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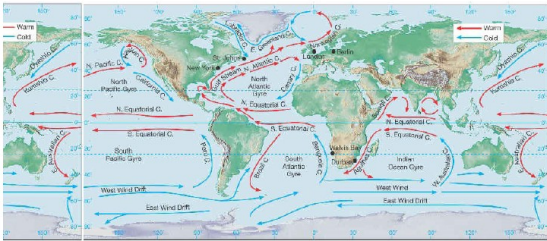
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La circolazione oceanica generale forzata dal vento



Carta delle principali correnti oceaniche

analogie fra i 5 bacini oceanici:

lato ovest **correnti calde verso i poli**

lato est **correnti fredde verso l'equatore**

Circolazione generata dal vento *Wind-driven circulation*

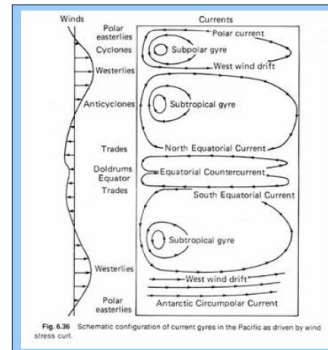


Fig. 6.36 Schematic configuration of current gyres in the Pacific as driven by wind stress curl.

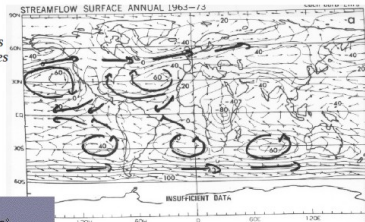
Principles of ocean physics by John R. Apel

Cinquanta urlanti
Quaranta ruggenti
Correnti occidentali

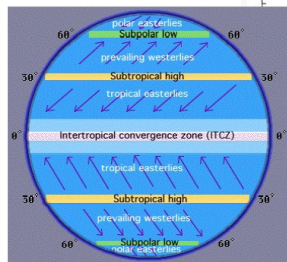
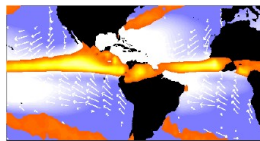
Furious Fifties
Roaring Forties
Westerlies

Alisei

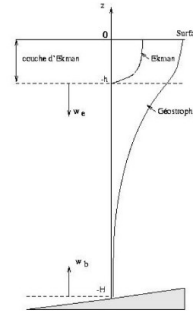
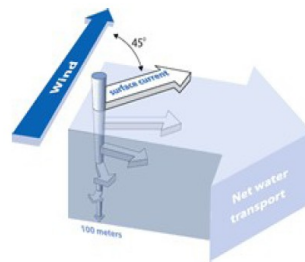
Tradewinds



PanAmerican Climate Studies (PACS)



Trasporto e pompaggio di Ekman



http://oceanservice.noaa.gov/education/kits/currents/media/ekman_spiral_240.gif

Equazioni di Navier-Stokes per l'oceano.

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = -g \frac{\partial \eta}{\partial x} + f v + A_h \left[\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right] + A_v \frac{\partial^2 u}{\partial z^2}$$

$$\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} = -g \frac{\partial \eta}{\partial y} - f u + A_h \left[\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right] + A_z \frac{\partial^2 v}{\partial z^2}$$

Equazioni integrate sulla verticale e linearizzate

$$U = \int_{-H}^0 u dz, \quad V = \int_{-H}^0 v dz$$

$$\frac{\partial U}{\partial t} - f V = -gH \frac{\partial \eta}{\partial x} + F_x - B_x$$

$$\frac{\partial V}{\partial t} + f U = -gH \frac{\partial \eta}{\partial y} + F_y - B_y$$

Soluzione di Ekman: la spirale, il trasporto ed il pompaggio

Allo stato stazionario, trascurando gli effetti della pressione e dell'attrito sul fondo le equazioni del trasporto diventano

$$\begin{aligned}
 -fV &= 0 \\
 +fU &= F_y \\
 \frac{\partial U}{\partial x} + \frac{\partial V}{\partial y} &= 0
 \end{aligned}$$

ed hanno per soluzione

$$\begin{aligned}
 U &= \frac{F_y}{f} \\
 V &= 0
 \end{aligned}$$

cioè un trasporto sulla destra (nell'emisfero nord dove f è positivo).

Valori tipici $F = 10^{-4} \text{ m}^2 \text{ s}^{-2}$, $f = 10^{-4} \text{ s}^{-1}$ corrispondono a $U = 1 \text{ m}^2 \text{ s}^{-1}$ (cioè una velocità della corrente di 0.1 m s^{-1} su uno strato di 10 m).

Per avere il dettaglio della spirale, si deve usare la viscosità verticale turbolenta costante A_z tutto lo strato e le equazioni diventano

$$\begin{aligned}
 -fv &= A_z \frac{\partial^2 u}{\partial z^2} \\
 fu &= A_z \frac{\partial^2 v}{\partial z^2}
 \end{aligned}$$

con le condizioni al bordo

$$\begin{aligned}
 A_z \frac{du}{dz} = 0, \quad A_z \frac{dv}{dz} = u_*^2, \quad (z=0) \\
 \frac{du}{dz} = \frac{dv}{dz} = 0, \quad (z \rightarrow -\infty)
 \end{aligned}$$

la scala spaziale è la profondità di Ekman

$$D = \sqrt{\frac{2A_z}{f}}$$

(1.50)

e la soluzione si può scrivere

$$\begin{aligned}
 \frac{u}{u_*} &= \frac{u_*}{fD} e^{z/D} \left(\cos \frac{z}{D} - \sin \frac{z}{D} \right) \\
 \frac{v}{u_*} &= \frac{u_*}{fD} e^{z/D} \left(\cos \frac{z}{D} + \sin \frac{z}{D} \right)
 \end{aligned}$$

depth to $e^{-2\pi} = 1/535$ th part for each time its direction rotates four right angles. The direction and velocity of the

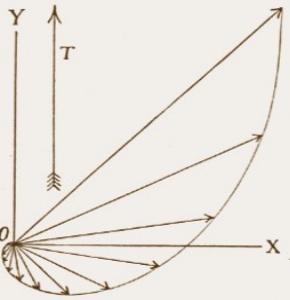
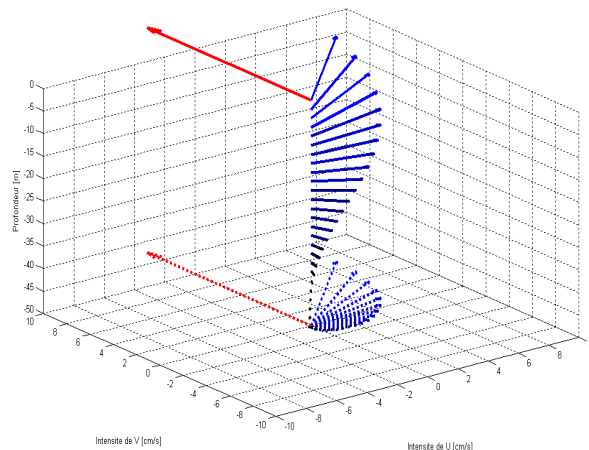


Fig. 1.

