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DEVELOPMENT OF AN INTEGRATED SOFTWARE FOR FORECASTING THE IMPACTS OF ACCIDENTAL OIL POLLUTION

OSERIT

V. DULIÈRE, F. OVIDIO, S. LEGRAND

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SCIENCE FOR A SUSTAINABLE DEVELOPMENT
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North Sea

FINAL REPORT

DEVELOPMENT OF AN INTEGRATED SOFTWARE FOR FORECASTING THE IMPACTS OF ACCIDENTAL OIL POLLUTION

OSERIT

SD/NS/10

Coordinator

Dr. Sébastien Legrand
RBINS/MUMM
Royal Belgian Institute of Natural Sciences
Management Unit of the North Sea Mathematical Models
Gulledelle 100, B-1200 Brussels
Tel: +32 (0)2 773 21 02, Fax: +32 (0)2 770 69 72

Authors

Dr. Valérie Dulière, Fabrice Ovidio and Dr. Sébastien Legrand
RBINS/MUMM
Royal Belgian Institute of Natural Sciences
Management Unit of the North Sea Mathematical Models
Gulledelle 100, B-1200 Brussels
Tel: +32 (0)2 773 21 07, Fax: +32 (0)2 770 69 72

D/2013/1191/5
Published in 2013 by the Belgian Science Policy Office
Avenue Louise 231
Louizalaan 231
B-1050 Brussels
Belgium
Tel: +32 (0)2 238 34 11 – Fax: +32 (0)2 230 59 12
http://www.belspo.be

Contact person: David Cox
+32 (0)2 238 34 03

V. Dulière, F. Ovidio and S. Legrand. ***Development of an Integrated Software for Forecasting the Impacts of Accidental Oil Pollution- OSERIT***. Final Report. Brussels: Belgian Science Policy Office 2013 – 65 p. (Research Programme Science for a Sustainable Development)

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SUMMARY

A. Context

The North Sea is important to the cultural, social and economic well-being of the Belgian society. It allows numerous activities as ship traffic, fishery, mineral resources extraction (sand, gravel, gas or oil), dredging and exploitation of renewable wind energy. It also offers great opportunities for recreation and tourism activities. The Belgian Authorities understood how important it is to protect the North Sea and to manage and exploit all its resources in a sustainable way. The efforts that have been made in this sense over the last years can be ruined in case of major oil pollution. Consequences could be harmful not only to the local and regional ecosystems but also to the people and economies that rely on them. Everyone has still in mind the oil damages following the "Prestige" and "Erika" accidents, and more recently, the explosion of the "Deepwater Horizon" platform in the Gulf of Mexico.

With about 150.000 ship movements per year and the constant increase in ships size, the risk of major marine oil pollution in the Belgian Waters is real. It is therefore crucial that prepared intervention teams are able to quickly access to data and tools that could help them to evaluate the potential pollution impacts and to decide on the best way to fight it. According to the Belgian Marine Environment Protection Act of the 20th January 1999, in case of a marine oil pollution, the net environmental benefit of each possible response strategy must be analyzed and documented in a scientific way; the best response strategy being the one that minimizes the environmental damages. The OSERIT project contributes to the implementation of this legal framework.

B. Objectives

The main objective of OSERIT is to develop a new integrated tool that is able to quickly provide relevant, scientific-based information to support the decision-making process of the best response strategy in case of marine oil pollution. The provided information is meant, among other things, to help the different Belgian governmental authorities involved in oil pollution response at sea to:

- Quickly evaluate the potentially oil impacted areas;
- Perform a Net Environmental Benefit Analysis (NEBA) for different possible strategies ;
- Decide whether chemical dispersants should be used or not;
- Quickly plan operational interventions to combat marine oil pollution ;
- Help identify likely polluters in case of oil illegally spilled at sea ;
- Continue to develop and refine the Belgian Intervention Plan for Pollution Response at Sea ;

To this end, the tool must balance at best the state-of-the-art in oil spill modeling with the operational needs and constraints. In particular, it must be accessible 24/7, reliable, easy to use and portable.

C. Conclusions

The OSERIT project was driven all along by the requirements of the potential users, namely the Agencies involved in the Belgian Intervention Plan for Pollution Response at Sea. This project required the development of a new generation oil spill model that is able to simulate the tridimensional drift and fate of marine oil pollution. A post-processing system was also developed to process the model results into maps and graphs of interest to the trained users. Finally, the OSERIT project required the development of a new interface that allows to quickly launch model simulations and to visualize the resulting information, including physical parameters influencing the sea state. The portability and permanent accessibility of the tool are ensured by its technical implementation entirely based on the internet.

More concretely, the Agencies involved in the Belgian Intervention Plan for Pollution Response at Sea can access the OSERIT tool anytime, anywhere (provided they have internet access). In a few clicks, they can setup an oil spill scenario and access the resulting relevant information using the OSERIT visualization tool, in less than 30 minutes. Resulting information goes from oil spill drift trajectory, oil concentration in sensitive areas, time residency of oil concentration to beaching risk, and portion of evaporated, emulsified and dispersed oil.

The OSERIT model has been validated against various academic and real case studies, including the Gannet platform accident in August 2011 (Legrand and Duliere, 2013).

D. Contribution of the project in a context of scientific support to a sustainable development policy

The OSERIT project clearly contributes to the scientific support for a sustainable development policy. For instance, it allowed the implementation of a legal requirement of the Belgian Marine Environment Protection Act of the 20th January 1999 that requires the completion of a net environmental benefit analysis for deciding the best response strategy against an oil spill. In addition, the OSERIT tool has also already demonstrated its added-value to support the activities of the Belgian Coast Guard Structure and environmental impact assessments (including for the installation of offshore wind farms). It also demonstrated its relevance to implement certain objectives of OSPAR.

E. Keywords

North Sea, Oil, pollution, web-based tool, drift, fate, model, chemical dispersant, protection of the environment, operational service.

1. INTRODUCTION

1.1. Context

Everyone still has in mind the damages following the "Prestige" and the "Erika" accidents, and more recently, the explosion of the "Deepwater Horizon" platform in the Gulf of Mexico. All three events strongly affected (and sometimes continue affecting) the marine environment and in turn, the local and regional communities. Each time this is hundreds to thousands kilometers of coastlines that were soiled.

With about 150.000 ship movements per year and constant increase in ships size, the risk of oil pollution in the Belgian Waters has to be taken very seriously. The North Sea is important to the cultural, social and economic well-being of our society. It allows ship traffic, fishery, mineral resources extraction (oil, gas, sand, gravel...), dredging, cables, pipelines or windmills parks. Recreation and tourism activities bring every year more than 20 millions of people to the Belgian coast. Major oil pollution in our waters could damage local and regional ecosystems on many levels and in turn affect the people and economies that depend on them. It is therefore crucial to be able to rely on intervention teams that are quickly able to decide and organize the best response strategy, *i.e. the strategy that minimizes the global negative impact of the oil pollution on the marine environment.*

The main oil combatting techniques which are considered in the Belgium Waters include "no-action", mechanical and chemical means. The "no-action" strategy is relevant for small spills that are usually naturally dispersed within 3 to 6 hours and that do not threat any oil sensitive area. Mechanical means (*e.g.* the use of booms and skimmers) are able to contain, divert or recover part of the oil in the sea. They are useful by relatively calm conditions. Chemical means involve the use of chemical dispersants that break surface oil into billions of tiny droplets. These droplets are then dispersed through the water column what decreases the maximal values of oil concentration. If the oil is not removed from the marine environment, chemical dispersion may -in some condition- decrease the oil concentration below lethal toxicity thresholds.

None of the combatting techniques is perfect and their efficiency greatly depends on field conditions. In some circumstances, some combatting techniques can lead to the development of new or existing negative impacts. For instance, the use of chemical dispersants "moves" oil from the sea surface into the water column, which in turn might affect different organisms. It is therefore crucial to clearly assess the added value brought (or not) by each response technique in order to define the best response strategy.

Each situation involving a marine pollution is very unique and depends among other things on the oil type and behavior, weather conditions, spill location and oil quantity. Therefore, no standard solution exists and each time, a custom made response strategy is required.

Up to now in Belgium, the choice of the best response strategy to fight marine oil pollution was guided by the "expert judgment" only, with no access to factual and scientific-based elements as a whole. Since 20 January 1999, the Belgian Marine Environment Protection Law imposes the choice of the oil response strategy to be supported by a documented and scientifically-based method. The OSERIT project fits directly into this scheme.

1.2. Objectives

The main goal of the OSERIT project is to develop a new operational service that can provide relevant, scientific-based information to support the decision-making process in case of marine oil pollution of the Belgian Waters. OSERIT is meant to help (1) operational users to quickly decide and organize the very first actions in case of oil spilled in the sea and (2) environmental representatives who need to consider several oil-combating scenarios, to compare their potential environmental consequences and to perform a Net Environmental Benefit Analysis (NEBA) before deciding the best response strategy to combat the oil pollution. To meet the needs of both users' categories, OSERIT must be able to help answer a large range of questions including:

- How to guide the intervention team to the spill that was observed a few hours ago and that might have drifted far away from its last known position?
- What is the current sea state? And for the next days?
- Which of the sensitive zones are directly at risk? To which level?
- Will the use of chemical dispersant help reduce the damages? When should the chemical dispersants be applied?
- What if the leaking ship is pulled to the refuge place before the leak is stopped?
- What if the damaged ship sinks down to the bottom?
- …

OSERIT must also be able to provide information to help developing contingency plan and backtrack mysterious spills.

1.3. Expected outcomes

The first expected result is a **user-friendly interface** that integrates all the relevant pieces of information in order to help rapidly assess the possible consequences of marine oil pollution and determine the best response strategy. The second expected result is a **new generation oil spill mathematical model** that is able to simulate the three-dimensional drift and fate of oil on the sea surface and in the water column. The model uses the most recent met-ocean forecast produced by MUMM (*i.e.* waves, currents, temperature or salinity) on the Belgian continental shelf. A third expected result is a **post-processing system** that processes the oil spill model results and generates maps and graphs of interest (e.g. maps of oil spill drift trajectory, beaching risk, oil exposure time ...).

Finally, the web-interface, the oil spill model and the post-processing system are expected to be linked together to result in an **operational tool** accessible 24/7 to the Belgian governmental authorities involved in oil pollution response at sea.

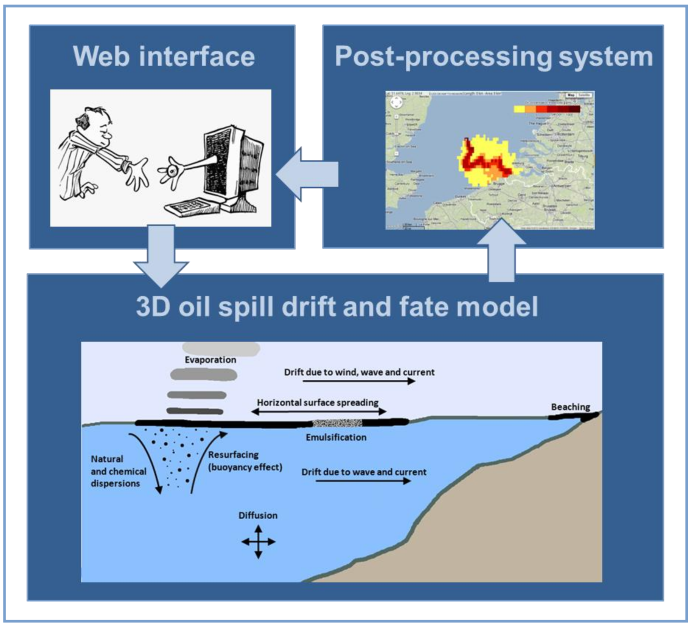


Figure 1 : The structure of the OSERIT operational tool

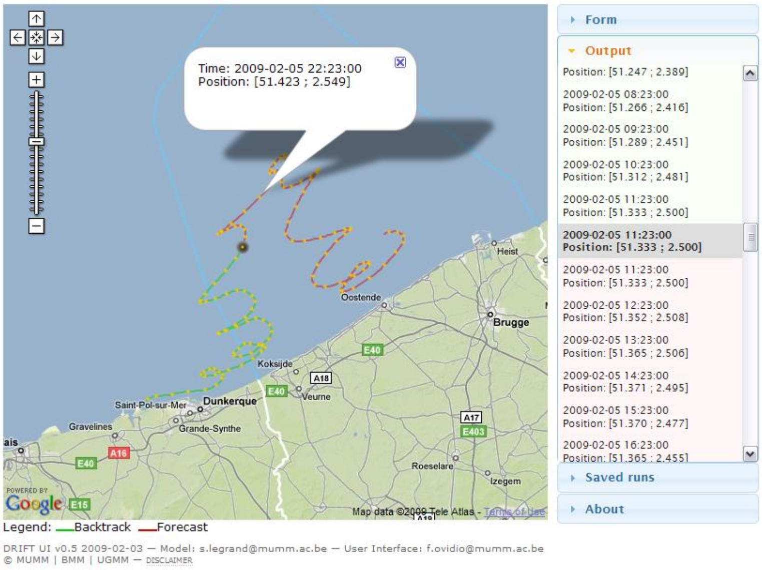
2. METHODOLOGY AND RESULTS

The very first outcome of the OSERIT project was the development of FLOAT, a light prototype of OSERIT. It gave the opportunity to the researchers to show what they had in mind, and to the potential users to test and comment on the prototype. This was an excellent way to build bridges among the different communities. It was also a good starting point for discussions to clearly identify the users' needs and operational constraints and then, to design the new OSERIT tool.

2.1. Operational efficiency: a key for designing OSERIT

2.1.1. FLOAT, a light prototype of OSERIT

FLOAT is a user-friendly tool that includes a web-based interface and an oil spill model. The interface has been especially developed for the occasion with a clear willingness of ease of use. Any logged users can easily start a model simulation in both forecast and backtracking modes, visualize the simulation results on an interactive Google Map, create a static map that can easily be printed out, reload an old simulation or even share it with another user. The oil spill model was developed in 2005 by MUMM. It is able to compute the 2D trajectory of any object (including oil) floating on the sea surface in the eastern English Channel and the southern North Sea. This model has proven its usefulness over the past years although it is limited to 2D surface drift due wind and surface current only.



```
Time: 2009-02-05 22:23:00
Position: [51.423 ; 2.549]
```

```
Output
Position: [51.247 ; 2.389]
2009-02-05 08:23:00
Position: [51.266 ; 2.416]
2009-02-05 09:23:00
Position: [51.289 ; 2.451]
2009-02-05 10:23:00
Position: [51.312 ; 2.481]
2009-02-05 11:23:00
Position: [51.333 ; 2.500]
2009-02-05 11:23:00
Position: [51.333 ; 2.500]
2009-02-05 11:23:00
Position: [51.333 ; 2.500]
2009-02-05 12:23:00
Position: [51.352 ; 2.508]
2009-02-05 13:23:00
Position: [51.365 ; 2.506]
2009-02-05 14:23:00
Position: [51.371 ; 2.495]
2009-02-05 15:23:00
Position: [51.370 ; 2.477]
2009-02-05 16:23:00
Position: [51.365 ; 2.455]
```

Legend: Backtrack Forecast

DRIFT UI v0.5 2009-02-03 — Model: s.legrand@mumm.ac.be — User Interface: f.ovidio@mumm.ac.be
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Figure 2: Snapshot of FLOAT, a light prototype of OSERIT

2.1.2. Advantages of FLOAT

The Agencies to which the Float interface was opened mainly reported positive feedback. They appreciate the **time saved** by directly requesting (and visualizing) their own model simulations from the web-interface instead of requesting simulations to the modeler on duty. They value the **ease of use** of the interface and the ability to simulate the drift of a floating object from an extended list of objects including oil spills. They appreciate the **portability** of the system guaranteed by the web-based interface.

2.1.3. Beyond FLOAT

From feedbacks on FLOAT, we could identify two different categories of users. The first category includes operational users as the MIK (Maritiem Informatie Kruispunt) and MRCC (Maritime Rescue and Coordination Centre) who need to quickly launch and visualize a drift simulation. The second category of users includes environmental representatives such as MUMM and DG5 who need to compare several scenarios in order to assess, among others, the potential environmental consequences of dispersant use. A priori, the first user's category needs a basic and ready-to-go tool while the second category needs a more advanced and flexible tool that offers several options and scenarios. The new tool should be **suitable and easy to use to both users' categories**.

