CENTRE D'OCÉANOLOGIE DE MARSEILLE
UNIVERSITÉ DE LA MÉDITERRANÉE AIX-MARSEILLE II

LOPB

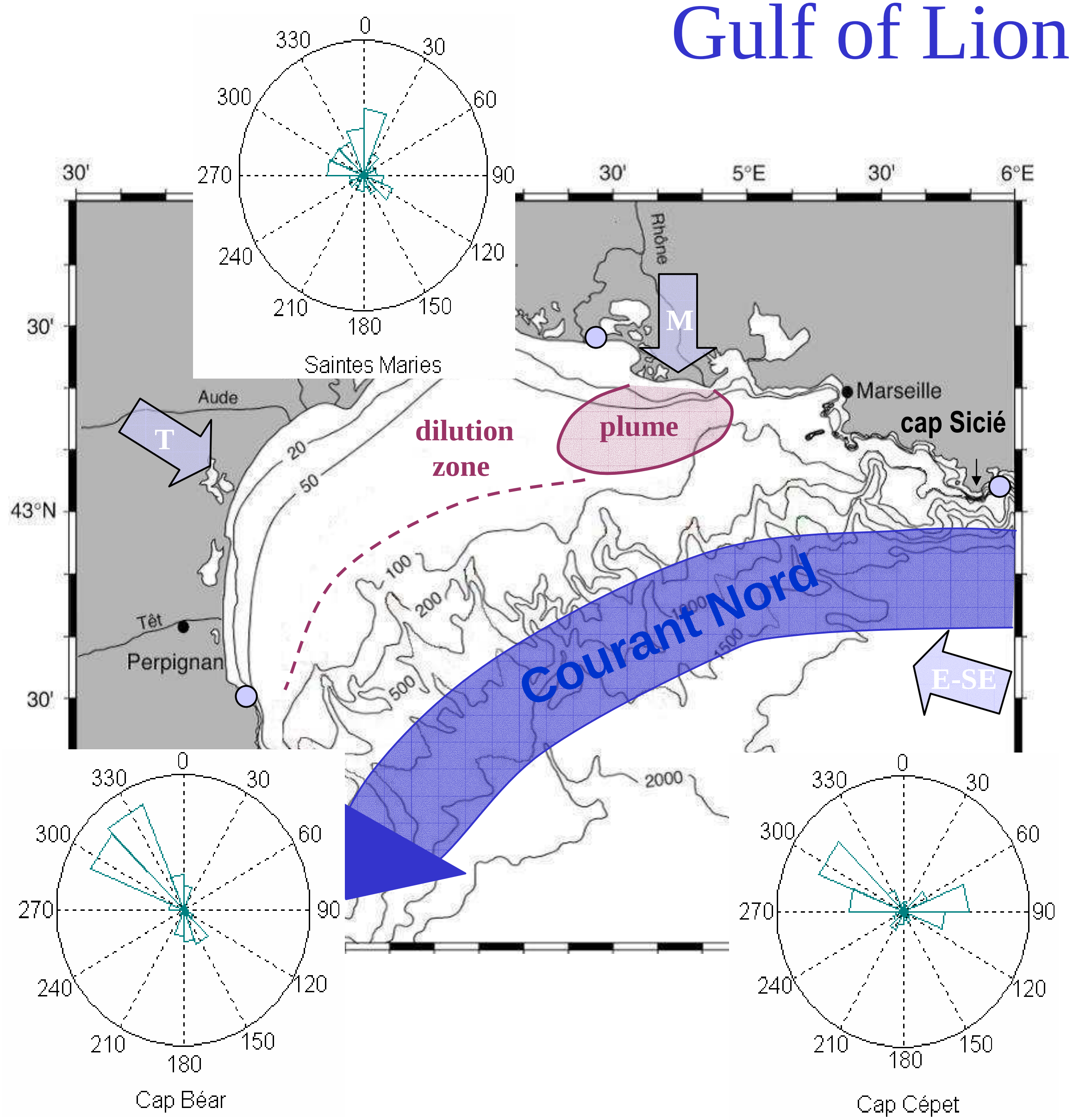
CNRS CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

INSU

Submesoscale eddies in the Gulf of Lion

A. Petrenko, A. M. Doglioli, Z. Hu
G.Rougier, J.-L. Fuda, F.Diaz, B. Queguiner, S. Blain (now Banyuls), P. Rimmelin, O. Grosso, R.Campbell

Gulf of Lion presentation



- <u>Description :</u>
  - surface ~ 11 000 km²
  - mean depth ~ 80 m
  - numerous canyons

1- Rhone plume

2- Winds : Tramontane,
Mistral,
East / South-East

3- Northern Current (NC)

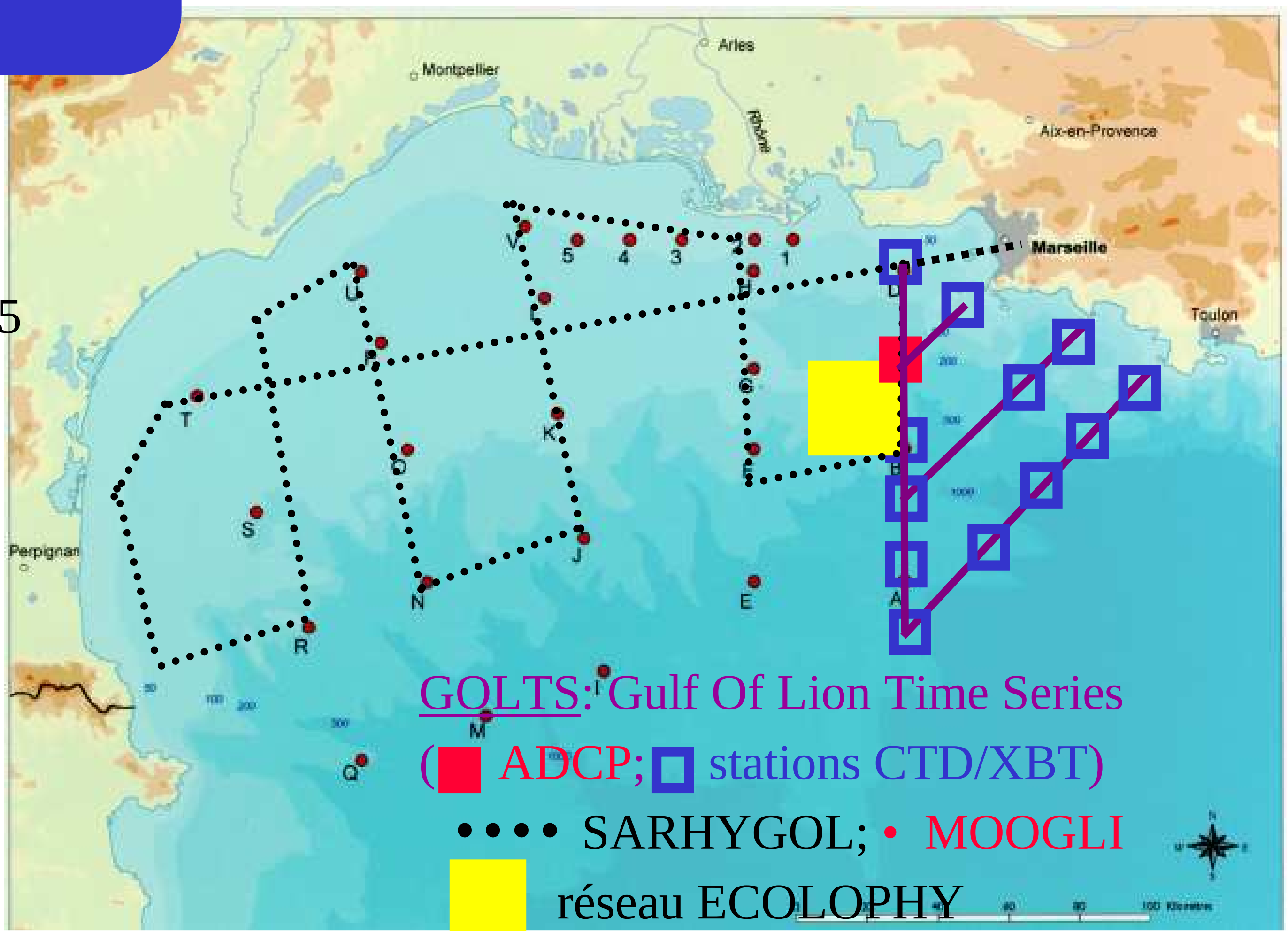
Cruises:

- Sarhygol (2000-01)
- Golts/Argol/Colargol (2002-04)
- Ecolophy (2005-06)

- Shelf circulation
- Intrusions of the NC
- NC instabilities

André et al., *Ocean Dyn.* 2005
Forget and André, *Sensors*, 2007
Gatti et al., *CSR* 2006
Ouillon and Petrenko, *Opt.Exp.* 2005
Petrenko et al., *CSR* 2005
Petrenko et al., *JMS* 2008

+ Symphonie
Dufau et al., *JGR* 2004
Estournel et al., *JGR* 2003
Herrmann et al., *JGR* 2008
Marsaleix et al., *OM* 2008 (etc...)



project LATEX (LAgrangian Transport EXperiment)

Pilot project 2007 – Main project 2008-11

Objective: influence of submesoscale coupled physics – biogeochemistry on cross-shelf (coast-offshore) exchanges

Methodology : lagrangian strategy to follow a submesoscale eddy using lagrangian floats and an inert chemical tracer (SF_6)

Multi-disciplinary project + multi-«tools» (lagrangian floats, SF6 hull-mounted ADCP, moorings, satellite images, modelling, gliders, radars) for the 2010 cruise

PIs: Frédéric Diaz and Anne Petrenko

Project LEFE/IDAO/CYBER – Région

State of the art before LATEX

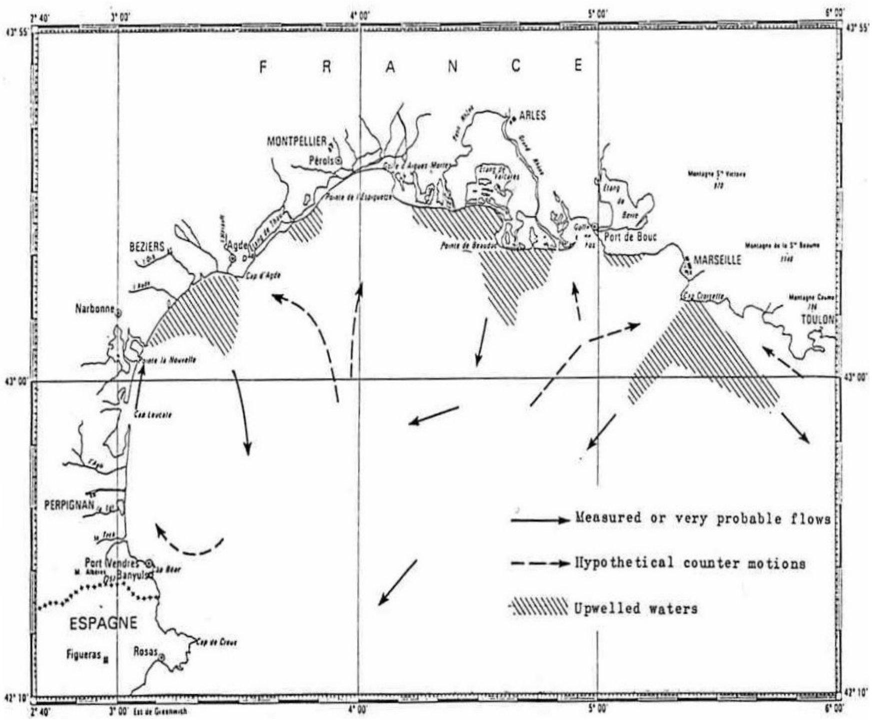


Figure 11 from Millot [1979], with a sketch of wind-induced circulation at the surface drawn coherently with infrared and in situ data.

