# Implementing local operational models based on an offline downscaling technique: The Tagus estuary case

**Authors: F. J. Campuzano (1), R. Fernandes (1), P. C. Leitão (2), C. Viegas (1), H. de Pablo (1) and R. Neves (1)**

(1) Maretec – Instituto Superior Técnico, Avenida Rovisco Pais, Lisbon 1049-001 Portugal. E-mail: campuzanofj.maretec@ist.utl.pt

(2) HIDROMOD, Modelação em Engenharia, Lda. Rua Rui Teles Palhinha 4, 1º. Porto Salvo (Oeiras) 2740-278 Portugal

**Abstract:** Reliable and consistent boundary conditions have been a permanent difficulty for coastal modellers. Presently, any coastal or estuary model located in the Portuguese continental zone is able to receive open boundary conditions from the hydro-biogeochemical Portuguese Coast Operational Model System (PCOMS), replacing the previously used climatological profiles.

The described technique produce modelling results for a desired area used as open boundary conditions in delayed mode (offline), allowing the local model to run independently, saving running time and improving results. This downscaling technique is applied to several estuaries in the Portuguese coast, including the Tagus estuary.

The Tagus 3D operational model aims to provide answer to different local services, including the assessment of estuarine mouth water quality monitoring, and to provide coastal and estuarine integrated boundary conditions to more refined models, replicating the mentioned technique. The water quality forecast for beaches around the estuary and for the Guia outfall area are applications implemented following this technique.

**Key words:** Tagus Estuary, Hydrodynamics, Ecological, Operational Modelling, Mohid, Downscalling

## 1. INTRODUCTION

In order to achieve satisfactory coastal forecasts, oceanographic processes at the different scales should be included. In the coastal transition zones where open ocean conditions meet continental and estuarine conditions it is necessary to apply an integrated approach. In addition, operational modelling requires that model forecasts are available with adequate time for being analysed and taken into account by coastal managers and decision makers.

In order to ensure the integration of the oceanographic processes at the different scales and obtaining forecasts at a reasonable time, it has been designed a window downscaling technique. In this paper, the technique and its application to the Tagus estuary is discussed.

## 2. STUDY AREA

The Tagus River is the longest river of Iberian Peninsula, around 1000 km long, and its estuary, covering an area of 320 km$^2$, is the largest in Portugal and one of the largest in Europe. More than 2.5 million people live at both estuarine margins composing the Lisbon metropolitan area, which includes Lisbon, the Portuguese capital, summing around 25% of the country population.

Morphologically, Tagus estuary can be divided in three main areas, from the coast, a straight and narrow W-E oriented seawater inlet channel about 6 km long, 2 km wide and reaching maximum depths around 45 m; a shallow inner bay 25 km long, 15 km wide with a SW-NE orientation; and the northern

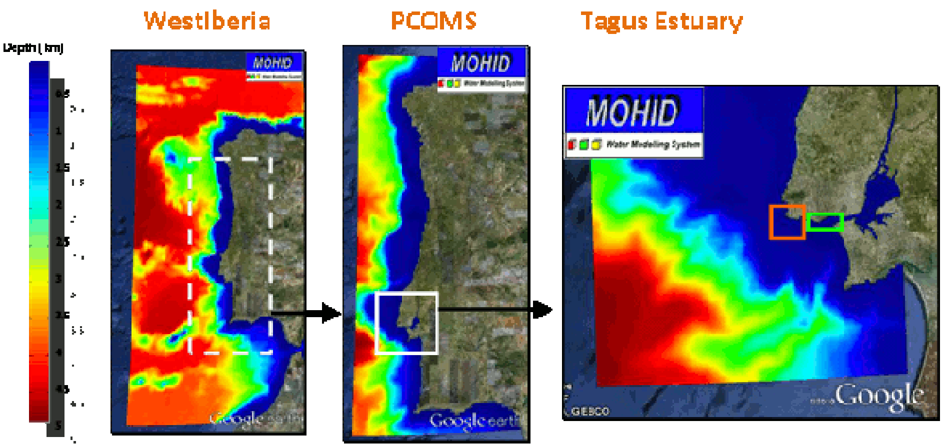


*Fig. 1. Downscaling scheme set for the Tagus mouth where a first domain (Left) provide tidal conditions to the PCOMS model (centre) that supply hydrodynamical and bio-geochemical boundary conditions to the Tagus Mouth model (Right). This model provides also boundary conditions to even more refined local models i.e. the Estoril coast (green box) and the Guia outfall (orange box).*

part of the estuary composed mainly of mudflats, salt marshes and shallow channels that cover a third part of the total area and where the main rivers discharge.

