ACTION INTERORGANISME SUR PROJETS

Les Enveloppes Fluides et l'Environnement

Demande de financement

La demande de financement doit parvenir **par courrier électronique à : pascale.ebner@cnrs-dir.fr**. L'envoyer en format DOC, en document attaché, nommé, avec les informations minimum suivantes : LEFE-ACTION-nom du responsable scientifique **N.B. Un exemplaire (imprimé recto-verso, simplement agrafé) signé par le directeur de laboratoire doit parvenir par courrier postal** à Pascale Ebner - INSU - BP 287-16 - 75766 Paris cedex 16

ACTION (S) CONCERNÉE(S) (cocher la ou les cases dont relève le projet)

Chimie Atmosphérique (CHAT)

Evolution et variabilité du climat à échelle globale (EVE)

☒ **Cycles biogéochimiques, Environnement et Ressources (CYBER)**

☒**Interactions et Dynamique de l'Océan et de l'Atmosphère (IDAO)**

Assimilation de données

Ce projet est-il aussi soumis au Programme National de Télédétection Spatiale (PNTS) :

Oui - ☒ **NON**

Ce projet est-il aussi soumis à d'autres programmes nationaux ? **NON**

Si oui, indiquez lesquels (PNTS, ECCO, TOSCA…) :

Statut du Projet (nouveau, déjà engagé) : **suite du projet pilote LATEX00 (2007)**

TITRE DU PROJET

LATEX (LAgrangian Transport EXperiment)

Responsable scientifique du projet (nom, prénom et qualité) :

PETRENKO Anne (MCF), DIAZ Frédéric (MCF)

Laboratoire du proposant (intitulé, appartenance, adresse et téléphone, e-mail) :

Si le laboratoire est associé au CNRS, indiquer explicitement les nom et prénom du Directeur du Laboratoire, les références de la formation CNRS de rattachement (n° UMR ou UPR, etc...) :

Laboratoire d'Océanographie et de Biogéochimie – UMR 6535, Directeur : Pr. Bernard QUEGUINER

Résumé du projet, résultats attendus, calendrier:

The LATEX project aims to study the influence of the coupled physics and biochemistry dynamics at (sub) mesoscales on the matter and heat transfers between the coastal zone and the open ocean. This aim corresponds to one of the priority listed by IDAO and CYBER ("Matter and energy transfer (…) at the interface between the continental slope and the coastal margin", Theme 3 of CYBER and 2 of IDAO). Mesoscale and sub-mesoscales hydrodynamic features, taking place at the interface between the continental slope and the coastal margin, are part of the processes that are important for the understanding of transfers between the coastal zone and the open ocean. Nonetheless, these processes are still not fully known. Indeed, at these scales, the influence of the physical processes on biogeochemistry is clearly shown in numerical studies. But confirmations by experiments are difficult, and hence rare, because experiment strategies generally differ greatly whether they are oriented towards a physical study or a biogeochemical one.

For the last 10 years, the LOB has been PI in a number of national projects which have included cruises in the Gulf of Lion (Moogli, Sarhygol, Golts, Golts/Argol, Ecolophy/Colargol). But the strategy of these cruises was oriented either towards physics or biogeochemistry. Now the LOB proposes a new experimental strategy to do a real coupled hydrodynamic and biogeochemical experiment. **The LATEX strategy is based on a combined use of satellite data, numerical modelling and Eulerian and Lagrangian *in situ* measurements (Lagrangian buoys and a tracer experiment).** The main objective of LATEX is to study the impact of a (sub) mesoscale eddy structure –present in the western part of the Gulf of Lion- interacting with the Northern Current (NC) on the evolution of conservative or biogeochemical tracers' distributions. Thanks to this study, questions such as the following ones will hopefully be answered: Do these structures facilitate the horizontal transfer across the continental slope and the slope current? What are the consequences on biogeochemistry of the interaction of the structure with the NC? What are the roles of such (sub)mesoscale coastal eddies in the structuring of the plankton community and primary production variability observed in the study area? Is the matter transferred by the (sub)mesoscale structures significant compared to the matter transferred by the general circulation over seasonal or annual scales?

LATEX, a 3-year project (2008-2010), is based on the emergence of a new experimental and interdisciplinary approach, both components favoured by the LEFE AO. It follows the pilot project LATEX00 (2007), which results are very satisfactory and detailed in Annexe 4.

LATEX will concentrate on the three following points:

• Part 1 – Increase our knowledge on the (sub) mesoscale eddies of the western side of the Gulf of Lion :

During Latex00, we have analysed Symphonie numerical outputs with the numerical software WATERS (Wavelet Analysis for Time-tracking Eddies) in order to identify eddies and have been able to confirm their presence on satellite images (See Annexe 4). Now we plan to correlate their generation and evolution to meteorological and topographic forcings. Moreover the Latex00 analysis was only done at one vertical level (20 m; apart for one anticyclonic eddy in 2001 that has been studied completely) and we plan to study the entire vertical structure of all selected eddies.

To achieve this task, the high resolution Symphonie model will be implemented on the COM cluster. The off-line numerical tool Ariane, already coupled with Symphonie during Latex00, will provide information about lagrangian numerical trajectories. Symphonie will also be coupled to the biogeochemical model Eco3M-MED, which is a multi-nutrients multi-functional plankton group (mNmFG) model, recently built and validated for the North-western Mediterranean basin (Herrmann, 2007). In this first part, the coupled model will be used as a diagnostic tool to assess the hydrodynamic mechanisms associated to the (sub)mesoscale structures probably at the origin of the plankton and primary production patchiness observed in this study area. The eddy structures of the Gulf of Lion will also be studied with satellite imagery, both in the visible and with altimetry (new treatment techniques are being developed for coastal uses; F. Birol).

• Part 2 - Coupling physics and biogeochemistry in a lagrangian approach.

The main objective of LATEX is to better understand the coupling between physics and biogeochemistry at (sub)mesoscales. This includes the effect, on biogeochemical processes, of horizontal and vertical motions associated with an eddy structure. Our knowledge of the impact of (sub)mesoscale eddies on biogeochemistry has largely emerged from modelling works. Very recently, few field studies (Benitez-Nelson 2007, McGillicuddy 2007) have also successfully addressed this issue but more is still to be done, particularly in coastal waters. Within this general context, biogeochemical studies during LATEX will focus on:

1) The determination and evolution, within the eddy structure, of the rate μ (in d^{-1}) of biogeochemical processes, mainly net community, gross primary production and ^{13}C primary production. This will be compared to the strain rate γ (in d^{-1}) estimated from SF_6 and drifting buoys. This will allow us to better understand how these biological and physical processes compete in the accumulation of biomass.

2) The observation of short term and/or (sub)mesoscale variations of some parameters (oxygen and carbon) which will be interpreted in the context of the 3D dynamical environment.

3) The construction of budgets for these elements within the eddy structure.

We will track the chosen (sub)mesoscale eddy with complementary methods:

- Floating buoys
- Dispersion of a conservative tracer (SF_6)
- 3-D mapping of the eddy and ambient circulation with gliders
- Classical survey of physical and biogeochemical parameters
- Surface synoptic mapping of non conservative tracer (e.g., Chl a or SST) from satellite observation

- **Part 3 - Quantification of the coast-offshore exchanges for the process studied during the Lagrangian survey and comparison with the matter and energy fluxes obtained with numerical coupled physical – biogeochemical modelling**. **Extrapolation of the transport budget by eddies at the seasonal and annual scales.**

The first goal of this part is to obtain a correct numerical representation of the studied (sub)mesoscale structure in terms of physical and biogeochemical patterns observed during the lagrangian survey. Hence, a realistic simulation of the whole 2009 year will be made. The simulated period of the lagrangian survey (September 2009) will be compared with *in situ* and satellite imagery data sets. Sensitivity analyses will be made by testing the variability associated with the range of Fhor and Fver calculated from *in situ* measurements. Secondly, the coupled model will enable us to characterize (dissolved and/or particulate) and quantify the organic matter transported by the (sub)mesoscale structure during the survey. A budget of the air-sea exchanges of O_2 during the survey will also be given by the coupled model and will allow us to know if the studied structure is a net source or sink of carbon over the experimental period. Thirdly, the realistic simulation made over the whole 2009 year will permit the extrapolation of the transports of matter and energy due to the interaction of coastal (sub)mesoscale eddies with the Northern Current at the seasonal and annual scales and the comparison of these results to the transport attributable to other coast-offshore exchanges or large scale circulation.

Time Table
2008-2010

	2008				2009				2010			
	Jan – Mar.	April - Jun	July - Sep	Oct - Dec	Jan – Mar.	April - Jun	July - Sep	Oct - Dec	Jan – Mar.	April - Jun	July - Sep	Oct - Dec
T0		P1			P2				P3			
T1												
T2												
T3												
T4		-------	T		-------	-------	LAT					
T5												
T6												
T7												

Task 0: P1= Kick –off meeting in May 2008; participation to the TWISTED meeting (PI: M. Levy) in June 2008; P2 = Cruise preparatory meeting in March 2009; P3 = Post-cruise workshop in Jan 2010,
Task 1 (T1): Analysis of satellite data, wind forcing and vertical structure of eddies in the Gulf of Lion,
Task 2 (T2): Implementation of Symphonie, Ariane, and coupling Eco3M,
Task 3 (T3): Development of the O_2 module,
Task 4 (T4): T: trial at sea during a 6 day cruise in September 2008; LAT: the LATEX cruise of September 2009, and their respective preparatory periods
Task 5 (T5): Follow-up of the implementation at LOB of the analysis of SF_6 by GPC-CED to be used during LATEX and design of the tracer dispersion system,
Task 6 (T6): Analysis of the data from the cruise – Models Validation and assessments of modelled and data-based budgets,
Task 7 (T7): Publications – Special session

Mots clés: Lagrangian survey, buoys, eddies, SF_6 tracer, matter transfer

Durée du projet : 3 ans

Budget détaillé demandé au programme LEFE et aux autres financements (€ HT)**:**

	2008	2009	2010
FINANCEMENTS DEMANDES AU PROGRAMME LEFE			
Fonctionnement	3820	33000	15500
Missions	15900	10650	24500
Analyses		20044	
Petit équipement	85800	24900	
Equipement mi-lourd			
Total demandé à LEFE	105520	88594	40000
AUTRES FINANCEMENTS DEMANDES ou OBTENUS (préciser) Financements de la Région PACA et BQR université obtenus en 2007 voir Annexe 4			

Instruments Nationaux sollicités :
2 largueurs et 2 balises Argos

Equipements mi-lourds demandés :
aucun

Services d'observation dont le projet utilisera les données :
Monitoring of the MOLA station

Demande de labellisation de bourses post-doctorales ou doctorale :
French PhD scholarship proposed by F. Diaz – see Section 4 p22.

Nombre de personnes collaborant au projet (en équivalent temps plein – indiquer la ventilation par année**) :**

33 personnes collaborant au projet, pour un équivalent temps plein de 675%

Personnel détaillé (% sur le projet), par laboratoire, et fonction dans le projet:

NOM	LABO.	FONCTION	Participation au projet		% Participation à d'autres programmes (INSU, EUROPE, ANR)
			% part	Expertise	
Blain, Stéphane	LOB	PR	15	SF_6 and O_2 determination	25 IPSOS-SEAL (ANR VC)
Diaz, Frédéric	LOB	MC	40	Eco3M-MED, coupled modelling	Bioprhofi 10, Boum 20, Chaccra 15, ICARE 15
Doglioli, Andréa	LOB	MC	50	Physical modeling and data analysis	30 LAPLACE
Fuda, Jean-Luc	COM	I mer	15	ADCP, moorings, software	15 BOUM, 15 EGYPT, 30 HydroChanges, 10 Massilia
Petrenko, Anne	LOB	MC	50	Data analysis, model validation	10 LAPLACE, 20 Massilia
Rimmelin, Peggy	LOB		35	SF_6 conception of the dispersion system and analysis	25 BOUM, 15 RetroBGM
Queguiner Bernard	LOB	PR	20	Biogeochemical data analysis	20 MERMEX
Rougier, Gilles	LOB	IE	30	ADCP, moorings, lagrangian buoys, Iridium communication	15 Massilia, 20 Toliara, 15 HydroChanges, 10 BOUM, 20 EGYPT
Baklouti, Melika	LOB	MC		X, Eco3M-MED	
X	LOB	PhD	100	Coupled modelling	
Hu, ZiYuan	LOB	PhD	100	Physical modelling	
Physique					
Marsaleix, Patrick	POC	CR	15	Physical modelling	Colargol 20
Blanke, Bruno	LPO	CR		X, implementation Ariane	GLAMOC (LEFE/EVE) 20
Grima, Nicolas	LPO	IR	15	Ariane implementation	Interup 30
Testor, Pierre	LOCEAN	CR	10	gliders, méditerranée occidentale/(sub)mésoéchelle	40 ANR/LEFE
Mortier, Laurent	ENSTA	MC		X, gliders, méditerranée	40 ANR/LEFE
Birol, Florence	LEGOS	IE	10	Coastal altimetry	Dycomed 40 ($\in$ OSTST 50)
Dumas, Franck	Ifremer	IE		X, tests Lagrangian buoys	
Griffa, Annalisa	CNR Italy	PR RSMAS Miami		X, Lagrangian spin	
Biogéochimie					
Aquilina, Luc	Geo. Re.	PR		X, SF_6 analyses	
Labasque, Thierry	Geo. Re.	IE	10	X, SF_6 analyses	
Claustre, Hervé	LOV	DR	10	Biogeochemistry gliders	
D'Ortenzio Fabrice	LOV	CR	10	Biogeochemistry gliders	
Bourrin, François	LOV	IR	25	Biogeochemistry gliders	
Bosc, Emmanuel	IAEA	CR	15	Satellite visible imagery	
Boutin, Jacqueline	LOCEAN	CR	10	Carioca data	EU IP CARBOOCEAN 45, SMOS-TOSCA 45
Pujo-Pay, Mireille	LOBB	CR	15	Carbon stocks and fluxes	Chaccra 15, Medea 10, Boum, 15, Sesame 10
Conan, Pascal	LOBB	MCF	15	Primary production	Chaccra 20,Sesame 10
Oriol, Louise	LOBB	AI	10	Carbon stocks and fluxes, Primary production	Chaccra 15, Medea 20, Boum, 15, Malina 10
Caparros, Jocelyne	LOBB	IE	15	Carbon stocks and fluxes, Primary production	Chaccra 15, Medea 20, Sesame 10
Obernosterer, Ing.	LOBB	CR1	15	Net/Gross Community Production and Dark Community Respiration, Calibration of O_2 sensors	MEDEA 50
Catala, Philippe	LOBB	AI	10		MEDEA 20, BOUM 25
Batailler, Nicole	LOBB	TCS	10		MEDEA 15, INDHYC 20
	TOTAL équivalent temps plein		675		

DOSSIER SCIENTIFIQUE
(Maximum 10 pages)

S'il s'agit de la continuation d'un projet ayant déjà été sélectionné par un programme INSU, indiquer dans cette partie de façon succincte les résultats obtenus et les articles soumis ou déjà publiés.

