Aspetti caratteristici della circolazione oceanica in prossimità di ostacoli

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Sala conferenze ISMAR-CNR, Venezia

Fluidi Euleriani e Flussi Potenziali

Fluidi
non
viscosi

$$\nabla \times \vec{v} = 0 \quad \text{et} \quad \nabla \cdot \vec{v} = 0$$

$$\vec{v} = \nabla \Phi \qquad \vec{v} = \nabla \times \vec{\Psi}$$

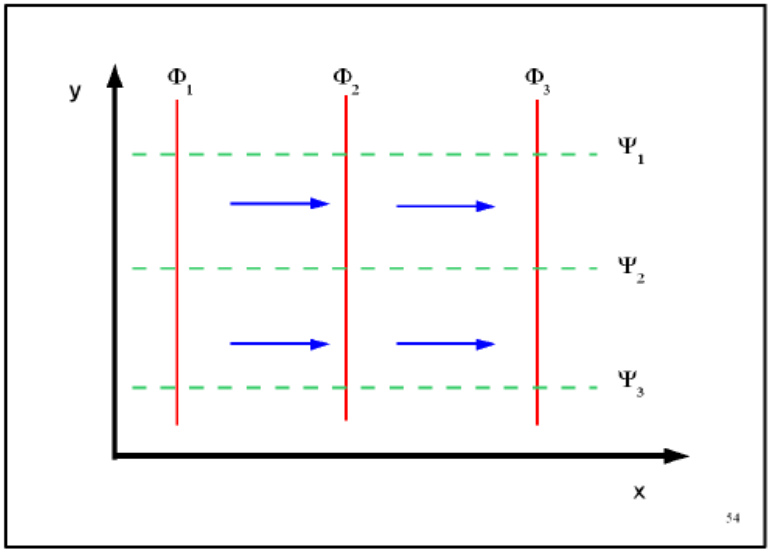
Écoulement parallèle uniforme

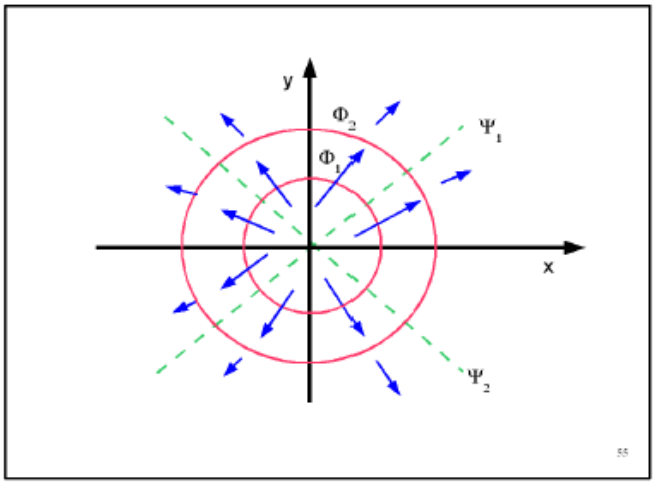
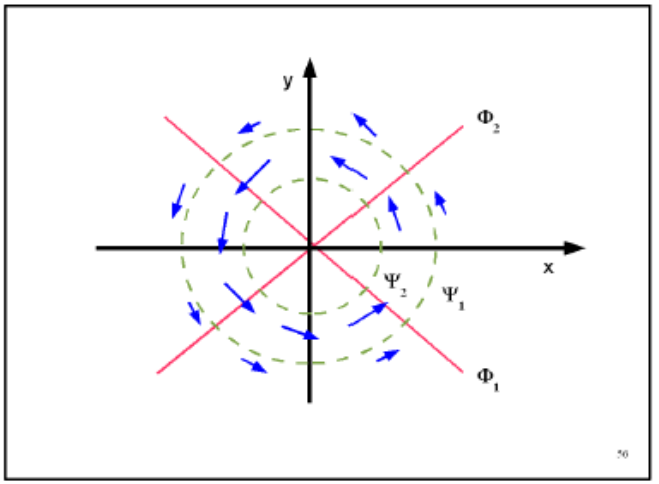
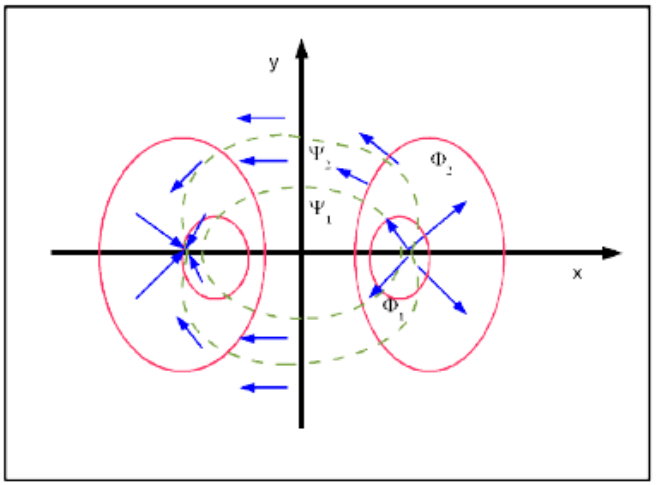
$$v_x = U \qquad v_y = 0$$

D'après les définitions (5.1) et (5.2)

$$v_x = \partial_x \Phi = \partial_y \Psi \quad \text{et} \quad v_y = \partial_y \Phi = -\partial_x \Psi \quad \text{d'où}$$

$$\Phi = U x \quad \text{et} \quad \Psi = U y$$

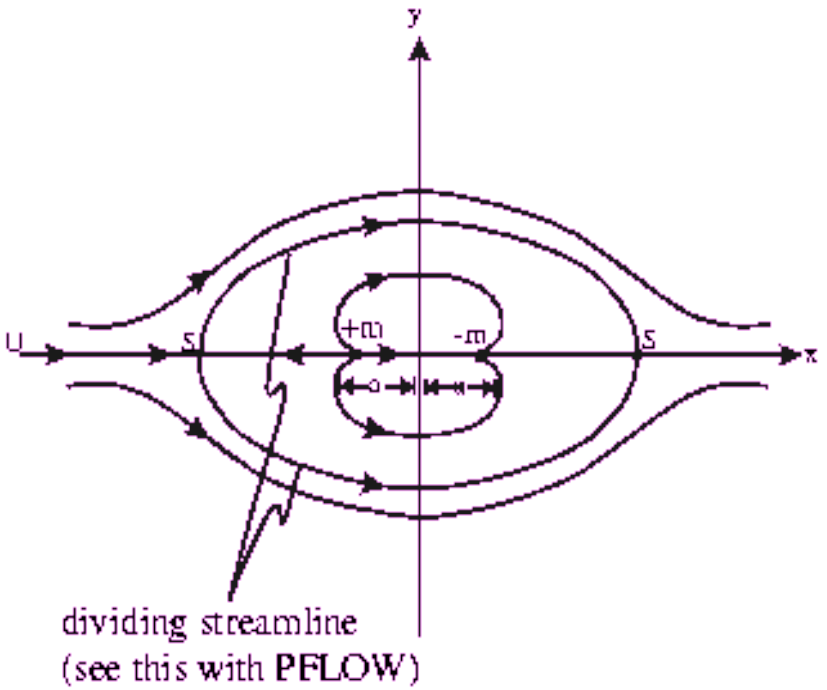


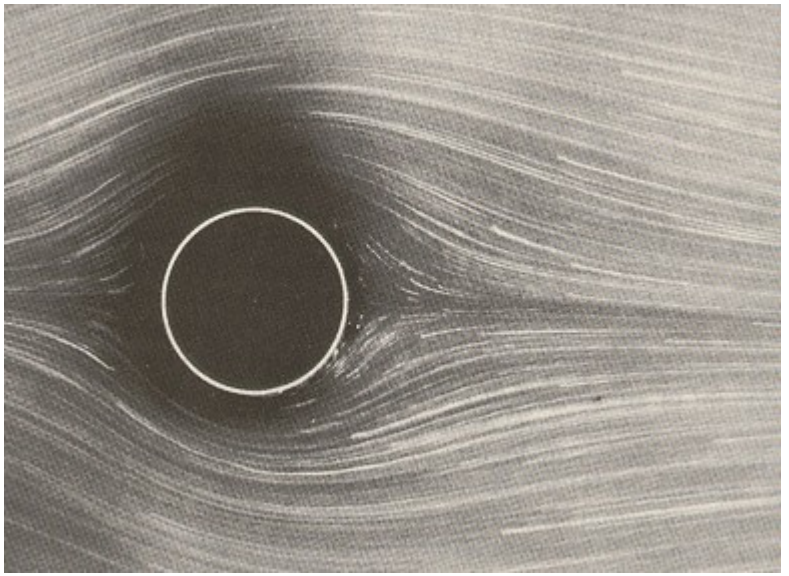
Source ou puits	$v_r = \frac{Q}{2\pi r} \qquad v_\theta = 0$ $\Phi = \frac{Q}{2\pi} \log\left(\frac{r}{r_o}\right)$ $\Psi = \frac{Q}{2\pi}\theta$	
Tourbillon	$v_r = 0 \qquad v_\theta = \frac{\Gamma}{2\pi r}$ $\Phi = \frac{\Gamma}{2\pi}\theta$ $\Psi = \frac{\Gamma}{2\pi} \log\left(\frac{r}{r_o}\right)$	
Dipôle	$v_r = \frac{p\cos\theta}{2\pi r^2} \qquad v_\theta = \frac{p\sin\theta}{2\pi r^2}$ $\Phi = -\frac{Q d \cos\theta}{2\pi r}$ $\Psi = \frac{Q d \sin\theta}{2\pi r}$	

Fluidi Euleriani e Flussi Potenziali

Cilindro circolare

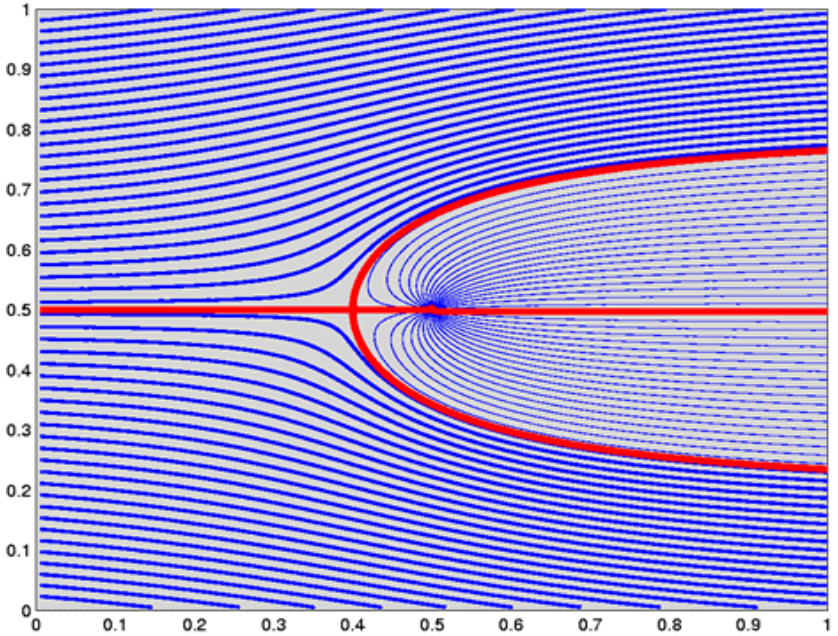
$$\Phi_{unifome} + \Phi_{dipolo}$$

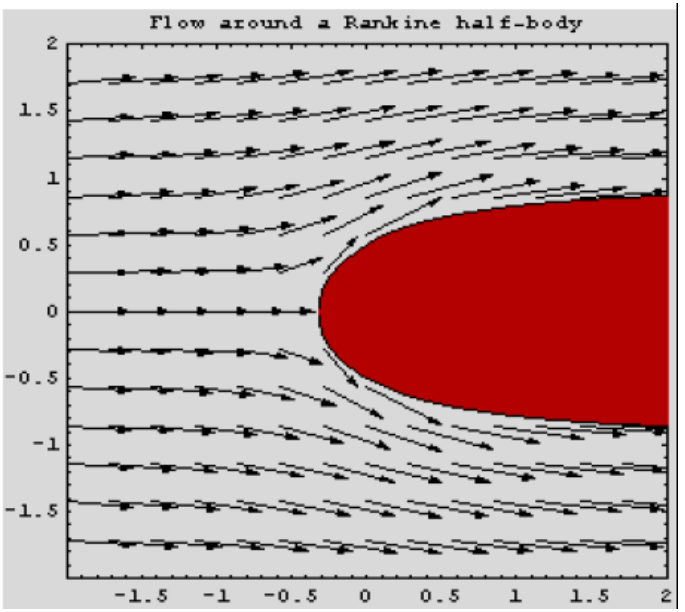


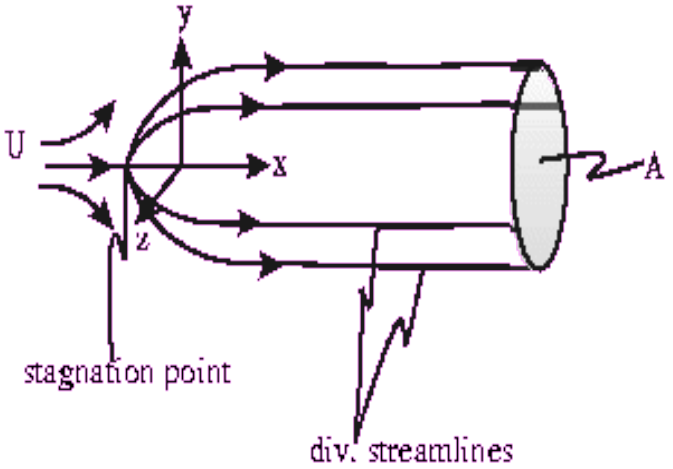


Solidi di Rankine

$$\Phi_{unifome}+\Phi_{source/puits}$$



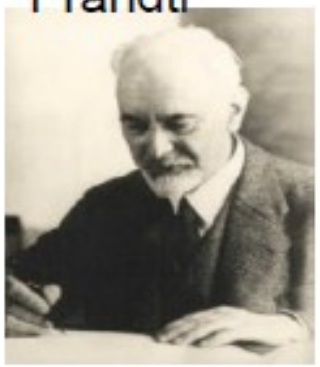




http://web.mit.edu/fluids-modules/www/potential_flows/LecturesHTML/lec1011/

STRATO LIMITE LAMINARE

Prandtl



Navier-Stokes Equation

Hydrostatic Pressure

fluid velocity field

Shear viscosity

vorticity

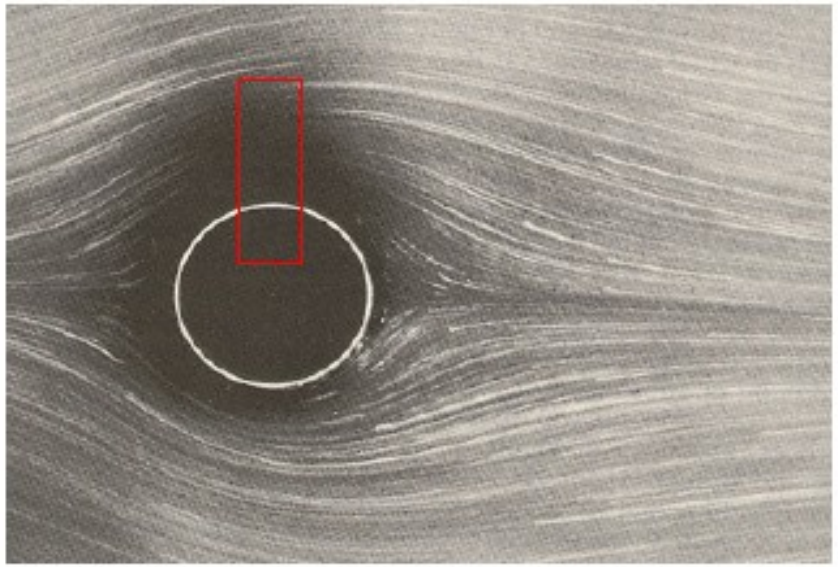
$$\frac{\partial v}{\partial t} + (v \bullet \nabla)v = -\frac{\nabla p}{\rho} + \frac{\eta}{\rho}\nabla \times \omega + g$$

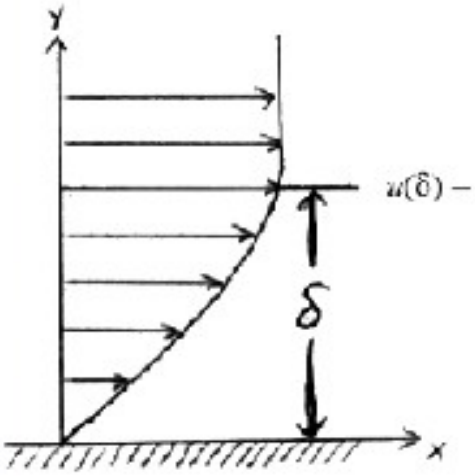
Density

Gravitational Acceleration

$$\nabla^2 v = \nabla \times \omega$$

. . .are these all accelerations?



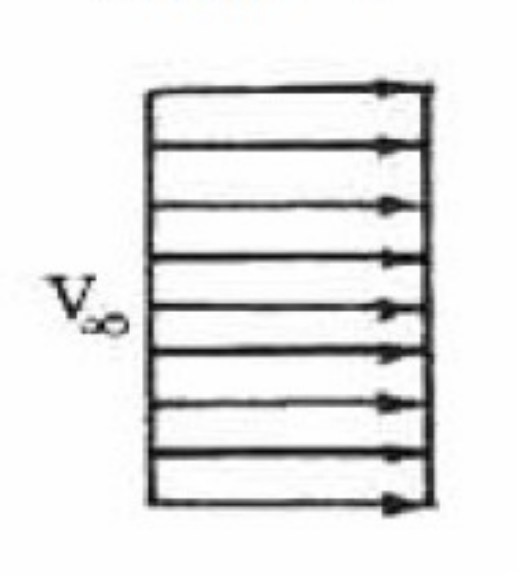


eq. Navier-Stokes

couche limite

Creazione di vorticità

viscosité = 0

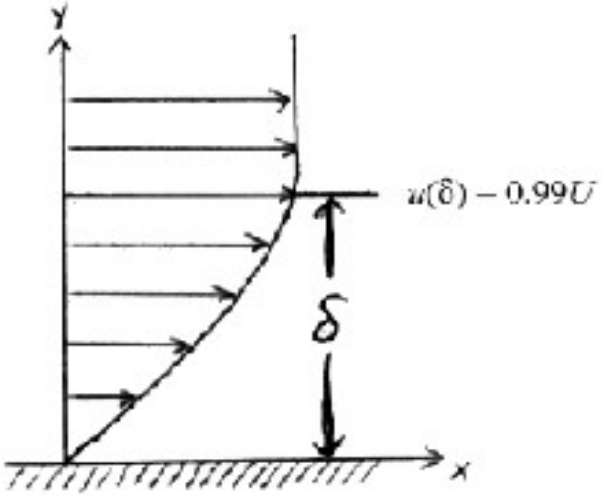


u=(u,v,w)=(u,0,0)

du/dy = 0

il n'y a pas de vorticité
:(

viscosité ≠ 0



u=(u,v,w)=(u(y),0,0)

du/dy ≠ 0

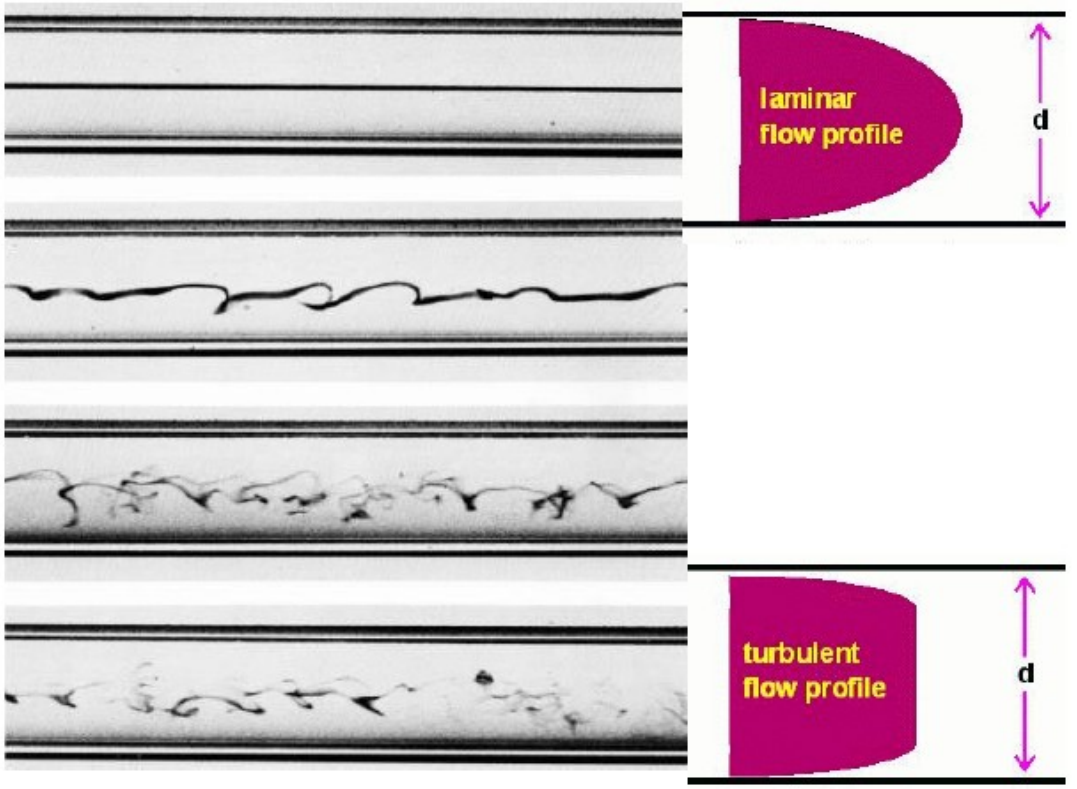
il y a vorticité
:)

