Forcing an oil spill drift model with high resolution Mercator Ocean forecasting system in the Mediterranean Sea

S. Law Chune (1), Y. Drillet (1), P. Daniel (2), P. De Mey (3)
(1) Mercator Ocean, (2) Météo-France, (3) POC/Legos
Contact: slaw@mercator-ocean.fr

Introduction :
Mercator Ocean, (French operational oceanography) daily delivers to Météo-France 2D mean currents fields to force its drift model MOTHY. Indeed, due to its barotropic configuration for its self ocean modelling (a compromise between speed of execution and description smoothness), MOTHY needs in turbulent areas like Mediterranean sea, complementary informations which can be provided by the operational oceanography (like great scale currents and baroclinic processes). This solution consists in adding the current under the oceanic mixed layer of these 3D systems to the one computed by MOTHY, in order not to take into account the wind effect twice. We aimed here to find more satisfying solutions of integration for the Mercator currents inside the MOTHY system, and to do so, worked in two direction; first in testing a new set of currents elaborated specially to Mothy expectations and second, in evaluating the forcing capability of an upgrade version of the Mercator operational system. Bench marks datas used for this study correspond to two real drift exercises conducted in the Mediterranean sea, taking parts of the Mersea Project.

DRIFT MODEL

• **Mothy** = Météo France operational drift model, marine pollution/rescue operation: Erika (1999) Prestige (2002)

• Particles constrained by:

- **Horizontal wind driven current** (2D barotropic + 1D turbulent viscosity)
- **Turbulent diffusivity 3D forces** (Lagrangian random walk)
- **Vertical buoyancy forces**

• 2D + 1D = fast execution and good description smoothness but **skewed results inside non well mixed water / great scale currents zones**

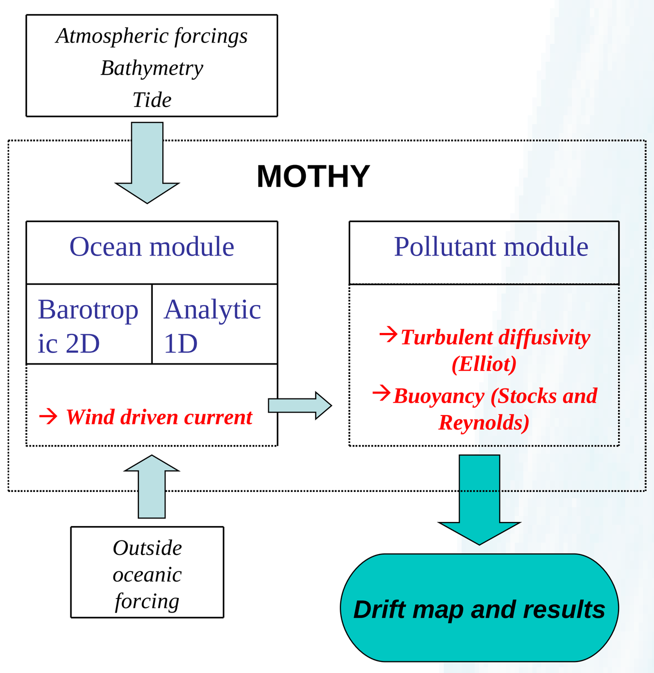


Figure 1: Mothy description.

BENCH-MARK DATAS

Two in-real-conditions drift exercises

Location and time: Mediterranean sea, winter 2007.

First exercise: Western Mediterranean, 6 surface drifters

Drift path and duration: From Azur coast (Oct. 10th 2007) to the Baleares area

Second exercise: Eastern Mediterranean, 3 Argosphere Oil Emulating System drifters.

Drift path and duration: released around Cyprus (Sept. 17th 2007), beached of two drifters on Oct. 16th and 31th on Lebanese and Israeli coasts.

End of exercise on 6th December for the un-beached drifters, hour per hour tracking.

