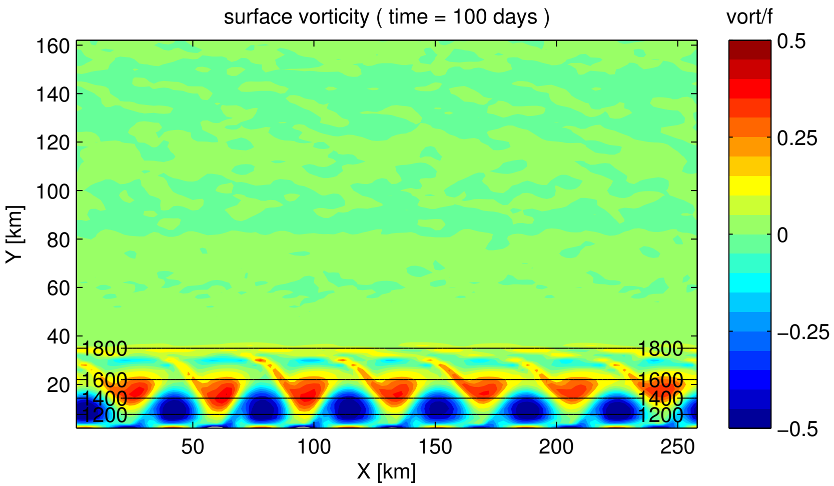
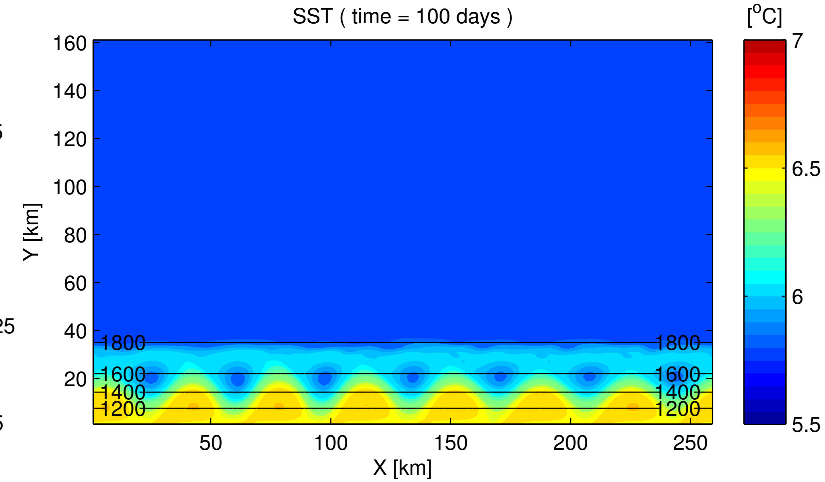
Meso and sub meso scale dynamics of coastal currents along a steep shelf bathymetry





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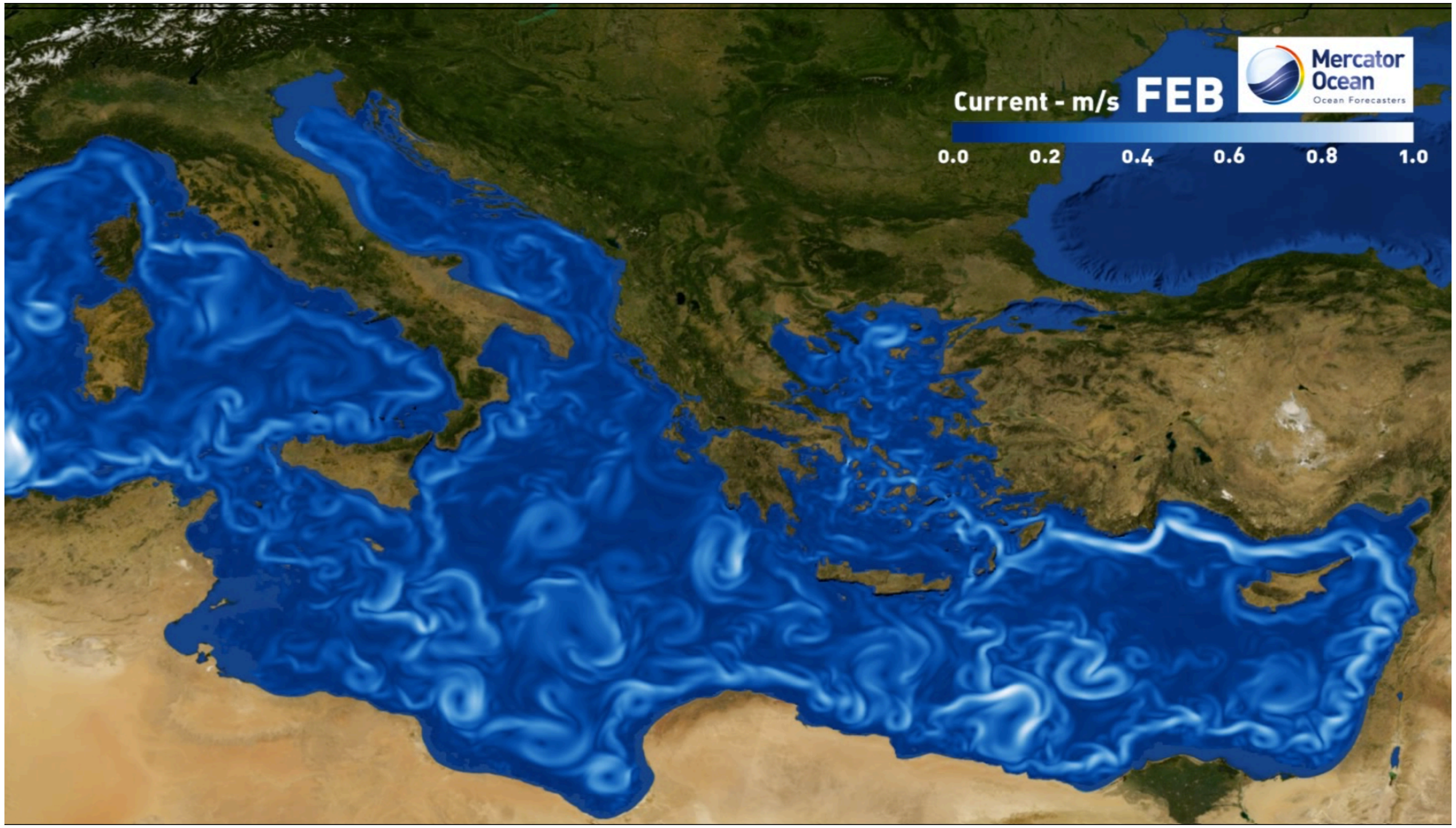
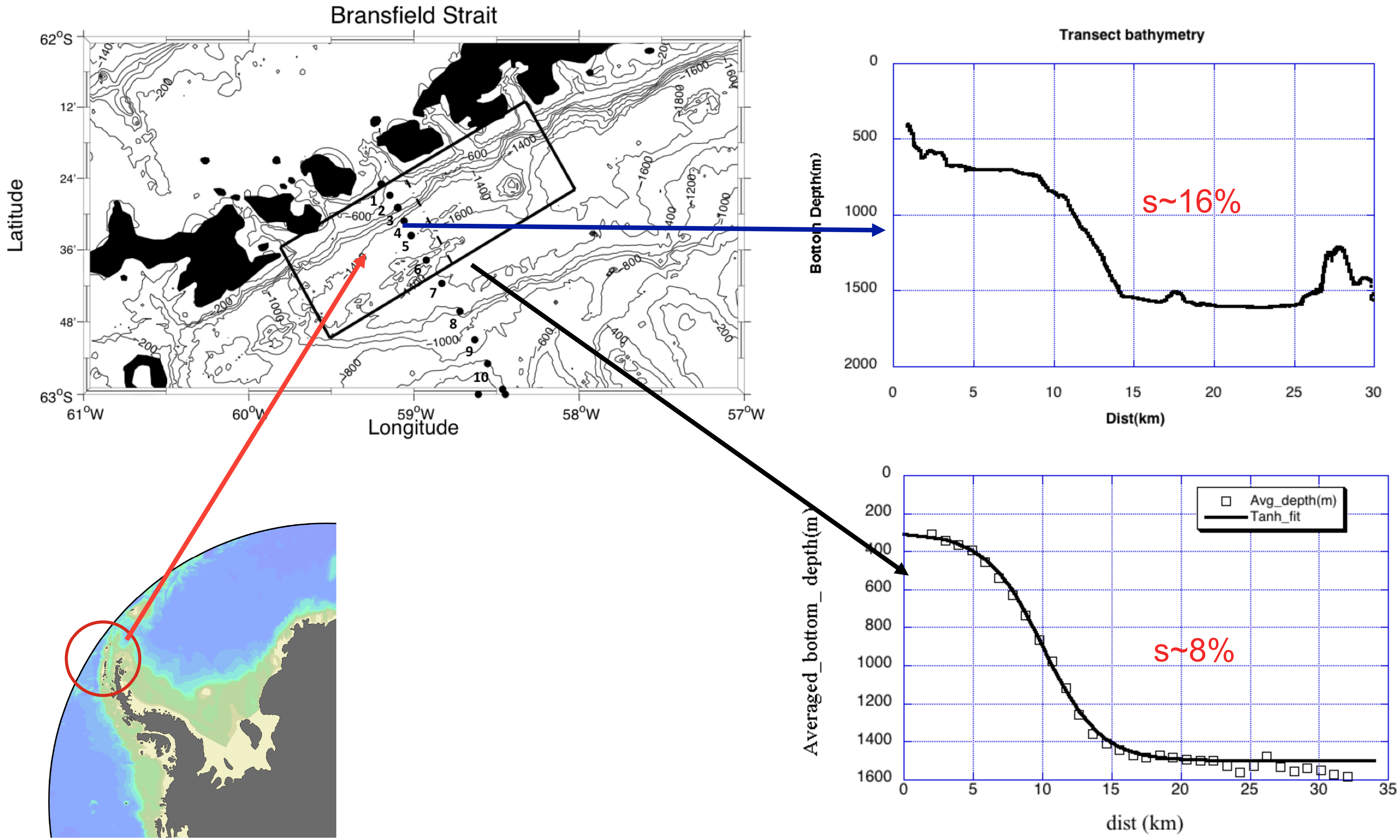
Motivations: 1/36° Mediterranean Sea *(MED36 runs)*

