CONNECT - Local coastal monitoring service for Portugal

Cases on added-value services

1. Methodology on designing forecast systems using field/remote measurements

2. Methodology to support monitoring infrastructures

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1 INTRODUCTION

This report proposes two cross-cutting methodologies for joint exploitation of information for monitoring and modeling in coastal regions taking advantage of the products developed and enhanced in the scope of the CONNECT project, namely the CONNECT coastal service (Rodrigues et al., 2024). The workflow for their implementation is demonstrated in the Tagus estuary taking advantage of the results of this project.

The proposed cases are:

1) a methodology for establishing forecast system grid limits based on the information provided by the in-situ and remote networks; and

2) a methodology to support monitoring infrastructures.

The analyses are conducted in a generic way, to be applied anywhere, and are then illustrated using the model forecasts and the in-situ and remote sensing data available at the CoastNet monitoring network (Castellanos et al. 2021; França et al. 2021). The demonstration sites, initially selected to be the Mondego estuary and Ria Formosa, were switched to the Tagus estuary. Indeed, while both the Tagus and the Mondego estuaries have a similar in-situ network, their spatial scales are quite different (the Tagus estuary is much larger), and the application of the methodology using the available remote sensing data would be less effective in the Mondego. In the case of the Ria Formosa, in-situ data is not currently available for the relevant variables. Therefore, both methodologies will be demonstrated in the Tagus estuary.

2 Methodology on designing forecast systems using field/remote measurements and its demonstration in the Tagus estuary - ocean boundary limit definition

The ocean and riverine limits of estuarine and coastal models are often defined based on the knowledge of the modeler on that particular site dynamics. As modeling becomes a global activity, local knowledge can be missing to support the model setup. While riverine limits can be easy to specify if water level and salinity data is available at upstream stations (by specifying the limit of tidal propagation and salinity intrusion), the ocean boundary is more complex to define.

2.1 Methodology description

Herein a methodology is proposed that takes advantage of both in-situ and remote sensing data. This methodology, that entails three phases, is presented in a generic way in Figure 1 and described in detail below.

Phase 1 - Defining the processes to be modeled/forecasted and the relevant data sources

The definition of a computational domain for estuarine and coastal modeling depends on the specific processes to be modeled. In addition, this domain should also include any areas to be intervened if new infrastructures are planned (e.g. new port areas, dredging locations). The processes at stake may also condition the area to be modelled. For instance if only tidal action is relevant the outer boundary of the domain should include the tidal jet, but no specific requirements are involved in the extension of the domain upstream and downstream along the coast. However, if wave action needs to be accounted for, the selection of the domain should address the longshore and cross shore transport processes. Likewise for baroclinic simulations, the selection of the outer boundary should be selected beyond the estuarine temperature and salinity plume.

Similar concerns should be addressed for the riverine boundary.

Time scales should also be accounted for in the definition of the procedure, as seasonal effects may affect the area to be defined. For instance the modeling of a winter plume may be affected by larger river flows and stronger wave action, requiring therefore a broader modeling domain.

Data sources to support the establishment of the ocean boundary can include both in-situ and remote sensing data, and be jointly used to quantify the relevant variables, by characterizing estuarine water masses (in-situ sensors) and define the limits of these water masses in space (remote sensing).

Earth observation data should be selected according to the variables that represent the relevant processes in both space and time, and at the adequate resolution. Copernicus Sentinel data is a good choice for the spatial and temporal scales for typical estuarine models, given their resolution and free access. The sources of the in-situ data should be selected taking into account the goal of defining an ocean boundary. Therefore, the downstream stations should be the most adequate if their temporal scales are comprehensive to include the required time period.

In-situ data should be subject to a quality assessment before being used to identify the signature of estuarine water masses as data is often plagued with outliers, drifts or other errors that can have an impact on the analysis (Jesus et al., 2021). After the quality assessment, data can then be used to calculate the signature procedure selected by the user.