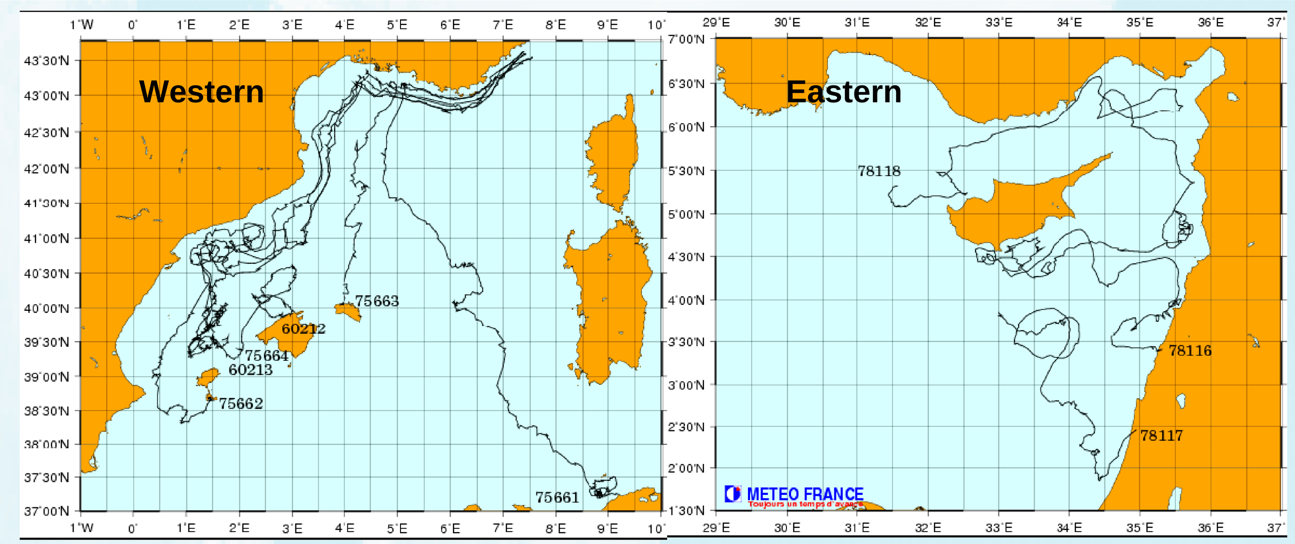


Figure 3 : Drift experiments used as reference cases, for Western (left) and Eastern (right) Mediterranean.

FORCING MOTHY WITH MERCATOR CURRENTS IN MEDITERRANEAN

• Mercator systems = OPA ocean modeling + data assimilation, ECMWF daily atm. forcings, no pressure and tide effects.

• North Atlantic and Mediterranean area systems:

PSY2V2 (previous system):

1/16 ° resolution on Med., 46 z levels (6 m at surface and 250 m at bottom)

PSY2V3 (actual system):

1/12 ° resolution on Med., 50 z levels (1 m at the surface, 400 m at the bottom)

Arakawa C grid

Introduction strategy: the outside oceanic forcing is **added** to the one computed by Mothy. Until now, only the **100 m depth 2D current** was used (extra wind introduction avoidance).

	PSY2V2 (previous system)	**PSY2V3** (actual system)
Ocean Model	OPA 8	NEMO 1.09
Assim. System	O.I	SEEK
Vertical grid	Full step	Partial step
Surface b.c.	Rigid leed	Free surface
Atm. Forcing	Flux	Bulk
Advection schema	Centered	T.V.D

