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

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Summary

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 a highly 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 indicate warming in the 1990s and cooling in the 2000s

Mean Hydrography and Pathways

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

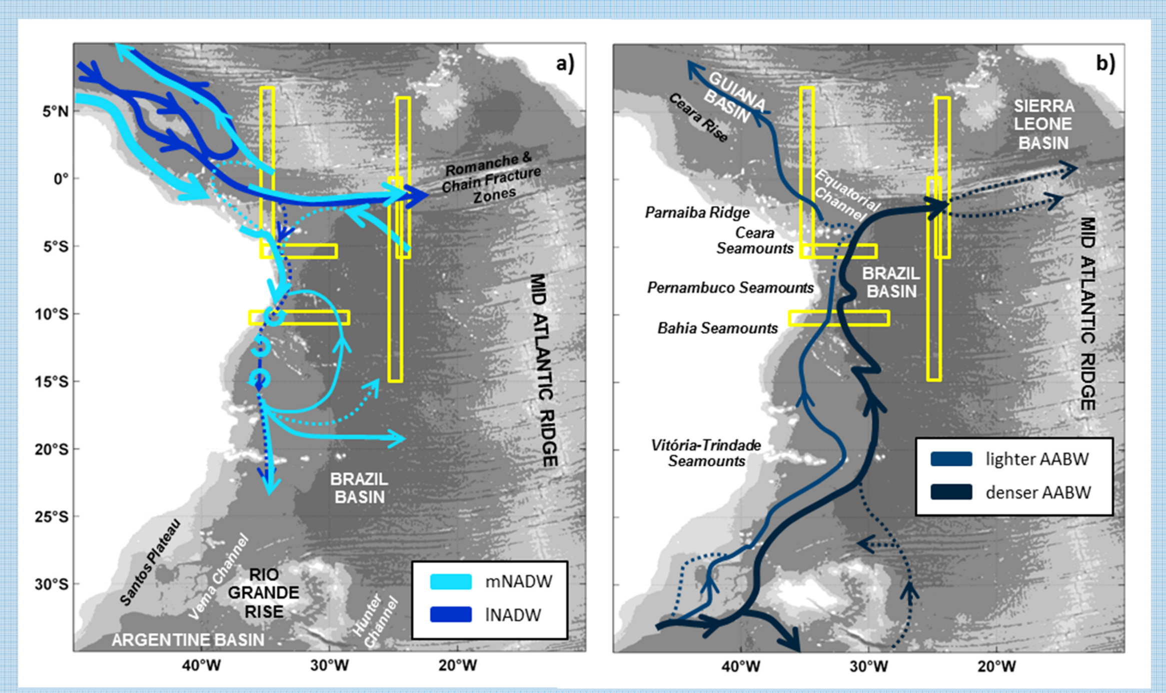
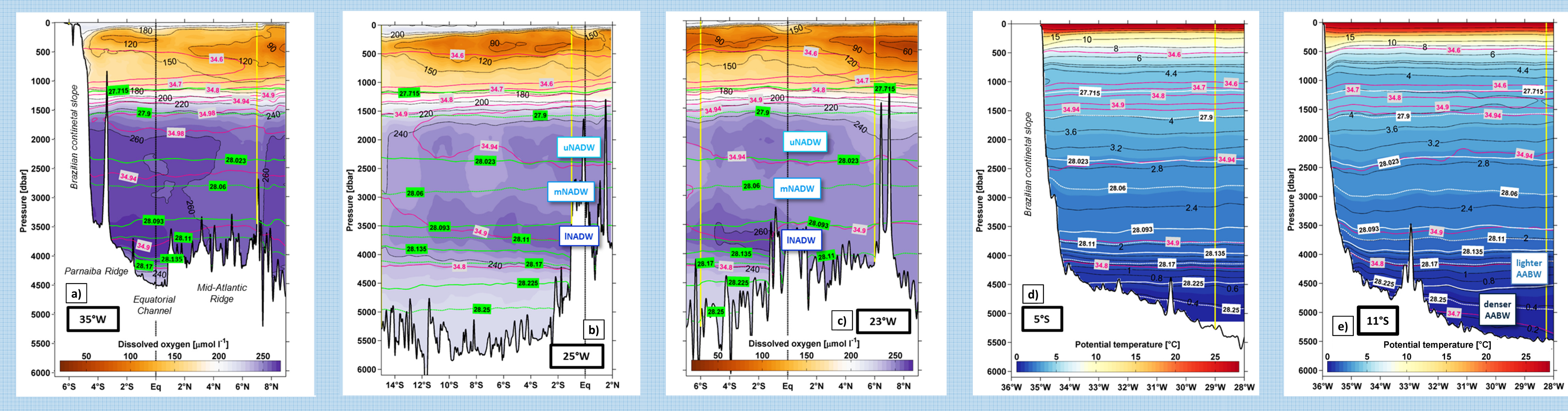


Fig. 2 Schematics of the assumed pathways of mNADW and lNADW (a) or of the light and dense AABW components (b).

