3D Hydrodynamic Modelling of the Tagus Region of Fresh Water Influence

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1. INTRODUCTION

Regions **O**f **F**resh water **I**nfluence (ROFI) are very complex study areas. In these regions physical processes of different scales overlap (Simpson, 1997), biogeochemical processes are intensified and they are the main paths of particle and dissolved matter input into ocean system (Henrichs et al., 2000). The location of ROFI's is characterized as transition zone~~s~~ between estuarine or lagoon environments with 2D physical behavior and costal environments with 3D behavior. Adjacent to ROFI's it is common to find large deposits of fine material of terrestrial origin. Due to high nutrient concentrations, associated with the fresh water inputs, these regions tend to be very productive and support intense fishery activities.

The Tagus estuary mouth is an area with the characteristics describe above, because it is the interface between the largest~~r~~ European estuary (Tagus Estuary) and the Atlantic Ocean. The main fresh water input into the Tagus estuary is the Tagus River with an average flow of 350 m^3/s and a basin with over 81 000 km^2. In the Tagus estuary mouth, complex biogeochemical processes occur associated with input of nutrients in the photic zone of a 3D environment. In the past, these processes have been studied using field data. A 3D hydrodynamic model coupled with a biogeochemical model can be an excellent tool to give spatial and time continuity to the field data. A tool with these characteristics can also be used to test hypothesis.

In the past, several authors applied hydrodynamic models to study the circulation in the Tagus estuary (Rodrigues et al., 1982, Hidromod, 1997). These applications had in common the fact of being barotropic and centered their attention inside the estuary, where the physical dynamic is mainly 2D. This work aims to study the estuary mouth where, besides barotropic effects, baroclinic processes are also important.

2. MATERIAL AND METHODS

To carry out the work presented in this paper, the Mohid water modelling system was used (http://www.mohid.com). This system allows the users to simulate physical processes coupled to biogeochemical process in the pelagic and benthic system. In the present case only hydrodynamic processes in the water column were simulated. The hydrodynamic module of the Mohid system solves the primitive equations with the hydrostatic and Boussinesq approximations. As spatial discretization this system uses finite volumes and as time discretization it uses a semi-implicit algorithm.

In the study area the dominant physical processes are tide, wind and stratification. The effect of local wind is conditioned by stratification. A way to simulate the overlap of processes with different scales is using nested models. The Mohid system allows the user to define an infinite number (limited only by computer memory) of nested models which communicate in one way direction.

In this application a 2D model forced with tide and wind was implemented for the Portuguese coast (Figure 1) with a course grid (dx=2 km). At the boundary, the water level taken from the FES95.2 global tide solution is imposed (Provost *et al.*, 1998). Wind was assumed equal in all domain to the one measured by a meteorological station locate in Lisboa.

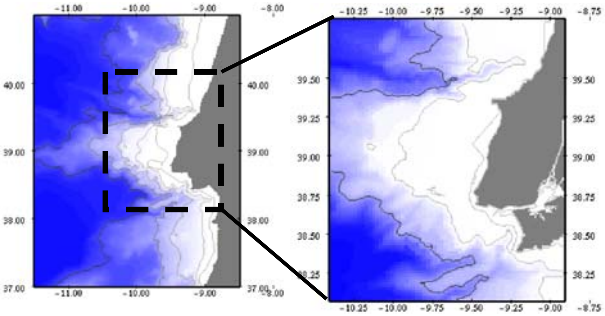


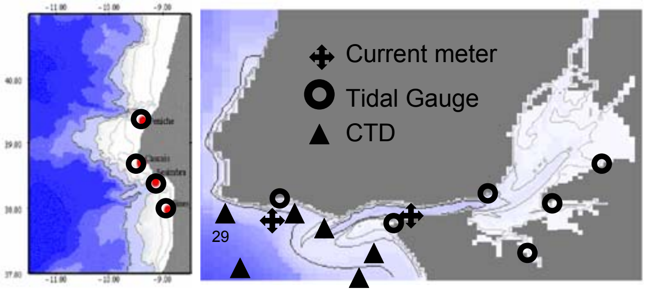
Figure 1 – Nesting a 3D model (Estremadura coast) in a 2D model of the Portuguese coast.