1. Intérêt scientifique

1) The coastal-offshore transfer

The coastal waters, in spite of their small surfaces and volumes (8% and 0.05% of the global ocean, respectively) are currently the object of crucial questions. This environment is the link between continents -under the pressure of human presence and their associated activities (40% of the world population live at less than 100 km of coast lines)- and the ocean, which is the main thermal and biogeochemical control of the Earth. The coastal domain then gathers crucial questions on both environmental management and functioning of the geosphere/biosphere system. The coastal zone is usually characterised by a high biological productivity due to a large availability in nutrients coming from the human or/and river inputs. Thus the coastal areas may contribute to an important part of the carbon sequestration in the deep ocean. 18 to 33% of the global primary production (Wollast, 1991), 80% of the organic matter sequestration in sediments and 90% of the global mineralization in the marine sediments are observed in these zones (Mantoura et al., 1991). The latter estimations provided at the Dahlem Conference in 1991 highlight the potential importance of the coastal areas in the global carbon budget but they have still required to be clarified. Therefore, since this conference, several international programmes (LOICZ, ELOISE) have been dedicated to the study of the areas and have tried to establish what the status of the coastal zone is: a source or a sink of carbon in the global ocean. The work syntheses of the latter programmes usually show that this question does not admit a single answer due to the diversity of coastal systems and the intricacy of the processes involved. The origin and the fate of the organic matter, its use by the trophic web, its sediment sequestration or export to deep ocean are a few of the many questions for which quantitative answers remain to be given.
These uncertainties mostly lie on the intricacy to characterise and quantify the matter transfer that can exist between the coastal and offshore domains and *vice versa*. The hydrodynamic processes able to exchange matter between the two latter domains are numerous: dense water formations, coastal upwelling, mesoscale instabilities of the continental slope current and internal waves, and are well reported (Huthnance, 1995). However, the dynamic of exchange (transport and mixing of water masses, temporal and spatial scales, exchanges timing) are well less known. This lack of knowledge on the exchange dynamics is mainly attributable to the difficulties in (1) acquiring *in situ* biogeochemical and physical data at both very high spatial and temporal resolutions and (2) simultaneously studying the hydrodynamic processes and biogeochemical processes at the meso- and submeso-scales. The numerical modelling and some new sampling tools (gliders, AUV…) currently offer the ability to catch the dynamic scales of the exchange processes.

2) Coastal-offshore exchanges in the Gulf of Lion

The exchanges between the Gulf of Lion and the western Mediterranean strongly depend on the presence of the Northern Current that flows along the continental shelf slope (Millot, 1990; Millot, 1999). The structure and variability of the Northern Current at the seasonal scale has been already well studied (Albérola and Millot, 1995; Petrenko, 2003; Sammari and Millot, 1995). At these temporal scales, its role in the transfer of matter fluxes has also been depicted (Durrieu de Madron et al., 1999). When the Northern Current is considered as being in geostrophic balance, it can act as a barrier along the shelf slope that blocks the coastal water masses on the shelf. An ageostrophic process will involve some transient alterations of the latter simple situation, and exchanges between the coastal waters and the meso-scale circulation. Intrusions of the NC on the continental margin typically occur at certain locations of the continental slope following specific wind conditions (Estournel et al., 2003; Petrenko et al., 2005; Petrenko et al., 2007). At the western side of the gulf, three types of circulation are observed: - currents flow southward towards the Catalan Sea, - no exchange occurs between the Gulf of Lion and the NC, - the NC intrudes on the shelf. This latter case seems to be more rarely observed (during stratified conditions, it occurs only after homogeneous tramontane, Petrenko et al., 2007).

Wavelet analysis technique (WATERS applied on relative vorticity, See Section 3 and Annexe 4 for more details) have shown that, during stratified conditions, there is a high probability for an eddy structure (Figure 1) to be present in the western side of the gulf.

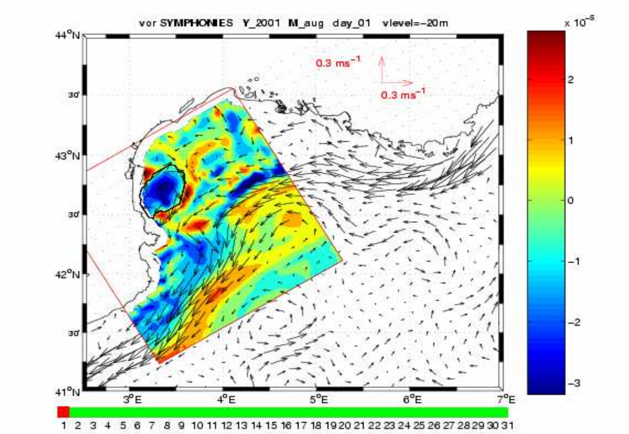


Figure 1: *Anticyclonic eddy A1 on August 1st; A1 was detected for 32 days from July 17, to August 18, 2001*

Indeed, in this area, both the curl of the wind stress (channeled tramontane) and the influence of the interior edge of the NC seem, very often, to be favorable to anticyclonic motions.

And, at least during the months studied in Latex00 (July to October), anticyclonic eddies turned out to be quasi permanent features. Indeed, the anticyclonic eddies observed at 20-m depth survived through very diverse wind conditions, even some which curls were opposed to anticyclonic eddies. Nonetheless, no correlation between the wind forcing and the eddy generation could be established on the limited amount of simulations studied up to now, so more work (definition of the 3D structure of anticyclonic eddies, multi-annual and high resolution new simulations, statistical analysis of wind forcing) is proposed to be done in Latex.

The studied area is also interesting because it is an area where downwelling can be observed (Millot, 1979). Hence it will be interesting to study the potential link between the coastal downwelling and the eddy. At times, filaments from the Rhone distal plume can also be entrained in this zone. The interaction of such filaments with the structure could bring nutrients and phytoplankton inside the eddy. Direct measurements and modeling of such events would be particularly interesting.

Otherwise, these anticyclonic eddies generally interact at some point with the Northern Current during their life time. Such interaction with the «outside» is generally considered to occur only at the end of the eddy's life when the anticyclonic structure collapses. In the few examples studied in Latex00, some interactions with the NC happened without being fatal to the anticyclone (e.g., August 10,11 and 13, 2001 for A1 –Figure 2- A1 "dies" between August 18 and August 23). But, as was written before, more work need to be done to understand and evaluate the exchange between the eddy and the NC, and check, for example, whether this interaction is fatal to the eddy or not.

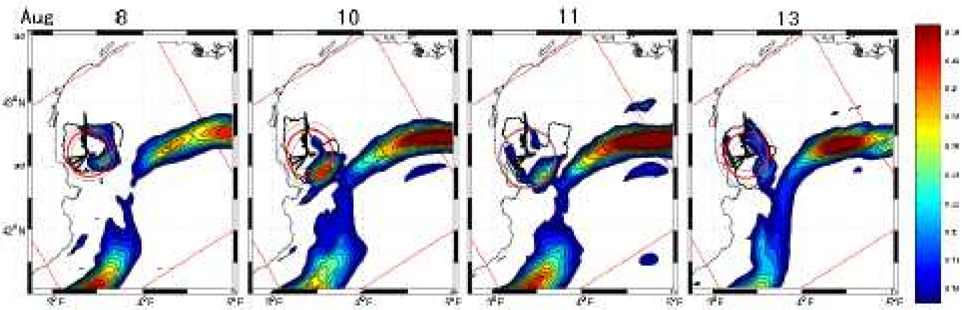


Figure 2: *Position of the anticyclonic eddy A1 (black line), with its mean diameter in red; velocity are contoured in color when superior to 15 cm/s, hence generally indicating the path of the NC.*

The impact of these coastal eddies on the biological activity and on the coastal-offshore transfer of matter has not been studied in this region up to now. The HFF experiment performed in the framework of the European program MATER tried to resolve this question for baroclinic instabilities of the NC (Flexas et al., 2004). The meso-scale activity of the NC in the eastern part of the gulf was clearly showed on the current measurements (Flexas et al., 2002) and on some biogeochemical parameters (Diaz et al., 2000). However it was not possible to firmly show the link between the latter two processes. In the same manner, the assessment of a carbon budget (Van Wambeke et al. 2002) over the area at a monthly scale clearly shows an unbalance due to transfers inside and out of the study zone with the inability to accurately quantify these transfers.

3) Tracer experiments

In the ocean, the spatial scales of mesoscale processes range from a few kilometers to about a hundred kilometers. The structures generated by mesoscale processes play a key role in the ocean dynamic, in the heat transport and in the biogeochemical fluxes controlling biological activity. Mesoscale hydrodynamic features started to be studied in the 60s, but their extent and importance have really been revealed by satellite images of Sea Surface Temperature (SST), Ocean Color (CZCS and following sensors), altimetry (TOPEX-Poseïdon, Jason…), and also by lagrangian floats (Reverdin, 2001). With the appropriate space resolution, numerical studies show the importance of these processes, particularly when coupled with biogeochemical processes, at the scales either of ocean basins (Oschlies and Garçon, 1998, McGillicuddy, 1998)) or of fronts (Lévy, 2003).

From an experimental point of view, characterizing and evaluating the impact of mesoscale activities on biochemistry remain hard tasks. Eddies and fronts have been studied extensively, in the open ocean, in French national programs such as: ANTARES4, ALMOFRONT or POMME. A good resolution of mesoscale features is obtained thanks to towyos (e.g., Seasoar) which, together with hull-mounted ADCP, provide a detailed description of the main hydrological and physical parameters and of a few optical and biogeochemical ones. But studies of specific biogeochemical processes generally depend on a eulerian network of stations, or on pseudo-Lagrangian stations (of relatively short periods). This difference in approach remains a major pull-back in experiments which aim at coupling physics and biogeochemistry and at comparing the results with theoretical or modelling studies. A recent study of a frontal zone in the North Atlantic (Allen et al., 2005) shows the impacts of vertical mesoscale circulations on primary production but also stresses the difficulties linked to the non synopticity of the sampling.

Mesoscale turbulence in the ocean is characterized by the presence of mesoscale eddies and sub-mesoscale filaments. The spatial limit between mesoscale and sub-mesoscale is arbitrary; Lévy* (in press) uses the range 20-100 km for mesoscale and 2-20 km for sub-mesoscale. Hence the terminology (sub)mesoscale refers to the range 2-100 km.

Vertical (sub)mesoscale circulation has an important role on heterogeneous nutrient inputs in the mixed layer, hence generating localized phytoplankton blooms (Lévy, in press). These vertical processes can be found in eddies (eddy pumping, (Martin and Pondaven, 2003), upwelling in anticyclonic eddies, Martin and Richards, 2001) as well as in filaments with high horizontal velocity gradients, and hence high vorticity. Such filaments can be found wrapped around or ejected by eddies. The contribution of filaments is complex: they can either generate turbulent diffusion or act as dynamic barrier preventing diffusion and strengthening eddies' coherence.

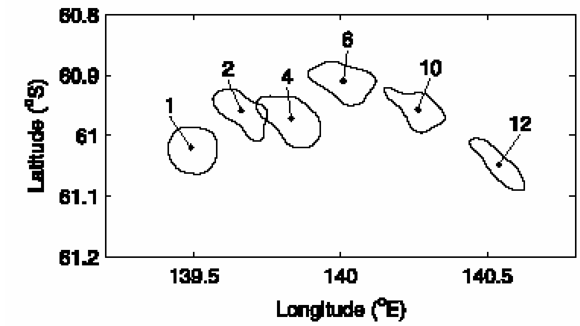
Horizontal (sub)mesoscale circulation is a major process since it controls the spatial distribution of tracers and nutrients, and hence the distribution of blooms. For example, (sub)mesoscale features can induce a strong patchiness in phytoplankton or zooplankton distributions. But the reasons for the distributions of these tracer (conservative or not) are not always clear (Abraham, 1998; Martin, 2003). Qualitatively, the horizontal dispersion of a patch is produced by the combined effect of stirring, that stretches or unfolds the patch in a filament, and turbulent diffusion, that mixes the tracer with ambient waters. The relations between stirring and mixing, and the dynamic behaviour of water masses, are extensively studied theoretically but much less experimentally.

Lately, experiment creating an artificial patch, where sulphur hexafluoride (SF_6) is used as a conservative tracer, have allowed approaching these questions *in situ*. Indeed SF_6 is used alone, or combined with a limiting (or supposedly limiting) nutrient, such as iron or phosphate, to generate patches of artificial phytoplankton blooms.

How the patch evolves depends mainly on the velocity field (Figure 3). If we consider that, far from fronts and at scales larger than 1 km, surface current is bi-dimensional and non divergent, the flow can be resolved locally into two components: a rotation and a pure strain. In an environment where rotation dominates, dispersion is relatively isotropic when the tracer is added close to the rotation axis (Figure 3c). On the contrary, in an environment where strain dominates, the patch rapidly stretches and becomes a filament (Figure 3d). The analysis of the tracer evolution inside the patch allows determining a number of parameters that quantify horizontal diffusion and strain rate. It will be interesting to make a sensitivity analysis of the model to these parameters and evaluate their impact on transport exchanges.

