From a nowcast-forecast information system to an oil spill risk assessment and response tool

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Abstract

This paper presents a custom developed WebGIS tool tailored for oil spill risk assessment and emergency response in coastal areas, built on a nowcast-forecast information system. The latter system was based on the custom deployment of a generic forecasting platform that integrates a suite of forecast models, as well as on the recent improvement in the models outputs visualization. Further developments have been made to support real-time monitoring through remote sensors and automatic comparison between data and model predictions. The system has now evolved to an integrated system that can assist in oil spills risk assessment and the rapid response to a possible emergency, as oil spills can have catastrophic effects both social-economic and environmental, endangering the sustainability and development of the coastal regions affected. The tool presented herein addresses the oil spills problem in two ways: a detailed risk assessment through risk maps and georeferenced information related with coastal areas, ports and estuaries to support the prevention and mitigation of accidents; and the visualization of georeferenced oil spill predictions produced by a real-time oil spill forecasting system.

Keywords: coastal oil spills, real-time forecasting, spatial data, nowcast-forecast, coastal systems, visualization tools

1 Introduction

1.1 Overview

Natural and man-made disasters worldwide, like oil spills, may induce damage of catastrophic proportions, affecting both human lives and property (Dietrich 2012). Even if the accidents and their consequences are unpredictable, many prevention and mitigation actions can be done to reduce the severity of the disaster effects. These problematics have being the motivation to create specific advanced tools to assist emergency agents in such environmental disasters, taking into account the various forcing mechanisms and relevant processes of oil spills in estuarine and marine environments.

Nowcast-forecast information systems are part of this effort (Gomes et al 2013), by integrating remote monitoring networks, distributed or parallel computing resources (due to high-demanding computation processes), either for short forecasting or resulting data analysis, and web-based information systems to support timely management decisions. In particular, coastal nowcast-forecast systems (Jesus et al 2012) are now operational tools for the management of harbors, marine resources and emergency operations, which provide precise and timely information on waves and currents conditions.

Building coastal nowcast-forecast systems that detail all processes of oil spill evolution and pathways can improve their importance as a real effective asset for coastal managers, oil companies and consulting firms. Indeed, they can significantly improve local contingency plans and contribute to effective emergency management and early warnings issue to protect assets at risk in the event of accidents.

2 Motivation

RDFS-PT is a custom-made, modular, able to accommodate several types of models, with several temporal and spatial scales and domain discretizations applicable for different types of water bodies, nowcast-forecast system for the Portuguese water bodies. Currently, it includes the wave prediction in the Portuguese coast, the hydrodynamic and water quality forecast at several estuaries and the drainage prediction in the largest urban basin in the Lisbon area (Jesus et al 2012, David et al 2013).

The main goal of this paper is to present new developments on RDFS-PT to include a new methodology on oil-spills management. It aims to optimize contingency plans at the local level in coastal areas, harbors and estuaries and provide real-time forecasts of the evolution of oil plumes in the event of an accident.

The proposed methodology was divided into two distinct phases with different purposes (Azevedo et al 2013). The new tool on RDFS-PT will be used as: i) risk assessment tool – in which the risk analysis support is based on the region's climatological scenarios, used to build a database of simulations of the most frequent hydrodynamic regimes, and also the more favorable scenarios for the occurrence of an oil spill (this set of hydrodynamic simulations are based on several simulation runs of spills, at various points of the domain and different types of oil), ordered by the probability of occurrence.; ii) a real-time forecast system of the evolution of oil plumes – consisting on the development and validation of an oil spills emergency support system, combining a multi-scale oil modeling system, based on the the integration of a numerical model 2D/3D oil spills (Azevedo et al 2009 and Azevedo 2010) with a real-time forecasting system (RDFS-PT).

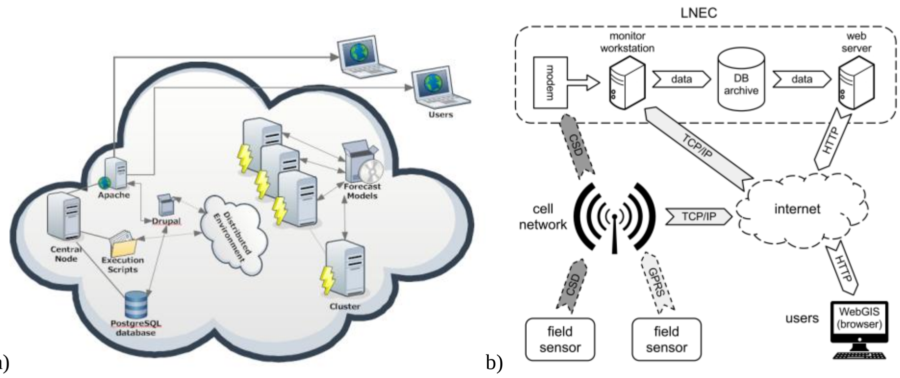
Since the beginning of the RDFS-PT development, it was recognized that one of the easiest and friendliest ways of reaching stakeholders and/or end users is to produce images and animations integrating the products of the running forecast models. Recent advances take advantage of the several visualization tool boxes, many of which support GIS (Geographic Information System) capacities.

