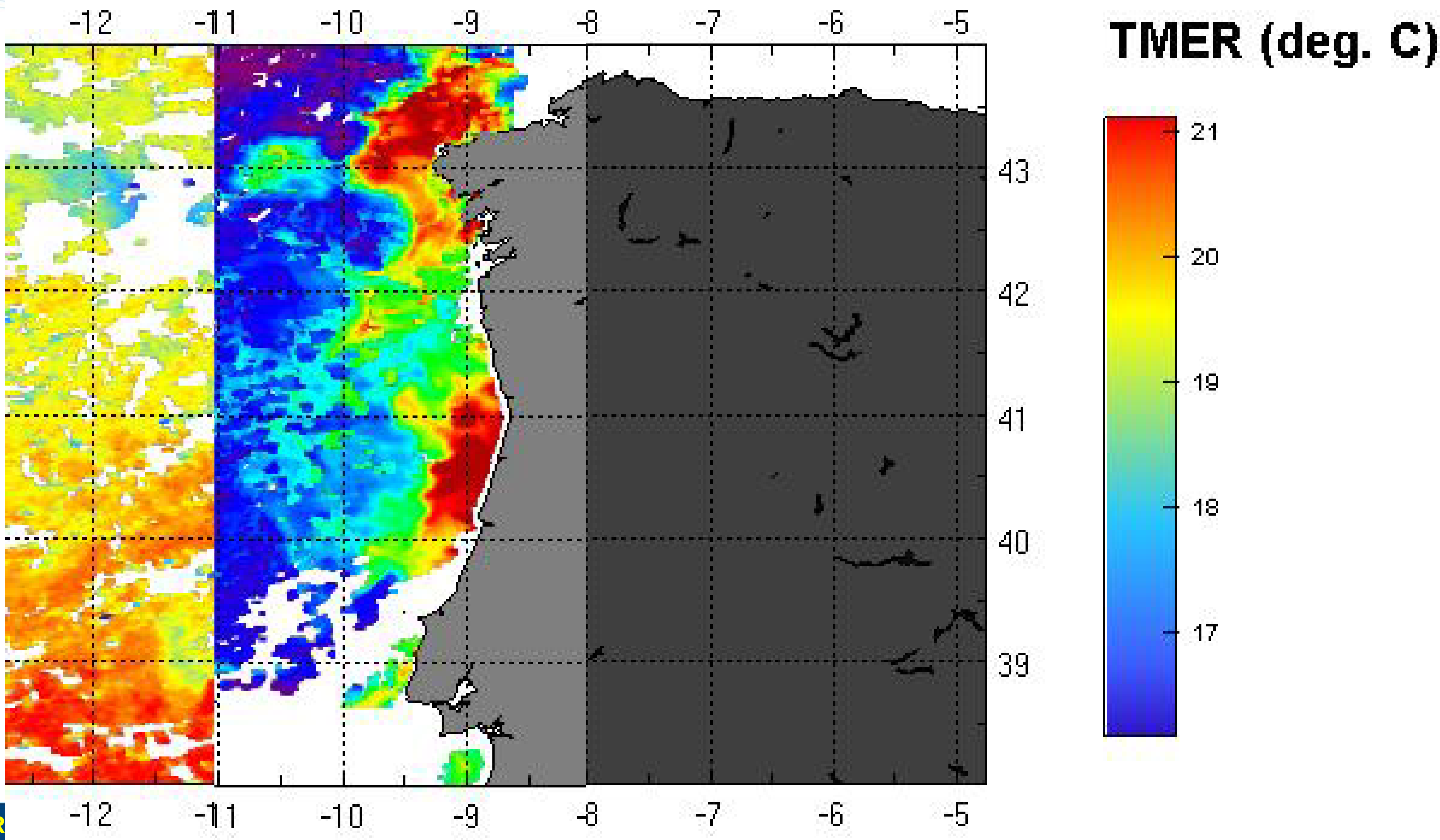
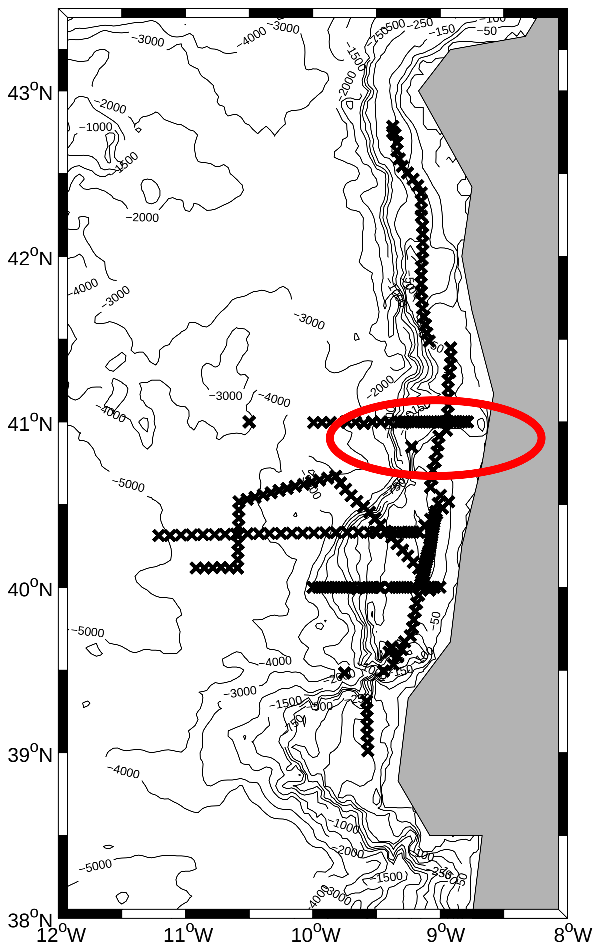
Secondary Upwelling along the shelf break

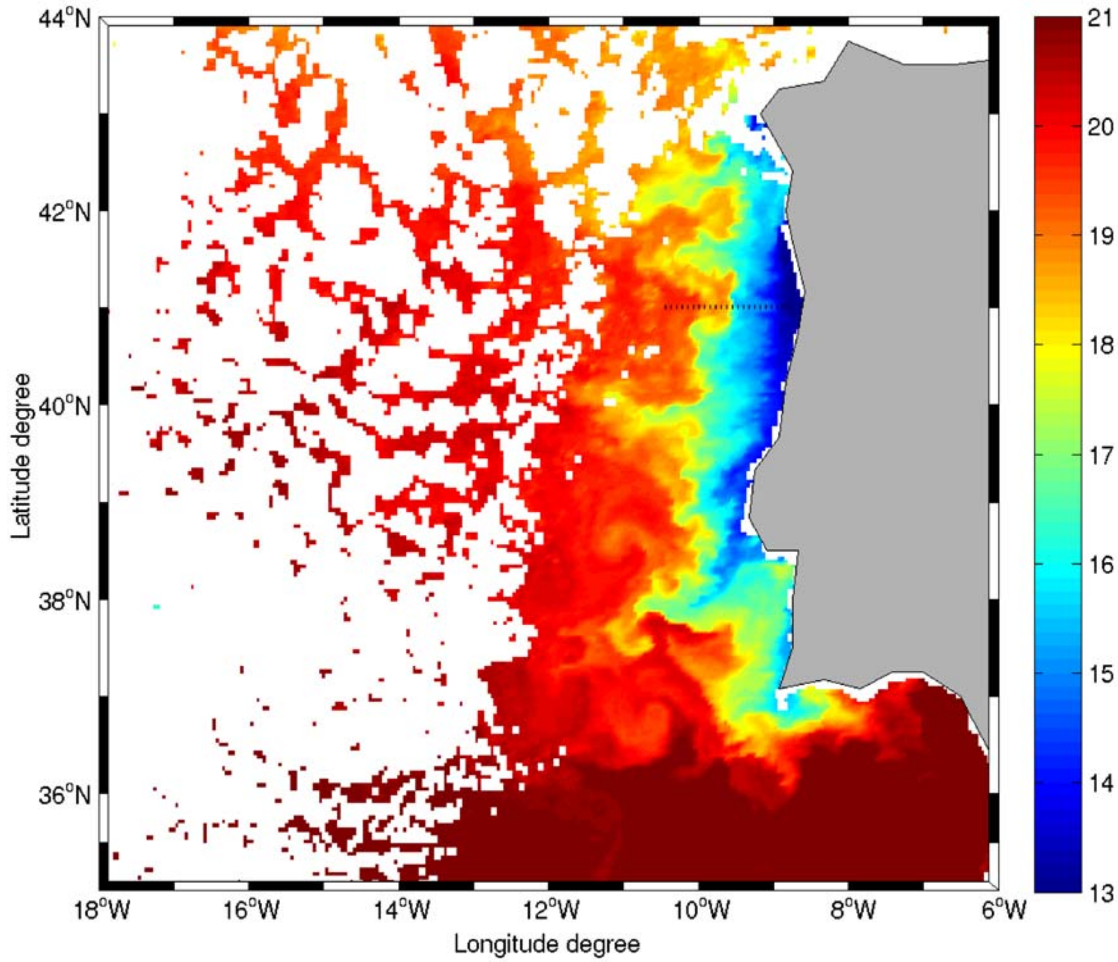
Vincent Rossi, *Yves Morel, Véronique Garçon*