In a filament, the tracer gradient in the filament direction is weak. The filament axis is taken along x and σ_y is the standard deviation of the tracer distribution in the y direction. For a pure-strain flow with no rotation, the exponential growth of the filament length is characterized by a strain rate γ, and the filament width rapidly becomes constant. This implies that the thinning of the patch is compensated by lateral diffusion. Hence, measuring the width of the patch σ_y provides the diffusion coefficient K_y ($\sigma_y^2=K_y/\gamma$). Once the patch width has stabilized, the tracer concentration decreases with a rate equal to γ. In reality, ocean flows are never pure strain, and this strain is not constant, hence an effective strain rate (or Lyapunov exponent) can be defined from the exponential growth of the length of the tracer patch. Once the length of the filament has reached the size of ambient eddies, the patch tends to bend and, eventually, to fold back on and remix with itself (Garrett, 1983).

* Contact has been taken with M. Levy (LOCEAN) for future participation to the LEFE TWISTED project.



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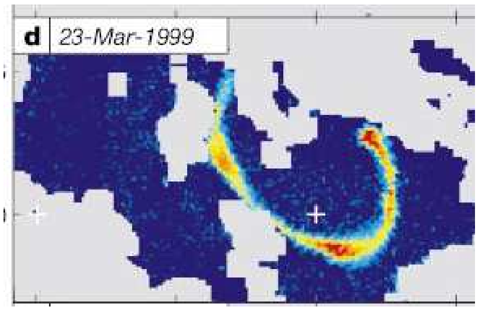

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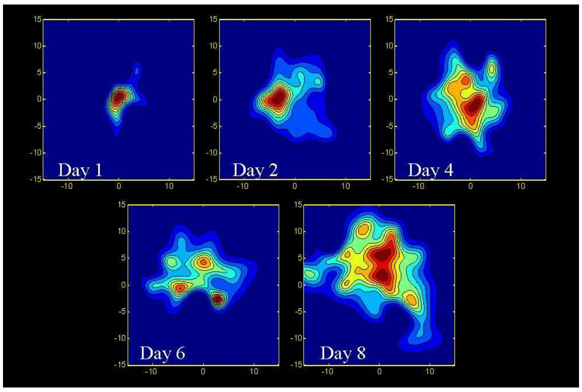

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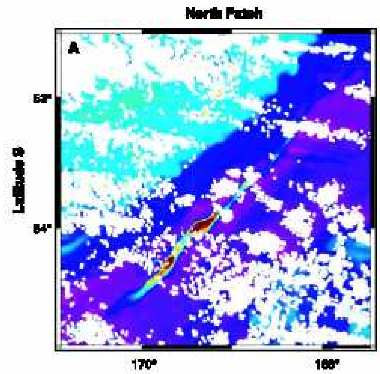

D

Figure 3: *Examples of patches in various dynamic environments (a) evolution of the SOIREE patch on days 1 to 12 (Law et al., 2003) and (b) after 23 days (Abraham et al., 2000). (c) the CYCLOPS patch at the centre of an eddy in the oriental Mediterranean basin (Law, 2005) (d) the SOFEX-North patch (Coale et al., 2004) in an environment with a high strain rate.*

Inside a patch, a non conservative tracer (e.g., chlorophyll or nutrient) is affected by horizontal turbulence in the same way as a conservative tracer. Hence the tracer concentration depends on the relative values of γ and μ (μ being the net growth rate of the tracer when dispersion is nil; μ can be positive or negative). If μ is superior to γ, the maximal tracer growth rate evolves at the speed μ-γ. If γ is superior to μ, isolated phytoplankton biomass will never grow more than the following concentration $\gamma C_0/(\gamma-\mu)$, C_0 being the ambient concentration assumed to be constant (Abraham et al., 2000).

Empirically, from the various situations encountered during patch dispersion, it seems that three typical situations can occur (C. Law, comm. pers.):

➢ Weak strain rate (eddy): situation where advection is weak. There is little chance to "lose" the patch. Dilution is rapid at first then slows down. This situation is relatively easy from a logistic point of view.

➢ Medium strain rate (<0.25 d^{-1}): in this situation, advection is important. On one hand, it is hard to localize the center of the patch and to follow it. On the other hand, dilution is constant and, in a sense, predictable. This situation is more difficult logistically than the previous one.

➢ High strain rate (>0.25 d^{-1}): advection is very strong. The tracer dilution is very quick, which makes it difficult to follow the patch.

4) Methodological developments

A) Lagrangian approach

Dispersion can be characterized by the Finite Time Lyupanov Exponent (FTLE). The Eddy Kinetic Energy (EKE) is commonly used to characterize mesoscale processes in the ocean. But, here, the interest is in scales smaller than the mesoscale processes.

Hence the velocity field should be used through its velocity field gradient decomposed in the strain rate γ and the vorticity ω (the dilatation parameter being neglected by the conservative hypothesis).

In fact, various criteria can be used to separate flow fields dominated either by strain or rotation. For example, the Okubo-Weiss criteria ($W = \gamma^2 - \omega^2$) has been used in the Mediterranean Sea (Isern-Fontanet et al., 2004) (Figure 4). The Okubo-Weiss parameter lies on an assumption that restricts eddy detection to eddy cores (Basdevant et al., 1994). Its use would prevent an efficient decomposition between background and eddy signals. A more general criterion "Hua Klein" has also been established (Hua and Klein, 1998).

Another method, consisting in processing relative vorticity with a wavelet-based decomposition, gives excellent results in terms of eddy identification (as already shown by Ruppert-Felsot et al., 1993). Nevertheless, relative vorticity tends to overemphasize frontal structures since it intensifies with the vertical motions that develop in oceanic fronts (Wang, 1993).

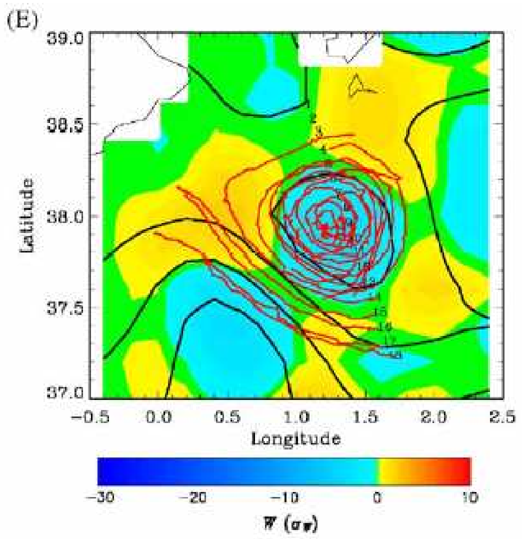

Figure 4: *Distribution of the Okubo-Weiss parameter and streaklines (black) derived from the SLA maps for 98-1 close to ALGERS98 cruise, May 22 1998 (σ_w=3.42 10^{-11} s^{-2}) and initial trajectories of drifters (red lines) launched during the cruise (from Isern-Fontanet et al. 2004).*

But, this quantity is free from large-scale gradients present in temperature, salinity and SSH. Hence, the use of relative vorticity does not require the somewhat arbitrary definition of a reference field to calculate anomalies. In fluid dynamics, both for numerical simulations and laboratory experiments (Ruppert-Felsot et al., 2005; Siegel & Weiss, 1997), the coherent and incoherent background components of a turbulent flow have been separated with a wavelet-based decomposition of the relative vorticity field.

These successful applications drove Doglioli et al. (2007) to apply the wavelet analysis technique used in 2D turbulence to the identification of eddies within horizontal slices of modelled relative vorticity. Their identification technique is based on the wavelet analysis of horizontal slices of relative vorticity from a realistic regional model. Then, in order to capture and track the full 3D envelope of each eddy, they developed an original and simple algorithm based on superimposing structures at different instants and different vertical levels (WATERS = Wavelet Analysis for Time-tracking Eddies).

Lagrangian particles also constitute a powerful tool to investigate the origin of water masses. Indeed, it is possible to separate the trajectories into two subsets associated with two different dynamical regimes:
i) the subset of particles embedded in coherent vortices, the so-called ``loopers'', and
ii) the subset of those remaining in a more quiescent ``background'' flow region, the so-called ``nonloopers''.
A simple qualitative criterion to identify loopers was initially introduced by Richardson (1993), who defined a looper as a trajectory that undergoes at least two consecutive loops in the same direction. The method applied by Veneziani et al. (2004) and Veneziani et al. (2005b) is more quantitative and suited to the treatment of extensive data sets. It is based on the computation of the spin parameter.
The spin Ω is related to the angular velocity of the Lagrangian eddy velocity vector and corresponds to the vorticity field for trajectories embedded inside vortex cores (Veneziani et al., 2005a); according to these authors, this parameter well characterizes the effects of rotating structures. It has previously been applied to in-situ data and numerical trajectories.

For the analysis of simulations run with numerical ocean models, the ARIANE toolkit is a suitable off-line Lagrangian diagnostic tool (Blanke et Raynaud, 1997). ARIANE provides both qualitative and quantitative numerical trajectories. In quantitative numerical experiments, the incoming transport across a given initial section can be described by hundreds of thousands of particles, and each of them is associated with an infinitesimal fraction of the mass flux. These infinitesimal volumes are conserved along model streamlines, and directional transports can be estimated by adding the transports of the particles that reach equivalent final sections. As described by Blanke et al. (1999), the passage of each particle is recorded, and the volume represented by this particle is summed up at each velocity point of the model grid.

Doglioli et al. (2006) have attempted to evaluate the contribution of trapping eddies to the Indian-Atlantic interocean exchange by successfully coupling ARIANE particle-following technique with a "spin"-based analysis of trajectories.

Recent works (Waugh et al., submitted) have shown that, for a specific oceanic region, there is a relation between the FTLE parameter and the parameters characterizing the velocity field (Figure 5, below).

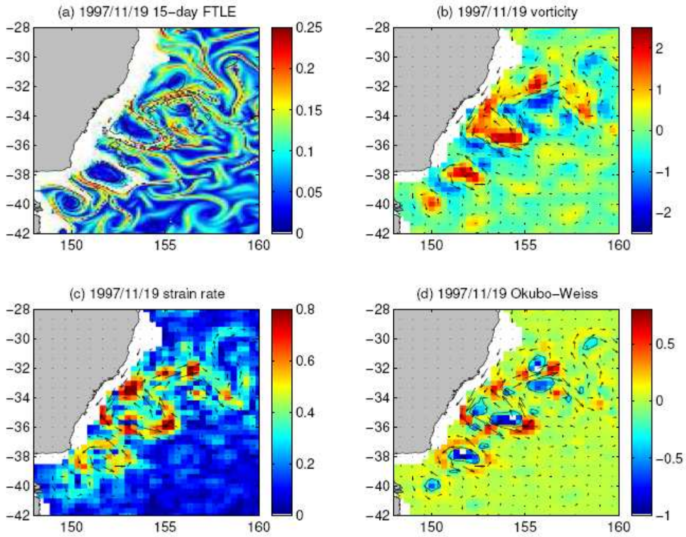

Figure 5: *Maps of (a) 15-day FTLE, (b) vorticity ω, (c) strain rate γ, and (d) Okubo-Weiss parameter Q for 19 November 1997. Vectors are surface currents, contours in (a) and (d) Q= -0.2 day^{-1}, and units of all fields are day^{-1}.*

This should allow predicting the future evolution of a patch depending on the velocity field in which the tracer is being dispersed.

B) Biogeochemical budgets

The net community production is an integrative measure of the biological activity in the surface layer and it is currently used to assess the impact of the biological production on the carbon cycle (Williams *et al.* 2004, Lefèvre *et al.* 2007, Reuer *et al.* 2007, Jouandet *et al.* accepted). Concentrations of dissolved oxygen (O_2) can be measured at high frequency using electrochemical or optical sensors. By combining different devices (CTD, glider, and drifting buoy) equipped with such sensors we will be able to produce a detailed temporal and spatial description of the *in situ* O_2 concentrations. The net community production (NCP) during the time Δt can then be derived from the following budget:

$$NCP_{O2} = \Delta O_2 + Fsea\text{-}air + F\ hor + F\ ver$$

where ΔO_2 denotes the variation of O2 during Δt, Fsea-air is the air sea flux of O_2 calculated from the O_2 concentration in the surface layer and transfer velocity deduced from wind speed using appropriate parameterisation (Ho et al. 2006). Fhor and Fver are derived from the coefficient of horizontal and vertical mixing estimated during LATEX from the SF_6 distribution.

This approach will be compared to the direct measurement of NCP based on bottle incubations.

Similarly to O_2 it also possible to determine the NCP_{DIC} for carbon based on the following budget:

$$NCP_{DIC} = \Delta DIC + Fsea\text{-}air + F\ hor + F\ ver$$

where ΔDIC denotes the variation of DIC during Δt, F sea-air is the air sea flux of CO2 calculated from pCO2 in the surface layer and transfer velocity deduced from wind speed using appropriate parameterisation. Due to technical limitation (no DIC sensor available for *in situ* measurement), the spatial resolution will be lower than for O_2. However, the high frequency measurements of pCO_2 in the centre of the structure (CARIOCA buoy) will provide a good temporal resolution. The determination of the alkalinity from salinity measurements will allow deriving DIC from pCO_2. This approach has already been used successfully with the CARIOCA buoys deployed during POMME (Merlivat et al. in revision) and in the Southern Ocean (Boutin et al., in preparation).

The net community production determined from changes in the concentration of O_2 during bottle incubations can be converted to carbon-units using a photosynthetic quotient (PQ) of 1.2 (Williams and Robertson 1999). The direct determination of NCP in terms of carbon is presently limited by the fact that TCO_2 measurements are not sensitive enough to detect the low fluxes typical for oligotrophic environments (see, for example, Lefèvre et al., 2007). This experimental approach will be compared with the NCP_{DIC} from the budget.

Based on measurements of NCP during late summer at station MOLA (project LEFE-CYBER MEDEA, PI Obernosterer) we expect variations of O_2 or DIC in the mixed layer in the range of 0.5-1 µmol l^{-1} d^{-1}. This means that the budget needs to be built using Δt= 5-6 days.