current at different depths are represented by the arrows in Fig. 1 above; the longest arrow refers to the surface, the the water) does not however vary appreciably with the height. within

figura dell'articolo originale di Ekman



RIPASSO: Approssimazioni del parametro di Coriolis

1) piano-f

$$f = f_0 = 2\Omega \sin\phi_0$$

ai poli $f_0 = 2\Omega \sin(\pi/2) = 4\pi/86400 = 1.45 \cdot 10^{-4} \text{ rad s}^{-1}$

alle medie latitudini $f_0 = 2\Omega \sin(\pi/4) = 4\pi/86400 = 1.0310^{-4} \text{ rad s}^{-1}$

à l'équateur $f_0 = 0$

2) piano- β

$$f = f_0 + \beta y.$$

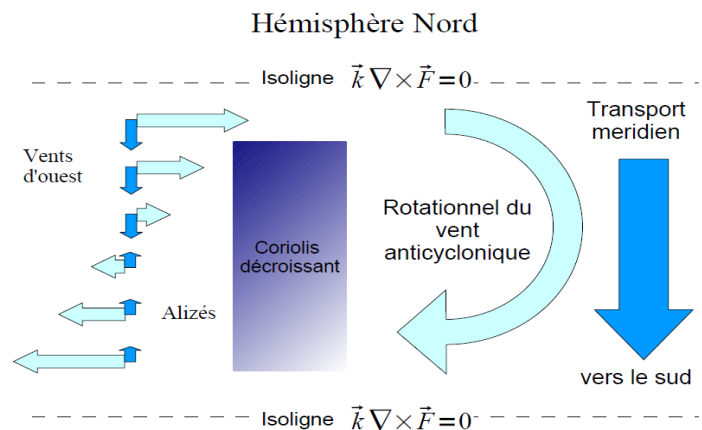
dove $\beta = \frac{\partial f}{\partial y} = \frac{\partial f}{\partial \Phi} \frac{\partial \Phi}{\partial y} = \frac{2\Omega \cos \phi}{R}$ avec $\partial y = R \partial \Phi$

$$\beta_{45} = 1,63 \cdot 10^{-11} \quad f = 1.03 \cdot 10^{-4} + 1,63 \cdot 10^{-11} \cdot 10^6 = 1,19 \cdot 10^{-4} \text{ rad s}^{-1}$$

Rappresentazione schematica della circolazione indotta dal vento in Atlantico Nord, semplificato come un bacino rettangolare con fondo piatto e vento esclusivamente zonale.

Il trasporto di Ekman è à 90° sulla destra rispetto al vento e varia seconsu la latitudine.

Il trasporto meridiano totale risulta quindi verso sud nella regione delimitata dalle due isolinee $\vec{k} \nabla \times \vec{F} = 0$ rappresentativa della zona subtropicale .



Definizioni

$$w_E = \frac{\vec{k}(\nabla \times \vec{F}) - \beta [M_y]_{-h}^0}{f \rho_0} \quad \text{pompaggio di Ekman}$$

$$[M_y]_{-H}^0 = \frac{\vec{k}(\nabla \times \vec{F})}{\beta} \quad \text{trasporto meridiano}$$

7.4 Ordres de grandeur des termes

Soit un point à 35°N dans l'Atlantique nord où le vent d'Ouest souffle à 7 – 8ms⁻¹. Alors $\tau_x \approx 10^{-1} \text{ N/m}^2$ et $\tau_y \approx 0$:

$$\vec{k} \cdot (\nabla \times \vec{\tau}) = -\frac{\partial \tau_x}{\partial y} \approx \frac{10^{-1} \text{ N/m}^2}{1000 \text{ km}} \approx -10^{-7} \text{ Nm}^{-3}$$

$$f \approx 10^{-4} \text{ s}^{-1} ; \quad \beta \approx 2 \cdot 10^{-11} \text{ m}^{-1} \text{ s}^{-1}$$

$$\Rightarrow M_{ye} = -\frac{\tau_x}{f} = -10^3 \text{ kg m}^{-1} \text{ s}^{-1}$$

$$M_y(w_b = 0) = \frac{\vec{k} \cdot (\nabla \times \vec{\tau})}{\beta} \approx -\frac{10^{-7}}{2 \cdot 10^{-11}} = -5 \cdot 10^3 \text{ kg m}^{-1} \text{ s}^{-1}$$

On voit que le transport méridien d'Ekman contribue au 1/5 du transport méridien total. Intégré sur la largeur de l'océan ($\approx 5000 \text{ km}$) le transport est de $-25 \cdot 10^9 \text{ kg s}^{-1}$, soit en volume, $-25 \cdot 10^6 \text{ m}^3 \text{ s}^{-1}$, ou 25 Sverdrup vers le sud.

Circolazione de Sverdrup

Sverdrup ha trovato una soluzione analitica per la funzione di corrente nel caso di un bacino rettangolare largo a e alto b su cui soffia un vento zonale, la cui tensione di seguito indicato col simbolo $\vec{\tau} \equiv (\tau_x, \tau_y)$ é schematizzata con una formula sinusoidale $\tau_x = -\tau_0 \cos(\pi y/b), \tau_y = 0$.

$$\beta M_y = \vec{k} \nabla \times \vec{\tau} = \frac{\partial \tau_y}{\partial x} - \frac{\partial \tau_x}{\partial y} = -\tau_0 \frac{\pi}{b} \sin \frac{\pi y}{b}$$

$$M_y = -\frac{\tau_0 \pi}{\beta b} \sin \frac{\pi y}{b} = +\frac{\partial \psi}{\partial x}$$

$$\psi(x, y) = \int \left(-\frac{\tau_0 \pi}{\beta b} \sin \frac{\pi y}{b} \right) dx = -\frac{\tau_0 \pi}{\beta b} \sin \frac{\pi y}{b} x + K(y)$$

Sui bordi ψ deve annullarsi, ma é impossibile con questa soluzione porre 2 condizioni a $x = 0$ et $x = a$, ma una sola. Sverdrup scelse di soddisfare la condizione $\psi = 0$ sul bordo Est sulla base del seguente ragionamento:

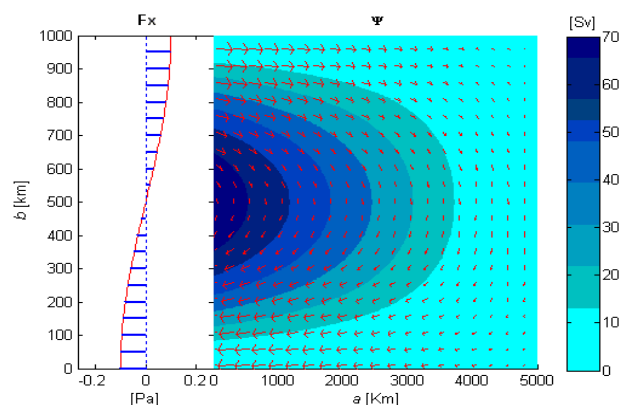
- le misure indicano per il vento una circolazione ciclonica ;
- tale tipo di circolazione genera una circolazione oceanica dello stesso segno ;
- la relazione de Sverdrup dice che una vorticitá negativa corrisponde ad un trasporto meridiano verso sud e questo avviene solo nella parte est del bacino ;