The main source of fresh water into the estuary is the Tagus River, with flow rates varying typically between 50 and 2000 $m^3s^{-1}$, showing a strong seasonality though is also controlled by dam releases. Sorraia and Trancão, the other two estuarine tributaries, present a mean discharge of 39 $m^3s^{-1}$ and 6 $m^3s^{-1}$, respectively.

The studied estuary is a semi-diurnal mesotidal estuary, varying from 1 m neap tides to almost 4 m spring tides. The tidal excursion is almost 80 km landward of Lisbon, with a mean residence time of about 25 days (Braunschweig *et al.*, 2003). The combined effects of low average depth, strong tidal currents, and low input of river water make the Tagus a globally well-mixed estuary, with stratification being rare and occurring only in specific situations such as neap tides or after heavy rains.

## 3. THE TAGUS MOUTH OPERATIONAL MODEL

The Tagus Mouth operational model runs the Mohid numerical model (http://www.mohid.com/) in full 3D baroclinic mode with a variable horizontal resolution ranging from 2 km to 300 m around the estuary mouth. The vertical discretisation consists in 50 vertical levels with a resolution close to 1 m near the surface.

Currently, in order to improve the model results of the Tagus Mouth model, its open ocean boundary receives hydrodynamic and ecological forcing from the 3D model PCOMS (Portuguese Coast Operational Model System) (Figure 1). In the atmospheric interface, the model is forced by atmospheric results obtained from a 3 km resolution WRF model application performed by the IST Meteorological team (Trancoso, 2012).

In the estuarine area, the model receives hourly river flow measurements of the Tagus River from the hydrometric station of Almourol, located upstream of the tidal signal and part of the National Hydrological Monitoring System. Water properties for the Tagus River discharge come from climatological analysis. For Sorraia and Trancão rivers, flow and water properties are both obtained from climatological data. Other 15 discharges related with urban waste water treatment plants are included in the model.

## 4. OPERATIONAL RUNNING TOOL

In order to manage the operational procedures, the Maretec team at the Instituto Superior Técnico developed a software for automatization of models simulations that pre-process the input files needed by the model, execute the Mohid model using the configured files and finally store, graph and distribute the model results via opendap, smartphone and publishing on WebPages (Figure 2).

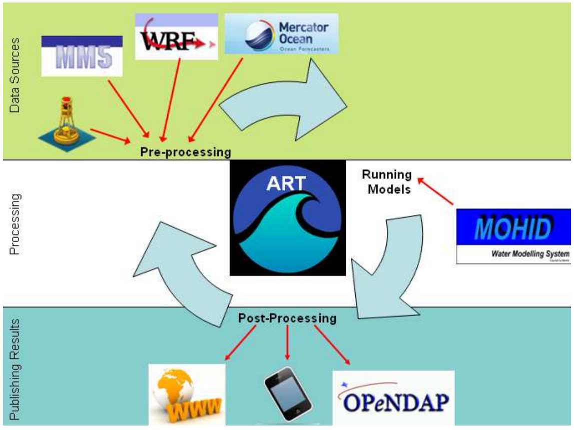


*Fig. 2.General scheme of the Automatic Running Tool (ART).*

At the pre-processing phase, ART (Automatic Running Tool) software adapts the different data sources to the model domain i.e. results from atmospheric models (i.e. MM5, WRF), global circulation model results (i.e. Mercator-Ocean), meteorological or flow monitoring stations, etc.

