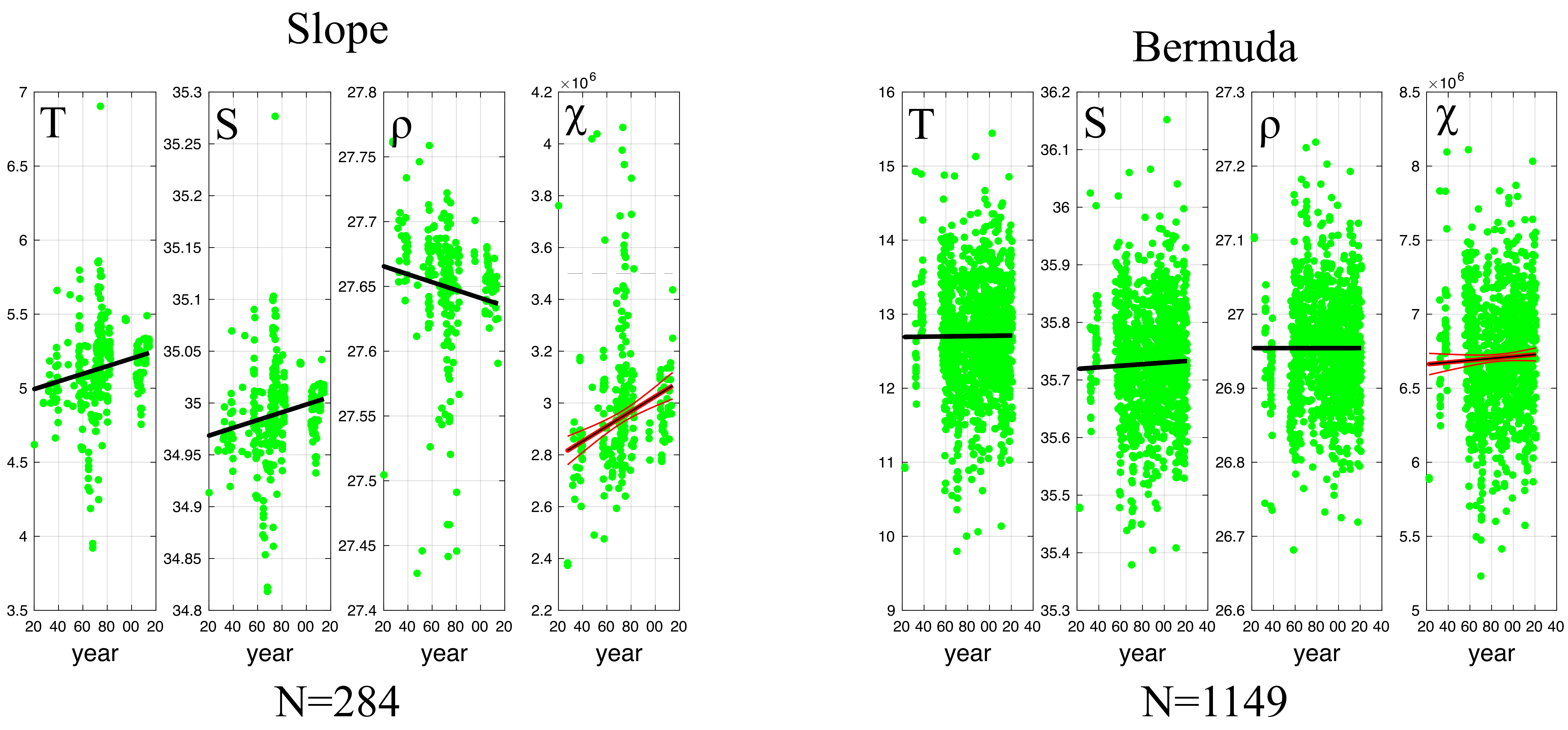
and

$$M = (\chi_2 - \chi_1)/f$$

The endpoints are defined as Slope and Bermuda indicated by the two polygons. All casts within these are considered to come from a uniform region, i.e. without internal gradients.

