Coastal circulation in the Gulf of Lion, the influence of mesoscale processes on interregional exchanges.

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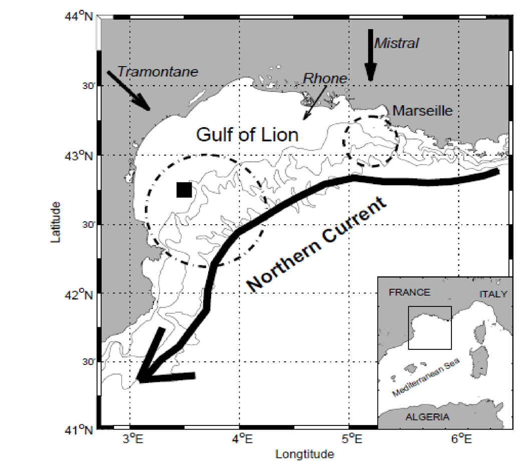
The coastal circulation of the Gulf of Lion has been studied over a ten year period with *in situ*, remote sensing and numerical data. Intrusions, eddies, transient structures and frontal jets can strongly influence water fluxes in and out of the gulf. Transport fluxes as well as horizontal diffusivities are being assessed with data from various *in situ* platforms. All these results bring new understanding on the influence of mesoscale processes on cross-shelf and interregional exchanges.

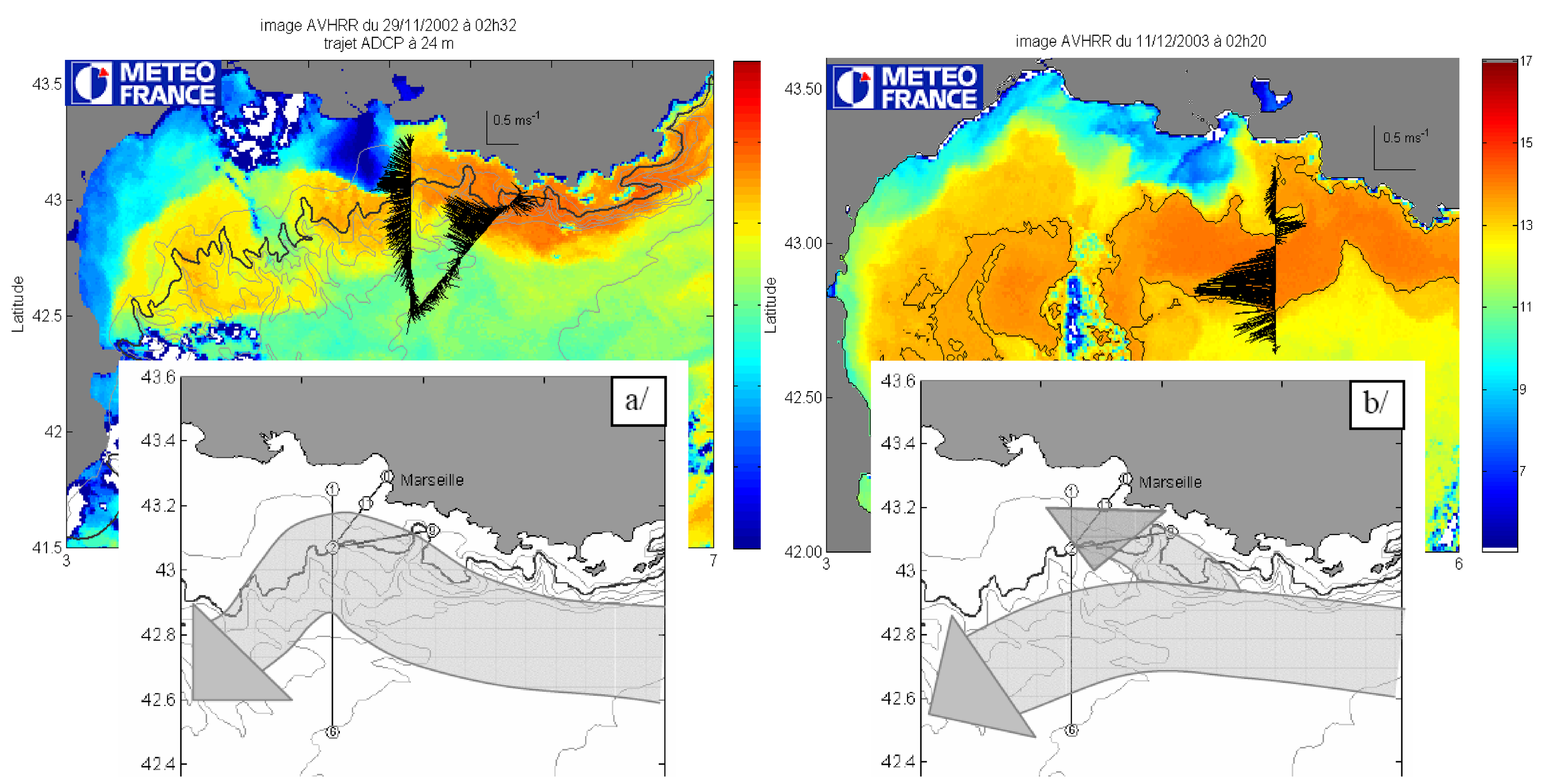
The circulation of the Gulf of Lion (GoL), northwestern Mediterranean Sea, is complex and highly variable [1]. It is strongly influenced by the Northern Current, generally considered to constitute a dynamical barrier along the shelf. Exchanges between the GoL and offshore waters are thought to be induced by processes associated with the Northern Current [2,3]. This poster focuses on mesoscale processes at the eastern and western sides of the GoL, as well as interregional exchanges. The present study includes *in situ* data acquired during SARHYGOL (2000-2001), GOLTS (2002-2005) and LATEX (2007-2011). A realistic 3D numerical model Symphonie is run from 2001 to 2010 at high resolution (1 km) [4].



