PIRATA
October 2018, Marseille

ON NEARSHORE HYPOXIA AND OXYGEN VENTILATION IN THE EASTERN TROPICAL NORTH ATLANTIC

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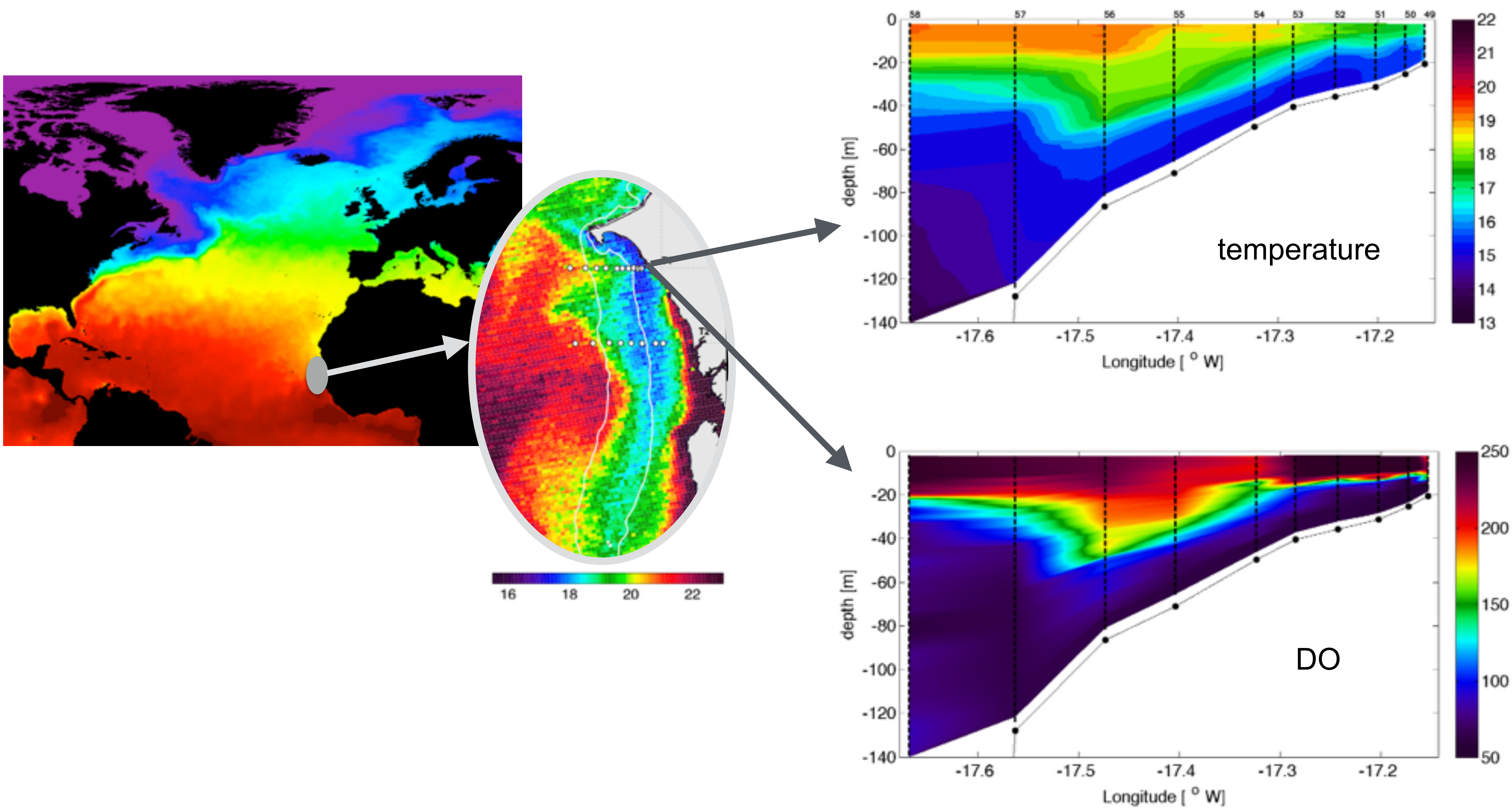
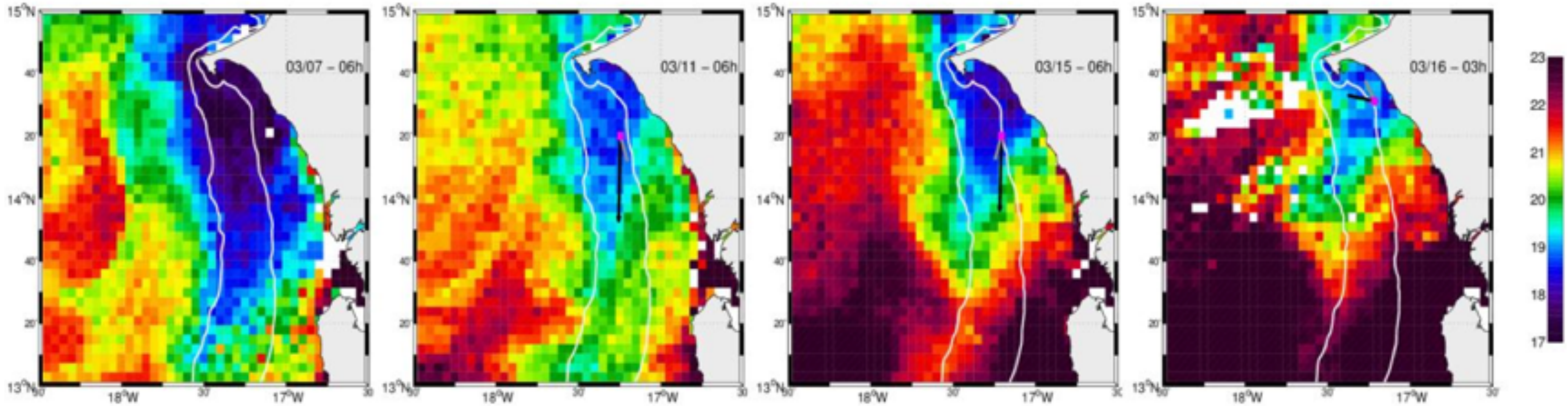
E. Machu (LOPS, Brest)
J. Jouanno (LEGOS, Toulouse)

The source waters are near hypoxic levels (~ 50 -60 µm/kg)

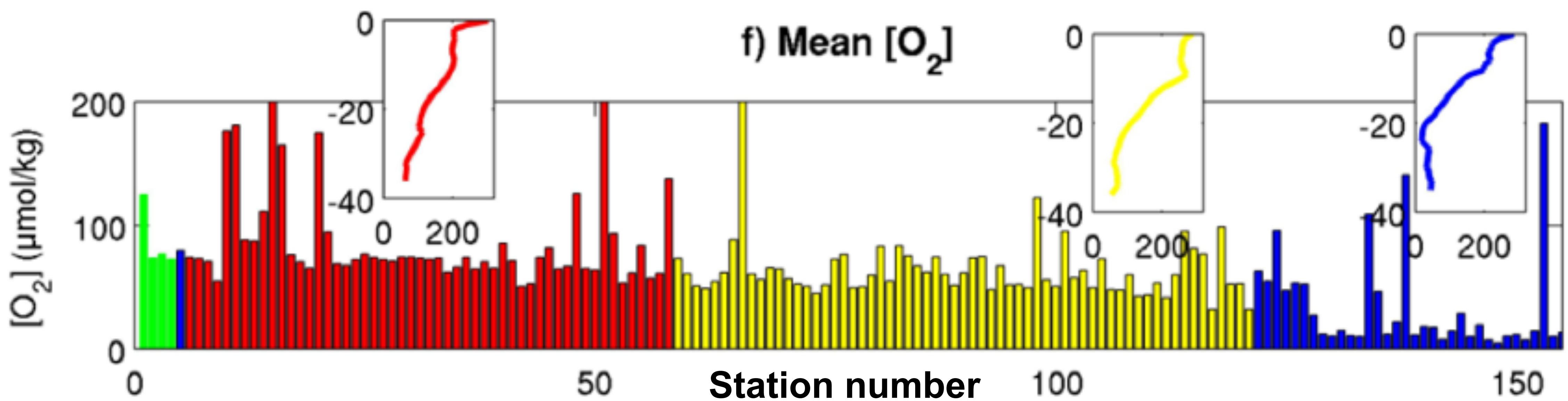


Capet et al, 2017

synoptic SST evolution (7 March 2012 → 16 March 2012): intensifying relaxation



Synoptic evolution of bottom dissolved oxygen



7 March 2012

Time

17 March 2012

Machu et al, GRL, submitted

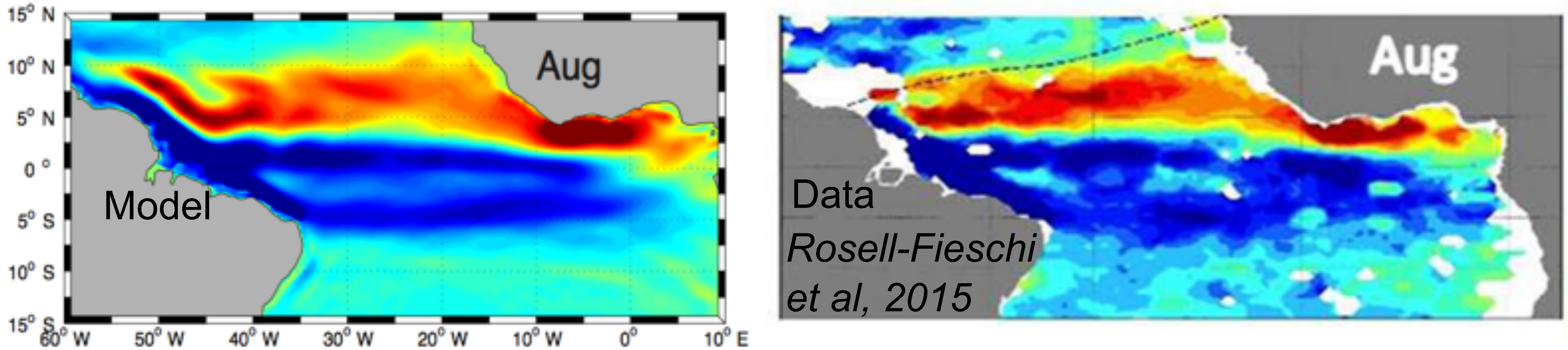
- Stress the importance of the ETNA circulation in the density range above 26.7 (above 150 - 250 m - SW and uCW) for the regional DO distribution and DO concentration in coastal upwelling source waters
- Question the traditional ways we describe and understand the circulation in that shadow zone sector (GD)
- Propose a renewed framework and key processes to study ETNA circulation

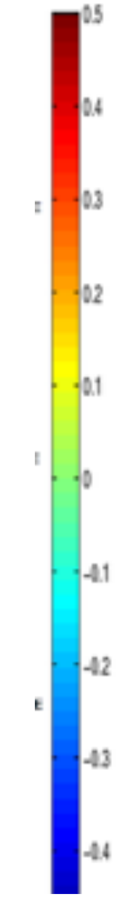
The TROP025 model

M&M

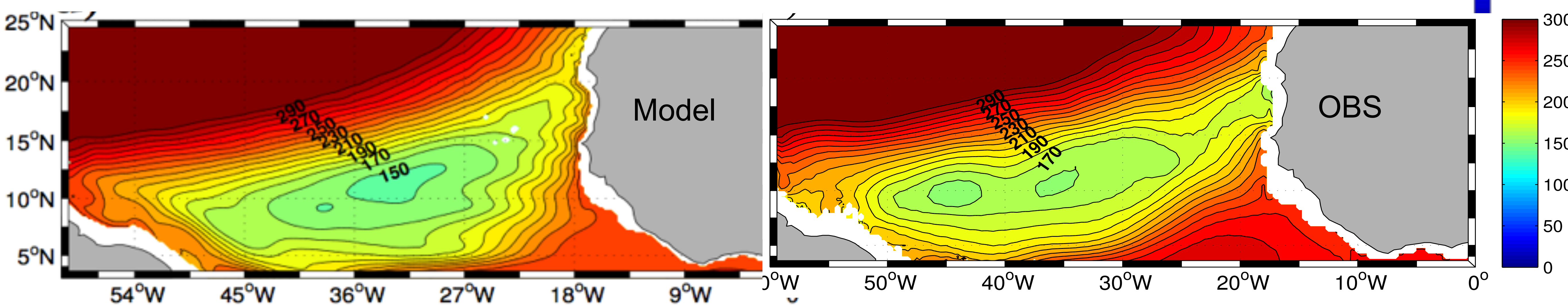
- 1/4o NEMO for the period 1979-2012 with DFS5.2 forcings
- Grid extension: 35°S–35°N,100°W–15°E
- Good realism on the key characteristics of the regional circulation

