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An Operational Oil Drift Forecasting System for German Coastal Waters

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An Operational Oil Drift Forecasting System for German Coastal Waters

Silvia Maßmann, Frank Janssen, Thorger Brüning, Eckhard Kleine, Hartmut Komo,
Inge Menzenhauer-Schumacher and Stephan Dick

Summary

Today, the presented (oil-) drift and dispersion model is a well-established component of the German marine pollution response system. The oil drift model is part of a comprehensive operational ocean forecasting system applied at the Federal Maritime and Hydrographic Agency (BSH). Development of the oil drift model started already in the 1980's, but it was considerably advanced in several directions over the years. The latest development is the operationalization of the SeatrackWeb system at BSH.

A 3-dimensional regional ocean circulation model provides – in combination with numerical weather forecasts of the German Weather Service (DWD) – the forcing for the oil drift component. The region covered by the model system is the whole North and Baltic Sea with special focus on the German Bight and the western Baltic Sea. Based on the pre-calculated and archived forcing data the oil drift model can be run on demand at any time. The basic approach is a Lagrangian particle tracking method, i.e. the simulated oil spill is described by a large number of particles which carry characteristics of specific types of oil. By this approach not only the drift but also the so-called "weathering" of the oil can be calculated. All fundamental processes which alter the oil during the fate of an oil spill, e.g. spreading, dispersion, evaporation and emulsification, are included.

The particle tracking and oil weathering components, which are at the core of the model are connected to a modern, interactive, graphical user interface (GUI), which provides the user, e.g., with the possibility to directly start simulations from satellite detections of oil spills. The GUI gives access to several layers of useful information, e.g. ocean currents, wind direction, the location of oil platforms or shipping routes. Besides that, it visualizes ship signals from the Automatic Identification System (AIS), which are important means when it comes to the identification the potential source of an oil spill.

In this paper we first present the current BSH operational ocean forecasting system highlighting some recent developments. The core of the oil drift component will be described in some detail. The main part of the paper will show results of some real cases. Based on these results some scientific questions like, e.g., the influence of wave induced Stokes drift will be discussed.

Keywords

SeatrackWeb, oil spill, ocean forecast, operational ocean model, North Sea, Baltic

Zusammenfassung

Heute ist das hier dargestellte (Öl-) Drift- und Ausbreitungsmodell fester Bestandteil des deutschen Meeresverschmutzungsbekämpfungssystems. Das Öldriftmodell ist dabei Teil eines umfassenden operationellen Vorhersagesystems des Bundesamtes für Seeschifffahrt und Hydrographie (BSH). Die Entwicklung des Öldriftmodells begann bereits in den frühen 1980er Jahren, wurde aber über die Jahre in mehrere Richtungen wesentlich weiterentwickelt. Die jüngste Entwicklung ist die Operationalisierung von SeatrackWeb am BSH.

Ein 3-dimensionales regionales Ozeanmodell liefert – in Kombination mit der numerischen Wettervorhersage des Deutschen Wetterdienstes (DWD) – den Antrieb für die Öldriftkomponente. Die vom Modell abgedeckte Region ist die gesamte Nord- und Ostsee mit speziellem Fokus auf der Deutschen Bucht

und der westlichen Ostsee. Basierend auf den vorberechneten und archivierten Antriebsdaten, kann das Öldriftmodell nach Bedarf jederzeit gestartet werden. Der Modellansatz ist eine Lagrangesche Partikelverfolgungsmethode, d.h. das simulierte Öl wird beschrieben als große Anzahl von Partikeln, die die Eigenschaften des spezifischen Öltyps tragen. Mit dieser Methode wird nicht nur die Verlagerung, sondern auch die sogenannte „Verwitterung“ des Öls berechnet. Es werden dazu alle fundamentalen Prozesse, die das Öl während des Abbaus einer Ölverschmutzung verändern, d.h. Spreading, Dispersion, Verdunstung und Emulsifikation, simuliert.

Die Partikelverfolgungs- und Ölverwitterungskomponenten, die den Kern des Modells bilden, sind mit einer modernen, interaktiven, graphischen Anwenderoberfläche (GUI) verbunden, die dem Anwender z. B. die Möglichkeit gibt, Simulationen direkt von Satelliten-detektierten Ölflecken zu starten. Die GUI ermöglicht die Darstellung verschiedener Layer mit nützlichen Informationen wie z.B. Ozeanströmungen, Windrichtungen, die Lage von Ölplattformen und Schifffahrtsrouten. Daneben visualisiert sie die Schiffssignale des Automatischen Identifikationssystems (AIS), welche ein wichtiges Mittel zur Identifikation möglicher Quellen von Ölverschmutzungen sind.

In diesem Artikel präsentieren wir zuerst das derzeitige operationelle BSH-Meeresvorhersagesystem mit Schwerpunkt auf den jüngsten Entwicklungen. Der Kern der Driftmodellkomponente wird in einigem Detail beschrieben. Der Hauptteil des Artikels wird Ergebnisse von einigen realen Fällen zeigen. Basierend auf diesen Resultaten, werden einige wissenschaftliche Fragen wie z. B. des Einflusses der welleninduzierten Stokes Drifts diskutiert.

Schlagwörter

Seatrack Web, Ölverschmutzung, Meeresvorhersagen, operationelle Ozeanmodelle, Nordsee, Ostsee

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1 Introduction

During and after the Deepwater Horizon oil spill caused by a drilling rig explosion in the Gulf of Mexico on 20 April 2010 oil spill models where intensively used to get an insight in pathways and fade of the enormous amounts of oil that have entered the ocean. Many countries around the world have built up an oil spill modelling capacity over the last decades which have been scrutinized in the light of this major accident at several places.