Fig. 3 a-e) 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.

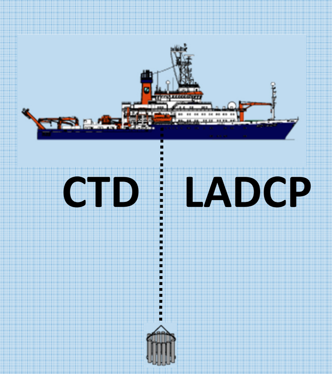


- after crossing the equator, **lNADW** is mainly transported eastwards; southward flow in the DWBC is instead dominated by **mNADW**
- vertical O_2 structure (25°W/23°W) hints towards nearly barotropic eastward jets at 2°S/4-6°S/9-11°S (e.g. Ascani et al., 2010*) reaching down into NADW layers
- **lighter AABW** is partly transported along the western boundary - flows through EQCH into North Atlantic
- **denser AABW** spreads northward, then turns eastward along 4500 dbar isobath

* *Ascani F, Firing E, Dutrieux P, McCreary JP and Ishida A (2010). Deep equatorial ocean circulation induced by a forced-dissipated Yanai beam. J Phys Oceanogr, 40, 1118-1142..*

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)

- supplementary measurements in Vema Channel (**VCH (18)**; e.g. Zenk & Visbeck, 2013*) over 1990 - 2010

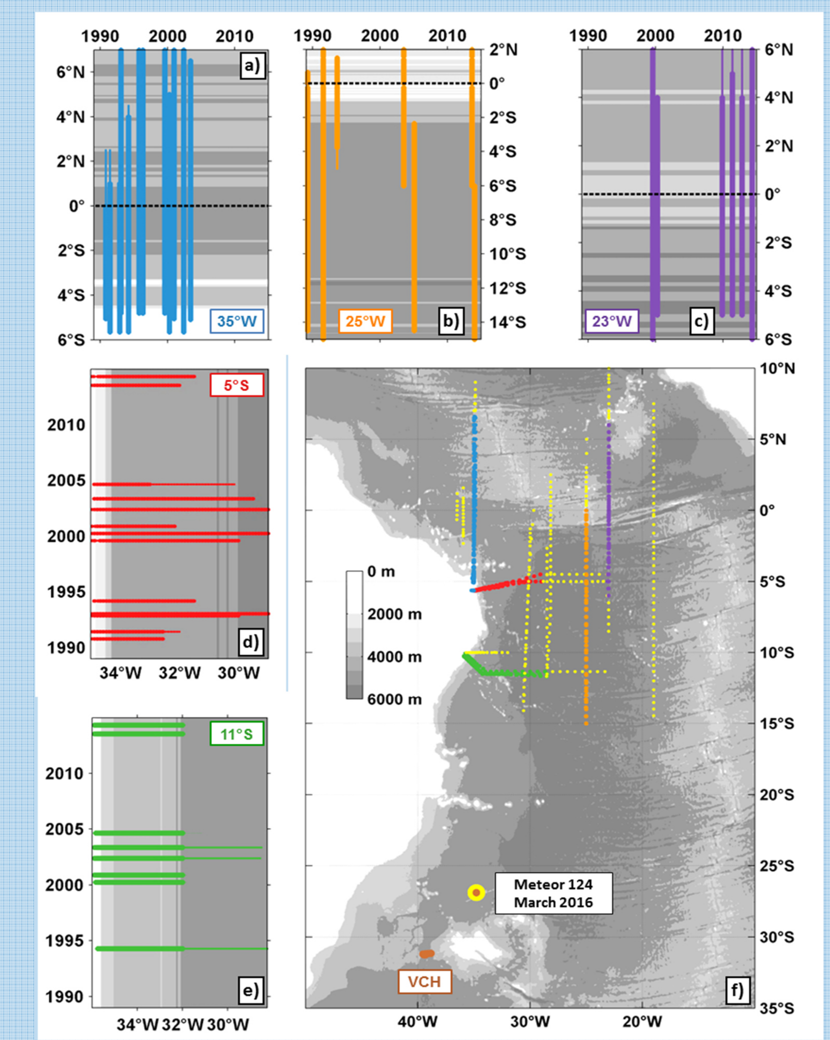


Fig. 1 f) Bathymetry of the South and Tropical Atlantic Ocean, with the locations of all analyzed ship (color coded as indicated above) The single brown/yellow dot represents an additional estimate from the Vema Sill in March 2016. a-e) Temporal data coverage along the five repeated CTD sections.

