

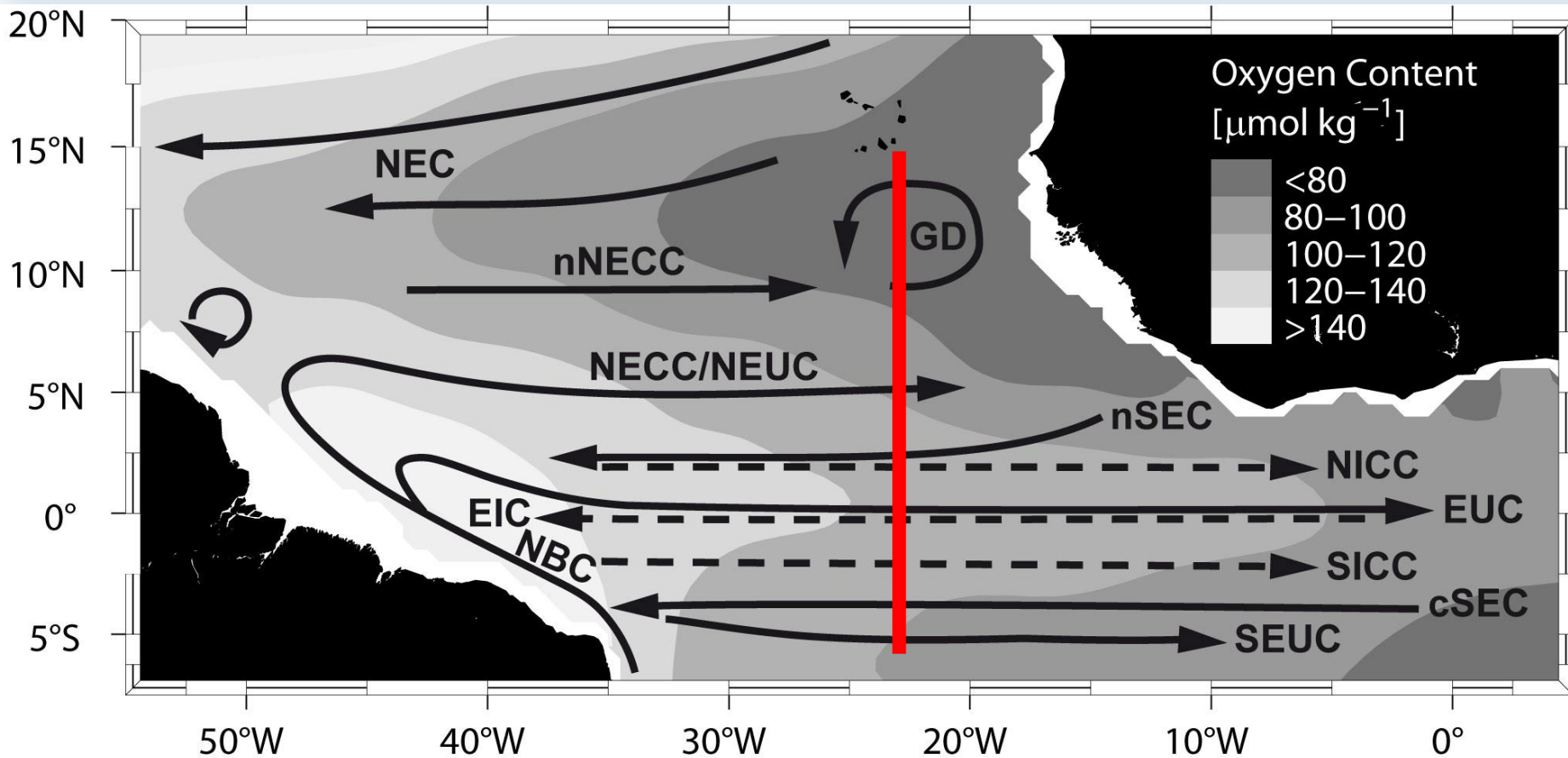


Ventilation of the Tropical Atlantic by Equatorial Deep Jets

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V. Hormann, J. Hahn, Y. Fu, M. Dengler, J. M. Toole

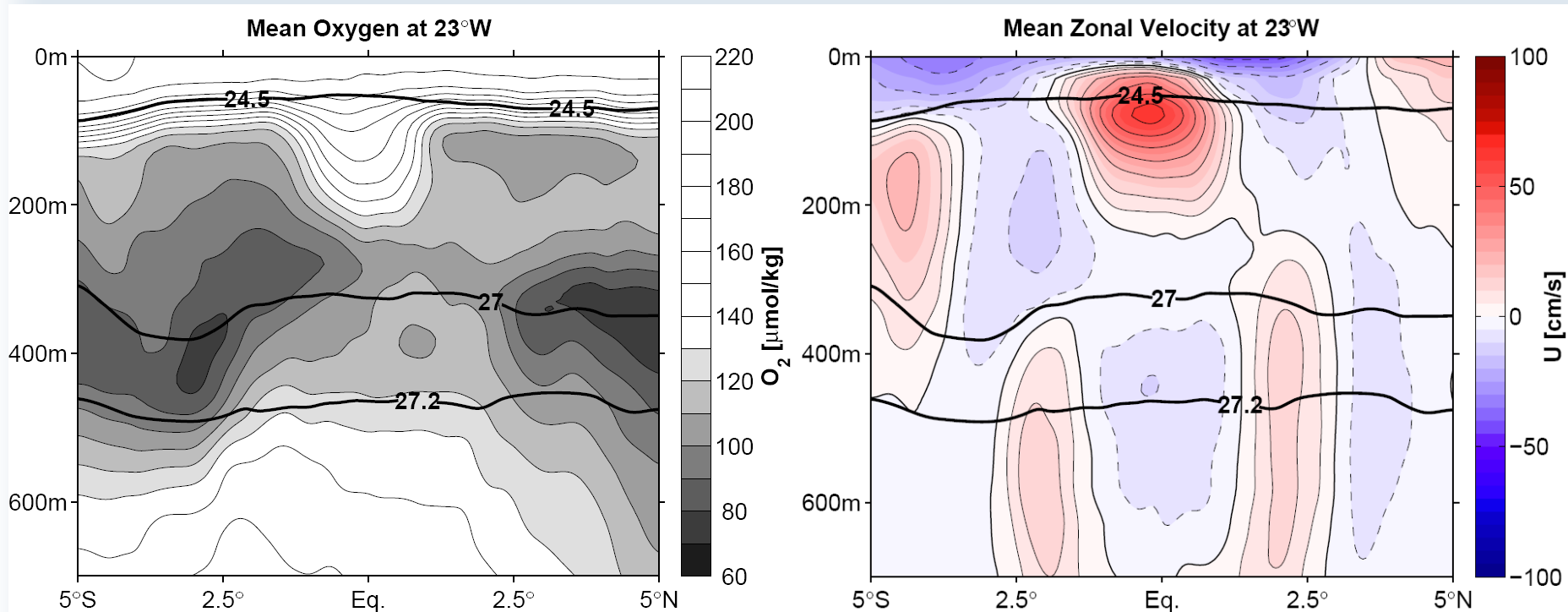
Mean Circulation and Oxygen Distribution

