Various regimes of instability and formation of coastal eddies along the shelf bathymetry

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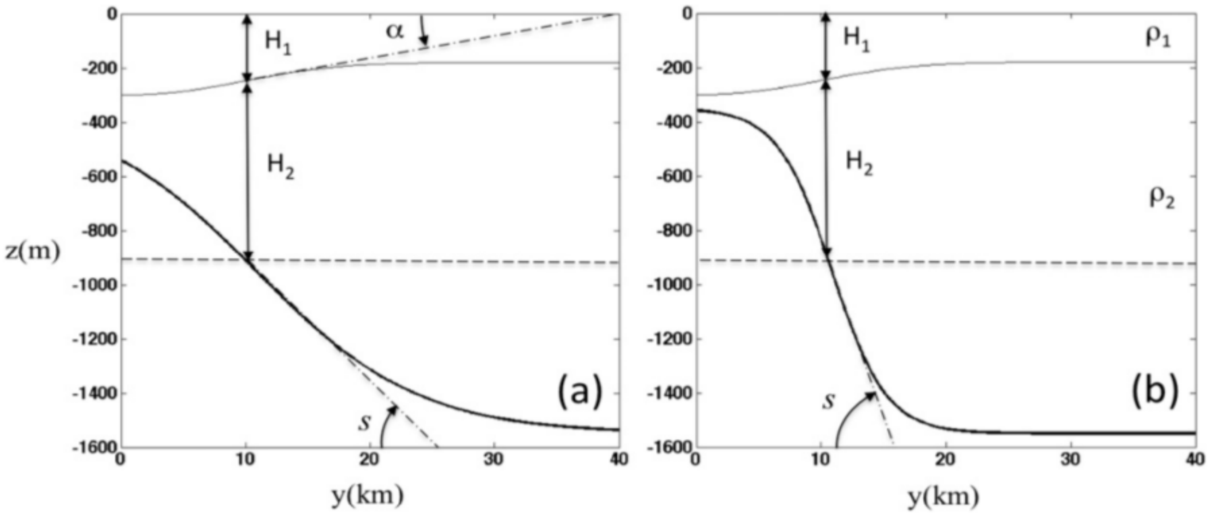
Motivations

Extend the linear stability analysis of Poulin et al 2014



Two-layer SW model

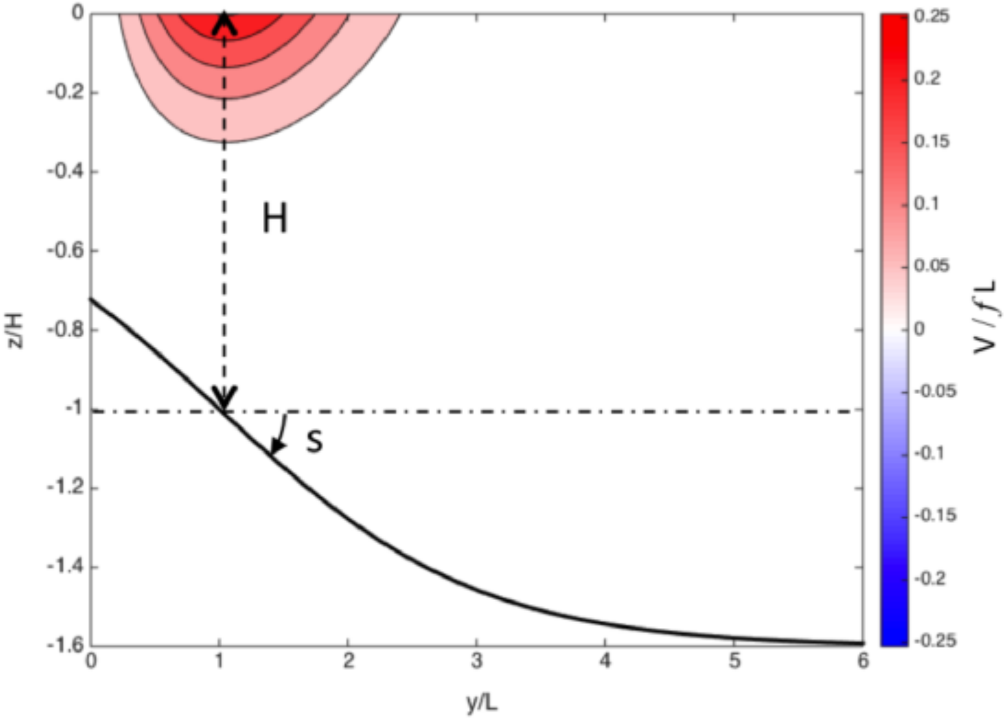
Prograde jet over a slope

Shear instability vs.
Baroclinic instability

To
- Continuous stratification
- Nonlinear evolution

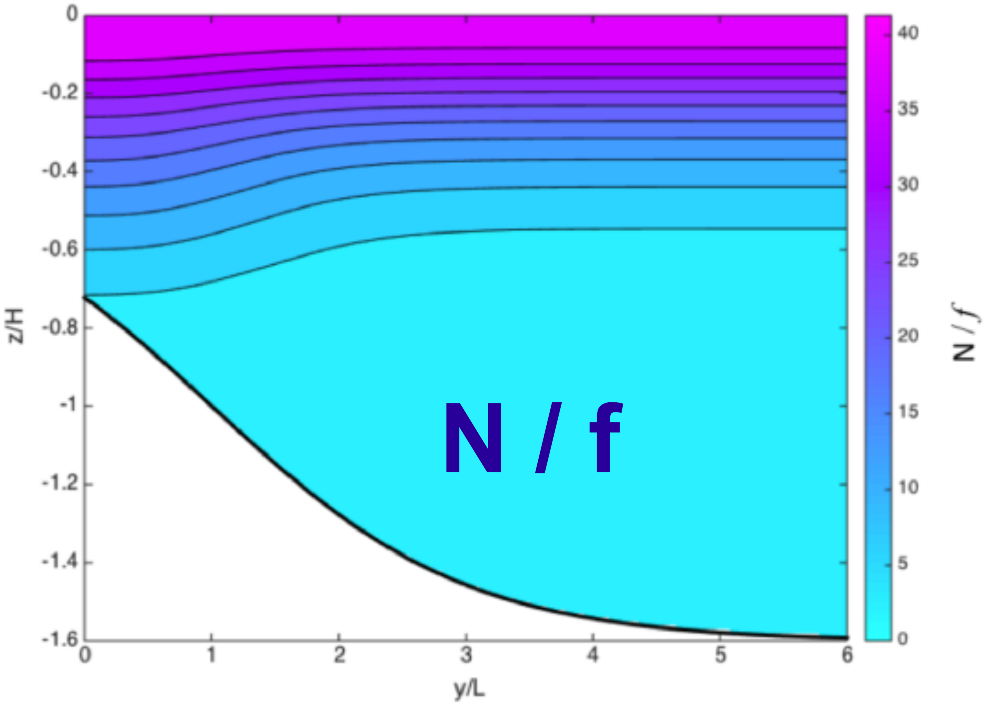
=> idealized simulations using ROMS / periodic channel

The jet configuration [Bransfield jet]



