



# OPENCoastS: A Tailored Coastal Forecasting WebGIS Service

Anabela Oliveira, Alberto Azevedo, André B. Fortunato, Marta Rodrigues, João Rogeiro, Pedro Lopes, Samuel Bernardo, Jorge Gomes, João Pina and Mario David

## Abstract

Predicting the circulation in coastal systems requires a combination of knowledge of physical processes, accurate numerical models that represent all relevant processes, and a computational tool that automates the prediction procedures and results' visualization. The OPENCoastS service addresses these challenges in a comprehensive way. Freely available to all, OPENCoastS allows any user with a basic knowledge of coastal dynamics and computational grids of his/her system of interest, to build a forecast system through a very simple interaction with a WebGIS platform. This platform serves the whole forecast roadmap: deployment, management, and visualization of results. Depending on the characteristics of the coastal system at study, distinct modeling approaches can be taken, with associated requirements of computational power to guarantee timely delivery of the forecasts. Initially developed as a simple forecast engine for 2D circulation, OPENCoastS has become a full-fledged service that addresses different issues of coastal circulation. Three options are available: the original 2D barotropic simulations without short waves; 2D barotropic simulations with wave–current interaction; and 3D baroclinic simulations including salinity and water temperature. OPENCoastS is demonstrated to understand how distinct physical processes can impact velocities in a real application in the Albufeira coast using a 3D baroclinic circulation and a 2D wave and current circulation deployments.

A. Oliveira (✉) · A. Azevedo · A. B. Fortunato · M. Rodrigues · J. Rogeiro · P. Lopes  
Hydraulics and Environment Department, National Laboratory for Civil Engineering, Lisbon, Portugal  
e-mail: [aoliveira@lnec.pt](mailto:aoliveira@lnec.pt)

S. Bernardo · J. Gomes · J. Pina · M. David  
Laboratório de Instrumentação, Física Experimental de Partículas, Lisbon, Portugal

## Keywords

OPENCoastS · WebGIS · SCHISM · Wave and currents · Baroclinic flow

## 1 Introduction

Coastal forecast systems have been under development for several decades (Baptista et al., 2008) and have now a solid role in coastal management procedures for all entities with responsibilities or economic activities in these areas. Their setup, usage, and continuous maintenance are, however, limited by technological evolution constraints and personnel cost (Oliveira et al., 2019), thus preventing their broad use for many systems.

OPENCoastS (<https://opencoasts.ncg.ingrid.pt/>) was designed to address these challenges in a comprehensive way. It was developed as a proof of concept that operational systems can be open to all, and every coastal system should have a forecast implementation, anchored on the availability of relevant computational resources. Since 2018, this platform has attracted over 200 users from over 20 countries, in spite of allowing only for simple 2D tidal dynamics. The simple way to build, manage, and visualize results in a WebGIS platform is considered a major advantage by the users.

Most coastal problems, however, cannot be addressed without accounting for wave interactions or the vertical structure of the flow. Therefore, OPENCoastS was extended to a multimodal strategy where the user can select the most adequate physical configuration. Building from the first service version (Oliveira et al., 2019), the user can now deploy 2D or 3D runs, with or without wave interaction. Each mode requires the user to upload different information and select different forcing options, along 7 steps in a WebGIS platform. Each step is customized for the selected mode, and help is available at every step.

## 2 The OPENCoastS Service and Its Current Functionalities

### 2.1 Summary of the OPENCoastS Service

OPENCoastS is a computational service of the H2020 EOSC-hub project, designed to build circulation forecast systems for any coastal system in the world. To facilitate its use by users that are not modeling experts, it requires the minimum information from the user and is supported by a simple workflow of 7 steps in a WebGIS interface. All the data required at each step is clearly identified and often available as a dropdown menu. For the setup of each simulation, pre-defined modeling parameters are provided, retaining the ability for most experienced users to define their own values.