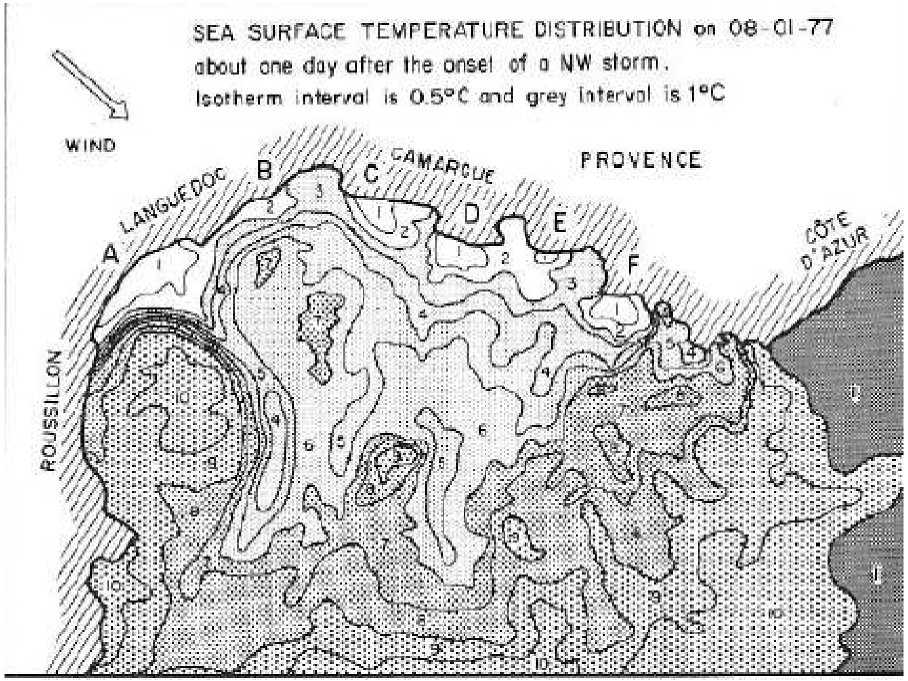
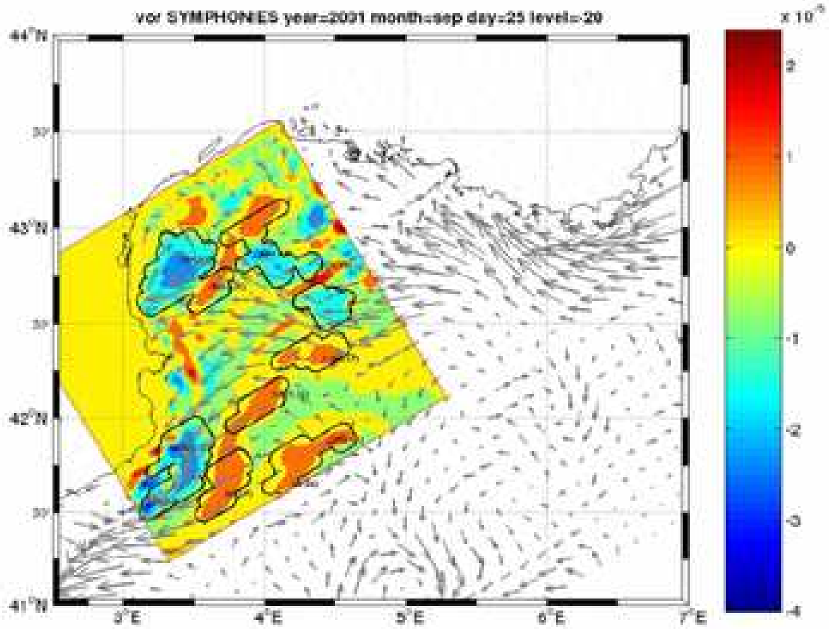


Figure 2 from Millot [1982], showing the infrared thermography obtained on the August 1, 1977 at about 09 00 TU

LATEX

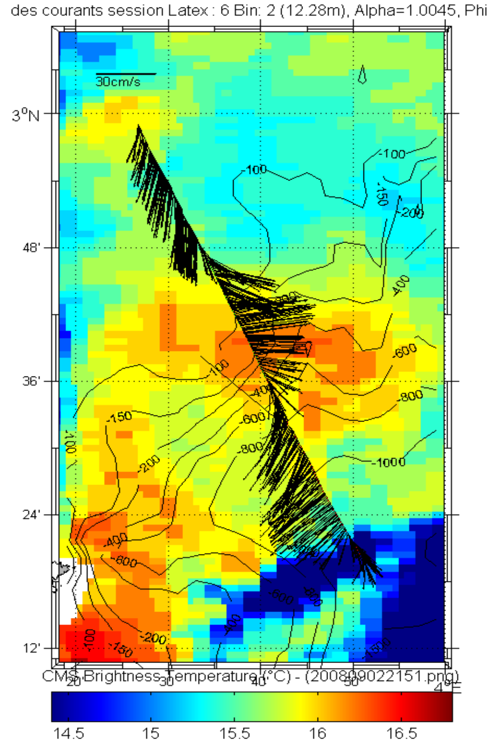
MODELLING

Wavelet analysis of relative vorticity fields modelled by Symphonie
with C. Estournel et P. Marsaleix [POC, Toulouse]
+ Lagrangian floats
with B.Blanke et N.Grimas [LPO, Brest]



EXPERIM

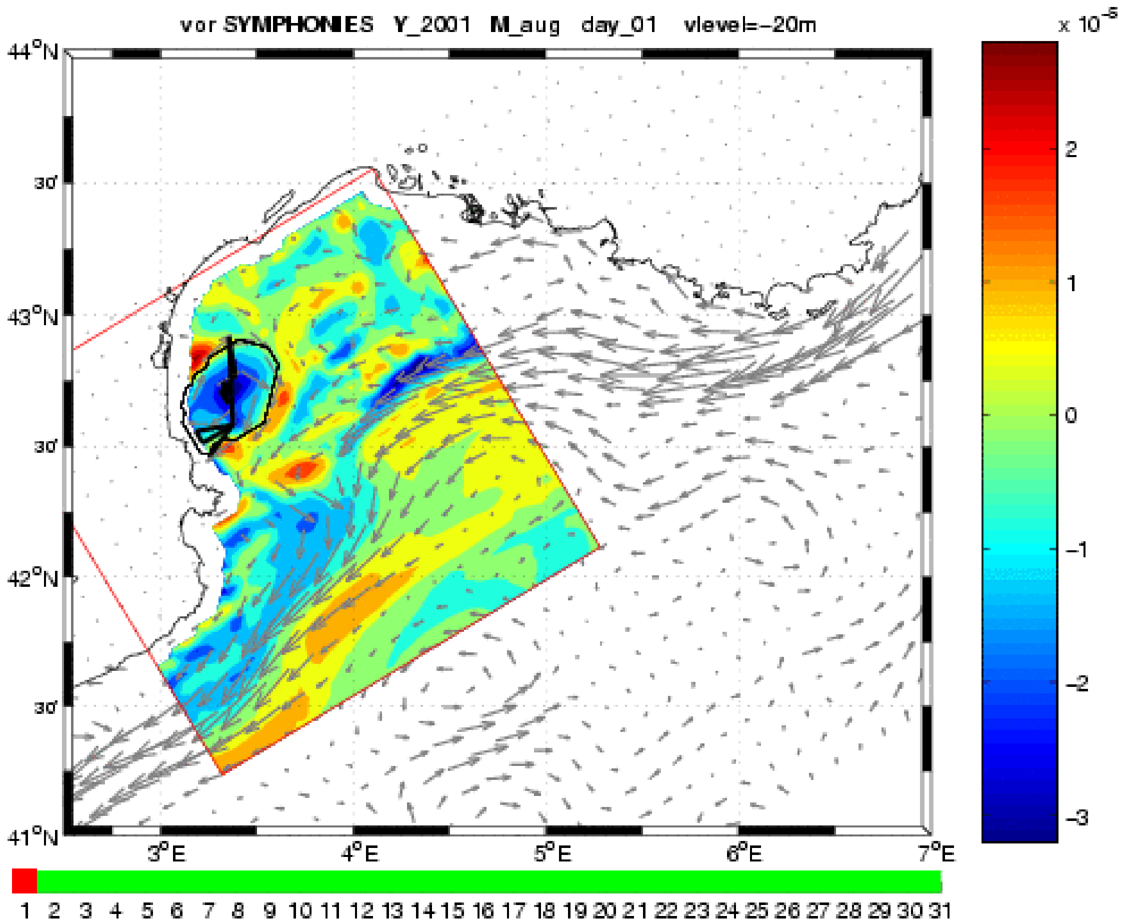
Sept 07 - Tests of real-time communication with floating buoys
Sept 08 – Eddy mapping

