Property Changes of Deep and Bottom Waters in the Western Tropical Atlantic

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Abstract

The western tropical Atlantic is an important crossroad for the interhemispheric water exchange of North Atlantic Deep Water (NADW) and Antarctic Bottom Water (AABW). Here, we analyze historic and recent ship-based hydrographic and velocity observations in this region:

- lower NADW and lighter AABW form an interactive transition layer in the northern Brazil Basin
- the strongest water mass transformations occur around the tip of Brazil
- proof of long-term abyssal warming on isobars in the western tropical Atlantic (1989-2014)
- warming of densest AABW is mainly caused by descent of isopycnal surfaces and volume loss of dense water masses
- changes on isopycnal surfaces show warming in the 1990s and cooling in the 2000s

Ship-based Observations

- **θ, S, O_2, U, V** measurements from all ship sections going to full depth
- within the period: **1989 - 2014**
- the focus is on 5 repeated sections:

35°W (12), 25°W (7), 23°W (6),
5°S (13), 11°S (8)

- measurements in **Vema Channel** (**18**; VCH) over 1990 - 2010 (Zenk & Morozov (2007), Zenk & Visbeck (2013))

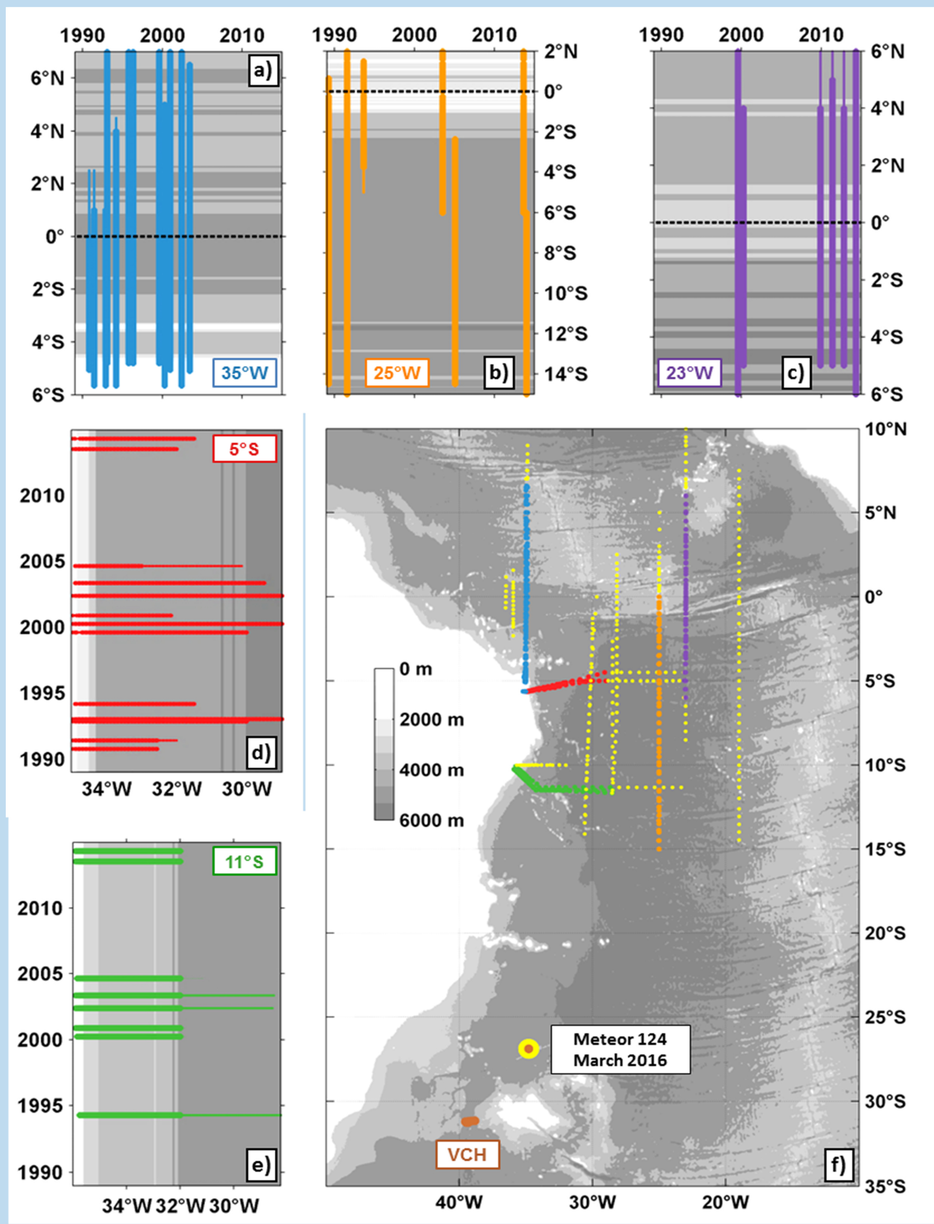


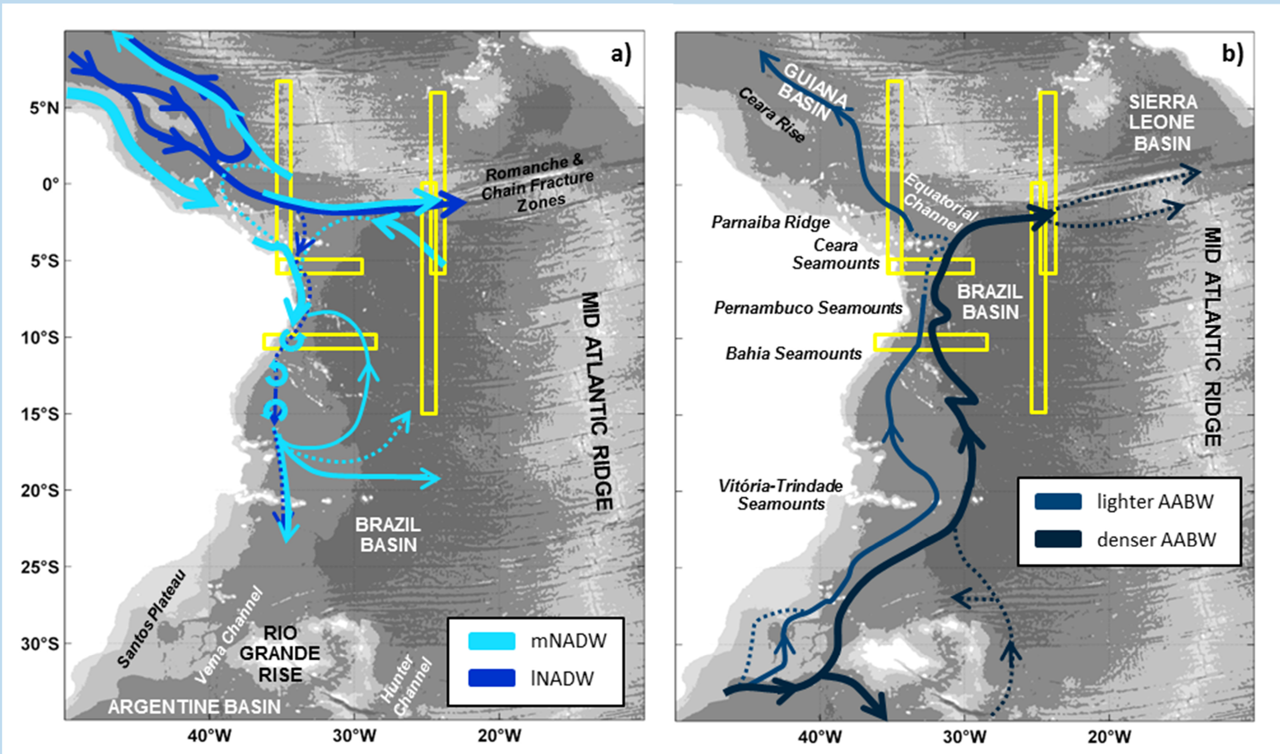
Fig. 1 f) Bathymetry of the South and Tropical Atlantic Ocean, with the locations of all analyzed ship (color coded as indicated above) a-e) Temporal data coverage along the five repeated CTD sections.

Mean Hydrography and Pathways

The northwest corner of the Brazil Basin represents a splitting point for the flow of NADW/AABW:

- **lNADW** is mainly transported eastward, southward flow in the DWBC instead dominated by **mNADW**
- **lighter AABW** is partly transported along the western boundary - flows through EQCH into North Atlantic
- **denser AABW** spreads northward/ eastward along the 4500 dbar contour

Fig. 2 Schematics of the assumed pathways of mNADW and lNADW (a) or of the light and dense AABW components (b).



