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Improvement of pollutant drift forecast system applied to the *Prestige* oil spills in Galicia Coast (NW of Spain): Development of an operational system

P. Carracedo [a,*], S. Torres-López [a], M. Barreiro [a], P. Montero [a,1], C.F. Balseiro [a], E. Penabad [a], P.C. Leitao [b], V. Pérez-Muñuzuri [a]

[a] *MeteoGalicia, CMA, Santiago de Compostela, Spain*
[b] *MARETEC, IST, Lisbon, Portugal*

Abstract

An integrated system named METEOMOHID, developed by MeteoGalicia in the first stage of the *Prestige* accident in November 2002 was used successfully in an operational form to support decision making and assist in recovering tasks. Afterwards, METEOMOHID has been enhanced with the aim of developing an operational oceanography system to be used in the NW of the Iberian Peninsula. The METEOMOHID system includes local area hydrodynamic coastal ocean modelling (MOHID), real time atmospheric forcing from a local meteorological model (ARPS). Using the available data from the *Prestige* crisis, a set of simulations were designed in order to reproduce the oil spill drift. The implementation of a detailed vertical resolution in the model has allowed obtaining a detailed surface dynamic, improving our knowledge of the behaviour of tarballs into the water column. Thus, the wind-driven Eckman drift, the direct dragging of the wind were detached, and the possible existence of subsurface oil was assessed. In addition, the present work evaluates the effects of introducing climatologic large scale currents in the METEOMOHID system.

Keywords: Oil spill; Drift forecast; *Prestige* accident; Trajectory studies; Galicia Coast

1. Introduction

Oil spills in marine environments can have wide spread impact, long-term consequences on wildlife, fisheries, coastal habitats as well as human recreational activities. Therefore, scientific and technological developments are required to assist in the implementation of pollution contingency plans.

The development of a forecasting system is crucial to assure a good management of a crisis. Accurate slick drift information is essential to help in pollution recovery tasks at sea and to prepare the response on the coastline. It is vital that oil spill response organisations have access to good information, well organised decision support systems. The tracking of oil spills, which are likely to impact the shoreline, is of prime importance in the effective deployment of oil spill response to protect environmental or economical sensitive areas. An oil spill trajectory model must meet a number of requirements to be of use to emergency responders and incident planners. They must provide accurate spill prediction for forecasting, hindcasting, rapid output of results regardless of spill geographic location, ability to adjust inputs considering changing conditions and field observations.

Literature on modelling oil spill trajectories is extensive. Mackay et al. (1980) divide oil spill models into (i) ‘‘weathering models’’ which take into account physicochemical processes, i.e. surface spreading, evaporation, dissolution, emulsification, hydrolysis, photo-oxidation, biodegradation, particulation, (ii) ‘‘trajectory models’’ which forecast

* Corresponding author.
E-mail address: pablo.carracedo@meteogalicia.es (P. Carracedo).
[1] Present address: INTECMAR, Vilagarcía de Arousa, Spain.

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the position of slicks with the aim of fight against pollution (Spaulding, 1988), (iii) "water column distribution models" which quantify the hydrocarbon concentration in the water column.

In this work, we are going to focus on the second type of models: "trajectory models". The current set up by the local wind (Eckman current), the motion due to wave propagation (Stokes drift), the motion relative to the water caused directly by wind (sailing effect), tidal currents, permanent or semi-permanent current systems on a large scale (Background current), are the main processes involved. Besides, tarballs of fuel may be overwashed by ocean waves, changing its position into the water column owing to the sea state. Also, as the oil weathers, changes in fuel physicochemical properties (e.g. density) and conditions (e.g. emulsification) produce a denser fuel, so less buoyant. Obviously, the fuel trajectory depends strongly on the depth at which the oil travels.

The purpose of this study is to describe the studies undertaken just after the *Prestige* disaster, focussing on evaluating the significance of each relevant physical mechanism involved in the fuel drift. The paper highlights some of the system details, features to be included in an operational drift model for the Galician Coast (NW of Spain), which could be potentially used in supporting marine pollution incidents. In order to set up such operational model we have tried to reproduce by means of numerical simulations the observed positions of the oil spill during the *Prestige* crisis, with the main objective of studying different physical processes and calibrate some parameters.

2. The *Prestige* disaster

On November 13th the tanker *Prestige* carrying a total of 77,000 tonnes of heavy fuel-oil, was damaged off the north coast of Galicia (NW Spain), suffering a severe structural failure of the starboard cargo tanks producing one of the worst, wide spread oil spill events in the history of the coast of Galicia. On November 14th, authorities considered an eventual risk of severe pollution of Costa da Morte, so the ship was towed away from the coast towards different directions (Fig. 1), travelling first north-eastward until November 15th, south-westward until November 19th, when the tanker broke in two sections spilling 20,000 Tm of fuel more at about 130 miles from the Galicia south-coast. The two parts of the wreck sank at a 3500 m depth. The path followed by *Prestige* spreaded the fuel-oil into a long "fuel front", threatening the entire Atlantic coast of Galicia. Although since November 13th the fuel-oil polluted a wide area, the main damage took place when the 20,000 tonnes of fuel-oil spilled on November 19th reached the coast near Cape Fisterra (Fig. 5) on November 30th.

Although the total amount of oil released to the environment is unknown, it is suspected to be more than 60,000 tonnes of heavy fuel were released into the marine environment. The heavy oil type suffered a strong emulsification (water uptake in the oil) and only very small evaporation (CSIC, 2002). The water content of the fuel aged at sea reached 60% with a viscosity of 100,000 cSt at 15 °C, a measured density of 1.01 kg/L, close to that of the water but slightly lower. The original slicks of heavy fuel oil (hundreds of tonnes each) drifting at sea broke into pieces, segregated into patches (up to a few meters of diameter), pan cakes (0.1–1 m diameter), discs (up to 10 cm diameter) and finally pellets (up to a few centimetre diameter) (Daniel et al., 2004).