Figure 4: PSY2V2 and PSY2V3 technical specificities

SIMULATION PROTOCOLS

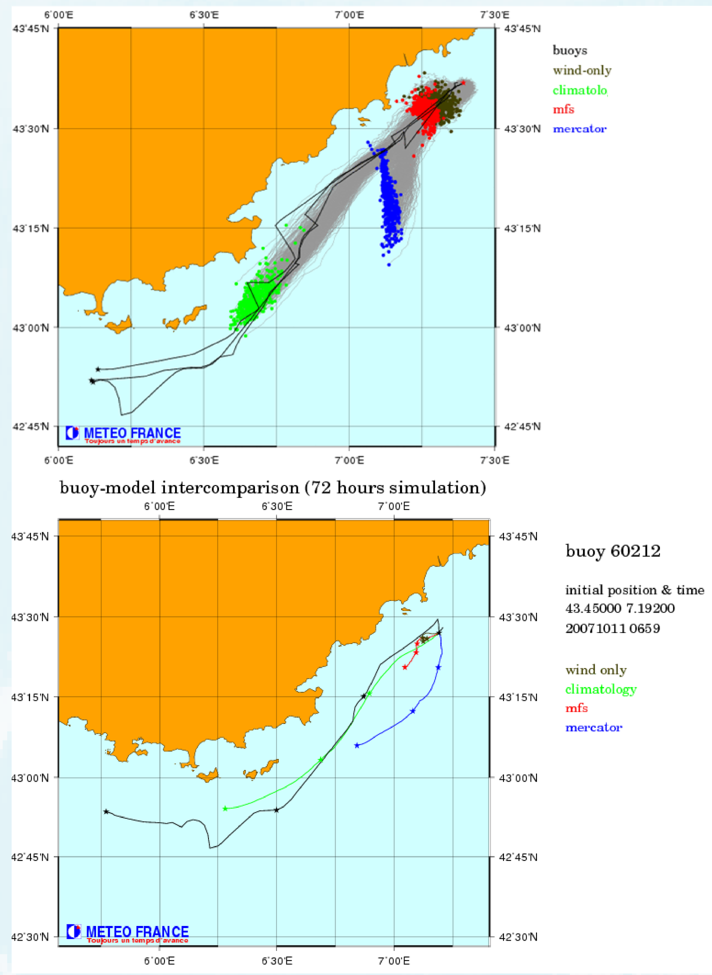


Figure 5: Example of a 72hr simulation, drifter n° 60212, different oceanic forcings evaluation.

Mothy's pollutant = independent droplets

→Comparison: modelised spill barycenter vs observed buoy.

Protocol: starting simulation point = each 48 hr spaced points on observed trajectory, 72 hr of simulation duration.

Scores = statistical comparisons in term of distance, speed and advection direction, all trajectories and all drifters accounted.

