EGU General Assembly 2021

fluids

MDPI

Article

From Mixing to the Large Scale Circulation: How the Inverse Cascade Is Involved in the Formation of the Subsurface Currents in the Gulf of Guinea

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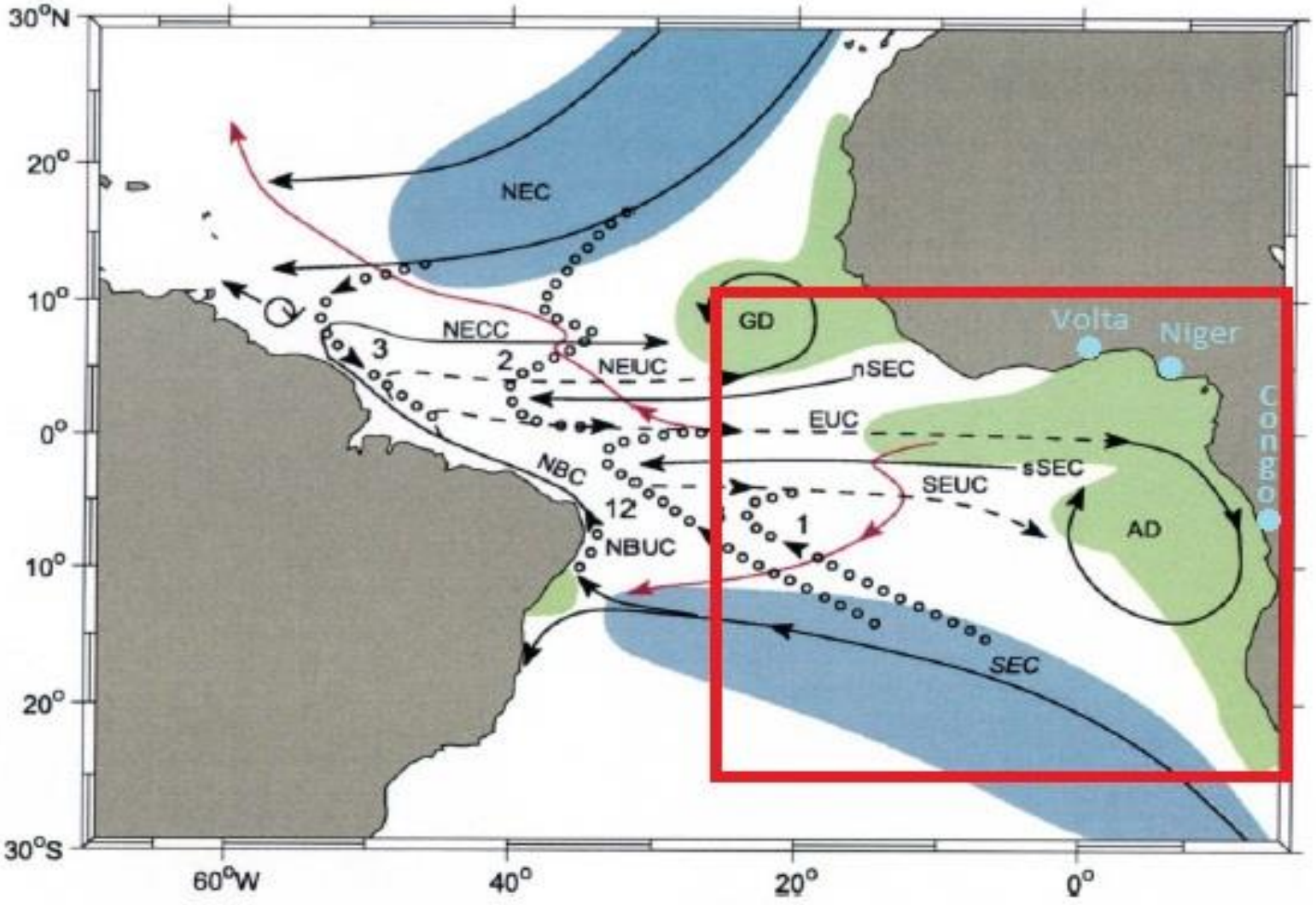
Projects
Alti-ETAO (OSTST)
TriAtlas (H2020)

Assene et al, fluids, 2020

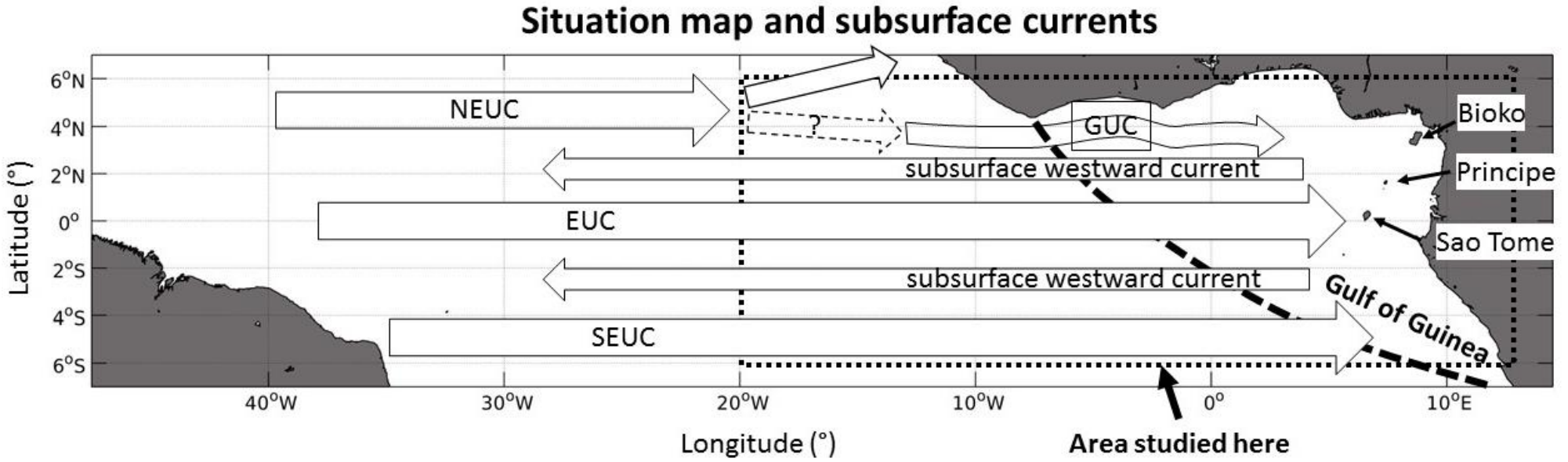
Introduction : General circulation in Tropical Atlantic

Most of current are zonal



Schott et al, 2004

Introduction : subsurface circulation in Gulf of Guinea



GOAL :