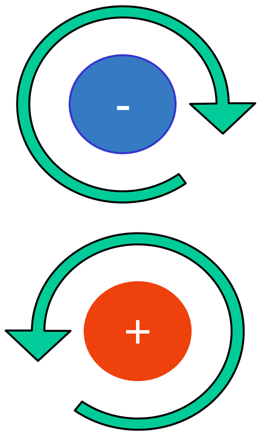


<u>Anticyclonic eddy **A1(01)**</u> **tracking duration: 32 days; movie shown for the second part of his life (August 1 – 18)**

WATERS: Wavelet analysis on relative vorticity (LPO*) calculated from Symphonie (POC) modelled currents

*[Doglioli et al., 2007]





Anticyclonique

Cyclonique

Hémisphère Nord

Web site ZiYuan Hu
http://www.com.univ-mrs.fr/~hu/

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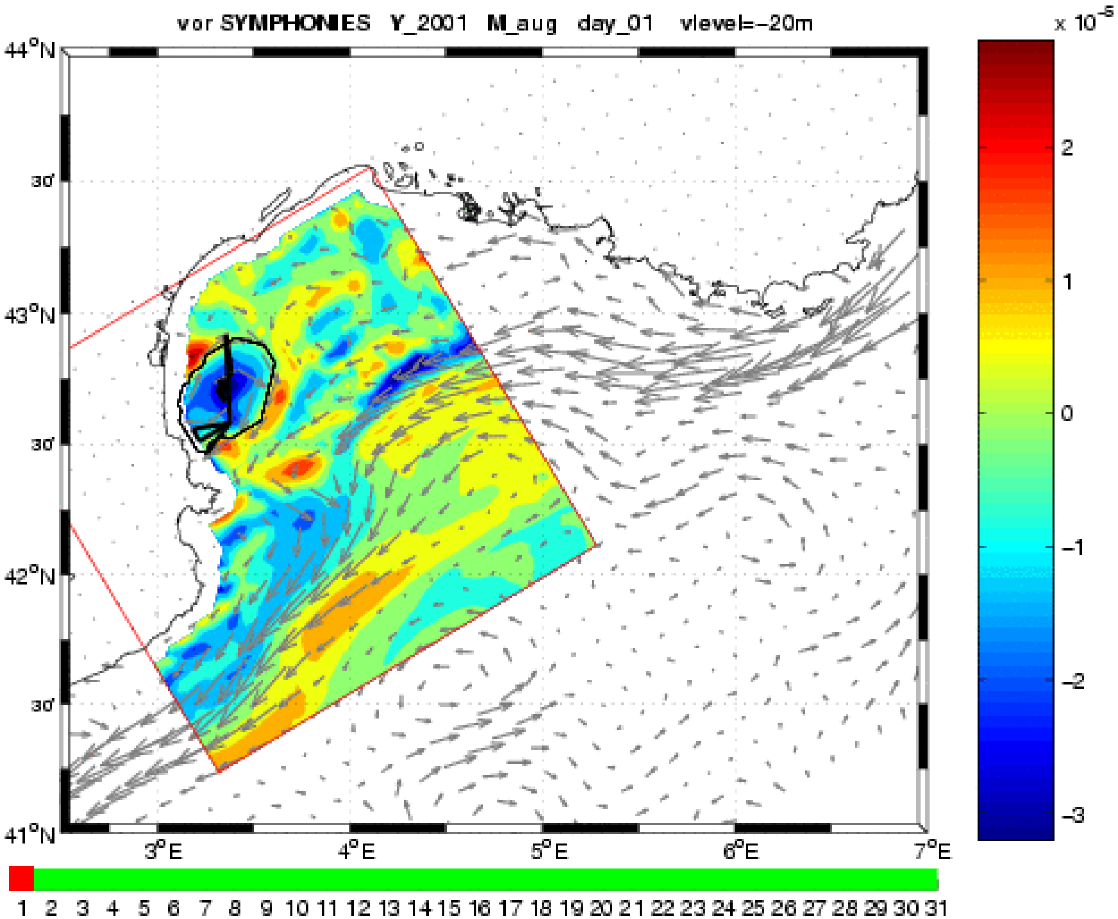
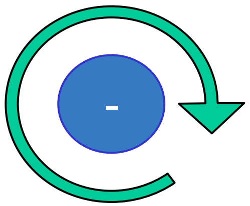
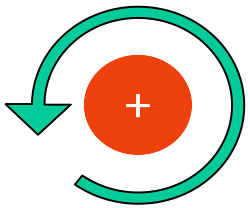




Anticyclonique



Cyclonique

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Submesoscales coastal eddies

Numerical results in the Gulf of Lion

- **Cyclonic eddies** moving westward

  mean characteristics: 20 days, diameter 35 km;

  - hot, + salty, SSH – high than ambient waters

[Zu, 2007]

Zonal eddy motion

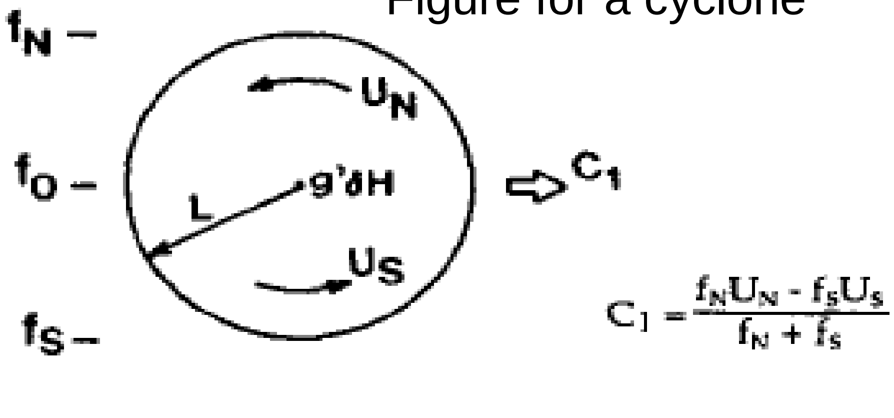
Zonal motion

[Cushman-Roisin et al., 1990]

- 2 effects:
  - a) Effet béta –Coriolis force non homogeneous in the eddy
  - b) Reaction on the eddy created by the displaced particles

