Numerical evaluation of the river nutrients influence for the Western Iberian coastal region

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Abstract: In order to evaluate the relative importance of the nutrients reaching the coast from the rivers watersheds and their impact in the coastal primary production an integrated catchment-estuarine system was incorporated to the Portuguese Coast Operational Modelling System (PCOMS). At the watershed level, the Mohid Land model provided operationally water flow and properties, including nutrients, for the main river catchments of Western Iberian with a 2 km horizontal resolution. Downstream, several operational hydrodynamic and biological estuarine applications used the previous results as fresh water input flows, filling the gaps in the observation network. From the estuarine models, the tidally modulated water and properties fluxes to the coast were obtained. These fluxes were finally imposed in the PCOMS System, a fully 3D baroclinic hydrodynamic and ecological regional model that covers the Iberian Atlantic coast.

Keywords: Numerical modelling, Mohid, Catchment, Estuary, PCOMS, Nutrients

1. INTRODUCTION

In the Iberian Peninsula, the largest rivers, with the exception of the Ebro River, discharge on the Atlantic coast draining on its way almost two thirds of the territory. They are an important source of nutrients and sediments to these coastal areas. In order to determine the inland waters contribution to the open ocean, in terms of volume and composition, an original methodology for integrating a system of models was set up.

In order to quantify the importance of these discharges, a watershed model has been applied to the Iberian Peninsula to characterise the river discharges and their influence in the coastal circulation and nutrients processes was evaluated by using a hydrodynamic and ecological model for the Portuguese coastal region.

The different interfaces found by the water from the watersheds to the open ocean were reproduced through numerical models for the first time for the Portuguese coast using the different components of the Mohid Water Modelling System.

2. MATERIAL AND METHODS

To reproduce the water continuum from the precipitation areas to its evacuation in the open ocean, a system of coupled models with different time and scale resolutions were designed in order to include the different spatial and temporal scales. At the watershed level, the Mohid Land provides operationally water flow, temperature and nutrient concentrations for the main river catchments of the Western Iberia coast. The MOHID land model is a 3D distributed, continuous, physically based, variable time step model using a finite volume approach based on mass and momentum balance equations. The simulated processes include water and property transport in porous media, river runoff, evapotranspiration and vegetation growth and water quality processes, i.e. mineralization, nitrification, denitrification in porous media and rivers. Sediment transport and erosion/deposition are also computed for surface waters.

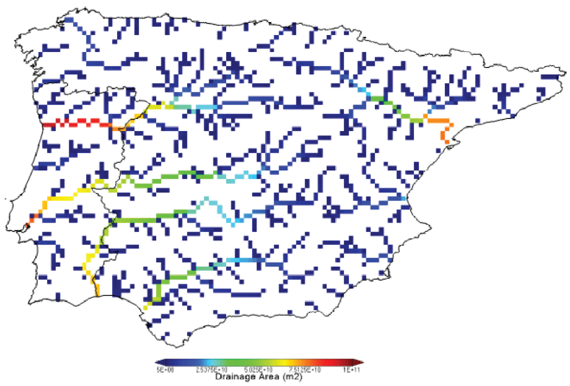

Fig. 1. Main water lines in the Iberian Peninsula indicating the drainage area obtained with the Mohid Land 10 km resolution.

Two applications domains with different resolution and area covered were designed in order to provide high resolution results for Portugal and also able to reproduce the spatial scale of large trans-boundary rivers discharging in Western Iberia as the Tagus, Douro and Guadiana rivers. Using the NASA digital terrain elevation, the Iberian Peninsula domain (IP domain) and the Western Iberia domain (WI domain) with 10 km and 2 km horizontal resolution respectively were obtained (Figure 1). Both domains were populated with data from the Corine 2006 land cover and JRC soil database allowing the model to estimates the amount of water flowing in the water lines without taking into account the human consumption, water reservoirs and dams that could influence the river flow and the amount of water reaching the coastline.

Downstream, several operational hydrodynamic and biological estuarine applications uses the previous results to provide fresh water input flows for those rivers where data is non-existent. The estuarine models would reproduce the inner dynamics of the estuary and its connection to the outer waters. Fluxes from the latter model, which are intermittent due to the tidal signal, are then imposed in the Portuguese Coast Operational Modelling System (hereafter referred as PCOMS, Figure 2, Mateus *et al.*, 2012).