* *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.*

+ *Meteor 124; https://doi.pangaea.de/10.1594/PANGAEA.863015*

Spatial Property Changes

- **two major routes** are sampled - along the deep western boundary & eastward, parallel to the equator
- lNADW & lighter AABW form a **highly inter-active transition layer**
- the strongest mixing/**water mass trans-formation** occurs around the tip of Brazil

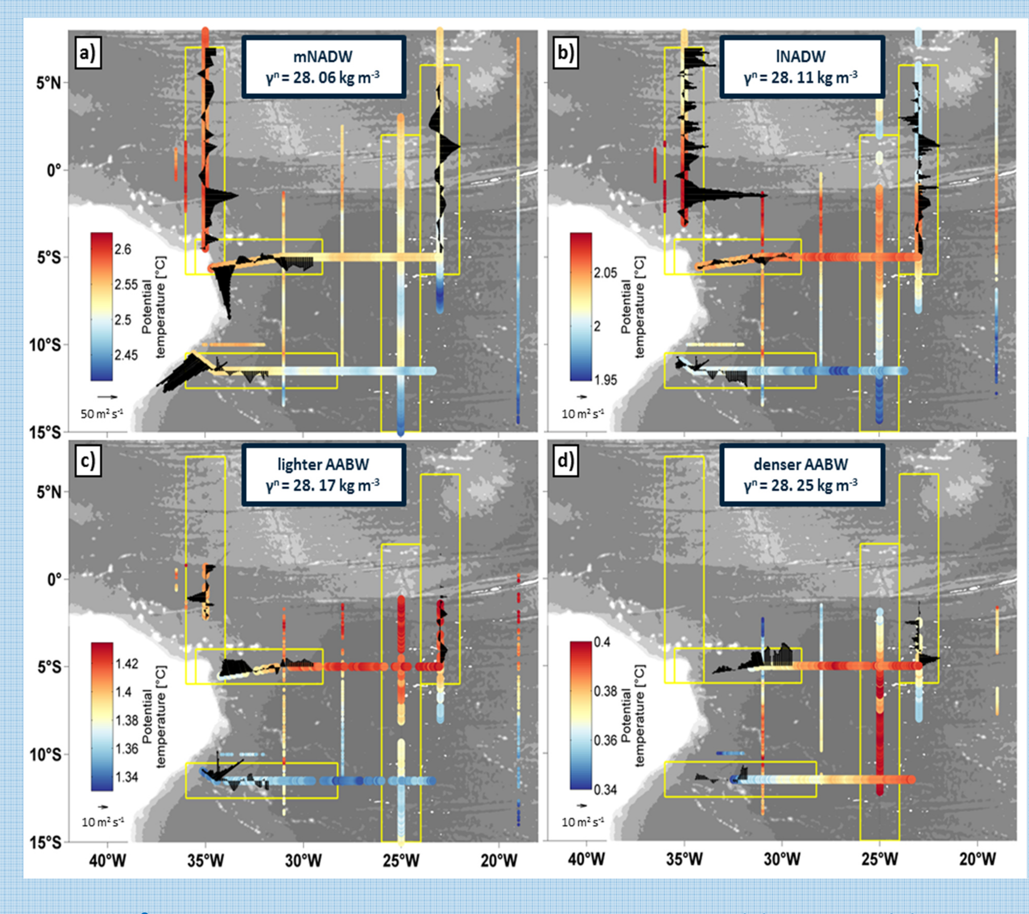


Fig. 4 θ [°C] on core neutral density surfaces of mNADW (a), lNADW (b), lighter (c), denser AABW (d). Black stickplots represent velocities normal to each section, averaged over and multiplied with layer height [m^2 s^{-1}].