Allora

$$K_{x=0} = +\frac{\tau_0 \pi}{\beta b} \sin \left(\frac{\pi y}{b} \right) a$$

e infine

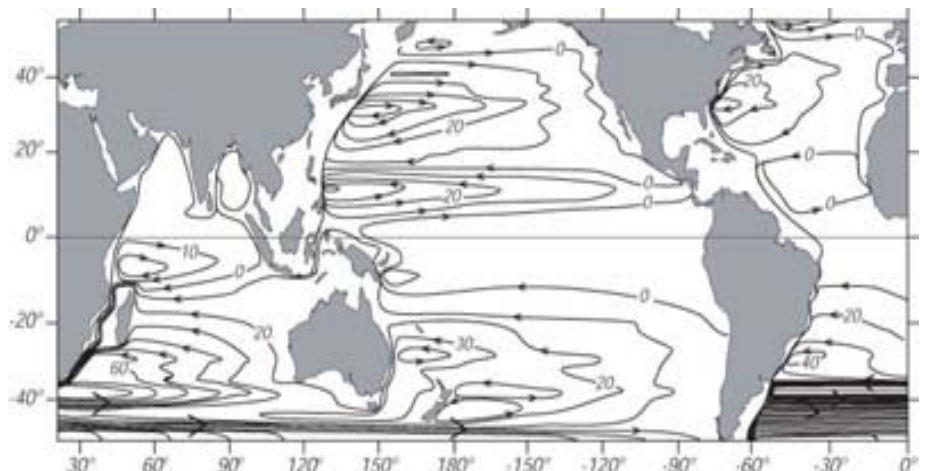
$$\psi(x, y) = -\frac{\tau_0 \pi}{\beta b} \sin \frac{\pi y}{b} (x-a)$$



Tale formula è utilizzabile a partire dai dati di vento osservati sull'oceano globale.

Il trasporto di Sverdrup è rappresentato dalla funzione corrente ψ tale che

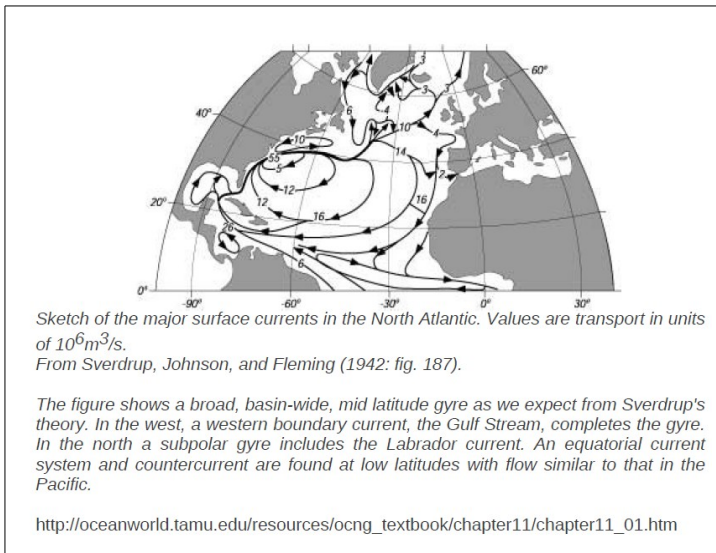
$M_x = \partial_y \psi, M_y = -\partial_x \psi$. Si osserva per i vari bacini l'esistenza di cellule di grande circolazione, i cosiddetti gyres subtropicali, separati dalle isolinee $\vec{k} \nabla \times \vec{F} = 0$



Depth-integrated Sverdrup transport applied globally using the wind stress from Hellerman and Rosenstein (1983). Contour interval is 10 [Sv].

From Tomczak and Godfrey (1994).

http://oceanworld.tamu.edu/resources/ocng_textbook/chapter11/chapter11_01.htm



H.Stommel

Intensificazione delle correnti di bordo ovest



Henry Stommel (left) and Lou Howard (right), both principal instructors in the Geophysical Fluid Dynamics program, demonstrate the effect of rotation on seawater. (Photo courtesy of WHOI Archives)

$$\frac{\partial \psi}{\partial x} + \frac{f d}{2\beta H} \nabla^2 \psi = -\frac{k(\nabla \times \vec{\tau}_0)}{\beta}$$

$$\Psi(x, y) = -\frac{T_0 L}{\pi \alpha} \cos \pi \frac{y}{L} \left[1 - \frac{e^{-\frac{\alpha}{2L}(W-x)} \sinh \alpha x + e^{-\frac{\alpha}{2L}x} \sinh \alpha(W-x)}{\sinh \alpha W} \right]$$

$$\alpha = \sqrt{\frac{\beta^2}{4\tau^2} + \frac{\pi^2}{L^2}}$$

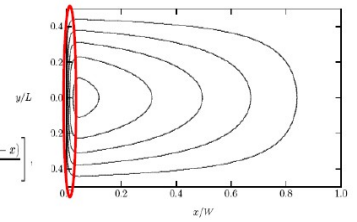


Fig. 52.2 Andamento della soluzione di Stommel per $\beta/\alpha = 10^{-4}$.

Applicazioni della legge della conservazione della vorticità potenziale

La vorticità rappresenta la tendenza di un flusso a girare. Si distinguono vari tipi di vorticità.

La vorticità relativa $\zeta = \vec{k}(\nabla \times \vec{V}) = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$ il cui segno varia secondo lo schema seguente :



Per un solido in rotazione la vorticità é uguale a due volte la velocità angolare. Alla latitudine Φ la velocità angolare rispetto all'asse verticale è $\Omega \sin \Phi$, la vorticità allora è

$$2\Omega \sin \Phi = f$$

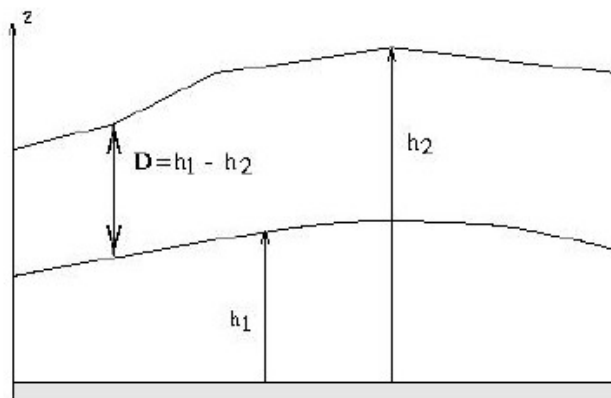
Una colonna d'acqua a riposo sulla Terra in rotazione possiede quindi una vorticità detta « planetaria » f . La vorticità planetaria corrisponde al parametro di Coriolis in approssimazione di « moto quasi-orizzontale » .