Phase 2 - Implementation of workflow and definition of limit

The workflow for image processing starts with the identification of the images acquired and available over the selected time period (for instance, to develop a modeling task related to summer conditions, all images within that season interval will be selected from all available years in the available remote sensing sources such as Copernicus). Then an automatic procedure is established to process all those images for the indicator defined in the previous phase. A collection of outer limits is gathered and an additional script is then used to define the most external limit (using for instance the distance along a cross section line for each outer limit).

Phase 3 - Developing of unstructured grid using an online, on-demand grid generator

Once the outer limit for the computational grid is defined, the grid generation is the next step. Several unstructured grid generators are available but they are either very complex to use or require specialized knowledge or require acquisition of software licences. Herein we propose a distinct approach, taking advantage of the new grid generation service OPENMeshS (Martins et al., in press) available within the OPENCoastS service platform (Oliveira et al., 2020) at https://opencoasts.ncg.ingrid.pt/.

The generation of unstructured grids requires some basic rules than can be found in Fortunato et al. (2011), so this limit should be adapted for grid boundary purposes (taking for instance a curvilinear shape). In order to use the improved outer limit in OPENMeshS, the user must then convert to .json format and upload it in the second step of the grid generation workflow.

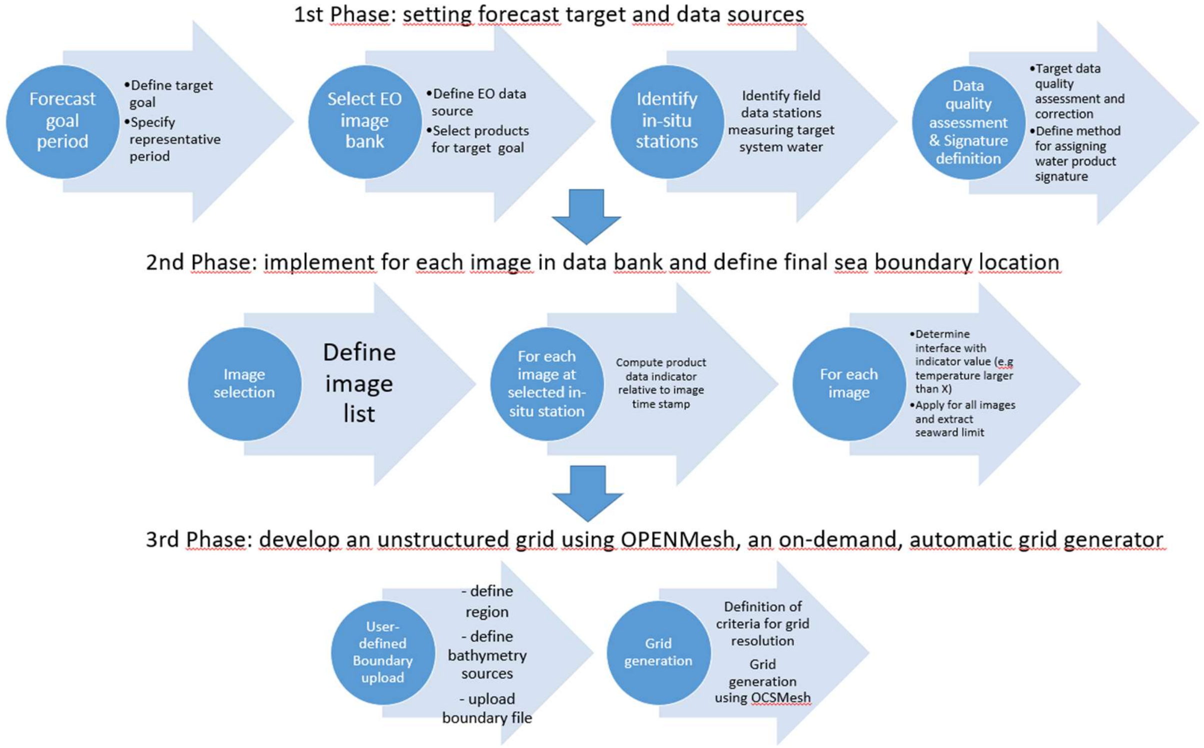


Figure 1. Workflow for implementation of seaward limit detection for grid boundary determination