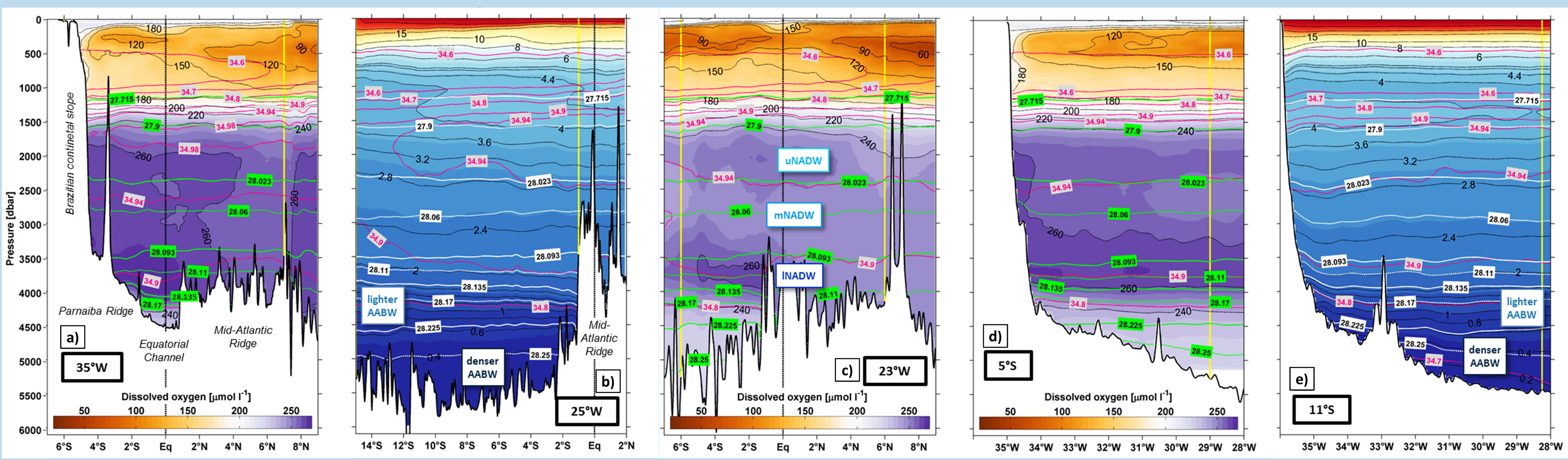
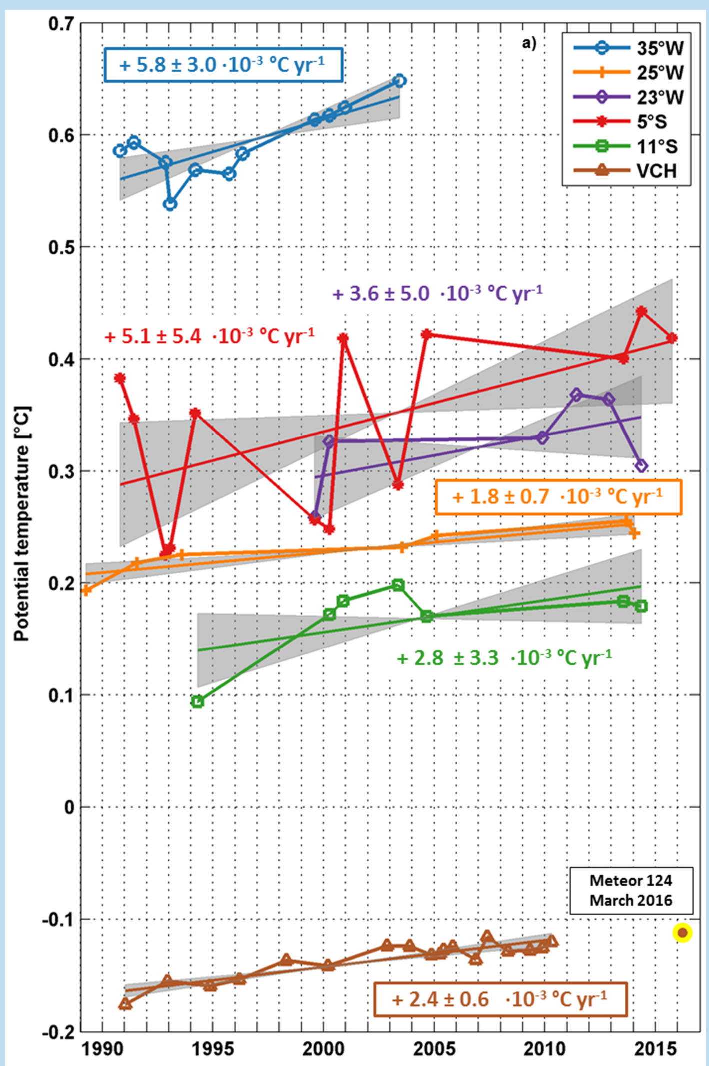