La cosiddetta vorticità assoluta è la somma della vorticità relativa e di quella planetaria $\zeta_{abs} = (\zeta + f)$. L'equazione seguente rappresenta il principio di conservazione di tale quantità :

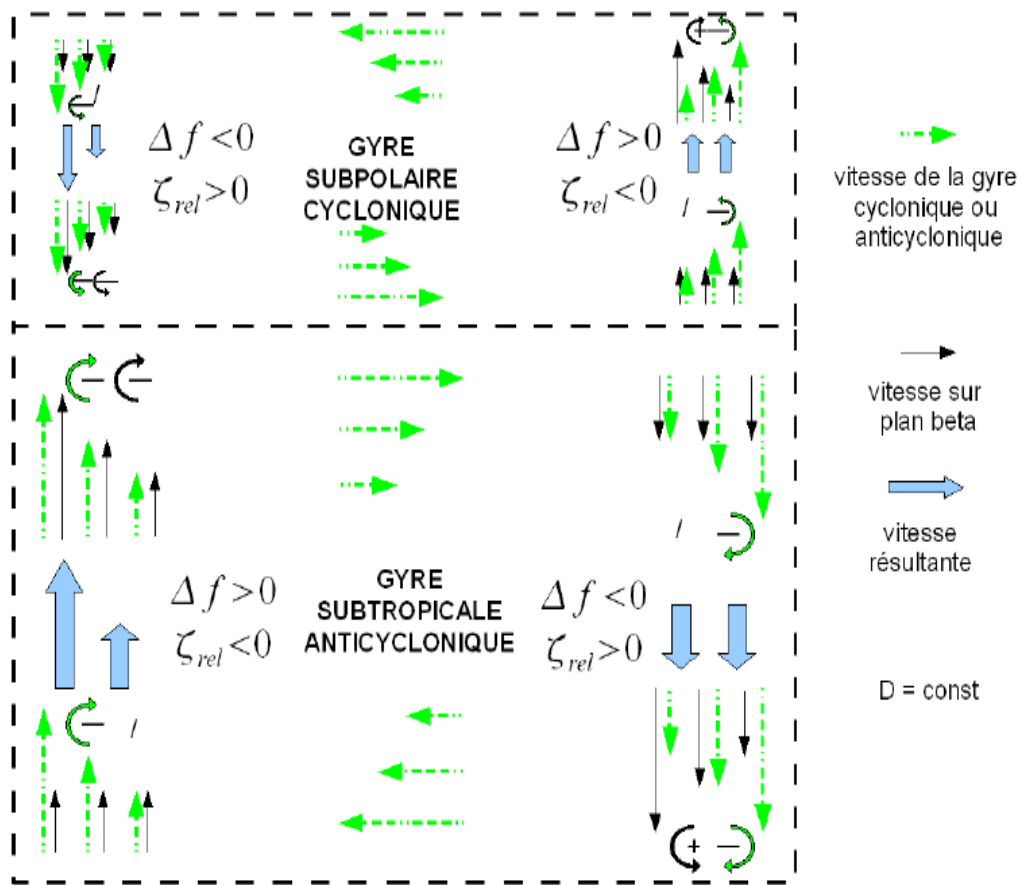
$$\frac{d(\zeta + f)}{dt} + (\zeta + f) \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \right) = 0$$

Per uno strato di spessore D , si può ottenere la legge della conservazione della vorticità potenziale

$$\frac{d}{dt} \left(\frac{\zeta + f}{D} \right) = 0$$



Conservazione della vorticità potenziale e correnti di bordo ovest



http://apl.umces.edu/ocean/sml_main.htm

I fenomeni fisici influenzano quelli biologici.
 E.G. Le correnti redistribuiscono i sali nutritivi e alcuni organismi viventi

I fenomeni biologici influenzano quelli fisici
 E.G. fioritura di plancton riduce la penetrazione della luce

COUPLING

The diagram illustrates the interaction between physical processes (like wind, waves, and currents) and biological processes (like phytoplankton blooms) in the ocean. A central image shows a cross-section of the ocean with various physical and biological processes labeled, and a large 'COUPLING' banner across it.

Effetti della circolazione sulla biogeochimica dell'oceano

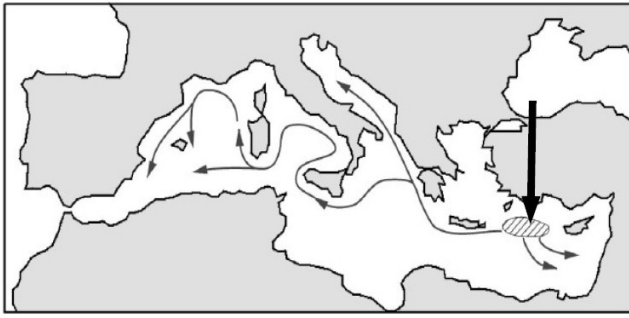
Hills & valleys in the ocean
 SPIN-UP IN TRANSFORMERS & EXAMPLES

→ Wind direction → Movement of water in the upper layer
 → Ocean current direction caused by the slope of the sea surface
 Views from above the ocean surface.

Coastal upwelling (southern hemisphere example)

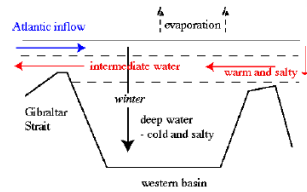
The block contains a world map showing ocean circulation patterns, diagrams of sea surface topography (hills and valleys), and a detailed diagram of coastal upwelling in the southern hemisphere. The upwelling diagram shows wind-driven surface currents moving away from the coast, causing water to rise from the depths.

Levantine Intermediate Water (LIW) circulation



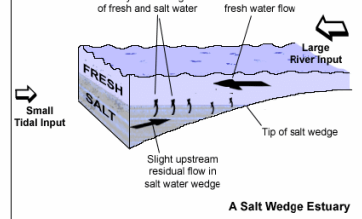
(b) Fig. 2. (a) The schematic of major basin current and gyres systems and their seasonal variability. Names of recognized features are given below the figure. (b) LIW dispersal pathways as synthesised from recent modelling and observational studies.

Mediterraneo



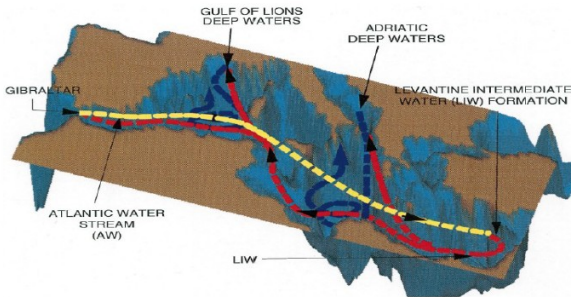
<http://www.lifesciences.napier.ac.uk/teaching/Env/Env70c06.htm>

Estuario tipico



<http://www.chemgapedia.de/vsengine/vlu/vsc/en/ch/16/uc/vlus/marinehydrology.vlu/Page/vsc/en/ch/16/uc/chemicalcycles/hydrological/estuarineenvironment.vscml.html>

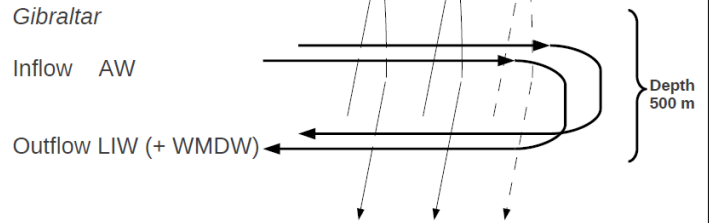
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3 systèmes:

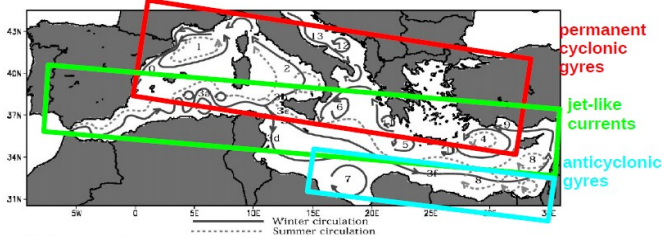
- 1 zonale: AW -> LIW; 0-500 m; timescale 10 ans.
- 2 méridiens: formation eaux prof. (avec contribution LIW); communicantes; timescale 50-80 ans.
- ?3em meridien en Mer Égée? -> Changement en Adriatique?