➔ Explain the formation of SEUC/NEUC-GUC + westward currents

➔ Role of (sub)mesoscale dynamics

TOOLS : Numerical simulation of the Equatorial Atlantic

Jouanno et al, 2016-2017, Hernandez et al, 2017

NEMO model / configuration

Initial+Boundary : MERCATOR – GLORYS2V4 reanalysis

Atm forcing DFS5.2 : ERAinterim reanalysis + CheapAML *(Deremble 2013)*

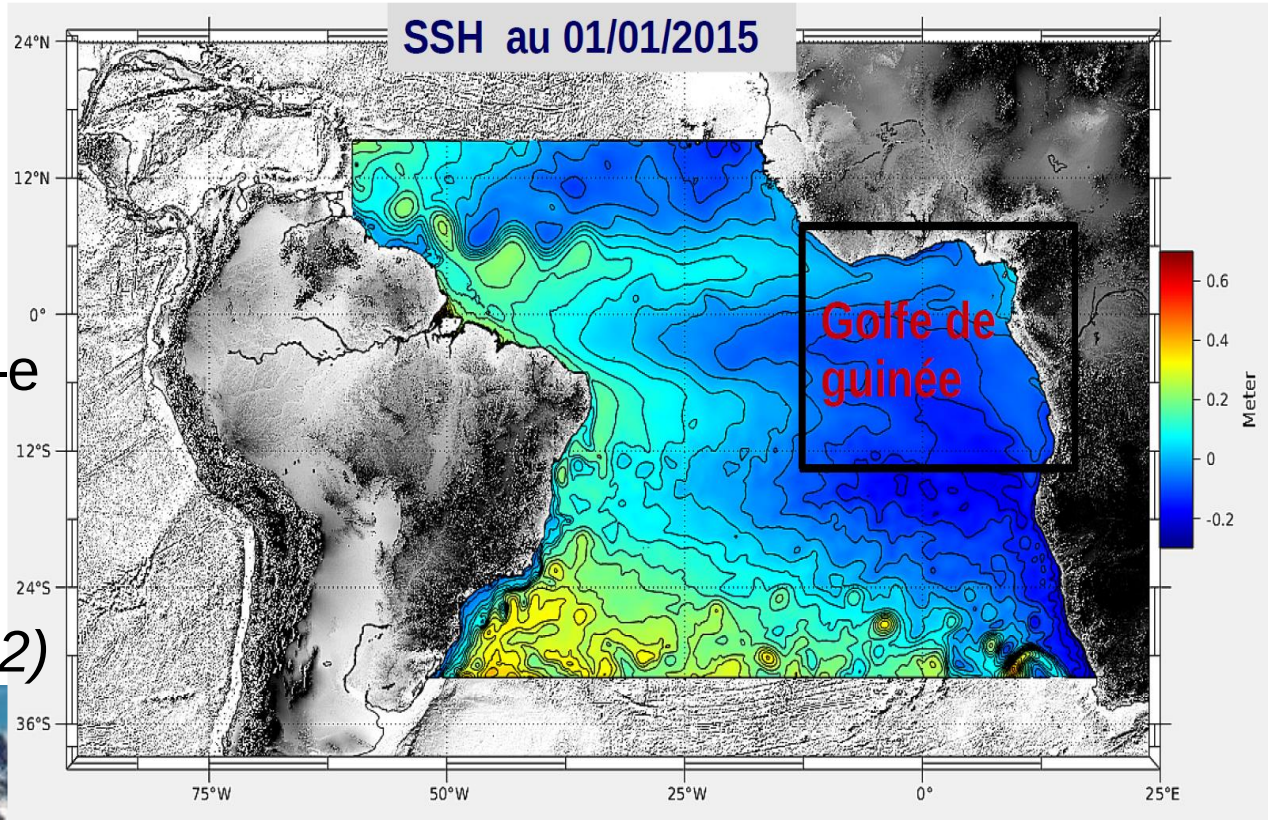
Resol : 1/12°

75 vertical levels

Closure scheme : GLS ~ K–e

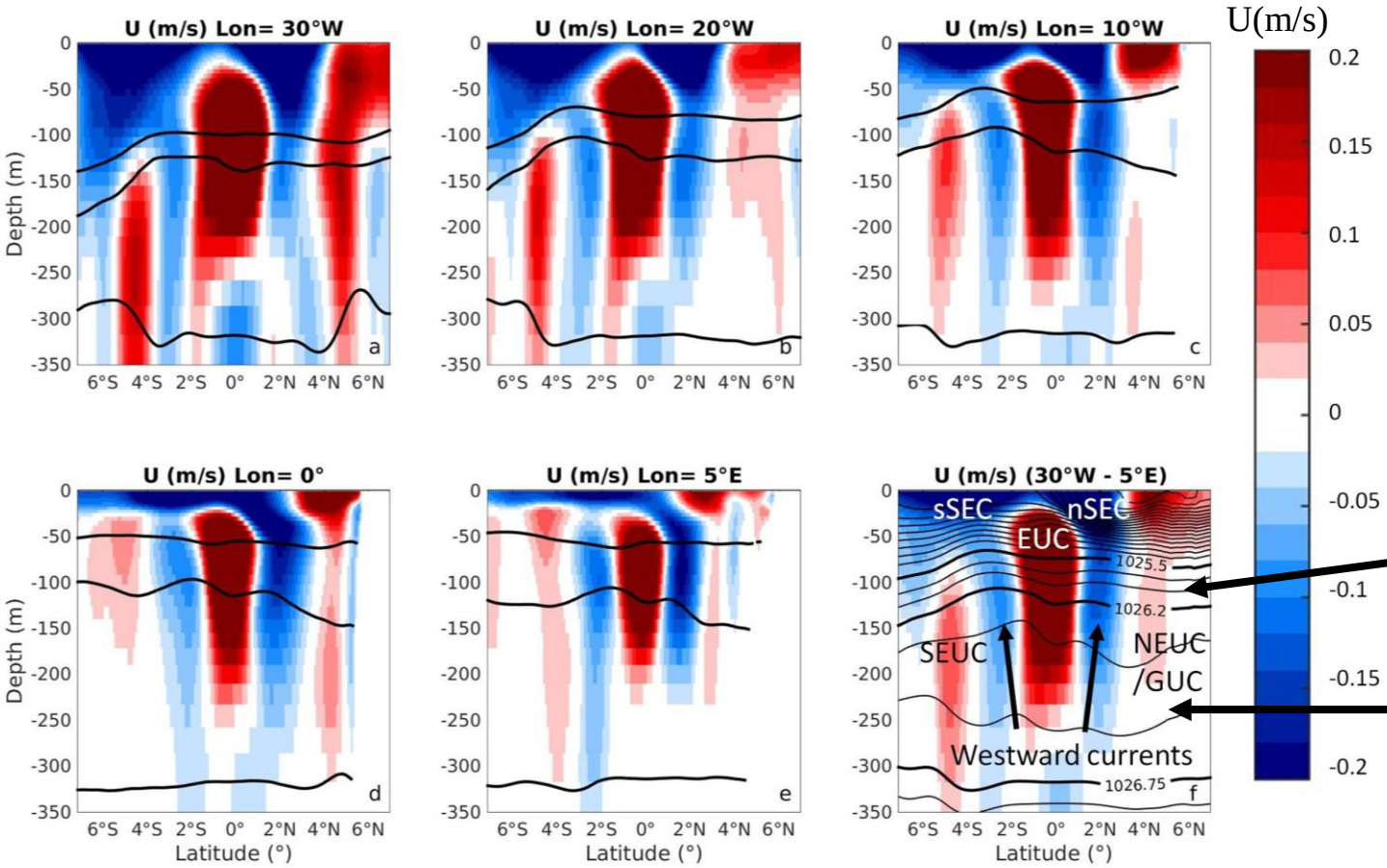
Year : 2015 *(spinup 20y)*

Rivers *(Dai et Trenberth,2002)*



Validation

Mean zonal velocity



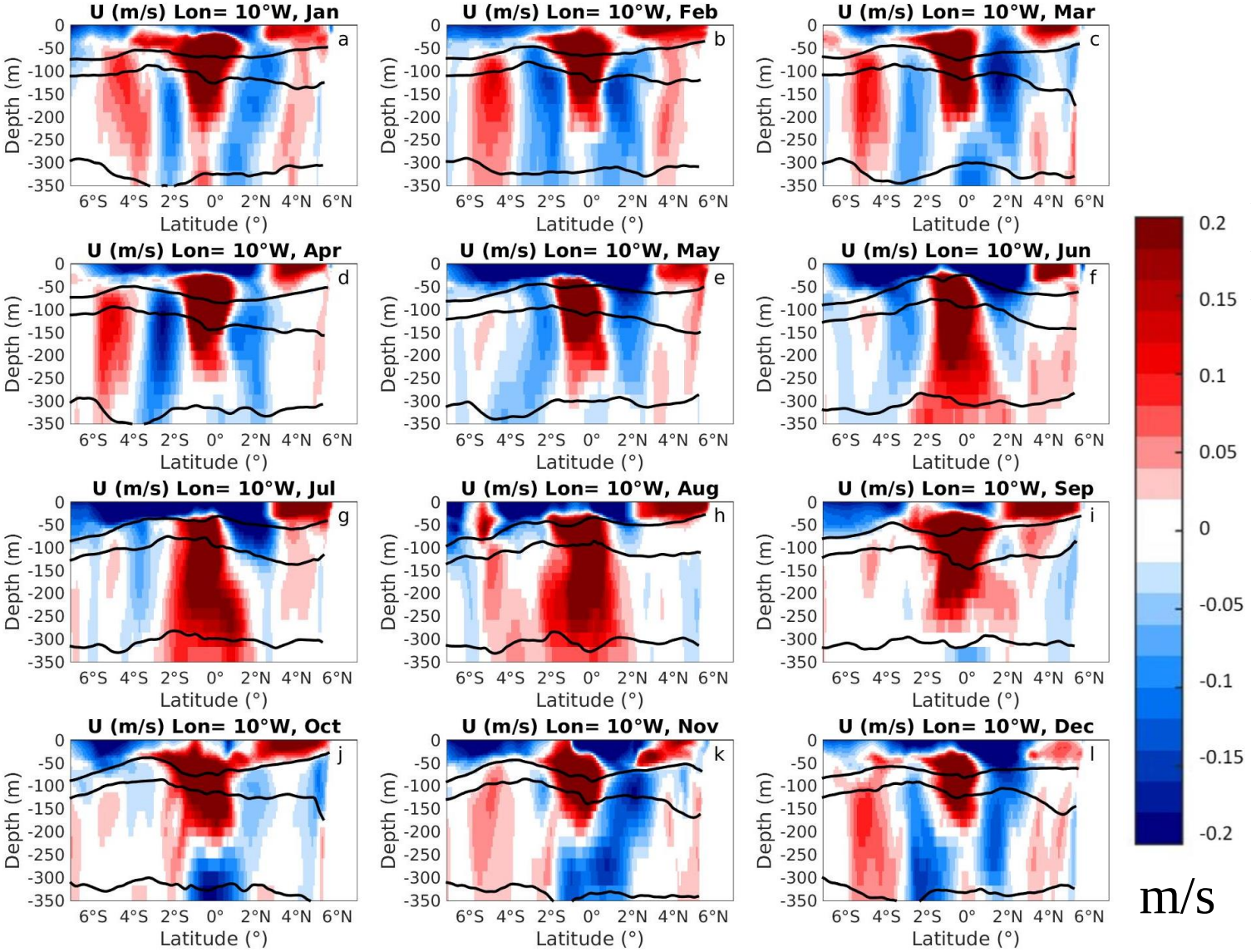
Bourlès et al, 2002
Brandt et al, 2010
Herbert et al, 2016
Kolodziejczyk et al, 2009
Kolodziejczyk et al, 2014
…

Layer 1 [25.5-26.2]