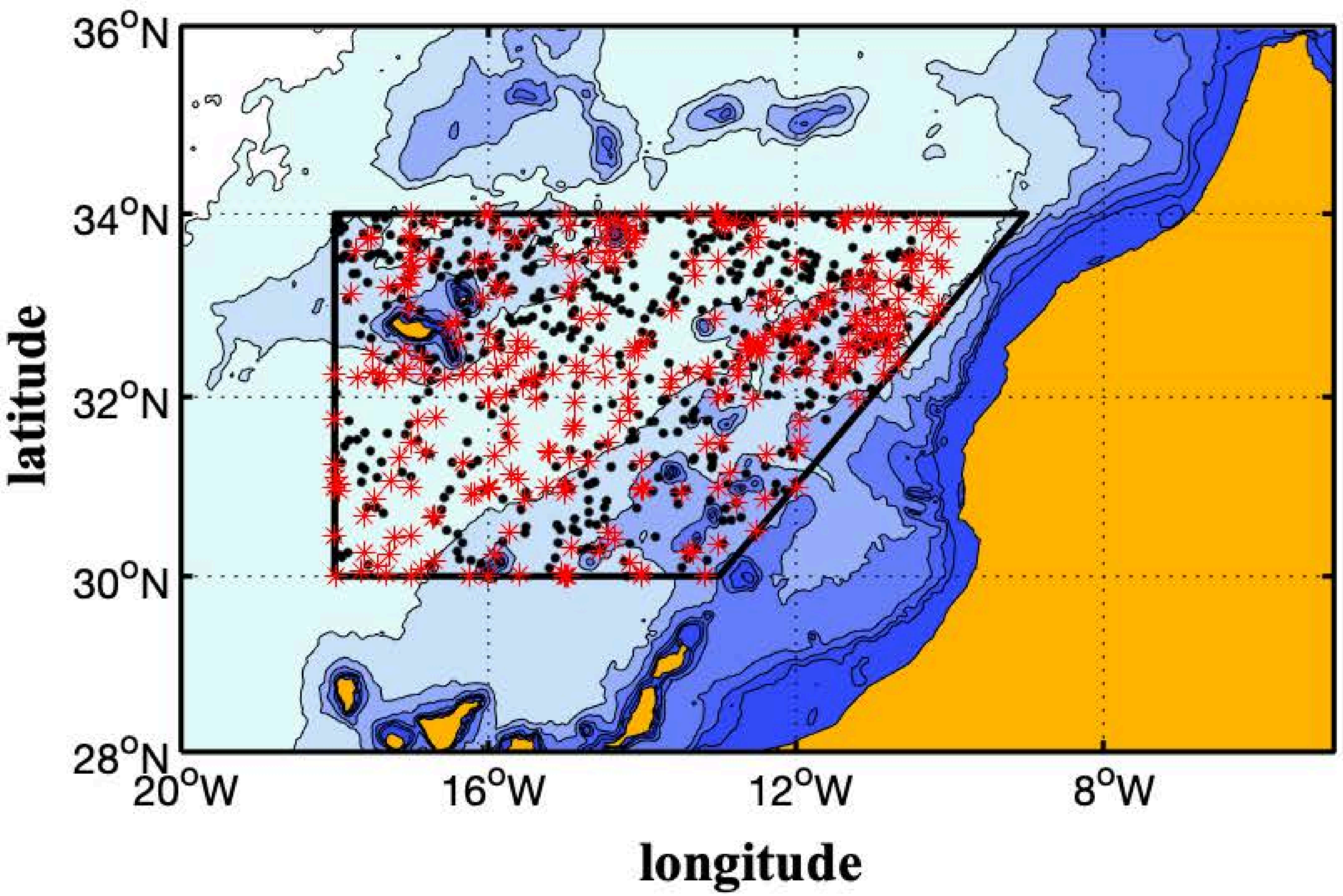


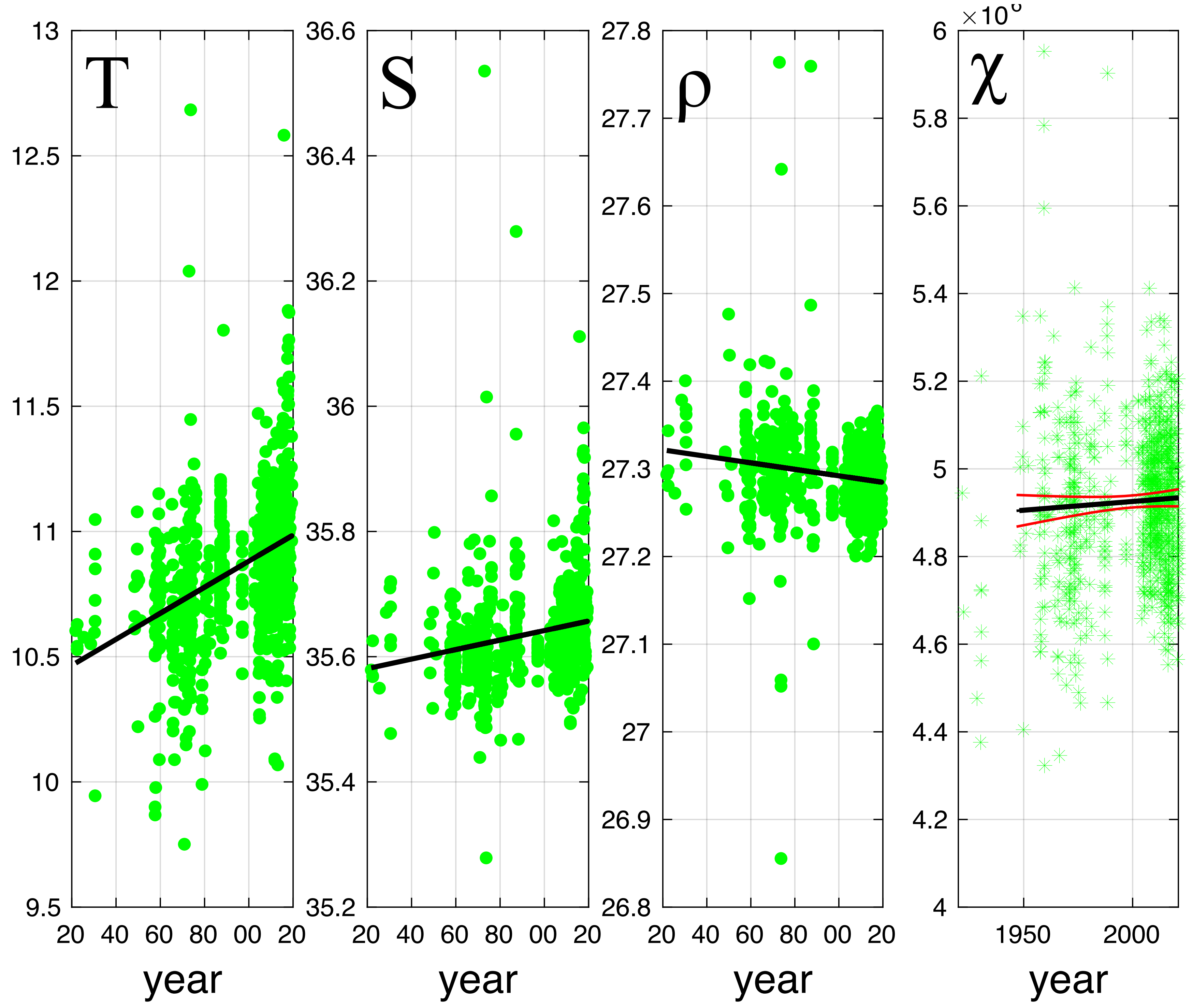

<u>The focus of this study is on the very longest time scale, i.e. estimating the trend in *M*.</u>




The left and right four panels show 400-1000 m average temperature, salinity, density, and 0-1000 dbar $\chi$ for Slope and Bermuda. Note substantial increase in $\chi$ at Slope over last century.