2.2 Demonstration in the Tagus estuary

To illustrate the application of the methodology, a hypothetical simulation target is defined for the Tagus estuary biogeochemistry annual dynamics. Data from the CoastNet repository is used from both remote sensing and in-situ stations. A one-year time series of chlorophyll-a in the station closest to the mouth of the Tagus estuary was selected to determine an average value representing estuarine conditions. Data can be purged from spurious values using a data reliability engine (Jesus et al., 2015) to establish the threshold to be used in the remote sensing images.

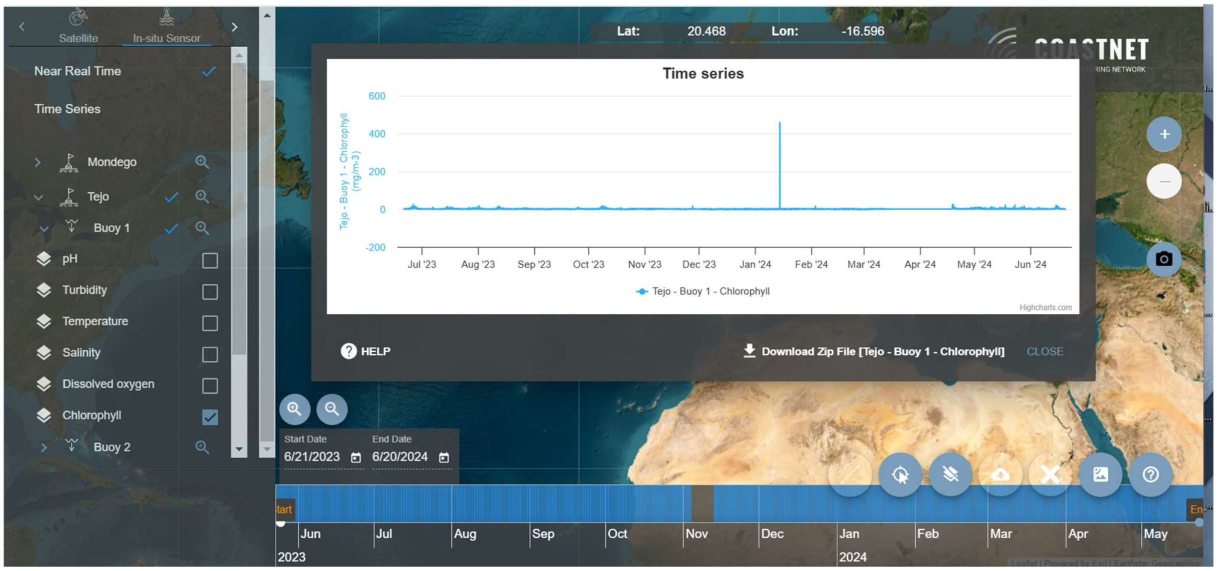


Figure 2. One-year time series of chlorophyll-a in Tagus outward station (CoastNet Buoy 1).

The available images from CoastNet and other sources can then be processed to define the limit of that threshold across the image. The most outward limit is then used to set up the grid ocean boundary location, by intersecting the several limits with a line defined across the estuary's mouth.

