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ORIGINAL RESEARCH ARTICLE

Calibration of backward-in-time model using drifting buoys in the East China Sea

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Summary In the process of oil exploitation and transportation, large amounts of crude oil are often spilled, resulting in serious pollution of the marine environment. Forecasting oil spill reverse trajectories to determine the exact oil spill sources is crucial for taking proactive and effective emergency measures. In this study, the backward-in-time model (BTM) is proposed for identifying sources of oil spills in the East China Sea. The wind, current and random walk are three major factors in the simulation of oil spill sources. The wind drag coefficient varies along with the uncertainty of the wind field, and the random walk is sensitive to various traits of different regions, these factors are taken as constants in most of the state-of-the-art studies. In this paper, a self-adaptive modification mechanism for drift factors is proposed, which depends on a data set derived from the drifter buoys deployed over the East China Sea shelf. It can be well adapted to the regional characteristics of different sea areas. The correlation factor between predicted positions and actual locations of the drifters is used to estimate optimal coefficients of the BTM. A comparison between the BTM and the traditional method is also made in this study. The results presented in this paper indicate that our method can be used to predict the actual specific spillage locations.

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1. Introduction

The East China Sea Shelf is adjacent to the South China Sea and the Yellow Sea and is connected with the Japan Sea via the Tsushima Strait (Takahashi and Morimoto, 2013), as shown in Fig. 1. It is known that the East China Sea Shelf contains large amounts of previously undiscovered oil over broad continental areas. At present, there are five oil fields in the East China Sea Shelf with the total area of 22,000 km^2. The development of oil drilling and transportation has posed a potential threat to the East China Sea ecological environment in case of oil spill. Due to long weathering period of an oil spill and northerly winds that prevail in winter in the region, the oil spill accidents are likely to harm a variety of marine biological resources and ecological environment (Liu et al., 2011), including the Zhou Shan fishing ground. In the summer, driven by wind field and Kuroshio, the oil spill can move across the East China Sea and reach Kyushu and Ryukyuan islands, resulting in local ecological damage (Andres et al., 2008; Guo et al., 2006; Ichikawa et al., 2008; Lee et al., 2001). Hence, it is crucial to identify possible oil spill sources and increase the emergency response efficiency. Currently, initial forecast information for oil spills derived from all kinds of numerical models is provided to scientific research institutions, marine industries, government sectors, as well as to the public, which helps increase the security and efficiency of marine navigation and increases the reasonable application of environmental resources in coastal seas (Alves et al., 2014, 2016; Cho et al., 2014; Lee et al., 2009; Park et al., 2009).

Simulating oil spill reverse trajectories can be dated back to the twentieth century, a couple of backward-in-time models have been presented by scientists from different institutions. Galt and Payton initially proposed the 'receptor mode' option (Galt and Payton, 1983; Torgrimson, 1981), using mean current and wind fields, which was then developed by the National Oceanic and Atmospheric Administration (NOAA). With the advent of more advanced technology, the more accurate prediction can be achieved. Lagrangian particle-tracking models (LPTMs) were developed and operated by the Oregon State University, in these models diffusive processes were included because the particles are not strictly passive (Batchelder, 2006). In addition, the two-way Lagrangian particle-tracking model (PTM) was proposed to identify oil spill sources integrating with constant random walk processes on the sea surface (Isobe et al., 2009). Ciappa and Costabile suggested a new reverse method using a sequence of current and wind data, which could be applied to several receptor points simultaneously (Ciappa and Costabile, 2014). Due to the wide application of backward-in-time methods, the reverse method has also been demonstrated to be effective in predicting accidental marine pollution in the physics of chaotic oil spill transport in the ocean (Prants, 2015).

However, recent Lagrangian backward-in-time models include only advective movement process or advection combined with simple directed diffusive movement process, and regional characteristics are rarely considered (Adlandsvik et al., 2004; Heath et al., 1998; Miller et al., 1998). In fact, as an important factor, the wind has strong uncertainty in different sea areas, to the extent that the wind drag coefficient cannot be simply defined based on an empirical value. In addition, irreversible random walk processes, a variable that contributes to oil spill movement, determined by the wind direction, density of oil, temperature and salinity of the water cannot be simply defined as a constant. In order to improve the accuracy and reliability of the BTM numerical method, both the optimal wind drag coefficient and random walk should be parameterized based on the characteristic of

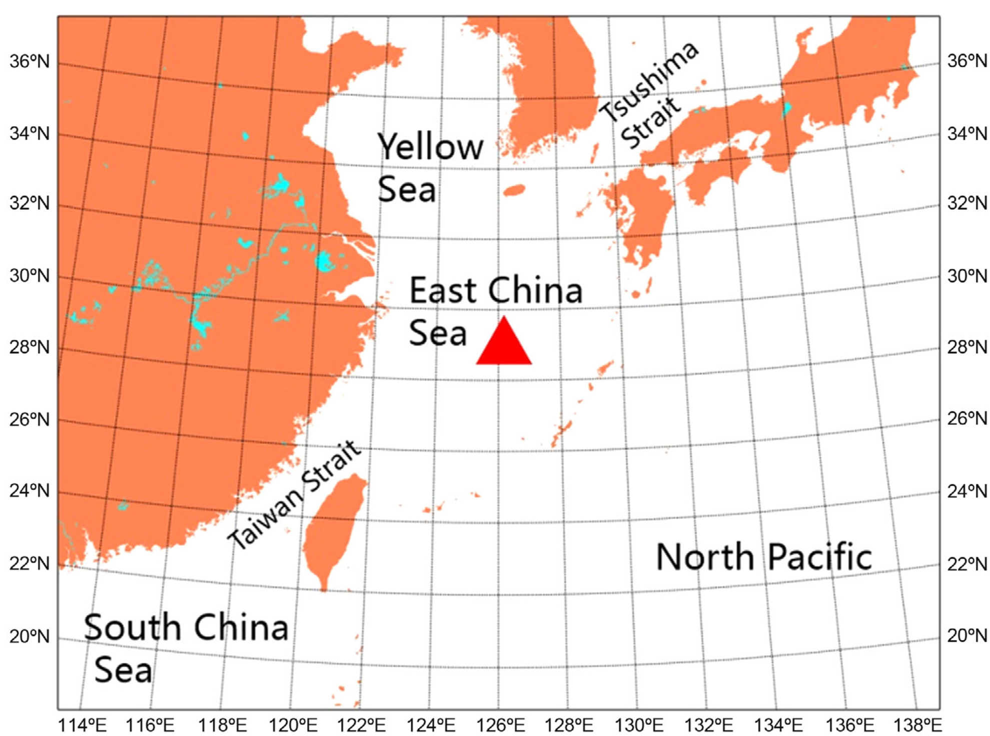

Figure 1 The schematic map of the East China Sea.