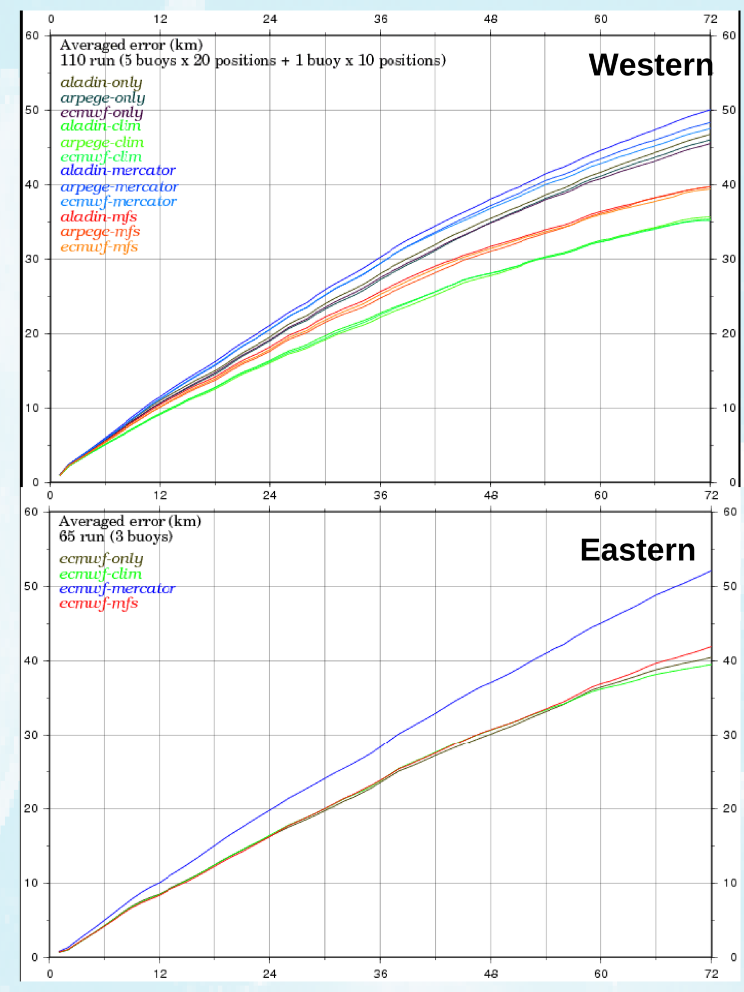


Figure 6: Temporal evolutions of the average distance error using several atmospheric (Aladin, Arpege, ECMWF) and outside oceanic forcings (no forcing, monthly 6m Mercator climatology, Mercator PSY2V2 100m, MFS operational system 100m). Best results are obtained with the climatology for both cases. For eastern Med., no outside oceanic forcing do not seem to degrade results.

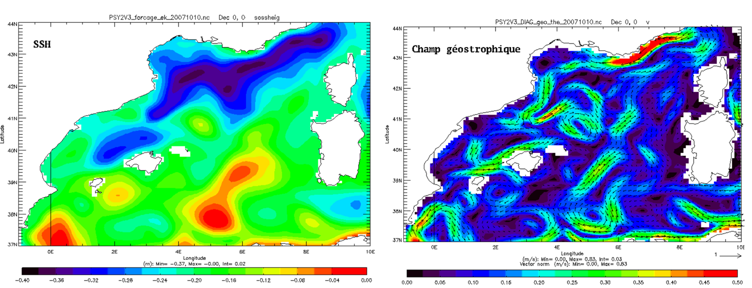
2D TEST CURRENTS

-The **geostrophic** current (added with buoyancy compensation, meaned over a *h* thickness layer)

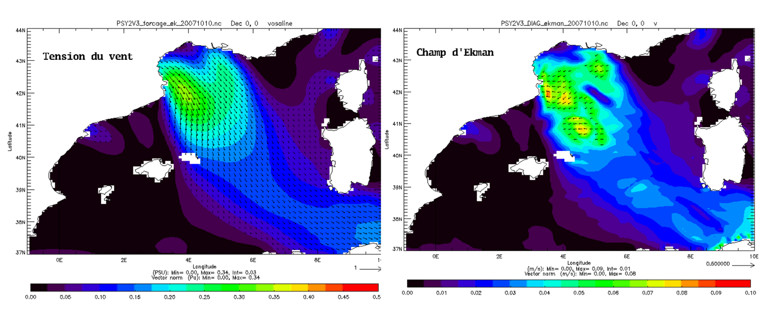
- The **withdrawn mean Ekman** current (meaned over a *h* thickness layer)

- **Under the Ekman layer depth *he*** current extraction.

→ 2D velocities fields representative of the background circulation, without wind effect.

