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Use of the operational oceanography production in the Météo-France oil spill fate system

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Toujours un temps d'avance

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Description of work & results

1 Introduction

The choice has been made at Météo-France to keep using the MOTHY drift forecast system, inserting into the computation of the ocean current a large-scale component provided by Operational Oceanography (OO) systems like Mercator-Ocean, FOAM or MFS. The difficulty is to extract part of the total current of the OO system and add it to the MOTHY drift system, which is built to compute the wind driven response as best as possible.
The first 18 month period was dedicated to analyse the question from a scientific point of view, and make trials on different cases in order to evaluate various techniques for introducing the oceanic forcing into the MOTHY system.

Dr Sergey Varlamov (MERSEA post-doc recruitment) has been the main player on this work, seconded by the permanent staff working in the marine forecasting department.
Different OO systems have been used, one of the goal being to improve the MOTHY system which has to work in all the areas of French interest (Europe and overseas territories) or where France plays a role in supporting other countries in case of maritime emergency (bilateral agreements between France and neighbour countries, or WMO/IOC JCOMM MPERSS). Within Mersea, the following OO systems have been used:

- Mercator-Ocean
- FOAM
- TOPAZ
- MFS
- HYCOM

2 MOTHY drift system improvement

2.1 The code of the drift modeling system MOTHY was updated so that it permits to simulate tidal current components in any parts of World Ocean using the LEGOS 2000 global tidal sea level constituents at open boundaries of the drift ocean model. However the objective of adding a global tide capability was not part of the present Mersea task, it appeared as a useful step. Evaluations can therefore be run with real cases taking tides into account.

2.2 Pre-operational program interface for the utilization of OO sea currents provided as NetCDF files or through the OPeNDAP interface was developed and tested. The France Mercator-Ocean, UK NCOF (FOAM), Norway TOPAZ and USA HYCOM data could be downloaded from the OPeNDAP servers in quasi-real time and re-interpolated into the drift model domain. Downloading the hindcast data from mentioned centers for area of exercise takes a few minutes (5-15 minutes). MFS data also could be utilized in the same way except that as for November 2005 total data sets for the whole Mediterranean sea are regularly downloaded from the local file server using FTP software and aggregated using local solution.

3 Operational oceanography products delivery technology assessment

3.1 Overview of tested data delivery methods

As for November 2005, operational oceanography products could be delivered to the end-users and / or added-value product developers using number of different technological solutions. We have assessed these approaches from the point of view of added-value product developers for the quasi-operational exercise with simulation of the wave buoy drift in the Atlantic Ocean July 3 –September 11 2005 and developing the integrated operational oceanography data analysis and visualization application for the Météo-France operational marine prevision service.Raw digital data are offered using following methods.

3.1.1 Traditional FTP access to the designated data sets.

Positive features : downloading is easily automated, method is relatively stable, after downloading of data sets they are easily reached from local data server and do not depend from the network traffic conditions.

Negative features : huge amount of data that have to be downloaded and stored on local servers, so duplicating the storage of data by generating centers; nomenclature, vertical and spatial domains are decided by generated centers. This delivery method is nowadays adopted by MFS group and considered as an alternative selection by HYCOM consortium group.

3.1.2 OPeNDAP technology (Open Project for Network Data Access Protocol, former DODS),that offer good server-side data aggregation and significantly decrease the users headache related with possibly complicated file system of downloaded data.

Positive features : downloading is easily automated; download could be only for requested parameters and for requested time range, vertical range and horizontal domain that significantly decrease the network traffic and makes it possible to download data not regularly, but only when requested. Usually OPeNDAP servers offer possibility of interactive data downloading, that could be useful for the non-operational research purposes.