GoL Adriatic Sea (Aegean Sea?)



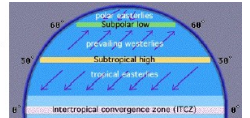
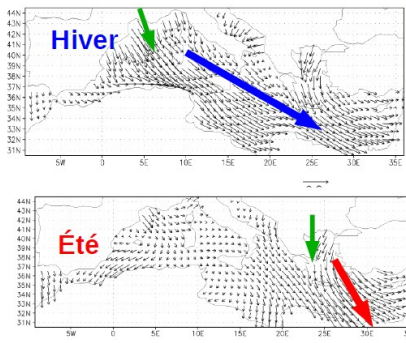
durée { circulation zonale : ~10 ans
circulation meridienne : 50-80 ans

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- 0 Ligurian-Provencal current
- 1 Lion Gyre
- 2 Thyrhenian cyclonic circulation with summer weakening and eastern anticyclone
- 3 Algerian Current (3a) and eddies, Atlantic-Ionian Stream (3b, 3c, 3d) and Mid-Med. Jet (3f)
- 4 Rhodes Gyre
- 5 Western Cretan Gyre
- 6 Western Ionian Gyre
- 7 Anticyclone in the Gulf of Syre
- 8 Shiktonia and Mers a-Matruh gyres system
- 9 Cilician and Asia Minor Current
- 10 Iera-tetra gyre
- 11 Pelops gyre
- 12 Southern Adriatic gyre
- 13 Western Adriatic Coast al Current

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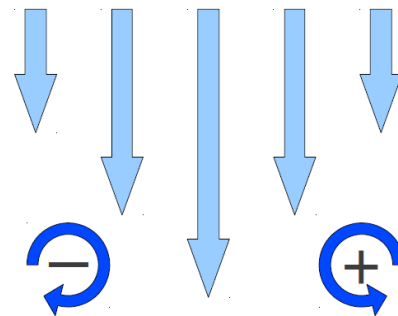
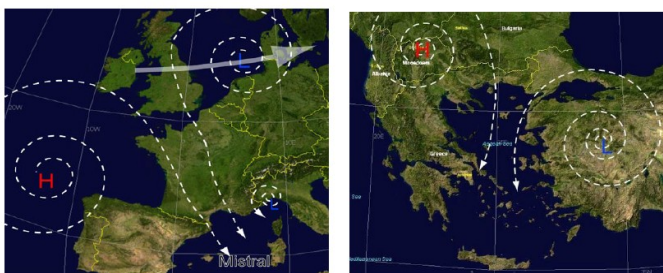
As Kendrew (1938) defined in his treatise: "The Mediterranean regions are between the Westerlies and the Trade winds; owing to the seasonal swing of the pressure belts of the globe they are dominated by the former in winter and the

+ regimes subregionaux:

- hiver : vents d'ouest + orographie (Mistral westerly jet)
- été : gradient T entre terre et mer (Etesian North-easterly jet)

Mistral

Meltemi



$$\zeta = \frac{\partial v}{\partial x} < 0$$

anticyclonique

$$\zeta = \frac{\partial v}{\partial x} > 0$$

cyclonique

Spiegazione « anemografica »

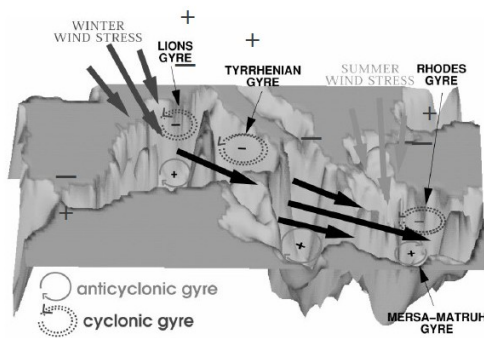
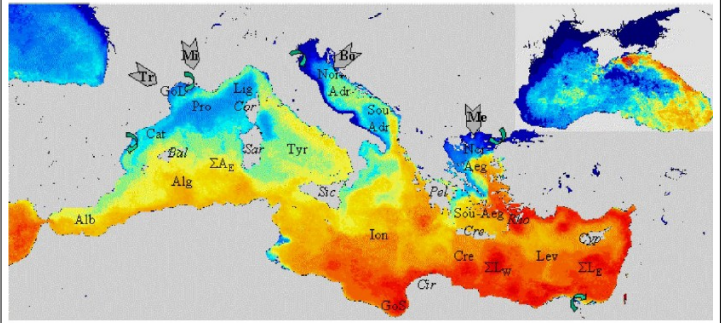
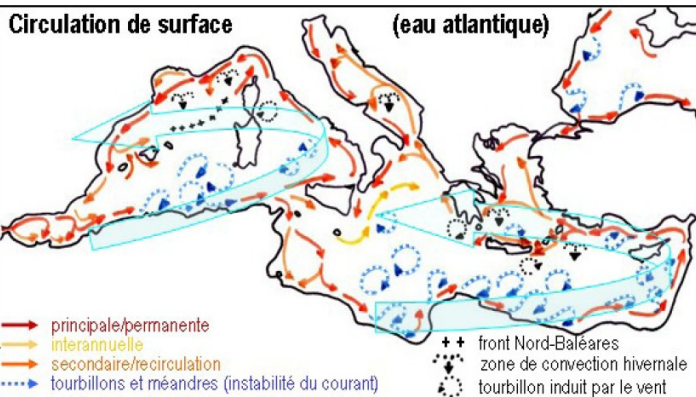


Fig. 4. Schematic of the wind driven circulation picture for winter time conditions. The thick arrows indicate schematically the direction of the surface wind stress field during winter and below the Sverdrup-induced wind driven gyres are drawn, consistently with the vorticity input from the two sides of the jet.