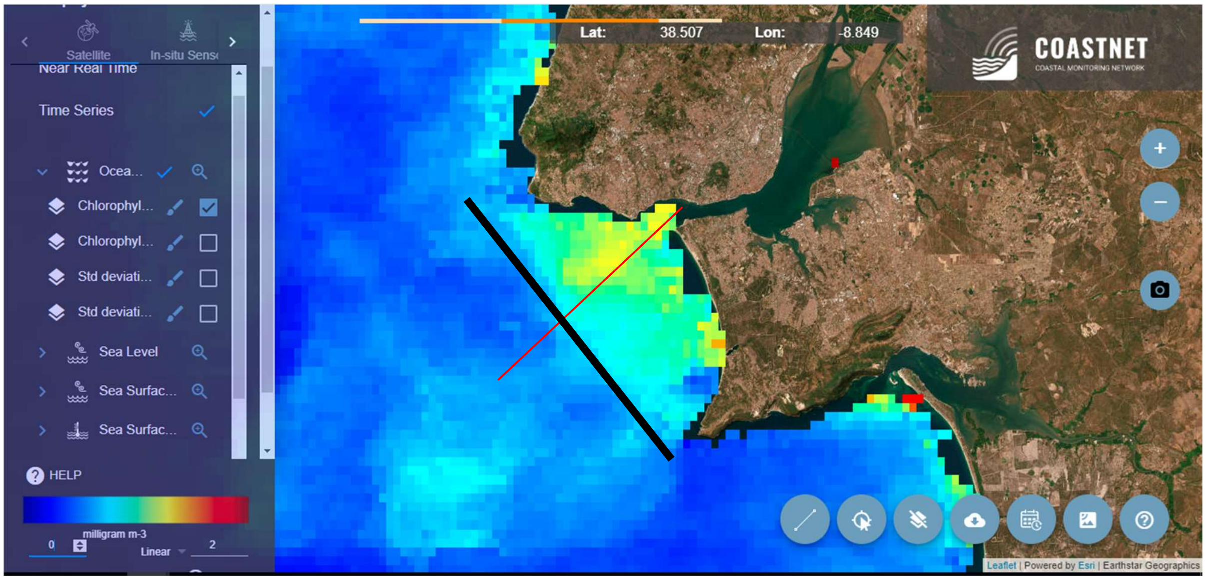
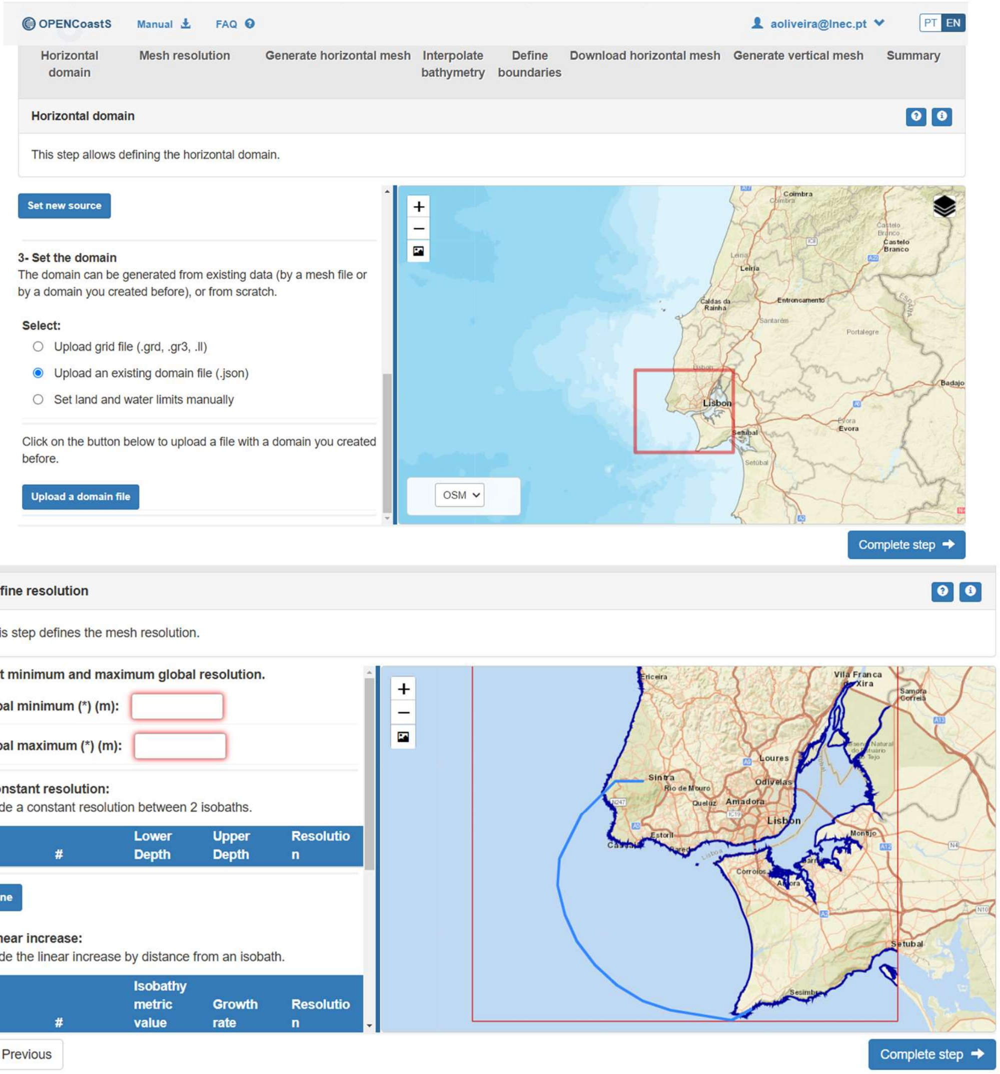