The users clearly required more detailed and specific oil-related information than what can be provided by FLOAT. A new oil spill model must therefore be developed. The model choice must be based on the user's need for specific information but also on the two main operational constraints, namely the lack of time for intervention and the common lack of information on the actual oil spill. On the one hand, the model should include the state-of-the-art in oil spill modeling in order to provide the best 3D forecasts of the oil drift and fate. On the other hand, it should remain fast and account for the fact that the behavior of oil strongly depends on the oil characteristics which remain often unknown in case of an oil spill. Observational reports usually mention the spill location and sometimes also an estimation of the oil-covered area and oil volume. These users' requests and operational limitations are of major concern to us and were seriously taken into account when defining the model architecture. In particular, it helped identify the major physico-chemical processes (advection, evaporation, horizontal spreading, vertical dispersion ...) to be included in the oil spill model and choose among the existing model parameterizations. On top of oil-related information, the new tool should also provide an access to the physical parameters influencing the sea state: currents, winds, wave height, sea elevation, temperature and salinity.

With the increased complexity level of the oil spill model but also of the requested information, a post-processing system needs to be developed. It allows to make the most of the model results and to provide "straight to the point" information to the users. The post-processing system is able to process the model results into maps and graphs that are relevant to the user (*i.e.* maps of beaching risk, oil exposure time in pre-defined oil-sensitive zones or maps of maximal oil concentration). Some maps should provide a global view of the model simulation results while others should provide information at a particular time or over a particular time period.

FLOAT was also useful to support Search And Rescue (SAR) operations and so should be OSERIT. Users put stress on the fact that the service should be reliable. The unique and common login for accessing FLOAT is considered as a potential source of problem. Each user should have his/her own login and should be able to share some of their simulation results with other users. Backup or duplication of the system should be done to provide an alternative in case of a breakdown of the nominal system.

Based on all the considerations described above, we have developed a new oil spill drift and fate model, a post-processing system and a new web-based interface that all together form the basis of the new operational support tool in case of marine oil pollution.

2.2. OSERIT: a new 3D oil spill drift and fate model

The OSERIT project required the development of a new generation mathematical oil spill model that is able to simulate the three-dimensional drift and fate of oil spilled on the sea surface and in the water column.

2.2.1. Model philosophy

The oil spill model was designed to include all physic-chemical processes needed to provide short-term (1-5 days) oil related information that is requested by the users. A study of the state-of-the-art allowed pointing out the latest outcomes in oil spill modeling. Different model approaches and parameterizations have been considered and only a few have been selected on the basis of their known performance to capture the behavior of oil and their operational suitability (*i.e.* mainly the short time window for intervention and the common lack of information on the spill itself).

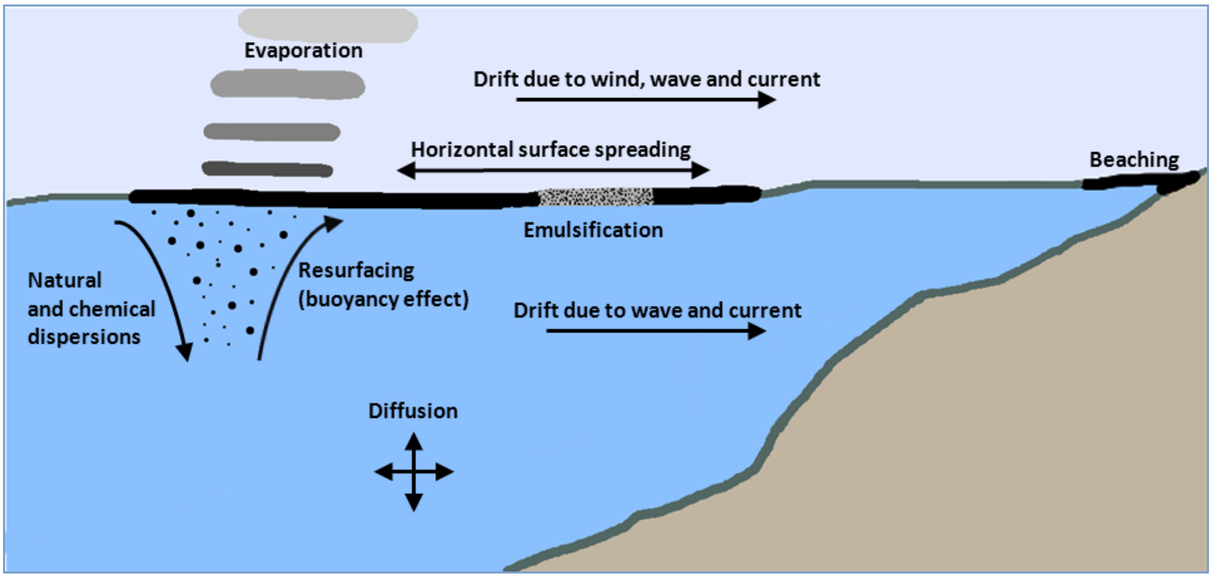


Figure 3: Physical processes included in the OSERIT oil spill model

The selected approach is a kinetic approach based on empirical data and parameterizations that simulates the 3D drift and fate of oil at the sea surface and in the water column (Fig. 3). It is based on the Lagrangian particle tracking method that represents spilled oil by the release of particles. The Lagrangian module computes the displacement of each particle independently under the combined action of the wind, water current and wave. The model also includes the buoyancy effect, turbulent diffusive transport, vertical natural dispersion of surface oil into the water column, horizontal surface spreading and beaching. The model is able to compute the drift of chemically dispersed oil. It can simulate the weathering of oil (*i.e.* evaporation and emulsification) and its effect on oil characteristics. Biodegradation is not included in the model since it is a slower process with relatively little impact on the oil behavior during the very first days. Due to the lack of information relative to oil sedimentation in the North Sea, no such parameterization has yet been implemented in the OSERIT model.

The model can be run forwards in time to provide forecast of the oil spill drift and fate or backwards in time to provide a backtracking of oil spill. For a maximum flexibility, each process implemented in the model can be activated and deactivated by designated model switches.

2.2.2. Available processes and parameterizations

a) Advection at the sea surface

The process of advection at the surface of the sea is dominated by winds, water currents and waves. Advection velocities are computed as follows:

$$\langle \vec{u} \rangle = D\vec{u}_w + \alpha_c \vec{u}_c + \vec{u}_{wave}$$

Where $\vec{u}_w$ is the wind velocity at 10 m above the surface; α_c is the current drift factor; $\vec{u}_c$ is the horizontal water current at the sea surface; $\vec{u}_{wave}$ stands for the advection component due to waves (or Stoke's drift). Because of their profile asymmetry and to surface gravity waves, drifting objects do not always drift directly downwind. There is often a significant component of the drift that is perpendicular to the downwind direction. D is the transformation matrix which allows introducing a deviation angle:

$$D = \begin{Bmatrix} \alpha_{dw} & \alpha_{cw} \\ -\alpha_{cw} & \alpha_{dw} \end{Bmatrix}$$

α_{dw} and α_{cw} are the wind drift factors in the downwind and crosswind directions, respectively.

For oil slick, the values of the downwind and crosswind factors are parameterized as a function of the wind speed:

$$\alpha_{dw} = \alpha \cos(\vartheta)$$
$$\alpha_{cw} = \alpha \sin(\vartheta)$$

Where α is taken as 3.15%. ϑ is equal to $40° - 8\sqrt{|\vec{u}_w|}$ when $0 \le |\vec{u}_w| \le 25 m/s$ and $\vartheta = 0$ when $|\vec{u}_w| > 25 m/s$.

For drifting objects, the values of the downwind and crosswind factors must be provided by the user or may be chosen from the US Coast Guard data base (Allen, 2005). In addition, the crosswind component of drifting objects has been observed to be either positive (right of the downwind direction) or negative (left of the downwind directions) and may change with a frequency rate of 4% per hour (Allen, 2005). As an option, a statistical model that switches the sign of the crosswind component has been implemented in OSERIT.

Oil particles are moving along with waves, following orbital motions that are not closed. This results in a net particles transport in the direction of wave propagation known as the Stoke's drift. The drift velocity associated with waves is computed as in Daniel et al. (2003):

$$u_{wave} = \omega\, k\, H_S^2 \frac{\cosh(2k\,z)}{8\sinh^2(k\,h)}$$

Where ω is the wave frequency, k the wave number, H_S is the significant wave height (the mean wave height computed from the highest third of the waves), z is the particle distance in meter above seabed and h is the mean water depth.

$$\omega = 2\pi / T$$
$$k = 2\pi / L$$

Where T and L are the wave period and wavelength, respectively and are given by:

$$L = C\,T$$
$$T = \sqrt{\frac{2\pi}{g} L \coth\left(\frac{2\pi h}{L}\right)}$$
$$C = \sqrt{\frac{g}{2\pi} L\, tgh\left(\frac{2\pi h}{L}\right)}$$

C stands for the wave celerity or the distance travelled by a crest per unit of time. These last equations are solved using a direct approximation based on Hunt's method (1979).

Two different numerical schemes have been implemented to compute the advection of the Lagrangian particles: an Euler forward method and the classical 4th order Runge-Kutta scheme. The tests carried out in the framework of the OSERIT project showed significant model results improvement of the Runge-Kutta scheme over the Euler one. For this reason, The Runge-Kutta scheme is set by default in the model.

b) Advection in the water column

In the water column, the advection is driven by 3D water currents $(\vec{u}_c, \omega_c)$, waves and oil droplets buoyancy velocities ω_0:

$$\langle \vec{u} \rangle = \alpha_c \vec{u}_c + \vec{u}_{wave} + (\omega_c + \omega_o)\vec{e}_z$$

$$\text{Where} \begin{cases} \omega_0 = \dfrac{g\, d^2\, (1 - \frac{\rho_0}{\rho_w})}{18\nu_w} & for\ d \le d_c \\ \omega_0 = \sqrt{\dfrac{8}{3} g\, d^2\, (1 - \dfrac{\rho_0}{\rho_w})} & for\ d > d_c \end{cases}$$

And $$d_c = \frac{9.52\,\nu_w^{2/3}}{g^{1/3}(1-\frac{\rho_0}{\rho_w})^{1/3}}\,.$$

ρ_0 and ρ_w are the oil and seawater density, respectively; ν_w is the seawater viscosity; g is the gravitational constant; d is the typical diameter of the oil droplets associated to the Lagrangian particle; and d_c is the critical diameter (~ 1 mm). This parameterization allows larger droplets to be more buoyant and to remain longer near the surface while smaller droplets are less buoyant and could be transported downwards due to turbulence (Korotenko et al., 2000). The model also allows imposing a predefined vertical velocity to the particles.

c) Natural vertical dispersion

Lagrangian particles can move from the sea surface into the water column through the process of vertical dispersion. Vertical dispersion is agreed that it plays a major role in the oil mass exchange between the slick and the water column. It is caused by a variety of natural processes but the influence of breaking waves by which surface oil is split into droplets that are propelled into the water column, is dominant. We decided to implement two approaches to describe the vertical exchange of the droplets from the slick to the water column.

The first approach uses an entrainment rate of surface oil into the water column that is specified by the user. This entrainment rate determines the number of particles that is randomly removed from the surface. To account for the fact that natural vertical dispersion breaks surface oil into small droplets, the radius of the dispersed oil droplets represented by the Lagrangian particles is randomly set between 0.1 and 3 mm. The intrusion depth of the Lagrangian particle (z_H) is computed as in Guo and Wang's (2009):

$$z_H = (1.5 + 0.35 * [R]_{-1}^{1})H_S$$

where $[R]_{-1}^{1}$ is the uniform distribution random number in the interval -1 to 1 and H_S is the significant wave height.

The second approach is very similar to the first one but uses a kinetic method based on Tkalich and Chan (2002) to compute the entrainment rate from the oil slick to the water column, λ_{ow} (1/s).

$$\lambda_{ow} = \beta \frac{k_e\, \omega\, \gamma\, H_s}{16\, \alpha\, L_{ow}}$$

where k_e is the coefficient evaluated from experiments (usually between 0.3 and 0.5); ω is the wave frequency; γ is the dimensionless damping coefficient; H_S is the significant wave height; α is a coefficient that concerns the mixing depth of the individual particles; and L_{ow} is the vertical length-scale parameter empirically estimated to 1m. β is a coefficient that depends on oil viscosity. $\beta = 1/\nu_o$ where the oil viscosity is greater than 100 cSt and $\beta = 1$ elsewhere. The parameter β mainly inhibits the natural dispersion of viscous heavy crude oil.

d) Turbulent diffusion

The turbulent diffusive transport is expressed using the random walk technique. The fluctuations velocity components (u', v' and w') are calculated following Wang et al. (2008):

$$u' = R_n \sqrt{4K_x / \Delta t}\cos(\varphi)$$
$$v' = R_n \sqrt{4K_y / \Delta t}\sin(\varphi)$$
$$w' = R_n \sqrt{2K_z / \Delta t}$$

Δt is the model time step; R_n is a normally distributed random number with a mean value equal to 0 and a standard deviation equal to 1; and φ is the directional angle randomly and uniformly distributed within the interval [0,π]. K_x and K_y are the turbulent diffusivity coefficients in the x and y directions, respectively. Their values must be specified. K_z is the vertical diffusion coefficient. It is taken from the turbulent module of the hydrodynamics model but can also be expressed as in Johansen (1982):

$$K_z = 0.028\left[\frac{H_S^2}{T}\right]e^{-2kz}$$

Where H_S is the significant wave height; T is the wave period; z is the vertical coordinate of oil droplets; and k is the wave number.

The vertical turbulent diffusion term is never computed for Lagrangian particles at the sea surface. Similarly, the horizontal turbulent diffusion term is not computed when the horizontal surface spreading of surface oil is computed.

e) Horizontal surface spreading

Horizontal spreading of surface oil is done in three phases. When oil is spilled on the sea surface, it immediately spreads horizontally over the water surface due to the gravity and inertia forces and the interfacial tension between oil and water. This first phase (*gravity-inertia*) lasts only a few minutes for all except the largest spill (Lehr et al. 1984). It is followed by the second phase which is known as the *gravity-viscous* spreading phase. The viscosity of the oil opposes the gravity and inertia forces (Fingas, 2011) and the spreading process continues but slower. The third and last phase of oil spreading (known as the *surface tension-viscous* phase) starts about one week after the oil was released and is therefore not considered here.

In OSERIT, two different approaches to compute the horizontal spreading of surface oil have been implemented:

(1) Fay's surface spreading

The solution of Fay's formula is approached by the computation of random velocities obtained using Monte Carlo sampling in the range of velocities that are assumed proportional to the diffusion coefficients D (Garcia et al. 1999). The diffusion is assumed to be isotropic. During the first spreading phase, the diffusion coefficients are computed as follows:

$$D = \frac{\pi\, k_1^2}{16}\left(\left(\frac{\rho_w - \rho_o}{\rho_w}\right) g\, V_o\right)^{1/2}$$

Where $k_1 = 1.14$ according to Fay (1971), g is the gravitational acceleration, ρ_w is the water density, ρ_o is the oil density and V_o is the initial spill volume. This corresponds to a circular slick of radius:

$$R = \frac{k_1}{2}\left(\left(\frac{\rho_w - \rho_o}{\rho_w}\right) g\, V_o\, t^2\right)^{1/4}$$

During the second spreading phase, the diffusion coefficients and corresponding slick radius are computed as follows:

$$D = \frac{\pi\, k_2^2}{32}\left(\frac{\left(\frac{\rho_w - \rho_o}{\rho_w}\right) g\, V_o^2}{\nu_w^{1/2}}\right)^{1/3} \frac{1}{\sqrt{t}}$$

$$R = \frac{k_2}{2}\left(\frac{\left(\frac{\rho_w - \rho_o}{\rho_w}\right) g\, V_o^2\, t^{3/2}}{\nu_w^{1/2}}\right)^{1/6}$$

k_2 equals to 1.45 (Fay, 1971) and ν_w is the water kinematic viscosity.