Area of study: Gulf of Lion; North-western Mediterranean sub-basin

On the eastern side of the gulf,

during specific conditions, a vein of the Northern Current (up to 1/3 of its measured flux) can intrude on the shelf. Both *in situ* measurements and numerical modelling show that intrusions develop either as a part of the NC itself encroaching on the shelf or as a separated branch of the main vein of the NC. These two types of intrusions can change from one type to the other, both in time and in space.



a) Enchoaching of the NC on the shelf; top: AVHRR image and ADCP data measured at 24 m on Nov. 29, 2002. b) Intrusion separated from the NC core by a barotropic eastward current; top: AVHRR image and ADCP currents measured at 24 m on Dec 11, 2003 (Courtesy, Gatti's thesis, 2008).

Three kinds of wind events are likely to generate intrusions: the Mistral cessations, episodes of inhomogeneous Mistral or periods of East winds. In the first two cases, intrusions are due to the inhomogeneity of the wind event. The intrusions during East wind could be due to two processes: the Ekman drift and the shift of the current's core towards the coast. Otherwise, intrusions cannot develop during homogeneous Mistral.

Other factors, such as the vertical and horizontal extents of the NC as well as its degree of mesoscale instability, can also influence the development of intrusions. However, neither the NC seasonal variability nor the variation of the GoL's water budget have an impact on the occurrence of intrusions.

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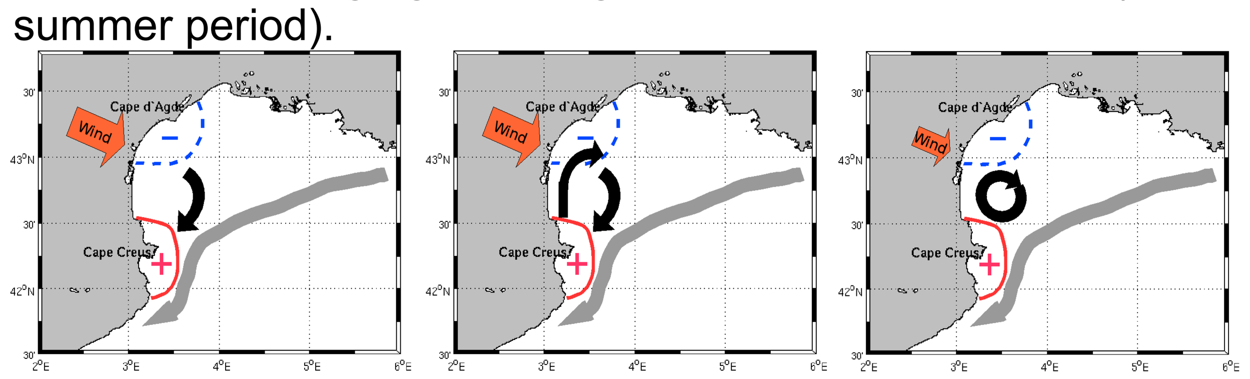
On the western side,

wind conditions can affect whether the current enters or exits the gulf [5]. In stratified conditions, intrusion of the NC at this end of the continental shelf can only occur during homogeneous northwesterly wind. During all other wind conditions (homogeneous northerlies, channelled northwesterlies or northerlies, combination of both), water exits from the gulf.

