MODELLING OF HAZARDOUS SPILLS IN AIR AND SEA AND FLOATING CONTAINERS

Best Rapid Environmental Assessment System

Environmental Decision Support System (EDSS)

User manual

UCPM-2019-PP-AG/UCPM/ 874439

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1. INTRODUCTION

The marine environment is continuously and increasingly threatened by pollution derived from maritime accidents that frequently cause spills of dangerous substances. A great amount of work has been devoted to endow the EU-Member States with common protocols, action plans, and operational tools regarding either oil or HNS spill. So far, however, it is not available a unified platform that covers the Oil and HNS spills. This is the main gap that the PROMPT project aims to fill by implementing an Environmental Decision Support System (EDSS), easily exportable to different geographical contexts, which models the most common sources of pollution.

The primary expected results of the PROMPT project will be the implementation of a reliable and complete Environmental DSS tool that effectively helps the final end-users in the response to marine pollution events. Indeed, coupling real-time forecast of met-ocean conditions to numerical models will increase the quality of the spill trajectories/fate prediction and, finally, the effectiveness of the disaster response. The oil and HNS fate models will consider the main weathering processes that these substances encounter during their transport.

2. PILOT SITES

Although the methodologies developed in the PROMPT project are feasible to be implemented worldwide, three ports have been selected for the first implementation of PROMPT Environmental DDS. The pilot sites selected respond mainly to the project partners involved as follows:

2.1. Port of La Spezia (Italy)

The port of La Spezia (see Figure 1), located in the Ligurian Sea (Northwestern Mediterranean), latitude 44° 5' 14" N and longitude 9° 51' 2" E, has been considered one of the largest commercial ports in the Ligurian Sea.

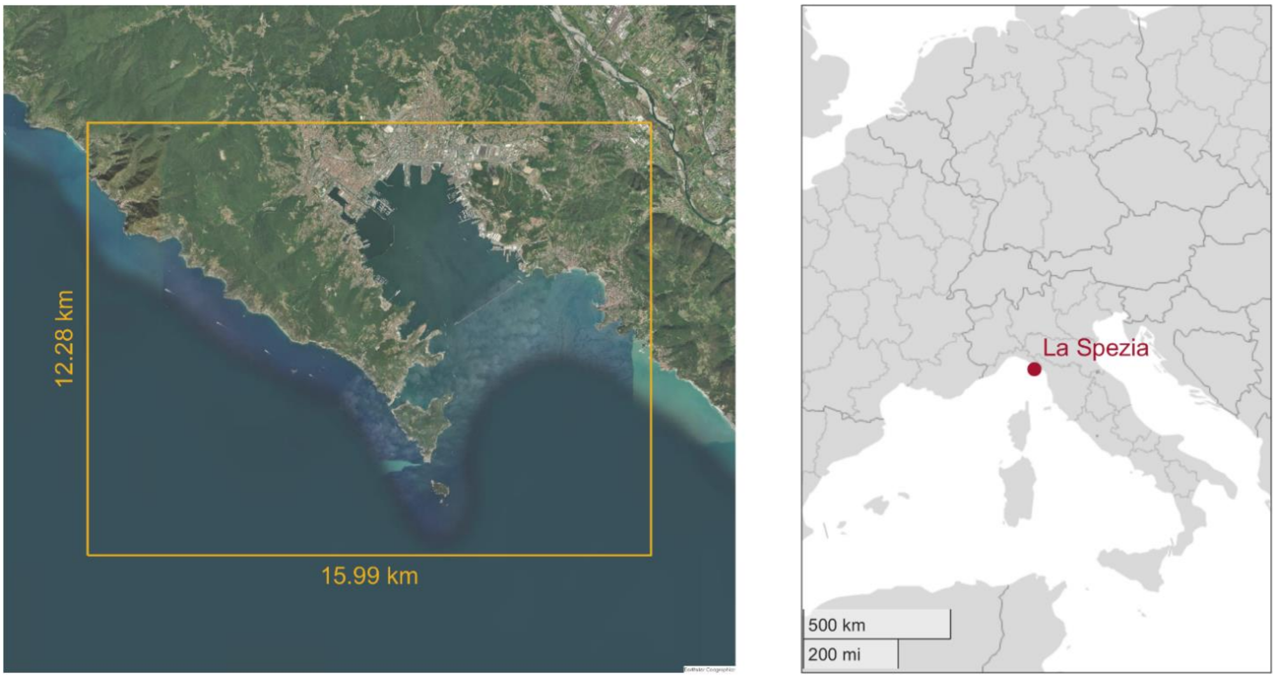

Figure 1. Plan view of the La Spezia harbor's computational domain

2.2. Port of Aqaba (Jordan)

The Gulf of Aqaba, located at 28°45′N 34°45′E, is a narrow, deep, and long northern extension of the Red Sea. The gulf is the only access of Jordan to the sea and is surrounded by dry desert mountains, no riverine inputs, and only a negligible runoff. The computational domain utilized for modeling this site is depicted in Figure 2.