Oil spill models have become widely accepted and applied tools to assist the combatting of oil spills at sea. Several different drift models are operated by marine agencies, coastguards and institutions around the North and Baltic Sea. The Norwegian Meteorological Institute (met.no) develops OD3D and uses this as well as OSCAR in their forecasts. In Belgium the drift models FLOAT and OSERIT are developed and hosted by RBINS-MUMM and are used by the Belgian coastguard agency. In the UK CEFAS is responsible for doing the operational drift forecasts and they use their in-house developed CEFAS SPILL and commercial solutions like OILMAP or OSCAR. In the Netherlands RWS and Deltares use as well the commercial software OILMAP and also CHEMMAP. METEO-FRANCE is also able to do drift simulations in the North Sea with their drift model MOTHY, although this is not their main region of interest. Most of the models are very specialized towards simulation of oil at sea, whereas others are more generalized drift and dispersion models which can be applied to a wide range of applications like search-and-rescue at sea, the drift of all kinds of objects, including lost containers or buoys that have broken loose, and last but not least the fade of floating or submerged oil.

The Federal Maritime and Hydrographic Agency (BSH) has, among several other duties, the task to support the combatting of oil pollution in German territorial waters. This includes both, the support of the parties involved in oil combatting, e.g. the Central Command for Marine Emergencies, directly after an oil spill has happened as well as – at a later stage – the support of the prosecuting authorities in identifying the polluter in case of an illegal discharge. In order to fulfill this task BSH runs and maintains a comprehensive numerical model system. The system consists of several components. Two of them, namely the three-dimensional ocean circulation model BSHcmod and the drift and dispersion model SeatrackWeb are of special importance for the topic at hand and will be described in some detail below.

2 Model system

This section provides an overview of the applied model system. Some of the important features of the core part of the SeatrackWeb drift model – PADM – and of the graphical user interface (GUI) are summarized. The area, where users can perform drift simulations with the BSH setup of SeatrackWeb is presented here as well.

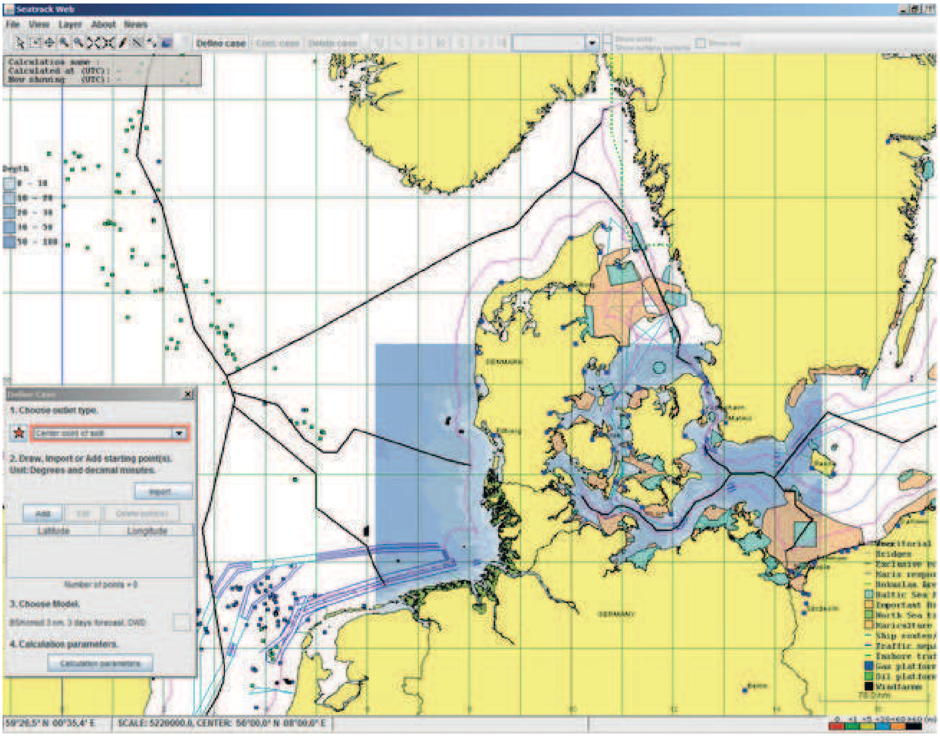
2.1 Overview

The numerical weather forecast models of the German Weather Service (DWD), COSMO-EU (LME) and GME, are at the top level of the applied model chain. LME and GME provide the needed atmospheric forcing for both ocean model components on a four-times-daily basis with a forecast lead time of up to 7 days. BSHcmod is run with a horizontal resolution of about 5 km for the whole North and Baltic Sea area and comes with a 2-way nested grid increasing the resolution to about 900 m in the German Bight and western Baltic Sea (DICK et al. 2001). A further refinement of grid resolution up to 90 m has recently been achieved for the sub-region of the Elbe estuary (MÜLLER-NAVARRA and BORK 2012). Besides the atmospheric forcing, the tidal water level at the open boundaries in the North Sea and freshwater inflow from the largest rivers are driving forces of the circulation model. At present BSHcmod provides a three day forecast of water level, current, temperature, salinity and ice coverage once a day in fully automatic fashion. The model output is archived with a time step of 15 minutes for water level and current and hourly for the other variables together with the atmospheric forcing. The model data archive provides the basis for all drift simulations and a range of further applications.