OPENCoastS evolution to more complete physics was made possible by the comprehensive representation of physical processes available in the SCHISM modeling suite (<http://ccrm.vims.edu/schismweb>), the open-source modeling engine behind OPENCoastS. Three options are now available, depending on the relevant physics:

- (1) 2D barotropic simulations—these simulations output water levels and depth-averaged velocities. Forcings are tides, wind, atmospheric pressure, and river flow.
- (2) 2D barotropic simulations with wave–current interaction (2D W&C)—these simulations provide additional wave parameters. Wave–current interactions are simulated and forcings also include short waves. It can only be used in the North Atlantic.
- (3) 3D baroclinic simulations—these simulations provide 3D fields of velocity, salinity, and water temperature, besides water levels. They can be forced by tides, river flow, temperature, and salinity at all the boundaries and also by the atmospheric surface forcing (wind, air temperature, pressure, humidity, solar radiation, and downwelling longwave radiation). These forecasts can be generated anywhere in the world.

As more complex physics required additional computational power, the availability of computational resources and IT services from the European Open Science Cloud community, through project EOSC-hub, was also fundamental to open the use of the enhanced OPENCoastS to all coastal communities.

The OPENCoastS interface also allows for deployment management. Duplicate, pause, restart, and end are some of the actions to be taken in the management board. Finally, a flexible visualization board is available to (i) display model layers for each variable, (ii) probe over the results, and (iii)

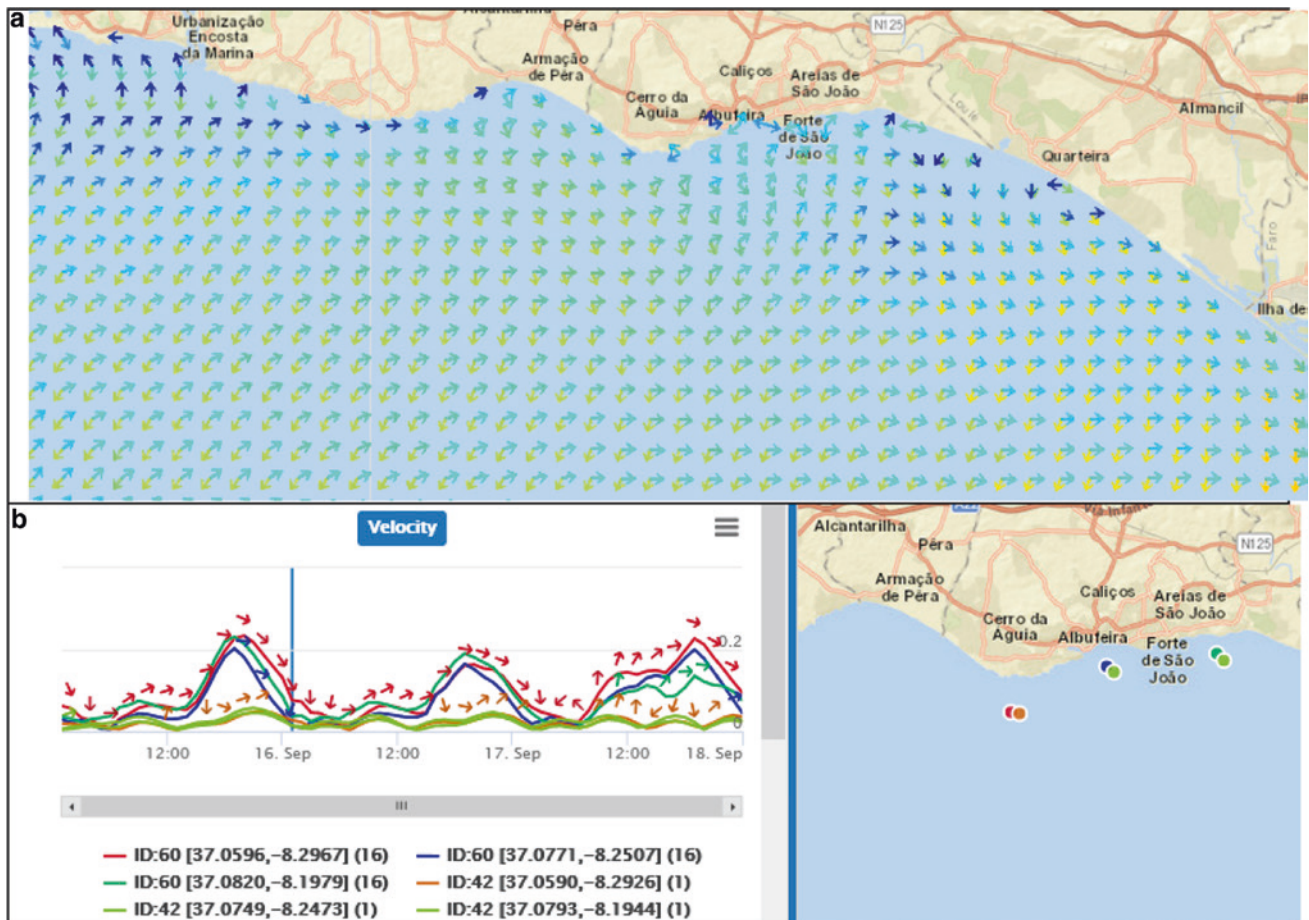
download the output files. Automatic comparison with field data validates the quality of the predictions and supports the usefulness of the tool for researchers and managers alike. OPENCoastS is linked to EMODNET Physics elevation data hub. The user selects the stations for the model/data comparison for each deployment and then visualizes the results in the viewer.