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

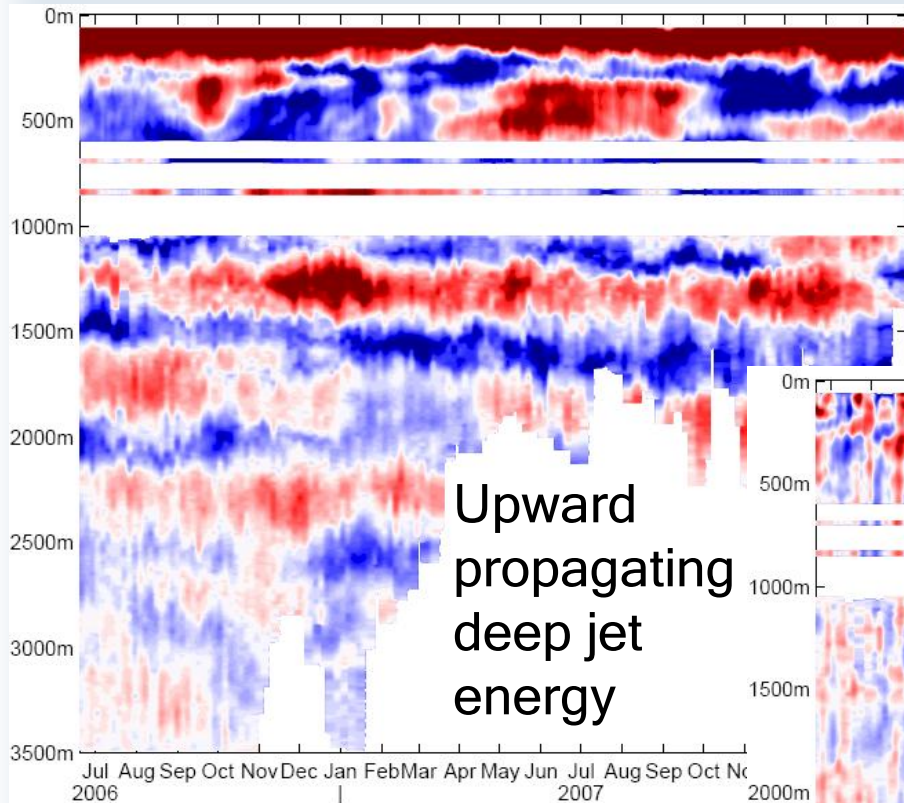


Mean Equatorial Zonal Velocity and Oxygen Distribution at 23°W

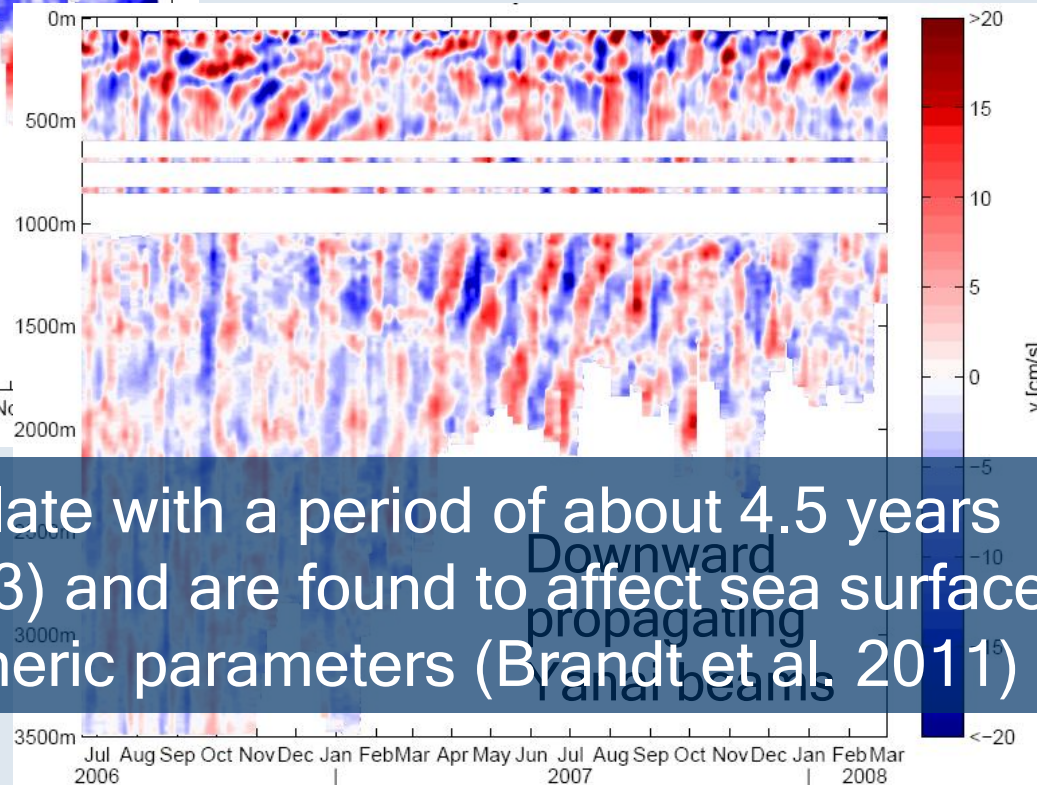
- ▶ Eastward/westward flow associated with high/low oxygen concentration (Tsuchiya et al. 1992)
- ▶ NICC/SICC at 2°N/S supplies oxygen to the eastern Atlantic (e.g. Stramma et al. 2005)



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)