(2) Lehr's surface spreading

Lehr et al. (1984) suggested a new approach based not only on the Fay formula but also on the fact that oil slick tends to be more elliptical than circular in shape with the major axis oriented in the direction of the wind. The length of the minor axis (Q) is a function of the relative density difference, initial spill volume (V_o) and time (t):

$$Q = 1.13\left(\frac{\rho_w - \rho_o}{\rho_w}\right)^{1/3} V_o^{1/3} t^{1/4}$$

The length of the major axis (R) is proportional to the sum of Q and a product of suitable powers of wind speed (W) and time (t):

$$R = Q + 0.0034 W^{3/4} t^{1/4}$$

Let consider a particle located on a concentric and similar ellipse with r and q for major and minor axes, respectively. Let (X, Y) be the coordinates of the particle relative to the principal axes of ellipse, with the x-axis following the wind direction. Then, $X = r \cos\vartheta$ and $Y = q \sin\vartheta$. If we assume that the particle is displaced outwards with the same elliptical angle ϑ and a displacement proportional to the ratio of the axes of the inner ellipse (where sits the particle) to those of the outer, then:

$$\Delta X_{spread} = \Delta r \cos\vartheta = \Delta r \left(X/r\right) = X \left(\Delta R/R\right)$$
$$\Delta Y_{spread} = \Delta q \sin\vartheta = \Delta q \left(Y/q\right) = Y \left(\Delta Q/Q\right)$$

That spreading can be stopped when the terminal thickness is reached based on data from McAuliffe (1987), as done in French (2003).

Oil Viscosity (mPa/s)	Minimum Slick thickness (mm)
< 10	0.01
10-20	0.05
20-1000	0.1
> 1000	1

Table 1: Minimum oil thickness for gravitational spreading based on data in McAuliffe (1987).

The first phase (gravity-inertia) of the Lehr approach is modeled by taking the initial spill state to be the end results of the gravity-inertia phase at the time when the gravity-viscous mechanism takes over. The pre-defined oil spill is then stretched to fit a circular slick of radius $R_o = 2.81\sqrt{V_o}$.

f) Beaching

The Lagrangian particle module includes beaching. For now, when a particle reaches a land point of the model domain, it is stopped and no re-entering is possible. Note that only surface oil is allowed to beach.

g) Evaporation

Two different approaches to compute the oil evaporation have been implemented: (1) the analytical approach of Fingas (1996; 1997; 2011) that treats the oil as a single substance and (2) the pseudo-component approach of Jones (1997) that divides the oil into a number of pseudo-components, computes the evaporation rate for each component, and combines them to get the total evaporation rate.

(1) Fingas' approach

Fingas suggests that oil evaporation is not air-boundary-layer regulated (in opposition to water) and is not a function of wind speed, turbulence level, slick area or thickness. Instead, oil evaporation can be analytically calculated as a function of time (t, in minutes), temperature (T, in degree Celsius) and empirically measured parameters (*a* and *b*).

$E_{vap} = \left[a - bT\right]\ln(t)$ for most oil types

$E_{vap} = \left[a - bT\right]\sqrt{t}$ for oil types such as diesel fuel with few different sub-components evaporating at one time.

Fingas (2011) provides parameters for more than 150 oils. For the rest, he suggests two methods to compute them using either the percentage of oil distilled at 180°C or oil density and viscosity at 15°C. A Runge-Kutta scheme was used with a sub-time step of 1 minute.

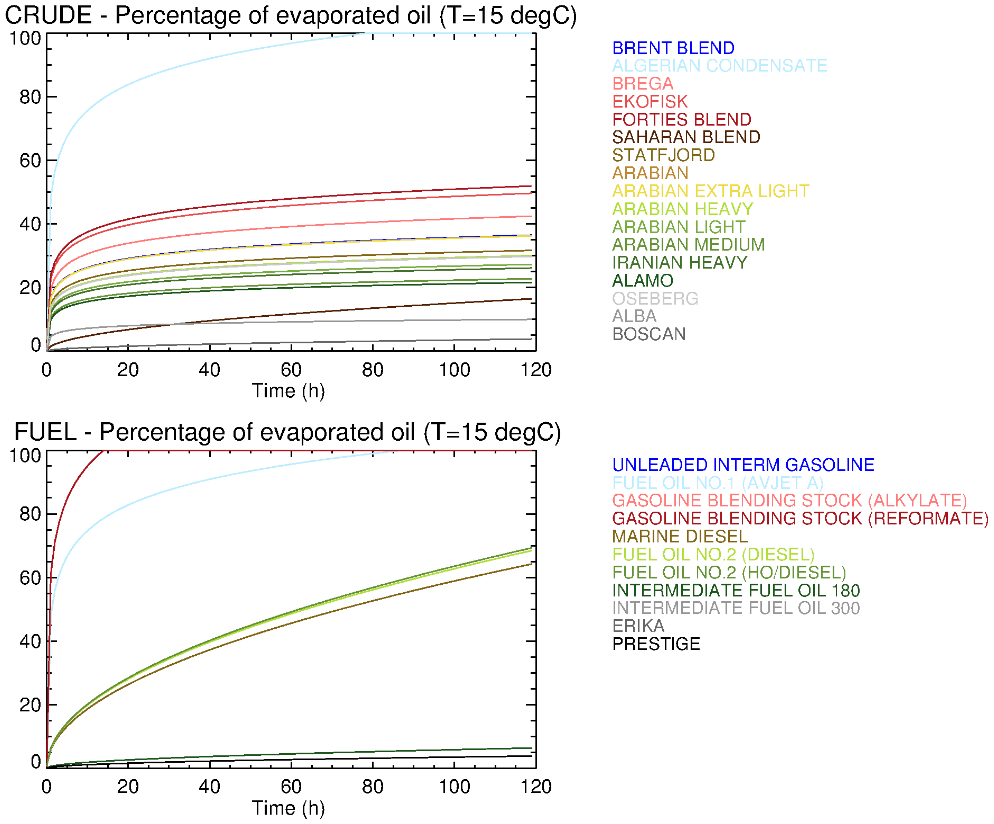


Figure 4: Time series of evaporated oil percentages as computed by the Fingas' approach for all oil types available from the OSERIT oil database. Oil evaporation is computed at a constant temperature of 15°C.

(2) Jones' approach

Jones et al. (1997) introduced a simplified pseudo-component approach. Most pseudo-components approaches require detailed information on the oil components. However, the approach of Jones requires information on the initial volume and boiling temperature of the oil components, only. Molar volume, vapor pressure, and molecular weight are related to the boiling point of the different oil components. This approach is therefore more appropriate from an operational point of view than other multi-components approaches and has been implemented into the OSERIT model.

Jones (1997) computes the evaporation rates for the different oil components as follows:

$$\frac{dV_i}{dt} = -\frac{A\,K_i\,P_i\,V_i}{R\,T\sum_{j=1}^{n_c}\frac{V_j}{\overline{V}_j}}$$

Where i refers to the ith oil component; V_i and $\overline{V}_i$ are the volume (m^3) and molar volume (m^3/mole), respectively; A is the spill area (m^2); K is the mass transfer coefficient (m/s); P is the vapor pressure (Pa); R is the gas constant; and T is the ambient temperature (K). The molar volume and vapor pressure are computed by:

$$\overline{V_i} = 7.000\,10^{-5} - (2.102\,10^{-7}\ BP_i) + (1.000\,10^{-9}\ (BP_i)^2)$$

$$\ln \frac{P_i}{P^0} = \frac{\Delta S_i (BP_i - C)^2}{R\ BP_i} \left[\frac{1}{BP_i - C} - \frac{1}{T - C} \right]$$

Where *BPi* is the boiling point temperature of the component, $C = (0.19\, BP_i) - 18$ and $\Delta S_i = 8.75 + 1.987 \log(BP_i)$. The mass transfer coefficient can be found following:

$$K_i = 0.0048 U^{7/9}\ Z^{-1/9}\ Sc_i^{-2/3}$$

Where *Sci* (Schmidt number) is the ratio of the air kinematic viscosity to the molecular diffusivity of the component, *Di*:

$$D_i = D_{water} \sqrt{\frac{MW_{water}}{MW_i}}$$

MWwater and *MWi* are the effective molecular weight of the water and of each pseudo-component of the oil. *MWi* can be computed using the following equation:

$$MW_i = 0.04132 - (1.985\,10^{-4} BP_i) + (9.494\,10^{-7}\ (BP_i)^2)$$

Evaporation is only calculated for oil on the surface.

h) Emulsification

Emulsification process has been implemented following Scory (2005).

$$\dot{V}_w = \frac{C_{18}}{1 - C_{18}} \frac{K_{em}}{C_{15}} V_r\ H_s$$

Where $\dot{V}_w$ is the rate of change in the volume of water caught in the emulsion; V_r is the untransformed oil volume at the surface; H_s is the significant wave height; K_{em} represents the oil ability to form emulsion and varies between 0 and 120; C_{15} is a constant (5.0 10^{-7} m s); and C_{18} is the ratio of the water volume in the emulsion to the total volume of the emulsion (0.8).

i) Chemical dispersion

Chemical dispersion enhances the natural vertical dispersion and has therefore been implemented in the model in a similar way. At the time of the dispersant application, some Lagrangian particles are randomly moved from the surface into the water column. The rate of entrainment is directly related to dispersant efficiency and the depth of entrainment is computed as in the natural vertical dispersion parameterization. The use of chemical dispersants breaks surface oil into small oil droplets of size uniformly distributed between 0.01 and 0.05 mm. In opposition to naturally dispersed Lagrangian particles, chemically dispersed particles cannot resurface. They remain in the water column and move under the combined effect of water current, wave, buoyancy and turbulent diffusion.

j) Oil properties

Oil viscosity associated to each Lagrangian particle changes due to emulsification and evaporation processes, and to temperature changes (Betancourt et al., 2005).

$$\mu = \mu_0 \exp\left[\frac{2.5F_{WC}}{1-0.654F_{WC}}\right]\exp\left[C_2 F_{evap}\right]\exp\left[c_{temp}\left(\frac{T_{ref}-T}{T_{ref}\,T}\right)\right]$$

Where μ_o is the initial oil viscosity, and F_{WC} the fractional water content in oil. C_2 varies from 1 to 10 from the light crude to heavy crude oil (Reed et al, 1988), and F_{evap} the evaporated fraction. T_{ref} is the reference temperature for μ_o and T is the oil temperature. T is usually not available so the temperature of the surrounding waters is used instead. C_{temp} = 5000K in SIMPAR (2003).

Oil density changes mainly due to evaporation and emulsification processes. The effect of evaporation on the oil density is computed as follows :

$$\rho = (0.6\rho_0 - 0.34)\, F_{evap} + \rho_0$$

Where ρ is the density of the remaining oil and ρ_0, the initial oil density (kg/m³). F_{evap} is the fraction of oil evaporated. The effect of emulsification can be computed as follows:

$$\rho_{sol} = F_{WC}\rho_w + (1-F_{WC})\,\rho$$

Where ρ_{sol} and ρ_w are the densities of the oil-and-water solution and water, respectively.

k) Eulerian Module

Next to the Lagrangian particle module, an Eulerian module has been implemented in the OSERIT model. It computes the transport and dispersion of oil concentration within the water column as it follows:

$$\frac{\partial C}{\partial t} + \frac{\partial (uC)}{\partial x} + \frac{\partial (vC)}{\partial y} + \frac{\partial ((w+w_o)C)}{\partial z} = \frac{\partial}{\partial x}(K_x \frac{\partial C}{\partial x}) + \frac{\partial}{\partial y}(K_y \frac{\partial C}{\partial y}) + \frac{\partial}{\partial z}(K_z \frac{\partial C}{\partial z}) + S$$

Where u, v and w are the components of the water current velocity in the x, y and z directions, respectively; w_o is the vertical velocity due to buoyancy effect; K_x and K_y are the x and y directional turbulent diffusivity coefficients, respectively. Their values can be specified or calculated directly from the Eulerian hydrodynamic model using the Smagorinsky's formula. K_z is the vertical turbulent diffusion coefficient. It can be taken from the turbulent module of the hydrodynamic model or can be expressed as in Johansen (1982):

$$K_z = 0.028\left[\frac{H_S^2}{T}\right]e^{-2kz}$$

Where H_S is the significant wave height; T is the wave period; z is the vertical coordinate of oil droplets; and k is the wave number. S represents sources/sinks. This last term allows the one way coupling (off-line) between the Lagrangian and Eulerian modules. Oil concentration at each grid node is then computed following:

$$C = \sum \frac{M_i}{\Delta A\, Z_i}$$

Where ΔA is the area of the grid cell; M_i is the mass of ith submerged particle in the considered grid cell and; z_i is the mixing depth of the individual particle.

Although the Eularian module has been implemented in the OSERIT model, it has not been fully validated yet and is therefore not included by default in the current version of OSERIT.

2.2.3. Model output

OSERIT results are provided in a netCDF file format that, for each Lagrangian particle, contains:

- Time of release
- Position (latitude, longitude, depth)
- Drifting state (*i.e.* not yet released, drifting, stopped)
- State (*i.e.* particle on the sea surface, within the water column, beached or out of the domain)
- Density and viscosity of associated oil
- Volume of evaporated, emulsified and remaining (not evaporated nor emulsified) oil associated to the particle
- Volume of water content

2.2.4. Model validation

The OSERIT model has been validated against various academic and real case studies, including the "Gannet" platform accident. On August 10th 2011, oil leaked from a sub-sea structure linking an oil well (Gannet F) to the main platform (Gannet A) approximately 180 km East of Aberdeen (UK) for more than 2 weeks. The OSERIT model has been set up to simulate the oil release from the Gannet platform. It used the hourly surface ocean current forecast from MyOcean NWS MFC and the 10m-wind forecasts from UK Met-Office forecasts. No wave forecast was available to us at that time. The model was set up to simulate the surface drift due to wind and water current, horizontal diffusion and natural vertical dispersion.

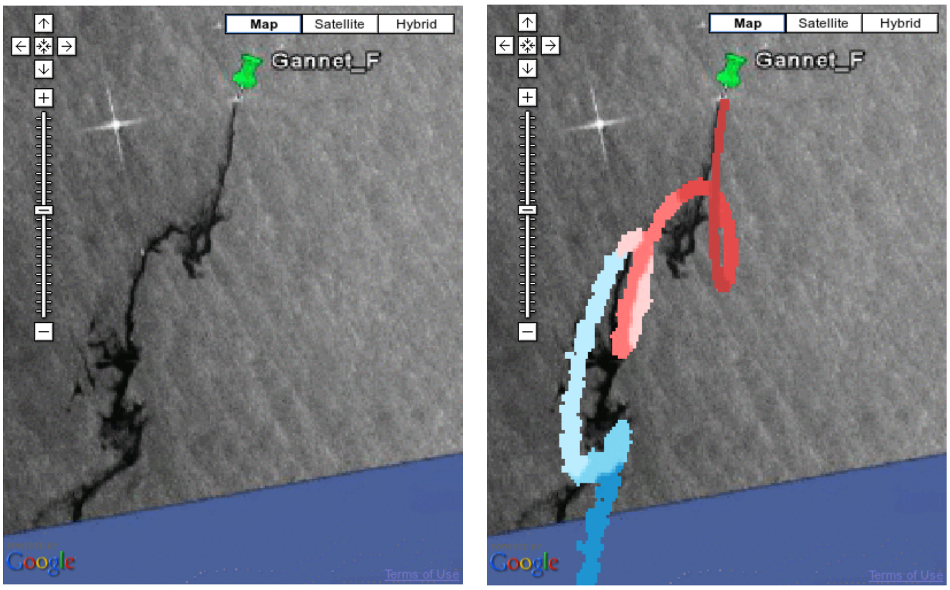


Figure 5: Satellite image taken on August 19th 2011 (5:31 UTC) by the COSMO SkyMed System (left) and the corresponding model estimation of the oil slick position superimposed on the same satellite image (right). The colours on the right panel represent time intervals of 6 hours during which the oil has been released. The dark red part of the slick represents oil that has been released during the 6 hours before the satellite image was taken while the dark blue part of the slick represents oil that has been released between 36 and 48 hours before the satellite image was taken. The Gannet F platform is represented by green drawing pin.