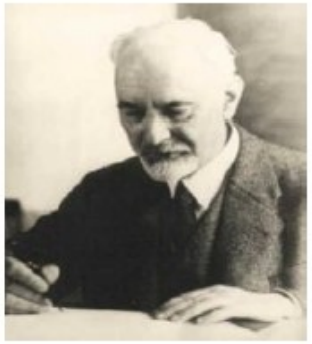
STRATO LIMITE **TURBOLENTO**

expérience de Reynolds

écoulement
de Poiseuille

écoulement
turbulent





Prandtl

Estensione del concetto di viscosità turbolenta

Numero di Reynolds

$$Re = \frac{\rho v_s D}{\eta} = \frac{v_s D}{\nu} \cdot \frac{\textit{Forces inertie}}{\textit{Forces visqueuses}} \quad \frac{\textit{temps de } \textbf{\textit{diffusion}} \textit{ de la quant. mouv.}}{\textit{temps de } \textbf{\textit{convection}} \textit{ de la quant. mouv.}}$$

vs - vitesse du fluide [m/s],

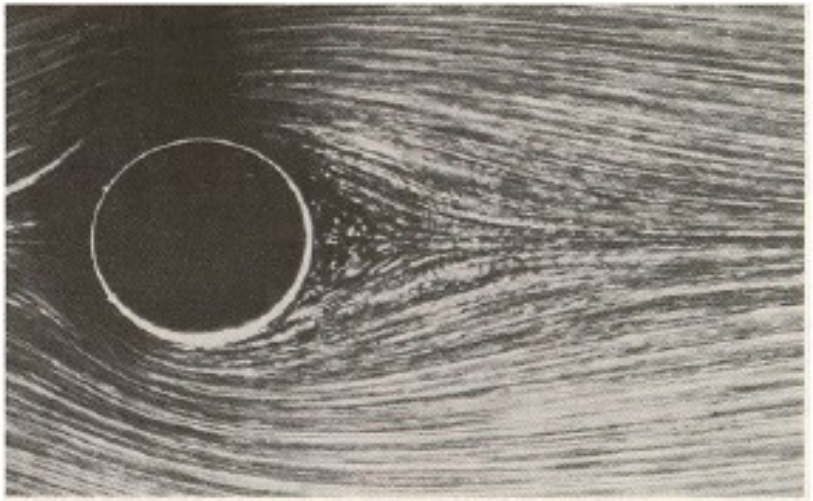
D - dimension caractéristique [m] du phénomène (diamètre pour une conduite de section circulaire, dimension jugée la plus pertinente pour une conduite ou un obstacle de forme quelconque, abscisse depuis le bord d'attaque pour une plaque plane),

ρ - *masse volumique du fluide [kg/m³],*

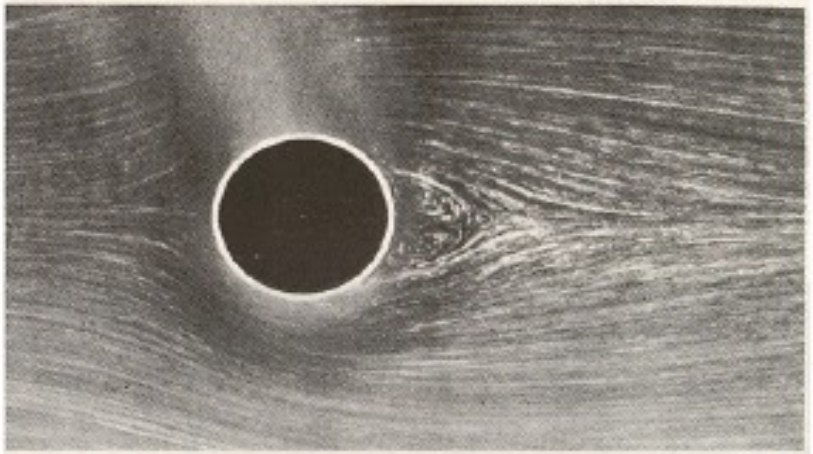
η - *viscosité dynamique du fluide [Pa.s],*

ν - *viscosité cinématique du fluide :* ν = η/ρ *[m²/s].*

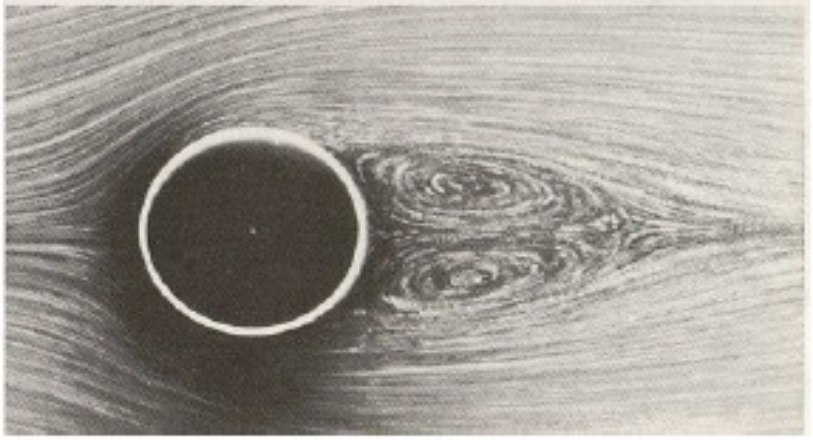
Cilindro in un flusso turbolento



Re = 1.54



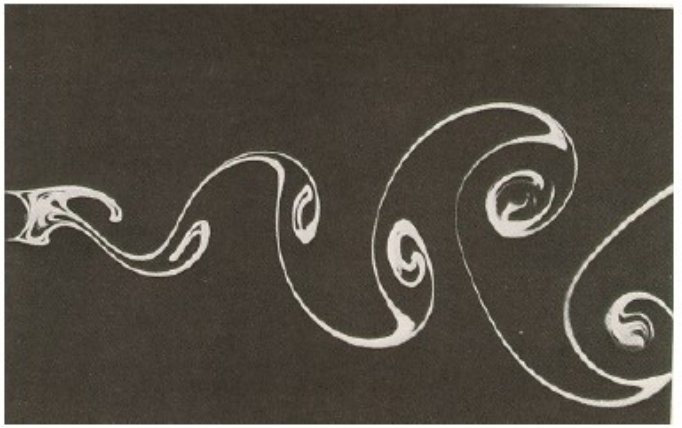
Re = 13.1



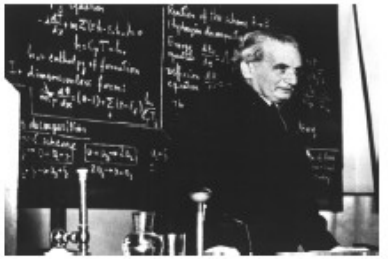
Re = 26

Allée de tourbillons

Re = 105



Re = 150



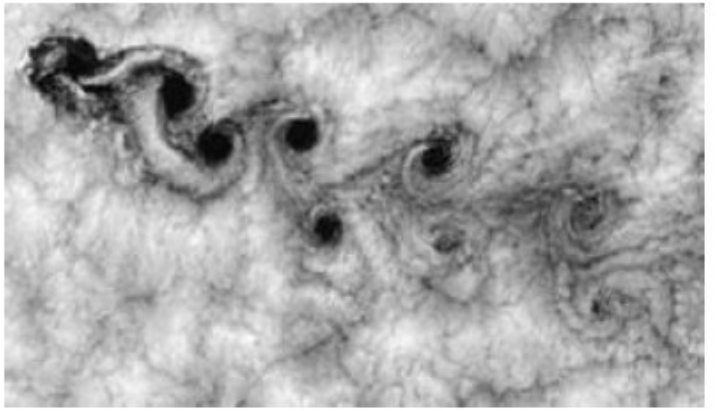
Von Kármán

Nombre de Strouhal

$$Sr = freq \frac{d}{U} = cnst$$

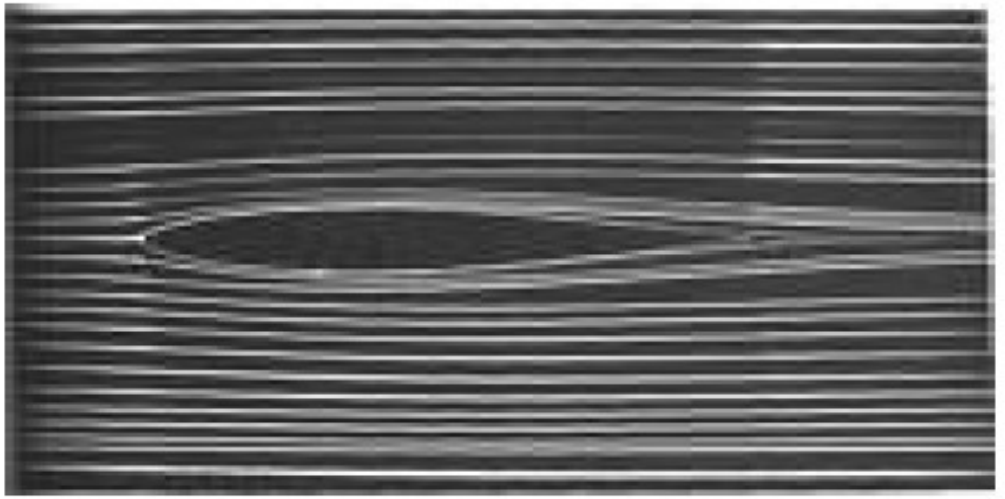
Osservazioni
In natura

Von Kármán vortex street off the Chilean coast near the Juan Fernandez Islands



Distacco dello strato limite

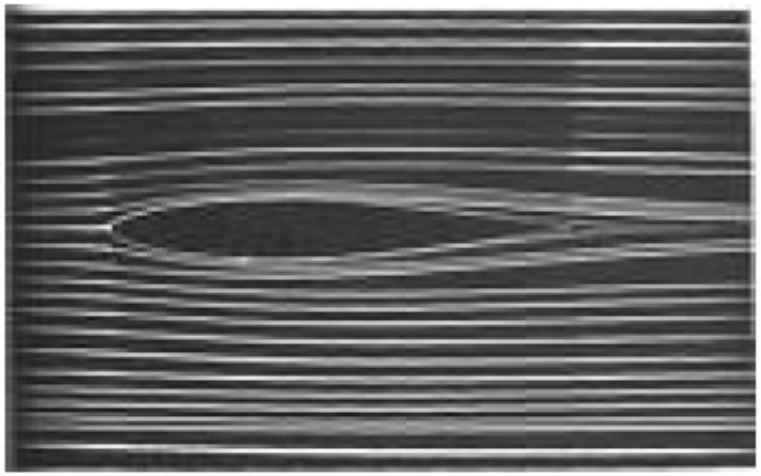
profilé

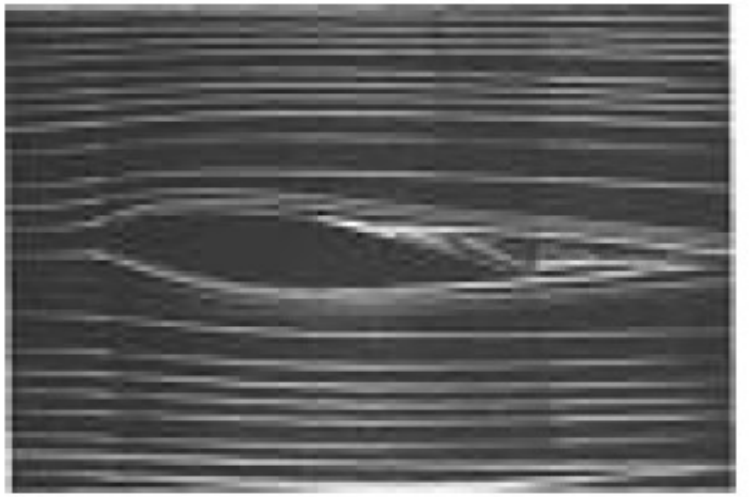


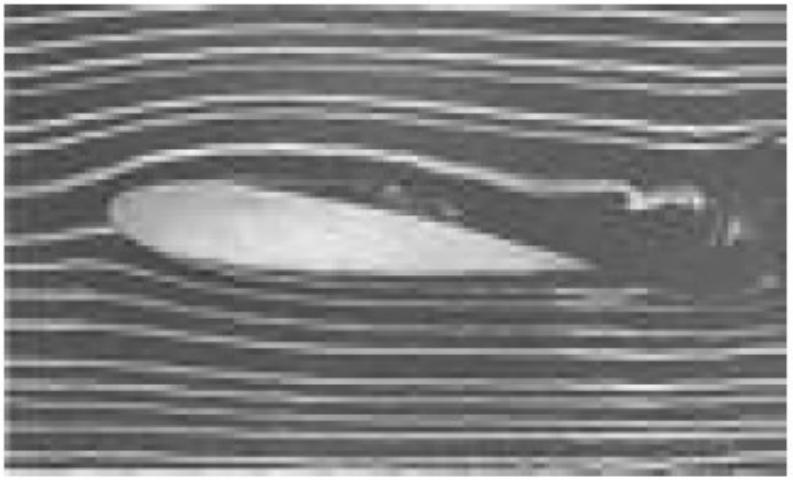
non profilé

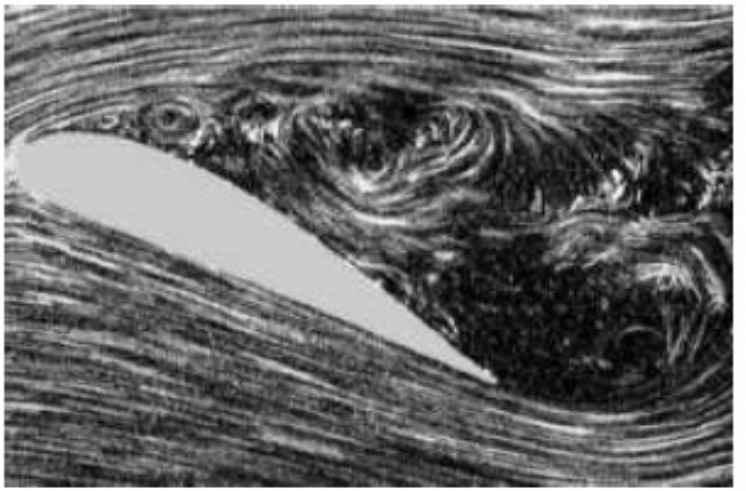
Re change !

Distacco dello strato limite ed iniezione della vorticità nel fluido interno



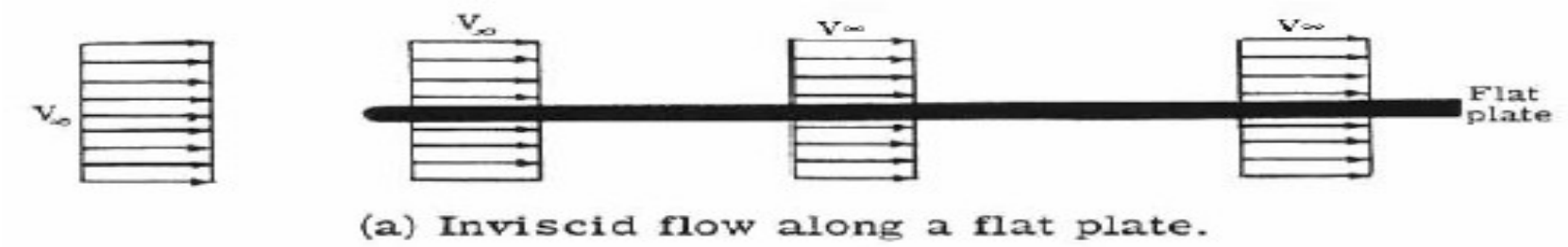




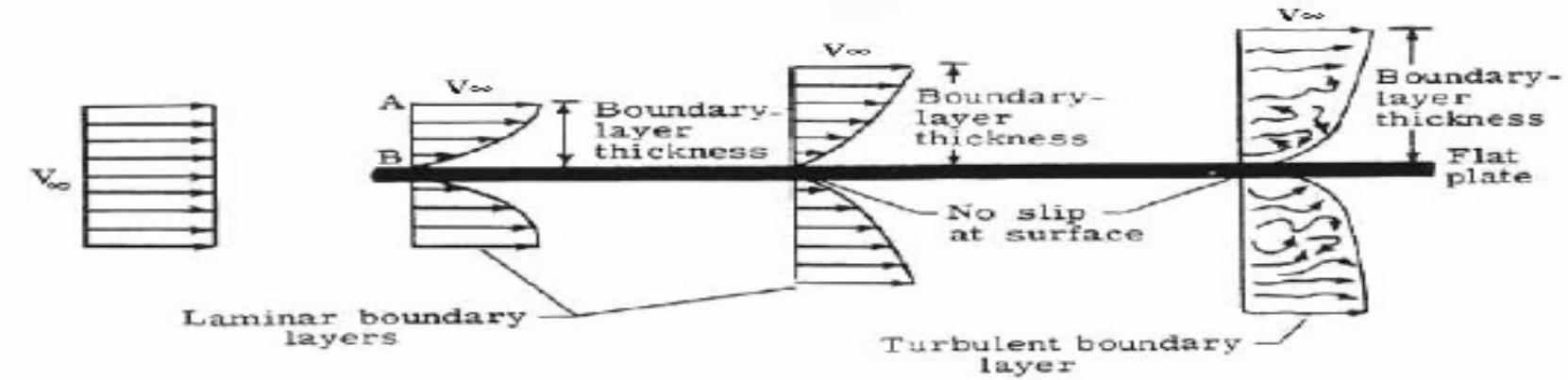


http://www.onera.fr/photos/tunnel.php
http://www.idi.ntnu.no/~zoran/NS-imgs/lics.html
http://www.media.mit.edu/physics/pedagogy/nmm/student/95/aries/mas864/obstacles.html

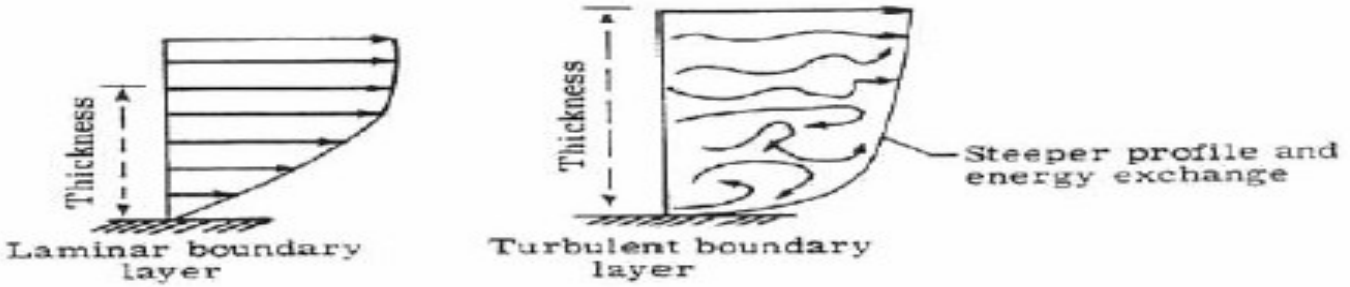
Riassumendo....



(a) Inviscid flow along a flat plate.



(b) Viscous flow along a flat plate.



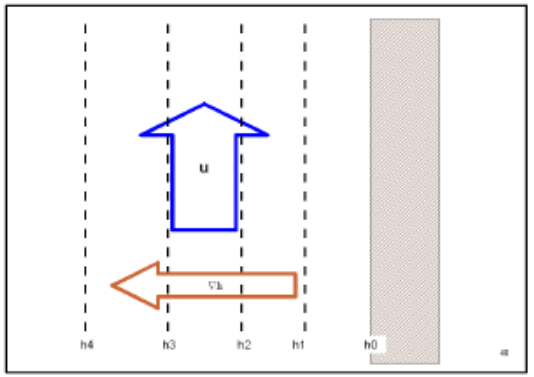
(c) Comparison of laminar and turbulent flow.

Come si produce la vorticità in acque costiere?

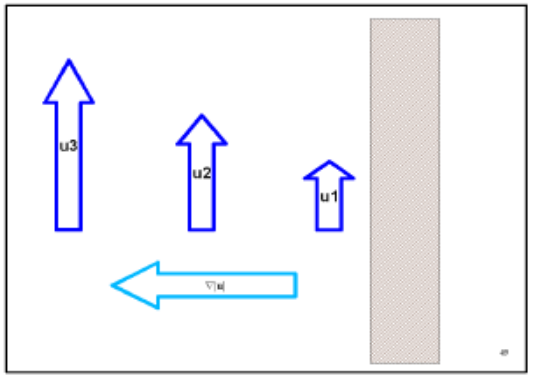
Termine d'attrito nelle equazioni d'acqua bassa

$$\left[\nabla\times\left(\frac{C_D\vec{u}|\vec{u}|}{H}\right)\right]\cdot\vec{k} = \frac{c_D|\vec{u}|}{H^2}[\vec{u}\times\nabla H]\vec{k} - \frac{c_D(\vec{u}\times\nabla|\vec{u}|)}{H} + \frac{c_D|\vec{u}|\omega}{H}$$

a) « slope torque »: création de vorticité quand il y a une composante de la vitesse perpendiculaire au gradient de la bathymétrie. Physiquement on peut expliquer ça en pensant que l'eau plus proche de la côte subie un frottement intégré sur la verticale plus fort que l'eau au large.