ART software tool allows running models in a cascade scheme, where downstream models are waiting a signal indicating that the immediate upstream model have finished running, and triggers the following model simulation. Thus reducing the computational time, as the different models can run in separate machines.

## 5. DOWNSCALLING TECHNIQUE

Typical downscaling techniques, consists on running simultaneously nested models being the running time defined by the most downstream model, usually the one with smaller time step and thus the slower model. In order to surpass this difficulty, a delayed mode (offline) technique has been designed to provide boundary conditions to the local models at the open ocean boundaries. The Window Downscaling Technique consists in saving a window of model results from the PCOMS model (Mateus *et al*., 2012; Pinto *et al.*, in this volume) with a high temporal resolution able to represent the main processes coming from the open ocean (i.e. the tide signal). The spatial domain of the results window must be larger than the local domain receiving the boundary conditions. Afterwards, in delayed mode the local model would be implemented as a nested model of the results window. The described technique allows the local model to run independently, saving running time and reducing redundancy, while improving results. This technique also does not increase the running time of the upstream models and allow running several downstream models at the same time. The window downscaling technique is implemented in several estuaries in the Portuguese coast, including the Tagus estuary, which is also able to provide boundary conditions to even more refined local models (Figure 3).

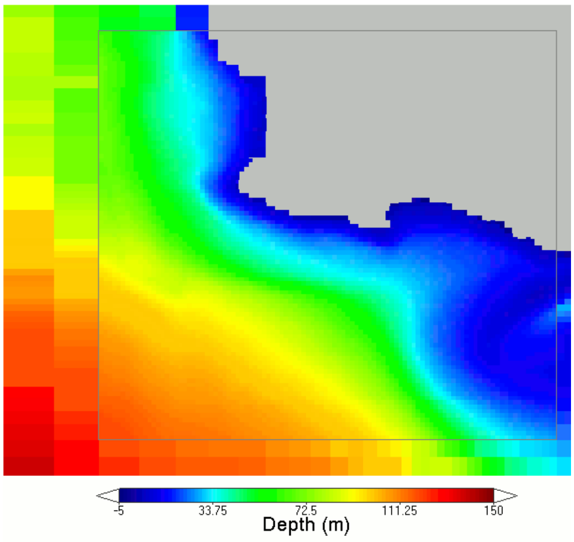


*Fig. 3.Bathymetryof the window from the Tagus Operational Model that provides boundary conditions to the Operational Guia Model with 200 m resolution (area inside the grey square).*

## 6. ACTIVITIES THAT BENEFIT FROM THE TAGUS MOUTH OPERATIONAL MODEL

The Tagus Mouth Operational model aims to give answer to different services at local level, including the Estoril coast water quality monitoring and to provide integrated conditions to more refined models i.e. monitoring and forecast for the Guia outfall model (Figure 3) and for the bathing water quality in the influence area of Estoril Coast. Actually, this model is able to provide boundary conditions to any model included in this domain using the window downscaling technique.

### *3.1. Beach faecal pollution*

Most of the beaches at the Estoril coast are crossed by temporary freshwater streams in their way to the estuary. These waterlines are able to modify the bathing water quality as they transport waters from mixed, urban and rural, origins. In order to evaluate the contribution of these streams on bathing water quality after rainfall events, a monitoring program funded by the water company SANEST SA was established. On a daily basis, the Tagus 3D model results are used as boundary conditions to simulate local hydrodynamics at very high resolution (30 m). Streams discharges are simulated following a lagrangian approach to forecast bathing waters quality. As a final product, in the scope of LENVIS project (LENVIS: Localised Environmental & Health Information Services lenvis.eu), an alert and forecast system for bathing water quality was implemented and operational since 2011 (Figure 4).

| Beach Contamination Risk Levels<br>Day Forecasted:17/03/2012 | | | |
|---|---|---|---|
| Time Period | Carcavelos | Torre | Santo Amaro |
| 00:00 - 03:00 | | | |
| 03:00 - 06:00 | | | |
| 06:00 - 09:00 | | | |
| 09:00 - 12:00 | | | |
| 12:00 - 15:00 | | | |
| 15:00 - 18:00 | | | |
| 18:00 - 21:00 | | | |
| 21:00 - 00:00 | | | |

| Legend | | | |
|---|---|---|---|
| | Bad Quality | Sufficient Quality | Excellent Quality |
| Contamination probability | >5% | ]1%-5%[ | <1% |