From the NCP_{DIC} it will also be possible to derive the carbon export (Jouandet et al., accepted) within the structure using the following equation:

$$Cexp= NCP_{DIC} - \Delta POC - \Delta POC$$

where ΔPOC and ΔPOC denotes the variation of POC and DOC within the structure. Measurements of POC with high spatial and temporal resolution can be derived from *in situ* measurements of backscattering at 4 wavelengths (glider) and light transmission at 660 nm (CTD). The calibration of the sensors will be performed by determinations of the POC concentration on discrete samples. Concentrations of DOC will be measured on discrete samples, but we will also investigate the possibility to use *in situ* determinations of CDOM by sensors mounted on gliders as a proxy of DOC. If this approach is successful, a 3D description of the DOC distribution will also be available.

It is important to note that, in the Lagrangian framework used during LATEX, deriving the carbon export from the carbon budget is the most appropriate approach compared to other possible methods (e;g. drifting sediment traps or 243Th deficit). The deployment of drifting traps below the mixed layer would fail because we cannot assure that the trap will stay below the water mass tagged with SF_6 where the other biogeochemical rates will be measured. The method deriving carbon export from thorium deficit is not easy to implement in the context of LATEX because it would require high temporal and spatial (vertical) resolution.

2. Plan de recherche: LATEX

2.1 Objectives

The main objective of LATEX is to better understand the coupling between physics and biogeochemistry at (sub)mesoscales. This includes the effect, on biogeochemical processes, of horizontal and vertical motions associated with an eddy structure. Our knowledge of the impact of (sub)mesoscale eddies on biogeochemistry has largely emerged from modelling. Very recently, some field studies (Benitez-Nelson *et al.* 2007, McGillicuddy *et al.* 2007) have also successfully addressed this issue; but more has still to be done, particularly in coastal waters. In the Gulf of Lion, the main goals of LATEX are to study the impact of coastal (sub)mesoscale eddies interacting with the Northern Current on the evolution of conservative or biogeochemical tracers' distributions, and to provide answers to questions such as:
Do these structures facilitate the horizontal transfer across the continental slope and slope current? What are the consequences on biogeochemistry of the interaction of the structure with the NC in terms of matter transport and patchiness of plankton and primary production distributions?

Within this general context, biogeochemical studies during LATEX will focus on:
1) The determination and evolution, within the structure, of the rate μ (in d^{-1}) of biogeochemical processes, mainly net community and gross primary production and ^{13}C primary production. This will be compared to the strain rate γ (in d^{-1}) estimated from SF_6 and drifting buoys. This will allow us to better understand how these biological and physical processes compete in the accumulation of biomass.
Note: It is clear that the investigation of the processes that control the rates, such as nutrient availability or the structure of the microbial community are outside the scope of LATEX mainly due to technical limitations (availability of methods of investigation (i.e. *in situ* measurements) suitable for (sub)mesoscale study and the limitation of the number of participants to the cruise).
2) The observation of short term and/or (sub)mesoscale variations of some parameters (oxygen and carbon) which will be interpreted in the context of the 3D dynamical environment.
3) The construction of budgets for these elements within the structure.

The objectives mentioned above can only be reached for few chemical elements due to technical limitations in measuring the stocks and the fluxes with an appropriate spatial and temporal resolution. However, we believe that the challenge is feasible for oxygen and carbon (see Section 1.3B for details), which are elements of high interest in biogeochemistry.

2.2 Strategy:

The LATEX strategy is based on a combined use of satellite data, numerical modelling, and Eulerian and Lagrangian *in situ* measurements.

The project has three components:

- **Part 1 – Increase our knowledge on the (sub) mesoscale eddies of the western side of the Gulf of Lion.**

During Latex00, we have analysed Symphonie numerical outputs with WATERS (WATERS = Wavelet Analysis for Time-tracking Eddies) in order to identify eddies and have been able to confirm their presence on satellite images (See Annexe 4). Now we plan to correlate their generation and evolution to meteorological and topographic forcings. Moreover the Latex00 analysis was only done at one vertical level (20 m) and we plan to study the entire vertical structure of the selected eddies.

This component has also a more technical and numerical part. Up to now the WATERS analysis has been done on Symphonie* outputs that Claude Estournel and Patrick Marsaleix (POC, Toulouse) were kind enough to provide us. And the Lagrangian tests were done by Nicolas Grima and Bruno Blanke (LPO, Brest). We need to proceed to a few developments at the LOB, Marseille. Hence we plan to implement Symphonie high resolution on the COM cluster, to install the off-line numerical tool Ariane (lagrangian particles) and connect it to the Symphonie outputs.
Symphonie will also be coupled to the biogeochemical model Eco3M-MED, which is a multi-nutrients multi-functional plankton group (mNmFG) model, recently built and validated for the North-western Mediterranean basin (Herrmann, 2007). This model is currently implemented in the modular tool Eco3M (Baklouti et al. 2006a) This numerical tool has been devised to handle mNmFG models (Baklouti et al. 2006b) with the main objective of being wholly modular as regards the model state variables and the associated functions for biogeochemical processes. New variables or processes can therefore be added or removed with simplicity. In addition, a numerical library of functions of biogeochemical processes is already available in Eco3M and many of these parameterizations rely on mechanistic basis. This latter tool will easily enable us to add an oxygen module to assess the air-sea O_2 budgets.

*Note: Symphonie has been declared a "community model" starting in 2007.

In this first part, the coupled model will be used as a diagnostic tool to assess the hydrodynamic mechanisms associated to the sub-mesoscale structures at the origin of the plankton and primary production patchiness observed in this study area.
The eddy structures of the Gulf of Lion will also be studied with satellite imagery, both in the visible and with altimetry (new treatment techniques are being developed for coastal uses; F. Birol).

- **Part 2 - Coupling physics and biogeochemistry in a lagrangian approach.**

To study the impact of coastal (sub)mesoscale eddies interacting with the Northern Current on the evolution of conservative or biogeochemical tracers' distributions, we plan a cruise in September 2009 in the western side of the Gulf of Lion. There, an anticyclonic eddy seems to be a quasi-permanent feature during stratified summer months. We will track the eddy *in situ* with complementary methods (see Annexes 2 and 5 for more details on the 2009 cruise):

a) Floating buoys

Floating buoys have been acquired during Latex00. One iridium buoy and one CARIOCA buoy will be deployed in the middle of the SF_6 patch, located on a radius of the selected eddy. The other buoys, GPS-Argos buoy, will be deployed either in the Northern Current or inside the eddy.

b) Dispersion of a conservative tracer (SF_6)

Sulfur hexafluoride (SF_6) is a gaseous electrical insulator with a very low solubility in seawater, which results in a background concentration in the seawater of 0.3 fmol l^{-1} (fmol = 10^{-15} mol). SF_6 can be detected at such low concentrations using the high sensitivity of gas chromatography with electronic capture detector (Law et al., 1994). Therefore SF_6 is a powerful inert tracer in marine systems. The main advantages of SF_6 are its relative low cost, chemical and biological inertness and absence of harmful effects on the handlers or on the environment. The potential of SF_6 as an excellent tracer has now been fully realised. SF_6 has been used to study current flows, air-water gas exchange (Wanninkhof et al., 1985; Watson et al., 1991), diapycnal mixing, biogeochemical investigations such as iron enrichment (Boyd et al., in press; Thingstad et al., 2005; Boyd et al., 2005). Finally SF_6 was also used to investigate the coupling between physics and biogeochemistry in mesoscale environments, *e.g.* eddy tracking during Plankton Reactivity in the Marine Environment (PRIME) (Martin et al., 2001), as we plan to use it.
During latex 00, we have measured the background concentrations of SF_6 in the surface mixed layer of the Gulf of Lion. the values are around 1.35 fM, which is the concentration of SF_6 expected for seawater in equilibrium with the atmosphere. Therefore, using 4000 L of seawater (temperature around 28°C and salinity around 38) saturated with SF_6, we will be able to create a patch of 50 km^2 *50 m with SF_6 concentrations roughly 200 times higher than the background value.

c) 3-D mapping of the eddy and ambient circulation with gliders

Several gliders (Testor et al. and Claustre et al.) will be used to make transects and collect hydrological and bio-optical data through the eddy and the neighbouring waters. The gliders will also be used to cross the Northern Current (NC) and may be programmed to make repetitive transects in the Zone of Intensive Observation (ZIO) corresponding to the area of interaction of the eddy and the NC.

d) Classical survey of physical and biogeochemical parameters

In parallel, more classical measurements will be performed: continuous current measurements with a hull-mounted ADCP, on-going measurements (i.e. without stopping the RV) of SF_6 concentrations and surface temperature, salinity, fluorescence and O_2. At selected stations, in the core of the structure and on transects crossing the structure, discrete samples will be collected for POC, DOC, chlorophyll a, O_2, DIC, alkalinity, SF_6.
Determination of net community production (NCP), dark community respiration (DCR) and gross community production (GCP) will be done using bottle incubations. Rates of NCP, DCR and GCP will be determined from changes in the dissolved oxygen (O_2) concentration over 24h incubations carried out *in vitro* in on-deck incubations. Rates will be measured at 4%, 8%, 15% 25%, 50% and 100% of surface Photosynthetically Available Radiation (PAR) levels, using optical density filters (Nickel). The corresponding depths for these light intensities are within the mixed layer depth (MLD) during late summer at Station MOLA. Incubations will be performed at sea surface temperature corresponding to the temperature in the mixed layer. Three sets of 8 replicate biological oxygen demand (BOD) borosilicate glass bottles (125 ml) will be filled with raw seawater and the changes in the concentration of O_2 followed after 24h light (for NCP) and dark (for DCR) incubations. After fixation with the Winkler reagents, the concentration of total iodine will be determined spectrophotometrically at a wavelength of 456 nm on a Hitachi U-1100 spectrophotometer using a 1-cm flow through cuvette (Roland et al. 1999). This method will allow us to do a large number of analyses during the cruise.

e) Surface synoptic mapping of non conservative tracer from satellite observation (e.g., Chl a or SST)

Satellite images will be used in real-time to help the structure survey and give an overview of the Northern Current position. Synoptic measurements from space before the cruise will also help to figure out the trophic level and the eddy activities of the study zone before the cruise. Remote sensing study of oceanic and coastal (sub)mesoscale eddy formation, propagation and fate are usually conducted by sea surface temperature derived from infrared emission. Additional characteristics are now available for the study of eddies derive from ocean color measurement (chromophoric dissolved organic matter (CDOM) absorption coefficient, phytoplankton absorption coefficient, and backscattering coefficient). Indeed the inherent optical properties of the water's constituents are a valuable supplement to SST images especially during the summer season when the temperature contrast is low. It is also interesting to note that September is usually one of the cloudless months of the year for the study area. This will allow us to use daily high resolution satellite scenes.

A short cruise will be done in September 2008 in order to familiarize ourselves with the study zone and test there our ability to do a real-size Lagrangian navigation test with an Iridium buoy. Moreover we will deploy three ADCP moorings, crossing the shelf from 60 m to 600 m between longitudes 42°27'N and 42°30'N, in order to obtain the flux across this potential exit zone of the Gulf of Lion.

An additional component may be added to the project if Dr. Meng Zhou is, in 2009, a visiting scientist at the LOB, COM. He would then come with his personal SeaSoar Acrobat and would like to participate to the cruise measurements with transects throughout the structure.

VHF surface radar, providing horizontal surface current velocities, would have provided a complementary view of the studied domain. Unfortunately our French colleagues from the LSEET, Toulon, specialists in this field, have indicated the impossibility of implementing the radar antennas at the coast near the study area.

- **Part 3 - Quantification of the coast-offshore exchanges for the process studied during the Lagrangian survey and comparison with the matter and energy fluxes obtained with numerical coupled physical – biogeochemical modelling**. **Extrapolation of the transport budget by eddies at the seasonal and annual scales.**

The first goal of this part is to obtain a correct numerical representation of the studied (sub)mesoscale structure in terms of physical and biogeochemical patterns observed during the lagrangian survey. To do this, a realistic simulation of the whole 2009 year will be made. The simulated period of the lagrangian survey (September 2009) will be compared with *in situ* and satellite imagery data sets. Sensitivity analyses will be made by testing the variability associated with the range of Fhor and Fver calculated from *in situ* measurements. Secondly, the coupled model will enable us to characterize (dissolved and/or particulate) and quantify the organic matter transported by the (sub)mesoscale structure during the survey. A budget of the air-sea exchanges of O2 during the survey will also be given by the coupled model and will allow us to know if the studied structure is a net source or sink of carbon over the experimental period. Thirdly, the realistic simulation made over the whole 2009 year will permit the extrapolation of the transports of matter and energy due to the interaction of coastal (sub)mesoscale eddies with the Northern Current at the seasonal and annual scales and the comparison of these results to the transport attributable to other coast-offshore exchanges or large scale circulation.

The following points will be studied (non exhaustive list):

1) Realistic hydrodynamic modelling of the Lagrangian survey with Symphonie model and validation with *in situ* and satellite data,
2) Realistic biogeochemical modelling of the Lagrangian survey with the coupled Symphonie/Eco3M-Med model and validation with *in situ* data set and satellite imagery. The latter step will be preceded by the implementation of a new oxygen cycle in the Eco3M-MED module.
3) Budgets (given by a coupled model) of biogenic organic matter (POC, DOC, C export…) carried along by the structure followed by SF_6, and of the exchanges (O_2) at the water-air interface; validation of the budgets with *in situ* data.
4) Extrapolation of the matter transport by eddies at the seasonal and annual scales given by the coupled model and comparisons to the matter transport by the general circulation.

