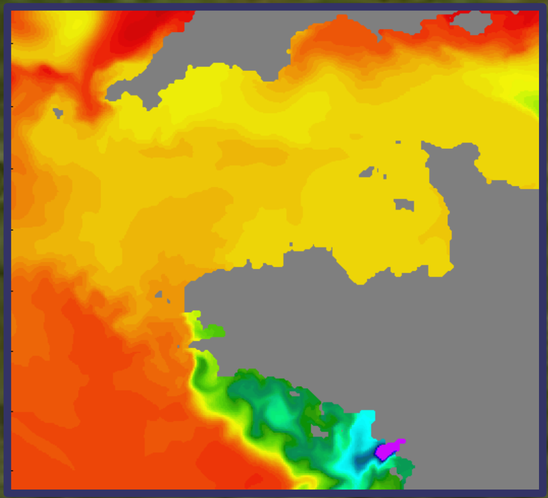
On river numerical implementation in OGCMs



F. Gouillon, M. Boutet, C. Lathuilière,
Y. Morel, R. Baraille

SHOM
L'océan à la carte

Context

- **River inflows** and their associated buoyant plumes are **a major source of nutrients, sediments and contaminants** to coastal waters, where they support diverse and productive ecosystems

- Considerable effort has been made to understand the circulation within river plumes (to determine the transport and dispersal of river-borne matter in the coastal zone)

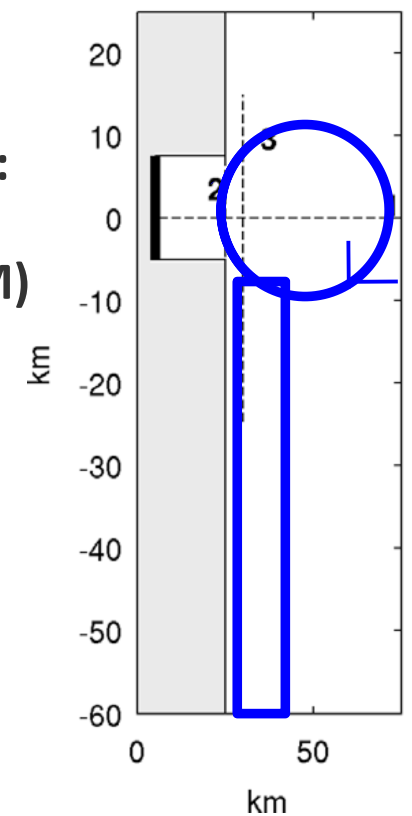
- **In the Bay of Biscay rivers are key** to understand coastal dynamics: Loire 900 m^3/s, Gironde estuary 1080 m^3/s, Adour 360 m^3/s (yearly mean discharge)

Past studies

"The dynamical behavior of the simplest model inflow, a buoyant discharge into a quiescent rotating basin, is not yet fully understood" - Horner et al. (2006)

1. *Nof and Pichevin* (2001) - theory
2. *Yankosvski* (2000) and *Garvine* (2001) – river treatment
3. *Chao* (1988) - estuarine circulation of crucial importance
4. *Schiller et al.* (2010) - estuarine mixing

2 types of river numerical implementation exist:
- Mass flux (NEMO, ROMS, HYCOM)
- Salinity Relaxation (POM, NEMO, HYCOM)

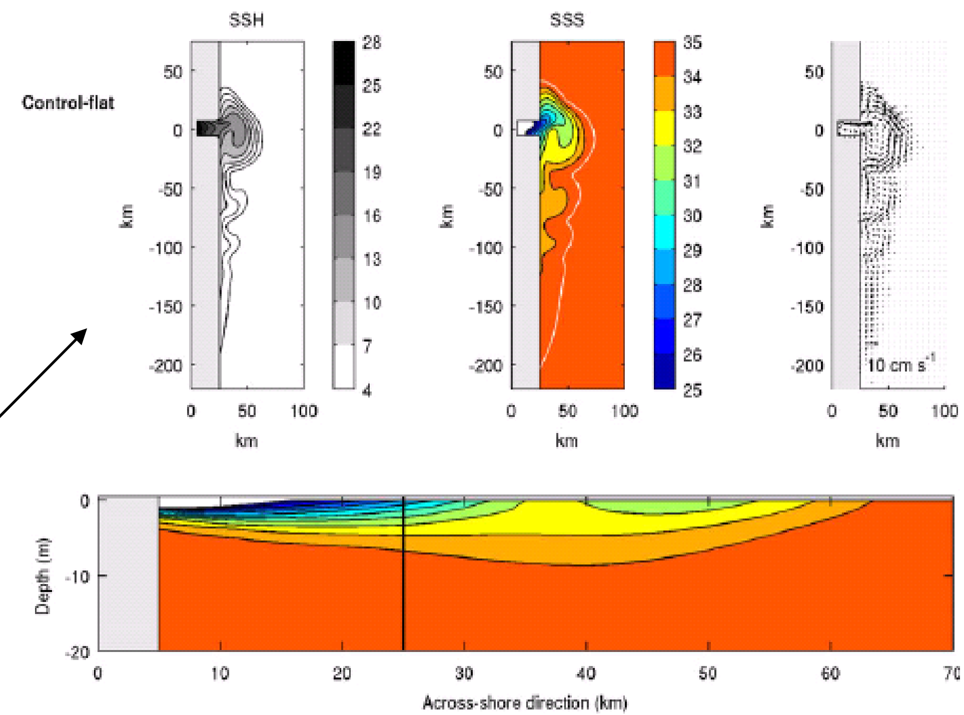


How does the river numerical implementation impacts the solution of the plume dynamics?

Momentum, buoyancy fluxes, controlling the prescribed discharge

Methods

- HYCOM (*z*- mode)
- ***Δx*= 2,5 *km*** (201x90x16)
- flat bottom, closed basin
- f-plane
- temperature passive
- discharge of 1000 m^3/s
- Mass added into the system
- KPP
- bottom friction
- 3 experiments performed :



