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Computational system for planning search and rescue operations at sea

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Abstract
The paper describes the main tasks and features for emergency interventions in the marine environment and describes the computation and information system required to support and planning fast and efficient operations. The most common causalities that activate emergency procedures are identified and the main features of the Search And Rescue (SAR) intervention are described as well as the inputs and details that are required. A more detailed description is given of the existing components for an integrated information system in the Portuguese coasts, from the computation of the environmental conditions to the adoption of dedicated graphical interface that provides all the necessary information in a clear and complete way.

Keywords: Search And Rescue, Marine emergency, Information System

1 Introduction

Safety in the seas has been more and more in the public attention and the political eye in the last decades (Guedes Soares and Teixeira, 2001). This is mainly to do with the damages caused by the major accidents that occurred, such has Herald of Free Enterprise (1987), Exxon Valdez (1989), Estonia (1994), Erica (1999), Prestige (2002), Costa Concordia (2012) and Sewol (2014). Considering that 90% of the international trades are made by sea (UNCTAD, 2007) and the steady increase of the world's merchant fleet, which grow of about 18% in ten years (reference period 2001-2011; Pike et al., 2013), Maritime Industry can be considered rather safe. Nevertheless the capability to effectively operate in emergency scenarios to prevent or to limit casualties and environmental disasters is an irreplaceable skill of any national government, often requiring the collaboration of the international community. Examples are the Marine Environment Monitoring Service, part of the Copernicus Programme within the European Union or the GODAE OceanView (Davidson et al. 2009) program that involves some of the most representative agencies and groups in the field, such as the US National

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Oceanic and Atmospheric Administration (NOAA), the Australian Bureau of Meteorology, the European Space Agency, the French Ifremer and many others.

The goal of Search And Rescue (SAR) in these scenarios is to use any available information such as “mayday”, current direction, wind direction and observations from rescue vehicles and find and rescue the target. Behind any SAR operation there has to be a well-established and coordinated system that collects and shares information before and during the operations and performs simulations of the possible path of the search target.

This paper gives an overview on the emergency operations at sea, considering the cases when an alert will activate the procedures (section 2) and the evolution to reach a strengthened and more standardized approach (section 3). The development of a forecast computational system to support emergency operations in the Portuguese coasts is described in section 4. Finally some consideration on the importance of a robust computational and information system in the crucial objective of reducing the time of intervention with a successful result will be highlighted in section 5.

2 When emergency intervention is required

Whenever an object without an active propulsion system is lost on the sea-surface, it is subjected to forces caused by the surrounding environment, mainly due to the effect of wind and surface currents. Those forces cause the drift of the object that will move from the original position; the amount of motion is called leeway (Allen and Plourde, 1999).

Such an emergency scenario can be caused by many accidents such as the fall of men, objects or hazardous material overboard, the launch of life rafts or the loss of an airplane in the ocean. In all these cases it is necessary to activate procedures aimed at finding the missing object or person in the shortest possible time. To do that a precise estimation of the track of the object must be provided in short time to the search and rescue group in order to delimit the search area, optimize the available SAR units to be exploited and start the operations, maximizing the probability of success.

From a modelling point of view, this is a similar problem to the assessment of the path of accidental oil spills (Sebastião and Guedes Soares, 2003) or the trajectory of icebergs (Korsnes & Moe, 1994).

In all these causalities the factors that strongly influence the evolution of the scenario are the real-time and predicted wind (Breivik et al., 2011), the near-surface current (Hackett et al., 2006) and the waves (Röhrs et al., 2012), which cause the drift of the object. Thus quickly available and well-organized information about those factors can be determinant in the success of the operation. Information regarding the sea temperature to estimate the survival time (if people are on the water) and the visibility can improve the awareness in the allocation of recourses.

