Anticyclonic selection through large-scale and cyclogeostrophic barotropic instabilities

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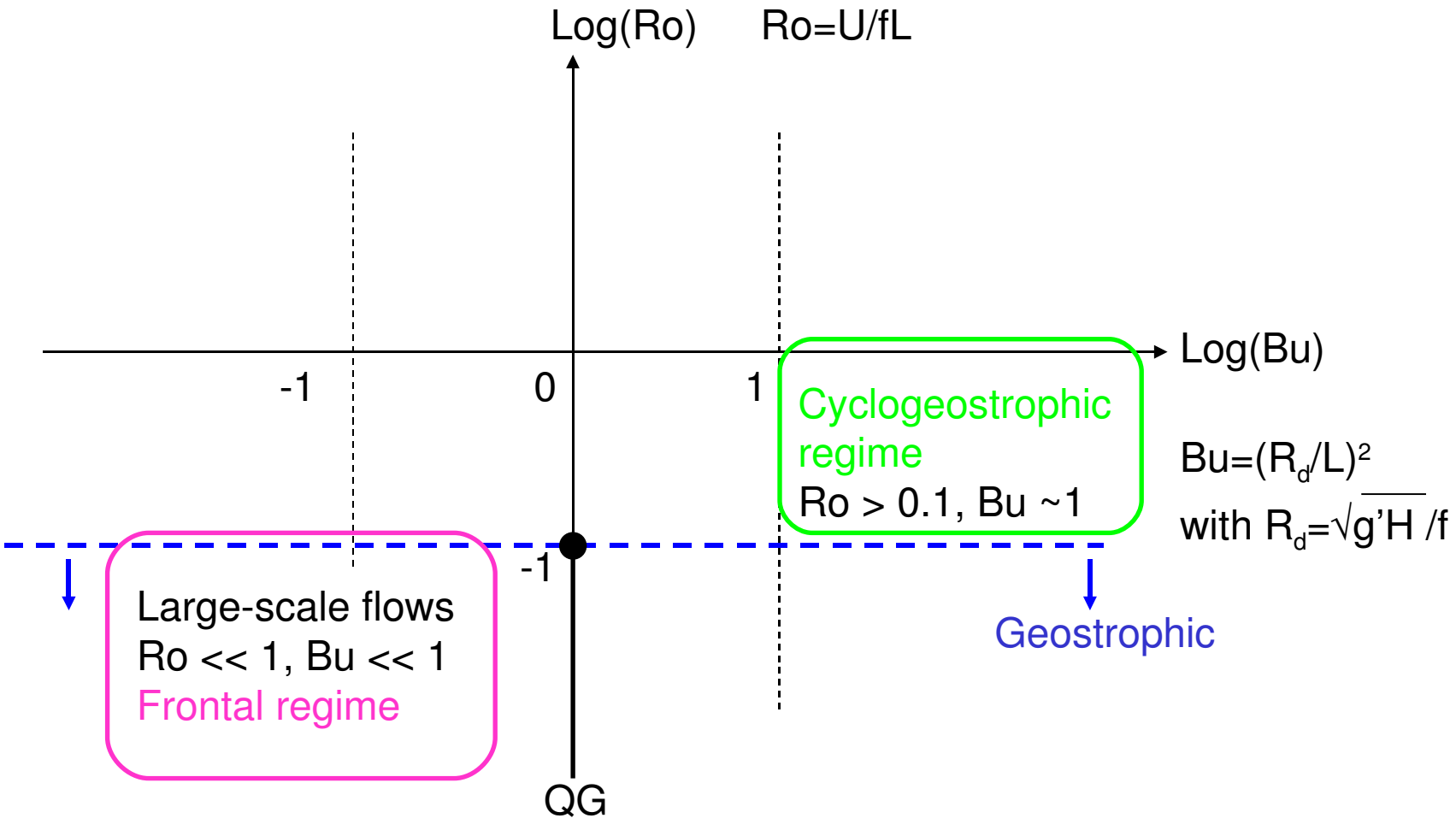
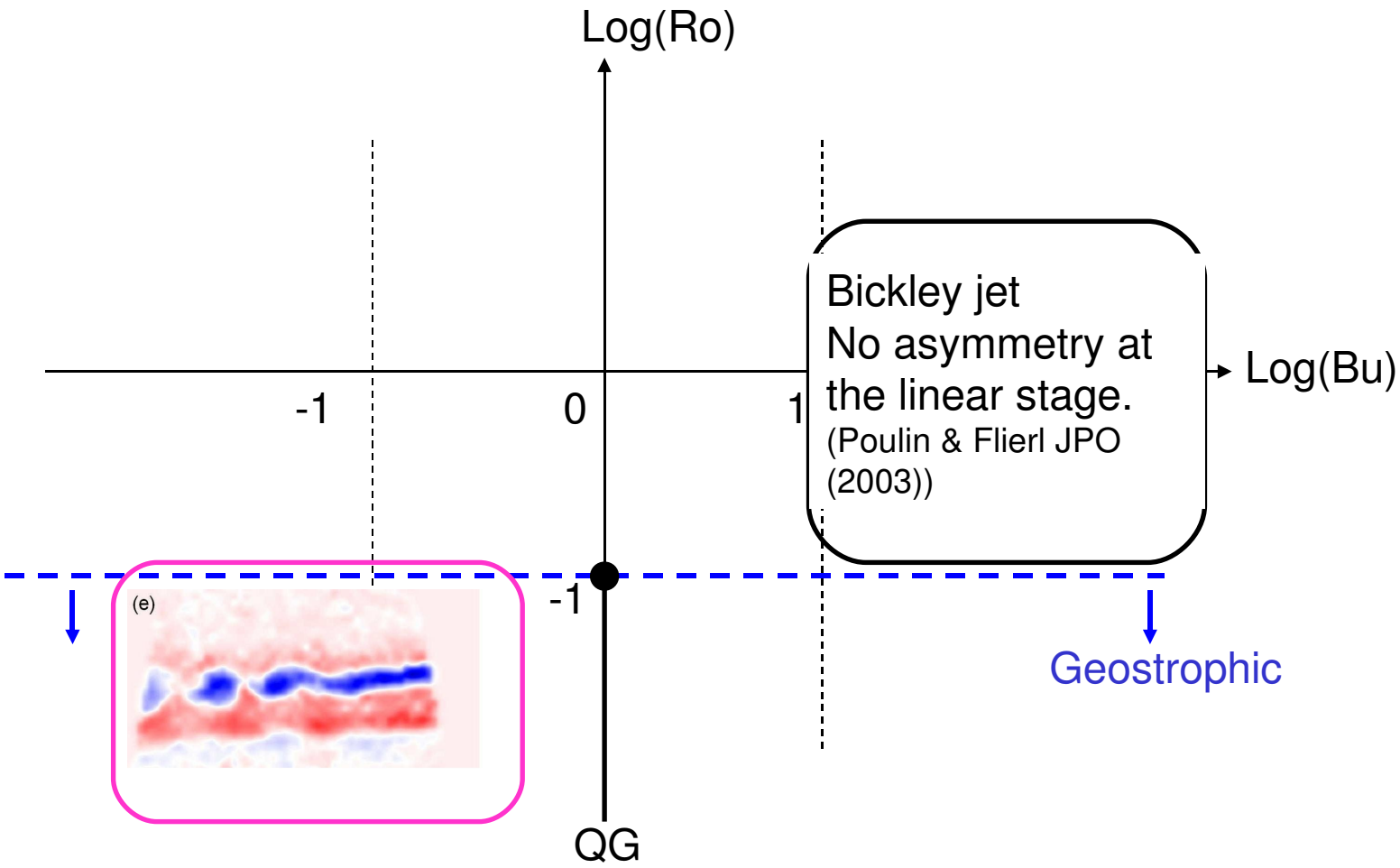
One layer, rotating shallow-water equations