Negative features : it could be mentioned relative instability of OPeNDAP services due to the relatively complex server-side system configuration; efficiency of operational online data downloading (required time) could depend from the current Internet network loading; utilization of OPeNDAP technology on client side requires installation of some of OPenDAP client programs and additional training of people involved in data processing. Nowadays OPeNDAP servers are operated by almost all operational oceanography centers involved into the MERSEA activity, except the MFS group, where the deployment of OPeNDAP is also planned.

3.1.3 LAS (live access server), Map-server or other interactive Internet data visualization and downloading technological solutions. Some kind of such application is operated by every MERSEA OO center. For example, HYCOM consortium and TOPAZ group use LAS UI software, UK NCOF (MetOffice) use own specially developed GDAS server Godiva as well as their own map servers are used by Mercator-Ocean and by MFS teams.

Positive features : such Internet applications usually have simple user-friendly interactive user interface and step-by-step guided process of data selection, visualization and downloading. Also mentioned could be possibility to visualize and analyze data before downloading. Once selected, the user could get the product here and does not need any additional operations. Selection and visualization or downloading of data subsets is possible etc.
Negative features : absence of standardization in interfaces provided by different centers. Often limited data subsets are offered for downloading and visualization. Visualization lack some desired features like vector fields visualization for some centers (LAS) etc. Data downloading is not obligatory feature(allowed by GDAS Godiva and LAS servers). Downloaded data sets could have non-regular names that require manual re-naming of data sets before utilization. Impossible or difficult automation of data downloading when it is possible (example: needs Java programming experience and software for automation of downloading from GDAS Godiva server, but it have to be mentioned that NCOF offer an OPeNDAP alternative for such operations with MERSEA data sets).

3.2 Integrated operational oceanography products analysis and visualization solution in Météo-France

Having multiple distributed and local data sources of operational oceanographic products it was developed and installed in the Météo-France an analog of LAS server that integrates all available products and provides to operational oceanographers single interface for data analysis and visualization. It is an improved version of data visualization software previously developed for the Japan Sea operational prediction system (S.Varlamov, http://jes.riam.kyushu-u.ac.jp/). It is an Internet application, whenever in Météo-France it is installed on local Intranet server as giving access to the restricted access data. Based on the DODS, GRIB and NetCDF-enabled GrADS client program and linked with the Python language CGI scripts and C language configurable FTP data retrieval and local data system management software, it provides single interface for accessing online the OPeNDAP bulletins of Mercator-Ocean (Psy2v2,Psy3v1 and Psy1v2 systems), TOPAZ and HYCOM; analysis of FOAM and POLCOMS models, local FTP-downloaded Mediterranean bulletins of MFS and the Météo-France global and regional wave prediction systems results.
Currently, we download automatically MFS forecasts on the Mediterranian Sea (2GB) of new information every day that includes 10 days forecasts data. The analysis data (200 MB for each day) are saved. And we start to do the same download for the Atlantic or Global Ocean data from Mercator...

Figure 1 shows an example of Mercator-Ocean Psy2v2 forecast for surface current in western Atlantic based on online OPeNDAP data. Color scale is for the sea currents absolute velocity and direction is presented by streamlines. Any available data could be downloaded by a request in digital form with immediate space interpolation into the drift model grid for its use in oil spill or objects drift prediction.

