# Idealized numerical modeling of ocean-atmosphere interactions in the presence of a surface eddy

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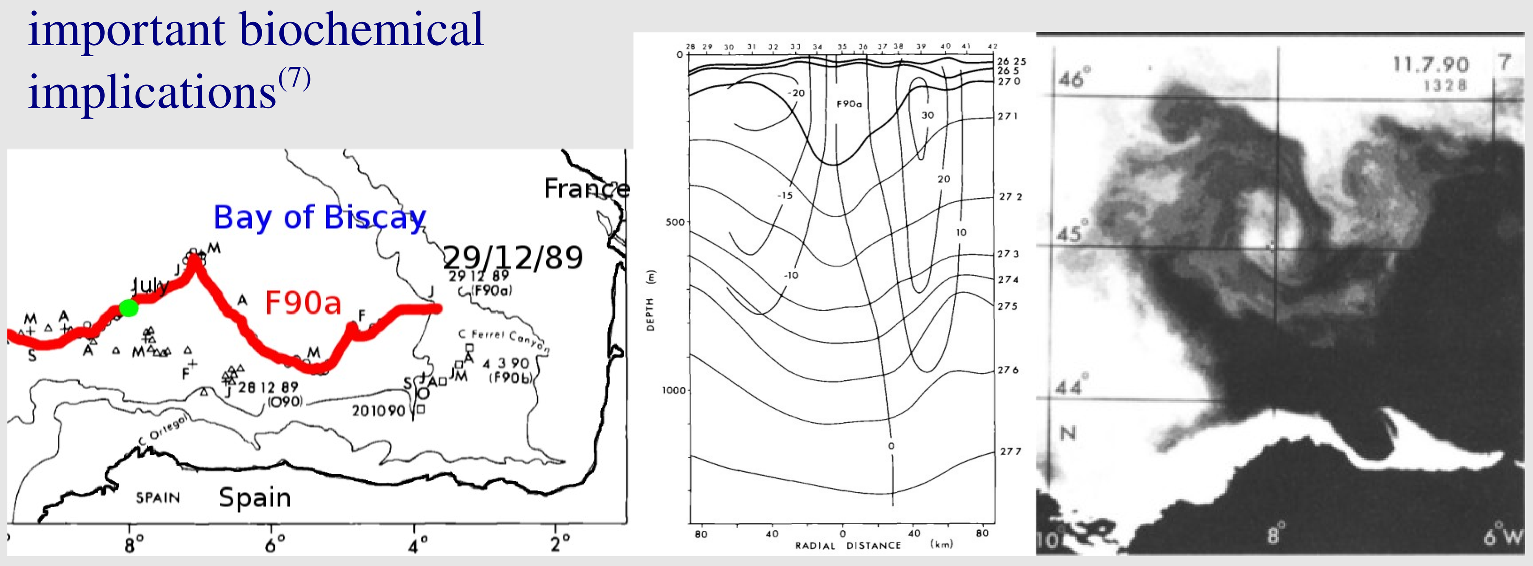
## *Observations*

- The southern Bay of Biscay is characterized by the presence of anticyclonic eddies (**SWODDIES, S**lope **W**ater **O**ceanic e**DDIES**) originating from current instabilities of the northern Spanish slope current
- In early summer 1990, the **SWODDY F90a** presented a specific doming of the seasonal thermocline above its center, associated with a cool patch of SST and higher Chlorophyll-A concentrations[3,4,8]
- The high concentration may be related to intense plankton blooms observed above anticyclonic and mode water eddies similar to **F90a**, with important biochemical implications[7]




*Trajectory of SWODDY F90a, formed in the vicinity of cap Ferret Canyon in late December 1989 - early January 1990 , and drift to the west until the end of 1990 (left); $\sigma_0$ section through the eddy F90a obtained from XBT measurements, and geostrophic velocities in ms$^{-1}$ (center) and NOAA infrared satellite image (right) on the 10th of July 1990. Reproduced from Pingree and Le Cann, (1992)[8]*

## *Motivations - Hypotheses*

- Usual parametrization of wind stress does take into account neither surface currents nor SST : $\vec{\tau} = \rho_{air} C_D |\vec{u}_{10}| \vec{u}_{10}$ (1)
- In the presence of an anticyclonic eddy, feedbacks of surface currents (via Ekman pumping) may explain the observed enhanced source of nutrients[6,7]
- SST may introduce similar feedbacks on the eddies[1]
- Implementation of two alternative parameterizations for wind stress with constant drag coefficient $C_D$ :