Surface intensified jet

$U = 0.35\ \mathrm{cm\ s^{-1}}$
L = 10 km
Hjet = 250 m

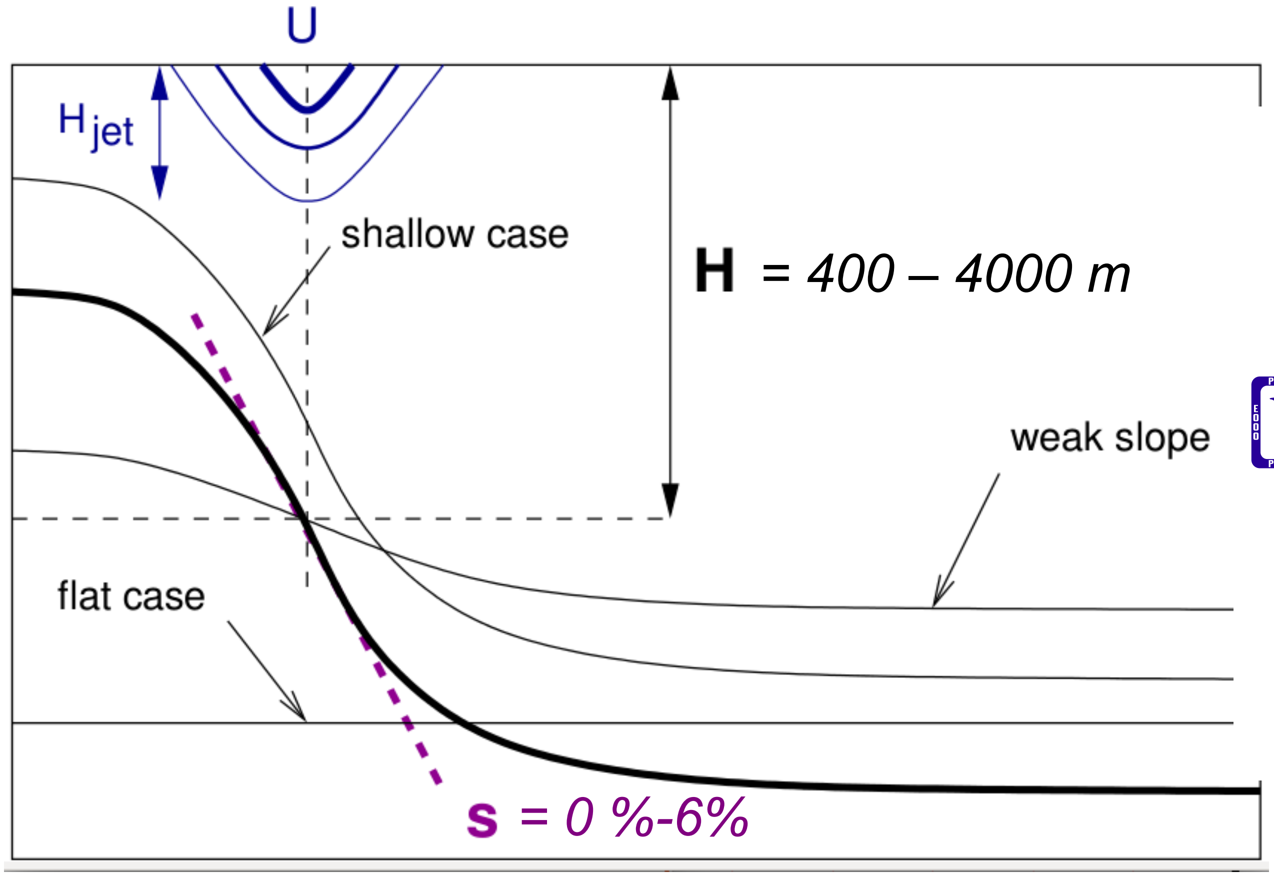


Weak stratification : $R_d \sim 5$ km
[Wedell Sea]

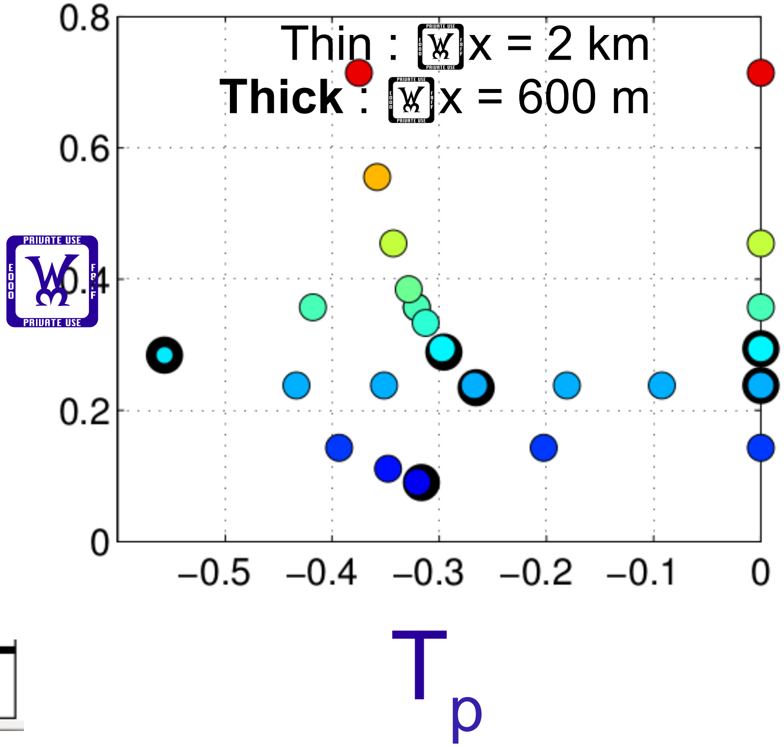
Rossby
$$Ro = 0.25$$

Burger
$$Bu = 0.25$$

Control parameters : T_p and



Experiments summary



Aspect ratio

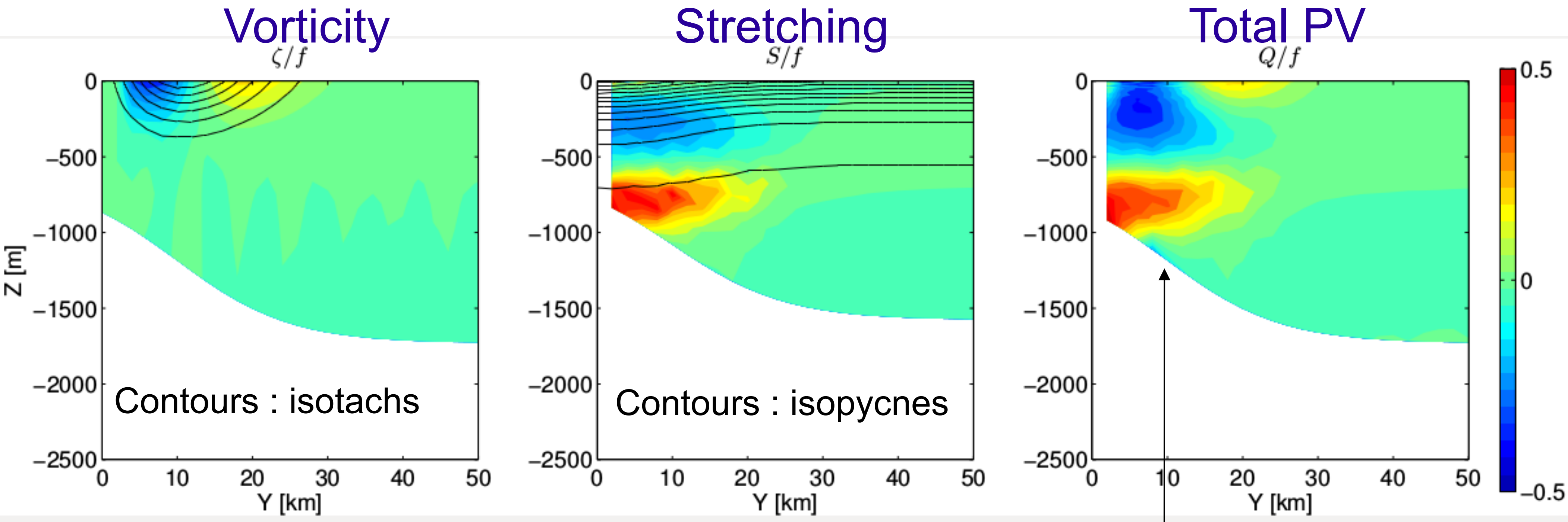
$$\gamma = \frac{H_{\text{jet}}}{\mathbf{H} - H_{\text{jet}}}$$

Topographic parameter [c_{TRW} / U]

$$T_p = \frac{\mathbf{s} f R_d^2}{\mathbf{H} U}$$

Note that $R_d = f(H)$

PV structure (QG interpretation)