The difference in $\chi$ for year 2015 (from the linear fits) gives us 41.8 ± 0.6 Sv for the combined AMOC and wind-driven circulations. We now estimate the latter using the same methodology.



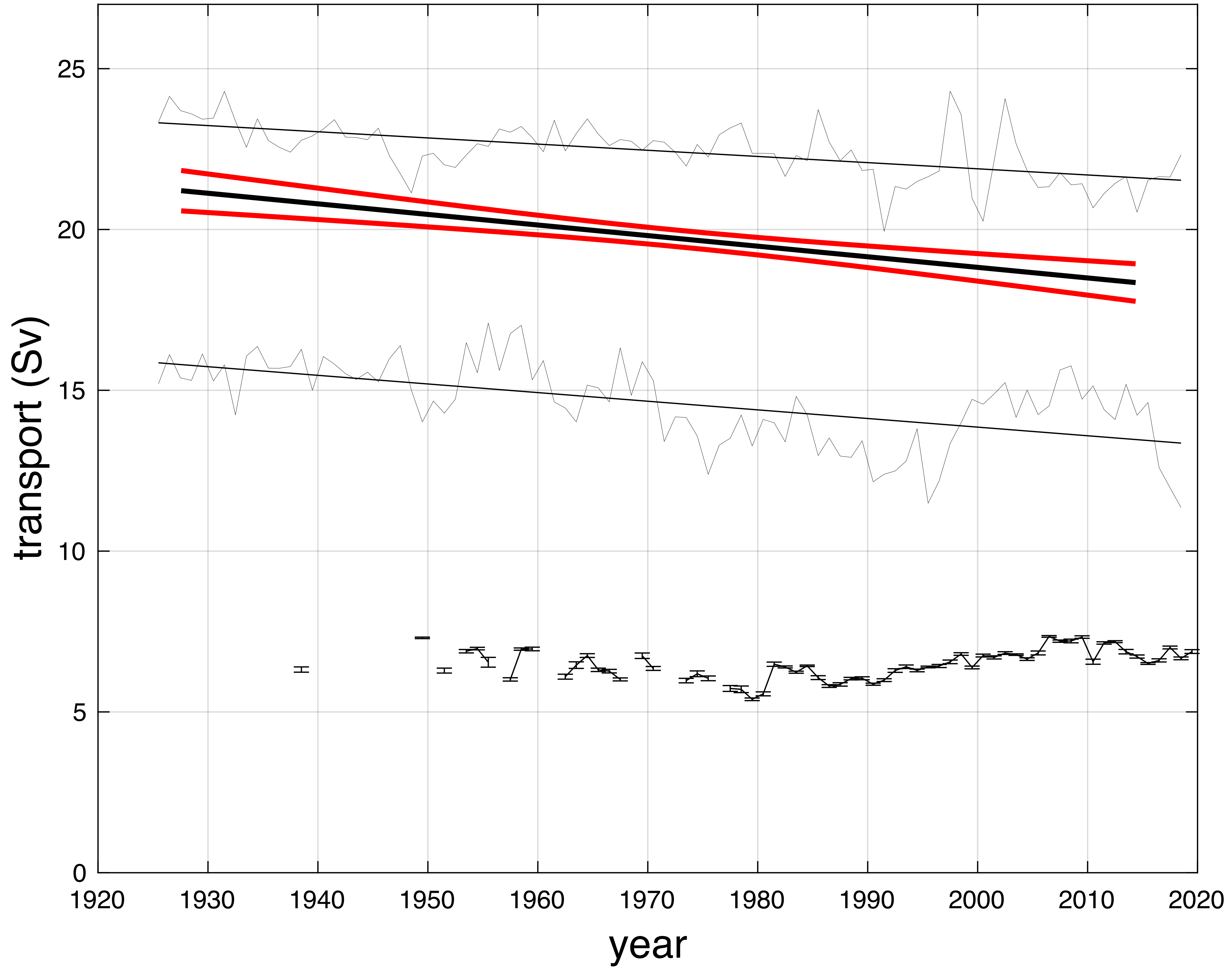

We define an area off West Africa at the latitude of Bermuda with N = 806 casts. Red stars hydrocasts (266 casts total) and 540 Argo profiles in blue.

400-1000 m average temperature, salinity, density, 0-1000 dbar χ. This gives us 23.3 Sv southward transport east of Bermuda. Lack of trend here and Bermuda = stable Sverdrup gyre.

| wind-driven | total | AMOC |
|---|---|---|

Subtracting 23.3 Sv from 41.8 ± 0.6 Sv = 18.5 ± 0.6 Sv with uncertainty dominated by Slope.

