CO-LOCATION OPPORTUNITIES FOR RENEWABLE ENERGIES AND AQUACULTURE FACILITIES, DECISION SUPPORT FOR OPERATIONAL MULTI-USE PLATFORM ACTIVITIES AT COASTAL AREAS"

(RENAQUA Decision Support System)

User Interfaces and User Experience
of the RENAQUA Service
15th January 2020

INDEX

List of Acronyms

DIAS	Data Information Access Service
DSS	Decision Support System
HSOM	Health - Safety and Operational Maintenance
IH-MSP	IHCantabria's Platform for Marine Spatial Planning
M2M	Machine to machine communication
Metocean	meteo-oceoanographic
MINECO	Spanish Ministry of Economy, Industry and Competitiveness
MITECO	Spanish Ministry for the Ecological Transition
MRE	Marine Renewable Energy
MUP	Multi-Use Platforms
NCEP	National Centers for Environmental Predictions
NCML	NetCDF Markup Language
NGA	National Geospatial Intelligence Agency
NOAA	National Oceanic and Atmospheric Administration
O&M	Operations & Maintenance
OGC	Open Geospatial Consortium
RENAQUA	RENewable energies and AQUAculture facilities
SDGs	Sustainable Development Goals
TDS	THREDDS Data server
UCLA	University of California, Los Angeles
UI	User Interface
UX	User Experience
WCS	Web Coverage Service
WEkEO	We knowledge Earth Obsevation
WMS	Web Map Service

1 INTRODUCTION

The RENAQUA Service has been included into the IHCantabria's Platform for Marine Spatial Planning (IH-MSP). The MSP Platform is an open access Web application that integrates technical and scientific knowledge from IHCantabria's researchers in support of the 2030 agenda for sustainable development and associated SDGs. The Platform includes results from several research projects in relation with marine activities from global to local scale.

The CMEMS downstream service, RENAQUA DSS, is focused on the global scale and, as the IH-MSP, it has been published under an **open access** strategy. Both, map visualisation and data sets, are accessible via any standard web browser (Firefox, Chrome) or through interoperability protocols (Web Map Service, http, Web Coverage Service).

The System has been designed providing a UI that allows answering the needs of targeted users through a high-quality UX. The following url provides access to the IH-MSP Portal, and therefore to the RENAQUA downstream service (global scale):

http://msp.ihcantabria.com

On the other hand, for those end users that require accessing MSP data sets and request analysis under interoperability protocols (M2M communication), three APIs have been implemented to facilitate the process.

The following lines describe the Marine Spatial Planning Web application (v.2.2.1). In spite that the RENAQUA DSS is focused on the global scale, the IH-MSP Web application is based on the interactions with end users from the MRE and Aquaculture sectors at local scale. Therefore, the TRL Plus DSS and PIAGUA DSS are also described.

2 MRE & AQUACULTURE

Marine Renewable Energy and Aquaculture sectors perform their Operations & Maintenance activities at Platforms and Farms that deal with the dynamism of metocean phenomena. In order to understand their needs and requirements, the TRL Plus DSS and PIAGUA DSS have been designed. The following sections describe the Web applications developed.

2.1 TRL PLUS DSS

The TRL Plus DSS Web Application is accessible through the following url:

http://dss.trlplus.com/

TRL+ DSS consists of six different modules: metocean forecast, metocean nowcast, metocean hindcast, virtual devices, daily report and complementary info. Each of them are described subsequently.

Metocean forecast

The Metocean forecast section provides the spatial visualization of the forecast of metocean dynamics: wind, currents, level and waves. Temporary information can also be consulted in a graph or in a table format for each of the four anchor points of the platform, see Figure 1.

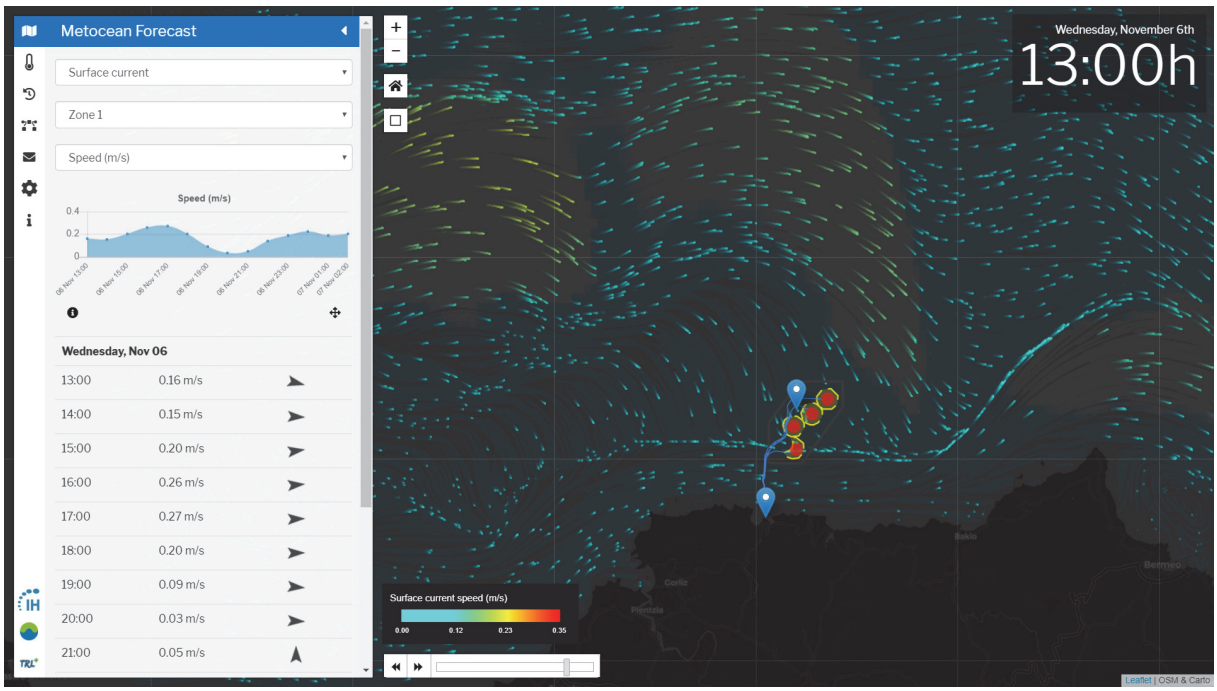

Figure 1. Metocean forecast of the TRL Plus DSS

Metocean nowcast

The Metocean Nowcast section provides the visualization of the data obtained by the in situ sensors in real time: the Wavescan meteoceanographic buoy and the coastal anemometer. The data is represented in the left panel in graphical format and table, see Figure 2.

