Bundesministerium für Bildung und Forschung

Projektträger Jülich Forschungszentrum Jülich GmbH

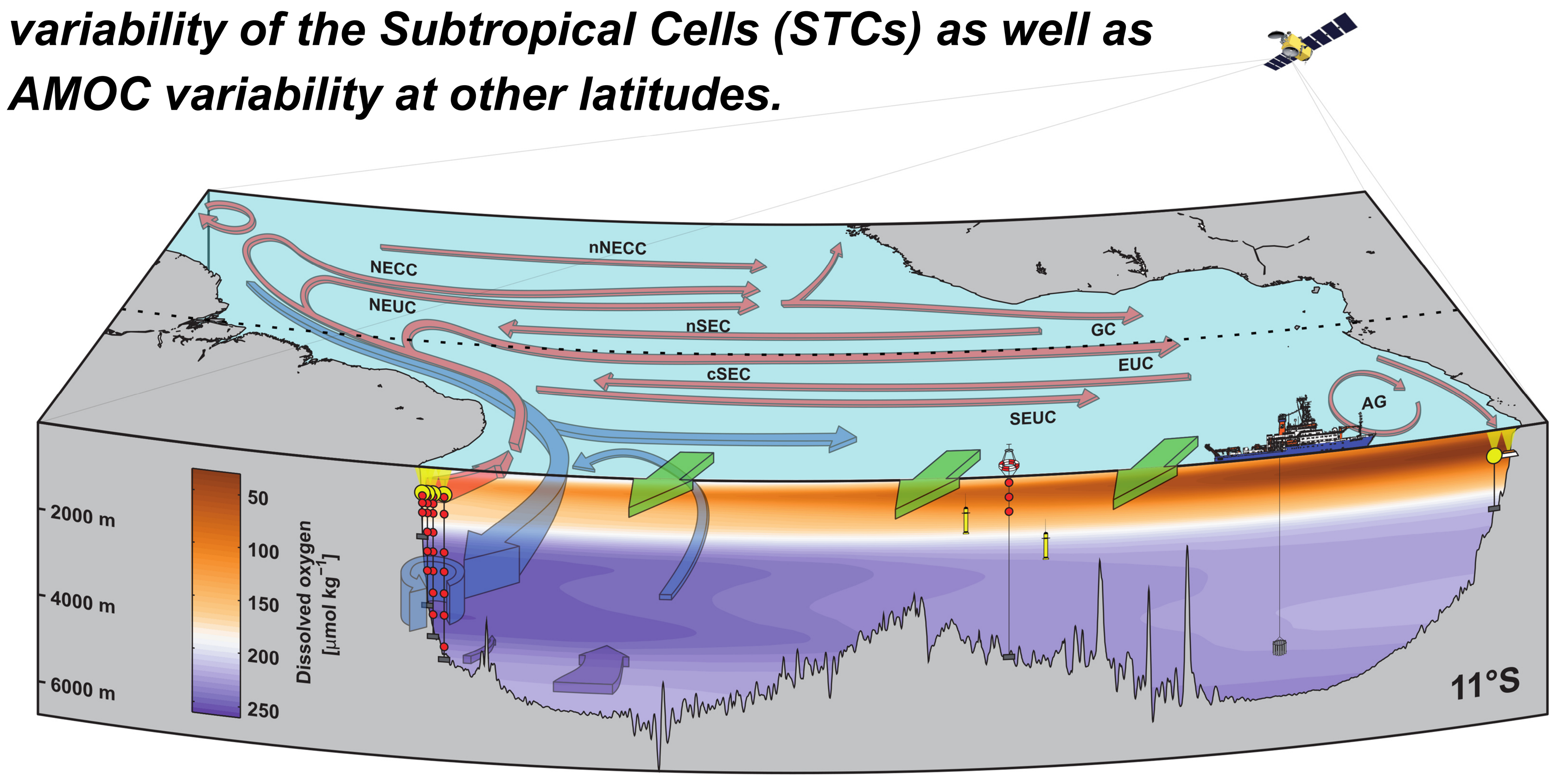
RACE TP 1.1

The role of the tropical Atlantic for climate variability in the Atlantic region

Herrford, J., Hummels, R., Dengler, M., Brandt, P.
GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel

GEOMAR

In order to understand the role of the tropical Atlantic for climate variability in the Atlantic region, this subproject aims at investigating the variability of the western boundary current (WBC) system off Brazil as well as the Atlantic Meridional Overturning Circulation (AMOC) at 11ºS. The assessed variability will then be related to the variability of the Subtropical Cells (STCs) as well as AMOC variability at other latitudes.



Observing the WBC system at 11ºS since 2000

- The WBC system is investigated with ship based observations and a mooring array (hydrographic as well as direct current observations).
- The variability of the WBC system - the North Brazil Undercurrent (NBUC) & the Deep Western Boundary Current (DWBC) - is investigated on time scales from intraseasonal to decadal.
- Reconstruction of the velocity fields from moored observations by inter- and extrapolation, as well as using a pattern regression method are tested.

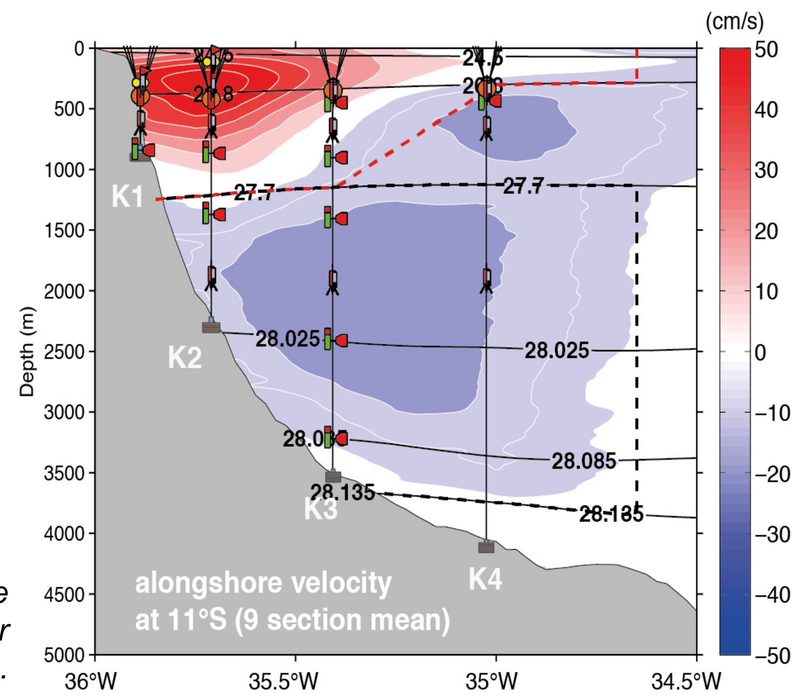


Fig. 2 Average section of alongshore velocity together with the mooring array design. Red/black dashed lines mark boxes for NBUC/DWBC transport calculations (Fig.3).