3. Model description, simulation conditions

The framework chosen for achieving this task consists in two numerical models coupled; the hydrodynamical model MOHID (www.mohid.com) and the meteorological model ARPS (Xue et al., 2000). The former is used daily in operational meteorology by MeteoGalicia (www.meteogalicia.es), the latter has been successfully used to reproduce the main observed circulation features of some of the Rías Gallegas (Taboada et al., 1998; Montero et al., 1999; Gómez-Gesteira et al., 1999; Ruiz-Villarreal et al., 2002).

During the *Prestige* crisis, MeteoGalicia developed the METEOMOHID, an integrated system that included hydrodynamic coastal modelling and real time atmospheric forcing from a mesoscale meteorological model. Both models are coupled in a one way sense by means of ARPS predicted wind velocity as the surface forcing for MOHID. The hydrodynamic model was linked to a lagrangian module to obtain oil tracks, where oil slick was considered as a distribution of independent droplets.

The ARPS model was chosen because its non hydrostatic dynamics, its generalized terrain following coordinate and its nesting capabilities were well suited for the complexities of the Galician region. ARPS has also been tested and operationally used (http://meteo.usc.es) for several years over Galicia, Southwest Europe by MeteoGalicia. The governing equations of the ARPS include conservation equations for momentum, heat, mass, water substance (water vapour, liquid, ice), subgrid scale (SGS) turbulent kinetic energy (TKE) and the equation of state of moist air. More details on the model formulation can be found in Xue et al. (2000) and Souto et al. (2003). For this particular application, the nesting was set up to permit the resolution of flows at two scales: the influence of local terrain features in the 10-km fine grid and the mesoscale circulations (particularly those concerning the passage of cold fronts from the Atlantic Ocean) by the 50-km coarse grid. Every day, the ARPS uses the boundary conditions obtained from NCEP AVN 1° resolution model at a 3-h interval on a coarse grid covering a 3000×3000 km^2 area. A fine grid covering a 430×430 km^2 area is nested within the coarse domain. There are 30 sigma-z levels in the vertical extending to 18 km. The fine grid uses its own high-resolution terrain with a gradual transition to the coarse grid terrain at the boundary zone to improve the match between solutions.

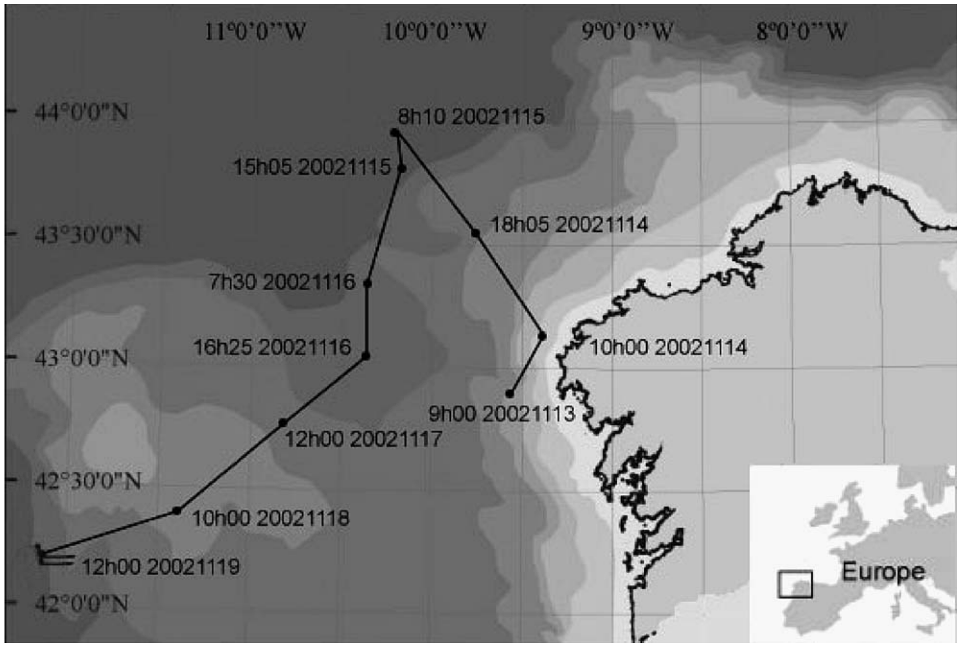

Fig. 1. *Prestige* course. The solid line shows the trajectory of the ship from November 13th to 19th. Time in UTC.

Wind data are obtained trough ARPS for the first day prediction horizon. This data are validated against data from meteorological stations collected by Conselleria de Medio Ambiente, covering all Galician territory, producing a monthly validation statistic (Fig. 2). The temporal window starts on 11th November 2002 until the end of January 2003.

On the other hand, MOHID is an object oriented 3-D baroclinic hydrodynamical ocean model originally developed by the MARETEC Group of the Instituto Superior Técnico (Technical University of Lisbon, Portugal). This model has shown its ability to simulate complex coastal, estuarine flows (Martins et al., 2001; Coelho et al., 2002). The model solves the three-dimensional incompressible primitive equations: hydrostatic equilibrium is assumed as well as Boussinesq approximation. Vertical eddy viscosity/diffusivity is determined using a second order turbulence closure squeme selected from those available in the General Ocean Turbulence Model (Burchard et al., 1999) incorporated into MOHID. The model uses a finite volume approach (Chippada et al., 1998; Martins et al., 2001) to discretize the equations. A more detailed description of MOHID model is in Coelho et al. (2002), Neves et al. (2002) and Martins et al. (1998).