Fig. 3 Mean θ [°C] or O_2 [µmol l^{-1}] along five repeated sections. White/green contours mark neutral density γ^n [kg m^{-3}], pink contours mean salinity.

Temperature Trends



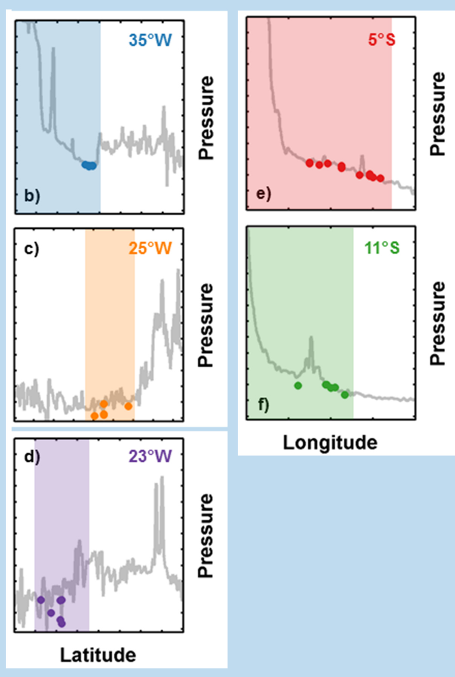
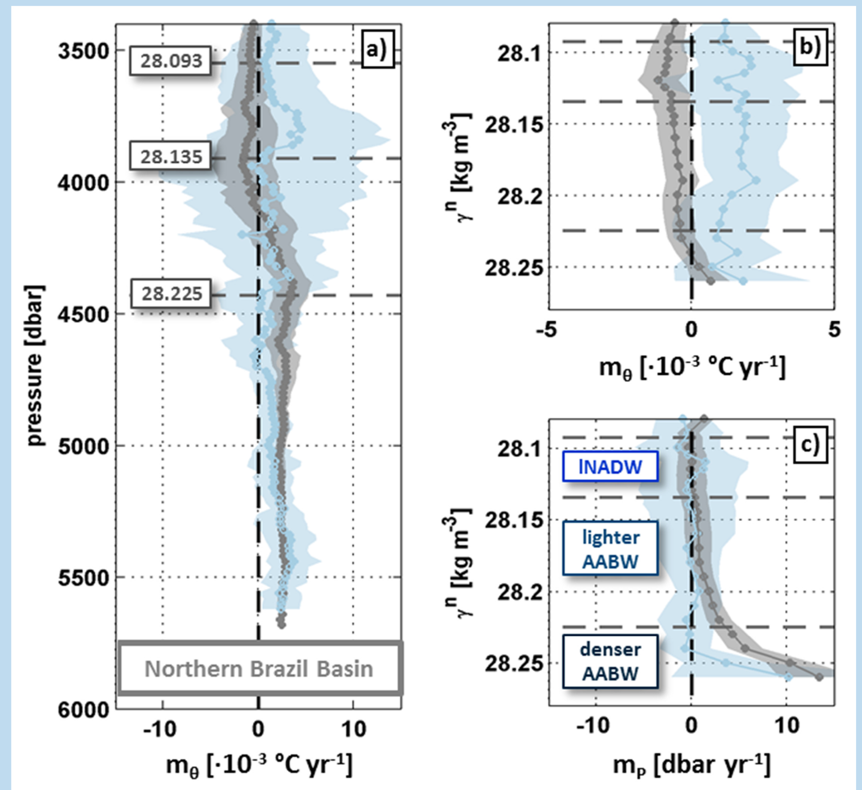


Fig. 7 a) Evolution of θ [°C] of the coldest AABW along 35°W, 25°W, 23°W, 5°S, 11°S, within VCH. Linear fits [10^{-3} °C yr^{-1}] with 95% confidence. Trends in boxes are different from zero with 95% confidence. b-f) Location of the lowest temperatures.