The model results have been compared against satellite images of the slick taken from radar sensors. It showed that OSERIT simulates the position of the observed oil slick well (Fig. 5, right). It captures not only its general shape, orientation and dimensions but is also able to capture more specific features of the slick such as the ring-shaped oil-covered area at the end of the first portion of the slick. Detailed information can be found in Legrand and Duliere (2013).

2.2.5. Operational configuration

2.2.5.1 Operational domain

Currently, OSERIT operational implementation is limited to the domain of MUMM operational hydrodynamic models that provide the forcing to OSERIT and covers the English Channel from 4°W and the southern North Sea up to 57°N (Fig. 6).

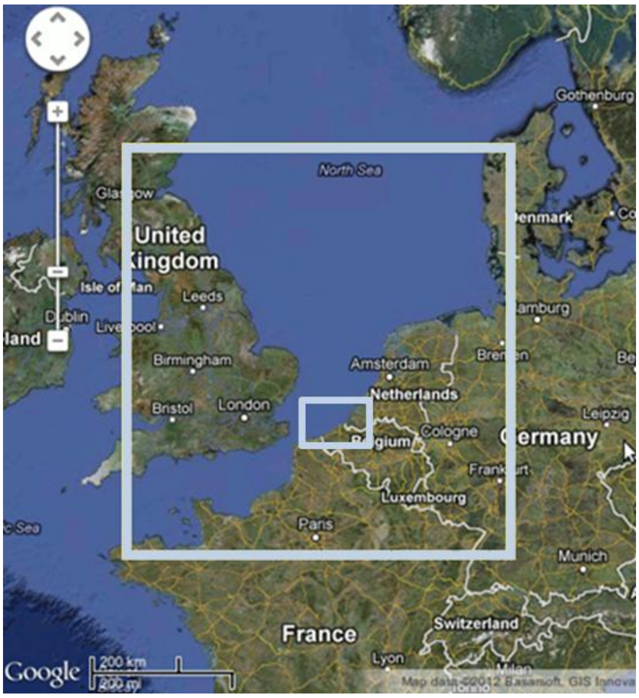


Figure 6: The domain covered by OSERIT. The inner blue rectangle shows area where high resolution hydrodynamic forcing is available.

2.2.5.2 Met-ocean forcing

The current met-ocean forcing comes from three different sources (Tab. 2):

- Atmospheric conditions (*i.e.* air temperature and wind at 10 meters above water surface) as forecasted by the global model of the UK Met Office
- Hydrodynamic conditions as forecasted by MUMM's operational hydrodynamic models OPTOS-NOS and OPTOS-BCZ (including 3D current, sea surface elevation and turbulent vertical diffusivity).
- Sea state as forecasted by MUMM's operational version of the model WAM (including wave period, direction and significant height)

	Atmos. conditions	**Hydrod. conditions**	**Wave**
Provider	UK met office	MUMM	MUMM
Time resolution	6 hours	1 hour	1 hour
Space resolution	~60 km	~750 m in the Belgian coastal zone ~5 km elsewhere	~2 km
Available time series	[Today -5 d; Today+ 5 d]; Updated twice a day	[Today -5 d; Today+ 5 d]; Updated twice a day	[Today -4 d; Today+ 4 d]; Updated twice a day

Table 2: Summary of the met-ocean forcing

The high resolution hydrodynamic forcing (OPTOS-BCZ) is able to better capture the effects of sand banks on local water currents than the OPTOS-NOS forcing (cfr. Fig. 7).

They are therefore more appropriate and used by OSERIT wherever they are available. Elsewhere, OPTOS-NOS forcing is used. A buffer zone has been set up at the junction of the two domains. A relaxation technique was implemented across the buffer zone at each vertical level. Values in the OPTOS-BCZ forcing are relaxed towards values from OPTOS-NOS with a weighting factor. Tests showed that at least 5 points (750 x 750 m) buffer zone was needed for a smooth transition.

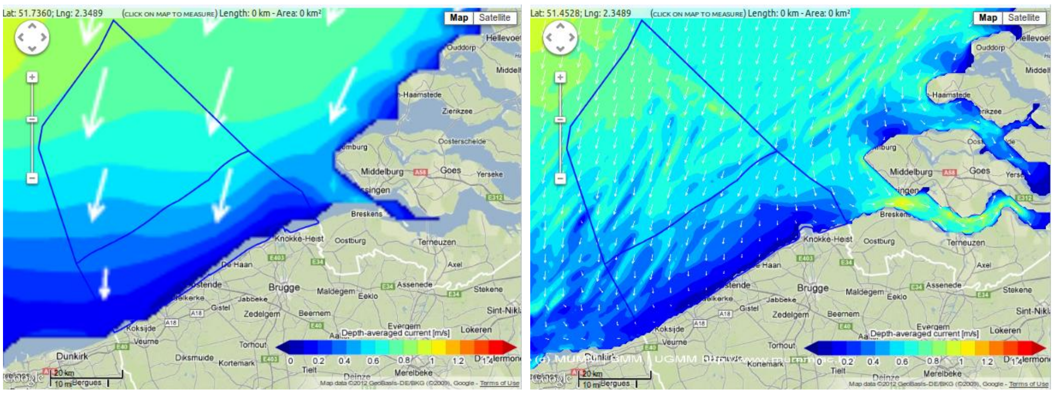


Figure 7: Depth-averaged water currents as provided by OPTOS-NOS (left) and OPTOS-BCZ (right) for 21/09/2012 at 1AM. The colors stand for the amplitudes of the water current velocities. Currents are also represented by the arrows; one arrow per model grid cell.

2.2.5.3 Initial conditions and spill scenarios

Oil spill can result from many different situations (e.g. a collision between two vessels, a sinking vessel, and an illegal discharge by a moving tanker or a broken pipe at the water bottom). The way the Lagrangian particles are released into the model should trace the actual oil release scenario. The OSERIT model requires start times and locations for each Lagrangian particle. They can be given in an ascii file. They can also be generated by the model which encounters for several options to help define a particular spill scenario based on pre-defined ones:

- The OSERIT model can generate spill scenario as a single point or an extended area (Fig. 8 – top panels). If the extended area is chosen, the oil spill is assumed to have either line, round or ellipse shape and its dimensions and orientation may be defined. This option can be used to differentiate very local oil spills from spills that have had the time to spread.
- Oil release is assumed to be either instantaneous or continuous (Fig. 8 – middle panels). This option can be used to differentiate a “one-shot” oil release with a leak that lasts some time. Note that the OSERIT allows the leak to remain at the same location (e.g. a still vessel or broken pipe) or to move from one location to another (e.g. illegal discharge or leak from a moving vessel).
- Particles can be released on the sea surface, at the bottom or anywhere within the water column (Fig. 8 – bottom panel).

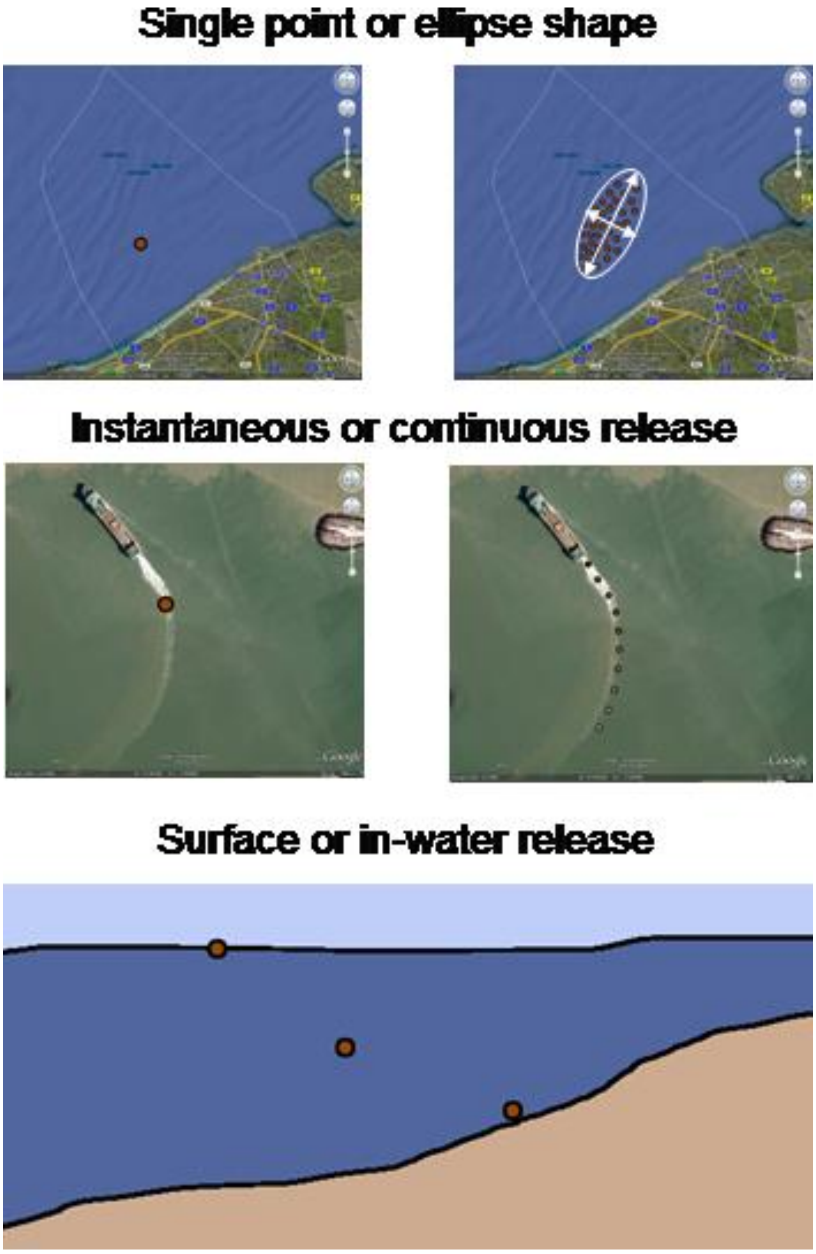


Figure 8: The different oil spill scenarios available in the OSERIT web-based model.

2.2.5.4 Oil database

Some oil processes implemented in the OSERIT model (such as evaporation, horizontal surface spreading, natural vertical dispersion, emulsification and buoyancy) strongly depends on oil properties. It is therefore crucial to provide the right oil characteristics to the model. To help with the lack of information on oil characteristics in case of most marine oil pollutions, the OSERIT model was built with an oil database. This database was kept intentionally short for ease of use and includes a wide range of oil types that are likely to cross the Belgian Waters (Fig. 9). Oil types go from light, medium, heavy and very heavy crude to main fuel types. Characteristics of oil involved in the Erika and the Prestige incidents are also available. The complete list of available oil is given in Fig. 10. The OSERIT database is based on oil characteristics provided in ADIOS, Jokuty (1999) and Fingas (2011) and by the CEDRE.

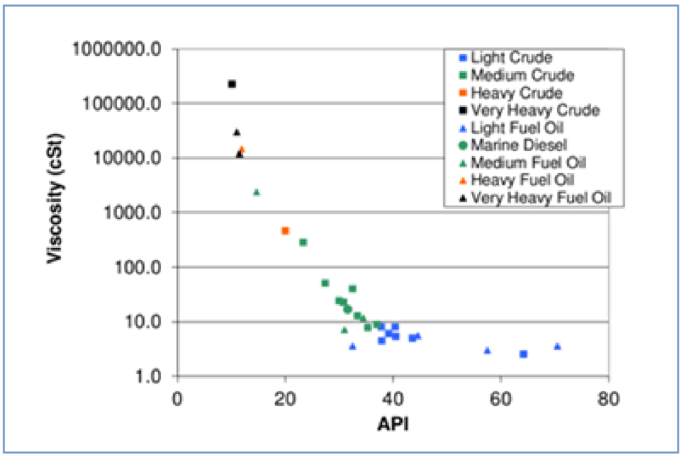
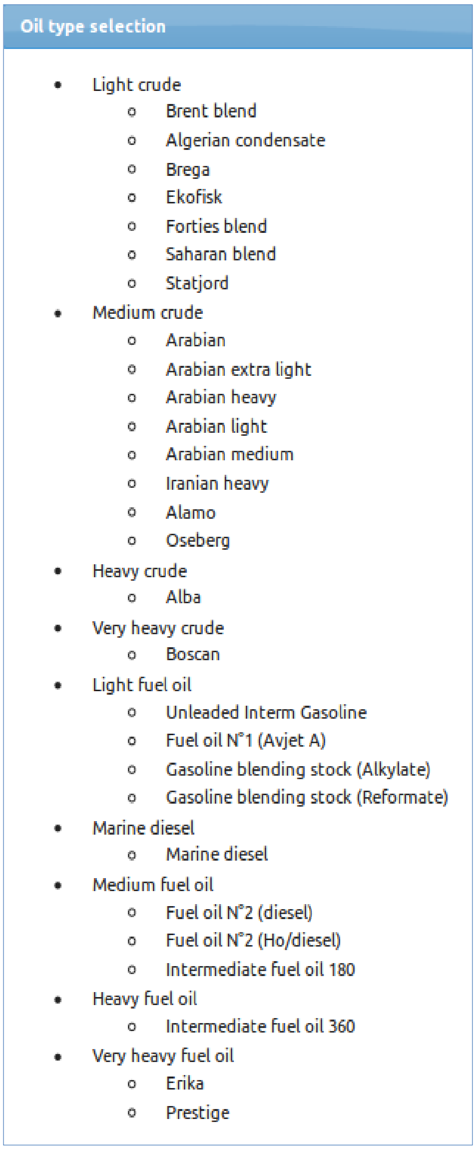


Figure 9: Scatter plot between viscosity and API for each oil type of the OSERIT database. Viscosity is given in cSt at 15°C.


Oil type selection

- Light crude
    - Brent blend
    - Algerian condensate
    - Brega
    - Ekofisk
    - Forties blend
    - Saharan blend
    - Statjord
- Medium crude
    - Arabian
    - Arabian extra light
    - Arabian heavy
    - Arabian light
    - Arabian medium
    - Iranian heavy
    - Alamo
    - Oseberg
- Heavy crude
    - Alba
- Very heavy crude
    - Boscan
- Light fuel oil
    - Unleaded Interm Gasoline
    - Fuel oil N°1 (Avjet A)
    - Gasoline blending stock (Alkylate)
    - Gasoline blending stock (Reformate)
- Marine diesel
    - Marine diesel
- Medium fuel oil
    - Fuel oil N°2 (diesel)
    - Fuel oil N°2 (Ho/diesel)
    - Intermediate fuel oil 180
- Heavy fuel oil
    - Intermediate fuel oil 360
- Very heavy fuel oil
    - Erika
    - Prestige

Figure 10: Selection box presenting oil type available within the OSERIT oil database

2.2.5.5 Object database

Because of their profile asymmetry and to surface gravity waves, drifting objects do not always drift directly downwind. There is often a significant component of the drift that is perpendicular to the downwind direction. To compute the drift of floating objects, the value of this crosswind component must therefore been known. To help with the lack of information on object characteristics, the OSERIT model was built with an object database. This database includes typical values of the downwind and crosswind drift factors for a wide range of drifting object types, including individuals, life rafts, boating debris, drums and containers (Allen, 2005; Daniel et al., 2002).

2.3. Data processing system

With the intention to provide OSERIT users with clear and straight-to-the-point information, a data processing system has been developed. This system processes the OSERIT model results into a set of relevant maps and charts. It uses the positions of the Lagrangian particles provided by the model and generates all kinds of maps including maps of spill trajectory, beaching risk, oil concentration, probability of presence and time residency. It also uses the oil characteristics and weathering state associated to the Lagrangian particles and produces time series.

For tridimensional model simulations, all maps are generated for three different zones, namely the *surface*, *water column* and *bottom* zones. The surface zone represents the oil which floats on the sea surface only for the trajectory maps, for the other maps (oil concentration and time residency), the surface zone represents the top first 3 meters of the water. The bottom zone stands for the first 3 meters above the sea bed and the water column zone for the zone in between the surface and the bottom ones. In waters less than 9 meters deep, the water column zone oversteps on both the surface and bottom zones. In very shallow waters (less than 3 meters), the surface, bottom and water column zones are merged together.

