High-resolution measurements and modelling of the Cape Ghir upwelling filament during the CAIBEX cruise

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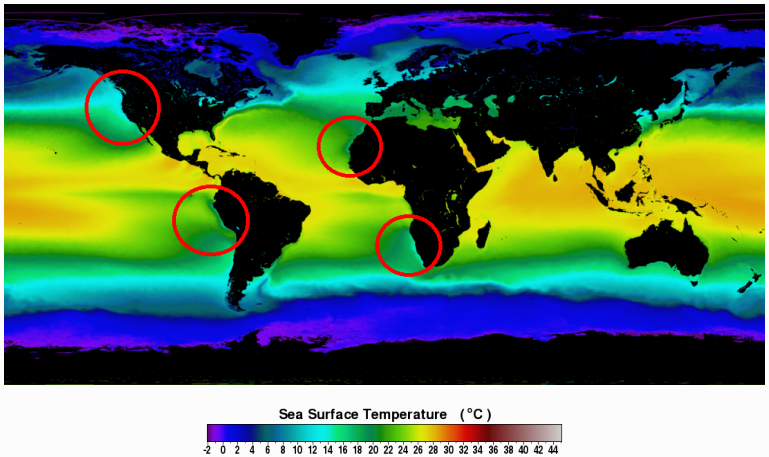
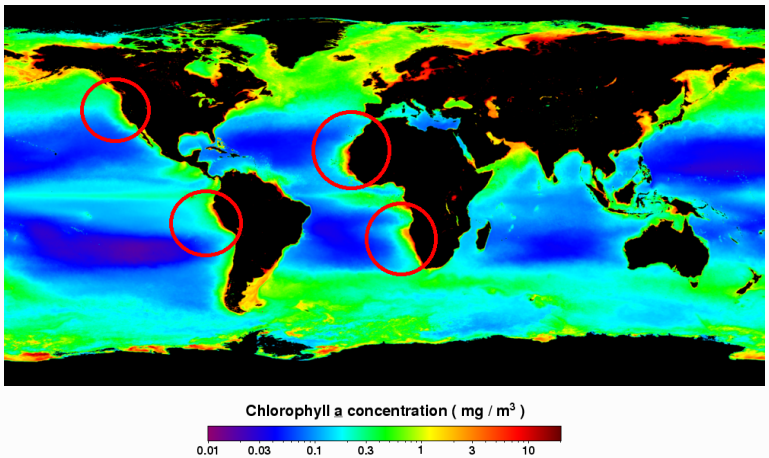
University of Liège

April 26$^{\mathrm{th}}$, 2010

Eastern Boundary Current Upwelling Systems



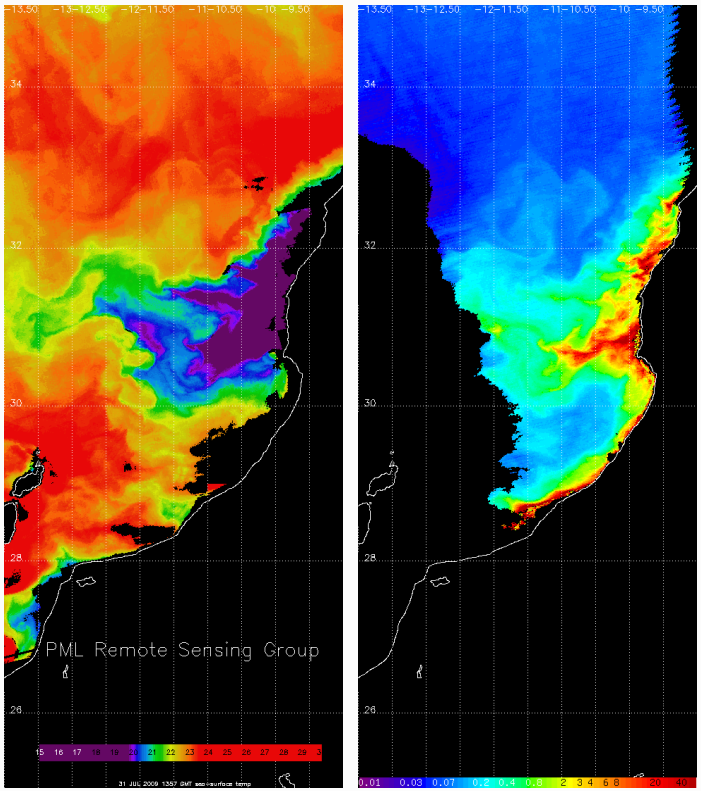


- 4 major upwelling systems: California, Canary, Benguela, Peru
- correspondence low temperature – high chlorophyll concentration
- 1% of the ocean surface $\longrightarrow$ 50% of the fisheries
- mechanism: wind + earth rotation
- local effects on weather

$\longrightarrow$ let's look at it closer...

Canary upwelling system

SST and chlorophyll
July 31st, 2009

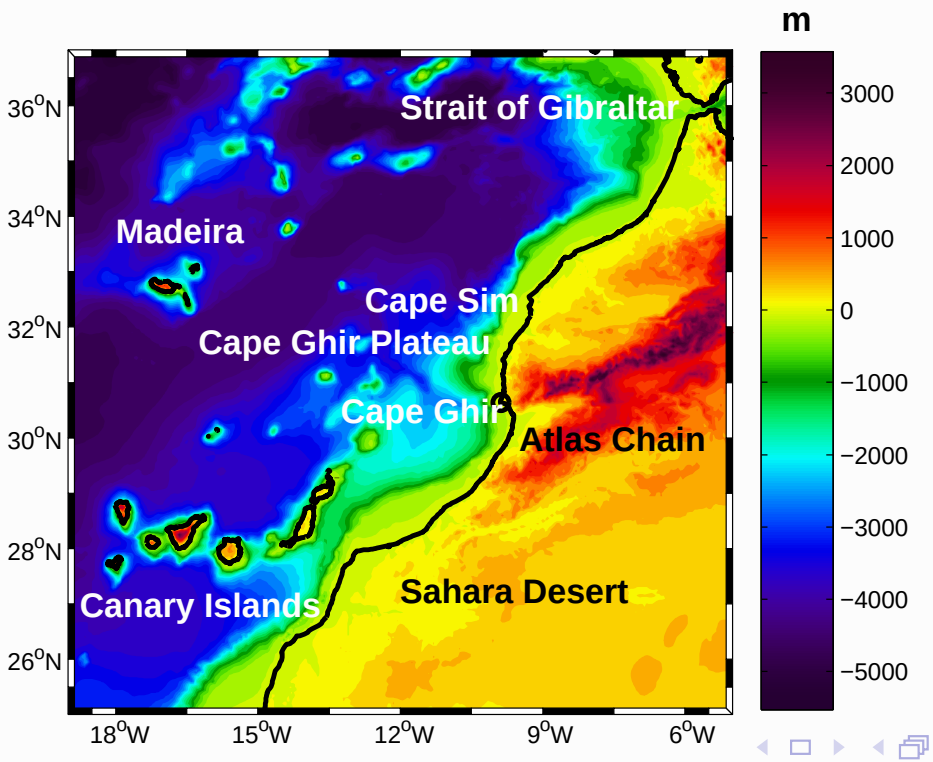


Upwelling filament

- exportation of cool water offshore
- nutrient-rich water $\longrightarrow$ upwelling water
- preference near the capes
- only surface view $\longrightarrow$ in situ measurements
- mechanism $\longrightarrow$ numerical model