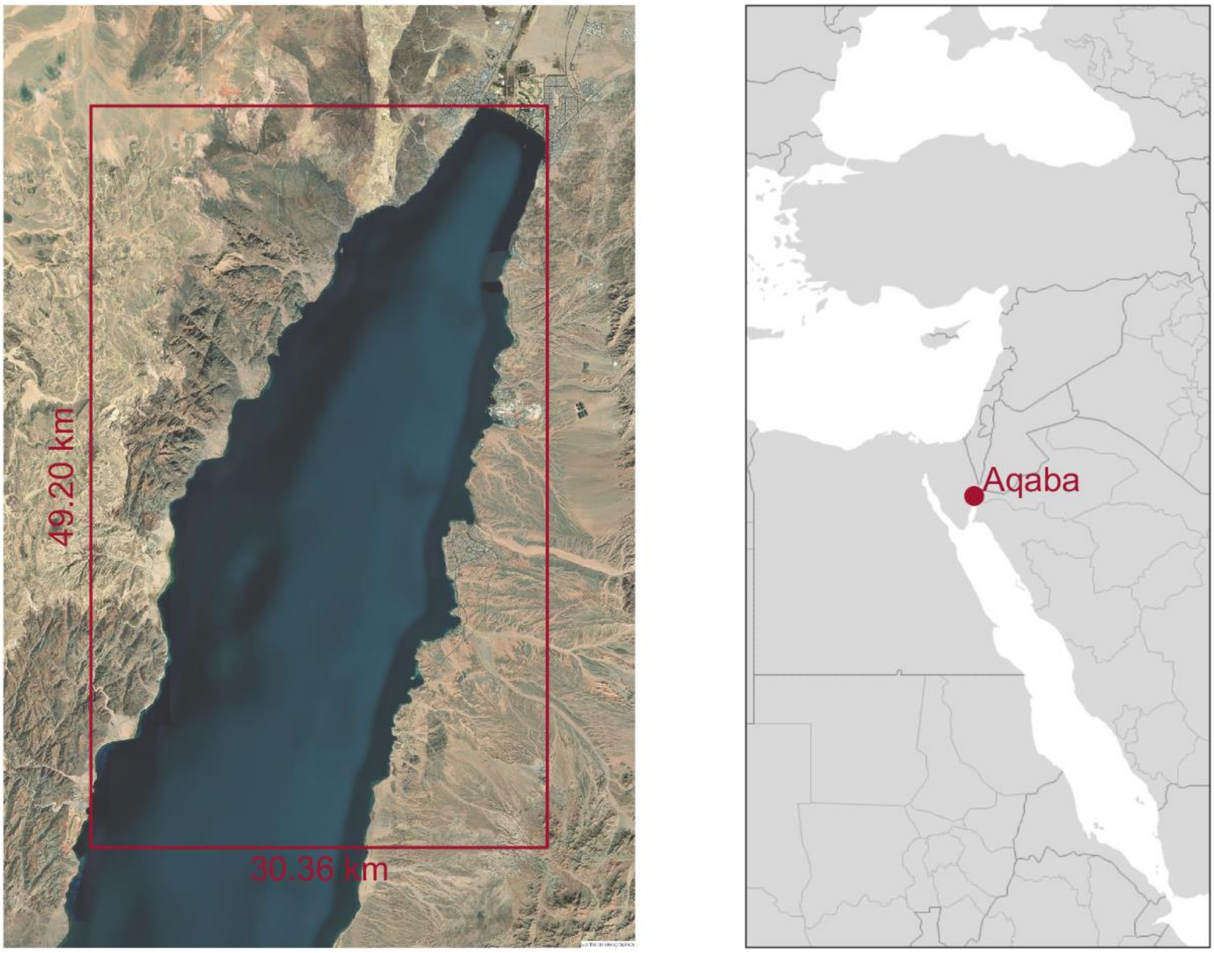

Figure 2. Plan view of the Aqaba harbor's computational domain

2.3. Port of Tripoli (Lebanon)

The port of Tripoli, geographically located in the Eastern Mediterranean Sea, Northern area of Tripoli city at 34° 27' 03" N 35°49' 43" E is among the most important port in the eastern basin of the Mediterranean Sea since it serves as a link between East and West. Figure 3 shows the computational domain implemented for this site.

Figure 3. Plan view of the Tripoli harbor’s computational domain

2.4 Port of Genoa (Italy)

The port of La Spezia (see Figure 4), located in the north of the Ligurian Sea (Northwestern Mediterranean), latitude 44° 24' 10.08" N and longitude 8° 55' 0.01" E, has been considered one of the most important commercial ports in Italy.

Figure 4. Plan view of the Genoa harbor's computational domain

3. ACCESS AND GENERAL INTERFACE

PROMPT DSS is a web map application that allows users to manage spatial and numerical data related to marine pollution, more specifically, related to oil and chemical spills. Access to the web can be done through this link (https://prompt.ihcantabria.com/) with the help of any conventional web browser.

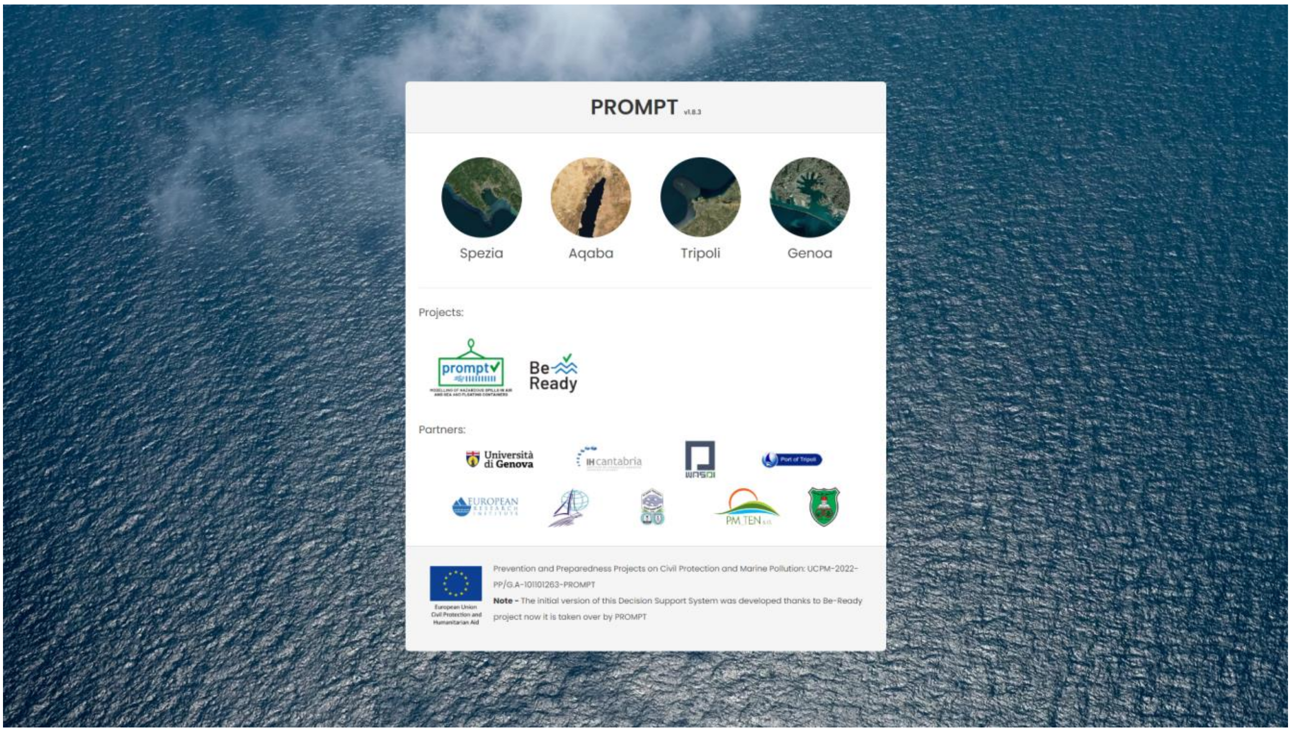

Figure 5 - Landing page of PROMPT Environmental DSS.

The first step after access to the web is to select one of the four pilot sites already implemented. Selection of the pilot site can be done by clicking on one of the four sites shown in Figure 5 (Landing page of the web).

Once the user access one of the pilot sites, the workflow and use of the system are exactly the same for each site. For this user manual, the pilot site of the Port of Tripoli has been used as an example throughout the entire document.

The general interface of the web is composed of three main areas:

- **Map Viewer area:** where the visualization of the site is performed and the main controls regarding visualization are shown (in/out zoom buttons and layer selection)

- **Menu component area:** where the panels to access the different components of the web app are shown.
- **Panel component area:** where the panel regarding the current panel is shown, ready to operate with the web app.

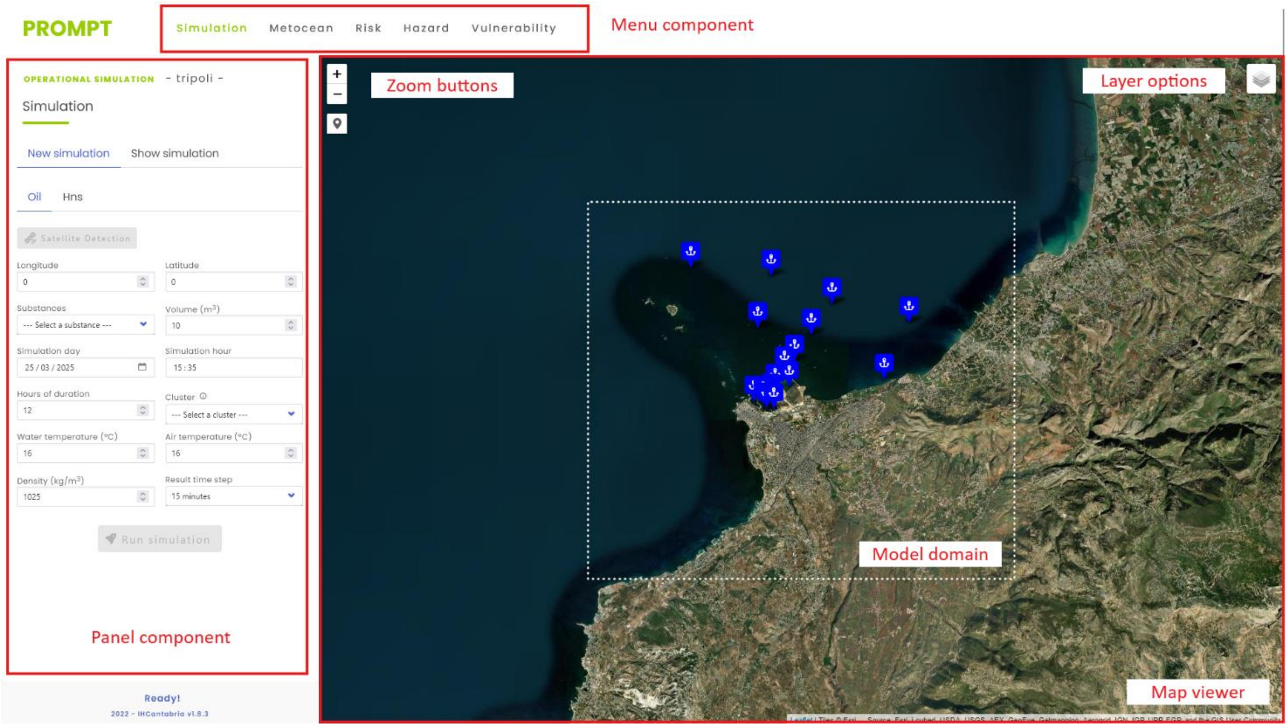

Figure 6 - General interface of the web after accessing the Port of Tripoli pilot site.