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3. Time table - Calendrier

2008-2010

	2008				2009				2010			
	Jan – Mar.	April - Jun	July - Sep	Oct - Dec	Jan – Mar.	April - Jun	July - Sep	Oct - Dec	Jan – Mar.	April - Jun	July - Sep	Oct - Dec
T0		P1			P2				P3			
T1	■	■	■	■	■	■						
T2	■	■										
T3	■	■	■									
T4		-------	T		-------	-------	LAT					
T5	■	■	■	■	■	■						
T6								■	■	■	■	■
T7										■	■	■

Task 0: P1= Kick –off meeting in May 2008; participation to the TWISTED meeting (PI: M. Levy) in June 2008; P2 = Cruise preparatory meeting in March 2009; P3 = Post-cruise workshop in Jan 2010
Task 1 (T1): Analysis of satellite data, wind forcing and vertical structure of eddies in the Gulf of Lion
Task 2 (T2): Implementation of Symphonie, Ariane, and coupling Eco3M
Task 3 (T3): development of the O2 module

Task 4 (T4): T: trial at sea during a 6 day cruise in September 2008; LAT: the LATEX cruise of September 2009, and their respective preparatory periods
Task 5 (T5): Follow-up of the implementation at LOB of the analysis of SF_6 by GPC-CED to be used during LATEX and design of the tracer dispersion system
Task 6 (T6): Analysis of the data from the cruise – Models Validation and assessments of modelled and data-based budgets
Task 7 (T7): Publications – Special session

Possibilité de fournir des noms d'experts français ou étrangers (avec coordonnées complètes : adresse postale et adresse électronique) susceptibles d'évaluer le projet et avec lesquels les équipes participant au projet n'ont ni conflit d'intérêt, ni collaborations en cours.

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Références bibliographiques du responsable et de l'équipe, en particulier sur le sujet de la demande (trois dernières années).

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MOYENS DONT DISPOSE OU QUE DEMANDE LE PROPOSANT POUR LA RÉALISATION DU PROJET

1. Personnels et laboratoires impliqués :

Baklouti Mélika, Blain Stéphane, Diaz Frédéric, Bernard Queguiner, Doglioli Andréa, Petrenko Anne, Rimmelin Peggy et Rougier Gilles, Ziyuan Hu –Laboratoire d'Océanographie et de Biogéochimie – UMR 6535, Marseille.

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2. Equipement disponible pour la réalisation du projet (préciser dans quel laboratoire)

Local cluster (PCs with Linux)	LOB (COM)
CTD Seabird 911+ rosette	COM
Currentmeters ADCP (RDI) + buoyancy BMTI : 3 ADCP Ocean Sentinel 300 kHz	LOB (COM)
Currentmeters VACM	LOB (COM)
Launcher of XBTs + XBTs T7 (~800 m) et T10 (~200m)	LOB (COM)
GPS-Argos buoys	LOB (COM)
Iridium buoy	LOB (COM)
GPC-ECD	LOB (COM)
Shimadzu TOC-V analyser	LOBB–Banyuls
compteur à scintillation Beckman LS6500	LOBB–Banyuls
Hitachi U3010 Spectrophotometer	LOBB–Banyuls
Metrohm Titrator	LOBB–Banyuls

3. Moyens demandés hors appel d'offre LEFE (indiquer ici les moyens demandés aux commissions scientifiques en charge de l'examen des demandes de campagnes à la mer, « Vols Avion », « Vols Ballon », les commissions de l'IDRIS pour le temps calcul, les demandes de soutien à la DT INSU, etc…). Pour les projets comportant une campagne en mer sur la flotte hauturière de l'Ifremer, les proposants doivent remplir l'annexe 2 (http://www.insu.cnrs.fr/pj/document/652.rtf) et **préciser le montant financier pour le fret et les missions ainsi que les organismes à qui ils seront demandés.** Pour les autres demandes de moyens indiquer précisément la nature de la demande et la justifier (joindre éventuellement une annexe qui pour les vols avion peut-être le dossier de demande disponible sur www.saphir.fr).

4. Labellisation de bourses post-doctorales ou doctorale : Le financement de bourses doctorales ou post-doctorales ne peut pas être pris en compte dans le cadre de l'Appel d'Offre LEFE. Par contre, **un soutien sous la forme d'un label** pourra être accordé à une demande de bourse doctorale ou post-doctorale déposée auprès d'un organisme partenaire de LEFE.

Nature de la bourse (doctorale ou post-doctorale) : doctorale
Organismes concernés par la demande : CNRS, MENRT
Nom de l'encadrant principal : Frédéric DIAZ

Titre de la demande : Quantification des échanges côte-large de matière et d'énergie due aux structures tourbillonnaires de (sub)mésoéchelle dans le golfe du Lion (Méditerranée nord-occidentale) : approches *in situ* et par modélisation couplée hydrodynamique-biogéochimie.

Résumé du sujet (500 mots maximum) :
La circulation dans le golfe du Lion est à la fois gouvernée par un moteur hydrodynamique puissant, le Courant Nord (CN) Méditerranée (Millot 1990) et aussi par d'intenses forçages atmosphériques (vents de nord-ouest, tempêtes de sud-est…). Ce dernier type de forçages, en particulier, est à l'origine de processus transitoires tels que la formation d'eau dense sur le plateau (Dufau-Julliand et al. 2004), d'upwellings côtiers (Millot 1990) ou encore d'intrusions du CN sur le plateau continental (Petrenko et al. 2005). La présence du Rhône apportant de l'eau dessalée en grande quantité amène également à observer des gradients de densité marqués dans cette région. Les interactions entre ces différents forçages se traduisent par la présence de nombreuses structures tourbillonnaires transitoires de mésoéchelle (20-100 km) et sub-mésochelle (<20 km) dans le golfe du Lion (Flexas et al. 2002, Estournel et al. 2003). Les observations satellitales (Bosc et al. 2004) et des études expérimentales menées à petite échelle (*e.g.* Diaz et al. 2000) révèlent une importante variabilité spatiale et temporelle du plancton et des flux biogéochimiques associés dans la zone d'étude ; cette variabilité est probablement à mettre en relation avec l'activité hydrodynamique de (sub)mésoéchelle mais cette hypothèse reste toutefois, encore aujourd'hui, à valider malgré la réalisation depuis une dizaine d'années de nombreuses campagnes expérimentales (Moogli, Sarhygol, Golts/argol, Ecolophy).
La structure tourbillonnaire étudiée durant la campagne LATEX de septembre 2009 sera donc l'objet principal d'étude de cette thèse. Les objectifs de la thèse sont de 3 types :
Le premier objectif consistera d'abord à obtenir une représentation numérique correcte de la structure étudiée aussi bien du point de vue hydrodynamique que biogéochimique grâce à la modélisation couplée. La validation des résultats numériques se fera par les jeux de données récoltés au cours de la campagne et à l'aide des images satellitales disponibles. Cet objectif permettra de vérifier si le type de structure tourbillonnaire ((sub)méso-échelle) étudiée est à l'origine ou non de la variabilité des quantités biogéochimiques qui est observée.
Le deuxième objectif sera de caractériser (dissous et/ou particulaire) et de quantifier la matière transportée par la structure tourbillonnaire durant la période d'étude. Enfin, le troisième objectif sera d'évaluer l'impact réel de ces structures dans le bilan global des échanges côte-large de matière et d'énergie dans cette région. La réalisation de cet objectif passera d'abord par une recherche systématique des structures tourbillonnaires (sub)méso-échelle dans une simulation numérique annuelle ou pluriannuelle de grande emprise spatiale essentiellement pour en quantifier l'occurrence. Le bilan des transports de matière et d'énergie attribuables à ces

structures pourra être comparé par exemple au transport lié à la circulation de grande échelle (Courant Nord) à l'échelle saisonnière ou bien annuelle.
Le doctorant aura à disposition le code hydrodynamique d'océan côtier Symphonie (développé au Laboratoire d'Aérologie par P. Marsaleix) et le code biogéochimique multi-nutriments multi-groupes fonctionnels Eco3M-Med implémenté sur la plate-forme numérique Eco3M du LOB.

5 Demande de financements dans le cadre de l'appel d'offre LEFE

NB : pour les projets pluriannuels présenter un calendrier

5.1 Fonctionnement : à détailler et justifier poste par poste pour toute la durée du projet. Comprend aussi les coûts ARGOS à indiquer en nombre de jours d'émission.

Objet	2008	2009	2010
Organisation réunion de démarrage (Marseille, mai 2008)	**500**		
Organisation réunion de préparation campagne sept 09 (Marseille, mars 2009)		**500**	
Organisation réunion post-campagne (Marseille, jan. 2009)			**500**
Logistique (transport bouées AR- Mrs PV)	**2000**		
Logistique transport échantillons DIC+alkalinité		**500**	
Logistique (transport bouées, cuveSF_6…) AR- Mrs La Seyne)		**2500**	
Transmission bouées Argos et Irridium (et abonnement)	**820**	**9300**	
Remise en état Carioca et transport		**16400**	
Transport AR 2 gliders physique Paris-La Seyne		**2000**	
Ticket modérateur Téthys	**500**	**1800**	
Publications (numéro ou sessions spéciale)			**15000**

52320 €, gestion du projet.

5.2 missions : à détailler et justifier poste par poste pour toute la durée du projet

Objet	2008	2009	2010
Mission (3 pers) EGS Vienne (résultats de LATEX00)	**4000**		

Missions (16pers.) réunion de démarrage (Marseille, mai 2008)	**9500**		
2 missions AR + séjour Marseille - Brest	**2000**		
1 mission AR + séjour Marseille - Toulouse	**400**		
Missions (16pers.) réunion de préparation campagne sept 09 (Marseille, mars 2009)		**9500**	
Missions AR Paris La Seyne/mer (glider physique)		**1000**	
Missions AR Villefranche La Seyne/mer (glider biogéochimie)		**150**	
Missions (16pers.) réunion de post-campagne jan. 2010 (Marseille)			**9500**
Missions pour congrès (2010)			**15000**

Sub total: **51050 €**

5.3 Analyses : pour les analyses (*in situ* ou au laboratoire) une justification détaillée (e.g. coût unitaire de l'analyse et nombre d'analyses prévues, coût total par poste) des dépenses envisagées doit être fournie (remplir l'annexe 1 ci-après). Reprendre ici le montant total de la demande.

Sub total : **20044** €

(Cf. Annexe 1, ci-après)

5.4 Équipement spécifique : à détailler et justifier pour toute la durée du projet.

Objet	**2008**	**2009**	**2010**
Cuve stockage SF_6	**12000**		
Equipement de traçage SF_6	**16000**		
Equipement cryogénique	**9000**		
Consommable SF_6 (gaz, traceur et gaz inerte)	**13000**		
Achat de 2 largueurs pour mouillage	**20000**		
Equipement pour mouillage (lest…)	**1500**		
2 balises Argos	**10000**		
Flaconnage DIC+ alkalinité		**2500**	

Petit matériel pour mesure prod. Comm. Nette et respiration		**3800**	
Optode pour survey O2 et data logger		**4000**	
Disques pour archivage données	**300**		
Unité de calcul pour cluster local	**4000**		
Petit matériel 2 glider physique (piles, toolbox…)		**9000**	
Petit matériel glider biogéochimie		**5600**	

Sub total: 110700**€**

5.5 Équipement mi-lourd **:** les équipements dont l'acquisition en 2007 est nécessaire à la réalisation du projet et ayant fait l'objet d'une demande INSU à l'automne 2006 devront être impérativement mentionnés ici. Pour les projets pluriannuels, dont la réalisation nécessite l'acquisition d'équipement mi-lourds au-delà de 2007, les demandes doivent être impérativement mentionnées ici accompagnées d'une justification scientifique et technique, d'une évaluation financière et d'une indication sur le co-financement.

Aucun

Sub total: **0 €**

5.6 Total général des crédits demandés au programme LEFE

TOTAL : 234114€

6. Autres financements (attribués ou demandés hors de l'appel d'offre LEFE, y compris dans le cadre européen)**.** A détailler et justifier pour toute la durée du projet.

LISTE DES ANNEXES

Annexe 1
Budget détaillé des analyses prévues
Annexe 2
Formulaire simplifié de demande de campagne à la mer pour le Suroît (Ifremer)
Annexe 3
Evaluation des risques et résultats obtenus
Annexe 4
Résultats du projet Latex00 (2007)
Annexe 5
Plan de campagne LATEX pour le RV Téthys (CIRMED)

LEFE Annexe 1 : Budget détaillé des analyses prévues (campagnes en mer ou projets expérimentaux de laboratoire)

POSTE	Nombres de mesures	Prix unitaire (€)	MONTANT total (K€)
Carbone organique particulaire	700	8	*5600*
Carbone organique dissous	840	6	*5040*
Production primaire ^{13}C	84	6	*504*
Pigments chlorophylliens HPLC	700	11	*7700*
O_2 et Prod. Comm. Nette	1400	0.85	*1200*
		TOTAL	**20044**

LEFE_Annexe 2 : Formulaire simplifié de demande de campagne à la mer

RÉCAPITULATIF -1-	DOSSIER DE DEMANDE : DATE : 24 SEPTEMBRE 2007

TITRE DE LA CAMPAGNE : LATEX 09

Année : 2009
Durée *(sur zone) :* 22
Escale éventuelle (à justifier) : NON
Période *(si impératif) : septembre à mi-octobre*

Zone : Méditerranée nord-occidentale, plateau du golfe du Lion
Pays dont les eaux territoriales sont concernées : France, Espagne

Pays dont la zone économique est concernée : France, Espagne

	Chef de projet	Chef de mission
Nom Prénom :	Anne PETRENKO et Frédéric DIAZ	Bernard QUEGUINER
Organisme :	Université de la Méditerranée – Centre d'Océanologie de Marseille	Université de la Méditerranée – Centre d'Océanologie de Marseille
Laboratoire :	Laboratoire d'Océanographie et de Biogéochimie	Laboratoire d'Océanographie et de Biogéochimie
Adresse :	Campus de Luminy – Case 901 – F 13288 Marseille	Campus de Luminy – Case 901 – F 13288 Marseille
Tél.:	0491829061/9337	0491829111
Fax :	0491921991	0491826548
E-mail :	anne.petrenko@univmed.fr frederic.diaz@univmed.fr	bernard.queguiner@univmed.fr

Travaux : Mise à l'eau de CTD et de bouées Argos GPS, Iridium et Carioca. Dispersion d'un traceur dans l'eau. Utilisation d'ADCP coque

Traitement des données
et Besoins informatiques : données ADCP. Pas de besoin particuliers hormis quelques postes pour messagerie électronique.