Figure 3. Sample image from chlorophyll-a database and an example of a schematic outward limit (black) and a possible cross section line (red)

Once this limit is specified, it can be used in OPENMesh (Martins et al., in review), an online, on-demand free tool, to contribute to the creation of the computational grid. The limit must be created in .json format and can then be uploaded in the interface. It can then be edited to comply with best practices in the definition of boundary limits for computational grids.

This procedure combines in-situ and remote sensing data to support model forecasting quality through the generation of a grid covering the adequate area that includes the relevant physical and biogeochemical processes.



Horizontal domain

This step allows defining the horizontal domain.

3- Set the domain

The domain can be generated from existing data (by a mesh file or by a domain you created before), or from scratch.

Select:

○ Upload grid file (.grd, .gr3, .ll)

● Upload an existing domain file (.json)

○ Set land and water limits manually

Click on the button below to upload a file with a domain you created before.

Define resolution

This step defines the mesh resolution.

1- Set minimum and maximum global resolution.

Global minimum (*) (m):

Global maximum (*) (m):

2- Constant resolution:

Provide a constant resolution between 2 isobaths.

#	Lower Depth	Upper Depth	Resolution

3- Linear increase:

Provide the linear increase by distance from an isobath.

#	Isobathy metric value	Growth rate	Resolution

Figure 4. Intermediate steps in grid generation: a) limit upload in .json format, and b) editing of limit for better grid construction.

3 Methodology to support monitoring infrastructures using numerical model forecast outputs and its demonstration in the Tagus estuary

Model outputs provide a wealth of information on coastal dynamics by solving the relevant processes at the adequate spatial and temporal scales. None of the existing monitoring choices currently available is able to cover space and time in the same detailed way. As such, the usage of numerical model information to complement field data is becoming more frequent. Traditional approaches include the definition of the field station location based on feature representation (e.g. the location of the estuarine plume - Burla et al., 2020 - or the sampling of water types based on salinity values). More recent examples include the use of numerical results to fill data gaps in monitoring networks using data fusion techniques.