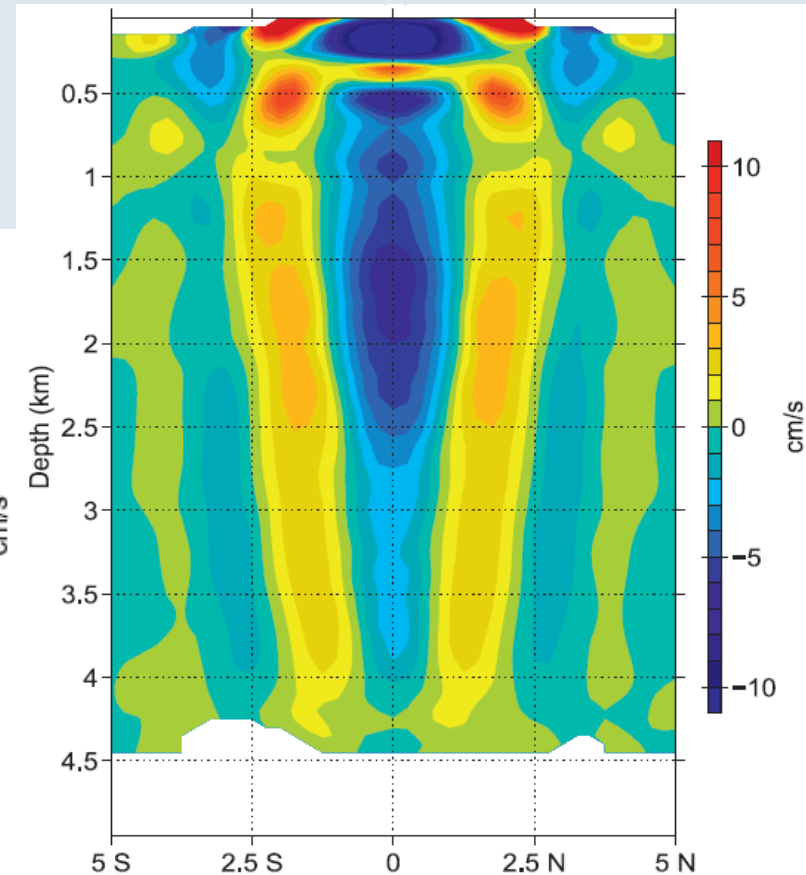
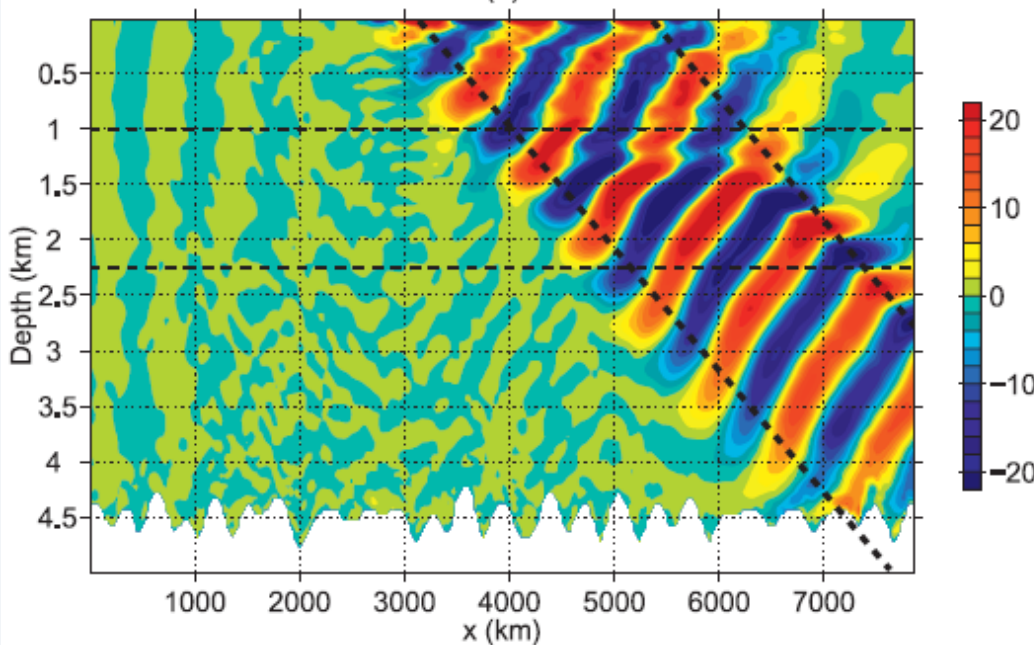


Equatorial deep jets oscillate with a period of about 4.5 years (Johnson and Zhang 2003) and are found to affect sea surface temperature and atmospheric parameters (Brandt et al. 2011)



Model for Latitudinally Alternating Zonal Jets

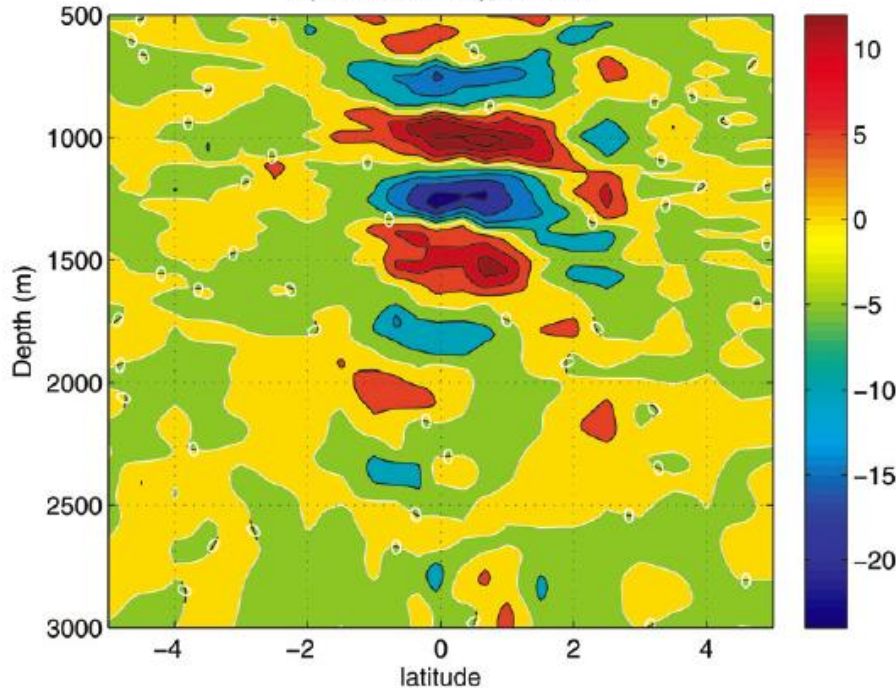
- ▶ Latitudinally alternating zonal jets generated by an artificially forced downward propagating Yanai beam
- ▶ Strongest jets near the equator (EIC, SICC, NICC)
- ▶ No equatorial deep jets!



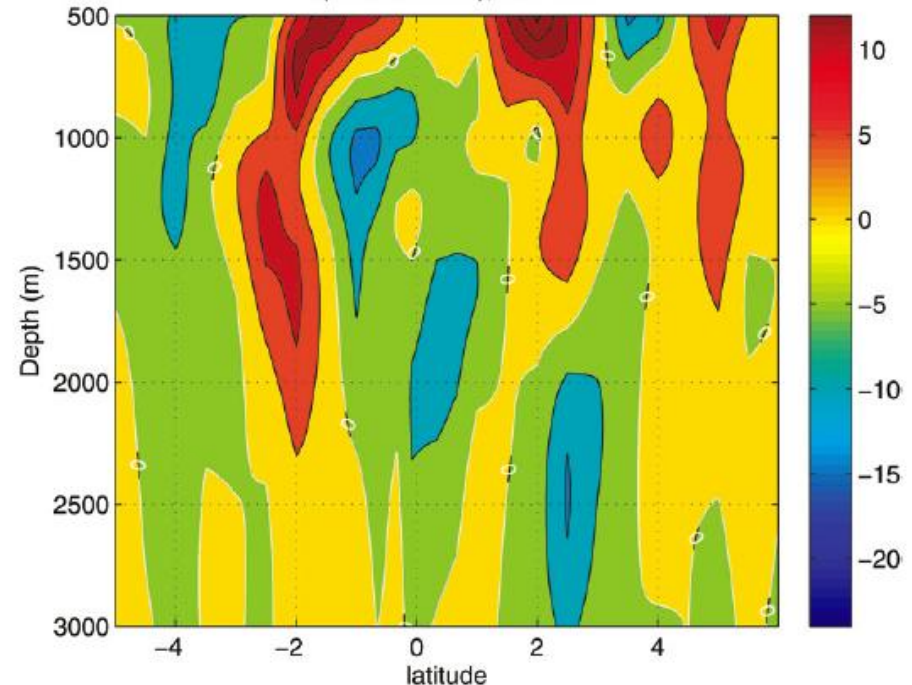
Idealized Simulations of EDJs

- ▶ Idealized model ($1/4^\circ$, 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