To forecast the drift of oil, objects and conservative substances a Lagrangian dispersion model is used. To date an in-house developed Lagrangian drift model, called BSHdmod.L (DICK and SOETJE 1990) is applied at BSH. BSHdmod.L uses the above mentioned archived BSHcmod model fields and wind forecasts of LME. It was one of the first Lagrangian dispersion models operationally predicting oil drift and fade in North and Baltic Sea and has been very successfully applied in the past e.g. during the Pallas wreckage in 1998 or the Baltic Carrier collision in 2001. Later on the model code was shared with neighboring North and Baltic Sea countries like Denmark or Sweden, where it developed in parallel. The Swedish Meteorological and Hydrological Institute (SMHI) and the predecessor institution of the Forsvarets Center for Operativ Oceanografi (FCOO) used BSHdmod.L to upgrade the common HELCOM modelling and drift forecasting system for oils and chemicals called SeatrackWeb. They continuously developed the drift model core (called Particle Advection and Dispersion Model, PADM), enhanced it with a graphical user interface (GUI) and made it accessible via the internet (AMBJÖRN et al. 2011).

Several institutes run SeatrackWeb separately and in different versions. For example SMHI hosts the official HELCOM site (https://stw-helcom.smhi.se/) and extra production sites for special users in Swedish lakes and fjords (Vänern and Brodfjorden) while FCOO hosts their own version for Danish users. BSH joined the SeatrackWeb developer group in 2006 and adapted SeatrackWeb for BSH special requirements for example the use of nested grids and an extended model area. Recently SeatrackWeb runs in operational mode using BSHcmod forcing. The BSH version of SeatrackWeb is available under http://stw.bsh.de/seatrack .

Mainly German authorities, including BSH itself, are the users of the BSH version of SeatrackWeb, so the target area of the model is the German Bight and the Western Baltic Sea with a 900 m resolution of the water current field (see blue area in Fig.1). Outside this area the currents have a resolution of about 5 km in the North-, Baltic Sea and in parts of the English Channel.



1. Choose outlet type.

2. Draw, import or Add starting point(s).
Unit: Degrees and decimal minutes.

3. Choose Model.
BSHcmod 3 nm, 3 days forecast, DWD

4. Calculation parameters.

Figure 1: Maps and geographic information displayed in SeatrackWeb Java GUI. The blue area indicates depth values of the fine North and Baltic Sea grid of BSHcmod. Land as defined by the coastline is displayed in yellow.

2.2 PADM

PADM stands for Particle Advection and Dispersion Model and is the core of Seatrack-Web calculating the advection of a substance or object by representing it by a cloud of particles (with the so called Lagrangian method).

Each particle represents a certain amount of the simulated substance. The particles move individually in three dimensions not affecting the surrounding flow field. Except for the gravitational spreading algorithm the particles do not influence each other (no collisions, etc.). When particles hit a boundary, like a coastline, the bottom or the boundaries of the model domain, it sticks to, slips along or passes through this boundary. Oil, for example, sticks at the coastline and at the bottom, while objects slip along these boundaries.

Each particle holds a part of the total mass and additional properties like viscosity, density, height, etc. The particle properties change due to substance specific processes. If for example oil is at the surface it evaporates depending - amongst others - on temperature.

The particles are placed in a grid with rectangular, six-sided cells, where the x-direction runs from west to east (longitude), the y-direction from south to north (latitude) and the z-direction points upwards. At the boundaries of the cells the x-, y-, z-velocities are given by the operational ocean model under consideration (e.g. BSHcmod), meaning that the particles move within the cell according to the given velocities resp. velocity gradients.

At the ocean surface the two-dimensional surface wind fields (e.g. LME) additionally move the particles, if desired. In each cell the bottom is flat and the location of the bottom depends on the bathymetry of the circulation model. For example a sloping bottom is represented by a staircase shape meaning the bottom consist of horizontal and vertical faces of the grid cells. In the horizontal the staircase shaped model coastline is replaced by a realistic coastline in order to have a more realistic representation.

Next to the purely advective displacement of the particles by a given wind and current field (as described above), horizontal as well as vertical spreading occurs as a result of water current or wind shear at various temporal and spatial scales (so called sub-grid processes). In SeatrackWeb the small-scale isotropic turbulent mixing is included by adding turbulent velocities depending on the turbulent kinetic energy and its dissipation rate randomly to the drift of the particles.

In case of an oil slick the density differences between water and oil and the viscous as well gravitational forces lead to horizontal surface spreading of oil at the interface between water and air. To compute this process slick heights computed from the Fay formulas (FAY 1971) give - by assuming cylindrical particles with individual particle volumes – particle radiuses. The spreading is then a result of an iterative procedure calculating non-overlapping discs.

The vertical dispersion of particles from the surface down into the water column depends on the kind of substance simulated. For dissolved substances the turbulent mixing is a major player, but for oil slicks breaking waves have to be included to simulate the breaking up of cohesive slicks and the dispersion of these droplets into the water column. For this purpose a dissipative energy due to breaking waves is computed from the significant wave height leading to a mass of oil to be dispersed for each droplet size. Then the new depth values are assigned randomly by adding extra negative vertical velocities to the movement of the particles.

Density differences between the particle and the surrounding water leads to sinking or rising. A formula primarily developed for oil (SOARES DOS SANTOS and DANIEL 2000) gives a buoyancy velocity depending on the reduced gravity, viscosity, diameter of the particle and a critical diameter. The critical diameter divides the particles into two regimes: the large, spherical-cap bubble and the small spherical droplet (Stokes's) regime. Other substances than oil also have a buoyancy velocity, which is simply the reduced gravity multiplied by an adjustable coefficient.