In addition to this general interface, PROMPT DSS is constituted by the following components / sub-components that can be reached through the menu component:

- Operational simulation
  - Simulation
  - Metocean
- Risk assessment
  - Risk
  - Hazard

- Vulnerability

By default, after accessing one of the pilot sites, the application access directly to the "Operational simulation" – "Simulation" panel to allow the user to execute a spill simulation.

4. OPERATIONAL SIMULATION

Operational simulation of an oil spill is the most deterministic approach that can be done in order to predict its evolution during the following hours. This component englobes the capacities of (1) set up, execute and visualize spill simulations inside the model domain implemented in the pilot site. And (2) visualize the metocean forcings that can be selected to drive the simulations (current and wind fields) provided by the statistical characterization techniques applied to obtain an ultra-fast approximation of these drivers.

4.1. Simulation

This component is in charge of performing the spill simulation (trajectories and weathering processes) based on some input information that the user has to define formerly to the spill simulation and also it is in charge of the visualization of the results of the simulations. To select one or another behavior at the top of the panel the user can choose between two tabs named "New simulation" or "Show simulation".

In the "New simulation" tab a formulary is shown (Figure 7) to define the simulation characteristics and allow the user to introduce the necessary inputs for the simulation. These input data can be summarized in three main groups:

- Characteristics of the spill:
  - Location: lon/lat coordinates where the spill is released.
  - Release date and time: exact date and time when the spill is released.
  - Substance: Name of the substance spilled from the available list implemented for the app.
  - Volume released: total volume of the substance released in cubic meters.
- Selection of the metocean forcings: selection of the meteocean cluster to be used, which implies wind and sea current conditions for the period of simulation.
- Simulation characteristics:
  - Duration of the simulation: time range to be simulated after the release of the substance in hours.
  - Seawater temperature: mean water temperature of the sea in the modeled area in Celsius degrees.
  - Air temperature: mean air temperature of the sea in the modeled area in Celsius degrees.
  - Seawater density: mean seawater density in the modeled area, units kg/m^3.

- Result time step: select the time step of the results, the user can choose between 15-, 30-, and 60-minute time steps. Note that decreasing the time step will increase the computational time.

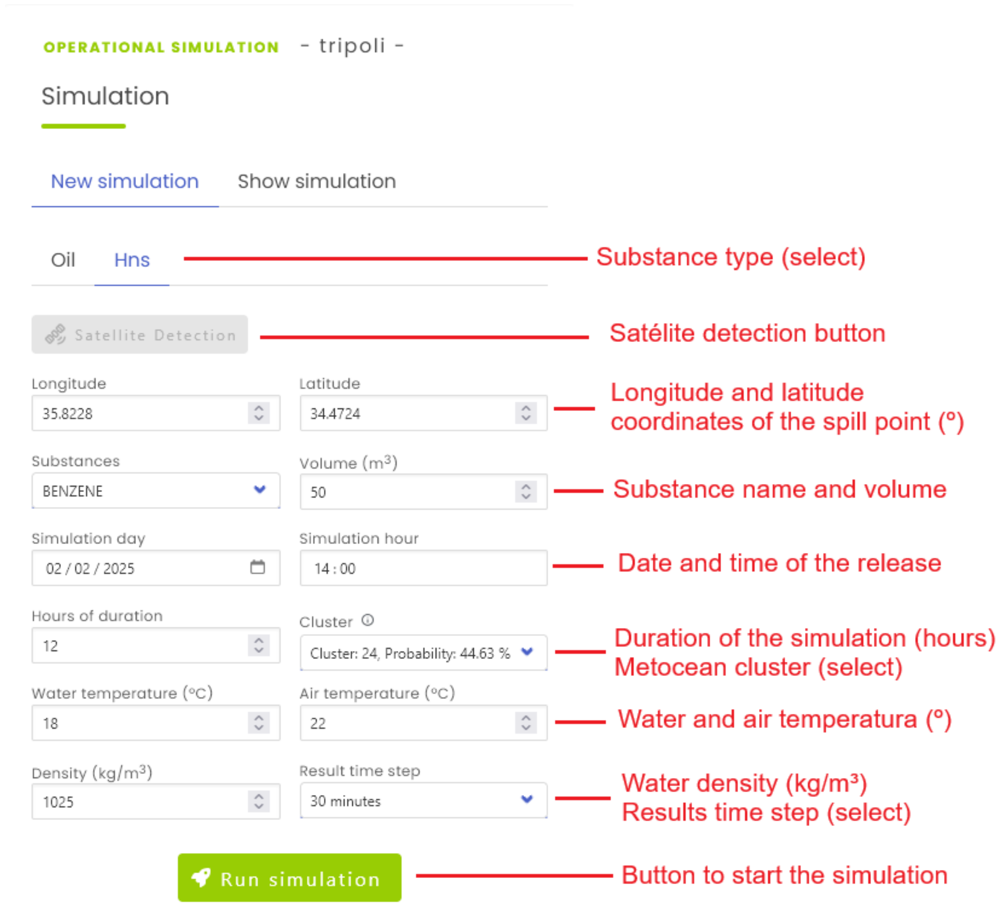

Figure 7 - Simulation panel where the user defines the simulation characteristics and triggers the simulation.

Additionally, to this “New simulation” panel, and only for the spill point location, a graphical approximation of this input can be done directly over the map inside the model domain. For this operation, the user has to click over the icon defined to set up a spill point graphically and then click again over the map where the spill point is preferred (see Figure 8).

