Oil spill forecasting in the Mediterranean Sea

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Abstract

In this work sensitivity experiments to the coupled MFS (currents) and MEDSLIK (oil spill) input parameters will be shown and results will be compared with observations. In these experiments the drift angle, the drift factor, the currents depth, the type of oil, horizontal diffusivity and the horizontal and temporal current resolution were changed.

Keywords: oil spill, operational oceanography, Mediterranean Sea

1. Introduction

For many years now the Mediterranean ocean Forecasting System (MFS, Pinardi et al , 2003) current forecasts have been coupled to the MEDSLIK fate and dispersal oil spill model (Lardner et al., 2006). Since 2006 several accidents occurred in the Mediterranean from the Lebanese coasts to the Gibraltar Strait that showed the importance of connecting GMES core service products (Ryder , 2007) to downstream services such as oil spill forecasting in real time. The flow field variability in the Mediterranean is as high as in other world ocean regions and there is a need to have real time currents together with climatologies to augment the accuracy of the fate and dispersal of oil spills.

In this paper, sensitivity experiments to oil spill model parameters will be shown for different coupled model forecasts that will be compared with observations from buoy trajectories to real accidents.

2. Description of the oil dispersion model: MEDSLIK

MEDSLIK is a user-friendly software package designed to predict the fate and transport of an oil spill. It uses a lagrangian representation of the oil slick, i.e., the oil slick is represented by a large number of particles. MEDSLIK requires as input data the type of oil and its characteristics, the wind field, the sea surface temperature and the thee-dimensional sea currents.

MEDSLIK is integrated with MFS currents and it is capable of reproducing the oil dispersion taking into account the weathering of the oil.

MEDSLIK simulates the transport of the surface slick governed by both water currents and by direct wind forcing. The advective velocity of each oil parcel can be a sum of the mean and turbulent fluctuation components of the drift velocity. The turbulent fluctuations are parameterized as horizontal turbulent diffusion based on the random walk hypothesis.

The mean advection of the slick is caused by the combined effects of surface currents and wind drag. MEDSLIK, like most oil spill models, uses a drift factor approach, which is considered to be a most practical approach for adjusting the mean advection of oil slicks coming from rather low resolution circulation models. With this method the mean drift velocity of the surface oil is considered to be a weighted sum of the wind velocity and the surface eulerian velocity field.

Let (X_i, Y_i, Z_i) be the position of the *i*-th parcel at the beginning of a particular step. Then at the end of the time step of length τ the parcel is displaced to the point

$$X_i' = X_i + \{u(X_i, Y_i, Z_R) + \alpha(W_x \cos\beta + W_y \sin\beta)\}\tau + \Delta X_i^{(d)}$$
$$Y_i' = Y_i + \{v(X_i, Y_i, Z_R) + \alpha(-W_x \sin\beta + W_y \cos\beta)\}\tau + \Delta Y_i^{(d)} \quad (1)$$
$$Z_i' = Z_i + \Delta Z_i^{(d)}$$

where $u(X_i, Y_i, Z_R)$ and $v(X_i, Y_i, Z_R)$ are the water velocity components in the *x* and *y* directions at a fixed reference water level, Z_R, W_x and W_y the components of wind velocity, α and β are the drift factor and the drift angle respectively and the diffusive displacements are given by

$$\Delta X_i^{(d)} = [2rand(0,1) - 1]\sqrt{6K_h \tau}$$
$$\Delta Y_i^{(d)} = [2rand(0,1) - 1]\sqrt{6K_h \tau} \quad (2)$$
$$\Delta Z_i^{(d)} = [2rand(0,1) - 1]\sqrt{6K_v \tau}$$

where K_h and K_v are the horizontal and vertical diffusivities respectively, chosen as fixed values and *rand*(0,1) is a uniform random number between 0 and 1. It can easily be seen that the root mean square values of the diffusive displacements are

$$r.m.s(\Delta X^{(d)}, \Delta Y^{(d)}, \Delta Z^{(d)}) = \{\sqrt{2K_h \tau}, \sqrt{2K_h \tau}, \sqrt{2K_v \tau},\}$$

It can be shown that a cloud of such particles undergoing random walks with these r.m.s. displacements satisfies the convection-diffusion equation with K_h and K_v the horizontal and vertical diffusion coefficients. The successive positions of the parcel of oil described by (1) and (2) is called the trajectory model of MEDSLIK.

In addition to convective and diffusive displacements, the oil spill parcels change due to various physical and chemical processes that transform the oil. The lighter fractions of the oil disappear through evaporation and the remaining fractions begin to be absorbed in water, or emulsify. Each particle of oil, while moving with the flow as described before, changes its oil properties, such as its density and viscosity. Finally, some of the oil is driven below the surface by wave action that is parameterized in a simple way in MEDSLIK. It may also happen that the horizontal displacement takes a particular parcel of oil onto the coast.