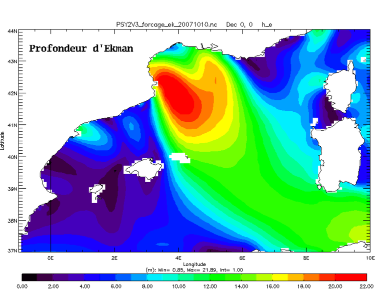


$$\begin{cases} \overline{u\_geo} = {}^{-g}/_{f}\dfrac{\partial \xi}{\partial y} + {}^{h}/_{2f}\dfrac{\partial \theta}{\partial y} \\ \overline{v\_geo} = +{}^{g}/_{f}\dfrac{\partial \xi}{\partial x} - {}^{h}/_{2f}\dfrac{\partial \theta}{\partial x} \end{cases}$$



$$\begin{cases} \overline{u\_ekman} = {}^{+1}/_{fh}\left(\tau^{y} - A\dfrac{\partial v}{\partial z}|_{-h}\right) \\ \overline{v\_ekman} = {}^{-1}/_{fh}\left(\tau^{x} - A\dfrac{\partial u}{\partial z}|_{-h}\right) \end{cases}$$

A= turbulent viscosity coefficient (depending on 10 m wind's strength)



$$he = {}^{2A}/_{f}$$

Figure 7 : Forcings and corresponding test currents.

Method inspired by Lagerloeff et al. 2002

$$\nabla\theta = g.\chi_t.\nabla SST$$

$$\xi = SSH + h$$

WESTERN RESULTS

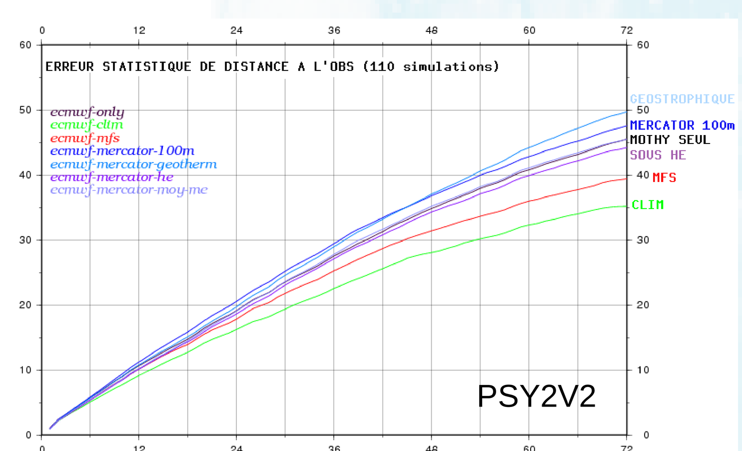


Figure 8: All test currents conducted with PSY2V2 are meanly better than the existing 100 m current: **6 % of improvement** for the under-Ekman current over 100 m Current