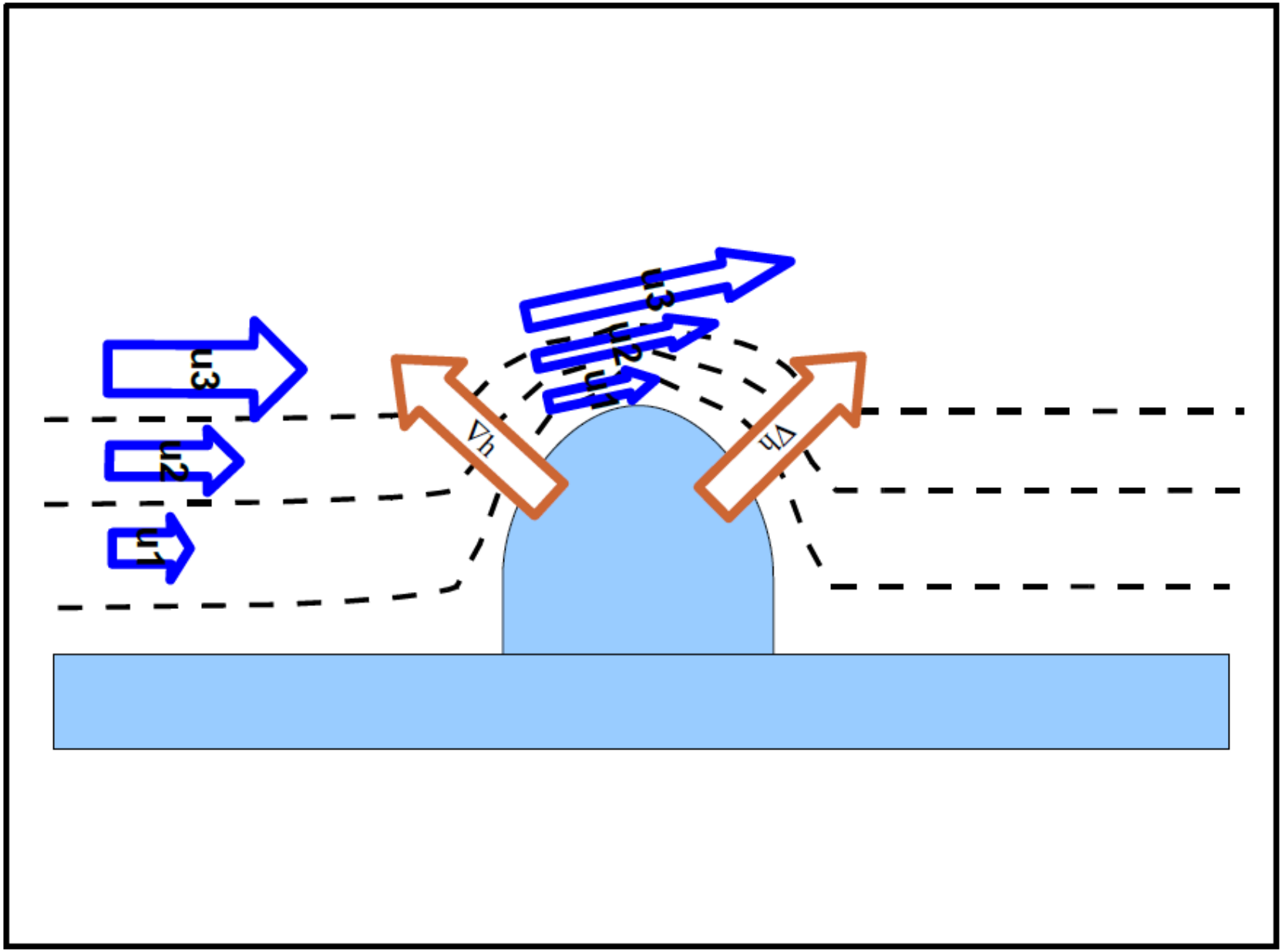
b) « speed torque »: il y a création de vorticité quand il y a une composante de la vitesse perpendiculaire au gradient de la vitesse même. Ce phénomène est lié au fait que le frottement obeit à une loi quadratique. Un écoulement plus rapide est beaucoup plus retardé que un écoulement un peu plus lent.

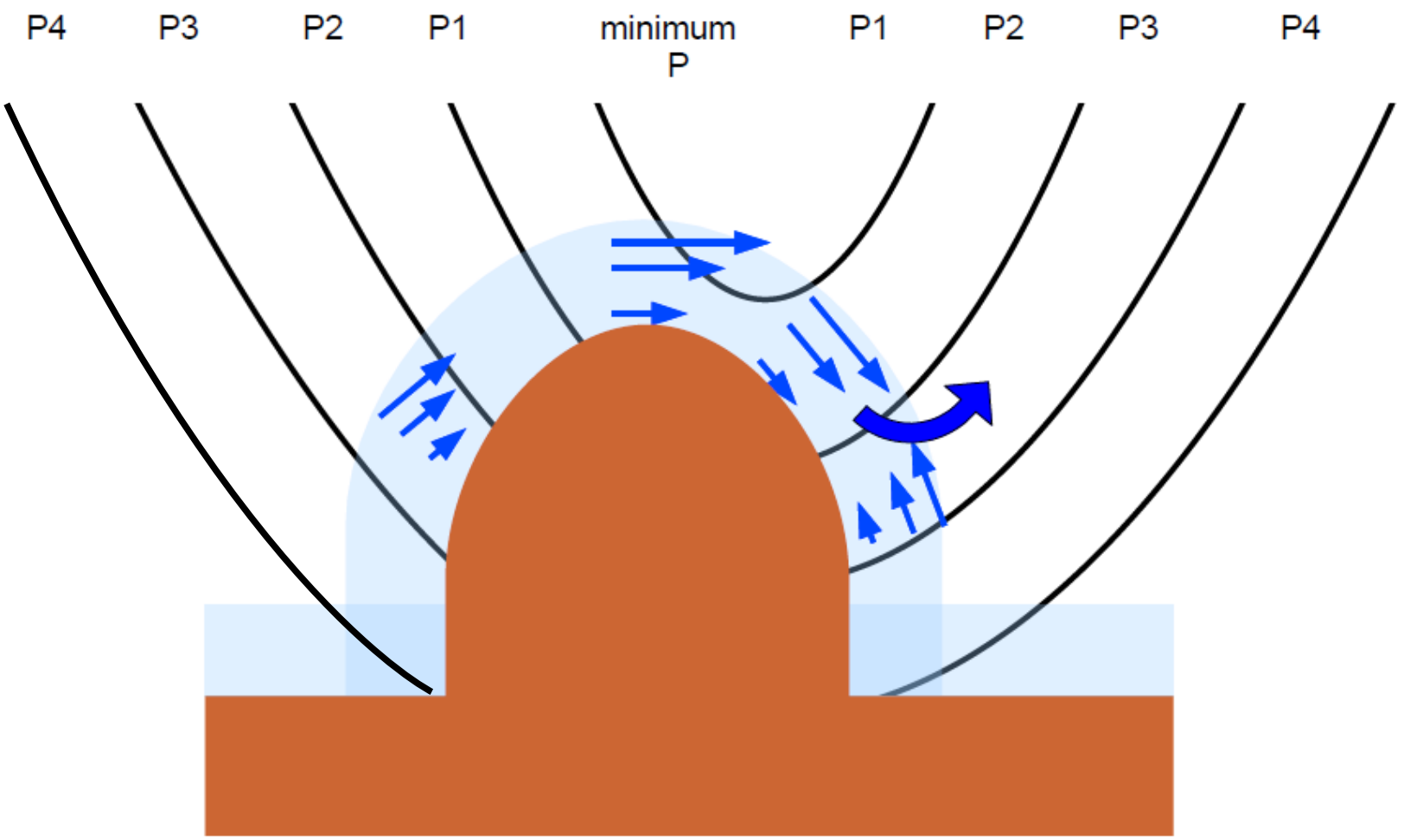


c) dissipation de la vorticité à cause du frottement. L'échelle temporelle du phénomène est

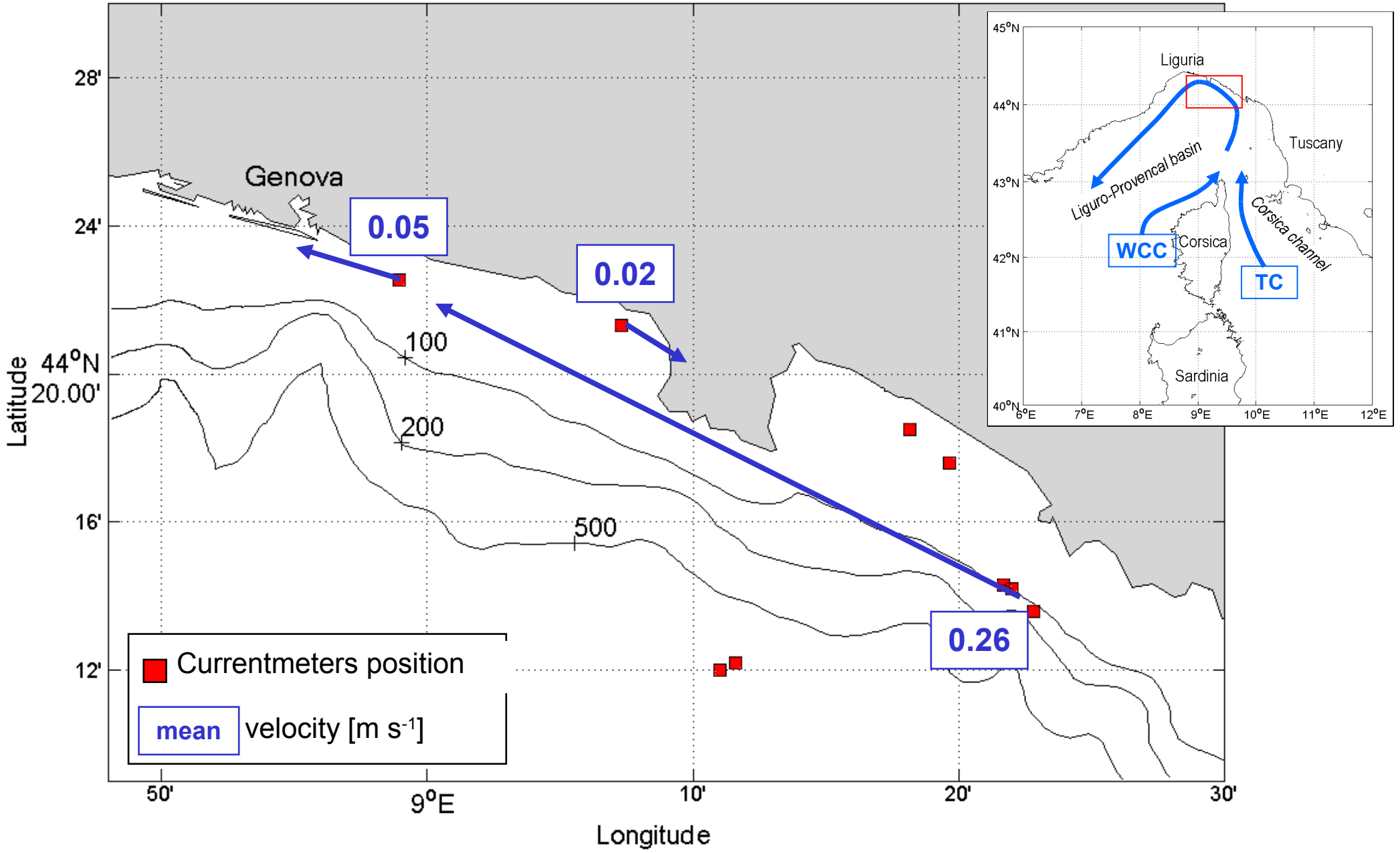
$$\tau = \frac{H}{c_D|\vec{u}|}$$

In presenza di un capo




P4
P3
P2
P1
minimum
P
P1
P2
P3
P4

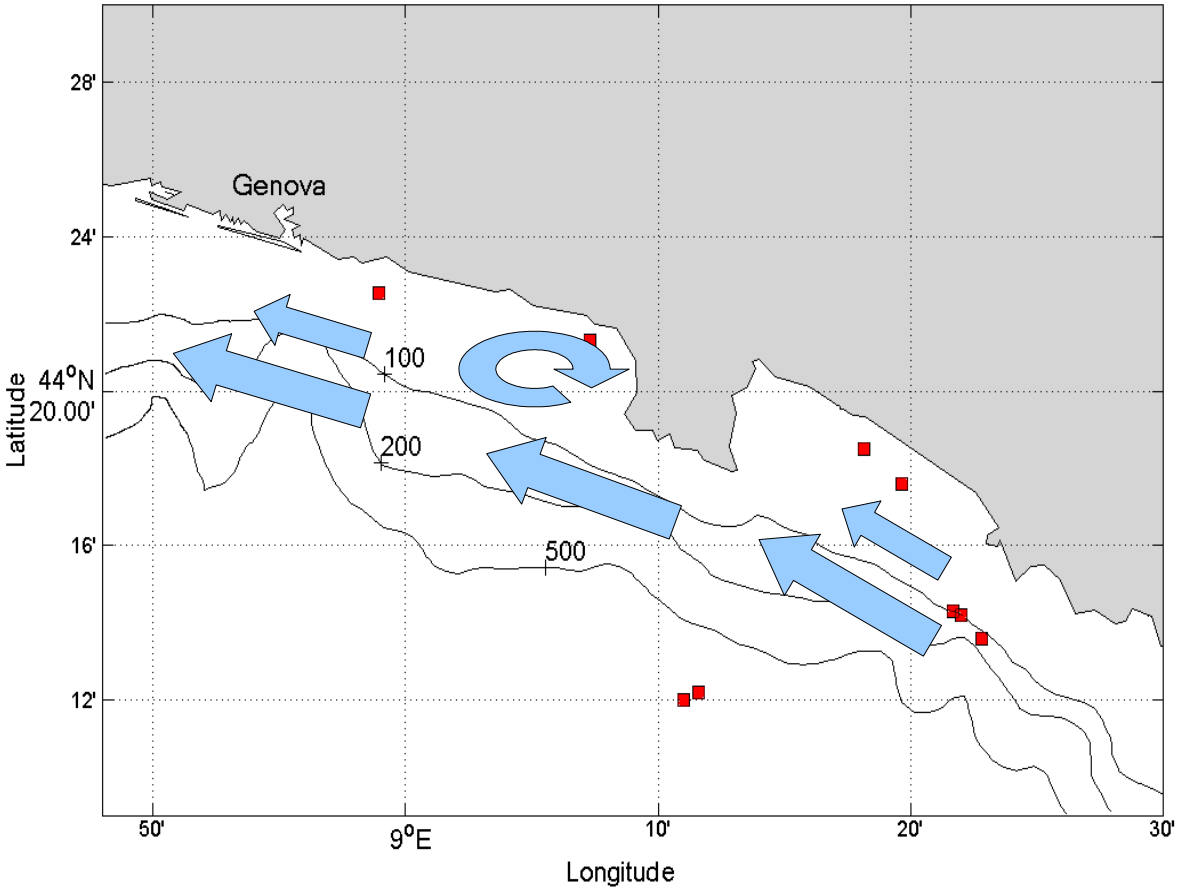
Misure storiche di corrente a Portofino

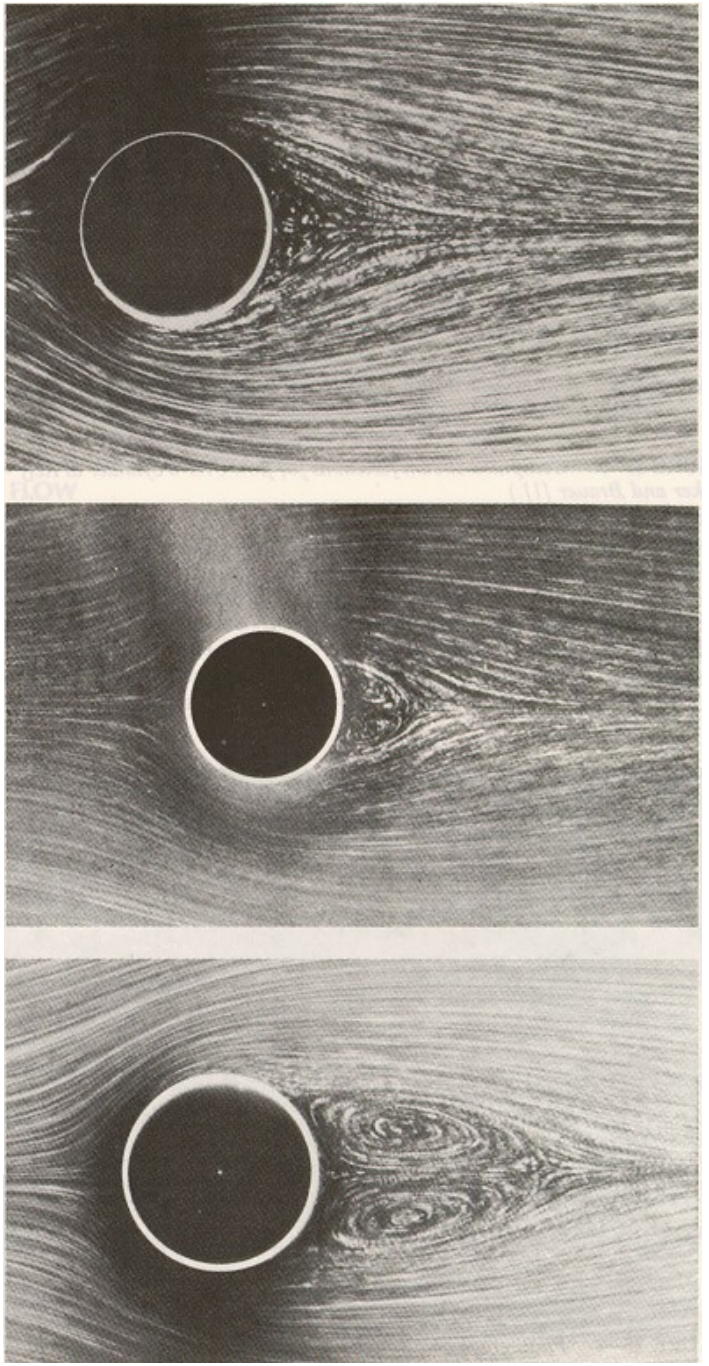


IOF-CNR, 1978-'82 *ENEA, 1986-'88, 1992-'94,1997* *(Astraldi and Manzella, 1982)*

Come spiegare questa circolazione?

Un vortice sottoflusso all'ostacolo!





Se é vero, allora come e perché si forma?

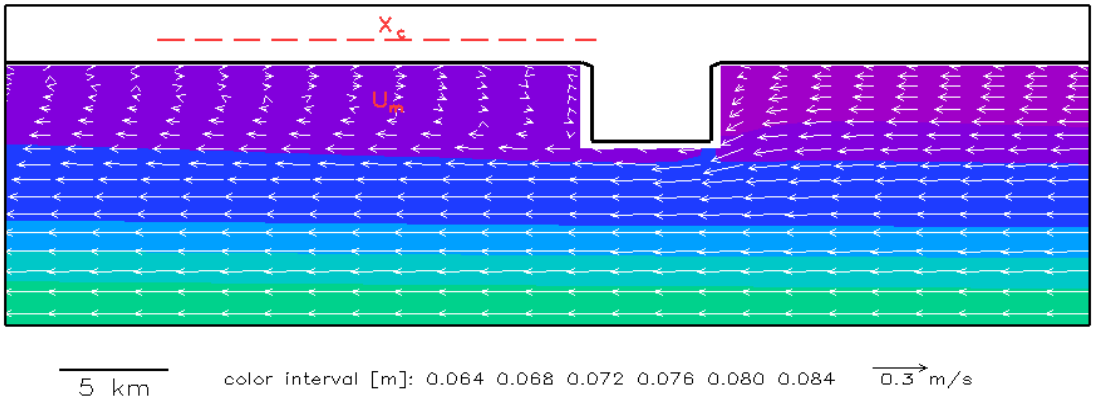
POM (Princeton Ocean Model)

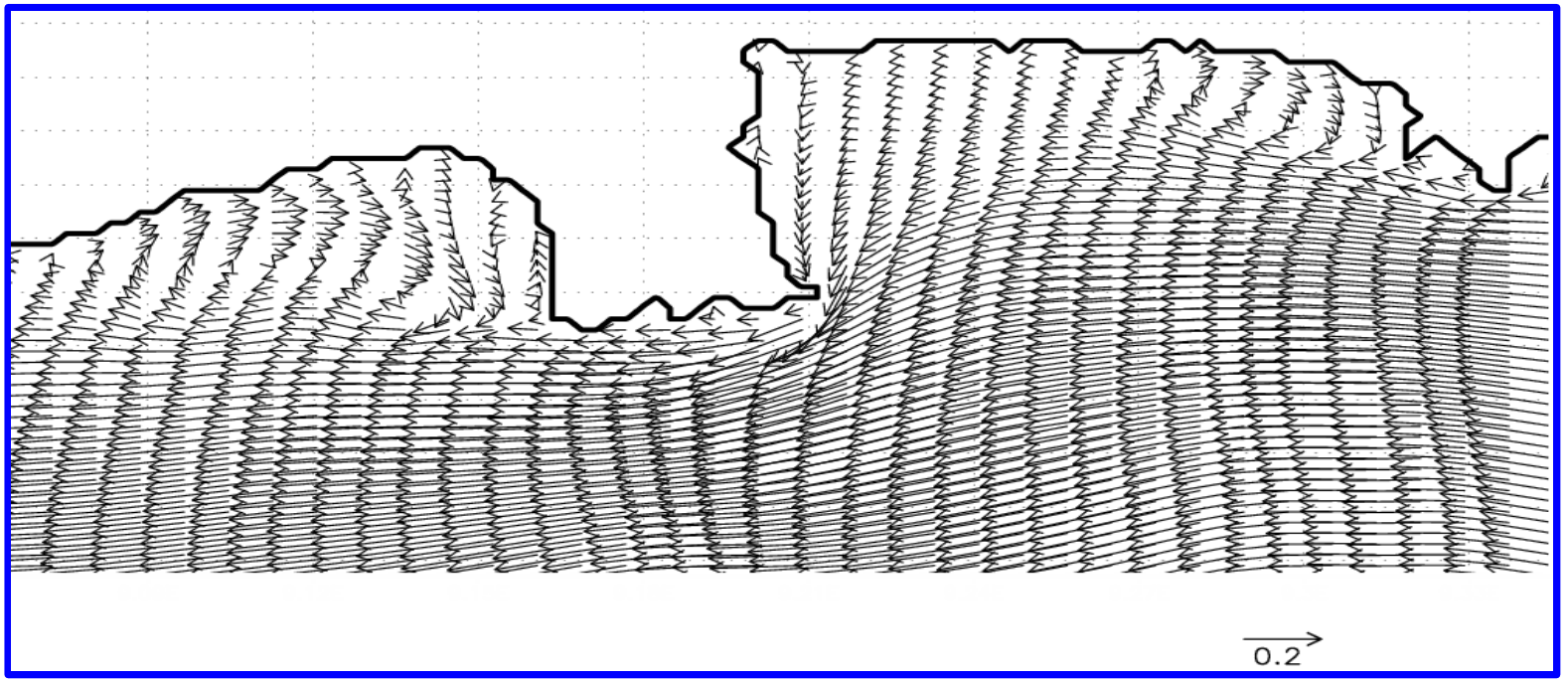
www.aos.princeton.edu\WWWPUBLIC/htdocs.pom.

