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OS 2.1
Poster n° XY 597

LATEX_tools: a software package for navigation in a Lagrangian reference frame

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The LATEX (LAgrangian Transport EXperiment) project aims to study the influence of coupled physical and biochemical dynamics at the (sub) mesoscale on matter and heat transfers between the coastal zone and the open ocean. One of the goals of the oceanographic field experiment Latex10, conducted during September 2010 in the Gulf of Lion (NW Mediterranean), was to mark a mesoscale feature by releasing a passive tracer (SF6) together with an array of Lagrangian buoys. In order to release the tracer in an initial patch as homogeneous as possible, and to study its mixing and dispersion minimizing the contribution due to the advection, it was necessary to adjust continuously the vessel route to keep the observations in a Lagrangian reference frame moving with the studied dynamical structure. To accomplish this task, we developed the "Lagrangian navigation" software presented here. The software is equipped with a series of graphical and user-friendly accessories and the entire package can be freely downloaded from the LATEX web site:

http://www.com.univ-mrs.fr/LOPB/LATEX

Why a Lagrangian cruise?

• **Mass balance for a Lagrangian control volume**

$$\frac{d}{dt}\int_V \psi\, dV + \oint_S \psi \mathbf{u}\cdot d\mathbf{S} + \oint_S \chi \cdot d\mathbf{S} = \int_V \xi\, dV$$

Temporal variation	Advection (to be neglected)	Boundary exchanges horiz+vert	Sources & sinks (null for SF_6)

$\psi = O_2, C, SF_6$

This makes possible to close the following biogeochemical balances

Net Community Production Δt=5-6 days

$NCP_{O2} = \Delta O_2 + F_{sea\text{-}air} + F_{hor} + F_{ver}$

$NCP_{DIC} = \Delta DIC + F_{sea\text{-}air} + F_{hor} + F_{ver}$

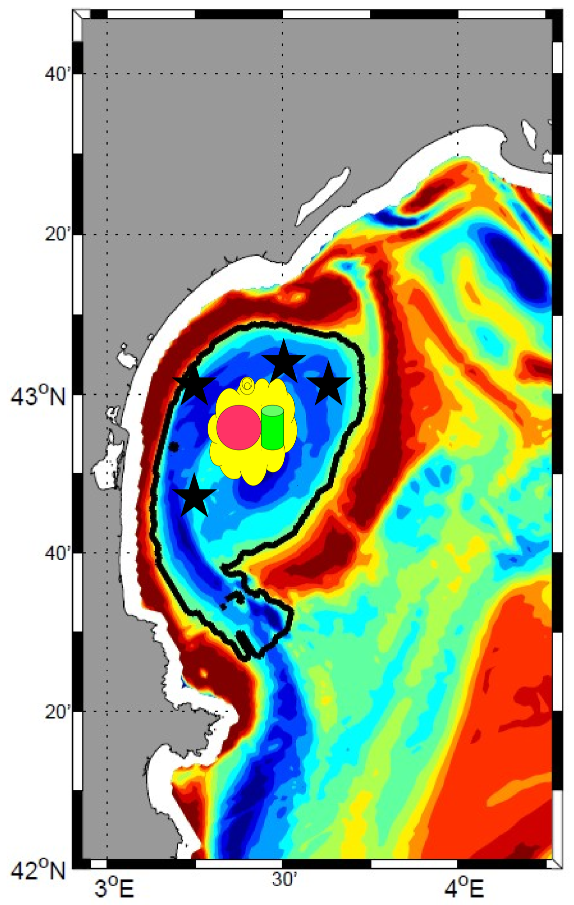
& comparison with bottle incubations

Carbon export

$C_{exp} = NCP_{DIC} - \Delta POC - \Delta DOC$

in situ bottle (*in situ*)