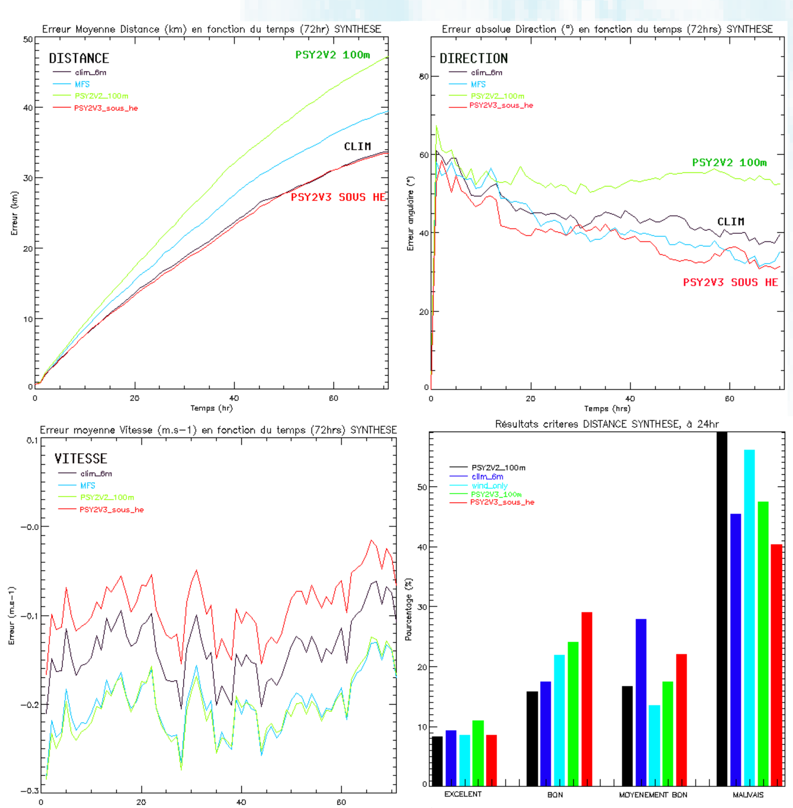


Figure 9: Summary of the mean results obtained in terms of distance, velocity and direction errors, between the replacement system PSY2V3 under Ekman current, the previous system PSY2V2 100m current, MFS system and the climatologic forcing.

- In term of distance error, **10 % of improvement** using the under Ekman extraction vs PSY2V2 100 m current, and finally **30 % of improvement** using both PSY2V3 and under Ekman current

- Lighter velocity bias using PSY2V3 under Ekman current and better direction constraining.

- Histogram: quick information build over arbitrary distance criterions for 24hr of drift. All systems are able to produce the same ratio of "excellent" results (less than 5km to observation), but PSY2V3 under Ekman current is better to obtain "good" results. More than the half of PSY2V2 100m and no forcing tests are classified in "bad" results.

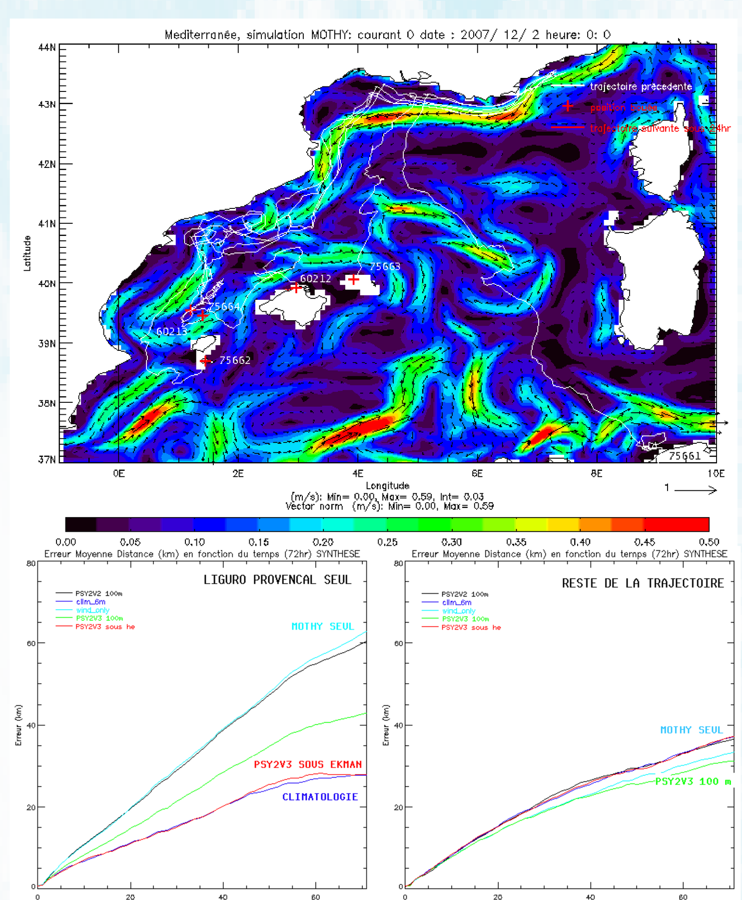


Figure 10: Buoys easy follow great scale currents (here the Ligure current) contrarily to their outside, where instability processes (eddies, filaments, etc.) perturb trajectories.

Inside Ligure current system session: Mothy alone final distance error (60.35 km for 72 hr) equals **twice** of the under-Ekman current error (27.65 km), comparable result with climatologic forcing (27.85 km).