# Putting it all together:



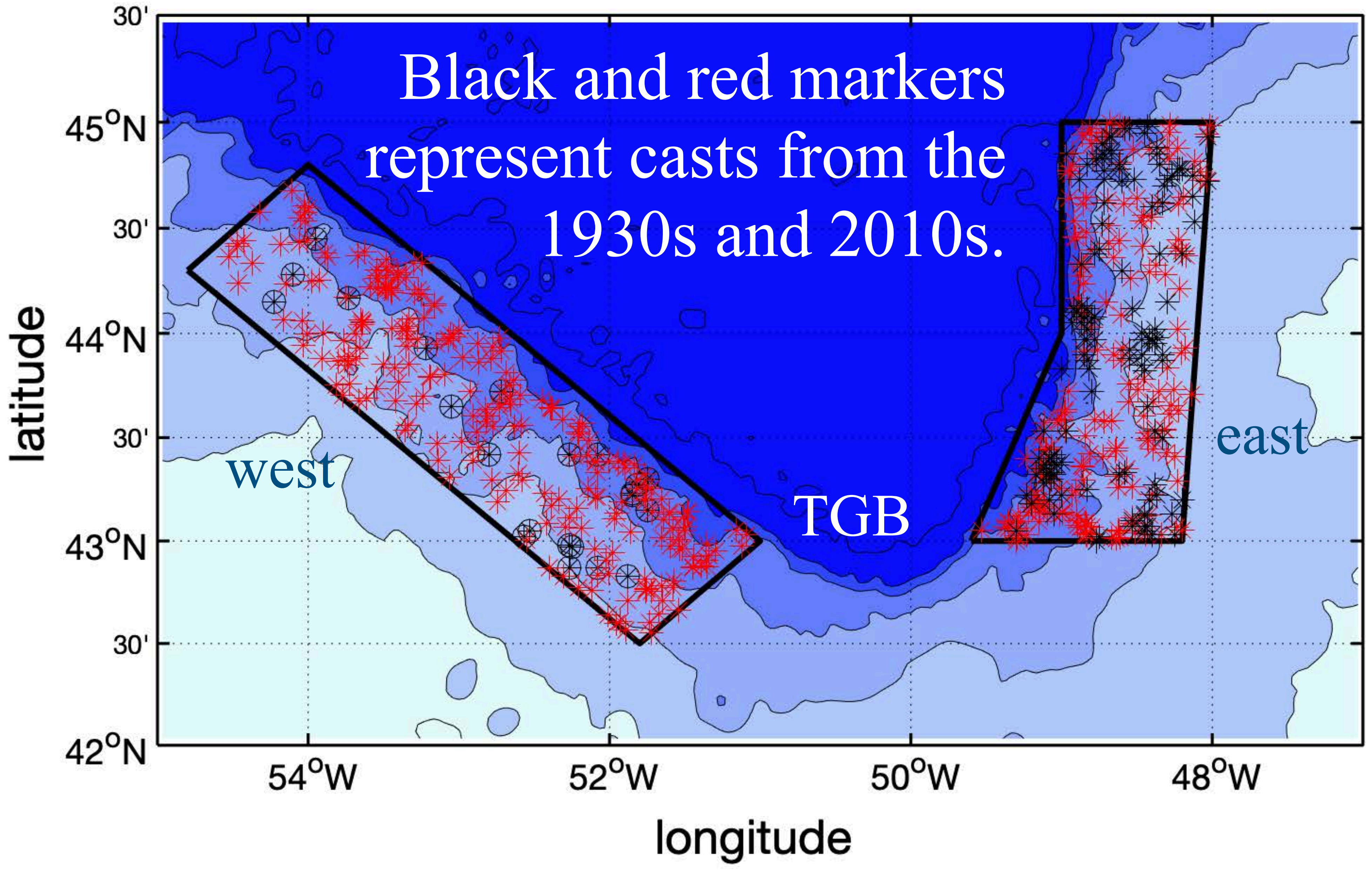

Piecuch, 2020

This study

Caesar et al., 2018

Rossby et al., 2020

Baroclinic transport based on χ differences including 95% confidence limits (this study). The Piecuch (2020) Florida St curve has been shifted down 10 Sv. Similarly, 15 Sv has been added to the Caesar et al. (2018) AMOC anomaly curve for ease of comparison. The Nordic Seas MOC shows no trend. So where does the AMOC trend come from?