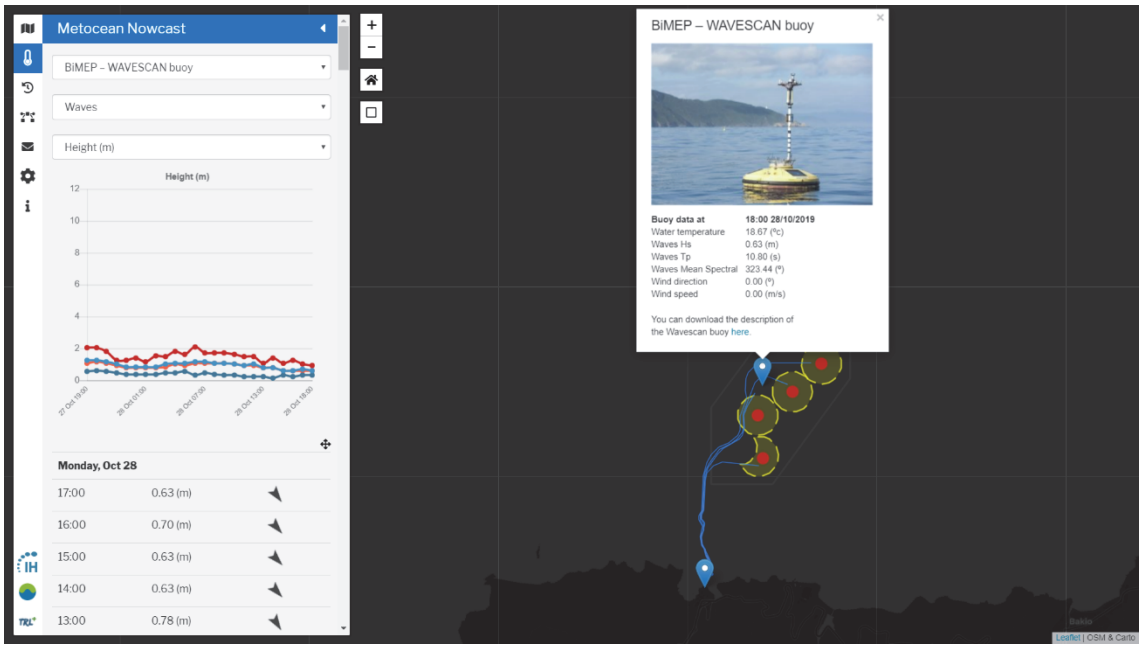

Figure 2. Metocean nowcast of the TRL Plus DSS

Metocean hindcast

The analysis of the metocean conditions of the test area are accessible and downloadable in the Metocean Hindcast section. The user can make requests for data by selecting the variable and range of dates of interest, see Figure 3.

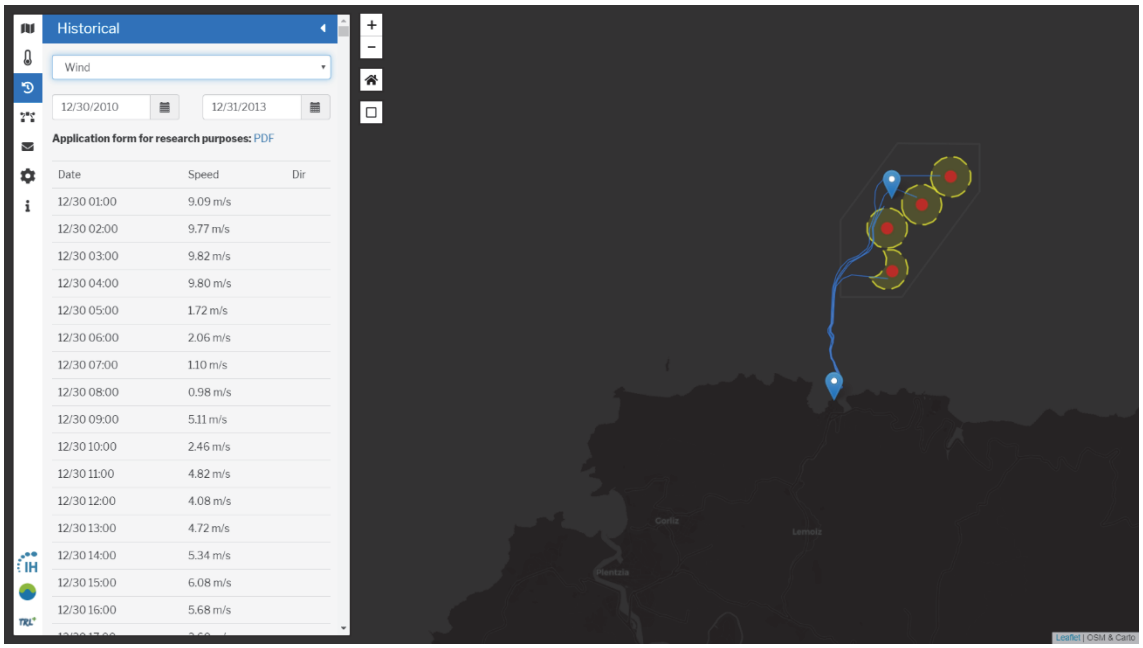

Figure 3. Metocean hindcast of the TRL Plus DSS

Virtual devices

The Virtual devices section allows the user to configure the module and input parameters for the calculation process, see Figure 4. Once requested, the system carries out the simulations and generates a report that is sent to the mail provided by the user.

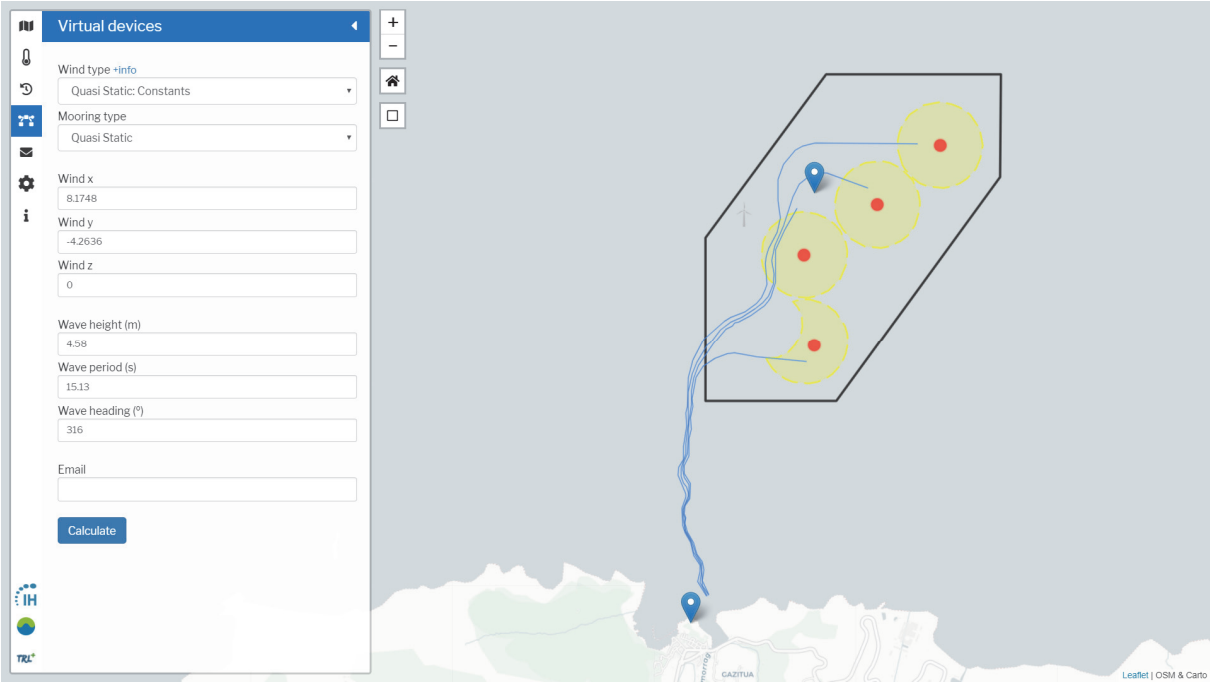

Figure 4. Virtual devices section of the TRL Plus DSS

Daily report

Daily, the DSS TRL Plus System sends a descriptive report, via mail, about the metocean conditions of the platform, performance of a virtual turbine and accessibility indexes. The Daily report section allows the subscription to the list of users interested in receiving the report daily, see Figure 5 and Figure 6