U(modesSL \geq 10), lon=-23

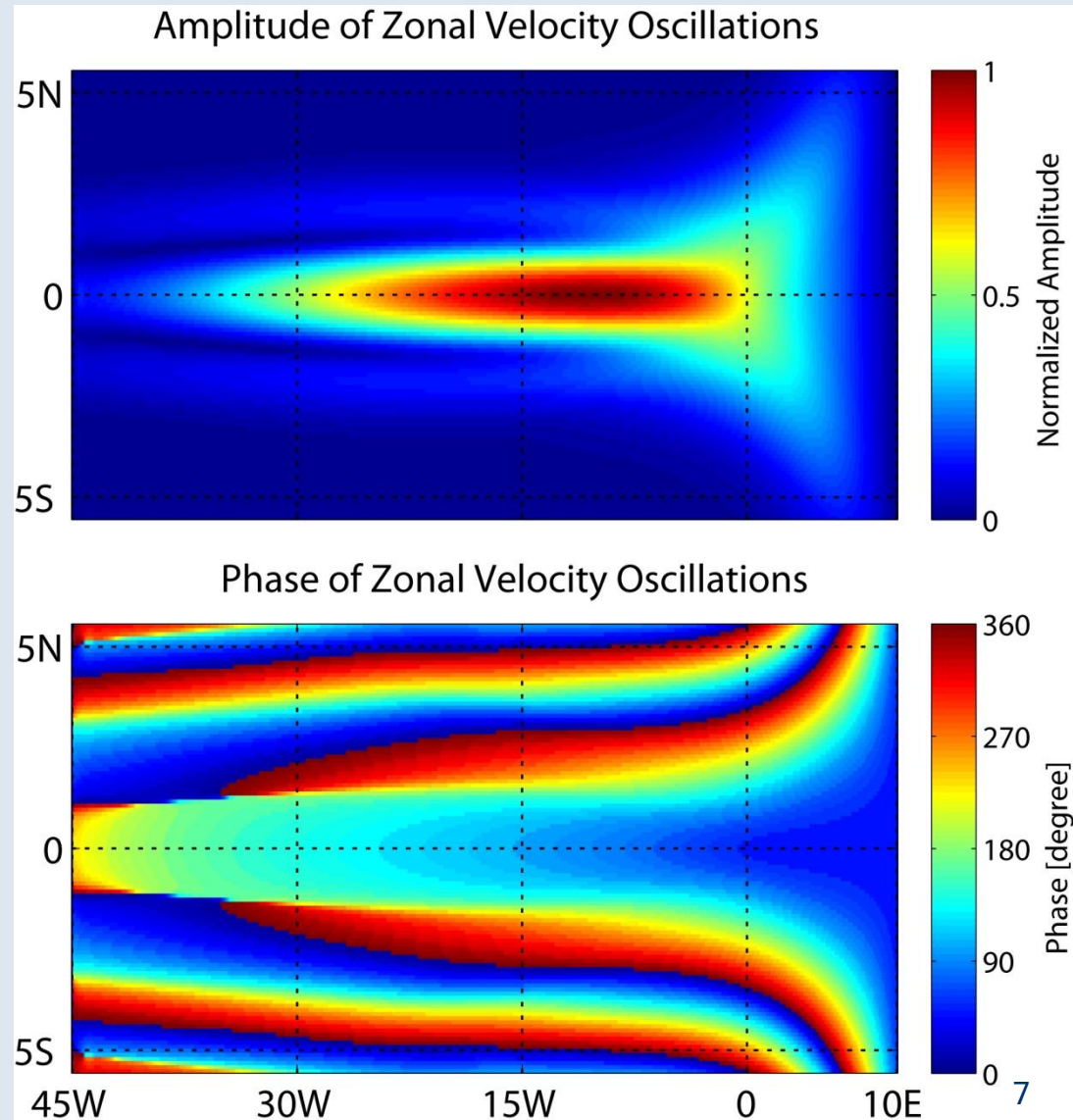


U(modesSL $<$ 10), lon=-23

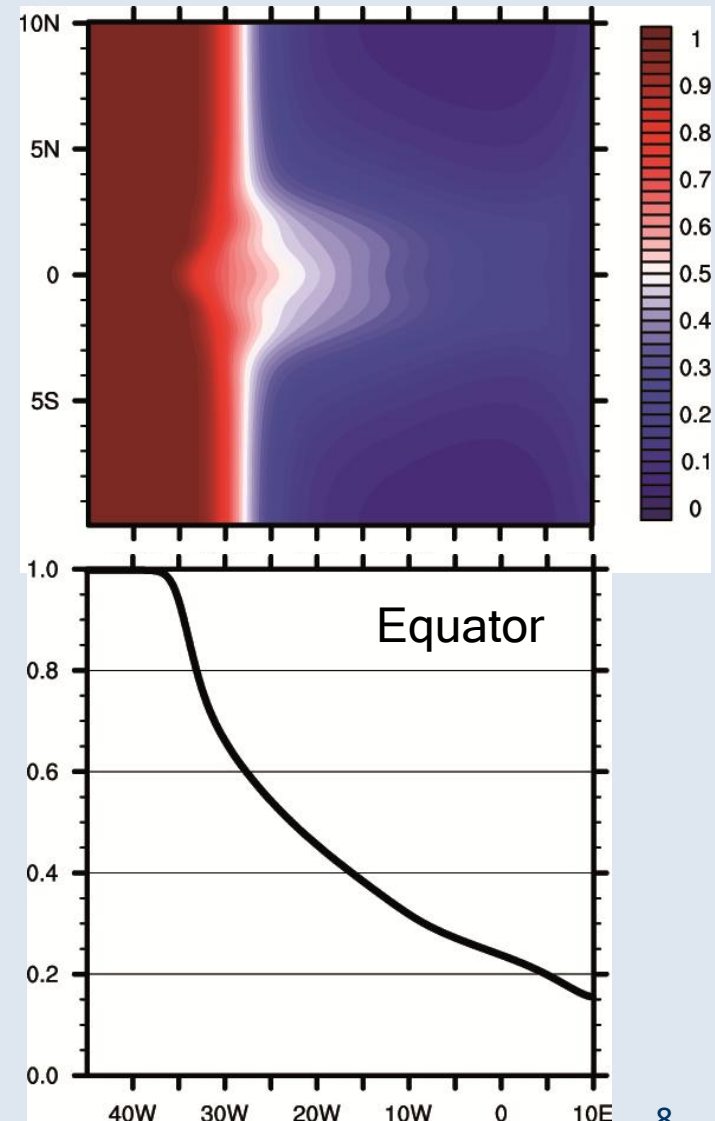


Equatorial Basin Mode

- ▶ 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 $200\text{-}300\text{m}^2/\text{s}$