Outline

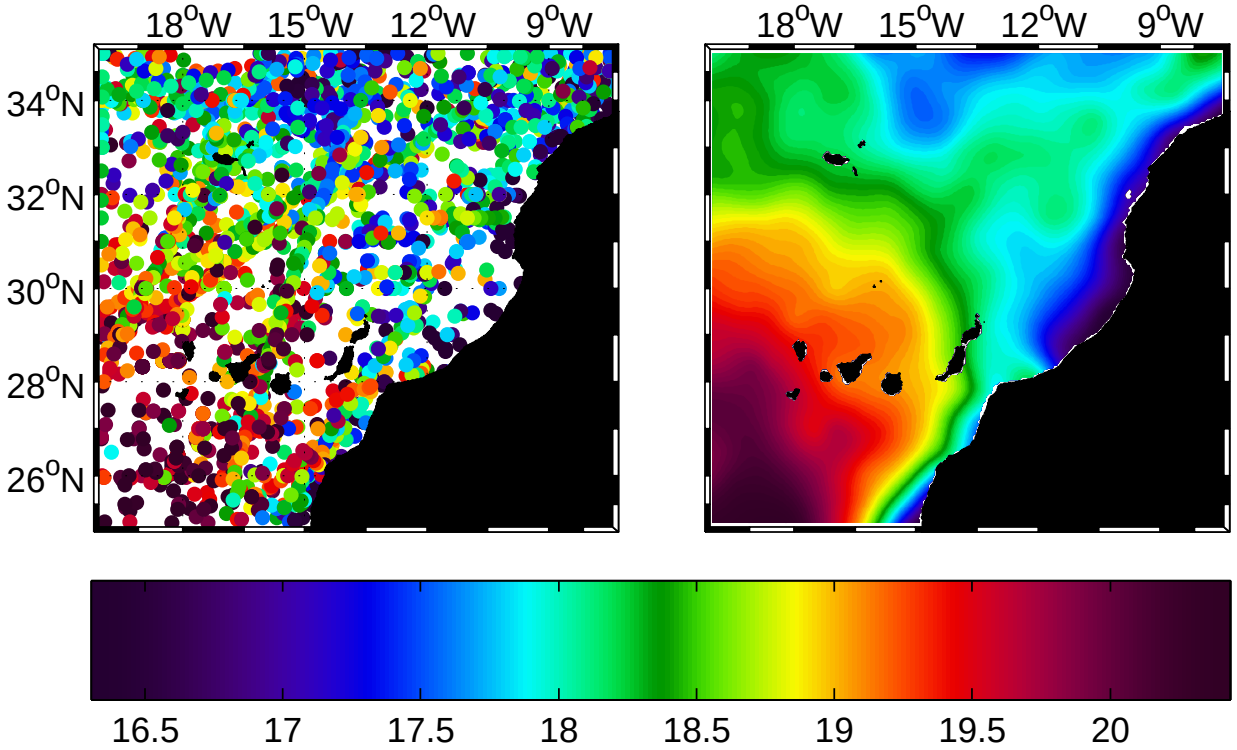
1. analysis of historical data
2. numerical model experiments
3. in situ measurements off Cape Ghir
   CAIBEX cruise, 16 August – 5 September 2009



Analysis of historical data

Objectives

1. in situ data $\rightarrow$ gridded field
2. representation of the mean situation in the studied region
3. hydrographic atlas for temperature and salinity
4. initialize numerical model



DIVA: Method formulation

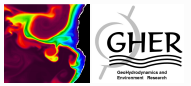
N_d data: d_j at (x_j, y_j)
Field to reconstruct: φ

$$\min J[\varphi] = \sum_{j=1}^{Nd} \underbrace{\mu_j}_{\text{weight}} \underbrace{[d_j - \varphi(\mathbf{r}_j)]^2}_{\text{misfits}} + \underbrace{\|\varphi\|^2}_{\text{field regularity}}$$

with

$$\|\varphi\|^2 = \int_D (\alpha_2 \underbrace{\boldsymbol{\nabla}\boldsymbol{\nabla}\varphi : \boldsymbol{\nabla}\boldsymbol{\nabla}\varphi}_{\text{variability}} + \alpha_1 \underbrace{\boldsymbol{\nabla}\varphi \cdot \boldsymbol{\nabla}\varphi}_{\text{gradients}} + \alpha_0 \underbrace{\varphi^2}_{\text{field value}}) \, dD,$$

α_0, α_1, $\mu_j \rightarrow$ related to data

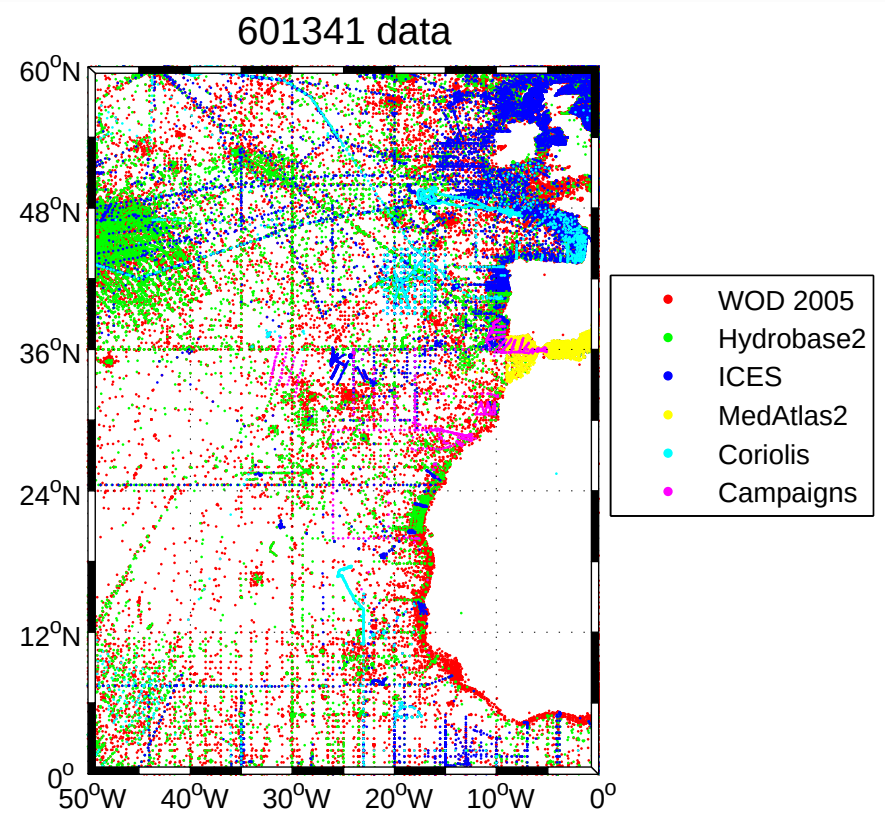


NE Atlantic climatology: data

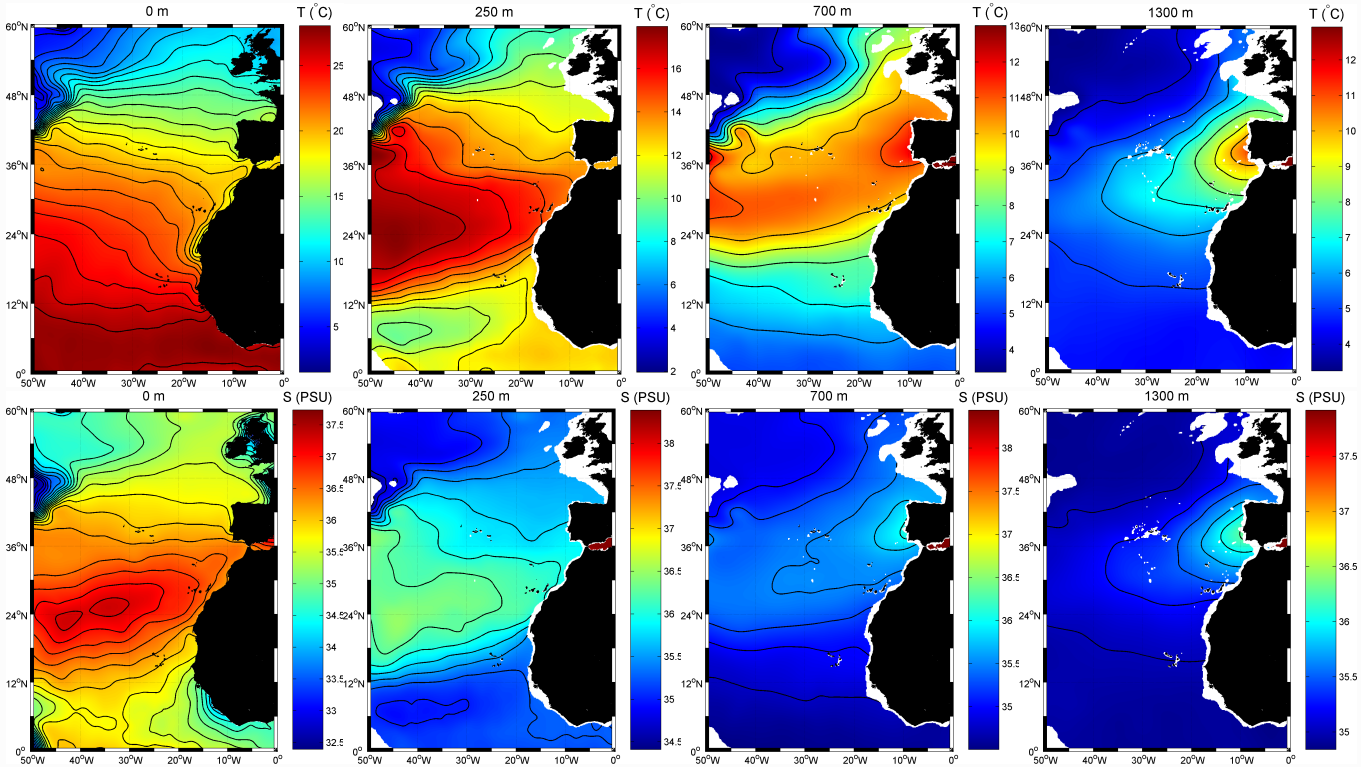
Objective: provide a better than WOA
Zone: $0 - 60^{\circ} N$, $0 - 50^{\circ} W$
Period: 1890-now
Type: CTD's and bottles

Table: Data sources.