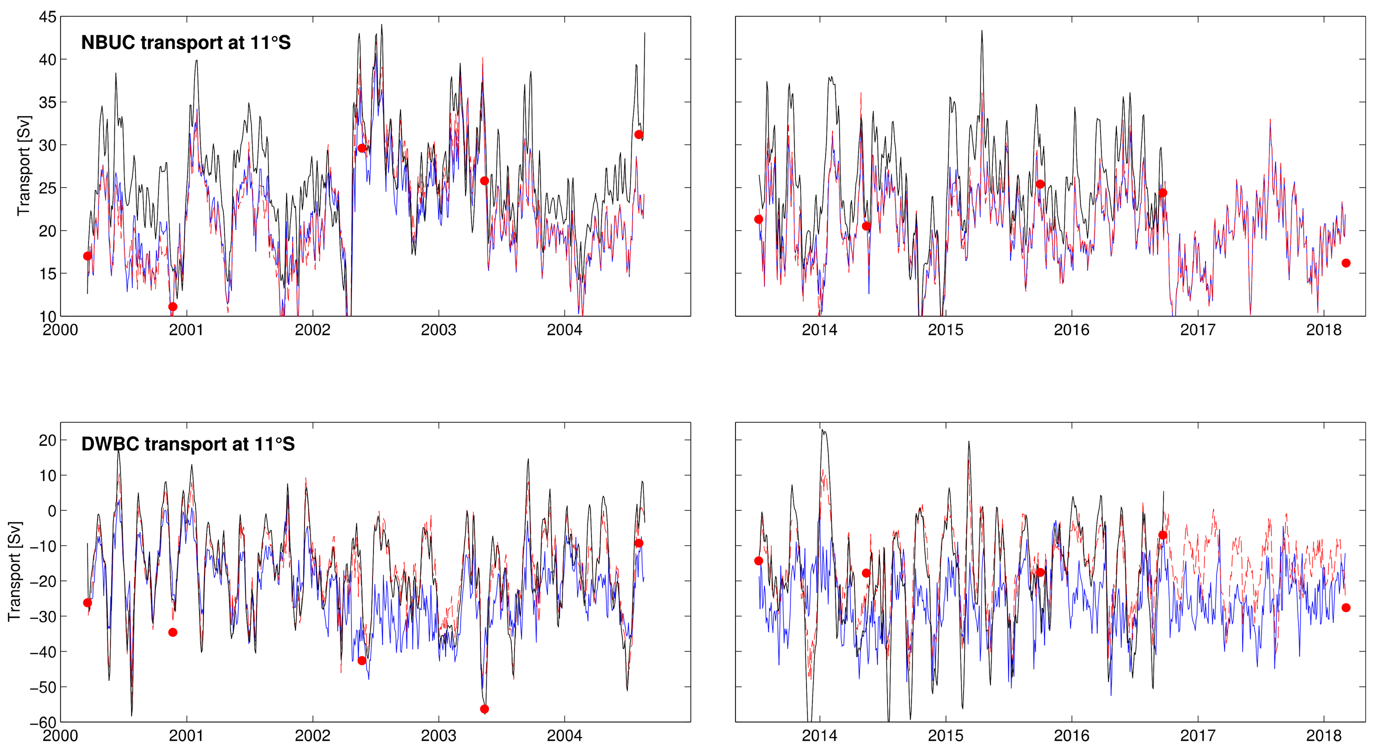


Fig. 3 Transport time series of the NBUC and the DWBC. Reconstruction of the velocity field for transport calculation is based on intra – and extrapolation of moored observations (black; Hummels et al. 2015) or pattern regression based on one joint pattern (blue) and separately fitted patterns for the NBUC/DWBC respectively (red).

- Pattern regression provides a quality estimate of the method by subsampling the ship sections to „moored observations", applying the regression and comparing the resulting transports.

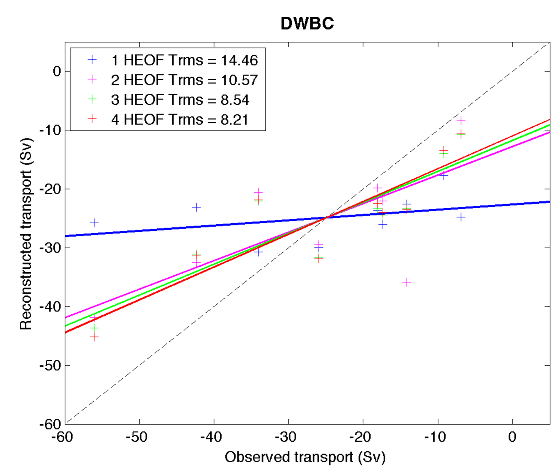
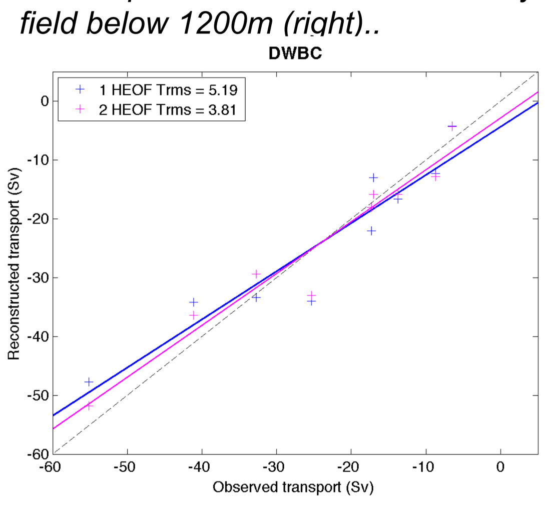