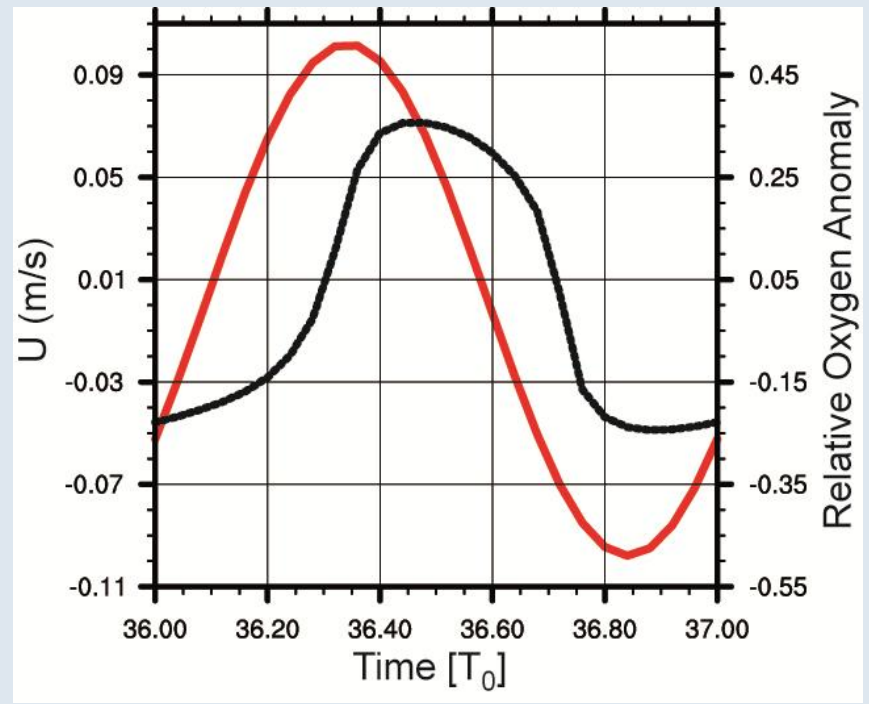
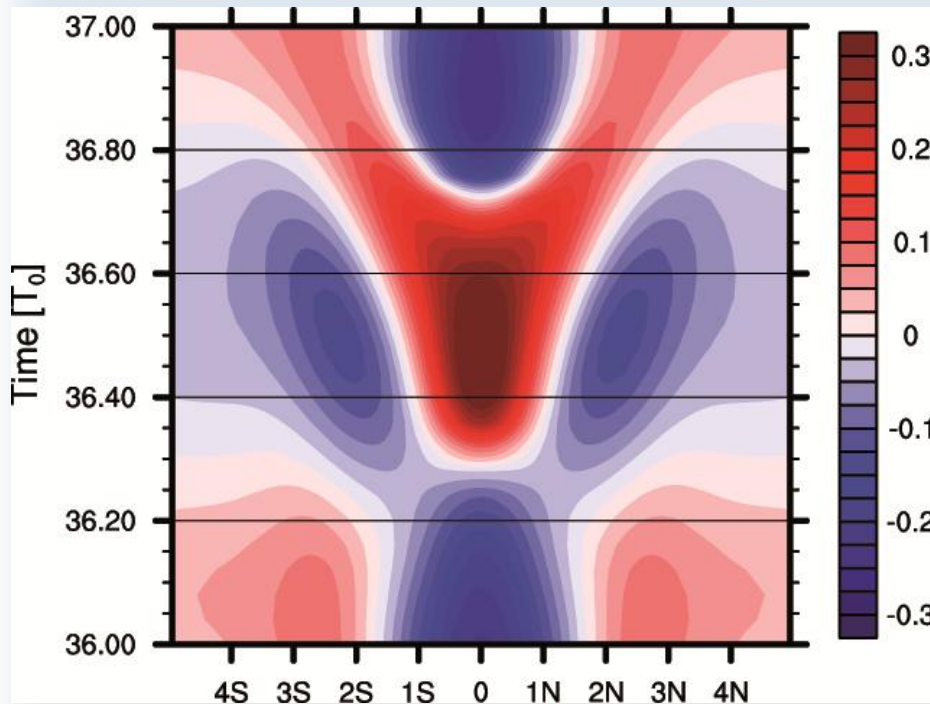


- ▶ Model is forced by the velocity field of the equatorial basin mode
- ▶ It includes a restoring to western boundary oxygen concentrations within a boundary layer and oxygen consumption (van Geen et al. 2006)
- ▶ Simulations are performed until a constantly oscillating state is reached (about 160 yr)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



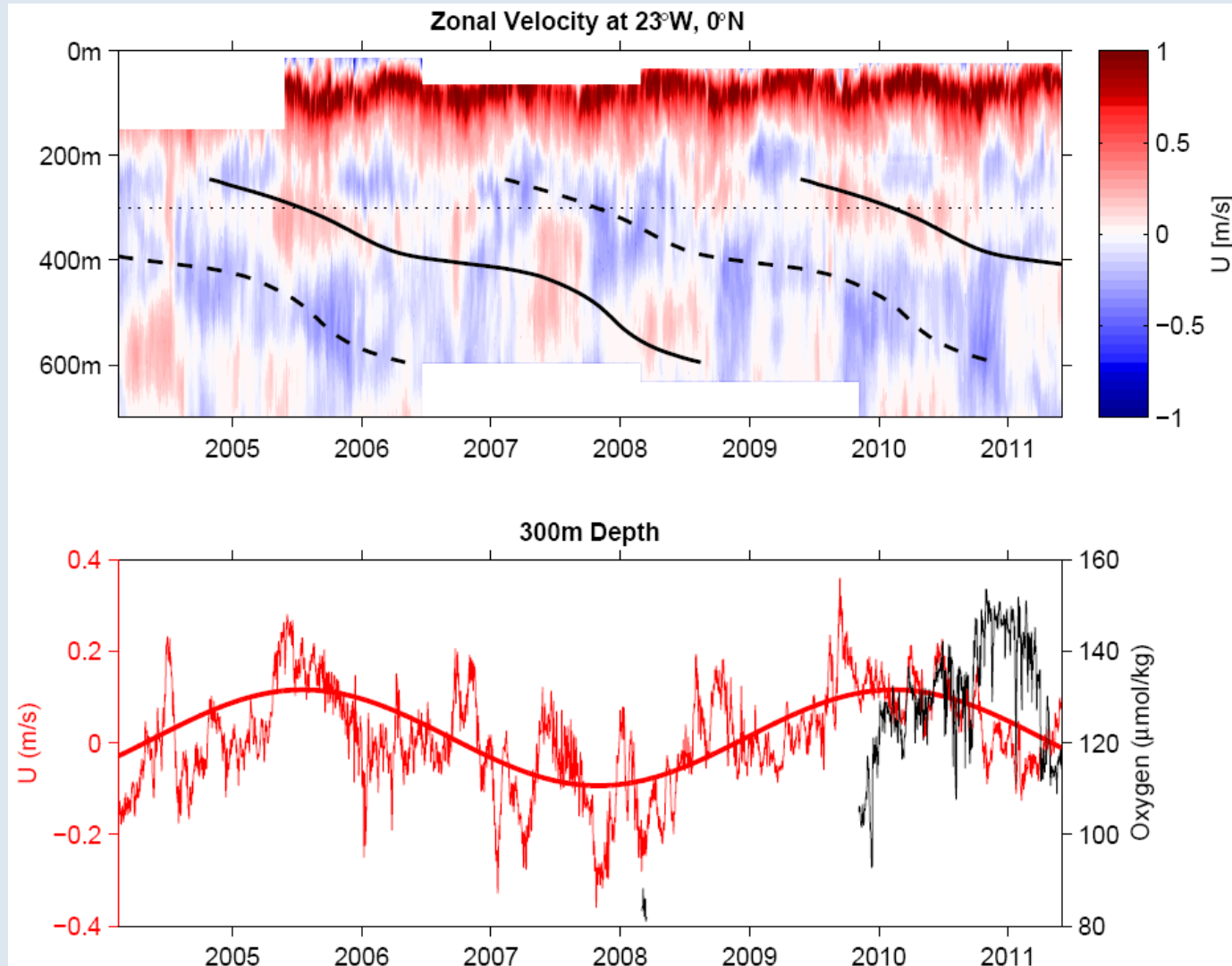
Simulated Relative Oxygen Concentration at 23°W