Source	N° of data
WOD05	304713
Hydrobase2	235007
ICES	45512
MedAtlas2	9413
Coriolis	4366
Campaigns	2330
	Total: **601341**



Results: annual fields



Troupin et al., Journal of Geophysical Research, *in press*

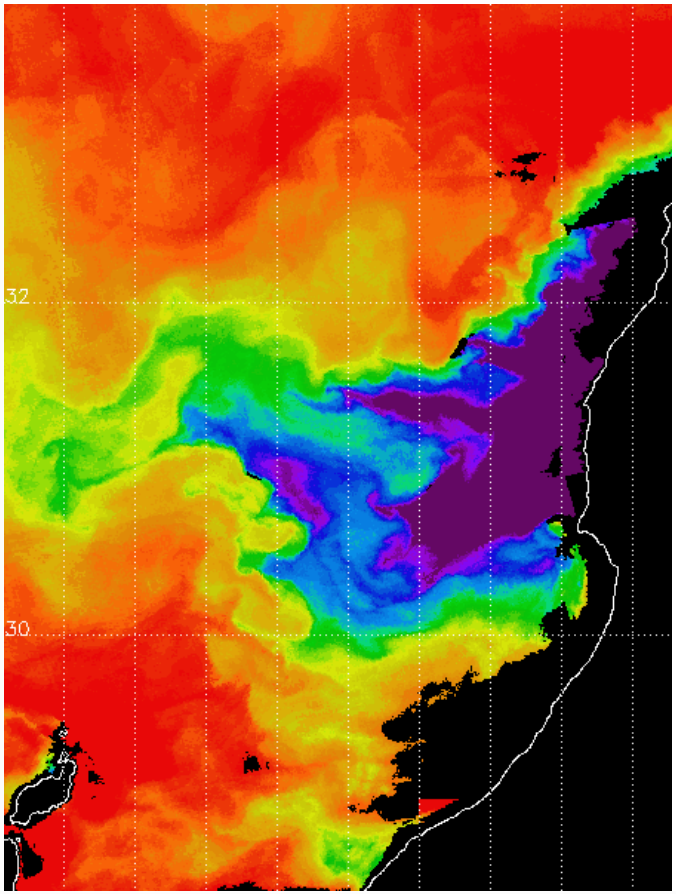
Climatology used in numerical simulations

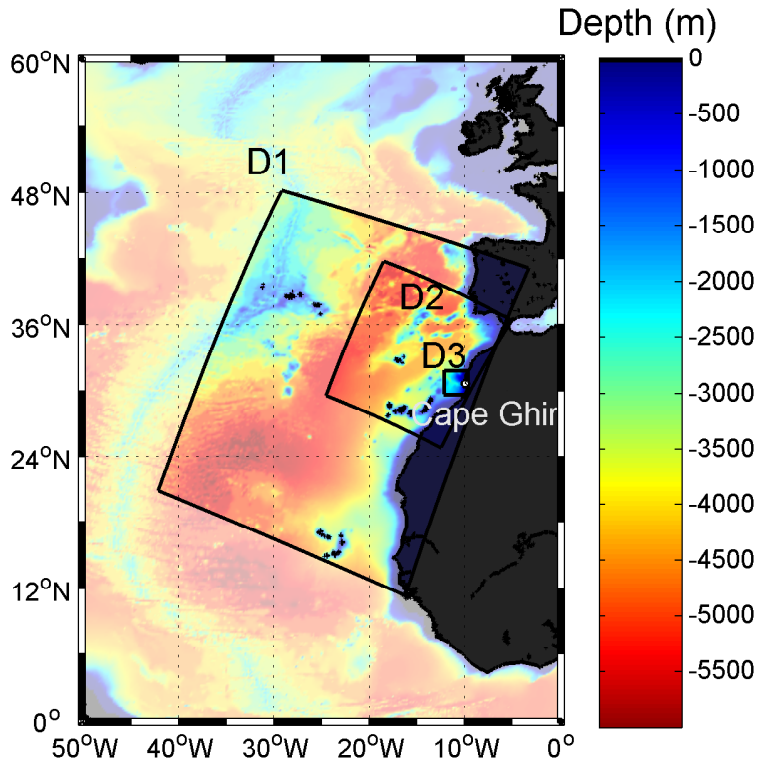
Distribution: http://gher-diva.phys.ulg.ac.be/data/GHER/NEAtlantic/
(OPeNDAP) http://gher-diva.phys.ulg.ac.be:8080/GHER/NEAtlantic/
Visualization: http://gher-diva.phys.ulg.ac.be/web-vis/clim.html

Filament numerical modeling

Cape Ghir upwelling filament

SST, September 2009





Resolution: $D_2 \rightarrow 4.5$ km

Resolution: $D_3 \rightarrow 1.5$ km

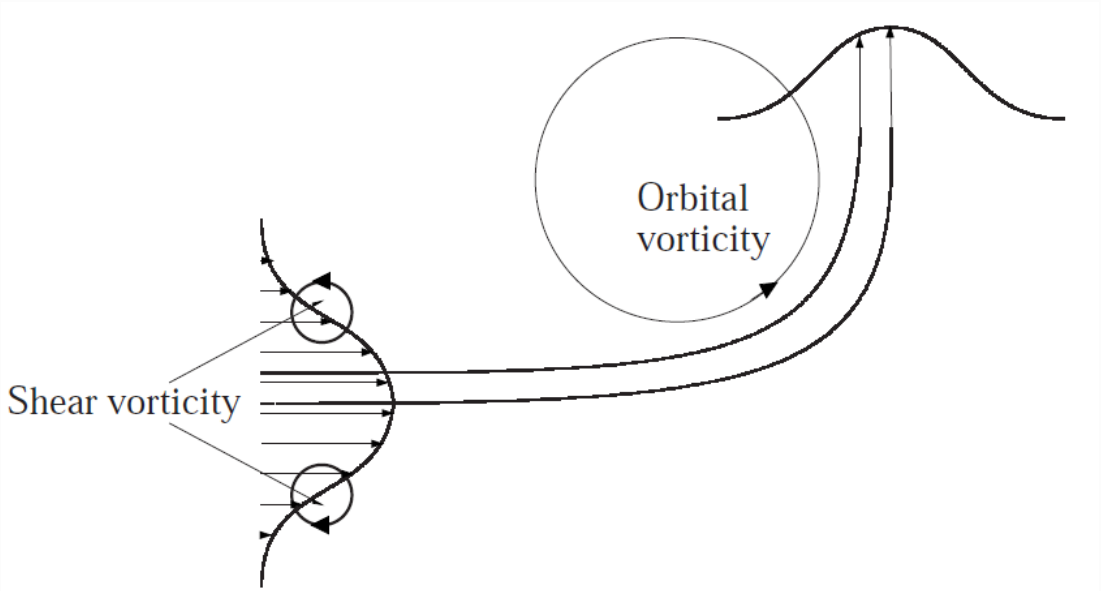
Offline nesting (Mason et al., submitted)

Process-oriented study

Objective: determine the processes generating the filament

Mechanism:

1. Conservation of potential vorticity
2. Injection of positive vorticity near Cape Ghir
3. Offshore turning of the jet

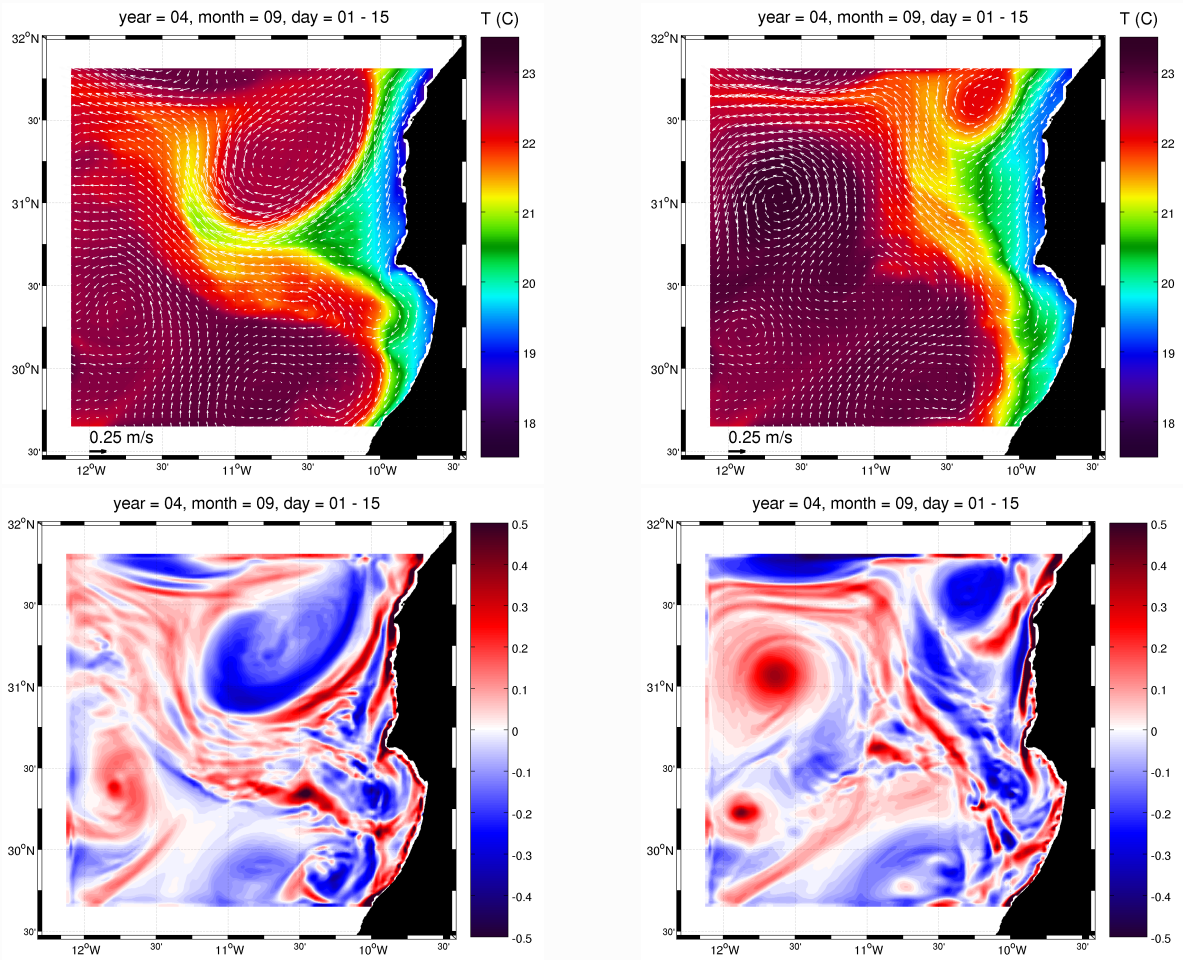


(Adapted from Cushman-Roisin and Beckers)

Design of experiments: modified wind, smoothed topography, flat bottom, uniform wind, β effect...

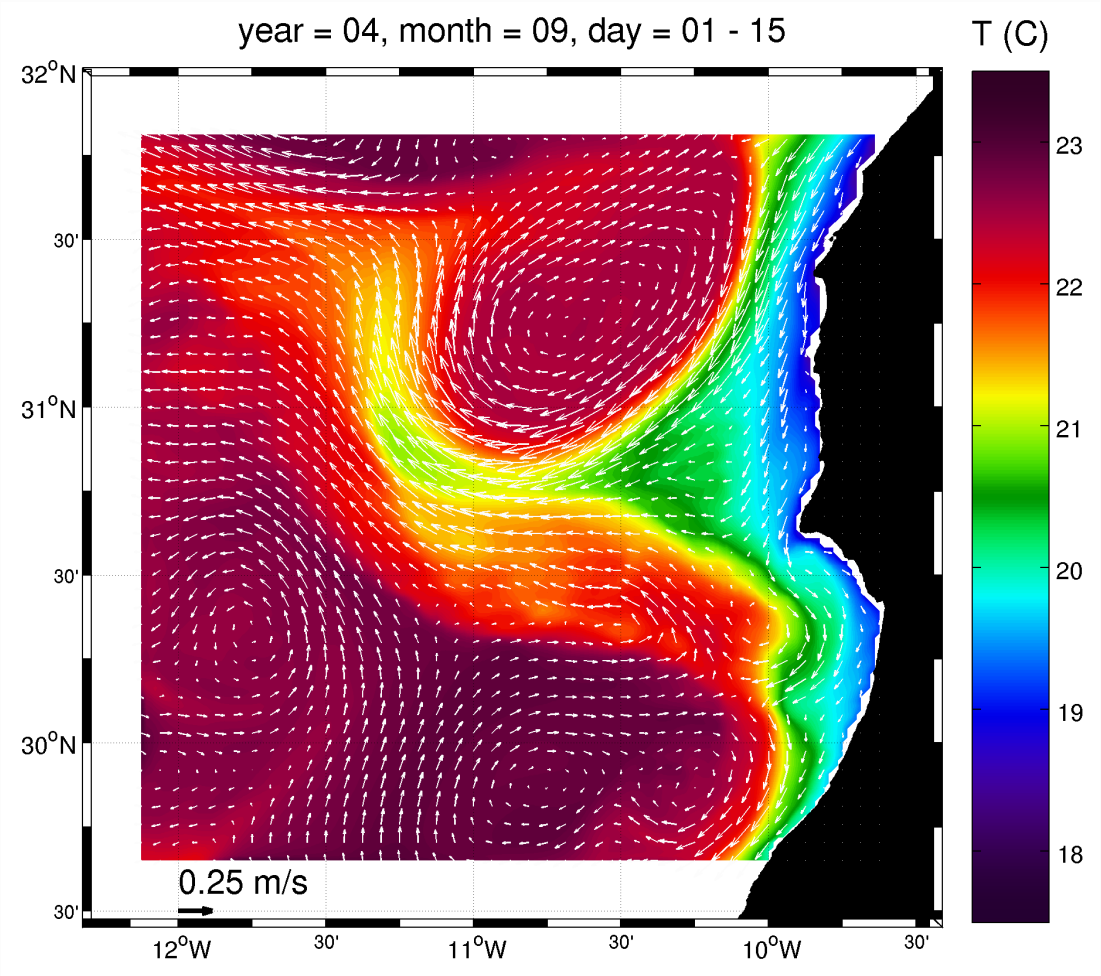
Results

15-day averaged temperature (top) and normalized relative vorticity (bottom) at 10m with β effect (left) and without



Results

Animation: temperature at 10 m



Summary of the results

1. realistic modelling of the filament
2. physical characteristics

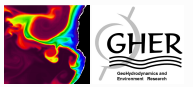
depth: $\mathcal{O}(100)$ m
with: $\mathcal{O}(10)$ km
length: $\mathcal{O}(100)$ km