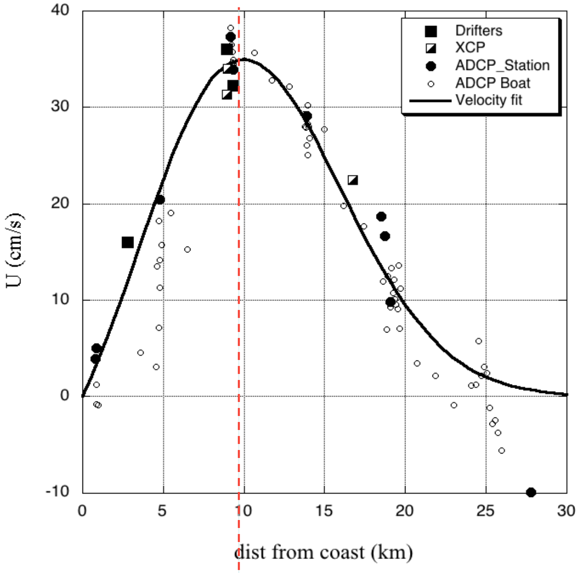


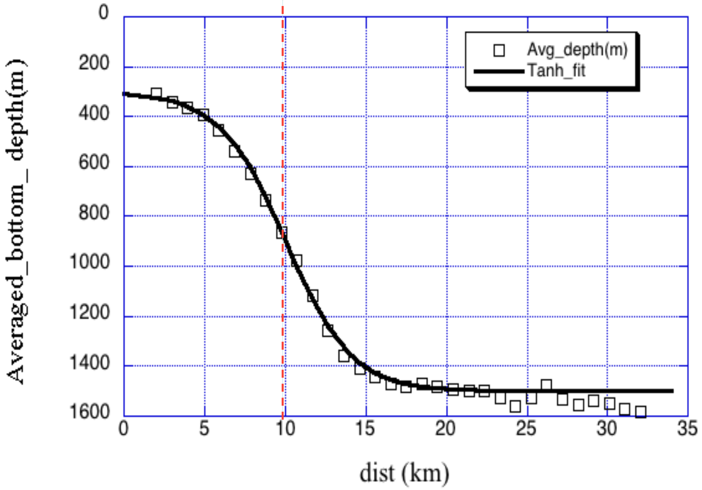
Buoyant coastal current : Bransfield strait bathymetry (Antarctica)



Buoyant coastal current : stable Bransfield current (Antarctica)

VELOCITY PROFILE



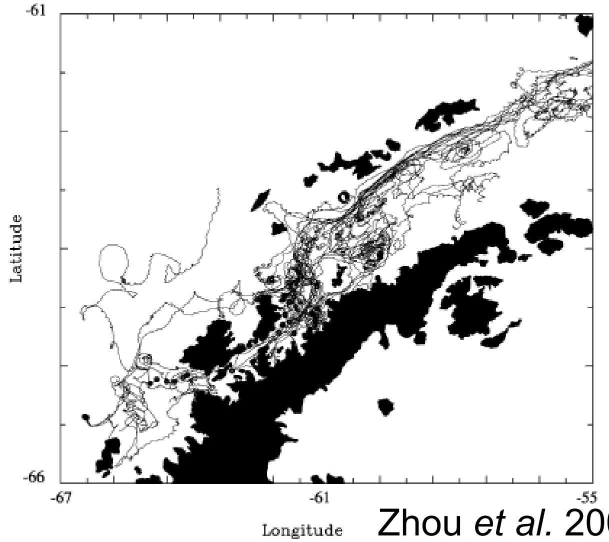


$$Ro = \frac{U}{f\,L} \approx 0.2 - 0.3$$

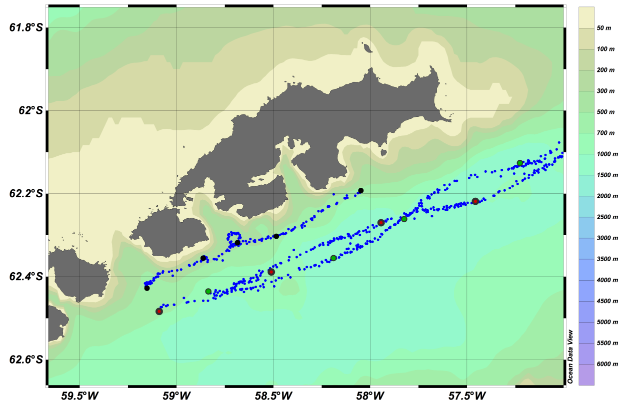
$$Bu = \left(\frac{R_d}{L}\right)^2 \approx 1$$