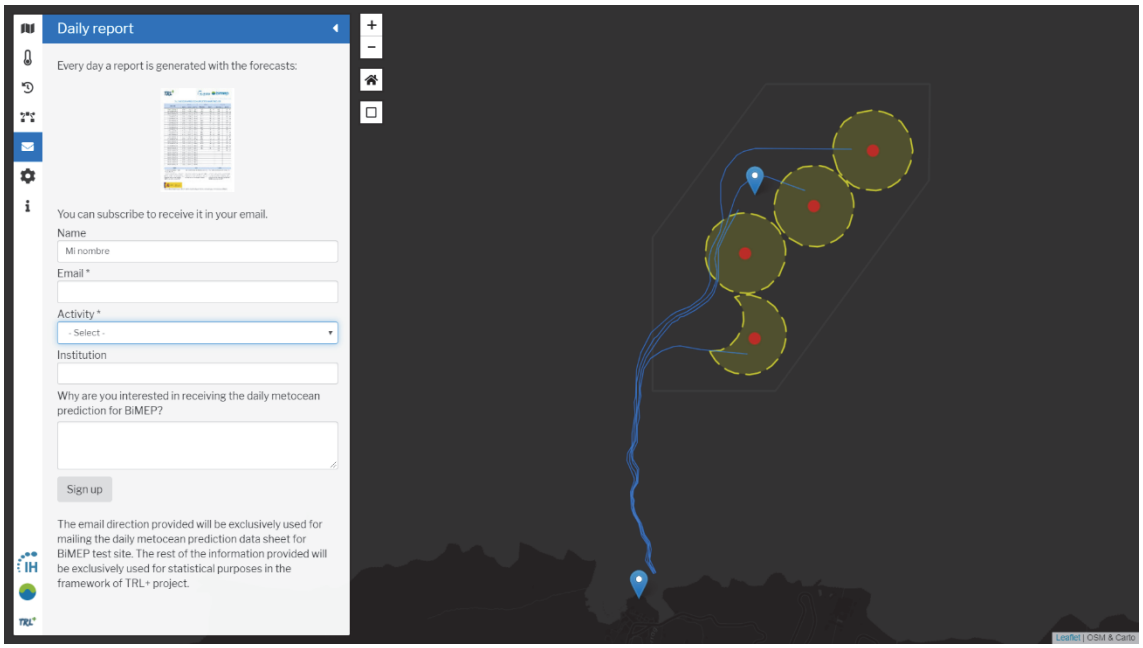

Figure 5. Daily report subscription of the TRL Plus DSS

2019-11-05 17:23:08

DAILY METOCEAN PREDICTION REPORT FOR BiMEP TEST SITE

Local time	Access	Waves			Wind		Currents	
		Hs (m)	Tm02 (s)	Dir (º)	V10 (m/s)	Dir (º)	Vsur (m/s)	Dir (º)
16:00 05/11/2019		4.41	6.31	312	13.24	303	0.62	96
17:00 05/11/2019		4.49	6.44	312	14.36	305	0.61	98
18:00 05/11/2019		4.53	6.50	311	14.49	320	0.63	101
19:00 05/11/2019		4.48	6.96	313	14.34	319	0.51	99
20:00 05/11/2019		4.47	6.90	314	12.98	316	0.51	101
21:00 05/11/2019		4.50	6.93	314	13.29	310	0.49	107
22:00 05/11/2019		4.58	6.96	314	14.23	315	0.50	108
23:00 05/11/2019		4.61	6.98	313	14.60	313	0.50	108
00:00 06/11/2019		4.60	6.97	312	14.84	302	0.49	103
01:00 06/11/2019		4.57	7.01	312	14.57	300	0.49	100
02:00 06/11/2019		4.55	6.92	311	13.72	307		
03:00 06/11/2019		4.56	6.89	312	13.42	306		
04:00 06/11/2019		4.51	6.90	312	12.64	303		
05:00 06/11/2019		4.42	6.89	312	13.03	303		
06:00 06/11/2019		4.33	6.92	312	12.18	299		
07:00 06/11/2019		4.23	7.11	313	11.99	298		
08:00 06/11/2019		4.09	7.09	313	10.67	297		
09:00 06/11/2019		3.91	7.18	312	9.33	296		
10:00 06/11/2019		3.72	7.23	312	9.20	266		
11:00 06/11/2019		3.53	7.15	312	8.38	266		
12:00 06/11/2019		3.37	7.02	312	9.95	263		
13:00 06/11/2019		3.23	6.85	312	10.31	259		
14:00 06/11/2019		3.19	6.16	311	11.16	260		
15:00 06/11/2019		3.09	5.91	311	7.50	253		
16:00 06/11/2019		2.88	6.07	312	5.99	219		

Waves	Wind	Currents
· Hs is the Significant Wave Height. · Tm02 is the Mean Wave Period. · Dir is the Wave Direction, it is measured in degrees clockwise from due north. Wave Direction provided is the direction from which the waves come (0: coming from the NORTH; 90: coming from the EAST).	· V10 is the Wind Speed 10 meters above sea level. · Dir is the Wind Direction, it is measured in degrees clockwise from due north. Wind Direction provided is the direction from which the wind comes (0: coming from the NORTH; 90: coming from the EAST).	· Vsur is the Currents Speed in the surface layer. · Dir is the Currents Direction in the surface layer, it is measured in degrees clockwise from due north. Currents direction provided is the direction towards which the currents go (0: going to the NORTH; 90: going to the EAST).

TRL+ is a National research project (RTC-2015-3836-3) funded by the Spanish Ministry of Economy, Industry and Competitiveness (MINECO).

Figure 6. Daily report of the TRL Plus DSS

Complementary info

The Complementary info section provides the display of geospatial information in the BiMEP area, such as bathymetry or background types. See Figure 7. It also allows activating or deactivating the display of map elements (buoy, cables, mooring areas, BiMET area), etc.