<u>1- Surface oceanic currents :</u>

- Difference between atmospheric and oceanic velocities instead of pure 10-meters wind speed :

$$\vec{\tau}_C = \rho_{air} C_D |\vec{u}_{10} - \vec{u}_c| (\vec{u}_{10} - \vec{u}_c) \quad (2)$$

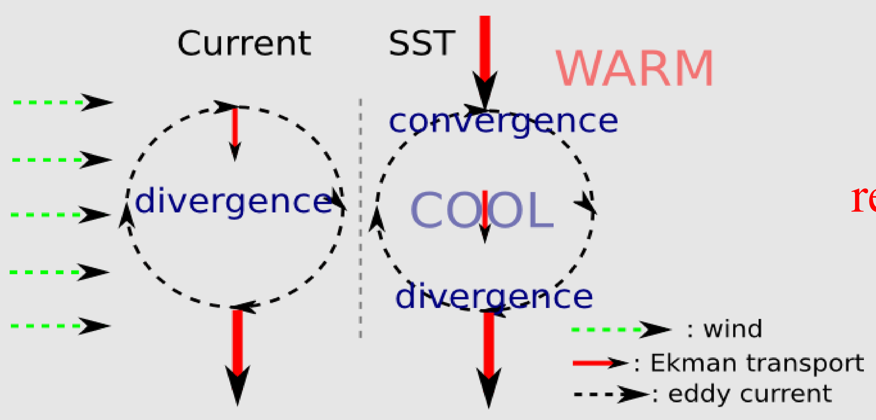
<u>2- Sea surface temperature :</u>

- Weaker wind stress over colder SST regions :

$$\vec{\tau}_{SST} = \rho_{air} C_D |\vec{u}_{10}| \vec{u}_{10} (1 + \kappa \Delta T) \quad (3)$$

with κ is a proportionality factor[1] and $\Delta T$ the SST anomaly

*Schematic representation of local modifications on wind-stress due to surface oceanic currents (left) and temperature (right)*



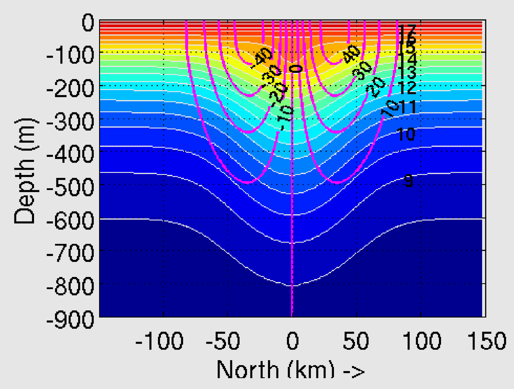

➔ Three runs of an idealized representation of **F90a** forced with three different **wind-stress parameterizations**

## *Model configuration and initial conditions*

- Idealized setup of the **MITgcm model**[5]
- **Hydrostatic Primitive Equations** with **linear free surface** resolved on a **f-plane** and with linear relation in temperature for density : $\rho = \rho_{ref}(1 + \alpha_T T)$
- **K-profile parametrization** : accurate way to resolve vertical viscosity and dissipation
- Horizontal resolution : 2km ; vertical resolution : 4m in the 800 first meters and 60m down to the bottom ; total depth $H_0$ = 2000 meters
- Integration over 70 days, corresponding to the delay between the formation of the seasonal thermocline over **F90a** (late spring) and the observations

Initial conditions

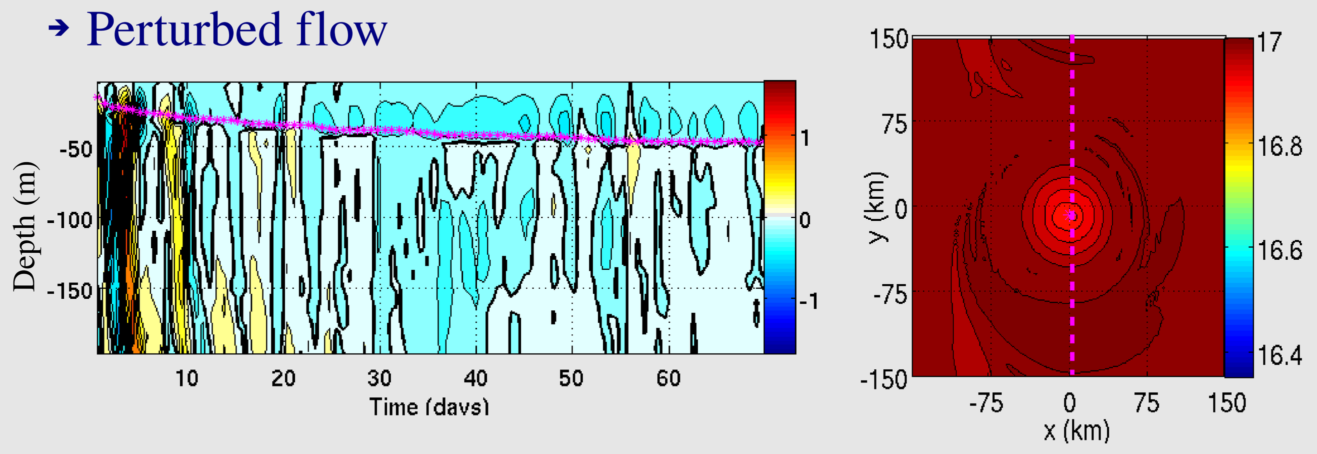
- Idealized representation of the **SWODDY F90a**
- Initialized in temperature, velocities, and free surface elevation
- Initial mixed layer of 32 meters with no horizontal temperature gradient
- Forced with constant eastward 10-meters wind ($u_{10}$ = 10 m.s$^{-1}$)