Vorticity

Stretching

Total PV

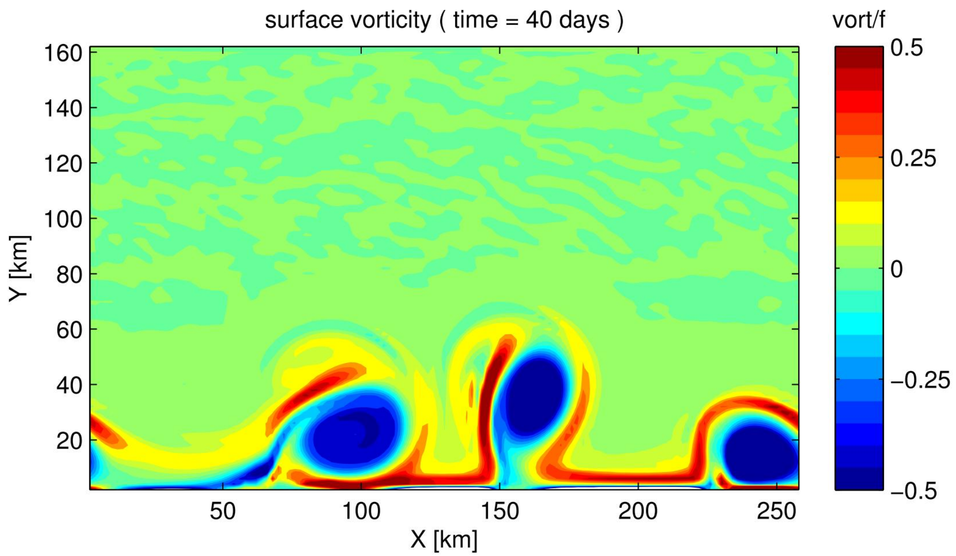
Shear instability

Baroclinic instability

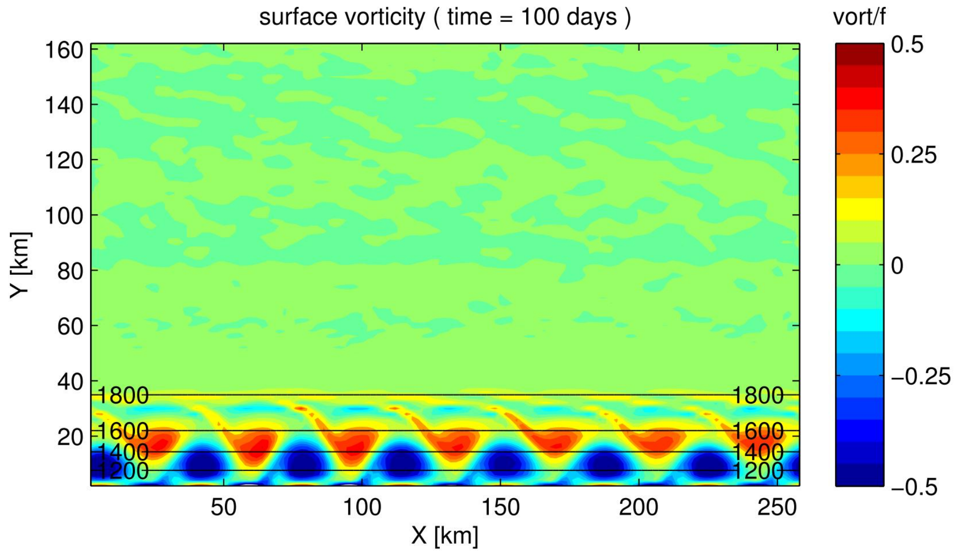
+ topographic PV sheet
at the bottom

Four regimes

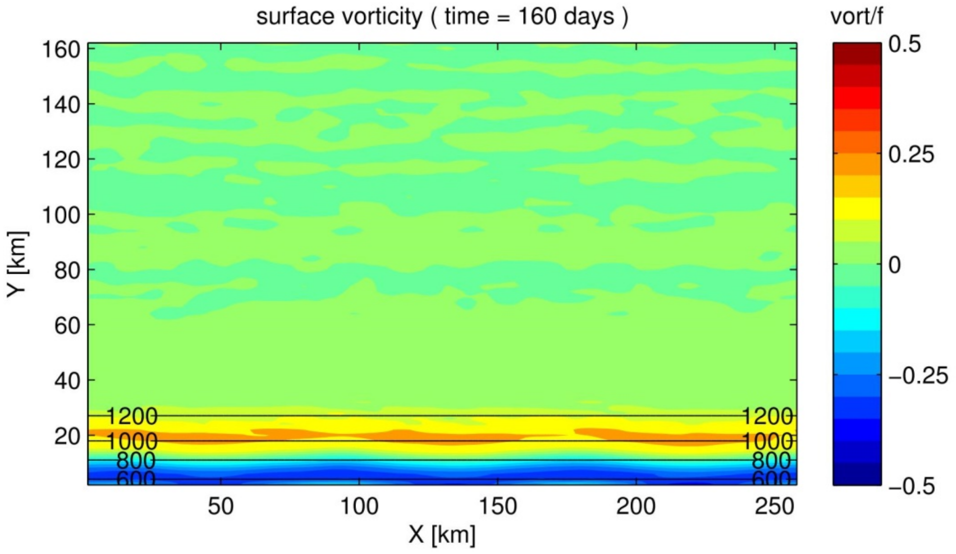
ndard baroclinic instability (**BI**)



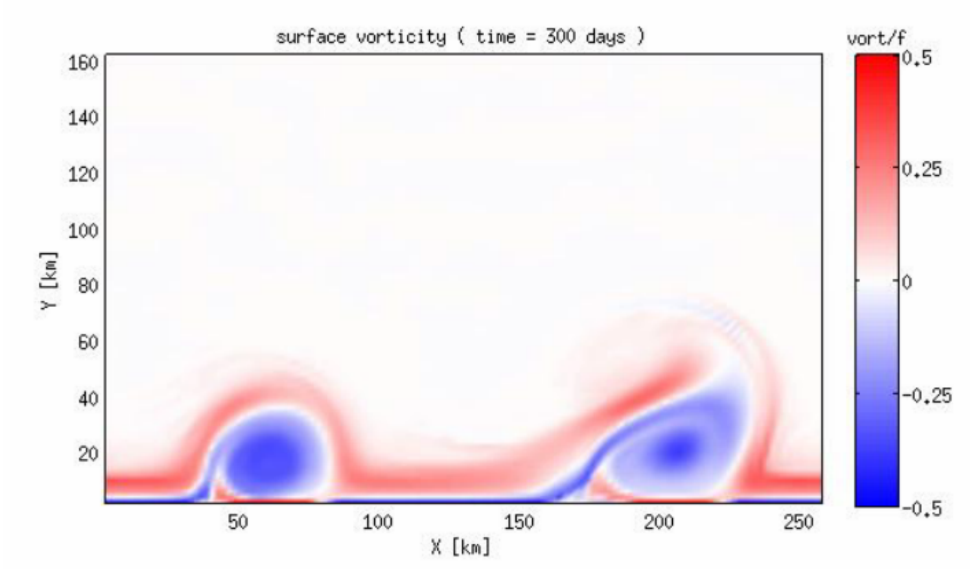
Regime 2: trapped coastal instability (**TCI**)



asi stable along-slope current (**ASC**)