(lower Pycnocline)

Layer 2 [26.2 -26.75]
(just below Pycnocline)

Validation

Variability of zonal velocity at 10°W (15th of each month)



Bourlès et al, 2002
Brandt et al, 2010
Herbert et al, 2016
Kolodziejczyk et al, 2009
Kolodziejczyk et al, 2014
...

Analysis based on POTENTIAL VORTICITY (PV)

~ CONSERVATION

ζ= rot (U) major physical quantity Conservation

BUT ζ IS NOT CONSERVED

$$PV_{Ertel} = \frac{\zeta + f}{h}$$

Conserved for each particle
if adiabatic evolution

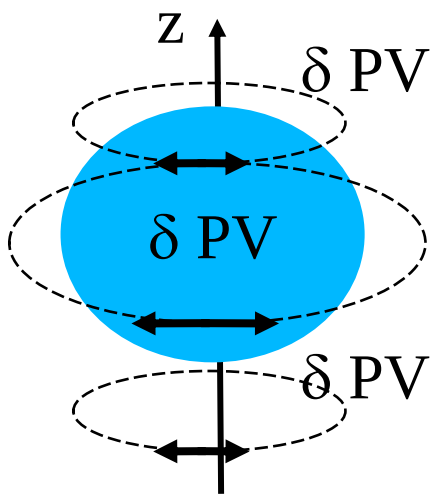
$$\frac{d}{dt} PV_{Ertel} = \text{diabatic terms}$$

PV = TRACER (lagrangian)

~ INVERSION

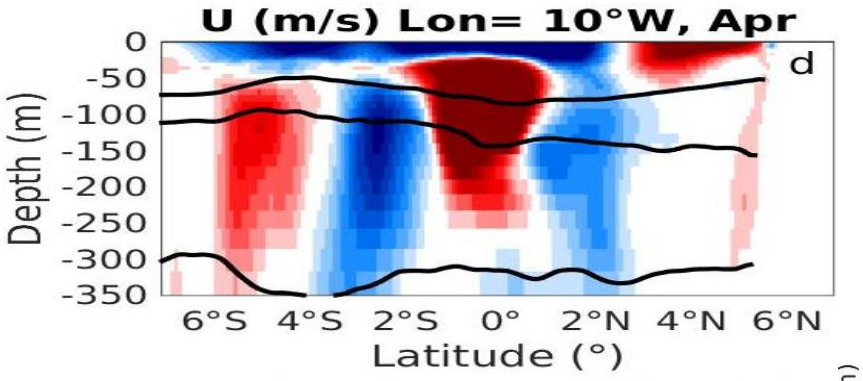
Velocity field can be evaluated from the PV (Anomaly) at geophysical scale (geostrophic equilibrium)