For modeling the *Prestige* spill, a zero initial conditions were applied for all modeled fields, a spin-up of five days. November climatologic temperature and salinity profiles offshore of Galicia (11°W, 42°N) (monthly, 1° resolution Levitus ATLAS, 1998) were considered as the initial condition; no horizontal density gradients were admitted at the open boundary in baroclinic simulations.

As it was mentioned in the introduction, the oil of the *Prestige* tanker is characterized by a relative high density, close to the water density, and a strong viscosity (611 centistokes at 50 °C, 30000 at 15 °C). It has a low evaporation rate, low natural dispersion and tends to mix with water to form an extremely viscous 'mousse' (CSIC, 2002). This feature produces that oil does not tend to dissolve in the water column, but it remains in the sea surface for a long time. As we are interested in forecasting the gross horizontal oil drift at different layers, the MOHID weathering module was switched off during all simulations performed. This approach was performed using the lagrangian transport module of MOHID model: the oil slick is modeled as a distribution of lagrangian tracers that move in response to currents, direct wind drift and horizontal mixing. In the following simulations, if a lagrangian tracer reached the coastal line, that was considered beached, took no further part in the simulation. But model also permits to reintroduce a percentage of the beached oil if we want to.

Forecasts strongly depend on the initial conditions, therefore on the position of the slicks. Slicks were located at sea by aerial surveillance managed by "the Prefet Maritime". From 18th November, SASEMAR produced daily a position chart of the observed pollution.

The next task was to choose the physical phenomena that would be included. During the reanalysis process, we just identified two main forcing factors: direct wind drift and advection due to surface current mainly driven by surface wind stress. The first one of these processes strongly depends on substance properties (e.g density), its buoyancy. This forcing is introduced into simulations as a percentage of wind velocity directly added to lagrangian tracers representing the fuel. For practical purposes, we choose a windage of 1.5%, 2.5% and 3.3%. Similar values can be found in the literature.

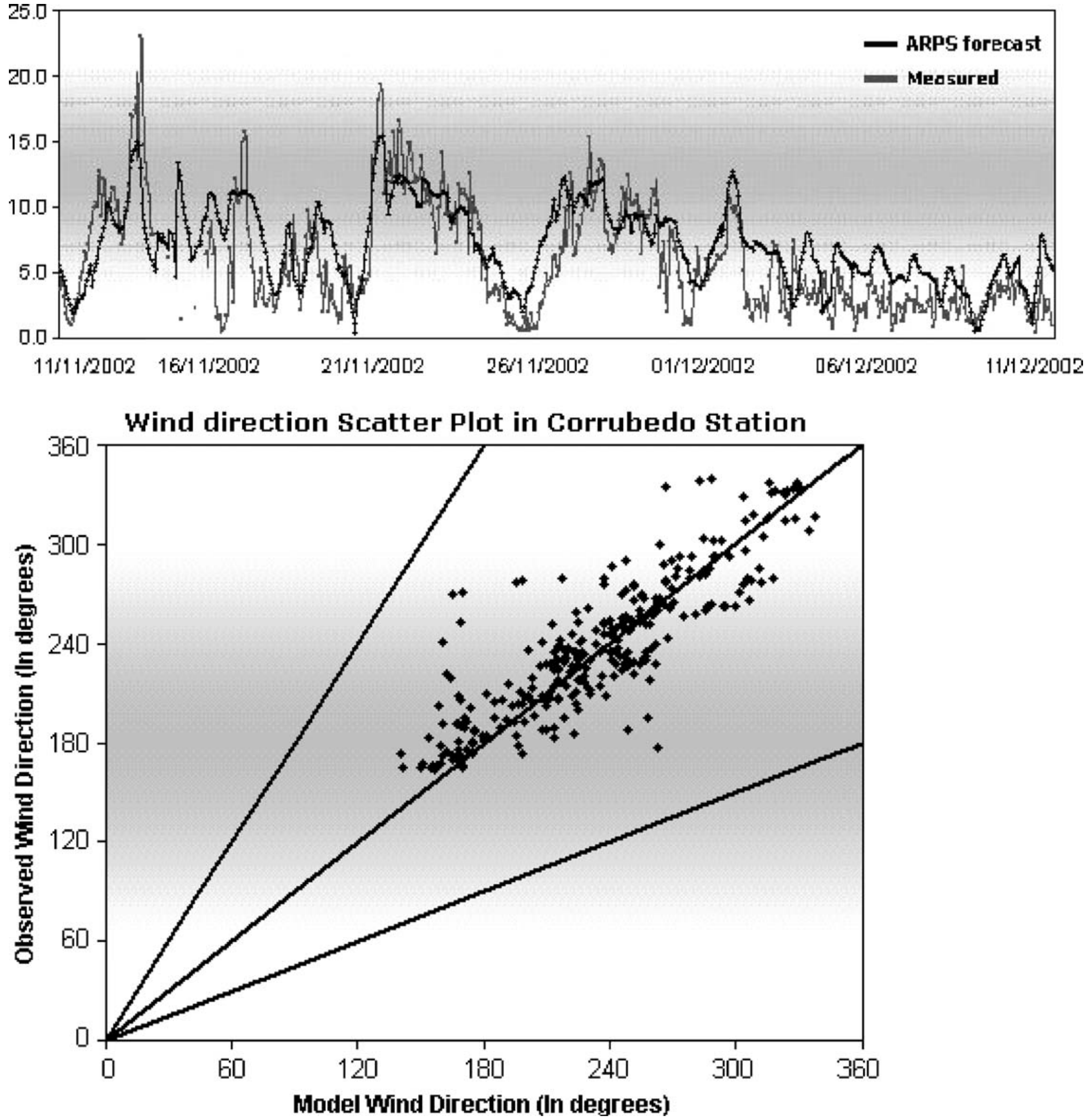

Fig. 2. Comparison of ARPS output wind data for the nearest grid point against data from automatic meteorological station at Corrubedo.