3 Search And Rescue main features

There are three fundamental theories that establish the bases of the search and rescue operations: the search theory outlined by Koopman (1956a, b; 1957), the studies on how a target object moves in the ocean (Washburn, 1980) and the weather forecast. The improvements in all these strongly depend on the improvements in the computer science, but in a different way. For the search management a robust and efficient information technology must be applied to store and exchange all the necessary information. Near-real-time forecast of environmental conditions at a high-resolution level requires fast computational routines and the assimilation of new available data during the operations.

Finally an assessment of the uncertainties in the path prediction is important in order to determine the area of possible drift of the object, as exemplified in the case of oil spill by Sebastião and Guedes Soares, (2007).

From the operational point of view, starting from the 50s, United States Coast Guard (USCG) promoted the main steps towards a standardization of the SAR procedures. Due to the poor computational capabilities of that time, they provided the guidelines for the manual calculation of the search planning methods, which have been later on implemented in a computer-base system. The Bayesian statistic played an important role in the Computer-Assisted Search Planning (CASP; Richardson and Discenza 1980) implemented in 1974, which estimated the location of the object giving a probability distribution produced by the Monte Carlo method.

The main weaknesses of these methods were the very simple drift model adopted to assess the particle motion and the coarse and poorly reliable forcing fields. In order to face these problems, the USCG started a program to measure surface current in near real-time, the Self-Located Datum Marker Buoys (SLDMBs; Davis, 1985), that now provides more and more reliable and detailed information and gives a great contribution in operational SAR. At the same time also the improvements of the numerical weather prediction models (Simmons & Hollingworth, 2002) contributes to a better definition of the forcing fields.

In 2007 the Search And Rescue Optimal Planning System (SAROPS; Kratzke et al., 2010) started to be operative. It consists in a user interface, an environmental data server that gathers wind and current data and prediction from different sources and a simulator that provides recommendations for the search path of the employed units. It has been thought to minimize the time in the chain from the receiving of the alert and the rescue and assistance.

The main problem remains the evaluation and reduction of the uncertainties. Usually stochastic models are adopted in the modern SAR planning to take into account the unknowns in the search object but not in the forcing fields. Studies of the effect of using the computational expensive full- or multi-ensemble models have been conducted in the last years (e.g. Scott et al. 2012) after the introduction of true ocean model ensembles. However the overall cost-benefit has still not been clarified.

Normally the drifting models neglect the direct effect of waves because only if the wave-length and the object dimension are comparable the excitation and damping forces are considered relevant (Mei, 1989). Nevertheless Röhrs et al. (2012) highlighted the importance of taking into account Stokes drift. It must be noted that in most of the cases the relations between wind and leeway are empirical (Allen and Plourde, 1999) and it makes difficult if not impossible to distinguish between the effect of wind and of the Stokes drift.

4 Computational implementation for the Portuguese coasts

In figure 1 a general scheme summarizes the operations that follow the reception of an alert. Firstly all the data regarding the emergency case (e.g. location of the loss, type of object, dimensions, etc) must be collected and always updated in a standard format and immediately available to all the subjects involved in the operations. The environmental condition is then assessed by means of numerical models and, when available, real-time measurements and used to assess the search object path and to build the probability density map. This information will then allow verifying the availability of the SAR units which are more suitable to be activated in the particular scenario and to plan the active intervention. Finally it is of prime importance that both the weather data and the ones relative to the searching object are updated with in-situ information during the intervention.

High-resolution models are required to resolve the mesoscale features in the regional circulation systems that can significantly contribute to the drifting forces. Moreover it must be considered that most of the interventions are within 40km from the shore (Breivik and Allen, 2008) where an even higher resolution can be necessary to describe the interaction of the circulation features especially in the presence of complex topographic structures such as canyons or caves and even the effect sea breeze should be included for successful estimations (Carretero et al., 2000).