2.3.1. Trajectories

The first part of the processing system generates maps refereeing to the spill trajectory. These maps combine all the particle trajectories. A color code is used to provide the time associated to the particle location. A first trajectory map is generated over the whole period of the model simulation to give a general sight of the simulation results. Other trajectory maps are then generated as snapshots where particle locations at the time of the snapshot are represented as black dots (Fig. 11). These maps have especially been requested by the users to help guiding observation and intervention teams to the spill location.

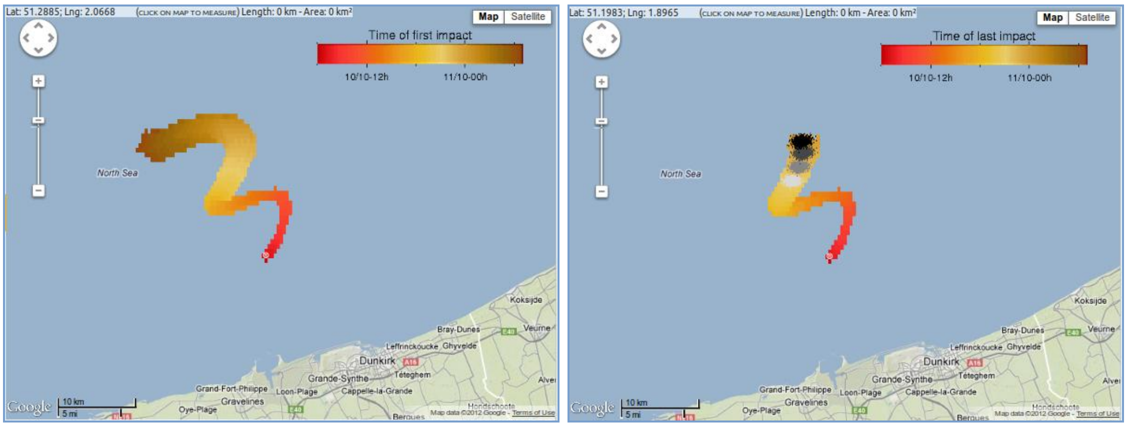
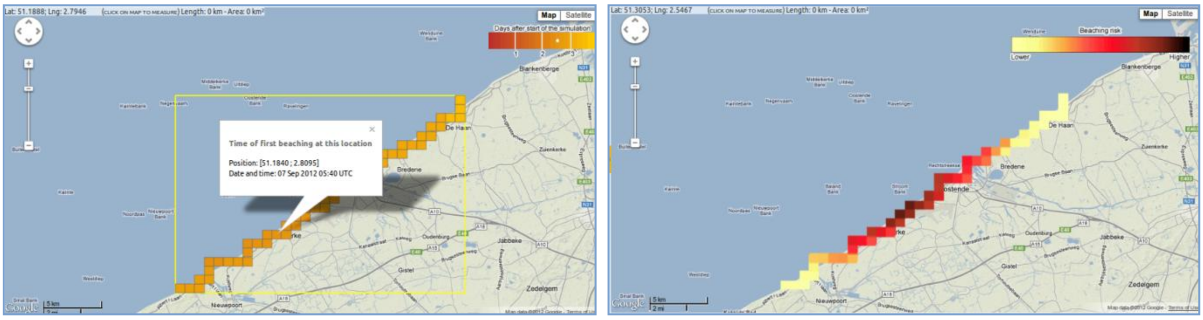


Figure 11: OSERIT maps of spill trajectory computed over the whole simulation period (left) and as snapshot (right). The red dot shows the location of the oil release. On the right panel, the black dots represent the location of all the Lagrangian particles at the time of the snapshot and the gray dots, the particles locations 1, 2 and 3 hours before the snapshot time.

The pre-defined times are set to the following round hours: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 18, 24, 48, 72, 96, after the rounded release start time (rounded down to the closest hour). Available times may be limited by the simulation length.

2.3.2. Beaching risk

A second part of the data processing system generates information which relates to the risk of oil beaching. It assumes beaching risk as soon as oil particles reach the first 750 meters off the coastline. 750 meters correspond to the grid cell size of the MUMM's hydrodynamic model that provides OSERIT with the sea conditions. The processing system generates a map with potential beaching computed over the whole model simulation (Fig. 12-left). This map highlights the total coastline possibly affected by the beaching of oil for that particular model simulation. It also provides information on the time of the first possible arrival of oil at the coastline. This last information is crucial to estimate the time window for intervention. The processing system also generates maps with levels of beaching risk (Fig. 12-right). The levels are computed over different pre-defined time intervals. The more the Lagrangian particles are found next to the coastal point, the higher the risk. The risk level also increases with the exposure time of the coastal point to oil particles.



Time of first beaching at this location

Position: [51.1840 ; 2.8095]
Date and time: 07 Sep 2012 05:40 UTC

Figure 12: First time of beaching risk (left) computed over the whole simulation period, and snapshot of beaching risk (right) computed over a specific time interval.

2.3.3. Oil concentration

A third part of the processing system deals with oil concentration. The concentration of oil into the water is computed at each time step on a high resolution grid (10''x10''x1meter) on the basis of the Lagrangian particle positions and the oil mass that each of them represents. Due to computational constraints, oil concentration is transformed to a coarser resolution grid with a horizontal resolution of 2.5'x2.5'. The oil concentration within each coarse resolution grid cell is set as the maximum oil concentration among all the high resolution grid cells within the coarse one. The data processing system then produces two kinds of map with oil concentration gridded on the coarser grid. The first kind of map presents the maximum oil concentration as computed over the whole period of the model simulation (Fig. 13-left). The second kind of map presents snapshots of oil concentration at selected times (Fig. 13-right). The colors on the map represent the following oil concentrations thresholds: 0, 1, 5, 10, 100 and 1000 ppm. These oil concentration thresholds correspond to the thresholds of reference used in the GESAMP classification (IMO et al. 2002) and toxicity studies.

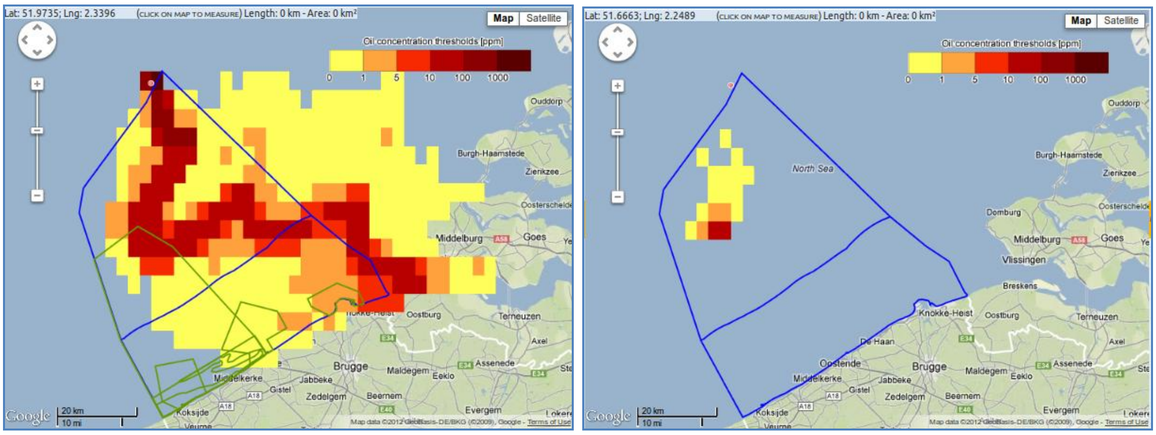


Figure 13: OSERIT maps of maximum oil concentration (left) and snapshot of oil concentration (right) at the sea surface.

2.3.4. Exposure time

The processing system computes the exposure time to different oil concentration thresholds. The exposure time is another important variable that help assessing the possible damages in case of marine oil pollution. In that sense, the processing system generates maps of global exposure time defined as the accumulated time computed over the whole simulation period and during which a particular grid cell is impacted by oil concentration above a pre-defined threshold (Fig. 14). The concentration thresholds are taken at 0, 1, 5, 10 and 100 ppm to correspond with the concentration thresholds in the GESAMP classification (IMO et al. 2002). Maps of exposure time during different time intervals of the simulation are also produced.

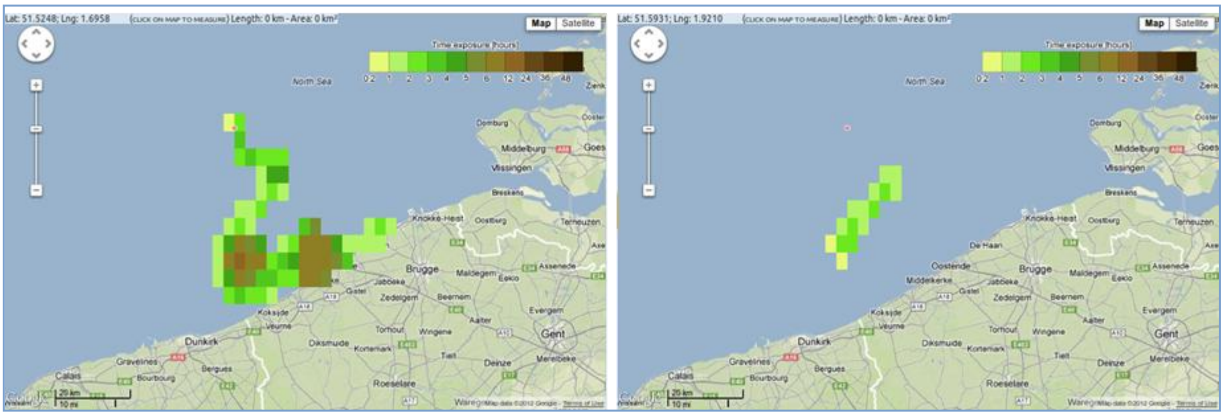


Figure 14: OSERIT maps of oil residence time computed over the whole model simulation (left) and of oil time residency computed over a limited time interval (right). The residence times are given for oil concentration above 1ppm.

2.3.5. Probability of presence

The two-dimensional model simulations are limited to horizontal oil drift and do not include the vertical dimension. The computation of oil concentration in the water based on the Lagrangian particle positions is therefore inappropriate. Instead, the data processing system produces maps with the probability of presence of oil. The probability of presence is computed as a function of the number of Lagrangian particles that are found at a particular time and in a specific area. The processing system builds map of maximum probability of presence computed over the whole model simulation (Fig. 15-left). It also produces snapshot maps with the probability of presence of oil at a particular time (Fig. 15-right).

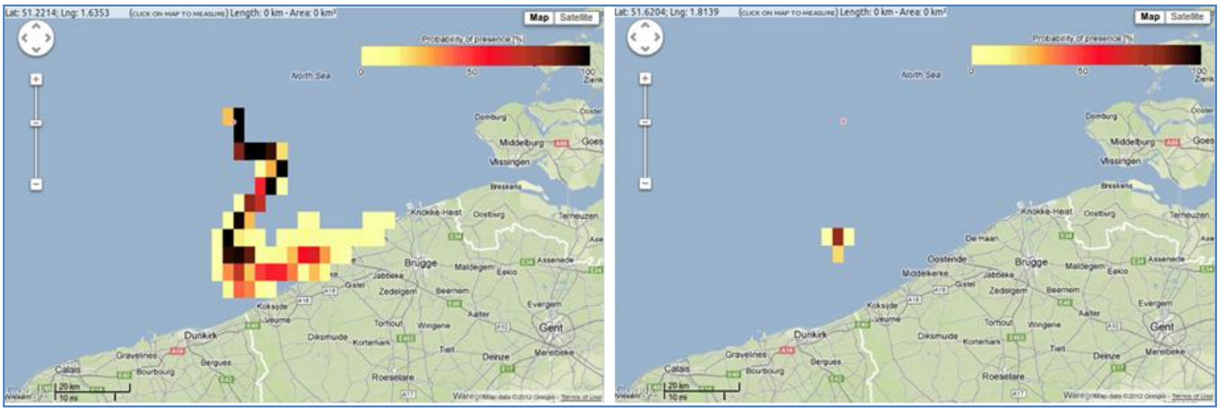


Figure 15: OSERIT maps of oil probability of presence computed over the whole model simulation (left), snapshot of object probability of presence (right).

2.3.6. Time series

The processing system also uses the OSERIT model output to produce time series charts including the time series of:

- Vertical distribution of the oil volume
- Oil volume balance
- Viscosity of surface oil
- Density of surface oil
- Oil water content
- Evaporated portion of oil
- Portion of oil that is chemically dispersed

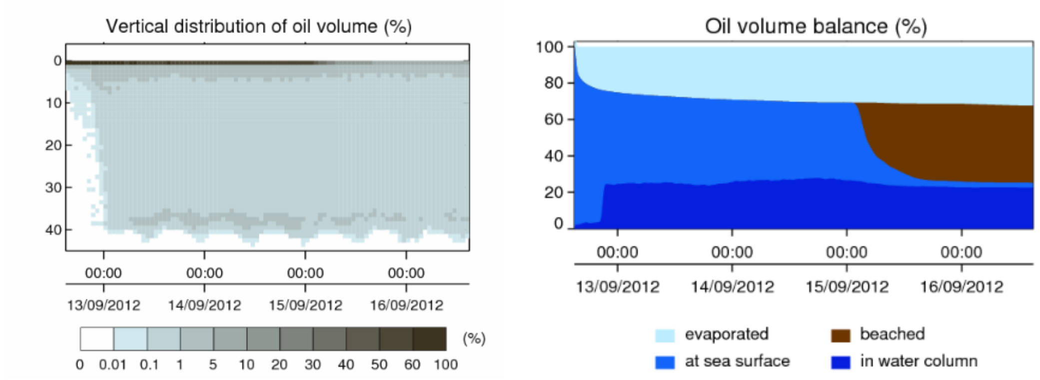


Figure 16: Time series of vertical distribution of oil volume (left) and oil volume balance (right) produced by the OSERIT post-processing system. Units are given in percentage.

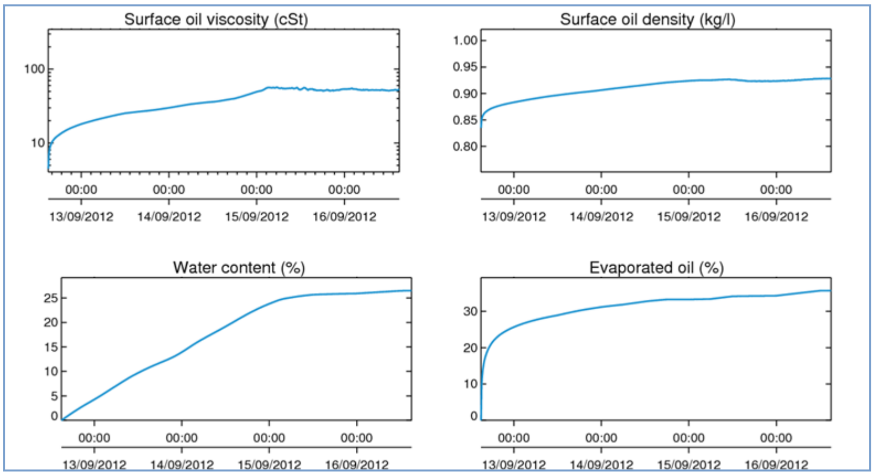


Figure 17: Time series of surface oil viscosity (top right), surface oil density (top left), percentage of water content (bottom left) and percentage of evaporated oil (bottom right).

2.4. Web-based interface

A new web interface has been developed to allow the users to quickly launch model simulations 24/7 and to access and visualize model results and other physical parameters influencing the sea state.

As represented in Fig. 18, the web interface allows users to communicate anywhere anytime with the web server machine of OSERIT, providing they have access to the internet. The web server then transfers the information to a high performance computer where the model computation and data processing are done. In return, the high performance computer sends the produced maps and charts to the web server. The web server sends an e-mail to the user to inform about the simulation completion. Finally, the user can access to the web server via the web interface and visualize or download the processed model results. The OSERIT web-interface offers two main functionalities: a simulation manager and a visualization tool.