Spiegazione « thermoalina »



Millot e Taupier-Letage



Millot e Taupier-Letage

Una diversa ipotesi per la circolazione nel bacino orientale

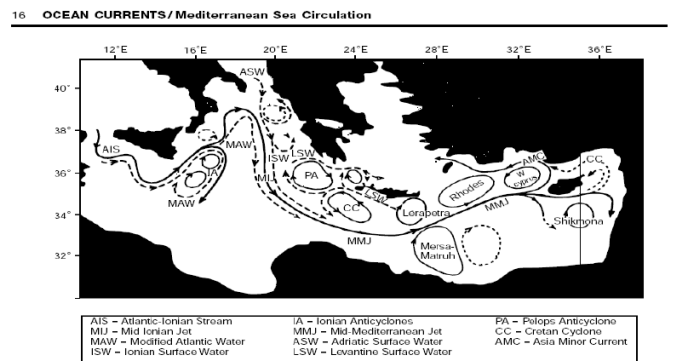
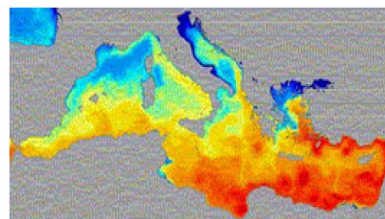
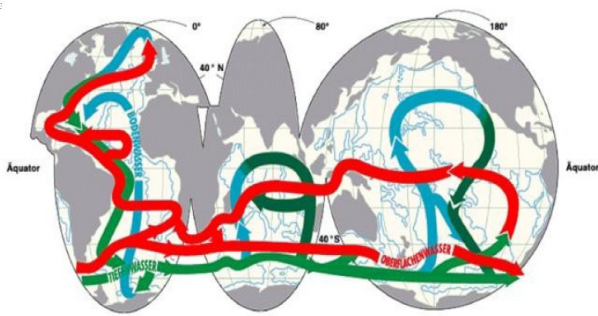


Figure 7 Sub-basin scale and mesoscale circulation features in the eastern Mediterranean (Reproduced with permission from Malanotte-Rizzoli et al., 1997).

Perché studiare il Mediterraneo ?

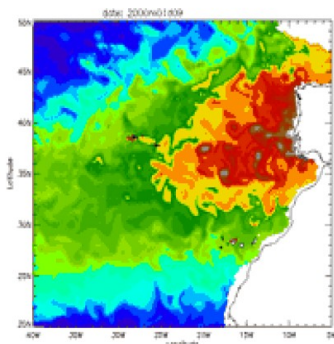
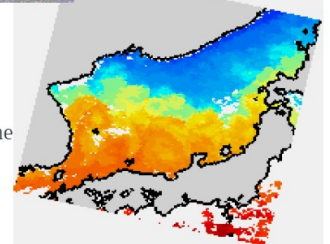
Un modello in scala della circolazione globale



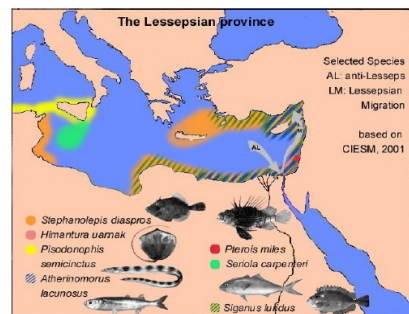
SST composita del Mediterraneo...

... e del mar del Giappone

<http://www.ifremer.fr/lobtln/>



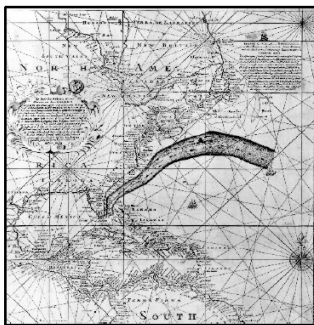
Simulazione numerica dell'acqua mediterranea in entrata nell'Atlantico modello Mercator-PAM, anno 2000, salinità a 870m



<http://www.sbg.ac.at/ipk/avstudio/pierofun/lm/lesseps.htm>
 Une liste des especes lessepsienne se trouve sur http://en.wikipedia.org/wiki/List_of_Lessepsian_migrants

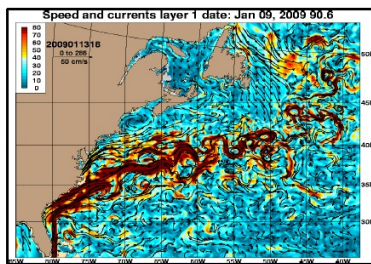
Principi di modellizzazione oceanica regionale e della dispersione in mare con esempi di applicazioni nelle acque costiere liguri

IERI



Mappa della Corrente de Golfo di Franklin-Folger, stampata nel 1769-1770.

OGGI

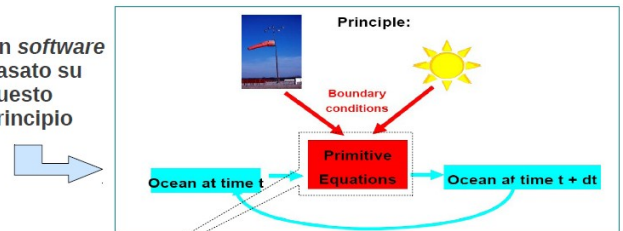


Intensità e direzione della corrente superficiale del 9 gennaio 2009 calcolata dal modello HYCOM

<http://www7320.nrlssc.navy.mil/GLBhycom1-12/navo/glfstrspdcurnowcast.gif>

Cos'è un modello numerico dell'oceano?

Un software basato su questo principio



Equazioni per

- Velocità
- Temperatura
- Salinità

Equations to solve : the primitive equations (PE)

$$\frac{\partial u}{\partial t} + u \cdot \nabla u - f v = -\frac{1}{\rho_0} \frac{\partial P}{\partial x} + A_h \nabla_h^2 u + A_v \frac{\partial^2 u}{\partial z^2}$$

$$\frac{\partial v}{\partial t} + u \cdot \nabla v + f u = -\frac{1}{\rho_0} \frac{\partial P}{\partial y} + A_h \nabla_h^2 v + A_v \frac{\partial^2 v}{\partial z^2}$$

$$0 = \frac{\partial P}{\partial z} - \rho g$$

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

$$\frac{\partial T}{\partial t} + u \cdot \nabla T = K_h \nabla_h^2 T + K_v \frac{\partial^2 T}{\partial z^2}$$

$$\frac{\partial S}{\partial t} + u \cdot \nabla S = K_h \nabla_h^2 S + K_v \frac{\partial^2 S}{\partial z^2}$$

$$[\rho = \rho(T, S, z)]$$

Cenni storici

1904 Bjerknes

se si conoscono con sufficiente precisione le condizioni iniziali dell'atmosfera e le leggi che ne governano i fenomeni è possibile prevedere l'evolversi del tempo

Bjerknes V., 1904 : Das problem von der Wettervorhersage, betrachtet vom Standpunkt der Mechanik und der Physik. Meteor. Zeitschrift, 21, 1-7. Le problème de la prévision du temps du point de vue de la mécanique et de la physique. Traduction en français par D. Gondouin, 1995, La Météorologie 8^e série, 9, 55-62.



1914 Bjerknes

identificazione dei problemi pratici per risolvere numericamente le complicate equazioni

1922 Richardson

si possono introdurre delle approssimazioni fisiche per semplificare il problema matematico e suddividere i conti da svolgere fra un gran numero di persone ben organizzate.

Idea della fabbrica per prevedere il tempo!

Richardson L. F., 1922 : Weather Prediction by Numerical Process. Cambridge University Press, reprinted Dover, 1965, 236 p.