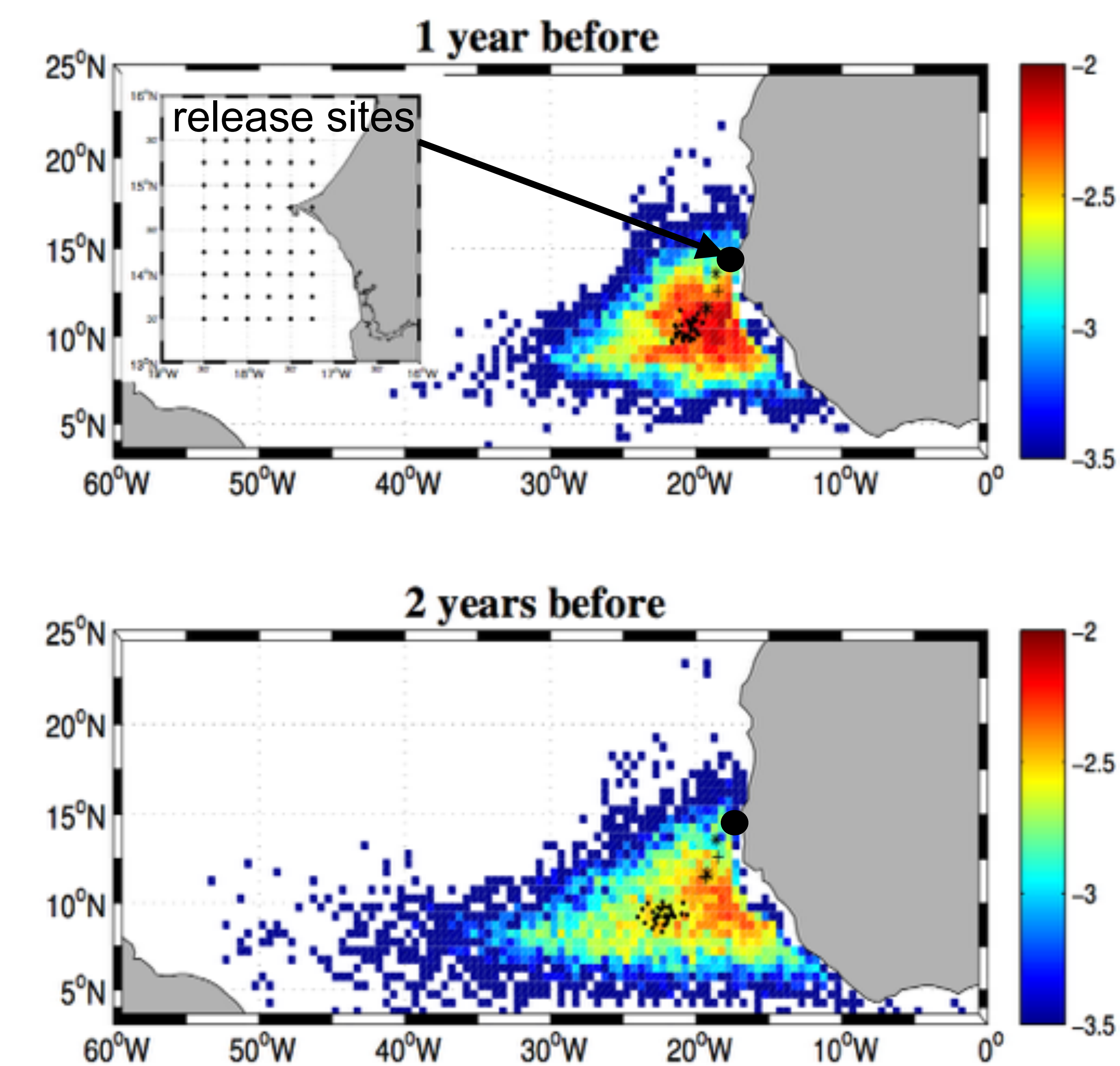
surface zonal flow

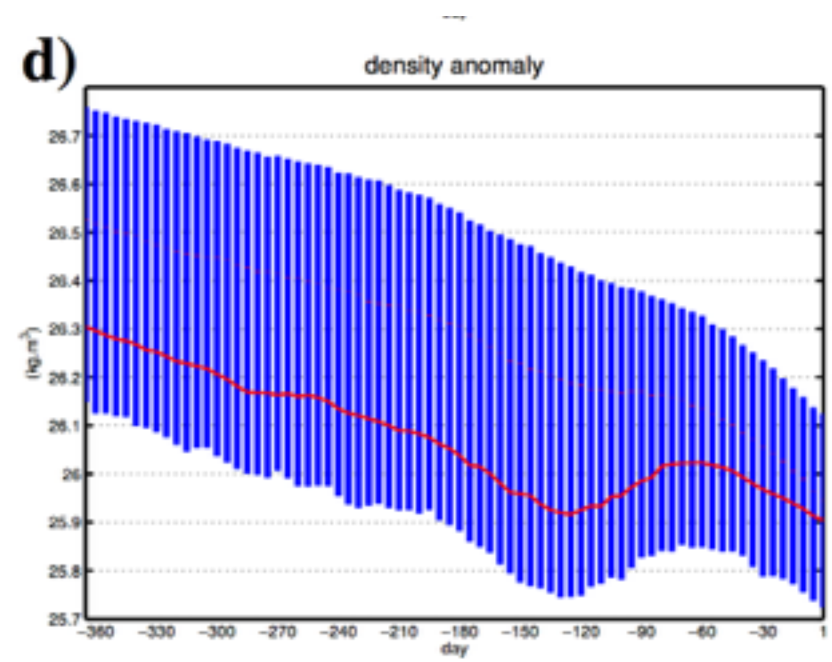




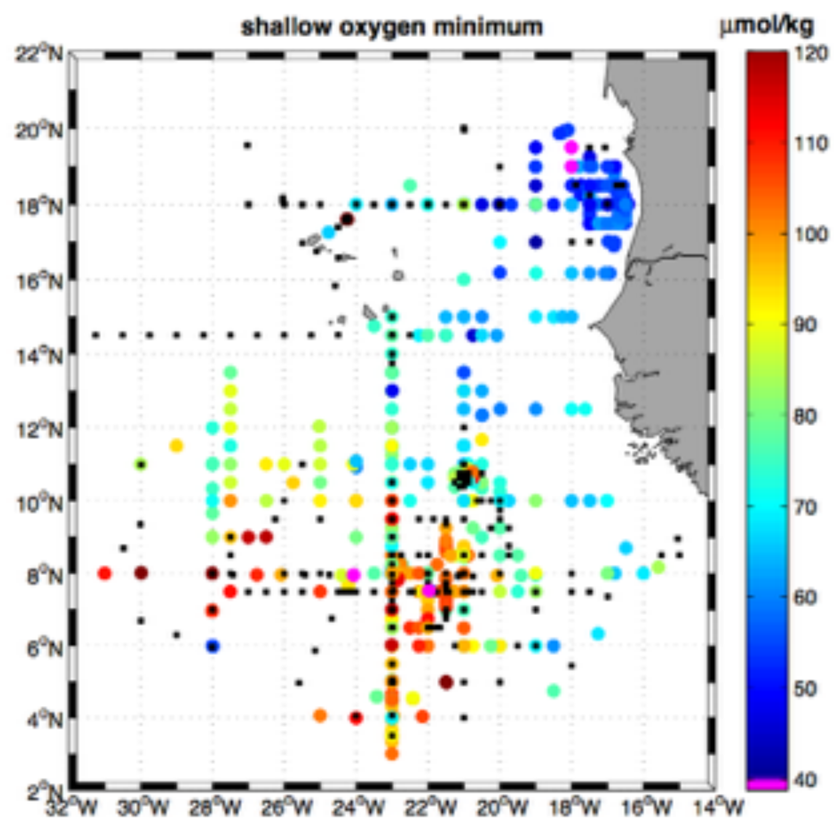
depth of the 26.7 isopycn





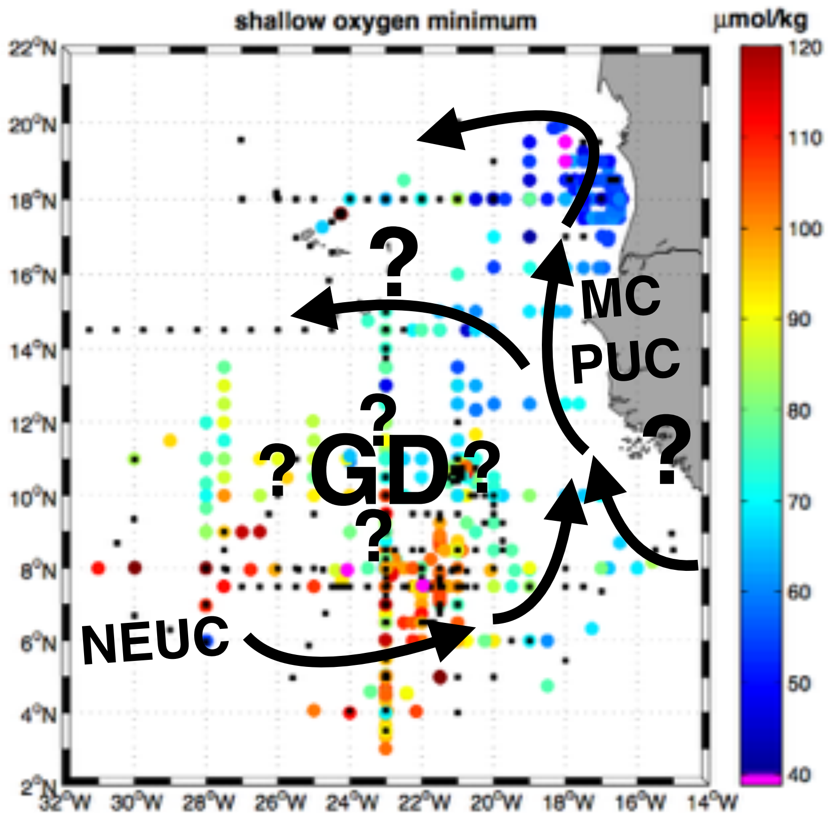


- Relevant waters are in the density range σ < 26.7 (SW and uCW)
- Time scales of interest ~ a few years (typical flow speeds along mean trajectories ~ 1-2 cm/s).
- NEUC/NECC are implicated in the main pathways on time scales > 1 y - connection to the Gulf of Guinea is more elusive
- Consistent with *Hüttl-Kabus & Böning* (*2008*; see also *Glessmer et al, 2009* + eulerian studies)