time: a few days
velocity: $\mathcal{O}(0.5)$ m/s

3. process-oriented experiments

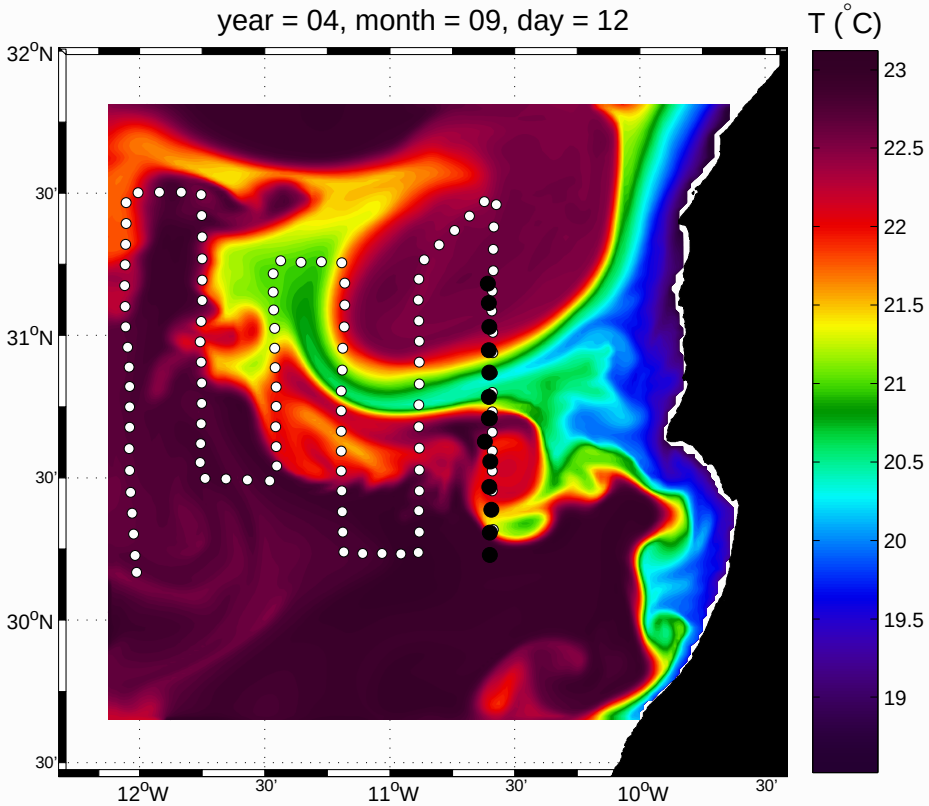
   importance of the wind and the bathymetry
   vorticity balance

CAIBEX cruise, August 16^{th} – September 5^{th}



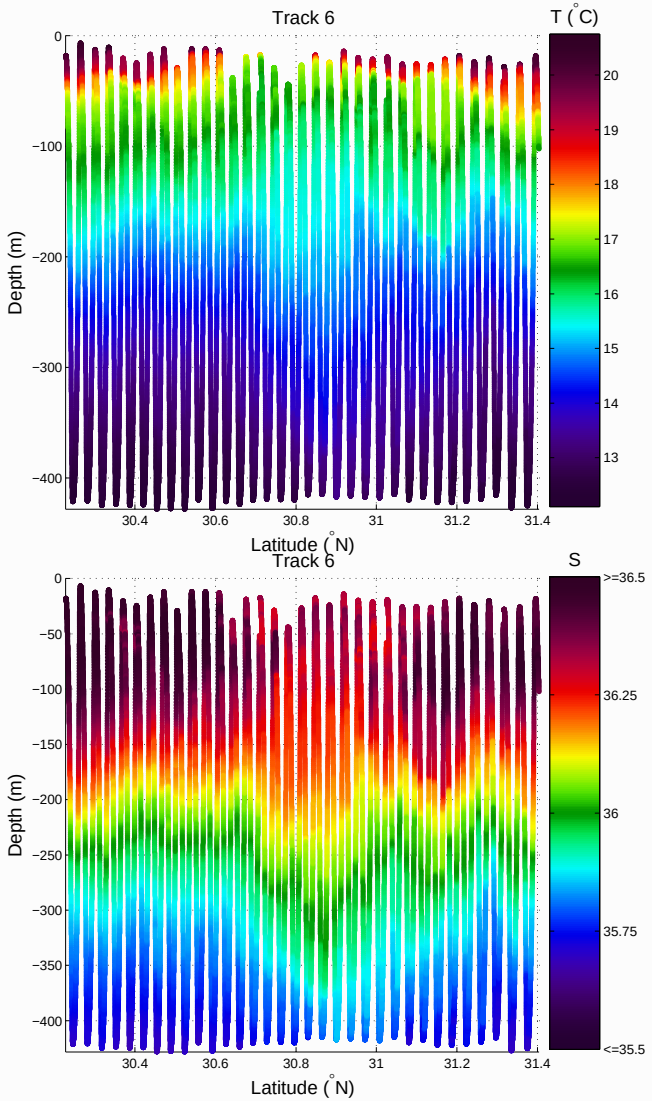
CAIBEX cruise, August-September 2009

CAIBEX = Exchanges between continental shelf and ocean in the Canaries-Iberian marine ecosystem
Objective: high-resolution sampling of physical and biological properties
Web page: http://www.iim.csic.es/~barton/caibex/index.html



- high-resolution measurements with SeaSoar (white)
- CTD transect (black)
- drifters in the core of the filament

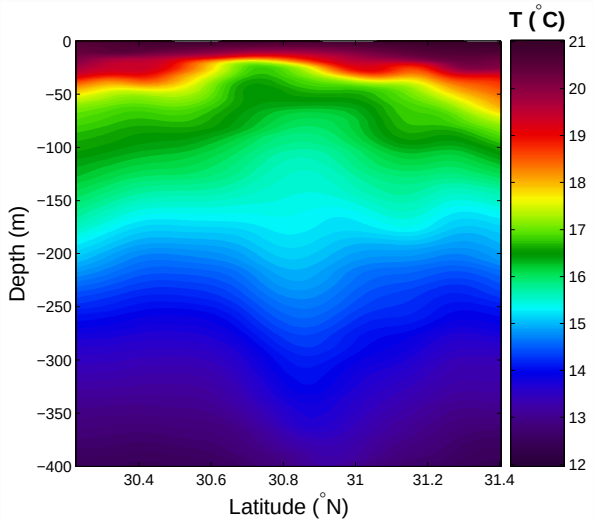
SeaSoar data

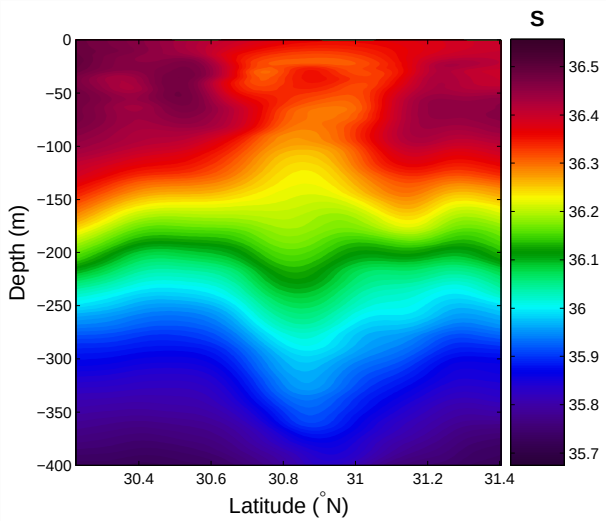


- filament signature $\rightarrow$ near surface T
- filament width $= \mathcal{O}(20\ km)$
- filament depth $= \mathcal{O}(100\ m)$
- dooming of iso-T and iso-S around 300 m, north of the filament
  $\rightarrow$ similar to Hagen et al. (1996) and
  $\rightarrow$ similar to Pelegrí et al. (2005)