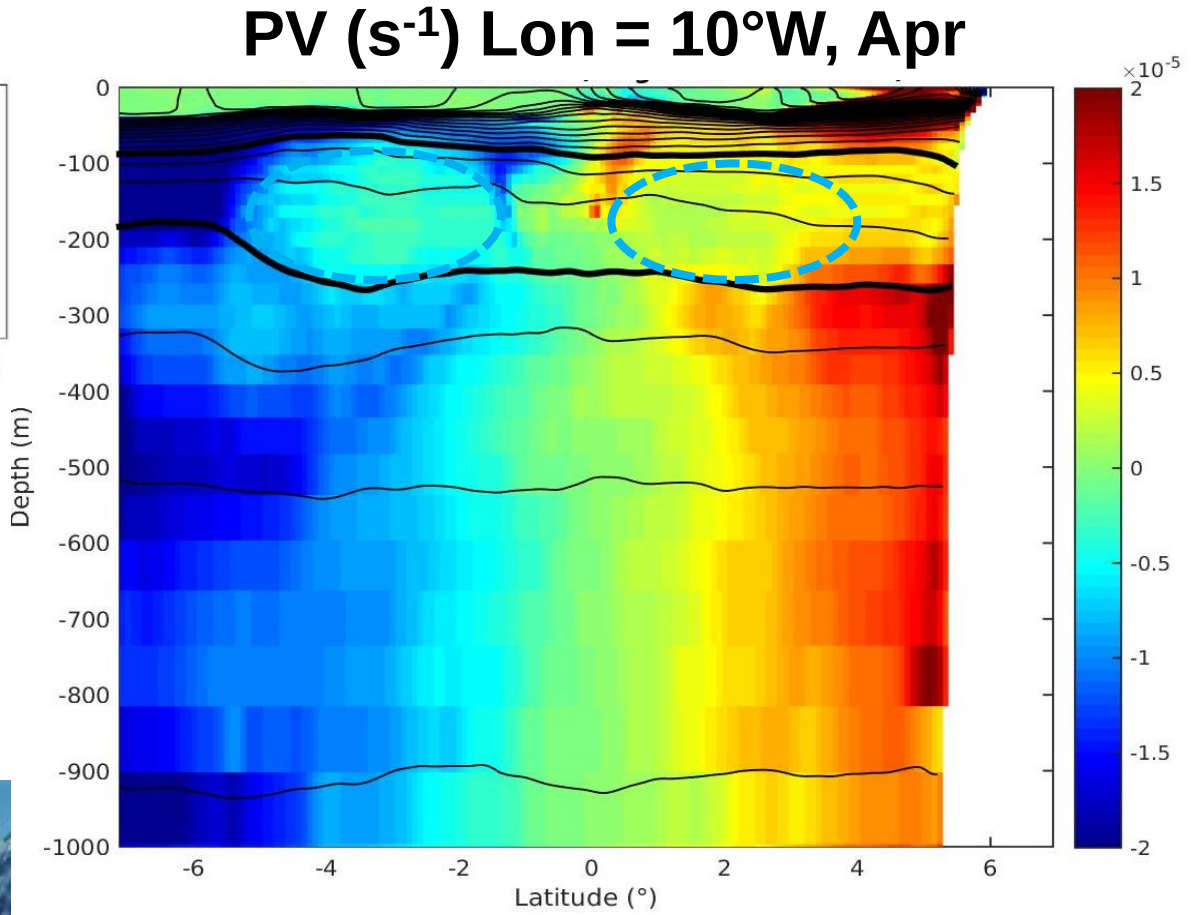
INVERSION PRINCIPLE



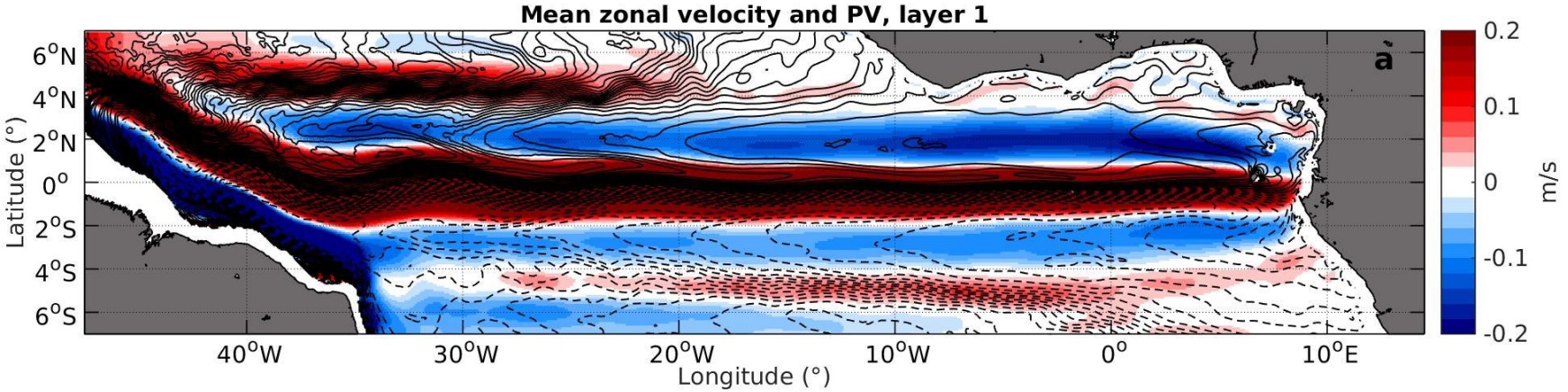
PV signature of the currents

SEUC/NEUC-GUC and westward currents associated with same PV anomaly, located in isopycnal layers 1 and 2

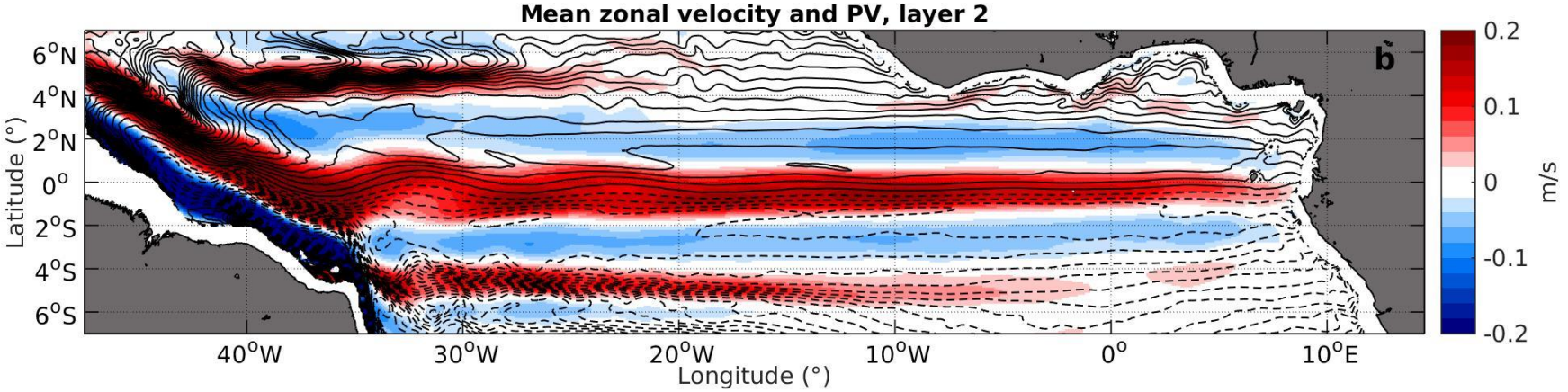




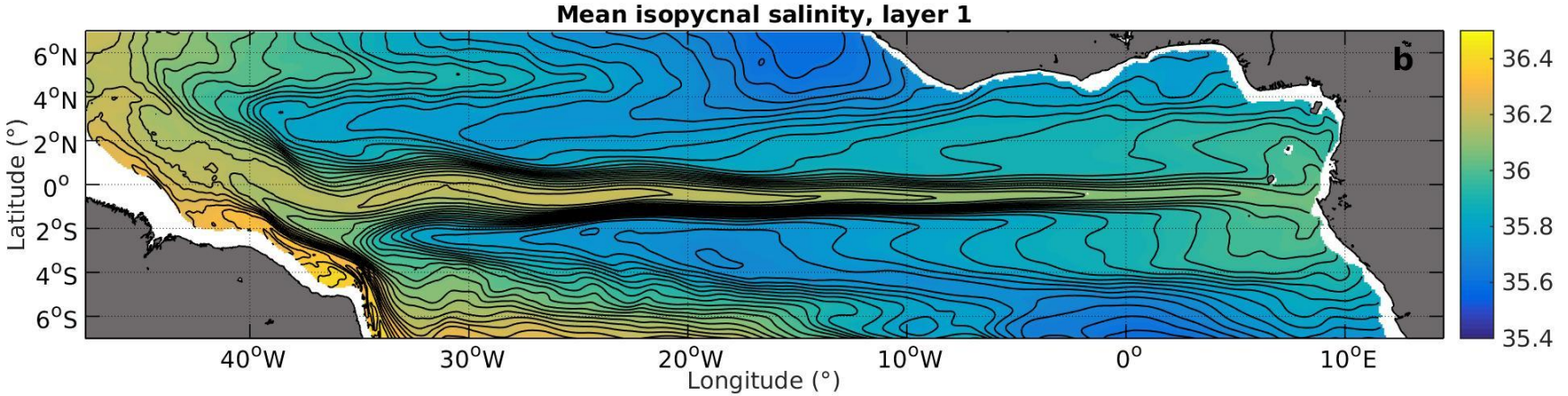
PV signature of the currents : Mean zonal currents