- the coldest AABW is **continuously warming** by **1.8 – 3.6 ·10^{-3} °C yr^{-1}** over 1989 - 2014
- trends are much stronger where lighter AABW was captured instead
- **spatial coherence** between different sections

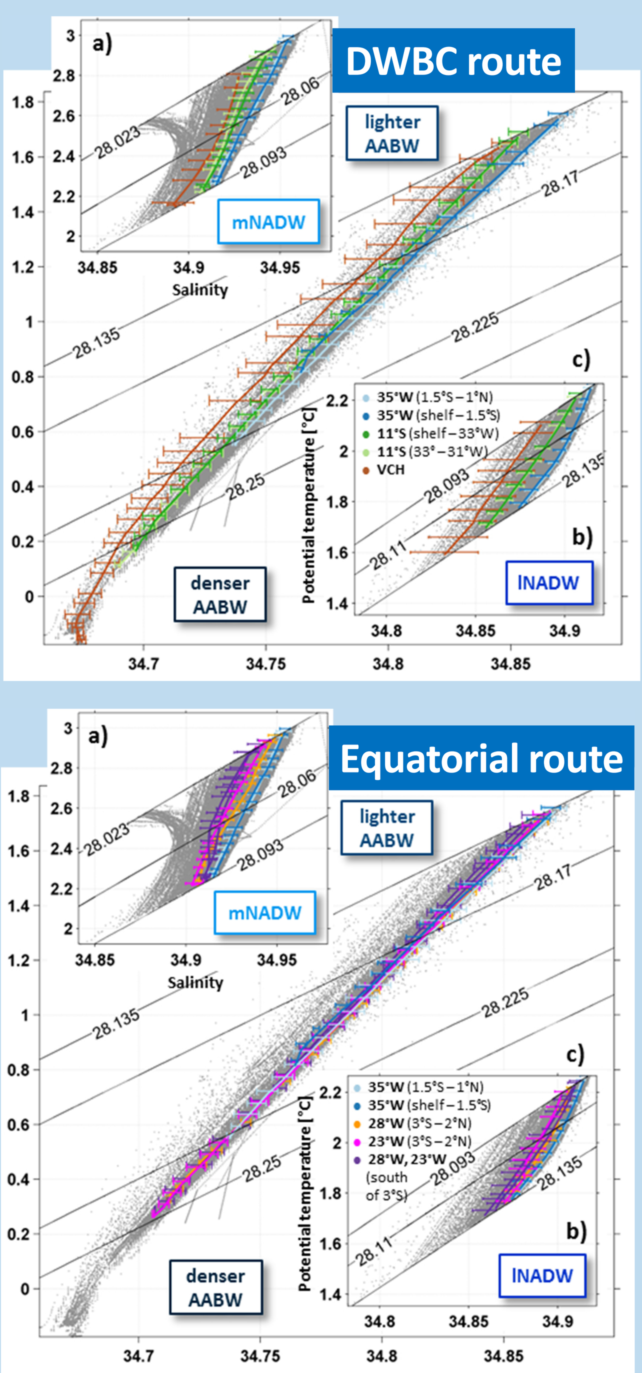
Fig. 8 Linear trends of θ [m_θ, 10^{-3} °C yr^{-1}] on pressure levels (a) or isopycnals (b), and of pressure [m_p, dbar yr^{-1}] of corresponding isopycnals (c) shown for lNADW & AABW layers. Grey are trends within the northern Brazil Basin, combining measurements along 11°S, 5°S, 25°W, 23°W over the period 1989-2014; light blue is a 1990-2003 subset. Shading is the 95% confidence interval estimate.



- combining measurements to **one northern Brazil Basin time series** increases significance
- the continuous warming of dense AABW is mainly related to **layer thinning/volume loss**
- concurrently, the **lNADW/light AABW transition layer** shows intrinsic **decadal variations**

Spatial Property Changes

- **two major routes** are sampled - along the deep western boundary & eastward, parallel to the equator
- lNADW & lighter AABW form a **highly interactive transition layer**



- the strongest mixing/**water mass transformation** occurs around the tip of Brazil
- further south modified or recirculated waters join the mNADW layer
- AABW north of 5°S is relatively homogeneous