$\rightarrow$ **anticylonic eddy signal?**

SeaSoar analysis





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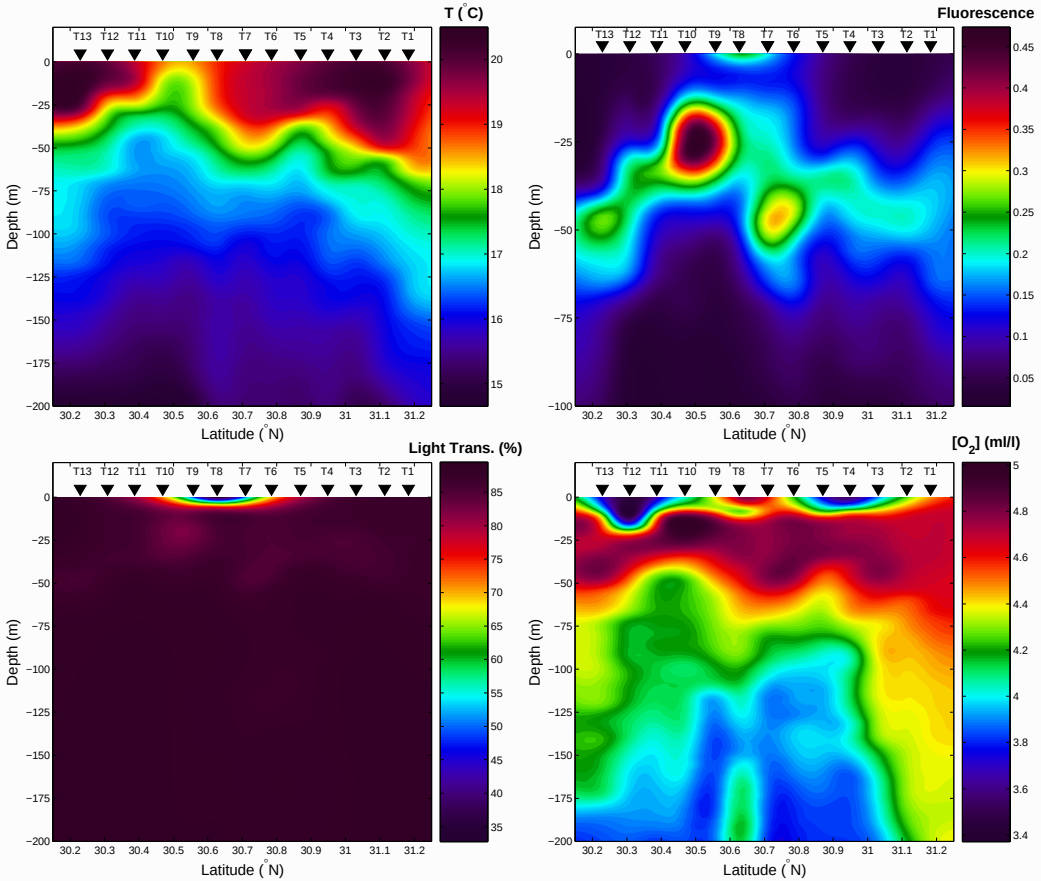
GHER

CTD

Temperature, fluorescence, transmittance, oxygen



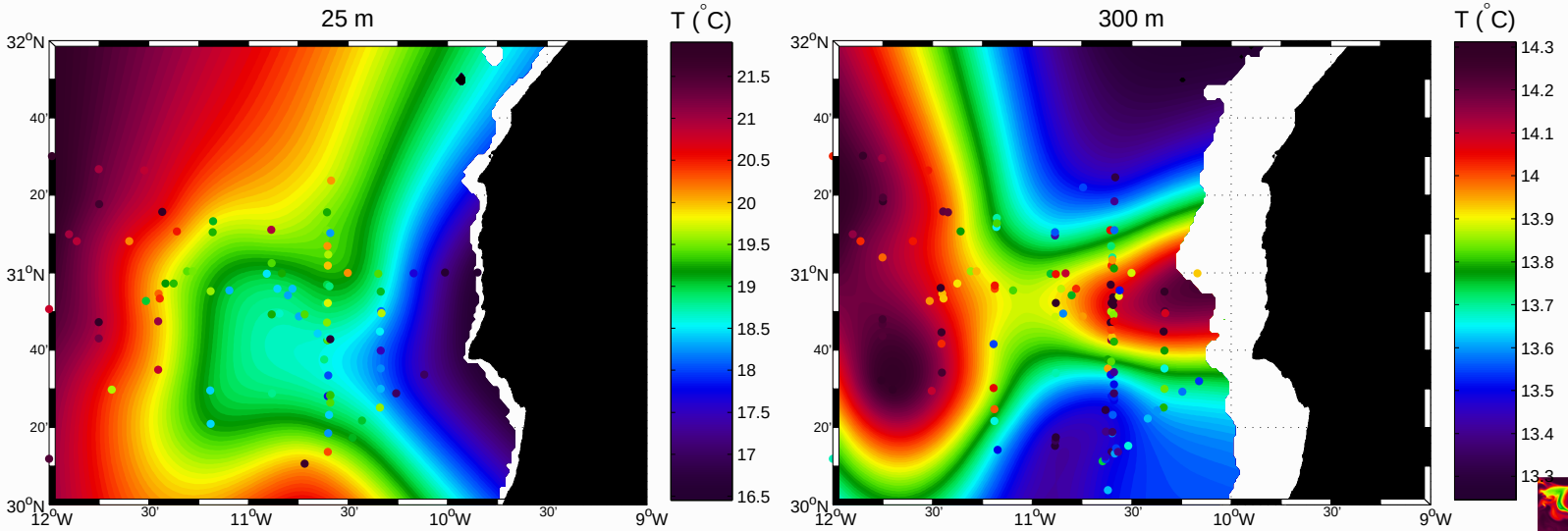
- surface temperature signature (T_9-T_{10})
- biological activity trigger (25 m)
- high particle concentration (T_7-T_{10})
- downward velocity signal

Analysis: horizontal

Compilation of all the cruise data ($\simeq$ 20 days)
Analysis with low signal-to-noise ratio
General picture of the situation:

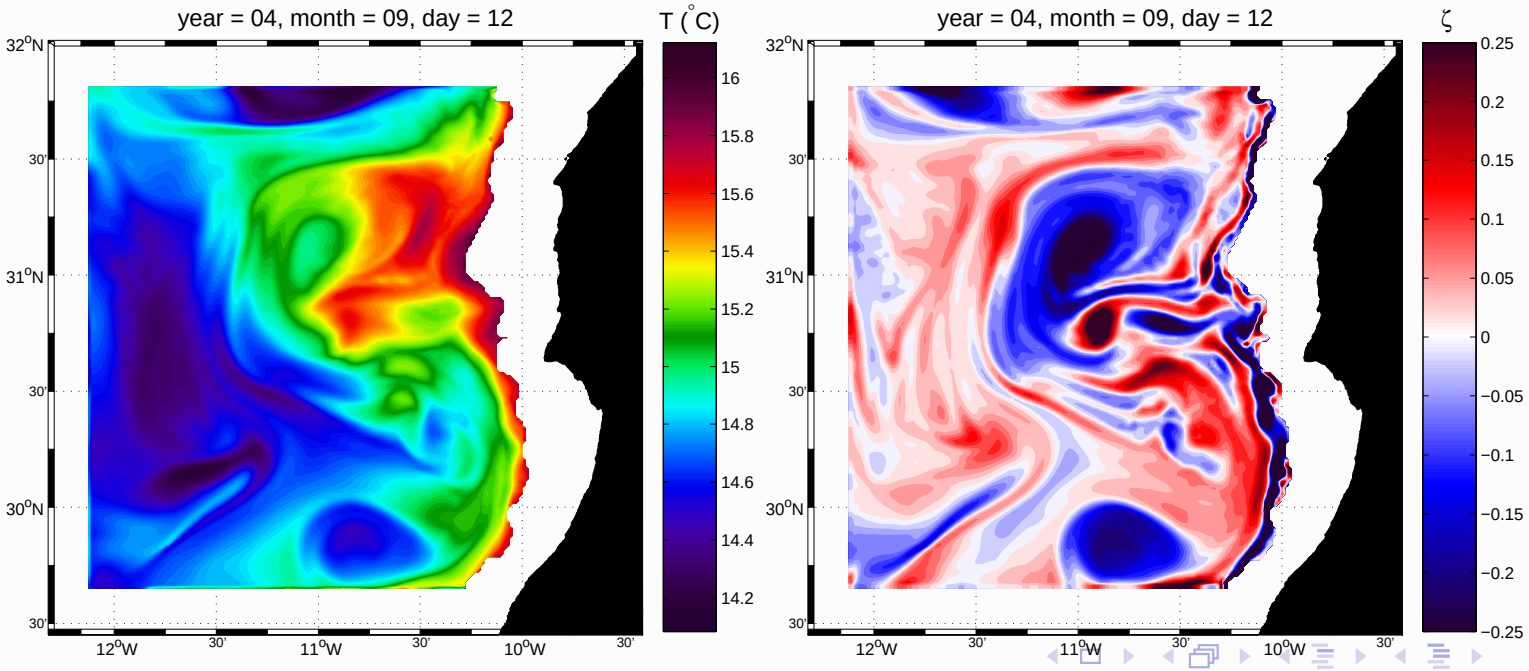
25 m: coastal upwelling + filament

300 m: warmer water near coast



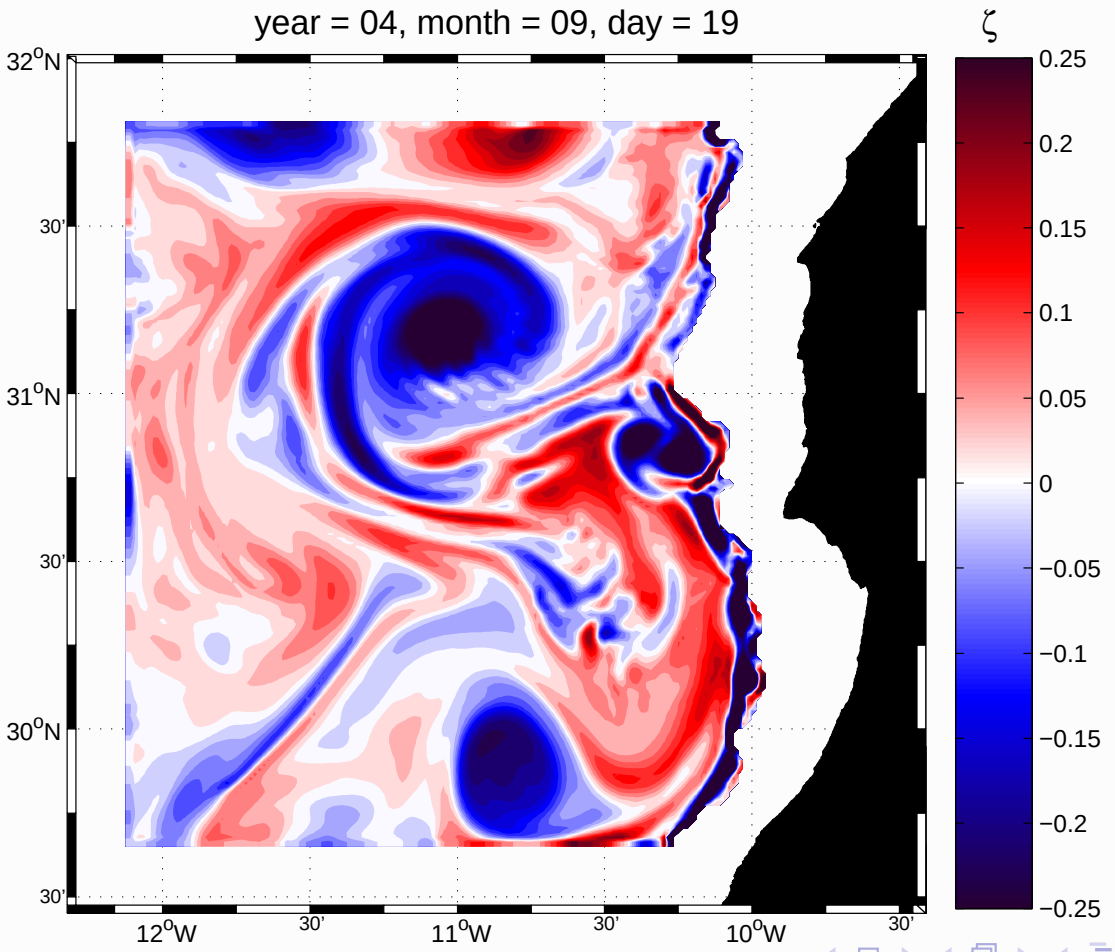
Model comparison

- temperature and relative vorticity at 300 m
- mechanism: interaction between undercurrent and topography**?**
- similar to California upwelling system
- filament generates eddy, or eddy generates filament**?**



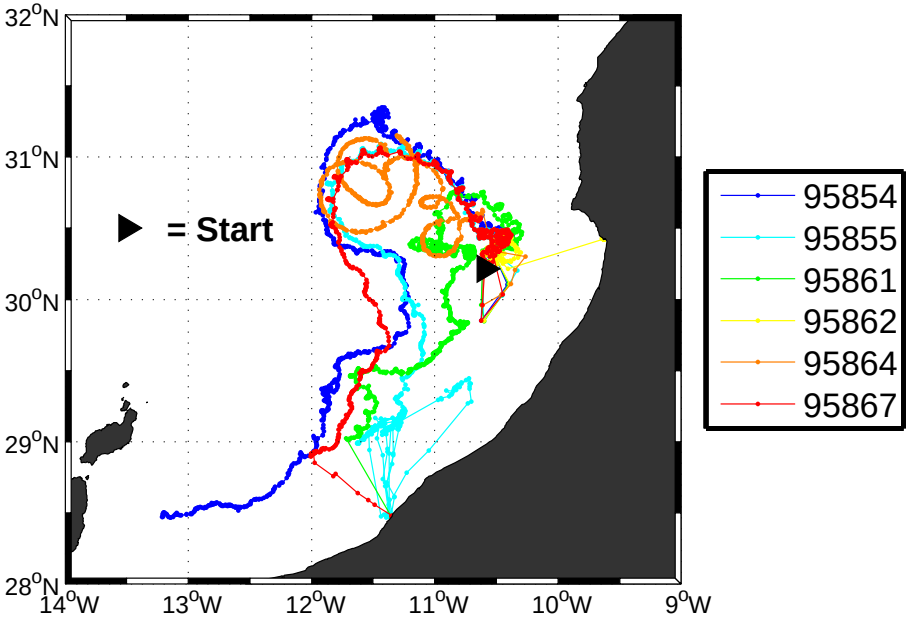
Filament-anticyclonic eddy interaction

Animation: relative vorticity at 10 and 300 m



ARGOS drifter tracking

Where to drop them? $\rightarrow$ analyze SeaSoar tracks (Sep 3$^{\mathrm{rd}}$, 2009)



5 near-surface (10 m), in the core of the filament

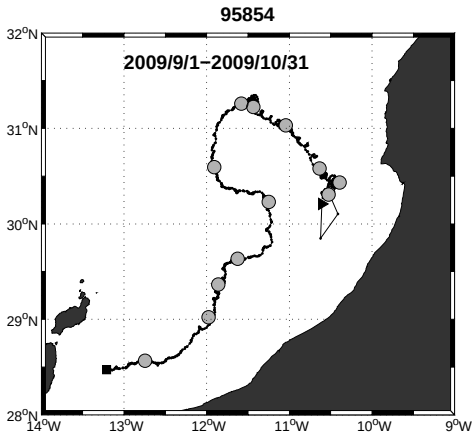
1 at 300 m (95864), in the convergence zone

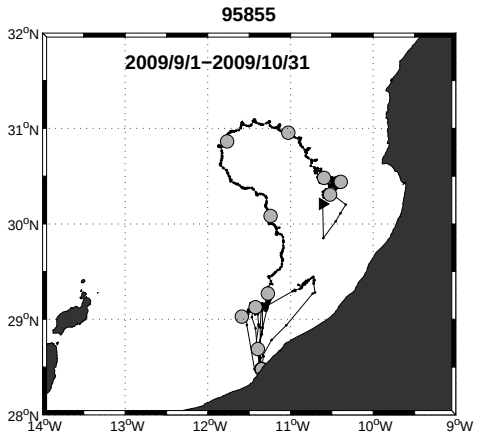
Observations:

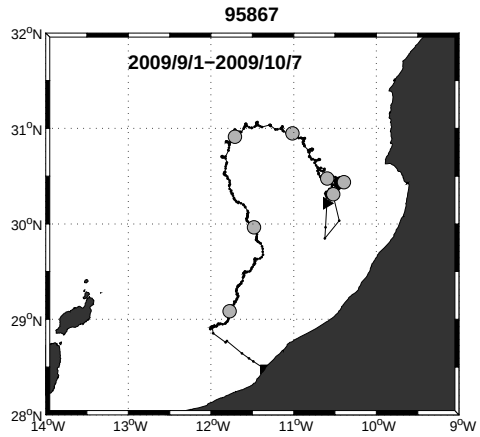
- start: northwestward motion
- 31°N: southward turn
- finally: southwestward trajectory

Surface drifters

Drifter trajectories
5 days between gray circles.