***Software* libero scaricabile da rete**

Studi prima semplificati,

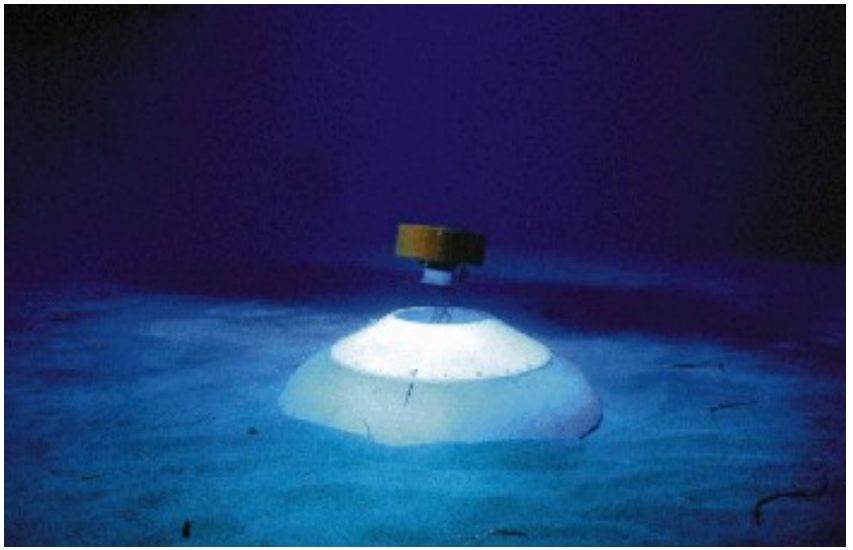
poi sempre più realistici





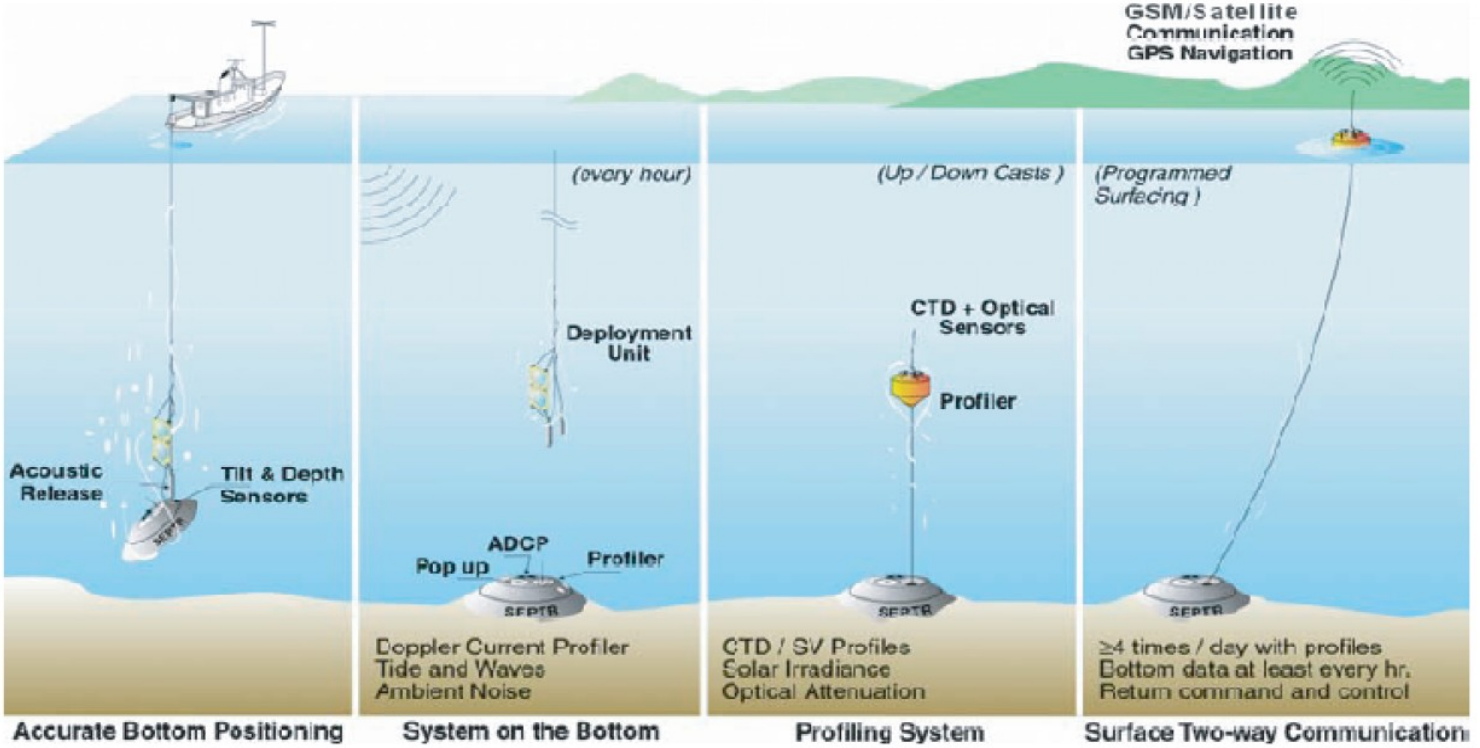
Approvato dai pescatori di Camogli!

Conferme da misure correntometriche e idrologiche

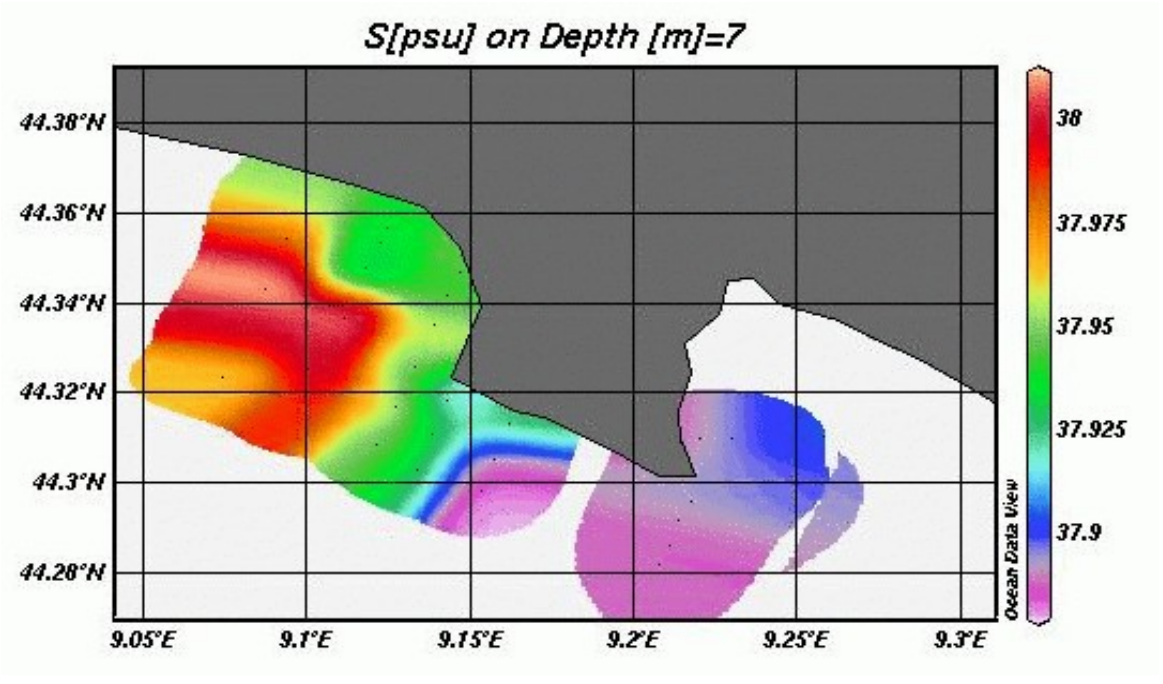


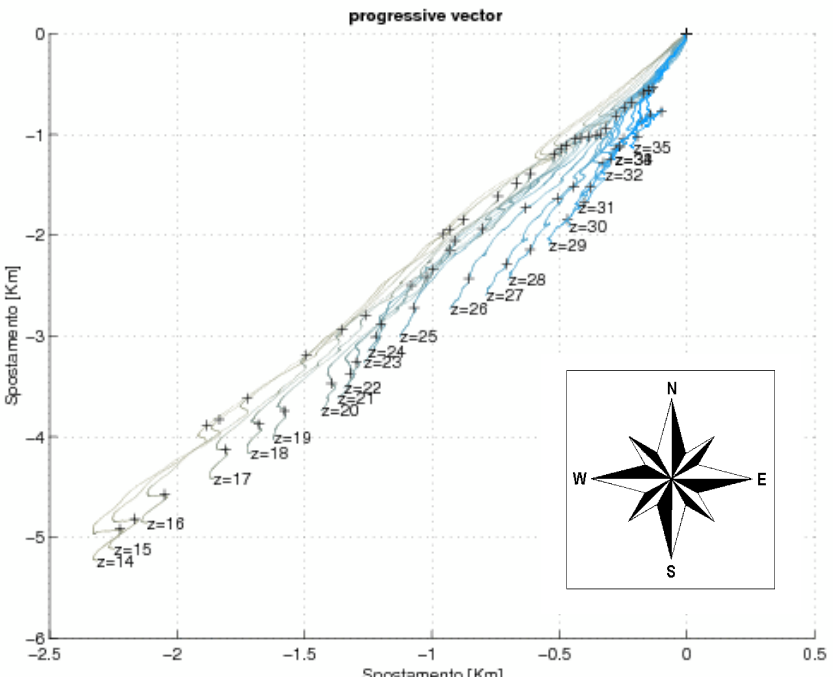
SEPTR

(Shallow water Environmental Profiler
in Trawl-safe Real-Time)



SEPTR operational scenario: deployment and operations

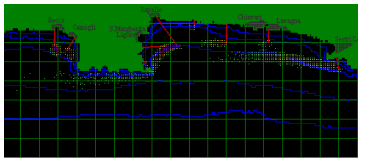




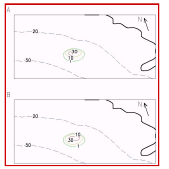
Applicazioni

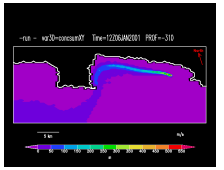
Studio del trasporto e della dispersione:

* Scarichi di condotte a mare



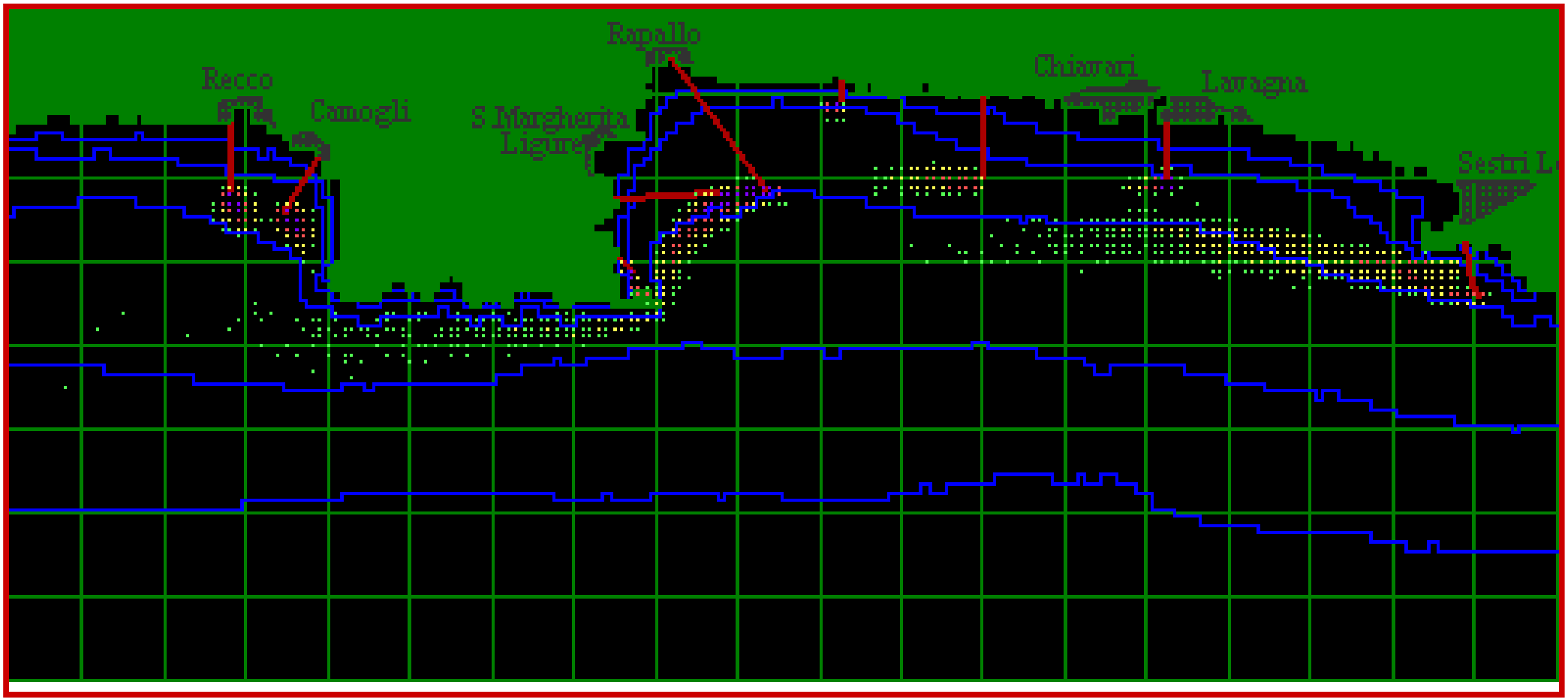
* Rifiuti da acquacoltura





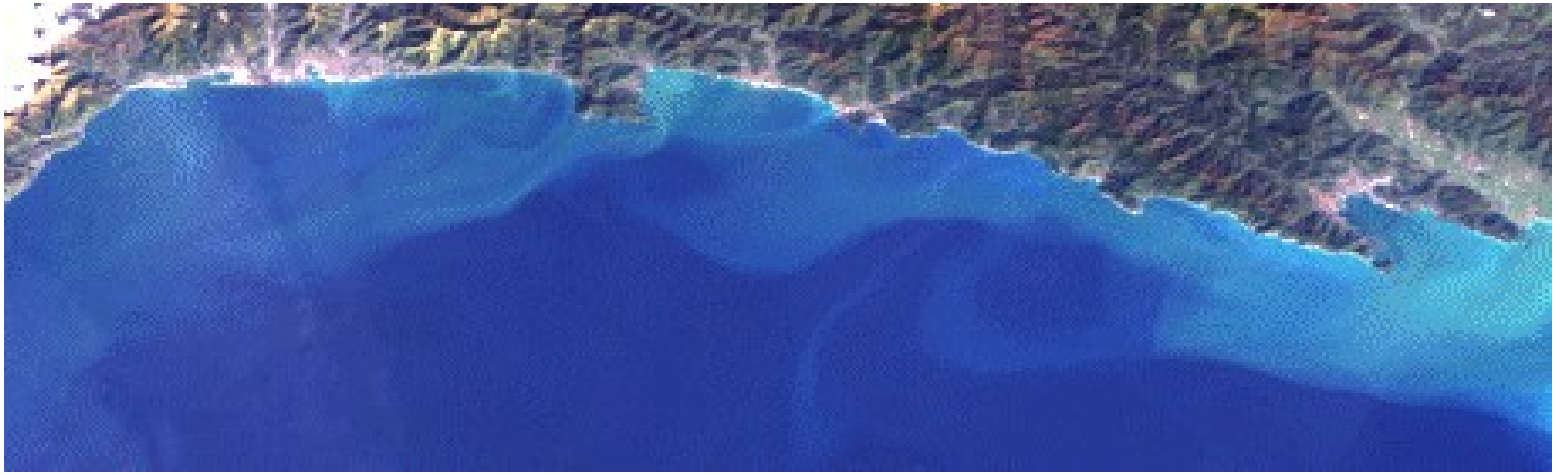
Dispersione degli scarichi delle condotte a mare

LAMP3D (Lagrangian Assessment for Marine Pollution model)



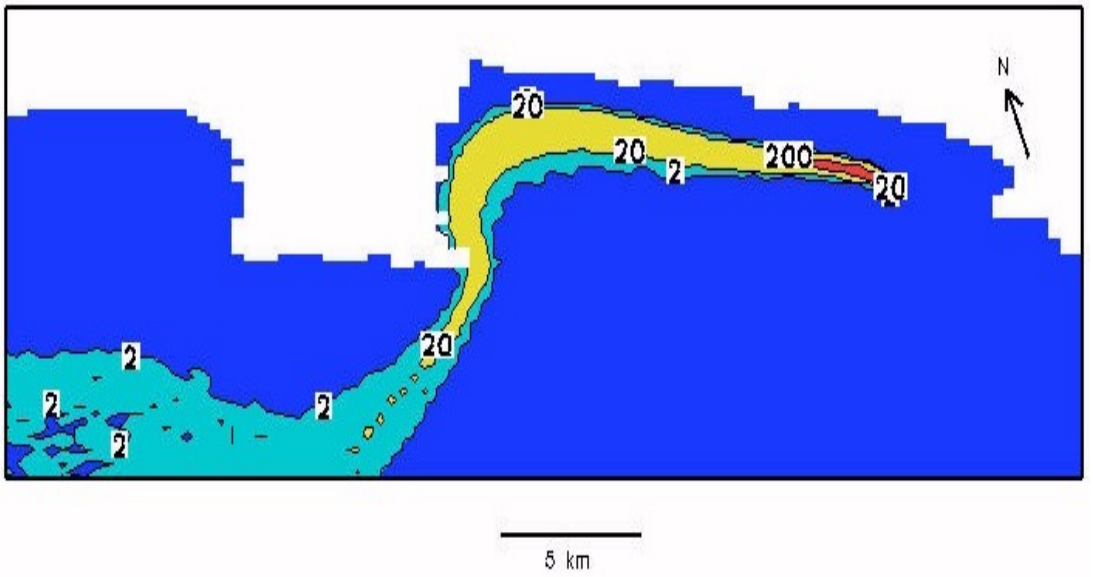
Solidi sospesi

Immagine satellitare MERIS-ENVISAT

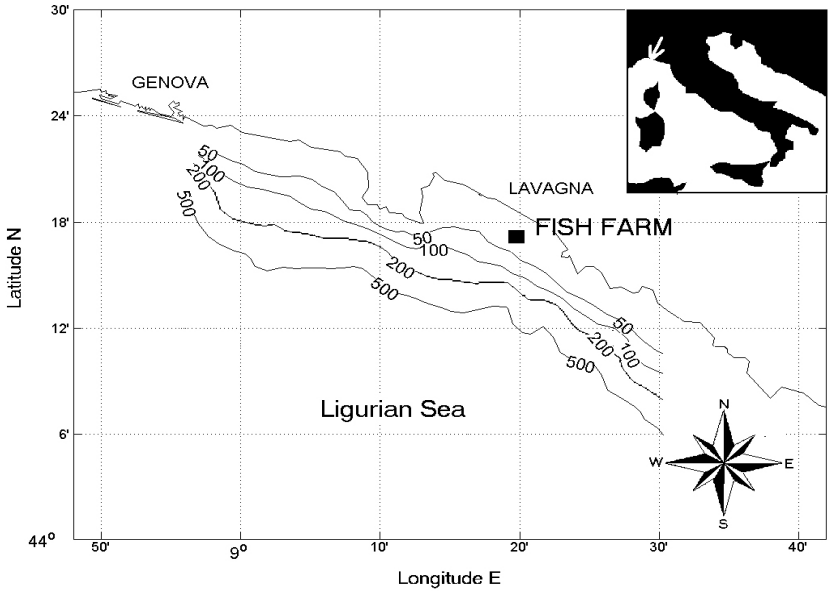


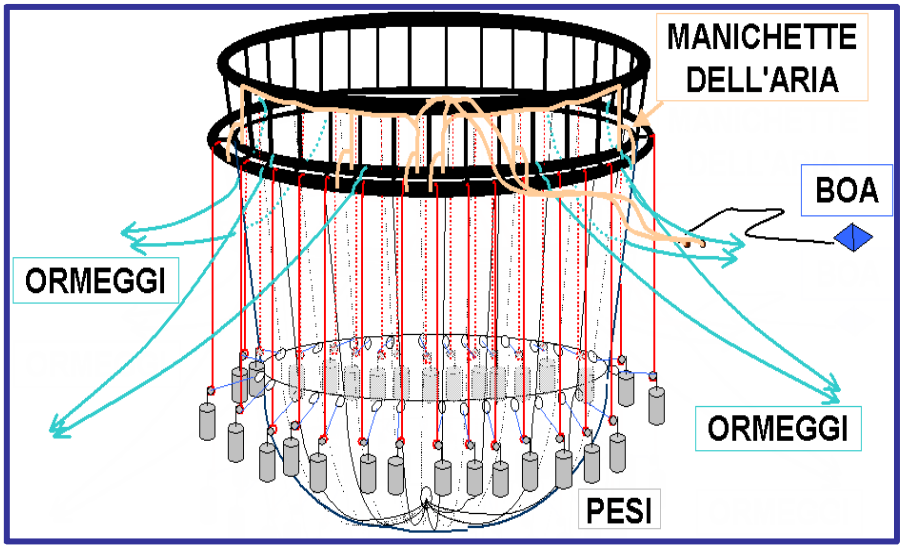
Modello POM-LAMP3D

concentration [particules/maille]



