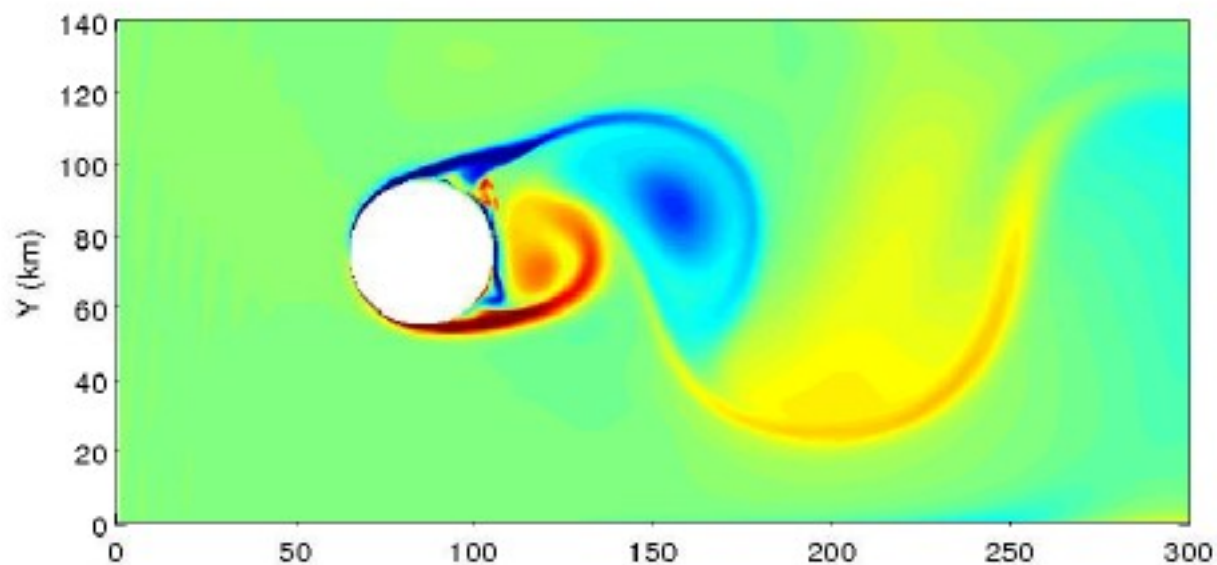
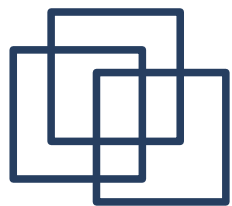


Deep water island wakes

Baroclinic case





Model configuration

ROMS – Regional Ocean Modeling System

<http://www.myroms.org/>

Hyperbolic function incoming flow:

$$u(z) = u_{m1} - u_{m2} \tanh\left(\frac{z + h_s}{h_d}\right), \quad -H_m < z < 0$$

u_{m1} – surface current h_s – shear layer thickness

u_{m2} – bottom current h_d – central layer thickness

Upstream density:

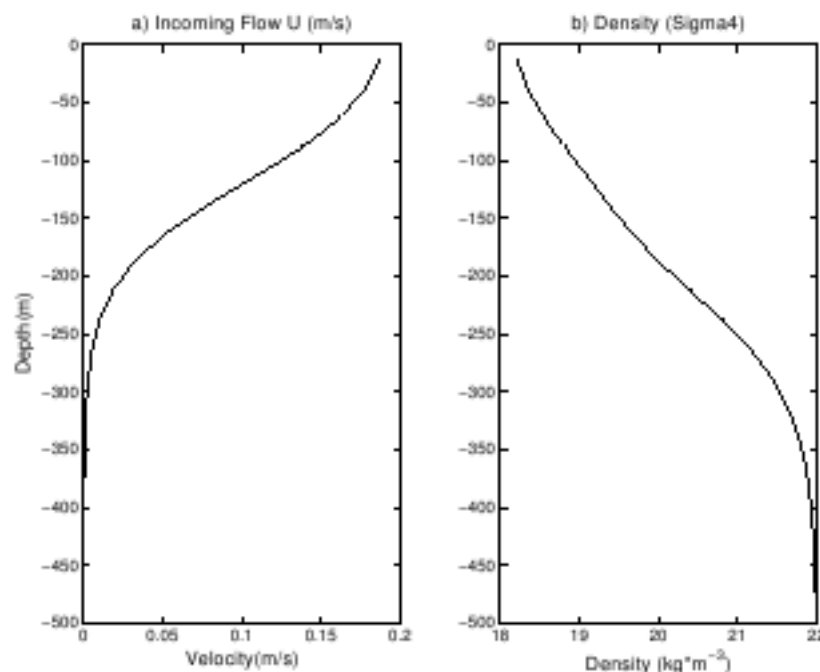
$$\rho(y, z) = \rho_0 + \frac{\rho_0}{g} \int_{y_0}^y f \frac{\partial u}{\partial z} dy + \delta \rho \tanh\left(\frac{z + h_c}{h_t}\right)$$