• **Latex10 cruise** : the planned ***in situ*** experiment



Iridium buoy
- *real time communication*
- *anchored at 12 m*

Carioca buoy
- *pCO_2 measurements*

15 Standard SVP drifters anchored at 15 m
- *Lagrangian drift*
- *patch deformation*

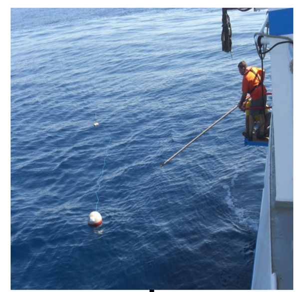
SF6 passive tracer
- injected at 10 m depth
- *deformation and mixing*

The algorithm

i) real-time acquisition of the positions of the buoy released at the array's center and of the vessel position;

ii) resolution of a simple system of ballistic equations projecting a pre-defined route in the moving frame,

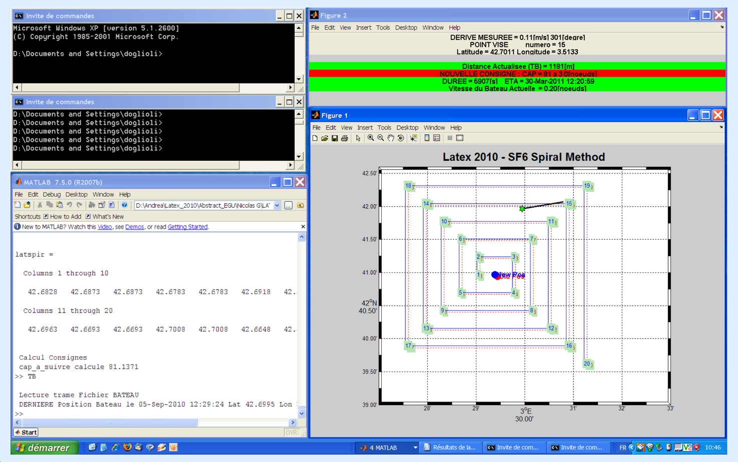
iii) calculation of the navigation instructions for the bridge with an interactive graphical output.



Vessel and buoy positions acquisition

$$\begin{aligned} x_{vessel} + u_{vessel}\,t &= x_{target} + u_{target}\,t \\ y_{vessel} + v_{vessel}\,t &= y_{target} + v_{target}\,t \\ u^2_{vessel} + v^2_{vessel} &= |\vec{v}_{vessel}|^2 \end{aligned}$$