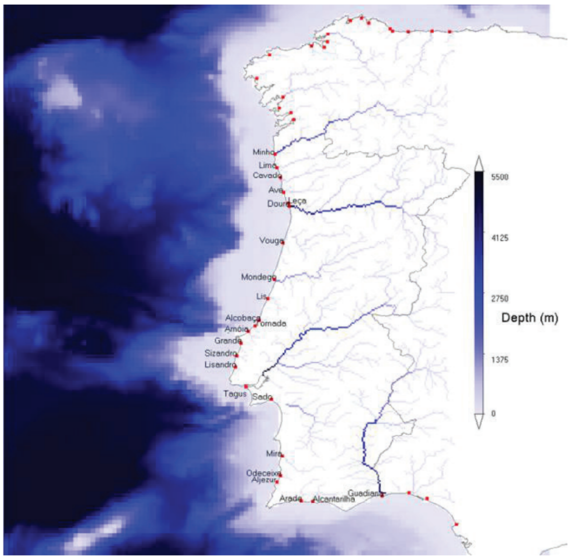

Fig. 2. Main fresh water courses in Western Iberia and the points where rivers discharges were implemented in the PCOMS domain.

The PCOMS model is a 3D full baroclinic hydrodynamic and ecological regional application that downscales the Mercator-Océan PSY2V4 North Atlantic solution with a horizontal resolution of 0.06º and with 50 vertical levels (43 in Cartesian and 7 in sigma coordinates) with a resolution of down to 1 m near the surface (Figure 2). Tides are forced using the global tide solution FES2004 along the ocean boundary (Lyard *et al.*, 2006). The estuarine and the PCOMS models are operated by the Mohid Water model. The set of models were forced with different spatial resolutions using meteorological numerical results from the MM5 and WRF models implemented by the IST meteorological group for the MM5 model (http://meteo.ist.utl.pt) and by Meteogalicia (http://www.meteogalicia.es) for the WRF model.

This complex system of models is integrated and synchronised through the ART software (Automatic Running Tool), a software for model simulations automation developed at IST. The ART tool pre-processes the boundary conditions from different sources needed to run the model; executes the Mohid water and Mohid Land depending of the application using the configured files and store, graphs and distributes the model results via opendap, smartphone and Webpages (Figure 3).

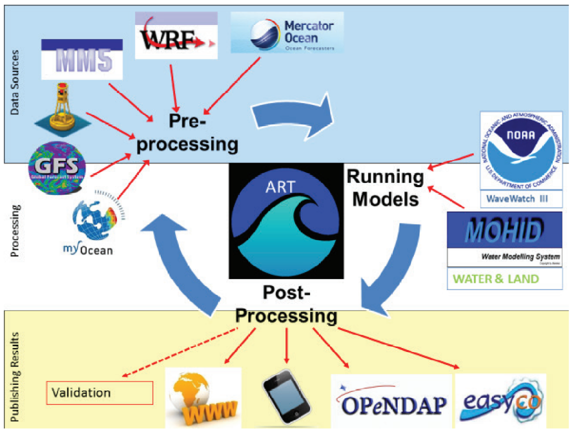

Fig. 3.General scheme of the Automatic Running Tool (ART).

3. DISCUSSION

3.1. Watershed Modelling

Modelling results analysed for a three years period, Jan 2011-Dez 2013, indicates that the 10 km resolution (IP Domain) could be regarded as a good approach for large rivers (i.e. Tagus, Douro, Guadiana) however smaller catchments (i.e. Mondego, Figure 4) are better represented by the 2 km resolution. For this reason, when entering the river discharges in the PCOMS model the results for the Guadiana and Guadalquivir will be considered more reliable from the IP Model. In the case of the Tagus and Douro rivers, observed data were used when available.

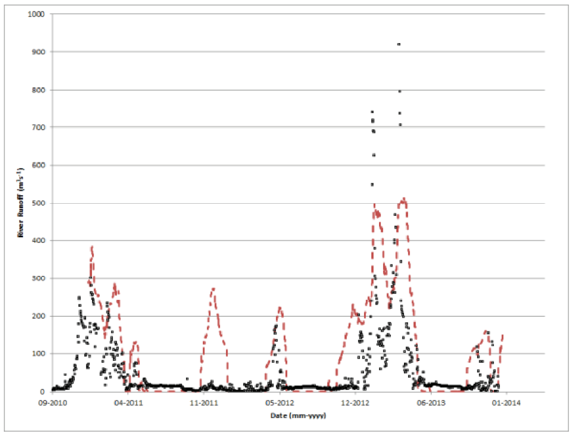

Fig. 4.Observed River Runoff (m^3s^{-1}) for the Mondego River at the Açude Ponte Coimbra station (dots, source:http://snirh.pt/) and Mohid Land WI domain results (dashed line) for the period 2010-2014.