$\delta \rho$ – 1/2 density difference h_c – thermocline central depth

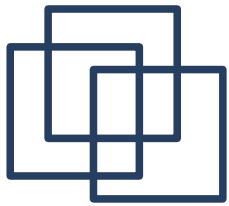
h_t – thermocline thickness

Surface elevation:
$$\eta(y) = -\frac{f(y - y_0)}{g} u|_{z=0}$$

Analytical prescribed conditions

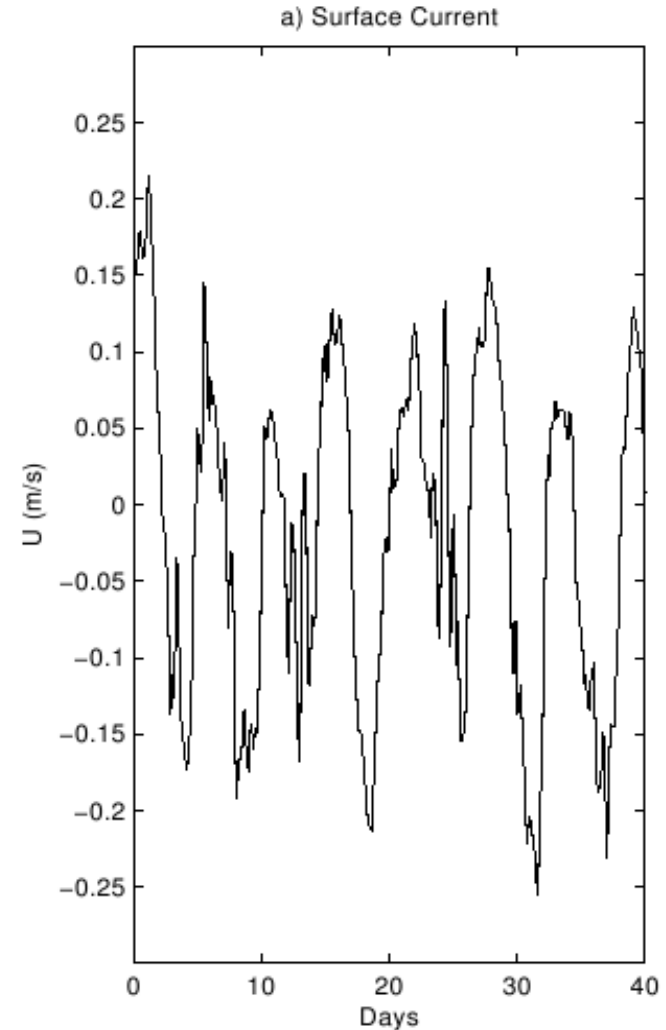


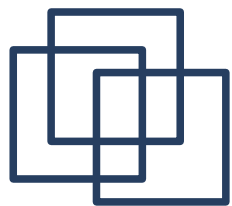
Geostrophic balance



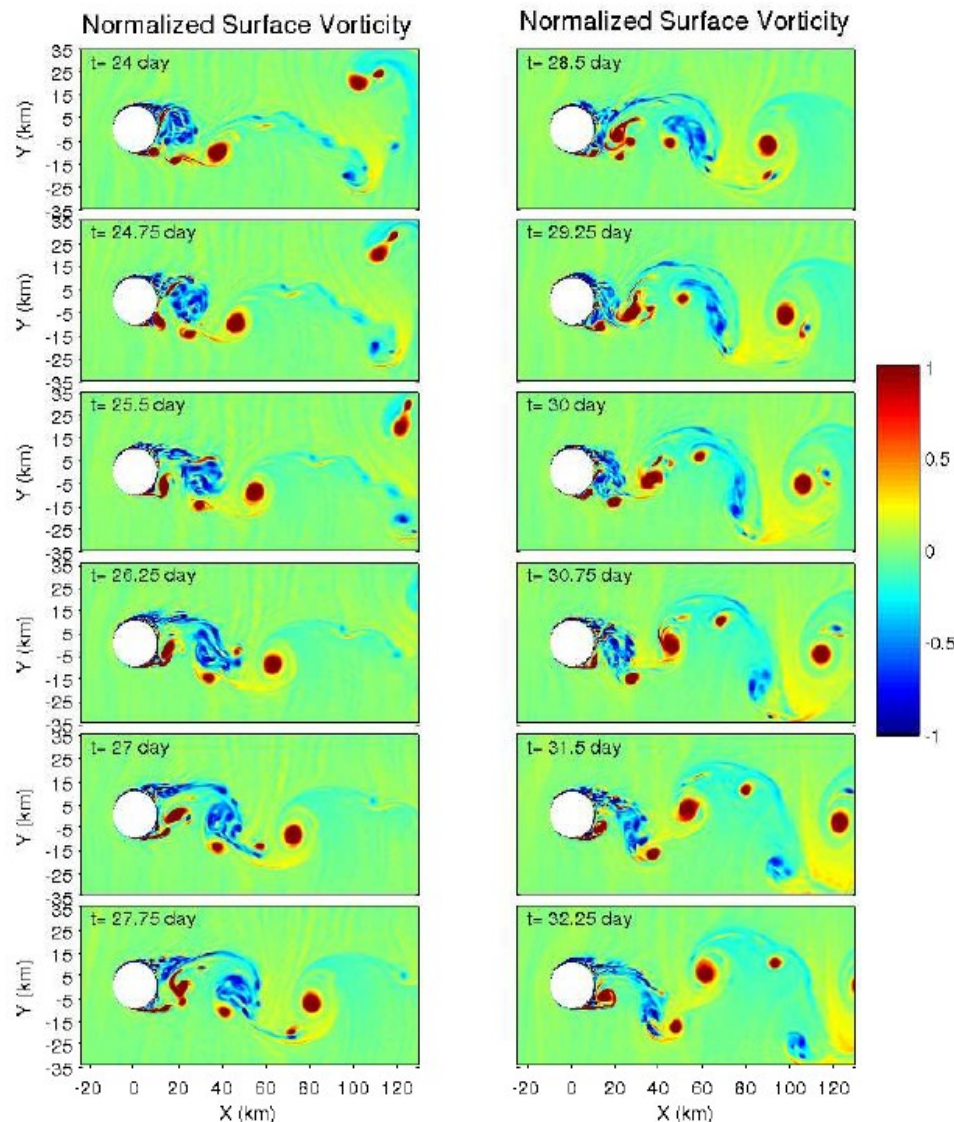
Baseline experiment

- $x=180\text{km}$; $y=80\text{km}$
- Island $\Rightarrow x=45$; $y=40$
- $D=20\text{ km}$
- $H_{\text{max}}=k=500\text{m}$
- Coriolis $=K=10^{-4}$
- Eddy viscosity $=0$
- $U_{\text{max}}=0.2$; $U_{\text{min}}=0.1\text{ m/s}$
- $Ro=0.1$
- $N \sim 2\text{Coriolis}$
- $Rd=20\text{km}$
- $Bu \sim 1$
- $Ri=0.25$





Baseline experiment



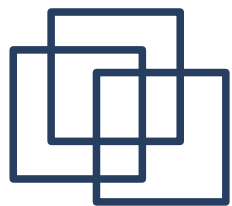
Eddies life cycles:

→ Asymmetry @ N-S edge

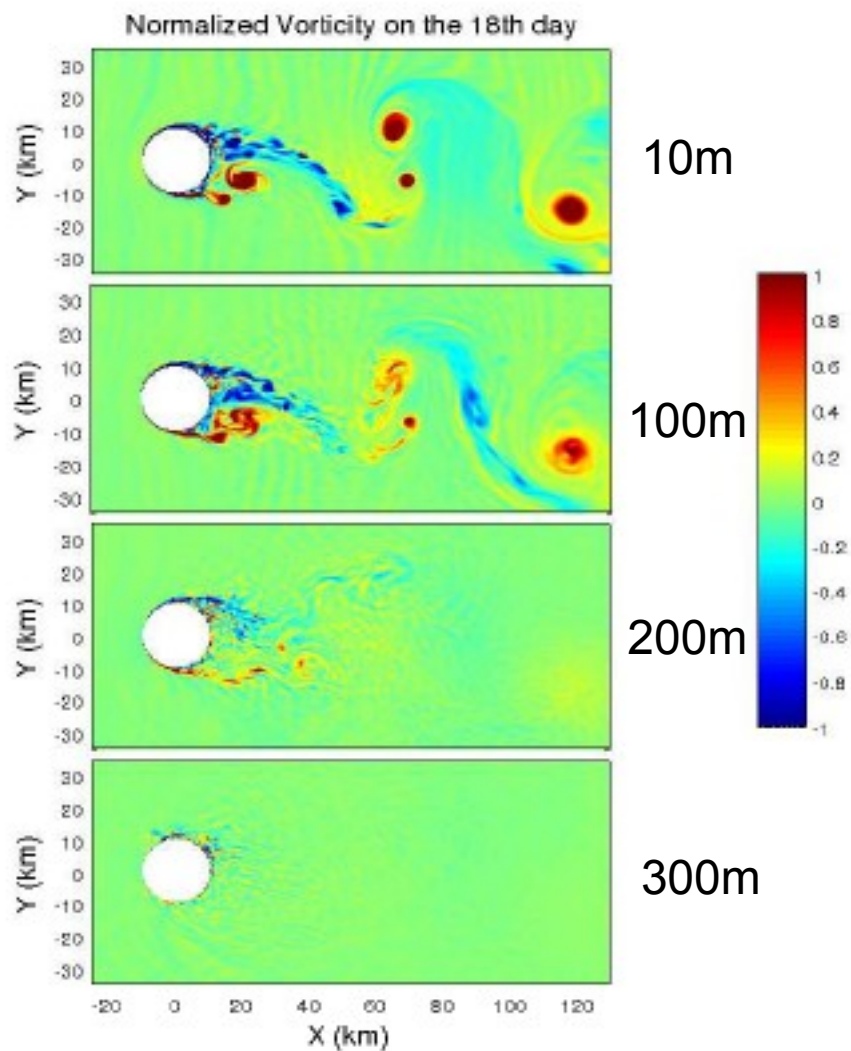
→ S => wavy cyclonic eddy pattern

→ N => small extrema + noise

→ Anticyclonic instability => centrifugal



Baseline experiment

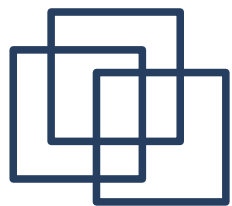


→ Weak flow @ depth

→ Wake 2D @ 300m

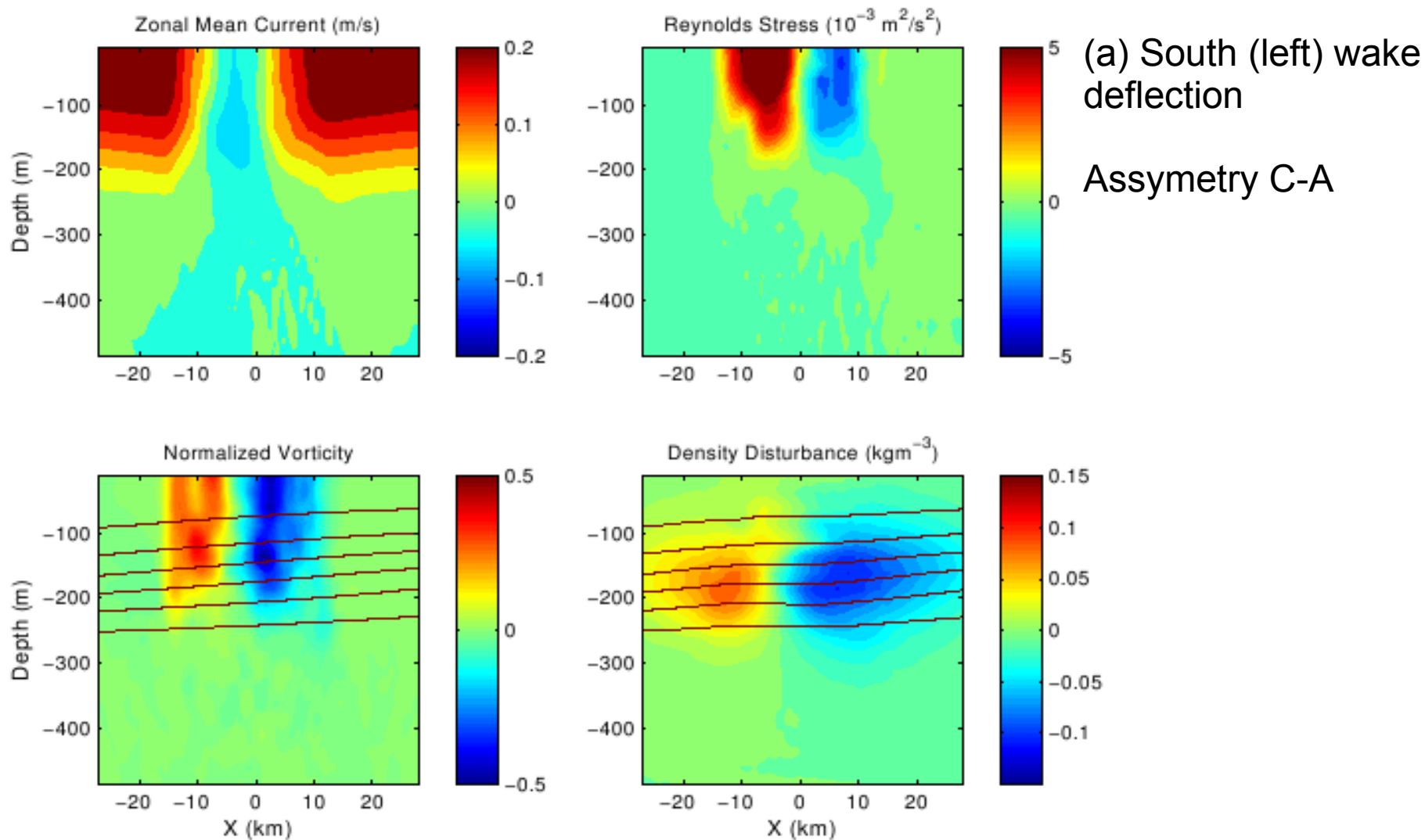
→ Cyclonic vort. max @ 10m => 0-150m

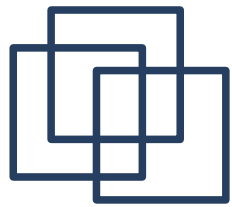
→ Anticyclonic vort. Max 130m



Wake vertical structure

9 day average => full A-C cycle





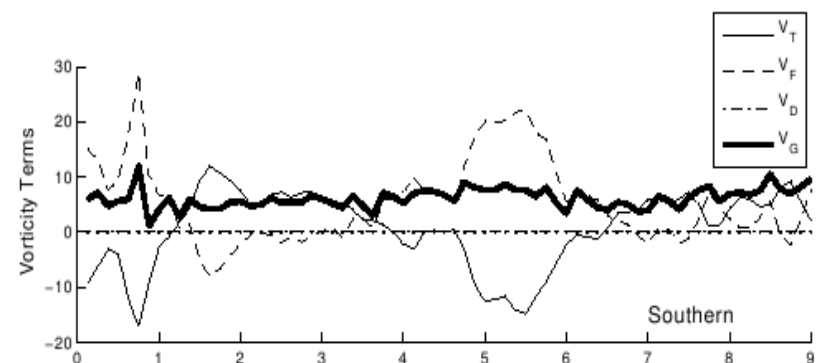
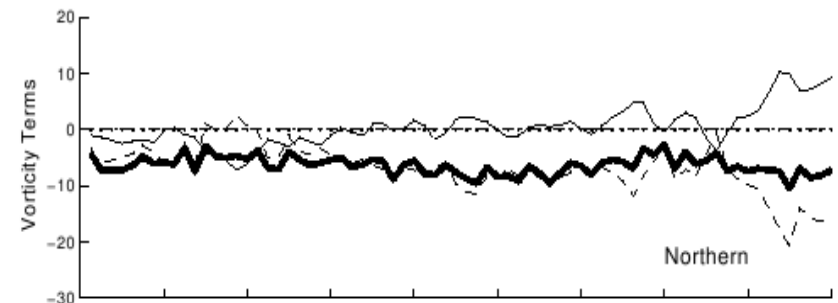
Island vorticity generation

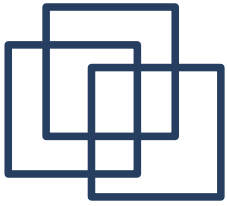
Volume integrated vorticity (from vertical vorticity equation):

$$V_G = \underbrace{\frac{\partial}{\partial t} \left\{ \iiint \zeta \, dx \, dy \, dz \right\}}_{\text{tendency } (V_T)} + \underbrace{\int \left\{ \oint_O (u_n (f + \zeta)) \, dl \right\} dz}_{\text{advective flux } (V_F)} - \underbrace{\nu_{eh} \int \oint_O (\nabla_h \zeta) \, dl \, dz}_{\text{eddy-viscous flux } (V_D)}$$

VG => steady in time

VG => ~symmetric C-A





Wake instability

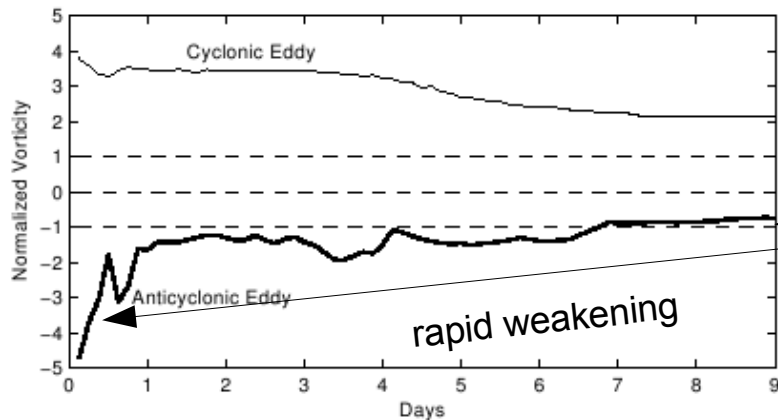
Types of instabilities:

lateral shear

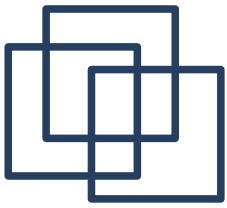
asymmetry C-A => centrifugal instability

PE => baroclinic instability ($L \gg R_d$)

Eddy evolution:

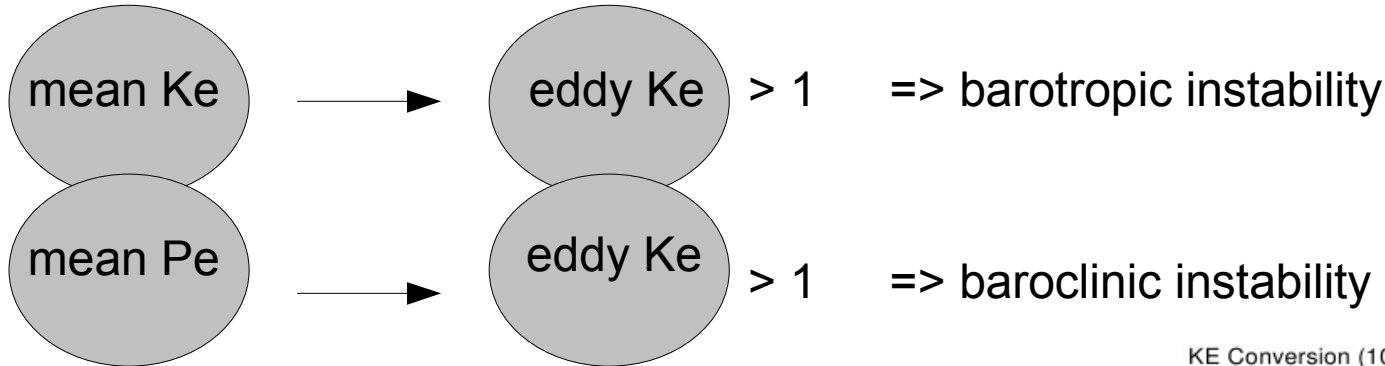


Centrifugal instability => Changes +/- f



Wake instability

Volume integrated

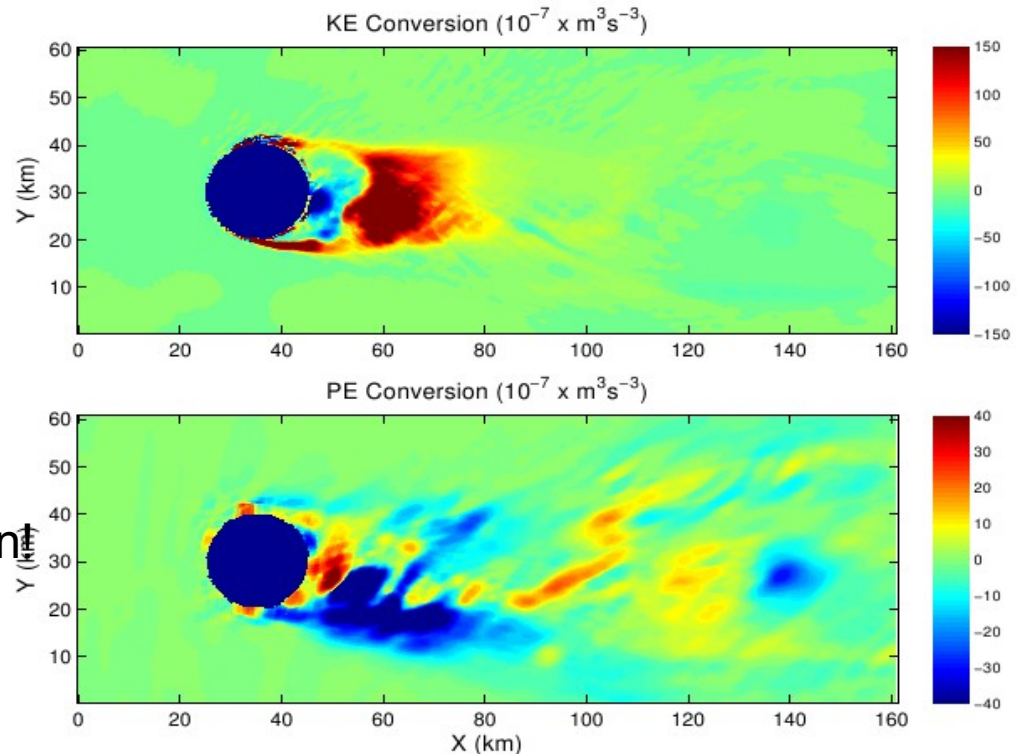
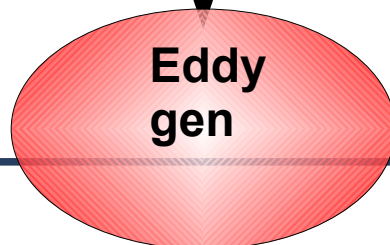


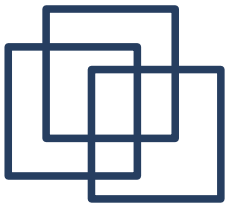
Vertical integrated KE & PE conversions:

Max barotropic conversion @ L (max KE)

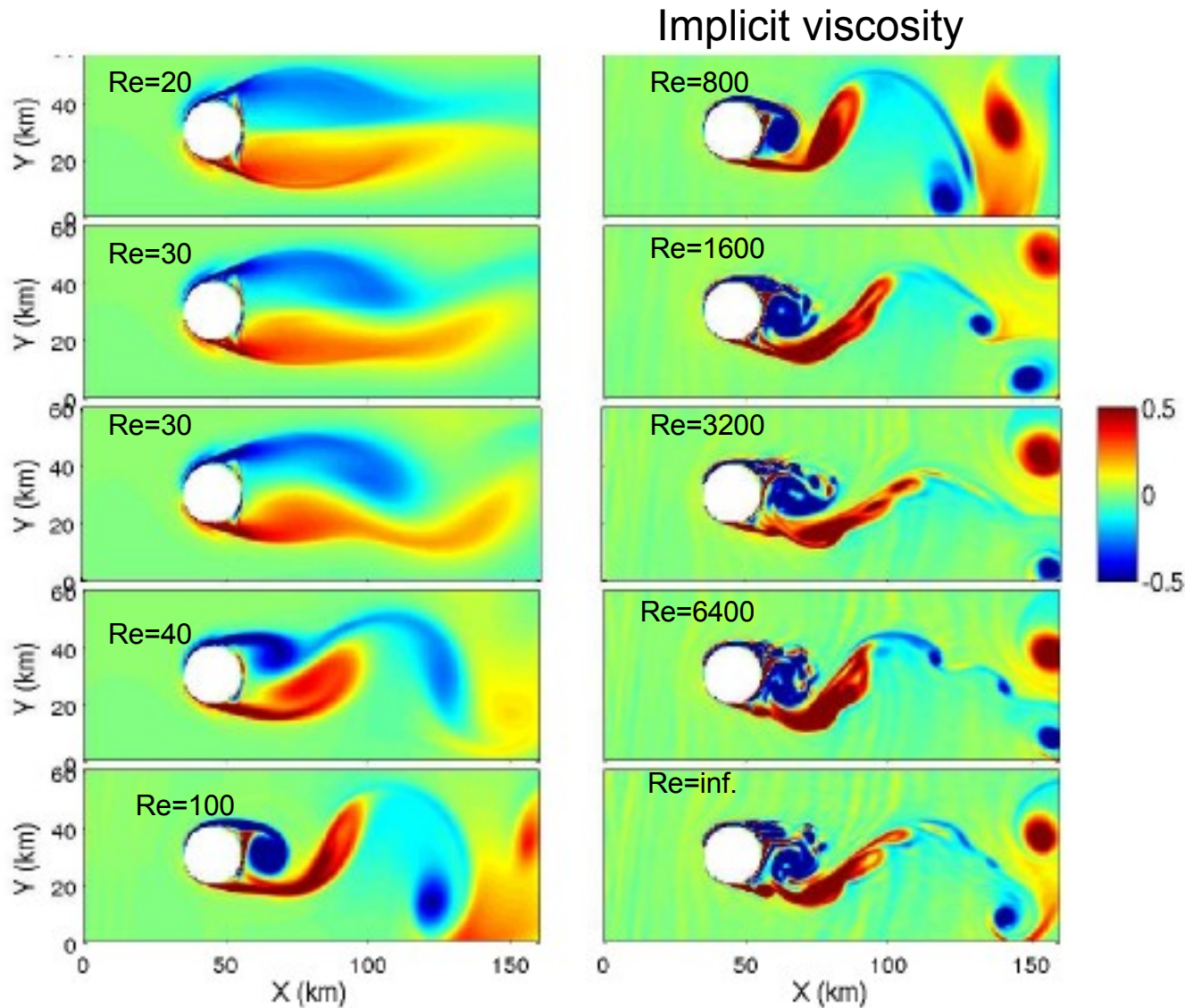
Max. (-ive) baroclinic conversion
 \Rightarrow Dominant Cyclonic region