Fig. 4 Difference in DWBC transports based on the observed & the reconstructed velocity fields using 4 joint patterns (left) & two DWBC patterns fitted to the velocity field below 1200m (right)..



- For the NBUC the regression for 4 joint patterns and separately fitted 3 NBUC patterns show similar transport time series (Fig. 3) and rms differences (1.76 Sv / 1.66 Sv). For the DWBC large differences occur using the 4 joint patterns or the DWBC patterns. The first 2 DWBC patterns can already explain ~90% of the variance & result in much lower rms differences.

Estimating AMOC variability at 11ºS from BPR measurements 2013-2018

- Bottom Pressure (BPR) observations on both sides of the basin at 300m & 500m are used to estimate the upper-ocean northward geostrophic transport contribution to AMOC variability at 11ºS on seasonal to interannual time scales.
- All BPR time series show strong seasonal variability – the combined annual & semiannual harmonics explain ~15% of the variance at the western boundary, up to ~40% at the eastern boundary.
- Seasonal variability can be compared to moored observations of the NBUC (Schott et al., 2005) & Angola Current (AC; Kopte et al., 2017) transports.
- Data gaps are filled with known relationships or seasonal variability from a 1.5-year period (yellow shading) with 5 sensors in place.

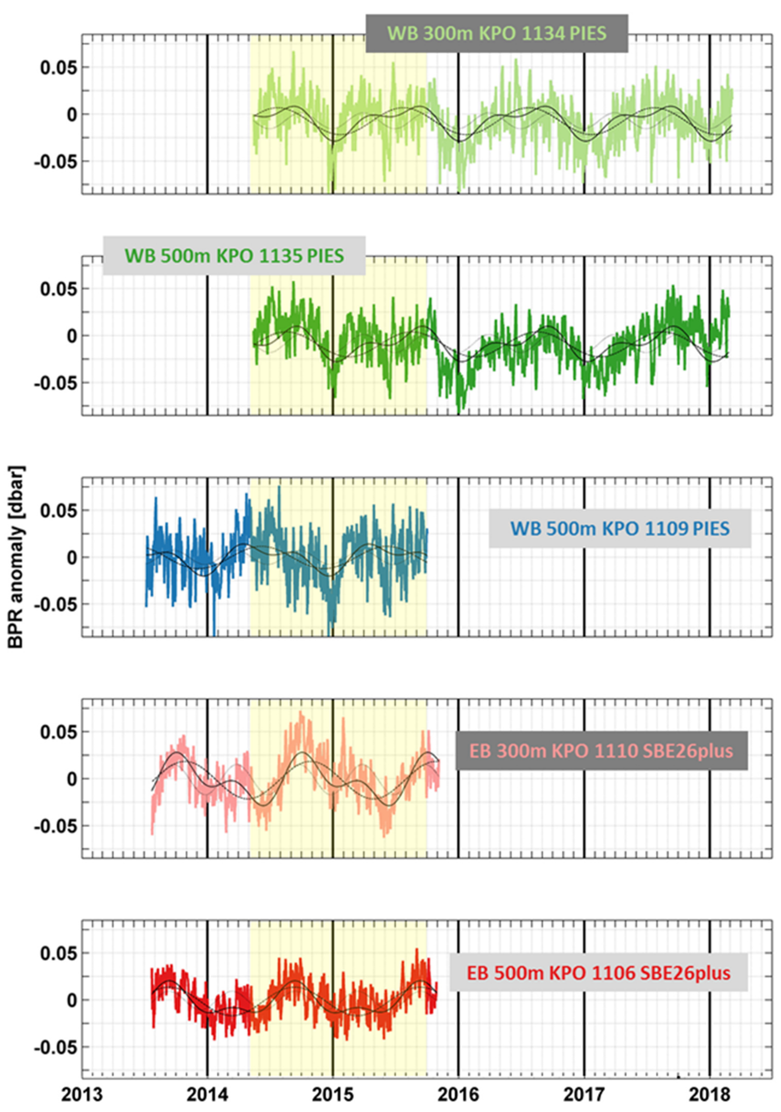


Fig. 5: Time series of BPR anomalies [dbar] from 5 sensors installed on the Brazilian & Angolan shelfs at 300m & 500m, respectively. Black lines are the individually fitted annual & semiannual harmonics.

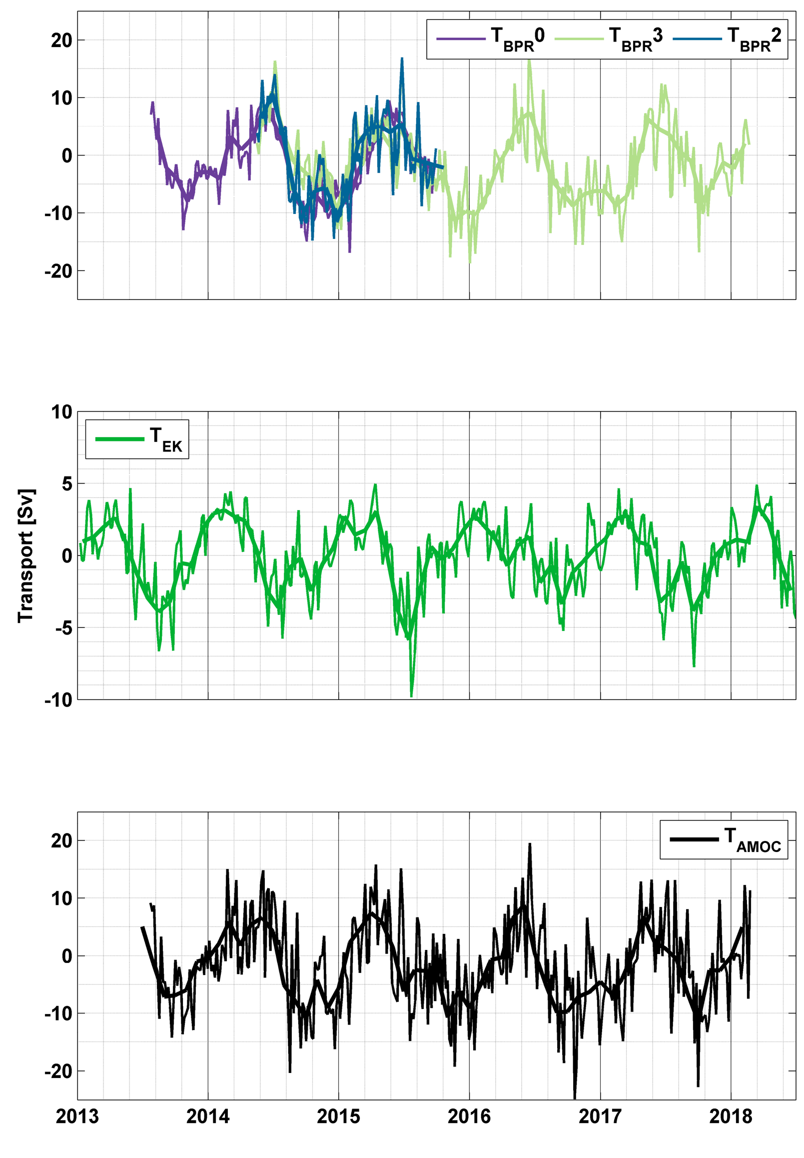
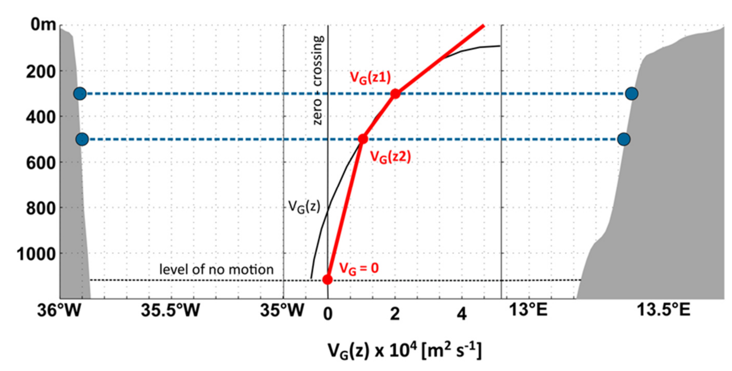