If the particles simulate the drift of oil, oil weathering processes like evaporation and emulsification influence its properties. Density depends on emulsification and evaporation. Each particle's viscosity changes due to temperature (the rate of evaporation) and the degree of emulsification. For details about the implementation of weathering processes we refer to AMBJÖRN et al. (2011) and the scientific documentation of SeatrackWeb (LIUNGMAN and MATTSSON 2011) accessible through http://stw.bsh.de/seatrack or https://stw-helcom.smhi.se/.

Stokes drift is a net drift caused by the orbital motion of deep-water waves, which is not exactly closed due to the decrease of orbital velocities with depth. In the considered hydrodynamic models this motion is neither resolved nor implicitly included in the surface boundary conditions; therefore the Stokes drift velocities are calculated within SeatrackWeb. Stokes drift velocities are computed from the two-dimensional wave energy spectrum. The wave spectrum is not yet imported from an operational wave forecast model, but is instead based on the parameterized spectrum presented in DONELAN et al. (1985) for fetch-limited growth.

The appearance of sea ice is taken into account and influences almost all processes mentioned above. For instance the hydrodynamic model velocities are replaced by the ice drift velocity if ice concentrations are higher than 70 % and the particle is at the surface. Also the Stokes drift linearly decreases from 100 %, when the ice concentration is zero, to 0 %, when the ice concentration is 70 % or higher. Also the gravitational spreading of an oil slick linearly decreases to zero with increasing ice concentration (DICKINS 1992; VENKATESH et al. 1990). Oil dispersion by breaking waves from the surface down into the water column is also reduced for high ice concentrations higher than 30 %. Ice strongly damps the waves and limits the dispersion.

Although many processes are included, still a high level of uncertainty originates from the ocean and wind model applied. To mimic some of the uncertainty it is possible to add extra uncertainty spreading randomly, whose magnitude is a function of the wind forecast uncertainty, to the movement of particles at the surface.

2.3 Graphical User Interface

SeatrackWeb users typically configure drift simulations and display the results via the graphical user interface (GUI). SMHI develops and continuously updates, respectively renews the SeatrackWeb GUI. At present two versions of the GUI exist: one is a Java Client/Server application and the other one is a JavaScript web application tested in common internet browsers. The web application version is the latest one, but the Java Client version is still commonly used. At the BSH the current operational setup uses Java Client and therefore, only this version of the GUI will be presented.

Java Web Start starts the Java Client application on the user computer. Since the drift simulations itself are performed on the server site there are no specific requirements for the personal desktop computer performance. For more details about the SeatrackWebs Client/Server Java Application we refer to AMBJÖRN et al. (2011).

After successful login a coastline map opens and more layers with additional information may optionally be added. Fig. 1 shows the SeatrackWeb GUI of the BSH installation. For example, as it can be seen in Fig. 1, it is possible to display the location of oil and gas platforms, borders of the exclusive economic zone, marine traffic routes and biological sensitive areas. Furthermore, the bathymetric depths showing the resolution of the BSHcmod circulation model can be visualized. This information helps to identify how well ocean current fields are resolved in the drift simulation.

To set up a drift simulation the user has to provide some information guided by the GUI through different menus, e.g. kind of substance/object, kind of outlet (continuous, amount, rate,…), position, start and end time of the simulation must be defined.

SeatrackWeb provides strong support for expert users, which can choose the forcing wind/current fields, give additional wind drag for floating objects, choose the kind of oil or add uncertainty due to wind.

In case of oil – depending on the availability of information on the kind of oil – SeatrackWeb gives the possibility to choose just an oil class (light, medium, heavy) or a specific oil (e.g. marine diesel, IFO 450, Bunker B, etc.). This choice has for example consequences on the rate of evaporation and emulsification.

Although the map is only 2-dimensional the drift simulation is 3-dimensional, meaning that it is possible to define an outlet in a certain depth and that the substance is dispersed in the water column if not prevented by buoyancy. The depth of a particle is color coded according to a legend shown in the lower right corner of the main window.

Further, the user has several options for analyzing the results. For example it is possible: to zoom in and out, add layers like for example traffic separation schemes, go forward and backward in time, show an animation, plot the trajectory of all particles or only of the barycenter of the particles, show wind and current data, and save map images. By saving the case the simulation result may be shared with other SeatrackWeb users or loaded in other systems through suitable interfaces. It is also possible to save tables and graphs showing the amount/percentage of oil at the surface, stranded, dispersed, emulsified, etc.

If the pollution source is unknown and a potential originator is searched for, AIS ship position can be loaded and displayed in combination with the drift simulation results. This helps to preselect ships to inspect. Displaying the EMSA provided oil spill detections in satellite images is also possible and helps finding possible polluters by backward simulations.

3 Results

In this section the performance of SeatrackWeb is demonstrated based on some real cases. First the results of an oil spill caused by the average of the cargo vessel “Full city” in the Skagerrak area in 2009 are shown. Then results of drifting objects, namely containers in the German Bight in 2012, are presented.

3.1 Ship average in Skagerrak area

On 30 July 2009 the cargo-vessel “Full City” anchored near the Norwegian coast in the Skagerrak area. During strong gale winds the anchor flukes broke off and the ship started to drift towards Sastein Island, where it ran aground by night losing about 300 tons of IF180 bunker oil (BROSTRÖM et al. 2011). Oil response action started next morning, but could not prevent a widespread pollution of the Norwegian coast causing ecological and economic damage. Drift models were used to predict the oil trajectory and a comparison of three model results – OD3D, SeatrackWeb and BSHdmod.L - was published by BROSTRÖM et al. (2011) afterwards. All models showed good agreement with observations. DAMSA used SeatrackWeb with HIROMB ocean model data and HIRLAM wind data. In this section the “Full City” case is considered again using SeatrackWeb with BSHcmod ocean model and GME+LME wind forcing data. The same forcing data was used by the drift model BSHdmod.L in the comparison in BROSTRÖM et al. (2011). Thus, differences in the oil spill trajectory are only due to the drift model.