Navire : SUROIT

Engin(s) : NON

Gros équipements : Cuve SF_6 ($4m^3$)

Nécessité d'une campagne pour récupération d'engin ? NON

Équipe scientifique embarquée

Gilles Rougier,
Bernard Queguiner (chef de mission),
Thierry Labasque,
Peggy Rimmelin,
Jocelyne Caparros,
Pascal Conan,
Ingrid Obernosterer,
Nicole Batailler,
Philippe Catala,
Frédéric Diaz,
Stephane Blain,
Gilles Rougier,
X

A terre :
Emmanuel Bosc

Cette proposition se rattache au(x) programme(s) (nationaux ou internationaux) avec comité scientifique : OUI
(L'avis des comités scientifiques sera sollicité)

Thème scientifique : Le projet LATEX (Lagrangian Transport EXperiment) a pour objectif d'étudier le rôle de la dynamique couplée physique biogéochimie à (sub) mésoéchelle dans les échanges de matière et d'énergie entre les zones côtière et hauturière avec comme zone d'étude le golfe du lion

Responsable d'unité : Bernard Queguiner
DATE : 25 SEPTEMBRE 2007 SIGNATURE :
Nombre de dossiers présentés pour 2007 au sein de l'Unité :

DOCUMENT N°2	DOSSIER DE DEMANDE : DATE : 25 SEPTEMBRE 2007

STRATEGIE D'APPROCHE ET METHODES

- **Méthodologie détaillée et liste précise des travaux pour atteindre les résultats escomptés - stratégie,**
- **Déroulement général de la mission, durée totale, *temps sur zone*, période souhaitée, escale éventuelle et raisons de ce souhait, *carte de situation générale***
- **Calendrier journalier prévisionnel des travaux (tableau J1 à Jx) précisant : travaux, trajets, stations, profils, les différentes zones d'études, ... documents cartographiques obligatoires. Pour les études de sismique et les levés sonars il est indispensable d'indiquer le nombre de milles nautiques des profils.**
- ***Pour les trajets, estimer les durées avec les vitesses suivantes : 10 nœuds pour le Suroît et Nadir, 11 nœuds pour Thalassa et L'Atalante***

A) Choix de la période et de la zone

Zone : zone ouest du golfe du Lion, au nord de 42°30' et à l'est de 3°40'
Période : Septembre 2009
Durée : 24 jours (22 jours sur zone)
Escale : non nécessaire mais il faut impérativement 22 jours de mer d'affilée pour pouvoir mener à bien la mission.

La zone d'étude a été choisie pour avoir la probabilité maximale de trouver des structures tourbillonnaires. Cette zone sera la partie ouest du golfe du Lion (sud Languedoc et Roussillon, Figure 6), le long des côtes françaises.
La période de septembre a été choisie pour être en situation d'efflorescence phytoplanctonique. Dans le golfe du Lion, le choix se portait donc sur l'efflorescence soit printanière soit automnale. Il y avait le risque que la période printanière ne soit pas idéale pour l'injection du traceur qui doit être faite dans des conditions de stratification forte et bien établie pour que le traceur ne soit pas dilué trop rapidement dans une épaisse couche de mélange. Donc nous avons décidé de cibler la période de début d'automne où nous devrions encore bénéficier de la stratification estivale (couche de mélange au maximum de 40-50m) et où nous commencerons à observer une activité biologique significative.

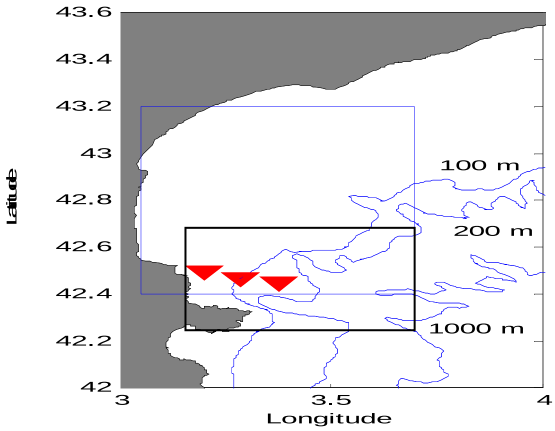


Figure 6: *la zone où LATEX 09 aura lieu est indiquée par le rectangle bleu. Les emplacements potentiels des mouillages sont indiqués par triangles, choisis pour constituer un transect cross-shore au large de Cap Béar. La Zone of Intensive Observation (ZIO), zone d'interaction du tourbillon avec le Courant Nord, est indiquée par le rectangle noir.*

B) Stratégie de la campagne LATEX 09

En septembre 2009, nous commencerons par effectuer à bord du RV Suroît un quadrillage de la zone ouest du golfe du Lion, au nord de 42°30' et à l'est de 3°40', pour localiser la structure tourbillonnaire, que nous aurons choisi d'étudier, sur les transects verticaux de courants mesurés grâce à l'ADCP de coque du RV Suroît.

La démarche expérimentale déploie plusieurs volets, présentés ici chronologiquement une fois que la structure aura été localisée:

- Bouées lagrangiennes
- Traceur SF_6
- Transects ADCP

- Mesures biogéochimiques

1) <u>Bouées lagrangiennes</u>

Des bouées lagrangiennes de type GPS-Argos auront été mises dans le Courant Nord lors du trajet du RV Suroît en départ du port de la Seyne sur Mer (où nous effectuerons le chargement de l'équipement) vers la zone d'étude.
Puis, à la fin du quadrillage de la zone, une fois la structure cartographiée, nous mettrons des bouées GPS Argos en pourtour de structure (Figure 7), et finirons en mettant la bouée de communication directe (HF ou Iridium) ainsi que la bouée CARIOCA au centre du patch de SF_6 (voir section suivante).

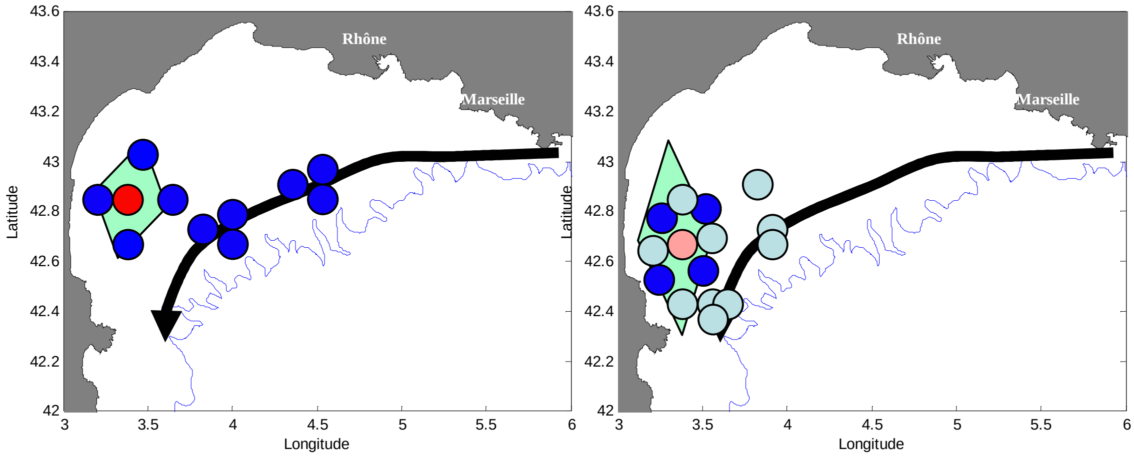


Figure 7 : *Carte du golfe du Lion (incluant isobathe 1000m), avec un trajet schématique du Courant Nord. La structure ciblée est représentée par un losange vert, dont le grand axe indique la direction schématique d'étirement de la structure. La bouée de type HF ou Iridium est indiquée en rouge (rose après 24h) et celles de type GPS-Argos en bleu (bleu pâle après 24h); a) position initiale des bouées lors de leur lâcher avant la mise à l'eau du traceur SF_6, b) position à la fin de la mise à l'eau du traceur SF_6*

2) <u>Traceur SF_6</u>

Le traceur SF_6 sera injecté à l'intérieur de la structure tourbillonnaire choisie pendant une période de 24 heures. Le SF_6 doit être introduit dans l'eau de la façon la plus homogène possible dans une zone d'à peu près 7x7km, soit de ~50km^2 (Figure 8). Pour cela, nous planifions de le mettre à l'eau en effectuant une trajectoire en spirale, en partant du centre, en navigation lagrangienne. La navigation lagrangienne est nécessaire pour prendre en compte le mouvement des masses d'eau dans lequel le traceur est introduit. Ce mouvement est calculé par communication en direct avec la bouée lagrangienne mise au centre du patch.

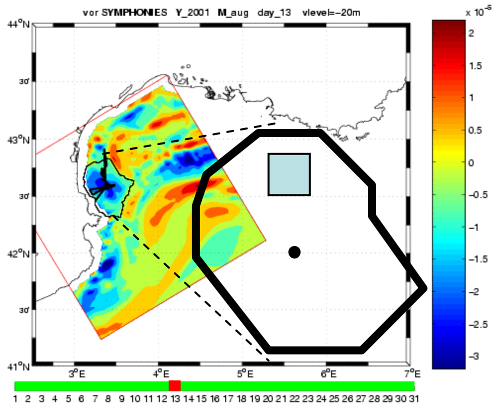


Figure 8 : *Carte de vorticité à 20 m du 13-08-2001 avec le contour du tourbillon anticyclonique détecté par la méthode d'analyse en ondelettes WATERS; zoom sur le tourbillon avec indication de la localisation potentielle du patch en grisé (*cf. note).*

Note : Il faut faire la différence entre le « patch » de SF_6 qui aura pour taille théorique un carré de 7km de côté et la taille de la structure étudiée, 40km de diamètre moyen si c'est un tourbillon anticyclonique, ce que l'on a plus de chance d'observer compte tenu des résultats obtenus jusqu'à présent.

Nous avons effectué des tests de navigation lagrangienne en juin 2007 dans le cadre de la campagne Latex00 (R/V Tethys II). On peut se rendre compte (Figure 9, à droite) au vue des trajectoires reconstituées en repère lagrangien que notre logiciel de navigation lagrangienne a très bien fonctionné.

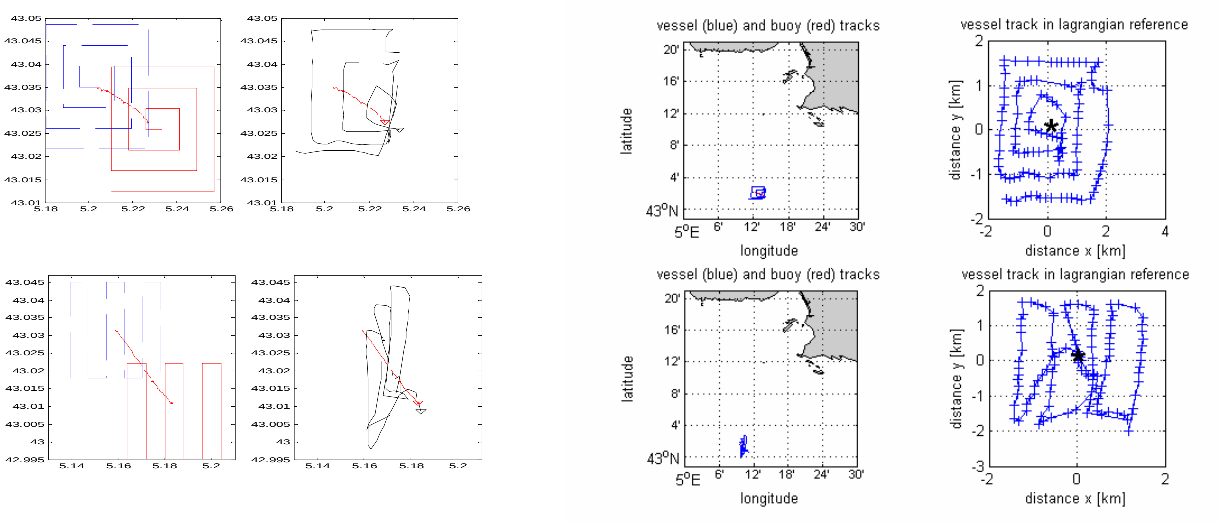


Figure 9 : *Tests de navigation lagrangienne de Juin 2007 Latex00 (haut : spirale, bas : radiateur) ; de gauche à droite : formes théoriques centrées sur le début et la fin de la trajectoire de la bouée suivie (début : rouge ; fin : bleu); trajectoire réelle effectuée par le Téthys II avec la trajectoire de la bouée en rouge, idem sur une carte plus grande pour localiser la zone ; trajectoire reconstituée dans un repère lagrangien.*

En juin 2007, nous avons effectué des tests de navigation lagrangienne en réalisant des trajectoires en spirale (Figure 9, haut), ou en radiateur (Figure 9 bas). Une « spirale carrée » revient, comme dans le cas du radiateur, à avoir un patch initial carré. En revanche, la navigation lagrangienne est simplifiée puisque la trajectoire en spirale se fait en partant près de la bouée lancée puis en augmentant la distance au centre de la spirale ; donc nous avons décidé d'opter pour cette option de « spirale carrée » lors de la campagne LATEX 09.

Le traceur sera introduit au milieu d'un rayon (plutôt vers l'extérieur) de la structure choisie (Figure 8). Faire l'hypothèse que, en première approximation et pendant les 24h d'injection du traceur le long de la trajectoire en spirale, le « patch » de traceur se déplacera avec un mouvement de translation (bien entendu non uniforme) à l'intérieur de la structure semble acceptable et permet donc de déterminer la navigation lagrangienne à partir des informations d'une seule bouée (la bouée HF ou Iridium).

En fait, la navigation lagrangienne est surtout importante pour la diffusion régulière du traceur de façon à pouvoir, par la suite, estimer avec précision sa dilution dans l'espace au cours du temps et donc des coefficients de diffusion horizontaux (et peut-être verticaux). Ces calculs de dilution sont rendus plus simples si l'on peut partir de l'hypothèse d'un patch homogène au départ.

3) Transects ADCP

Une fois le traceur mis à l'eau, le RV Suroît partagera son temps journalier en périodes d'échantillonnages biogéochimiques (de 3 ou 6h à 12 ou 15h, cf. ci-après) et périodes de détection en temps réel du patch (de 12 ou 15h à 3 ou 6h du matin) avec mesures en continu de la concentration en SF_6. Durant cette phase de détection, le Suroît effectuera des transects type « papillon » (Figure 10A et B), qui s'adapteront à la forme du patch détecté. Par exemple, il est bien évident que l'«aile» du papillon sera raccourcie si on arrive à des concentrations de SF_6 de l'ordre de la concentration ambiante.