Instructions for the bridge (direction and speed) and graphical interface

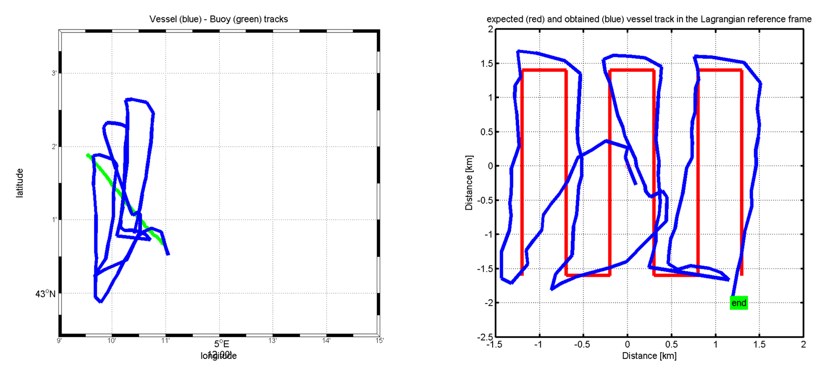


The choice of the transmission system

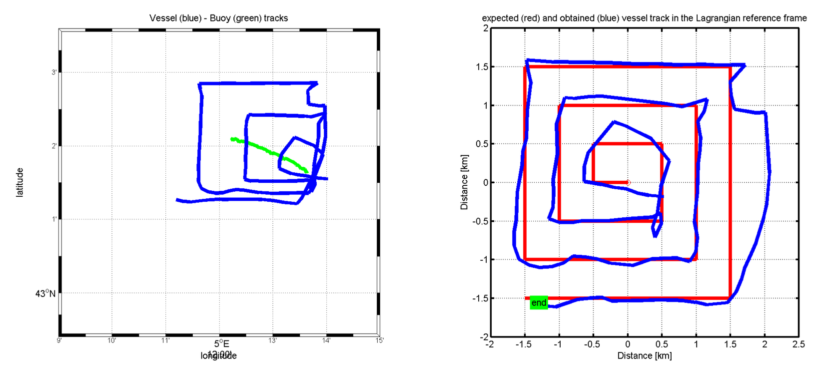
HF radio
Despite its long range performance (theoretically 150 miles theoretical) the HF solution has been excluded, since the required large size of the antenna would influence the buoy drifting.

Argos
The Argos solution has been adopted for the first tests at sea during LATEX00 cruise. A receiver board Martec RMD03 and an external antenna did not provide a far enough range: only one mile was obtained, whereas five were expected, probably due to the fact that the receiver, despite placed as high as possible on the masts, was only 10 meters above the floating buoy level.
However, this configuration allowed us to perform the tests necessary to validate the method.

In 2007, during Latex00 cruise, we tested the Argos communication system and two different shapes of routes, a radiator...



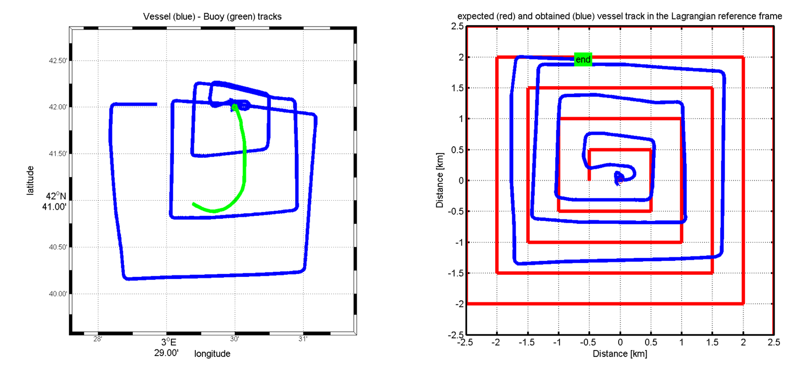
... and a spiral.
The latter revealed to be easier to follow and it had been chosen for the next cruise.



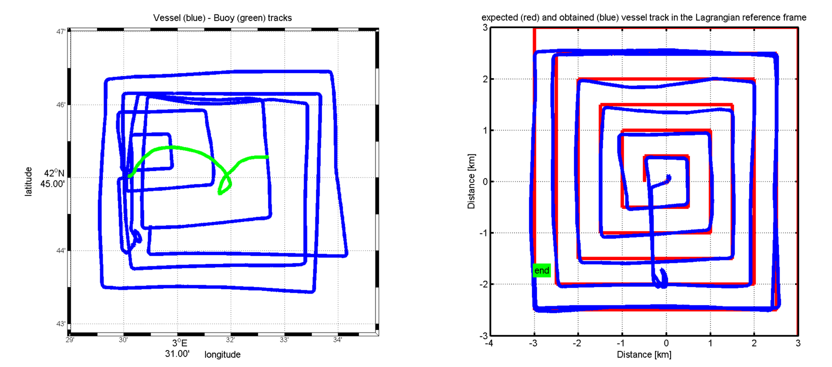
Iridium communication
In 2009, the emergence of the first drifter with Iridium transmission led us to develop our own prototype buoy. In a standard SVP buoy we replaced the Argos system with an Iridium transmitter/receiver developed by e-Track Systems (http://e-track.ect-industries.fr/e-track). It is based on a satellite telephone system, bi-directional, allowing communication worldwide and transmit data as SBD (Short Burst Data, somewhat equivalent to SMS).