In this paper SeatrackWeb uses the same initial setup as described in BROSTRÖM et al. (2011) including some additional uncertainty spreading due to wind as proposed in the paper. Fig. 2 shows the oil distribution 6 h, 12 h, 24 h, 36 h, 48 h and 60 h after the initial release of oil. The particle distribution is almost equal to the BSHdmod.L results in BROSTRÖM et al. (2011), because the same forcing applies. The spreading is a bit stronger in SeatrackWeb, causing the oil spill to widen faster and more oil gets further southwestwards. Since SeatrackWeb uses a coastline instead of the model boundaries, it allows particles to strand on the coastline and the stair case shape of the model boundaries as seen in the BSHdmod.L results (see Fig. 9 in BROSTRÖM et al. (2011)), is not present any more.

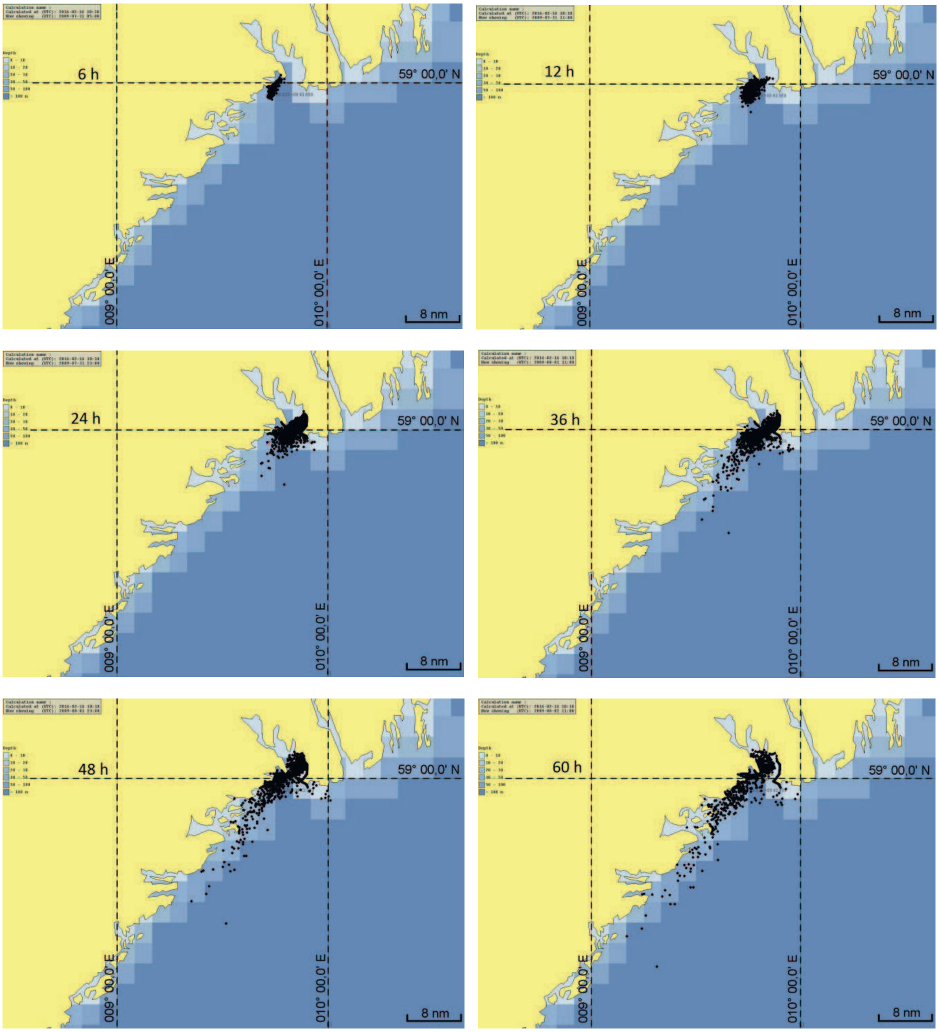


Figure 2: The Seatrack Web oil drift simulation results for the "Full City" case (6 h, 12 h, 24 h, 36 h, 48 h and 60 h after the initial release) using BSHcmod and LME/GME forcing. Black dots represent oil positions, the blueish area shows the depth used in the BSHcmod model (5 km resolution) and yellow is the land according to Seatrack Webs coastline.

The beaching of oil 72 h after the accident is shown in Fig. 3. Comparing it with the simulation results in BROSTRÖM et al. (2011) the extension of the oil beaching is approximately as far south as the OD3D results using 1.5 km resolution. One difference is that SeatrackWeb with BSHcmod forcing also has beaching of oil at Molen while OD3D does not predict this. Comparing our results with the SeatrackWeb results using HIRLAM/HIROMB forcing more oil is beached near the accident location and the oil does not travel that far south. The SetrackWeb simulations presented here and in BROSTRÖM et al. (2011) differ not only because of different forcing fields also because of additional uncertainty spreading.