3. Results

3.1 Study case: the Lebanon Accident

On the 13 and 15 of July 2006 the oil tanks at Jieh power station, located 30 km south of Beirut and directly on the coast, were hit by bombs. The amount of oil spill was reported as being between 15000 and 20000 tons and the type of oil was believed to be a heavy fuel oil of about API 20.

Different simulations have been carried with the MFS current fields and the ECMWF wind forcing. The position of the spill was 33° 41’ N and 35° 10’ E (actually the spill was on the coast, but we must choose the MFS grid point nearest to the coast), the spill volume was 20000 tons and the duration of spill was supposed equal to 96 hrs.

Figure 1 shows the comparison between the results of the simulations carried out with different wind correction factors, wind angles, current reference depths and horizontal diffusivity. Figure 2 show the temporal evolution of the percentage of oil evaporated and the percentage of oil on the surface for three different type of oil. From satellite images of the accident we know that the case of Fig. B and C are realistic (Sciarra et al., 2006).

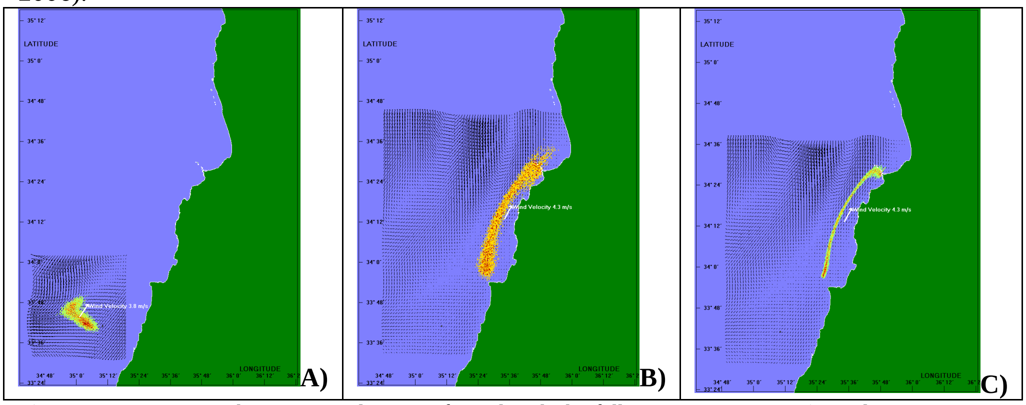

Figure 1: Comparison between simulation performed with the following parameters: A) wind correction factor: 0, wind angle: 0, current reference depth: 30 m and horizontal diffusivity: 2 $m^2 s^{-1}$; B) wind correction factor: 0.03, wind angle: 0, current reference depth: 30 m and horizontal diffusivity: 2 $m^2 s^{-1}$; C) wind correction factor: 0, wind angle: 0, current reference depth: 30 m and horizontal diffusivity: 0.1 $m^2 s^{-1}$.

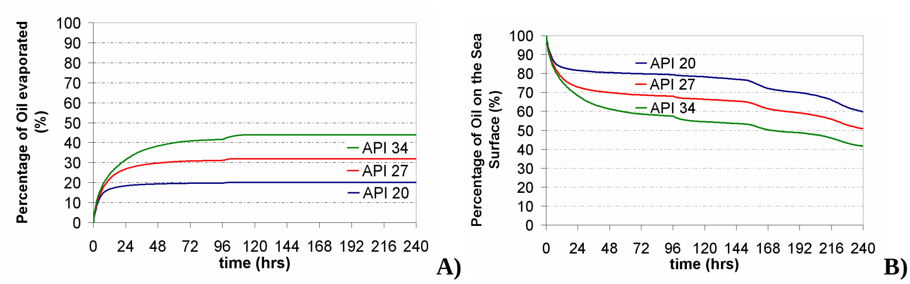

Figure 2: Temporal evolution of **a)** the percentage of oil evaporated and of **b)** the percentage of oil on surface in simulation with different type of oil, with the following characteristics : 1) API=20, Density of oil (ton/m^3): 0.934, Viscosity: 136.9; 2) API=27, Density of oil (ton/m^3): 0.893, Viscosity: 33.7; 3) API=34, Density of oil (ton/m^3): 0.855, Viscosity: 8.3