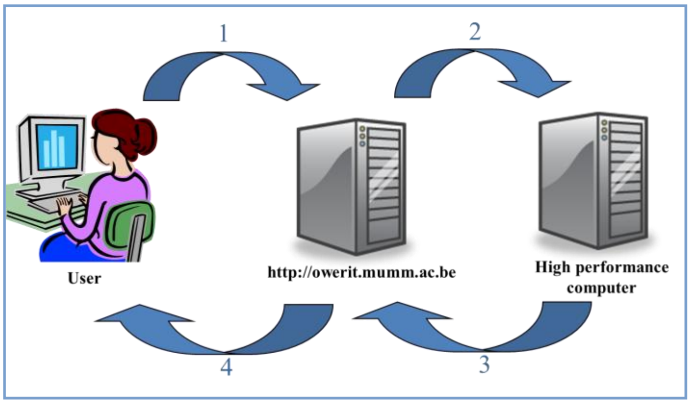


Figure 18 : The communication system in the OSERIT tool.

2.4.1. Simulation manager

The simulation manager allows users to manage existing model simulations and to request new ones. To ease its use by all categories of users, OSERIT was created with two modes: *basic* and *advanced*. In a few clicks, the basic mode helps request forecast or backtracking two-dimensional model simulation. The advanced mode is more flexible but its proper use requires extra training. It helps request forecast of three-dimensional model simulation. In any case, a setup form must be filled in. Basic inputs consist in initial time and location of the slick and simulation type (forward or backward in time). Advanced options include the oil characteristics, oil release and spill scenarios, oil physical processes to be taken into account, and possible use of chemical dispersant.

Through the advanced mode, users have access to a full range of pre-defined spill scenarios (instantaneous or continuous release; still or moving source; surface or submerged leak; punctual, line or ellipse-shaped). They can select an oil type from the model database. They can decide whether to include or not physical processes that might affect the behavior of oil. Oil can be chemically dispersed. The advanced mode can be used as is or to draw a baseline scenario and compare it against other scenarios.

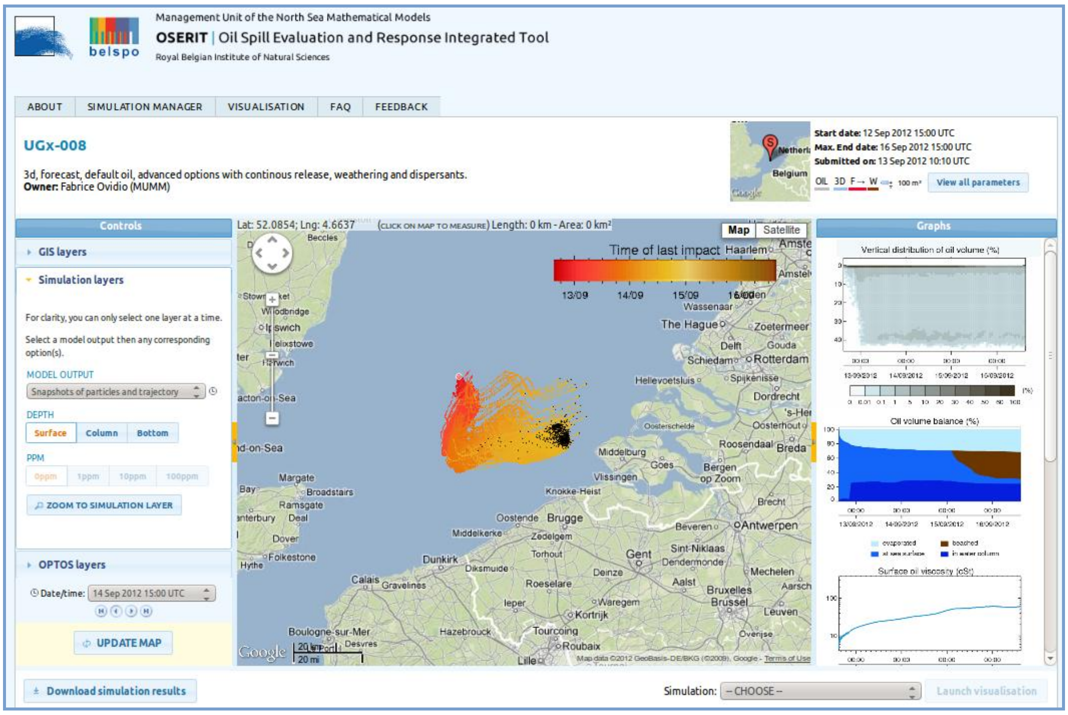
The interface also allows using the OSERIT model to track or backtrack objects that drift at sea. To this end, the user can select an oil object from an extensive database including survival rafts, individuals, containers, etc.

2.4.2. Visualization tool

The visualization tool (Fig. 19) enables users to visualize maps and charts of various diagnostics derived from the OSERIT model simulation but not only. It also provides users with marine forecast and environmental and economic GIS layers.

The layout of the visualization tool is divided in three: a control box, a map and a time series section. From the control box, users can select what is to be displayed on the map. They can chose from OSERIT model diagnostics including probability maps, oil impacted areas, oil concentrations and exposure times. They can also choose to superimpose GIS layers. All the available GIS layers are listed in Tab. 3. Finally, they can select one variable from the OPTOS operational models which is then underimposed to the selected OSERIT diagnostic. This part of the interface is based on Google Maps and allows many features such as zooming in and out, finding latitude and longitude or, measuring distance and area.

In the time series section, time series of oil vertical distribution, volume balance and oil characteristics can also be displayed. Results are available for download in order to import them in the user's own visualization and GIS tools.



3d, forecast, default oil, advanced options with continous release, weathering and dispersants.
Owner: Fabrice Ovidio (MUMM)

Start date: 12 Sep 2012 15:00 UTC
Max. End date: 16 Sep 2012 15:00 UTC
Submitted on: 13 Sep 2012 10:10 UTC

Lat: 52.0854; Lng: 4.6637 (CLICK ON MAP TO MEASURE) Length: 0 km - Area: 0 km²

For clarity, you can only select one layer at a time.

Select a model output then any corresponding option(s).

MODEL OUTPUT: Snapshots of particles and trajectory

Date/time: 14 Sep 2012 15:00 UTC

Simulation: – CHOOSE –

Map data ©2012 GeoBasis-DE/BKG (©2009), Google - Terms of Use

Figure 19: The OSERIT visualisation tool.

Territorial sea and EEZ	Borders of the Belgian territorial sea and of the continental shelf
	Official Belgian baseline
	Official Belgian coastline
	Official 12 nmiles limit
Main sand banks	Vlaamse Banken bathymetry - from the D11 map
Protected marine areas	Natura 2000 zone
	Ramsar zone
	Special Protection Areas
	Special Areas of Conservation
	Managed marine reserve
Navigation routes	Anchorage area, Westhinder
	Main navigation routes and traffic separation zones
Dredging and dumping	Sand and gravel extraction areas
	Zones of dredging activities
	Dumping sites
Offshore windmills	Windmill park C-Power, Thornton
	Windmill park Eldepasco
	Windmill park Belwind
	Windmill park Norther
	Windmill park Rentel
	Windmill park Seastar
Mariculture	D1 – Nieuwpoort Bank
	D2 - Oostdijck
	D3 – Westhinder
	D4 – Belgian windmill zone

Table 3: The GIS layers available within the OSERIT visualization tool.

2.5. Preliminary conclusions and recommendations

During this project, a new Oil Spill Evaluation and Response Integrated Tool (OSERIT) has been developed in order to quickly provide relevant, scientific-based information to support the decision-making process of the best response strategy in case of marine oil pollution.

This new tool has been designed to meet the expectations of two different categories of users. The first category includes operational users as the MIK (Maritiem Informatie Kruispunt) and MRCC (Maritime Rescue and Coordination Centre) who need to quickly launch and visualize a drift model simulation. The second category of users includes environmental representatives such as MUMM and DG5 who need to compare several scenarios in order to assess, among other things, the potential environmental consequences of the use of chemical dispersant. The first user's category needs a basic and ready-to-go tool while the second category needs a more advanced and flexible tool that offers several options and scenarios. All along the project, a strong emphasis has been put in order to make the tool suitable and easy-to-use to both users' categories, taking into account the operational needs and constraints regarding the accessibility, reliability and portability of the new tool. To meet all these expectations, a web-based solution was chosen.

The tool had to provide information on oil spill drift and fate. A new generation tri-dimensional oil spill drift and fate model has been developed. The oil spill model was designed to include all physic-chemical processes needed to provide short-term (1-5 days) oil related information that is requested by the users. A study of the state-of-the-art allowed pointing out the latest outcomes in oil spill modeling. Different model approaches and parameterizations have been considered and only a few have been selected on the basis of their known performance to capture the behavior of oil and their operational suitability (*i.e.* mainly the short time window for intervention and the common lack of information on the spill itself).

An operational configuration of the model has been set up. This configuration covers the English Channel from 4°W and the southern North Sea up to 57°N and is forced by the latest met-ocean forcing produced by MUMM operational hydrodynamic and waves models. Atmospheric forcing are taken from the UK met office global model. To guarantee the ease of use of the tool, the web-based interface comes with a simulation manager that allows to easily set up a simulation thanks to the extended lists of predefined (but tunable) oil spill scenarios, combat strategies and oil and object databases.

The interpretation of three-dimensional simulation results is rarely straightforward. A post-processing system was therefore developed to process the model results into maps and graphs of interest to the trained users. The information provided by this post-processing system includes drift trajectories and beaching risks, oil concentration and exposure time near the surface, near the seabed and within the water column, probability of presence for search and rescue objects as well as oil weathering information such as time series of surface oil density and viscosity, oil water content and fractions of evaporated, emulsified, beached and dispersed oil. In addition to this, OSERIT visualization tool also allows to visualize met-ocean forcing and predefined GIS layers.

The OSERIT model is able to simulate the main physic-chemical processes that can significantly affect the behavior of oil. OSERIT sometimes offers different parameterization to compute the same process (e.g. evaporation, natural vertical dispersion, turbulent diffusion). Even if the model has passed some validation tests, further investigation is needed not only to validate but also to tune the model and choose from the different available parameterizations. For instance, the Eulerian module needs a thorough validation before being used in operational. Further investigations are requested to improve sedimentation parameterization (process not included) and the emulsification parameterization (the emulsification rate appears to be quite low). Users should keep in mind these limitations when interpreting OSERIT maps and graphs.

3. POLICY SUPPORT

During the development phase, the OSERIT model was already very useful in diverse situations, mainly related to forecast delivery and consulting activities. Its prototype (FLOAT) has been used on a regular basis over the last years by the Belgian coastal guards to help in many different tasks. These are described hereafter.

3.1. Support to the Belgian coastal guards

The prototype of OSERIT (FLOAT) was a tool of reference to the Belgian Coast Guard Structure over the past years and is now being replaced by OSERIT. It is used on a regular basis by the Belgian Coast Guard Structure to help in many different tasks. Examples are provided hereafter.

3.1.1. In case of spill detection

The use of the MUMM oil spill model is clearly mentioned in the emergency plan in force for the Belgian coast which is coordinated by the Governor of Occidental Flanders. Also at the level of the federal ministry of the environment, it is recognized in the reference manual "Operational plans for intervention" in case of marine oil pollution. FLOAT (and more recently OSERIT) is known as an operational tool that is essential to the estimation of the possible consequences in case of oil pollution in the surrounding of the Belgian Waters.

Regularly, the satellite surveillance system CleanSeaNet from the European Maritime Safety Agency identifies possible oil spills, the operators from the maritime information cross point (MIK) then use the oil spill model to quickly determine if our coasts or other oil-sensitive zones of the Belgian marine ecosystems are at risk. In case of threat, the MUMM oil spill model is also used to define the area where to lead surveillance and intervention teams.

3.1.2. Backtracking potential polluters

As part of MUMM official reports against polluters, the MUMM model simulations helped (and continue to help) confirm the link between a marine pollution and a ship that is first identified as a potential polluter by the MUMM aerial surveillance team. More particularly, in November 2011, the OSERIT tool allowed to link the aerial observations of pollution and its polluter together with the satellite image taken a few hours later. In this case, OSERIT helped reinforce the file which was then transmitted to the competent prosecution.

3.1.3. Search-and-Rescue (SAR) tasks

FLOAT is frequently used with success by the Belgian Coast Guard Structure to help search for objects drifting at the sea surface such as safety rafts, containers and even dead bodies. It allows categorizing the search areas and optimizes the use of available search forces. For instance, in June 2012, the MUMM model helped find the provenance of a dead body (Schamp, 2012). The body had travelled more than 100 km before it was found in the Belgian Waters.

3.1.4. Exceptional case : The Flaminia

The MSC Flaminia is a German container ship of 300m long and 40m wide. On the 14th of July 2012, there was a fire and explosion on board of the ship, approximately 700 nm from the southwest UK coast. At the time of the incident, it carried 2.876 containers among which 151 with toxic substances and has suffered considerable damage. The container ship was towed to Europe and arrived at a refuge place in Wilhelmshaven, Germany, on 9th of September 2012. It crossed the Belgian Waters on Septembre 6th. For the occasion, the OSERIT model was used by the Belgian Coast Guard Structure in anticipation of possible marine pollution.

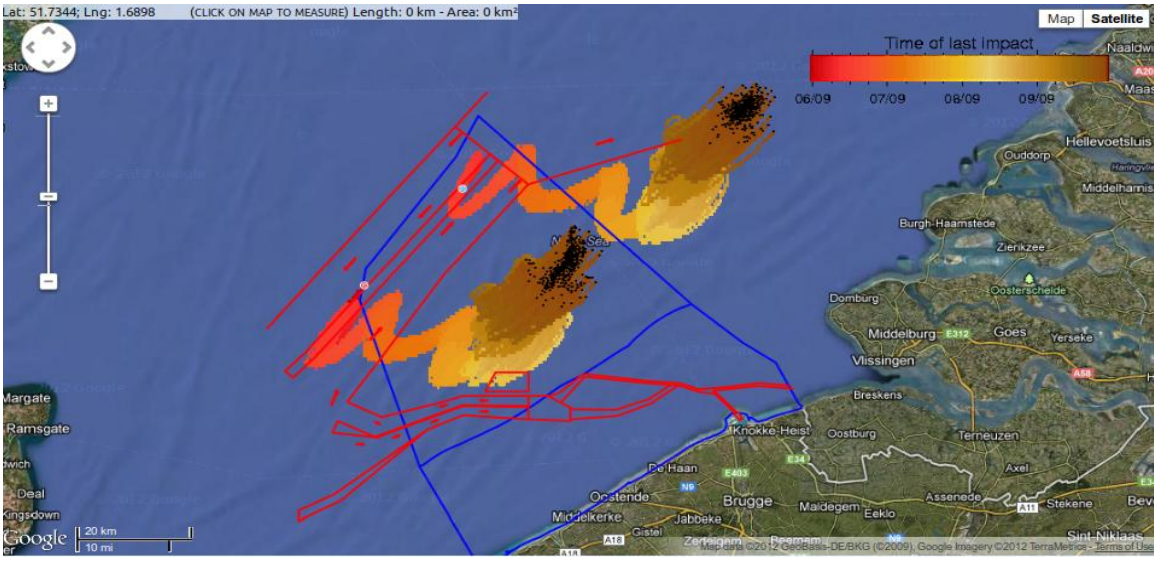


Figure 20: Drift trajectories of potential oil spilled at two locations along the anticipated path of the MSC Flaminia, as forecasted by the OSERIT model.

3.2. Environmental risk assessment

The OSERIT model has been involved in the environmental risk assessment of the NORTHER windmills park. This windmills park will be located at only 15 nm from the port of Zeebrugge and a few nm from the only fairway towards the port of Antwerp. The risk for navigation accident and therefore also for marine oil pollution increases with the installation of the NORTHER infrastructure. In addition to this, NORTHER is very close to the coast so the time window for combating the possible oil spill before it reaches the coasts and other sensitive areas is very narrow. The OSERIT model was used to identify the oil-sensitive zones that are the most at risk in case of oil spilled in the NORTHER zone. The OSERIT model was able to provide an estimation of the time before oil reaches the coast and other sensitive zones. This was done for different hydro-meteorological conditions that range from calm weather to standard and heavy ones, different spill locations and different spill times in relation to the tides cycle (Dulière and Legrand, 2011; Rumes et al., 2011).

