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Use of a probabilistic particle tracking model to simulate the Prestige oil spill

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Abstract

A probabilistic particle tracking model is used to simulate the oil dispersion after the Prestige wreckage. This oil spill constitutes a suitable benchmark to analyze the capabilities of a probabilistic model, since the time elapsed from wreckage to oil landing (12 days) is much longer than the reliability time associated with forecast winds, usually on the order of 3–4 days. The particle model can be run in two different modes: real time mode (when existing reliable wind fields for the event under scope) and in probabilistic mode (in absence of reliable wind fields but with historical fields corresponding to a similar period). The validity of the particle model is first evaluated in a hindcast way, running the Prestige case with the wind fields corresponding to the period November 19 to November 30, 2002, which were not available at the moment of the wreckage. Calculations show the accuracy of the model to provide the right impact point and timing. The probabilistic model is then used to simulate the same event by means of historical data. The region where the oil landed is shown to be the area with the highest probability to be impacted.

Keywords: Oil spill; Probabilistic particle tracking models; Prestige

1. Introduction

Marine pollution events are a major concern nowadays. An essential element for oil spill management is the assessment of risk for coastlines and nearshore waters that are considered to be vulnerable to damage by oil pollution. Although there are a number of regulations in place, the problems of ship structural weaknesses, traffic control systems and others are still to be solved. All these unsolved problems have a direct influence on the risk of accidents.

All maritime countries agree on the necessity of putting in place tools to better respond to marine pollution emergencies. Such tools, which aim to provide the best possible information and decision support systems for spill response organizations, are usually based on: emergency planning (risk assessment, command chain, decision trees, communication); environmental information (ecosystems, geomorphologic, human occupations); logistical and infrastructure for emergency response; models (operational or probabilistic); and informatics (GIS and database platform). These tools can be summarized in a contingency planning, which should evaluate not only the probability of a region to be influenced by spilled oil, but should also assess the time taken for the oil to reach the location, as well as estimate the exposure of the region to oil.

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The use of numerical models to predict the movement and diffusion of water borne pollutants is widespread (Reed et al., 1999; Elliott and Jones, 2000). Pollutants at the sea surface are transported by a combination of currents, winds and waves. Oil near surface moves at a speed between 1% and 5% of the wind speed (Smith, 1976; Large and Pond, 1981; Elliott, 1991), being the net transport of the whole spill about 3% of the wind speed. According to Jones (1999), a buoyant spill drifts at approximately 0.3 m s^{-1} under moderate winds (10 m s^{-1}). Mean (i.e. non-tidal) currents, away from the major ocean gyres, are typically less than this speed and the medium term (1–4 weeks) transport of such spills tends to be wind dominated.

In order to make oil spill contingency calculations it is necessary to have access either to a deterministic archive of recorded winds, or to make use of statistical descriptions of the wind field which have traditionally been provided by wind roses. However, wind roses do not contain information on the time variability of the wind such as the duration of wind events and the probability of the transition between wind directions. These deficiencies can be remedied through the determination of the dominant time scales and the derivation of a direction transition matrix that describes the probability of two specified wind directions following in succession. Using these concepts, Elliott (2004) developed a probabilistic description of wind with application to oil spill simulations.

Galicia (NW, Spain) is situated in one of the most important maritime routes with numerous merchant ships crossing through its waters and even close to the coast. The frequent storms which affect the coast during winter time have provoked a large number of accidents. Actually, three notable oil spills have affected the Galician coast from the seventies (Urquiola, 1976; Aegean Sea, 1992 and Prestige, 2002). These spills seriously affect the local economy which depends on the richness of marine ecosystems (bivalves, octopus, sardine, sole and barnacle).

In the particular case of the Prestige, following Freire et al. (2006), the oil tanker loaded with a cargo of 77,000 mt of heavy bunker oil ran into problems off the Galician coast on November 13, 2002. After a 6-day odyssey following an erratic course, it finally sank 130 miles west off the southern coast of Galicia. Over the course of these 6 days about 19,000 mt of oil were spilled, and in the following months around 40,000 mt of fuel leaked into the sea with large slicks drifting towards the Galician coast. The oil spill reached first the Atlantic shores of Galicia and later the Spanish Cantabrian and the French Atlantic shorelines up to Brittany, and to a lesser extent, the northern coast of Portugal. This oil spill may be considered as one of the worst in history, both in terms of the type and volume of hydrocarbons spilled as well as the extent of the disaster, affecting the coastline, subtidal and continental shelf bottoms.

The Prestige oil spill constitutes a valuable test case to check the validity of the probabilistic method proposed by Elliott (2004). The wreckage took place at about 130 miles from coast, in such a way that oil landed more than a week later, which is an optimal time scale for a probabilistic approach. Note that real time simulations are especially valid near shore, when the delay between oil spill and impact is of only a few days. Nevertheless, this kind of simulation cannot be used in a forecast way when the event lasts more than 4–5 days since weather forecast accuracy decreases significantly beyond the next few days. On the other hand, there are numerous field data relative to the oil spill evolution. Finally, the Regional Weather Agency (METEOGALICIA) provides forecasted data with a fine resolution both in time and in space over the affected area.

The following study will be conducted as follows: first, the full wind data series corresponding to the time elapsed from the wreckage to the oil arrival to the coastline (12 days) will be used to validate the particle tracking model. Second, the probabilistic method (Elliott, 2004) will be used to determine the regions with the highest probability to be impacted by the Prestige oil spill.

2. Materials and methods

2.1. Area under scope

According to Gómez-Gesteira et al. (2006) the Galician coast can be macroscopically divided in three coastal areas (see Fig. 1); the western coast, stretching from the Miño River mouth to Cape Finisterre, with an approximate angle of 90° relative to the equator; the middle coast, from Cape Finisterre to Cape Ortegal, with an approximate angle of 55°; and the northern coast, from Cape Ortegal to Cape Peñas, approximately parallel to the equator. Wind field in this region is far from homogeneous due to the particular coastal geometry (Torres et al., 2003; Herrera et al., 2005). Summer and winter wind fields have a small number of dominant patterns which are not necessarily representative because summer patterns may dominate in winter and vice versa depending on the coastal area. Therefore, wind observations at a single point, coastal or offshore, will not necessarily be representative of the wind conditions along the entire coast. However, wind conditions inside each coastal region are quite regular (Álvarez et al., 2005; Gómez-Gesteira et al., 2006). In the case of the Prestige oil spill, the real oil trajectories from the wreckage to the landing point