An integrated framework for implementing operational coastal models

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Abstract: The process based, spatially distributed numerical models included in the MOHID Modelling System have a large spectrum of application, but its complexity poses challenges to model implementation and operationalization.
MOHID Studio (Graphical User Interface) and ACTION Server (operational service) aims to, i) ease model implementation, providing straightforward pre and post processing tools, (ii) operationalize global/regional model results downloads (e.g. GFS, Mercator), (iii) operationalize data downloads from monitoring networks (e.g. SNIRH) (iv) operationalize high resolution local model runs (e.g. MOHID, WRF) and (v) publish results via different formats (emails, RestAPI, WMS). Many of these technologies are being developed in the context of the European research projects MARPOCS and MARINER.
The work will present an example of a fully working implementation of the system in the Douro Estuary and Leixões seaport. In this place two operational models (MOHID and WRF) are implemented and a mobile friendly user interface allows to visualize the results and run on-demand simulations.

Key words: MOHID, WRF, operational modelling, port operations.

1. INTRODUCTION

MOHID Modelling System has been developed since the 80's, started as 2D model in coastal areas (Neves, 1985) and capabilities were successfully enlarged to water quality (Portela, 1996), tridimensional flows (Martins, 2000), oil dispersion, effluent dispersion, sediment transport and consolidation, resulting in a numerical model for surface water bodies (MOHID Water), which has been applied to large variety of scales and challenges (www.mohid.com).

The model capability of describing different complex systems (interaction between tide, currents, atmosphere, bottom, river input, property transport, near-field and far-field outfall and spill processes), create a high level of complexity also for the end-users, having to deal with all the model input data files, pre-processing of data (download of data, conversions to MOHID formats and to model grids) and post-processing of results.

MOHID Modelling system has a large list of publications[1], representing a mature state-of-the-art modelling reference where recent implementations focus on management driven solutions as bathing water early warning system (Viegas et al., 2012), and the development of operational systems for coastal water quality management (Fernandes et al., 2016, Fernandes et al. 2013, Brito et al., 2015, Mateus et al., 2012).

The need for alert and operational systems to take the predictive capacity of the models make it almost impossible to run such kind of system manually.

In order to overcome the complexity to operate these kind of systems ACTION MODULERS developed a set of solutions, in which MOHID plays a central role, addressed to advanced modeler and to decision makers in the water business.

One of the solution developed, ACTION Seaport, was implemented for demonstration purposes in Douro Estuary and Port of Leixões. This demo provides daily metocean forecasts and allows running passive tracers, oil spills, search & rescue on-demand simulations through a mobile friendly web interface.

2. THE MODELLING INTEGRATION FRAMEWORK

The framework that integrates external data sources and numerical models and provides user interfaces for the user is presented next.

[1]http://wiki.mohid.com/wiki/index.php?title=Mohid_Bibliography.

2.1. External Data sources

The framework can integrate data from several external data sources, such as data from monitoring networks (e.g. meteorological stations, hydrographic buoys), numerical predictions (e.g. weather forecast), static geographic layers (e.g. coastal sensitivity index) and dynamic data layers (e.g. vessel positions obtained from Automatic Identification System (AIS) – Marine Traffic[2] AIS data is seamlessly integrated with the platform).

2.2. Numerical Models

The framework allows installing different modelling tools with three main objectives: i) run numerical models for scenarios (or hindcast periods); ii) run numerical models in an operational way in order to refine the hydrodynamic / meteorological solutions obtained from global numerical predictions; (iii) perform on-demand simulations on top of operational results (using the best available hydrodynamic / meteorological conditions).

The framework contains plugins for the following numerical models: (i) MOHID Water (hydrodynamic forecast), (ii) MOHID Lagrangian (spill simulations); (iii) Weather Research and Forecasting (WRF) model (meteorological forecast); (iv) Simulating Waves Nearshore (SWAN) model (waves forecast) and (v) ACTION MODULERS in-house ship traffic emission model.

2.3. Integration Platform

The integration platform is based on ACTION MODULERS' core products: i) ACTION Server and ii) MOHID Studio. These products are supported by a central data base.

2.3.1. Action Server

ACTION Server is a window's based application server, designed to make it extremely flexible to configure and install. Current features include, among others, plugins for downloading data from monitoring networks and numerical predictions and running operational models locally, as described previously. In addition, ACTION Server allows developing, with little effort, new plugins which allow processing data from local sources (e.g. hydrographic buoys, regional meteorological forecasts).