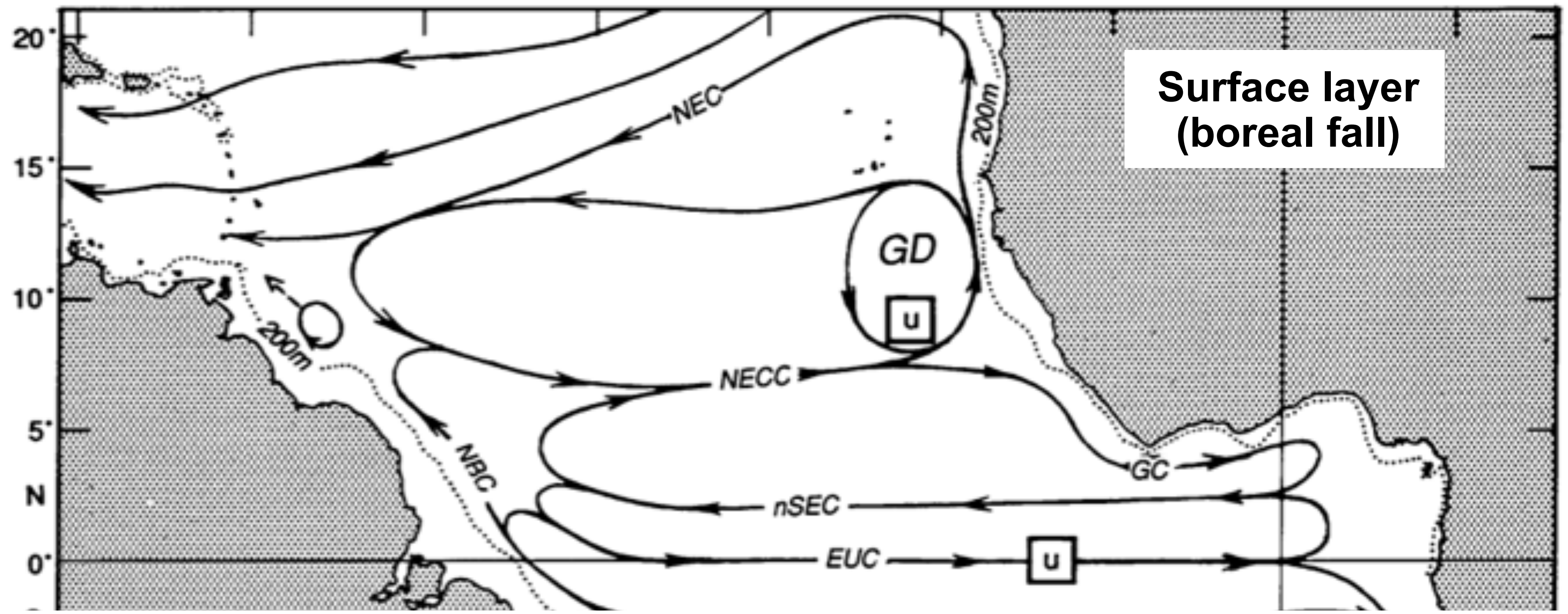
Brandt et al, 2015

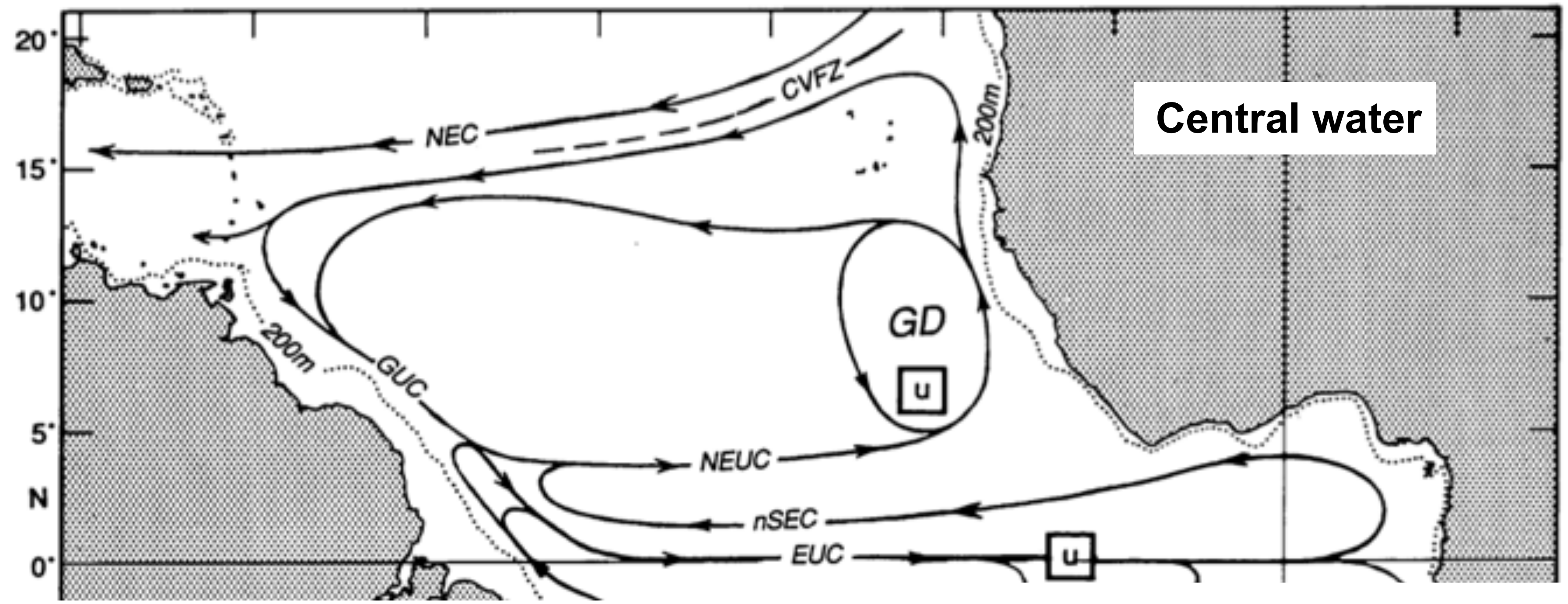
In the upper thermocline DO decreases toward the north and toward the shore. Source waters in the NEUC have much larger DO levels. Substantial DO drawdown thus seems to be taking place during their journey toward coastal upwelling sectors. Mean circulation/advection must be one important element of their DO budget.



- Mean currents are slow (vanishing in idealized ventilation theories with 0 diapycnal fluxes)
- Conflicting views on the Guinea thermal Dome (exact position, seasonal cycle, underlying circulation and dynamics)
- Limited knowledge about boundary currents along West Africa which are often vaguely described as a combination of the Mauritanian current near the surface and a poleward undercurrent. Forcing processes for the Mauritanian current are not identified.

The GD stands out as the central feature around which the ETNA circulation is being organized (SW,CW)



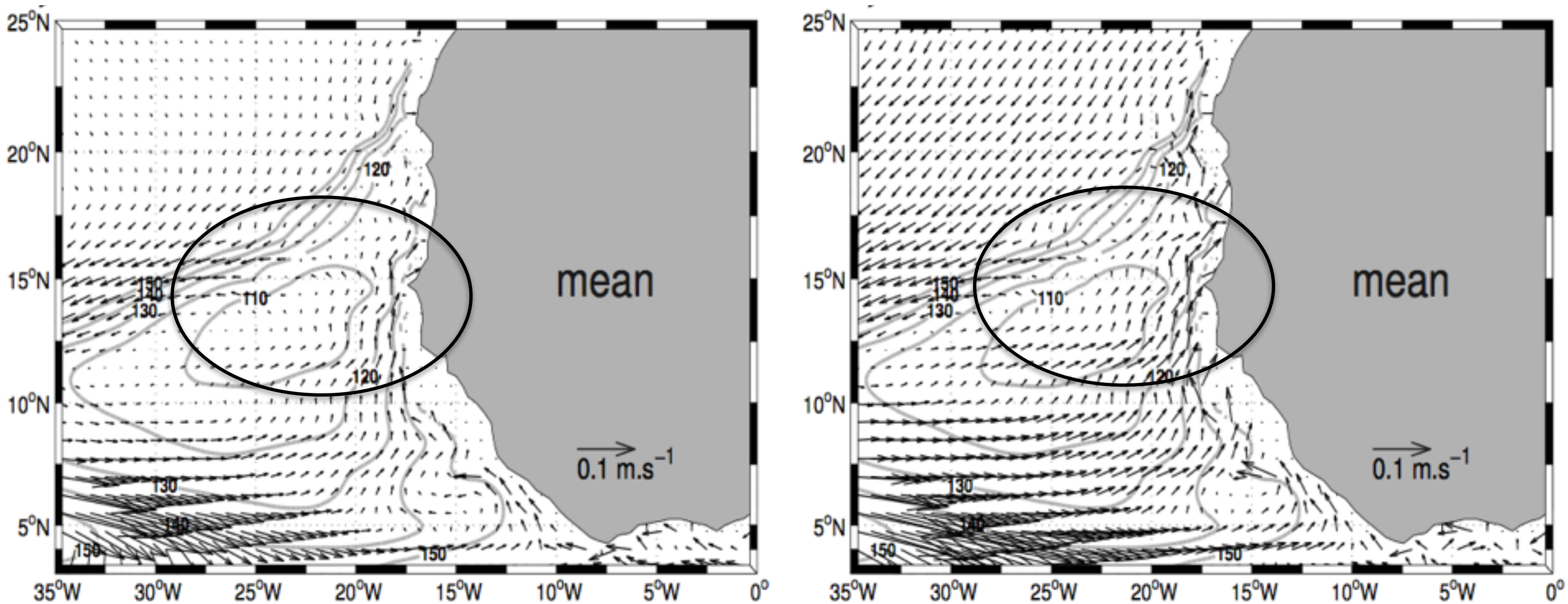


The mean flow field of the tropical Atlantic Ocean

Lothar Stramma*, Friedrich Schott

Deep-Sea Research II 46 (1999) 279–303

Climatological depth of the 15oC isotherm & geostrophic flow at 100 m depth with ref level at 200 m depth (left) and 1000 m depth (right)



$$u_g = \frac{g}{\rho_0 f}\int_{z_1}^{z_2}\frac{\partial\rho}{\partial y}dz; v_g = -\frac{g}{\rho_0 f}\int_{z_1}^{z_2}\frac{\partial\rho}{\partial x}dz$$

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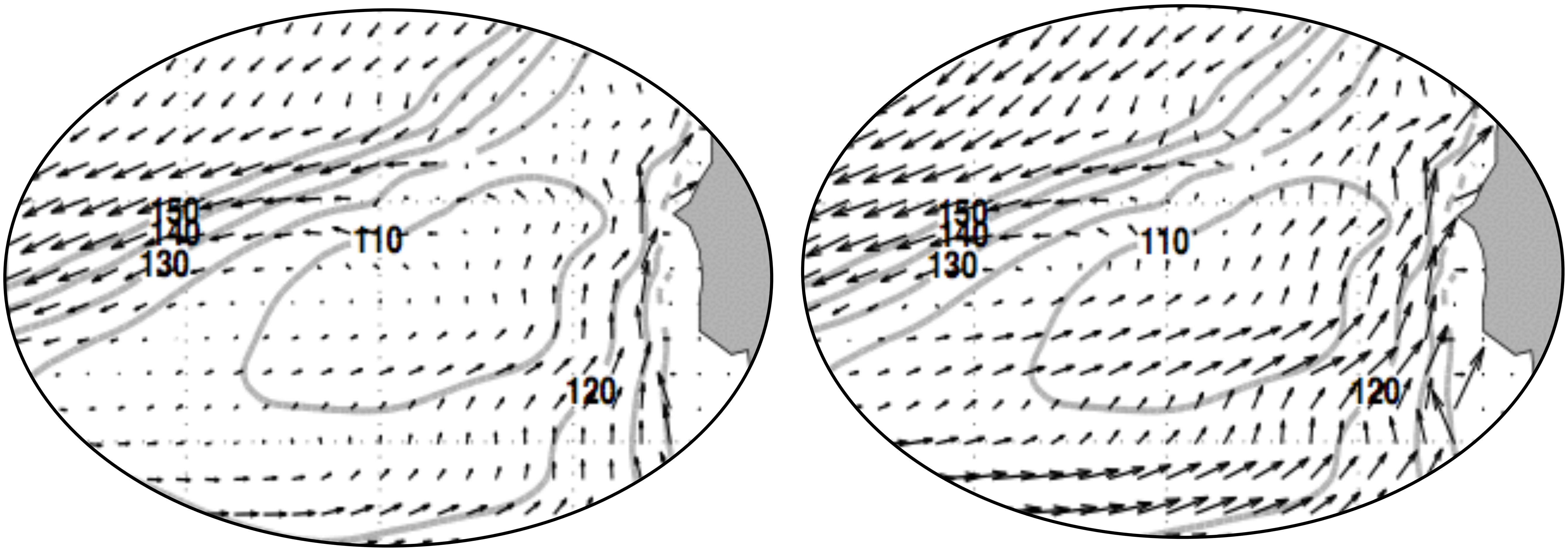