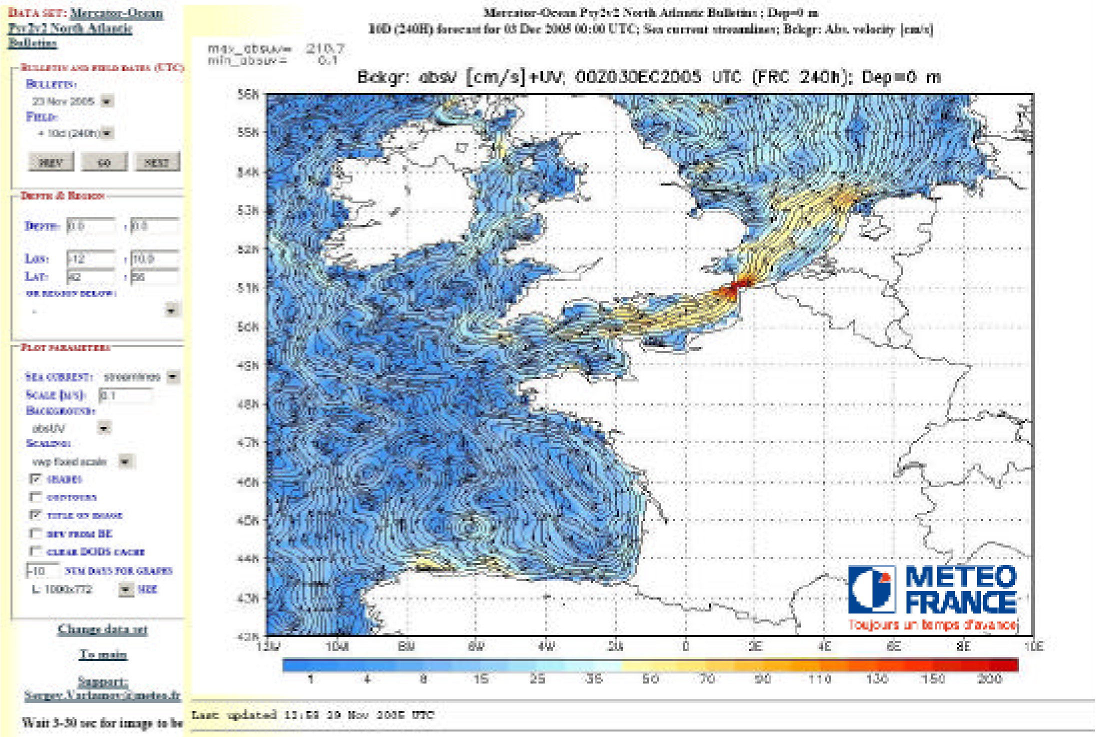

Figure 1. *Interface of the Météo-France operational oceanography data analysis and visualization system with an example on Mercator-Ocean sea surface currents forecast for December 3, 2005 (10 days prediction).*

3.3 Summary and recommendations for oceanic data delivery

Operational oceanographic modeling and prediction systems products become now really available for users and value-added product developers in frame of European MERSEA project. Following our experience in using it, one could state that:

- OPenDAP technology (including aggregation servers etc.) seems practically very useful and reliable for the data access. It avoids downloading of huge data files with information that could be rarely requested, by leaving this information available on remote server.
- FTP access also could be used as primary or secondary solution for data delivery as more stable method. The nomenclature of available data (and size of files) for downloading on regular basis could be revised, leaving mainly near-surface parameters as example. Such nomenclature could be discussed in frame of the MERSEA meetings.
- Establishment and support of regular schedule of data production and delivery on the OPeNDAP and FTP servers are important for data users.
- Structure of data sets, that includes their names, the time range of saved data, list of parameters, domain specifications etc. should not change too often and, if possible, warn the registered users of such modifications in advance. Standardization of used parameter names is desirable, but not critical. Utilization of 'shifted grids' when providing data (HYCOM and MFS u and v fields) adds more difficulties when visualizing these data, etc…

It seems clear that further work toward stronger consolidated operational frameworks has to be planed. Indeed, the operational emergency response capability in case of maritime accidents has to be based on a zero failure suite. This said, we can consider at the end of the Mersea task that the foreseen objectives regarding the set-up of pre-operational conditions for the use of operational oceanography information in order to improve the drift forecasts is achieved.

4 Test on the use of operational oceanographic products for drift simulations

The National Forecasting Centre, at Météo-France, runs an operational service to support the authorities in both the oil spill response and search and rescue operations. The essential issue of such service is the rapidity of the response and the ability to use the drift system in any region of the World Ocean.