Typical summer situation :

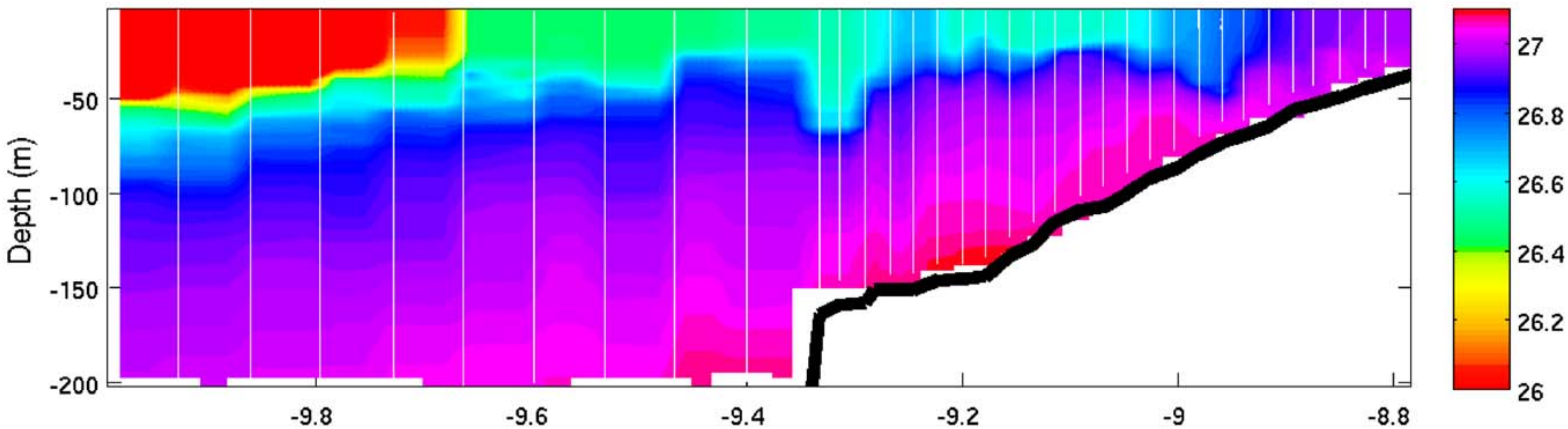


Operations during MOUTON2007

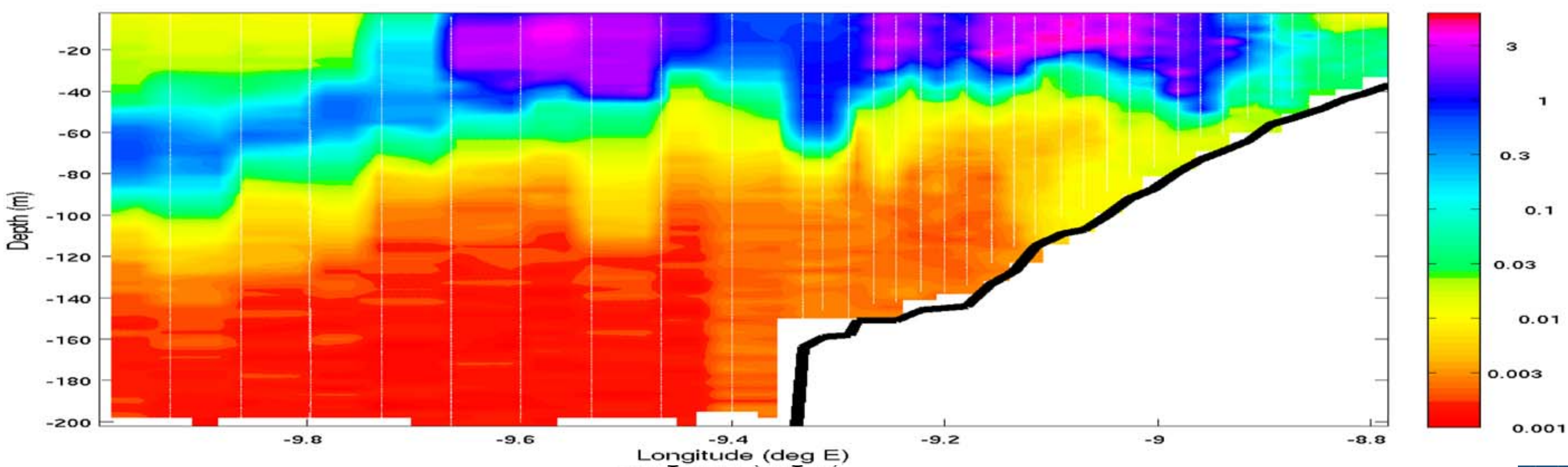


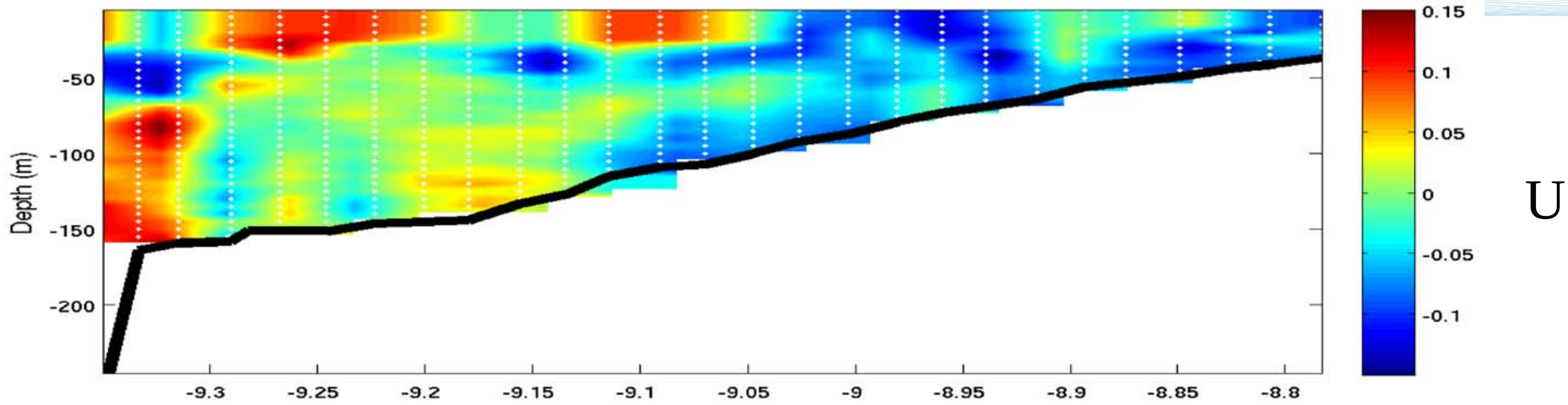


Density

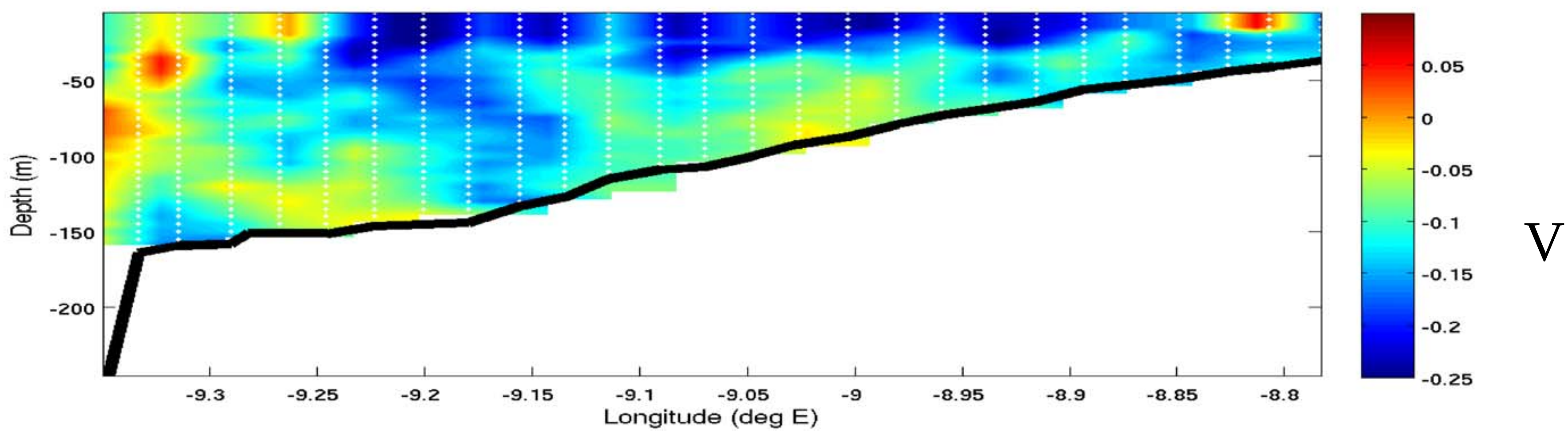


Chl a





Depth (m)
-50
-100
-150
-200
-9.3
-9.25
-9.2
-9.15
-9.1
-9.05
-9
-8.95
-8.9
-8.85
-8.8
0.15
0.1
0.05
0
-0.05
-0.1
U



Depth (m)
-50
-100
-150
-200
-9.3
-9.25
-9.2
-9.15
-9.1
-9.05
-9
-8.95
-8.9
-8.85
-8.8
Longitude (deg E)
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
V

A « PV thinking » approach of upwelling dynamics