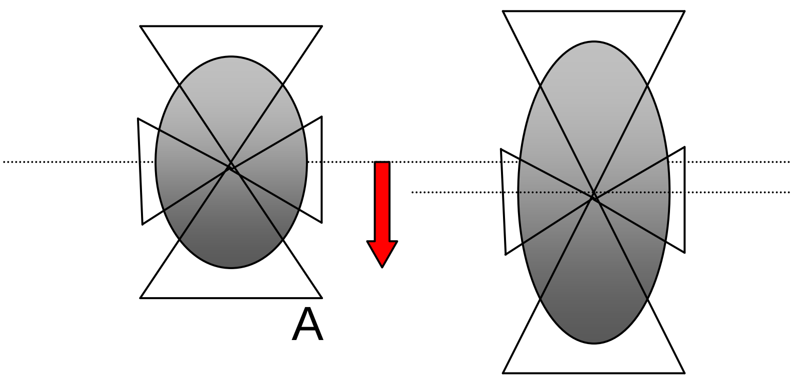


Figure 10 (gauche) : A) Schéma des transects type « papillon » effectués par le RV Suroît dans le patch de SF_6, B) adaptation des transects à l'étirement du patch ; le sens de l'étirement est indiqué par la flèche rouge.

4) Mesures biogéochimiques

Deux types d'échantillonnages biogéochimiques journaliers sont prévus et seront alternés un jour sur deux.
1[er] type (journée dite « production ») : échantillonnage dès 3h du matin pour les prélèvements d'eau qui serviront aux incubations de production (Prod. Comm. Nette, Prod. Primaire…) et à l'évaluation des stocks de carbone et oxygène dissous. Le prélèvement se fera toujours au centre du patch de SF_6. Puis, entre 06h du matin et 15h00, plusieurs prélèvements (environ 4) seront réalisés en divers points du patch en vue d'avoir une cartographie des stocks de carbone (POC, DOC, DIC, alcalinité) et d'autres paramètres (O_2 dissous, pigments chlorophylliens…). La suite de la journée sera dédiée à la cartographie du patch SF_6 avec des mesures de concentrations en SF_6 en temps réel.
2[e] type (journée dite « stocks ») : échantillonnage en début de matinée (06h00) en divers points du patch (environ 5) en vue d'obtenir une cartographie des stocks de carbone (POC, DOC, DIC, alcalinité) et d'autres paramètres (O_2 dissous, pigments chlorophylliens…). A partir de 12h00, la cartographie intensive de la géographie du patch démarre jusqu'à 03h00 du matin le lendemain.

Calendrier journalier prévisionnel des travaux :

J_1 : embarquement des scientifiques à la Seyne/Mer, trajet jusqu'à la zone d'étude, déploiement de bouées GPS-Argos dans le Courant Nord.

J_2-J_6 : recherche de la structure tourbillonnaire dans la zone d'étude ; 2 stations de prélèvements biogéochimiques avec profils CTD durant cette période et préparation sur le pont de la cuve SF_6 en prévision de la dispersion du traceur (remplissage, saturation du traceur).

J_7 : dispersion du traceur et mise à l'eau de différentes bouées. Durée 24h complète.

J_8 : 1[ère] cartographie de la distribution du traceur SF_6.

J_9 : mesures biogéochimiques avec journée de type « production » et tous les jours impairs (J_{2x+1}) jusqu'au **J_{21}**.
J_{10} : mesures biogéochimiques avec journée de type « stock » et tous les jours pairs (J_{2x}) jusqu'au **J_{22}**.
J_{23} : retour à La Seyne/Mer, débarquement matériel et scientifiques

DOCUMENT N°3	**DOSSIER DE DEMANDE :** **DATE : 25 SEPTEMBRE 2007**

MOYENS A METTRE EN OEUVRE

- **Navire support, submersibles* et positionnement ; NON**
- **Équipements de base : *matériel mis en œuvre par* GENAVIR*, par* l'I.F.R.T.P.*, ou par* l'IRD *et matériel propre de l'équipe demanderesse***

Quel matériel prévoyez-vous d'emprunter aux Parcs Nationaux (INSUE, IFREMER-GENAVIR, IRD, Météo-France, EPSHOM…) : 2 balises Argos et 2 largueurs, 1 bouée CARIOCA

- **Installations du navire qui doivent être utilisées :**
- **Personnel spécialisé : NON**
- **Besoins en équipements ou matériels complémentaires : quels types ? Quelles spécifications ? NON**
- **Est-il prévu d'embarquer des produits chimiques ou radioactifs (lesquels) ? NON**
- **Matériel fournis par des organismes extérieurs**
- **Évaluation du coût de fonctionnement à la charge de l'équipe scientifique**

Pour l'installation de nouveaux équipements sur le Nautile il faut se conformer à la procédure **« Qualité de l'intervention sous-marine : Procédure d'évolution du Nautile » Ref : DITI/LB/98-04 .*

*Pour la qualification des conteneurs pour les travaux sous-marins les tests doivent être réalisés selon la **spécification technique IFREMER d'intervention sous-marine** Ref : N° 31 SE 06-B**.** Pour obtenir ces spécifications contacter la DMON.*

LEFE ANNEXE 3

Evaluation Risks and potential feedbacks

Potential Feedback : Strong

The results of the project will be extremely helpful (restricted list):

- to the oceanographic coastal-offshore community by establishing a realistic budget of heat and transport across the continental margin
- To the modelling community by calculating adequate parameterisations of diffusive coefficients to be used in other models. This will useful for both operational and hindcast modelling.
- To the biogeochemical community by estimating the potential impact to the ecosystem of coastal (sub)mesoscale eddy structures interacting with the general circulation.

Evaluation of the risks: Average

Everytime a cruise is planned, there is an associated risk. Indeed meteorological conditions and/or sea state can be too bad to go out at sea. In our project, there is indeed a certain risk associated with the cruise. If a very strong gust of tramontane was to happen during the experiment, the SF_6 will mix very rapidly and will not be able to be followed long after the onset of the wind gust.
On the contrary, another risk lies in the eddy remaining stationary with no interaction with the NC. In that case, we plan on taking advantage of the gliders and the ADCP of the Tethys II to obtain very good measurements on transects from the continental margin to the continental slope and calculate the potential inhibitor impact of coastal eddy to the coastal-offshore exchange. In a way, it would be a “contrary” LATEX.

With the two preceding criteria, the global note of the LATEX project is 4.

LEFE ANNEXE 4

SUMMARY of the results of LATEX 00 (2007)

Latex00 has two components, a numerical one and an experimental one. The time table of the tasks was scrupulously followed; hence, only 6 months after the start of Latex00, we already have a lot of results to present (as was shown at the LEFE IDAO presentation of Latex on September 10, 2007, presentation which can be found on our web site http://www.com.univ-mrs.fr/~doglioli/latex.htm).

1) **The first component consisted in deepening our knowledge of the (sub) mesoscale processes** occurring in the Gulf of Lion with the analysis of numerical hydrodynamic outputs in order to identify an eddy or a filament with given characteristics (longevity > 10 days and weak or medium strain rate) in a stratified environment (mixed layer about 50 m). These constraints are imposed on the structure for the logistics of the tracer experiment.

The wavelet analysis technique (WATERS) was used in order to track the eddy or filament structures of the Gulf of Lion. WATERS was applied to horizontal maps of relative vorticity, calculated from the velocity outputs of the SYMPHONIE model (data provided by Claude Estournel and Patrick Marsaleix, POC, Toulouse).

Daily or bi-daily data have been analysed for three years: 2001, 2004 and 2005 (Z. Hu, Master 2nd year, report 2007) and have shown that:

– the weak to medium strain rate forces us to follow an eddy structure rather than a filament;

– there is a higher probability, during stratified months, for a structure to be present close to the coast, in the western side of the Gulf of Lion (Figure 11), than elsewhere in the gulf.

So we have decided that the big **LATEX experiment with the SF_6 tracer will take place in September 2009 in the western part of the Gulf of Lion.**

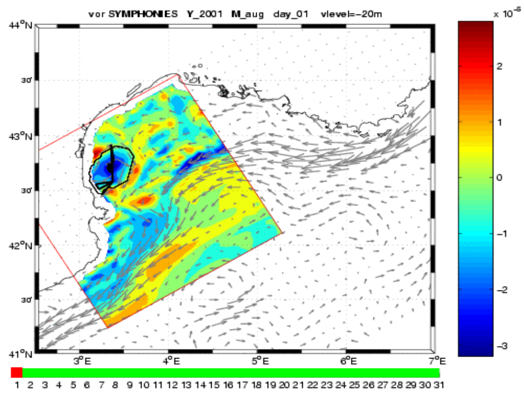


Figure 11: Anticyclonic eddy A1 on August 1st; A1 was detected for 32 days from July 17, to August 18, 2001

A vertical analysis has been done for the anticyclonic eddy A2 of 2001 (lifespan: Sept 4 – Oct 6, 2001). The anticyclone has a clear hot anomaly. Eddy boundaries, detected by the wavelet analysis, fit well the steepest gradients of T (Figure 12b) and S (data not shown). The bottom of the eddy seems to reach 65 m depth.

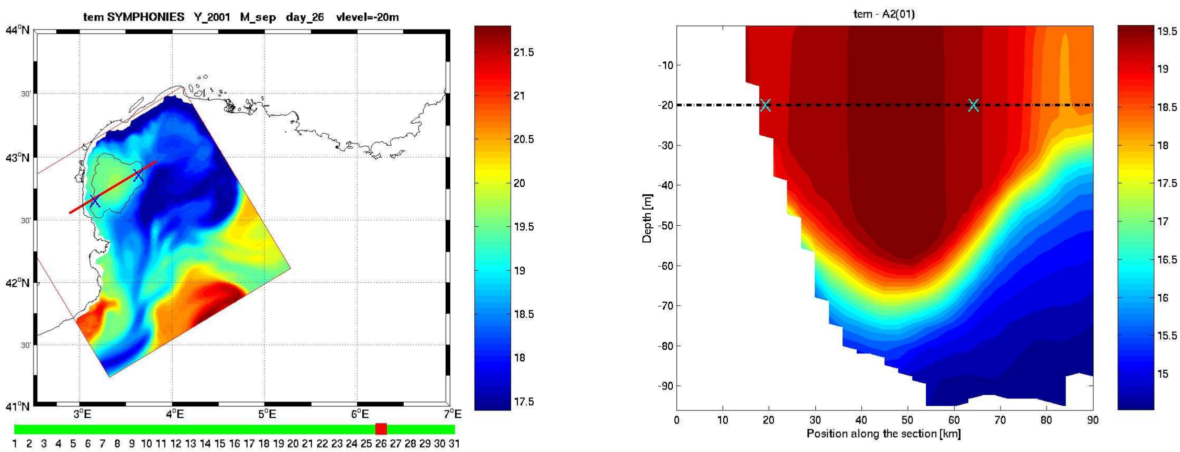


Figure 12 a) Horizontal slice of temperature at 20 m depth. The black contour represents the eddy area, as detected by the wavelet analysis. The red line shows the vertical section position and blue crosses show the intersections with the eddy boundary.

12 b) Vertical slice of temperature at the section represented in the horizontal slice. The black crosses at 20 m depth show the intersections with the eddy boundary, as detected by the wavelet analysis.

During mid-July to mid-October of the three studied years, 7 anticyclonic eddies and 7 cyclonic eddies were followed and studied in details (start and end of the eddy, centre of the eddy, speed of the centre, trajectory of the centre, diameter of the eddy, mean salinity and temperature, mean kinetic energy). Most results are presented in the Master report of ZiYuan Hu. Otherwise, some of their characteristics are summed up in the following table.

	7 anticyclonic eddies	**7 cyclonic eddies**
Mean life span	37 days	16 days
Mean speed of the eddy center	5 cm/s	6 cm/s
Mean diameter	43 km	35 km
Characteristic anomalies (compared to ambient waters)	less salty warmer higher SSH	saltier colder lower SSH

The centers of both anticyclonic and cyclonic eddies, defined as the gridpoint of local maximum of absolute relative vorticity over the eddy area, is observed to move at a mean speed of 5-6 cm/s. Caution need to be taken in the interpretation of this result. The cyclonic structures do generally move (some have very linear trajectory). But the anticyclonic eddies are generally trapped north of Cap Creus, between the coast and the shelf break, as shown in Figure 11. Furthermore, the mean speed of the anticyclonic center reflects the uncertainty on the eddy contour due to the 3*3km Symphonie resolution, result that will be improved with the higher resolution Symphonie model.

In the framework of LATEX00 pilot project, Nicolas Grima's work has been dedicated to developing the ARIANE-SYMPHONIE coupling. The ARIANE toolkit is an off-line Lagrangian diagnostic tool dedicated to the analysis of simulations run with numerical ocean models. ARIANE provides both qualitative (Figure 13) and quantitative numerical trajectories.