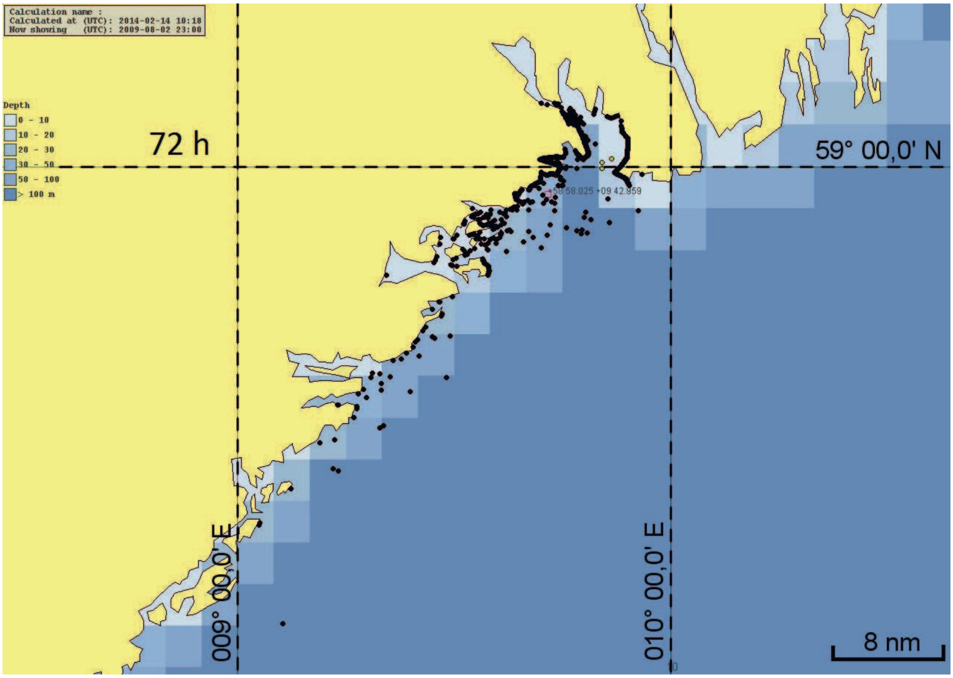


Figure 3: SeatrackWeb simulation results of the "Full City" case 72 h after the initial release using BSHcmod forcing.

3.2 Container drift in the German Bight

At 05:35 UTC on 06. January 2012 - just after a northwest gale causing a rough sea state and a storm surge - a cargo ship reported loss of ten 40-ft containers about 22 nm WNW of Helgoland near the German Bight Western Approach. Seven containers contained wood piles, two containers were empty reefer containers and one container included car spare parts. These containers were partly connected with twist locks, drifting in packages of two, three or four containers until most of them probably broke off distributing their content. Consequently, the pollution was more a danger for shipping than for wild life although there is always impact on ecology, tourism and economy in general by such accidents.

Container, container parts and wood piles were observed over ten days from ships and aircrafts. They were monitored by radar, accompanied by ship and - if possible - salvaged.

In the morning container and flotsam have been reported in a positions south-west of the accident location. This was about four hours after the average and pictures of some connected containers were made (see Fig. 4).

Figure 4: Container package observed at position 54° 18,06' N, 007° 13,30' E on 06.01.2012 at 09:36 UTC (the picture was kindly provided by the crew of the ETV Nordic).

The distance between some container packages was already more than ½ nm. Whether the containers have been lost subsequently or whether processes like water turbulence or different flotage led to this separation is hard to tell. In the afternoon and evening of 06.01.2012 more observations have been made finding containers or remaining of containers respectively their content in direction WNW, SW and SE of the accident location. Since it is not possible to distinguish containers in these observations, it is not clear, whether the containers were observed several times or if each time different containers were found. Very valuable observations were made by the ship GS Neuwerk in the evening of 06.01.2012, when a container package was plotted by the ship radar for about 6 hours (see Tab. 1). Within this period we compare the drift simulations with these observations (see below).

About 33 h after the accident (afternoon 07.01.2012) an overflight sighted a container and a container package being about 8 nm apart. Probably the same objects were observed later SW-wards with a distance of about 13 nm apart from each other (SW-wards and E-wards of Helgoland) in the afternoon of 08.01.2012 (about 58 h after the accident). Since we cannot verify that the objects were double sightings, we do not compare these observations with drift simulations. But this illustrates, that although the containers have been dropped off probably very close to each other (or even at the same position) at nearly the same time, the objects-over-board have already taken very different trajectories. The increasing distances between the containers observed 4 h, 33 h and 58 h after the accident (1/2 nm, 8 nm and 13 nm) illustrate the different behavior of drifting object depending on size, drowning, shape, etc.. Without knowing any of these properties the uncertainties of a drift simulation are very high. Additionally the turbulence and other processes of different scales in wind, waves and currents put a random forcing on the objects, which is not possible to predict deterministically.

Table 1: Observation of a container package made by GS Neuwerk 06.01.2012.

Time in UTC	Latitude	Longitude
17:18	54° 18.2‘ N	007° 11.6‘ E
17:30	54° 18.1‘ N	007° 11.9‘ E
17:45	54° 18.0‘ N	007° 12.4‘ E
18:00	54° 17.8‘ N	007° 12.9‘ E
18:15	54° 17.7‘ N	007° 13.4‘ E
18:30	54° 17.6‘ N	007° 13.9‘ E
18:45	54° 17.5‘ N	007° 14.4‘ E
19:00	54° 17.3‘ N	007° 14.9‘ E
19:30	54° 17.3‘ N	007° 15.5‘ E
19:45	54° 17.1‘ N	007° 16.4‘ E
20:00	54° 16.9‘ N	007° 16.9‘ E
20:15	54° 16.8‘ N	007° 17.4‘ E
20:30	54° 16.8‘ N	007° 17.9‘ E
20:45	54° 16.8‘ N	007° 18.3‘ E
21:00	54° 16.8‘ N	007° 18.6‘ E
23:30	54° 17.5‘ N	007° 21.4‘ E

Further the objects drifting characteristics may change over time. In the evening two connected containers, which were probably the ones reported east of Helgoland in the afternoon, were sighted by GS Neuwerk southwest of Helgoland. Again the positions were radar plotted, but in the morning of 09.01.2012 the containers broke off, and one deteriorated distributing wooden planks and a package of wood. Later the remaining blue container was salvaged. In the subsequent 6 days wood, wood packages and fragments of containers were found in the Elbe estuary and at the North Frisian coast near the Eider estuary.