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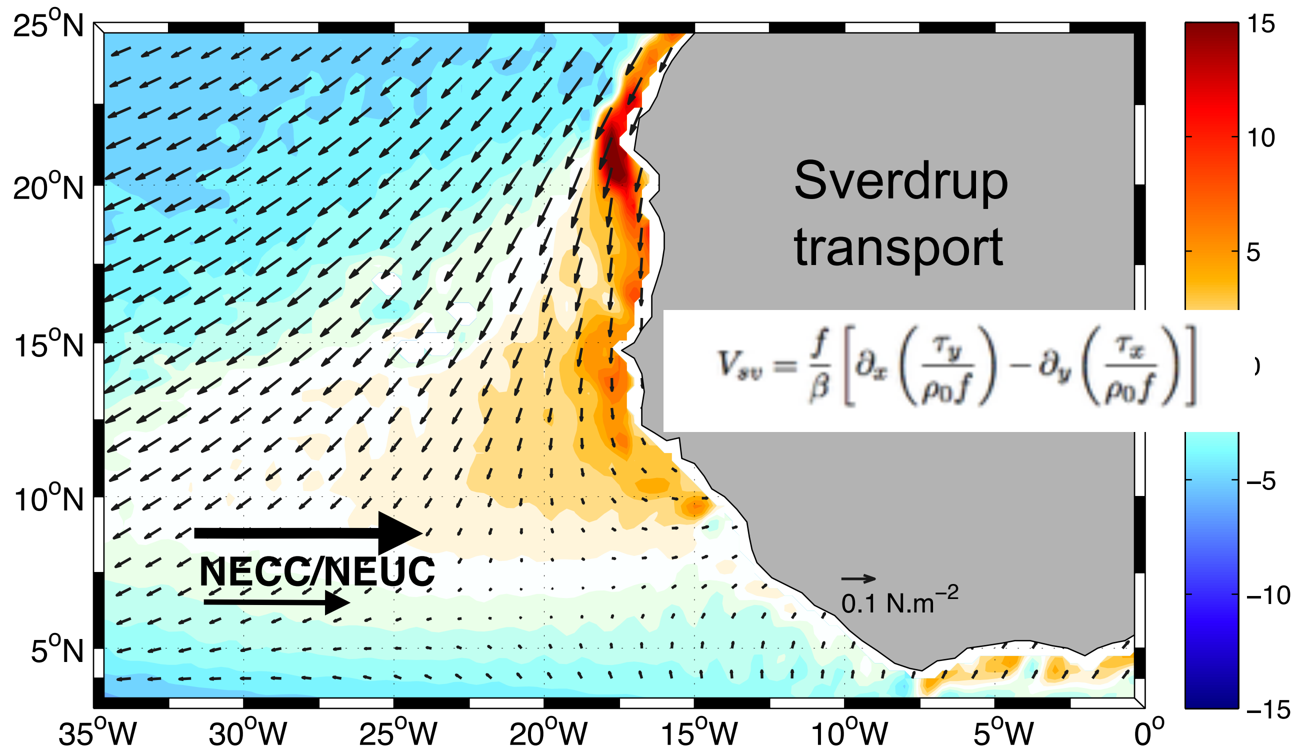
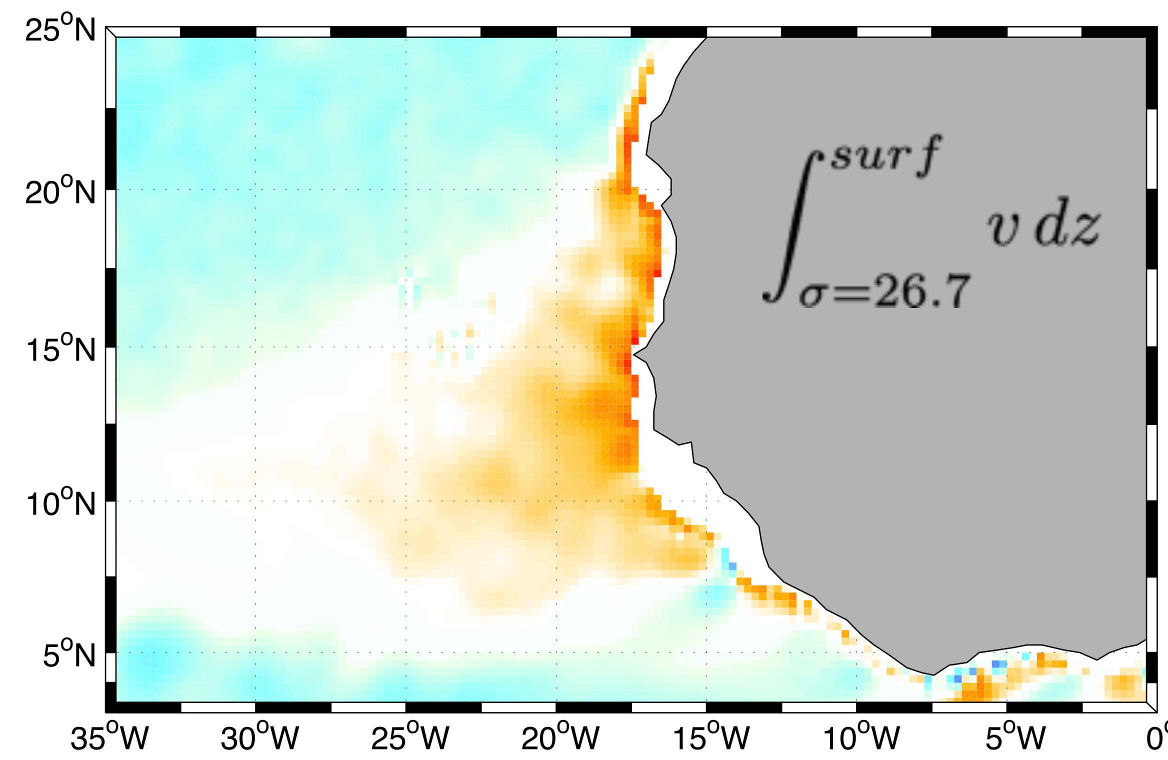
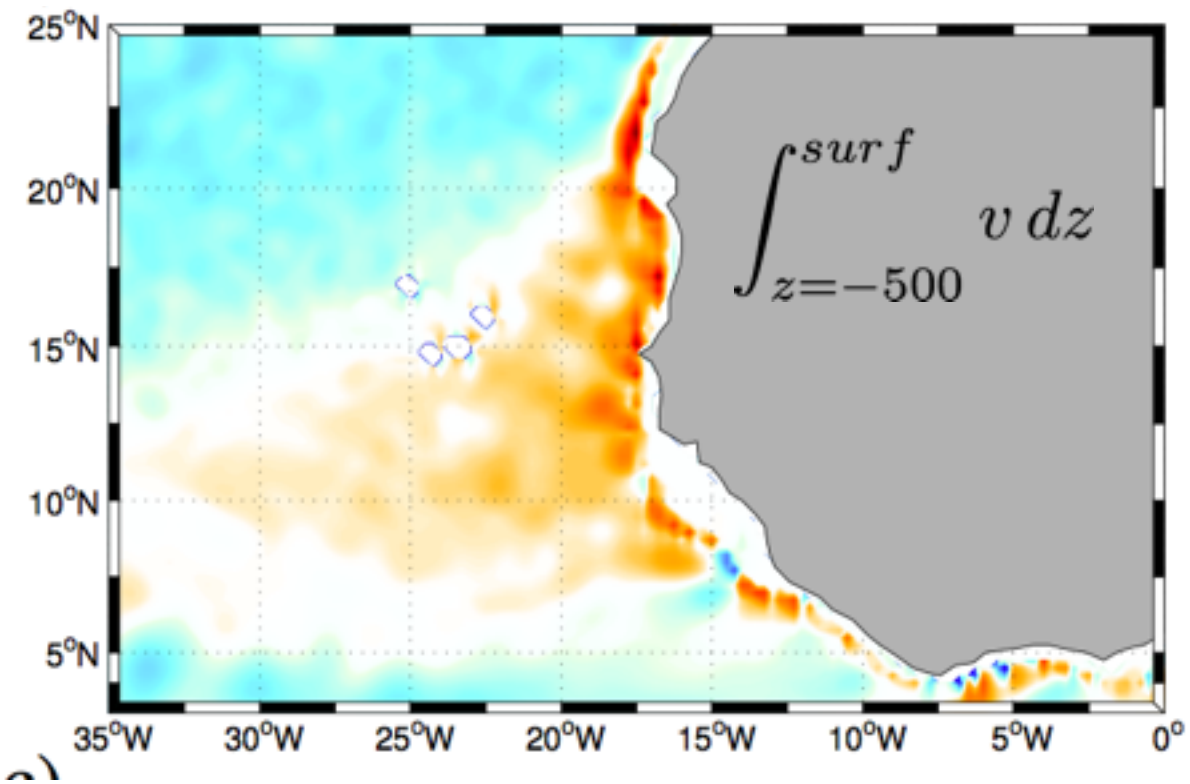
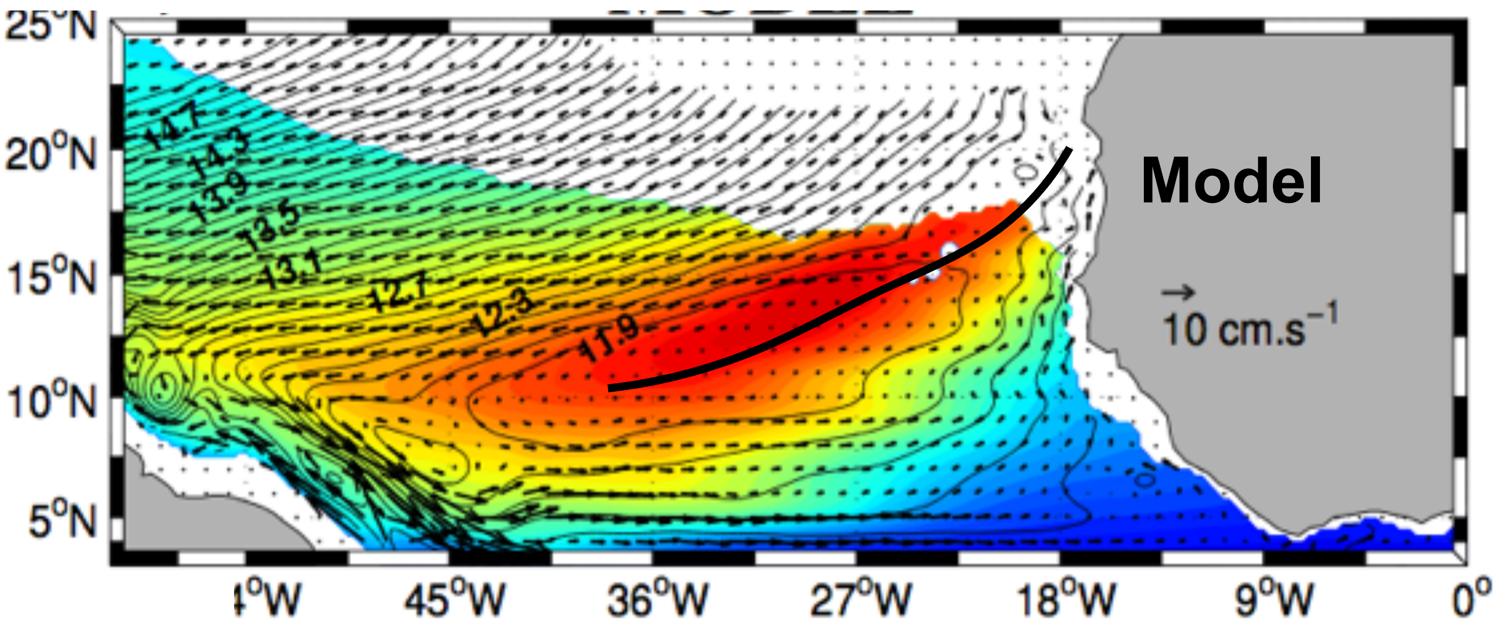
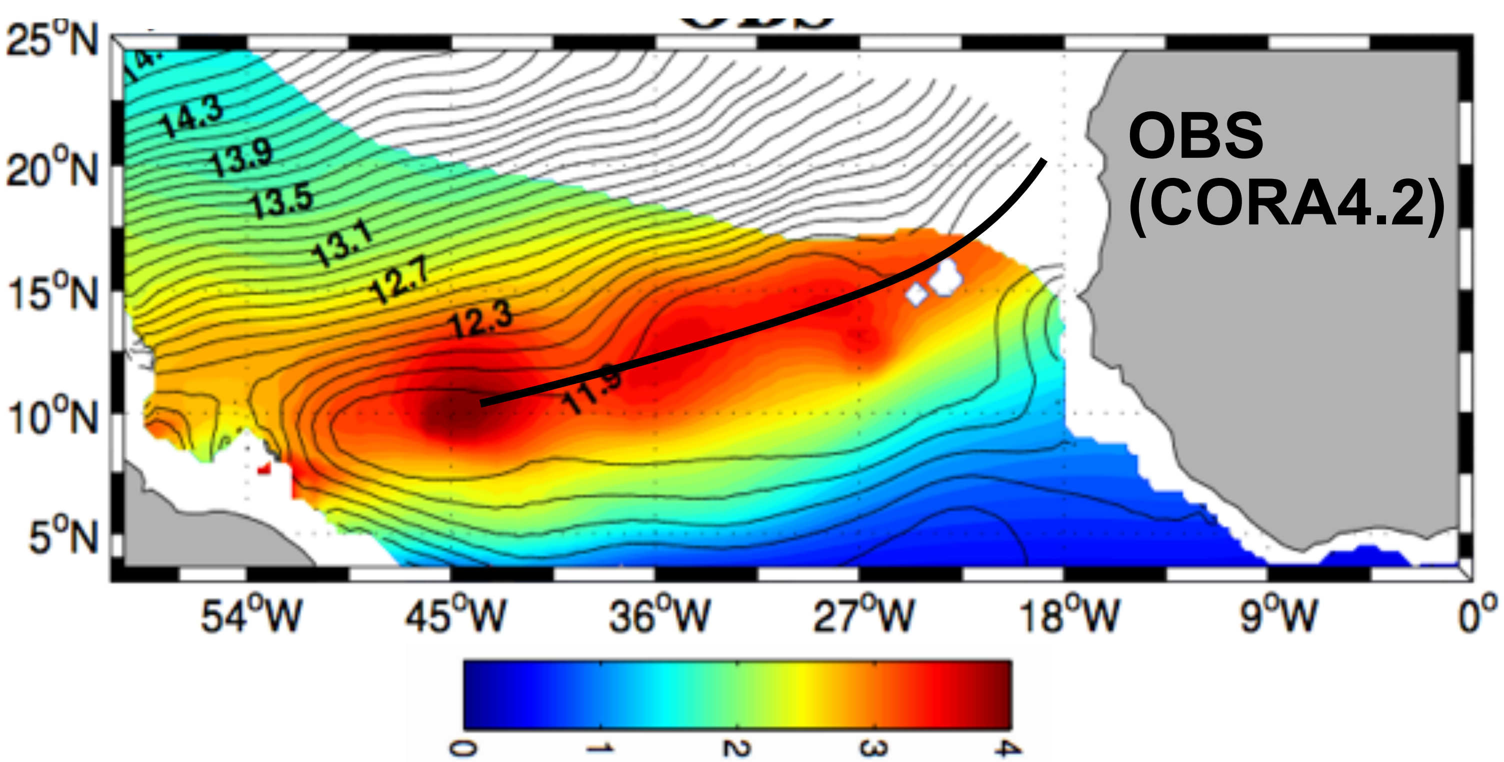