One layer, rotating shallow-water equations



Wakes behave as two shears.
(Perret et.al. Pof (2006))

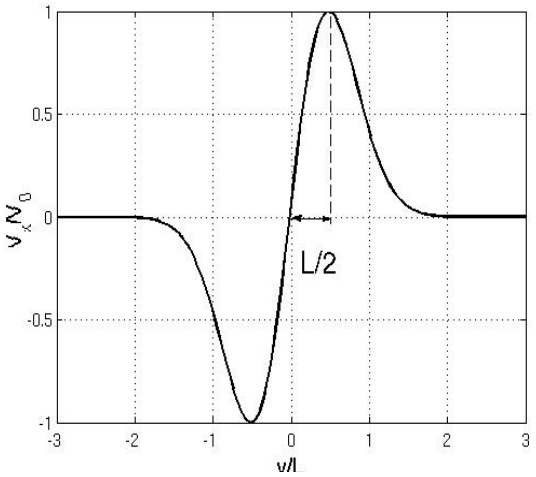
Objectives

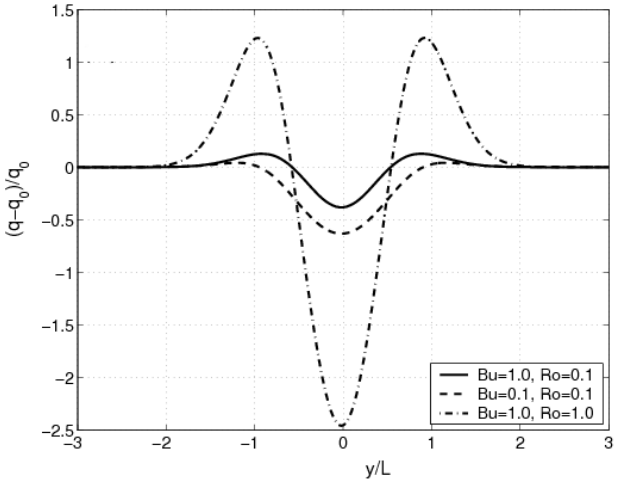
- How the vortex formation process itself, through destabilization of parallel barotropic flows, may induce cyclone/anticyclone asysmmetries ?

- Why the cyclone/anticyclone asymmetry appears in the linear stage in some cases and through nonlinear development of instabilities in other cases ?