3.2 Study case: the Mersea drifters and MREA07 drifters

The trajectory model within MEDSLIK has been used to simulate drifters trajectories.
In the simulations the currents were taken from MFS analyses and winds are from ECMWF analyses. A subset of the user defined model parameters has been studied. In these experiments the drift angle, the drift factor and the current reference depths were changed.
The first study case is the Mersea Project Oil Spill Demonstrations in the Western Mediterranean. Seven drifters (75660, 75661, 75662, 75663, 75664, 60212 and 60213) were deployed on October 10, 2007 south of Nice. The drifters are oil monitoring buoys to emulate a surface oil spill.
The second study case is the Marine Rapid Environmental Assessment (MREA07) experiment. During this experiment five drifters (74871, 74872, 74873,74874 and 74875) were deployed on May 14, 2007 in the Ligurian sea.
Figure 3 shows the Medslik trajectories with the different model parameters. We can see that in the Mersea case the model is capable to reproduce the trajectory in at least few of the parameter cases while in the MREA07 case the model is not capable to reproduce the correct direction. When higher resolution modeling is used for the eulerian velocity field, the trajectory in the Ligurian Sea is reconstructed (not shown).

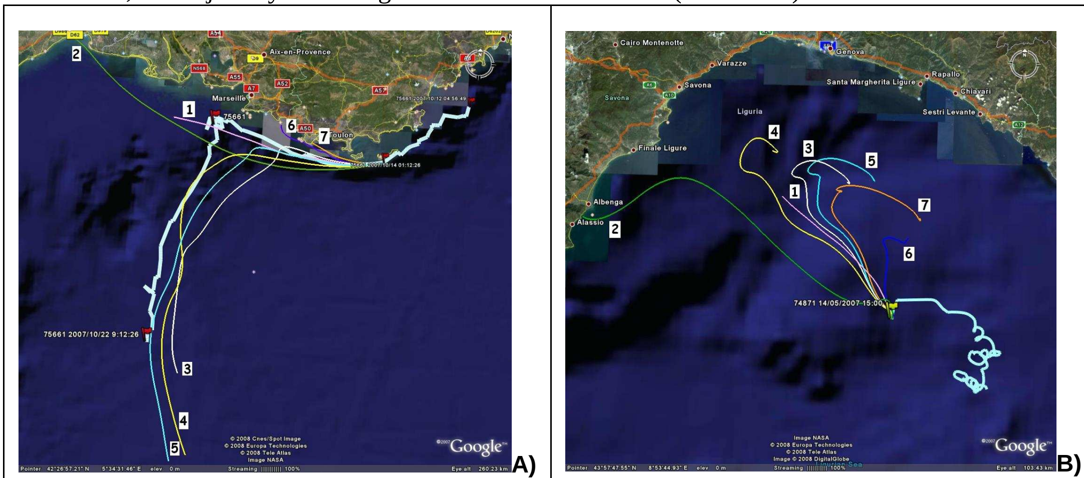

Figure 3: Overlay of the observed drifter trajectory (bold white-light blue line) and the Medslik trajectories: 1) Wind Correction: 0, Wind Angle: 0, Current depth: 30 m; 2) Wind Correction: 0.15, Wind Angle: 0, Current depth: 30 m; 3) Wind Correction: 0.03, Wind Angle: 13, Current depth: 30 m; 4) Wind Correction: 0.03, Wind Angle: 25, Current depth: 30 m; 5) Wind Correction: 0.03, Wind Angle: 0, Current depth: 30 m; 6) Wind Correction: 0, Wind Angle: 0, Current depth: 0 m; 7) Wind Correction: 0.03, Wind Angle: 0, Current depth: 30 m. The simulation in the panel A) is from 12/05/2007 to 22/05/2007, in the panel B) is from 14/05/2007 to 24/05/2007.

The model parameter sensitivity experiments are capable to capture the correct trajectory of the drifting buoy, at least for the Mersea experiment, and give enough spread in the final trajectories. Thus an ensemble of such sensitivity experiments could be a starting point for the determination of the model trajectory forecast uncertainty.
On the other hands, when the eulerian velocity field is inaccurate enough, as the MREA07 case, the change of coupled model parameters does not capture completely the uncertainty of the predictions. Thus there is a need to add a more detailed

representation of the currents, at higher resolution and this will be part of the future developments.

4. Final remarks

In conclusions we have shown that the coupled MFS-MEDSLIK oil spill forecasting system can have skill in reproducing both real accidents and drifter trajectories in the Mediterranean Sea.

The sensitivity experiments carried out in this paper show that changes in the oil spill model parameters could offer some insight in the uncertainty of the oil spill predictions by the MFS and MEDSLIK coupled systems. In the future we will re-cast the deterministic forecast in terms of such ensemble of different model projections giving thus the probability of the hazard for oil spills.

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