- |c2|>|c1| westward motion for both cyclones and anticyclones

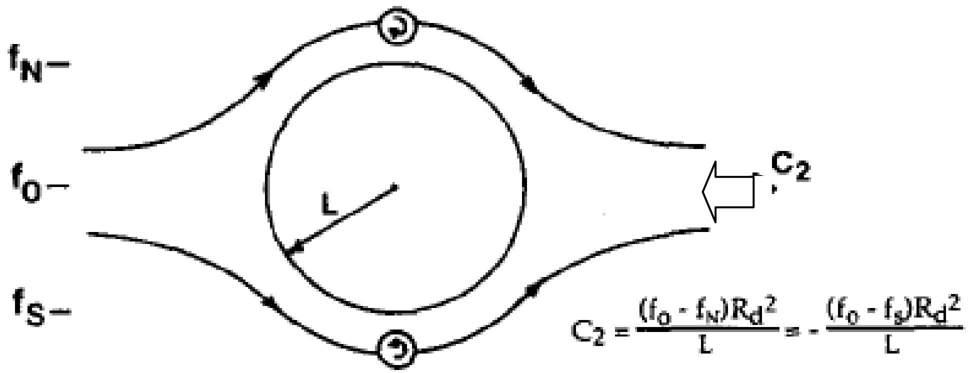
Figure for a cyclone



(a)

Anticyclone – westward

Cyclone – eastward



Anticyclone and cyclone – westward

(b)

Submesoscales coastal eddies

Numerical results in the Gulf of Lion

- **Cyclonic eddies** moving westward

  mean characteristics: 20 days, diameter 35 km;

  - hot, + salty, SSH – high than ambient waters

- **Anticyclonic eddies "**stuck" on the western side of the gulf

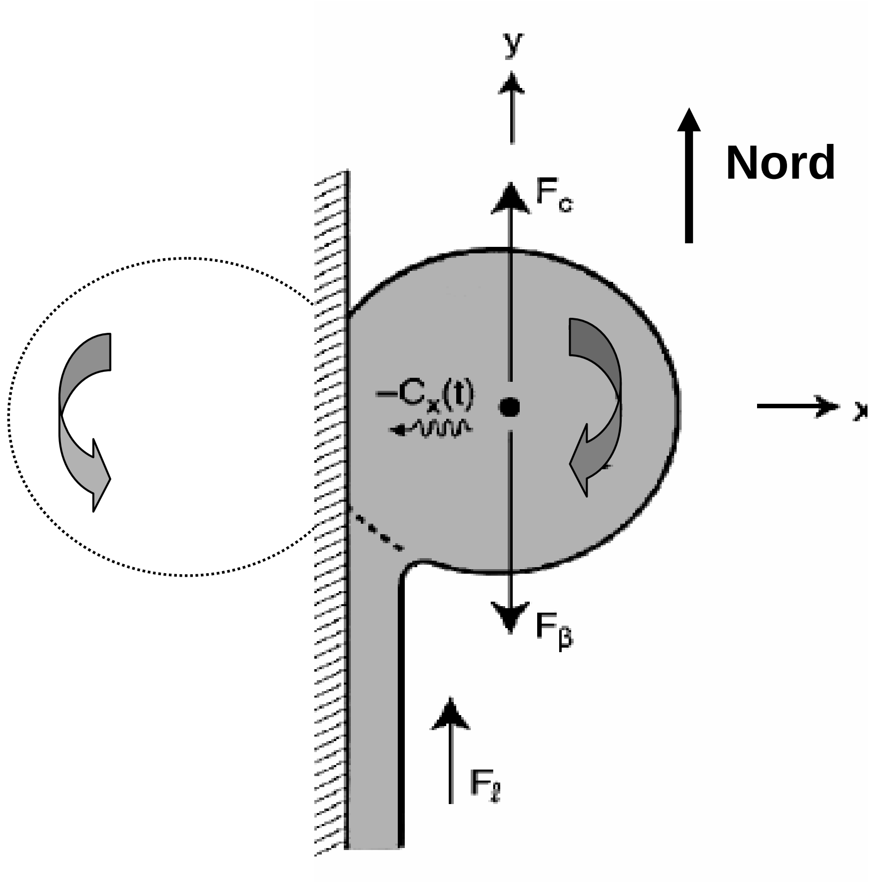
  mean characteristics: 40 days, diameter 45 km;

  + hot, - salty, SSH + high than ambient waters

[Zu, 2007]

Meridional eddy motion

« Strange encounters of eddies with wall » [Nof, 1999]



3 processes:

– **« Mirror » effect**: motion poleward [Minato, 1982]

– **Meridional motion**: compression of the water column by the eddy+ vorticity conservation: Force equatorward

– **« Rocket » effect:** poleward due to the gradually peeling onion [Nof, 1988]

Meridional eddy motion

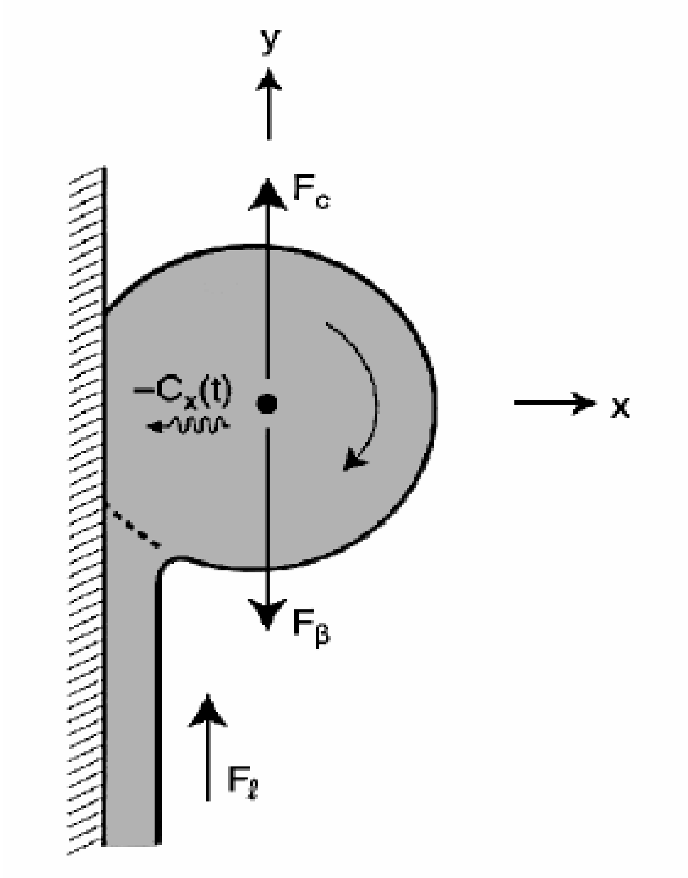
« Strange encounters of eddies with wall » [Nof, 1999]

Non-linear analytical solution
(+ numerical simulations)
with the 3 effects show that:

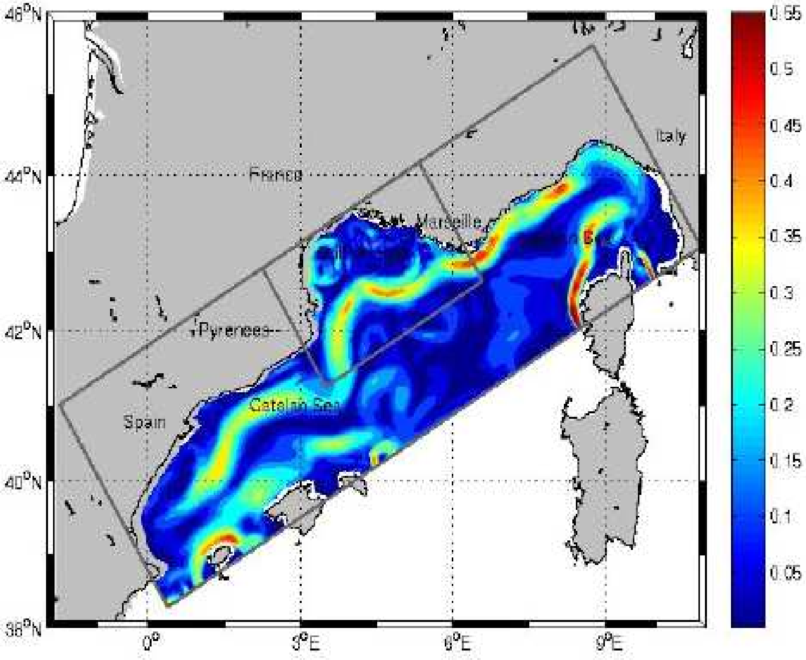
- mirror effect: negligeable

- the eddy stays at a constant latitude

- leaks fluid toward the equator until its « death »



Work in progress; latest numerical results)



Sensitivity tests

* on the spatial resolution
  - 3 km resolution
  - nesting « one way » 1 km
* on the attenuation coefficient δ of the diffusion scheme

$$\frac{\phi_i^{t+\Delta t}-\phi_i^{t-\Delta t}}{2\Delta t} = -\frac{c_{i+1/2}}{\Delta x}\frac{\phi_i^t+\phi_{i+1}^t}{2} + \frac{c_{i-1/2}}{\Delta x}\frac{\phi_i^t+\phi_{i-1}^t}{2} + \frac{A_{i+1/2}}{\Delta x}\frac{\phi_{i+1}^{t-\Delta t}-\phi_i^{t-\Delta t}}{\Delta x} - \frac{A_{i-1/2}}{\Delta x}\frac{\phi_i^{t-\Delta t}-\phi_{i-1}^{t-\Delta t}}{\Delta x}$$

Advection scheme:
upwind scheme [James, 1996]
+ a Leapfrog time-stepping scheme

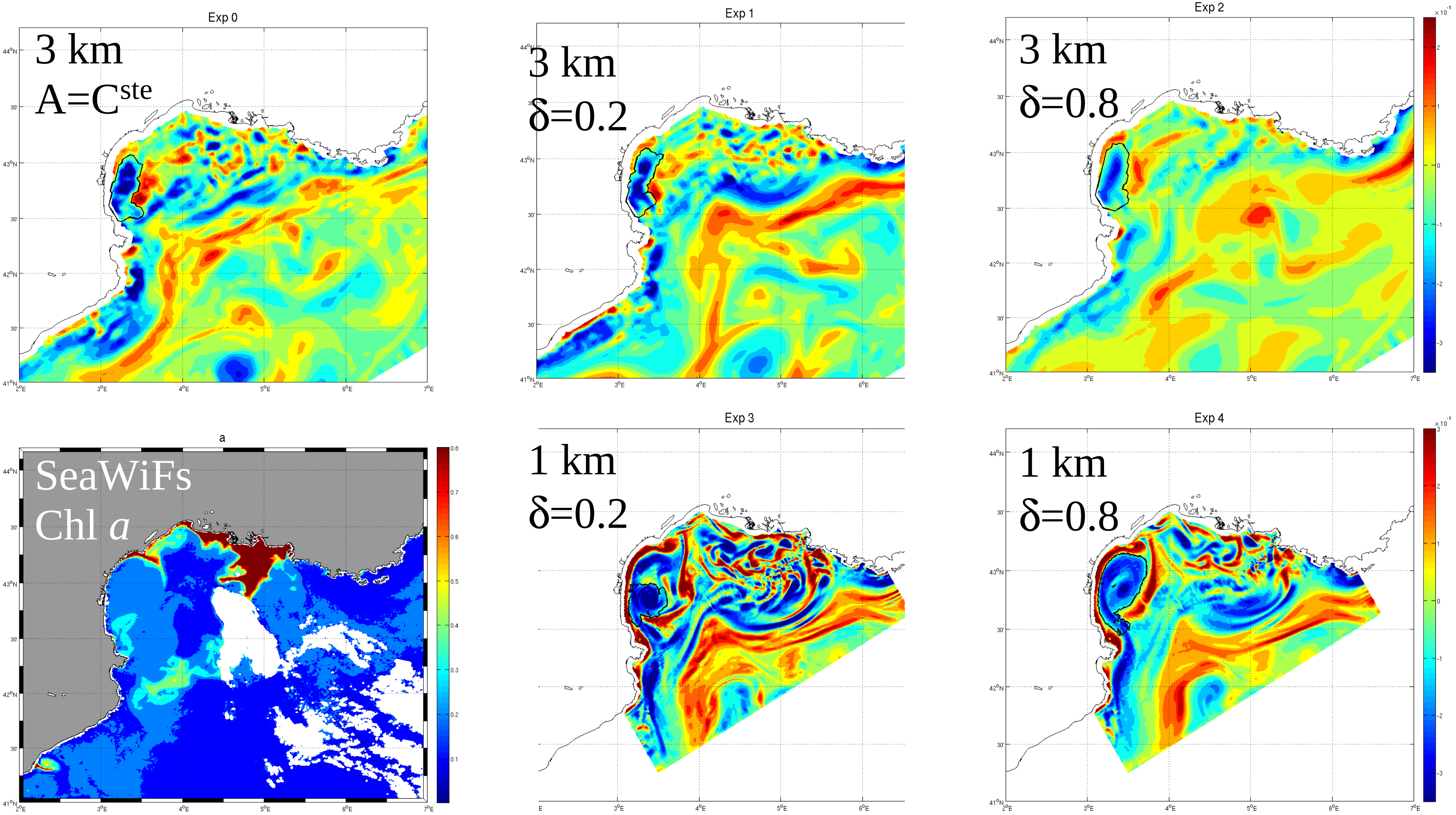
$$A = |u|\frac{\Delta x}{2} \dashrightarrow \tilde{A} = \delta \cdot |u|\frac{\Delta x}{2}$$

$0 \leq \delta \leq 1$

δ=0 no dissipation
δ=1 maximum dissipation

(Φ either u or v)

Work in progress; latest numerical results)



Work in progress; latest numerical results)

experiment code	resolution [km]	δ [non-dimensional]	eddy area mean $\pm$ std [km^2]	tracking duration [days]
exp0	3	* $\tilde{A} = 15$ [m^{2}s^{-1}]	1035 $\pm$ 407	42
exp1	3	0.2	950 $\pm$ 398	33
exp2	3	0.8	1853 $\pm$ 1753	45
exp3	1	0.2	694 $\pm$ 446	70
exp4	1	0.8	1193 $\pm$ 543	56

- The model resolution affects the accuracy in reproducing the eddy structures in both position and size.
- The variation of the coefficient δ plays a role in the coherence of the eddy, with diminishing importance as the resolution increases.
- Satellite imagery suggests that, to obtain a comparable size and position of the eddy, we have to use the 1-km resolution and $\delta = 0.8$.