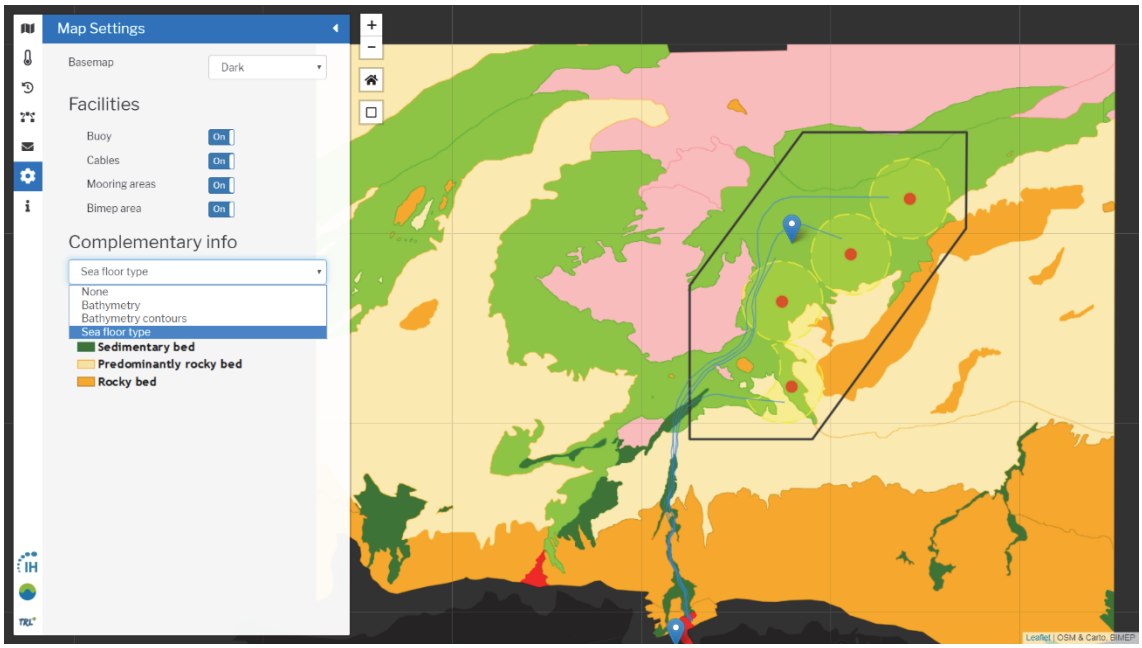

Figure 7. Complementary info section of the TRL Plus DSS

2.2 PIAGUA DSS

The PIAGUA DSS Web application is accessible through the following url:

http://piagua.ihcantabria.com/

PIAGUA DSS consists of four different modules: dashboard, SFR status, operability and map location. Each of them are described subsequently.

Dashboard

The landing site of the PIAGUA DSS is the dashboard, which provides information about the current metocean conditions at the PIAGUA farm, including indicators about SFR and operability, see Figure 8.

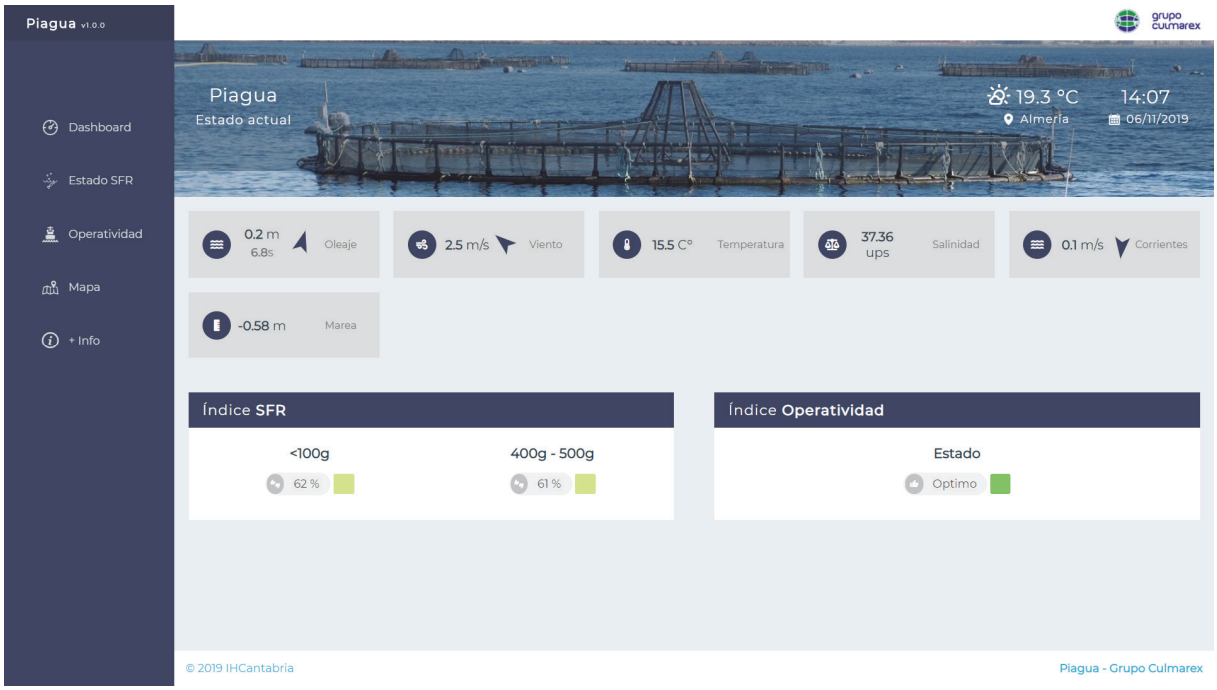

Figure 8. Dashboard of the PIAGUA DSS

SFR status

The SFR status section provides forecasting information about water temperature, currents and the Suggested Feeding Rate (SFR). The information can be visualized through graphs, see Figure 9, or tables (html formatted), see Figure 10.

