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# An online platform for rapid oil outflow assessment from grounded tankers for pollution response

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ABSTRACT

The risk of oil spills is an ongoing societal concern. Whereas several decision support systems exist for predicting the fate and drift of spilled oil, there is a lack of accurate models for assessing the amount of oil spilled and its temporal evolution. In order to close this gap, this paper presents an online platform for the fast assessment of tanker grounding accidents in terms of structural damage and time-dependent amount of spilled cargo oil. The simulation platform consists of the definition of accidental scenarios; the assessment of the grounding damage and the prediction of the time-dependent oil spill size. The performance of this integrated online simulation environment is exemplified through illustrative case studies representing two plausible accidental grounding scenarios in the Gulf of Finland: one resulting in oil spill of about 50 t, while in the other the inner hull remained intact and no spill occurred.

## 1. Introduction

Ship groundings and collisions are among the major accident types in maritime transportation, both globally (Eliopoulou et al., 2016) and in specific sea areas (Valdez Banda et al., 2015; Sormunen et al., 2016a; Ventikos et al., 2017). Historic accidents have clearly shown that such accidents can lead to major oil spills, such as e.g. in the case of the Exxon Valdez grounding (NTSB, 1990) or the Heibei Spirit collision (MAISSPB, 2008) accidents. On the short term, major oil spills lead to very costly oil recovery operations (Montewka et al., 2013). On the longer term, they can have detrimental effects on sensitive marine ecosystems (Lecklin et al., 2011), cause disruptions to the sustainability of specific economic activities (García Negro et al., 2009), lead to high overall disutility costs (Ventikos and Sotitopoulos, 2014), and have sociocultural impacts and cause psychological stress (Gill et al., 2016). Hence, extensive governance frameworks have been established for strategic and operational planning of pollution prevention and response activities. These frameworks are typically transnational in nature, and have a legislative basis as result of political agreements between states with a common interest in protection of the marine environment. Examples of such legislative governance frameworks include the Helsinki convention for the Baltic Sea area (HELCOM, 2008) and the OSPAR convention (The Convention for the Protection of the Marine Environment of the North-East Atlantic) for the North-East Atlantic (OSPAR, 2007). Oil spills from shipping are also active areas of scientific research, both related to illegal discharges (O'Hara et al., 2013) and accidental spills (Li et al., 2016).

For strategic and operational pollution prevention and response planning, it is important to obtain an understanding of the oil drift in the sea area. This is relevant e.g. for planning the required response capacities in different coastal areas (Lehikoinen et al., 2013), or for tactical decisions where to locate which response equipment to minimize the negative impacts of the spill (Grubesic et al., 2017). Several oil spill drift models have been developed, e.g. OILTRANS (Berry et al., 2012), GNOME (Marta-Almeida et al., 2013), and Seatrack Web (Ambjörn et al., 2014; Arneborg et al., 2017). Several applications of such oil drift models have been presented in the literature, providing insights in the effects of spills in particular sea areas, e.g. in the Finisterre Traffic Separation Scheme (North-West Iberia) (Otero et al., 2014), the Chinese Bohai Sea (Liu et al., 2016), and the Arctic Ocean basin (Blanken et al., 2017).

Typically, applications of oil drift in sea areas for oil spill response planning rely on assumed oil spill scenarios, either applying worst-case accidental spills or more plausible spills based on best available expert judgements. Improving the definition of the oil spill scenarios is possible e.g. through making use of data from historic spill sizes (Dalton and Jin, 2010), or applying dedicated oil spill consequences models for shipping accidents. Several such models have been proposed, e.g.

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simple regression models (Lee and Jung, 2013) or more comprehensive models based on the evaluation of damage to the vessel in accidental conditions (van de Wiel and van Dorp, 2011; Goerlandt and Montewka, 2014). Presently available models however have significant limitations, as these rely on the conservative assumption that all oil of damaged ship compartment is spilled, and include no time-dependency in the oil outflow dynamics. However, experiments (Tavakoli et al., 2011) and analytical models (Kollo et al., 2017) clearly indicate that, depending on the conditions, large fractions of the oil can remain inside the damaged vessel. These also show that the oil spill can take a long period of time.

This paper closes this gap by presenting and applying a novel model for assessing the oil outflow in a tanker grounding accident, and its implementation in an online platform simulation environment. This Accidental Damage and Spill Assessment Model (ADSAM) relates the main dimensions of typical tankers with information about tanker design configurations, enabling accurate oil spill estimates also with limited information about the tankers, e.g. only the data available from the Automatic Identification System (AIS). Based on a specified accident scenario, the model determines the accidental damage extent, which is subsequently used to assess the time-dependent oil outflow from the grounded vessel. In its current form, the model can only handle hard groundings with rigid rock. Novelty of the model is its capability to operate with only very limited data and the connection to the oil outflow model. Thereby, the model delivers an easily interpreted outcome in a form of spilled oil amount and duration, instead of more abstract collision force or absorbed energy. The online ADSAM platform can be used by experts with minimal to no previous knowledge about grounding simulations.