POTENTIAL VORTICITY "thinking"

ζ= rot (U)   important quantity

BUT NOT CONSERVED

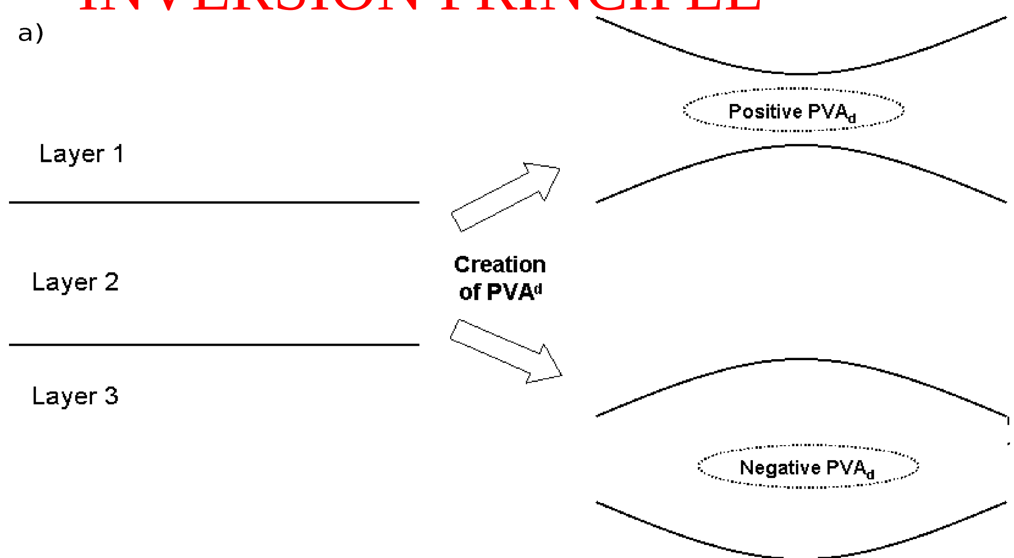
$$PV = (\zeta+f) \,.\, \vec{\nabla} \rho \quad (= (\zeta+f)/h\,)$$

is conserved for each particles if adiabatic motion

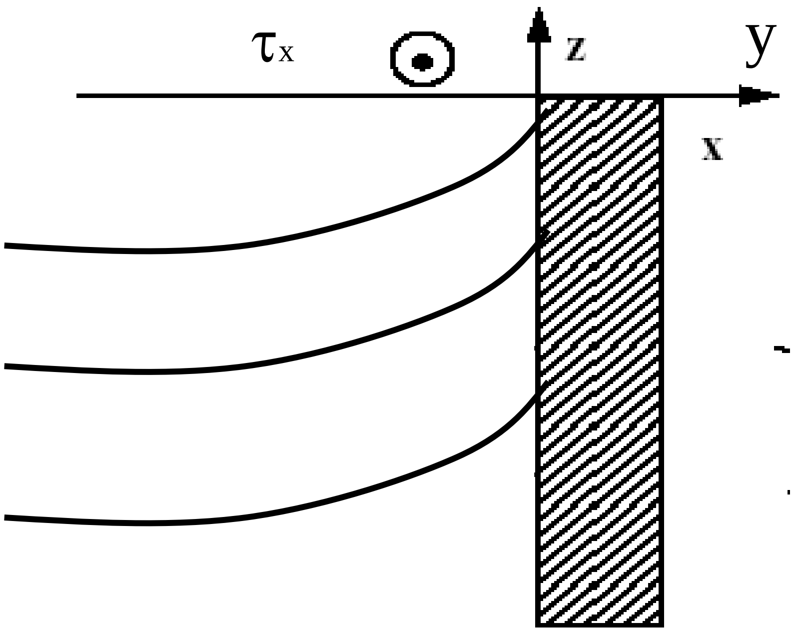
PV = TRACER

The velocity/stratification field can be reconstructed from the knowledge of **PVA** (if geostrophic balance is assumed)

INVERSION PRINCIPLE



Upwelling development



PV = cstt $\Rightarrow \zeta = f \; h/H_{rest}$

+ geostrophy

=> « Kelvin » currents :