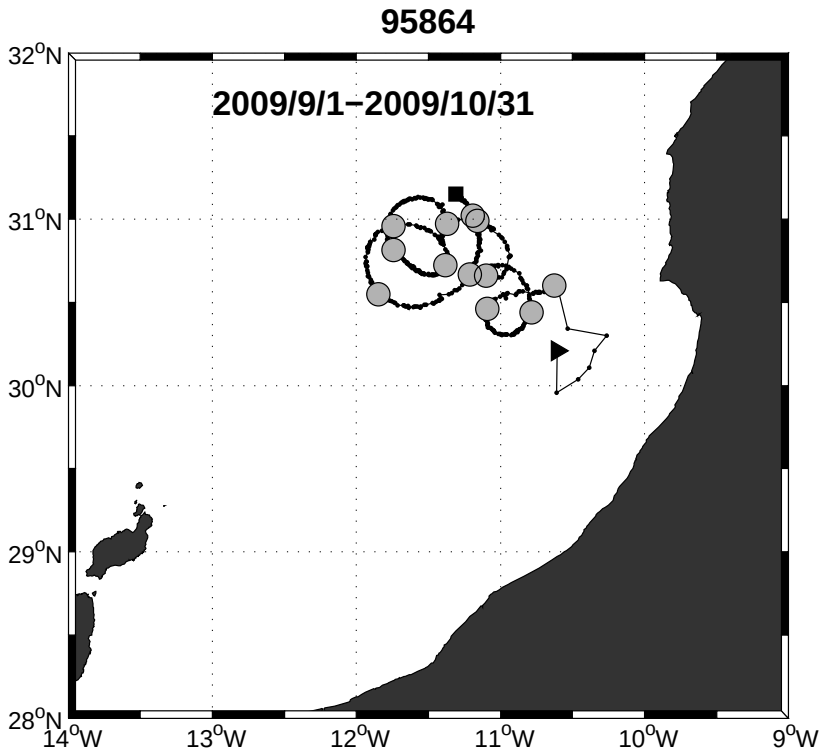






- little motions during ˜ 2 weeks
- possible entrainment by the filament → to check
- cyclonic trajectory
- 30°N: Canary Current trajectory

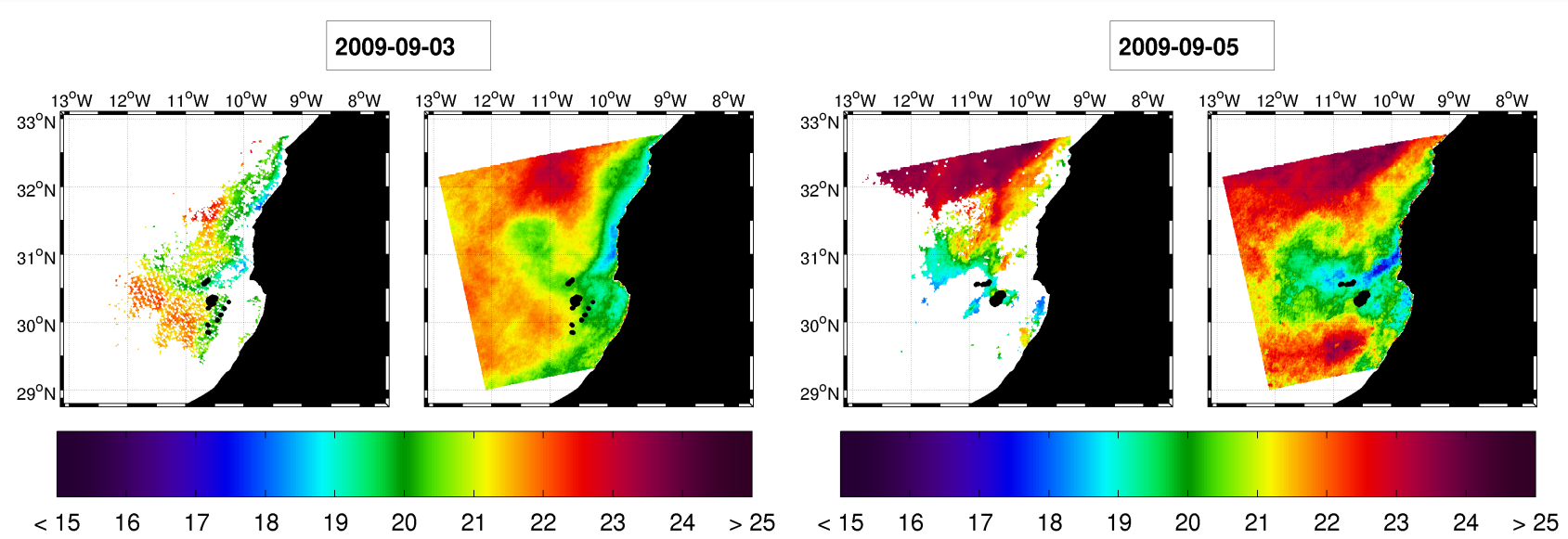
300 m drifter



- cyclonic motion → eddy?
  eddy corridor
  [Sangrà et al., 2009]
- real depth of the drifter?
- overall northwestward direction
- relatively low velocities

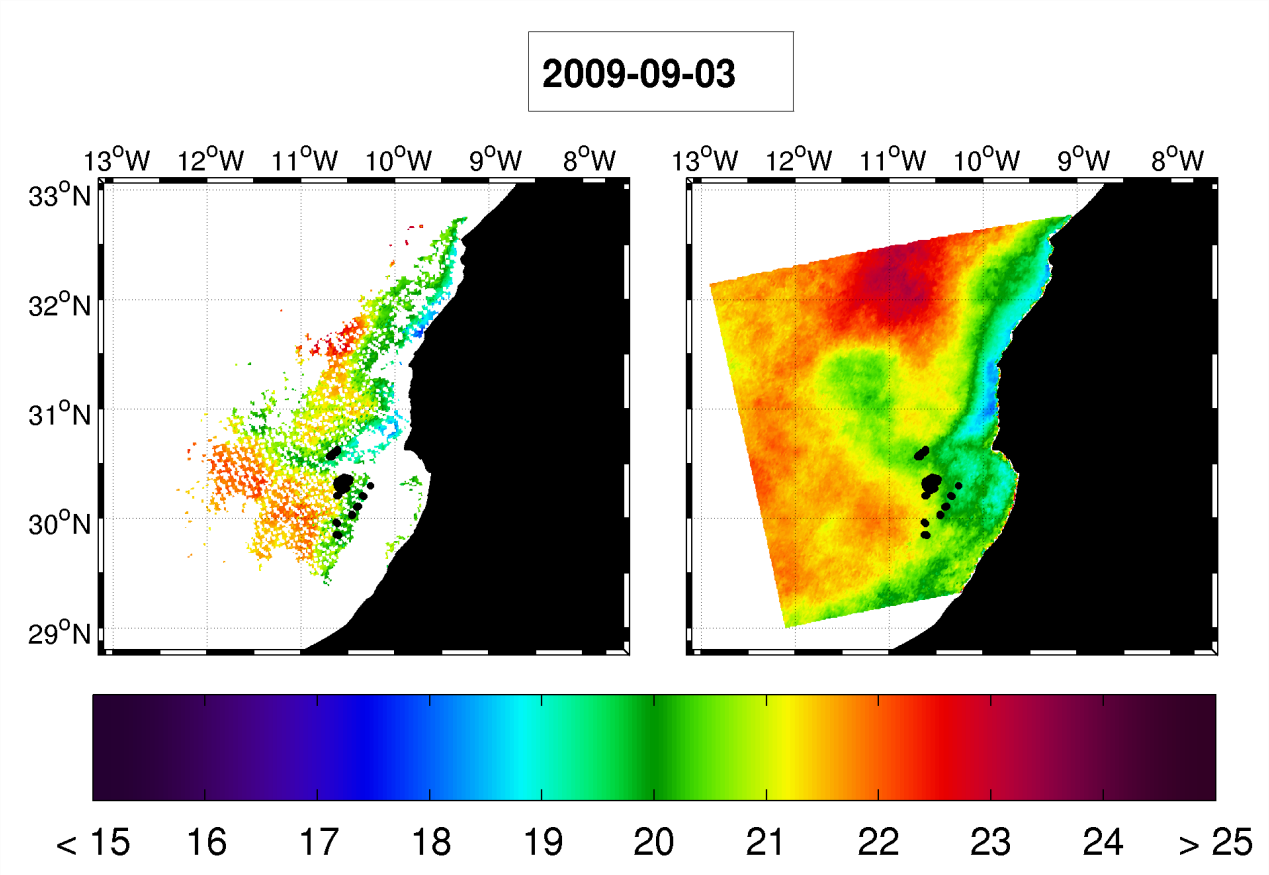
Satellite imagery

Left: original satellite data (Medspiration)
http://www.medspiration.org
Right: DINEOF reconstruction
http://modb.oce.ulg.ac.be/mediawiki/index.php/DINEOF
Black dots = drifter positions



Surface drifters

Animation: drifter trajectories on SST field



Conclusions

1. high-resolution **climatology** of the NE Atlantic
2. **process**-oriented modelling of the filament:
   a. importance of wind and bathymetry
   b. possible **mechanism** of filament generation
3. **small-scale** sampling of the filament properties (work in progress)

Thanks for your attention