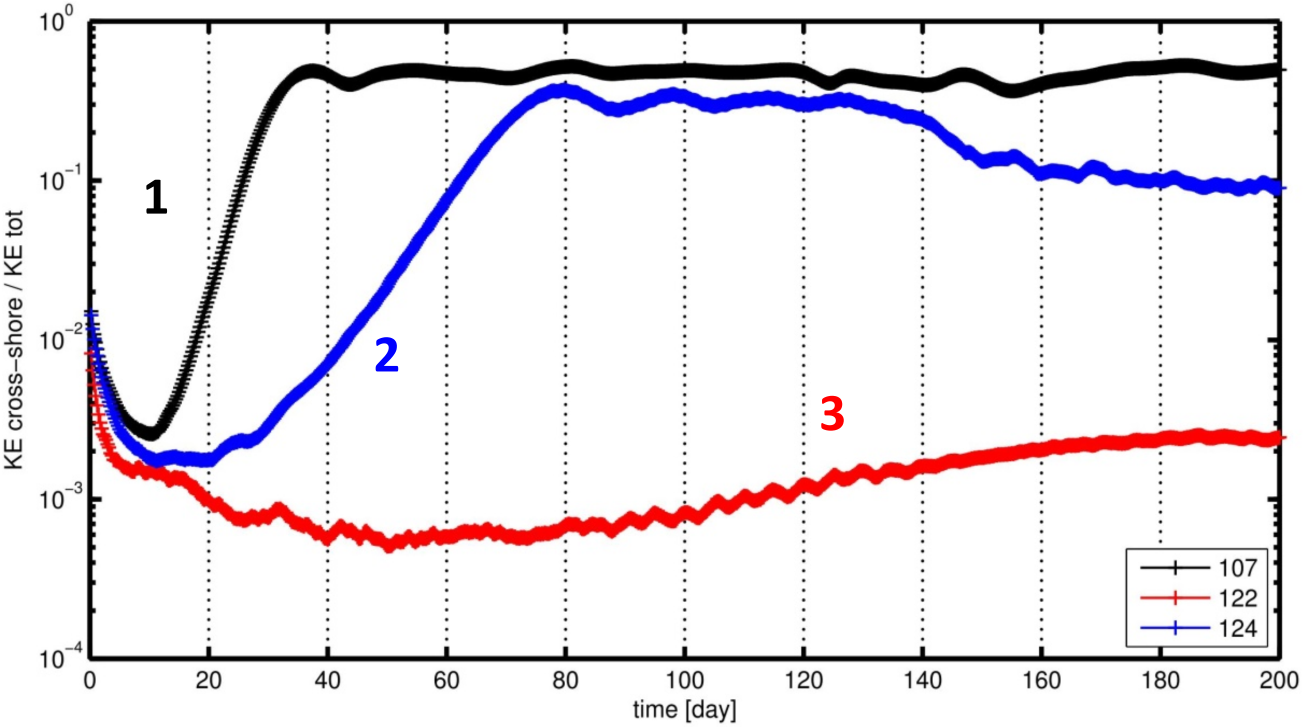
Regime 4: shear instability (**SI**)



Saturation parameter

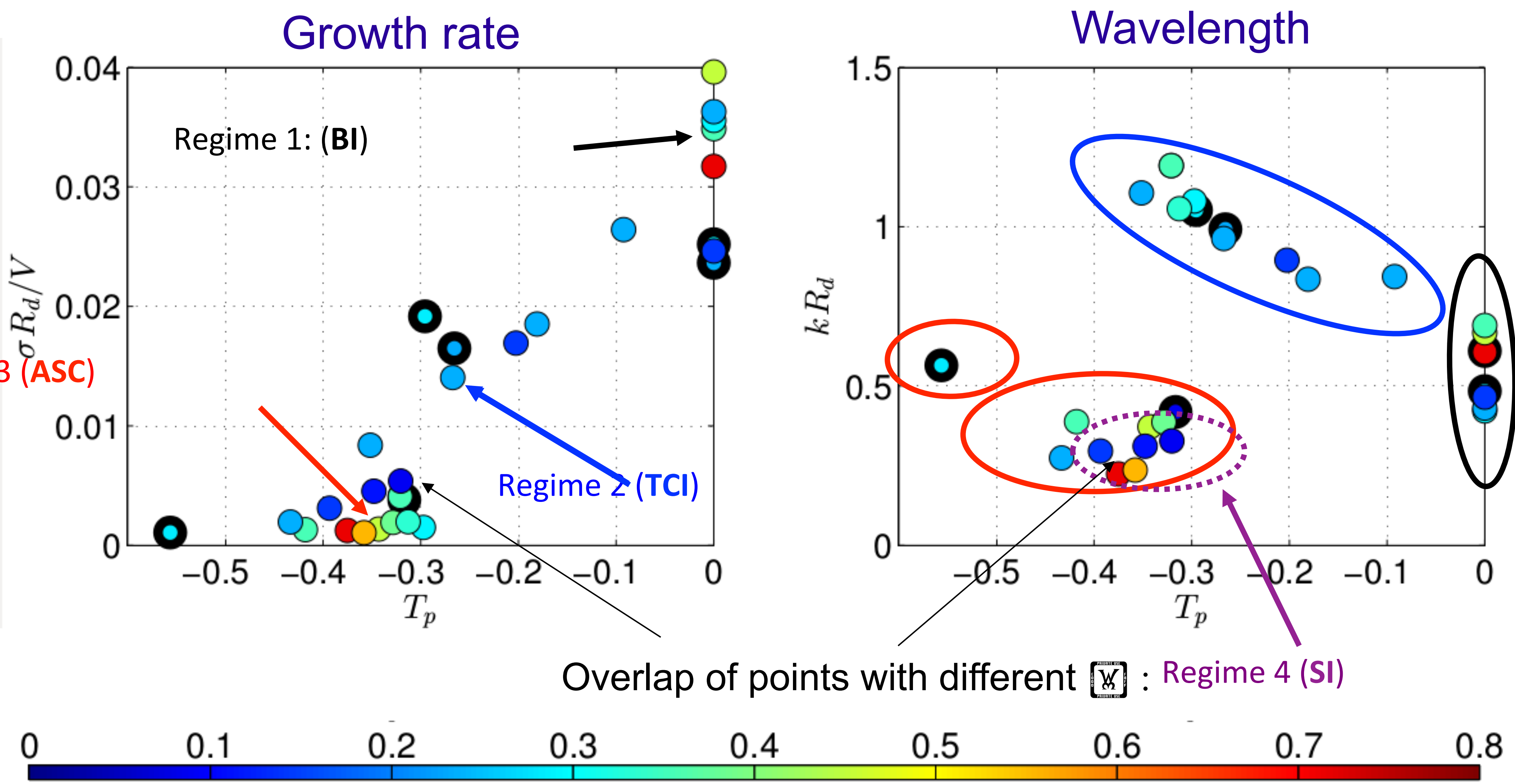
$$\epsilon = 2\frac{\int v^2\,dv}{\int u^2 + v^2\,dv}$$

2 * Cross shore KE / total KE



time

Linear growth



Growth rate

Wavelength

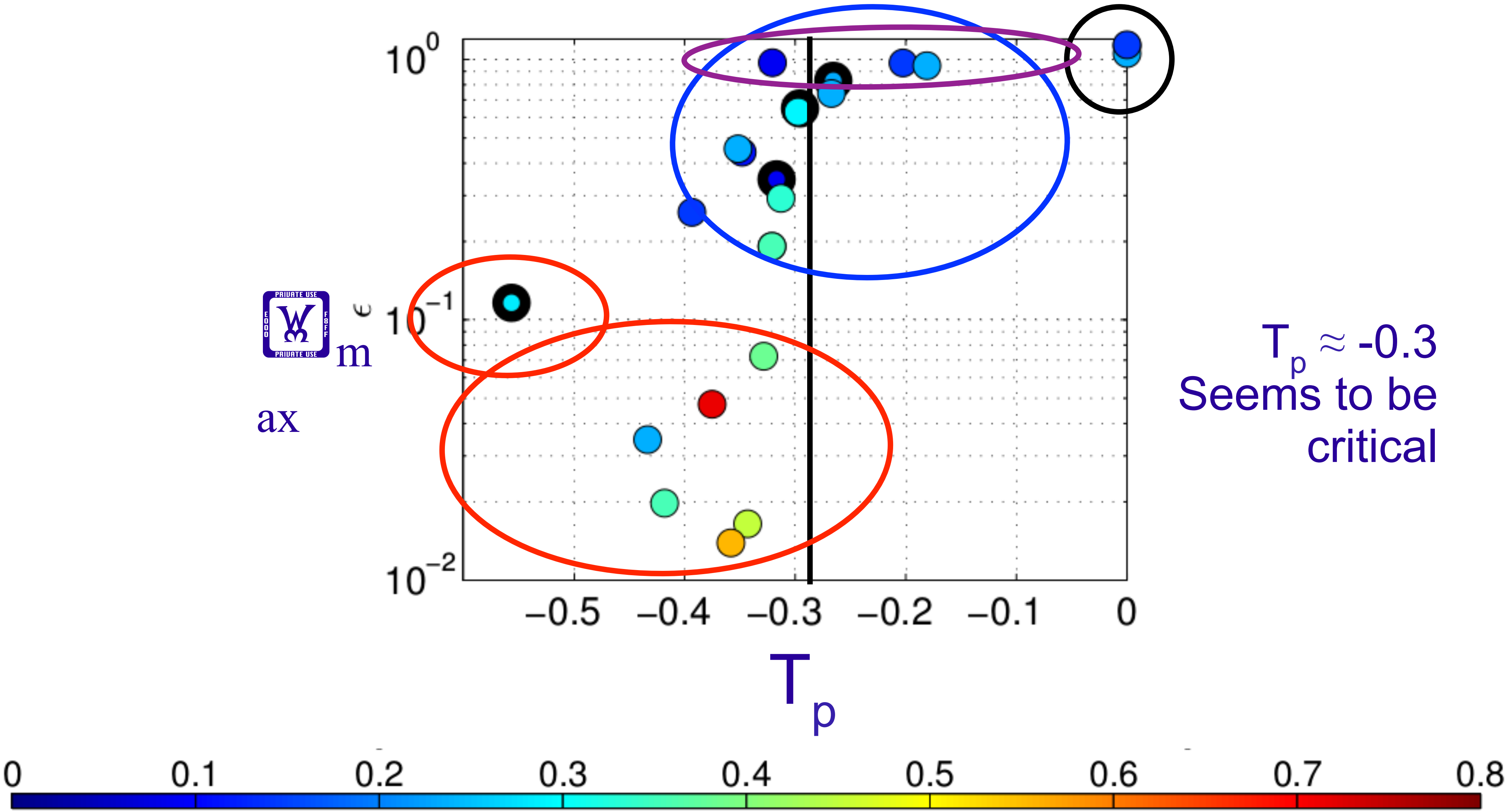
Regime 1: (**BI**)