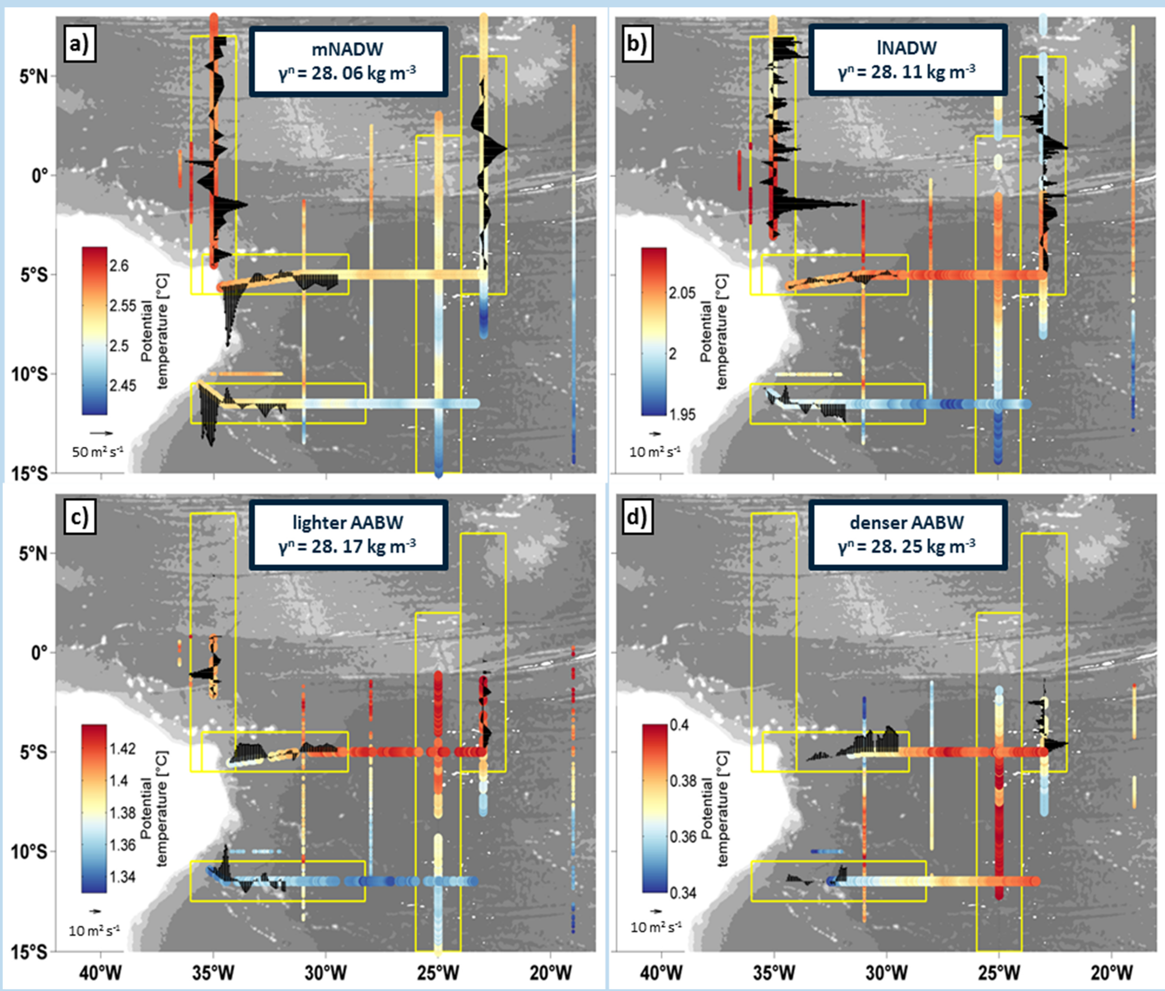


Fig. 4 θ [°C] on core neutral density surfaces of mNADW (a), lNADW (b), lighter (c), denser AABW (d). Black stickplots represent velocities normal to each section, averaged over and multiplied with layer height [m^2 s^{-1}].

Fig. 5 & 6 θ-S-diagrams including all ship sections - for mNADW (a), lNADW (b) and AABW (c). Colored curves are mean salinities & their standard deviation per density class.

Zenk W and Morozov E (2007). Decadal warming of the coldest Antarctic Bottom Water flow through the Vema Channel, *Geophys Res Lett*, 34, L14607.
Zenk W and Visbeck M (2013). Structure and evolution of the abyssal jet in the Vema Channel of the South Atlantic, *Deep-Sea Res II*, 85, 244–260.