Allevamento “AQUA”





Indicatori

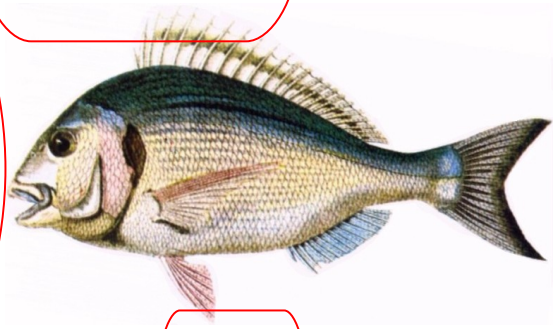
Azoto
(disciolto e particolato);

Fosforo
(disciolto e particolato);

Carbonio Organico
(particolato).

in

- Escrezioni
- Cibo non mangiato
- Feci



Modello

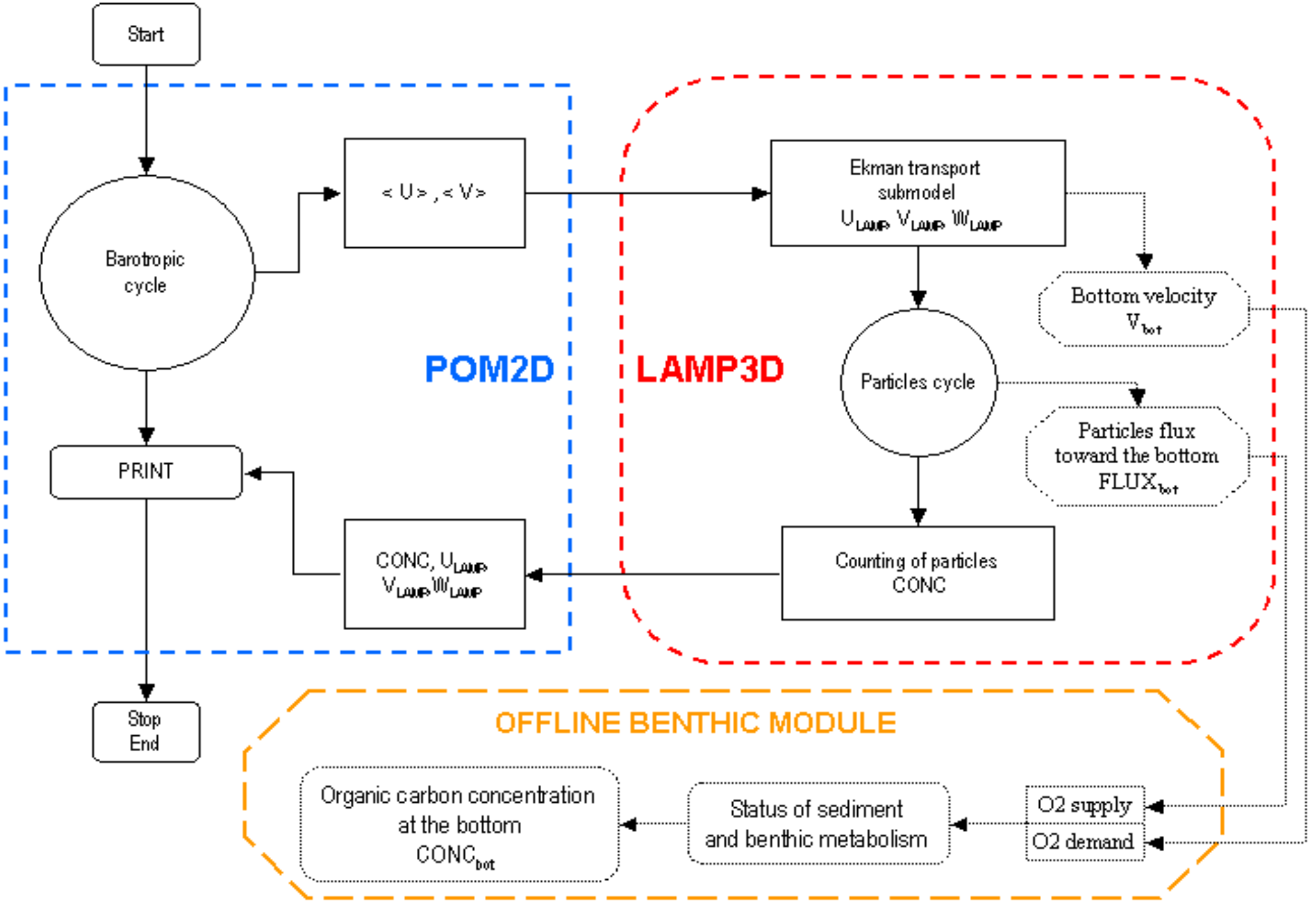
LAMP3D

(*Lagrangian Assessment for Marine Pollution 3D model*)

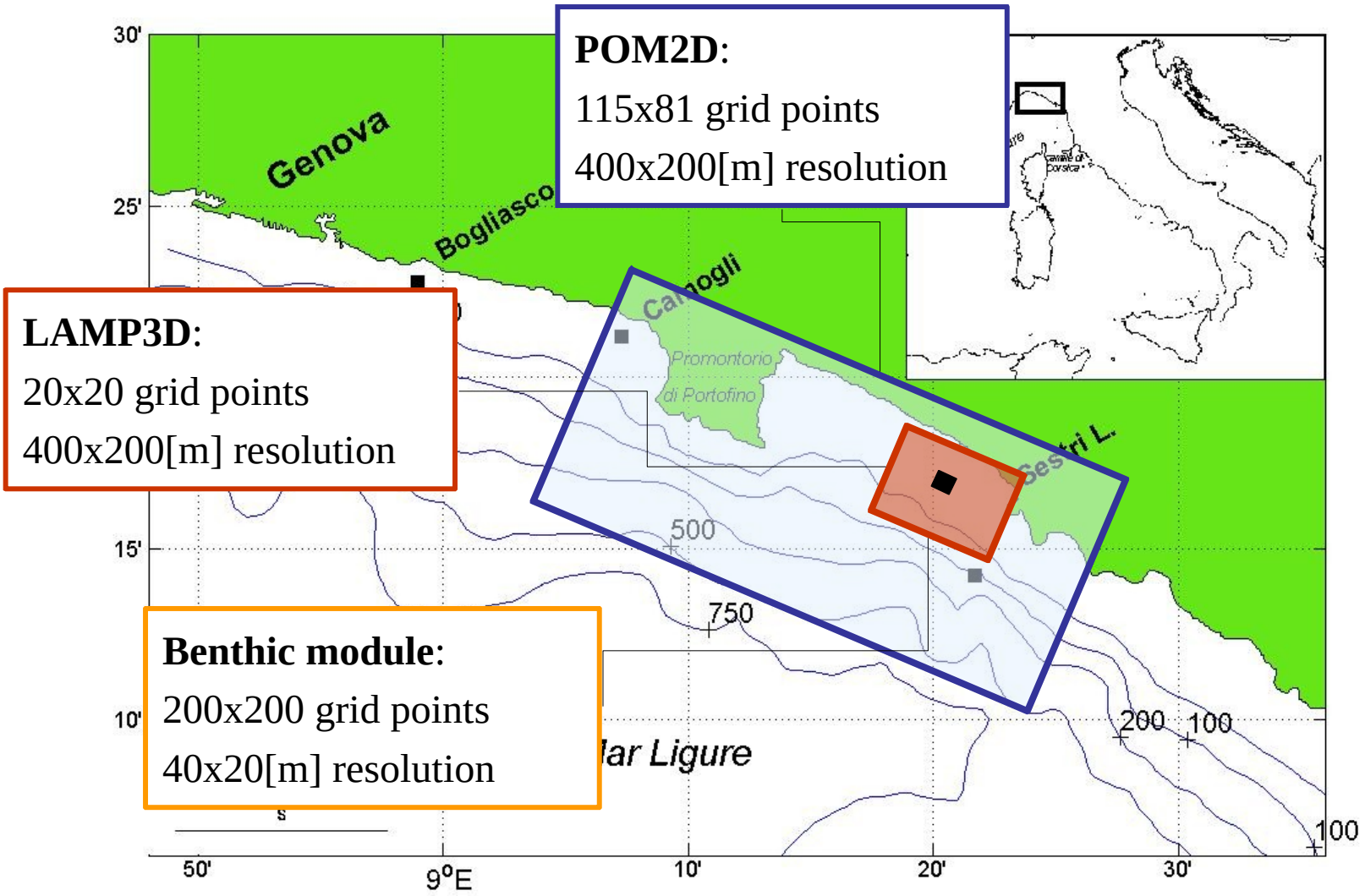
- posizione particelle
- da modello circolazione
- *Random jump*

$$\mathbf{r}_{n+1} - \mathbf{r}_n = \overline{\mathbf{v}}\Delta t + \boldsymbol{\varrho}_n$$

POMLAMP coupled model



NUMERICAL GRIDS and NESTING



POM2D:
115x81 grid points
400x200[m] resolution

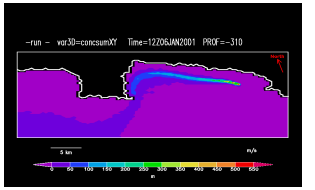
LAMP3D:
20x20 grid points
400x200[m] resolution

Benthic module:
200x200 grid points
40x20[m] resolution

Risultati

Disciolto

N e P da escrezioni



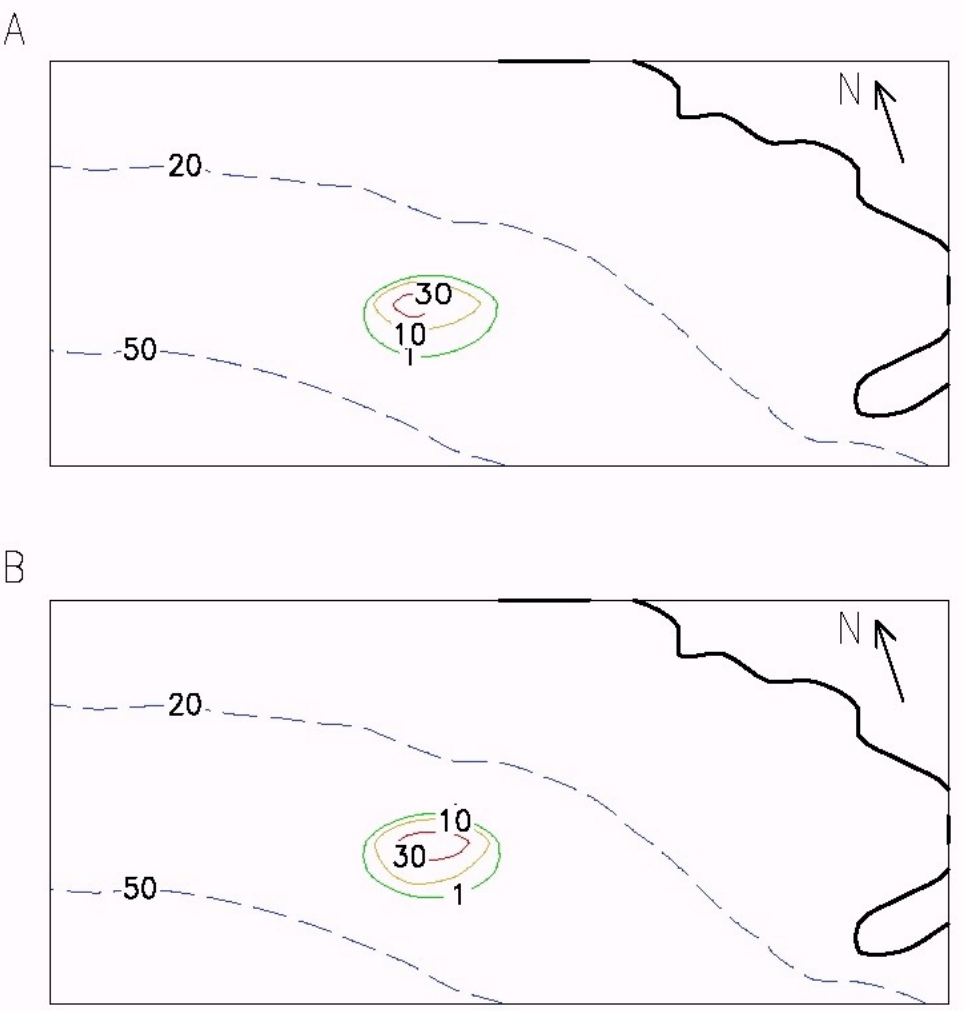
Particolato

N, P e C

da feci

e

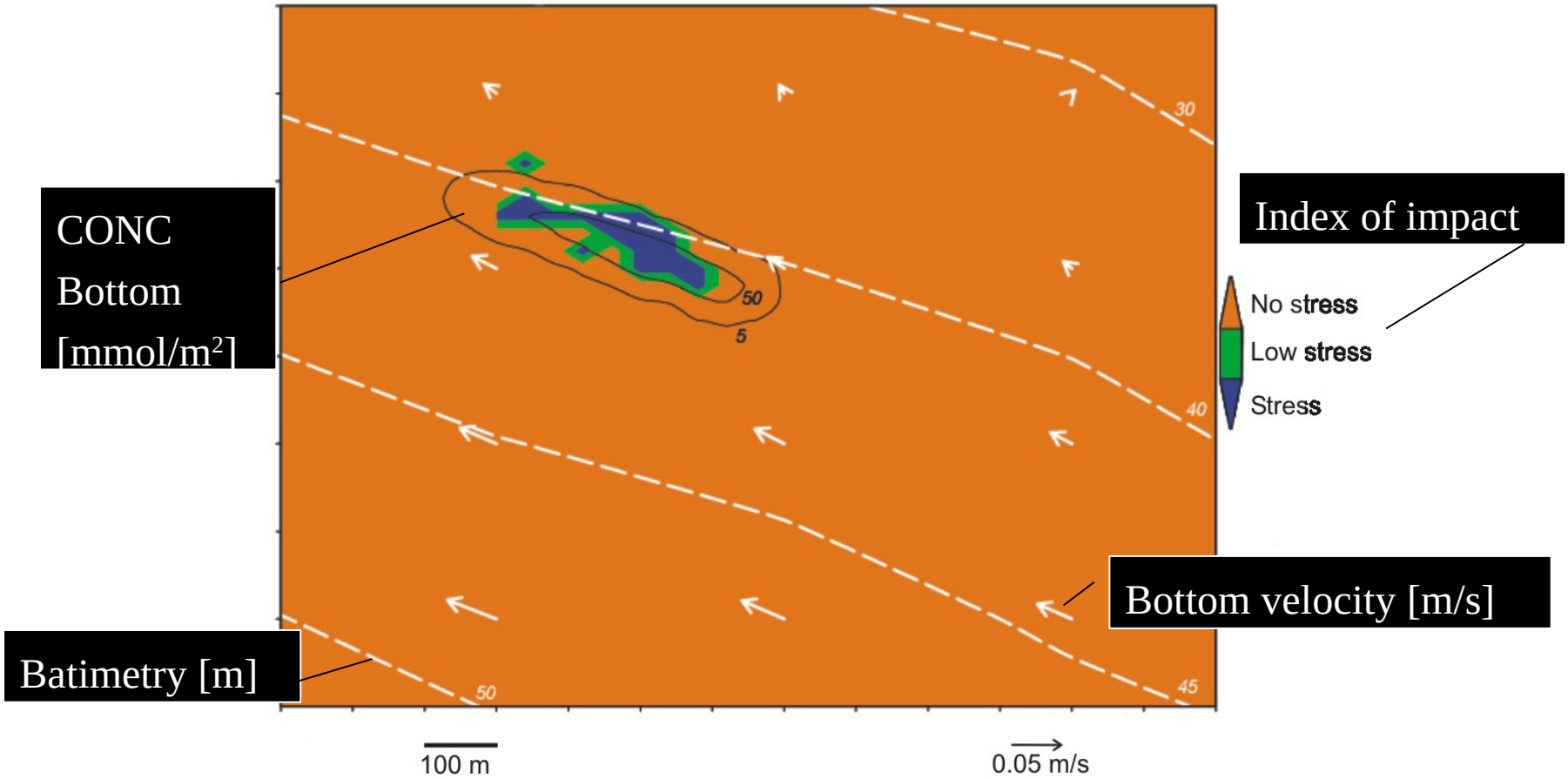
cibo non mangiato



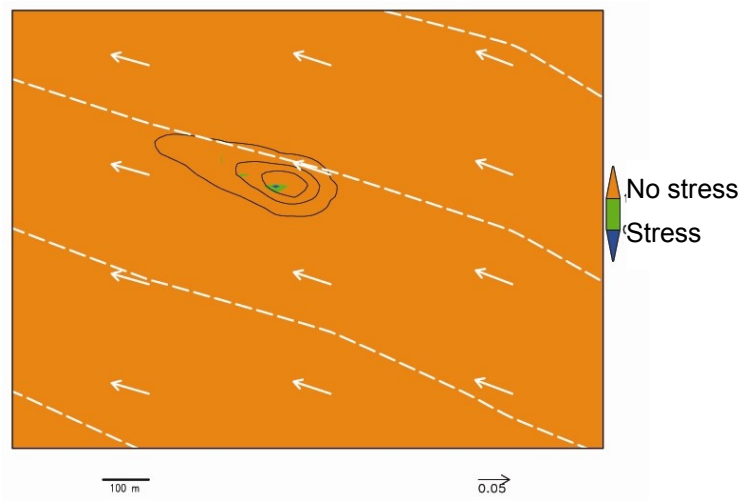
Index of impact and bottom concentration

NE wind (typical):

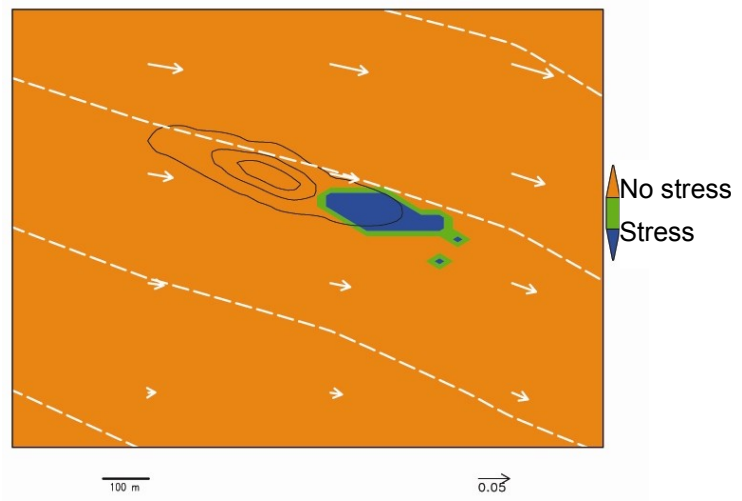
higher C concentration ⇔ most stressed sediment



Index of impact and bottom concentration



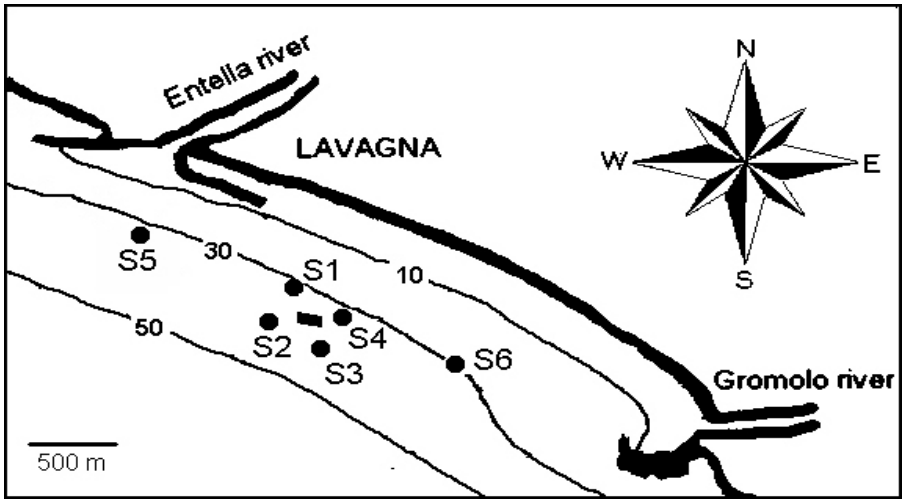
Current intensification ⇔ low stress condition