Regime 2 (**TCI**)

3 (**ASC**)

Overlap of points with different : Regime 4 (**SI**)

Nonlinear saturation vs. full instability

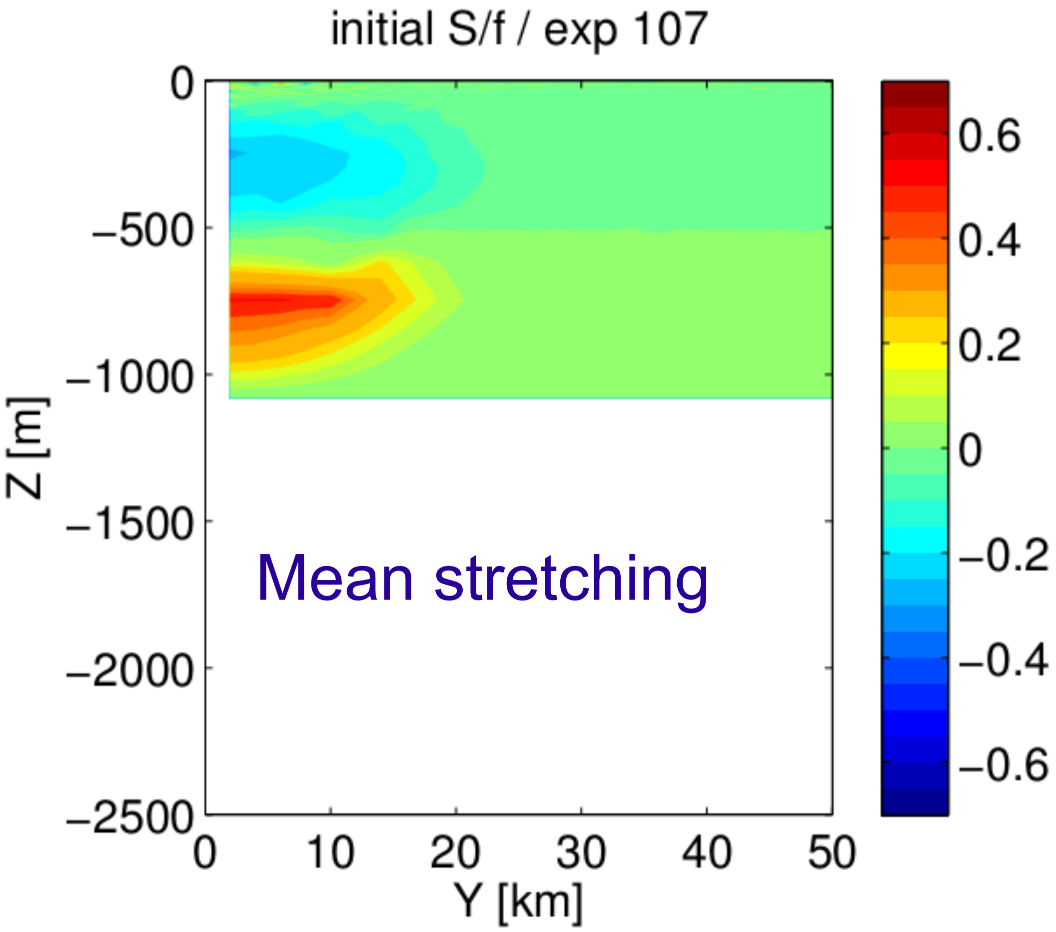


$T_p \approx$ -0.3
Seems to be
critical

PV interpretation :
the standard baroclinic instability (1)

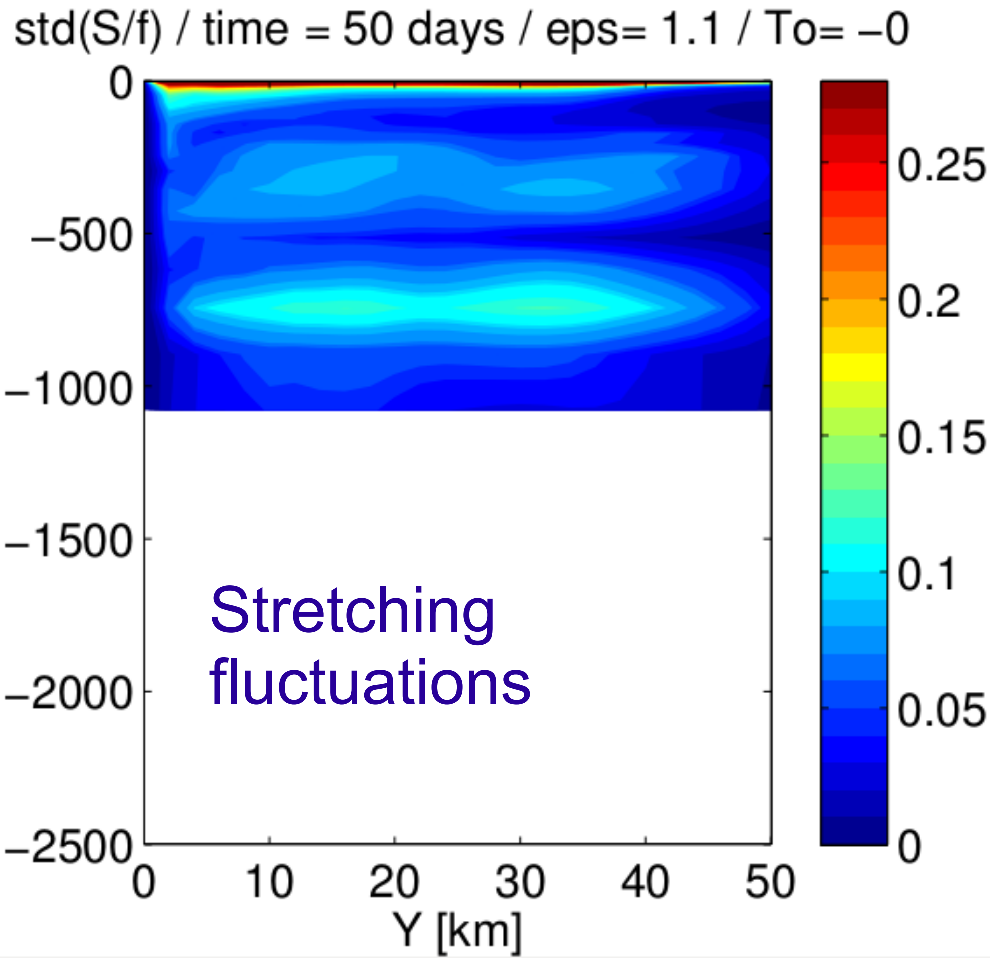
Classical BI : **dipole of stretching in the vertical**