$$U = \Sigma_k \; U_k \, e^{-x/R_k}$$

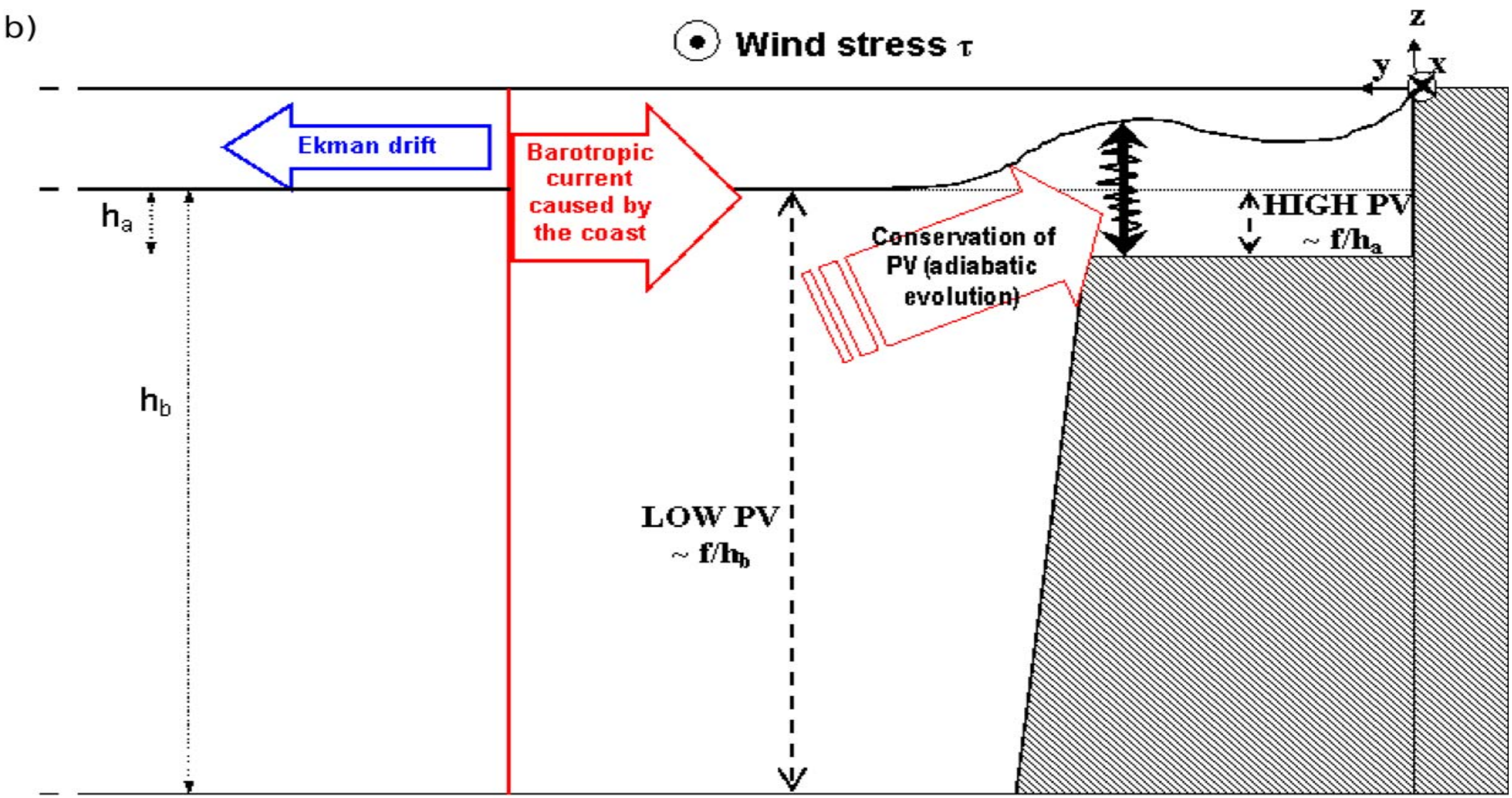
At the coast $V_{(x=0)} = 0$

$\Rightarrow \partial_t U = \tau$

$\Rightarrow U_k = \tau_k \, t$

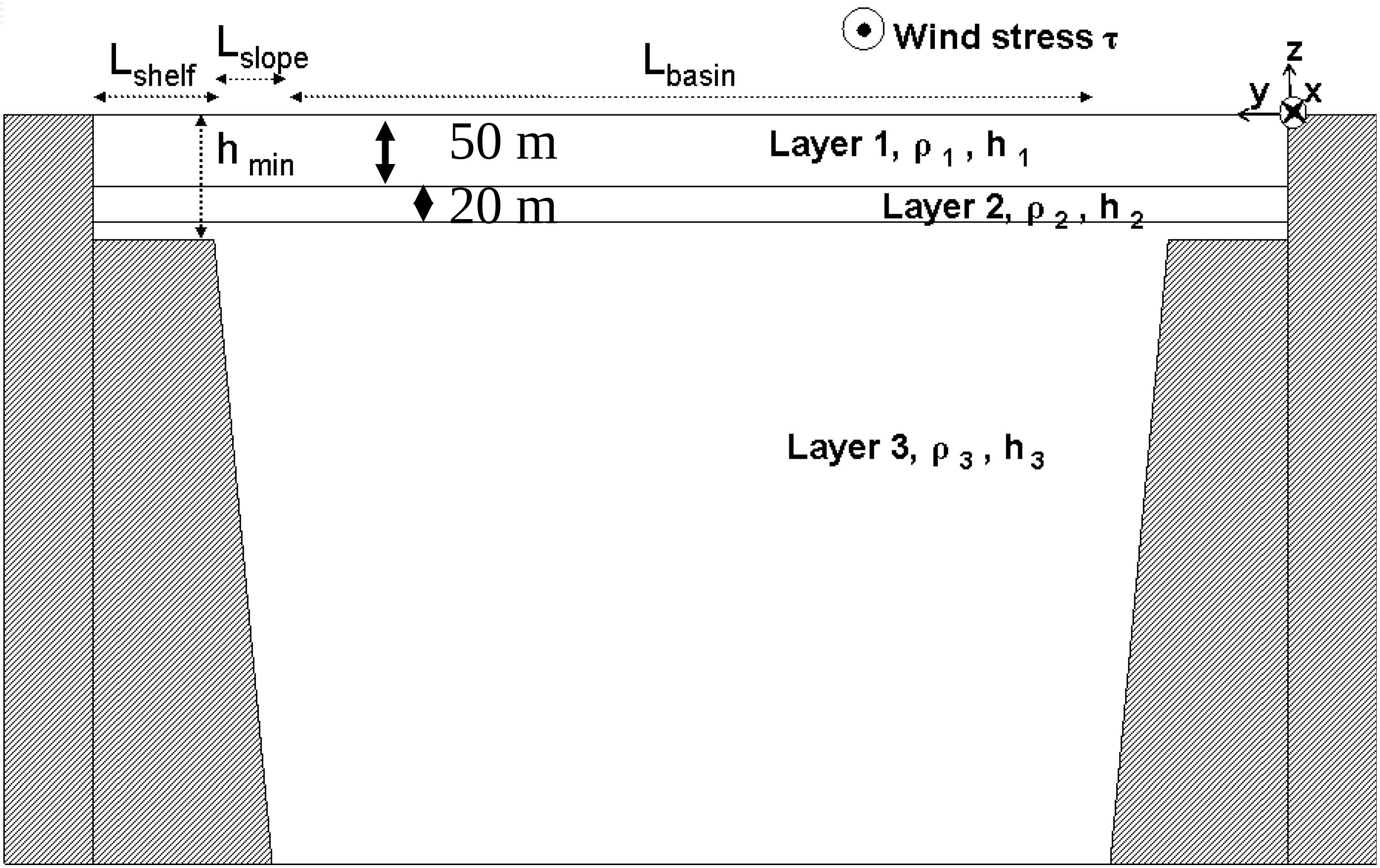
Importance of barotropic mode (Ro ~ 500 km)