Currents produced by the wind stress are 100% added to the velocity of the lagrangian tracers. So, vertical resolution must be as good as possible to resolve conveniently the Eckman spiral. This is accomplished using a finer vertical resolution in near surface layers, but the aim of developing an operational predictive model introduces a compromise solution between resolution and execution time. As a consequence, vertical configuration includes a surface layer with a thickness of 10 cm in order to obtain a detailed surface dynamic. Additional factors such as river discharges along coast line, baroclinic currents, tidal currents and stokes drift were not considered during this study. Some authors (Castanedo et al.) include also stokes drift as an important factor, calibrating their transport models in the framework of ESEOO project, using drifting buoys deployed during the *Prestige* accident. They split stokes drift into swell and sea induced drift velocity, but concluded that sea stokes drift velocity can be modeled modifying windage value. However, the relative importance of stokes drift is still not well understood, so that more work must be performed in this task.

4. Results and discussion

METEOMOHID turned out to be a fundamental tool during the *Prestige* crisis. Using that previous experience, a set of test were carried out with the METEOMOHID system, trying to find an operative approach to simulate accurately the oil tracks in emergency situations.

During the *Prestige* crisis, preceding works accepted the hypothesis that oil tarballs followed the wind direction with a windage between 1% and 4%. The best results were obtained applying a windage of 2.8% of the wind intensity (Montero et al., 2003). However, no predicted patches were distinguished along the Galicia coast on the right side of the main predicted patches. In spite of their invaluable assistance, simulations were remade in order to improve the results without an unfeasible increase of time of simulations.

As it was explained in above sections, wind effect can be divided in two processes: the movement of the tarballs due to wind-induced currents and the displacement due to direct wind stress slipping along the seawater surface (sailing effect). Both processes are analysed below.

Two simulations were performed: one called "first oil spill simulation" to model the behaviour of the spill just after the accident of the *Prestige*, the other one to simulate the "main spill" in the sinking area. The former was a mobile, continuous release from the initial vessel position on 13th November to the sinking position on 19th November. The latter was a simulation of the instantaneous release of oil when the vessel sunk, from 19th November to 30th November. The first oil spill simulation allowed us to adjust the windage parameter involved in the simulations, meanwhile main oil spill simulation has been used to validate the model using field data on the first impact zone of the oil spill.

4.1. First oil spill simulation

When modelling the *Prestige* first oil spill, we assumed that oil was spilled continuously, uniformly from the first SOS signal at 30 nautical miles away from Cape Fisterra on 13th November (9:00 am) to the sinking point on 19th November (12:00 am). On 25th November, the first spill left behind the most northern cape of Galicia (Estaca de Bares), after polluting some beaches. Although the course of the vessel was along the west coast of Galicia, most of the patches surrounded the north-western coast, reaching the Bay of Biscay in Northern Spain. An ASAR-ENVISAT ESA satellite image showing the oil spill on 17th November (Fig. 3a) was used to calibrate the model results. During this track, the tanker spills more than 6000 tonnes of fuel. The main wind was around 7 m s^{-1} west direction except on 16th and 17th November, when the wind blew from the north.

In this simulation, the horizontal domain was 41°–45°N, 12°–6°W with a non-uniform spaced grid varying from 12′ on the deep ocean to 1.2′ on near shore points. We tried to quantify the direct influence of the wind on the fuel trajectories. Dealing with this, different windages (1.5%, 2.0% and 3.0%) were tested. The results were compared to the oil distribution obtained without considering the "sailing effect", i.e. 0% of direct dragging. In all simulations, currents are just due to the surface wind stress, fixing a constant climatologic stratification. As it is discussed below at the "main spill simulation", this limitation is justified because we are considering surface contaminant spills, circulation patterns are mainly determined by the wind in surface and subsurface layers. Tidal currents were neither considered because simulation took place far away from the coastal shore. A moving origin for passive lagrangian tracers was set based upon course positions reported by French office Le Cedre (Table 1).

The shape of the first spill was described mainly by the vessel track and the wind forces, as shown in Fig. 3b. The wind effect over tracers released at surface reproduced a simple branch of oil which agrees with the most intense of the observed branches. However, the sailing effect and wind current transport were not enough to explain the oil distribution observed in the ENVISAT image: two branches of oil painting the ship course, black areas located southerly (Fig. 3a).

As we use a 3D hydrodynamic model, in order to improve the simulation enabling to consider a greater number of possible behaviours, we introduced the lagrangian tracers into the water column, focusing the horizontal drift at different layers. This allowed getting tarballs under different hydrodynamical conditions. We considered tracers emitted at different depths (1.0 m, 0.5 m, surface), but they stayed at the same depth during all the simulation. Obviously, the wind-induced current changes with depth, getting weaker at higher depths and turning slightly to the right. But the most important difference is that superficial tracers were directly pulled by wind velocity in the percentages mentioned above (3.3%, 2.5%, 1.5% and 0%) while subsurface tracers were dragged just only by wind-induced currents.

The presence of sub-surface fuel was suggested during the *Prestige* crisis. Strong winds and water turbulence could induce a vertical movement of the fuel down a few metres depth (Delvigne and Sweeney, 1998), decreasing its visibility from the surface. This behaviour could explain why these amounts of oil were not observed by overflights. Furthermore, the buoyancy force depends on the density and the size of the oil tarballs; so, larger (more buoyant) tarballs tended to remain in the surface layer whereas smaller tarballs were mixed downwards (Elliott, 1986). The two branches could be formed because of the presence of two products of different density. Chemical analysis showed the existence of at least two types of oil inside the tanker (CEDEX, personal communication), which could also explain the presence of fuel at different depths.