full breaking of the jet



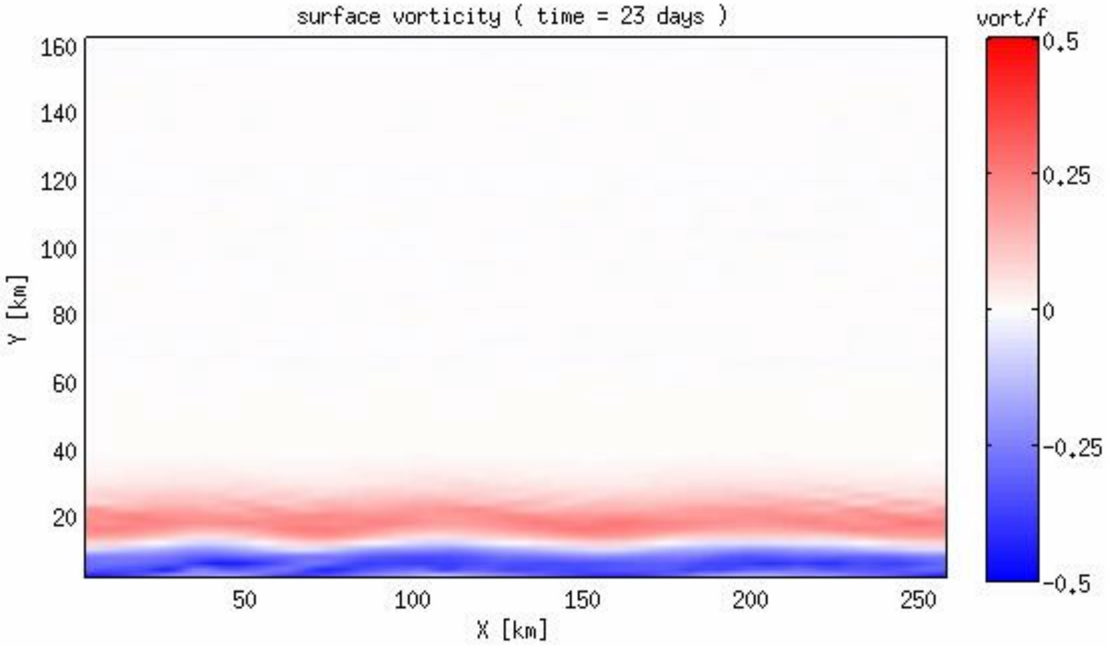
initial S/f / exp 107

Mean stretching



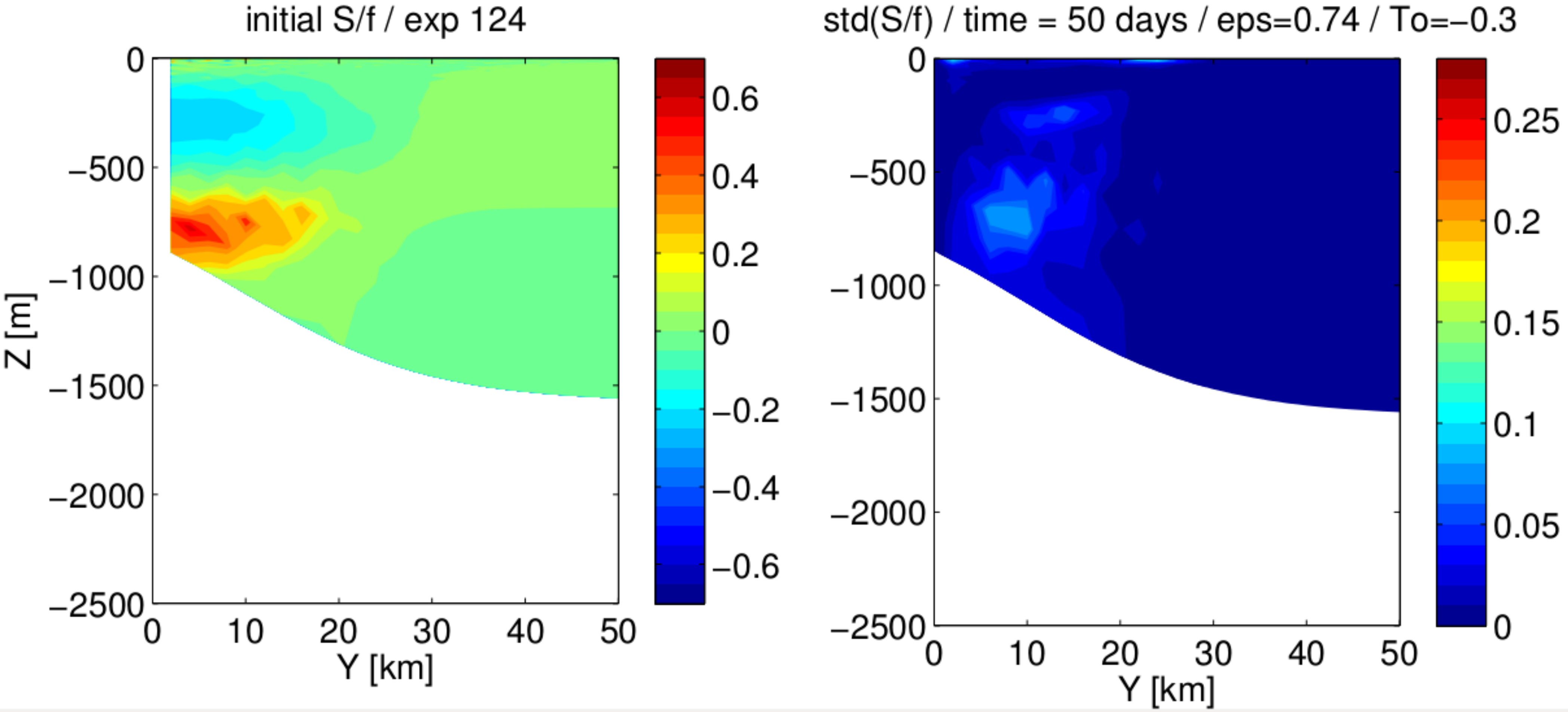
std(S/f) / time = 50 days / eps= 1.1 / To= −0

Stretching fluctuations

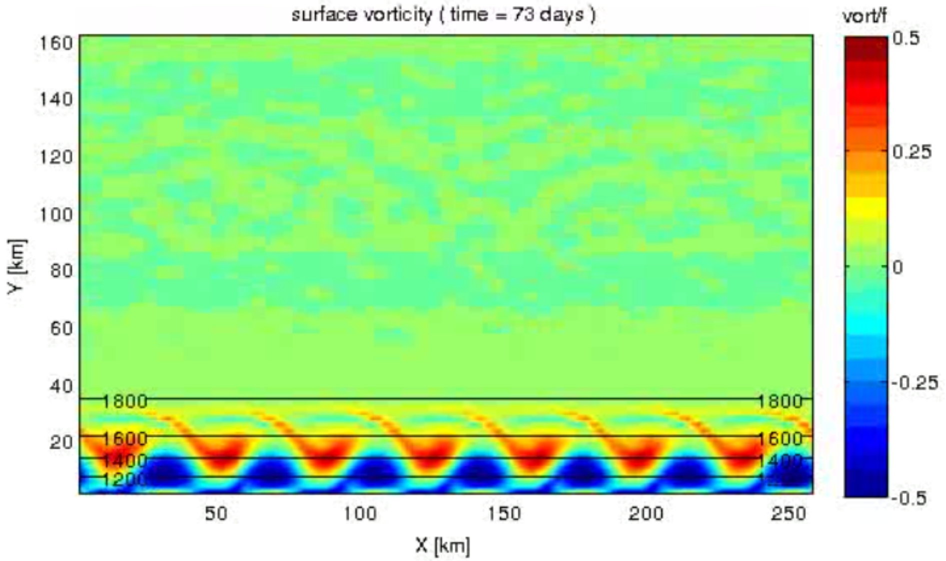

surface vorticity (time = 23 days)
vort/f
0.5
0.25
0
-0.25
-0.5
160
140
120
100
80
60
40
20
Y [km]
50
100
150
200
250
X [km]