Fig. 6: Time series of the upper-ocean northward geostrophic transport anomalies (dark blue; [Sv]) – purple & light green curves are reconstructed for periods with missing sensors, near-surface northward Ekman transport anomalies from AScat winds (green) & the derived AMOC transport anomalies (black).



- AMOC transport variations can be derived by adding the wind stress forced, near-surface northward Ekman transport:

$$T_{AMOC} = T_{BPR} + T_{EK}$$

- The Ekman transport in the Tropics is large with ~ 10 Sv southward. Seasonal variability is dominant, but differs in amplitude between products (NCEP/NCAR, QuickScat, Ascat, ERAI, CCMP, CORE-II, JRA55-do).
- Comparing individual products with wind observations at different PIRATA bouys, shows, that scatterometer winds are the best choice for the tropical South Atlantic with correlations >0.7 at all locations.

Seasonal variability in the WBC and AMOC components at 11ºS

- Seasonal variability is strong in the Tropics in both components T_{BPR} & T_{EK}:
  - for T_{EK} more pronounced in the western basin
  - for T_{BPR} eastern boundary density fluctuations seem to outweigh
- In contrast to the situation at RAPID & SAMOC (e.g. Kanzow et al.,2010; Dong et al., 2014), the T_{BPR} contribution to seasonal variability at 11ºS exceeds the T_{EK} contribution by a factor of 3.
- There are hints towards a baroclinic compensation at depth within the DWBC core (Schott et al., 2005). After removing the mesoscale variability (<130d; Deep Eddies as in Dengler et al., 2004), seasonal variability of the DWBC transport at 11ºS can balance T_{BPR}.