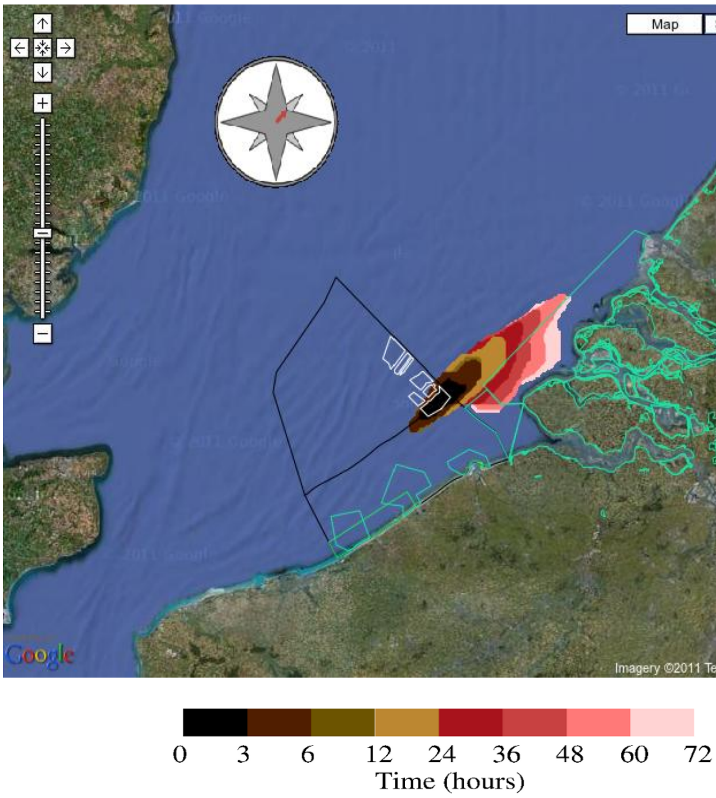


Figure 21: Oil impacted areas over different intervals of time after the release of oil in the middle of the NORTHER zone under 4.5 m/s southwestern wind conditions. The colors represent the oil-impacted areas over different periods of time. The black, white and green lines indicate the Belgian part of the North Sea and the 12 nm limit, the wind farms sites, and protected areas, respectively.

3.3. Preparedness

The OSERIT model was used in a first attempt to estimate the maximum oil volume that can be chemically dispersed into the Belgian Waters with no significant negative effects on the environment (Evrard, 2012). For this study, the OSERIT model was used to simulate the drift of chemically dispersed oil that was released in the Belgian part of the North Sea under common weather conditions. The resulting oil concentration levels into the water were compared to levels given by toxicity tests. The possible impacts on the marine environment were identified and quantified according to the GESAMP classification (IMO, 2002).

This study highlighted the suitability of the OSERIT model for this kind of study. It led to the adjustment of a new method to estimate the maximum volume of oil that can be dispersed with no significant negative effects on the environment. It also highlighted the lack of information on the lethal toxicity levels for the species living in the Belgian Waters and finally, the lack of information on the precise geographical location of the different species.

The methodology developed in this study could be used in the future to further refine the Belgian contingency planning and therefore to increase Belgium's preparedness.

3.4. OSPAR (as perspective)

In its last quality status report (OSPAR, 2010), OSPAR acknowledged : "oil discharges with produced water have fallen on average by 20 % in the OSPAR area and most countries have met the OSPAR 15 % reduction target, but volumes of produced water are expected to increase. Pollution from drilling fluids and cuttings piles has been considerably reduced. Impacts of offshore oil and gas activities have reduced around some installations, but the evidence base for environmental impacts is limited. OSPAR Contracting Parties should therefore cooperate to continue efforts to phase out discharges of hazardous substances and reduce discharges of oil through a risk-based approach to management of produced water; (...) to continue monitoring and assessment and to improve the evidence base for evaluating the impacts of the offshore industry on marine ecosystems".

OSERIT may be a valuable tool to support the monitoring and the assessments of the impacts of the offshore industry on marine ecosystems. In particular, the Gannet study case (Legrand and Dulière, 2013) demonstrates OSERIT's ability to link observed oil pollution to its likely origin (*i.e.* offshore platform). OSERIT should help OSPAR Contracting Parties to apply the "polluter pays principle", one of the central guiding principles of the OSPAR Convention.

4. CONCLUSIONS

In the framework of the OSERIT project, a new operational service has been developed in order to provide relevant, scientific-based information to support the decision-making process in case of marine oil pollution of the Belgian Waters. The OSERIT service targets two different categories of users. The first category includes operational users from MIK and MRCC who need to quickly decide and organize the very first actions in case of oil spilled in the sea. The second category of users are the environmental representatives from MUMM and DG5 who need to consider several oil-combating scenarios, to compare their potential environmental consequences and to perform a Net Environmental Benefit Analysis before deciding the best response strategy to combat the oil pollution. To meet both users' needs, OSERIT must provide answers to a large range of questions including:

- How to guide the intervention team to the spill that was observed a few hours ago and that might have drifted far away from its last known position?
- What is the current sea state? And for the next days?
- Which of the sensitive zones are directly at risk? To which level?
- Will the use of chemical dispersant help reduce the damage? When should the chemical dispersants be applied?
- What if the leaking ship is pulled to the refuge place before the leak is stopped?
- What if the damaged ship sinks down to the bottom?
- …

Answering these questions required the development of a new generation oil spill model that is able to simulate the three-dimensional drift and fate of marine oil pollution. The new model was designed in a way that it balances the state-of-the-art in oil spill modeling with the operational constrains. A post-processing system was also developed to process the model results into maps and graphs of interest to trained users. Finally, the OSERIT project required the development of a new interface that allows to quickly launch model simulations and to visualize the resulting information, including physical parameters influencing the sea state. The interface is web-based to ensure its portability and 24/7 access.

More concretely, thanks to the OSERIT project, the Agencies involved in the Belgian Intervention Plan for Pollution Response at Sea can now access the OSERIT tool anytime, anywhere, provided they have Internet access. In a few clicks, they can setup an oil spill scenario and access the resulting relevant information using the OSERIT visualization tool, in less than 30 minutes. Resulting information goes from oil spill drift trajectory, oil concentration in sensitive areas, time residency of oil concentration to beaching risk, and portion of evaporated oil.

OSERIT has already been used in several real cases and has demonstrated its relevance and added-value to

- Quickly evaluate the potentially oil impacted areas;
- Delimit search and rescue areas;
- Perform a NEBA (Net Environmental Benefit Analysis);
- Decide whether chemical dispersants should be used or not;
- Quickly plan operational interventions to combat marine oil pollution;
- Help identify likely polluters in case of mysterious oil spills;
- Continue to develop and refine contingency plan;
- Contribute to environmental impact assessments;
- Contribute to the implementation of certain OSPAR objectives.

We have seen with the FLOAT interface that the more we offer, the more is requested by users. The same conclusion holds for OSERIT. By providing a quite sophisticated tool to intervention teams, they have a better idea on what model can do and how they can be of any use. Feedbacks we have received from the follow-up committee and from the training sessions clearly show interests for new developments and perspectives including extending the service to harmful and noxious substances (MARPOL annex II) and developing a full service for maritime safety in case of drifting objects, lost containers (and other freightage) and search and rescue operations.

5. DISSEMINATION AND VALORISATION

5.1. Outreach to users

5.1.1. Web-interface

The web-interface of OSERIT was developed in a way that it is as intuitive and as easy to use as possible. Users not familiar to the world of mathematical modeling should quickly be able to request basic model simulations and visualize and understand the resulting model output.

5.1.2. Users' manual

A detailed and user-friendly manual was written to guide the OSERIT user through the OSERIT web-interface. The manual provides a general description of the tool. It also gives step-by-step explanations on how to use OSERIT for several typical situations (*i.e.* for backtracking potential polluters, forecasting oil spill drift, evaluating oil impacts on sensitive areas). The manual can be found in Annex 4.

5.1.3. Training meeting

As part of the OSERIT project, a training meeting has been organized to introduce the new OSERIT tool to the users, its use and limitations. Although the tool is very intuitive, it is of great interest to the users to know about all the options and features available in OSERIT in order to set up their model simulation in the best appropriate way. The users training meeting paid a particular attention on the interpretation of model results. The training materials include a PowerPoint presentation and hand-on exercises (Annex 5).

5.2. Scientific outreach

Various papers were published. The OSERIT tool and project were presented at numerous national and international conferences and workshops (oral and poster presentations; invited speaker). For details, please refer to Section 6.2 and 6.3.

5.3. Public outreach

G. Pichot was invited by the Académie Royale de Belgique to present « La plate-forme Deep Horizon et le principe de précaution » at the Colloque international sur l'esprit d'aventure et le principe de précaution en sciences et en arts, Brussels, 18/09/2010.

In October 2011, V. Dulière gave an interview to RTL-TVI on the use of chemical dispersants during the major spill that occurred in the Gulf of Mexico (at the Deepwater Horizon platform).

V. Dulière was invited by the Association belge des journalistes scientifiques to give a presentation on « La modélisation des marées noires en Belgique » at the FNRS in February 2012.

V. Dulière gave an interview to the ATHENA magazine (a scientific review for general public) published in Athena, n°280, Avril 2012: La mer du Nord sous haute surveillance by P. Devuyst.

V. Dulière gave the presentation "A new Tricolor: are we prepared?" at the symposium "Our Seas of Tomorrow", Brussels, 31st of October 2012.

5.4. Added values

FLOAT and OSERIT were presented in various international networks and working groups including euroGOOS, NOOS, OTSOPA (Bonn Agreement), GMES and EGEMP. This allowed reaffirming the Belgian expertise in oil spill modeling. FLOAT was at the heart of a small pilot project with the European Maritime Safety Agency (EMSA) aiming at demonstrating the feasibility of linking an oil drift model with CleanSeaNet. The OSERIT results were echoed by Mike Bell (from the UK Met Office) as a typical GMES national service at the opening event of the MyOcean-2 kick-off meeting in Brussels (March 2012) and at the conference on "Advance and implement a marine monitoring and forecasting system using a European Centre(s) approach" in Nicosia, Cyprus (October 2012).

As experts in oil spill modeling, S. Legrand became the leading scientist of the NOOS working group on drift in 2009 and V. Dulière was invited as panelist at CEDRE Science Workshop on "Oil Spill Drift Modelling" organized during the Interspill meeting in London, UK (March 2012).

5.5. Follow-up committee

Valorization took place during meetings with the follow-up committee, consisting of members from institutes involved in the evaluation phase of the Belgian Operational Intervention Plan for Pollution Response at Sea (*i.e.* MUMM, DG Leefmilieu, MIK and MRCC). First a kick-off-meeting took place in Brussels during which all the members of the follow-up committee have been informed about the scientific and the operational goals set within this proposal. All the committee members have had the opportunity to express their specific interests and bring forward eventual questions and advices. A second meeting was organized mid-term to present the project progress and a virtual mock-up of the finalized OSERIT tool. A training meeting was organized to present the completed OSERIT tool to the users.

6. PUBLICATIONS

6.1. Main reports

Dulière V., F. Ovidio and S. Legrand (2012) OSERIT 1.0 User's Manual, 60 pp.

Legrand S. and V. Dulière (2010) Development of an Integrated Software for Forecasting the Impacts of Accidental Oil Pollution – OSERIT, Annual scientific report, 32 pp.

6.2. Peer-reviewed publications

Legrand, S. and V. Duliere (2013) OSERIT: a downstream service dedicated to the Belgian Coast Guard Agencies. In: H. Dahlin, N. C. Flemming, and S. E. Petersson (Eds.) Sustainable Operational Oceanography, Proceedings of the Sixth International Conference on EuroGOOS, 4 - 6 October 2011, Sopot, Poland, pp 159-167.

6.3. Conference abstracts

V. Dulière, F. Ovidio, R. Schallier, J. Ozer and S. Legrand (2013) A brand new oil spill response tool for Belgium. 13th VLIZ Young Marine Scientists' Day 2013, Brugge, Belgium, 15th of February 2013.

S. Legrand and V. Dulière (2012) OSERIT: An Oil Spill Evaluation and Response Integrated Tool, 4th International Conference on Application of Physical Modelling to Port and Coastal Protection, Ghent, Belgium, 17th-20th of September 2012.

S. Legrand, V. Dulière and F. Ovidio (2012) A Guided Tour of OSERIT's new web-based interface. NOOS Annual Meeting 2012, Copenhagen, Denmark, 6th of September 2012.

V. Dulière and S. Legrand (2012) OSERIT: a Belgian support tool in case of oil pollution, Interspill meeting, London, UK, 13th-16th of March 2012.

V. Dulière (2011) OSERIT: A new tool to combat oil pollution. Empollex meeting, MUMM, Brussels, 08/12/2011.

S. Legrand and V. Dulière (2011) OSERIT: a downstream service dedicated to the Belgian Coast Guard Agencies, 6th EuroGOOS conference (Sopot, Poland) October 4-6 2011.

V. Dulière, J. Ozer, R. Schallier, and S. Legrand (2011) Belgian intervention support tool in case of oil pollution, European Geophysical Union General Assembly, Vienna, Austria, April 3-8 2011

V. Dulière and S. Legrand (2011) Operational efficiency as key to designing OSERIT, an intervention support tool in case of oil pollution, VLIZ Young Scientists' Day, Brugge, Belgium, February 25th 2011

S. Legrand, V. Dulière, F. Ovidio and J. Ozer (2010) Belgian activities in oil spill modelling: Applications at National and Regional Levels. Presented at the NOOS Annual Meeting 2010, Hamburg, Germany, 08/09/2010

S. Legrand, V. Dulière, F. Ovidio and J. Ozer (2010) Belgian activities in oil spill modelling: Applications at National and Regional Levels. Presented at the Annual Meeting of OTSOPA (Bonn Agreement), Antwerp, 25/05/2010

6.4. Others

Devuyst, P. (2012) La mer du Nord sous haute surveillance, Athena, n°280, Avril 2012.

Evrard, L. (2012) Utilisation du logiciel OSERIT pour l'aide à la gestion d'une pollution aux hydrocarbures dans la zone côtière belge. Master in Sciences et Gestion de l'Environment, University Libre de Bruxelles, 105 pp.

AKNOWLEDGMENTS

We acknowledge the Belgian Science Policy Office (BELSPO) for funding the project. We also thank the follow-up committee and the end-users who were involved into the numerous discussions about OSERIT. More particularly, we thank Goram Brostrom (met.no), David Cox (Belspo), Pierre Daniel (Météo-France), Pascal Depoorter (Kustwacht), Eric Donnay (DG-leefmilieu), Capt. Réjane Gyssens (MRCC), Ronny Schallier (MUMM), Serge Scory (MUMM), Jean-Pierre Vogt (MUMM) and Ben Wouters (MIK).

