Mini-Projects ocean

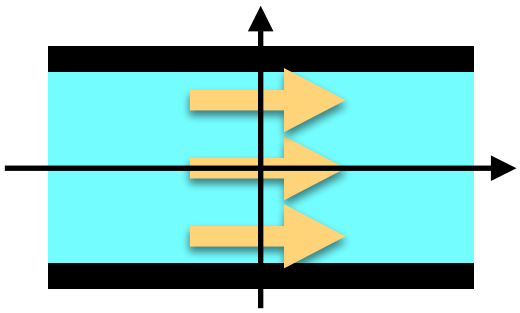
2. Formation of ocean eddies

The aim of this project is to characterize the destabilization of a barotropic jet in an east-west periodic channel, and the impact of the numerical schemes on the instabilities.

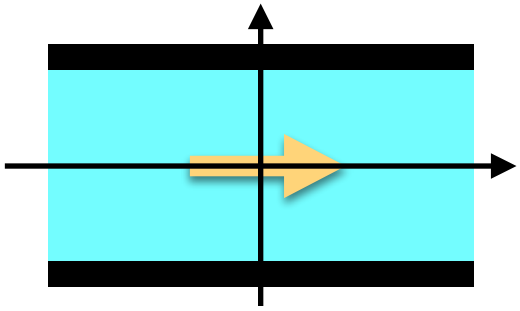
The basin has a flat bottom (no topographic obstacles) and is initially forced by a current in geostrophic balance, homogeneous in the along channel direction (x) and in vertical (z). For simplicity, Coriolis is either supposed to be constant (f-plan) or to vary linearly with latitude (beta plan) and the equation of state is linear in temperature. Density thus does not depend on salinity which can be used as a passive tracer for visualization purposes.

4 experiments will be designed by the students using the ocean model NEMO and the configuration called "CANAL". The main idea is to find in which conditions a barotropic current can be destabilized

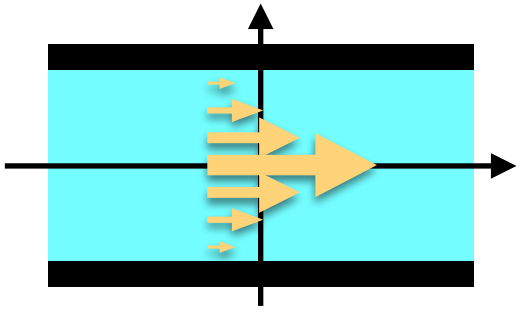
1) Uniform zonal current [f-plane and β-plane]



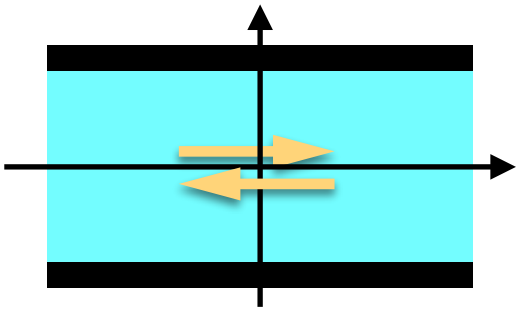
2) Zonal jet "uniform shape" (confined in between 2 latitudes) [f-plane and β-plane]



3) Zonal jet "gaussian shape" [beta-plane]



4) Double jets “uniform shape” (high shear) [f-plane]



Rappel: équilibre géostrophique

$$u_{geostrophique} = -\frac{1}{f\rho_0}\frac{\partial p}{\partial y}$$

$$v_{geostrophique} = +\frac{1}{f\rho_0}\frac{\partial p}{\partial x}$$

$$\frac{\partial p}{\partial z} = -\rho g$$

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z} = 0$$

le “plan f”

$$\boldsymbol{f = f_0 = 2\Omega sin\varphi_0}$$

le “plan β”

$$\boldsymbol{f = f_0 + \beta y}$$
$$\boldsymbol{\beta = 2\Omega cos\varphi_0 / R_{earth}}$$

To do:

- Design experiment (1) and show that the current stays in geostrophic equilibrium (in theory and in the model). tip: Find the expression of η, the height of the ocean surface above the reference z=0. Start with f-plane.

$$u = u_0$$
$$v = 0$$
$$\rho = \rho_0$$

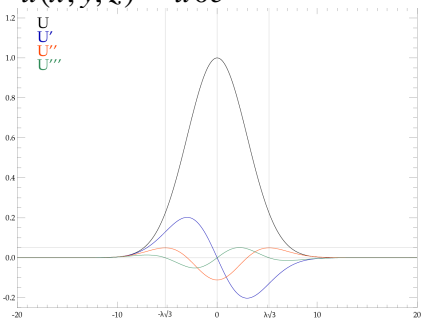
- Design experiment (2)

- Run it. Do you see eddies forming? Why?
- Add a random noise to the background sea surface height. Do you see eddies? Why?
- Do we need the North-South walls?

- Design experiment (3)
  - Calculate (theoretically) which shape is unstable/stable depending on the latitude
  - Verify with the model's behavior
  - Characterize the instabilities (do they depend on the shape?)
  - Do we need the North-South walls?

Tips:

- the gaussian shape for the zonal current takes this form: $u(x,y,z) = u0e^{-\frac{y^2}{2\lambda^2}}$



- the condition of instability (stabilizing effect of beta) is

$$\frac{\partial^2 \boldsymbol{u}}{\partial \boldsymbol{y}^2} - \boldsymbol{\beta}\ \boldsymbol{change\ de\ signe} \Rightarrow \frac{\partial^2 \boldsymbol{u}}{\partial \boldsymbol{y}^2} = \boldsymbol{\beta}$$