2.3.2. MOHID Studio

MOHID Studio is ACTION MODULERS' flagship product, used by hundreds of professionals worldwide. This product is normally used to pre-process, implement, post process and validate models from the MOHID Modelling System (MOHID Water, MOHID Land. MOHID River). This product can also be used to configure models to run operationally, to configure functional modules of ACTION Server, described earlier, and to visualise all data stored by the Integration Framework.

2.4. User Interfaces

In order to facilitate the usage of the framework for non-modelling experts, ACTION MODULERS also developed a mobile friendly web interface in order to get access to most relevant information produced by the system and to perform on-demand simulations using a user friendly wizard. These interfaces use a responsive layout, so it can be used from desktop clients, tablet and smartphones.

3. TEST CASE – DOURO ESTUARY AND LEIXÕES SEAPORT

The implementation to Douro Estuary and Leixões Seaport is a demo version of the ACTION MODULERS, ACTION Seaport product that is a generic Integration Framework product designed for port operation.

3.1. Site Description

Douro Estuary is 22 km long, with the tide propagation being limited upstream by Crestuma dam. The salt penetration depends on the river flow and tidal amplitude and can only reach the dam at exceptionally low flow conditions. The estuary consists of a narrow valley, with a minimum width of 135 m at the bridge D. Luís (6 km from the mouth). Downstream of the Arrábida bridge, the estuary extends reaching the maximum width of 1300 m.

Leixões seaport, located 4km north of the estuary, is one of the larger Portuguese seaports handling per year more than 2000 ships, around 30 000 000 gross tonnages, 17 000 000 tons of goods and 400 000 containers[3]. The volume of goods handling and ship traffic asks for management tools to aid for example in operation support and emergency response actions.

3.2. Action Seaport

ACTION Seaport is an integrated and novel solution to promote intelligent monitoring and enhancement of environmental, safety and operation performance for port and shipping activities, taking advantage of the combination of state-of-the-art model-based decision support systems and data management technologies developed in ACTION MODULERS along the recent years.

In detail, ACTION Seaport can be used to support and enhance the following Port activities:

- Operation support: navigation, pilotage and (un)loading support through the visualization of high resolution forecasts of marine weather conditions, including surface currents, wave and wind data;

[2] https://www.marinetraffic.com.

[3] http://www.apdl.pt/.

- Vessel tracking: including all relevant information about vessel general characteristics (e.g. length, width, MMSI, photo), voyage (e.g. origin, destination, ETA) and real time data (e.g. position, heading, state – anchored, moored, underway);
- Emergency response: support to marine pollution tactical response through advanced and reliable on-demand oil, chemical (HNS) and inert spill forecasting, as well as simulation of the drift of floating containers and search and rescue operations;
- Port performance indicators: continuous evolution of operational port performance indicators, including time, volume and movement elements from vessels (e.g. average ship turn-round times).

The system is able to publish, distribute and interface results in multiple traditional and technological platforms, including periodic digital reports, tailor-made SMS and email alerts, mobile-friendly websites, GIS desktop systems.

The conceptual design of ACTION Seaport is shown in Figure 1. This figure shows, on the top, possible data sources and, at the right, the numerical modelling tools and on bottom the outputs of the system. In the middle the integration platform with the functional modules is shown.

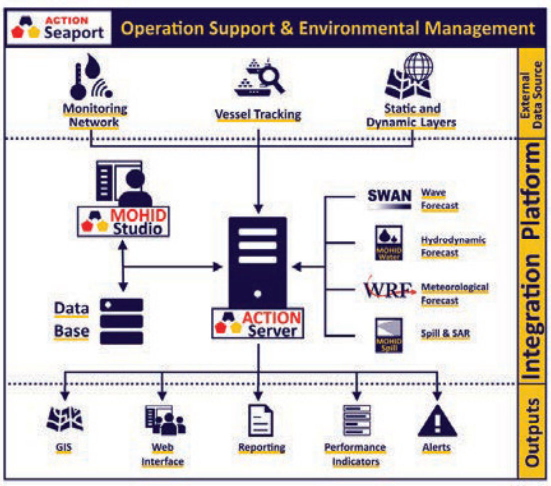

Fig.1. Conceptual design of ACTION SEAPORT.