- ▶ Oxygen oscillates with the basin mode period ($T_0 = 4.5$ yr) cycle having amplitudes of about 25% of western boundary values
- ▶ Maximum oxygen concentration occurs after maximum eastward velocity (not in quadrature \rightarrow mean flux)



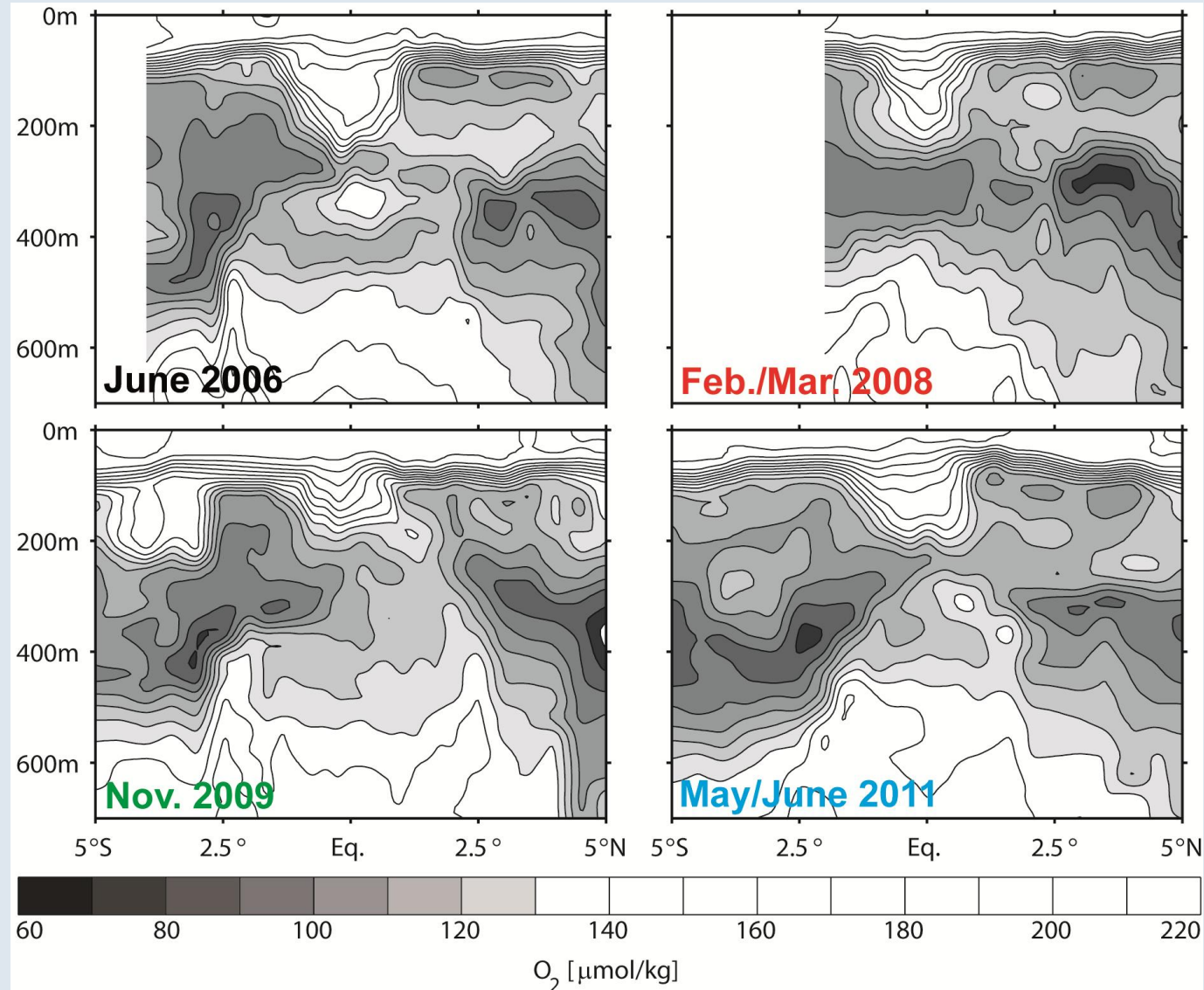
4.5-yr Deep Jet Cycle in Moored Observations at 23°W

- ▶ EDJ at intermediate depth with amplitudes of about 10 cm/s
- ▶ Oxygen concentration increases during phases of eastward flow