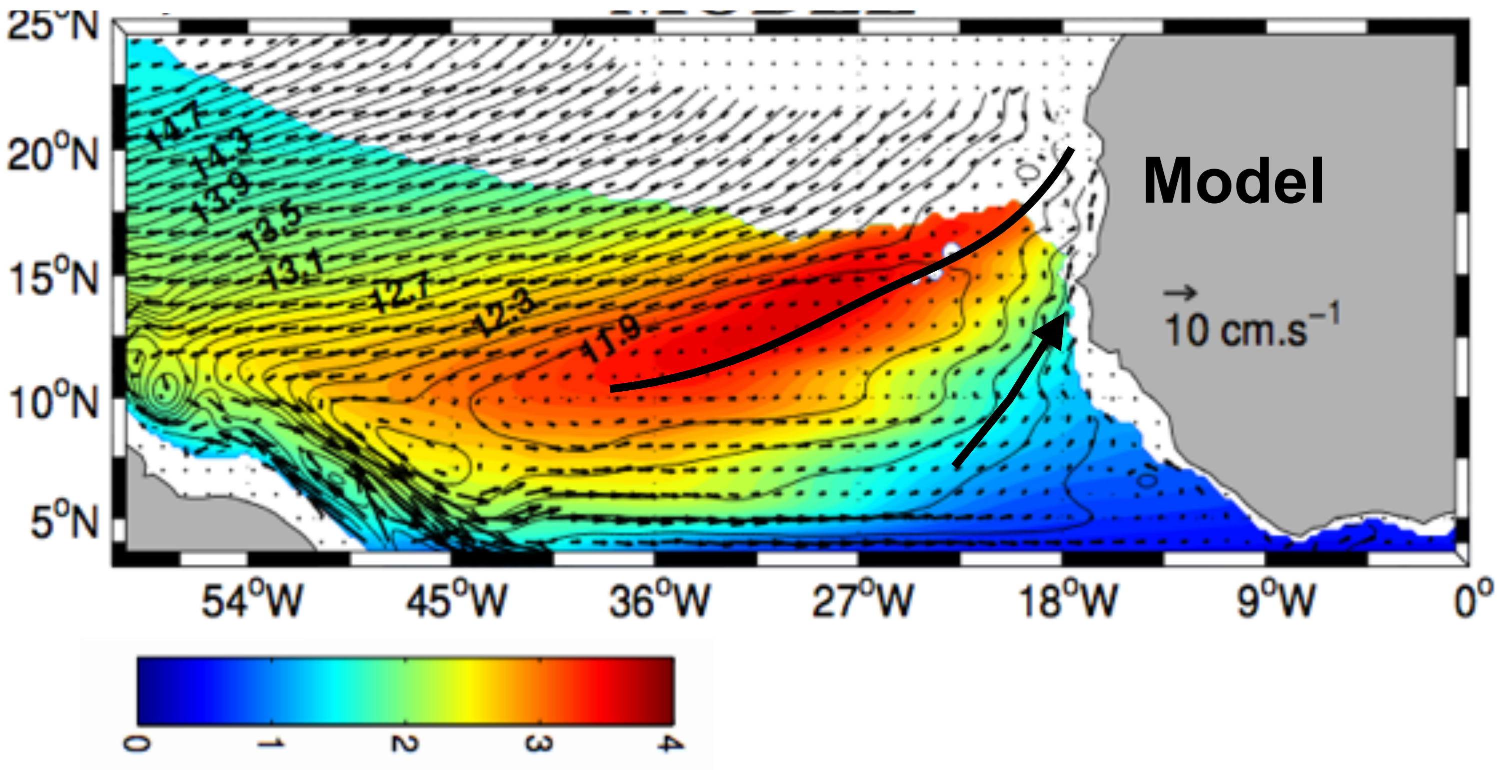
The SW and uCW layers concentrate a very large fraction of the Sverdrup transport although they only occupy the upper ~ 200 m.





The PV structure strongly departs from that deduced from planetary vorticity f alone.
The ETNA characterized by large departure from planetary geostrophy Q=f(Mρ), particularly in the observations

colour: PV=f/h where h is the thickness of the isopycnal layer between 25.2 < σ < 26.7
contours: Mρ=Montgomery potential at σ = 26.1(⇔ pressure on isopycnal surface)



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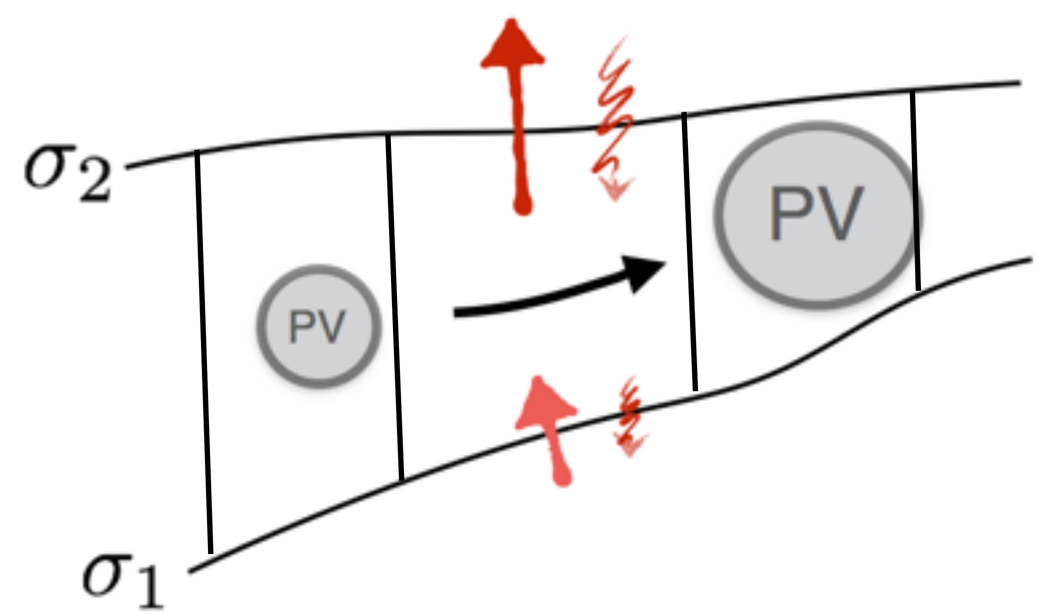
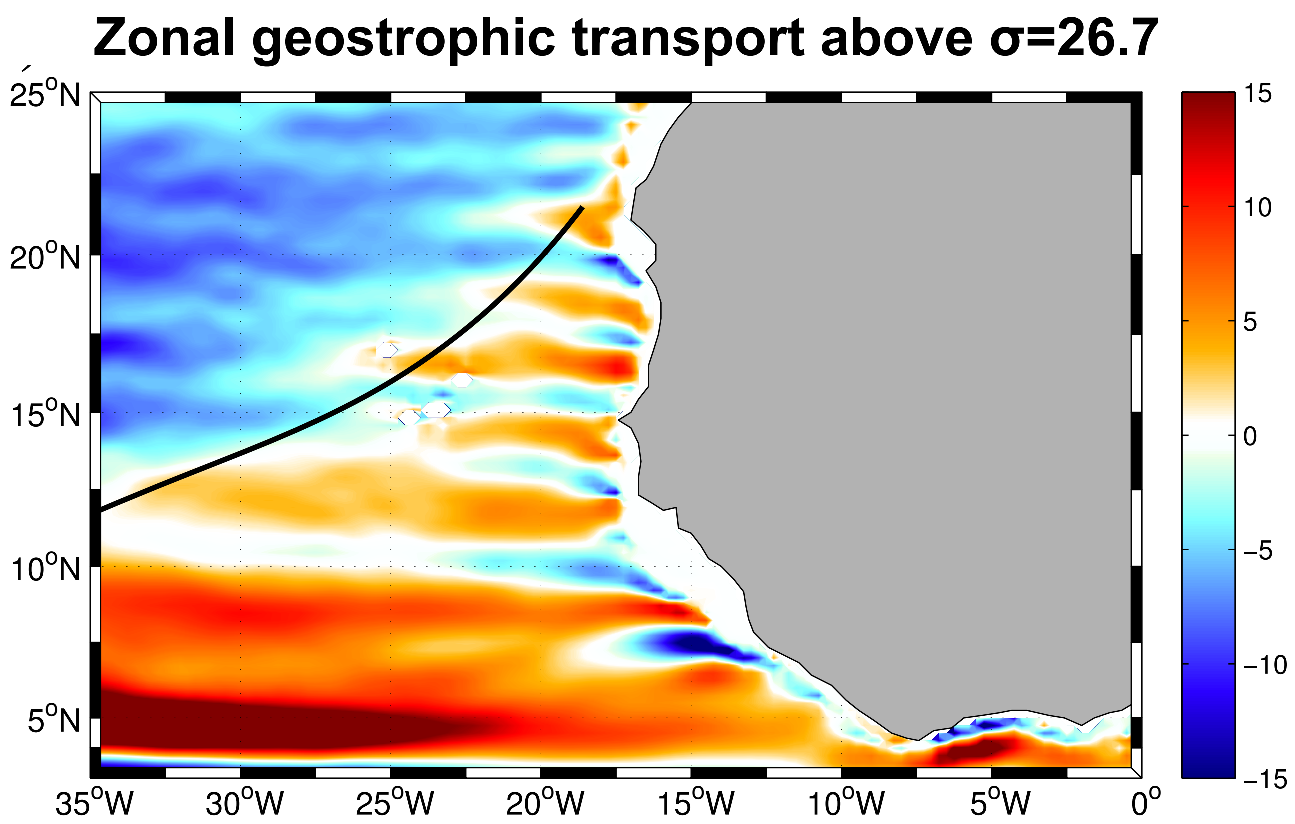


Downward transfer of heat decreases with depth

→ during their journey northward isopycnal fluid volumes in the upper thermocline tend to loose more mass in favor of lighter layers than they gain mass from deeper layers

→ PV concentration (impermeability theorem; Haynes & McIntyre 1990)

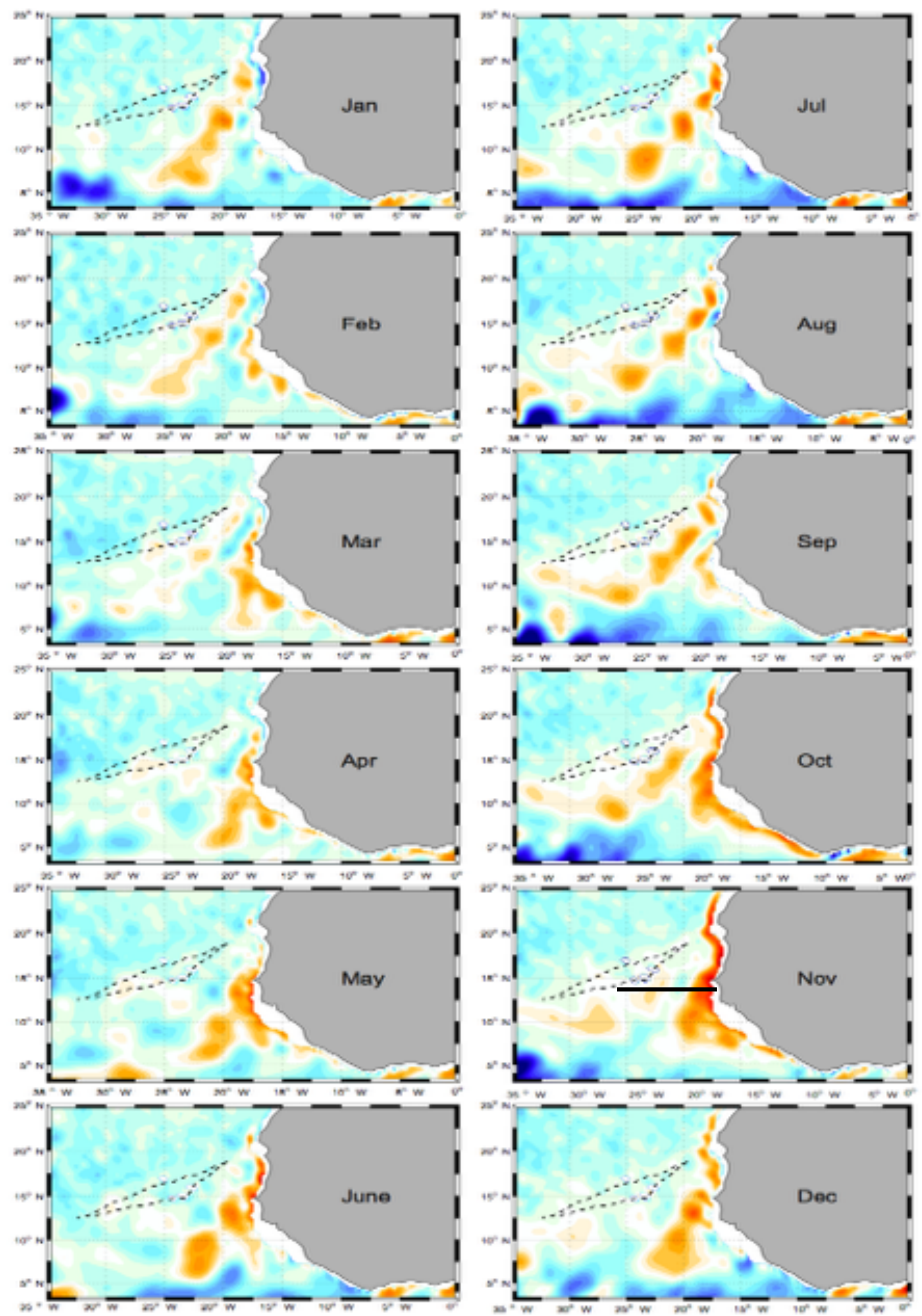


The PV structure strongly departs from that deduced from planetary vorticity f alone.