3.3. Implementation

The specific implementation of ACTION Seaport in Douro Estuary and Leixões Seaport is a demo implementation of the system that runs operationally where:

MOHID Water model was implemented with:

- Horizontal grid with around 200x400 cells with cells of around 50x50 m
- Bathymetry obtained for the horizontal grid with Instituto Hidrográfico surveys
- Tide obtained from FES2004 global solution
- River inflow obtained from Crestuma reservoir data download (source: SNIRH[4])
- Meteorology from ACTION MODULERS WRF Portugal model implementation (9km resolution)

Vessels position are downloaded from Marine Traffic website every hour for the Portuguese Coast and coastal sensibility indexes are displayed based on Arcopol project outcomes[5].

These components are presented in demo web site (http://seaportdemo.actionmodulers.com) where forecast and historic model results are shown in form of maps and time series. Crestuma data is also presented in time series. In map format is also presented vessel positions and coastal sensitivity indexes – Figure 2.

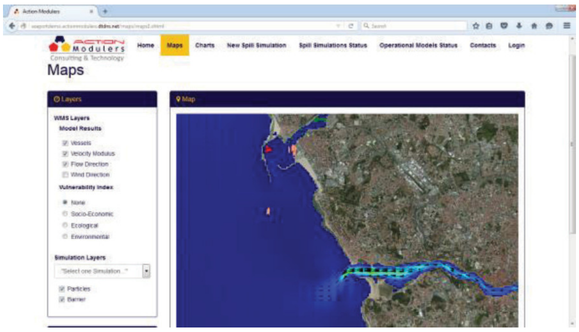

Fig. 2. Web Interface with operational model results in map display.

MOHID Lagrangian model is implemented on-demand (via the same web site) to aid on port incident response where a wizard allows to choose the type of substance (oil, passive tracer, human body), the location and date of the incident. In case of oil spills also containment barriers location can be chosen in order to test different containing approaches (Figure 3).

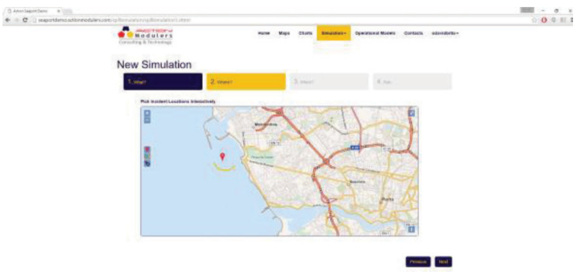

Fig. 3. Web Interface with on-demand spill simulation wizard.

The simulation is run on ACTION MODULERS server using the best hydrodynamic and meteorological forecast and after run the results can be visualized in the web interface – Figure 4.

[4] http://snirh.pt.

[5] http://arcopol.maretec.org/.

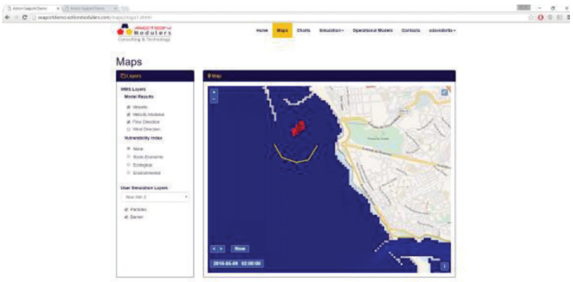

Fig. 4. Web Interface with on-demand spill simulation result.

The implementation also includes a MOHID Studio Lagrangian Wizard similar to the online version but where boundary conditions can be chosen from the available operational models (including waves) and exists an extensive database on oil substances to simulate more advanced options associated to spills.

4. CONCLUSIONS

The Modelling Integration Framework presented here allows to integrate online data (e.g. network stations, etc.), online global model results (to produce boundary conditions to local models) and local high resolution numerical models that can help both: i) the advanced modelling users in model implementation and validation, and ii) water managers in creating valuable digested information in the form of web or desktop based interfaces, reports and alerts. The framework is the basis for coastal and inland water modelling products adapted to end-users needs.

One of the Modelling Integration Framework products is ACTION Seaport that handles specifically port management where real-time vessel information from AIS (position, destination, speed, heading, navigational status, draught, load, etc.), together with operational high resolution hydrodynamic, meteorological and wave models can be used to aid for example in operation support and emergency response actions.

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