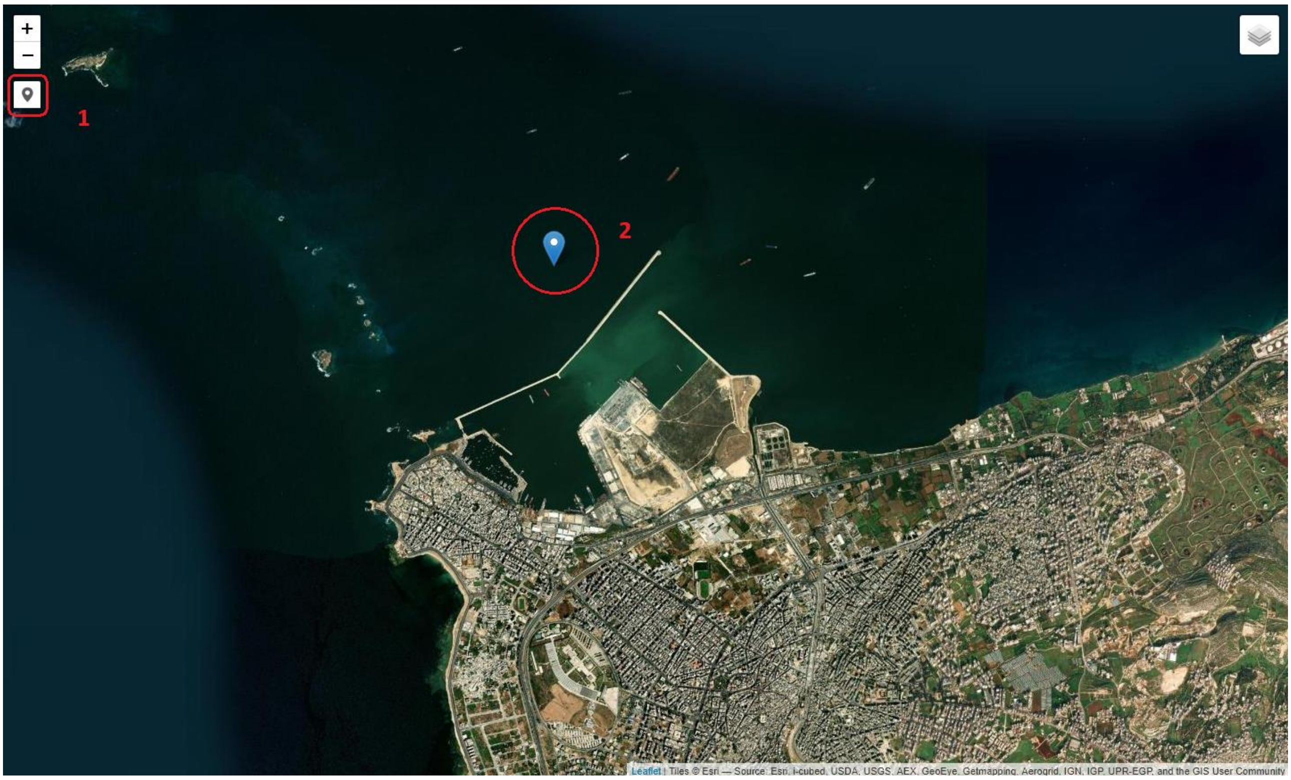

Figure 8 - Graphically selection of the spill point. (1) activate the graphical input and (2) define the location of the spill point.

The execution of the model can take around 1-2 minutes; during this period, a waiting message will appear below the map viewer area reading:” Simulating particle spill…”.

After the simulation process, the user will be asked if he wants to run an atmospheric simulation. This will happen only if the simulated substance is a chemical, and there is an emission of mass to the atmosphere derived from evaporation or/and volatilization processes. After the user approval, a waiting message will appear below the map viewer area reading:” Running atmospheric simulation…”.

Note that this coupling of marine and atmospheric models is only possible with HNS simulations.

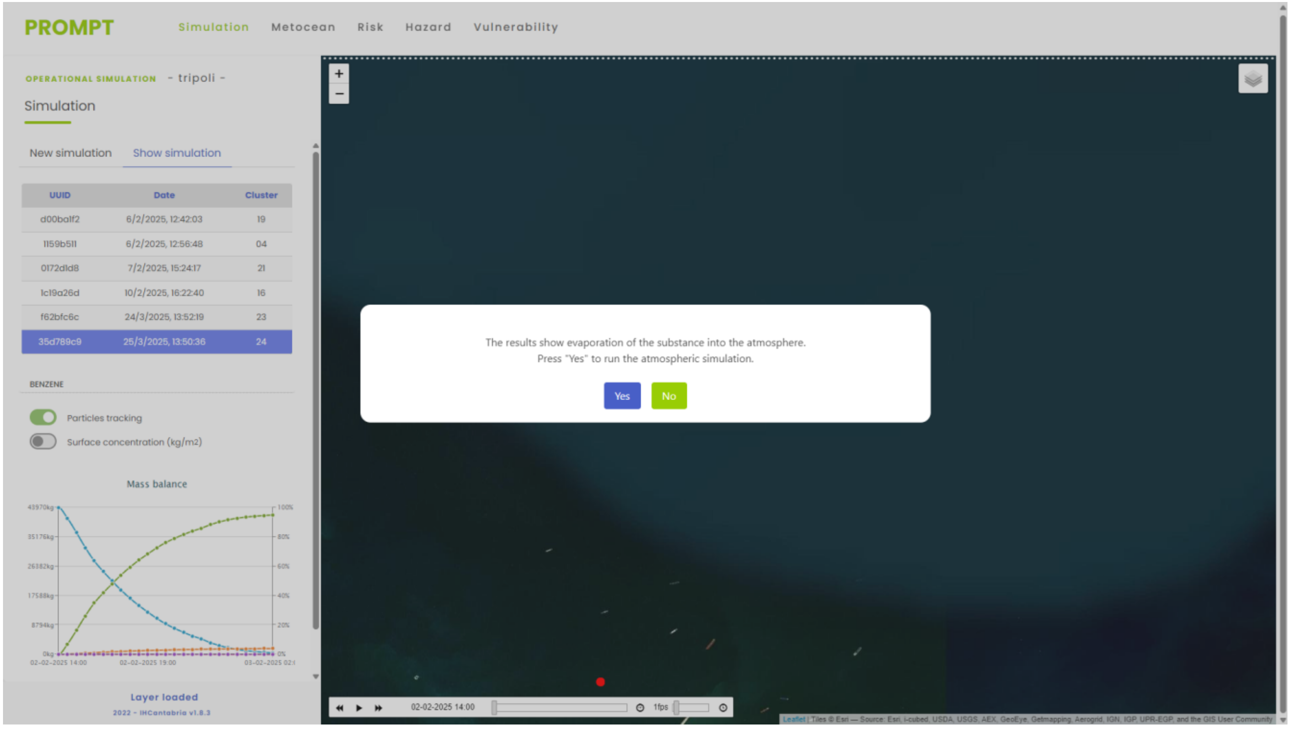

Figure 9 - Show simulation panel (left panel), map viewer example of particles tracking visualization (top-right image), and surface concentration visualization (bottom-right image)

After the simulation ends, the “Show simulation” panel will be automatically selected. The results provided by the system are an interactive chart of the evolution of the mass balance of the slick, a representation of the evolution of the particle tracking, a representation of the evolution of the mass concentration at the sea surface and a representation of the evolution of the atmosphere concentration.

In Figure , the “Show simulation” panel is presented, where the visualization of the mass balance and the switches for selecting the particle tracking, surface concentration representation, or atmosphere concentration are located.

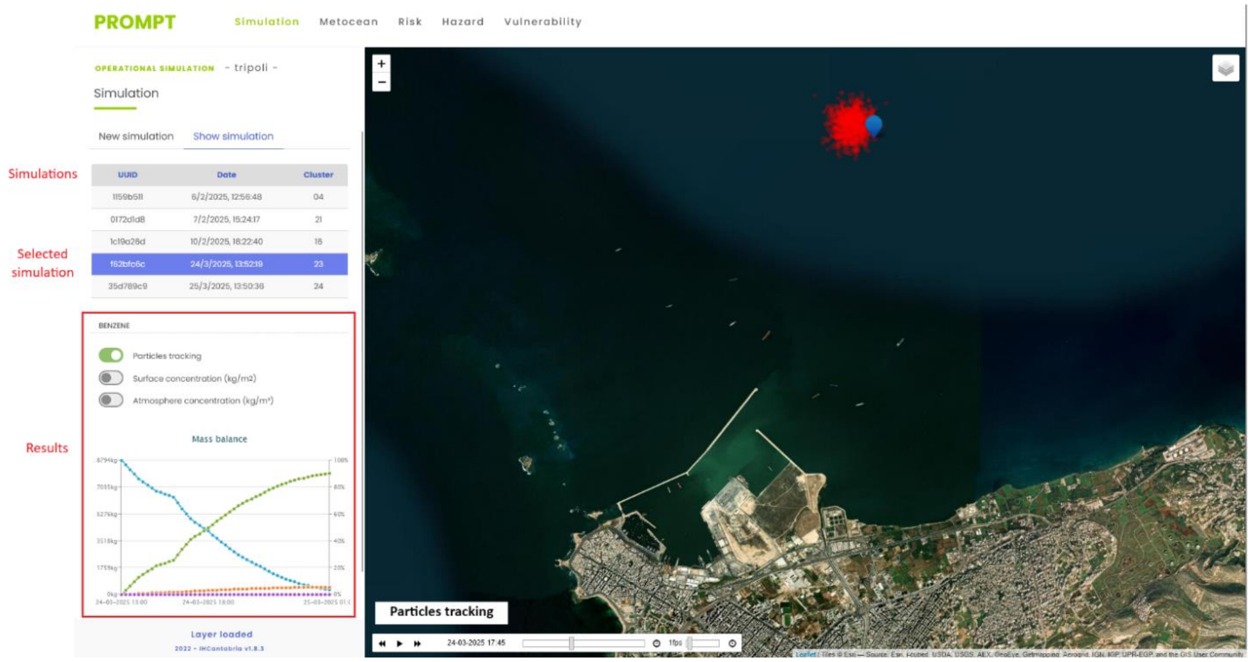

Figure 10 - Show simulation panel (left panel), map viewer example of particles tracking visualization

