Ventilation of the Tropical Atlantic by Equatorial Deep Jets

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Mean Circulation and Oxygen Distribution

Complex zonal current system connects high-oxygen western boundary regime with sluggish flow in the eastern basin.

Brandt et al. 2008, 2010
Mean Equatorial Zonal Velocity and Oxygen Distribution at 23°W

- Eastward/westward flow associated with high/low oxygen concentration (Tsuchiya et al. 1992)
- NICC/SICC at 2°N/S supplies oxygen to the eastern Atlantic (e.g. Stramma et al. 2005)

Section mean from about 25 ship sections along 24°W-23°W
Moored Velocity Observations at the Equator, 23°W

Zonal (left) and meridional (right) velocity [m/s] measured at 23°W, 0°N with ADCP and moored profiler (Brandt et al. 2011)

Equatorial deep jets oscillate with a period of about 4.5 years (Johnson and Zhang 2003) and are found to affect sea surface temperature and atmospheric parameters (Brandt et al. 2011)
Model for Latitudinally Alternating Zonal Jets

- Latitudinally alternating zonal jets generated by an artificially forced downward propagating Yanai beam
- Strongest jets near the equator (EIC, SICC, NICC)
- No equatorial deep jets!
Idealized Simulations of EDJs

- Idealized model (1/4°, 100 levels) forced by oscillations at the western boundary producing Rossby-gravity waves
- Both, EDJ and extra-equatorial jets (EEJ) are generated in this simulation

Méneguen et al. 2009
Greatbatch et al. (2012) used a reduced-gravity model to simulate regular high-baroclinic-mode oscillations with a period of 4.5 years.

Width of the EDJs could be correctly simulated by including lateral eddy viscosity of about 200-300 m²/s.
Advection-Diffusion Model

- Model is forced by the velocity field of the equatorial basin mode
- It includes a restoring to western boundary oxygen concentrations within a boundary layer and oxygen consumption (van Geen et al. 2006)
- Simulation are performed until a constantly oscillating state is reached (about 160 yr)
- Mean relative oxygen concentration shows ventilation of the equatorial band due to basin mode oscillations
Simulated Relative Oxygen Concentration at 23°W

- Oxygen oscillates with the basin mode period \((T_0 = 4.5 \text{ yr})\) cycle having amplitudes of about 25% of western boundary values.

- Maximum oxygen concentration occurs after maximum eastward velocity (not in quadrature → mean flux).
4.5-yr Deep Jet Cycle in Moored Observations at 23°W

- EDJ at intermediate depth with amplitudes of about 10 cm/s
- Oxygen concentration increases during phases of eastward flow
Oxygen Distribution along 23°W from Ship Sections

- Large variability associated with different current bands
- What is the time scale of the variability?
Oxygen Distribution along 23°W from Ship Sections

- Depth range 280-380m particularly strong variability
- June 2006: oxygen tongue at the equator extending from 35°W to 10°W (Brandt et al. 2008)
Meridional Oxygen Structure at 23°W

Meridional oxygen structure is dominantly affected by EDJ

Agreement between observed and simulated phases of high/low oxygen at the equator

Slightly overestimated amplitude of oxygen oscillations due to missing mean advection
Shipboard and moored observations show

- Presence of EDJ superimposed on the mean east-/westward currents (SICC, EIC, NICC)
- EDJ oscillate with a period of about 4.5 years
- Equatorial oxygen concentration is strongly affected by EDJ

Advection-diffusion model based on the equatorial basin mode explain

- Contribution of EDJ to the mean equatorial ventilation
- Phase shift between zonal velocity and oxygen anomalies found in moored observations at the equator, 23°W
- General structure of oxygen variability in ship section
Annual mean AOU \([\text{mol/m}^3]\) at 300m in different global models and observations
Observations versus Model

- State-of-the-art, high-resolution model (ORCA, 45 vertical levels) does not represent EDJ (pers. comm. C. Böning)
- Simulation is dominated by low-baroclinic mode variability
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