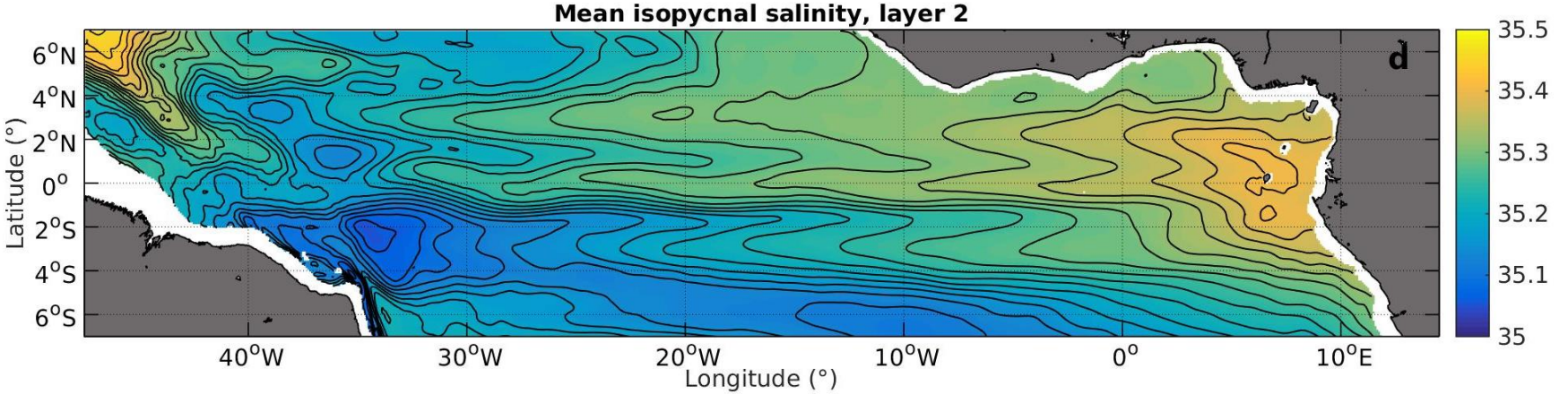


Zonal PV tongues



Salinity signature of the currents : Mean field





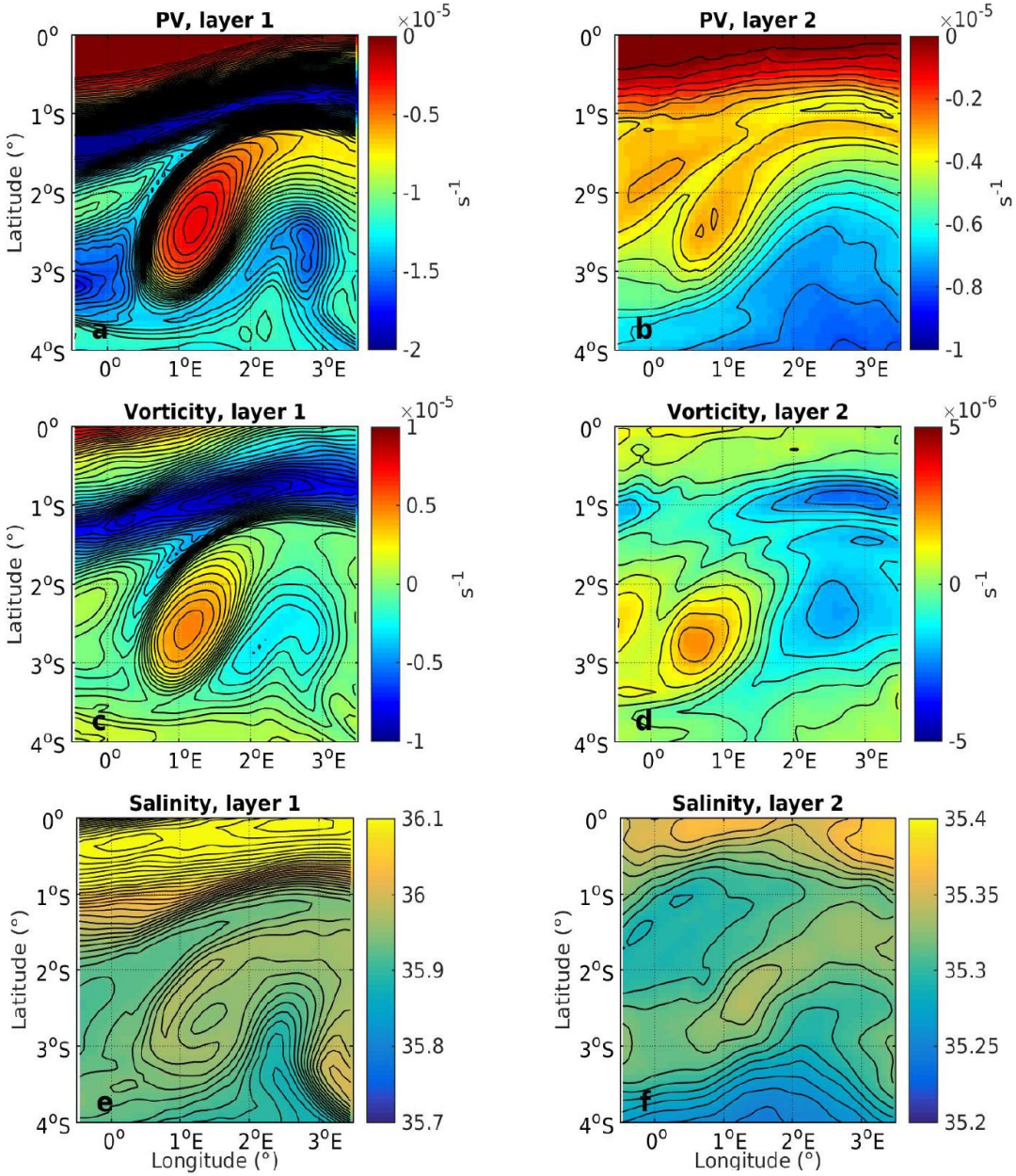
Salt transport by EUC from west to east, an then mixing occurs

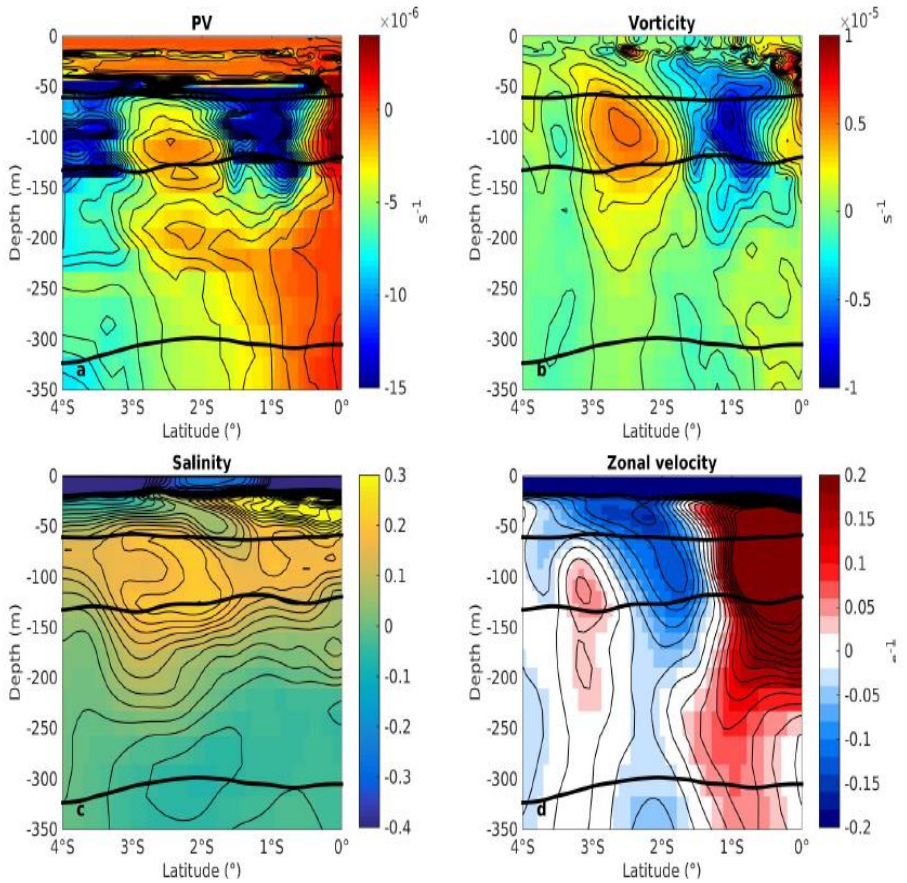
Instantaneous fields : zoom on a specific vortex (10th of May)