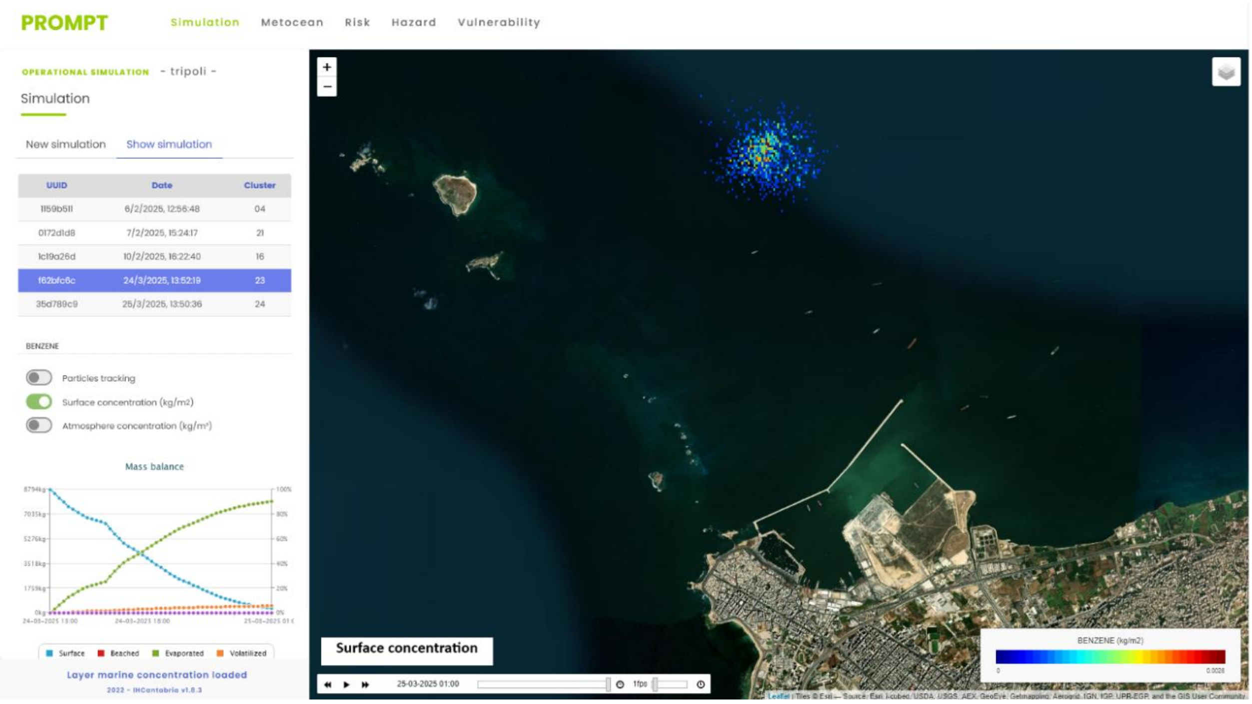

Figure 11 - Show simulation panel (left panel), map viewer example of surface concentration visualization (bottom-right image)

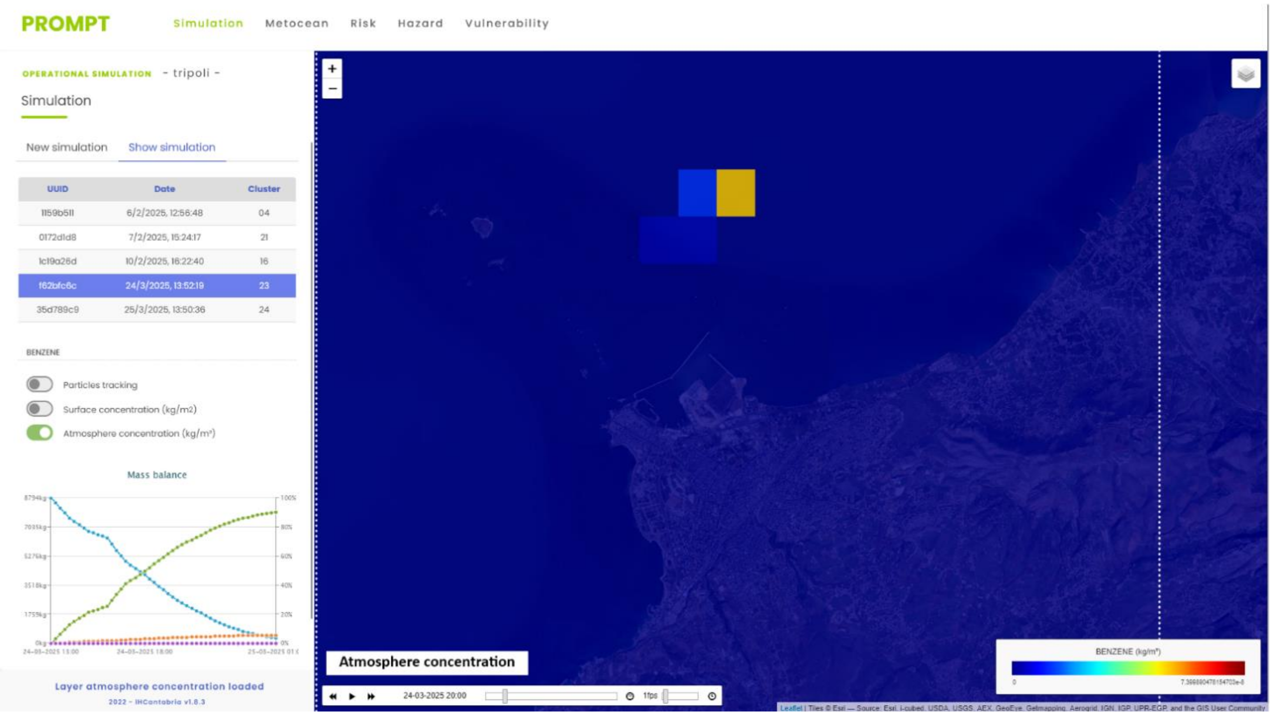

Figure 12 - Show simulation panel (left panel), map viewer example of atmosphere concentration visualization

Mass balance interactive chart displays all the temporal evolution of the slick, however temporal management of the representation of the surface concentration, atmosphere concentration and particles tracking is provided through a small interactive date and time controller located at the bottom-left area of the map viewer. This controller allows users to advance forward and backward, pause and start the animation of these map results and also adjust the frame rate of the animation (Figure 13).

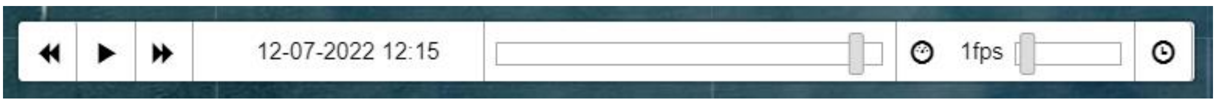

Figure 13 - Interactive date and time controller located at the bottom-left area of the map viewer.