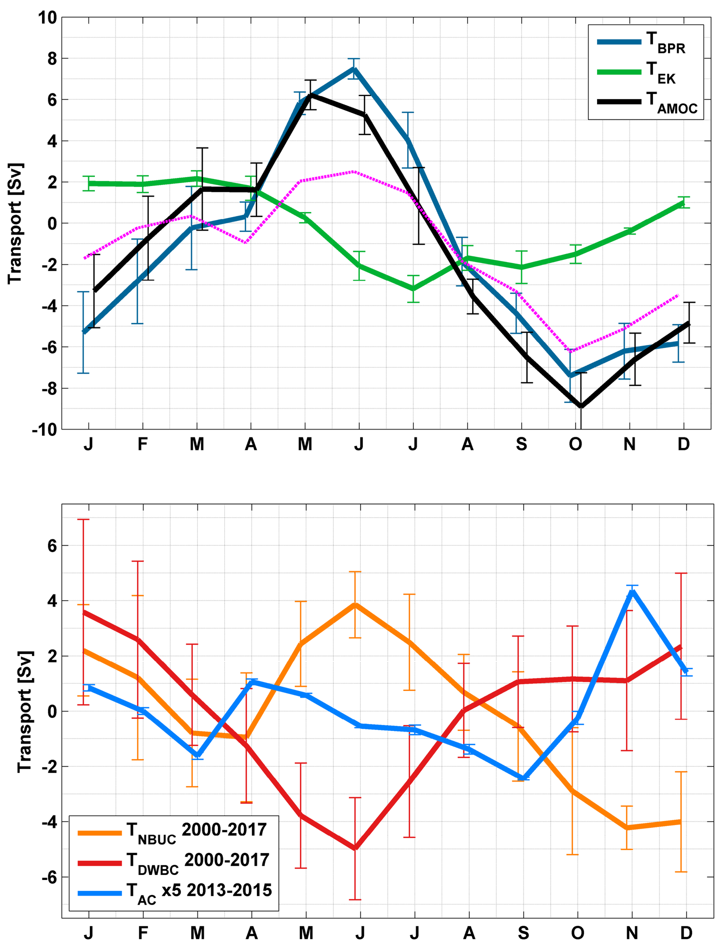


Fig. 3: Mean seasonal cycles for AMOC transport anomalies & its individual components averaged over the period 2013-2018, as well as for the NBUC, DWBC & AC averaged over availabe data.

Aims for RACE Synthesis

- The long-term observations off the Brazilian coast at 11ºS & on the Equator at 23ºW will be continued. Additional maintenance cruises are proposed for autumn 2019.
- Water mass changes will be analyzed & independent AMOC estimates calculated based on two full-depth transatlantic ship sections along 11ºS from 1994 & 2018.
- The impact of changes on mixed layer heat & freshwater balances will be investigated.
- All available hydrographic measurements in the tropical South Atlantic will be combined to extend time series of the WBC system & AMOC to investigate longer-term variability.
- In a circulation synthesis it will be investigated how the WBC system & AMOC at 11ºS are related to the equatorial & tropical circulation, as well as AMOC variability in the Subtropics of both hemispheres.
- The analysis of observations & models will allow for a model validation, to identify key processes of circulation & climate variability, and show the prediction skill of models.

- Dengler, M., F. A. Schott, C. Eden, P. Brandt, J. Fischer, and R. J. Zantopp (2004), Break-up of the Atlantic deep western boundary current into eddies at 8 degrees S, Nature, 432(7020), 1018–1020.
- Dong, S., Baringer, M., Goni, G., Meinen, C., and Garzoli, S.: Seasonal variations in the South Alantic Meridional Overturning Circulation from observations and numerical models, Geophys. Res.Lett., 41, https://doi.org/10.1002/2014GL060428, 201.
- Hummels, R., P. Brandt, M. Dengler, J. Fischer, M. Araujo, D. Veleda, and J. V. Durgadoo, 2015: Interannual to decadal changes in the western boundary circulation in the Atlantic at 11° S, Geophys. Res. Lett., 42, doi:10.1002/2015GL065254.
- Kanzow and Coauthors, 2010: Seasonal variability of the Atlantic meridional overturning circulation at 26.5° N. J. Climate, 23, 5678–5698, doi: 10.1175/2010JCLI3389.1.
- Kopte, R., P. Brandt, M. Dengler, P.C.M. Tchipalanga, M. Macuéria, M. Ostrowski, (2017) The Angola Current – flow and hydrographic characteristics as observed at 11° S, J. Geophys. Res., published online, Jan. 7.
- Schott, F. A., Dengler, M., Zantopp, R., Stramma, L., Fischer, J.,and Brandt, P.: The shallow and deep western boundary circulation of the South Atlantic at 5◦S–11◦S, J. Phys. Oceanogr., 35, 2031–2053, 2005.

RACE Final Workshop, 8.-9. November 2018, House of Science, Bremen

Universität Hamburg DER FORSCHUNG | DER LEHRE | DER BILDUNG · GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel · ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG · Max-Planck-Institut für Meteorologie · Universität Bremen · BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE