Do the Atlantic climate modes impact the ventilation of the eastern tropical North Atlantic oxygen minimum zone?

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Key Points

- focus on variability of North Equatorial Undercurrent (NEUC)
- Atlantic Meridional Mode (AMM) associated with meridional shift and anomalous intensity of NEUC
- Atlantic Zonal Mode (AZM) associated with anomalous intensity of NEUC

Variability of the ETNA OMZ

Oxygen levels in the Eastern Tropical North Atlantic (ETNA) Oxygen Minimum Zone (OMZ) vary on daily to multi-decadal time scales. The long-term trend mainly consists of a deoxygenation (Stramma et al., 2008: Brandt et al., 2015).

Changes in oxygen levels are associated with changes in the eastward zonal current bands like the NECC, nNECC, or NEUC (Fig. 1; Brandt et al. (2010)).

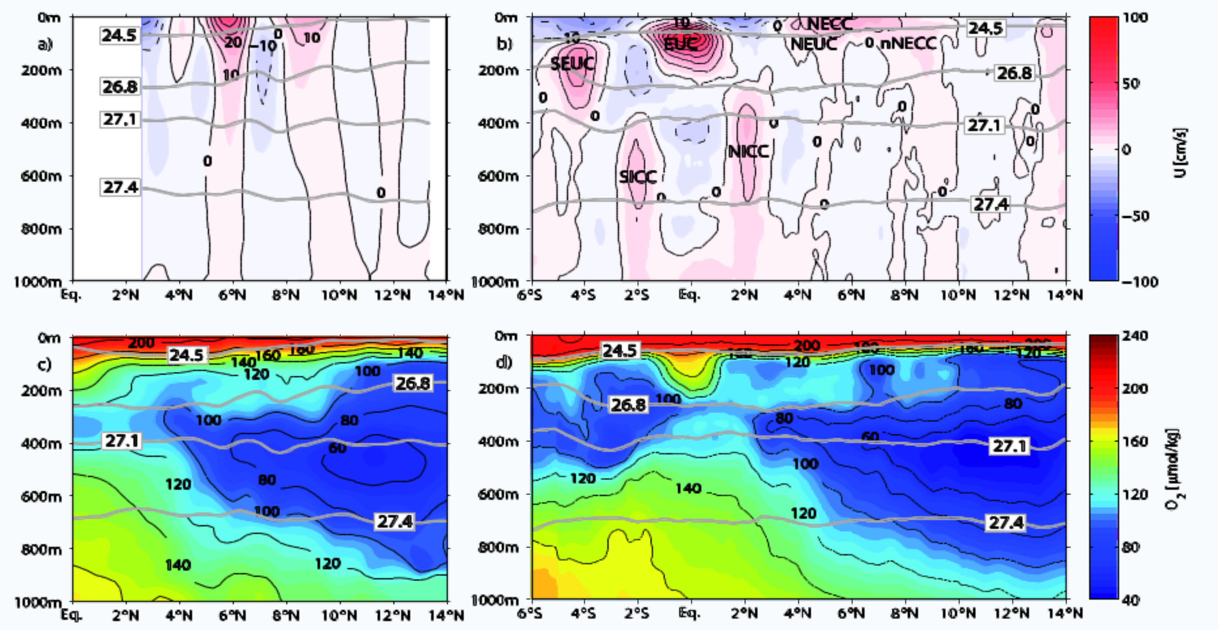
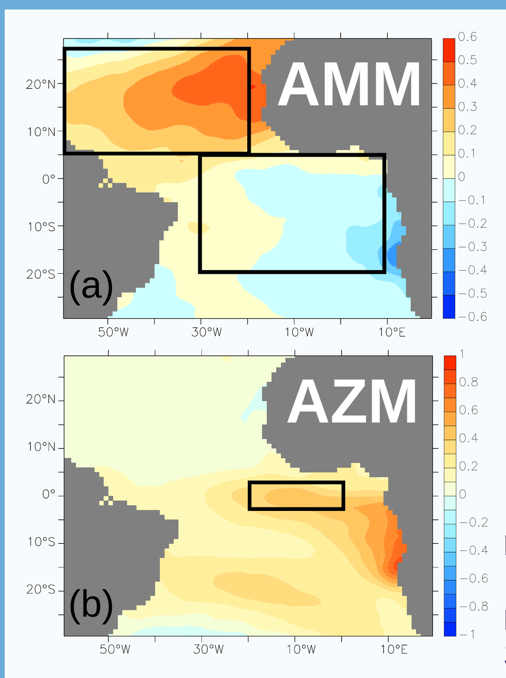


Fig. 1: Mean zonal velocity (a,b) and dissolved oxygen (c,d) along 23°W for 1972-85 (a,c), 1999-2008 (b,d). Note stronger zonal currents, generally higher oxygen levels; more pronounced oxygen maxima associated with eastward currents during 1972-85. From Brandt et al. (2010).

One important question is how much of the deoxygenation is due to the natural variability of the ETNA zonal current field. Here we focus on the potential impact of the Atlantic climate modes onto the NEUC.

The Atlantic climate modes

The AMM and AZM dominate tropical Atlantic variability (Fig. 2). Hormann et al. (2012) observed a relationship between NECC variability and the Atlantic climate modes. Our model data confirm their results.



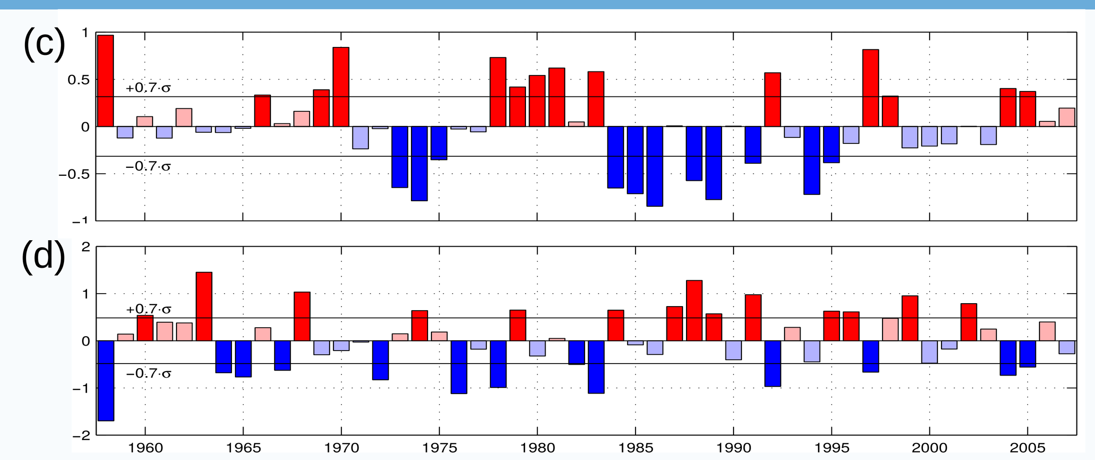


Fig. 2: First (b) and second (a) empirical orthogonal function of reanalysis (NOAA) Sea Surface Temperature (SST). March to May mean of AMM index (c; Servain 1991) and June to August mean of AZM index (d; Zebiak 1993) estimated from TRATL01 SST. Black boxes mark region for index calculation.

Impact of Atlantic Climate Modes on the NEUC

Model data

- high-resolution (0.1º) tropical Atlantic nest (TRATL01) within global ocean model NEMO-ORCA05
- coupled with biogeochemical model
- CORE forcing for time period 1958 to 2007

(Duteil et al., 2014)

Estimation of NEUC central location Y_{CM} & intensity INT

$$Y_{CM}(x,t) = \frac{\int_{z=Z_b}^{z=Z_t} \int_{y=Y_S}^{y=Y_N} y\ u(x,y,z,t)\ dy\ dz}{\int_{z=Z_b}^{z=Z_t} \int_{y=Y_S}^{y=Y_N} u(x,y,z,t)\ dy\ dz} \quad (1)$$

$$INT(x,t) = \int_{z=Z_b}^{z=Z_t} \int_{Y_{CM}-W}^{Y_{CM}+W} u(x,y,z,t)\ dy\ dz \quad (2)$$

Equ. 1 & 2: Central location Y_{CM} and intensity INT calculated according to Hsin (2016). Where x is longitude, t is time, z is depth, y is latitude, and u is zonal velocity (only positive values for NEUC).
Integration limits for NEUC are the sigma-level of top (bottom) of flow Z_t = 24.5 kg m^{-3} (Z_b = 24.5 kg m^{-3}), the southern (northern) limit of flow Y_S= 3.6°N (Y_N = 5°N), and the half-mean-width of flow W = 2°.