Anticyclonic vortex

Westward propagation

~150 – 200 m vertical extension



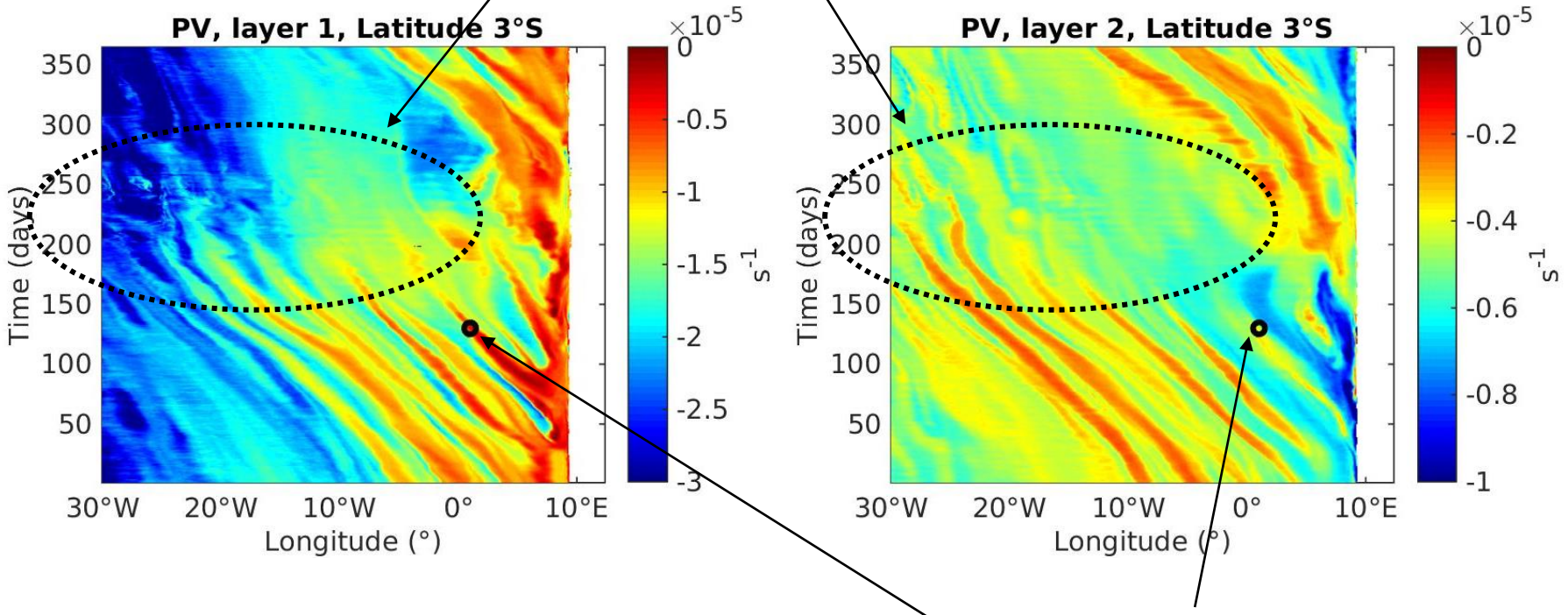


Isopycnic maps

Vertical sections

Annual cycle / seasonal variability

Equatorial Upwelling Season



5 vortices generated each year

Westward propagation

Destroyed during Upwelling season

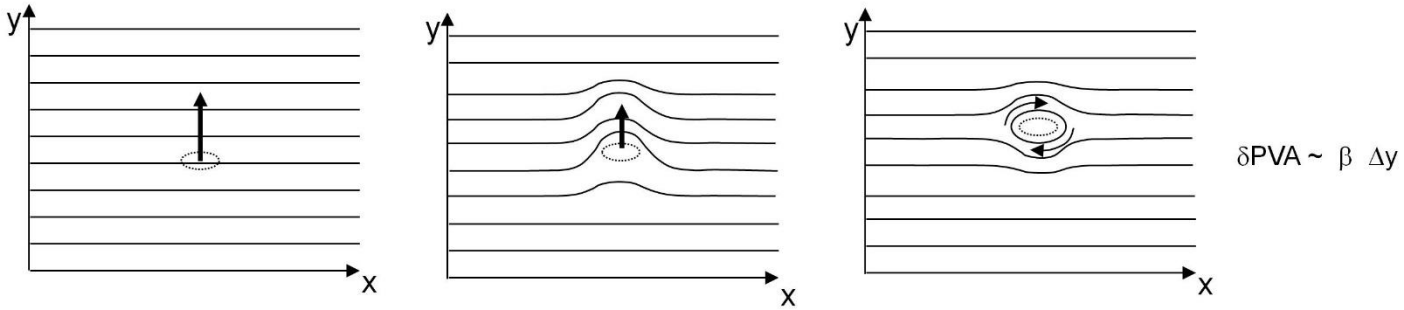
Mean signature => zonal jets

NOT THE END OF STORY !!!!

What are the mechanisms responsible for the creation of the PV anomalies in the vortex cores ?

Adiabatic process PV is conserved

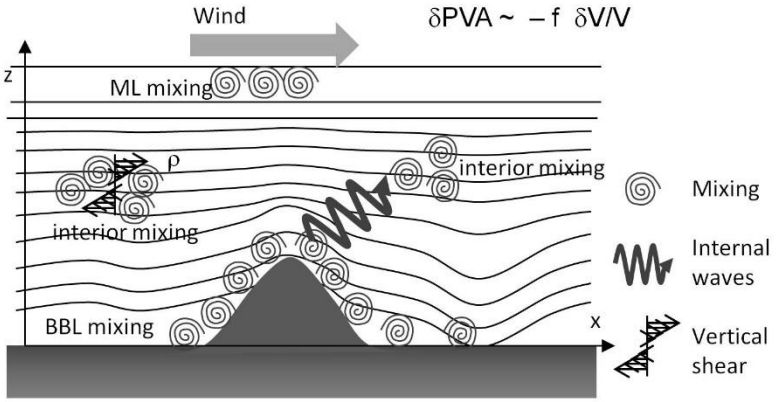
a/ Transport of PV (tracer) through background (meridional) gradient