GEOSTROPHIC CURRENT

DRIFTERS TRAJECTORIES

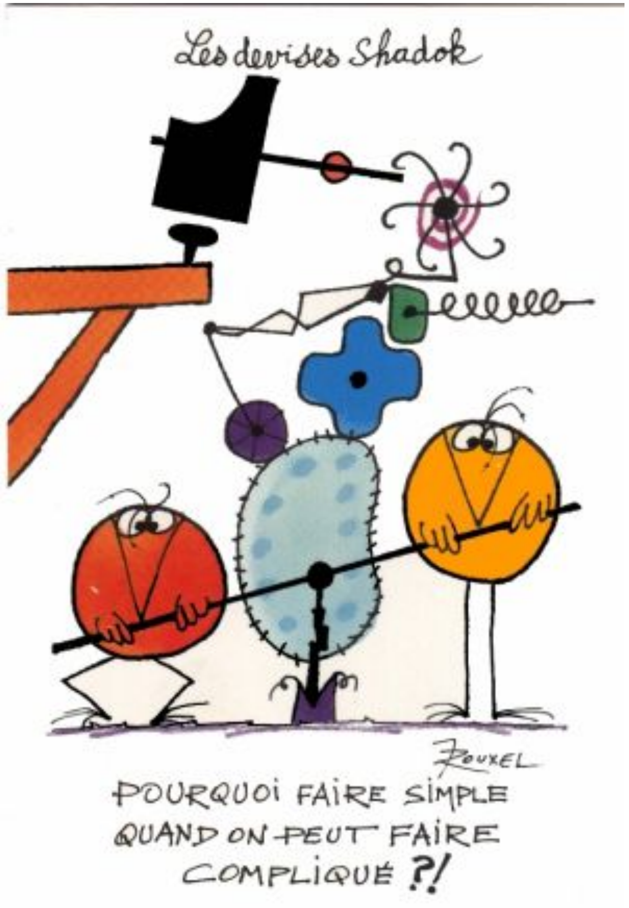


Zhou *et al.* 2002

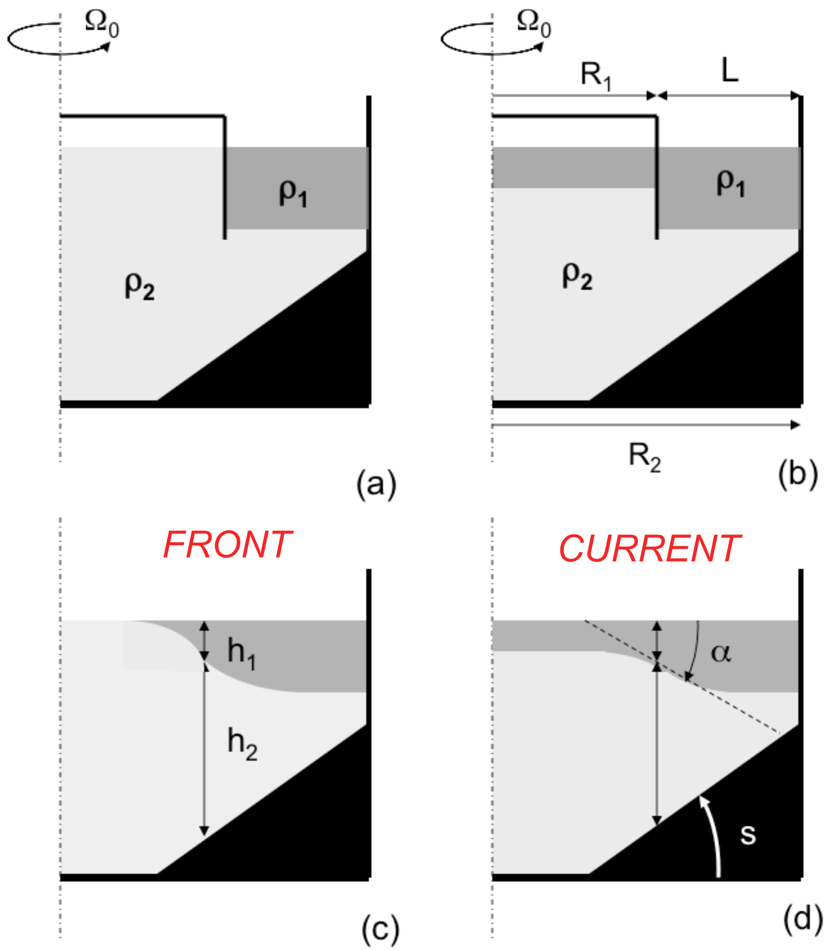


Poulin *et al.* 2014

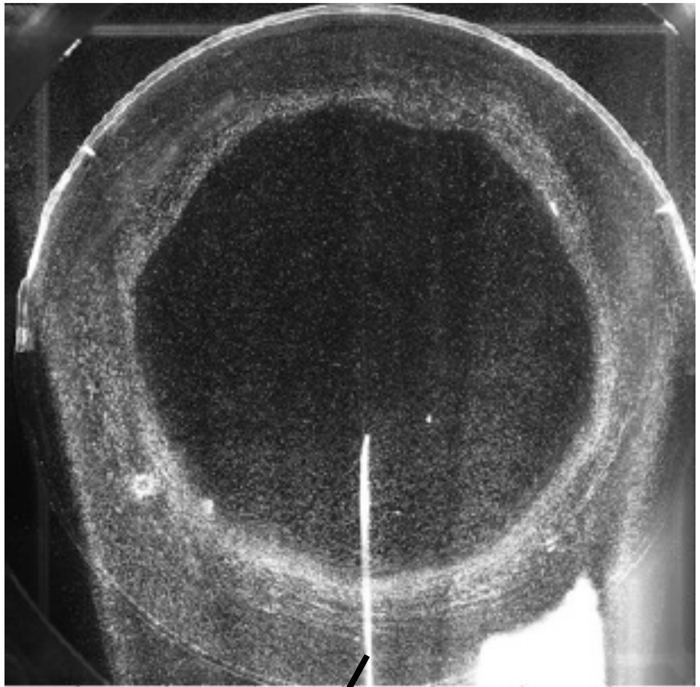
What do we learn from laboratory experiments ?



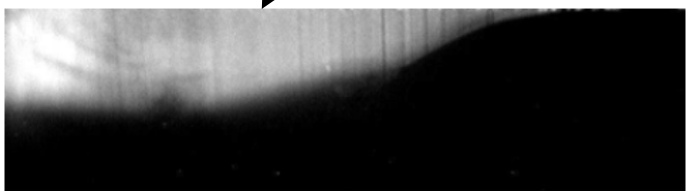
Idealized configuration: experimental setup



Initial and adjusted configurations
side view of the two layer salt stratifications