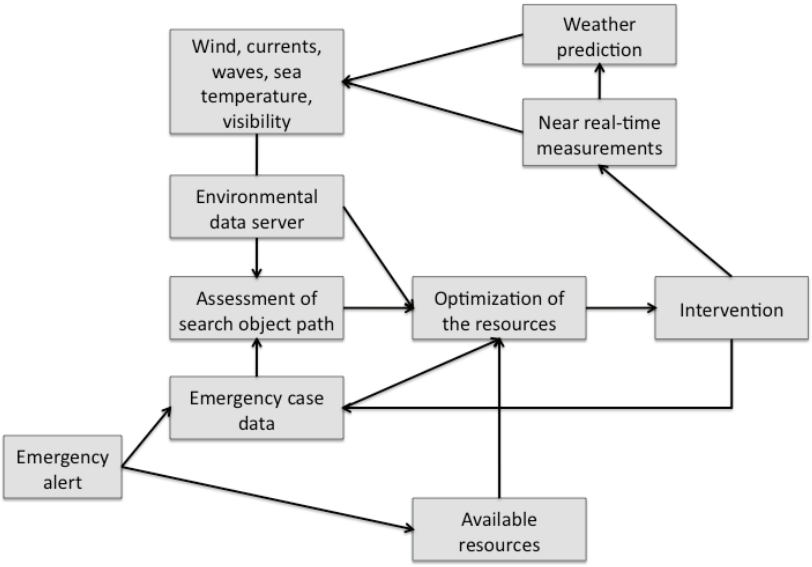

Figure 1. General scheme of intervention.

An operational forecasting system for the Portuguese coasts has been developed and validated (Guedes Soares et al. 2011) and is operational since October 2008. It is based on a set of nested grids with higher resolutions (up to 4.1km) in the most critical areas, such as around the archipelagos of Madeira and Azores and in the coasts between Lisbon and Sines in the south and Porto and Viana do Castelo in the north. It provides waves and wind predictions for a time window of four days. It uses the Fifth-Generation NCAR/Penn State Mesoscale Model (MM5; Grell et al. 1994) designed to predict mesoscale and regional-scale atmospheric circulation and two state-of-the-art third-generation spectral wave models WAM Cycle 4 (WAMDI Group, 1988) and SWAN version 40.51 (Booij et al. 1999) for the propagation to the coastal environment. The atmospheric model MM5 is presently being upgraded with the more recent WRF model (Salvação et al 2014). The system must be coupled with a surface current prediction model to take into account ocean and tidal currents, which have been already studied in Sauvaget et al. (2000) with a resolution up to 1km capable to interface World Ocean and coastal circulations. It has also been used for computation of combined tide and wind currents.

Once the forcing are established, the trajectory of the search object or oil mass (Beegle-Krause, 2001) have to predicted and sent to the management unit that as an input for a Geographical Information System (GIS) tool for storing, analysing and displaying data for the decision maker. A pre-operational system for oil spill simulation on the Iberian Peninsula has been developed (Sebastião and Guedes Soares, 2003). It allows simulating and visualizing the trajectory and fate of oil spills taking into account wind waves and currents. The system can be upgraded by including models for the assessment of the drift of different objects.

5 Conclusions

The main characteristics and requirements to provide information and assist operations in marine emergency events such as search and rescue interventions or oil spills environment protection activities have been described. The most important aspects to improve these important operations can be summarized as following:

- uncertainties in the prediction of weather or in the characteristic of the search object can significantly affect the results and the extension of the search area (thus the duration and efficacy of the operation);
- forcing fields must be carefully modelled taking into account the effect of many environment factors besides wind and near-surface current, for instance Stokes drift;
- local high resolution models are necessary to resolve the mesoscale features and the eddy activities near-coast where most of the operations are required;
- the assimilation of near real-time data in numerical models must be improved adopting new observing platform to increase the reliability of the input data;
- providing spatial data management and visualization GIS tools specifically designed to support decision in maritime emergency reduces the time of intervention and allows a better optimization of the resources, increasing the probability of success.
- computational forecasting models for waves, wind and currents as well as for oil spills trajectories have been already constructed for the Iberian Peninsula and they can be integrated in a comprehensive system to support emergency operations.

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