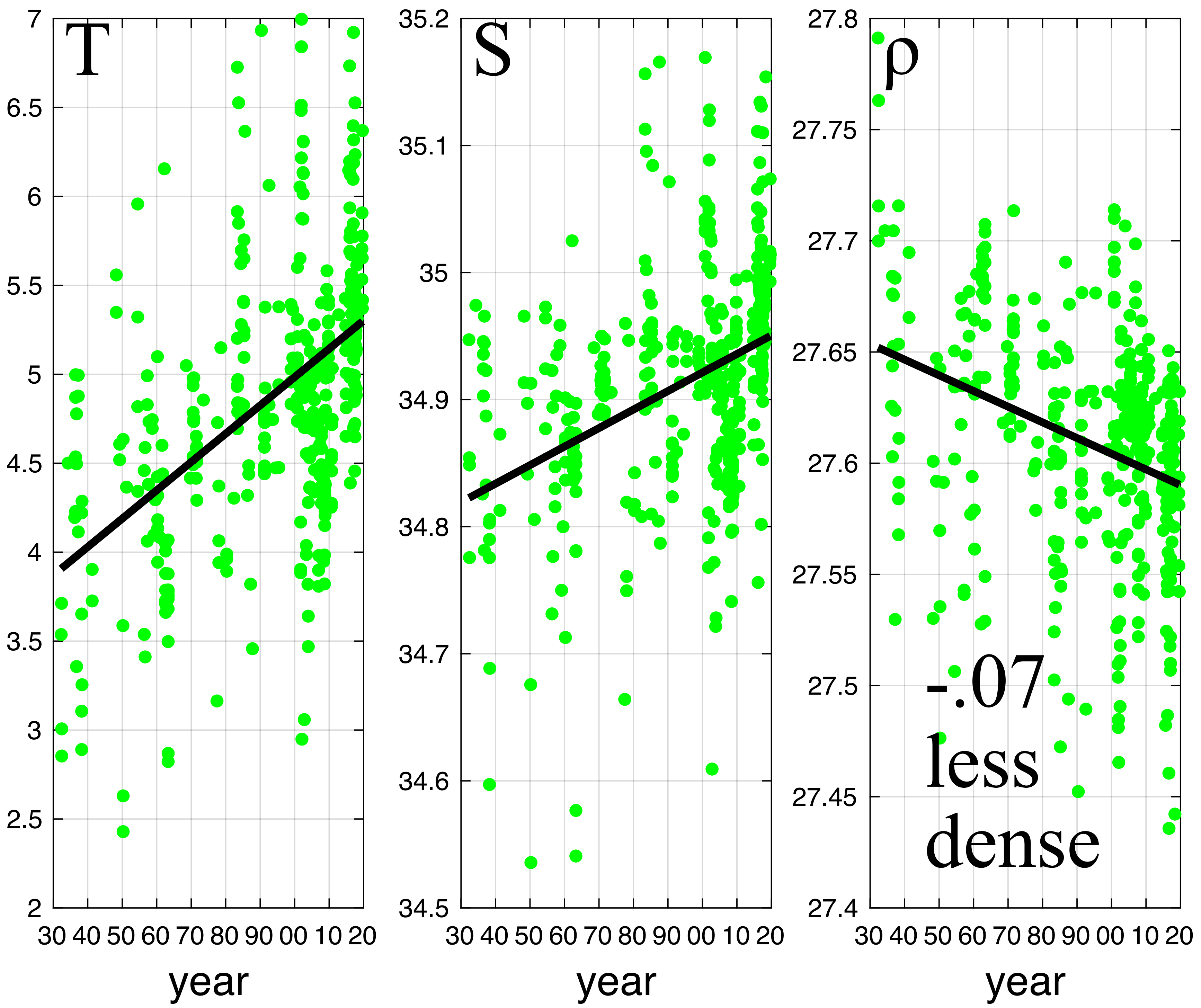

The left and right three panels below show 400-1000 m average temperature, salinity, and density for for all casts in the polygons west an east of the TGB, respectively.
The increases in T and S west of TGB can only come from the GS, i.e. it is making greater contact with the slope waters at the TGB. We conjecture that a lesser flow from the north allows this, i.e. a weakened outflow from the subpolar gyre.