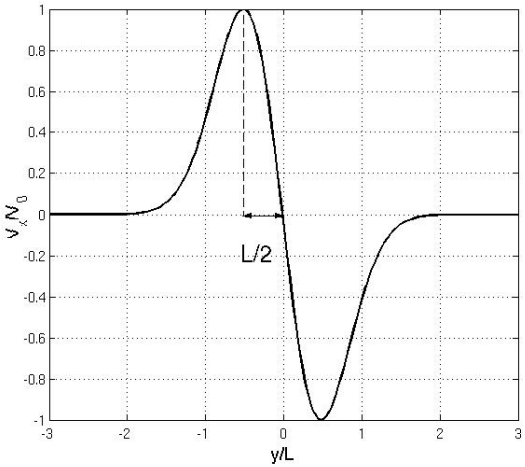
Linear stability

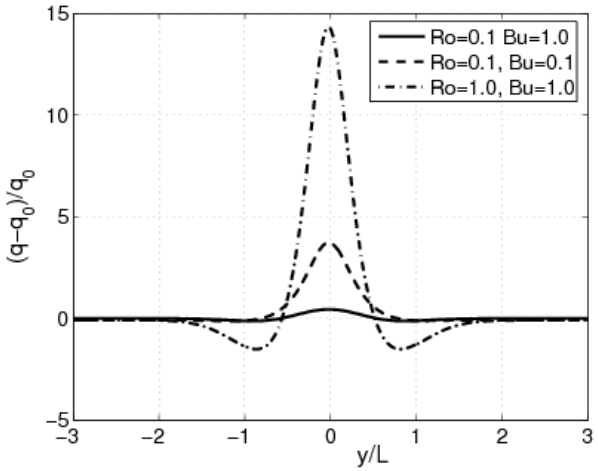
Anticyclone





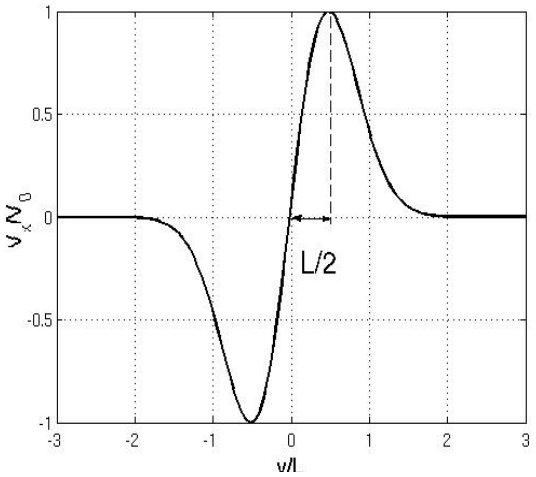
Cyclone

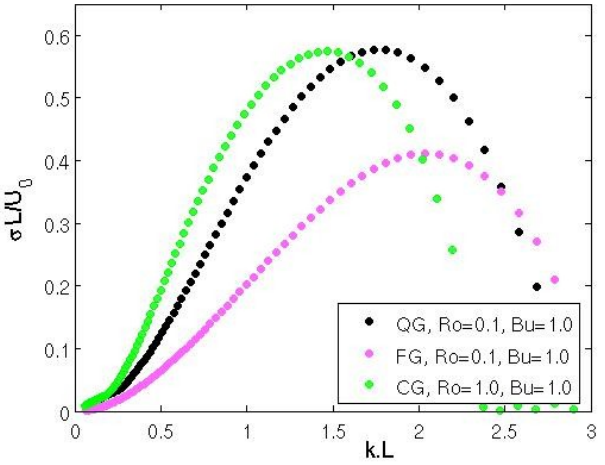




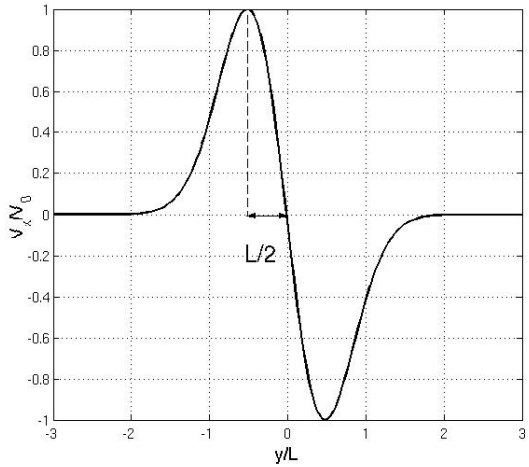
Linear stability

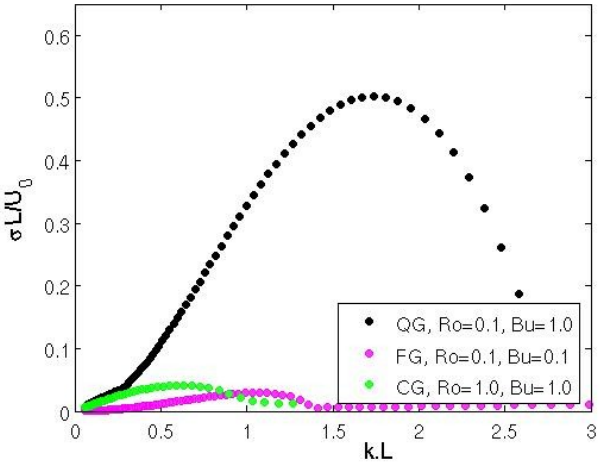
Anticyclone





Cyclone



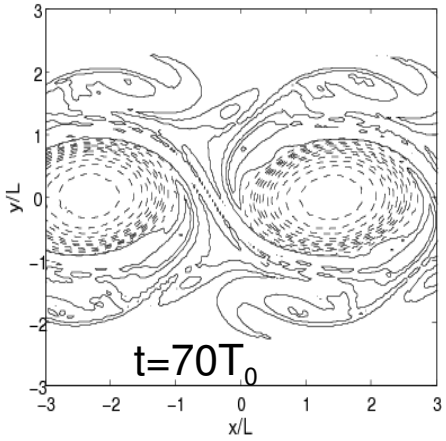


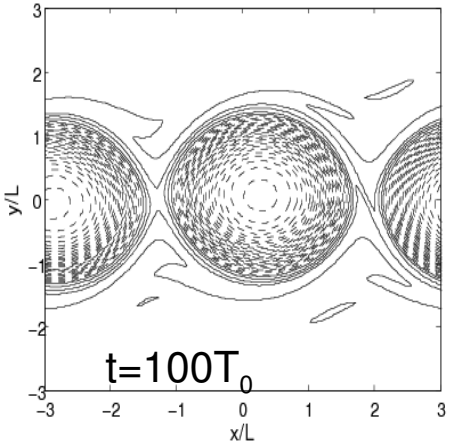
⇒ Linear selection of anticyclonic shear

