Modelling the intrusions of the Mediterranean Northern Current on the eastern part of the Gulf of Lion's continental shelf

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Introduction

The Mediterranean Northern Current (NC) flows along the Gulf of Lion (GoL) continental slope southwestward from the Ligurian Sea to the Catalan Sea (Fig. 1). The NC sometimes intrudes on the continental shelf (Estournel et al., 2003; Millot and Wald, 1980; Petrenko, 2003; Petrenko et al., 2005). A branch of the NC entering the gulf is considered an intrusion when it flows across the 200m-deep isobath. This study focuses on the **intrusions of the NC** occurring at the **eastern edge of the GoL**.

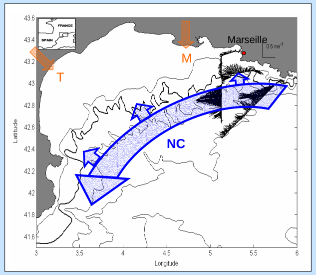
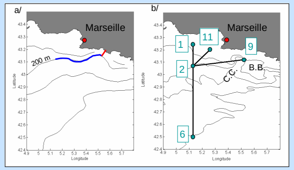


Figure 1: Map of the Gulf of Lion with the NC and its intrusions, and the Tramontane (T) and Mistral (M) winds. Isobathes 100m, 200m (bold), 1000m, 2000m and 2500m are drawn. ADCP currents measured at 24m along 4 GOLTS transects on 03/12/12 are shown in black.

The presence of NC's intrusions in this region has been demonstrated with the 2002-2004 GOLTS cruises current (Fig. 1) and hydrological data. Despite the good coverage of the zone of interest during the cruises, the measured data are not sufficient to understand the generating processes of these eastern intrusions. Thus, **modelling with the 3D circulation Symphonie model** (described by Estournel et al., 2003) has been chosen to study these shelf-edge processes.

Flux calculation

Current flux calculations are used in two ways :



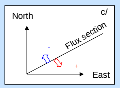


Figure 2: a/ section of flux calculation across 200m-deep isobath (blue) prolongated to the coast (red). b/ GOLTS transects, C.C.: Canyon of Cassis, B.B.: Blauqueires Bank. c/ convention sign for the flux calculation

1. to systematically detect cross-isobath intrusions. The flux calculation is done across the 200m-deep isobath prolongated to the coast (Fig. 2.a).
2. to validate the Symphonie circulation by comparing the simulated and the observed intrusion's flux across specific GOLTS cruise transects (Fig .2.b).

Both methods use the same convention sign : a negative flux means the current is going westward and entering onto the Gulf (Fig. 2.c).

I. Wind forcing and modelled intrusions

Symphonie uses the ALADIN wind forcing on a 0.1°×0.1° grid, every 3 hours. The wind forcing is important in the GoL. The prevailing wind are, by order of high occurence: Mistral and Tramontane (respectively North and North-West winds), Southeast and East winds.

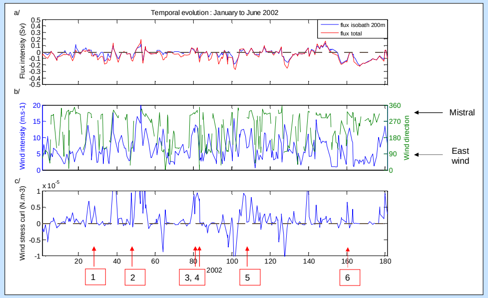


Figure 3: temporal evolution (julian days in the year) of a/ flux intensity across 200m deep isobath (blue) and total flux prolongated to the coast (red), b/ wind intensity and direction, c/ wind stress curl. Red arrows indicate events of the third category of Fig.4.

The temporal evolutions of the currents' flux (method 1 in flux calculation) and of the wind on the first 6 months of the year reveal that these two parameters may be correlated when the wind is blowing at least at 10 m.s-1 (Fig. 3.a and 3.b). Indeed, without any criterion, the intrusion's flux and the wind intensity presents no correlation (r=0.301, with r the correlation coefficient). Whereas when only the data with the wind superior to 10 m.s-1 are selected, the correlation coefficient increases up to 0.736.

The link between **the wind direction and the currents' flux**, considering winds higher than 10 m.s-1, can be resume in three categories (Fig. 4) :

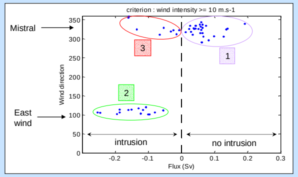


Figure 4: wind direction as a function of the total flux for winds superior to 10 m.s-1. 3 categories can be differentiated.