We apply SeatrackWeb with BSHcmod/LME forcing simulating two connected containers drifting on 06. January 2012 between 17:18 UTC and 23:30 UTC and compare the results with observations (given in the Tab. 1). Fig. 5 shows the trajectory of the drift simulation in blue and of the observation in magenta. At the beginning the simulated trajectory follows nicely the observations, later the containers move more southwards than in the simulation. At the end of the simulation the distance between observed and simulated position is about 1.2 nm. The mean minimal distance of the whole simulated trajectory to the observed trajectory is about 0.6 km and the mean error is about 0.7 km.

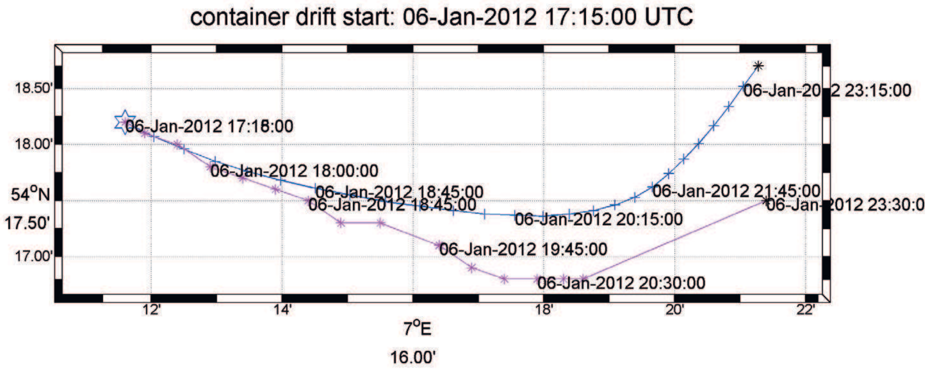


Figure 5: Seatrack web drift trajectory (blue) and observed trajectory (magenta) of two connected containers starting from a ship observed position (54° 18,2'N, 007° 11,6'E) at 06.01.2012 at 17:15 UTC ending at 06.01.2012 at 23:30 UTC (plot is made with Matlab). The star marks the starting point of the simulation. Seatrack Web uses a wind drag coefficient of 2.3 %.

To track possible error sources, we compare wind and wave measurements with the wind forcing used by the drift model. In Fig. 6 wind speed and direction at the simulated container position are plotted over time (the wind model data refers to 10 m height). The dots in magenta show the observed values at Fino1 station (measurements are in 33 m height). The observed wind speed is about 12 m/s increasing to 15 m/s and the wind model data is about 2-4 m/s lower than the observed one (increasing from 10 m/s to 13 m/s). Measured wind speed at Helgoland is generally a bit lower than the model wind, while TW Ems had a bit higher wind velocities. So overall the wind speed seems to match quite well.

The measured and modelled wind direction match quite as well (the measurements are systematically about 5° smaller than the wind direction used in the drift model) and show that the wind backed from WNW to WSW. The differences between observed and modelled values could be due to the height differences. Wind directions measured at TW Ems are almost equal to the ones at Fino1, while at Helgoland the wind direction is a bit more northerly and having more variations than the model wind. In general the wind forcing used in the drift simulation seems to be consistent with measurements, so errors in wind forcing seem not be the source of error for the drift simulation.

At Fino1 the measured significant wave height decreases from about 2.9 m to 2.6 m and the mean wave direction was from NNW until 22:15 UTC. At 23:15 UTC the wave direction reacts on the changing meteorological conditions and backs to WNW. At the wave rider station south of Helgoland the wave height was 1.7 m at the beginning and increased later to 1.9 m after 21:40 UTC. The wave direction was WNW backing to W at about 22:40 UTC. This turn in direction coincides in time with the wave direction changes at Fino1. These observations show spatial and temporal variability of the wind wave and swell.