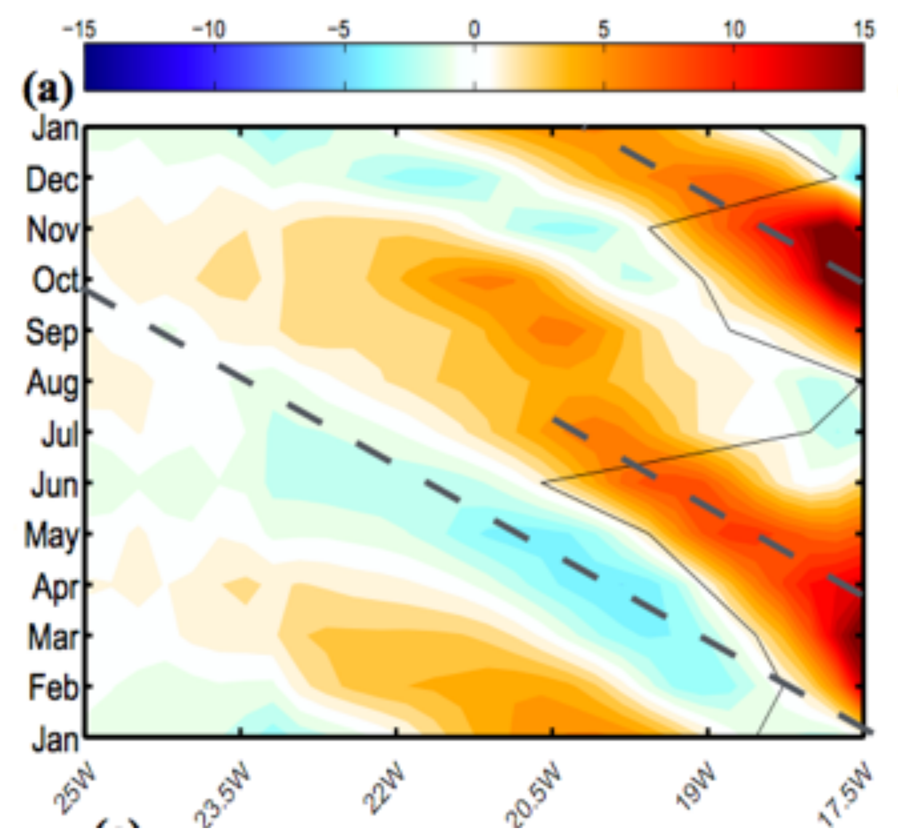
This seems to have important implications on zonal jet dynamics.

The PV structure and RW patterns

Meridional geostrophic transport above σ=26.7

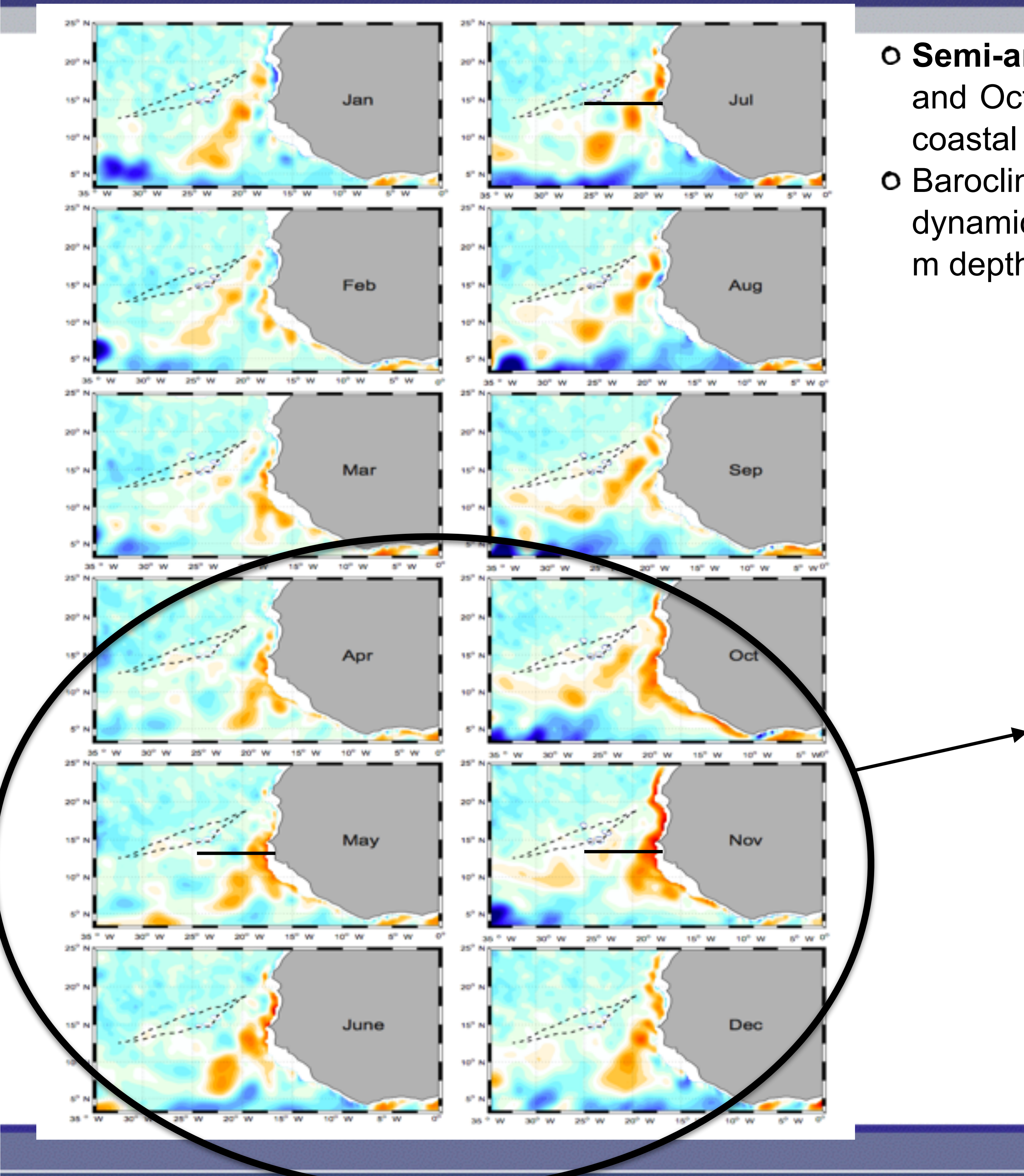


The PV structure strongly departs from that deduced from planetary vorticity f alone.
This has important consequences for the RW and perhaps zonal jet dynamics.

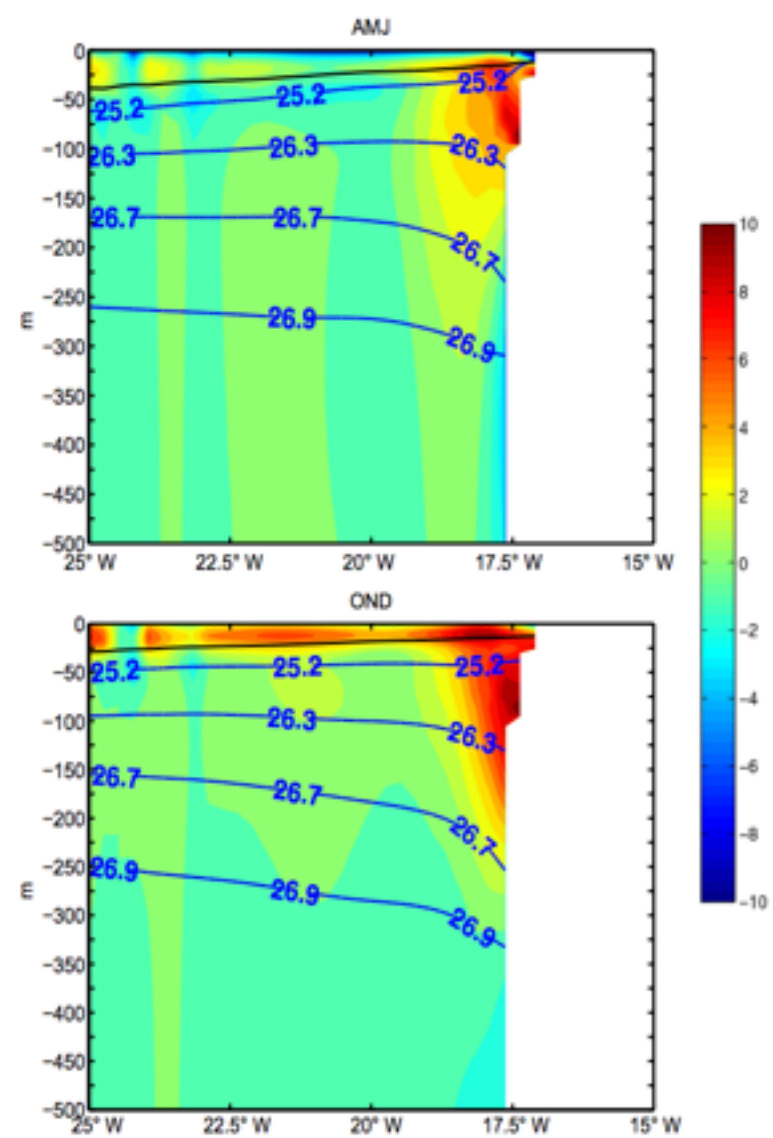


Hovmoller at 14oN

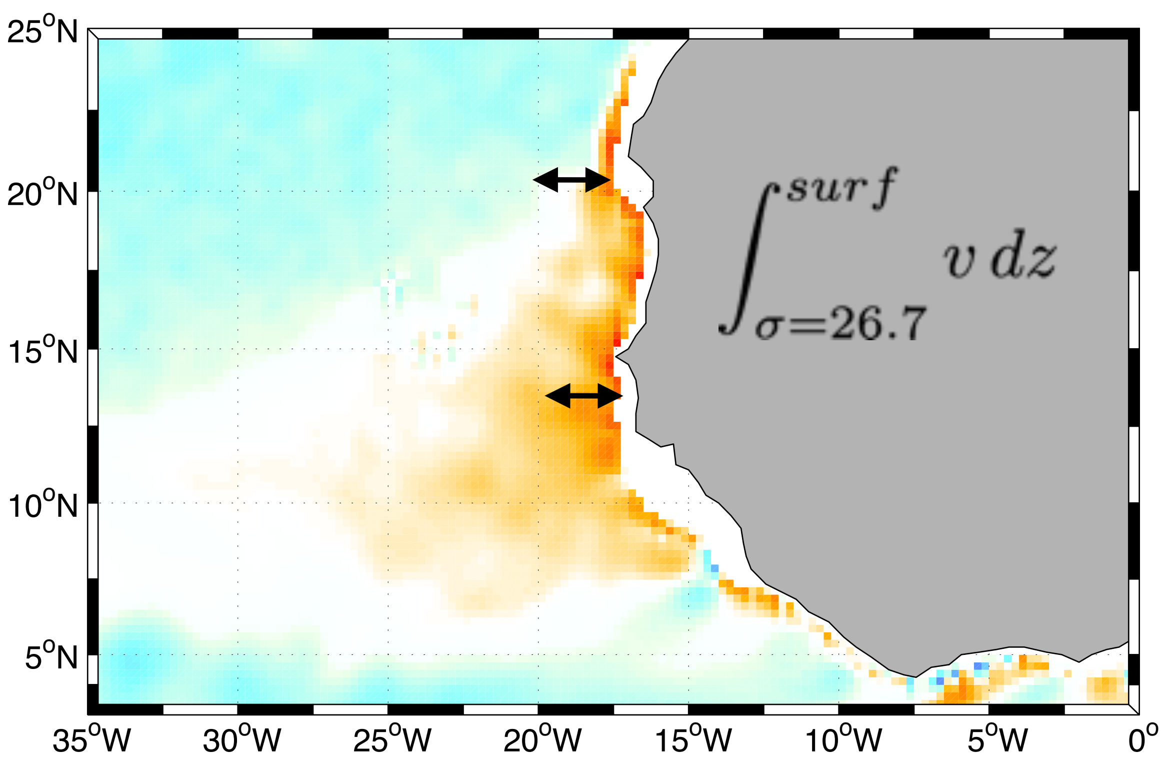
The WABC seasonal cycle



- **Semi-annual cycle** with two peaks (March-June and Oct.-Dec. Forced by the wind variability in the coastal wave guide. Generates RWs in the sector
- Baroclinic mode 2 is important to the WABC dynamics (circulation intensified above 26.7 - 200 m depth and zero crossing of mode 2 at ~ 250 m).