1) Surface salinity relaxation
'precipitation bogus,' (RELAX SURF)

$$S_1^{n+1} = S_1^n - \alpha_{river} \frac{S_1^n \delta t}{h_1^n}$$

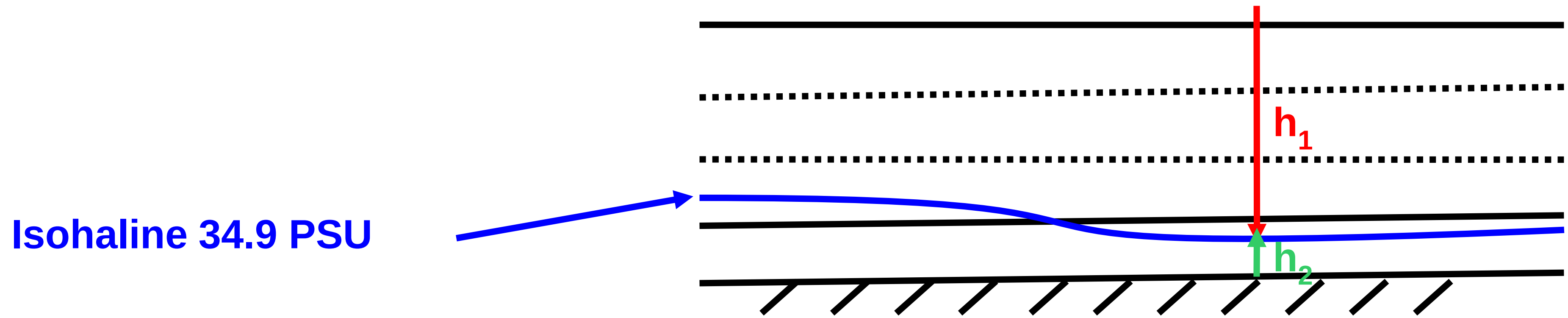
$$\alpha_{river} = \frac{h_1^n \delta h_1}{\delta t (h_1^n + \delta h_1)} \approx \frac{\delta h_1}{\delta t} \left(1 - \frac{\delta h_1}{h_1^n}\right) \approx \frac{\delta h_1}{\delta t}$$

2) The surface salinity relaxation is vertically redistributed (equally added mass in each layer) (RELAX VERT)

3) A true mass flux (MASS FLUX)

Methods

- Dividing the system in a 2-layer flow



Potential vorticity:

$$\text{PV} = \frac{\zeta_n + f}{h_n}, \text{ où } \zeta_n = rot(\mathbf{U}) = \partial_x v - \partial_y u$$

f : facteur de Coriolis

h_n : épaisseur de la couche n

Potential vorticity anomaly

$$\text{PVA} = \frac{\zeta_n + f}{h_n} - \frac{f}{H_{n_{rest}}},$$

où $H_{n_{rest}}$ est l'épaisseur initiale de la couche n

Cannot use the PVA in the first layer (thickness is zero initially)

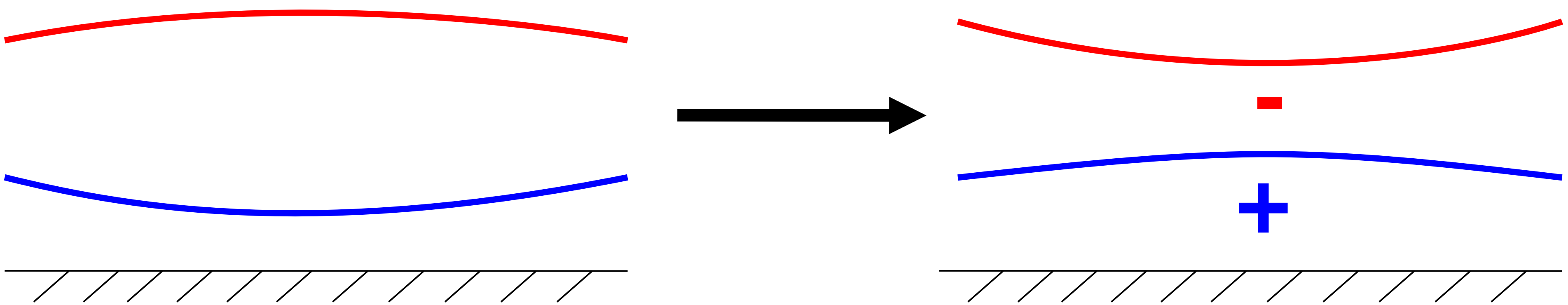
→ Use of the potential height anomaly

$$\text{PH} = \frac{h_n}{\zeta_n + f}$$

$$\text{PHA} = \frac{h_n}{\zeta_n + f} - \frac{H_{n_{rest}}}{f}$$

Why using potential vorticity?

- In adiabatic conditions PV / HP are conserved
- Mixing creates PVA/PHA



Losing mass: PVA > 0 ↔ PHA <0

Adding mass: PVA < 0 ↔ PHA >0

For geostrophic dynamic:

- knowing the potential vorticity field allows to reconstruct the dynamic of the system
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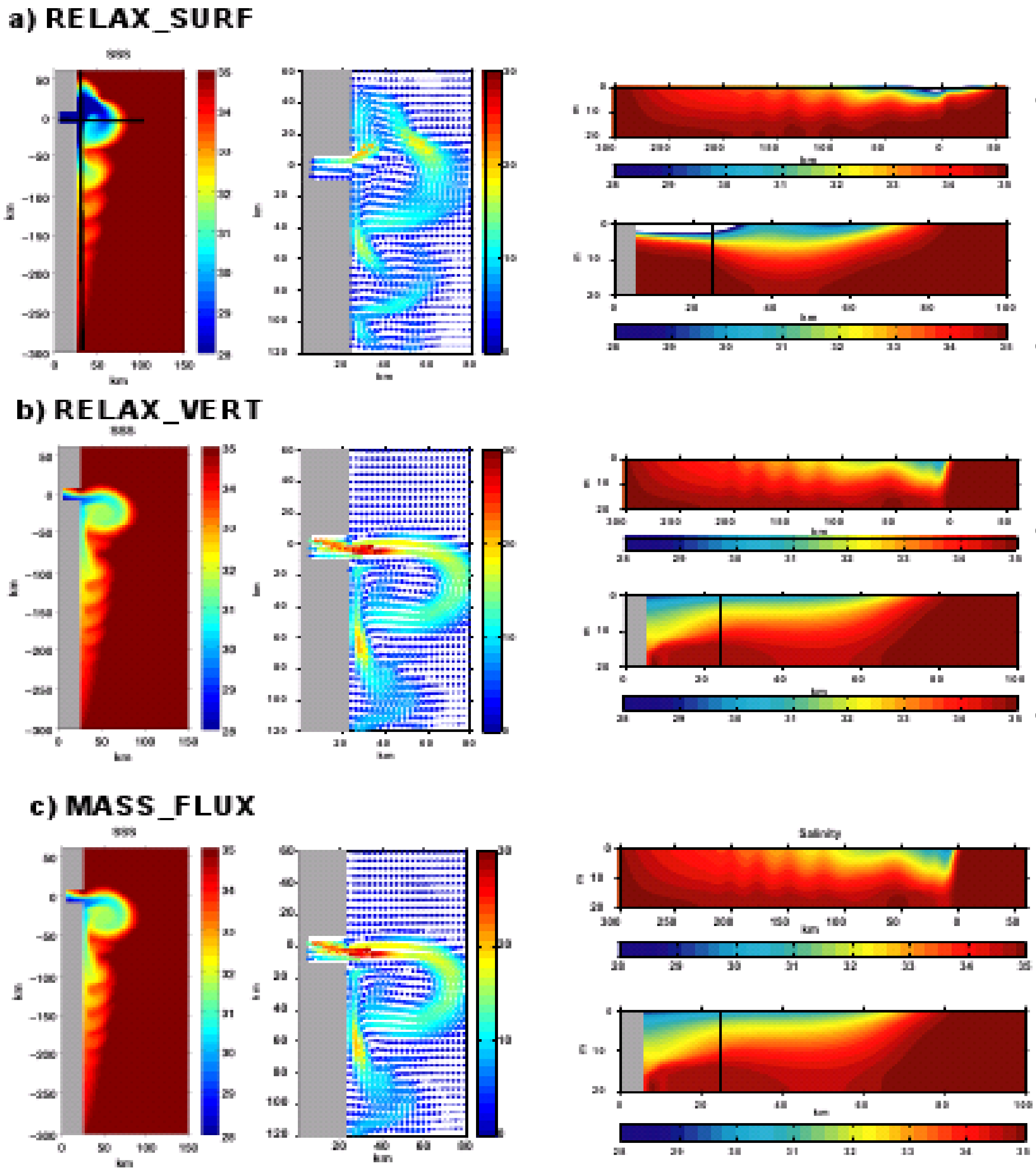
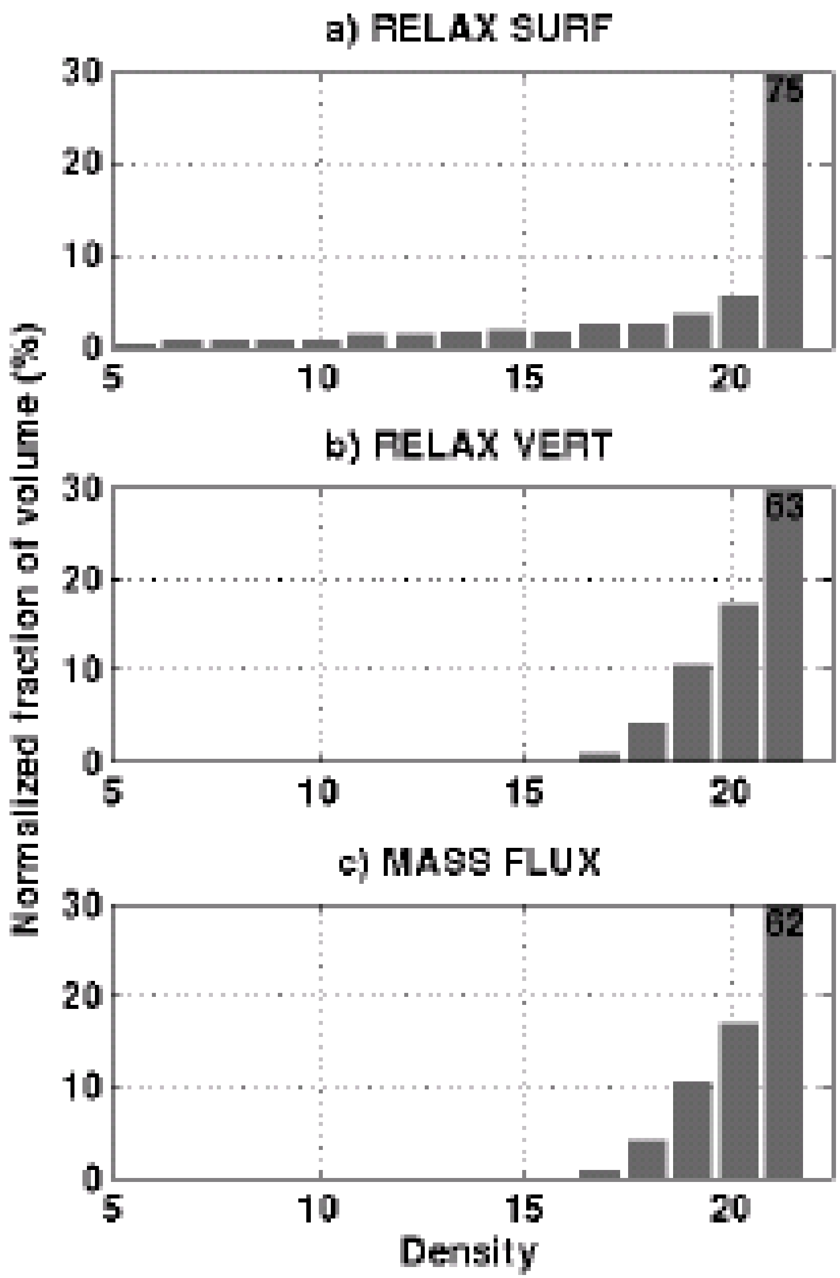
Qualitative comparison (salinity, currents)



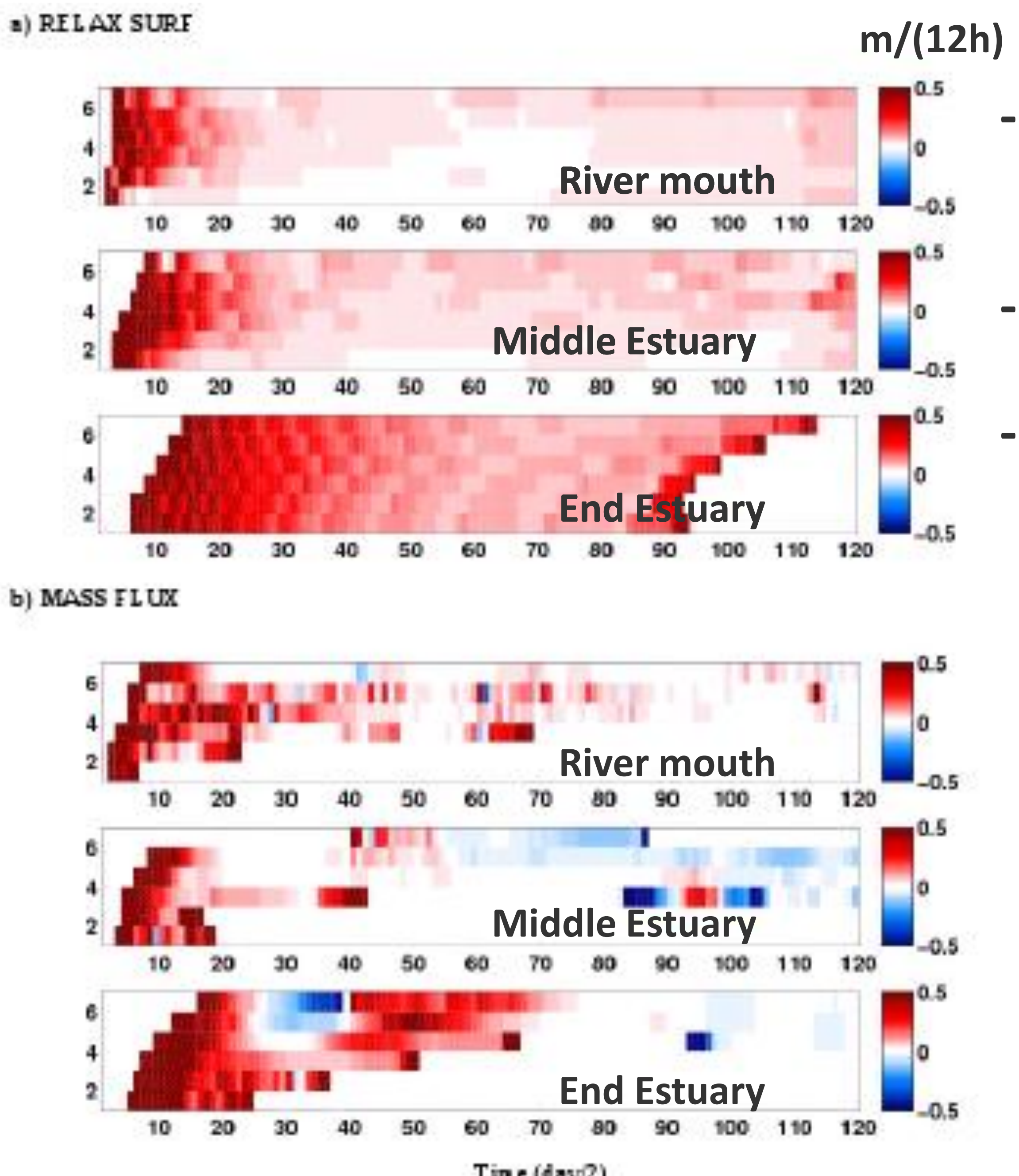
- Fresher water at the surface for the RELAX SURF
- Front location quite similar
- Weaker surface velocities for RELAX SURF
- Higher vertical distribution for RELAX VERT and MASS FLUX