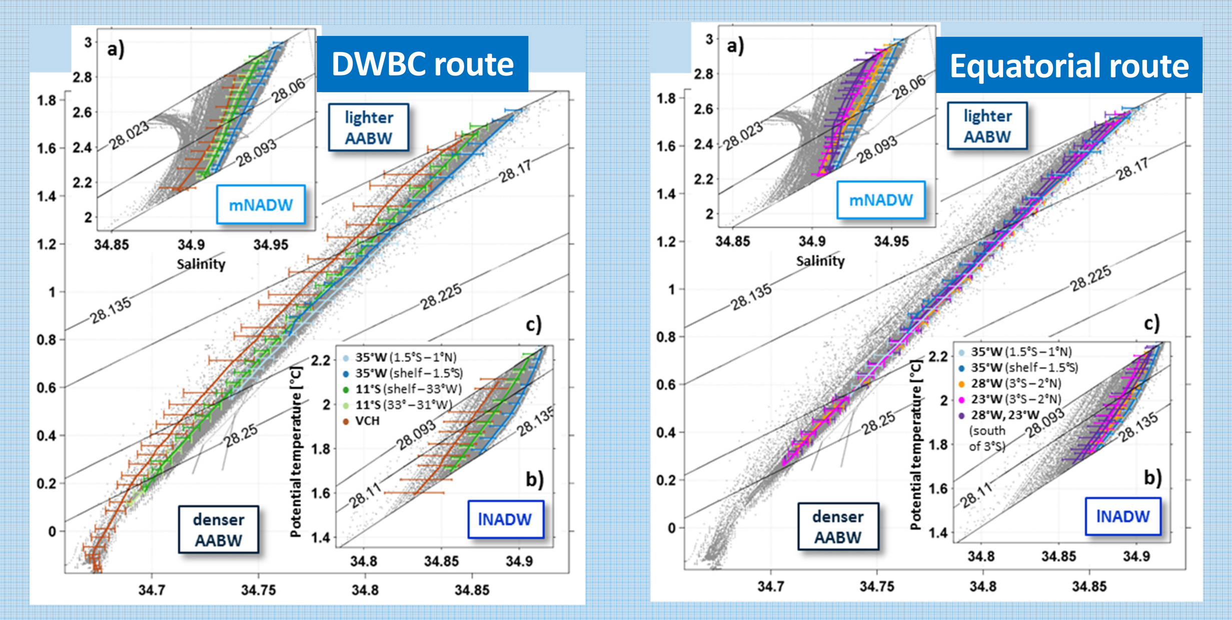


Fig. 5 & 6 θ-S-diagrams including all ship sections - for mNADW (a), lNADW (b) and AABW (c). Colored curves are mean salinities & their standard deviation per density class.

- all AABW north of 5°S is relatively homogeneous
- south of 5°S modified or recirculated waters join the mNADW layer

Temperature Trends

- the coldest AABW is **continuously warming** by **1.8 – 3.6 ·10^{-3} °C yr^{-1}** during 1989 – 2014 (in agreement with e.g. Johnson et al., 2014)*
- trends are much stronger where lighter AABW was captured instead
- **spatial coherence** between different sections → combining measurements to **one northern Brazil Basin time series** increases significance