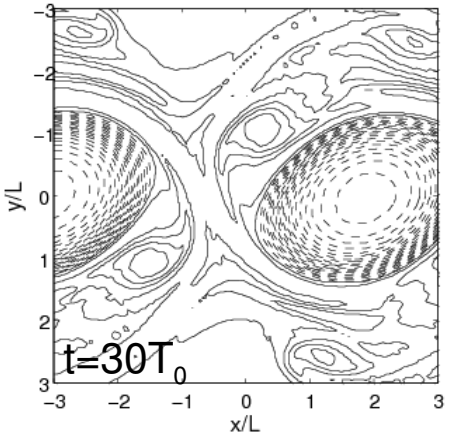
Non linear evolution

QG | Frontal regime | Cyclogeostrophic

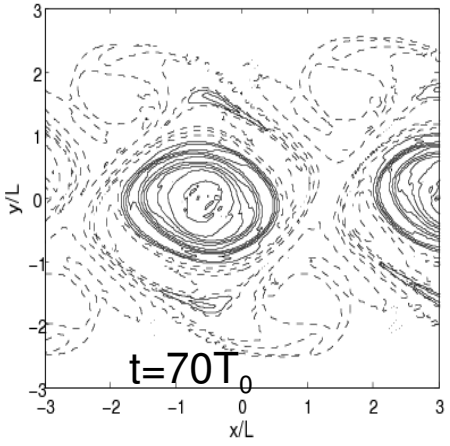
Anticyclone

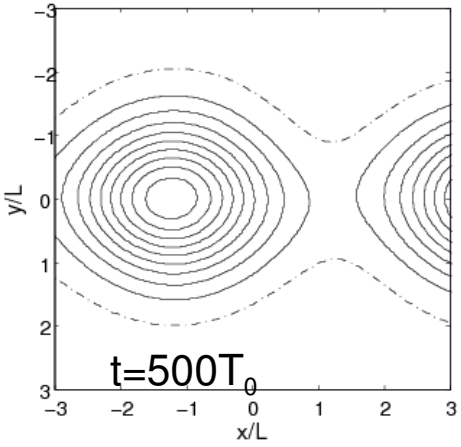


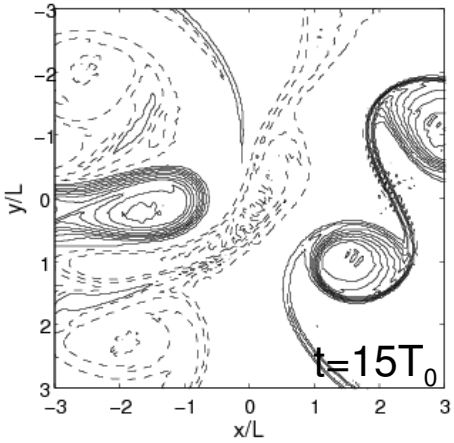




Cyclone







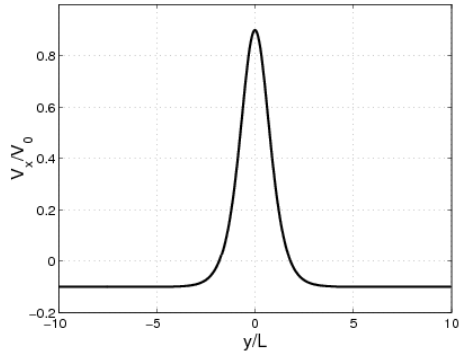
Similar evolution

Anticyclones develop faster
Cyclones are more elongated

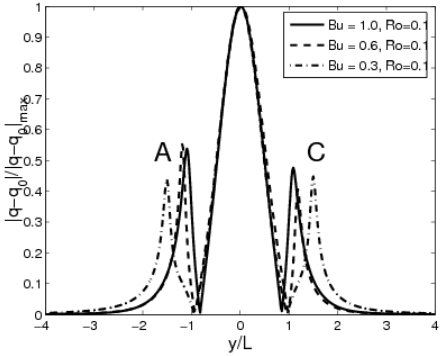
Non linear evolution

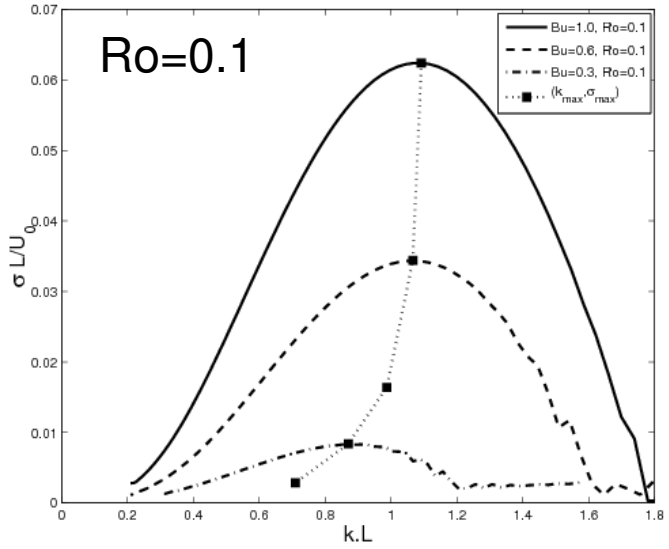
- What happens when several shears are correlated ?