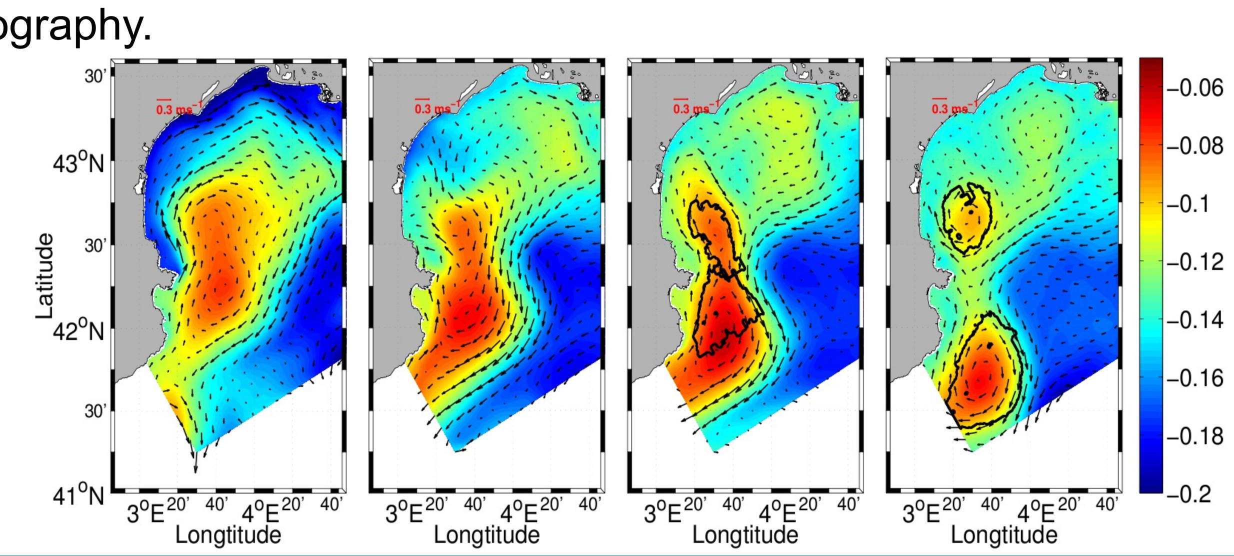
During stratified summer conditions, elliptical, shallow, anticyclonic eddies are observed North of Cape Creus [6,7], generally following northwestern wind events [8]. Two different generation processes can create them [9,7]. In both cases, the local topography, characterized by a curvilinear shape and the presence of a cape (Cape Creus), plays an important role.

First generation process [9] - Eddies are generated through a process that requires both: i) strong channeled wind forcing, generating Ekman transport and ii) strong stratification (as in the summer period).



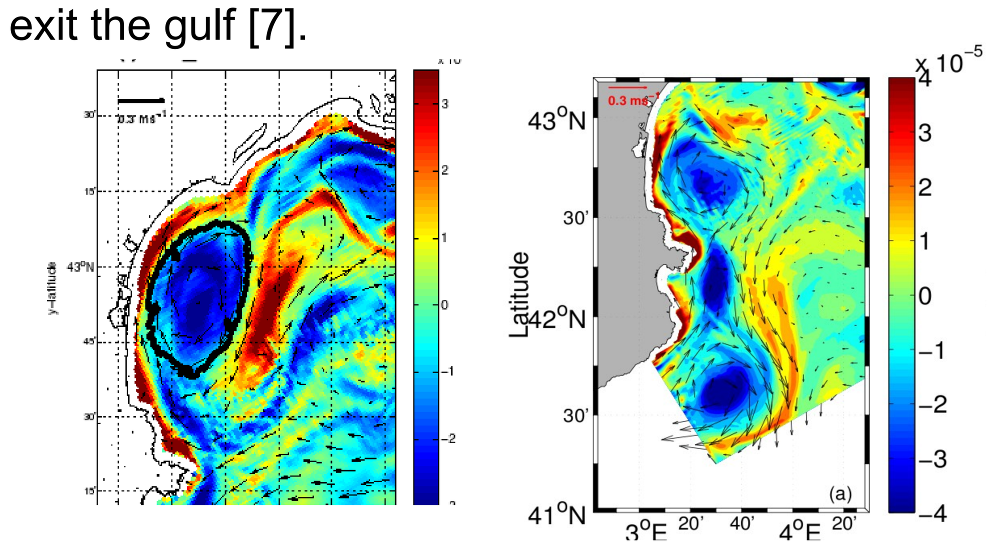
Second generation process [7] - This process requires the presence of a rather large anticyclonic circulation in the northwestern part of the GoL as well as a strong meandering activity of the NC. The latter "pushes and pinches" the anticyclonic structure against the topography.