The development of the european operational oceanography and the data assimilation systems during last few years made it possible to use the results of global and regional ocean analysis and forecasts in real time for the improvement of existing drift prediction services. Operational oceanographic systems use different operational capacities, data streams and expertise. Remote sensing and in-situ data are acquired and assimilated in state-of-the-art ocean general circulation models to analyse and forecast the 3D state of the Global Ocean, North Atlantic, adjacent European Shelf Seas, and the Mediterranean Sea. They aim to support a wide range of scientific and operational services and applications including oil spill monitoring, marine safety as well as offshore oil industry. The efforts of authors are directed on finding solution for optimal merging of best features of available prediction systems: 3D ocean circulation patterns reproduced by eddy resolving global ocean models, and high frequency surface current variations caused by corresponding wind and tidal variability that could be reproduced by existing drift models.

The present work focuses on evaluating the operability and effects of introducing large scale currents in the Météo-France drift modelling system MOTHY. Assessment is done here for the case of free wave buoy drift in the western Atlantic using the operationally downloaded from Internet modelled sea current analysis data of Mercator-Ocean (France), FOAM (MetOffice, UK), HYCOM Consortium (USA) and TOPAZ (Norway) modelling systems.

Many other cases have been used in different locations, at different periods of the years. They helped focusing on the main issues. The "Guadeloupe" case is chosen here as a very informative case, showing the impact but also the remaining difficulties that operational oceanography will have to deal with - and consequently the users of operational oceanography products like the Météo-France marine weather forecast group in charge of emergency responses in case of accidents at sea.

4.1 Atlantic Ocean wave buoy "Guadeloupe" drift simulation

July 3, 2005 a wave buoy "Guadeloupe" anchored East of Guadeloupe island at 16.4N and 60.9W after some accident was detached from the anchor and started to drift in Atlantic Ocean. It quickly moved in the North - North - East direction, not consistent with prevailing Eastern trade-wind. Buoy construction with only small part of it being over the sea surface and about 100 m of 1 inch diameter rope left under the water also impacted resulting drift to be dominated by sea currents. Buoy drift had been being traced during more than 70 days, until September 11, 2005 using its ARGOS transmission system (Figure 2).

It was impossible to predict this drift using traditional shallow-water and wind-dominated drift models like MOTHY. As result, the drift prediction system MOTHY was applied for these simulations assuming that 'object' drift is regulated by wind impact (about 10%) and 'external' sea current taken from the operational oceanographic products. Météo-France global ARPEGE atmospheric model wind analysis data were used. Total drift time was divided in seven 10-days intervals and modelling was performed from observed buoy positions at start of every interval, from points marked by stars on the Figure 2. Simulated trajectories for ensemble of nine model objects are plotted by grey lines starting from intermediate start points ("star" points). Figure 2 shows the drift simulation using the Mercator-Ocean Psy2v1 system sea surface (0 m) current data. As it could be seen from this figure, the first, second and third simulation stages quite well correspond to observed drift with total error reaching about 100 - 200 km after 10 days of simulation. It clearly demonstrates nice quality of Mercator-Ocean sea surface current simulation results, which well represents local eddy structure of ocean circulation. On the second stage (July 13 - July 22) total drift distance was overestimated, on the third stage (July 23 - August 1) it was underestimated when generally well reproducing the complex drift trajectory shape. However, for the following fourth, fifth and sixth stages there are significant discrepancies between the observed drift and model results. The reason for that could be clarified by analysing the Mercator-Ocean sea surface currents patterns on the Figure 3.