The applied damage scenario can be defined in strategic response planning based on expert judgment or based on knowledge extracted from accident analyses (Goerlandt et al., 2017a). In tactical response planning, the actual accident scenario can be deduced from on-site observations and/or from information available in Vessel Traffic Service (VTS) or in response coordination centres.

The rest of this article is organised as follows. Section 2 provides an overview of the accidental grounding oil spill model, including the scenario definition, damage extent calculation method, and method for oil outflow assessment. Section 3 describes the online platform, which aims at facilitating the use by response practitioners. Section 4 focuses on the sensitivity and uncertainties involved in ADSAM model. In Section 5, the model and online platform are exemplified through two case studies of plausible grounding accidents in the Gulf of Finland. A discussion and conclusions are provided in Section 6.

## 2. System description

The architecture of the model forming the ADSAM online platform is presented in Fig. 1. The application of the model starts with the definition of the ship and the accidental scenario. The system is aimed to be used also in situations, where only limited data is available for ships. The system can simulate the scenarios where the only available parameter is the ship's length $L$ and the other ship parameters are defined either from statistics or based on minimum rule requirements, see Section 2.1. The scenario is defined via ship size $a$, the penetration depth $\delta$, the location of the initial contact between the ship and the rock, and the season of the accident. Optionally, several other parameters can be provided such a ship's structural resistance, double hull dimensions, loading conditions, cargo characteristics, tank arrangement, ice conditions for wintertime accident simulation etc. Once the ship and the scenario are defined, the size of the damage opening is calculated as explained in Section 2.2. The dimensions of the damage opening are input for the oil spill model (Section 2.3), where the amount and duration of the spill is defined based on the damage size and the loading conditions.

This information can be further passed into the oil spill propagation model SeatrackWeb (SMHI, 2012) and to the environmental consequence models such as SmartResponseWeb (Aps et al., 2009, 2014), where the spatial and temporal spill propagation can be evaluated and the environmental consequences can be assessed. However, these links are not described here. With all these simulation tools combined, the accidental outcome can be presented not only as a description of structural damage or as the amount of oil spill, but the outcome becomes dependent on the weather conditions that affect the location and the length of the impacted shoreline as shown in (Tabri et al., 2015).

### 2.1. Definition of ship parameters

The scenario definition includes the description of the ship involved in the accident and the main characteristics of the accidental scenario such as the water depth and the bottom topology. In pollution prevention and response operations, it is typical that not all the required parameters to define the ship are given (Grubesic et al., 2017), because of which several parameters have to be obtained from statistics or as minimum requirements put on by the rules. For example, the main dimensions of the ship are rather easily obtained, while the dimensions of its double-bottom or the information on the tank arrangement is not equally readily available. In order to operate, the ADSAM model requires as a minimal input the length of the ship. In order to obtain the potentially missing data, two sources of data are utilized; (i) - the traffic data of the tankers navigating in the studied area based on the AIS data of the Gulf of Finland from the year 2012, obtained from HELCOM-statistics (Baltic Marine Environment Protection Commission - Helsinki Commission); (ii) - The characteristics of the tankers navigating in the Gulf of Finland, such as main dimensions and deadweight (DWT), are extracted from the IHS Fairplay® (IHS, 2013) database connecting the ship's IMO number to its main dimensions and technical parameters.

The IHS Fairplay® database provides the statistical dependency between the various characteristics of the typical tankers navigating in the area. Fig. 2 shows the statistical relations between length and DWT and draft of the tankers navigating in the Gulf of Finland as examples. Similar dependences are constructed for other main parameters such as breadth, side height, etc.

If the tank arrangement is not provided, the number of tanks is assumed based on (DNV, 2013) as follows:

- for ships with L < 105 m four tanks in longitudinal direction are assumed
- for ships with L < 125 m five tanks in longitudinal direction are assumed
- for ships with L ≥ 125 m six tanks in longitudinal direction are assumed
- for ships with L ≥ 105 m, central longitudinal bulkhead is assumed.

The minimum value for the double-bottom height is defined as follows:

- $h_{db} = \frac{B}{20}[m]$ for $L < 150$ with minimum 0.76 [m] and maximum 2 [m] (DNV, 2012; DNV, 2013)
- $h_{db} = \frac{B}{15}[m]$ for $150 \leq L$ with minimum 1 [m] and maximum 2 [m] (DNV, 2010)

The minimum value for the double-side width is defined as follows:

- $W_{ds} = 0.05 + \frac{DWT}{20000}[m]$ for $90 \leq L$ with minimum 1 [m] and maximum 2 [m] (DNV, 2010)

### 2.2. Damage assessment in grounding

In ship grounding, the initial kinetic energy of the ship is transformed into structural deformation energy and into work done to overcome the forces from the surrounding environment such as