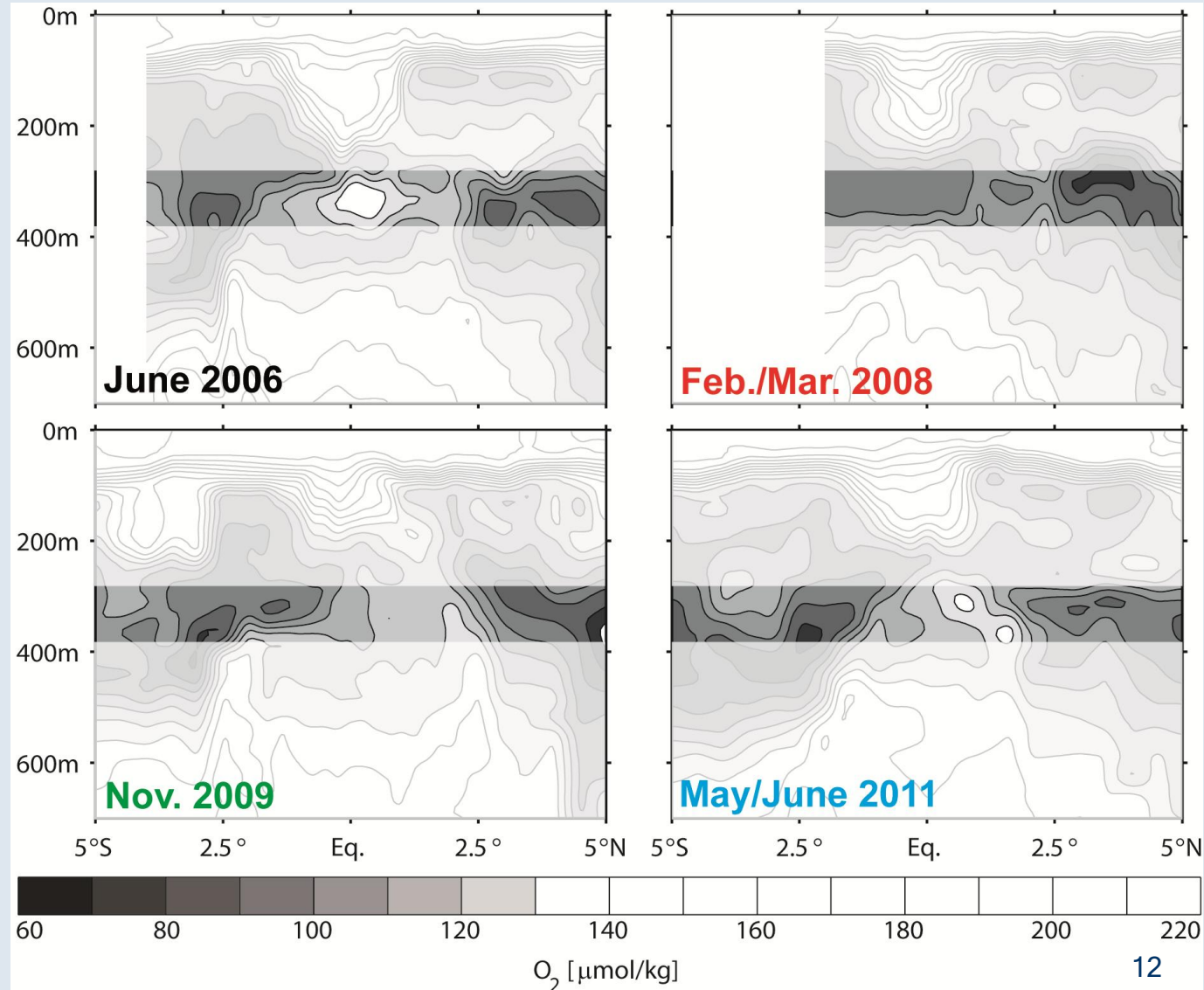
Oxygen Distribution along 23°W from Ship Sections

- ▶ Large variability associated with different current bands
- ▶ What is the time scale of the variability?



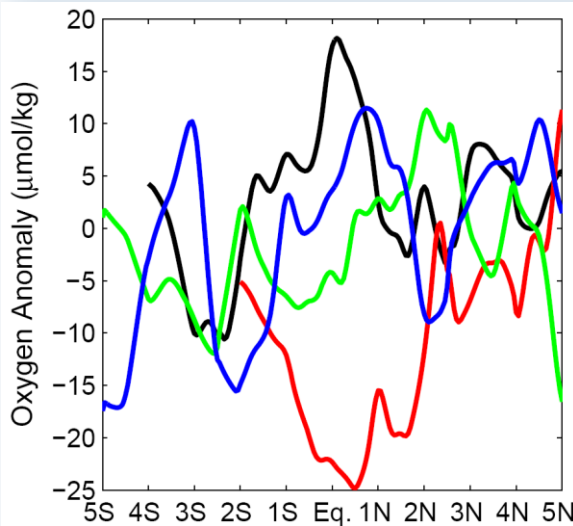
Oxygen Distribution along 23°W from Ship Sections

- ▶ 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

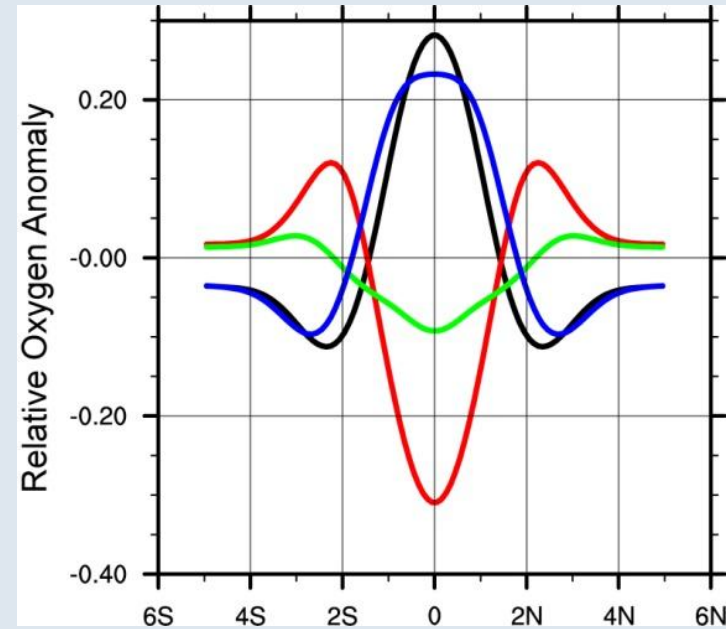
Observations ↓



Simulations →

June 2006 \triangleq 263 d
 Feb/Mar 2008 \triangleq 884 d
 Nov 2009 \triangleq 1505 d
 May/June 2011 \triangleq 403 d

(time of simulated structure given in days after maximum eastward velocity)