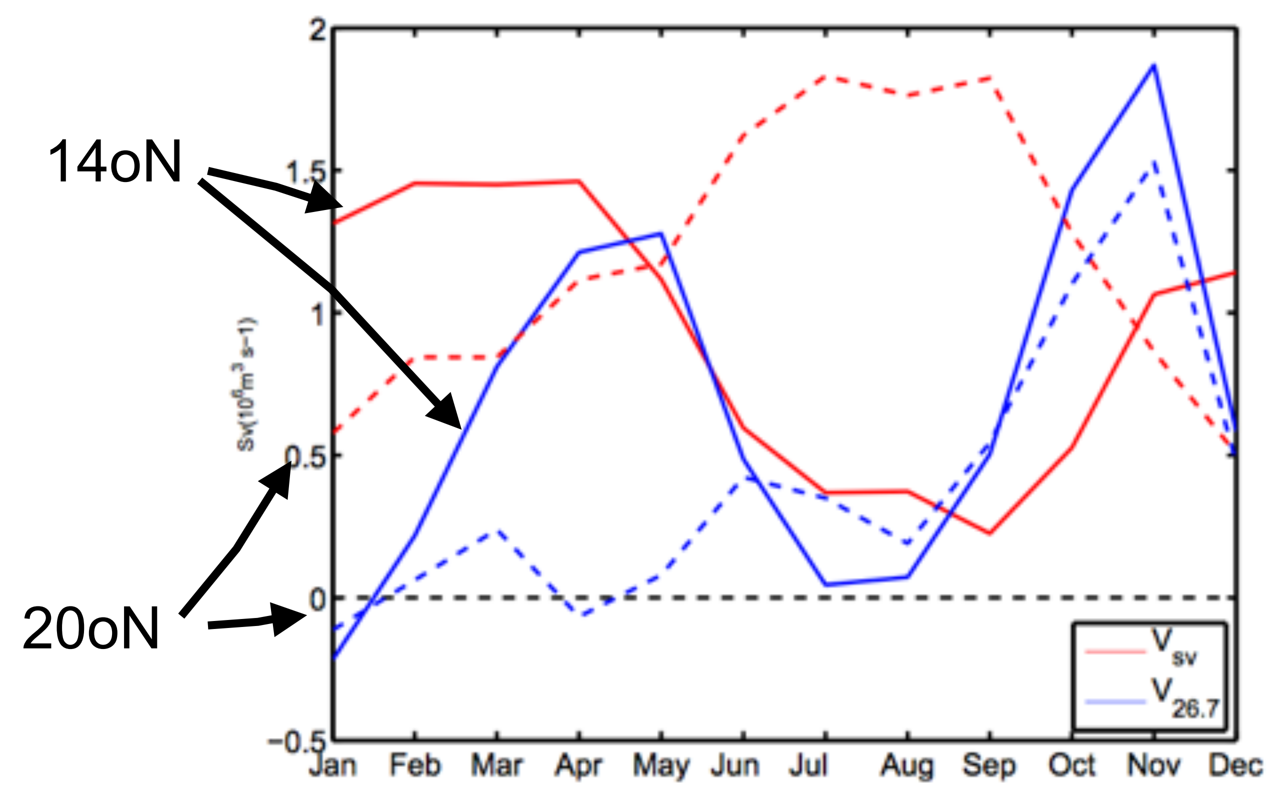


Kounta et al, 2018



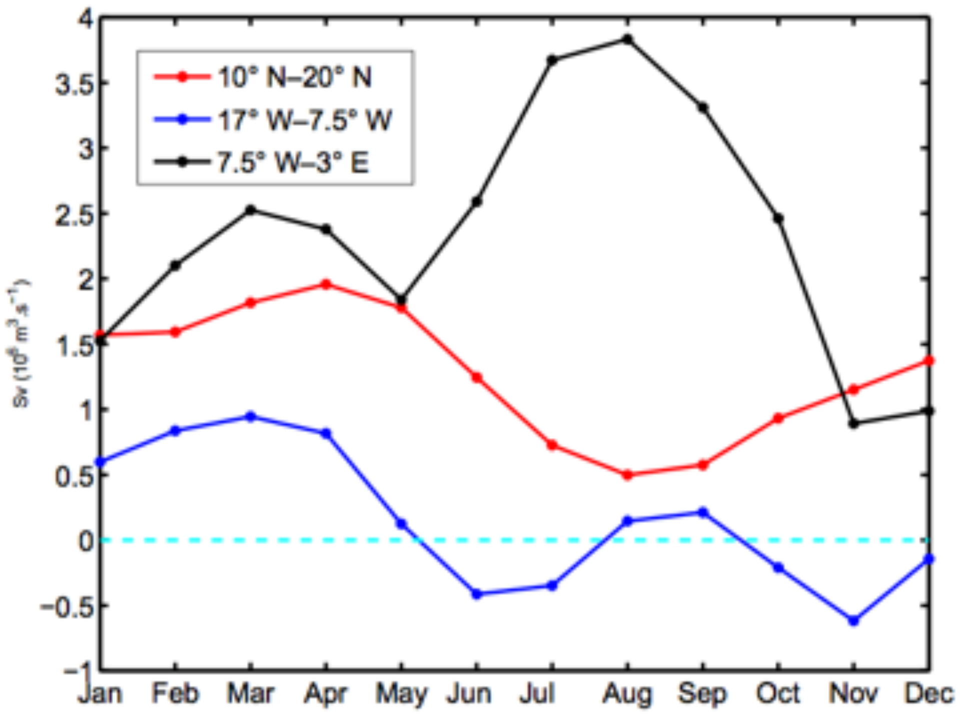
- **Semi-annual cycle** with two peaks (March-June and Oct.-Dec. Forced by the wind variability in the coastal wave guide.

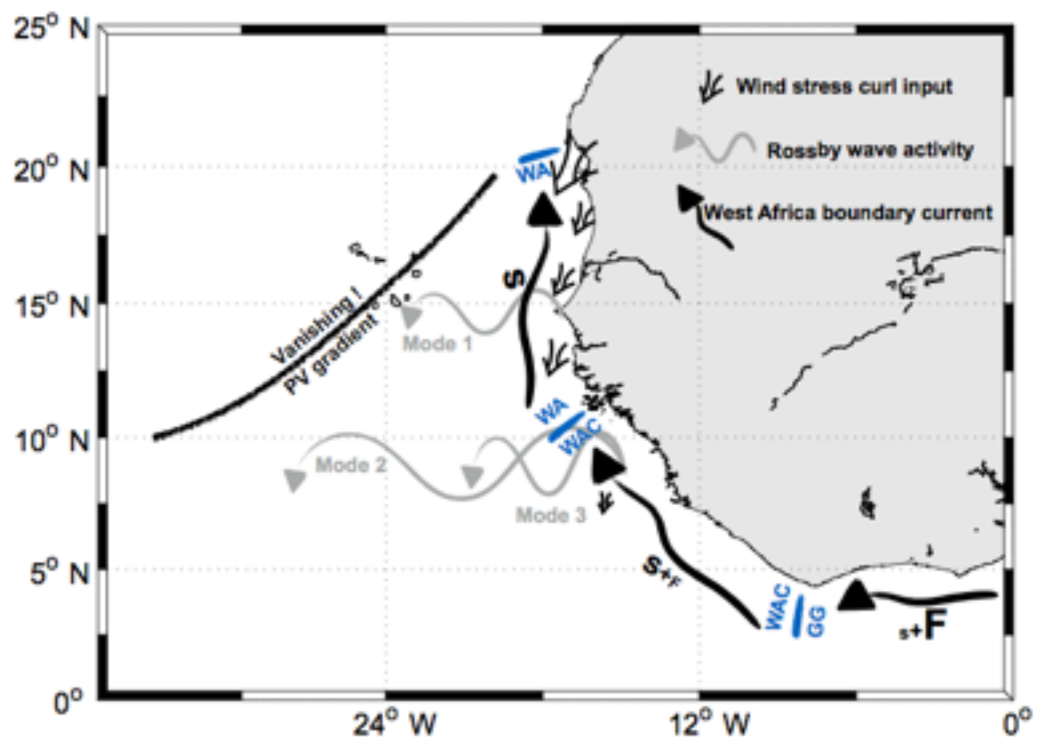
Is it wind stress or wind stress curl ?
Sverdrup transport seasonal cycle is completely inconsistent with the seasonal cycle of model meridional transport at 14oN.

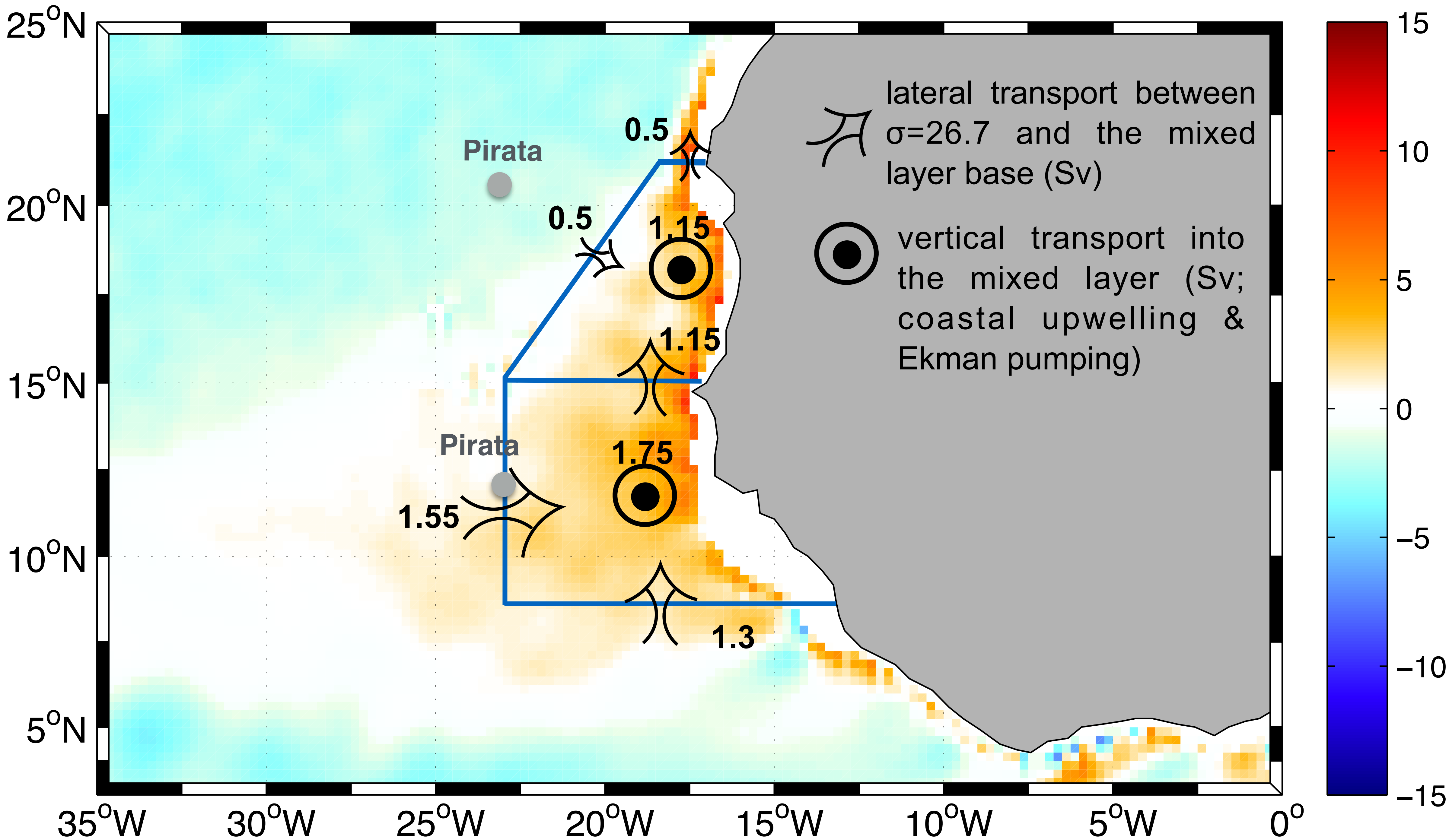


The WABC seasonal cycle (follow up on Marcus)

- By looking at upwelling indices along three different sectors (WA, WAC, GG) we suggest that relaxation and intensifications of alongshore winds along these three sectors are the main forcing agents for the WABC.
- There are differences in the forcings for the two peak seasons (more remote in fall, more local in spring) but the flow at these two seasons is not fundamentally distinct in nature so the terminology "Mauritanian current" is perhaps more confusing than helpful