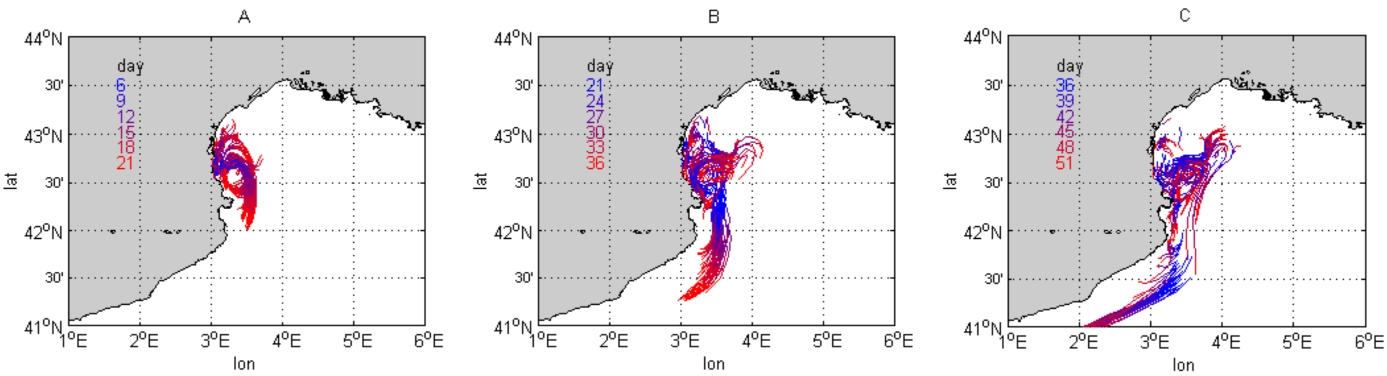
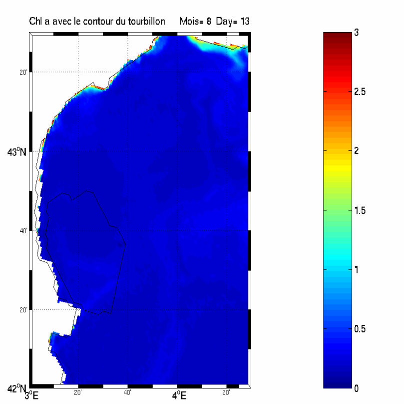


Figure *13: Ariane qualitative test: 170 lagrangian buoys were released in A1 on August 11, 2001 and followed for 51 days as shown in the three figures above (left to right) from day 6 to day 21, day 21 to day 36 and day 36 to day 51 (N. Grima, LPO).*

Satellite imagery was used in order to check the presence of the structures found with WATERS. Good agreement was generally obtained despite the fact that the model resolution (3*3km) is not sufficient, as already mentioned, to obtain reliable accuracy on the location of the eddy contour (Figure 14).

Figure 14 (right): SeaWiFs image of the Gulf of Lions on August 13, 2001 12h13; data treated by E. Bosc



2) Tests of Lagrangian survey and determination of the background natural SF_6 concentration

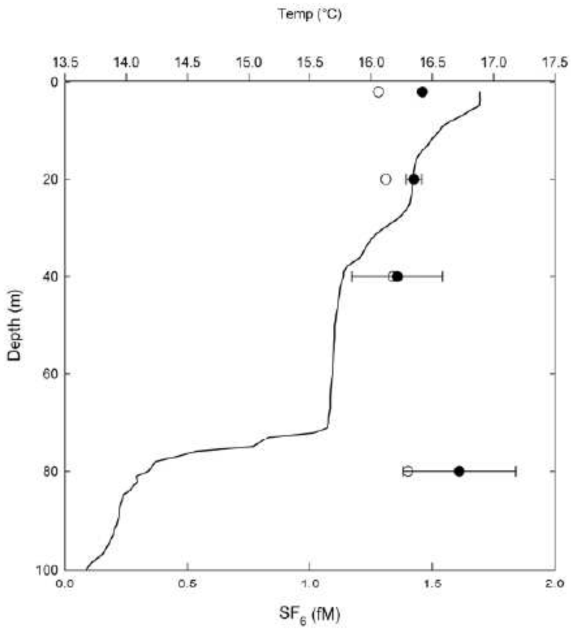
Lagrangian navigation was tested since it is crucial in tracer dispersal studies such as LATEX. Dispersion of the tracer in a zone of about 50 km^2 lasts about 24 hours. During this period, the RV is supposed to follow a trajectory in the shape of a radiator or of a squared spiral (that we call an "Egyptian spiral"), in the zone where the tracer is to be dispersed. Since water masses are continuously moving, this procedure is not trivial and navigation must be done in a Lagrangian referential. Hence a short cruise of 3 days was done on the Tethys II in June 2007 in order to check our ability to reproduce the "radiator" or the spiral in a Lagrangian moving referential.

This requires the precise knowledge, at a high temporal frequency, of the centre of the patch. Since we had not received the money to buoy an Iridium buoy, we performed a small-size test with a classical SVP buoy (GPS-Argos) in direct communication. We obtained pretty good navigation results (Figure 9).Locating the buoy is fine with just a GPS and does not require a DGPS. But, of course, to calculate precisely the buoy speed, the speed is calculated by difference between two GPS positions. The RV direction is continuously corrected depending on the buoys' information received and processed through a software developed by J.-L. Fuda (COM).

In Latex00, money was asked and was partially granted to fund GPS-Argos buoys and HF buoys. As far as the latters were concerned, it was mentioned in the proposal that we were going to make comparisons with other technologies such as Iridium or others. For various reasons (lack of future technical development for HF, size of the HF antenna, lack of oceanic use, recent developments of Iridium, see "Evaluation of SVP-B drifters reporting through iridium", Pierre Blough, Jean Rolland, Jean-Paul Jullien, Météo-France, sept. 6, 2007), we have finally chosen to use Iridium buoys in Latex.

The first results (Figure 15) of SF6 contents measured in the studied area show that the observed concentration is that of a water mass at the equilibrium with the atmosphere contents. According to these results we plan to work on an initial solution of 0.146mM. Thus on the basis of a 4m3 tank and a tracer dispersion over 50km2 in a mixing layer of 40m depth, the final content of SF6 in the seawater will about 300 times higher than the ambient concentration. This tracer enrichment should be able to follow the (sub)mesoscale structure during two weeks.

Figure 15 (right): Vertical profile of ambient content of SF_6 (circles) and temperature (black line) at MOLA Station (42.52°N, 3.54°E) measured on May, 25 2007. Black circles are the mean values of SF_6 contents (n=2) and their error bars. Open circles are the SF_6 solubility in the sea water at the salinity and temperature measured by CTD for a molar fraction of SF6 in the atmosphere of 6.1 pptv in 2007.



Summary of the budget obtained for Latex00 in 2007

	LEFE	Région PACA	BQR université	Total autres financements
Fonctionnement	**6 000**			
Mi lourd flotteurs	**14 000**	**19000**	**10 000**	**29000**
Equipement mi-lourd CPG	**14 800**	**13500**	**6 000**	**19500**
Total	**34 800**	**32500**	**16 000**	**48500**

Demande du RV Téthys II en 2009

Embarquants (6-7 maximum):

A. DOGLIOLI, J.-L. FUDA, Z. HU, A. PETRENKO (chef de mission) LOB-COM
P. TESTOR, H. CLAUSTRE, X gliders LOCEAN - LOV

Port d'embarquement et de débarquement: Port-Vendres

Date : Jour J7 à Jour J23 (voir calendrier du Suroît en Annexe 2) soit 17 jours

Si la pression est forte sur le RV Téthys II en Septembre 2009, il serait envisageable de scinder la demande en deux plus petites périodes : J7 à J14 + J18 à J23 soit 8 + 6 = 14 jours

Travaux scientifiques à effectuer

En septembre 2009, après que le RV Suroît ait effectué un quadrillage de la zone ouest du golfe du Lion, au nord de 42°30' et à l'est de 3°40', pour localiser la structure tourbillonnaire, les « Physiciens/Spécialistes des gliders» embarquerons à bord du Téthys II. Leur tâche principale sera de prendre le relais du Suroît pour sillonner la zone de façon à obtenir une couverture quasi permanente de la circulation de la zone d'étude (centrée sur la structure tourbillonnaire). Tous les 4 jours, le Téthys II ira effectuer un transect à travers le Courant Nord (J8, J12, J16, J20). Dès qu'une interaction de la structure avec le CN sera remarquée, le RV Téthys II se concentrera alors sur la ZIO. De plus, le RV Téthys II interviendra, si besoin est, au niveau de gliders.

La démarche expérimentale du projet LATEX a plusieurs volets, dont la plupart ont été détaillés dans la demande du Suroît. Sont présentés ici, très brièvement : l'aspect eulérien de l'étude, les transects effectués avec le Téthys II et les gliders.

Mouillages eulériens

Pour obtenir des données eulériennes classiques de courant dans la zone, nous proposons de mettre à l'eau, des septembre 2008 (demande du Téthys II), trois ADCP mouillés sur des fonds de 60 à 600 m. Ces mouillages seront de configuration simple (Figure 16).

Les mouillages seront positionnés pour constituer un transect cross-shore au large de Cap Béar (Figure 6) et permettre d'évaluer l'intensité et la direction dominante du courant dans la zone clef d'échange avec le Courant Nord. Néanmoins l'activité halieutique étant très importante dans la zone, les positions exactes de mouillage seront choisies avec soin (bouées Nord ou Sud de la réserve, les «Ruines», plateforme MOLA...); et d'éventuelles solutions pour caréner nos ADCPs seront envisagés.

Ils seront relevés à la fin de la campagne LATEX de septembre 2009 à partir du Téthys II.

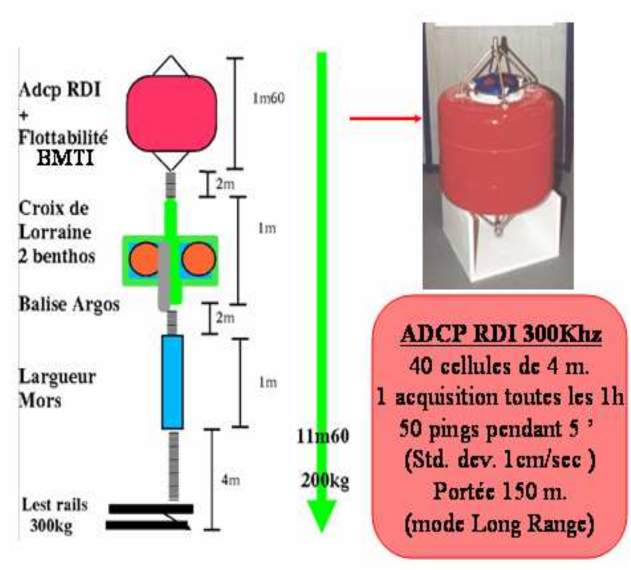
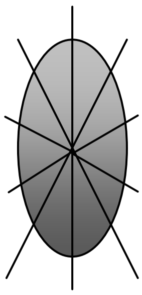


Figure 16 (à droite) Schéma du mouillage et photo de l'ADCP RDI Sentinel

Transects ADCP



Les contributions des courants et oscillations d'inertie au champ de vitesse seront évaluées grâce à des trajets aller-retour effectués par le Tethys II (Figure 17). Cette démarche a été testée avec succès lors des campagnes Golts/Argol/Colargol effectuées à l'est du Golfe du Lion pour détecter les intrusions du Courant Nord sur le plateau (Gatti, thèse 2007).

Figure 17 : transects effectués par le RV Téthys II, par opposition aux trajectoires en « papillon » effectuées par le Suroît

Gliders
Plusieurs gliders seront utilisés pour effectuer des transects et collecter des données hydrologiques, et parfois optiques, à travers la structure tourbillonnaire et les eaux ambiantes. Les gliders seront aussi utilisés pour traverser le Courant Nord (Figure 18) et seront programmés pour effectuer des transects, de façon répétée, dans la ZIO (Figure 6). Ils permettent aussi de détecter avec précision des langues de remontées ou de subduction d'eaux grâce à leur signature (par exemple en fluorescence, 0_2 ou CDOM) différente des eaux ambiantes (Niewiadomska et al., 2007 soumis à *Limnol. Ocean*.).

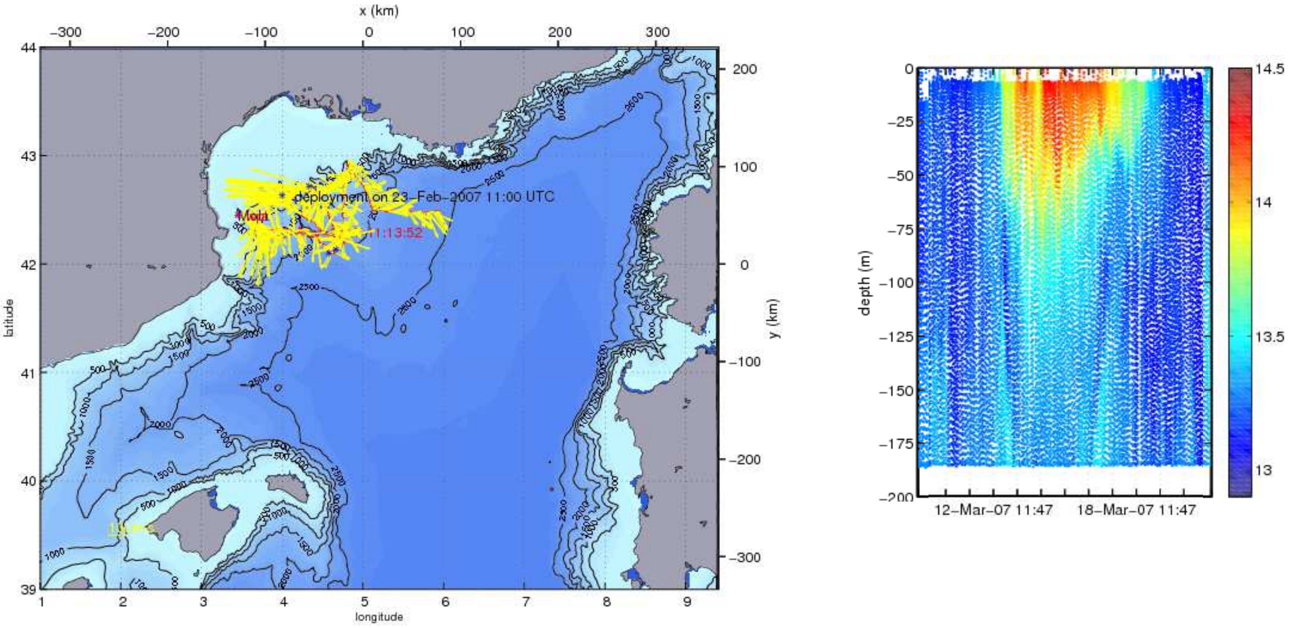


Figure 18 : Pythéas cruise in the Gulf of Lion (Feb 23 to March 30, 2007) A) trajectory of the glider and measured horizontal speed; B) section of temperature measured by the glider through the Northern Current (http://www.lodyc.jussieu.fr/gliders/GROUNDSTATION/PYTHEAS/m_lon-m_lat.html)