Model results are also a very convenient tool to explore estuarine water dynamics and to support advanced monitoring techniques. Herein we explore these features in support of mobile water monitoring platforms. Water drones have been gaining importance in recent years in the monitoring of estuarine waters. Recent products are becoming better equipped to deal with the strong currents and short wave dynamics in these environments with the advantage of small size to deal with complex geometries and bathymetric features. Application of swarm methodologies in a group of water drones permits for the first time the monitoring of contamination plumes and their evolution in time and space. While the data exchange within the swarm can build a time stamped vision of the plume, it is very important to anticipate the plume's movement to decide the swarm's next movements. Model forecasts can provide this information to the drones and even adapt and correct the forecast with the swarm's previous data through assimilation procedures.

3.1 Methodology description

Herein a methodology is proposed that takes advantage of both model forecast and in-situ dynamic field data. This methodology, that entails two phases, is presented in a generic way in Figure 5 and described in detail below.

Phase 1 - Setting forecast source information and drone simulator

Contamination plume pathways in estuaries and coastal zones require a fine and accurate definition of the underlying currents and waves to properly address advection and diffusion processes as well as other contaminant specific processes. The main variable to identify plume dynamics should be selected at this stage.

In order to set up an adequate forecast system, the user can take advantage of the OPENCoastS service (Oliveira et al., 2020) to set up a deployment with all the necessary complexity that represents the site dynamics. This service does not require expert knowledge of modeling or information systems as the user interacts with a user-friendly web platform and performs a guided implementation through multi-choice procedures.

Results of the forecast can then be integrated in a drone movement simulator either running centrally along with the forecast (and only transmitting to the drone the next position) or run locally at each drone using edge computing. The resulting workflow can be tested under no-contamination conditions to verify the trustworthiness of the solution and to verify data transmission procedures either to or from the swarm. Mechanisms for data assimilation and creation of the enhanced prediction also need to be implemented and verified at this stage.

Phase 2 - Plume tracking operation based on intelligent swarm monitoring

The workflow for plume tracking starts with the deployment of the forecast system using OPENCoastS. At the same time, a swarm of adequate drones that measure the plume relevant characteristics must be built using a number of drone units large enough to follow all plume dynamics. Schematic plumes can be simulated using the source plume forecasting inside OPENCoastS to support the definition of the swarm size, if no other information is available on the plume location. If remote sensing data is available for the initial conditions, it can be used to select and place the drones.

The drone simulator and the forecast outputs need then to be either linked at the central computing resources or the models outputs need to be transferred to the drones. Then the next swarm movement is computed and new plume data is collected and transferred to the forecast systems.

Similarly to the previous application, in-situ drone data should be subject to a quality assessment before being used for assimilation. Data reliability will be processed using neighbour drones´ data as well as the model predictions (Jesus et al., 2021). This procedure can also be used continuously to detect any malfunctioning in any drone. After the quality assessment, data can be assimilated with model predictions and generate an updated plume movement prediction to guide the next swarm pathways.