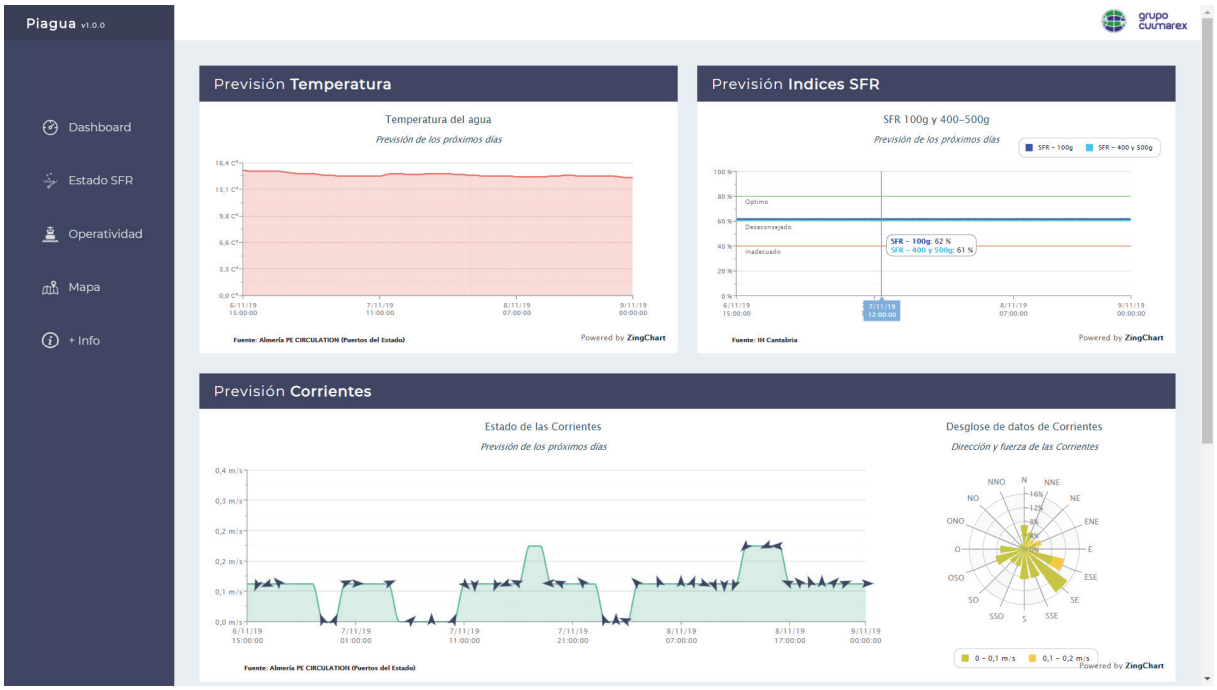

Figure 9. SFR status of the PIAGUA DSS - graphs

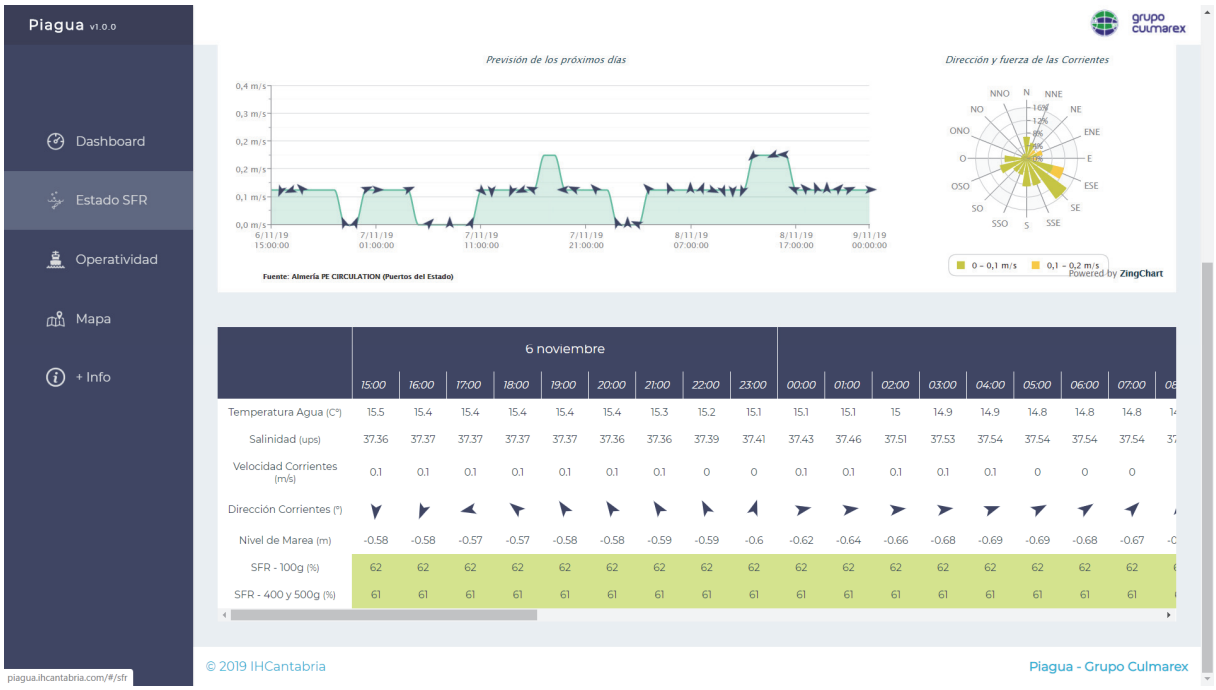

Figure 10. SFR status of the PIAGUA DSS - tables

Operability

The Operability section provides forecasting information about waves, wind and the operability based in these dynamics. The information can be visualized through graphs, see Figure 11, or tables (html formatted), see Figure 12.