This model generates barotropic flows used as reference flows in the boundary condition of the finer grid 3D model (Figure 1). This model has a variable horizontal spatial step with minimum resolution of 300 m at the Tagus Estuary mouth. At the open boundary a flow relaxation condition is used. Near the open boundary this condition makes the 3D solution tend to the courser 2D solution in a gradual way. In the vertical direction a lagrangian coordinate with 10 layers is used. As fresh water input only the Tagus River is considered. The heat and momentum fluxes exchange with the atmosphere is also computed and was considered variable only in time.

3. RESULTS

The hydrodynamic model validation was done in two steps. In the first step the coarse and the nested model were run both in 2D forced only by tide. In this way it is possible to validate the tide forcing. For the 2D case the coarser model was validated with the tidal gauges present in the Figure 2a (Peniche, Cascais, Sesimbra e Sines). The finer grid model was validated with the tidal gauges presented in Figure 2b.

In the second step of validation the finer model was run in 3D and atmospheric forcing and density gradient effects were considered. Winter (January of 1997) and summer (July 1998) scenarios were simulated. In the winter scenario the river flow was always greater than 1000 m^3/s and the wind was characterized by weak intensity blowing mainly from south. In the summer scenario the wind blown strong from NW and river flow was always below 300 m^3/s. In the first case dominant processes were the tide and the stratification due to fresh water input. In the second case strong wind with a North component induce upwelling.



a) b)

Figure 2 – a) tidal gauges location used to validate the 2D coarser solution; b) point where the finer model solution was validate by comparing models results with current meters data, CTD profiles and tidal gauges.

The 3D model results were compared with velocities and CTD profiles (Figure 2b). In both scenarios a simplified initial condition was assumed (null velocity and density profiles similar to the ones observe off-shore). The main goal was to verify if the model with real forcing tends to the "real solution". For the winter situation only CTD data was available but the profiles evolution in time show the ability of the model to reproduce the observed profiles, even in stations located far away from the mouth like station 29 (Figure 3 – see in Figure 2b the location of station 29).

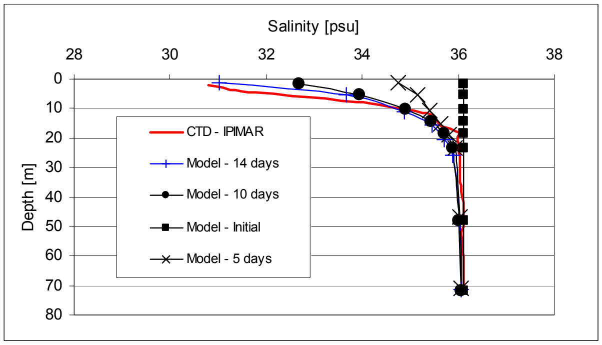


Figure 3 – Salinity profile evolution in the winter scenario in station 29 (Figure 2). This station is the most far away from the mouth.

In the summer scenario, similar CTD results are obtained for the CTD stations except in stations located along Costa do Estoril. In these stations the model is not able to reproduce the profiles, especially the salinity profiles. The validation of model velocities with current meter profiles (ADCP) obtained near Cascais shows that the model is able to reproduce the variability but it is not able to reproduce the observed barotropic residual current of 10 cm/s toward the NW direction. The model residual current had the same direction but an intensity one order of magnitude lower.

4. DISCUSSION

The hydrodynamic model implemented was able to reproduce the 2D tidal forcing and the density gradient effects induce by fresh water input and heat fluxes. However, when the wind blows strong from the North quadrant the model is not able to reproduce a strong barotropic residual current observed near Cascais in an area of 40 meters depth. After exhaustive sensitive analysis of the model forcing conditions the conclusion was that the effect of topography in the wind field (ex: Serra de Sintra) can induce strong rotation in the wind field. This mechanism can generate strong barotropic currents. A similar mechanism was studied by Munchow (2000) in Point Conception, California.

5. CONCLUSIONS

A 3D baroclinic model was validated for the Tagus estuary mouth. To improve the results it is necessary to couple~~d~~ the hydrodynamic model with a small scale atmospheric model (dx= 1 km) to simulate explicitly the effect of topography over the wind field. This is important specially to simulate upwelling events. However, the foundations of an integrated numerical tool were set. Another future step is to couple this model with a biogeochemical one and simulate in an operational way not only the physical processes but also biogeochemical ones. A tool with these characteristics could be use to help decision makers in planning waste water treatment policies and manage accidents.

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