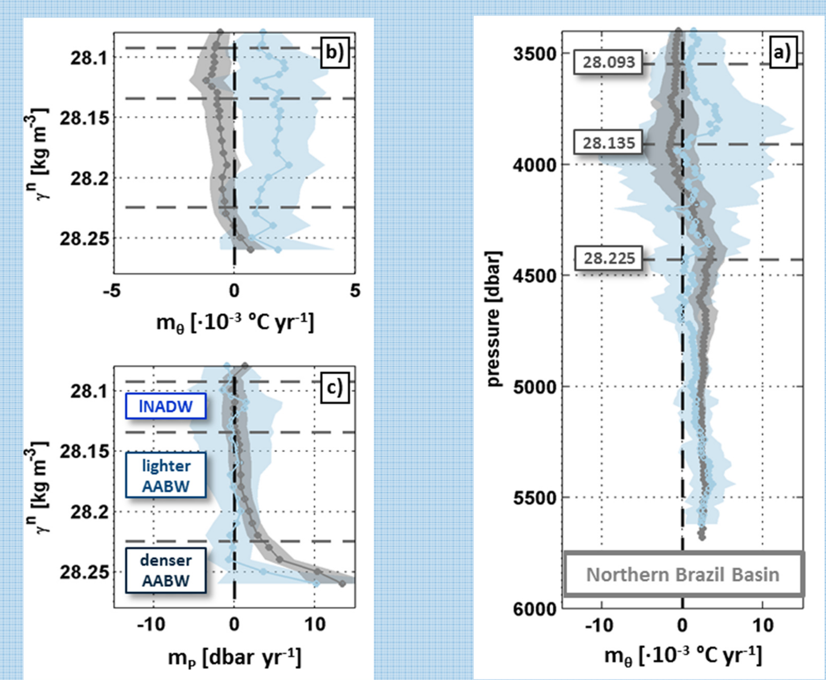


Fig. 8 Linear trends of θ [m_θ, 10^{-3} °C yr^{-1}] on pressure levels (a) or isopycnals (b), and of pressure [m_p, dbar yr^{-1}] of corresponding isopycnals (c) shown for lNADW & AABW layers. Grey are trends within the northern Brazil Basin, combining measurements along 11°S, 5°S, 25°W, 23°W over the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

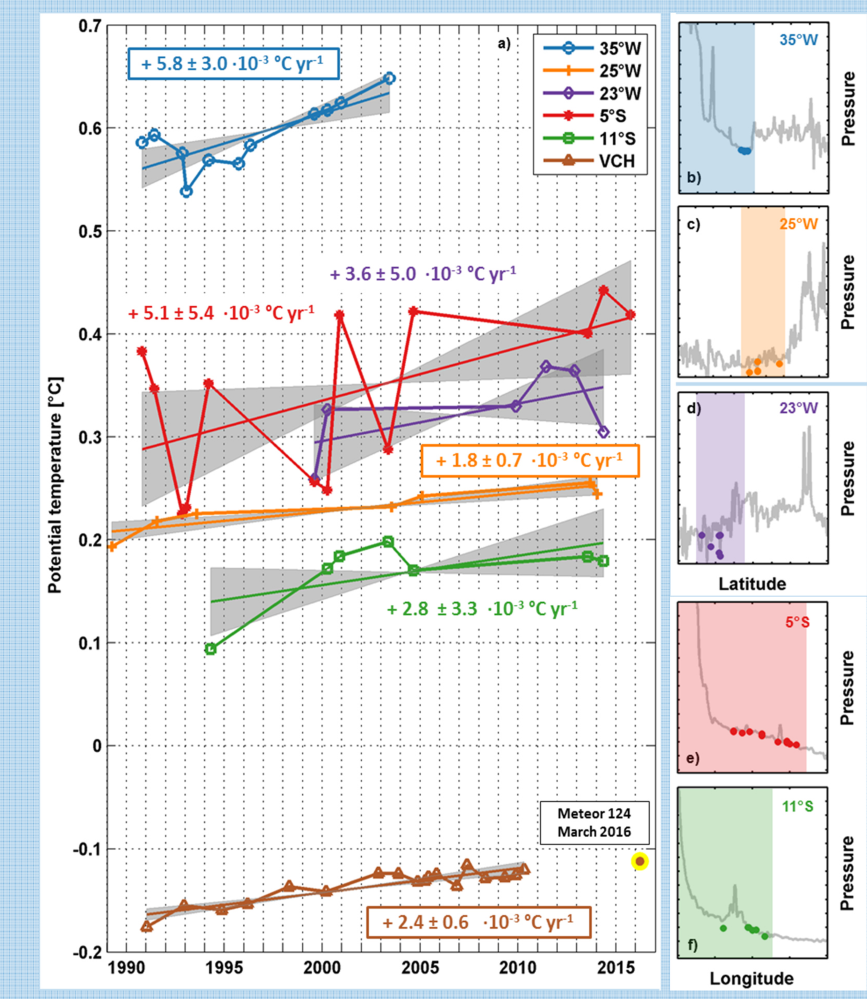


Fig. 7 a) Evolution of θ [°C] of the coldest AABW along 35°W, 25°W, 23°W, 5°S, 11°S, within VCH. Linear fits [10^{-3} °C yr^{-1}] with 95% confidence. Trends in boxes are different from zero with 95% confidence. b-f) Location of the lowest temperatures.

- the continuous warming of dense AABW is mainly related to **layer thinning/ volume loss**
- concurrently, the **lNADW/light AABW transition layer** shows intrinsic **decadal variations** - 1990s warming, 2000s cooling

* *Johnson, GC, McTaggart KE and Wanninkhof R (2014). Antarctic Bottom Water temperature changes in the western South Atlantic from 1989 to 2014. J Geophys Res Oceans, 119, 8567–857.*