*Fig. 4. Forecast of beach contamination risk levels for Carcavelos, Torre and Santo Amaro bathing waters.*

### *3.2. Monitoring of Guia submarine outfall*

The Mohid model has been used in this project to assist the management of a coastal area under the influence of a submarine outfall. Since the beginning of this project in 1997, funded by the water company SANEST SA, a combined monitoring and modelling approach has been used in an ongoing effort to study the transport and dispersion of the submarine outfall plume. The Tagus Mouth model provides boundary conditions to the operational Guia model, a refined local model in the area where the Guia outfall is located (Figure 3). This model consists in a regular grid with 200 m resolution and a lagrangian input of the submarine outfall, providing both real-time estimates and 3-day forecast for the hydrodynamic and water quality in the study area.

As an outcome, the combination of open ocean boundary conditions from the PCOMS model, the estuarine plume conditions from the Tagus Mouth and the local outfall conditions result in the improvement of the model results and predictions (Figure 5).

## 7. CONCLUSIONS

The integration of processes occurring at different scales in coastal numerical modelling improves the local models results and predictions. The application of the window downscaling technique, supported by the trigger feature, allows a significant reduction of computational time needed to run simultaneous models and produce forecasts in a reasonable time from oceanic scale models to local scale models. As a consequence, model results are delivered earlier to the different local model end-users.

A point to be highlighted is the versatility of the methodologies and tools used by this technique, that could be applied to any estuary or coastal area as there is no limitation of windows created by a model.

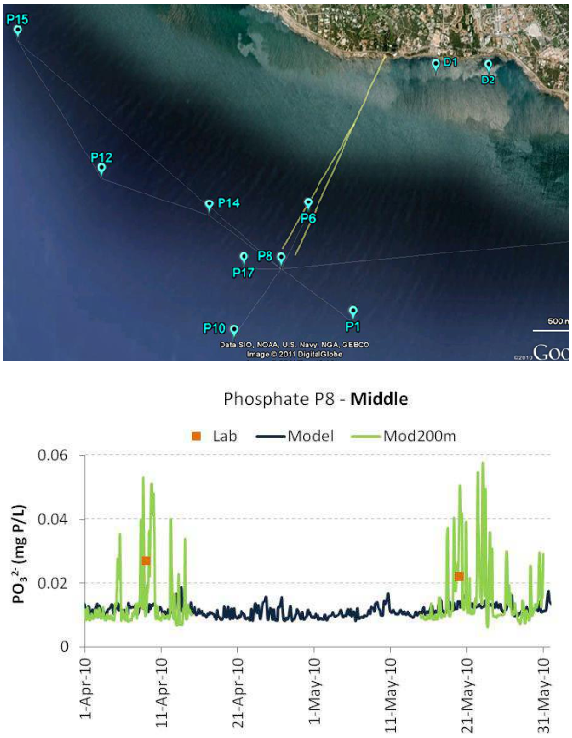


*Fig. 5. Location of the monitoring stations (blue marks) around the outfall diffuser (yellow lines) and phosphate values obtained through downscaling models to the Guia 200m model (green line) compared with the Tagus Mouth model (blue line) and observed values (orange dots) at the middle of the water column.*

## 8. FUTURE WORK

In the near future, a webpage including the model results forecast and automatic validations will be made public. The Tagus Mouth model will eventually provide conditions for the Envitejo project. This project, set up by the Tagus hydrographical region administration (ARH-Tejo), and the water treatment companies SIMTEJO and SIMARSUL, aims to implement water monitoring and modelling tools to provide observed data and forecasts.

The results from the Tagus Mouth model are planned to be incorporated into the PCOMS model to improve the quality of the Portuguese coast hydrodynamics and water quality forecast, in a sort of two-way nesting being designed at this moment.

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