The computed results (Fig. 4b–d) were compared against observations from ENVISAT image (Fig. 4a). As it is shown in the figures, windages of 2.5% and 3.3% introduced an excess of dragging for the surface branch (represented in green), without reproducing the pattern observed by satellite. A windage of 0% (not shown) showed a behaviour closed to lagrangian tracers released in depth (shown in red), which was not enough to explain the observed two branches. Optimal results have been obtained for a configuration where: (i) one branch of fuel corresponds to surface oil that was dragged by current advection with a windage of 1.5%; (ii) another branch corresponds to under water oil travelling between 0.5, 1 m depth, moved only by currents.

Therefore, when tarballs were introduced at different depths (1.0 m, surface), a dragging coefficient of 1.5%

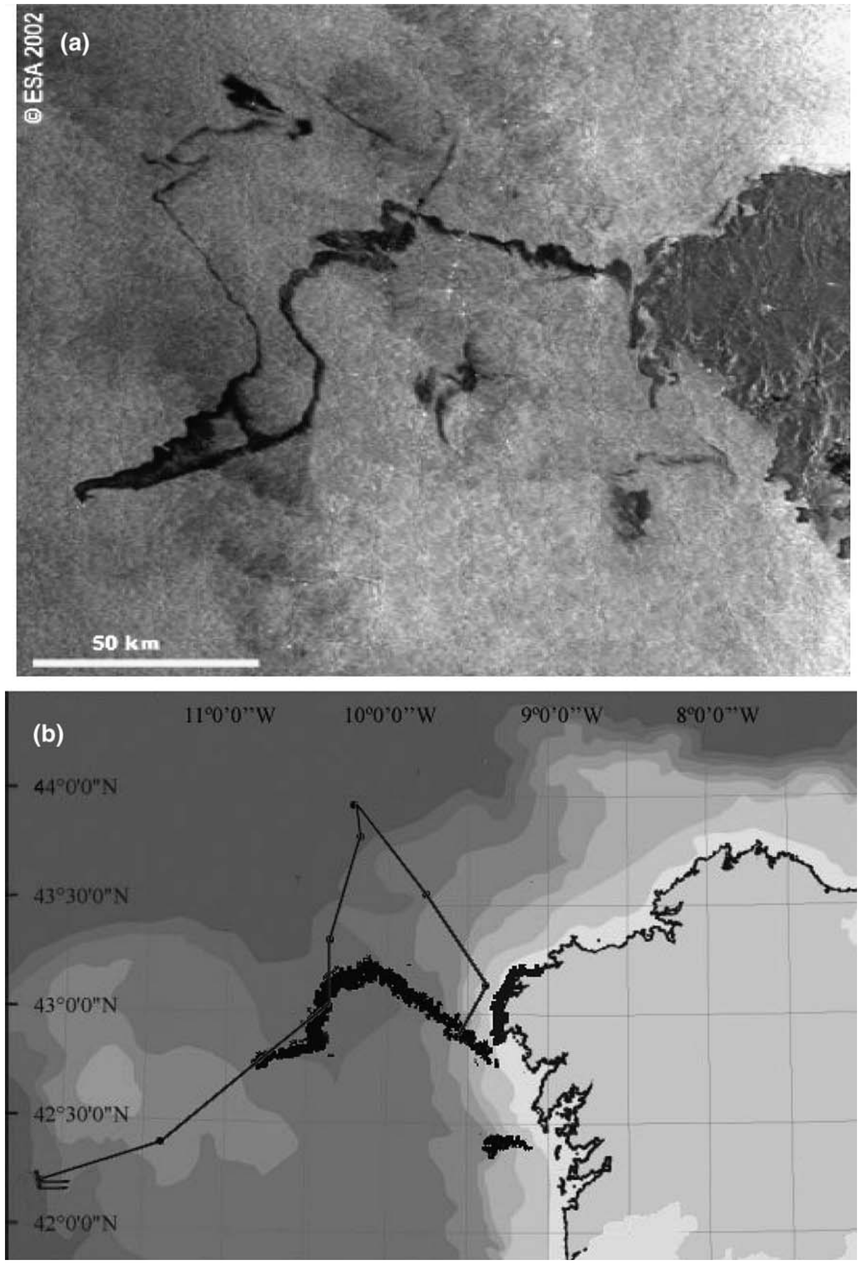

Fig. 3. (a) November 17, 2002—ASAR-ENVISAT ESA Satellite image showing the wake of fuel oil, (b) METEOMOHID simulation of the track of the first spill on November 17th, 2002 at 12h00 UTC, the *Prestige* course: barotropic conditions, tracers are released at surface. Compare with (a).

Table 1
Ship positions reported by Le Cedre

Date	Latitude	Longitude
13-10-2003 19:00	42°52′	9°33′
14-10-2003 10:00	43°10′	9°25′
14-10-2003 18:05	43°33′	9°45′
15-10-2003 08:10	43°50′	10°15′
16-10-2003 16:25	43°05′	10°23′
16-10-2003 03:35	43°20′	10°22′
17-10-2003 09:00	42°47′	10°50.5′
18-10-2003 10:00	42°26′	11°24′
19-10-2003 08:50	42°15′	12°08′
19-10-2003 12:00	42°12′	12°03′

These positions have been used to fix the moving origin of the tracers.

was applied at surface and two branches of fuel appeared with a similar shape of that showed in the ENVISAT image (Fig. 3a): the southern branch drift along the surface and the northern branch underneath the surface. The real picture cannot be reproduced exactly as is described here, where tracers travel on fixed depths, since it is expected that a tarball of fuel changes its vertical position in time.