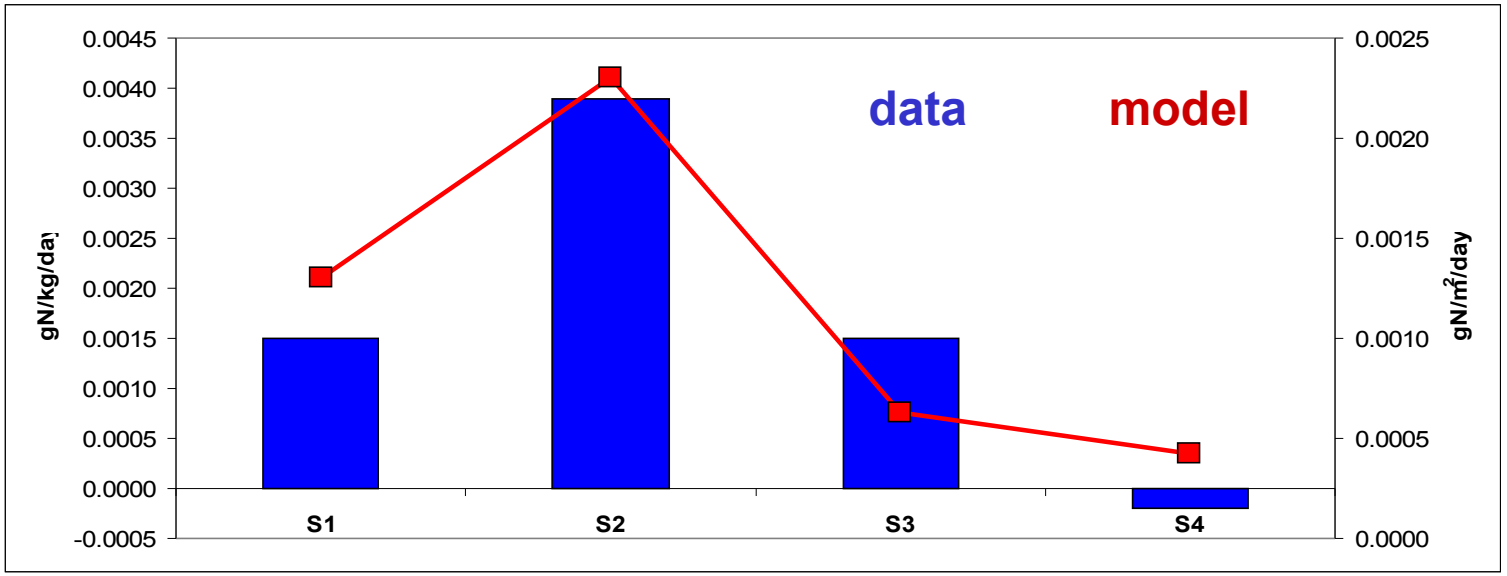
Current direction reversal ⇔ change of stress area

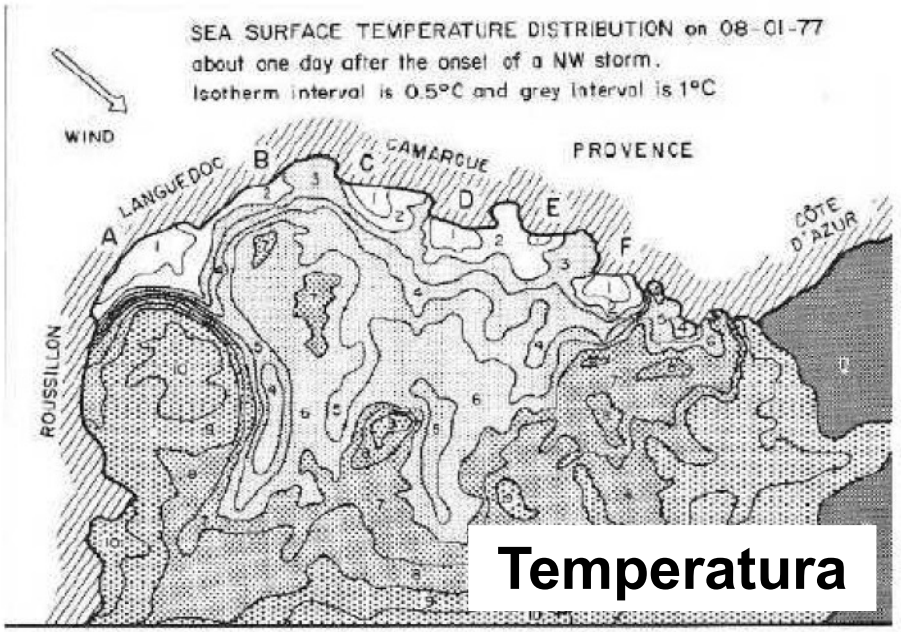
Validazione

campioni acqua e sedimento
luglio 2000 – settembre 2003
6 stazioni
(VIA Regione Liguria)



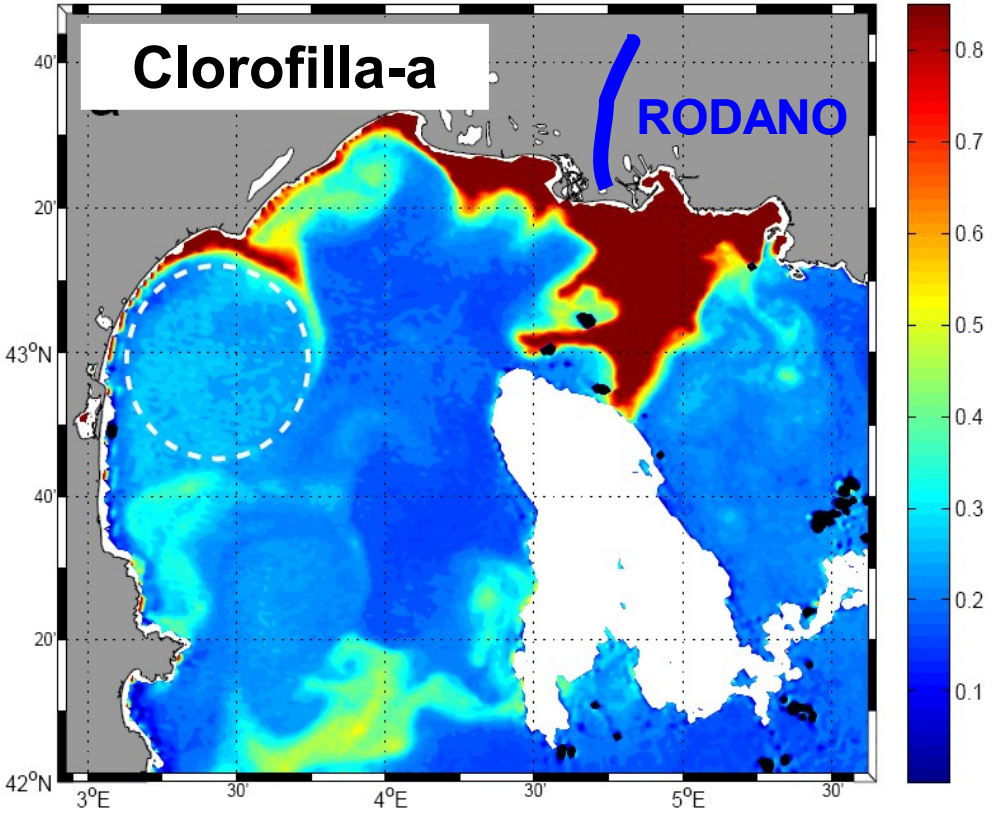
Flusso verso il sedimento di AZOTO in forma particolata

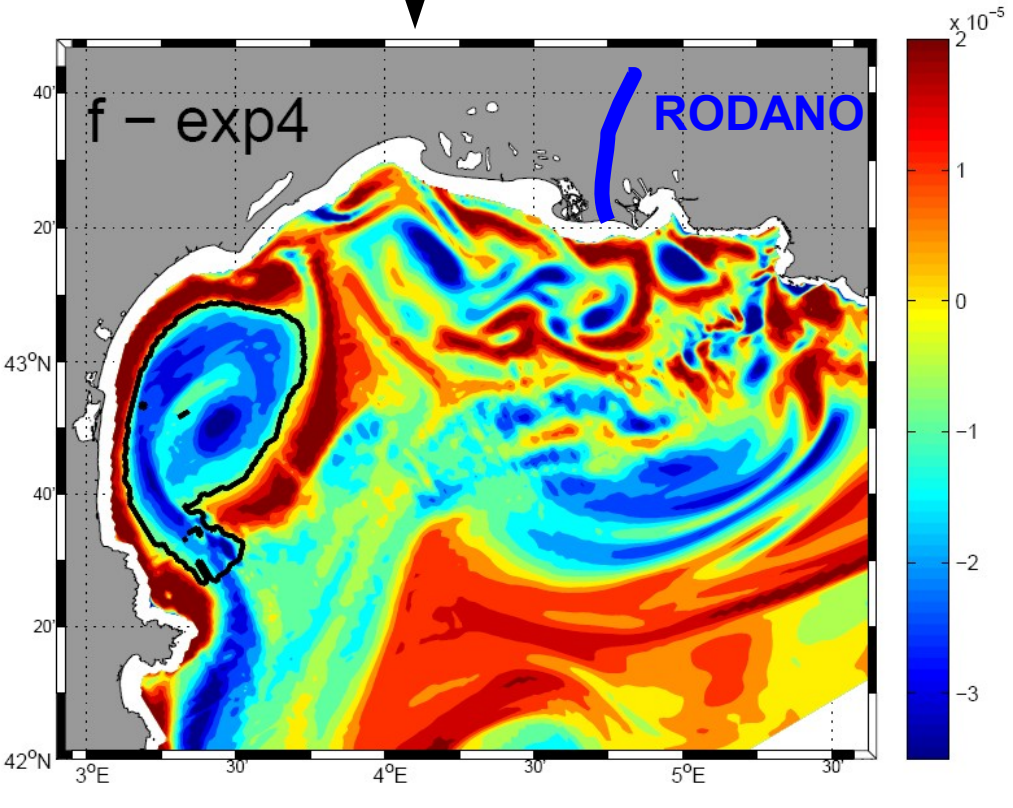




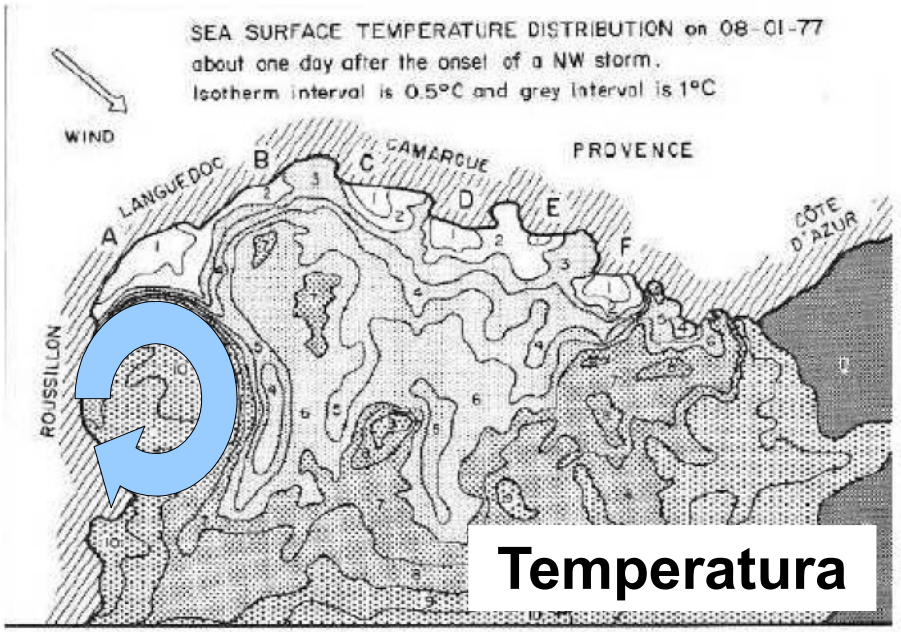
Immagini satellitari

Modello SYMPHONIE segnala la presenza di un vortice anticiclonico

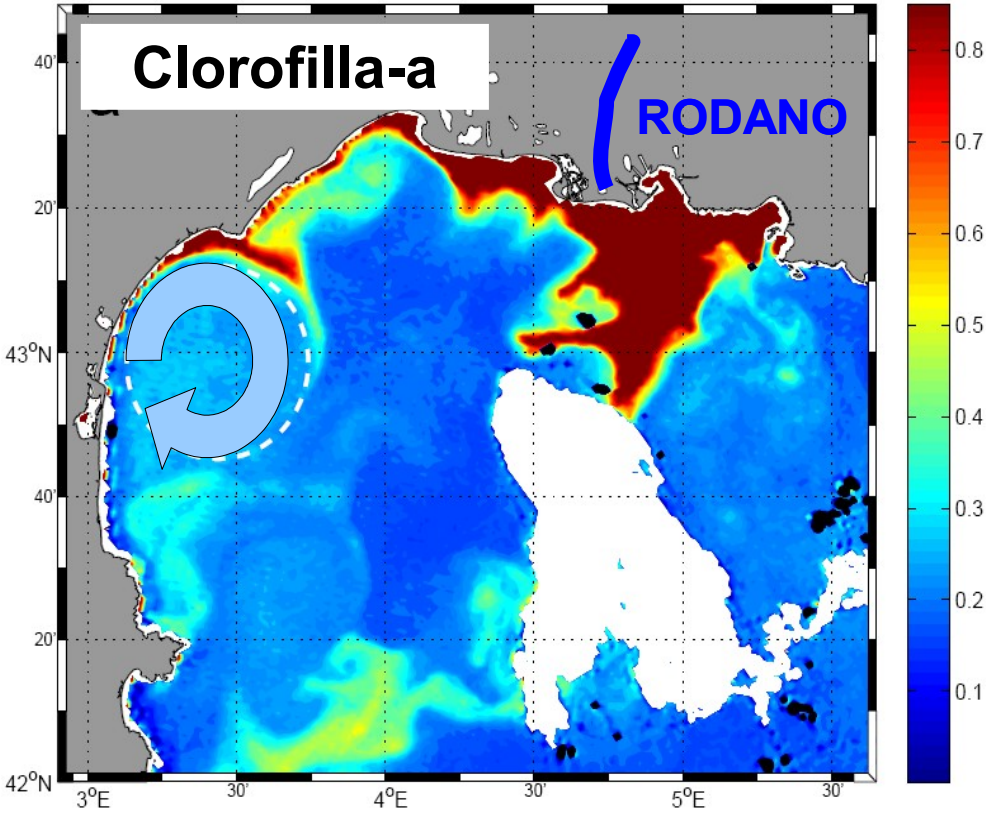


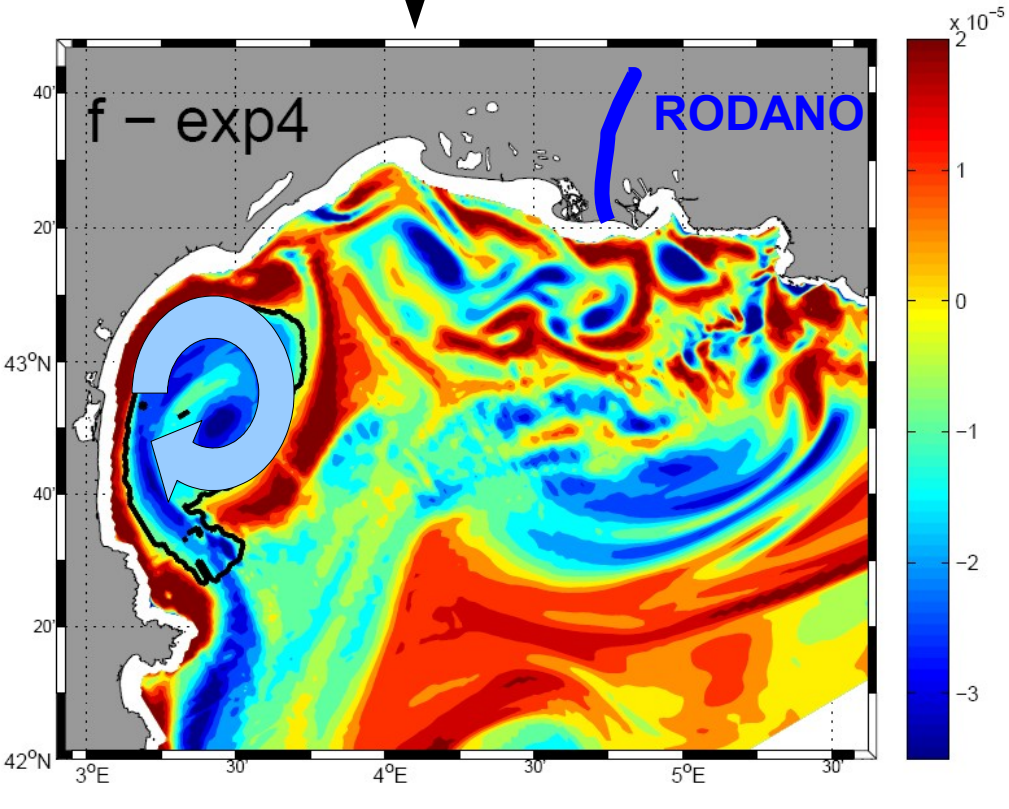


Immagini satellitari

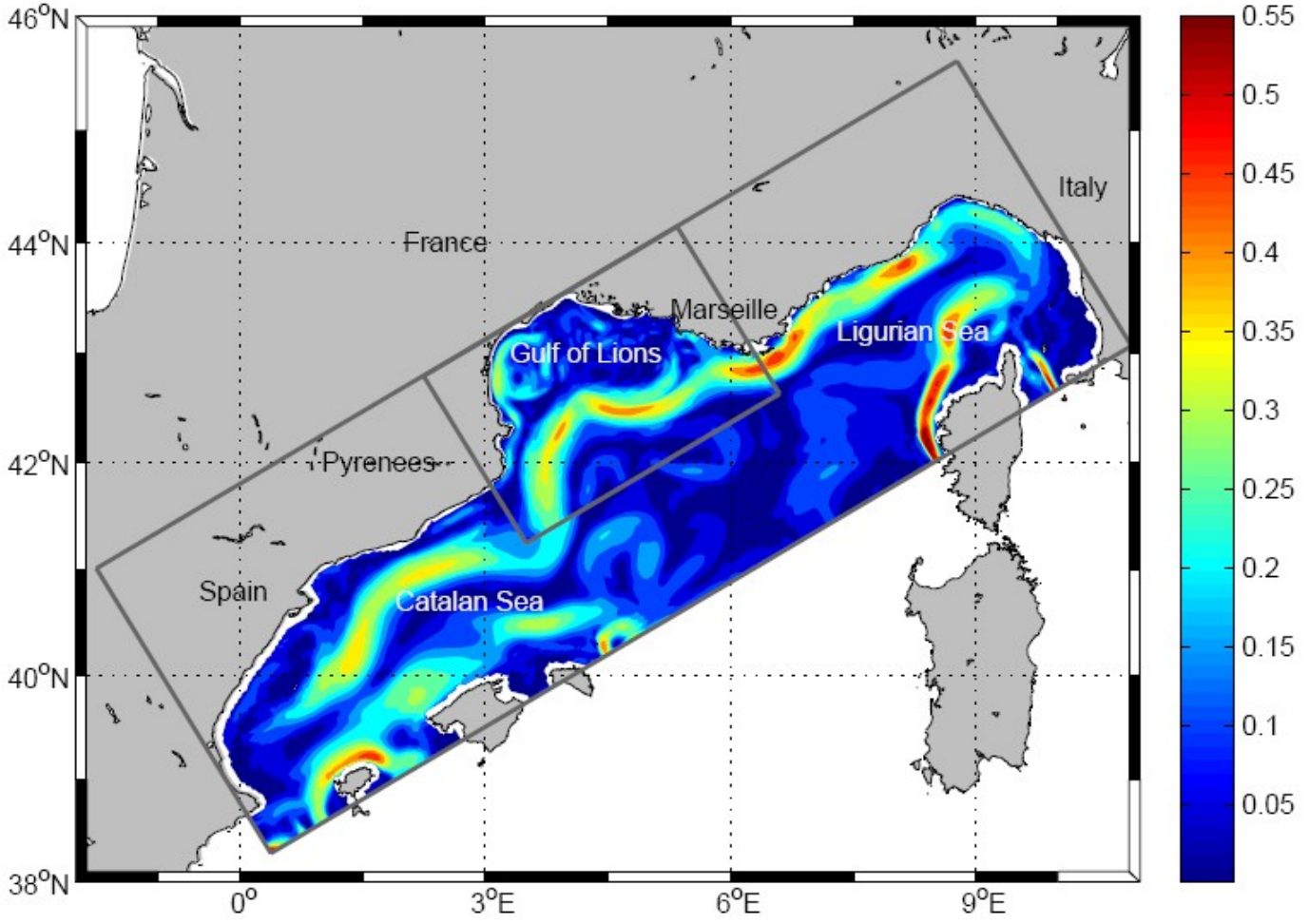


Modello SYMPHONIE segnala la presenza di un vortice anticiclonico





Misura e modellizzazione della Corrente Nord Occidendale Mediterranea e dei vortici costieri del Golfo del Leone

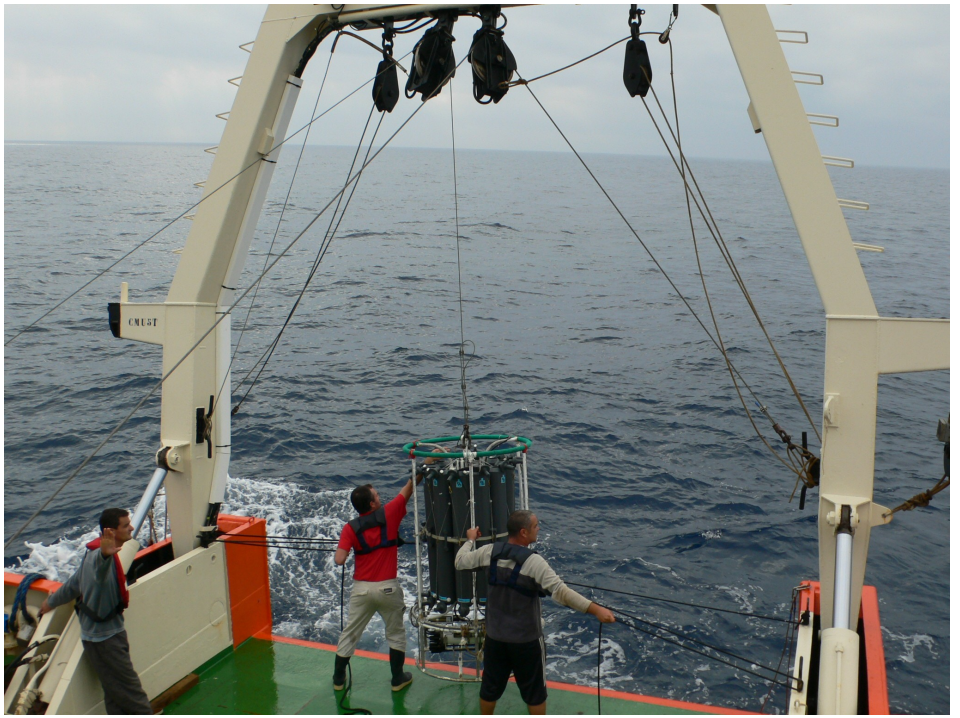


Qual'é il loro ruolo negli scambi tra la zona costiera (ricca di sali nutritivi) e il mare aperto (povero di sali nutritivi) ?