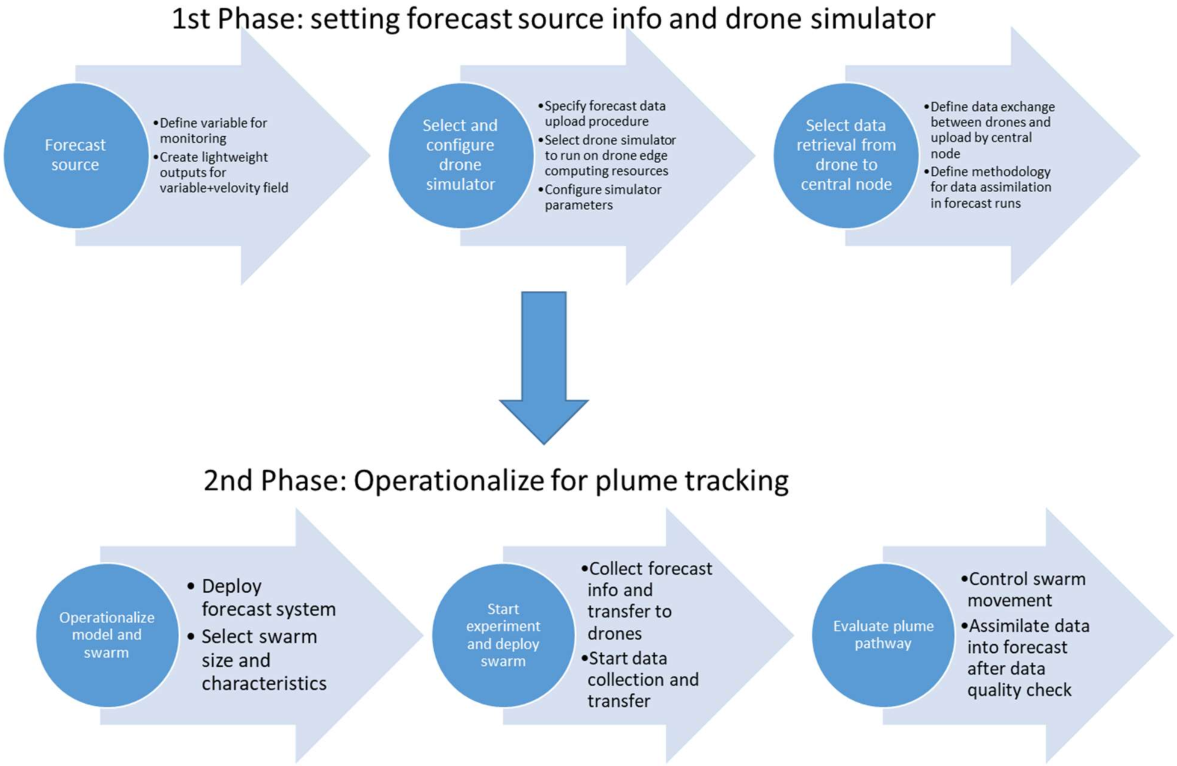
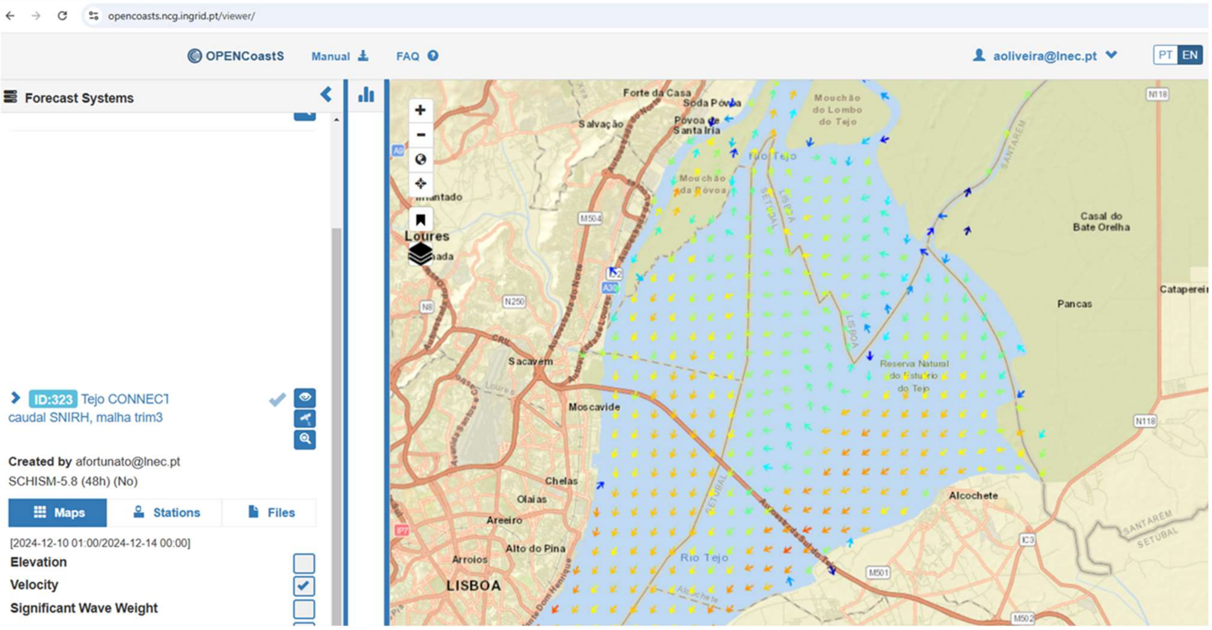