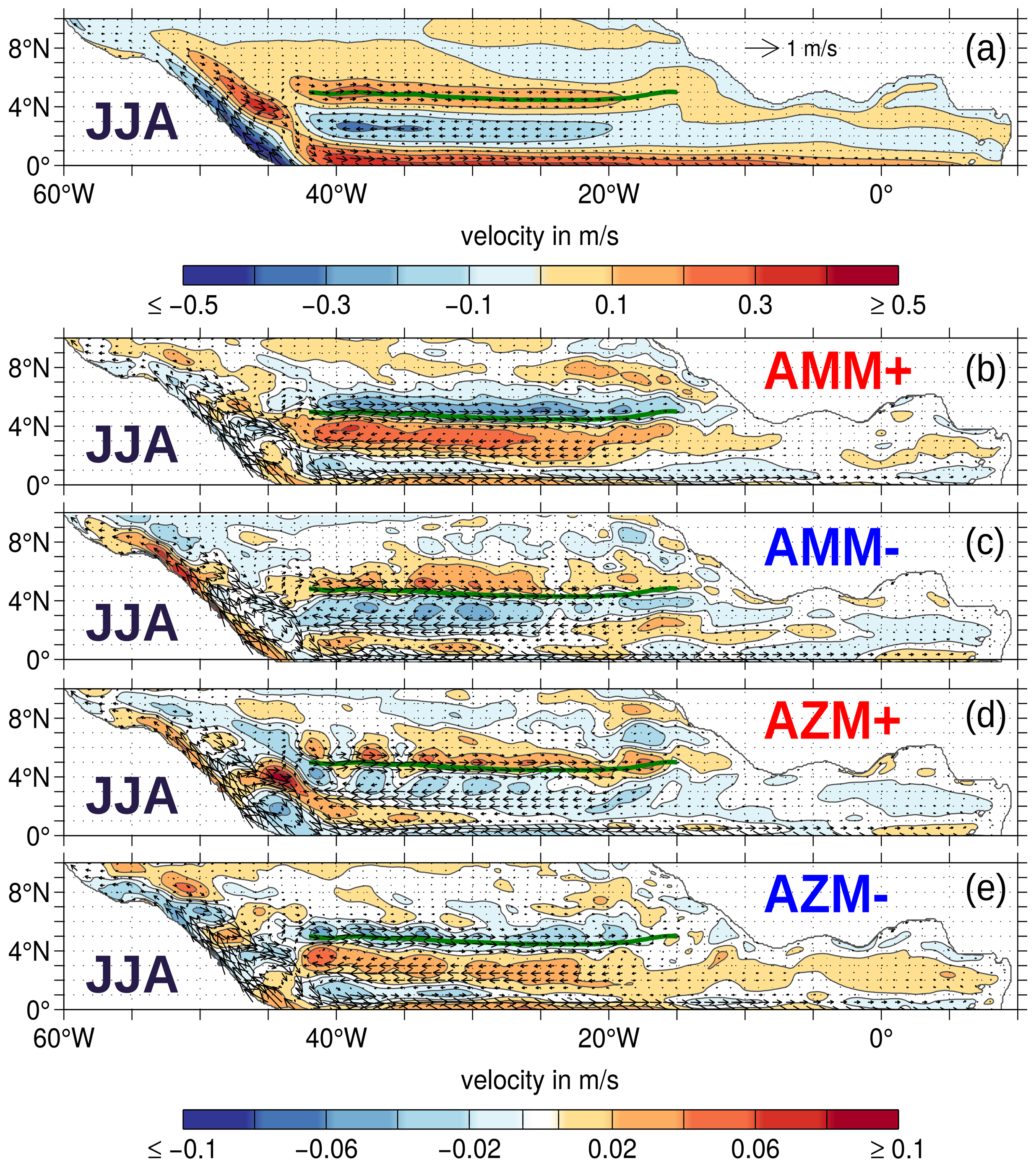


Fig. 3: (a-e) JJA mean of TRATL01 horizontal velocities (arrows) within 100m to 400m depth and NEUC Y_{CM} (green line) from 1958 to 2007. Shading marks (a) JJA mean of TRATL01 zonal velocities from 1958 to 2007 and JJA mean of TRATL01 zonal velocity anomalies within 100m to 400m depth during years of (b) positive AMM events, (c) negative AMM events, (d) positive AZM events, (e) negative AZM events. All zonal velocity anomalies are calculated with respect to the JJA mean from 1958 to 2007.