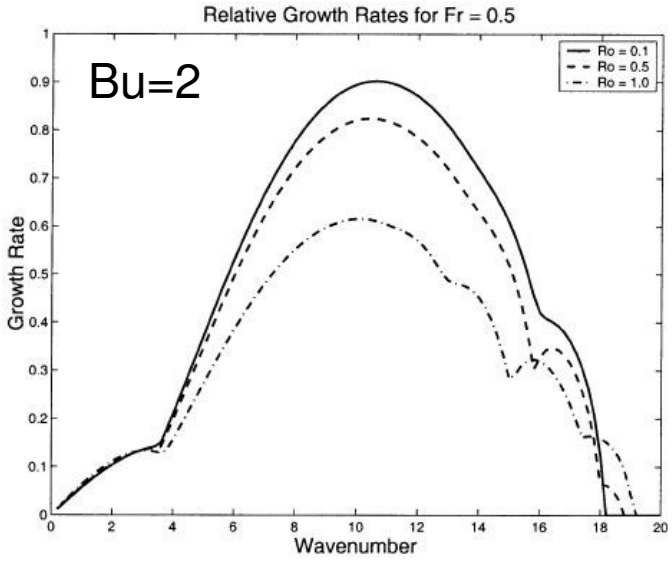
Linear stability



⇒ most unstable mode is a sinuous mode





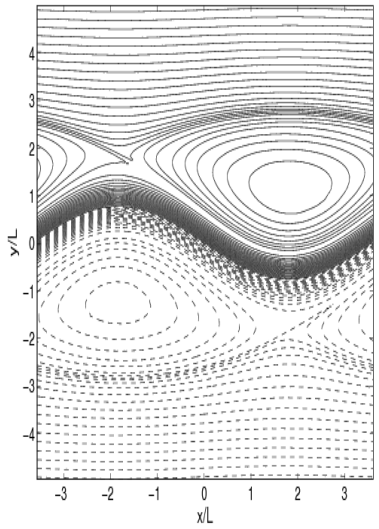


Poulin & Flierl, 2003, JPO (33)

⇒ No linear selection of anticyclonic or cyclonic instability

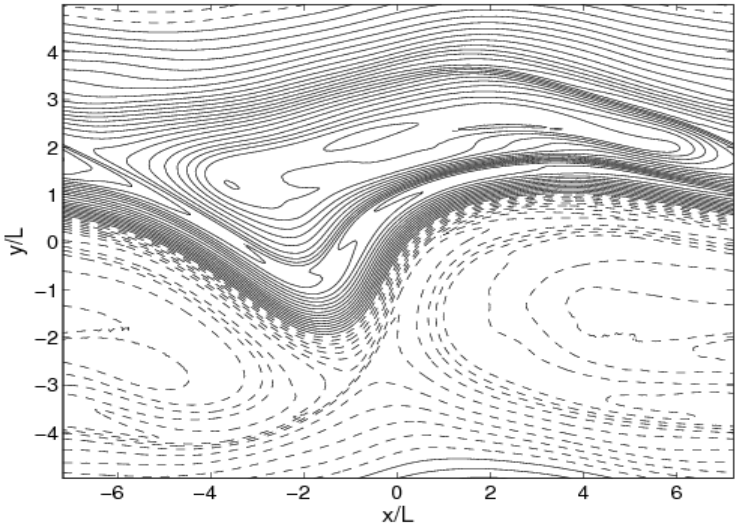
Non linear evolution

QG
Ro=0.1, Bu=1.0



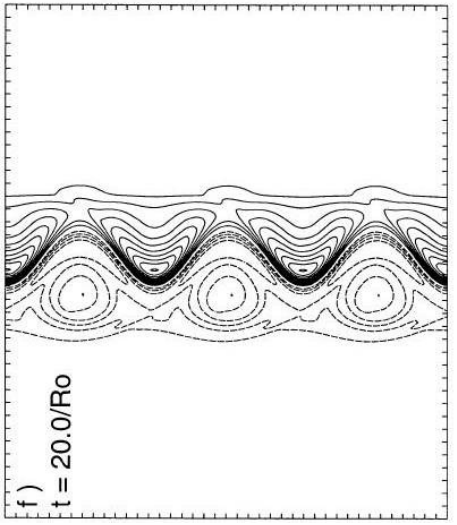
t =741 T_0

Frontal regime
Ro=0.1, Bu=0.2



t =1892 T_0

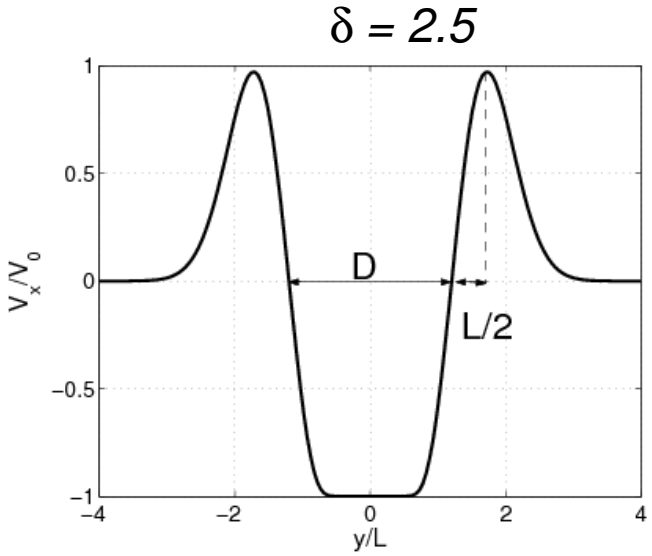
Cyclogeostrophic
Ro=1.0, Bu=2.0

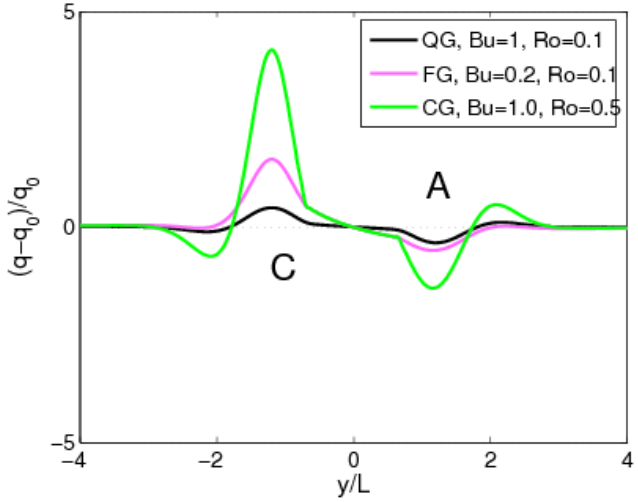


Poulin & Flierl, 2003, JPO (33)