This system has been successfully used during Latex10 cruise.

First, we performed a 6-hours test. The Iridium communication worked well, while we identified a bug in the code, generating a NW-ward shift of the route with respect the theoretical spiral, that was rapidly fixed.



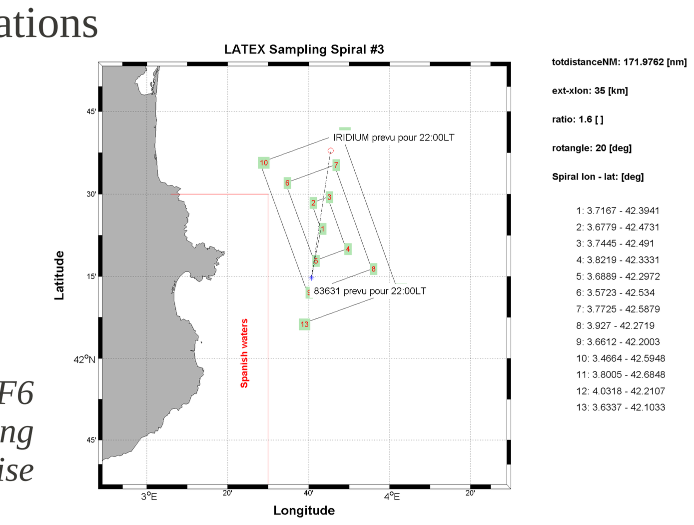
Afterwards, the software worked very well during the tracer dispersal!



Other software

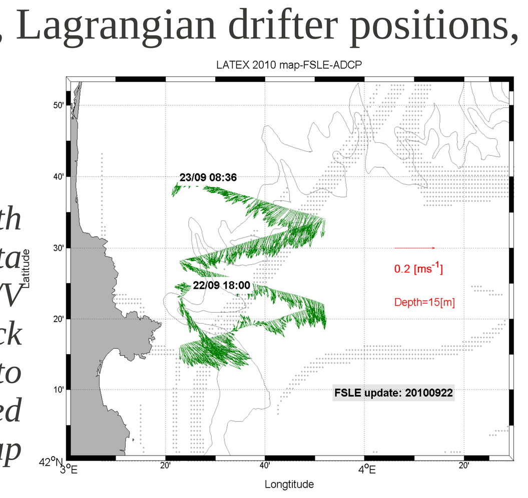
The LATEX_tools package contains also scripts for:

• Planning in near-real time the vessel route and sampling stations



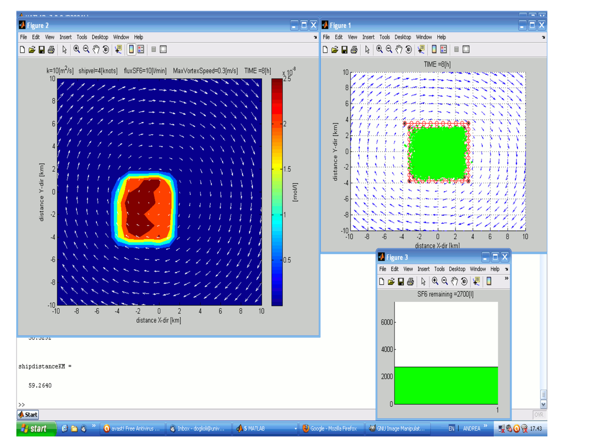
Planned SF6 sampling during Latex10 cruise

• Treating and mapping oceanographic cruise data (ADCP, CTD, Lagrangian drifter positions, etc.)



10-m depth ADCP data along the R/V Tethys II track superposed to satellite derived FSLE map

• Simulating tracer injection and dispersion in idealized conditions (cylindrical eddy and random walk diffusion)



Idealized vessel route, concentration of the SF6 patch and saturated water level in the container

Acknowledgments
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Credits
The LATEX_tools package uses M_Map (http://www.eos.ubc.ca/~rich/map.html).