top view with PIV particles

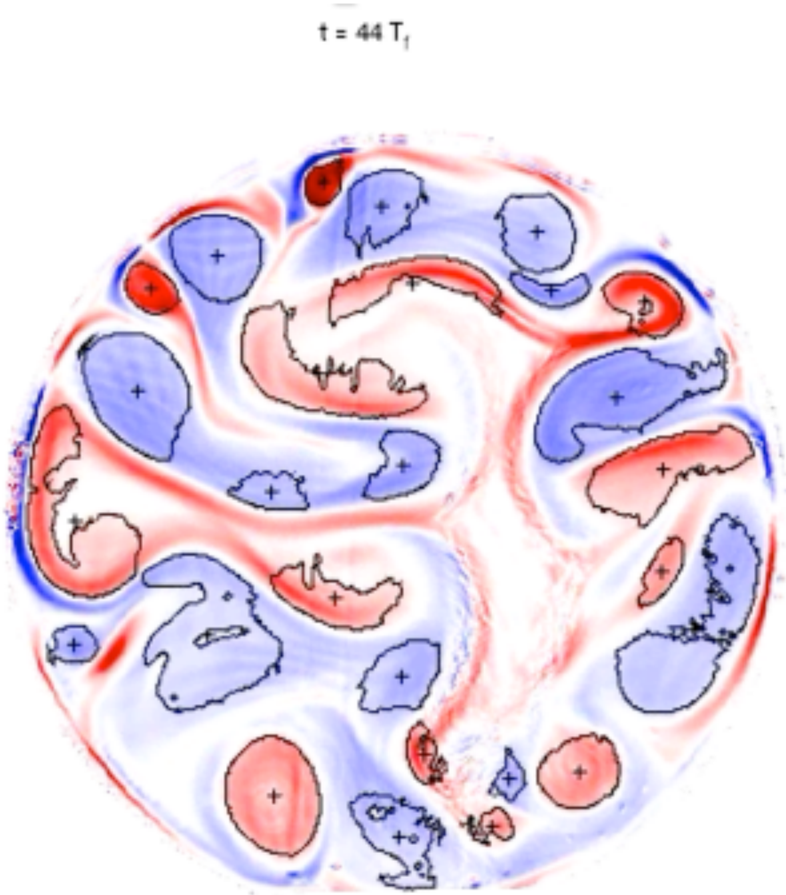


side view LIF visualization

High resolution
PIV measurements:
4800x3200 pixels camera

COASTAL FRONT
FLAT BOTTOM CASE

High resolution
PIV measurements:
surface vorticity

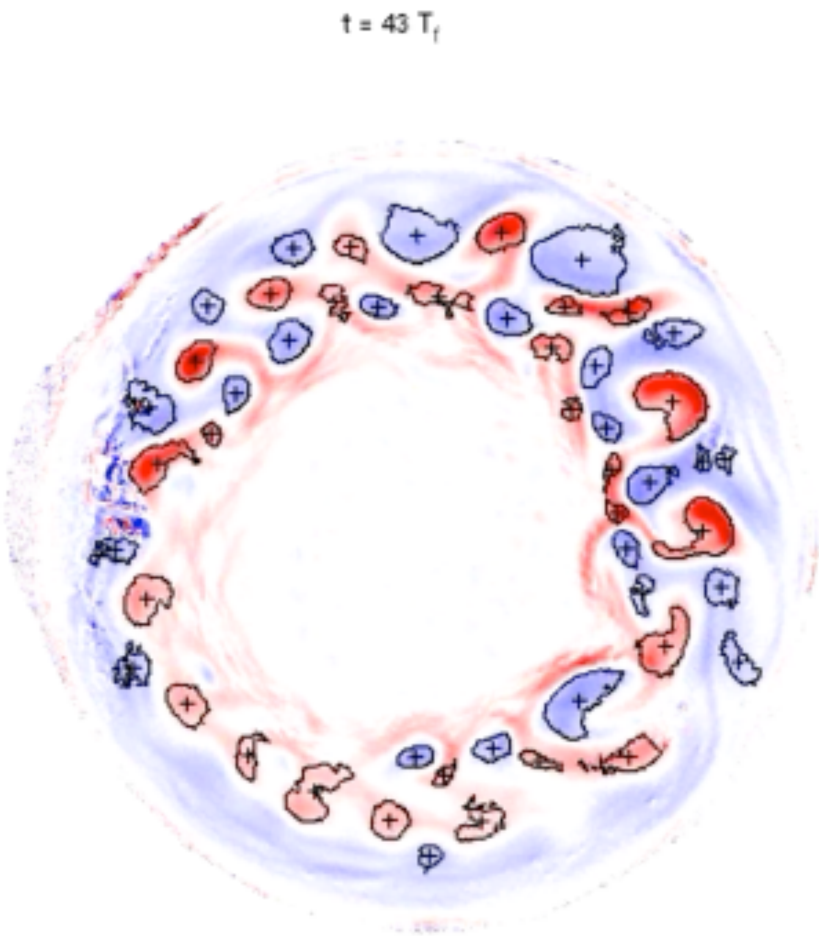


blue: anticyclonic
red: cyclonic

COASTAL FRONT
FLAT BOTTOM CASE

Black contours Okubo-Weiss criterion
(Isern-Fontanet et al. 2003)

High resolution
PIV measurements:
surface vorticity



blue: anticyclonic
red: cyclonic

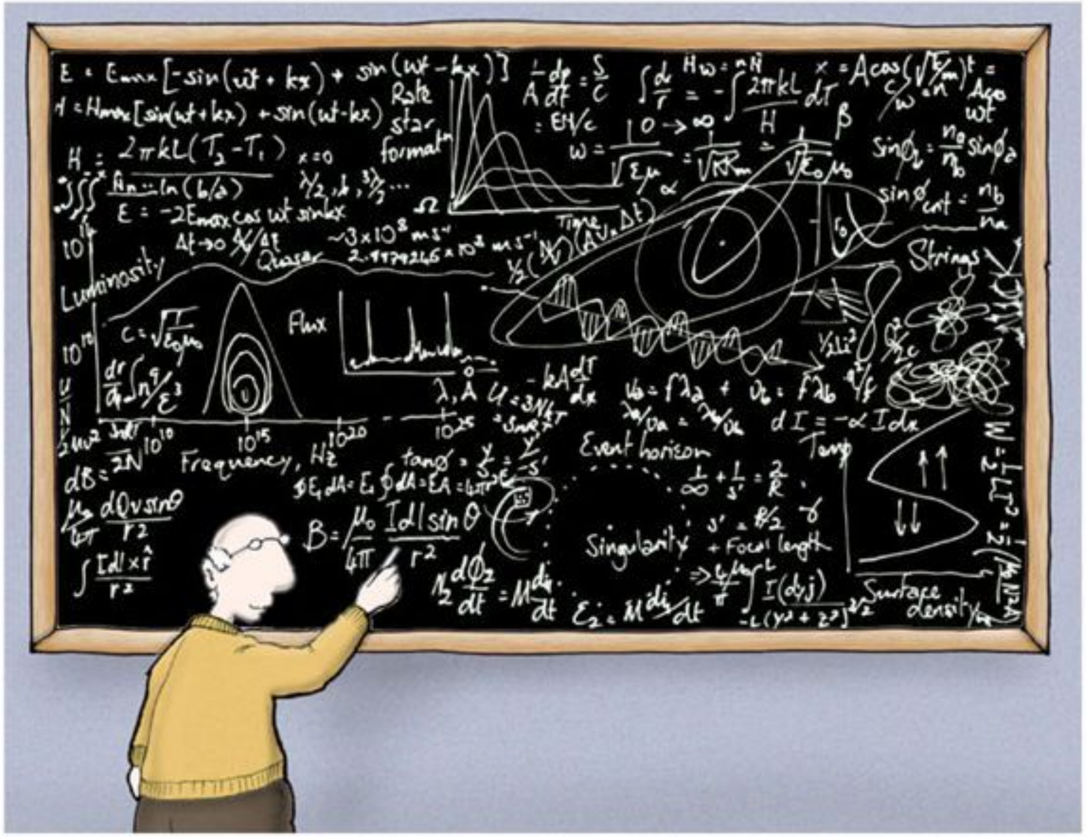
LINEAR SHELF

Topographic parameter

$$To = \frac{s}{\alpha} = -1.3$$

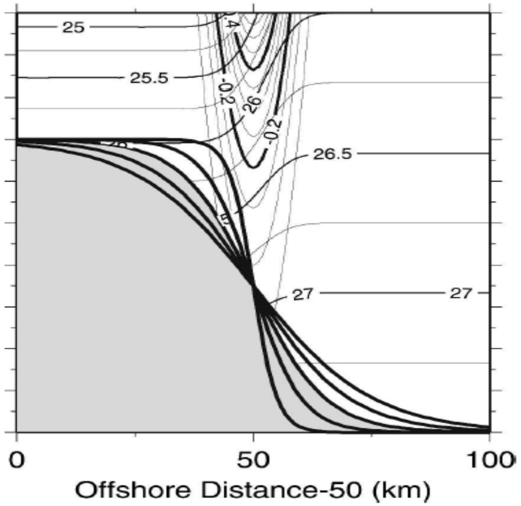
Géhéniau *et al.* (in preparation)

What do we learn from linear stability analysis ?

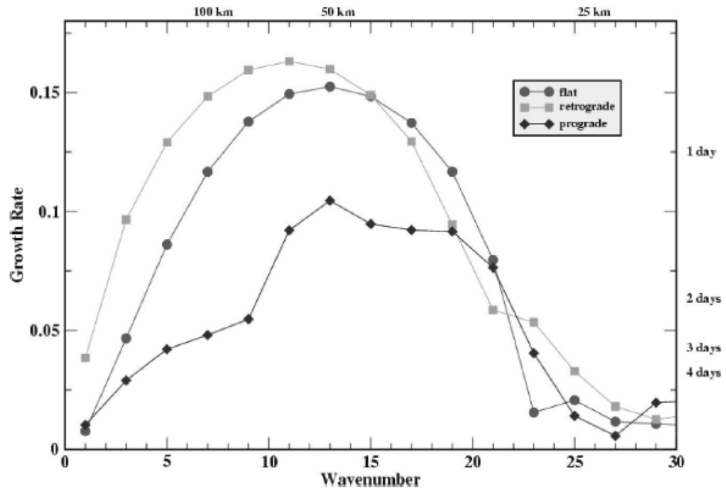


Some previous studies … not exhaustive !