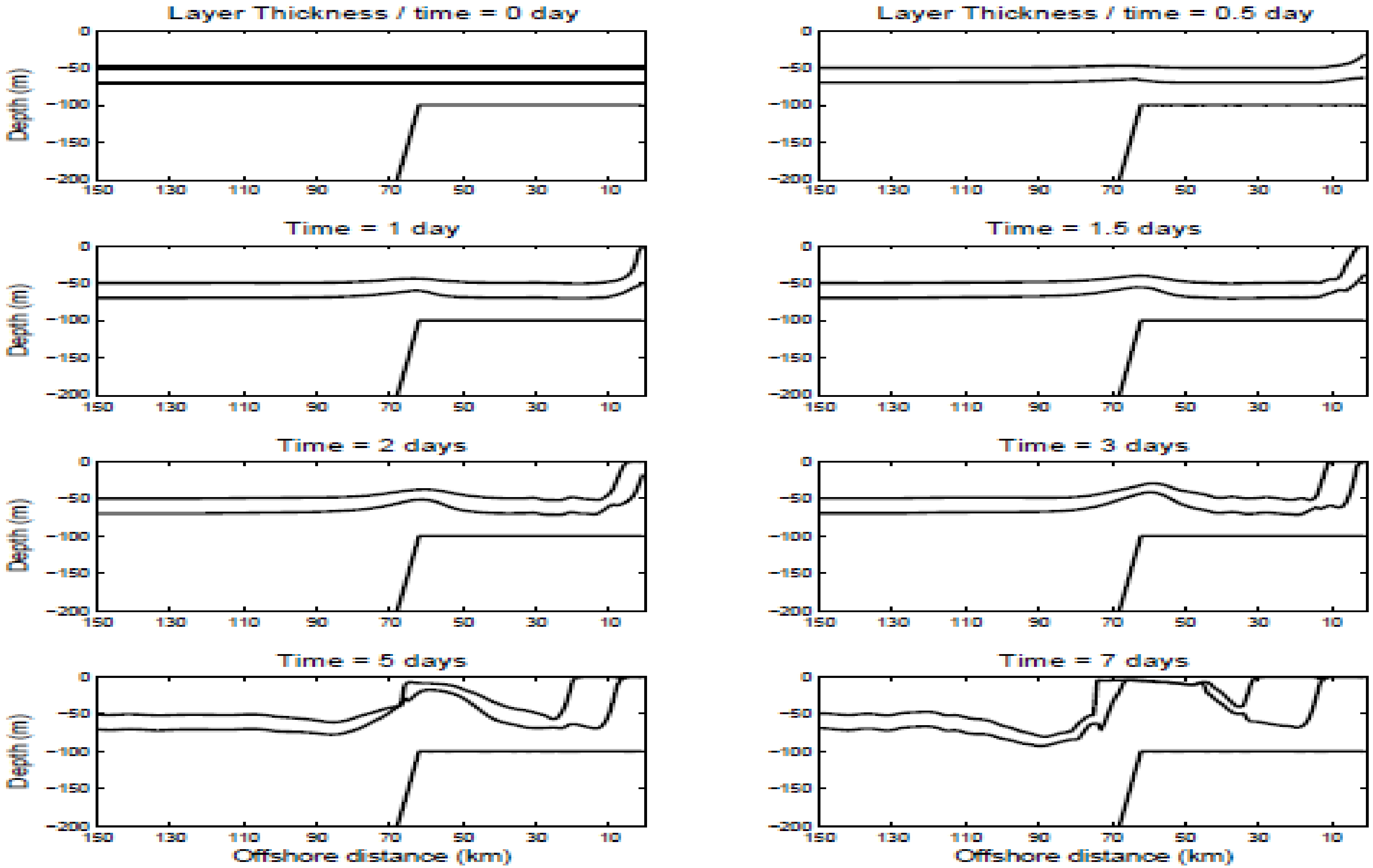
O'Brien & Hurlburt (1972)



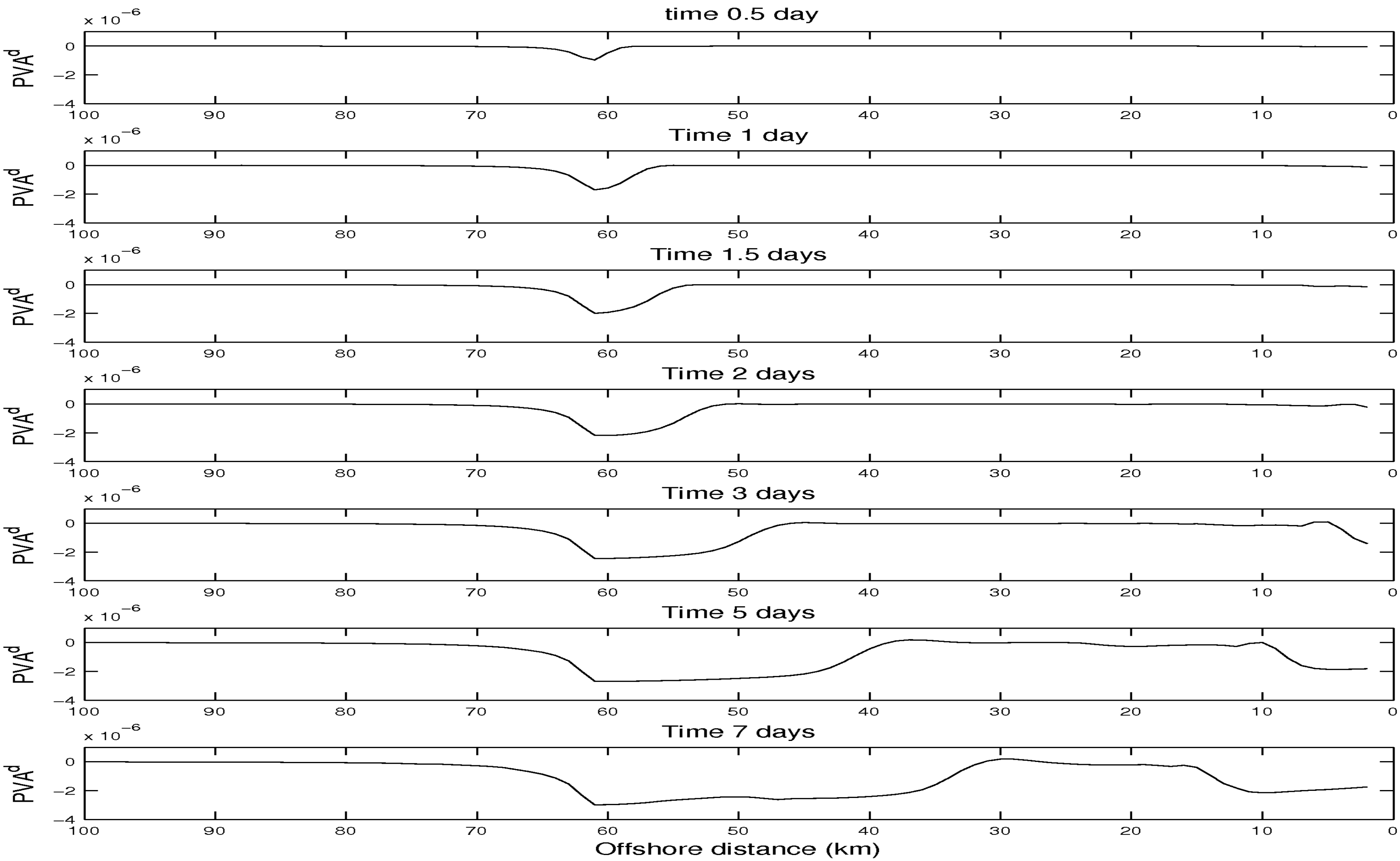
Reference Numerical experiments

Configuration (2D)




Layer Thickness / time = 0 day
Layer Thickness / time = 0.5 day
Time = 1 day
Time = 1.5 days
Time = 2 days
Time = 3 days
Time = 5 days
Time = 7 days
Depth (m)
Offshore distance (km)

PVA layer 3



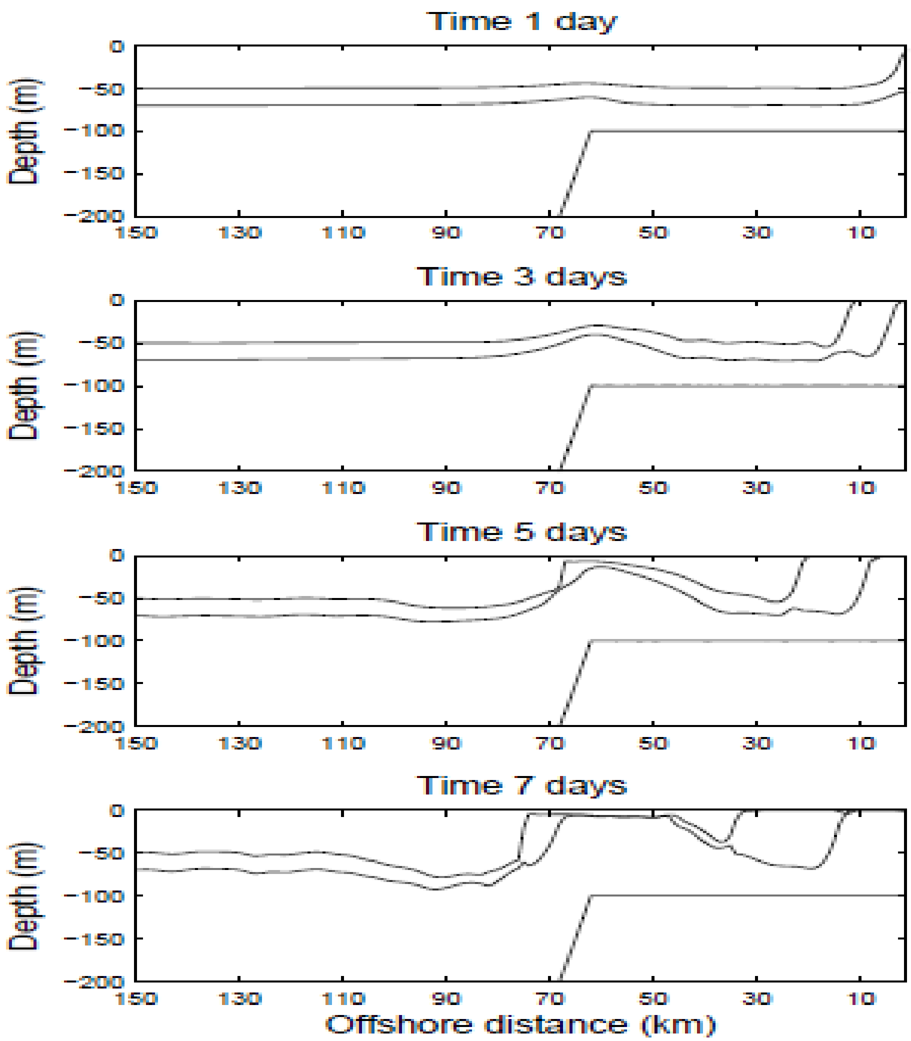
time 0.5 day
Time 1 day
Time 1.5 days
Time 2 days
Time 3 days
Time 5 days
Time 7 days
x 10^−6
PVA^d
0
−2
−4
100
90
80
70
60
50
40
30
20
10
0
Offshore distance (km)