LATEX

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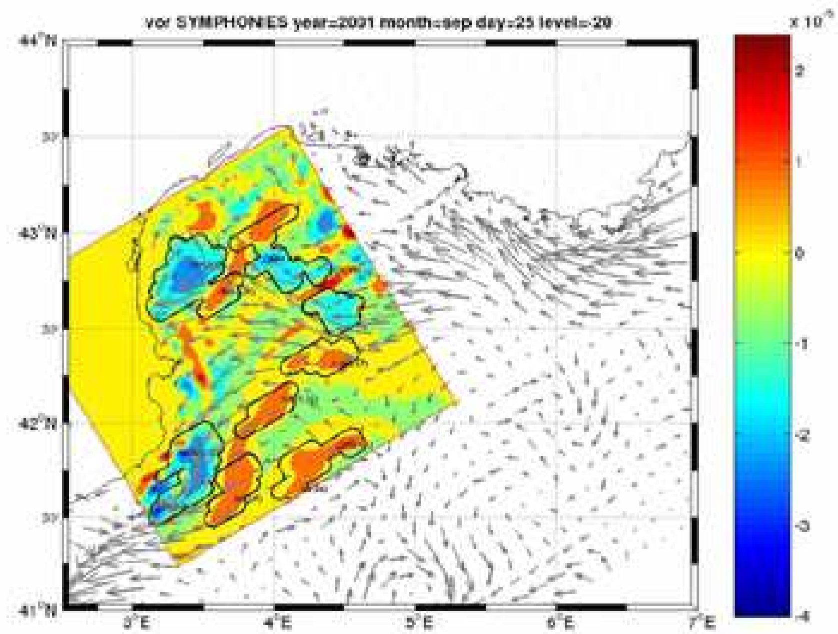

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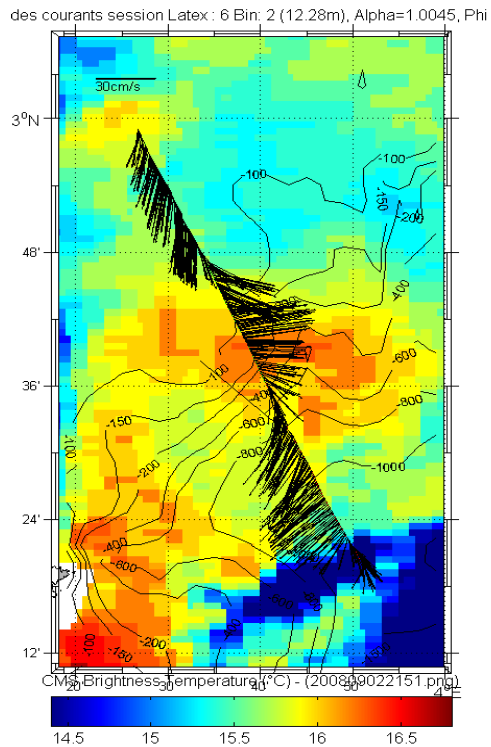
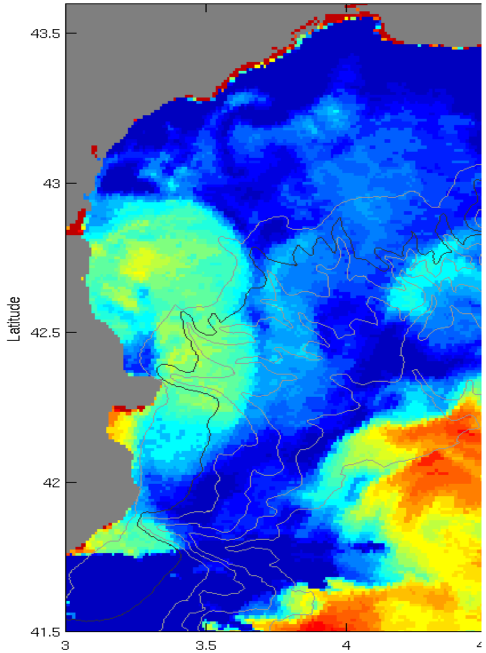


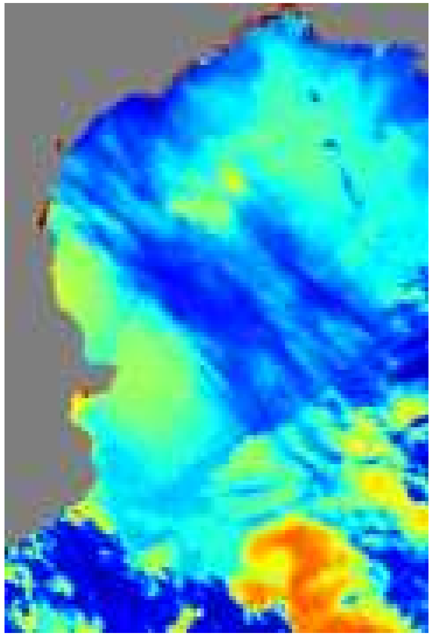
Submesoscale eddies

Mini-cruise Latex 08 (Sept 1-6, 2008)