Coastal current over shelf slope



Shelf slope ***destabilize*** *the current*



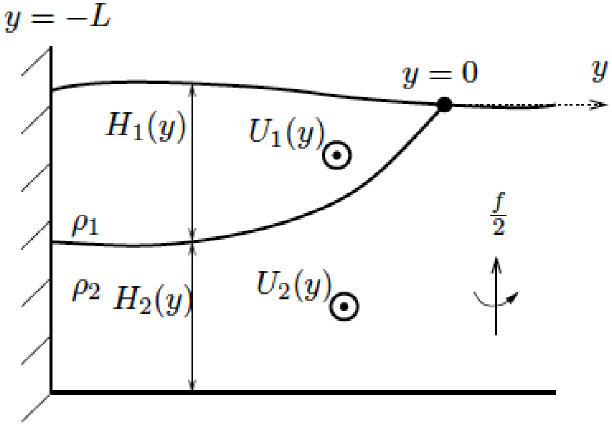
Lozier & Reed, *JPO*(2005)

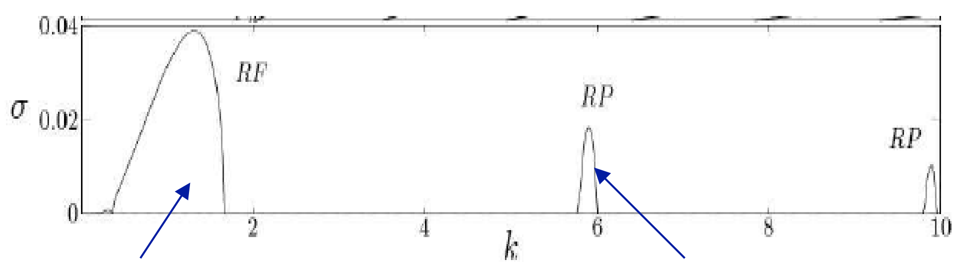
s ↗

λ_{max} ↗

σ_{max} ↗

Coastal front over flat bottom



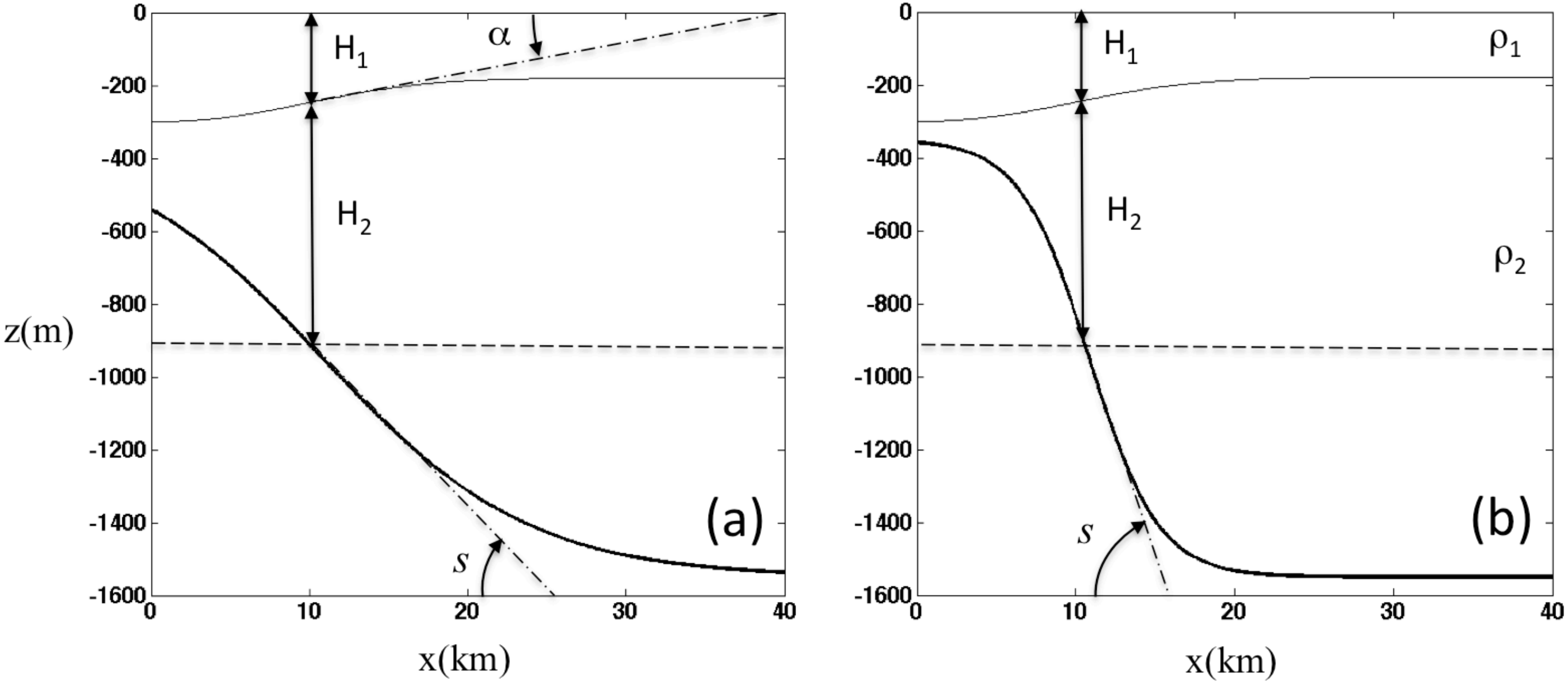


Frontal-Rossby modes

Poincarré-Rossby modes

Boss et al. (1996); Gula, Zeitlin & Bouchut, *JFM* (2010)