west

$\Delta T$=1.4

$\Delta S$=.14

$\Delta\rho$=-.06

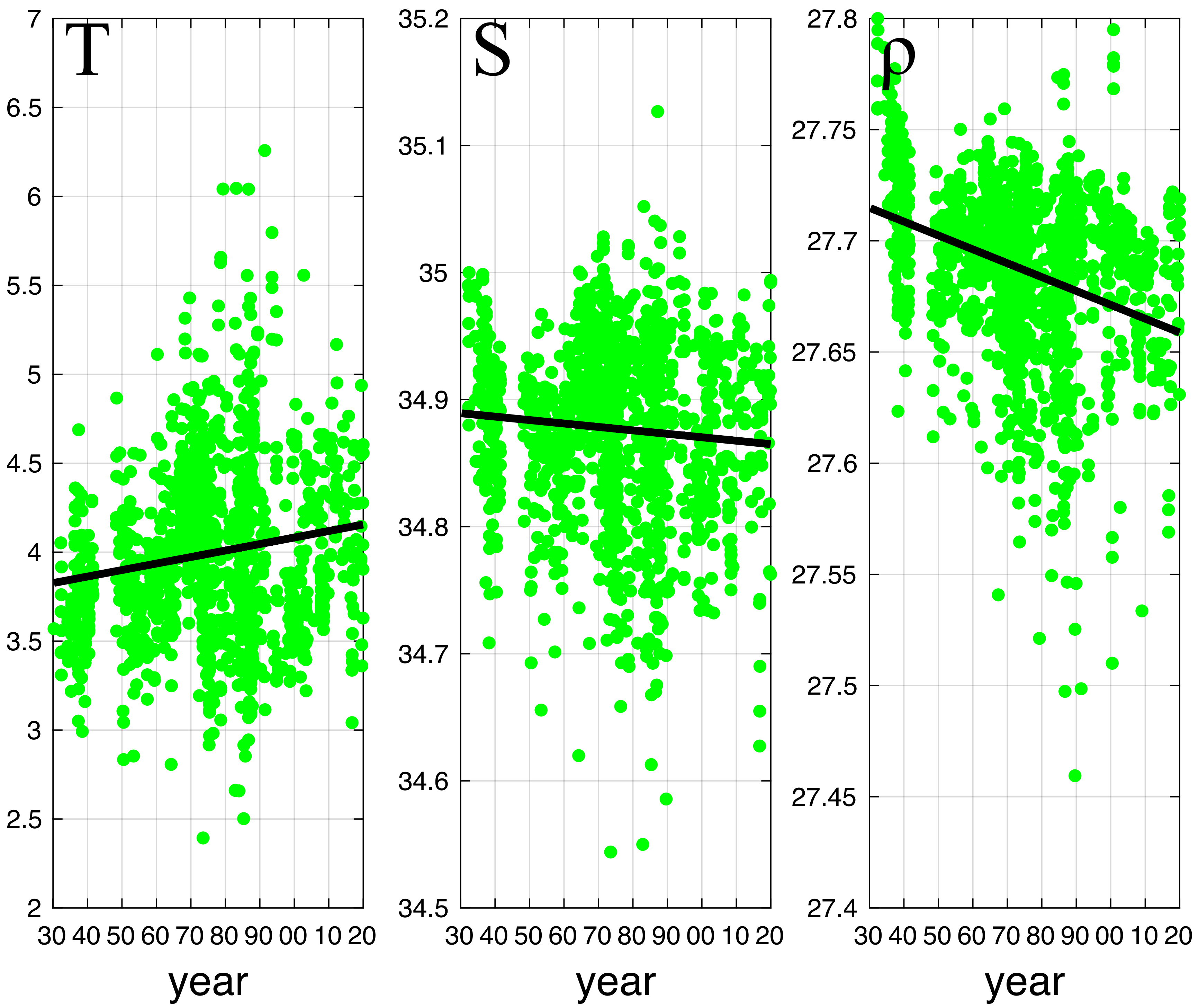



east

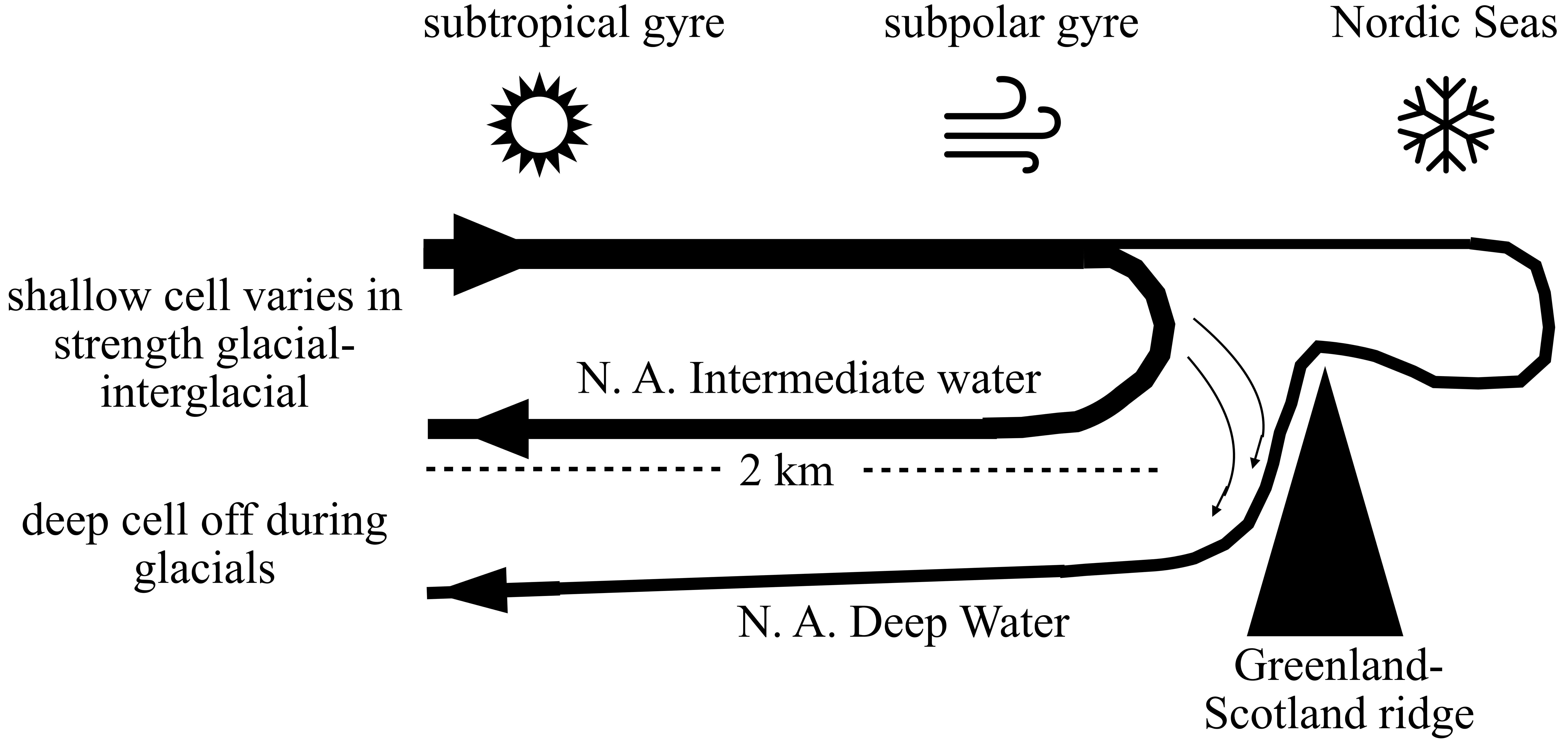
$\Delta T$=0.2

$\Delta S$=-.02

$\Delta\rho$=-.05



# The AMOC has two distinct overturning cells:




We know AMOC return waters are produced in both the subpolar region and the Nordic Seas. The shallow return water should be referred to as North Atlantic Intermediate Water (NAIW) to clearly distinguish it from Deep Water. NAIW cannot be turned off whereas the NADW production was clearly turned off during glacial times.