4.2. Main spill simulation

The other simulated scenario was named the "main spill simulation". On November 19, at 7h00 UTC the tanker split in two parts about 130 miles away from Galician

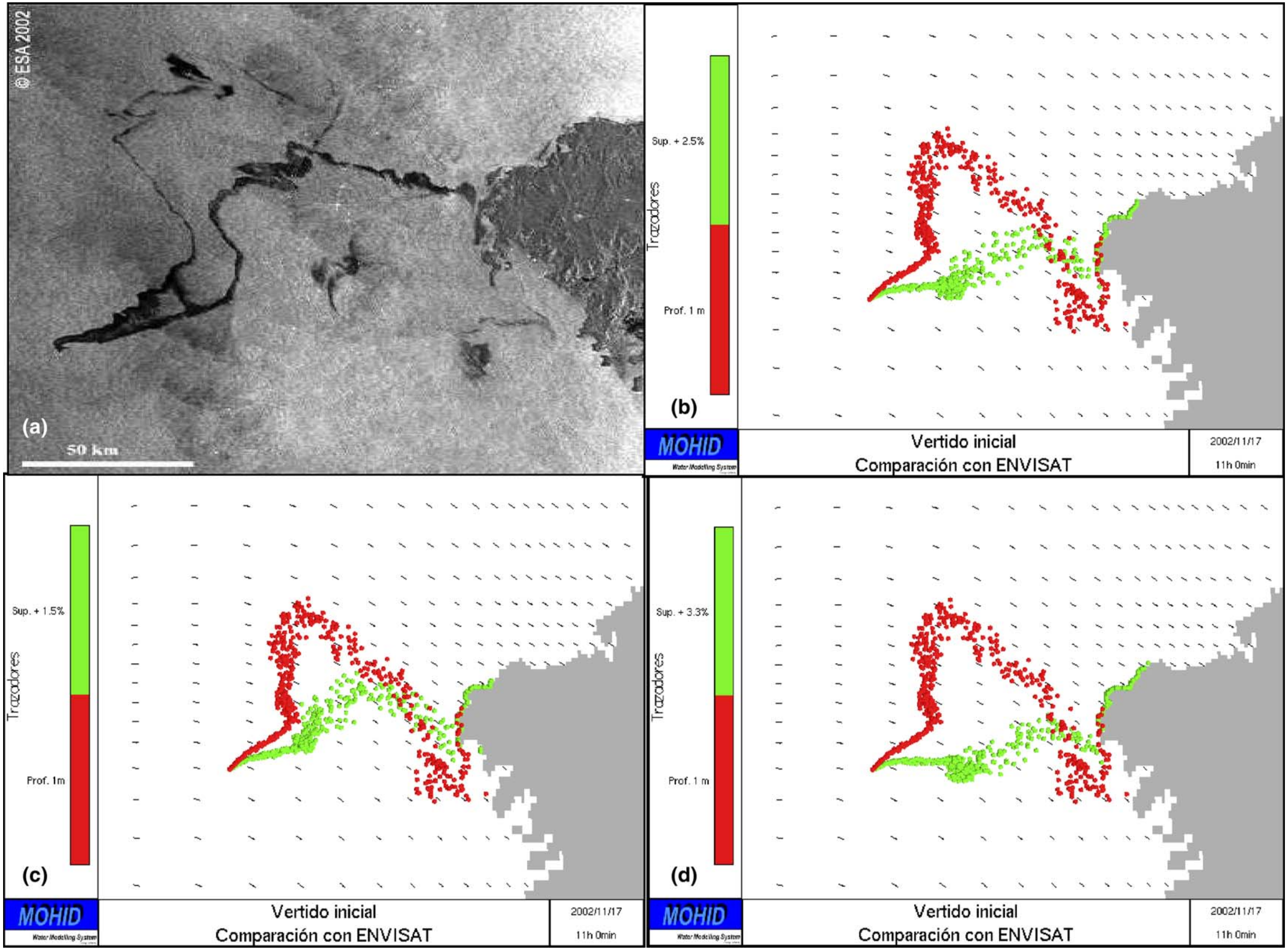

Fig. 4. Tracers are released at different depths: surface tracers (red), 1 m depth tracers (green). Surface tracers are directly pulled by wind with a velocity proportional to the wind velocity in a percentage of (b) 1.5%, (c) 2.5%, (d) 3.3%. Results are compared with ENVISAT satellite image (a) taked on November 17th. (For interpretation of the references in colour in figure legends, the reader is referred to the Web version of this article.)

Coast at 42°15N 12°08W, over the southern edge of the Galician Bank (42°12.6N 12°03.0′W). More than 11,000 tonnes of fuel were spilled when the ship broke. This new slick is called second or main spill.

In the same way as the first spill, the main spill was forced mainly by surface winds. Using calibration data obtained from the previous simulations, we tried to validate the drift model with the available observed data of the main spill. Besides, we tried to explain how unobserved patches appeared near the coast unexpectedly and why pollution did not go into the Rías Baixas. Simulation conditions were identical to those utilized in the first spill scenario, but horizontal geometric mesh has been modified in order to accomplish predictability and take care of the long time period simulation. The new domain covers from 39° to 44°N, from 15° to 8°W with a constant spaced grid (6′).

In this simulation, the main spill was forced by surface winds, all tracers traveling on surface. In Fig. 5, both simulation results from METEOMOHID simulations (coloured spots) and maximum fuel concentration daily observations collected by overflights (numbers in black spots) are represented. They present good agreement on the fuel trajectory, showing certain delay from November 24 to 28.

However, likewise happened in the fist spill scenario, the appearance of southern spots on 29th and 30th November (described in Montero et al., 2003) were not predicted. To try to minimize the disparity between observations and modeled results, we considered tracers at different depths (again 1.0 m, 0.5 m and surface). In addition, we focused on evaluating the effects of introducing large scale currents in the METEOMOHID system.