Citazione da Richardson (1922)

"After so much hard reasoning, may one play with a fantasy? Imagine a large hall like a theatre, except that the circles and galleries go right round through the space usually occupied by the stage. The walls of this chamber are painted to form a map of the globe. The ceiling represents the north polar regions, England is in the gallery, the tropics in the upper circle, Australia on the dress circle and the antarctic in the pit.

A myriad computers are at work upon the weather of the part of the map where each sits, but each computer attends only to one equation or part of an equation. The work of each region is coordinated by an official of higher rank. Numerous little "night signs" display the instantaneous values so that neighbouring computers can read them. Each number is thus displayed in three adjacent zones so as to maintain communication to the North and South on the map.

From the floor of the pit a tall pillar rises to half the height of the hall. It carries a large pulpit on its top. In this sits the man in charge of the whole theatre; he is surrounded by several assistants and messengers. One of his duties is to maintain a uniform speed of progress in all parts of the globe. In this respect he is like the conductor of an orchestra in which the instruments are slide-rules and calculating machines. But instead of waving a baton he turns a beam of rosy light upon any region that is running ahead of the rest, and a beam of blue light upon those who are behindhand.

Citazione da Richardson (1922)

Four senior clerks in the central pulpit are collecting the future weather as fast as it is being computed, and despatching it by pneumatic carrier to a quiet room. There it will be coded and telephoned to the radio transmitting station. Messengers carry piles of used computing forms down to a storehouse in the cellar.

In a neighbouring building there is a research department, where they invent improvements. But these is much experimenting on a small scale before any change is made in the complex routine of the computing theatre. In a basement an enthusiast is observing eddies in the liquid lining of a huge spinning bowl, but so far the arithmetic proves the better way. In another building are all the usual financial, correspondence and administrative offices. Outside are playing fields, houses, mountains and lakes, for it was thought that those who compute the weather should breathe of it freely."

1922 Richardson: la fabbrica per prevedere il tempo

Un sistema di calcolo umano (64000 persone) automatico e parallelo con una potenza di calcolo di circa 1 Flops (Floating point operations per second).



«Il sogno di Richardson»

Disegno di François Schuiten (2000)

Il modello di Richardson, 1922

Una prova con un numero ridotto di personale diede un *risultato molto deludente*:

- prevista una variazione di pressione circa 145 hPa in 6 ore, un valore praticamente impossibile (già 20 hPa sono un caso eccezionale)
- in realtà poi la variazione reale fu quasi nulla...

Dove fu l'errore?

Non nella concezione del modello, ma nella **poca potenza** di calcolo e nei **dati sperimentali, scarsi e poco precisi**

Oggi esiste una fitta rete di misure meteorologiche

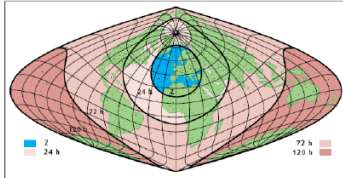
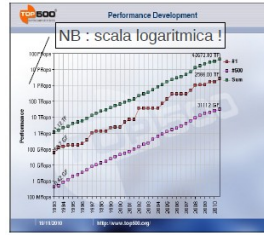
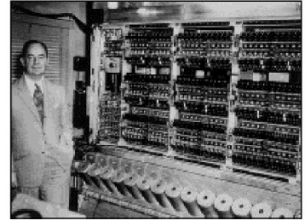


Figure 4 - Répartition mondiale des stations de radiosonde et indication des régions sur lesquelles des observations sont nécessaires pour réaliser des prévisions à échéance de 1, 3 et 5 jours sur la zone centrale Z. (Document CEPMMT)

Apparizione e rapida evoluzione dei calcolatori elettronici

- 1946 ENIAC (*Electronic Numerator Integrator Analyser and Computer*), 500 Flops
- Von Neumann propose d'utilizzarlo per le previsioni meteorologiche
- 1949 modèle barotrope de Charney



Legge di Moore (empirica) : le prestazioni dei computer raddoppiano ogni 18 mesi

25 maggio 2008: *Roadrunner*, costruito da IBM per l'esercito americano ha raggiunto 1 PetaFlops (10^{15} Flops)

Classifica attuale

- #1 2.6(4.7)PetaFlops *Tianhe-1A* (China, since Nov.2010)
- #2 1.8(2.3)PetaFlops *Jaguar* (USA, #1 Nov.09 – Nov.10)
- #3 1.3(3.0)PetaFlops *Nebulae* (China)

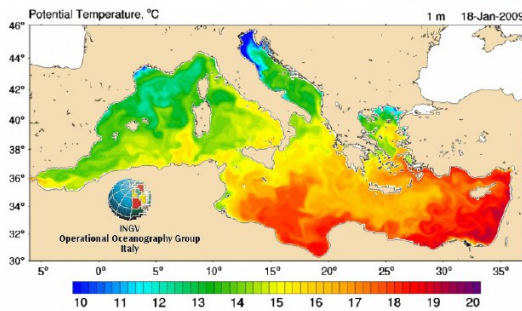
<http://www.top500.org/> <http://en.wikipedia.org/wiki/TOP500>

Primi modelli oceanici

1963 (2D) Bryan e colleghi del GFDL Geophysical Fluid Dynamics Laboratory (GFDL) (Princeton University & the National Oceanic and Atmospheric Administration);

1969 : modello 3D di Bryan e colleghi.

Oggi, in Italia: *Mediterranean ocean Forecasting System* <http://gnoo.bo.ingv.it/mfs/>



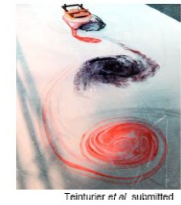
una ricerca « troppo » avanzata ?!



«l'entusiasta che studia i vortici»



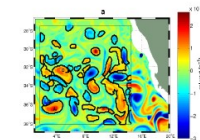
Laboratorio del Politecnico di Parigi



Taniuti et al. submitted

Esempi di applicazioni di modelli numerici :

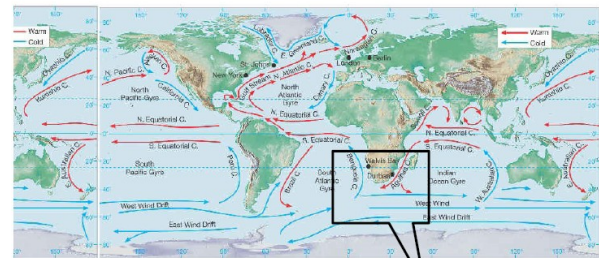
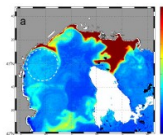
- studio dei vortici oceanici in Sud Atlantico



- circolazione e dispersione di inquinanti nelle acque del Promontorio di Portofino




- misura e modellizzazione dei vortici costieri del Golfo del Leone




Carta delle principali correnti oceaniche analogie fra i 5 bacini oceanici:
lato ovest correnti calde verso i poli
lato est correnti fredde verso l'equatore

Retroflessione delle Agulhas e Agulhas Rings del Cape Caudron





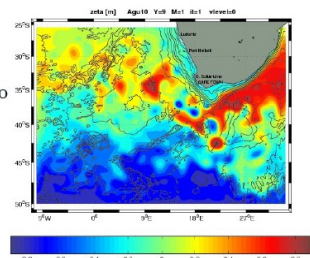
Wavelets
Analysis for
Time-tracking
Eddies in
Regional models