⇒ Cyclones are more elongated than anticyclones

Linear stability

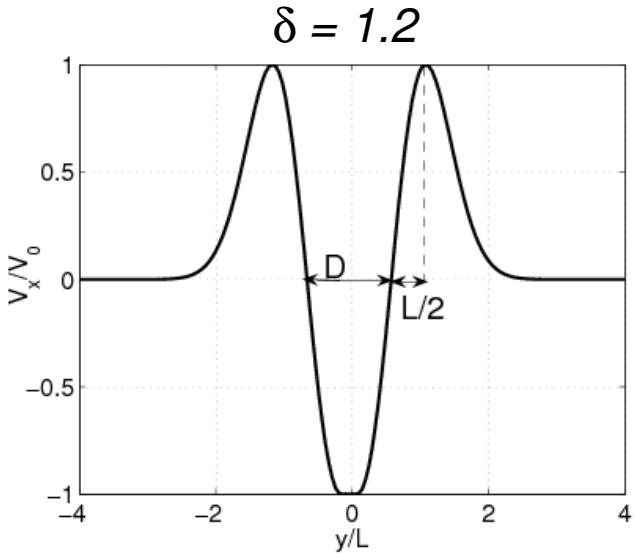




⇒ We define a new parameter to characterize the correlation of opposite sign shears :