Before the cruise

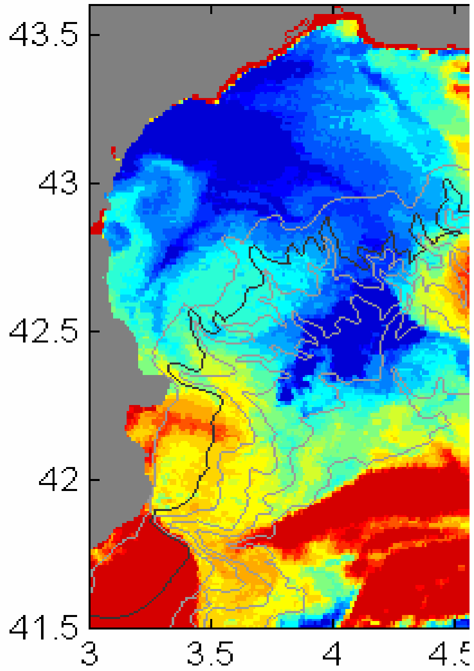


Aug. 24
10h34

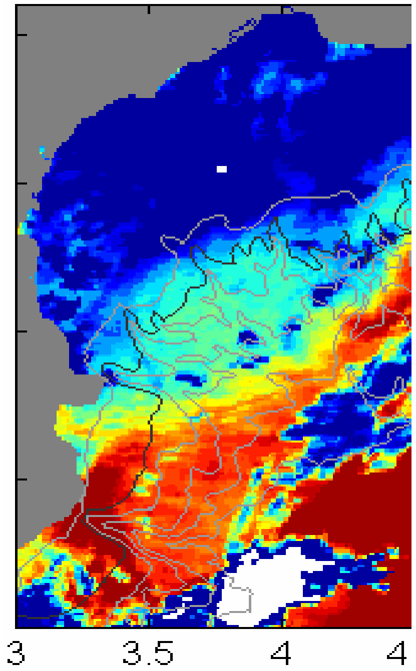


Aug. 26
12h49

During the cruise



Sept. 2
10h26



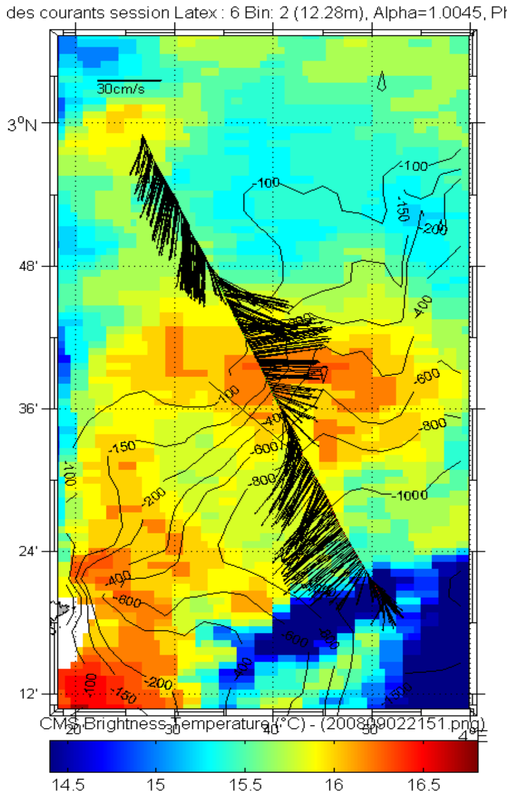
Sept. 3
21h28

AVHRR images

Submesoscale eddies

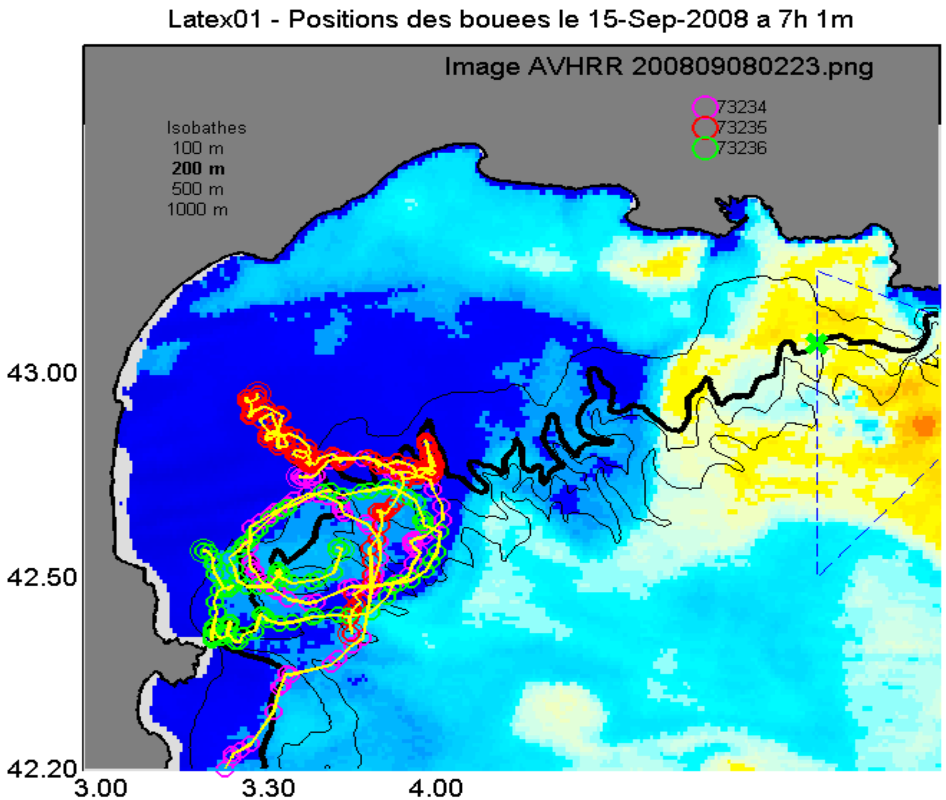
Latex08 – Eddy on the continental slope

Hull mounted ADCP



SST 2/09 – ADCP 5/09

Lagrangian floats



at 20-25 km from the center, ellipse completed in 5 days at 30 cm/s

Submesoscale eddies

Remaining questions (among others):

• **Where is the water of the eddy coming from ? Where is it going ?**
Use of the numerical tool ARIANE (Blanke et Grima, LPO)

• **What is the impact of these eddies on biogeochemistry ?**
Use of a coupled physics-biogeochemistry model: Symphonie (POC) + Eco3M (Baklouti et al., LOPB)

• **What is the impact of these eddies on cross-shelf exchanges ?**
Use of WATERS-3D + ARIANE to study the interaction between the eddy and the Northern Current
+ Analysis of *in situ* measurements post- LATEX 2010

LATEX financed by LEFE, PACA Region and BQR

LATEX team (LOPB, COM): ***A. Petrenko*, A. M. Doglioli, Z. Hu, G. Rougier, J.-L. Fuda, *F.Diaz*, B. Queguiner, S. Blain (now Banyuls), P. Rimmelin, O. Grosso, R.Campbell**

Partners:

C. Estournel et P. Marsaleix, POC, Toulouse (hydrodynamic model)

B. Blanke et N. Grimas, LPO, Brest (ARIANE; lagrangian floats)

T. Labasque et L. Aquilina, CAREN, Rennes (tracer SF_6)

F. Birol, LEGOS, Toulouse (coastal altimetry)

M. Zhou, sabbatical at LOPB (towyo)

H. Claustre, LOV, Villefranche (gliders with bio-optic sensors)

P. Testor et L. Mortier, LOCEAN-ENSTA, Paris (gliders)

A.-L. Griffa, RSMAS Miami- CNR Italie (lagrangian floats, meso-scale)

J. Boutin, LOCEAN, Paris (CARIOCA buoys, pCO_2)

E. Bosc, AIEA, Monaco (satellite imagery)

I. Obernosterer, LOBB, Banyuls (bacteria)

M. Pujo-Pay, LOBB, Banyuls (carbon fluxes) **and others …**