max KE $>$ max PE \Rightarrow barotropic conversion



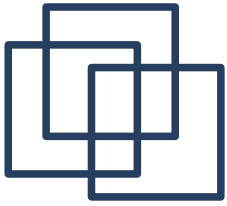


Re study



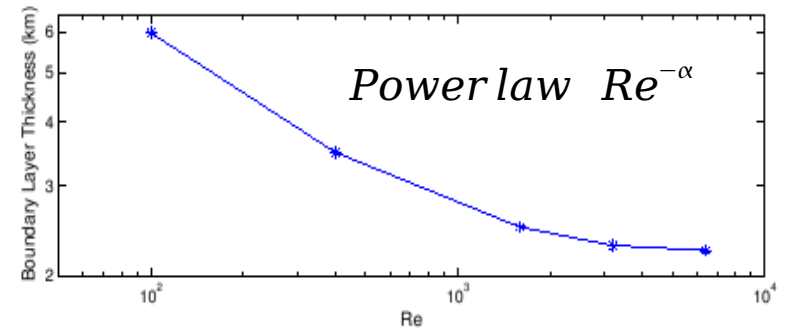
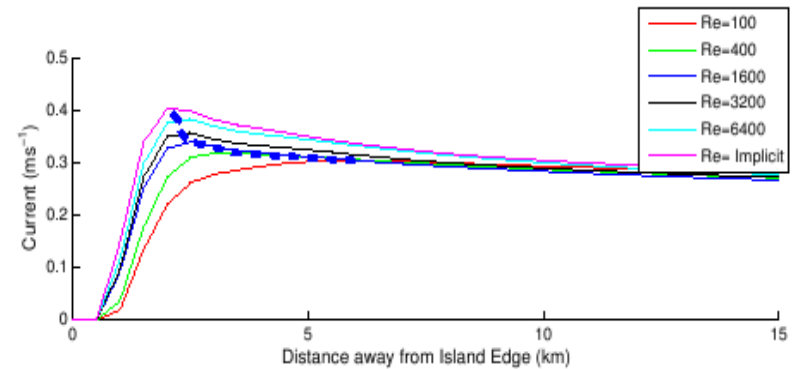
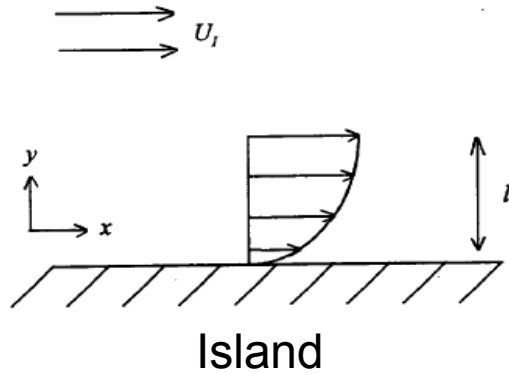
Re=20 symmetric eddies

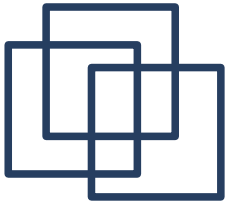
Re~100 detachment



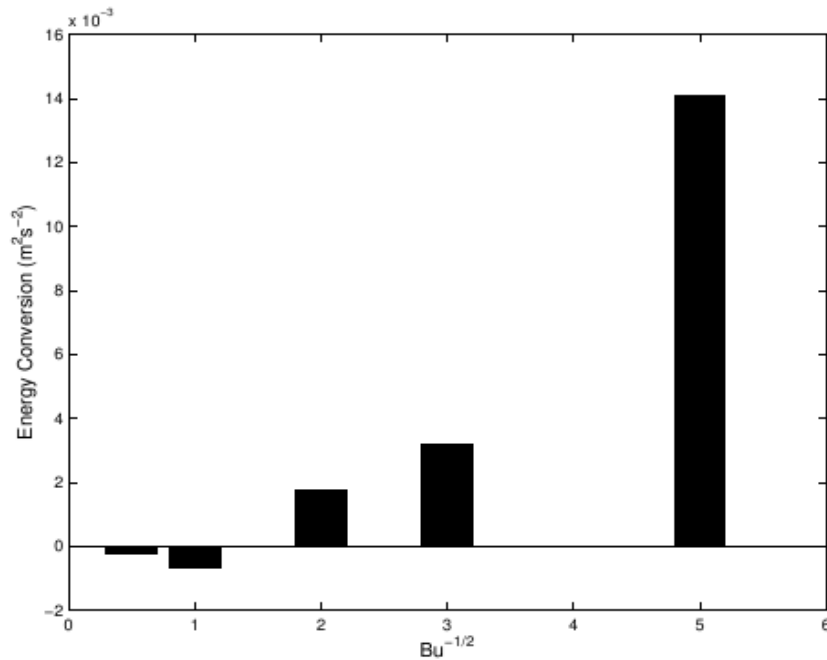
Re study

Lateral boundary layer thickness





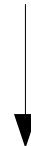
Bu study



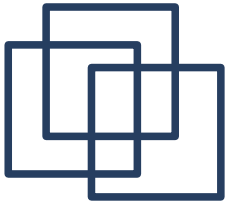
$$Bu = \left(\frac{R_d}{L}\right)^2 \quad Bu = \left(\frac{NH}{f}\right) \quad N = \sqrt{\frac{-g}{\rho_0} \frac{\partial \rho}{\partial z}}$$

Baroclinic instability theory:

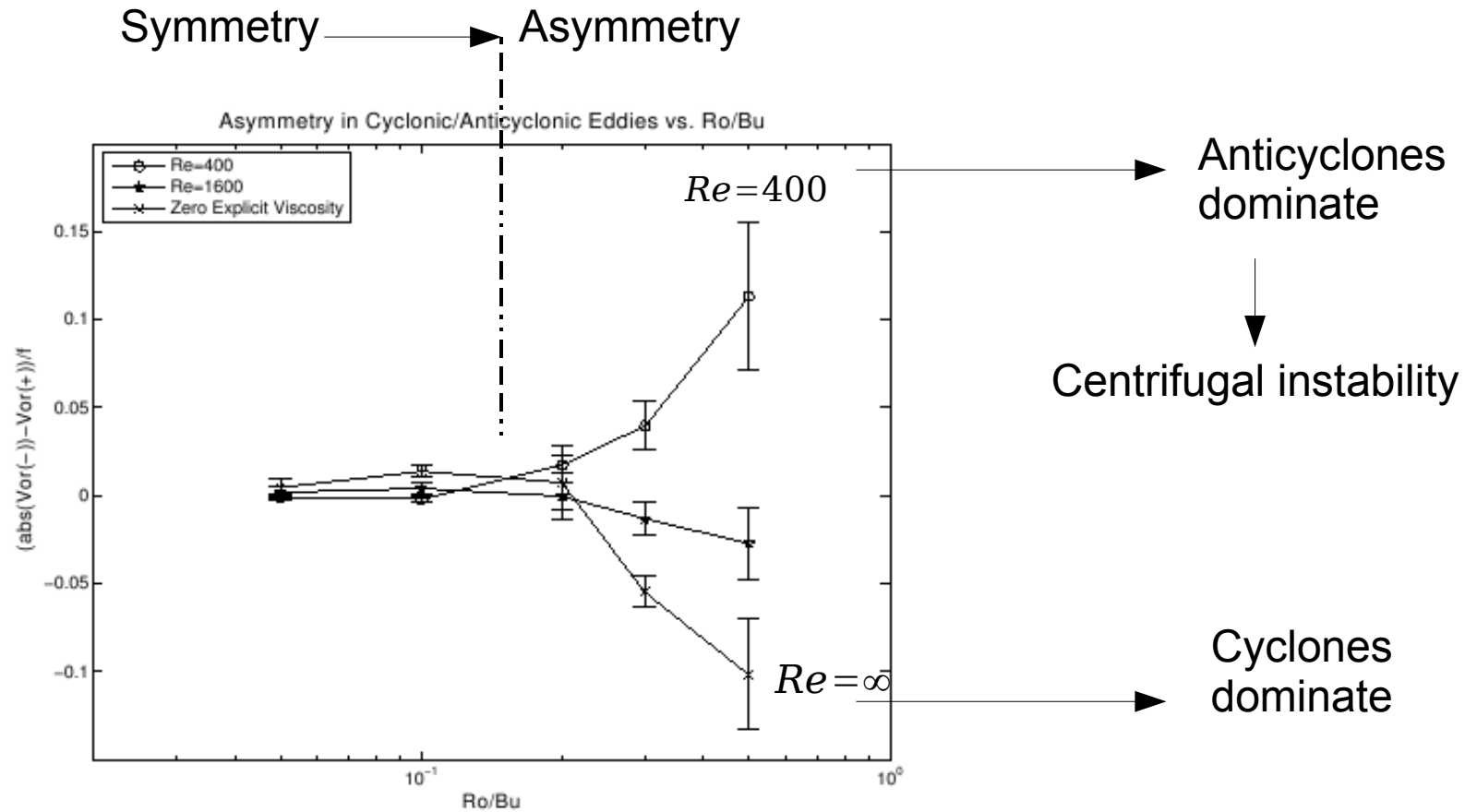
$L \gg R_d \Rightarrow$ Eddy size $\gg R_d$

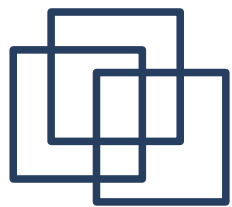


Weakens anticyclonic eddies

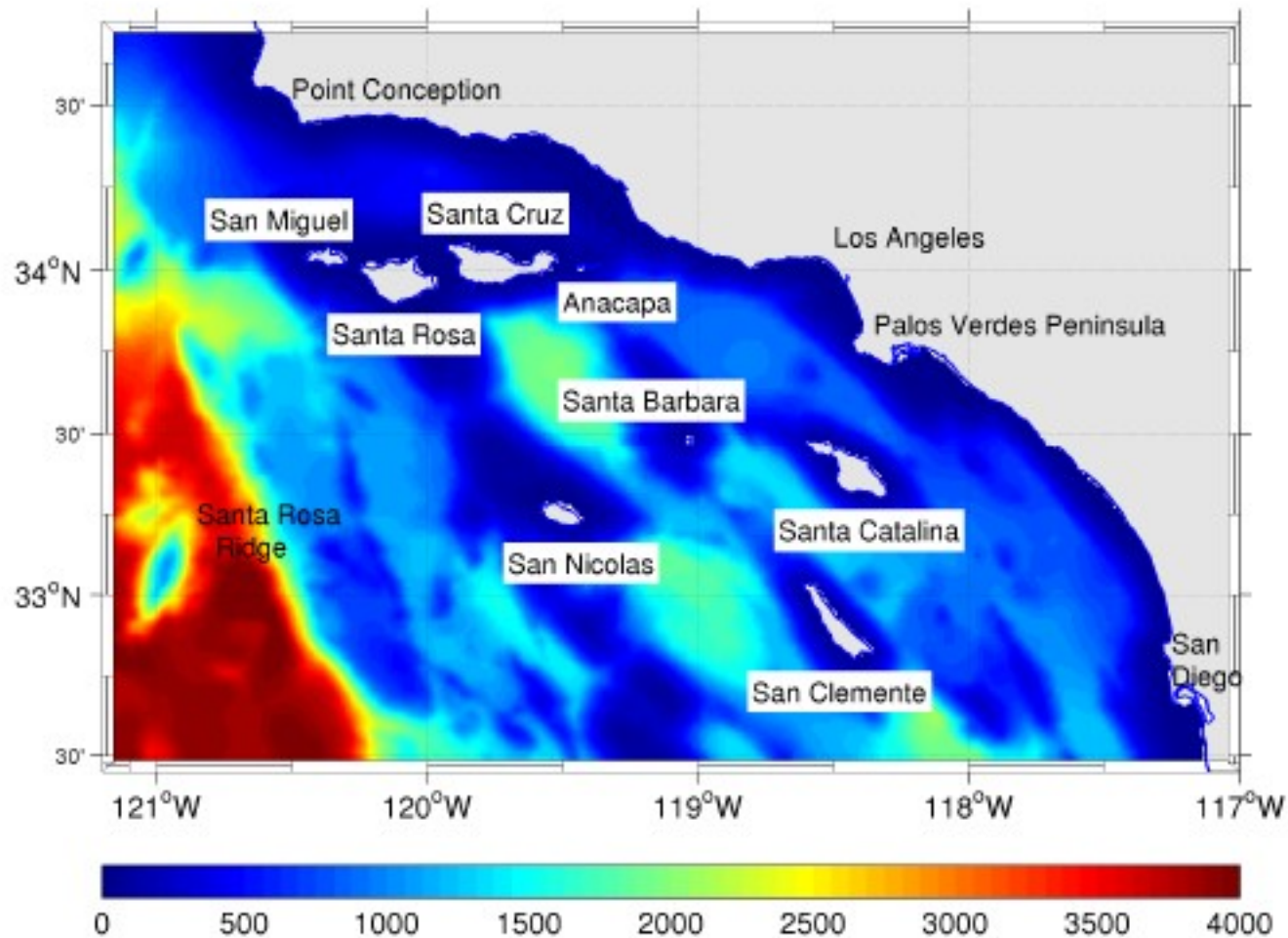


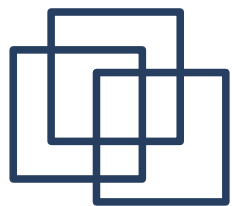
Ro/Bu study





Southern California Bight study





Model configuration

ROMS – Regional Ocean Modeling System

<http://www.myroms.org/>

Numerical experiments:

Exps.	Topography	Wind Forcing
Exp. 1	ETOP2	2km MM5 Wind
Exp. 2	Sunken Islands	2km MM5 Wind
Exp. 3	Flat Bottom	Steady Wind

ROMS setup:

$dx=dy=1\text{km}$

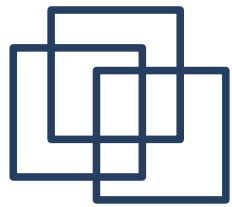
40 z levels

Orlanski => tangential flow

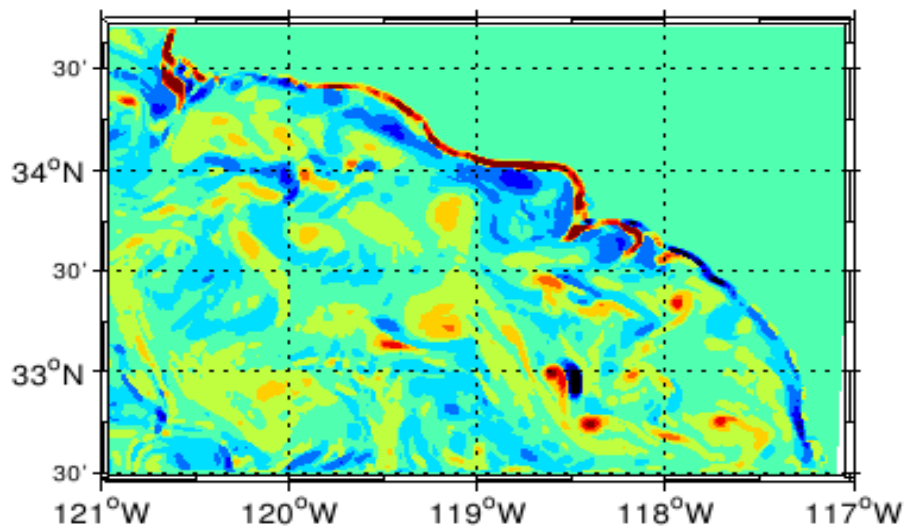
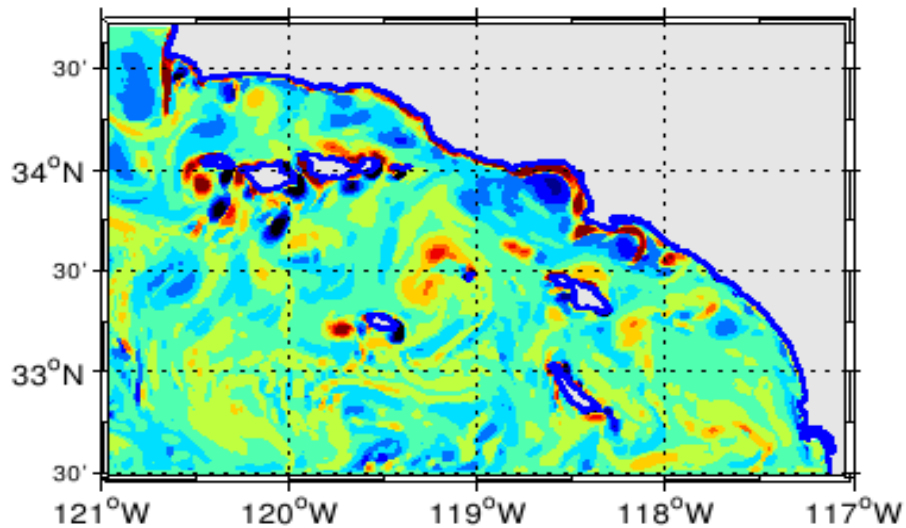
Flather => normal flow

To => nudging 1996-2003 ROMS

MM5 wind forcing (54/18/6/2km)