4.1.1. Simulation after satellite detection

During a real oil spill, remote sensing capabilities can help to configure the initial hypotheses about where to locate the slick. Based on the service implemented on the DSS, the user only needs to fulfil the date required at the panel shown in Figure 14 to start the satellite detection for this specific day.

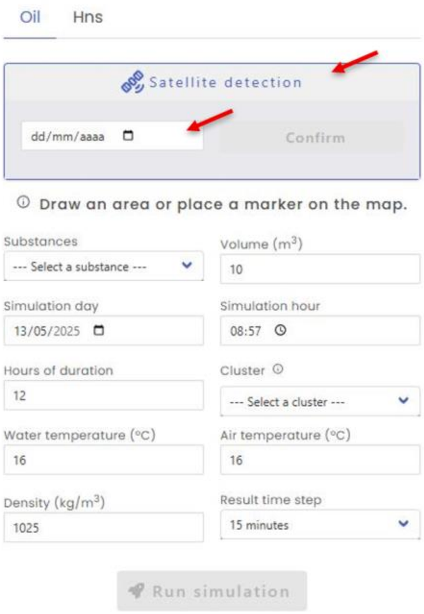

Figure 14 - Satellite detection panel

The result of this service is access to two different layers:

1- A layer of probability of the presence of an oil spill on the sea surface (Figure 15)
2- A layer of detection of an oil spill on the sea surface (Figure 16)

This information is shown on the DSS, and the opacity of these layers can be adjusted at the same Satellite detection panel.

Finally, the user can take advantage of this information to draw a rectangle around the area of the oil slick using the red icon in Figure 16. Selecting this configuration rather than setting the initial release point causes the model to randomly disperse the particles representing the oil slick within the rectangle. This improves the initial location of the slick based on information gathered from the oil spill detection service.

Note that user supervision of the identification of the oil spill is extremely required due to several reasons:

- These novel algorithms still produce a significant number of false positives that require user supervision.
- The capability to make decisions based not only on satellite detection but also on information provided by on-field detection should be used to verify satellite information.
- Manual definition of the rectangle provides flexibility to define the core area of the slick or to identify and simulate different slicks that may be present at the same time.

Also, it is worth clarifying that the use of the initial area definition defines only the geometry of the spill at this moment, but it doesn't take into account the age of the oil at sea. The weathering processes carried out until this point are not calculated; consequently, noted that the model treats this slick as pure fresh oil of the product selected.

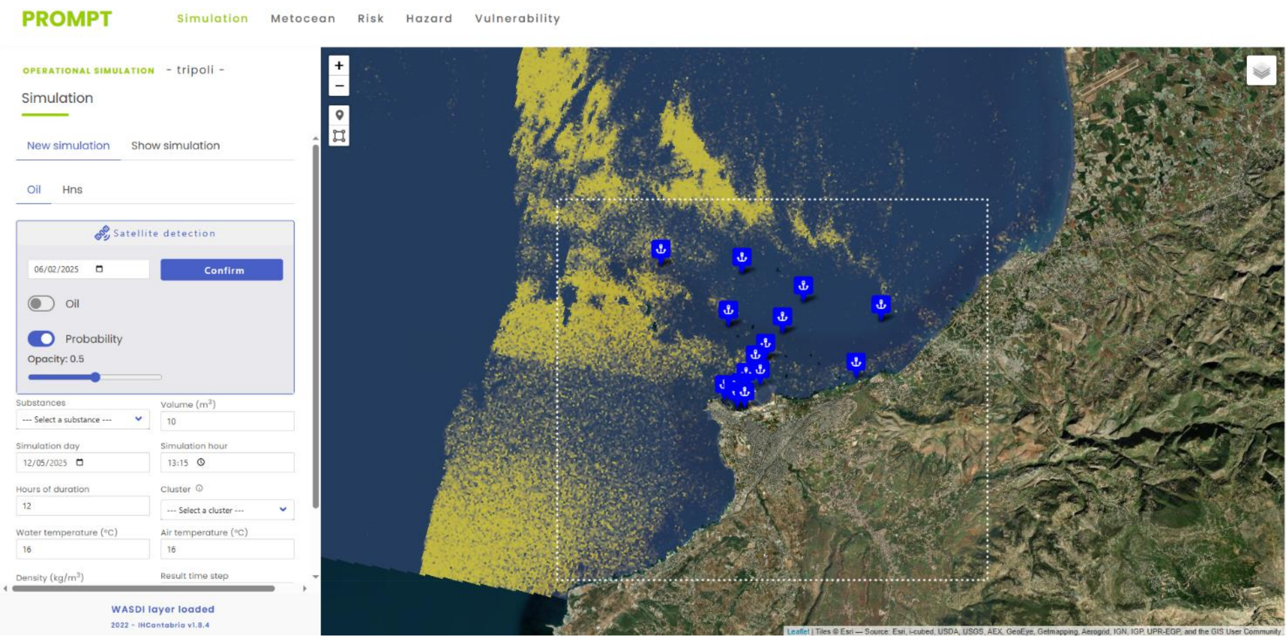

Figure 15 - Satellite Detection (Probability)

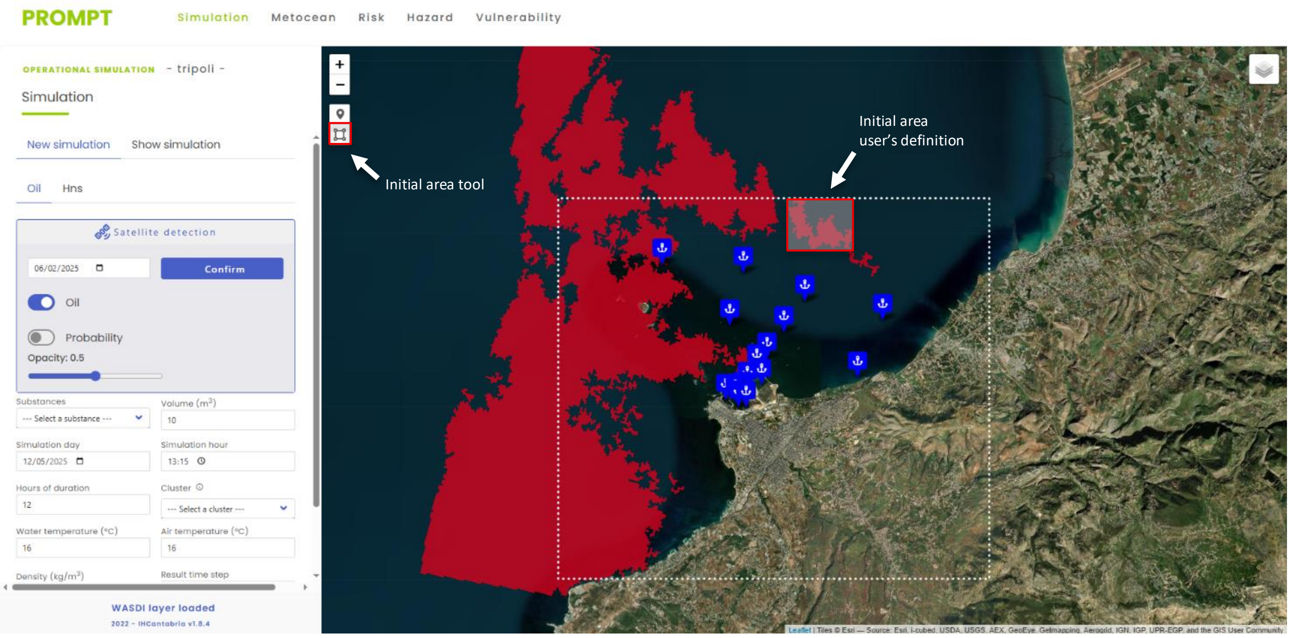

Figure 16 - Satellite Detection (Oil)

4.2. Metocean

Metocean component provides users the availability to visualize meteocean variables that feed simulations. The workflow required by the user to visualize any of the meteocean variables used in the simulations is simple, the user only must select the metocean cluster required to obtain the visualization of the surface currents and wind for each hour. Again, the temporal management of the visualization is controlled by an interactive date and time controller located at the bottom-left area of the map viewer.