$$\delta = \frac{D}{L}$$

Linear stability

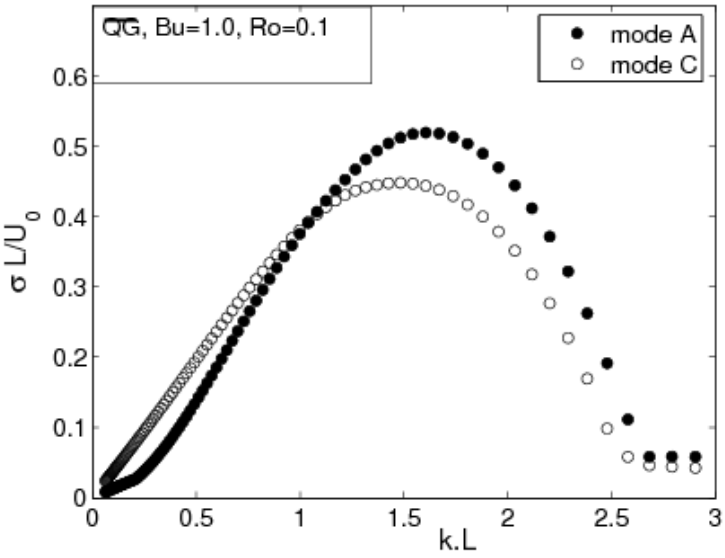


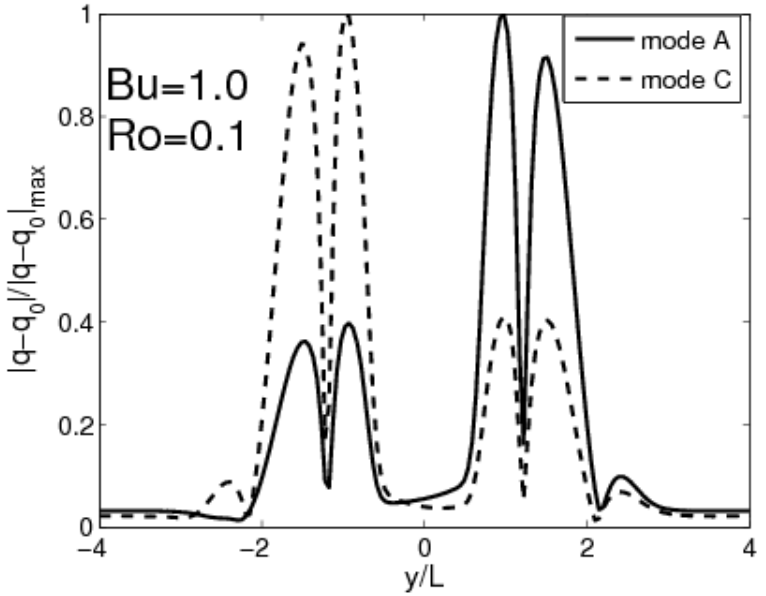
$$\delta = \frac{D}{L} \rightarrow 1$$

$\Rightarrow$ Parallel wake becomes similar to a jet flow

Linear stability

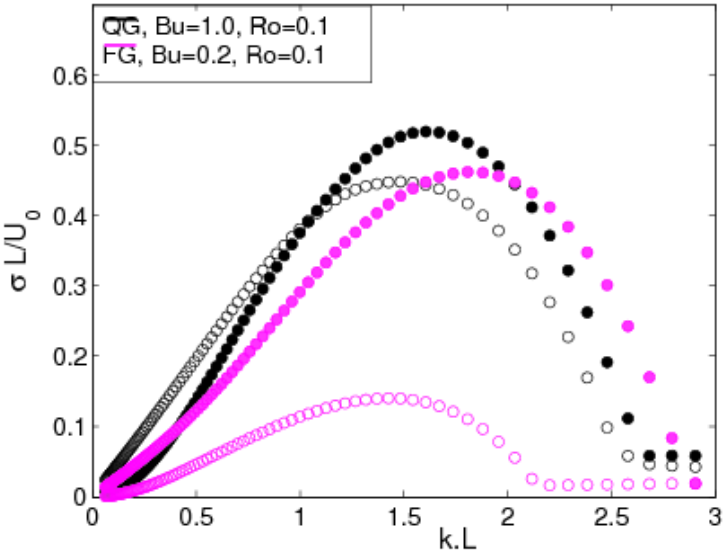
$\delta = 2.5$

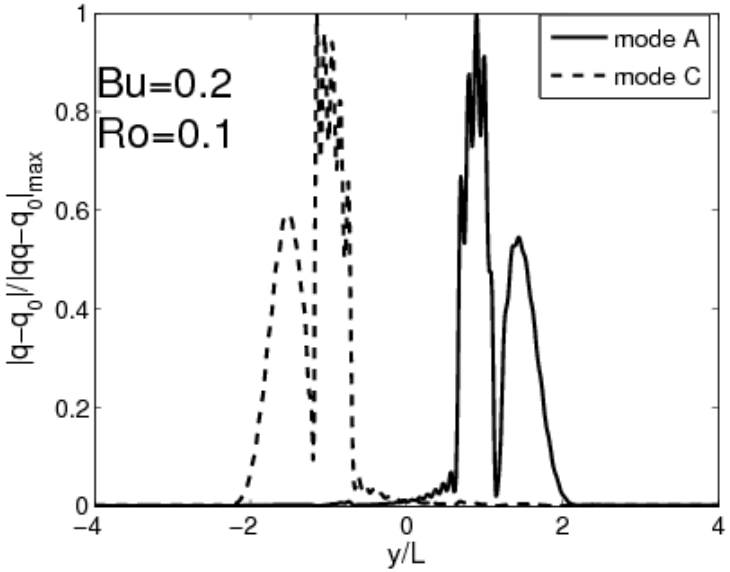




Linear stability

$\delta = 2.5$

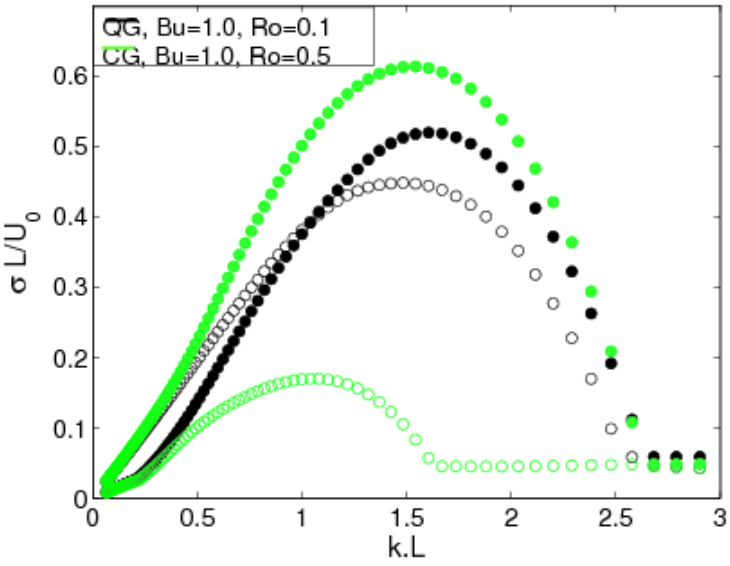


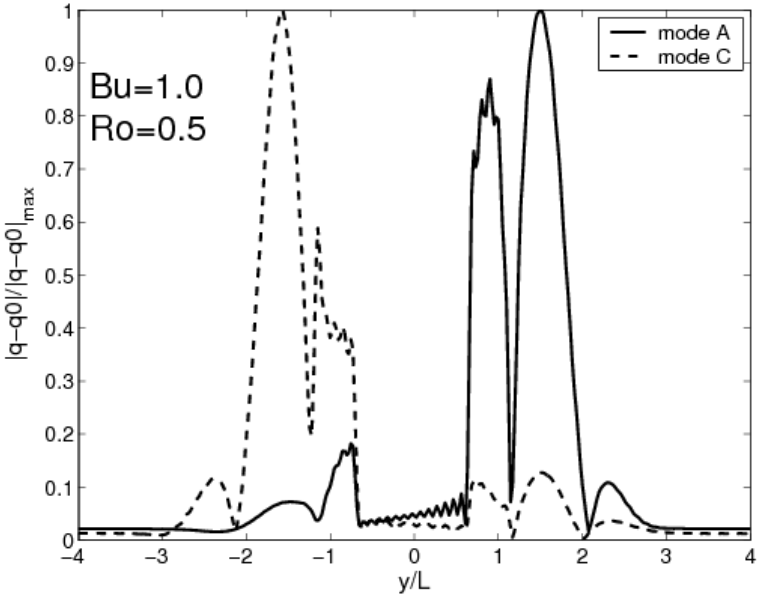


⇒ Decorrelation of the modes

Linear stability

$\delta = 2.5$

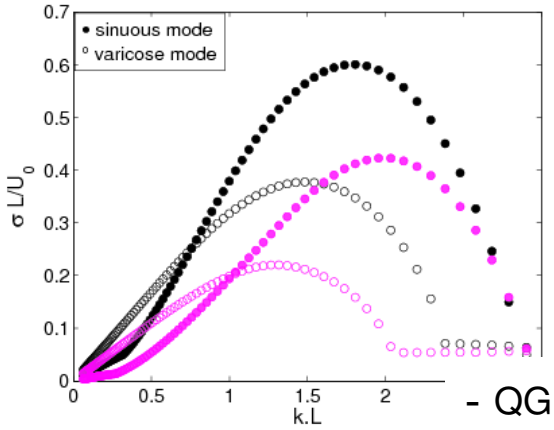


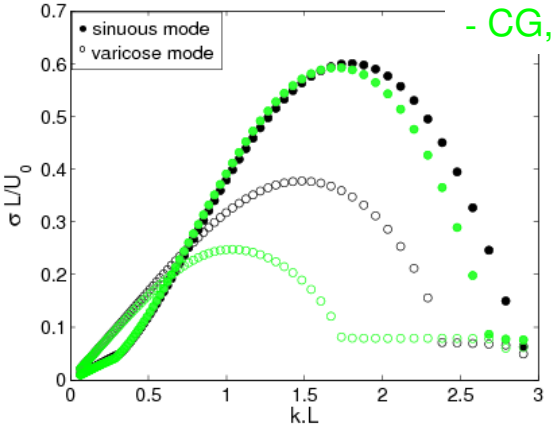


⇒ Linear selection of anticyclonic part of the flow

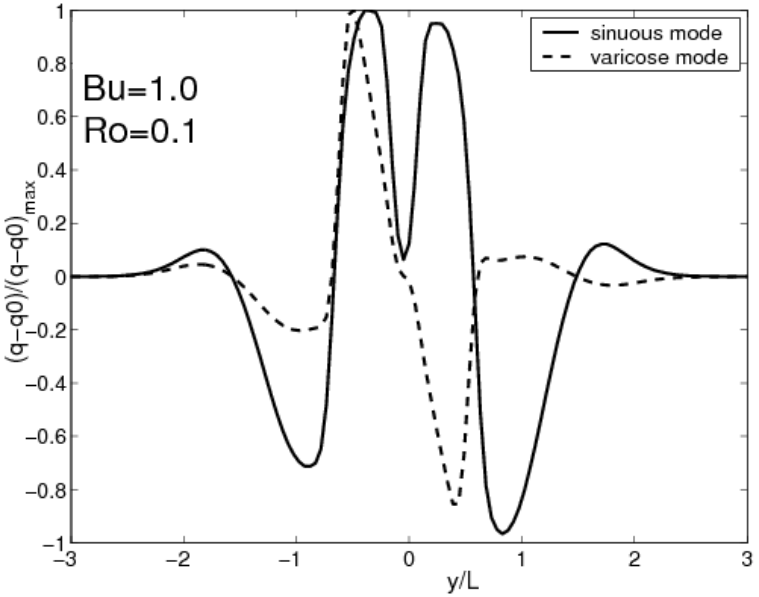
Linear stability

$\delta = 1.2$



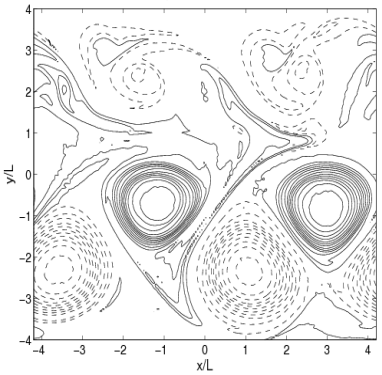
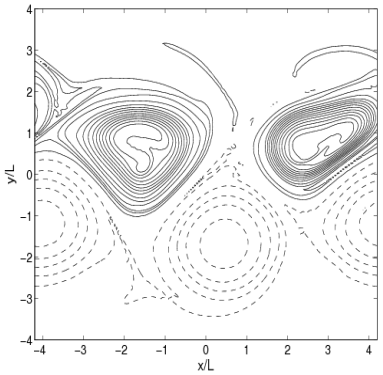
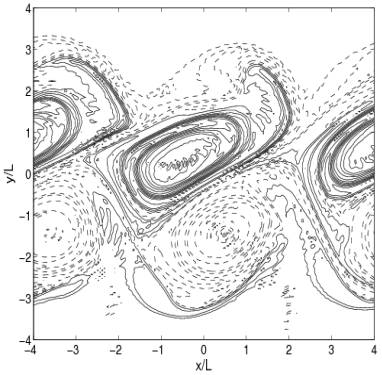
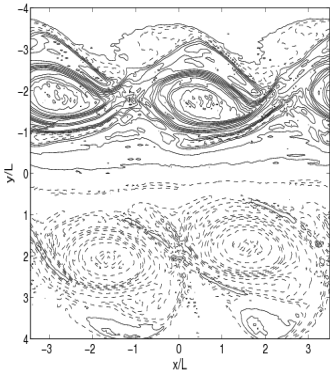
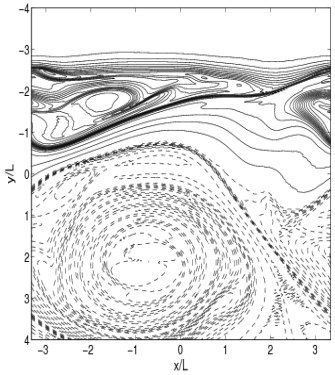
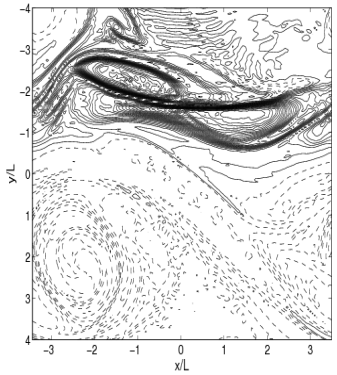


- QG, Bu=1.0, Ro=0.1
- FG, Bu=0.2, Ro=0.1
- CG, Bu=1.0, Ro=0.5



⇒ When (D-L) ≤ 2 R_d, the most unstable perturbation is a sinuous mode, no cyclone/anticyclone asymmetry.

Non linear evolution

	QG Bu=1, Ro=0.1	Frontal regime Bu=0.2, Ro=0.1	Cyclogeostrophic Bu=1, Ro=0.3
$\delta = 2.5$			
$\delta = 4$			

• In frontal and cyclogeostrophic regimes, cyclones are deformed by the strain induced by the formation of anticyclones

Conclusion & perspectives

- At the linear stage, in non-QG regimes,
  - Localised anticyclonic shears are more unstable than cyclonic ones.
  - Whereas the development of instability in the Bickley jet reveals no distinction between regions of positive and negative vorticity.
  - Stability properties of parallel wake flows depend on the distance between the opposite sign shears, their coupling may suppress the cyclone-anticyclone asymmetry.
- The nonlinear saturation of instability leads, to coherent and axisymmetric anticyclones while cyclones are more elongated and deformed.