Newly density range created (in estuary)



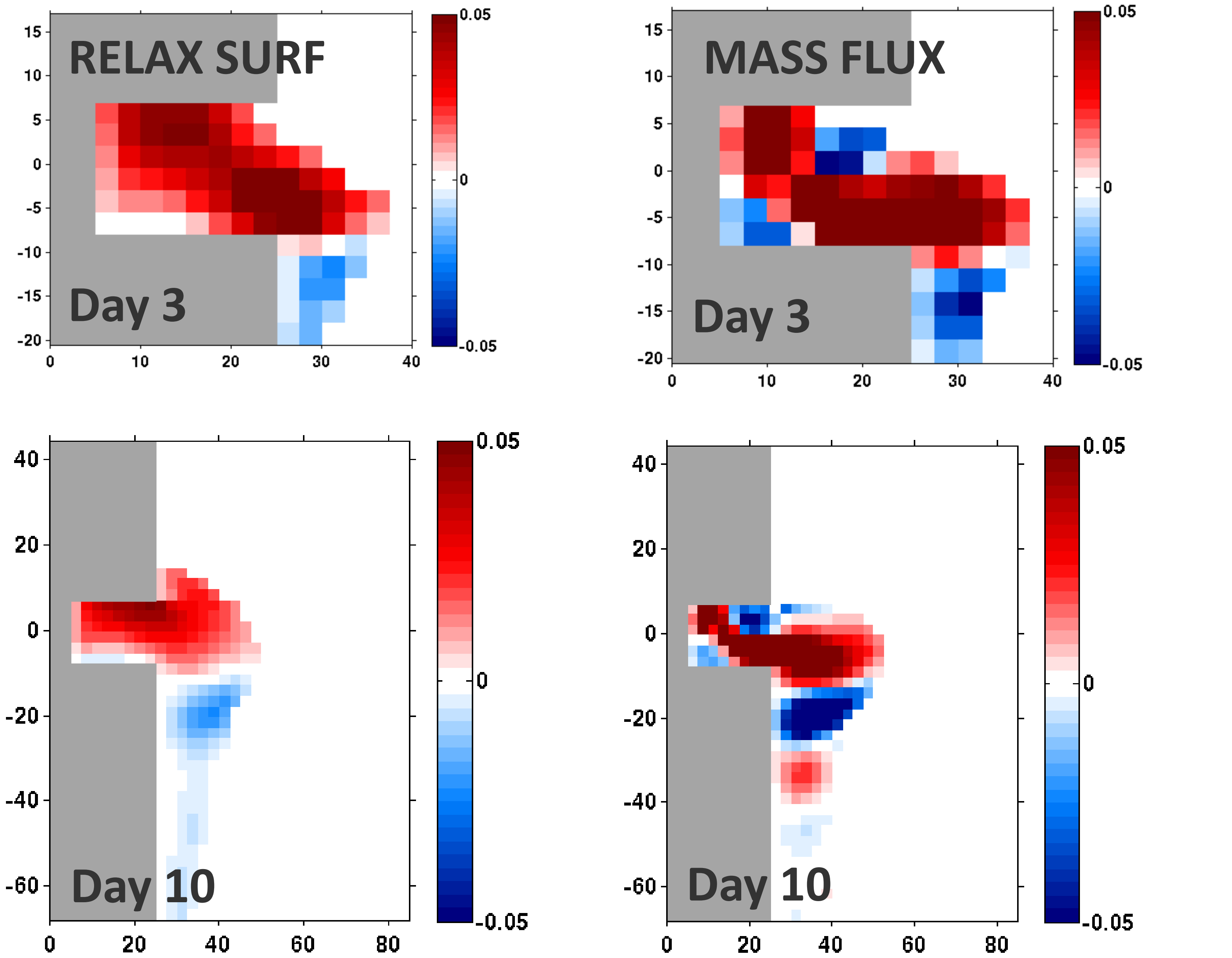
- Higher occurrences of initial density for the RELAX SURF due to less mixing : bottom waters are not impacted
- Wide tail of density ranges created in RELAX SURF due to the relaxation approach
- RELAX VERT and MASS FLUX are similar !

Upper layer thickness variability



- Homogeneous variability in the RELAX SURF experiment
- Reach a stationnary state
- More variability in MASS FLUX with a decreasing thickness at some times north of the estuary (due to the higher baroclinic behavior)

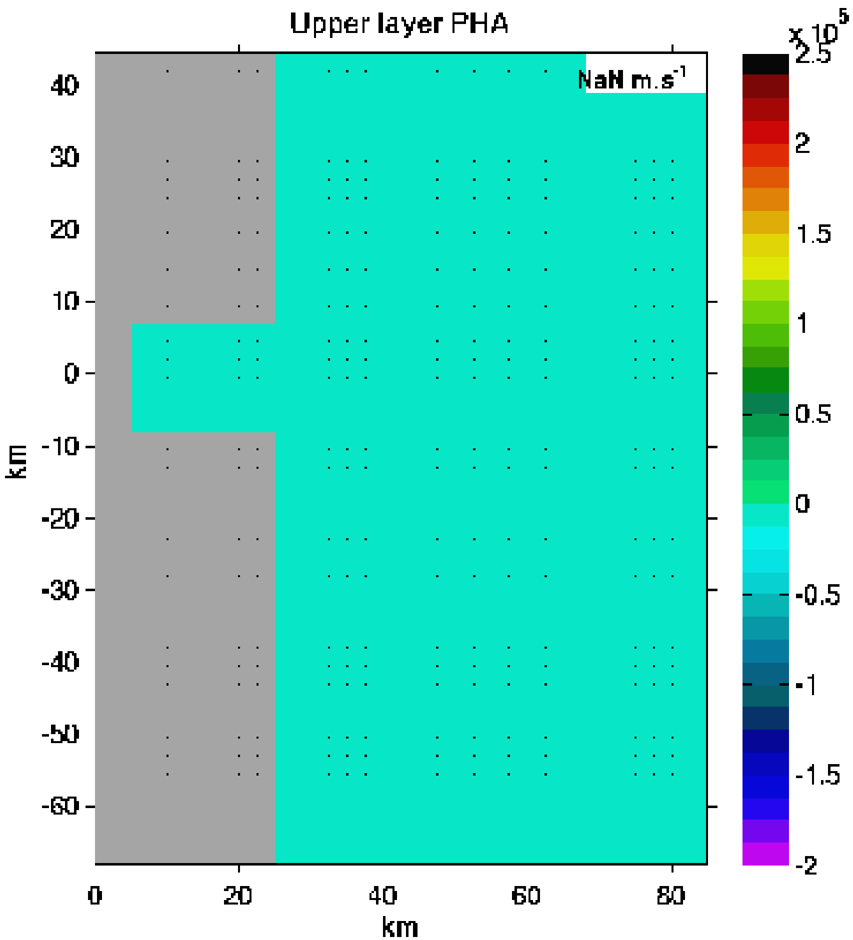
Zonal Velocity field



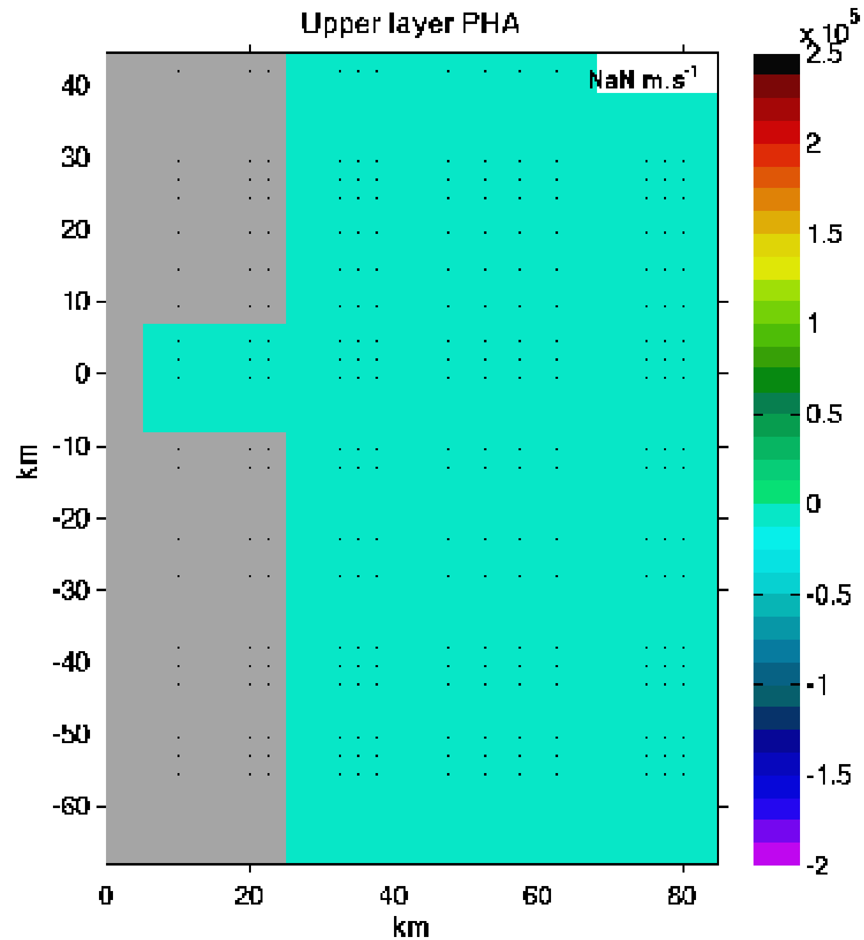
PHA field

Upper layer PHA (colored), Lower layer PHA (contoured)