Figure 5. Workflow for implementation of plume pathway detection using drone swarms

3.2 Demonstration in the Tagus estuary

To illustrate the application of the methodology, a hypothetical algae plume monitoring is simulated in the Tagus estuary, using chlorophyll as the adequate tracer. First OPENCoastS is used to set up the hydrodynamic forecasts in the Tagus in order to provide the velocity field for the drone simulator. The biogeochemistry deployment is then set up to provide the initial plume conditions, forced by IBI CMEMs and climatology at the Tagus estuary. Based on the plume conditions, a number of drones is selected, “X”, based on the plume shape, location and dimensions. The pathways for the drones are then computed using SCHISM’s predictions and data sampling is simulated based on model results. As hypothetical data and model results are the same, no assimilation (using external tools) is used to correct the next predictions.



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Created by afortunato@lnec.pt
SCHISM-5.8 (48h) (No)

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Elevation ☐
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Figure 6. OPENCoastS hydrodynamic deployment sample result.

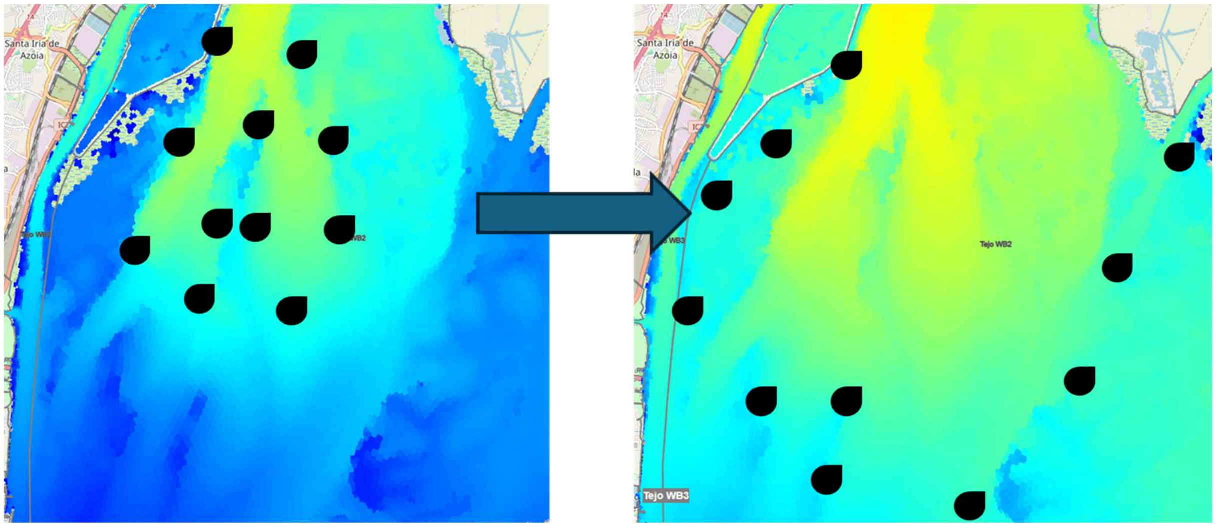

Figure 7. Plume evolution and potential swarm pathways for a specific isoline of the selected value

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