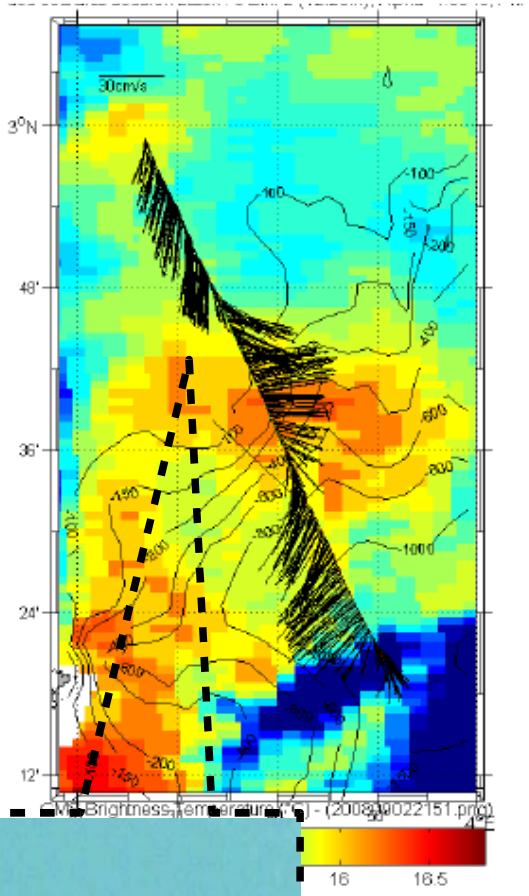
LATEX

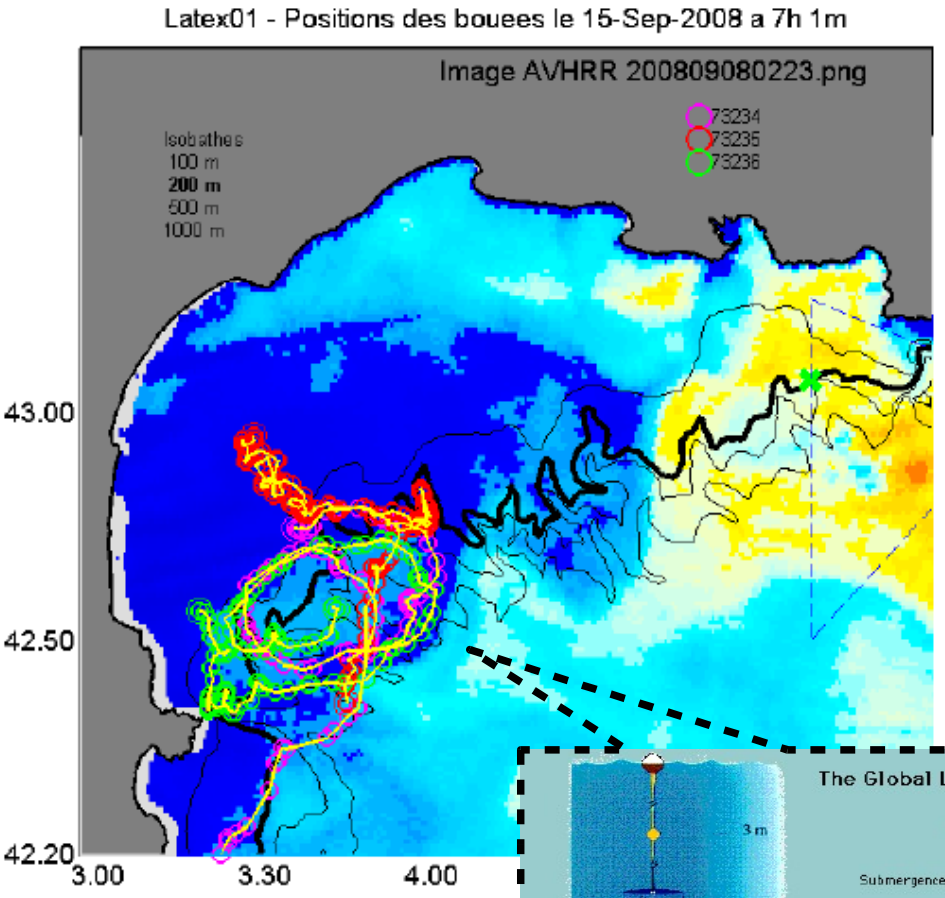
LAgrangianTransportEXperiment

Campagna Settembre 2008



Dopo 4 giorni finalmente ne abbiamo trovato uno!

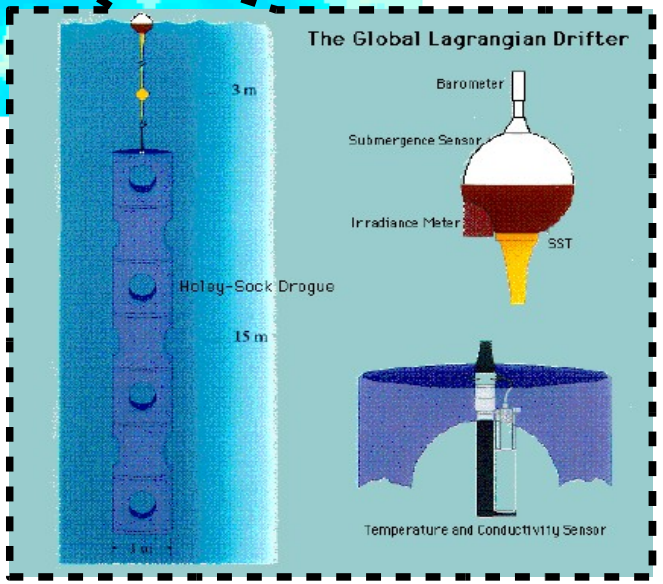




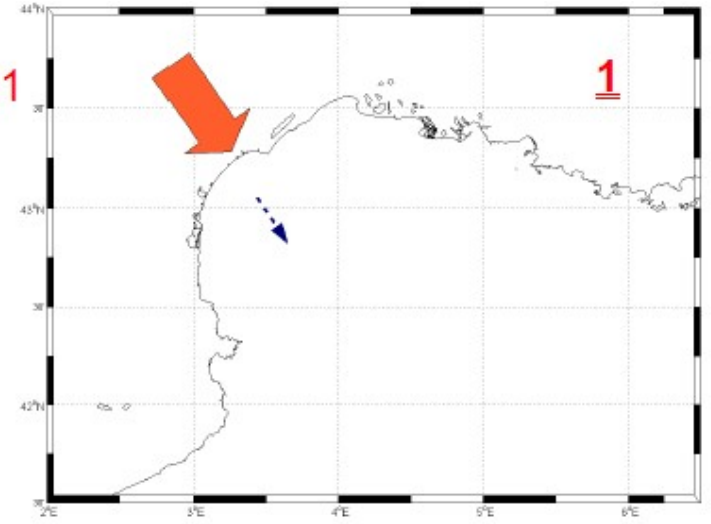
Temperatura (satellite)

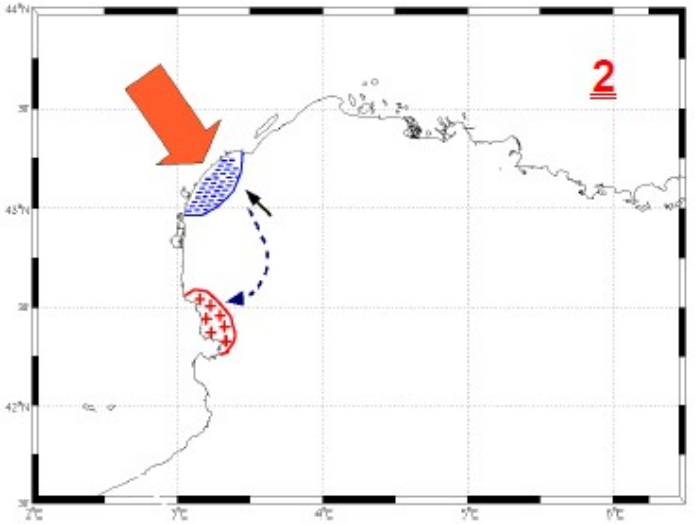
corrente (barca)

e traiettorie (boa)