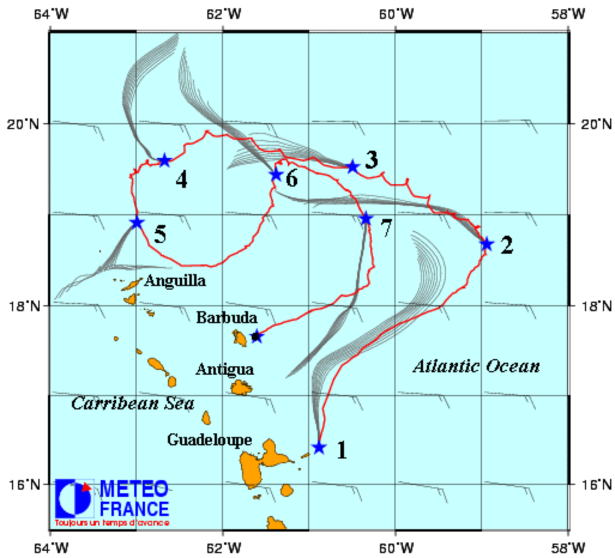

Figure 2. Observed drift of wave buoy "Guadeloupe" for July 3 - September 11, 2005 (red line) and its simulation (grey lines)

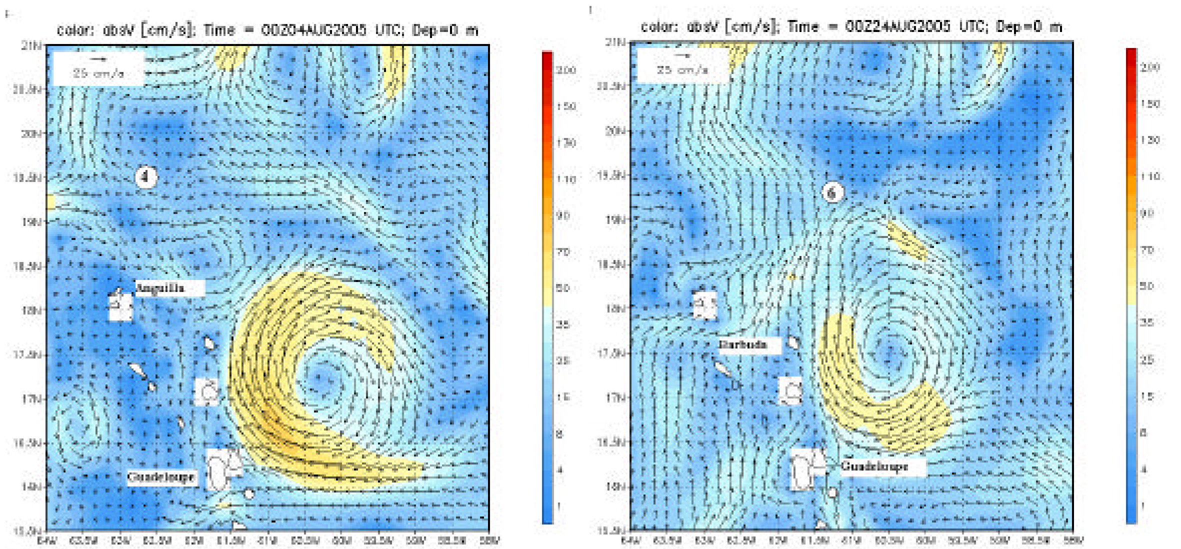

Figure 3. Mercator-Ocean surface sea current for August 4, 2005 (left panel) and August 24, 2005 (right panel)

According to the first map, August 4, 2005 drifting wave buoy was in the sea currents divergence zone between weak cyclonic ocean eddy at the south and anticyclonic eddy at the north. Buoy location is approximately marked by white circle with model stage number "4". Deterministic simulation in this case resulted in a northward drift due to the northern anticyclonic eddy circulation, when actually the buoy had been drifting southward, that could be explained by its involvement in to the southern cyclonic eddy circulation. Very similar situations were found for stages 5 and 6 of the simulation. For example, at the start of the stage 6 wave buoy also went into the sea currents divergence zone (Figure 3, right panel) and in present simulation it was trapped by northward sea current when, according to the observations the buoy had been actually transporting south-eastward by currents of the anticyclonic oceanic eddy, located in the south. These examples demonstrate the large uncertainty in drift prediction that could have place when the drifting object enters the ocean current divergence zones. In addition we have to keep in mind some uncertainties in the operational ocean modelling especially when predicting mesoscale ocean eddies. Possible solution here is the estimation of simulation uncertainties by some kind of ensemble predictions and/or making use of qualified experts before delivering the final drift prediction to end-users. As example, combining production of different operational oceanographic centres could create the ensemble of ocean forecasts. The MOTHY drift prediction model also does the ensemble object drift simulation assuming some uncertainty in object buoyancy and geometry properties. Additionally, some uncertainties in initial object position could be introduced in order to take into account the uncertainties of the oceanic current prediction.