PV interpretation : the trapped coastal instability (2)

Dipole of stretching=> BI => barotropization
Topographic PV halts the barotropization

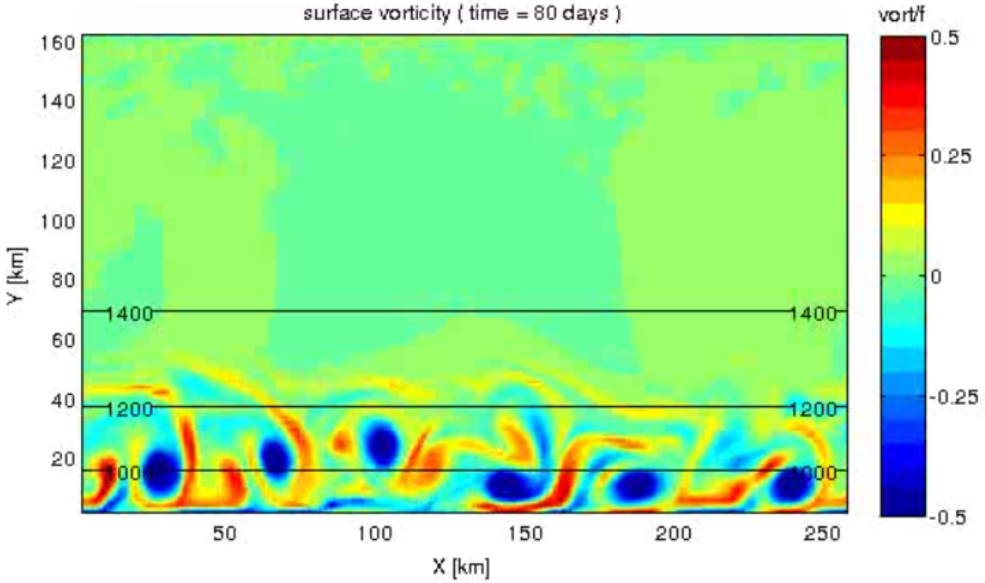


Trapped coastal instability



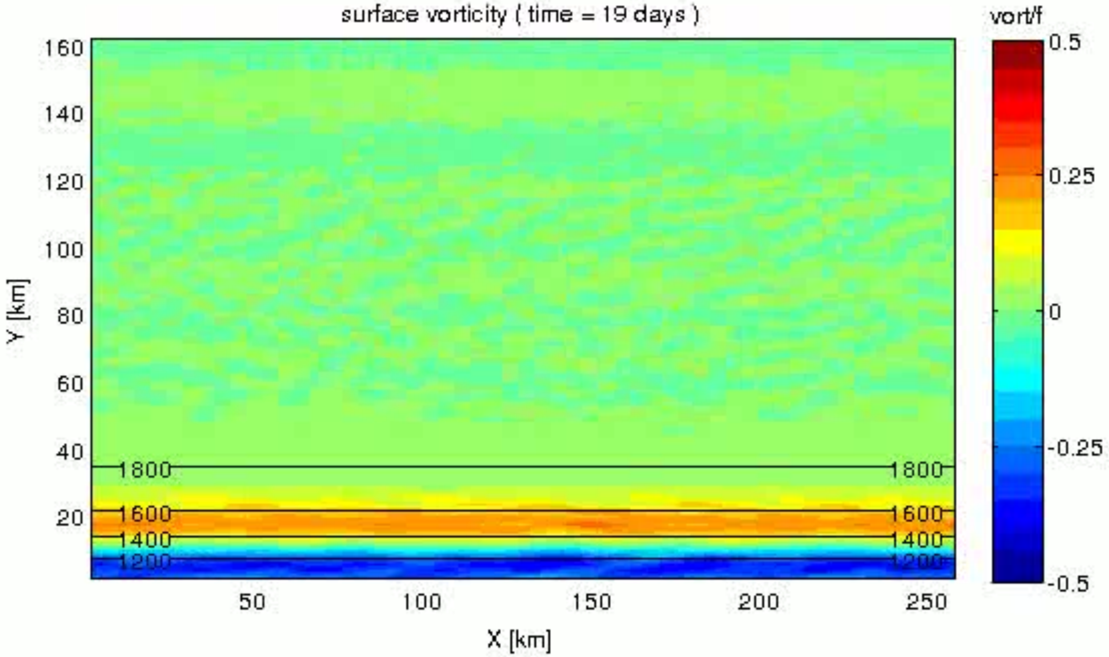
nonlinear stabilization :
$T_p \sim -0.3$ / $\omega_{max} \sim 0.75$