Summary

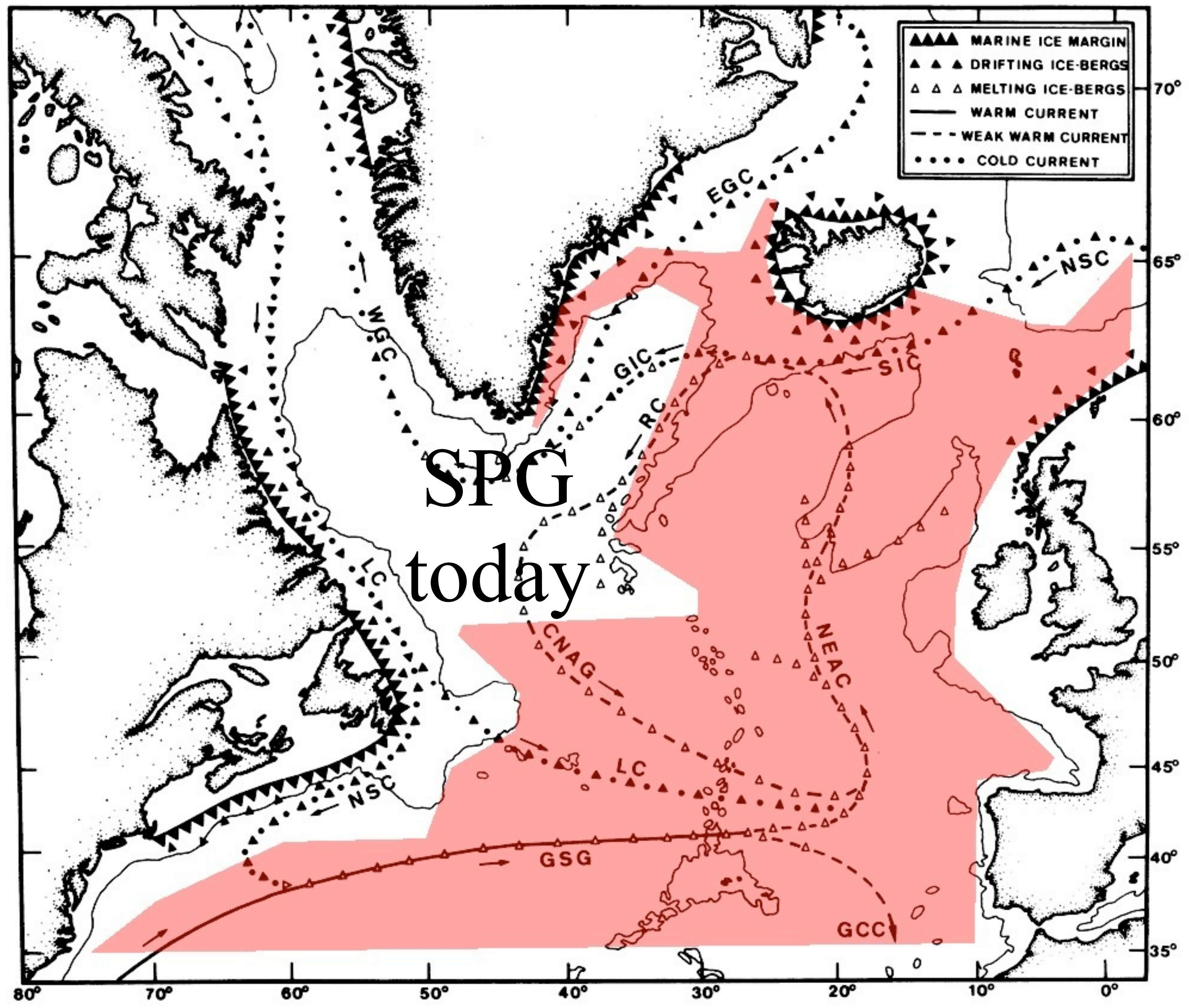
The ~2.5 Sv AMOC decrease manifests itself from changes in Slope Water properties.

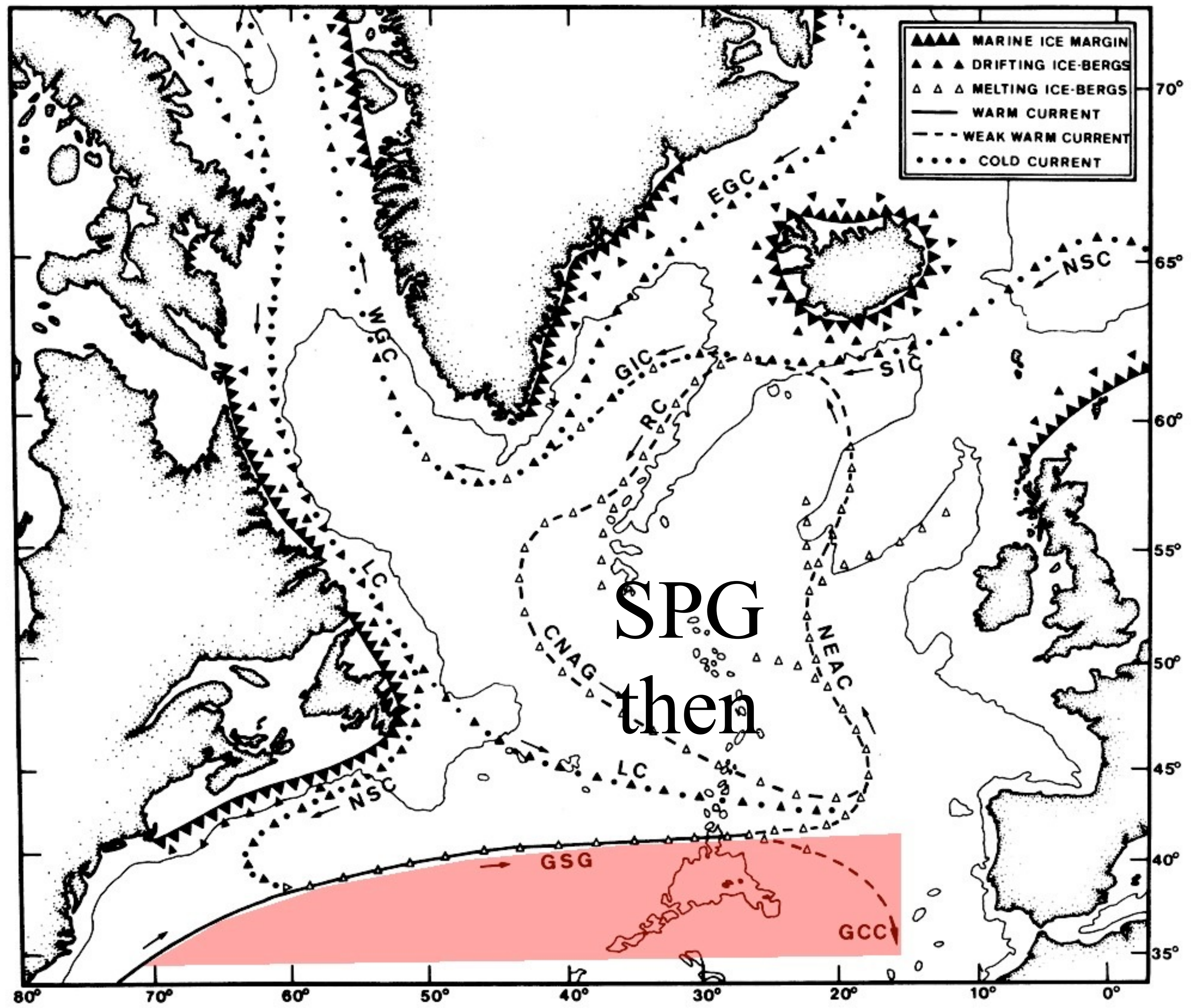
Estimating the AMOC trend does not depend upon knowing the LZT accurately.