More on LATEX during EGU2011:

Coastal eddies, Petrenko, OS2.1 Poster XY624
Lyapunov exponents, Nencioli NP6.1, Thursday 9:30
Biogeochemical modeling, Campbell, OS3.2, Wed. 11:00
Physics on biogeochemistry, Nencioli OS3.2, Poster XY 599

ADDENDA
TO THE POSTER XY 597 (Doglioli et al., LATEX_tools, EGU 2011)
(update 21/02/2013)

Defining

1) $\vec{v}_{vessel} \equiv (u_{vessel}, v_{vessel})$ the vessel speed, which modulus during LATEX experiments was fixed $|\vec{v}_{vessel}| = 4\,\mathrm{kn}$ for technical reasons associated to SF6 release system ;

2) $\vec{v}_{target} \equiv (u_{target}, v_{target}) = \vec{v}_{buoy}$ is the drift speed of the « target », i.e. the point (x_{target}, y_{target}) corresponding to a corner of the experimental route (radiator, spiral or an other shape) ;

we need to solve the following closed equation system :

$$x_{vessel} + u_{vessel} t = x_{target} + u_{target} t$$
$$y_{vessel} + v_{vessel} t = y_{target} + v_{target} t$$
$$u_{vessel}^2 + v_{vessel}^2 = |\vec{v}_{vessel}|^2$$

The above system can be reduced to the quadratic equation in time $at^2 + bt + c = 0$
where

$$a = u_{target}^2 + v_{target}^2 - |\vec{v}_{vessel}|^2$$
$$b = 2[(x_{target} - x_{vessel})u_{target} + (y_{target} - y_{vessel})v_{target}]$$
$$c = (x_{target} - x_{vessel})^2 + (y_{target} - y_{vessel})^2$$

Excluding the trivial case in which vessel and buoy are both at rest and positioned at the same point, the discriminant of Eq. (3) is always strictly positive. In fact, c > 0 and, under the assumption that the vessel speed is faster than buoy speed, a < 0. Therefore, in case of practical oceanographic applications, Eq. (3) admits two real solutions which are always of opposite sign. The time required for the vessel to reach the target $\hat{t}$ is thus the positive solution.

With $\hat{t}$, we can estimate the updated vessel velocity (u^{vessel}, v^{vessel})

$$\hat{u}_{vessel} = \frac{(x_{target} - x_{vessel})}{\hat{t}} + u_{target}$$
$$\hat{v}_{vessel} = \frac{(y_{target} - y_{vessel})}{\hat{t}} + v_{target}$$

which, in turn, provides the distance beetween the vessel and the turn point

$$\hat{d} = (\hat{u}_{vessel}^2 + \hat{v}_{vessel}^2)^{1/2}\,\hat{t}$$

and the updated direction of the vessel (angle $\hat{\alpha}$ in relation to the North) that takes into account the drift of the water mass :

$$\alpha = 90^o - \arctan(\hat{v}_{vessel}/\hat{u}_{vessel}) \qquad \text{for } \hat{u}_{vessel} > 0 \;,$$
$$\alpha = 180^o \qquad \text{for } \hat{u}_{vessel} = 0 \text{ and } \hat{v}_{vessel} < 0 \;,$$
$$\alpha = 0^o \qquad \text{for } \hat{u}_{vessel} = 0 \text{ and } \hat{u}_{vessel} > 0 \;,$$
$$\alpha = 270^o - \arctan(\hat{v}_{vessel}/\hat{u}_{vessel}) \qquad \text{for } \hat{u}_{vessel} < 0 \;.$$

with $\arctan(\hat{v}_{vessel}/\hat{u}_{vessel}) \subset (-90^o, +90^o)$.

In the rare case that both $\hat{u}_{vessel} = 0$ and $\hat{v}_{vessel} = 0$, the previous direction is maintained.