In next figures, an example of the metocean panel, and related visualizations of surface currents and wind are shown.

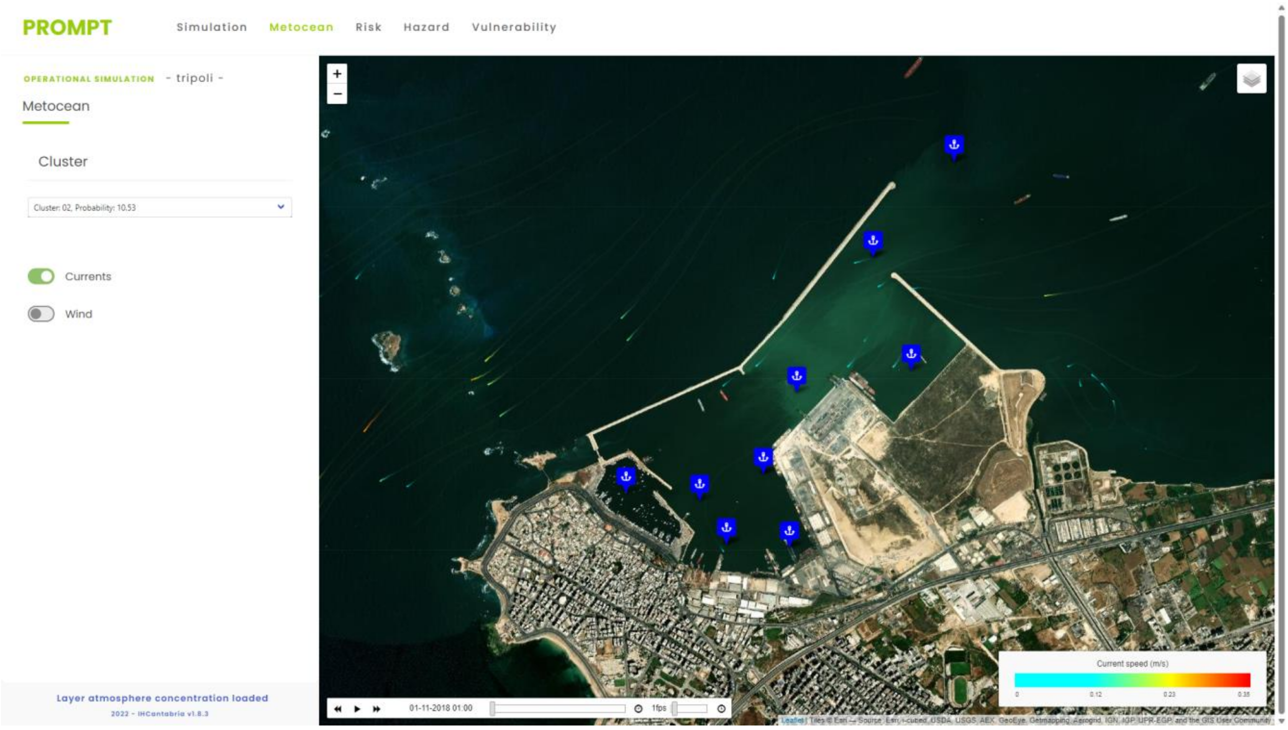

Figure 17 - Metocean component providing surface currents (map viewer) related to cluster 02 in the port of Tripoli.

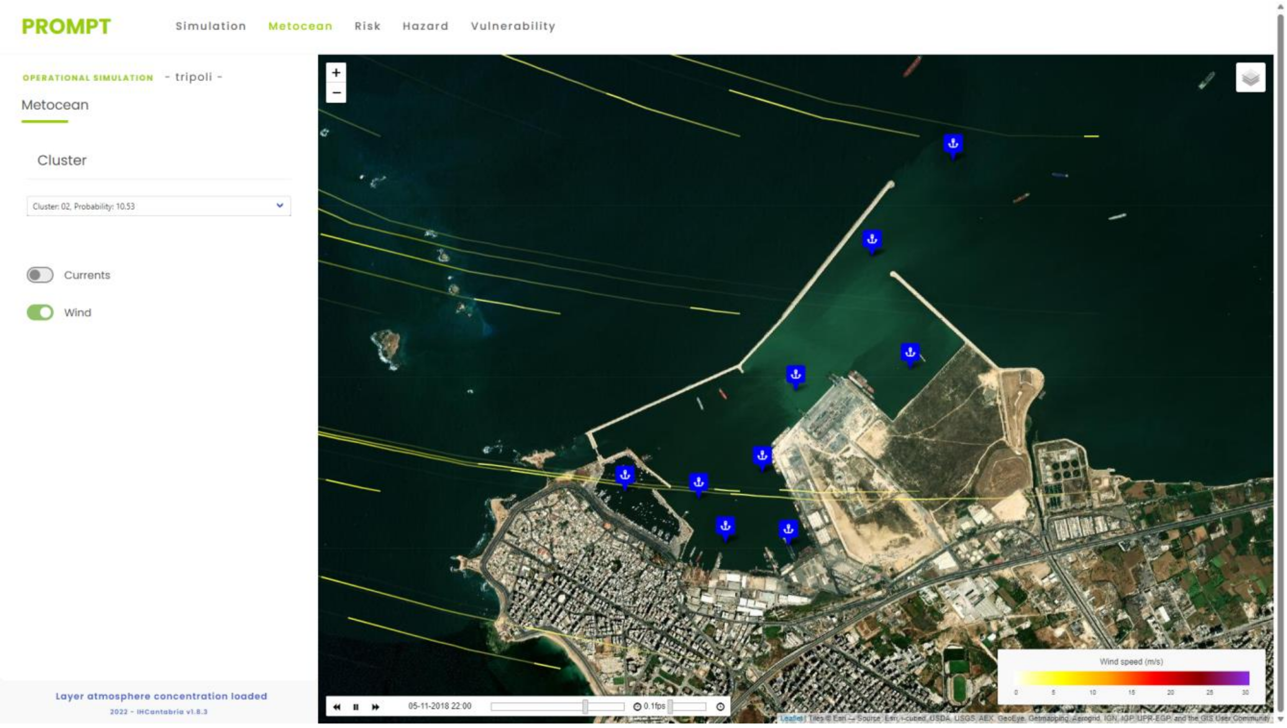

Figure 18 - Metocean component providing wind (map viewer) related to cluster 02 in the port of Tripoli.

5. RISK ASSESSMENT

Risk assessment component focus on the statistical analysis of the pollution risk against a release of the top substances transported at each port and at the most probable points of release detected in each one.

This assessment is composed of three main result variables: the hazard, the vulnerability, and finally, the pollution risk. This information is relevant to producing contingency plans, general protocols, or analyzing probable situations that can take place in the future. The analysis has been carried out for each substance and spill point for two different control volumes of substance spilled, obtaining for each of these combinations the classification of the before mentioned variables.

Risk assessment sub-sections are available in the present menu component at the navbar (see Figure 6).

5.1. Hazard

The probability of contamination of the sea because of a substance spill evolution is calculated by means of multiple spill simulations at the selected release point, substance, and volume for all the metocean clusters that describe the probability of the metocean conditions (sea currents and winds) of the selected port. As a result of these simulations, the envelope of all the evolutions of the particles simulated over the numerical domain provides the statistical probability of contamination. Also, as a derived result, the initial time when any particle reaches any cell of the computational domain is registered. Thus, if a cell in the domain suffers contamination the minimum time when the contamination reaches this cell is processed as a minimum arrival time result.

To access this information the user has to access the tab “Hazard” through the menu component panel at the top of the website (see Figure 6). The system now will require the user to select the substance type, the mooring point, and the combination of substance and volume spilled preferred by the user. Finally, to visualize the results the user must select one of the two results calculated: “Probability of contamination” (percentage from 0 to 100%) or “Minimum arrival time of the contamination” (hours). In Figure 19, an image of the selection panel and the corresponding result of probability at the port of Tripoli is shown as an example.