→ **interest in using oceanic forcing inside stable and strong currents.**

Outside of Ligure current: model forcings are less good, it is a better worth to use a lighter information like in-depth current (100m current: 31.19km) or then Mothy alone (33.73 km)

EASTERN RESULTS

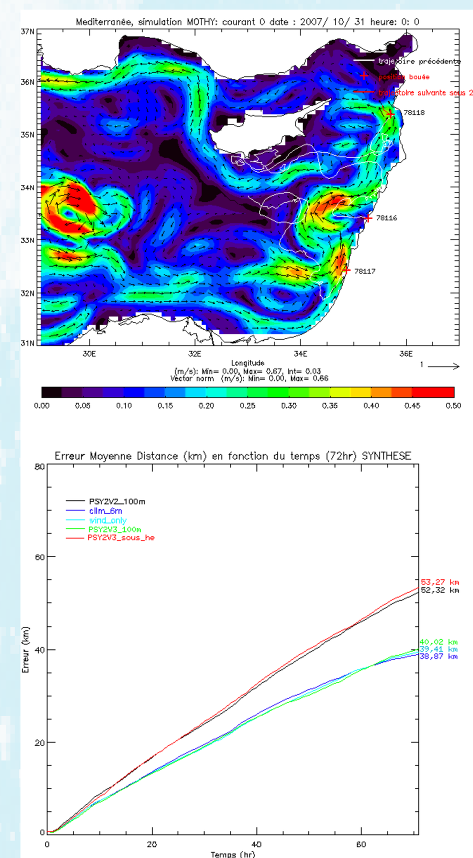


Figure 11: Surface model current Vs buoys trajectories (up), distance error results (down)

→ difficulties for 1/12 resolution models to efficiently represent short scale movements.

• Best results = climatologic forcings or no outside forcings at all

Using oceanic forcing in turbulent areas = adding the right quantity of information

→ in depth currents (PSY2V3 100 m)

→ good compromise between miss-described meso-scale processes and well-described great scale circulation.

3 AXES OF PERSPECTIVES

1st axe: Sensibility study relating to the modeling parameters in Mercator systems, impact on drift forecasts forcing efficiency: horizontal and vertical resolution, atmospheric forcing frequency/parameterization, new physical processes additions, etc.

2nd axe: Mothy forcing mode: coupling frequency between Mercator system / Mothy, possibility of using new physical parameters in source of Mercator systems (like SST, vertical mixing). Direct forcing of Mothy particle module by Mercator forecasts.

3rd axe: Relevance to generate overall simulation. Analyzing of the impact of several sources of errors on Mothy performances in a statistical point of interest.

References:

Daniel P., Varlamov S. and Ph Dandin, 2006: Impact of operational ocean forecasting on improvement of oil spill and fate modelling in Meteo-France, Proceedings of the World Maritime Technology Conference, London UK

Hackett B., Zodiatis G., Daniel P., Broström G., 2008, Oil spill fate forecasting in the MERSEA Integrated Project, Mercator Ocean Quarterly Newsletter#29, april 2008.

Bonjean F., Lagerloeff S. E., 2002, Diagnostic Model and Analysis of the surface currents in the Tropical Pacific Ocean, Journal of Physical Oceanography, vol. 32

Jorda G, Comera E. et al, 2005, Impact of forcing errors in the CAMCAT oil spill forecasting system: a sensitive study, Journal of Marine systems, 2005

CONCLUSION: We put here in evidence the strong operational oceanography's potential to assist and improve forecasts of a drift model. The coupling experiment between Mercator and Mothy shows that the success of results is hardly linked to the good description of meso-scale processes, and particularly eddies structures, inside the oceanic outside forcing system. The ideal would probably be some nested systems completely dedicated to Mothy, which could be activate on express demand. They could moreover be completed with geographical maps of confidence level of use.