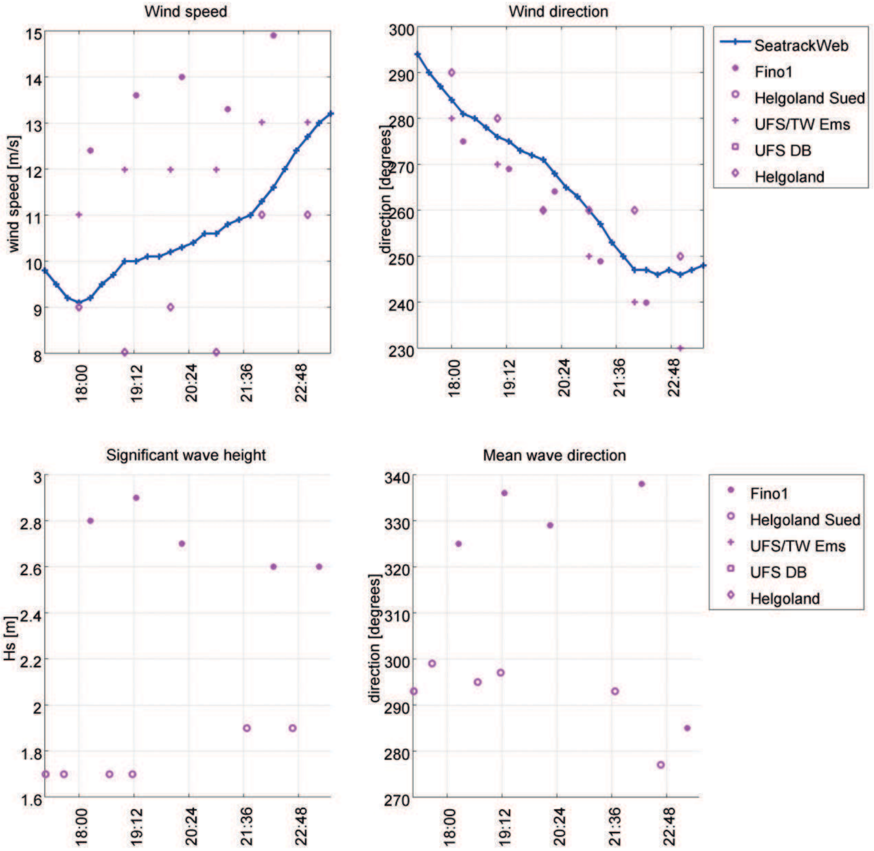


Figure 6: In blue wind speed and wind direction (in 10 m height) over time used by the drift model (GME+LME model data) at the simulated container positions. The dots in magenta show wind speed, wind direction, significant wave height and mean wave direction as measured at the station Fino1 (54° 0.86’ N, 006° 35,03’ E). The wind measurements of Fino1 are in 33 m height. The magenta circles show significant wave height and mean wave direction from the wave buoy at Helgoland Sued (54° 10.783’ N, 007° 53,467’ E). Wind speed and direction measurements at light vessel TW Ems (54° 10,0’ N, 006° 20.8’ E) in magenta crosses and at Helgoland in magenta diamonds.

SeatrackWeb uses parameterized Stokes drift from the model wind. This means that the displacement due to waves is computed from wind speed and direction. If the wind and wave direction match well (what is usually the case in fresh wind sea), the Stokes drift has the correct direction and size. In conditions when the wind and wave directions are different the parameterized Stokes drift cannot catch this change in direction. Probably this is the reason why the simulated container positions are more northwards than the observed ones.

4 Concluding remarks and perspectives

In this paper the application of the Lagrangian drift model SeatrackWeb to two real cases is presented. In the first case the drift of heavy oil in the Skagerrak released during the average of the "Full City" tanker in 2009 is simulated. The reported and simulated beachings are quite consistent. The other case dealt with the drift forecast of objects, namely containers. The results showed reasonably good agreement with observation considering the uncertainties of the weather model and the resolution of the ocean model. We identified that differences in swell and wind direction lead to errors in the drift forecast. Since the wave induced displacement is computed using the so called Stokes drift, which is parameterized by the wind, this component could be improved by directly using the Stokes drift from an operational wave model. The BSH has already access to wave model results of WAM (WAMDI 1988) run by the German Weather Service (DWD). In future the Stokes drift could be included in the wave model result files and SeatrackWeb could read in the Stokes drift velocities instead of computing it internally in the parametrized wave model of PADM. As a side effect the computing time of the drift simulation would also be reduced.

Concerning PADM the horizontal spreading of objects and oil is still an ongoing field of research. For example the influence of unresolved eddies, Langmuir circulations and gusts is an unsolved problem. These processes may increase the spreading. Also the thickening of oil in downwind direction and tar ball formation is not yet fully solved in SeatrackWeb.

Another factor for accurate results is the performance of meteorological and ocean models. BSHcmod runs only once a day due to limitations of computer resources, so the latest meteorological forcing is not used. In general the forecast quality of ocean models improves with the more recent wind forcing. The development of a modernized version of BSHcmod (so called HBM, see article in this journal) aims to have a faster model code suitable for modern, parallelized computer architectures. If the validation shows that the predicted currents are of the same or even better quality and HBM can run several times a day, the drift model forecasts will improve. Changing to HBM would only require small changes in the SeatrackWeb routines for reading and producing the setup and forcing files. Furthermore, HBM is already applied to the Elbe estuary. Including Elbe forcing as a further nesting level in SeatrackWeb will give finer resolved currents for the Elbe and would therefore increase the drift forecast quality in this region.

In case of oil spills the Central Command for Emergencies may choose for example dispersants and booms for oil combatting at sea. Applying dispersants changes the trajectory of the oil pollution, since the oil disperses in the water column having different currents and no direct wind drag. Any means of combatting oil will have to fulfill the condition that the intervention leads to less negative consequences than without. Where the oil or oil dispersant mixture will drift is very important information. To give predictions of the oil dispersant mixture is not yet possible in SeatrackWeb, but ongoing development together with Helmholtz-Zentrum Geesthacht (HZG).

Another important means for combatting oil at sea are booms. Booms keep oil in an area, prevent further spreading and facilitate oil recovery. SMHI currently sets a new version of the GUI in operation, where it is possible to simulate the application of booms. It is possible to estimate how much oil is trapped by each boom, which facilitates finding their optimal position. BSH may update to this new version of the GUI, if the users of the BSH SeatrackWeb desire to use the new feature. Apart from new features the new GUI has the advantage that it does not need the Java Web Start, because it is simply web based meaning that only a web browser is needed, which makes it easier to use SeatrackWeb on mobile devices.

Also interfaces to AIS web services, CSN oil spill detections and to PADM are constantly updated to facilitate the exchange of input data and drift results for different applications. The AIS data covers mainly the Baltic Sea, since suitable data bases and interfaces to the North Sea data are still under development. Having AIS data of the North Sea would especially be important for prosecuting authorities to display AIS ship tracks and drift trajectories in a common window.

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