Sensitivity studies

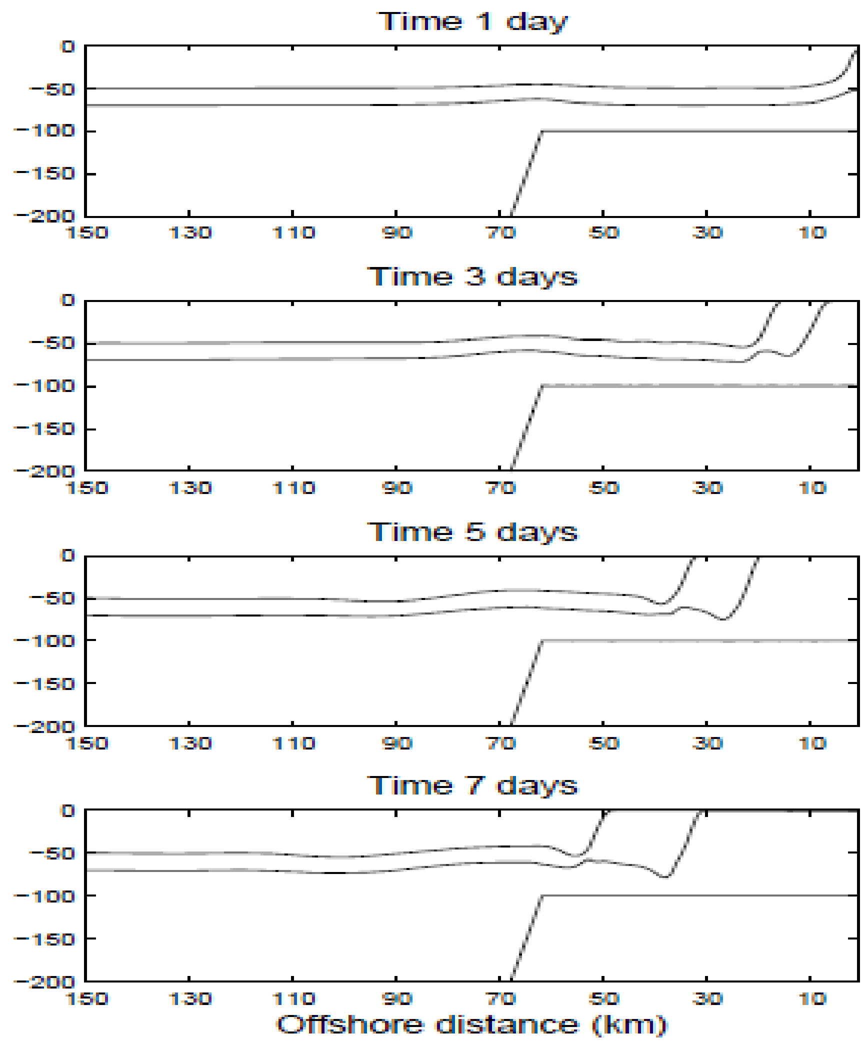
Bottom stress
Shelf width
margin slope
3D

Effect of the Bottom stress

Cd=0 (ref)