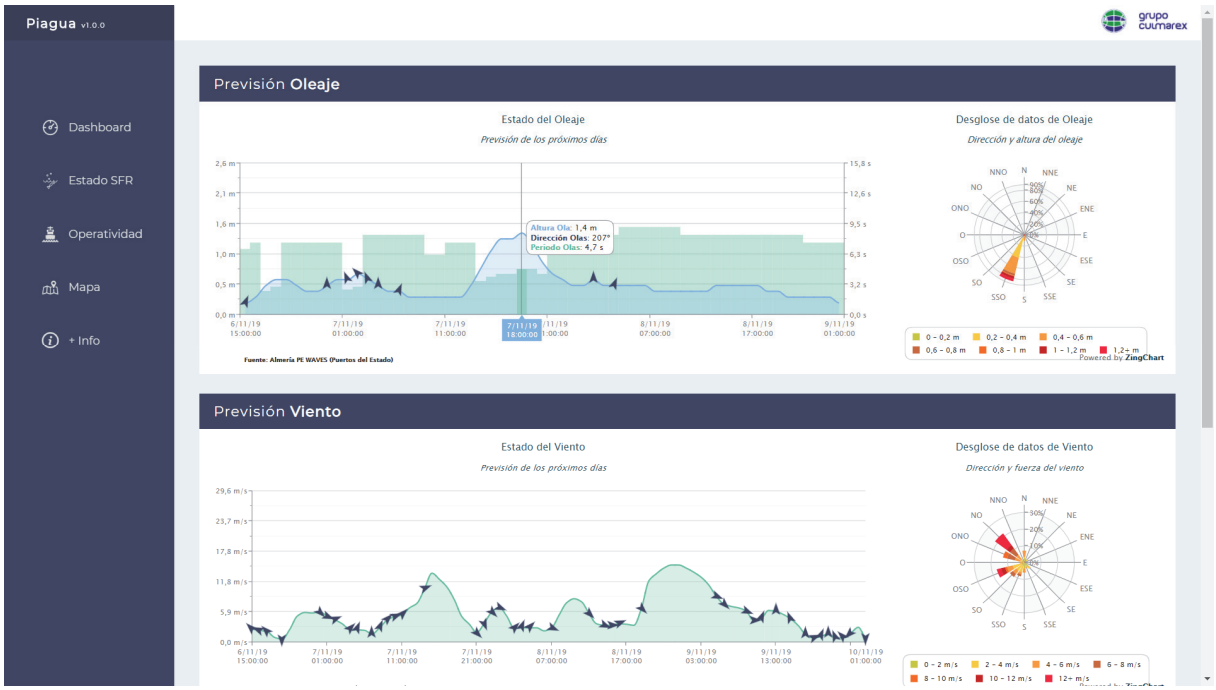

Figure 11. Operability of the PIAGUA DSS – graphs

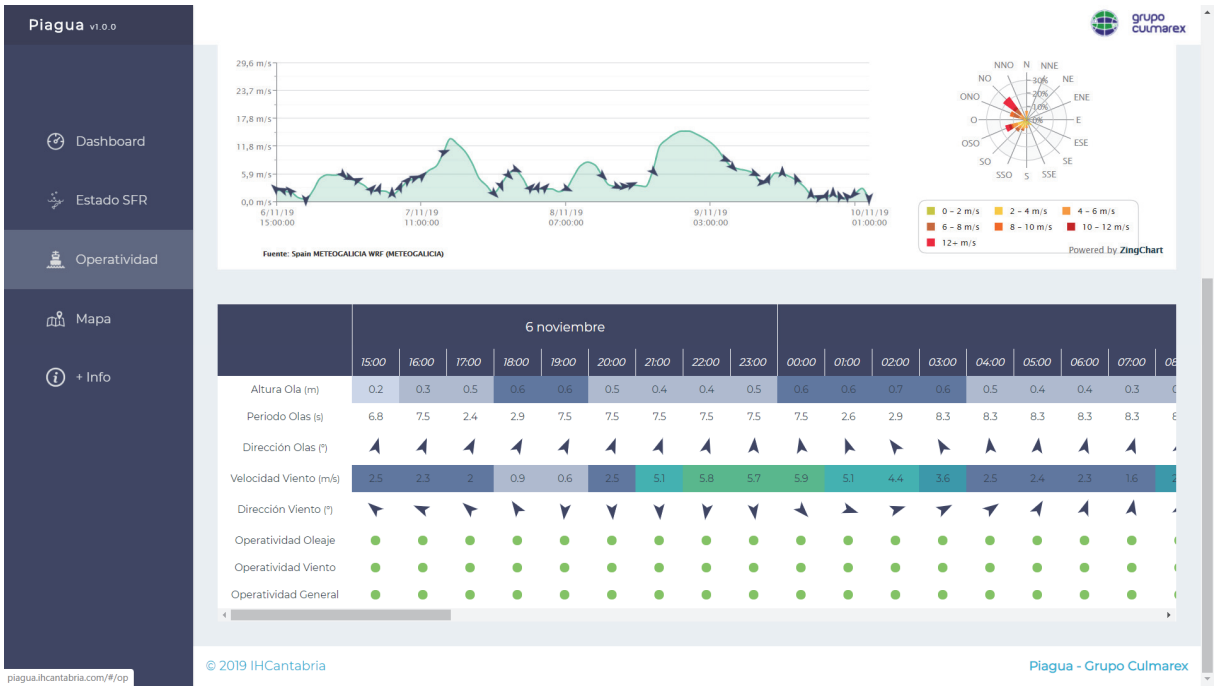

Figure 12. Operability of the PIAGUA DSS - tables

Map location

The location of the PIAGUA farm is showed in the Map section through a Web Geoviewer, see Figure 13.

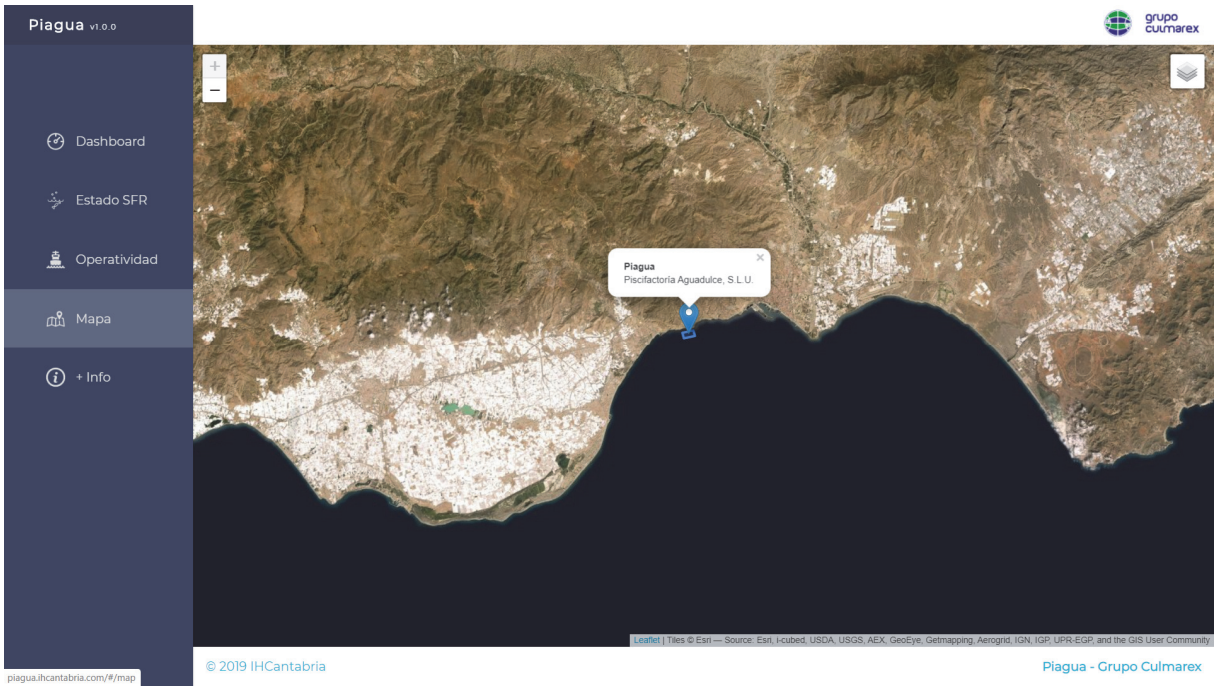

Figure 13. Location of the PIAGUA farm

3 MSP PLATFORM

The Marine Spatial Panning Platform is a Geospatial Web application that aims to create a more comprehensive picture of our marine areas in order to ensure a sustainable future for our Oceans, Seas and Coasts.

The MSP Platform provides open access to technical and scientific knowledge from several projects in relation with marine activities. The Web application is divided in four sections, see Figure 14:

1. Roots
2. Suitability Indexes
3. Socioeconomic and thematic mapping
4. The Blue Time Machine

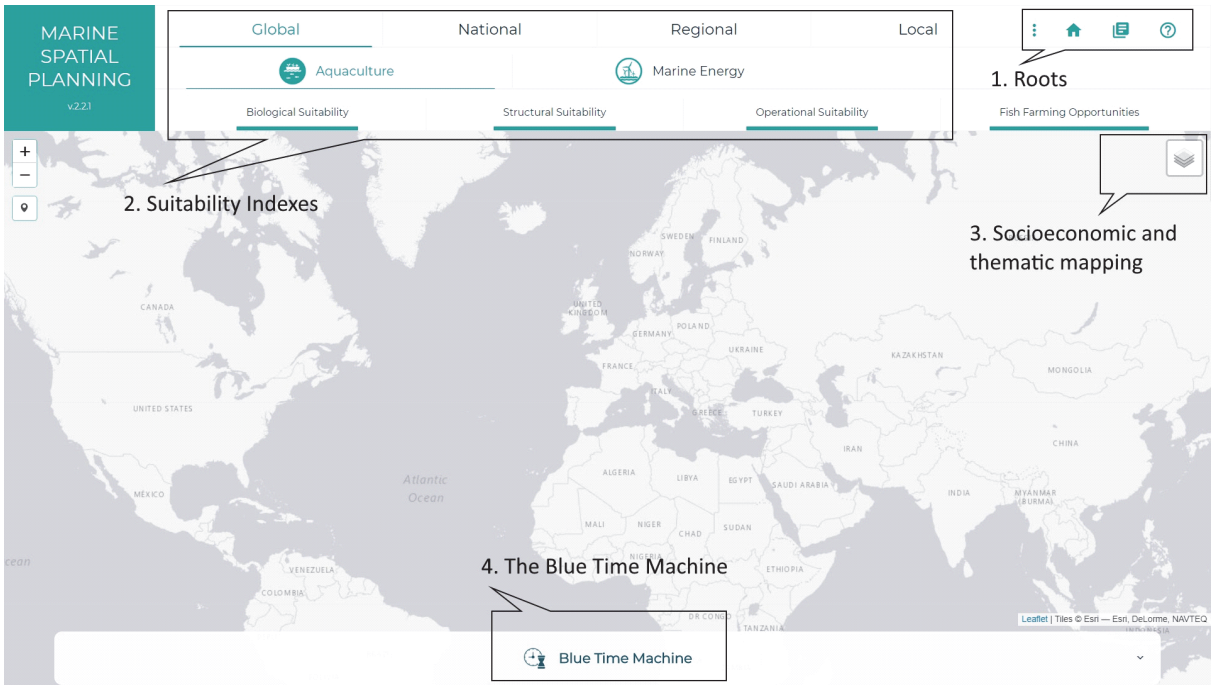

Figure 14. Sections of the MSP Platform

The following lines describe each of the listed sections and also the interoperability capabilities of the System.

3.1 ROOTS

The "Roots" section provides two main functionalities to contextualize the MSP Platform. On one hand, it shows the science that is behind the whole service and, on the other hand, the projects or initiatives that allow building the Platform.