Figure 4 demonstrates results, as for the Figure 2, but with the Mercator-Ocean Psy2v1 current at different depths: 0, 15, 50 and 100 m. The mixed layer depth in the concerned region was about 30 m. The results for 15 m sea current are close to the case when surface current was used, except that for the 5th stage of drift it was reproduced that part of test objects turned to the Atlantic Ocean as it was observed. All other cases do not reproduced such behaviour.

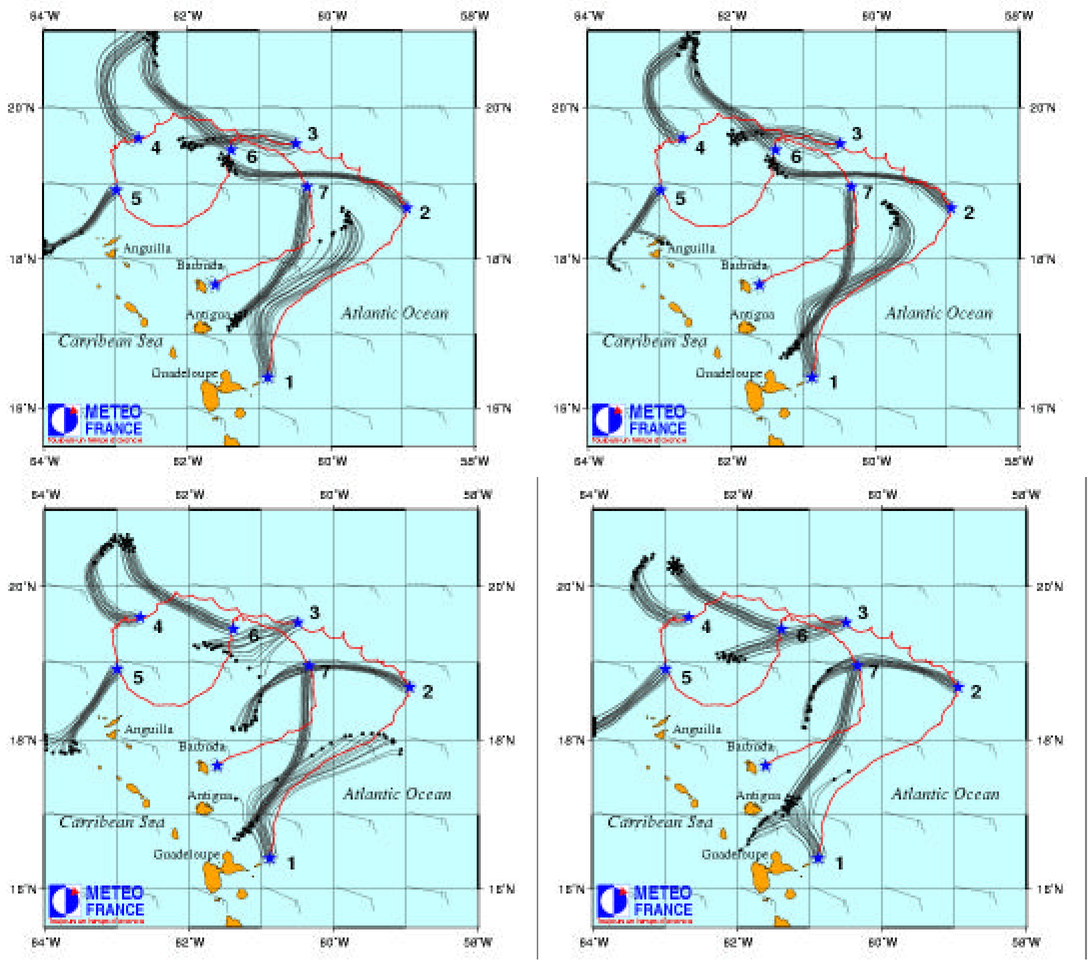

Figure 4. Drift simulation with the Mercator-Ocean Psy2v1 sea current at different depths: upper left 0 m, upper right 15 m, lower left 50 m and lower right 100 m.

To estimate the difference in drift simulation as function of different operational ocean prediction models, the same drift simulation was run with the current data of other Mercator-Ocean system realization (Psy1v2) and with data of other operational ocean forecasting centres. Figure 5 demonstrates final composite maps of these simulations when the upper layer or mixed layer (HYCOM) sea currents were used. Comparing all results it could be seen, that for the given simulation period and for drift region in Western Atlantic the Mercator-Ocean Psy2v1 system failed to give good drift estimation for stages 4, 5 and 6, when generating relatively small errors in the buoy drift reproduction on other modeling stages (Figure 4). Older Psy1v2 realization of Mercator-Ocean system but with more advanced multivariate data assimilation scheme significantly underestimates drift for all stages and at the same time does not generate large 'overshooting' as the Psy2v1 system did (Figure 5, upper left panel). For some stages it gives smallest errors (stages 4 and 5) and reproduce buy drift in observed direction (stage 5). Good results of simulation are received with the HYCOM model data, but again not for all stages of simulation (Figure 5, upper right panel). Both the FOAM (Figure 5, lower left panel) and TOPAZ (Figure 5, lower right panel) systems sea current analysis results lacked some important mesoscale ocean circulation features in this part of Atlantic Ocean and were not able to help in drift prediction except on stages 2 (TOPAZ) and 3 (FOAM) when drift was going in general westward direction consistent with prevailing winds.