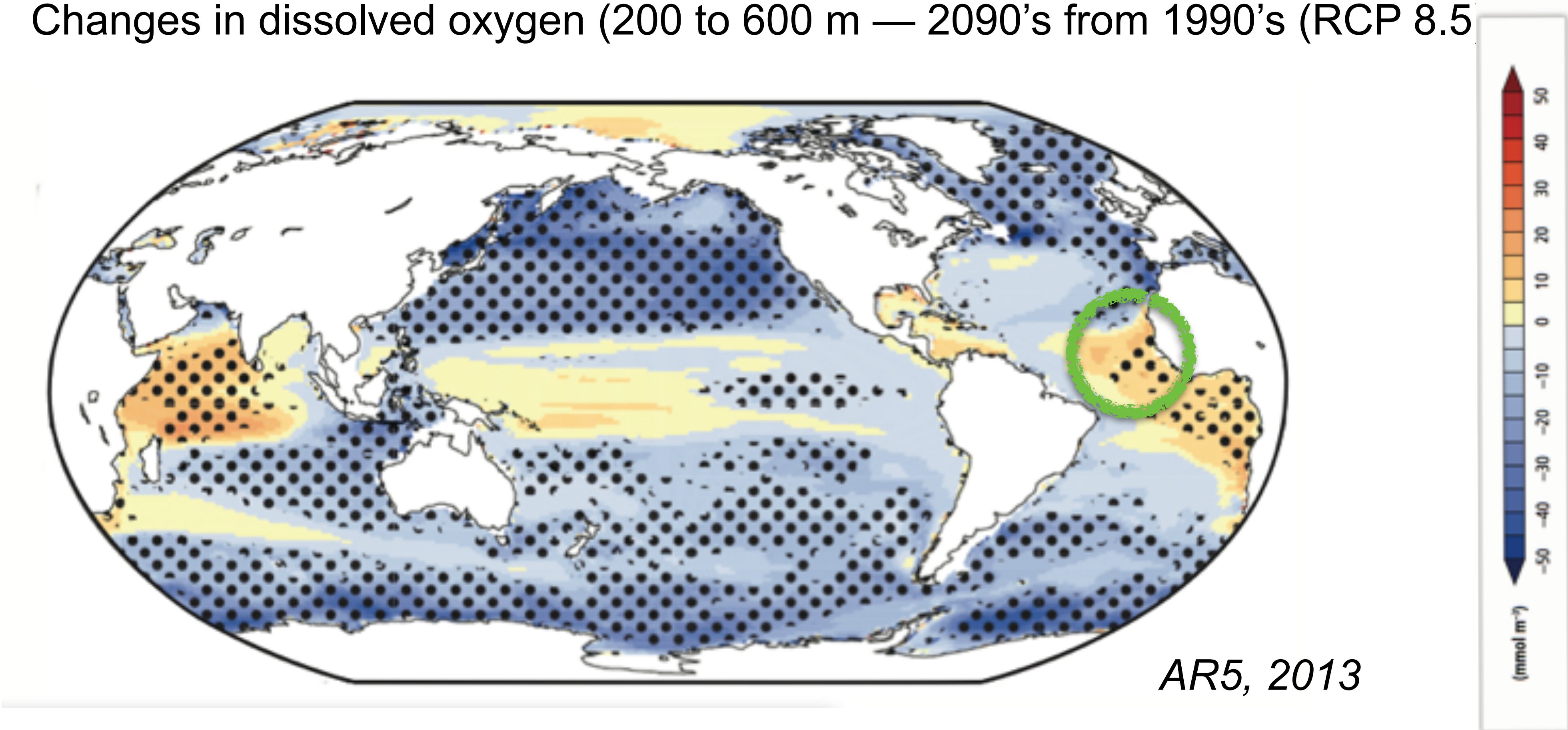
We are concerned with ~ three Sverdrup of water moved horizontally and of upwelled. These 3 Sv are of vital importance to the WA societies. The understanding of the ETNA dynamics is insufficient.

→ models will have a crucial role to play but observations are needed

- There is a interesting boundary current along WA.
- Waters in the density range 25.2-26.7 are the relevant ones (time scales of interest are of the order of a few years, typical flow speeds along mean trajectories are of the order of 1 cm/s)
- The upper thermocline depth range is the one in which the largest fraction of the wind-driven (Sverdrup) circulation is taking place. Related to the importance of the baroclinic mode RWs which are effective enough
- The GD is perhaps not the main dynamical feature. The circulation at the GD level is not so well related to the rather the problem is best posed when looking at the PV structure and the deviations of the circulation from planetary geostrophy: f/h = constant (still partly an intuition) → on explique la structure en PV et ses deviations. la structure en pv explique la dynamique des ondes de Rossby associéés

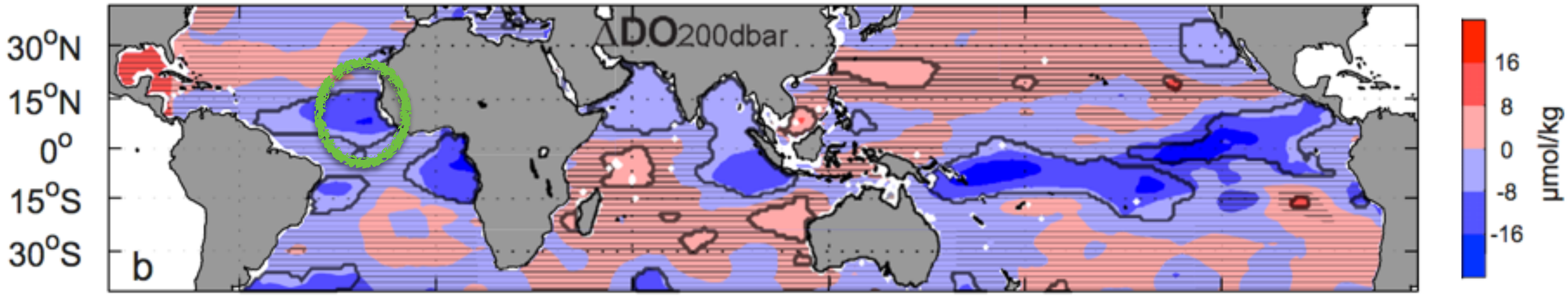
→

Changes in dissolved oxygen (200 to 600 m — 2090's from 1990's (RCP 8.5



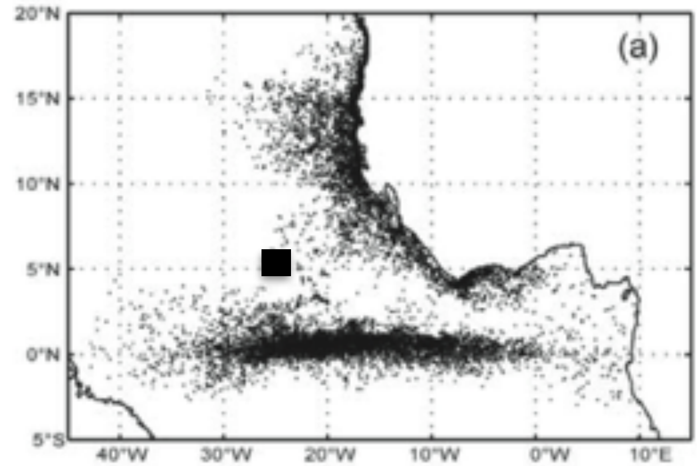
AR5, 2013

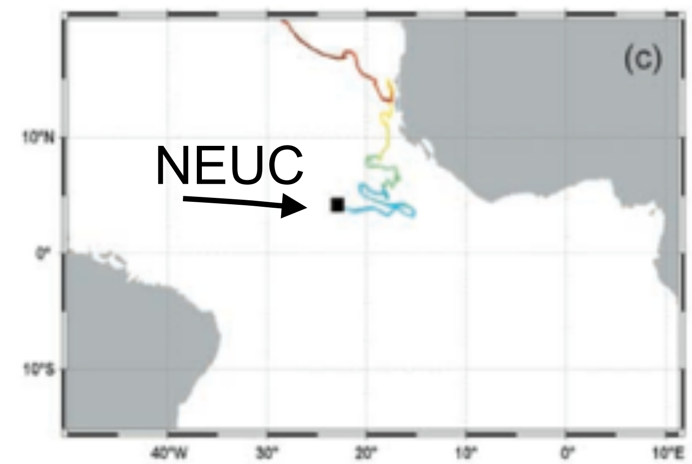
Changes in dissolved oxygen (200 m — 1990-2008 from 1960-1974



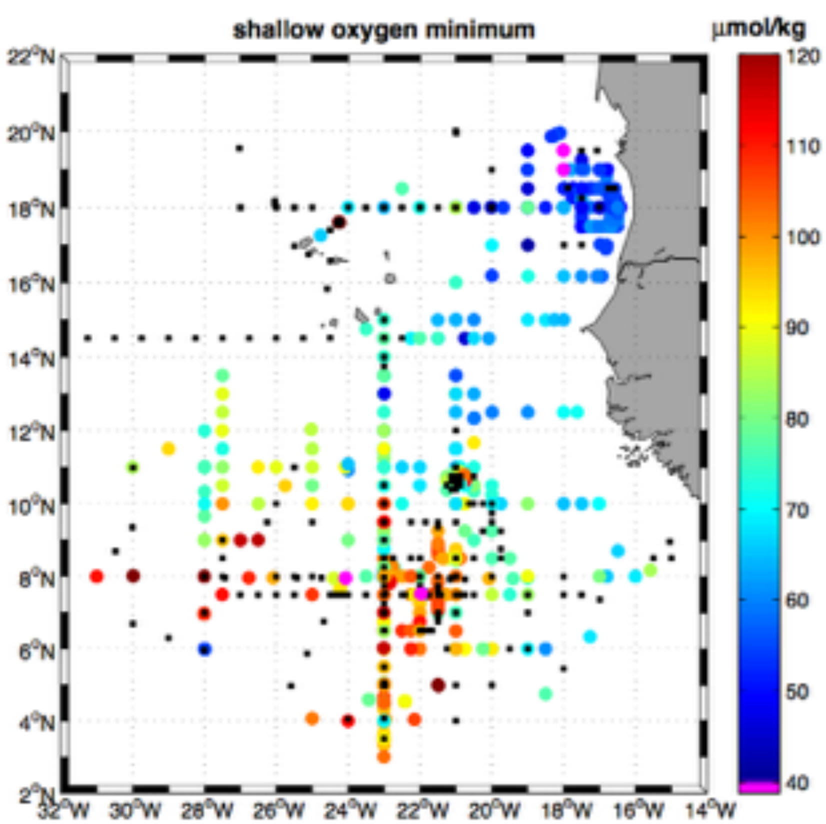
Stramma et al, 2010

Broadly speaking, the source waters are advected at upper thermocline levels from the equatorial Atlantic with an important contribution from the NEUC





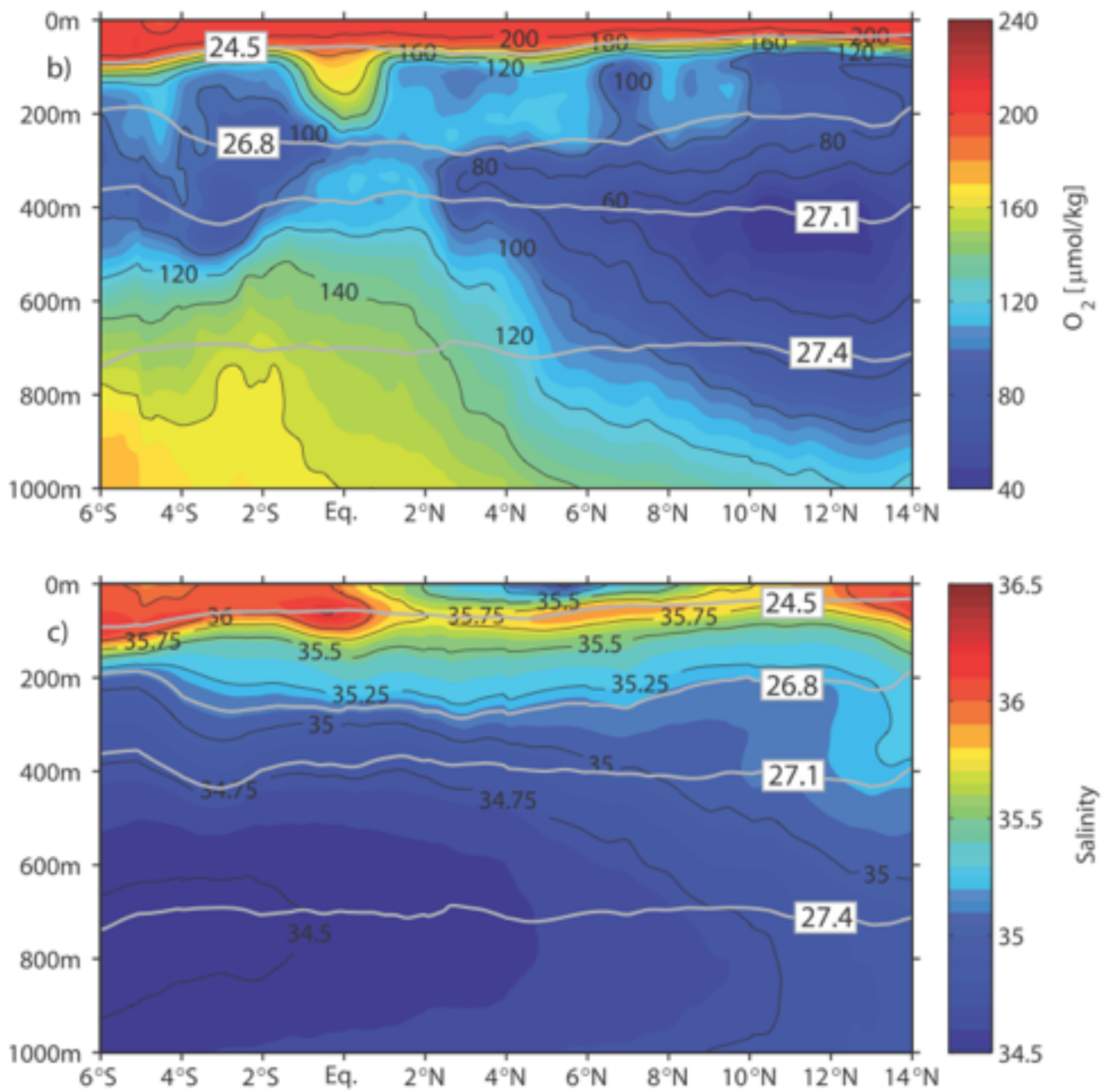
Hüttl-Kabus & Böning, 2008, (see also Glessmer et al, 2009 and many eulerian studies)



Brandt et al, 2015

In the upper thermocline low DO seem confined near the WA seaboard while source waters in the NEUC have much larger DO levels.

Changes in dissolved oxygen (200 to 600 m — 2090's from 1990's (RCP 8.5)



Brandt et al, 2010