The "About" section of the MSP Portal shows a set of project cards that include title of the project, sponsors & partners and link to additional information. Currently, version v.2.2.1 includes four cards, see Figure 15:

- MSP – The first card is dedicated to introduce the Platform, which is an open access Web application that integrates technical and scientific knowledge from IHCantabria researchers in support of the 2030 agenda for sustainable development and associated SDGs. The Platform includes results from several research projects in relation with marine activities from global to local scale. This section also includes a video tutorial that guide end uses through the different functionalities of the System. The video is hosted in vimeo http://vimeo.com/ihcantabria/msp
- ATLAS – [national & local scale] - Viability ATLAS for the development of offshore aquaculture in the Spanish coasts

- RENAQUA DSS – [global scale] - Co-location Opportunities for RENewable energies and AQUAculture facilities, decision support for operational Multi-Use Platform activities at coastal areas.
- BTM – [global scale] – Blue Time Machine is a digital representations of the past, present and future conditions, including climate change scenarios from our "Blue Planet". The BTM was awarded with the second prize at the EUDatathon2019, in the challenge “tackling climate change”. Another video tutorial was designed to guide end users through questions that could be answered making use of the Blue Time Machine, the video is also hosted at vimeo https://vimeo.com/ihcantabria/btm

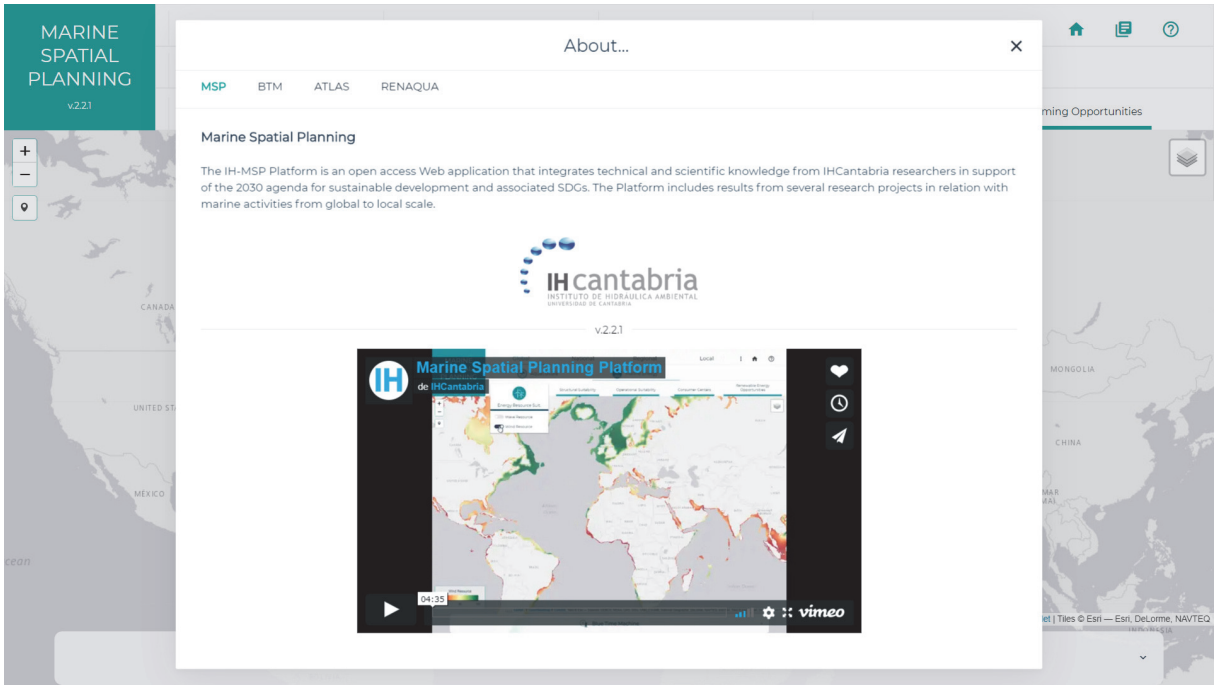

Figure 15. MSP Project cards

The MSP Platform provides outcomes from the implementation of scientific and technical advances. The section “Science on the IH-MSP” provides a list of scientific communications in which the MSP Platform is based, see Figure 16.

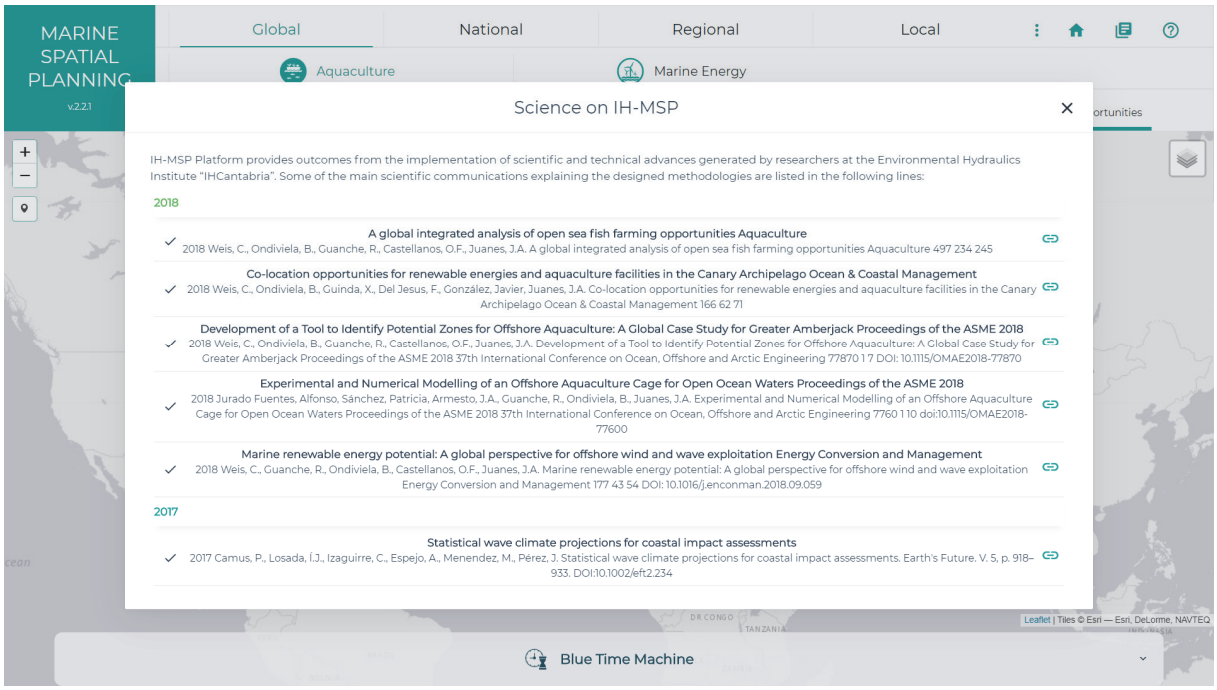

Figure 16. Science as a pillar of the MSP Platform

3.2 SUITABILITY INDEXES

Marine Renewable Energies and Aquaculture are some of the most promising activities in the context of developing marine economies. Results of MRE and Aquaculture co-location analysis are accessible from the top navigation panel of the MSP Platform, which provides access to suitability mapping at three scales (global, national and regional) and also links to local scale Decision Support Systems for MRE and Aquaculture.

The RENAQUA Service focuses on the Global scale, in which end users could navigate through the Aquaculture section or the Marine Renewable Energy section.