Shallow-water model: idealized two layers configuration



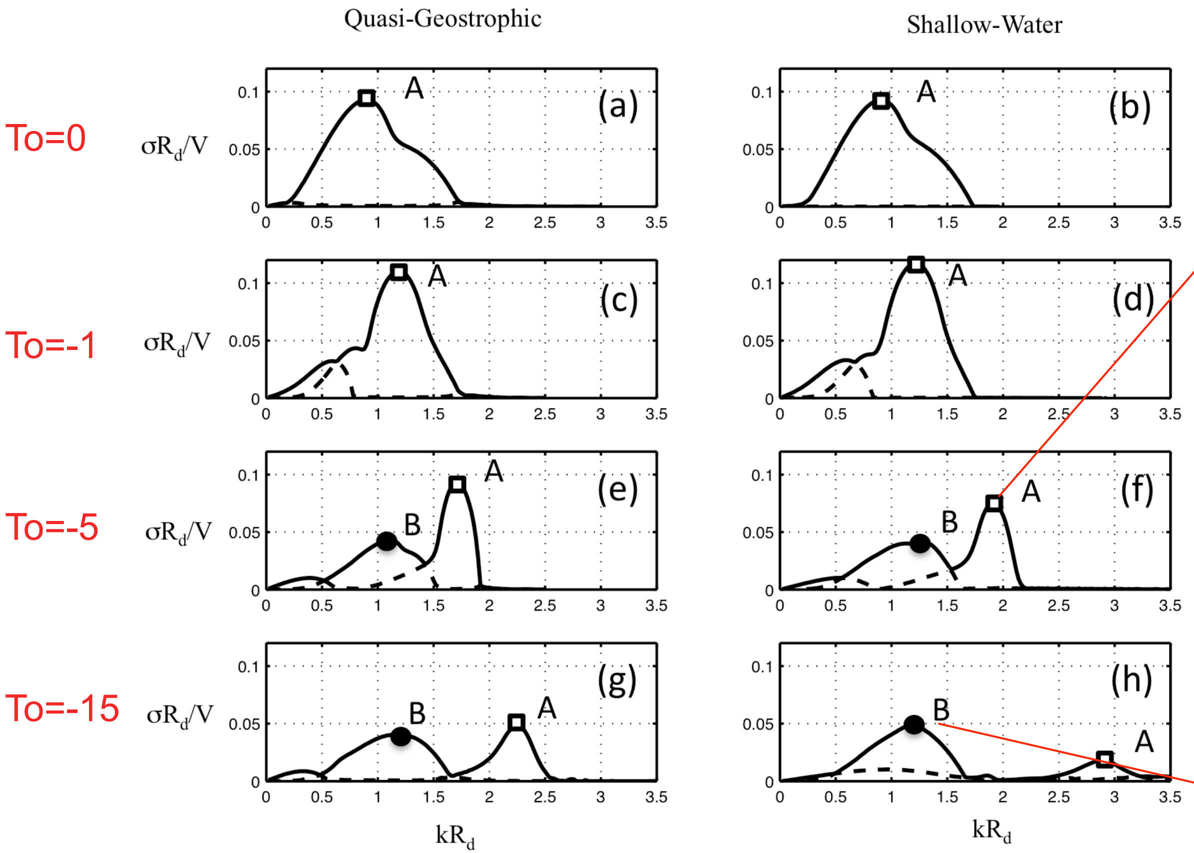
Vertical stratification parameter

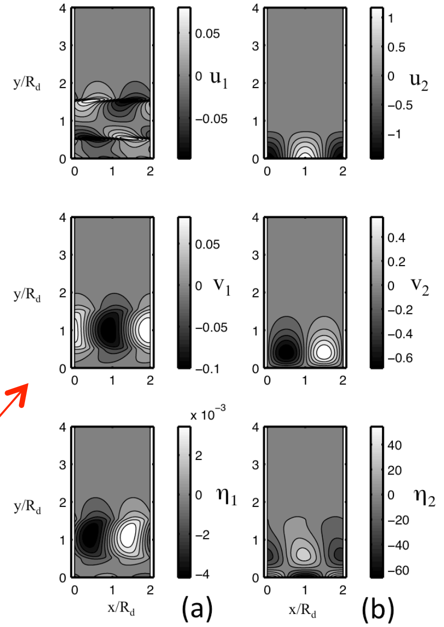
$$\gamma = H_1 / H_2 = 0.4$$

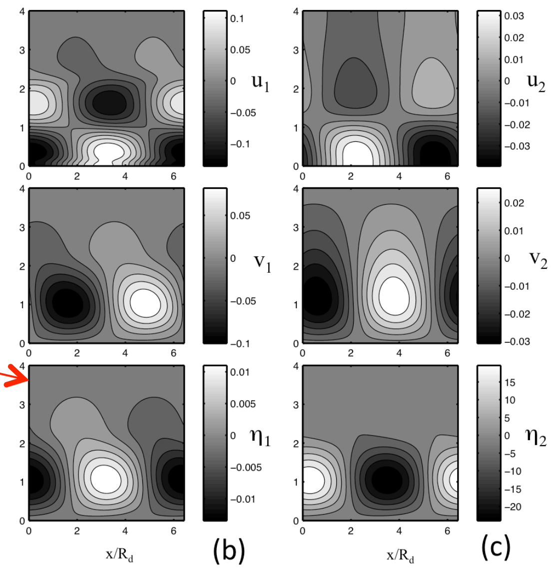
Topographic parameter

$$To = s / \alpha < 0$$

Shallow-water model:
idealized two layers configuration







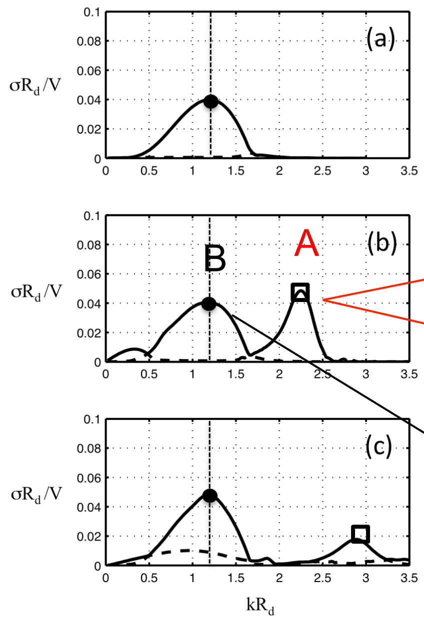
Two unstable modes: A,B

Shallow-water model:
idealized two layers configuration

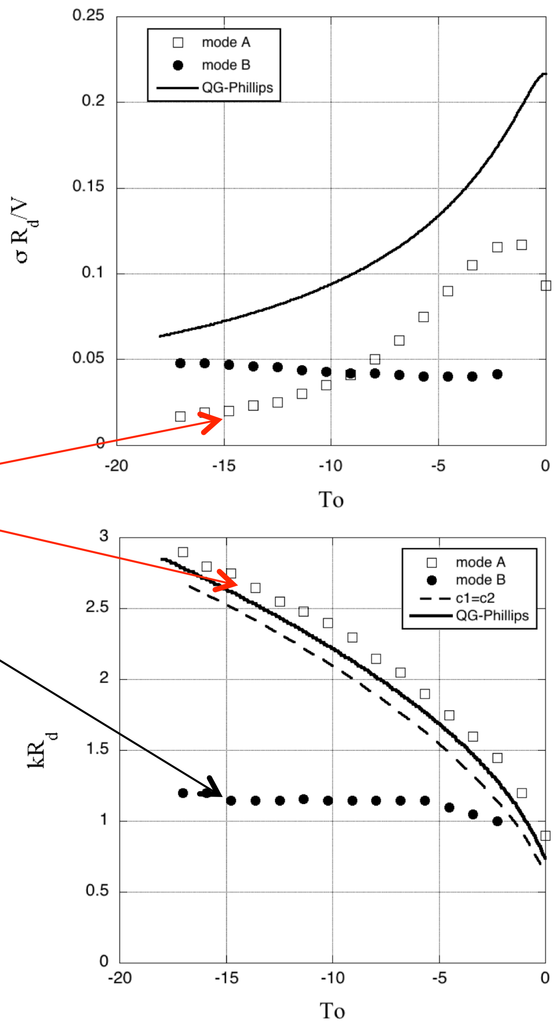
QG
1 layer