## *Idealized experiments*

1. Reference experiment (EWR)

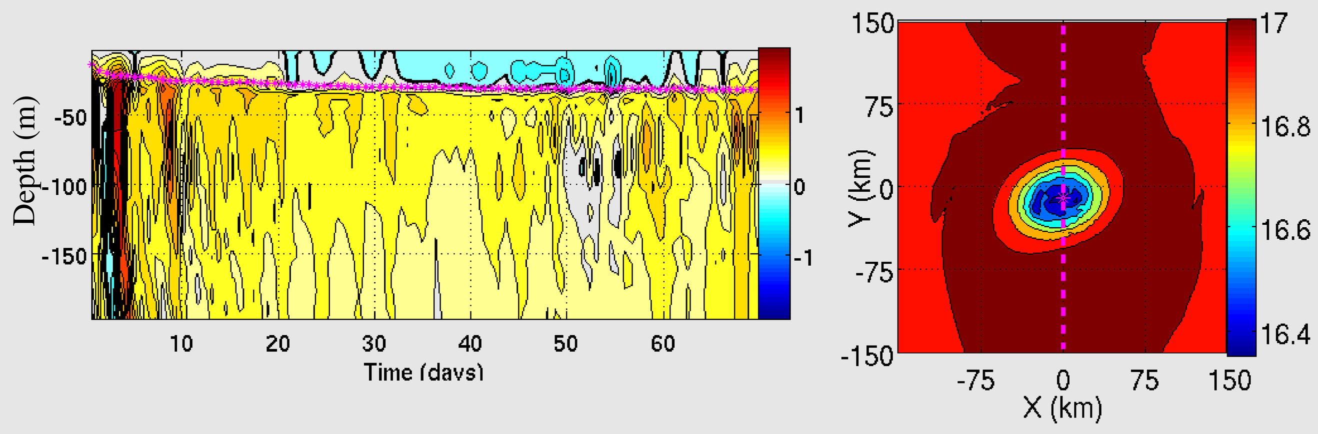
- Usual parametrization of the wind-stress (no eddy/wind interactions (eq. 1))
- ➔ Abrupt initial wind forcing :
  - ➔ Generation of vortex Rossby waves around eddy center and inertia-gravitational waves
  - ➔ Perturbed flow




*Vertical velocities at the eddy center (colorbar) with mixed layer depth (pink) for the 70 days of integration (left) and final SST signature (right) for the reference experiment*

2. Eddy Current/wind experiment (EWC)

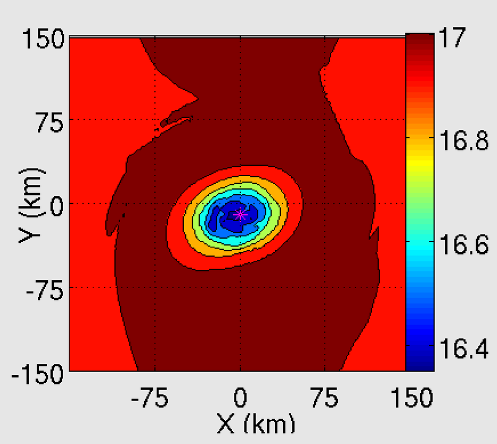
- Modify the wind stress parametrization (eq. 2)
- ➔ Production of **upward vertical** velocities below the mixed layer
- ➔ Upwelling at the center of the eddy → **cold SST signature**




*Vertical velocities at the eddy center (colorbar) with mixed layer depth (pink) for the 70 days of integration (left) and final SST signature (right) for the current /wind interaction experiment*