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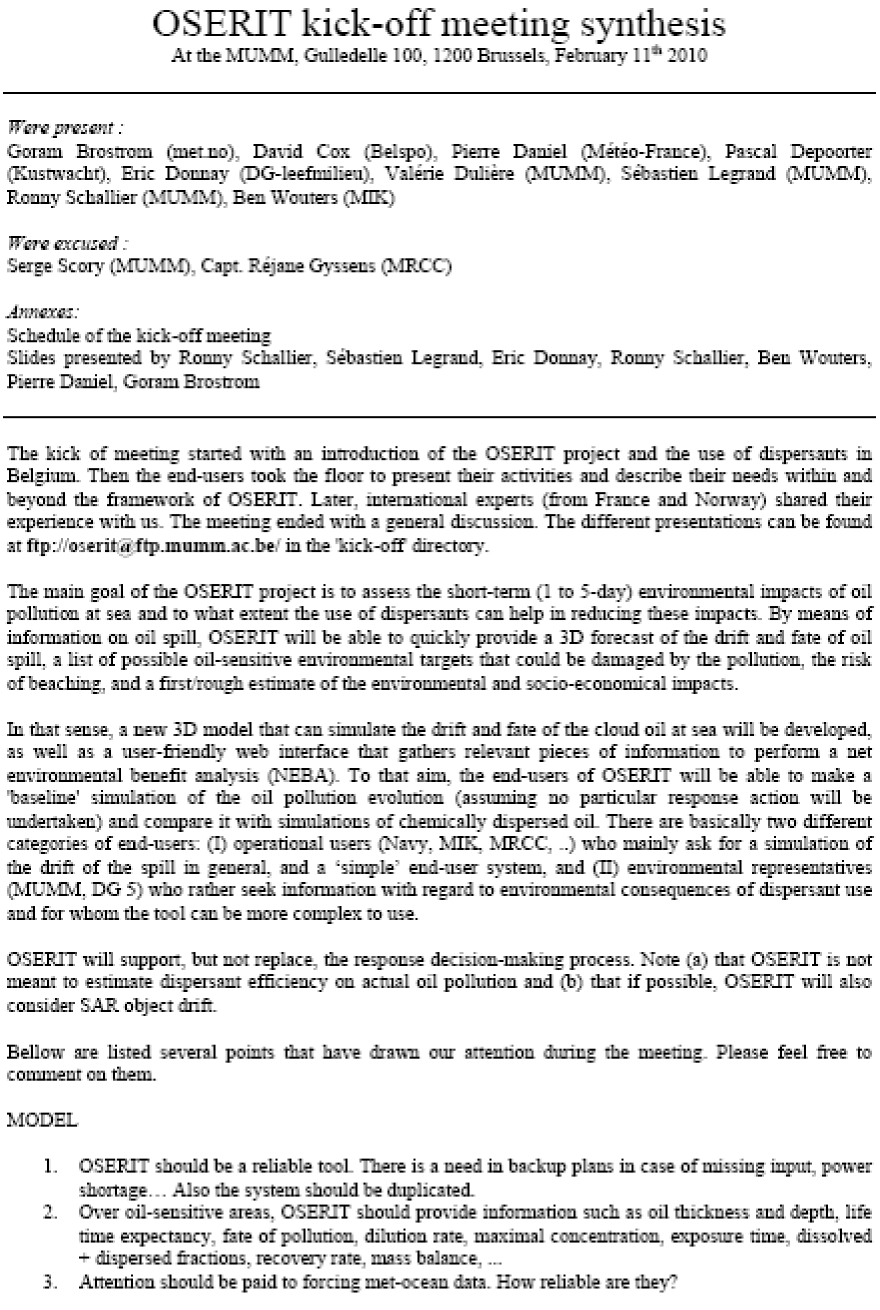
ANNEX 1: MINUTES OF THE FIRST FOLLOW-UP COMMITTEE MEETING



OSERIT kick-off meeting synthesis

At the MUMM, Gulledelle 100, 1200 Brussels, February 11th 2010

Were present :
Goram Brostrom (met.no), David Cox (Belspo), Pierre Daniel (Météo-France), Pascal Depoorter (Kustwacht), Eric Donnay (DG-leefmilieu), Valérie Dulière (MUMM), Sébastien Legrand (MUMM), Ronny Schallier (MUMM), Ben Wouters (MIK)

Were excused :
Serge Scory (MUMM), Capt. Réjane Gyssens (MRCC)

Annexes:
Schedule of the kick-off meeting
Slides presented by Ronny Schallier, Sébastien Legrand, Eric Donnay, Ronny Schallier, Ben Wouters, Pierre Daniel, Goram Brostrom

The kick of meeting started with an introduction of the OSERIT project and the use of dispersants in Belgium. Then the end-users took the floor to present their activities and describe their needs within and beyond the framework of OSERIT. Later, international experts (from France and Norway) shared their experience with us. The meeting ended with a general discussion. The different presentations can be found at **ftp://oserit@ftp.mumm.ac.be/** in the 'kick-off' directory.

The main goal of the OSERIT project is to assess the short-term (1 to 5-day) environmental impacts of oil pollution at sea and to what extent the use of dispersants can help in reducing these impacts. By means of information on oil spill, OSERIT will be able to quickly provide a 3D forecast of the drift and fate of oil spill, a list of possible oil-sensitive environmental targets that could be damaged by the pollution, the risk of beaching, and a first/rough estimate of the environmental and socio-economical impacts.

In that sense, a new 3D model that can simulate the drift and fate of the cloud oil at sea will be developed, as well as a user-friendly web interface that gathers relevant pieces of information to perform a net environmental benefit analysis (NEBA). To that aim, the end-users of OSERIT will be able to make a 'baseline' simulation of the oil pollution evolution (assuming no particular response action will be undertaken) and compare it with simulations of chemically dispersed oil. There are basically two different categories of end-users: (I) operational users (Navy, MIK, MRCC, ..) who mainly ask for a simulation of the drift of the spill in general, and a 'simple' end-user system, and (II) environmental representatives (MUMM, DG 5) who rather seek information with regard to environmental consequences of dispersant use and for whom the tool can be more complex to use.

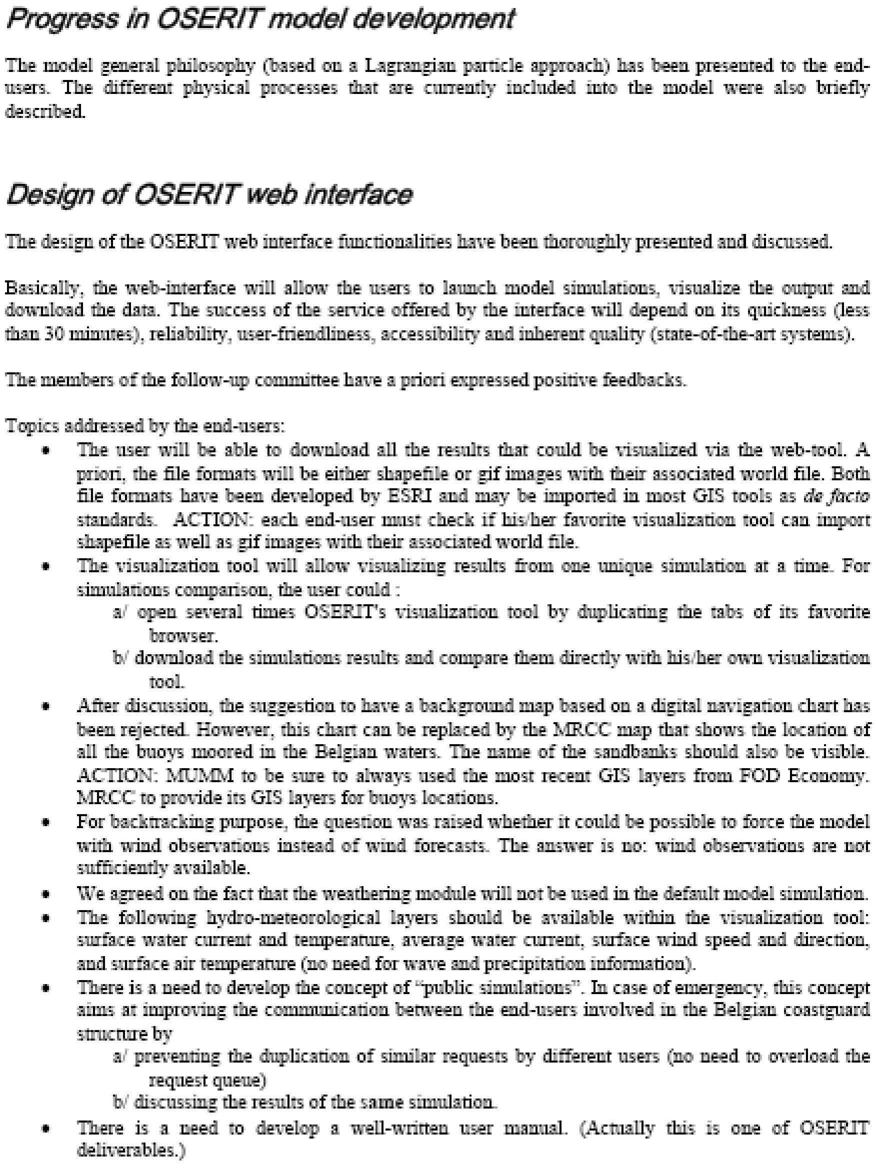
OSERIT will support, but not replace, the response decision-making process. Note (a) that OSERIT is not meant to estimate dispersant efficiency on actual oil pollution and (b) that if possible, OSERIT will also consider SAR object drift.

Bellow are listed several points that have drawn our attention during the meeting. Please feel free to comment on them.

MODEL

1. OSERIT should be a reliable tool. There is a need in backup plans in case of missing input, power shortage… Also the system should be duplicated.
2. Over oil-sensitive areas, OSERIT should provide information such as oil thickness and depth, life time expectancy, fate of pollution, dilution rate, maximal concentration, exposure time, dissolved + dispersed fractions, recovery rate, mass balance, ...
3. Attention should be paid to forcing met-ocean data. How reliable are they?

ANNEX 2: Minutes of the second follow-up committee meeting



Progress in OSERIT model development

The model general philosophy (based on a Lagrangian particle approach) has been presented to the end-users. The different physical processes that are currently included into the model were also briefly described.

Design of OSERIT web interface

The design of the OSERIT web interface functionalities have been thoroughly presented and discussed.

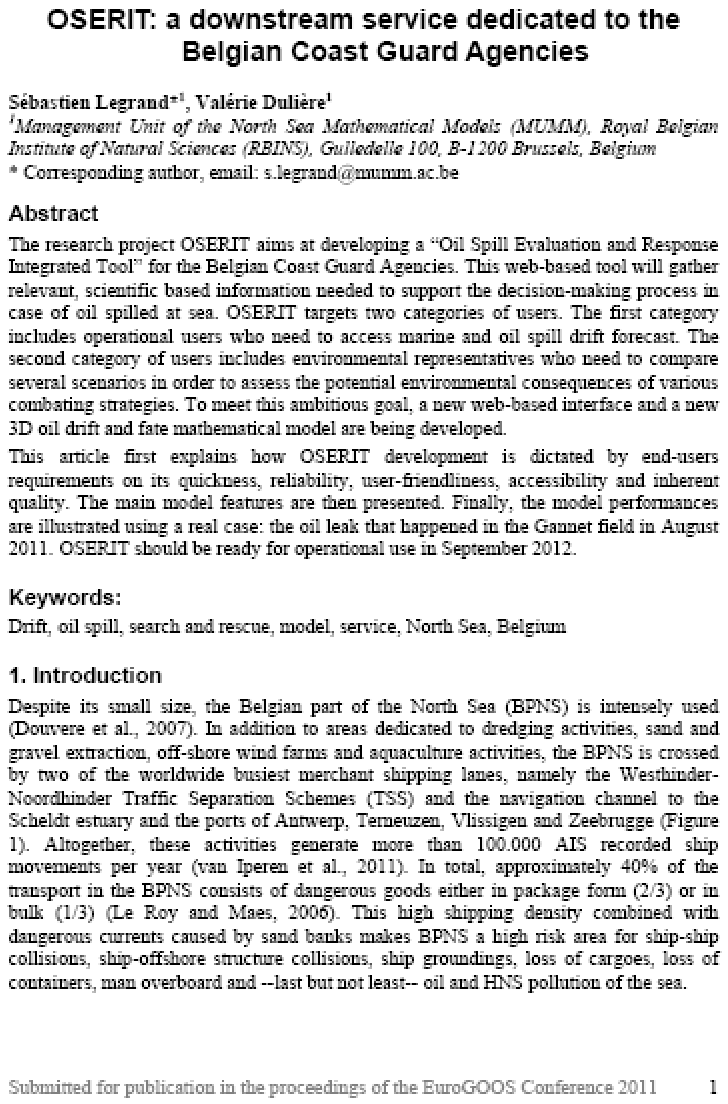
Basically, the web-interface will allow the users to launch model simulations, visualize the output and download the data. The success of the service offered by the interface will depend on its quickness (less than 30 minutes), reliability, user-friendliness, accessibility and inherent quality (state-of-the-art systems).

The members of the follow-up committee have a priori expressed positive feedbacks.

Topics addressed by the end-users:

- The user will be able to download all the results that could be visualized via the web-tool. A priori, the file formats will be either shapefile or gif images with their associated world file. Both file formats have been developed by ESRI and may be imported in most GIS tools as *de facto* standards. ACTION: each end-user must check if his/her favorite visualization tool can import shapefile as well as gif images with their associated world file.
- The visualization tool will allow visualizing results from one unique simulation at a time. For simulations comparison, the user could :
  - a/ open several times OSERIT's visualization tool by duplicating the tabs of its favorite browser.
  - b/ download the simulations results and compare them directly with his/her own visualization tool.
- After discussion, the suggestion to have a background map based on a digital navigation chart has been rejected. However, this chart can be replaced by the MRCC map that shows the location of all the buoys moored in the Belgian waters. The name of the sandbanks should also be visible. ACTION: MUMM to be sure to always used the most recent GIS layers from FOD Economy. MRCC to provide its GIS layers for buoys locations.
- For backtracking purpose, the question was raised whether it could be possible to force the model with wind observations instead of wind forecasts. The answer is no: wind observations are not sufficiently available.
- We agreed on the fact that the weathering module will not be used in the default model simulation.
- The following hydro-meteorological layers should be available within the visualization tool: surface water current and temperature, average water current, surface wind speed and direction, and surface air temperature (no need for wave and precipitation information).
- There is a need to develop the concept of "public simulations". In case of emergency, this concept aims at improving the communication between the end-users involved in the Belgian coastguard structure by
  - a/ preventing the duplication of similar requests by different users (no need to overload the request queue)
  - b/ discussing the results of the same simulation.
- There is a need to develop a well-written user manual. (Actually this is one of OSERIT deliverables.)

ANNEX 3: PROCEEDINGS OF THE 6TH EUROGOOS CONFERENCE



OSERIT: a downstream service dedicated to the Belgian Coast Guard Agencies

Sébastien Legrand*[1], **Valérie Dulière**[1]
[1]*Management Unit of the North Sea Mathematical Models (MUMM), Royal Belgian Institute of Natural Sciences (RBINS), Gulledelle 100, B-1200 Brussels, Belgium*
* Corresponding author, email: s.legrand@mumm.ac.be

Abstract

The research project OSERIT aims at developing a "Oil Spill Evaluation and Response Integrated Tool" for the Belgian Coast Guard Agencies. This web-based tool will gather relevant, scientific based information needed to support the decision-making process in case of oil spilled at sea. OSERIT targets two categories of users. The first category includes operational users who need to access marine and oil spill drift forecast. The second category of users includes environmental representatives who need to compare several scenarios in order to assess the potential environmental consequences of various combating strategies. To meet this ambitious goal, a new web-based interface and a new 3D oil drift and fate mathematical model are being developed.

This article first explains how OSERIT development is dictated by end-users requirements on its quickness, reliability, user-friendliness, accessibility and inherent quality. The main model features are then presented. Finally, the model performances are illustrated using a real case: the oil leak that happened in the Gannet field in August 2011. OSERIT should be ready for operational use in September 2012.

Keywords:

Drift, oil spill, search and rescue, model, service, North Sea, Belgium

1. Introduction

Despite its small size, the Belgian part of the North Sea (BPNS) is intensely used (Douvere et al., 2007). In addition to areas dedicated to dredging activities, sand and gravel extraction, off-shore wind farms and aquaculture activities, the BPNS is crossed by two of the worldwide busiest merchant shipping lanes, namely the Westhinder-Noordhinder Traffic Separation Schemes (TSS) and the navigation channel to the Scheldt estuary and the ports of Antwerp, Terneuzen, Vlissigen and Zeebrugge (Figure 1). Altogether, these activities generate more than 100.000 AIS recorded ship movements per year (van Iperen et al., 2011). In total, approximately 40% of the transport in the BPNS consists of dangerous goods either in package form (2/3) or in bulk (1/3) (Le Roy and Maes, 2006). This high shipping density combined with dangerous currents caused by sand banks makes BPNS a high risk area for ship-ship collisions, ship-offshore structure collisions, ship groundings, loss of cargoes, loss of containers, man overboard and --last but not least-- oil and HNS pollution of the sea.

ANNEX 4: OSERIT USER'S MANUAL

OSERIT 1.0 User's Manual

Manual Version 1.0

Last Modified: 09/10/2012

Authors : Valérie Dulière, Fabrice Ovidio and Sébastien Legrand
Royal Belgian Institute of Natural Sciences
Management Unit of the North Sea Mathematical Models
Gulledelle 100, B-1200 Brussels

belspo

ANNEX 5: TRAINING MATERIAL

OSERIT User's Training

Author : Valérie Dulière
Royal Belgian Institute of Natural Sciences
Management Unit of the North Sea Mathematical Models
Gulledelle 100, B-1200 Brussels