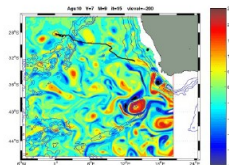
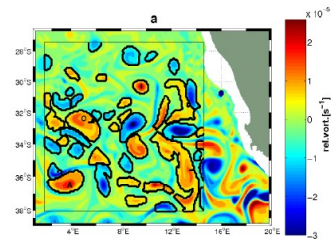
Obiettivi del progetto

identificare nei dati forniti da un modello i vortici con metodo oggettivo

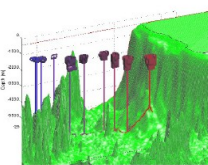
seguirli nel tempo per capire le loro caratteristiche e gli scambi tra i due oceani



ESEMPI DI VORTICI STUDIATI

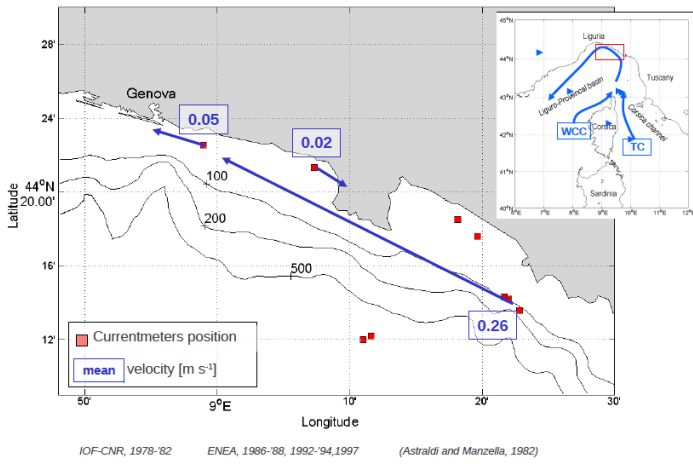


IDEFIX 2D



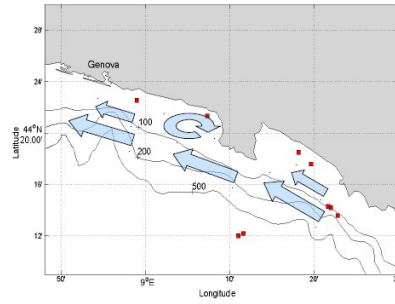
IDEFIX 3D

Misure storiche di corrente a Portofino

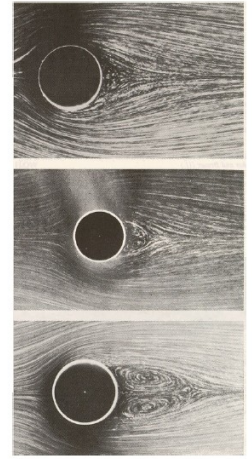


Come spiegare questa circolazione?

Un vortice sottoflusso all'ostacolo!

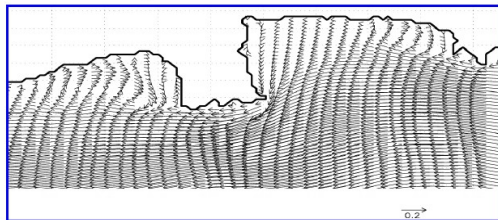
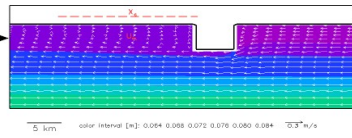


Se é vero, allora come e perché si forma?



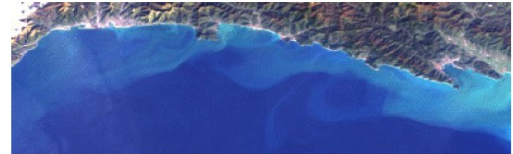
Software libero
scaricabile da rete

Studi prima semplificati,
poi sempre più realistici

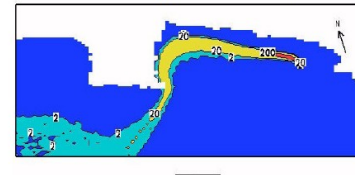


Approvato
dai pescatori
di Camogli!

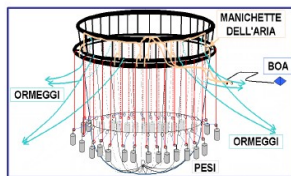
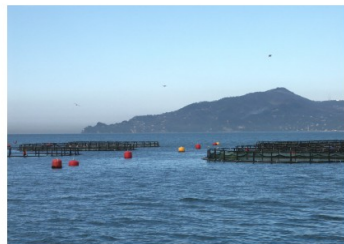
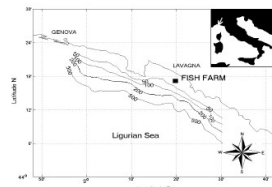
Immagine satellitare MERIS-ENVISAT



Modello POM-LAMP3D
concentration [particules/maille]



Allevamento "AQUA"



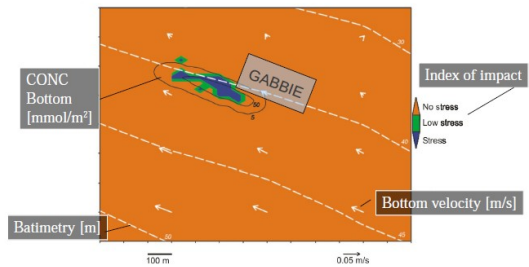
Organic Carbon

in

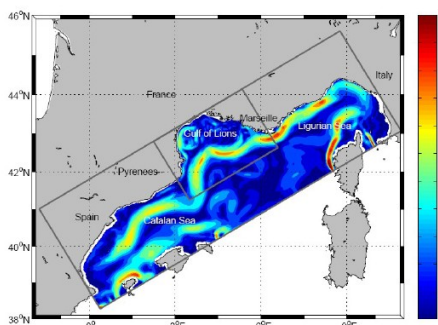
Uneaten feed



Faecal matter

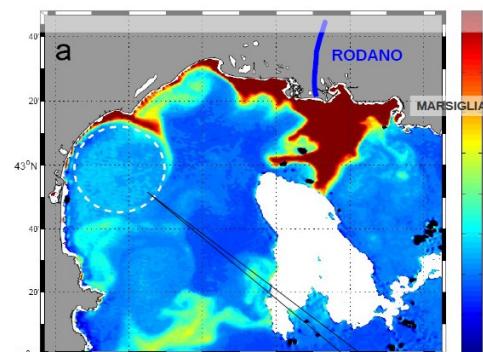


Misura e modellazione della Corrente Nord Occidentale
Mediterranea e dei vortici costieri del Golfo del Leone



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

Distribuzione spaziale della Clorofilla-a in luglio 2001



Modello SYMPHONIE
segnala la presenza di un vortice anticiclonico



LATEX

LAgrangianTransportEXperiment
Campagna Settembre 2008



PROPOSIZIONE DI TRACCIATA LATEX
Dopo 4 giorni finalmente ne abbiamo trovato uno!

IFREMER - IPEV - IRD

Latex01 - Positions des bouees le 15-Sep-2008 a 7h 1m