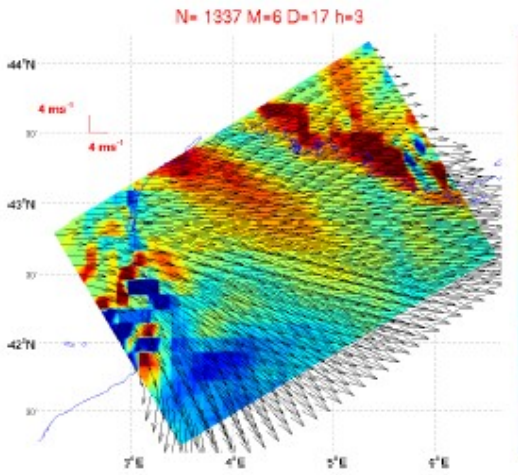


17 June 2001

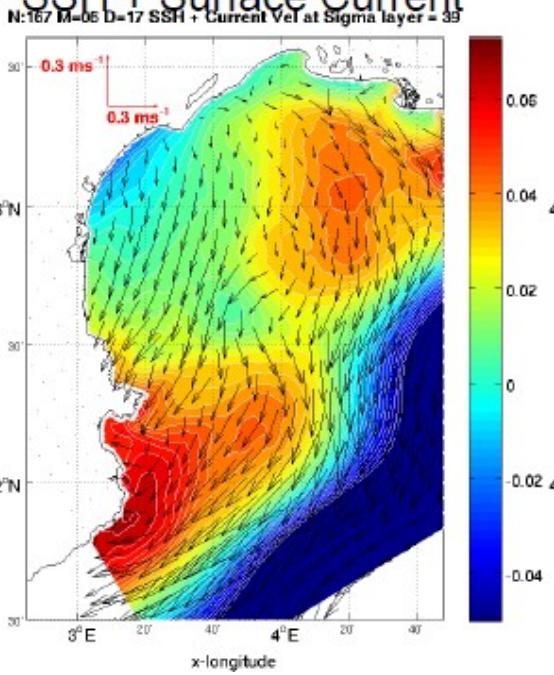




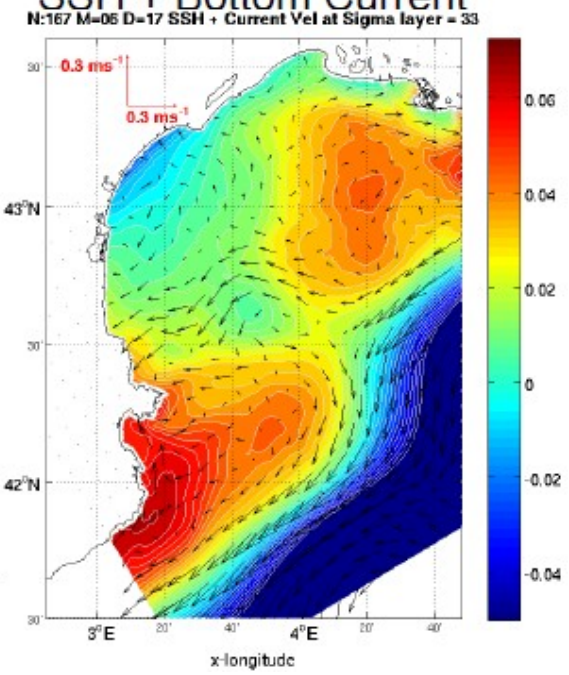
Wind



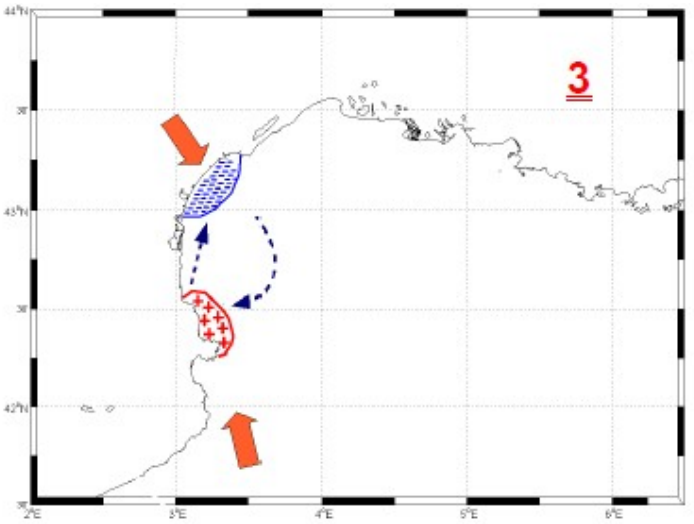
SSH + Surface Current



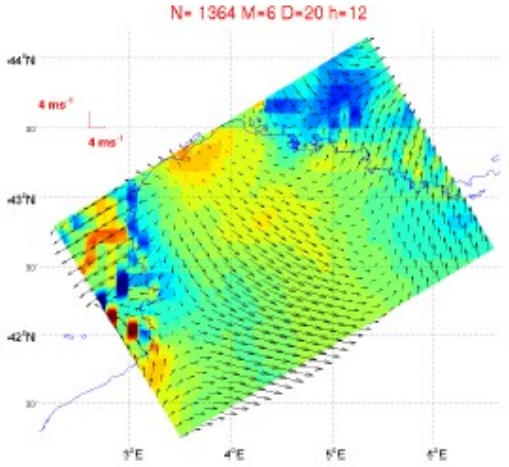
SSH + Bottom Current



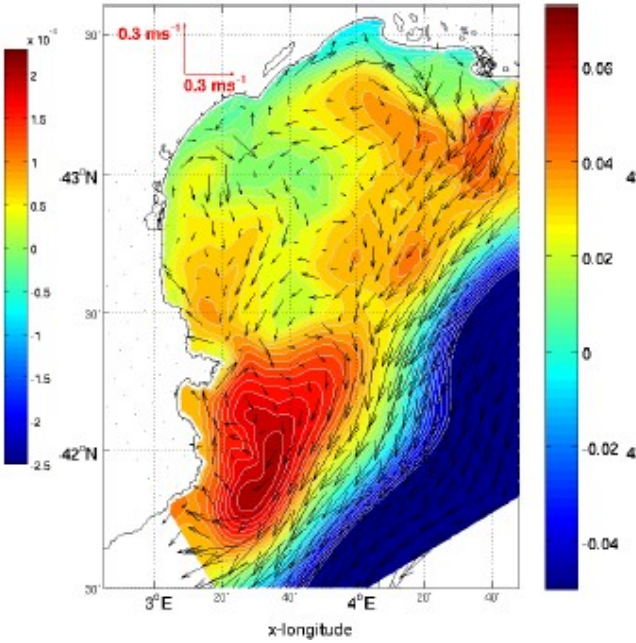
20 June 2001



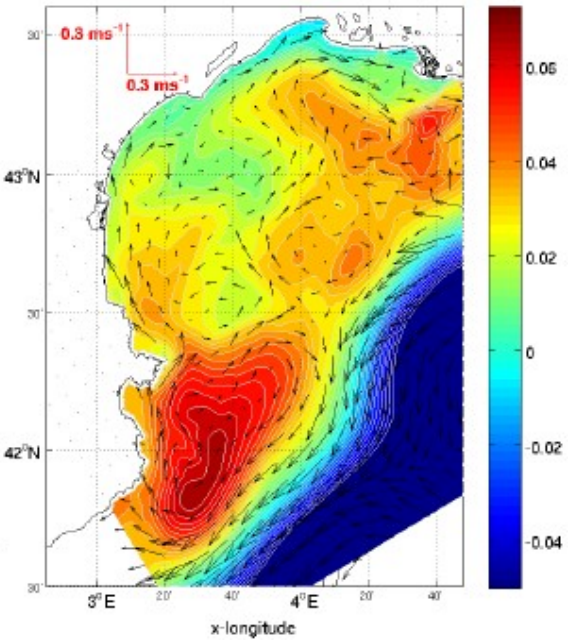
Wind



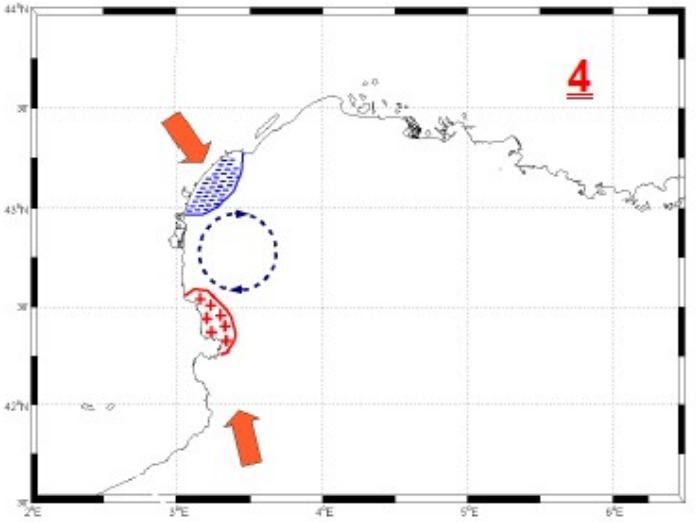
SSH + Surface Current



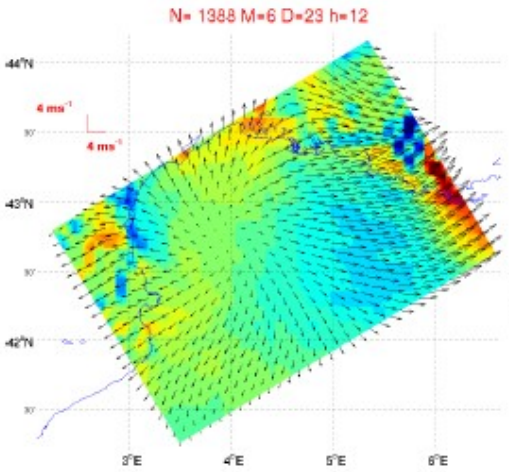
SSH + Bottom Current



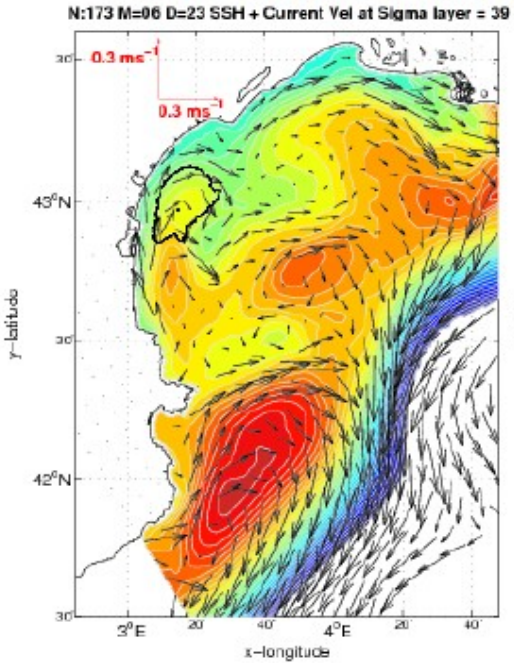
23 June 2001



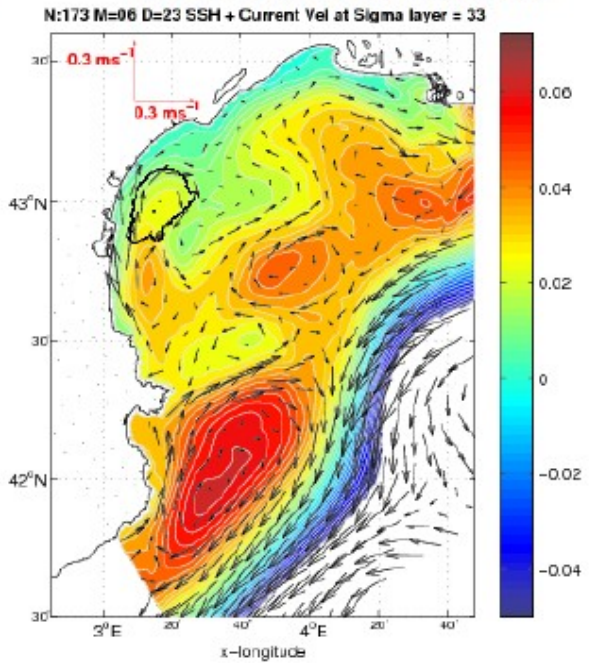
Wind



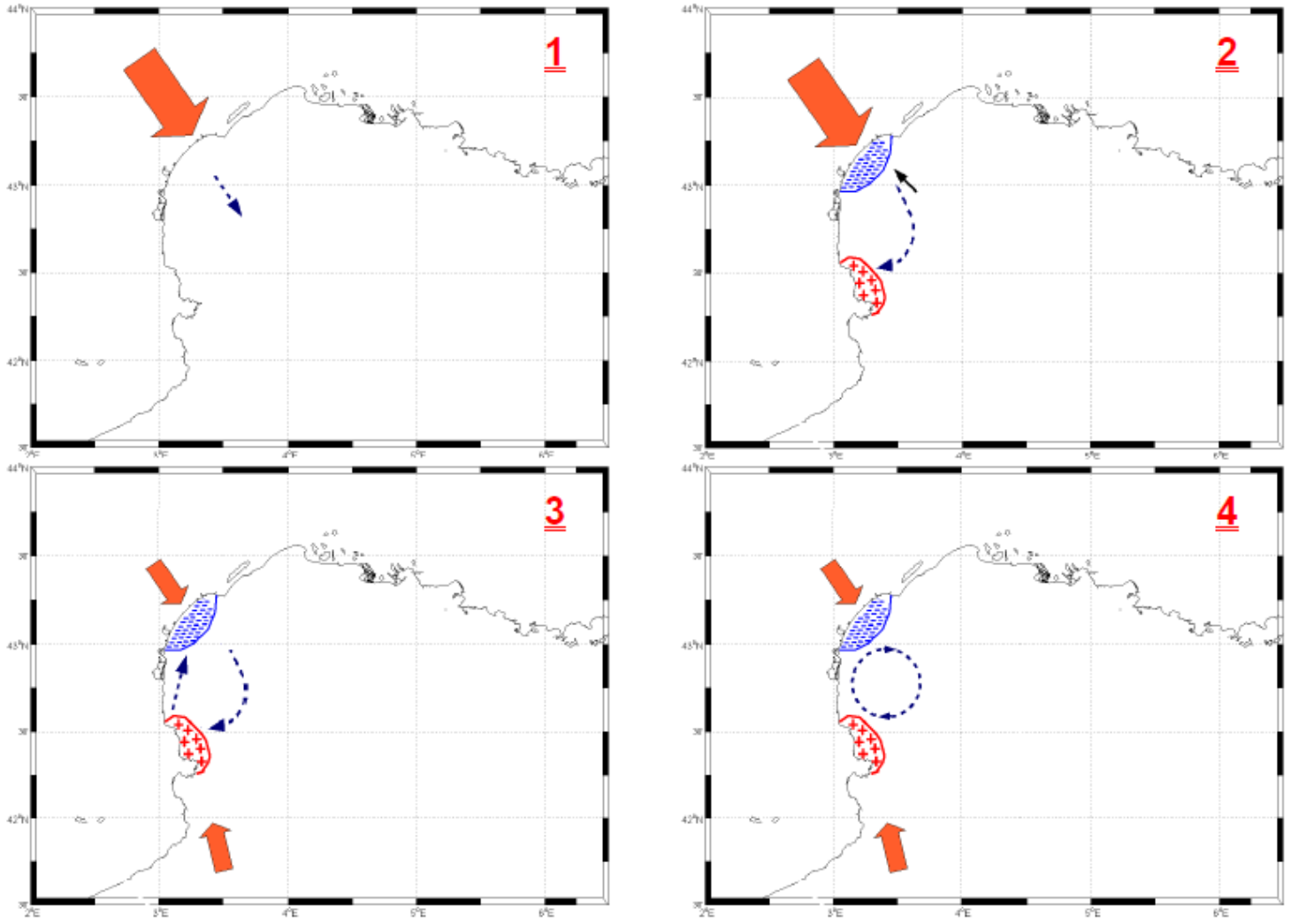
SSH + Surface Current



SSH + Bottom Current



- Mechanism of Generation and evolution of the anticyclonic eddy



EXPERIMENTAL – the basic idea (theory - *biogeochemistry*)

Mass balance approach applied to a Lagrangian control volume

$$\frac{d}{dt}\int_V \psi\, dV + \oint_S \psi \mathbf{u}\cdot d\mathbf{S} + \oint_S \chi \cdot d\mathbf{S} = \int_V \xi\, dV.$$

$\Psi = O_2, C, SF_6$

Temporal variation | Advection | Boundary exchanges horiz+vert | Sources & sinks

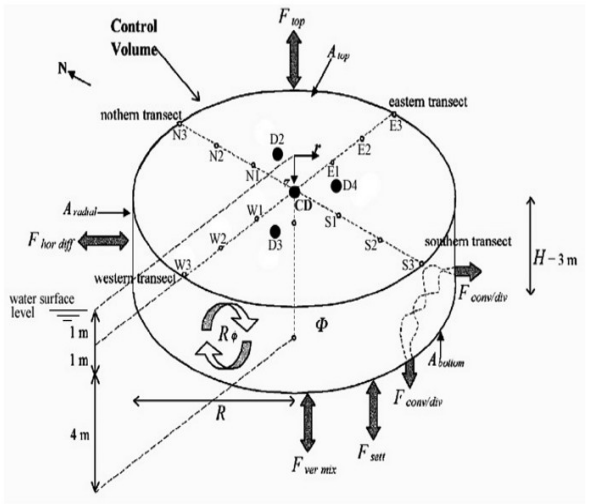


Fig. 1. Scheme of the experiment design, showing the control volume, the drogues' initial arrangement (●; CD, D2, D3, and D4), the sampling stations (○; N_i, S_i, E_i, W_i; $i = 1,2,3$), and the internal and external fluxes. Φ represents the concentration of a biological or chemical species, R_ϕ is the rate of internal biogeochemical changes, $F_{hor\ diff}$ represents the fluxes due to horizontal diffusion across the radial surface A_{radial} of the control volume, and $F_{conv/div}$ represents the advective fluxes across the surface A_{bottom} and A_{radial}. $F_{ver\ mix}$ and F_{sett} represent the fluxes due to vertical mixing and due to settling, respectively, across the bottom surface, A_{bottom}, and top surface, A_{top}. In the figure, F_{top} represents the combination of $F_{ver\ mix}$ and F_{sett} across the surface A_{top}. H is the height and R the radius of the control volume.

Net Community Production Δt=5-6 days

$$NCP_{O2} = \Delta O_2 + F_{sea\text{-}air} + F_{hor} + F_{ver}$$

$$NCP_{DIC} = \Delta DIC + F_{sea\text{-}air} + F_{hor} + F_{ver}$$

& comparison with bottle incubations

Carbon export

$$C_{exp} = NCP_{DIC} - \Delta POC - \Delta DOC$$

in situ bottle (*in situ*)

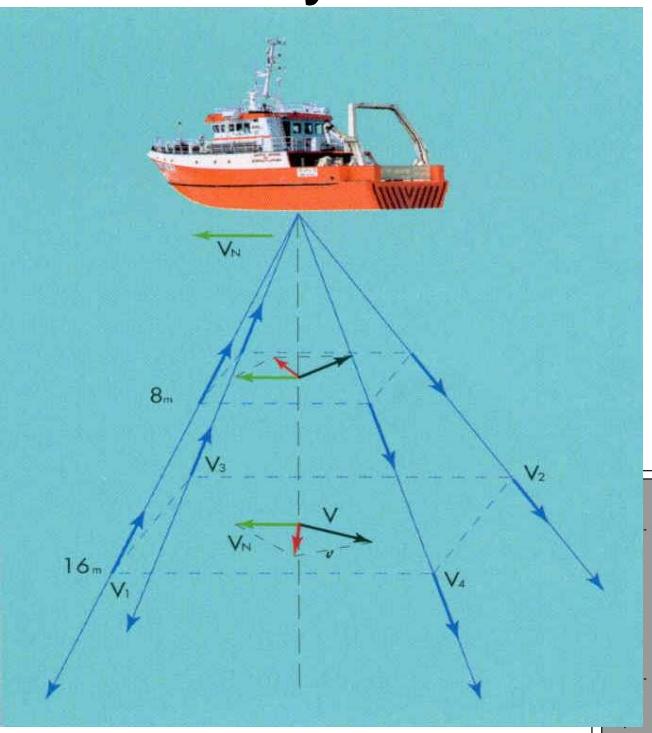
+

Cartography of

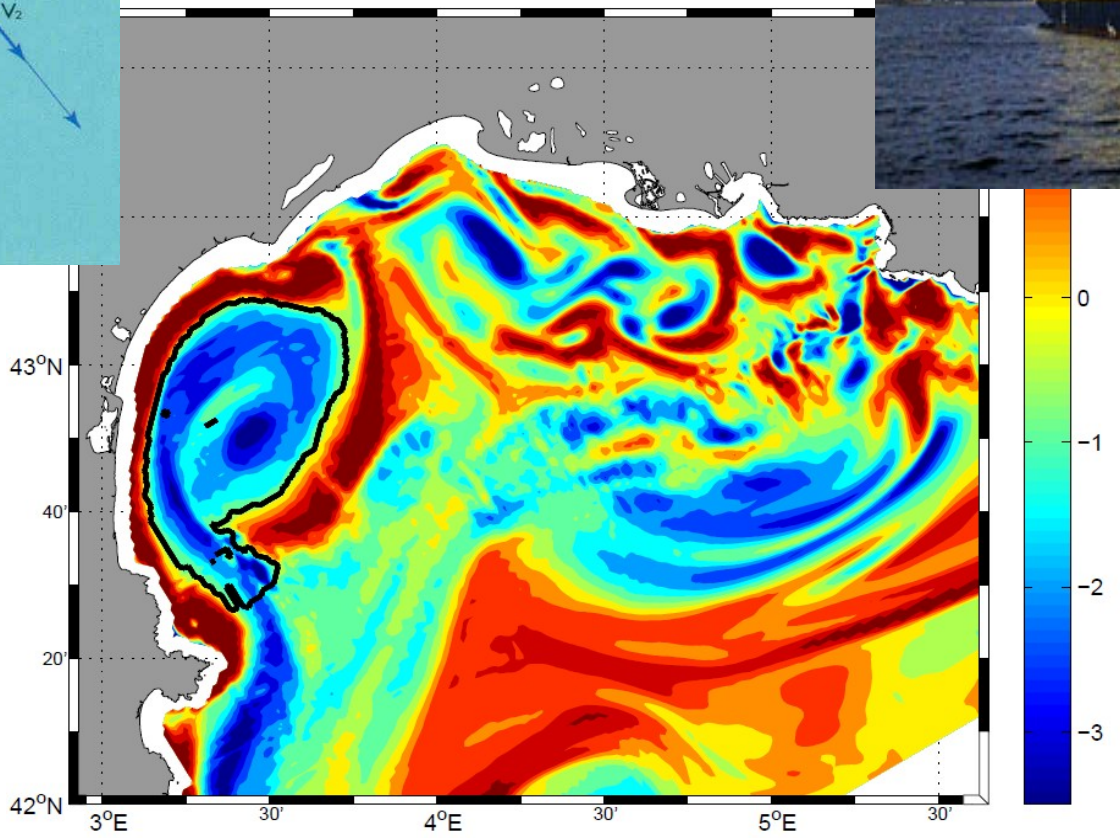
Chl-a, NO_3^{2-}, NH_4^+, Silicates

EXPERIMENTAL – the basic idea (in situ - *horizontal*)

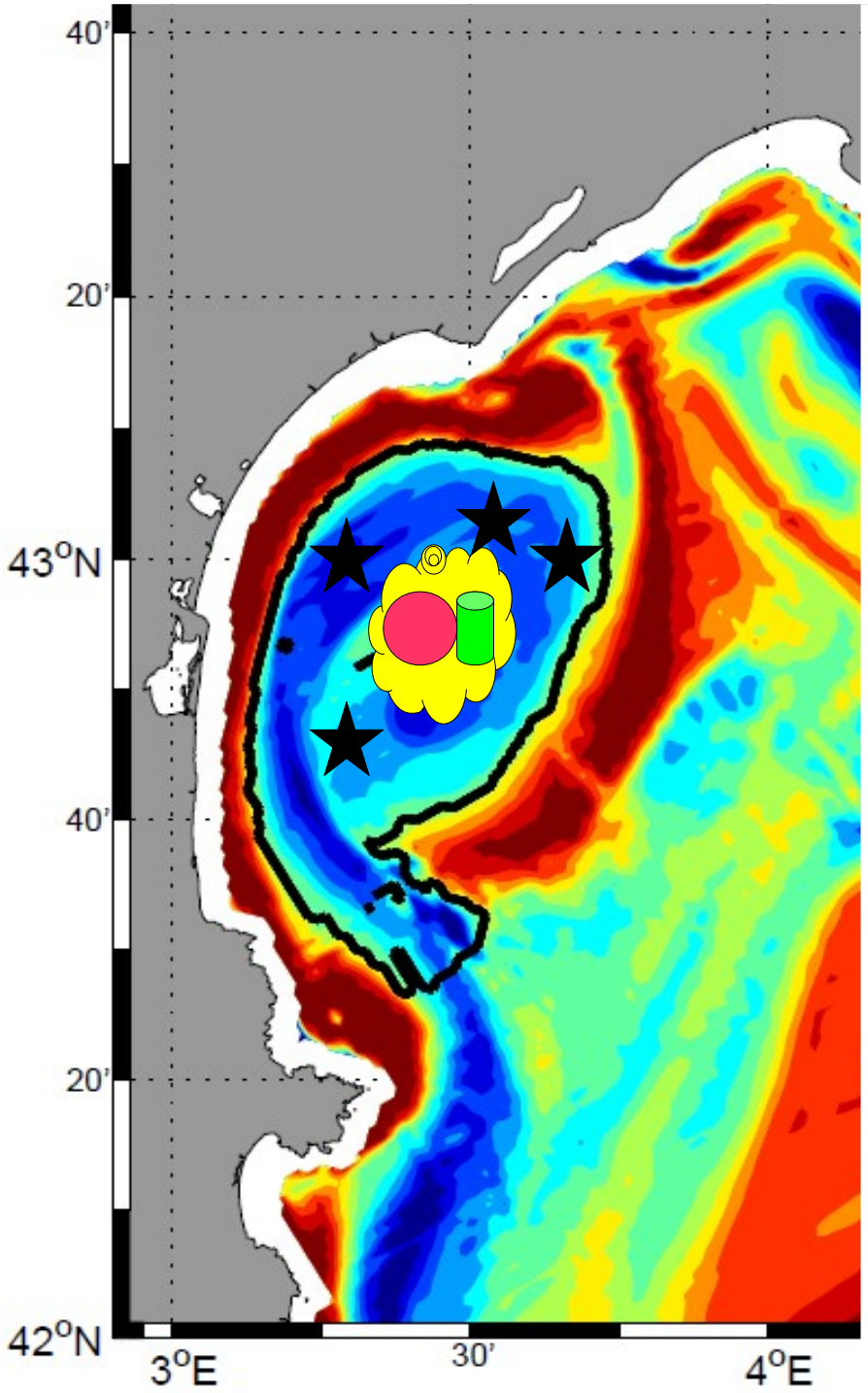
Tethys II



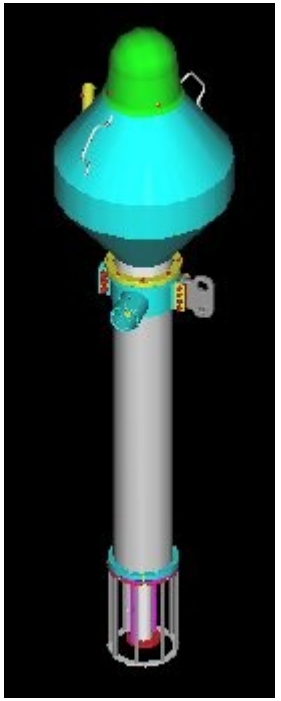
Suroît



EXPERIMENTAL – the basic idea (in situ - *horizontal*)



Iridium buoy
real time communication
anchored 12 m



Carioca buoy
pCO_2 measurements

★ 15 Argos buoys
Lagrangian drift and deformation

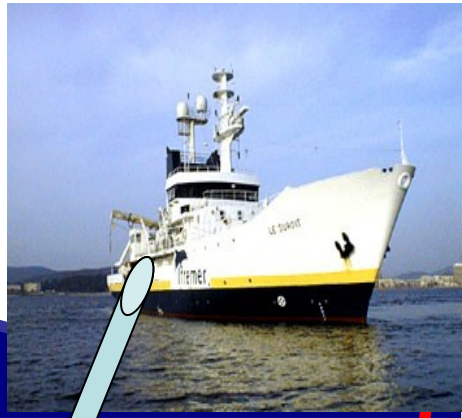
SF6 passive tracer
injected at 10 m depth
deformation and mixing

EXPÉRIMENTAL – idée de base (in situ - *vertical*)

SF_6 = *hexafluoride de soufre*

traceur passif

(gas isolant avec très faible solubilité en eau de mer)



Surface → No échanges air-mer

10 m → couche de mélange pour piéger le traceur

Bloom automnale pour une plus forte stratification

40 m → *profondeur moyenne de la couche de mélange*

profond → *problèmes techniques*

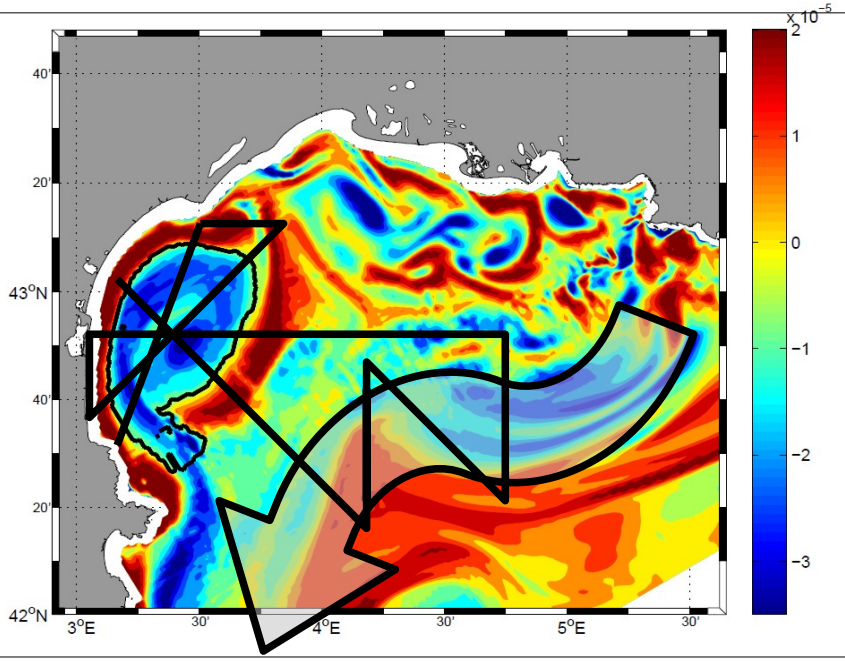
SF_6

profile vertical de Temperature

EXPERIMENTAL – the basic idea (in situ - *horizontal*)

GLIDERS

in collaboration
with
LOV & LOCEAN



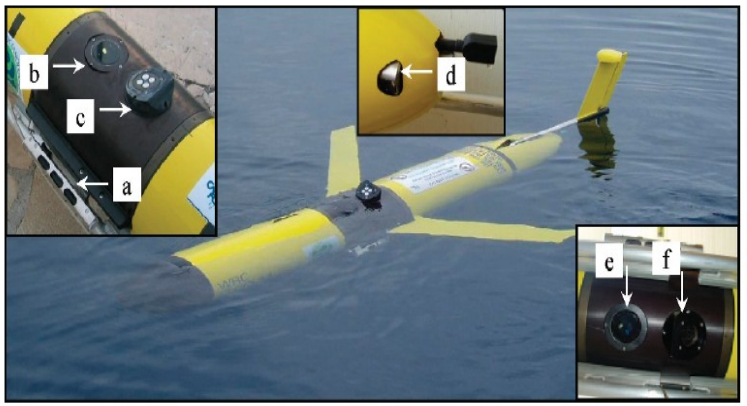


Fig. 1. Glider *Tournesol* and the associated sensors: (a) Seabird CTD cell (S,T); (b) Wetlabs BB2FLS (b_{bp}(660, 880 nm) and CDOM); (c) Satlantic OCR504I Radiometer (E_d); (d) Aanderaa 3830 optode (O_2); (e) Wetlabs BB2FLS (b_{bp}(470, 532) and Chl *a*); (f) Satlantic OCR504R Radiometer (L_u).

COASTAL RADAR

Associated Project
Gyre Identification by Radar Observations (*GIRO_LATEX)*

in collaboration with LSEET

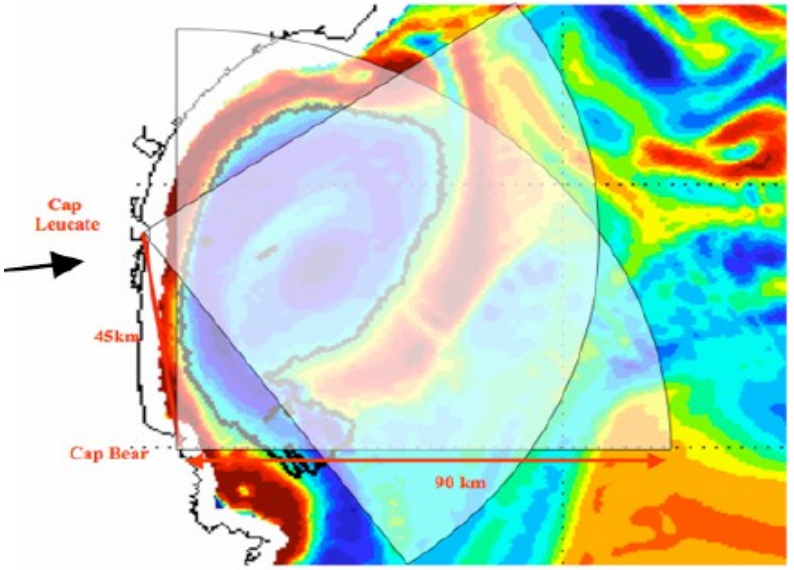


***Fig. 2** : Plan de disposition et de couverture optimale des radars pour la campagne GIRO-LATEX superposé au champ de vorticité obtenu à partir de simulations numériques*

Radial resolution ~3 km

LATEX web site

http://www.com.univ-mrs.fr/LOPB/LATEX

LA