According to the Mohid Land model results some small rivers located in high precipitation areas could transport high flows to the coast in a short period. Rivers with larger drainage areas present higher river flows in the entire domain. However, rivers located in the northern area of the Iberian Peninsula present a higher average discharge per unit of area than southern rivers. Table I lists the average river discharge in terms of flow and inorganic nutrients for the rivers discharging in the Portuguese coast. From these results it can be highlighted that the Douro River, the Tagus River and Guadiana River, in this order present the highest average runoff.

Tab. I. Average river runoff and dissolved inorganic nutrients for the rivers discharging in the Portuguese continental coast during the 2011-2013 period. The values were obtained using the Mohid Land: (IP) stands for IP Mohid Land domain results and (WI) for WI Mohid Land domain results. Rivers are ordered from North to South.

River	Average Runoff ($Hm^3\ y^{-1}$)	Dissolved Nitrogen ($Ton\ y^{-1}$)	Dissolved Phosphorus ($Ton\ y^{-1}$)
Minho (WI)	7730	15665	172
Lima (WI)	2120	8255	150
Cavado (WI)	1581	3605	27
Ave (WI)	1241	2775	47
Leça (WI)	120	203	4
Douro (WI)	29359	75049	1119
Vouga (WI)	1869	4447	79
Mondego (WI)	3269	8238	204
Lis (WI)	312	866	23
Alcobaça (WI)	162	334	11
Tornada (WI)	68	176	5
Arnoia (WI)	127	374	11
Grande (WI)	239	399	6
Sizandro (WI)	109	273	9
Lisandro (WI)	67	185	6
Tagus (IP)	16767	43266	413
Sorraia (WI)	624	1772	52
Sado (WI)	1255	3438	105
Mira (WI)	357	957	18
Odeceixe (WI)	65	150	3
Aljezur (WI)	42	93	2
Arade (WI)	148	411	8
Alcantarilha (WI)	214	495	9
Alcantarilha (WI)	214	495	9
Guadiana (IP)	13889	42796	843
Total	**81734**	**214221**	**3327**

In total, the twenty four rivers discharging in the Portuguese continental coast accounted in this study for the period January 2011- December 2013, discharge in average around 82000 Hm^3 per year and around 215000 Tons of dissolved inorganic Nitrogen per year and around 3300 Tons of dissolved inorganic phosphorus. It could be concluded that the Douro River accounts for a third of the nutrients and flow contributions while the Tagus River and the Guadiana River account approximately for a fourth part of the natural contributions.

3.2. Linking Models

The watershed models are linked through estuarine models that receives the water from the watershed models (i.e. Aveiro, Minho, Lima,.) or when existing from the SNIRH observing system (Douro, Tagus, Mondego). From these estuarine models section fluxes are obtained and in the next step introduce in the 3D hydrodynamic and ecological regional model PCOMS. If the estuarine model is 3D, the discharge would be distributed in the corresponding depths, as is in the case of the Tagus estuary mouth (Campuzano *et al.*, 2012), the rest of the estuarine models are 2D and thus the discharge is imposed in the surface layer. The rest of the river discharges are directly imposed in the regional circulation model PCOMS.

3.3. Ocean Modelling

In order to estimate the influence of the rivers discharges in terms of nutrient fluxes a set of 3D polygons where defined in the Portuguese domain of the PCOMS model. In the present study eight horizontal boxes were considered, numbered from 1 to 8 from south to north, in correspondence of the main Portuguese riverine systems (Figure 5). In this sense, the Tagus estuary would discharge in Box 4, the Mondego River in Box 5 and the Douro River in Box 6. Each box was discretized into five vertical layers covering the first 500 m with variable with from top to bottom of 10 m, 10 m, 30 m, 150 m and 200m.