Near the coast, an eastern surface poleward slope warm current, the Iberian Poleward Current (IPC), is found (Maze et al., 1997; Ambar et al., 1986) mainly as a consequence of the southern density gradients (Peliz et al., 2003, 2004). The IPC is known to be a winter circulation feature (e.g., Frouin et al., 1990); notable in its thermal signature at the surface, consisting of a warm tongue that spreads along the slope, that usually develops in autumn at the mid-western Iberia coast latitudes (Pingree and Le Cann, 1989). During the summer period, this zone is under the influence of strong upwelling-favorable winds (e.g., Isemer and Hasse, 1987) and the IPC is often not clearly observed at the surface. Close to the coast, river run-off could become an important factor stopping fuel at the shelf salinity front too. Moreover, when fresh water discharge is strong it will constitute a very close coast current towards North.

The use of full baroclinic models involves solving two extra equations: the conservative equations for salinity and temperature, which mean a considerable increase of CPU time. Besides, to carry out a baroclinic simulation properly, it is essential to have temperature, salinity fields at the beginning of the simulation (initial conditions), temperature, salinity boundary conditions, river discharge data and set up or compute heat flux during the simulation period. Heat flux data would be provided by meteorological models, but the rest of the data are not easy to obtain for operational applications.

Consequently, a simpler solution was assessed: a baroclinic flow field forced by November climatologic density gradients (Levitus and Boyer, 1994) was added linearly to the barotropic solution forced by atmospheric fluxes (Fig. 6). The baroclinic flow field was obtained with a regional version of the MOHID model successfully used

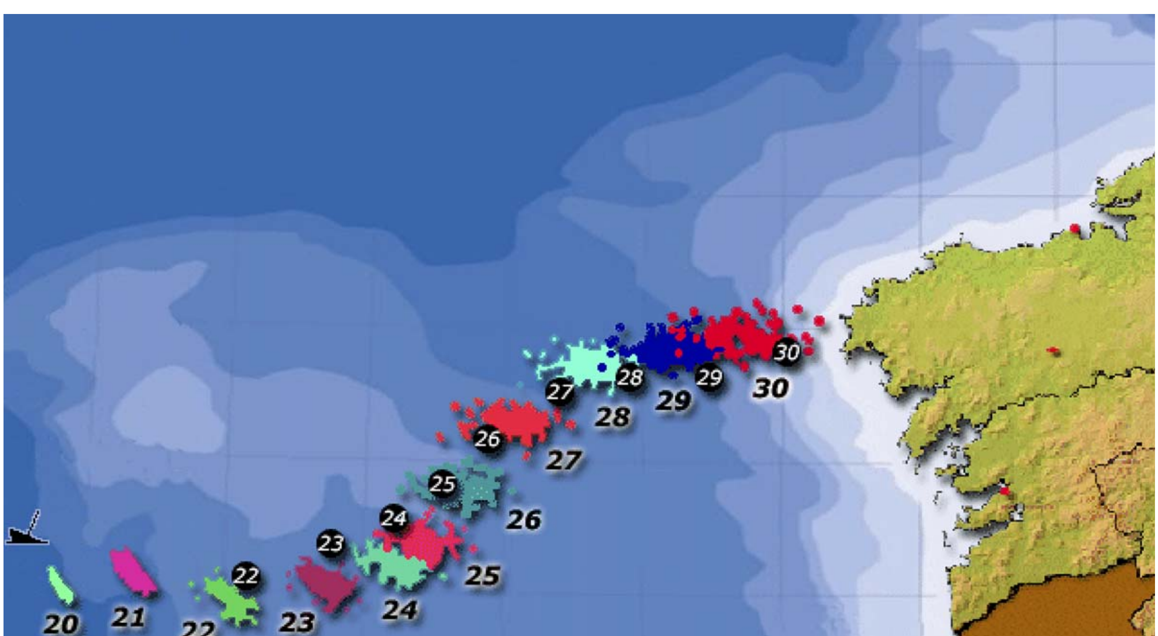

Fig. 5. METEOMOHID simulation of the main spill track. Comparison of the forecasted position (coloured spots) with overflight observed position (black circles).