- the Atlantic NEUC is an eastward zonal undercurrent within 100m to 500m depth - during June to August (JJA) it is centered around 4.8°N and has a averaged intensity of 5.6Sv
- positive AMM events: NEUC is shifted southward (Fig. 3b and 4 a,b) and weakens up to -1.5Sv (Fig. 4 c,d)
- negative AMM events: NEUC is shifted northward (Fig. 3b and 4 a,b) and slightly intensifies (Fig. 4 c,d)
- intensity anomalies during negative AMM events are weaker compared to positive AMM events (Fig. 4d)
- no anomalous meridional shift of NEUC during AZM events (Fig. 3d,e and 4 e,f)
- NEUC intensity strengthens (weakens) up to 1Sv (-1Sv) during positive (negative) AZM events

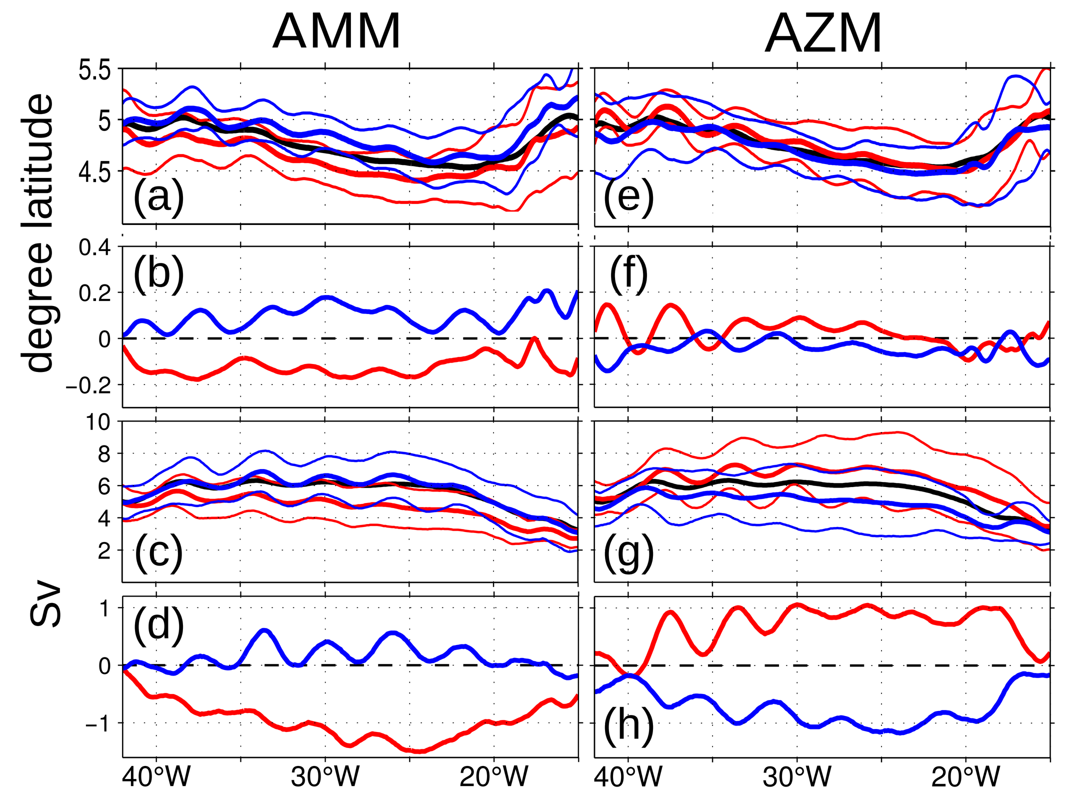


Fig. 4: JJA mean of NEUC Y_{CM} (a, e) and INT (c, g) (bold lines) ± corresponding standard deviations (thin lines) for all years from 1958 to 2007 (black), for years of only positive (red) and negative (blue) AMM (a,c) and AZM (e,g) events. JJA anomalies of NEUC Y_{CM} (b,f) and INT (d,h) with respect to the JJA mean from 1958 to 2007 for positive (red) and negative (blue) AMM (b,d) and AZM (f,h) events.

Outlook

- repeat analysis for nNECC and NEC
- correlation of variability of the water mass distributions in and the ventilation of the ETNA OMZ
- correlation with Sverdrup relation
- comparison to observational and reanalysis data

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