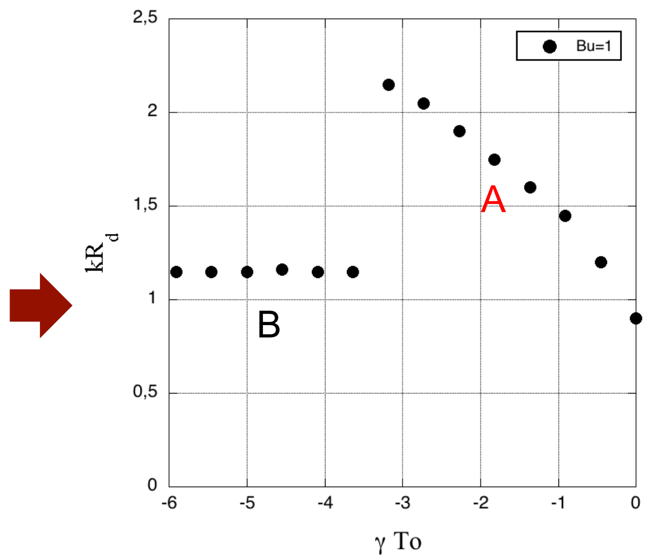
QG
2 layers

RSW
2 layers



γTo = -5





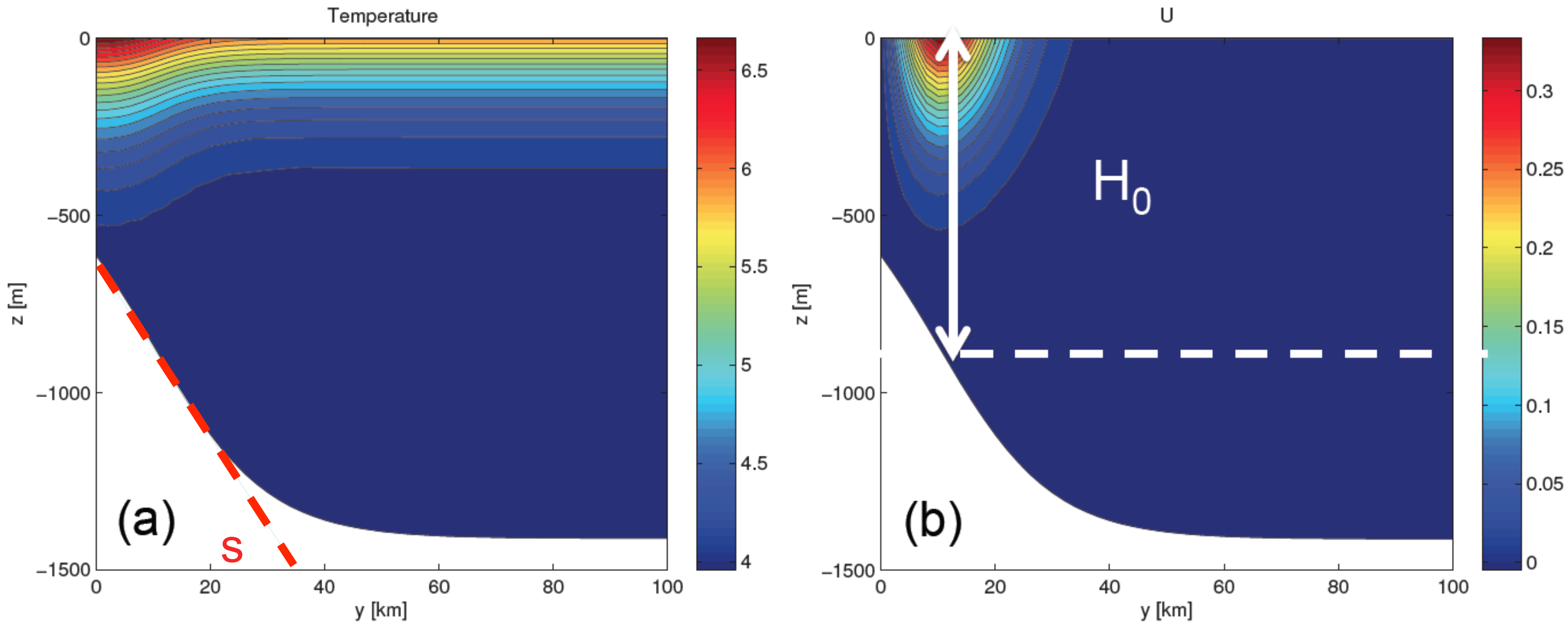
mode B
barotropic
shear
instability

mode A
baroclinic
instability

Poulin *et al.* JPO (2014)

What do we learn from numerical simulations ?

ROMS coastal current: continuous stratification



s: shelf slope below the jet

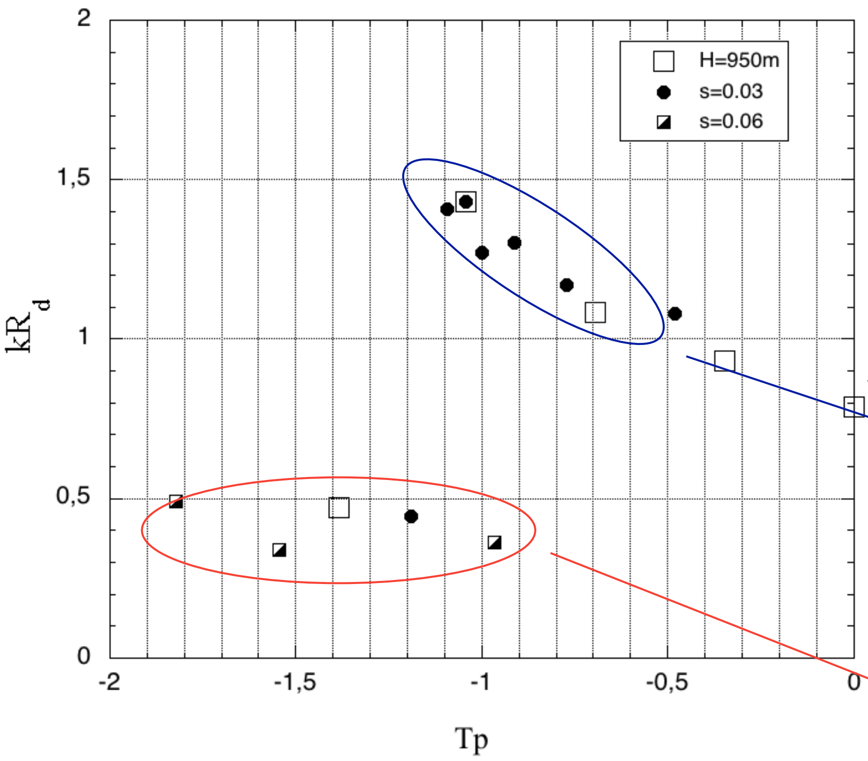
H_0: water depth at the jet position

R_d: first baroclinic deformation radius

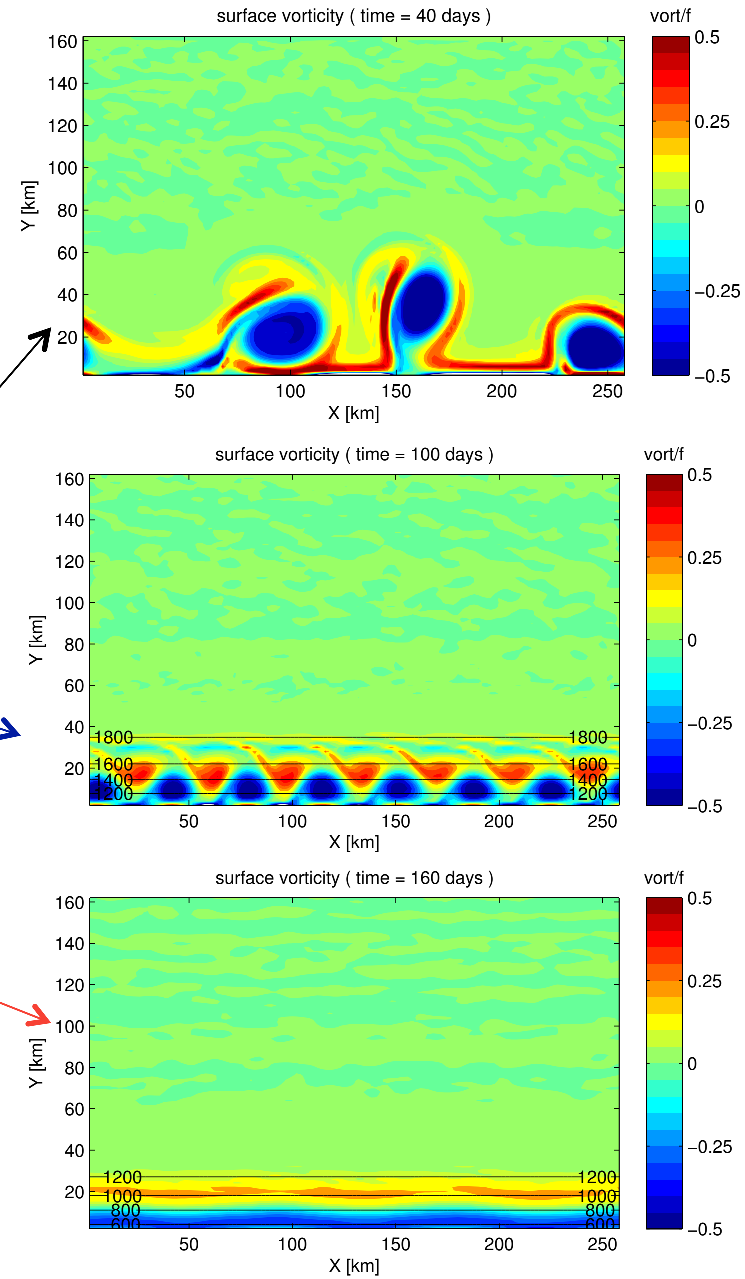
U_0: surface jet velocity (constant)