Unlike 2D forecasts, the setup of a 3D run requires an additional file at Step 2: the 3D vertical grid, in the SCHISM modeling suite format. Given the need to provide input forecasts for other variables, new sources of boundary conditions were added, for usage in all forecast options. OPENCoastS now integrates two CMEMS deployments: global and IBI models. The outputs viewer was also extended to allow the users to visualize maps, probe results, and download data for the 3D output variables. Outputs are also extended to the vertical dimension, with results at each node and at each vertical layer of the new 3D variables: velocity, temperature, and salinity.

## 3 Understanding the Circulation Drivers at the Albufeira Coast

The city of Albufeira, located on the southern Portuguese coast, has a complex drainage network that includes a vast system of pipes, several coastal outfalls, and wastewater treatments plants and pumping stations. Discharges at the coast only occur during severe precipitation events which lead to inundation downtown and the contamination of urban beaches. This combined problem has led to massive investments from several end-users to redirect pluvial flows and treat and dispose of wastewater far away from the urban beaches. LNEC is building a modeling and forecasting deployment for this region to support the decision-makers to deal simultaneously with inundation and beach contamination, and reduce energy consumption.

Given the complexity of the modeled system, from the upstream basins to the ocean, a careful definition of relevant physical processes is necessary for coastal modeling to avoid prohibitive computational resources. Each day, a series of hydrodynamic and water quality forecast runs will be done, modeling the upper basins, wastewater and stormwater pipe networks, and the adjacent coast for several water infrastructure operation options. In order to define which processes have the most impact on the contamination plumes from the land discharges and the outfalls, OPENCoastS was used in two distinct modes: 2D with wave and current interaction and 3D baroclinic modes. This strategy also helps to define the coastal monitoring program to be undertaken this fall, to provide data for model calibration and validation for the final modeling effort.



**Fig. 1** 16/9/2020, 0:00, **a** velocity, **b** velocity time series (ID60: 3D; ID42: 2D W&C)

Results show that velocity magnitudes and directions are quite distinct in each run. In particular, the directions are almost opposite in the area near Albufeira, making any plume simulations lead to transport to East or West depending on the chosen forcing conditions (illustrative layer shown in Fig. 1). These differences would be even more relevant under stormy conditions, with large waves. These differences show that both wave/current interaction and the 3D structure of flow need to be accounted for in the simulation of the urban outflow plumes. Since neither process can be neglected, simulations must include both baroclinic and wave effects. As SCHISM already includes these very complex physics, the WIFF forecasting infrastructure (on which OPENCoastS is based) needs to be extended too.

## 4 Conclusions

OPENCoastS, an on-demand coastal forecast service, is presented here to address multiple types of circulation physics and demonstrated in the Albufeira region.

**Acknowledgements** Funding: European Commission by H2020 project EOSC-hub (No 777536) and ANI through project SINERGEA (Project 33595, program 03/SI/2017).

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