The anticyclonic structure separates into two eddies: the northern one (e.g. Latex09 eddy) and a southern one in the Catalan basin (hereafter refered to as Catalan eddy).



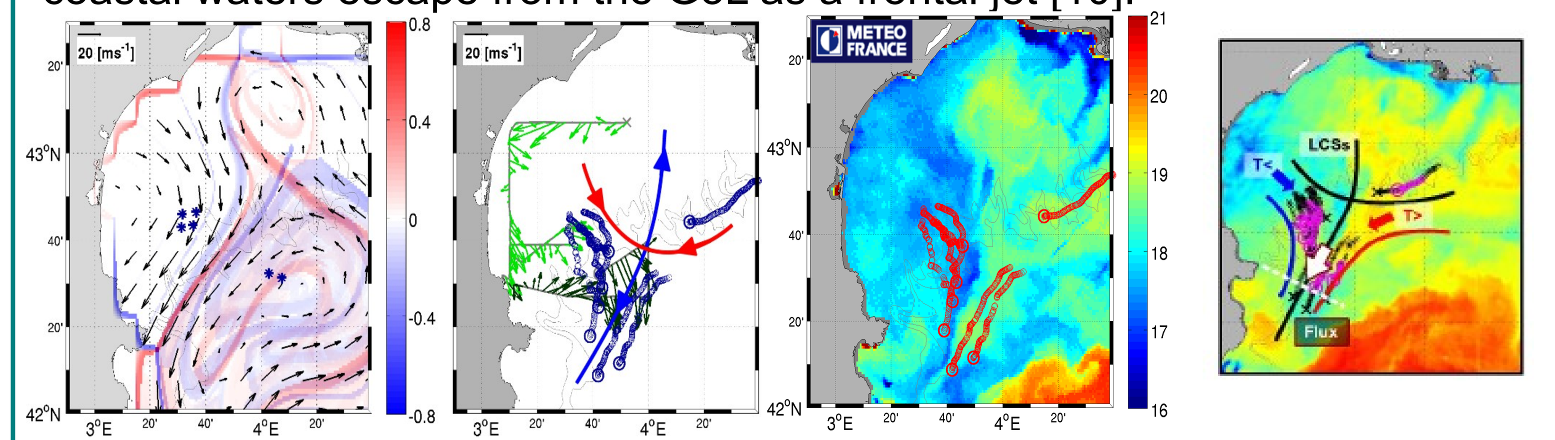
Interregional exchanges

- Generally eddies are associated with water retention; however, transient structures can also detach from them and rapidly exit the gulf [7].



Modeled relative vorticity and horizontal currents at 20m depth (left) case of water retention in Latex A1_2008 eddy, on July 2008 (right) case of a transient structure originating from the LatexA2_09 eddy and « feeding » the Catalan eddy; Sept. 3, 2009 [7].

When no eddies are present, frontal structures can develop detected via Lagrangian Coherent Structures (LCS) analysis. During the LATEX 2010 cruise, coastal waters escape from the GoL as a frontal jet [10].



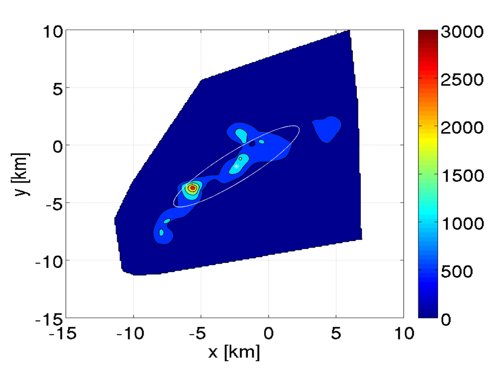
From left to right: altimetry-derived LCSs, *in situ* LCSs based on ADCP data and Lagrangian drifters' trajectories, AVHRR SST and Lagrangian trajectories, summary of the frontal jet with coastal cold waters on the west and NC warm waters on the east.