3 Recent developments on RDFS-PT

3.1 Overview of RDFS-PT architecture and technologies

Several computer servers and a shared file server constitute RDFS's physical architecture. The shared file server provides physical storage for all models' outputs and tools for accessing data and managing the daily, real-time forecasts. The connections between the hardware components and the used files, web and database servers, as well as how users connect to RDFS-PT through a web browser are shown in Figure 1a.

The RDFS-PT forecasting process runs on daily basis, executing the forecasts scripts and producing results outputs, among others, with a permanent interaction with the database in order to get the physical location of the running forecast model and remotely generating the products through the central node.



a) b)

Figure 1. a) Physical architecture of the RDFS and b) general overview of the real-time data collection

The final results can be visualized using the RDFS user interface (UI). This UI is basically a customized deploy of Drupal, a PHP-based Content Management System (CMS), that is used to access model metadata, status and products. GIS support for the generated products and to provide a more interactive and intuitive UI for their visualization was also included. Map server support (Geoserver) and Web Map Services (WMS) have been added to the RDFS-PT, allowing geospatial placement of products, as well as model output query capabilities. The Web Geographic Information System (WebGIS) is being developed in Flex, using the OpenScales library to handle geospatial information. This WebGIS is built in a modular and generic way, allowing not only the visualization of RDFS data, but also spatial data from other sources (Figure 1b).

This platform provides forecasts of several variables in selected water systems, validated by data in near-real time. The user has the possibility to compare the results of the numerical model with the data downloaded from the instruments in-situ, thus evaluating the performance of the modeling system whenever he wants.

3.2 Oil spills model integration

The RDFS-PT platform was composed of three open-source models, Wave Watch III (WW3) for wave forecast, and ELCIRC and SELFE for hydrodynamic runs. Recent new developments towards an oil spills emergency management led to the integration of oil spills model VOILS that calculates the transport and transformation processes of oil on the surface and in the water column. VOILS contains the most significant processes for the transport and rheological changes of the oil, such as advection, evaporation, scattering at the surface, emulsification, dispersion and dissolution in the water column and coastal retention. It is particularly suited for the representation of complex coastlines and coastal studies, as it based on unstructured meshes to simulate physical processes on a multi-scale approach and multi-level.

3.3 Improvements on GIS products querying capabilities

Daily-generated products are developed automatically for each type of model forecasting and published on Geoserver to be mapped in the WebGIS tool. Till now the graphic visualization through isoline-based time frames images was the only way to get an insight on the models results. A recent development on RDFS-PT allows querying data on-the-fly, where the user chooses a pair of coordinates by mouse click and selects the pretended product and level, getting a chart of the selected data and its corresponding information table (Figure 2b).

a) b)

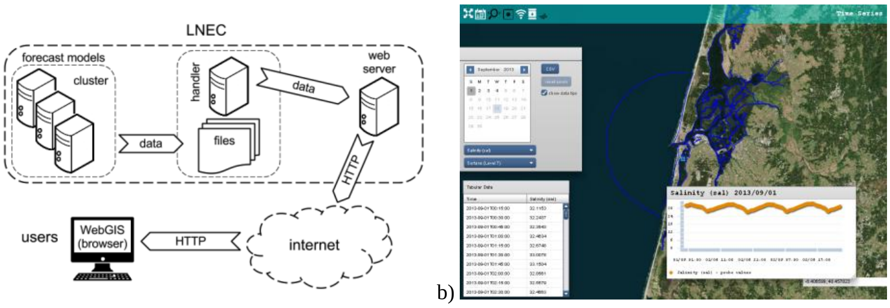


Figure 2. a) general overview of the on-the-fly products querying and b) example of GIS output

SELFE and VOILS models output their results in a well-known format NetCDF. Querying a high amount of data remotely demands a straightforward process to do so, in order to be fast and effective. The process is described in Figure 2a and technology-wise consists on a web service developed in Python with NetCDF library.

4 Introducing an Oil spills emergency management tool

4.1 Risk assessment tool

The RDFS-PT UI presented previously was not developed to be used to this particular goal, but the mentioned modular capabilities allowed it. In order to fulfill the methodology of a risk assessment tool, several geographical feature maps had to be incorporated: sensitivity maps; vulnerability maps; hazard maps; and risk maps. Along the database referred in Section 2 these maps contain also georeferenced environmental susceptibility index, the vulnerability index and information regarding resources available for spill response, etc.