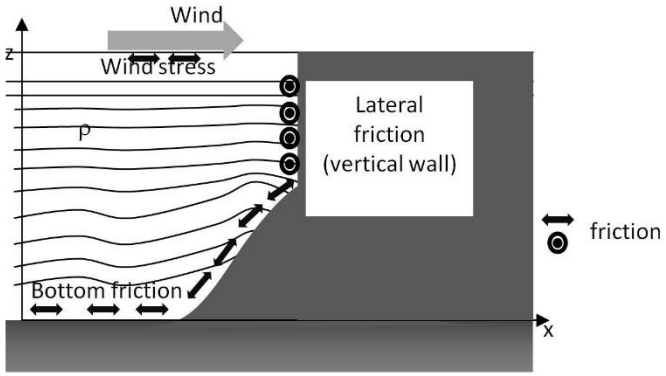
$\delta PVA \sim \beta \, \Delta y$

Diabatic processes PV is NOT conserved

b/ Mixing of density field

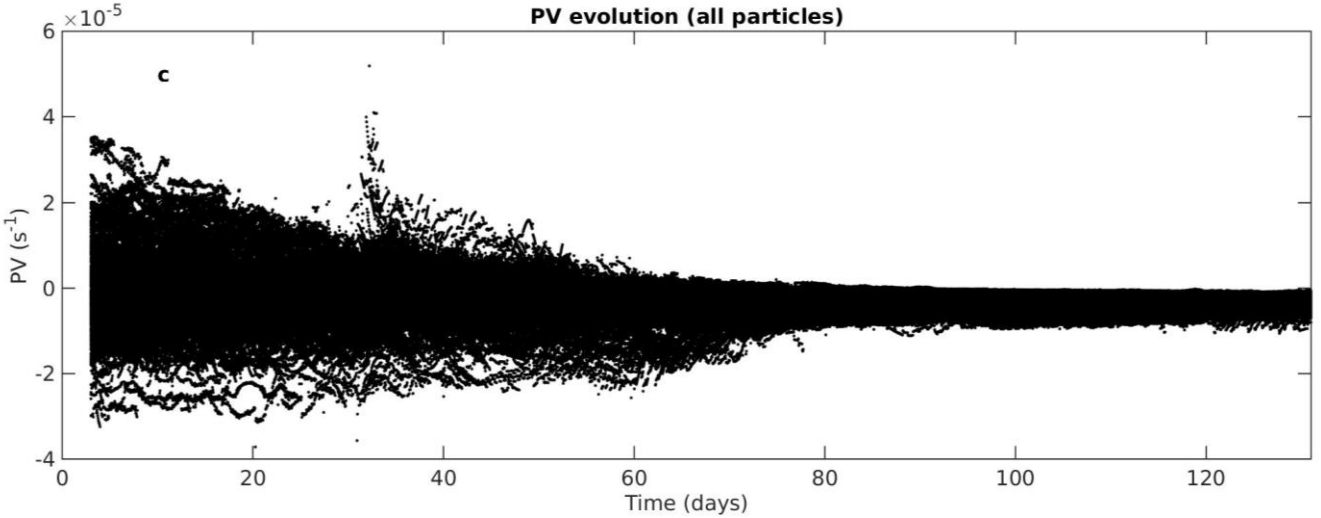


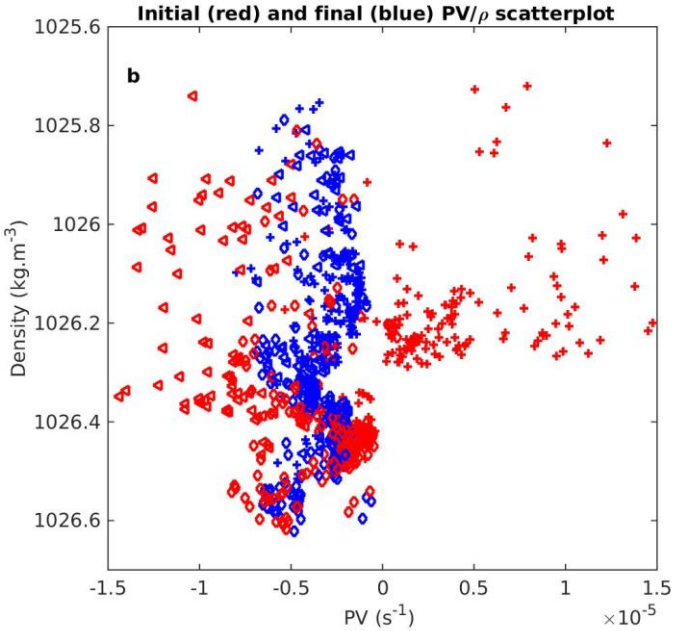
c/ Friction



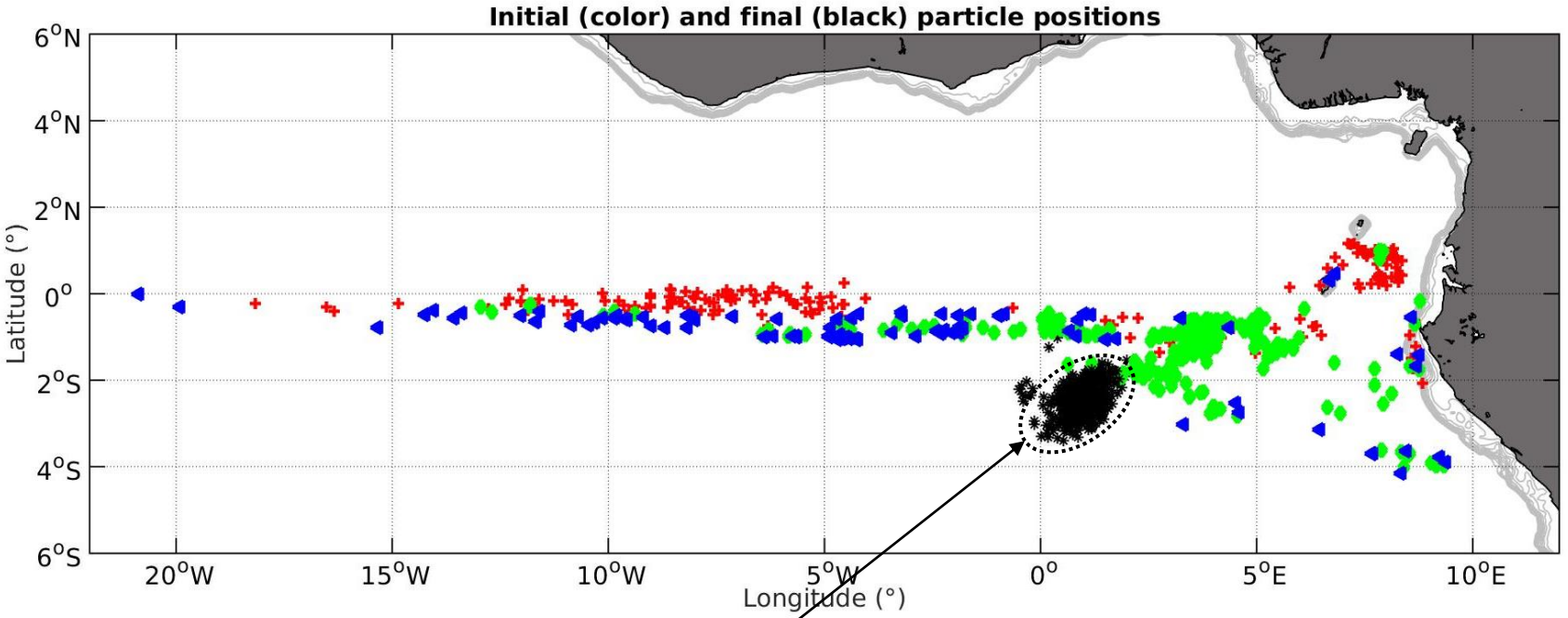
Langrangian analysis

follow particles (backward from fluids parcels of vortex core)
evaluate of PV is conserved or not during trajectory
if not, try to evaluate which diabatic mechanism involved