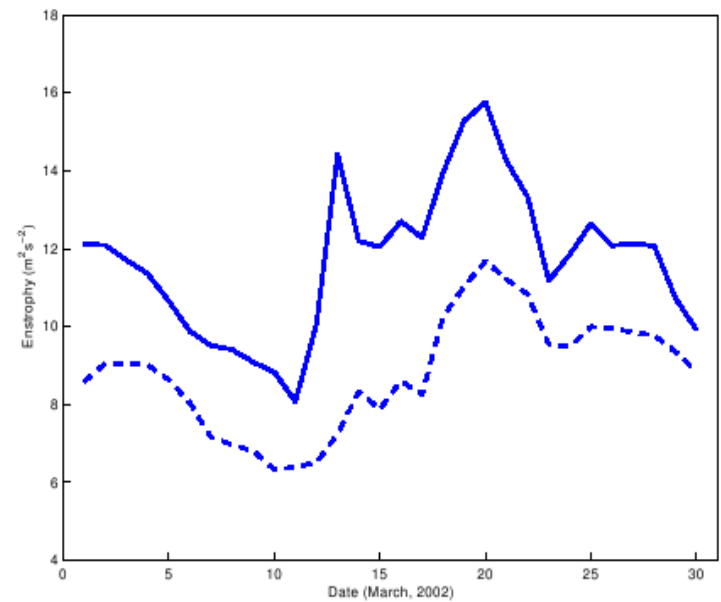
Island induced vorticity

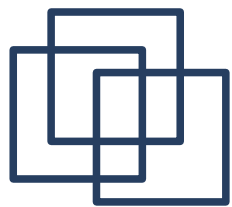


Decrease eddy activities

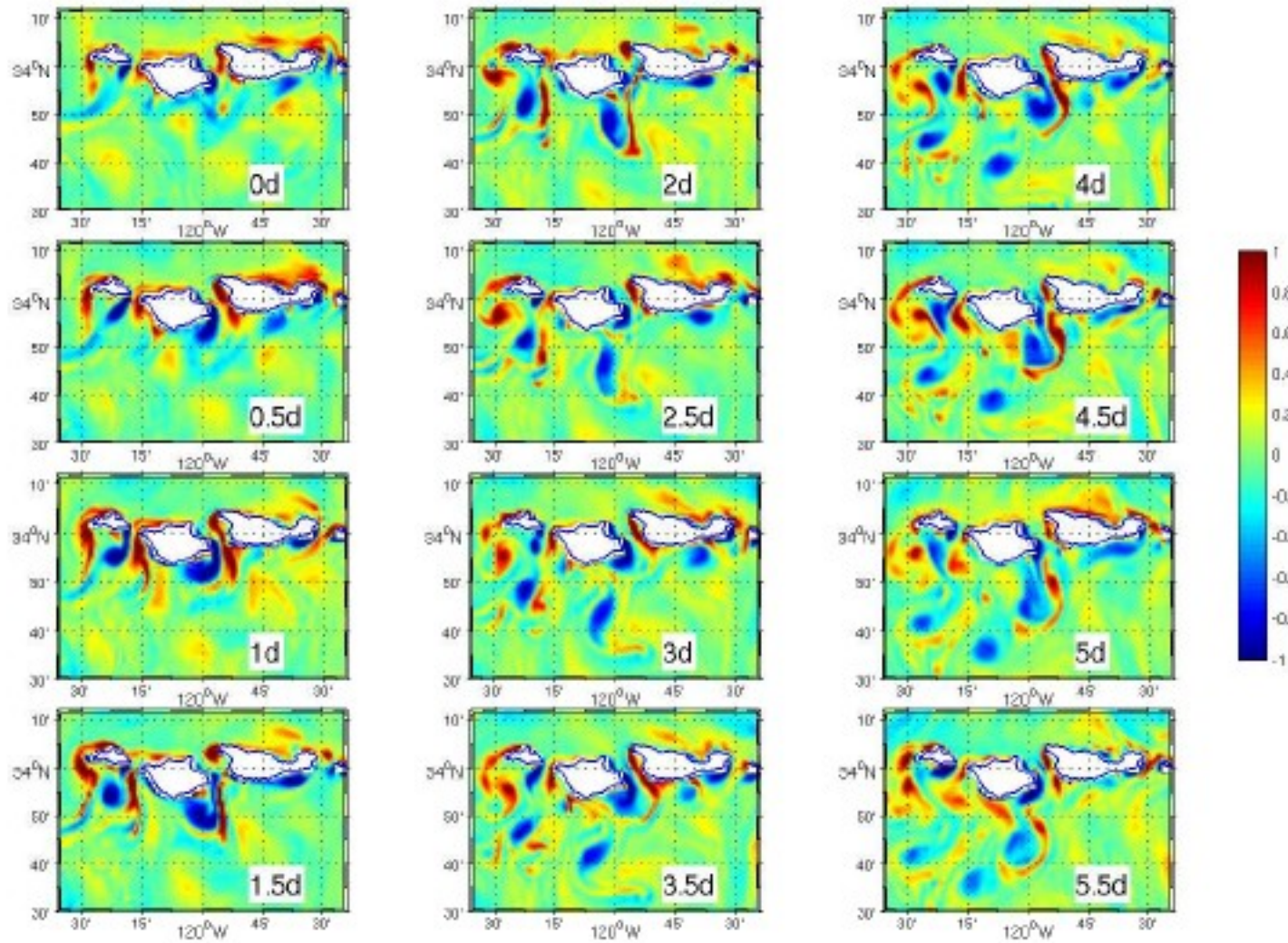
28.9% decrease in enstrophy ω^2

Upwelling event





Channel Island wakes



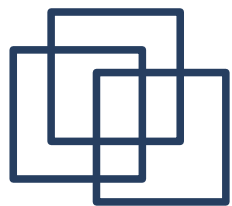
Island - gaps



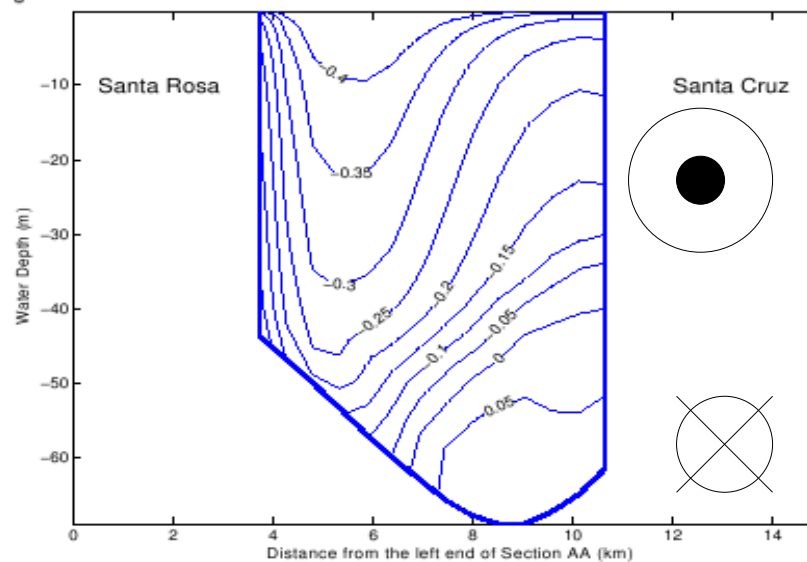
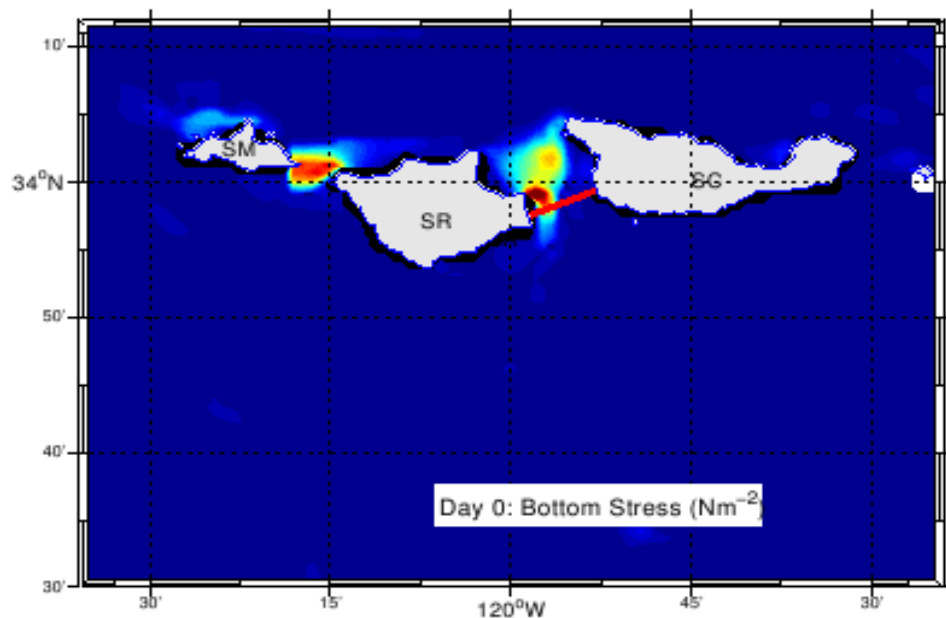
Large current shear

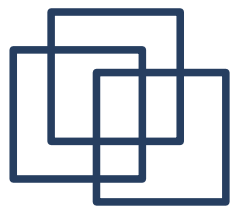


Eddy shedding

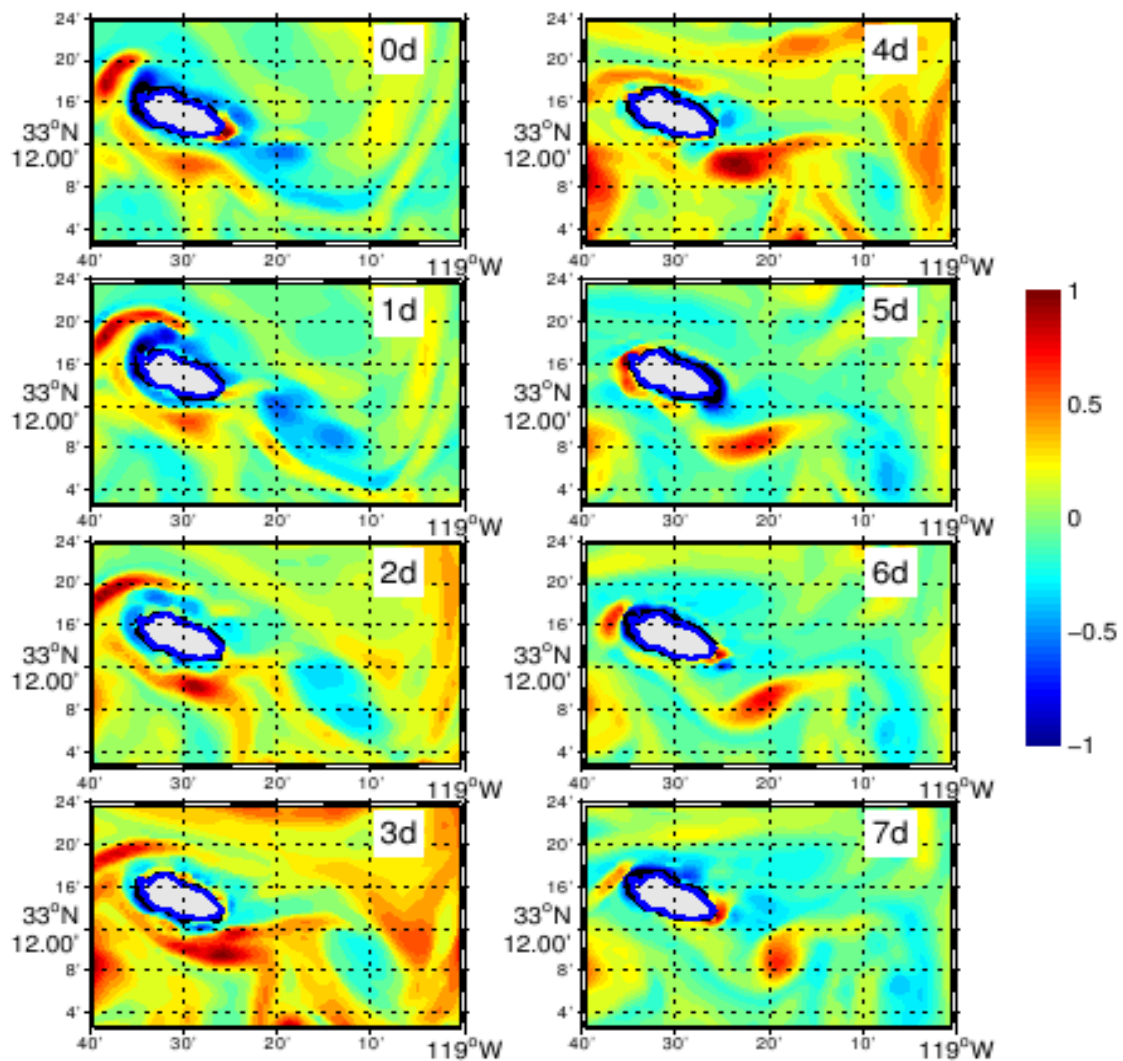


Velocity profile





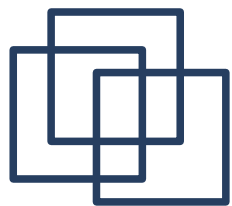
San Nicolas Island wake



Wake asymmetry



Centrifugal instability



Santa Catalina Island wake