We conjecture that the decrease is due to weaker NAIW production.

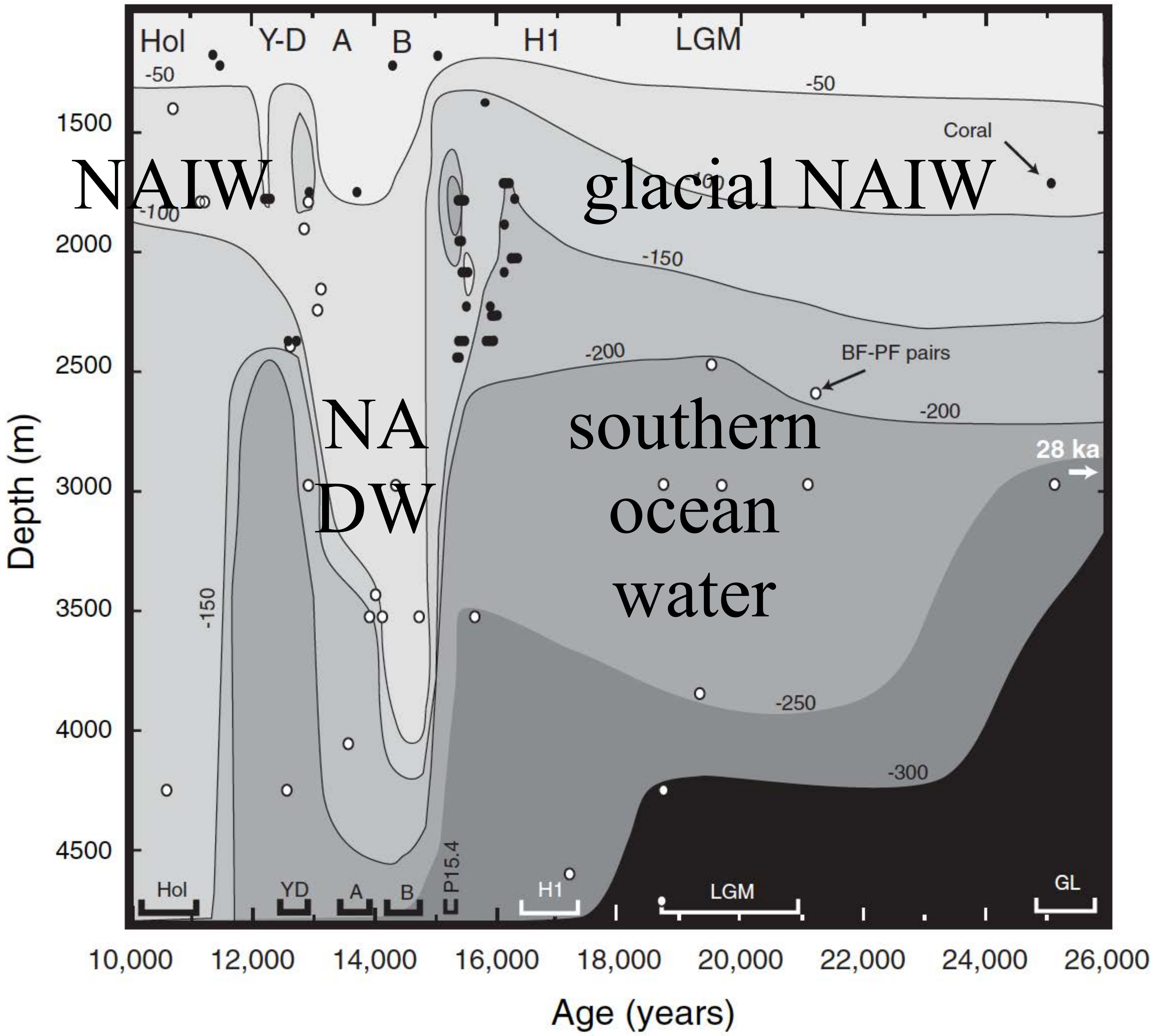
To the best of our knowledge no risk that NAIW production can cease.

Glacial conditions depend upon cessation of NADW production from the Nordic Seas.




S. Robinson et al., PaleoOc., 1995




L. Robinson et al., Science, 2005

warm water reach today

warm water reach in glacial times

Spread of warm water across North Atlantic. Plenty of moisture for Greenland

Glacial North Atlantic looks like Pacific today - a zonal GS.

Presence/absence of NADW depends upon Nordic Seas overflow.