Meso and sub meso scale dynamics of coastal currents…

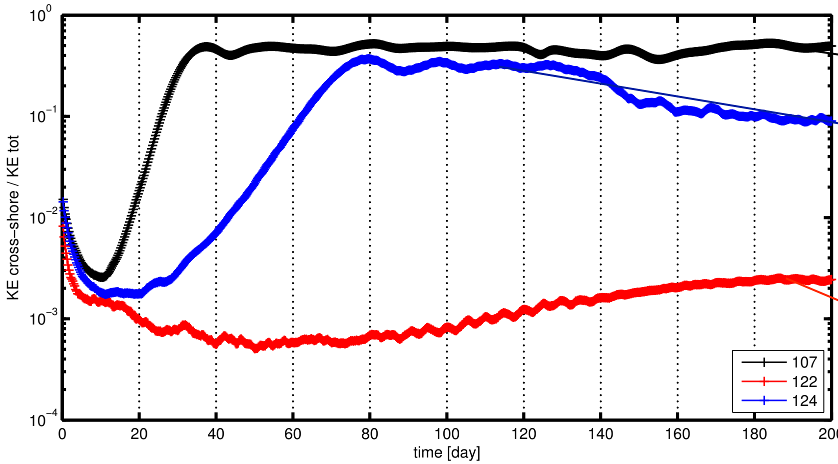
ROMS coastal current:
wavelenght selection and eddy formation

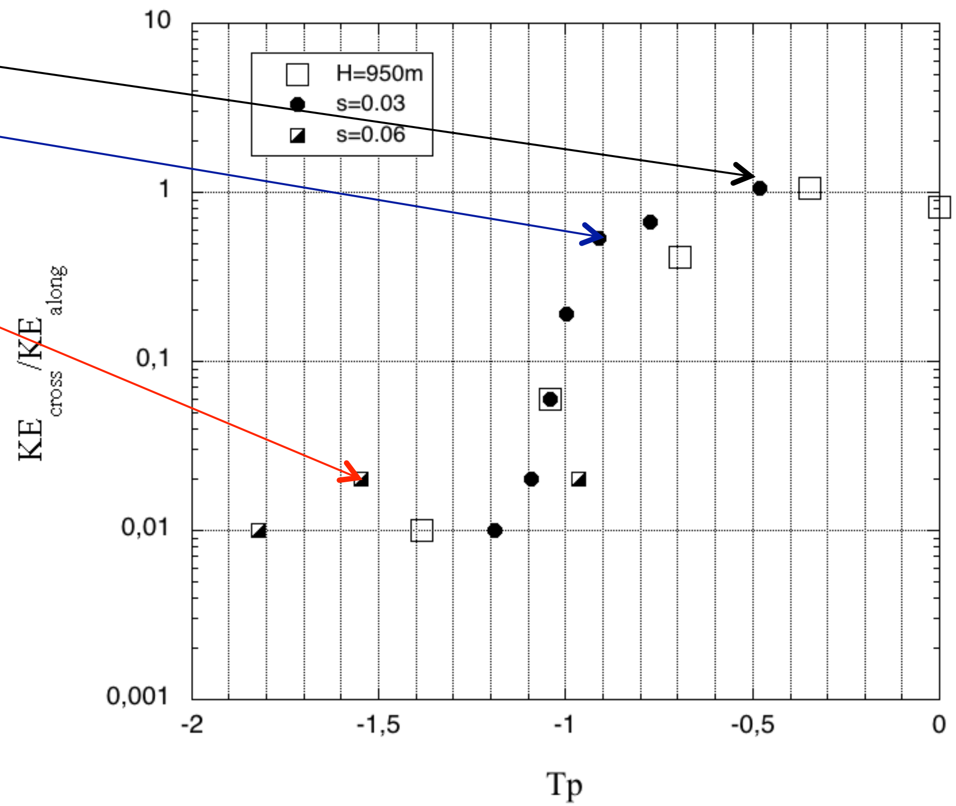


$$Tp = \frac{s\,(1 + h_1 / h_2)^2\, f\, R_d^2}{H_0\, U_0}$$



ROMS coastal current: non linear saturation





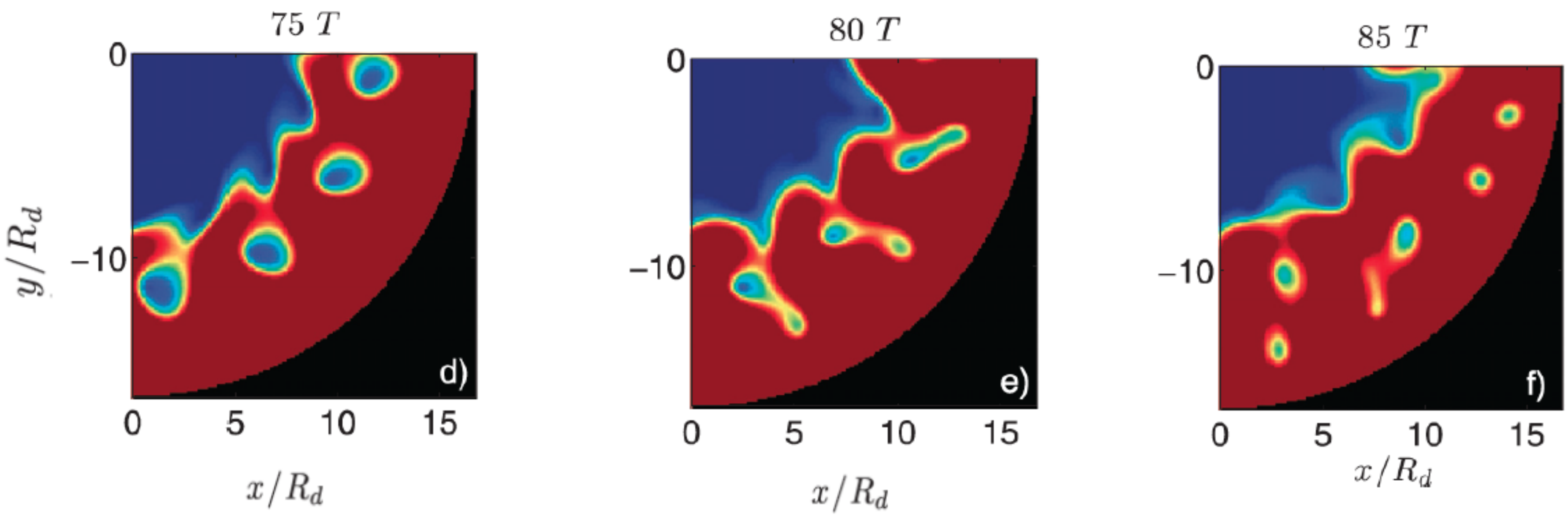
Standard baroclinic instability

Small-scale shelf trapped eddies

Strong non-linear stabilization

Direct cascade towards sub meso-scale eddies

NEMO model (high grid resolution 1/8 R_d equivalent to 1/72° MED) :
coastal front in idealized circular geometry



$R_{eddy} \sim \lambda/4 \sim R_d$ → $R_{eddy} \sim R_d / 2$

splitting of cyclones over the shelf

Pennel *et al.* JPO (2012)

We doesn't need ageostrophic instabilities (Rossby-Kelvin or Rossby-Poincaré) to trigger sub meso scale structures !

CONCLUSIONS

The coastal shelf steepness induces on geostrophic coastal currents

Three dynamical regimes

1- Standard baroclinic instability, meso-scale anticyclones
strong cross-shelf exchanges

2- Rossby-TopoRossby instability, trapped anticyclones & cyclones
reduced cross-shelf exchanges, local cyclonic upwelling

3- Strong non-linear stabilization, weak barotropic shear disturbances
no cross-shelf exchanges, strong along shore transport

Direct cascade towards sub meso-scale eddies may occurs !

Our goal: relevant generalized topographic (slope) parameters
for two-layer and 3D models and impacts on coastal biology.