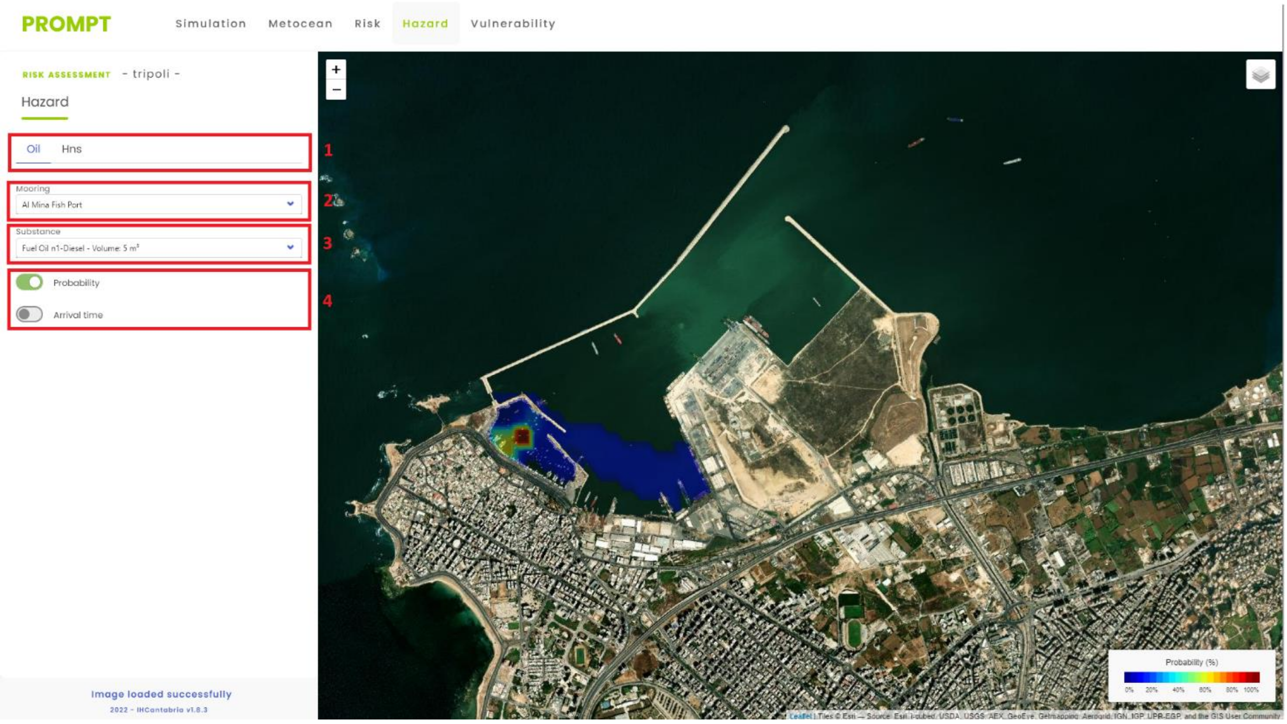

Figure 19- Probability calculated at the port of Tripoli. 1) Substance type (OIL or HNS), 2) Mooring selection, 3) substance and volume selection, and 4) selection of the result to be visualized on the web map.

5.2. Vulnerability

The vulnerability of a resource against a hazard is a key factor for risk estimation. For the analysis of the vulnerability of the resources and assets in the port areas three main indexes have been developed:

- Physical index
- Socio-economic index
- Environmental index

Vulnerability results can be consulted by accessing the “Vulnerability” tab from the menu component (see Figure 6). Once the user has accessed this site, the procedure to consult vulnerability results is quite straightforward. The user has 1) to select the type of substance and 2) to select the result desired between the following ones (see Figure 20):

- One of the three indexes mentioned before.
- Integral vulnerability as the composed vulnerability considering the three indexes.

Figure 20 - Vulnerability results from Risk Assessment. 1) Selection of substance type and 2) selection of the index assessed.

Vulnerability results are presented as a classification of 5 categories that represented the level of vulnerability of the area based on the selected index to oil and hns marine contamination. The levels are:

- Very low
- Low
- Moderate
- High
- Very high

5.3. Risk

Risk is calculated as the combination of hazard and vulnerability, so that, results depend on the substance type, mooring, substance, and volume spilled but also on the vulnerability index considered (integral, physical, socio-economic, or environmental).

As in any Risk assessment sub-section, risk results are accessed by the "Risk" tab located at the menu component (see Figure 6). Once the user accesses this interface is ready to select substance and mooring information (step A). After selecting this information, the available risk results will appear in the component panel to be activated and shown on the web map (step B). In Figure 21, these panels and the result of integral risk are shown as an example.

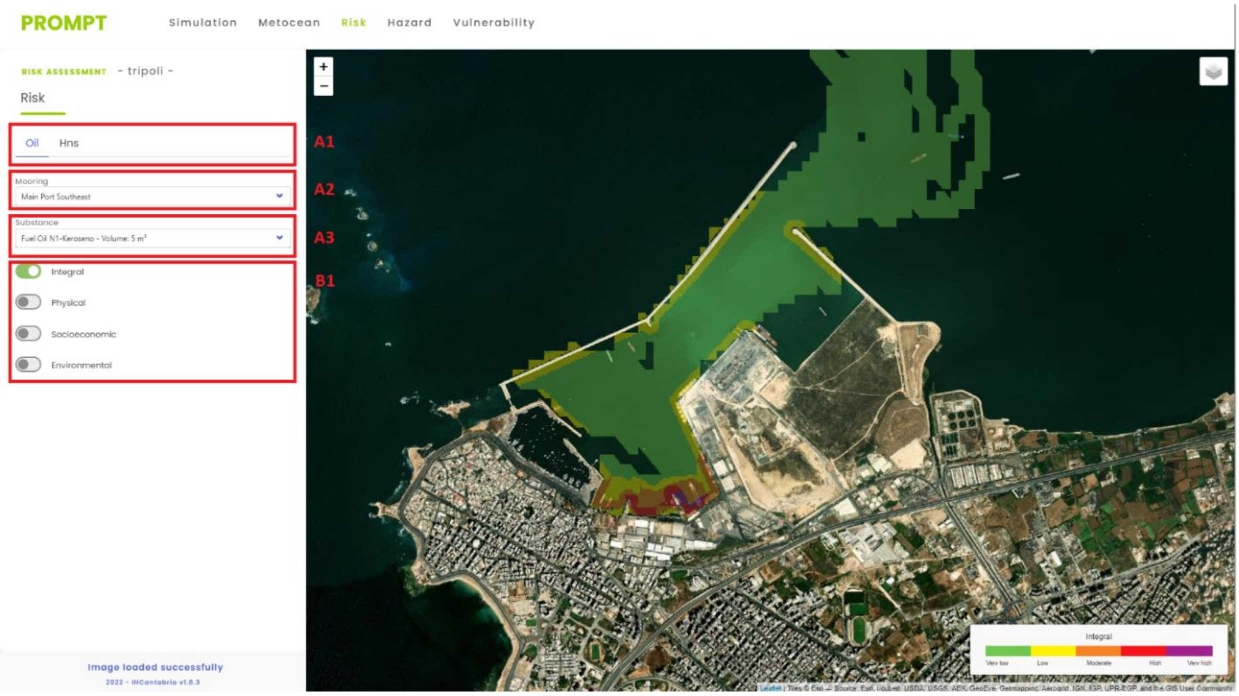

Figure 21 - Risk results from the Risk Assessment component. A1) substance type selection, A2) mooring selection, A3) substance and volume selection, and B1) risk selection.

Risk results are presented as a classification based on five categories that represent the level of risk at each modeled grid cell, these categories are:

- Very low
- Low
- Moderate
- High
- Very high