- ▶ 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

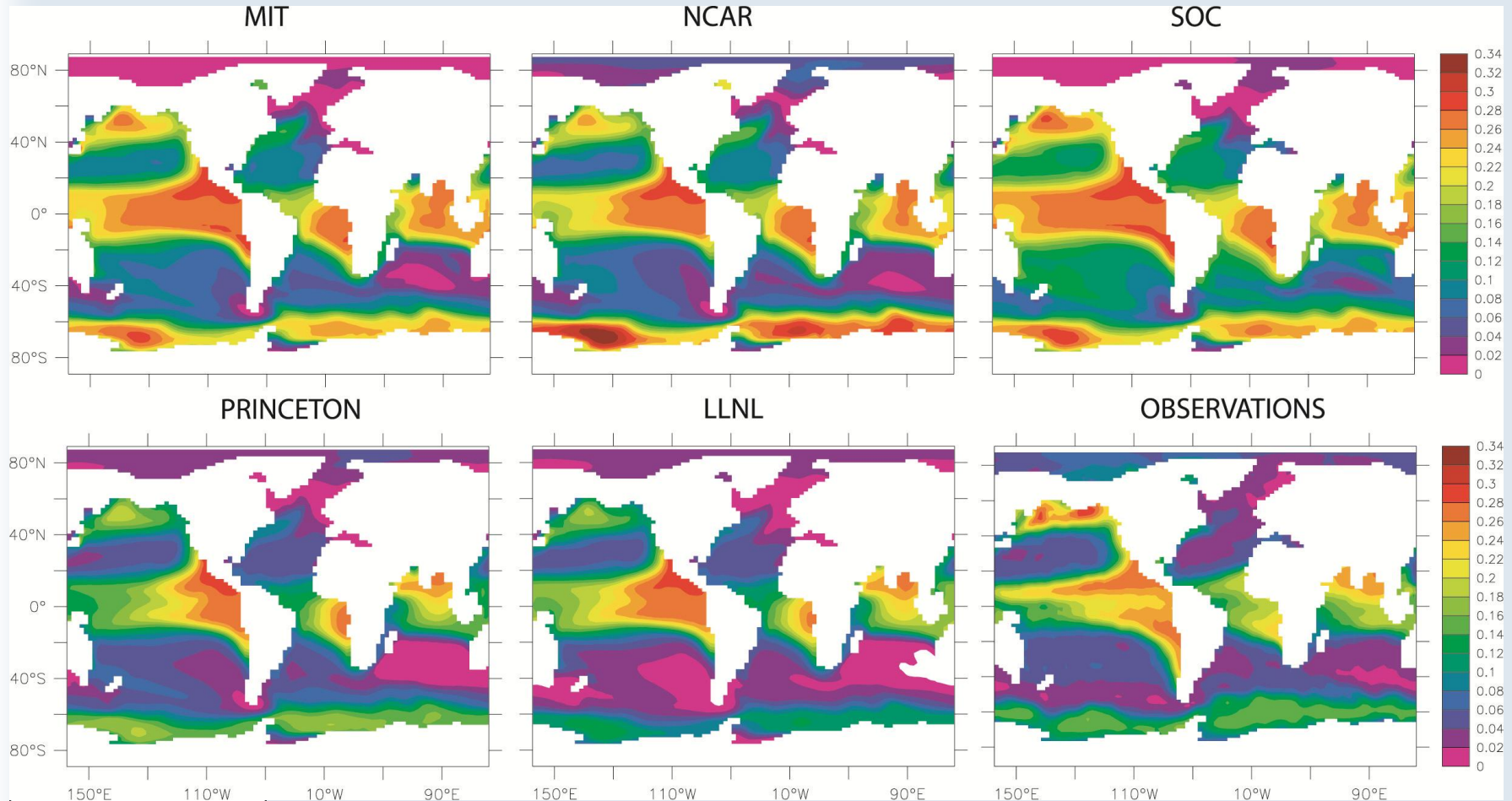
Shipboard and moored observations show

- ▶ 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

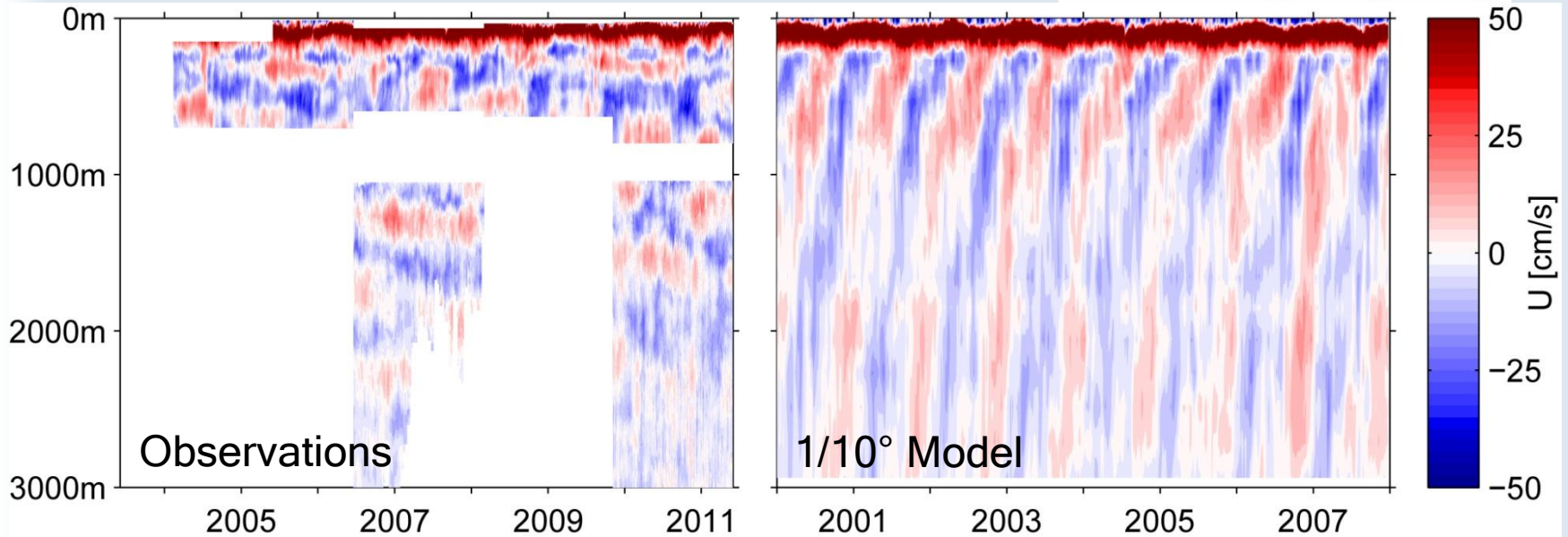
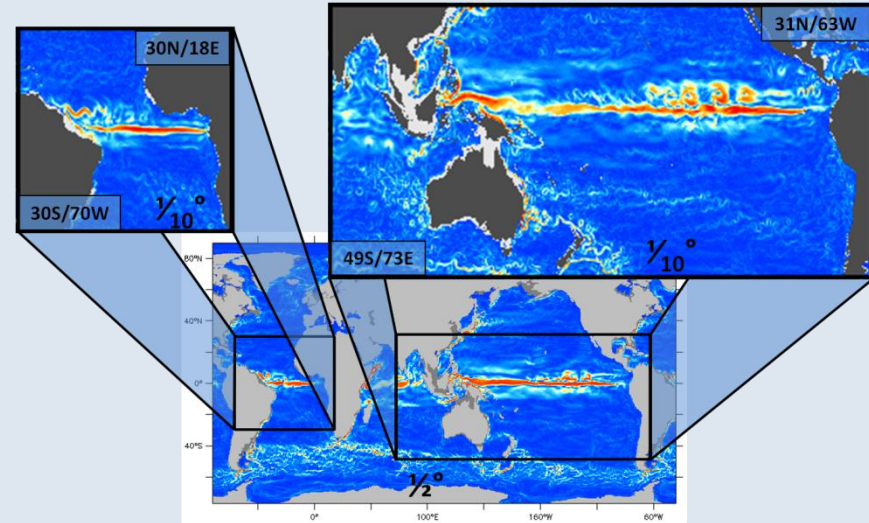
- ▶ Contribution of EDJ to the mean equatorial ventilation
- ▶ Phase shift between zonal velocity and oxygen anomalies found in moored observations at the equator, 23°W
- ▶ General structure of oxygen variability in ship section

Annual mean AOU [mol/m³] 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



- ▶ This study was supported by the German Science Foundation (DFG) as part of the Sonderforschungsbereich 754 “Climate-Biogeochemistry Interactions in the Tropical Ocean” and by the German Federal Ministry of Education and Research as part of the co-operative project “North Atlantic”.
- ▶ Moored velocity observations were acquired in cooperation with the PIRATA project.