1. North, North-Western winds export waters from the inner continental shelf (positive flux).
2. East winds are associated with NC's intrusions.
3. North (N), North-Western (NW) winds coincide with NC 's intrusions.

Whereas the first two categories were expected, the third one was surprising. In fact, the wind stress curl (Fig. 3.c) brings an explanation to this striking event. Each time an intrusion is detected during a N-NW wind, the wind stress curl is positive in the intrusion area. In fact, two cases can be differentiated :

3.a. The intrusion already exists. When the N, NW winds appear, the intrusion is maintained for a while before disappearing (Fig. 3 n°6).

3.b. The Mistral is not homogeneous but canalized. Hence, on the eastern side of the wind channel, the positive wind stress curl (Fig. 5) can create a local intrusion (Fig. 3 n°4).

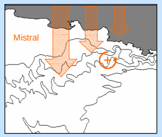


Figure 5: positive wind stress curl

II. Modelling with a downscaling method

The study of the influence of steep bathymetry requires a high-resolution grid to accurately define the canyons of the GoL's slope (Fig. 6) and to better reproduce the small-scale structures. The influence of the general circulation is taken into account through a classic downscalling method using one level of grid nesting.

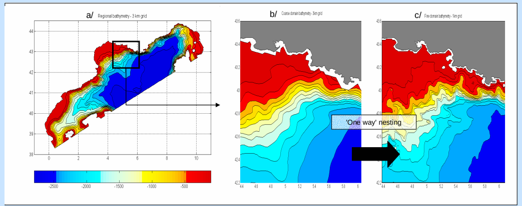
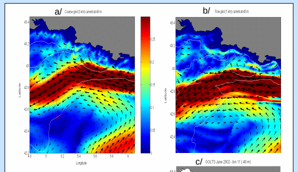


Figure 6: a/ regional bathymetry of the coarse grid, b/ zoom of the regional coarse bathymetry on the zone of grid raffinement, c/ bathymetry of the fine grid.

A realistic simulation of the circulation of the northerwestern Mediterranean Sea was computed with a coarse grid (3km×3km) for the year 2002. The outputs of this large coarse-grid model are used to initialize and to force a high-resolution model (1km×1km) of the GOLTS region at its open boundaries, on selected periods (Fig. 6). These selected periods are chosen to coincide with the GOLTS cruises of 2002 in order to compare the modelled intrusions to the observed intrusions.



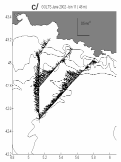


Figure 7: simulated currents (m.s-1) at 48 m on 02/06/15 with: a/ the coarse grid simulation and b/ the fine grid simulation. The Golts cruise transects are in red line. c/ ADCP currents measured at 48m on 02/06/15. Isobathes 100m, 200m, 1000m, 2000m and 2500m are drawn.

Good agreement is obtained with ADCP measurements (Fig.7). The **higher resolution** of the fine grid bathymetry **improves** quantitatively the calculations of **the intrusions' fluxes** (Fig.8). The fine grid simulation decreases the part of the NC that penetrates on the continental's shelf. Indeed, contrary to the coarse grid simulation, the fine grid simulation allows the generation of an anticyclonic eddy on the Blauquieres Bank (Fig. 2) bringing a part of the intrusion eastward (Fig. 7.b). This is consistent with the observation.

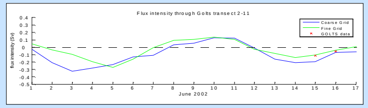


Figure 8: flux intensity (Sv) through GOLTS transect 2 - 11

Conclusion and perspectives

As expected, **East winds** can create intrusions of the NC in the eastern part of the GoL. But N-NW winds have a more complex role. They usually prevent intrusions; but, in some cases, the wind stress curl of **N-NW winds** can also **create intrusions of the NC**. The role of these specific winds will be further studied with sensitivity tests.

The nested finer grid better reproduces the **bathymetric irregularities** of the GoL's continental slope. This improves qualitatively (current comparisons) and quantitatively (flux) the modelling of NC's intrusion by allowing the formation of NC's instabilities. Sensitivity analysis will be done to test the respective influence of the **Canyon of Cassis** and of the **Blauquieres Bank** on these processes. This will allow us to determine whether one of these two topographic accidents or the combination of the two **favour the NC's intrusions**.

Acknowledgements

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