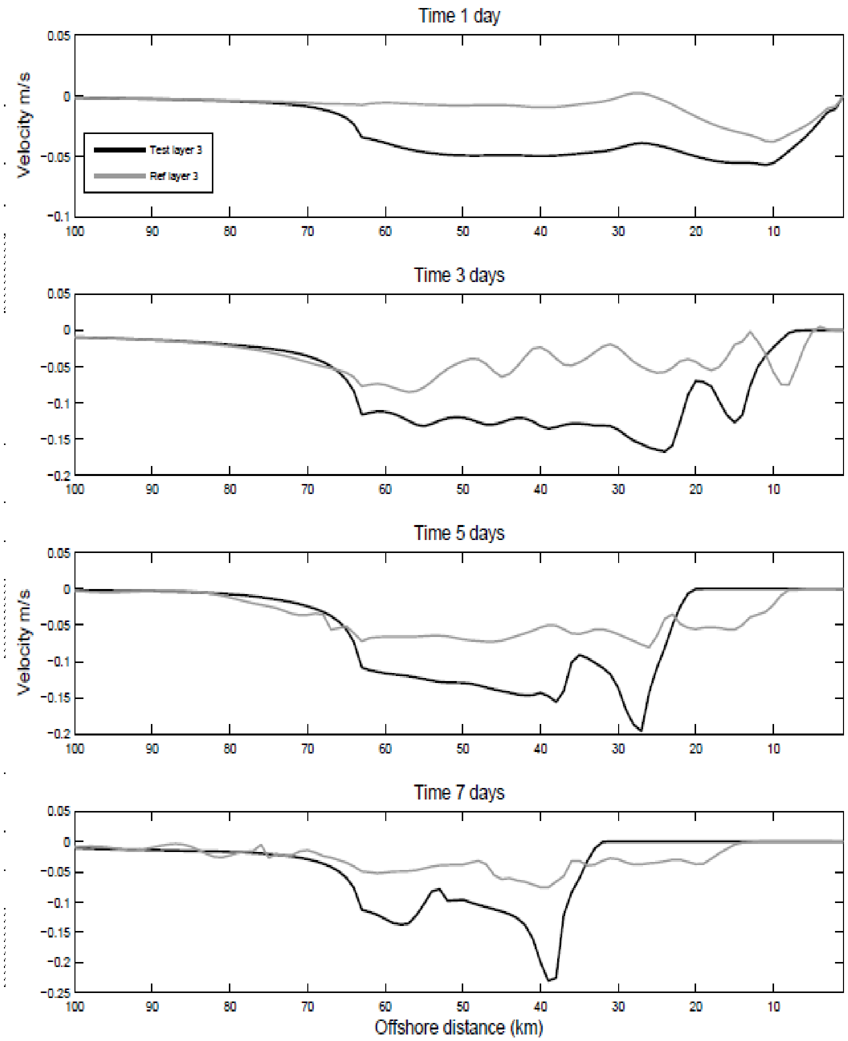


Cd = 3. 10^-3



Effect of the bottom stress : competition between two processes

Acceleration of cross-shelf circulation
=> Enhances shelf upwelling



Modifies PVA in BBL (layer 3)
=> Diminishes PVA and shelf upwelling

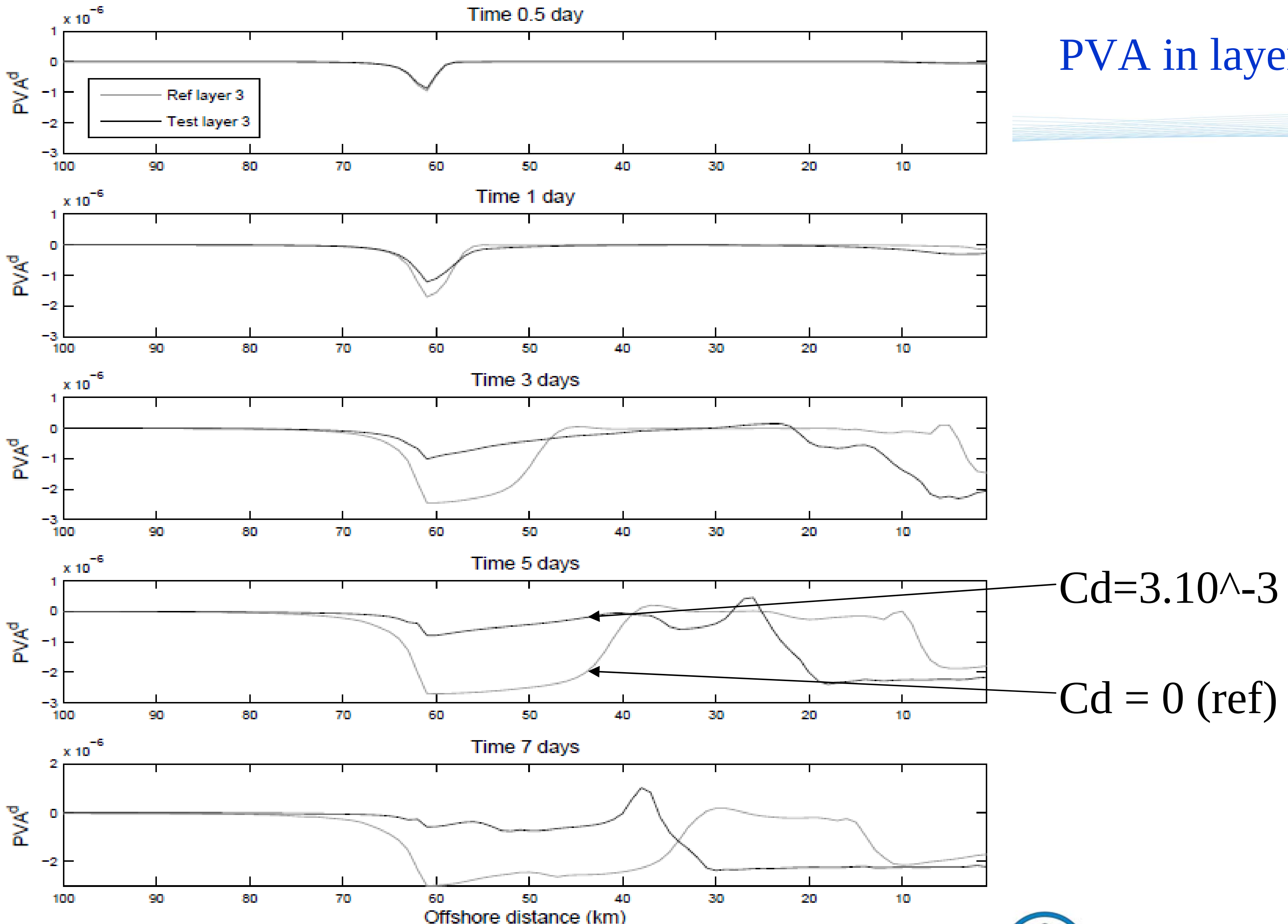
$$\frac{d\ PV_k}{dt} = \frac{1}{h_k} rot(\vec{\tau}_k / h_k)$$

$$\begin{aligned} \frac{d\ PV_k}{dt} &= -\frac{1}{h_k}\partial_y(\tau_x/\rho h_k) \\ &\simeq -\frac{1}{h_k}\partial_y(-C_d \bar{u}\bar{u}/h_k) \\ &= -\frac{1}{h_k}\partial_y(C_d u^2/h_k) \end{aligned}$$

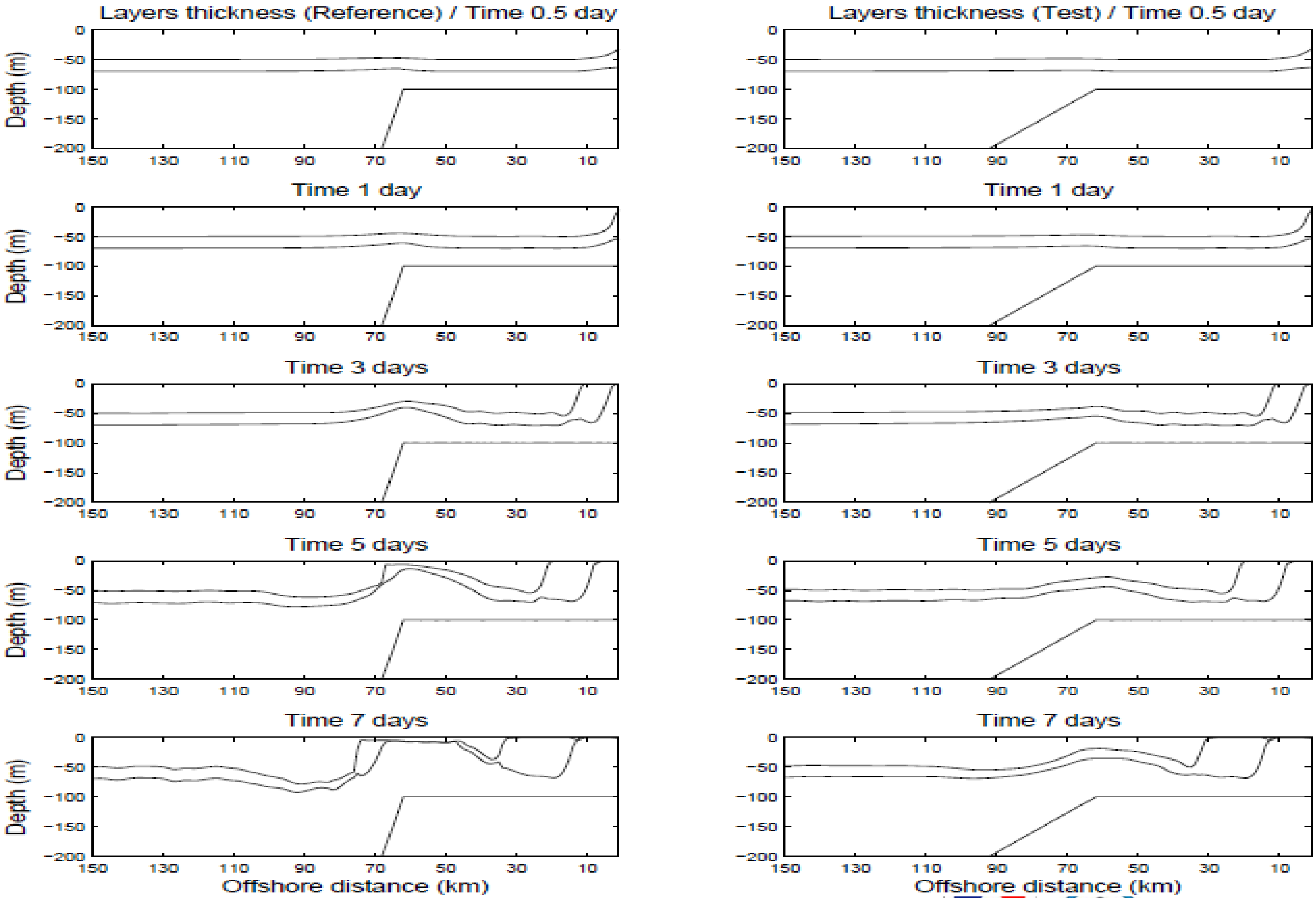
Close to the shelf break, U and 1/h diminishes