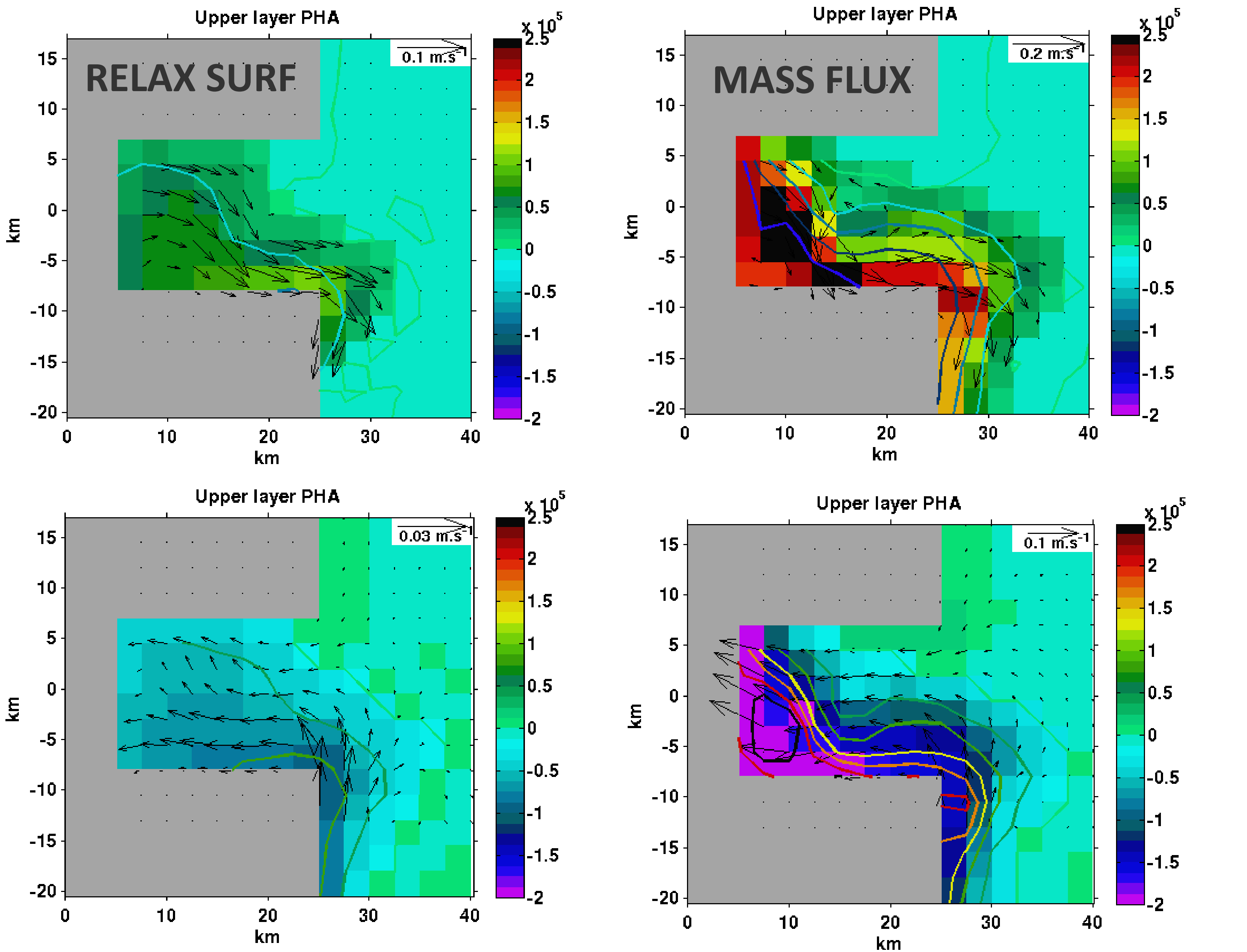
RELAX SURF



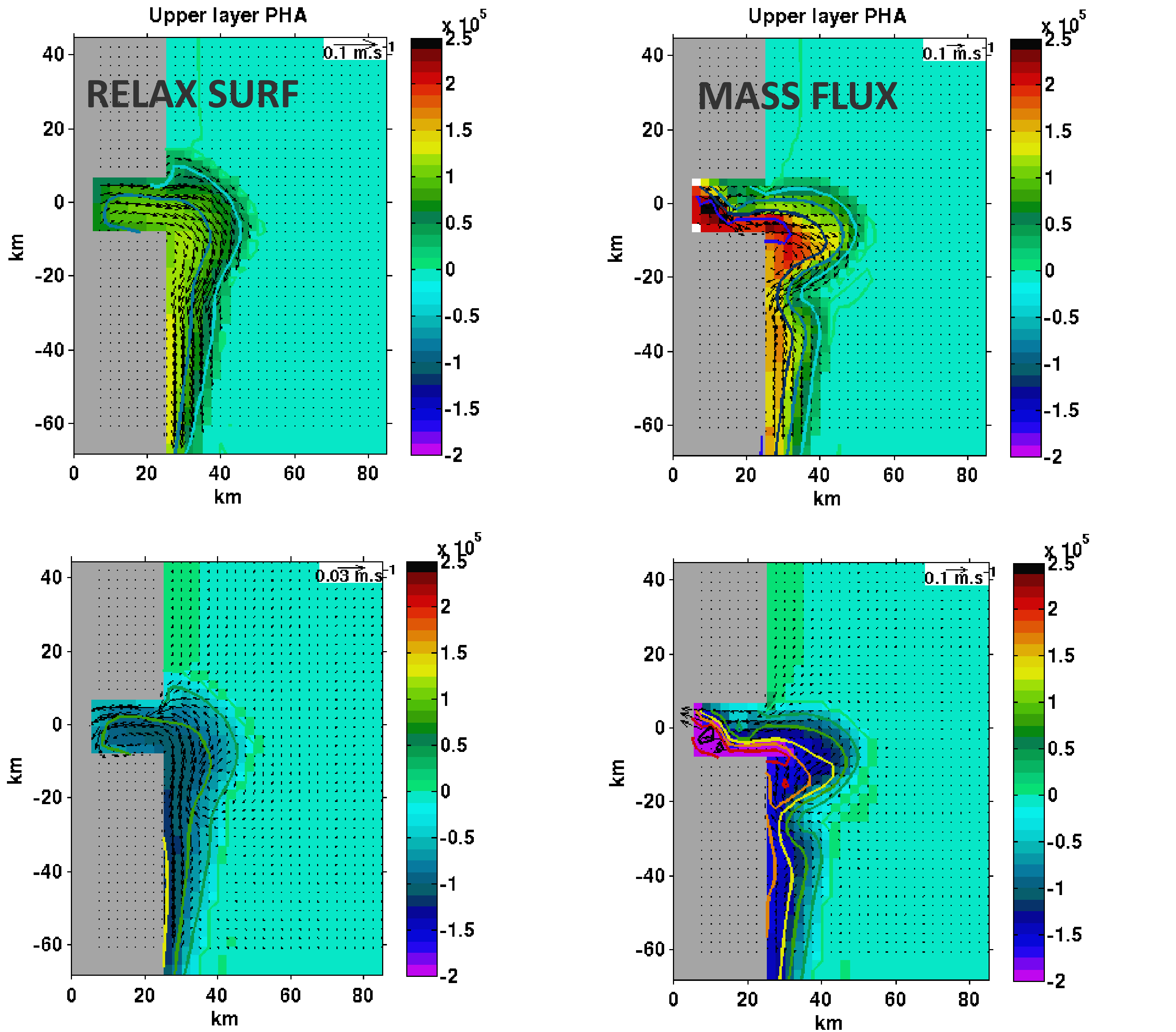
MASS FLUX



PHA field (day 3)