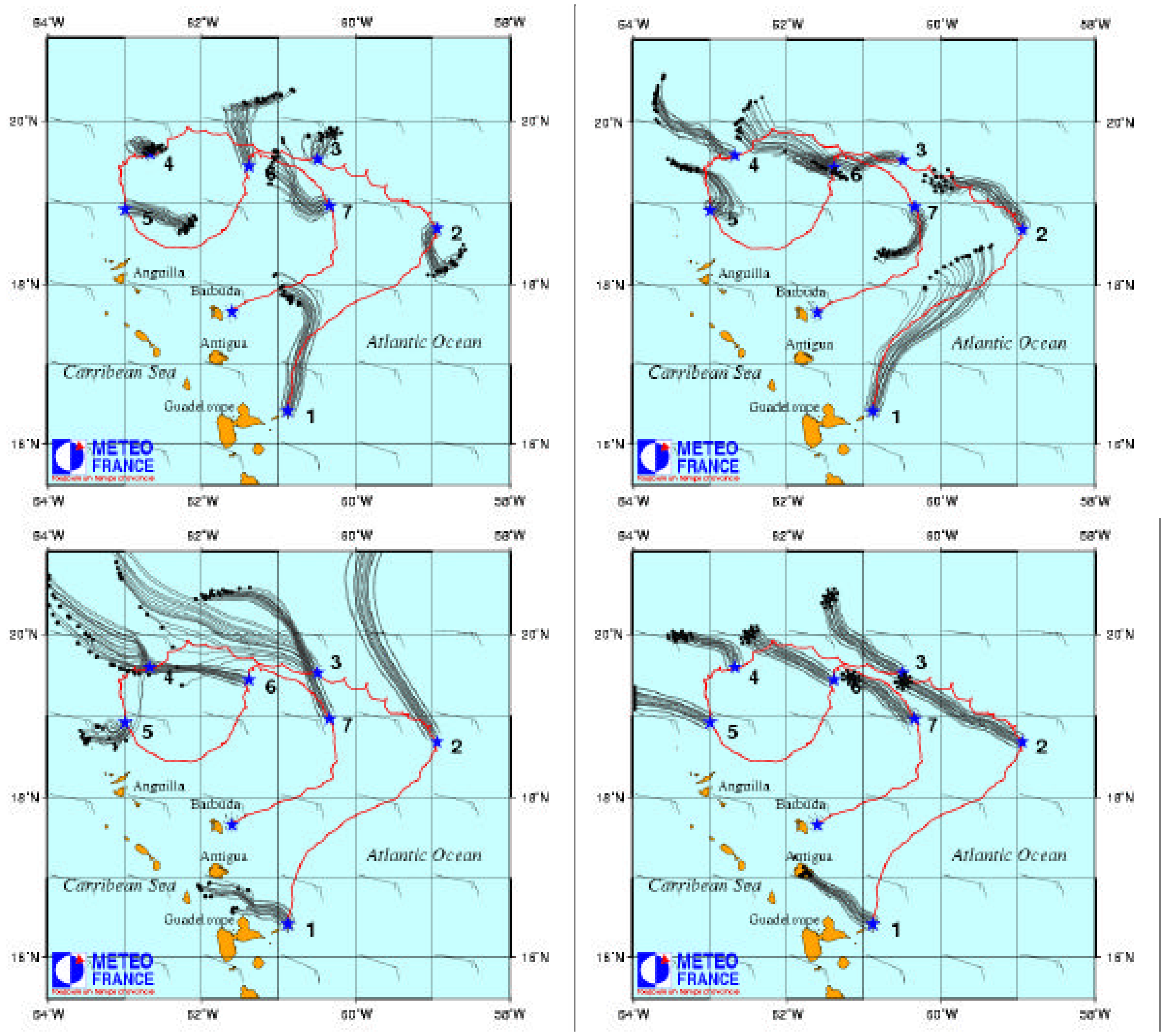

Figure 5. Drift simulation with the Mercator-Ocean Psy1v2 surface sea current (upper left panel), HYCOM mixed layer sea current (upper right panel) , FOAM 5 m sea current(lower left panel) and TOPAZ 5 m sea current (lower right panel).

5 Summary

The MOTHY oil spill drift forecast system has been interfaced to the MERSEA real time oceanic currents by putting in place pre-operational protocols for retrieving the useful needed data. Some recommendations for the data delivery have also been formulated.

This tool allowed to make interesting tests on a 70 days observed drift of a wave buoy near the Guadeloupe Island in the Antilles. It showed first the capability to use the operational oceanographic production from the European and the international oceanographic centers in near-real time and both in coastal and remote ocean : operational oceanographic services become a reality at Météo-France for quasi-operational drift forecasting, by using existing data delivery technologies. This will be used in search and rescue operations too.

However, we show that the quality of the products that are delivered by operational oceanography systems are critical for such systems as drift predictions.

Work needs to be continued, both from the theoretical point of view, as well as from the operational point of view. Dedicated products could be needed, in order to permit the introduction of a large scale oceanic current whatever the location and the period of the year. The dispersion of the OO systems solutions will also make it compulsory to define the practical way to use the OO information in real operations. It will so require further investigations.

The results obtained during this first period of work are very encouraging but open the floor to many tricky questions, for science and real world production.
Next steps will be to define the needed fields to be provided by operational oceanography systems on a regular basis, and set up the operational conditions for a robust delivery. Many numerical tests will again be carried on, and each new available case at sea will be used.