Langrangian analysis



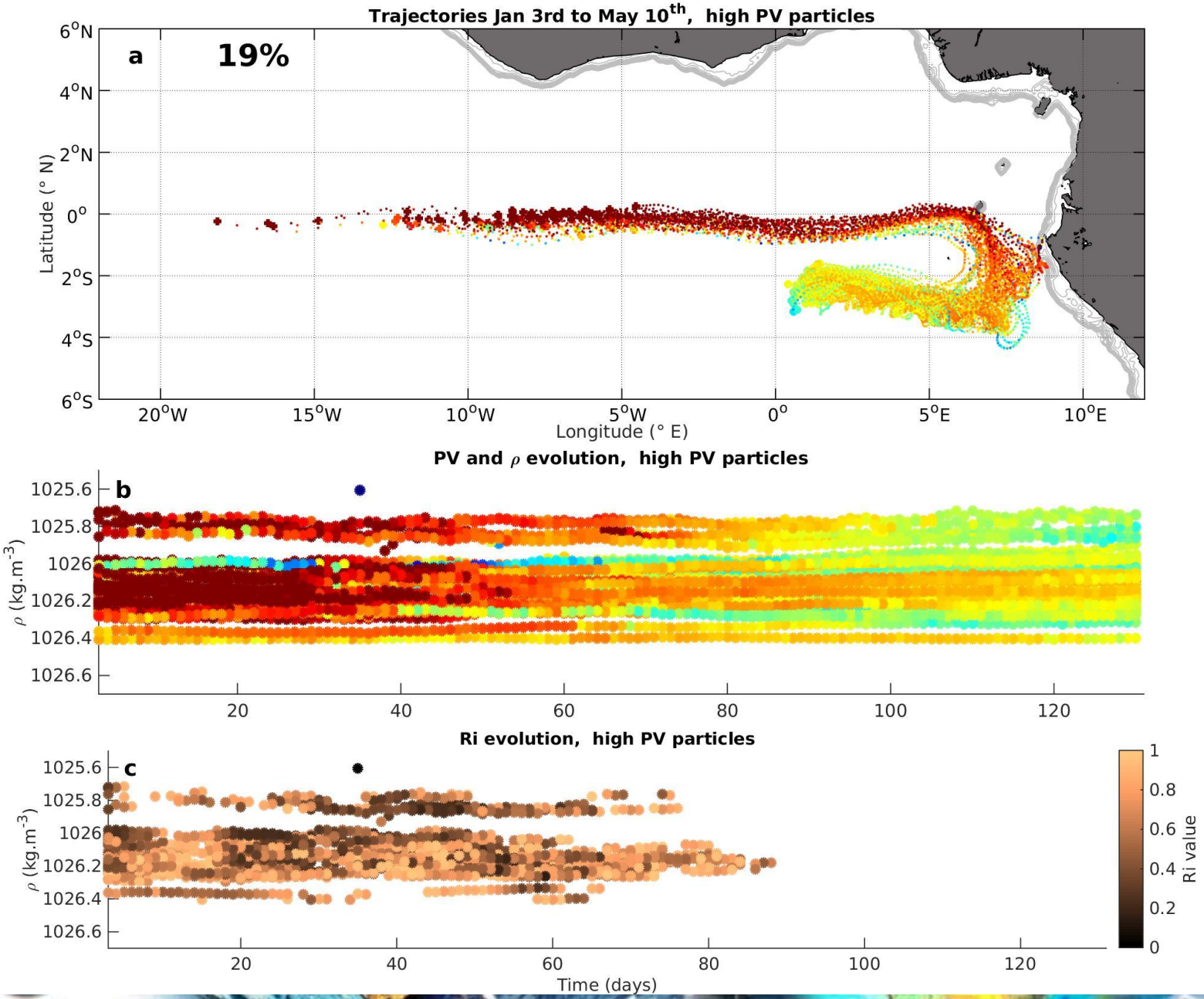
Final position/PV value (vortex core)

Initially high PV => 37 %

Initially low PV => 18,5 %

Initially similar PV => 44,5 %

Langrangian analysis : example of the high PV particles



Conclusion/Summary

Mixing / friction

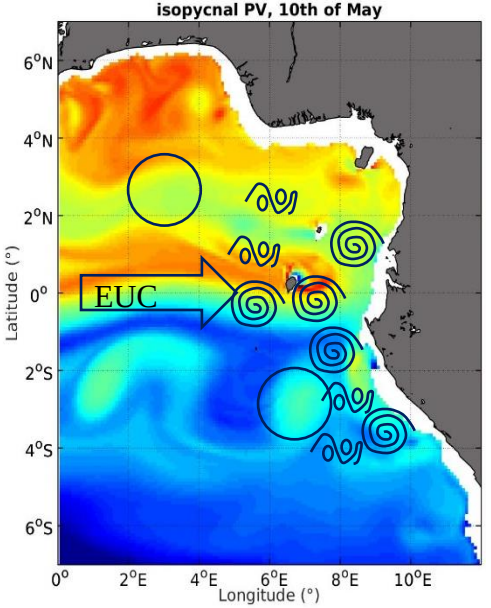
Large scale currents

Submesoscale eddies

Mesoscale vortices

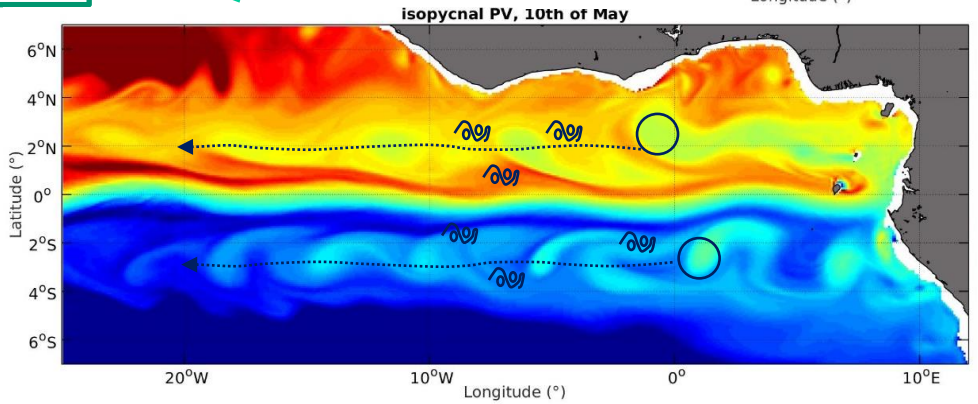
-3 -2 -1 0 1 2 3
x10^{-5} (s^{-1}) PV colorscale

Inverse cascade

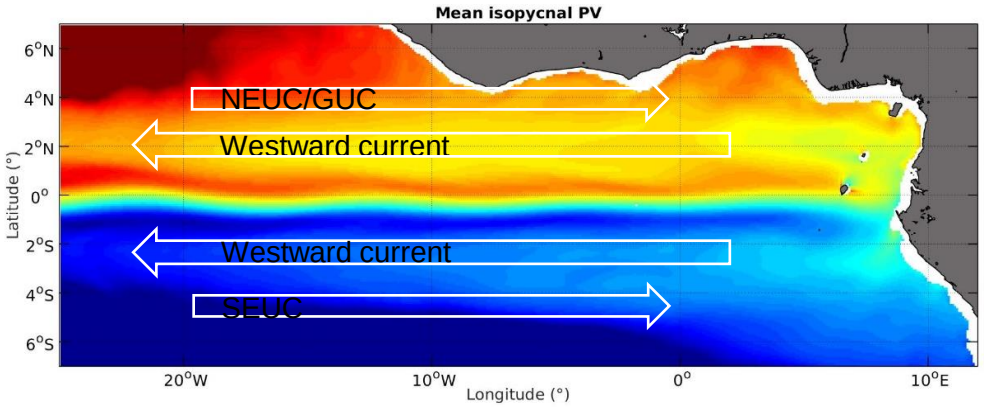


1. The collision of the EUC with the eastern boundary leads to mixing, frictional-topographic effects and meridional recirculation that forms submesoscale PV anomalies below the pycnocline.

2. These submesoscale PV anomalies fuse and align to form anticyclonic mesoscale vortices.



3. These mesoscale vortices propagate westward, modifying the large scale PV structure by filamentation and homogenization.



4. The mean circulation is shaped by this resulting large-scale PV structure, with mean westward currents in homogeneous regions, and eastward currents (SEUC and NEUC/GUC) where the PV gradients are strong.

LEGOS

Conclusion/discussion

Many processes can lead to the formation of (sub)mesoscale eddies

To infer which is the major one (adiabatic/friction/diapycnal mixing)
⇒ more detailed diagnostics needed on diabatic terms
⇒ Sensitivity to parameterization of diabatic processes

Continuity / discontinuity with Western area (NEUC / GUC) ?

Deepen the analysis of the effect of Equatorial Upwelling on vortex destruction and PV redistribution

Inter-annual variability ?

This is « truth » from a realistic simulation, is it similar in nature? => identify vortices