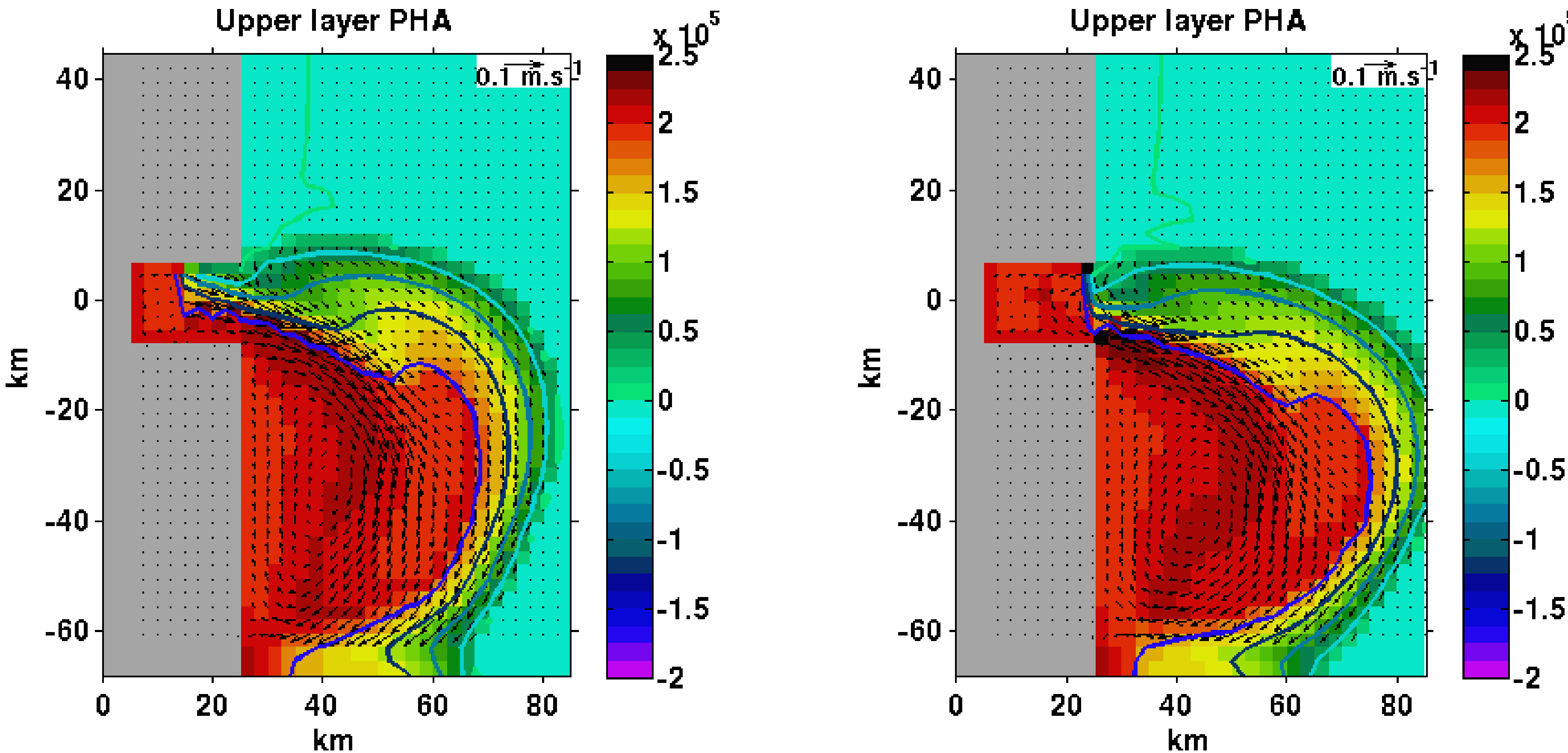


PHA field (day 10)



Sensitivity to relaxation spreading

Half estuary **Full estuary**



The cyclonic recirculation also exists when spreading the relaxation forcing

Conclusion

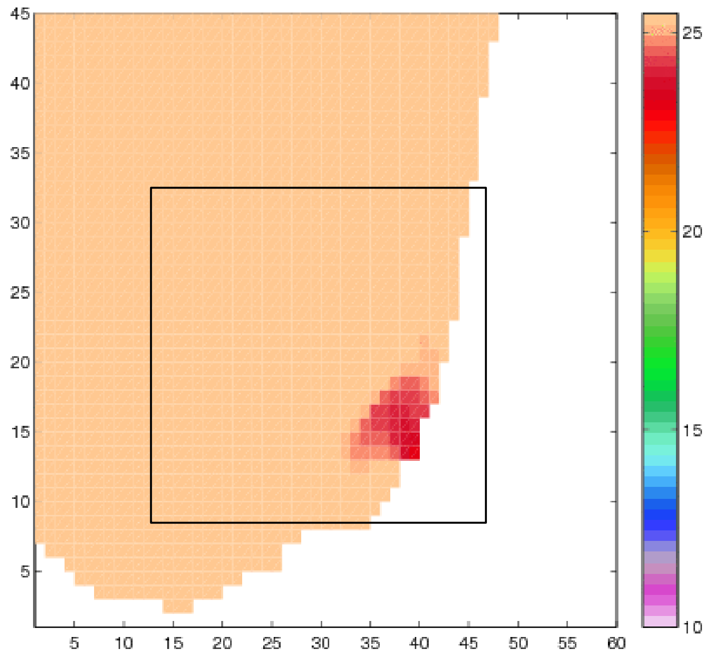
- Documentation of the impact of river numerical implementation has been made
- Mixing and geometry of the basin are critical for near and far field circulation circulation
- RELAX VERT = MASS FLUX for this specific configuration (geostrophic adjustement dominates)
- PV diagnostics allows an explanation for the river plume dynamics

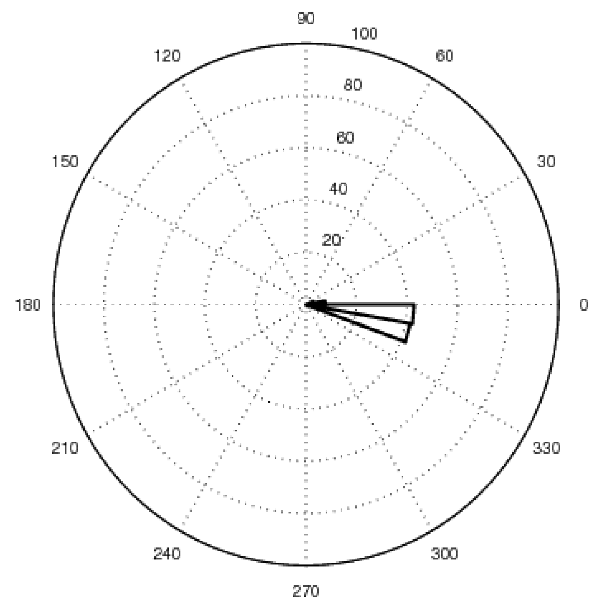
- Sensitivity tests have been performed but not yet fully analyzed (model horizontal and vertical resolution, lateral conditions, mixing schemes, etc.)

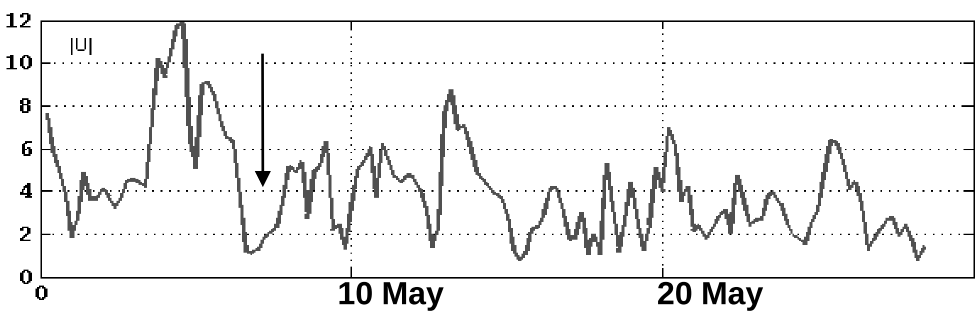
- Future work includes adding analytical tides and wind forcing to this configuration and realistic studies