=> $$\frac{d\ PV_k}{dt} > 0$$

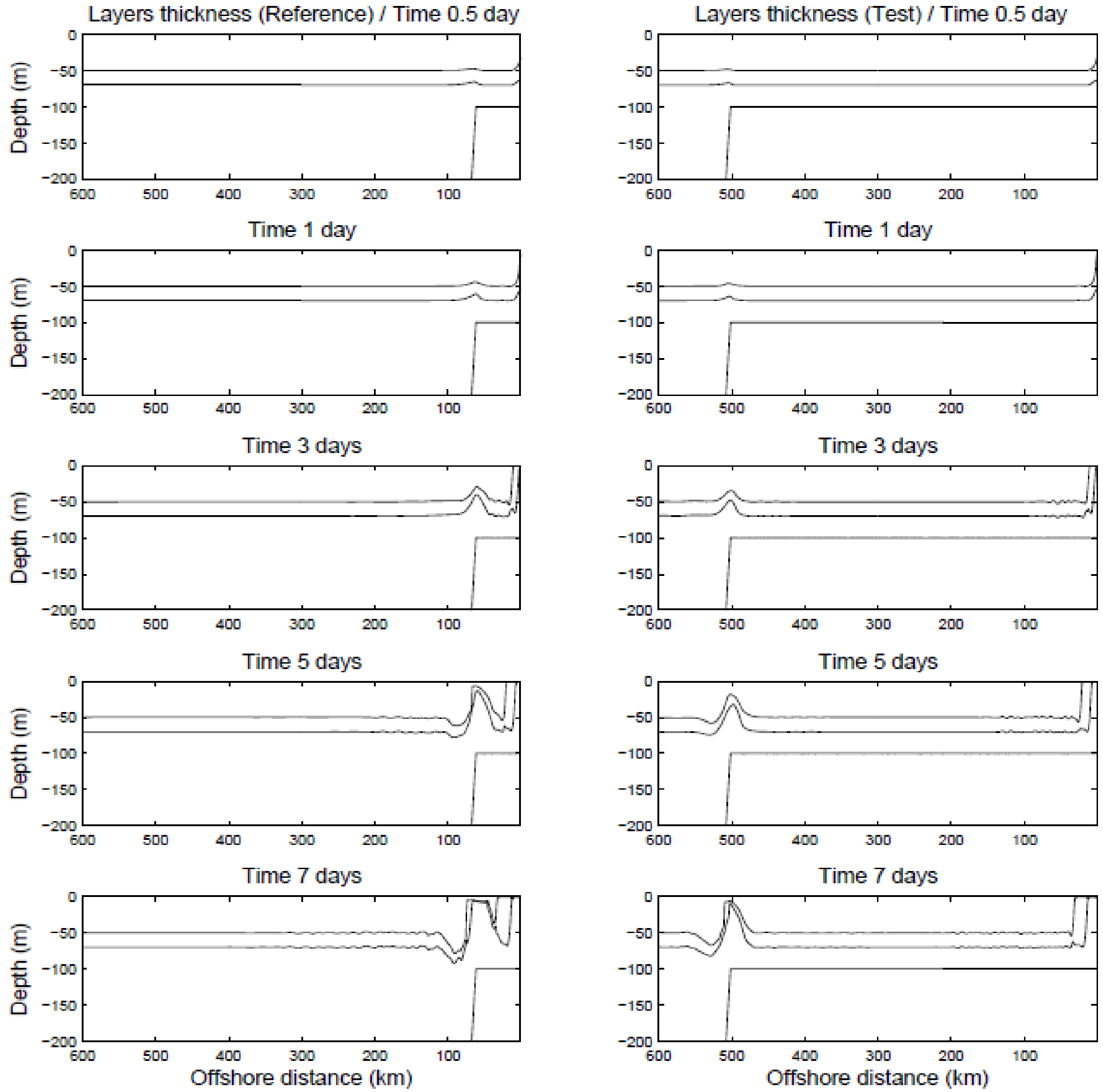
PVA in layer 3



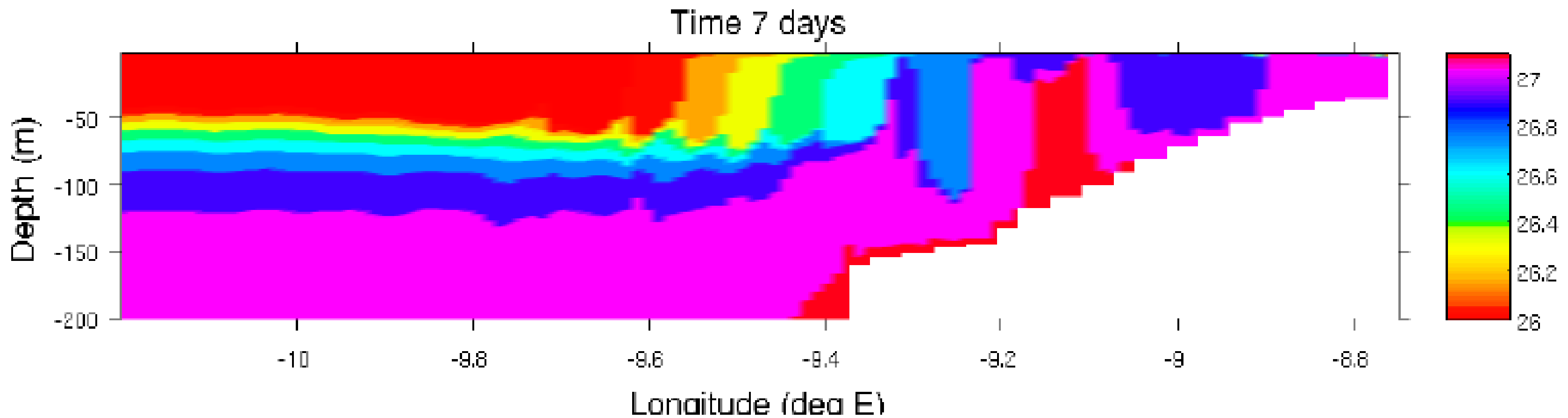
Effect of the continental shelf slope



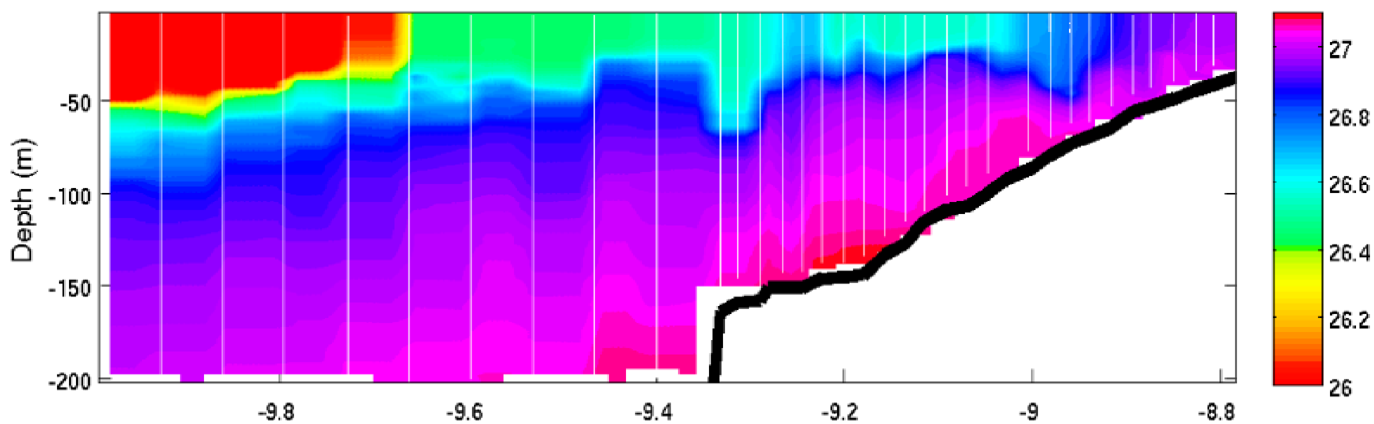
Effect of the shelf width



More « realistic » (2 D) experiment (16 layers)



Observations



Conclusion

There exists shelf break upwellings along portuguese coasts

They can be explained by low PV advection from off-shore
by the barotropic circulation developing on an extended shelf

Bottom friction :
- equilibrates the wind stress effect and the barotropic circulation
- accelerates the cross shore circulation (=> no steady state)
- diminishes the PVA (diabatic process) and the shelf break upwelling

3-D effects play an important role to limit velocity (not taken
Into account here)

These results can be extended to downwelling winds