Transport fluxes associated with the jet are assessed (0.45 Sv), as well as horizontal diffusivities. The latter are estimated using two approaches:

i) combining stirring rates with surface temperature gradients $K_H=\frac{\gamma}{2C_3^2}$ with γ the strain rate calculated from the Lyapunov Exponent analysis of the Lagrangian drifters and C_3 estimated from the surface temperature (or salinity) profiles accross the front (x direction) fitted with [Nencioli et al., in revision]:

$$T(x)=C_1+C_2 erf(C_3(x-C_4)) \text{ with } C_1=\frac{T_1+T_2}{2}, C_2=\frac{T_2-T_1}{2}, C_4=x_0.$$

ii) mapping a passive tracer (SF6)'s dispersion, $K_H=\sigma_w^2\delta$ with δ the strain rate (function of the increase of the patch's length) and σ_w the width of the patch [Kersale et al., in revision]. Mean values obtained are i) 4.06 $m^2.s^{-1}$ ii) 7.6 $m^2.s^{-1}$



SF6 mapping on Sept. 12, 2010

These mesocale processes (intrusions, eddies, transient structures, fronts) have an influence on interregional exchanges that can have strong impacts on biogeochemical and biological systems.

Bibliography
[1] Millot, C. (1990), The Gulf of Lions' hydrodynamics, Cont. Shelf Res., 10, 885–894, doi:10.1016/0278-4343(90)90065-T.
[2] Flexas, M. M., X. Durrieu de Madron, M. A. Garcia, M. Canals, and P. Arnau (2002), Flow variability in the Gulf of Lions during the MATER HFF experiment (March-May 1997), J. Mar. Sys., 33-34, 197–214, doi:DOI: 10.1016/S0924-7963(02)00059-3.
[3] Petrenko, A. A., Y. Leredde, and P. Marsaleix (2005), Circulation in a stratified and wind-forced Gulf of Lions, NW Mediterranean Sea: in situ and modeling data, Cont. Shelf Res., 25, 7–27, doi:10.1016/j.csr.2004.09.004.
[4] Hu, Z. Y., A. A. Doglioli, A. M. Petrenko, P. Marsaleix, and I. Dekeyser (2009), Numerical simulations of eddies in the Gulf of Lion, Ocean Model., 28 (4), 203 – 208, doi:10.1016/j.ocemod.2009.02.004.
[5] Petrenko A., C. Dufau and C. Estournel (2008), Barotropic eastward currents in the western Gulf of Lion, north-western Mediterranean Sea, during stratified conditions. J. Marine Syst., doi:10.1016/j.jmarsys.2008.03.004
[6] Hu, Z. Y., A. A. Petrenko, A. M. Doglioli, and I. Dekeyser (2011a), Study of mesoscale anticyclonic eddy in the western part of the Gulf of Lion, J. Mar. Sys., 88, 3–11, doi:10.1016/j.jmarsys.2011.02.008.
[7] Kersalé, M., Petrenko, A.A., Doglioli, A.M., Dekeyser, I., Nencioli, F. (2013), Physical characteristics and dynamics of the coastal Latex09 Eddy derived from in situ data and numerical modeling. J. Geophys. Res., Vol.118, pp.1-11, doi:10.1029/2012JC008229
[8] Millot, C. (1982), Analysis of upwelling in the Gulf of Lions - Hydrodynamics of semi enclosed seas: Proceedings of the 13th International Li`ege Colloquium on Ocean Hydrodynamics., vol. 34, 143-153 pp., Elsevier Oceanogr. Ser., Amsterdam, The Netherlands.
[9] Hu, Z. Y., A. A. Petrenko, A. M. Doglioli, and I. Dekeyser (2011b), Numerical study of eddy generation in the western part of the Gulf of Lion, J. Geophys. Res., 116, C12030, doi:10.1029/2011JC007074.
[10] Nencioli, F., F. d'Ovidio, A. M. Doglioli, and A. A. Petrenko (2011), Surface coastal circulation patterns by in-situ detection of Lagrangian coherent structures, Geophys. Res. Lett., 38 (L17604), doi:10.1029/2011GL048815.