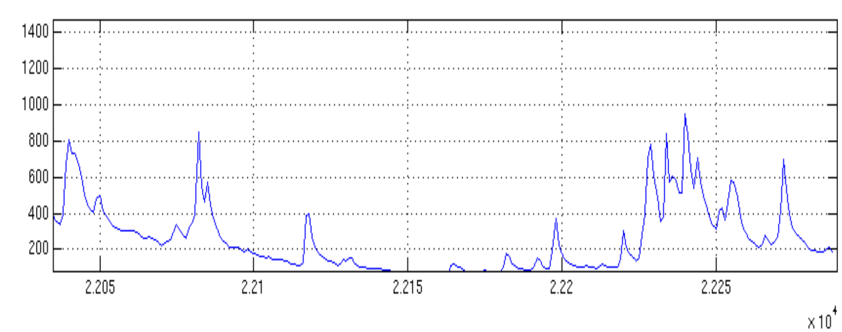
A realistic case: Adour

Is the Adour a good choice for application (weak tides, discharge and forcing, coast geometry)?



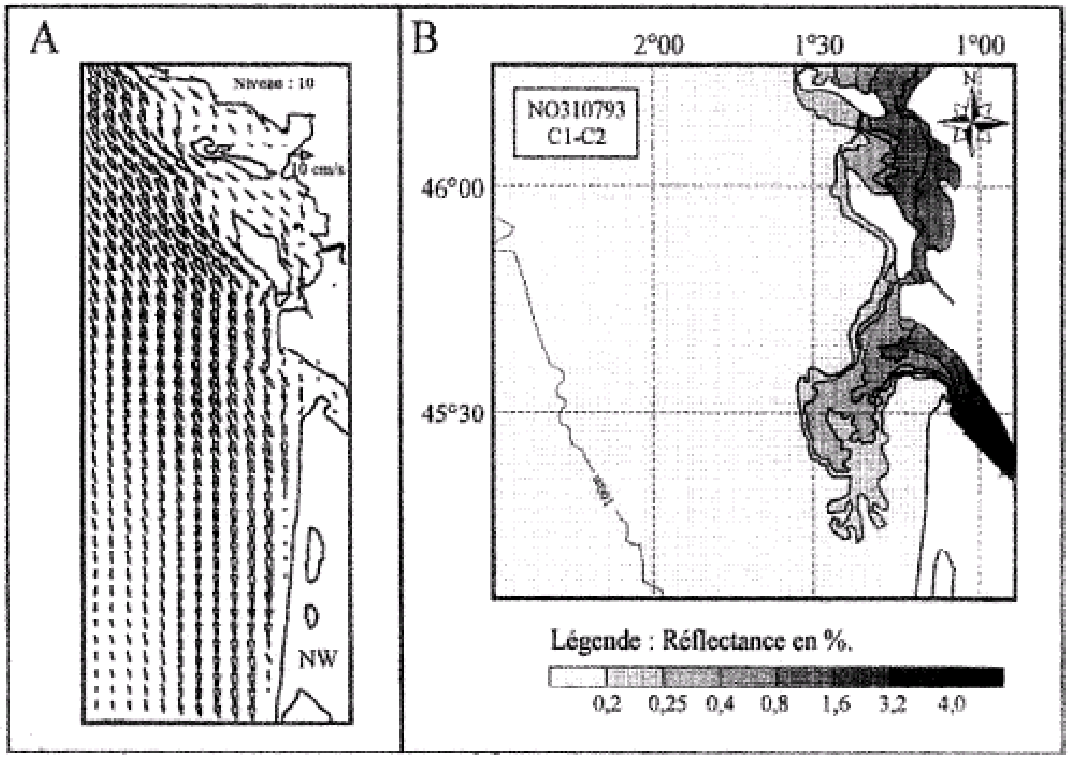






A realistic case: Gironde

North-westerly winds (reversal) during Spring with weak discharge: favor the advection of river plume to the open ocean and South (*Lazure and Jégou* 1998, *Hermida et al.* 1998) which last all Summer.



Surface currents

Image AVHRR/NOAA

Is it the case in 2010?

A realistic case

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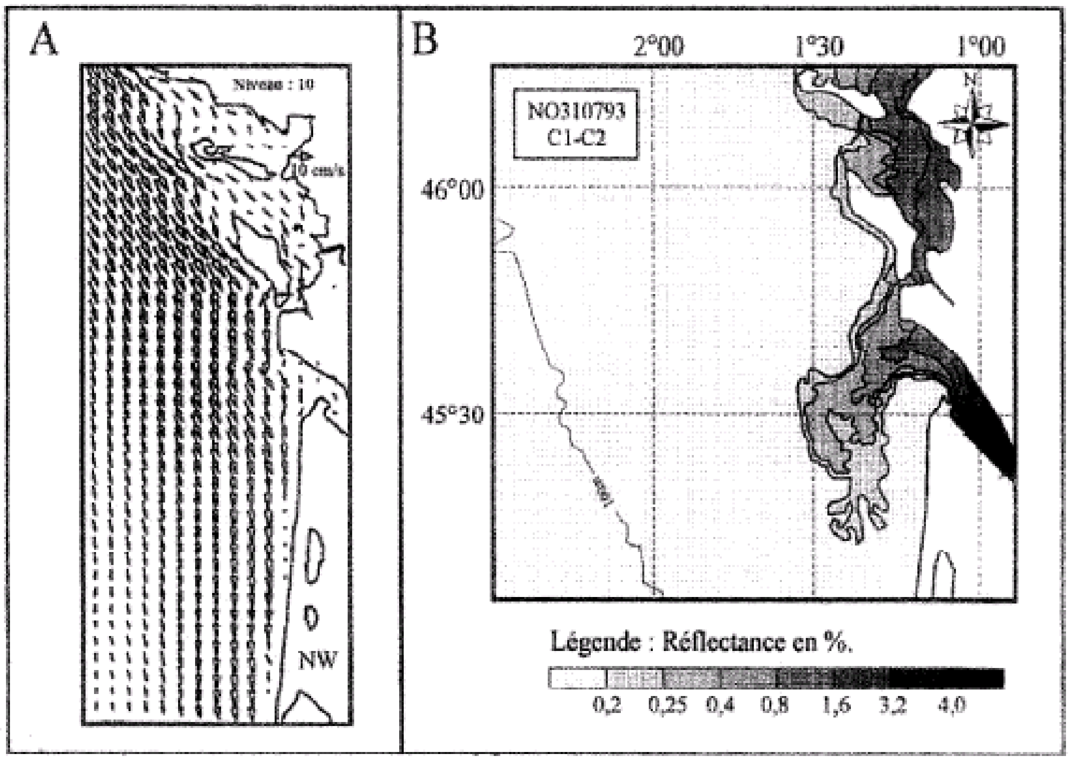

Surface currents

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