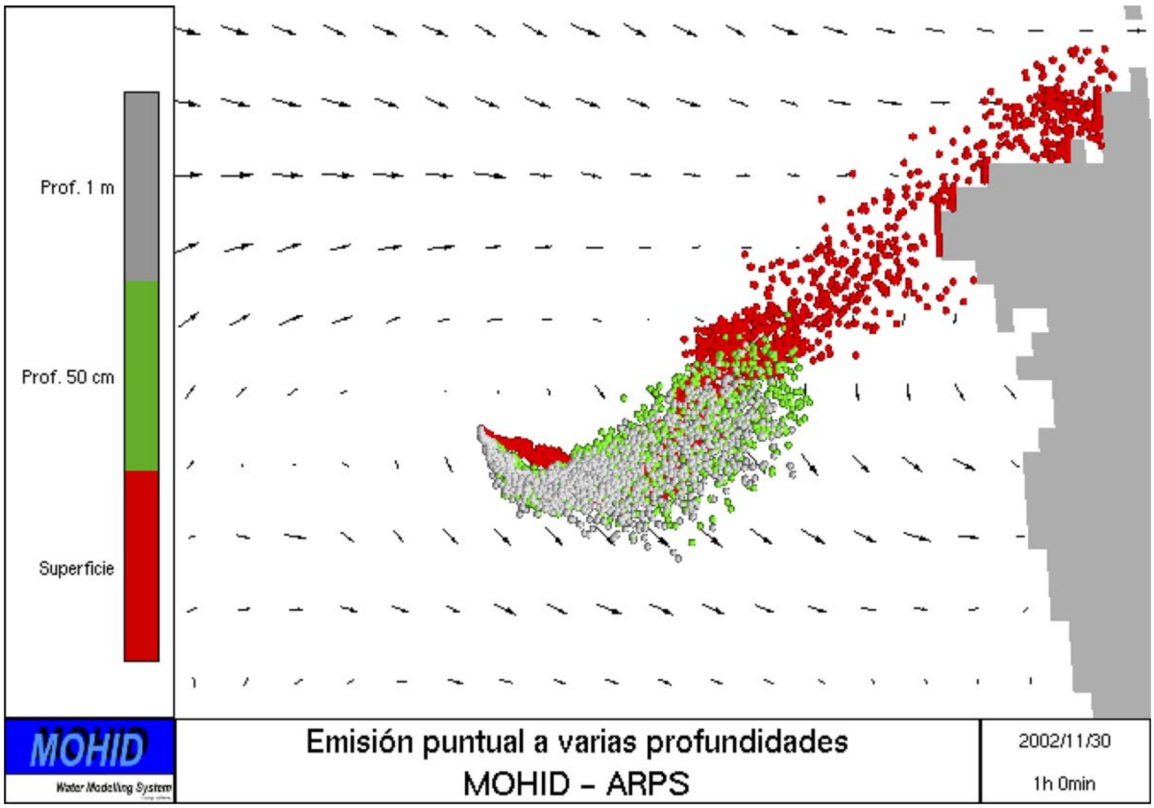

Fig. 6. METEOMOHID simulation of the main spill track taking into account the slope current. Oil displacement was computed adding to the barotropic currents the baroclinic ones obtained with November climatologic temperature, salinity fields. Red lagrangian tracers indicate surface tracers, green ones represent 0.5 m depth tracers and the grey ones are tracers at 1 m depth.

to compute large-scale flow fields in the framework of OMEX project (Coelho et al., 2002; Neves et al., 2002).

Fig. 6 shows that the inclusion of a climatic baroclinic current produce an intensification of northward transport, especially near coast locations, which is in accordance with previous experiences (Coelho et al., 2002; Peliz et al., 2003). However, in contrast to the delay of barotropic solution, the northward transport is overestimated since oil beached one day before than in reality. Therefore, climatological conditions were not enough accurate to quantify baroclinic fluxes properly although they permit to know the behaviour of the baroclinic field and its influence on the oil transport.

Recently, Daniel et al. (2004) uses the current field below the layer directly affected by the wind, computed with global models (MERCATOR, FOAM), as the baroclinic flux to add to the barotropic solution. In the Galicia coast, he found that the prediction is sometimes worse including these baroclinic fluxes. In fact, in the Bay of Biscay there is a scarce difference between oil drift with barotropic model, MERCATOR or FOAM baroclinic solution added to barotropic results. So, further work is needed to develop a more accurate baroclinic solution other than using climatology. In this sense, some improvements are being developed in the framework of ESEOO project (www.eseoo.org), focused on developing operational oceanography products for Spanish coast.

On the other hand, once more, underwater released tracers (grey and green points) could explain the presence of southern oil spots. Here we assume that tarballs always travelled at a fix depth, however, again a more realistic picture must be that the position in the water column changes as a consequence of the oil weathering, namely overwashing. For this reason, the tarballs would undergo intermittently the direct dragging of the surface wind. Daily reports of the positions of the main slick did not take into account an important amount of oil which came within the subsurface layer at the south of the main slick. When the subsurface tarballs arrived to near coast regions, changes in water density driven by river run-offs of fresh water, caused this tarballs to increase buoyancy and appear in the surface. These sunken amounts of oil were not observed by overflights but were detected when arrived near the coast. A lot of patches appeared southern of the main slick and polluted the outer zone of the Rías Baixas. This situation was reinforced by the light winds from the north.

This behaviour of subsurface oil could explain why the main spill reached the coast out of the "Rías Baixas", but not why tarballs didn't go into the Rías. To explain this, hypothetical fully baroclinic simulations were made during the *Prestige* crisis with a greater horizontal resolution taking into account climatologic river run-off. The results showed that positive circulation patterns inside the

Rías favoured by river discharge and north winds, help to stop pollution outside the Rías (Torres López, 2003).

5. Conclusions

The simple drift forecast system is carried out by means of a numerical model system, named METEOMOHID, which describes meteorological conditions and the ocean dynamics in an operational way.

Since the *Prestige* disaster, MeteoGalicia has developed a tool based on MOHID hydrodynamic model for oil spill drift prediction. Based on previous experience, the model has been assessed using data available from meteorological numerical models used daily in operational meteorology. This information combined with observational data were the starting point to set up the prediction system named METEOMOHID. This system succeeds in predicting the main features of the first oil spill. Two branches observed with satellite are predicted, taking into account a very limited set of physical forcings.

The implementation of a detailed vertical resolution permits to obtain a detailed surface dynamic, improving the results. It allows to separate the oil transport due to wind currents advection and the sailing effect, also to assess the possible existence of subsurface oil. While the surface oil slick drifts mainly under the direct wind effect, the subsurface oil is mainly moved by the shear sea current. The division into surface and subsurface oil results in a wider oil redistribution. Later, in nearshore regions, the subsurface travelling oil could reappear at the sea surface due to the buoyancy effect. This effect is also known as ''resurfacing'' effect that was observed in many cases of oil spills (Delvigne and Sweeney, 1998; Varlamov et al., 1999, 2001).

Anyway, near shore simulations showed that the selected set of processes is not enough to explain some additional features. Further work is needed at this point to understand better the interaction between the deep ocean, continental shelf and estuaries (Rías).

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