Subsequently, considering the richness of the geographical information, a detailed risk assessment is made available to coastal managers through the WebGIS tool. It is possible to consult online all maps required as well as to take advantage of several analysis tools inherent in a GIS environment (Figure 3).

This tool proves to be of great benefit to the development and optimization of the contingency plans and the proper management of logistic resources to mitigate spill accidents. In the RDFS-PT Hazard Maps WebGIS UI, it is possible to scroll through a database with all the possible scenarios of an oil spill occurrence (see Figure 4), so coastal managers can perform training actions based on the simulated scenarios, as well as review existing contingency plans to mitigate efficiently the consequences of a spill.

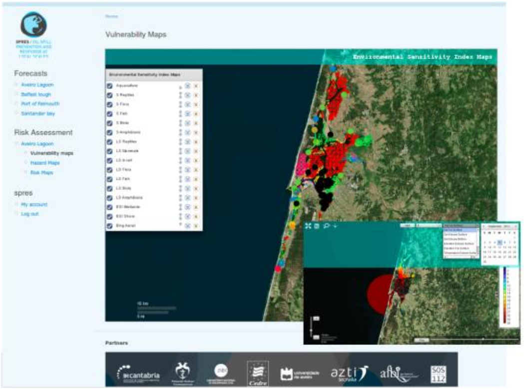


Figure 3. RDFS-PT UI with Environmental Sensitivity Index Maps and salinity product visualization

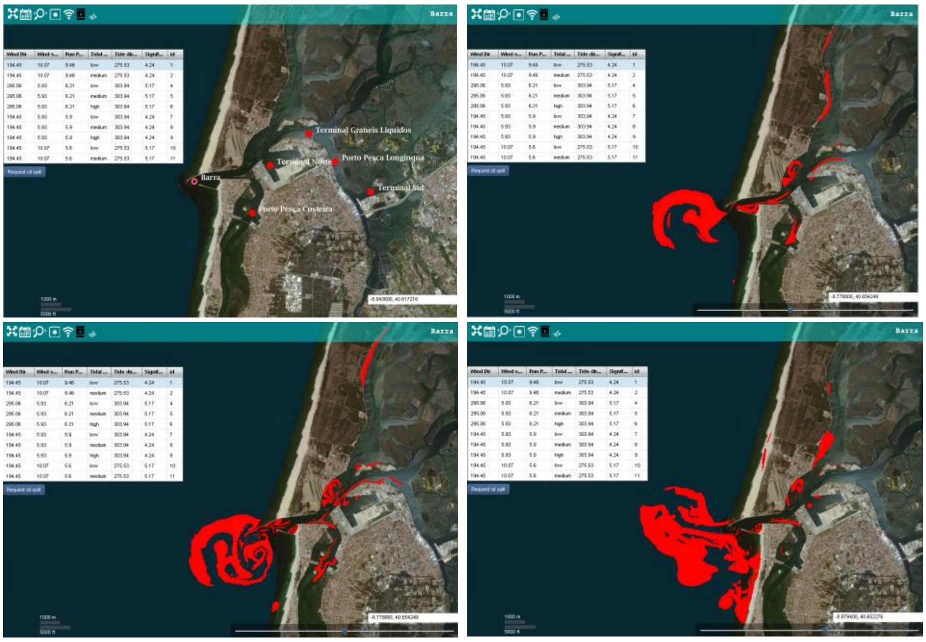


Figure 4. Screens of the WebGIS tool running one oil-spill scenario simulations, showing different visualization steps.

4.2 Operational oil spill simulator tool

In an operational oil spill simulator tool a real-time forecast system of the evolution of hydrocarbon plumes is required. The processes of coupling SELFE hydrodynamics forecasts with the VOILS oil spill simulations, that will produce daily forecasts of the evolution of the plume simulating an oil spill occurrence at various sites, is still under-development. The end result will be similar visually to Figure 4, but instead of a pre-determined scenario, the stakeholders can analyze a possible spill in a forecast window and the related impacts.

The future operational tool will integrate, besides the real-time forecast of the evolution of a plume, an on-demand oil spill simulator. With this simulator a stakeholder can input all the current variables related with a hypothetic spill, such as oil type and quantity, time of occurrence. Using these inputs the spill simulation is run in the servers, using past or forecasted hydrodynamics. The customization aspects of this tool allow the emergency agents to act timely and to reduce possible catastrophic damages.

5 Conclusions and future research

Our vision is to develop a multi-purpose, broader nowcast-forecast information system. The current RDFS-PT is now a few steps closer towards a broader nowcast-forecast system and an emergency management system. It includes now oil spills and other water quality issues. In the future it will integrate satellite data products, and an early warning system for coupled circulation due storms surges, waves, tides and river floods, targeting the extended application of the European Flood Framework Directive to river-to-coastal domains.

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