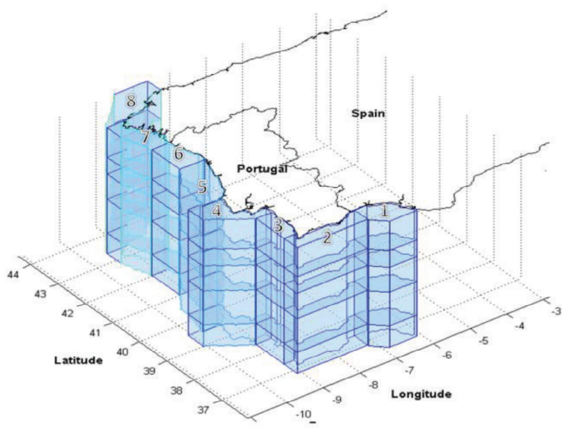

Fig. 5. 3D Monitor boxes defined for the Portuguese coast, numbered from 1 to 8 from south to north, in correspondence of the main Portuguese riverine system.

Water and nutrients fluxes were calculated across the surface of the boxes enabling to assess the exchanges of water masses and nutrients between boxes along the Portuguese coast. To assess the impact of river nutrients across the different boxes, the fluxes across the first box was obtained for the year 2013 (Table II). Modelling results present a picture of a coastal area almost dominated by upwelling with the exception of the box 8 where a net downwelling was obtained for this year.

Regarding nutrients fluxes, it should be considered that they are influenced by the primary production, organic matter respiration and by exports to deeper areas in organic forms. The first layer of the 3D boxes corresponding to the first 10 m, mainly receives nitrogen, nitrate and ammonia, from deeper waters with the exception of boxes 5 and 6 that correspond to the Douro-Mondego region. That region makes that the overall result is a net input of dissolved inorganic nitrogen to deeper waters. On the other hand, inorganic phosphorus fluxes are positive for the entire domain. When compared with the river discharges, Table I, deeper waters are an order of magnitude higher in the case of the phosphorus. In the case of Nitrogen, fluxes for all boxes are positive in interface at 50 m with values of the same magnitude of the rivers discharge, so a deeper analysis should be performed taking into account the primary and secondary production.

Tab. II. Water fluxes and dissolved inorganic nutrients between the surface and the boxes below for the year 2013.Positive values indicate fluxes to the surface layer while negative values indicate fluxes to the beneath box. Boxes are ordered from North to South.

Box	Water Flux ($Hm^3\ y^{-1}$)	Nitrate ($Ton\ y^{-1}$)	Ammonia ($Ton\ y^{-1}$)	Inorganic phosphorus ($Ton\ y^{-1}$)
1	17756	1110	3856	1402
2	949110	5578	3232	11199
3	512337	1767	1050	5522
4	1128480	2342	3880	12267
5	602879	-1550	-618	7863
6	527218	-9830	-23448	5935
7	548840	394	-8017	7417
8	-31797	77	2301	828
Total	**4254823**	**-112**	**-17764**	**52433**

4. CONCLUSIONS

This set of operational models when combined are able, through this methodology, to provide gapless data of fresh water discharge and to improve coastal hydrodynamic and ecological models when compared with the use of river climatologies. Also they are a valuable tool for understanding the nutrient budgets, paths and fate. The developed methodology is generic and is already applied to different estuaries in the Portuguese coast favouring the achievement of more precise coastal circulation and to study their influence in the creation of salinity and temperature fronts and the nutrient coastal input all of which are relevant to fisheries management.

REFERENCES

Campuzano, F.J., Fernandes, R., Leitão, P.C., Viegas, C., de Pablo, H. and Neves, R. (2012). Implementing local operational models based on an offline downscaling technique: The Tagus estuary case. *2.as Jornadas de Engenharia Hidrográfica*, 20-22 June 2012, Lisbon, Portugal. Extended abstracts: 105-108.

Lyard, F., Lefevre, F., Letellier, T. and Francis, O. (2006). Modelling the global ocean tides: modern insights from FES2004, *Ocean Dynamics*, 56, 394-415.

Mateus, M., Riflet, G., Chambel, P., Fernandes, L., Fernandes, R., Juliano, M., Campuzano, F., de Pablo, H., Neves R. (2012). An operational model for the West Iberian coast: products and services, *Ocean Science*, 8, 713-732.

Neves, R. (2013). The MOHID concept. In: M. Mateus & R. Neves (eds.). *Ocean modelling for coastal management - Case studies with MOHID*. IST Press, Lisbon, 1-11.