3. Eddy SST/wind interaction experiment (EWCT)

- No initial SST pattern : add the current/wind interactions into equation 3 to produce a SST signature
- ➔ SST anomaly has much **weaker impact** on eddy dynamics
- ➔ **By a scale analysis, we show that feedbacks of SST on vertical velocities are one order of magnitude weaker than feedbacks of currents**

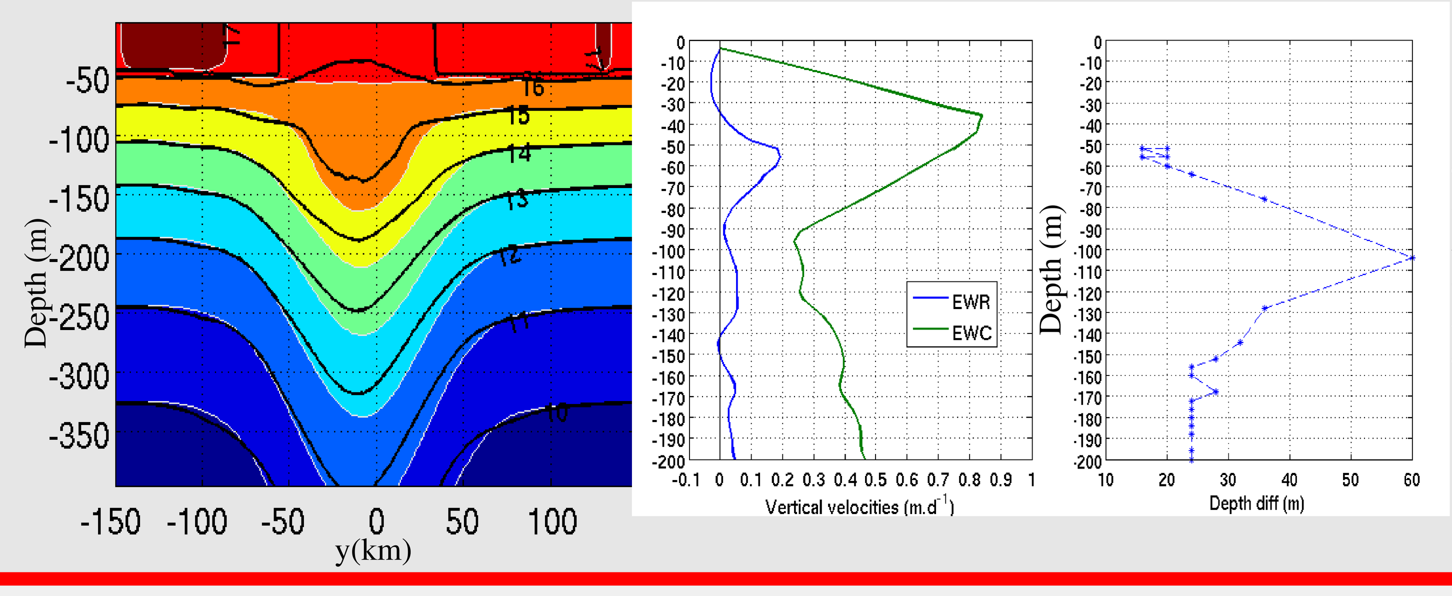



*SST signature after 70 days of integration*

## *EWR vs EWC : impacts of eddy current/wind interactions*

- Sensitive to surface currents feedbacks via eddy/wind interactions, the **relative vorticity** of the eddy **decreases of about 20% in 70 days**, coherent with previous studies[2]
- The SST signature in EWC is related to the **uplift of isotherms** at the eddy center, which is of about 20m from 200-800m (not shown), and reaches 60m below the mixed layer
- The uplift of isotherms is the response of **upward vertical velocities** of about ~0.5 m.day$^{-1}$ at the center of the eddy, reaching ~1 m.day$^{-1}$ at the bottom of the mixed layer

*Final temperature meridional cross-section across eddy center for EWR (color) and EWC (black contours) experiments*




*Vertical velocities (m.day$^{-1}$, left) and isotherms depth difference between EWR and EWC (right) at eddy center in the 200 first meters after 70 days of integration*

## *CONCLUSIONS*

**Reproduction of the observed domed seasonal thermocline and the cool patch of SST above SWODDY F90a center with the use of an idealized simulation**

**Current feedbacks produce upward Ekman pumping at the center of the eddy, intensified at the bottom of the mixed layer**

**Feedbacks of SST on the dynamics of the eddy are much weaker than those induced by surface currents**

**The current/wind coupling via the wind stress is a plausible mechanism to explain plankton blooms in Bay of Biscay SWODDIES**

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