Full breaking:
$T_p \sim -0.1$ / $\omega_{max} = 1$

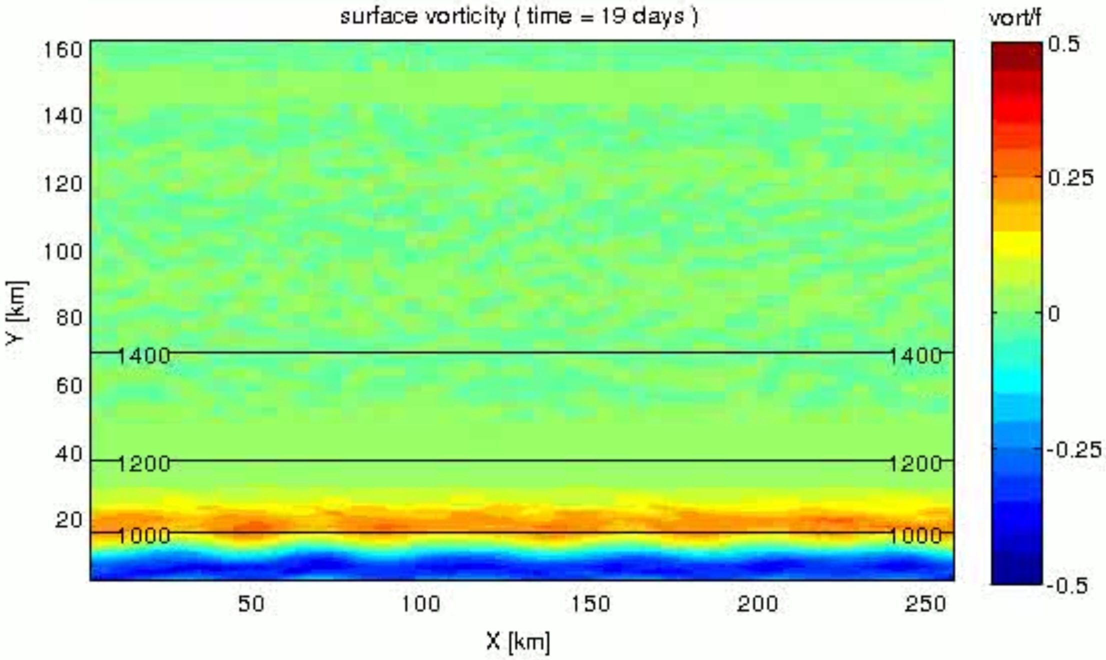


In all cases : **trapping on the slope**, no cross-slope exchange

nonlinear stabilization :
$T_p \sim -0.3$ / [illegible]$_{max} \sim 0.75$



Full breaking:
$T_p \sim -0.1$ / [illegible]$_{max} = 1$

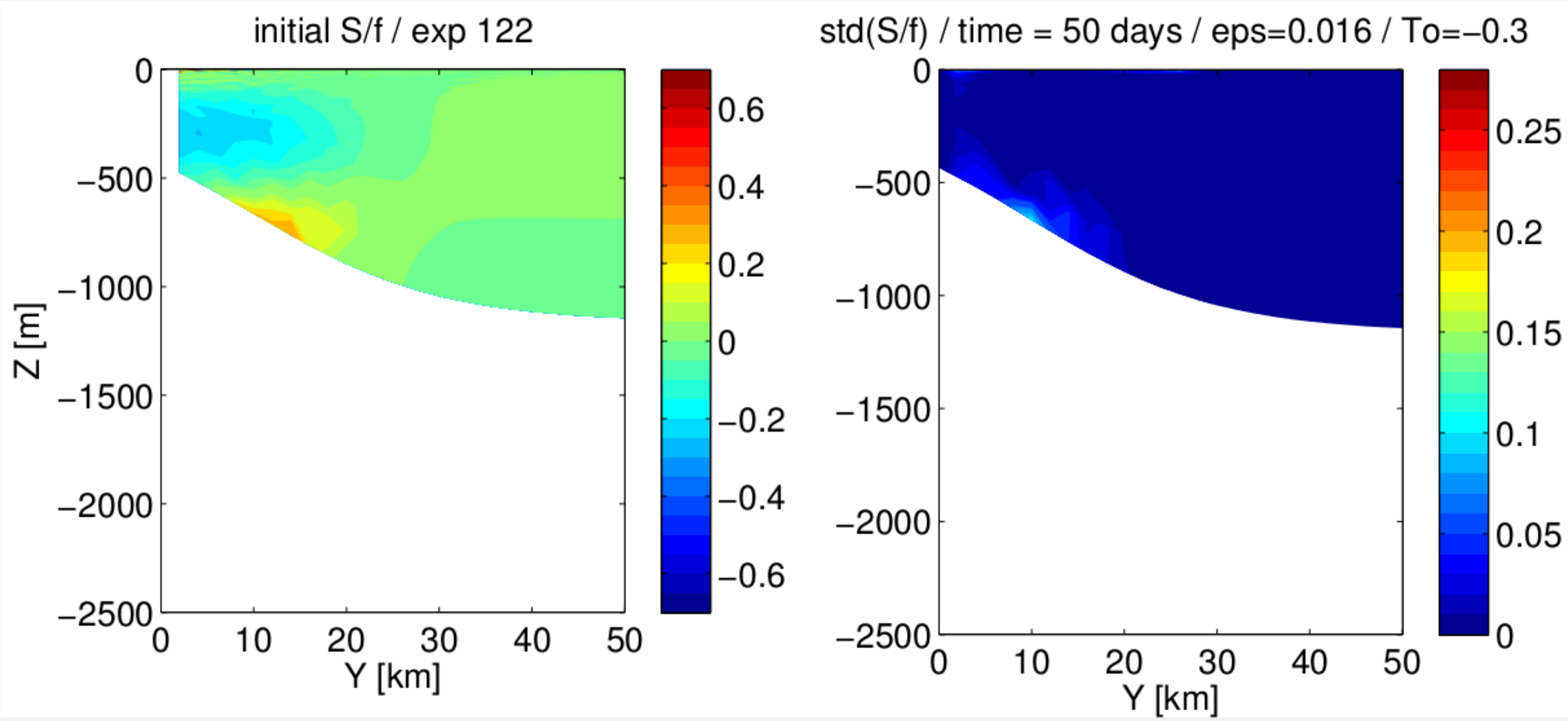


PV interpretation : the quasi-stable case (3)

Screening of the interior cyclonic core of stretching => no BCI

Almost barotropic jet => [q ~ (f+[illegible])/H]

Topographic PV dominates vorticity => quasi stable



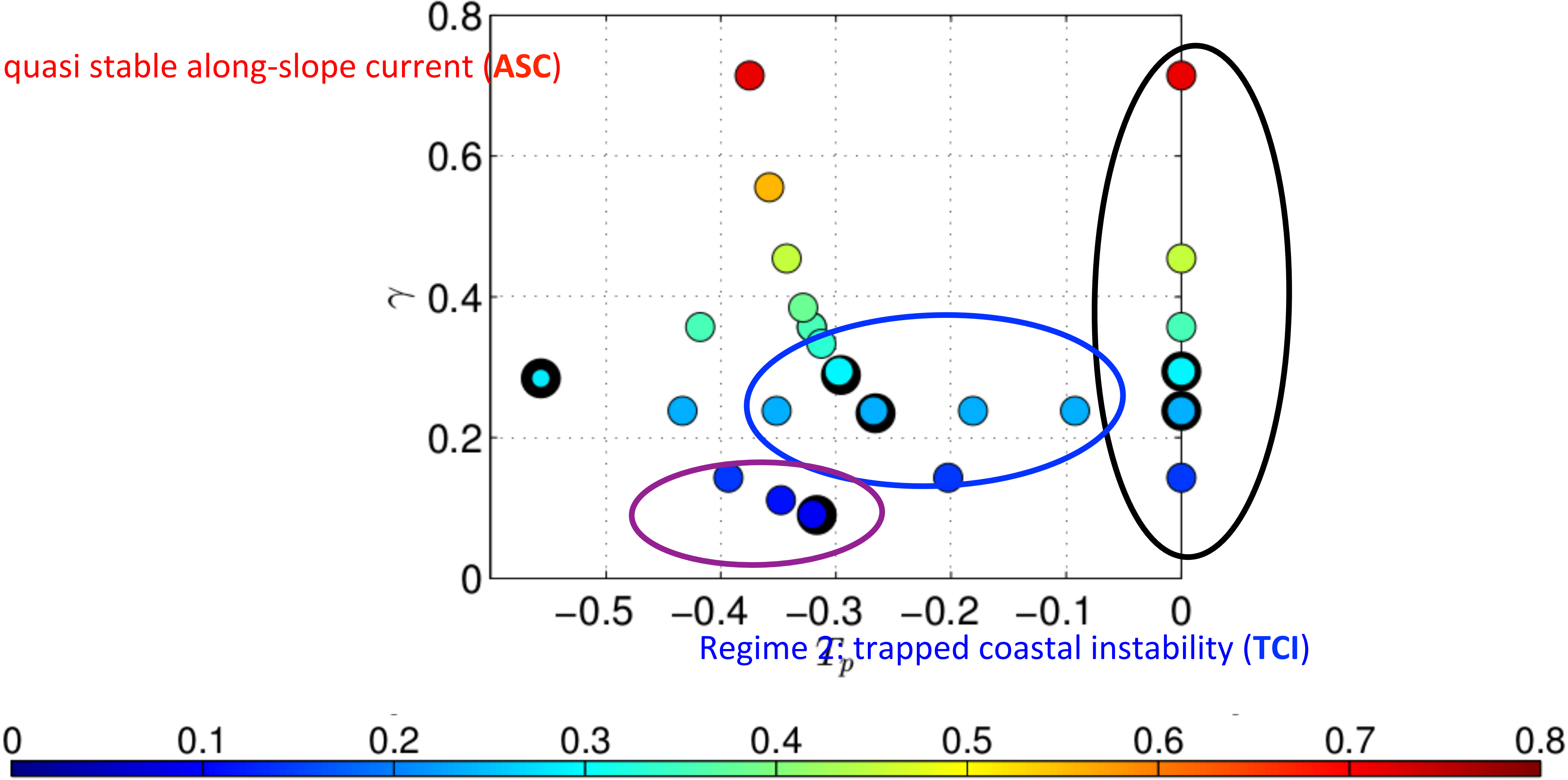
Shear instability (4)

Large H => BCI growth rate goes to 0

Shear instability takes over

Independent of the topography => full breaking $\square_{max} = 1$

Summary



standard baroclinic instability (**BI**)

: quasi stable along-slope current (**ASC**)

Regime 2: trapped coastal instability (**TCI**)

Summary

- Standard baroclinic instability : $T_p < -0.05$ (weak slope)

- Trapped coastal instability (mild slope + mild depth)
  $-0.4 < T_p < -0.05$ and $0.1 <$ < 0.3

- Quasi-stable current (steep slope + shallow)
  $T_p < -0.2$ and > 0.3

- Shear Instability : < 0.1 (very deep ocean)