The **Aquaculture section** includes four sub-sections that allow visualizing three suitability indexes: (1) biological, (2) structural and (3) operational, and the result of combining all of them, fish farming opportunities. All the indexes and the combining result can be queried at any location worldwide, see Figure 17.

The biological suitability includes the environmental adequacy analysis of seven species worldwide: Atlantic Bluefin tuna, Atlantic salmon, cobia, European seabass, gilthead seabream, greater amberjack and meagre.

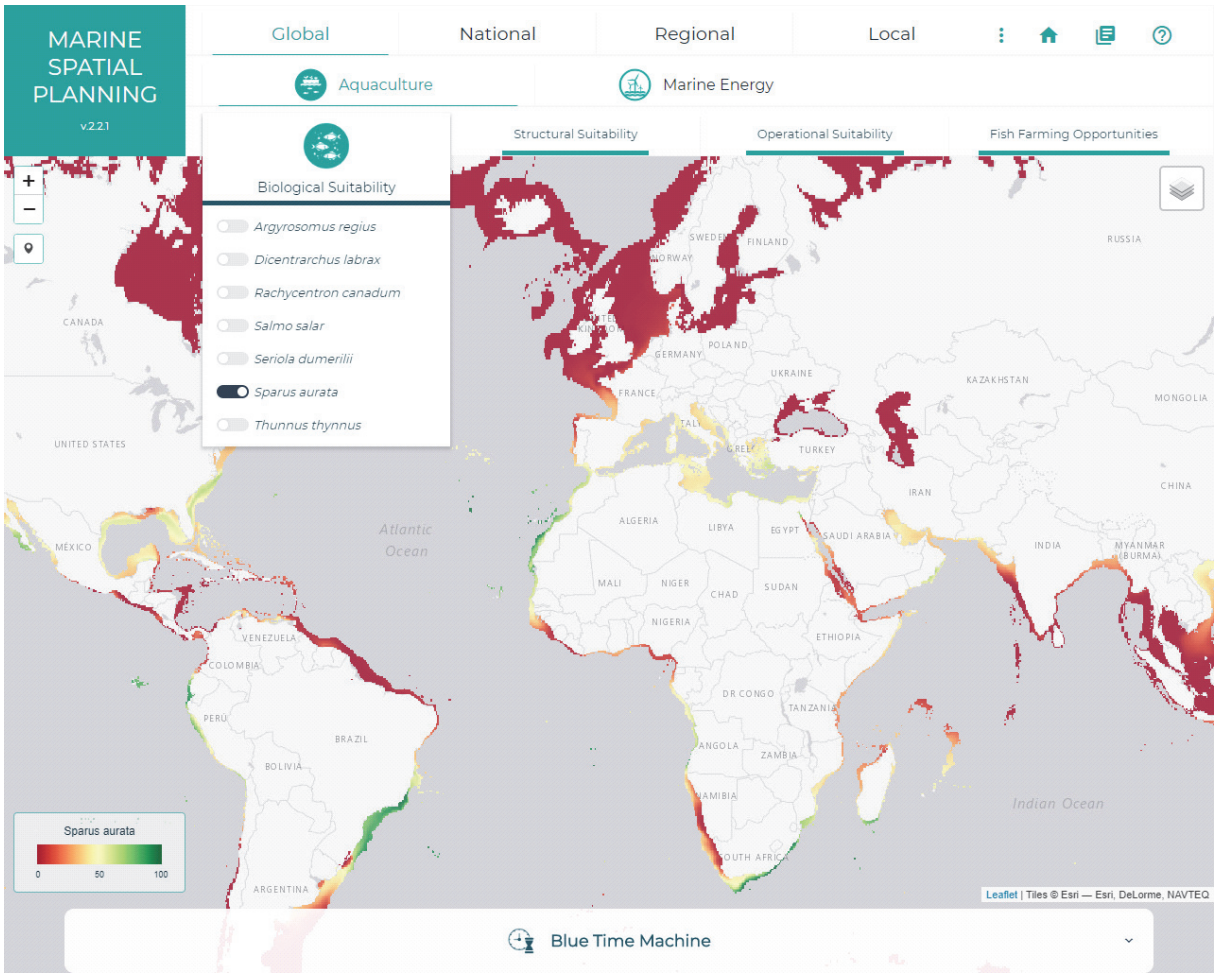

Figure 17. Biological suitability at global scale

The strucutural suitability for aquaculture activities provides the integrity and durability evaluation of the cage against the hindcasting metocean conditions, see Figure 18.

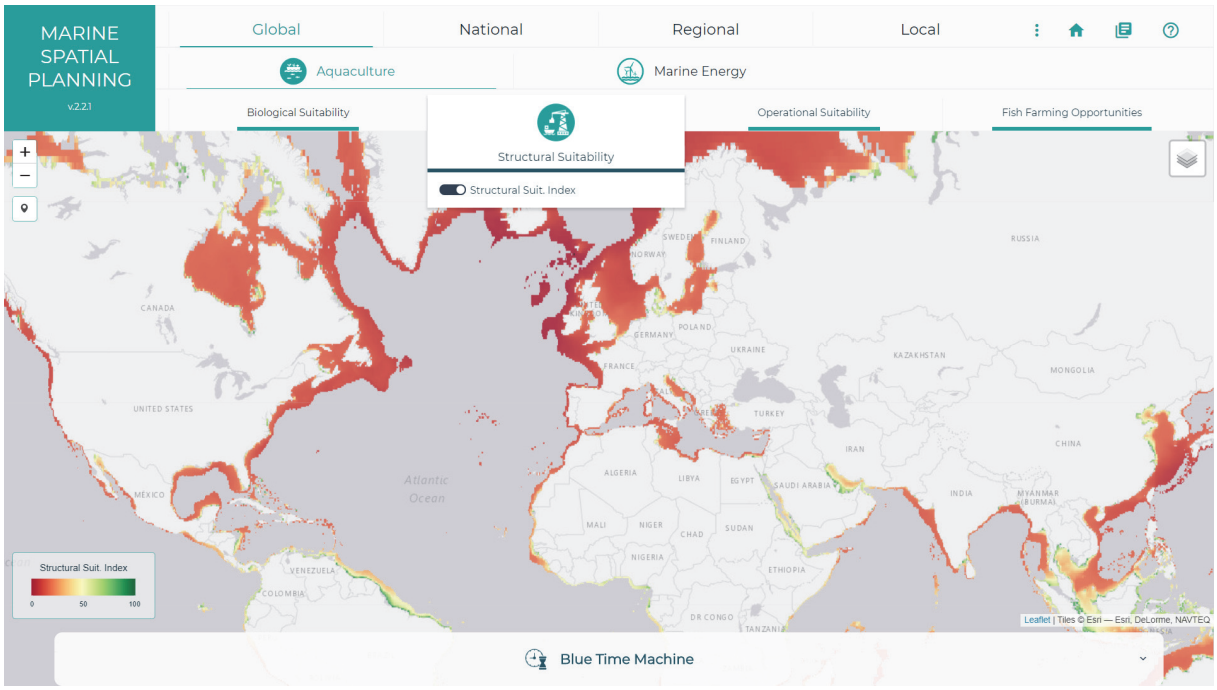

Figure 18. Structural suitability for aquaculture activities at global scale

Offshore farming requires significant operational and maintenance tasks (O&M), the operational suitability index provides feasibility of carrying out O&M activities, see Figure 19.

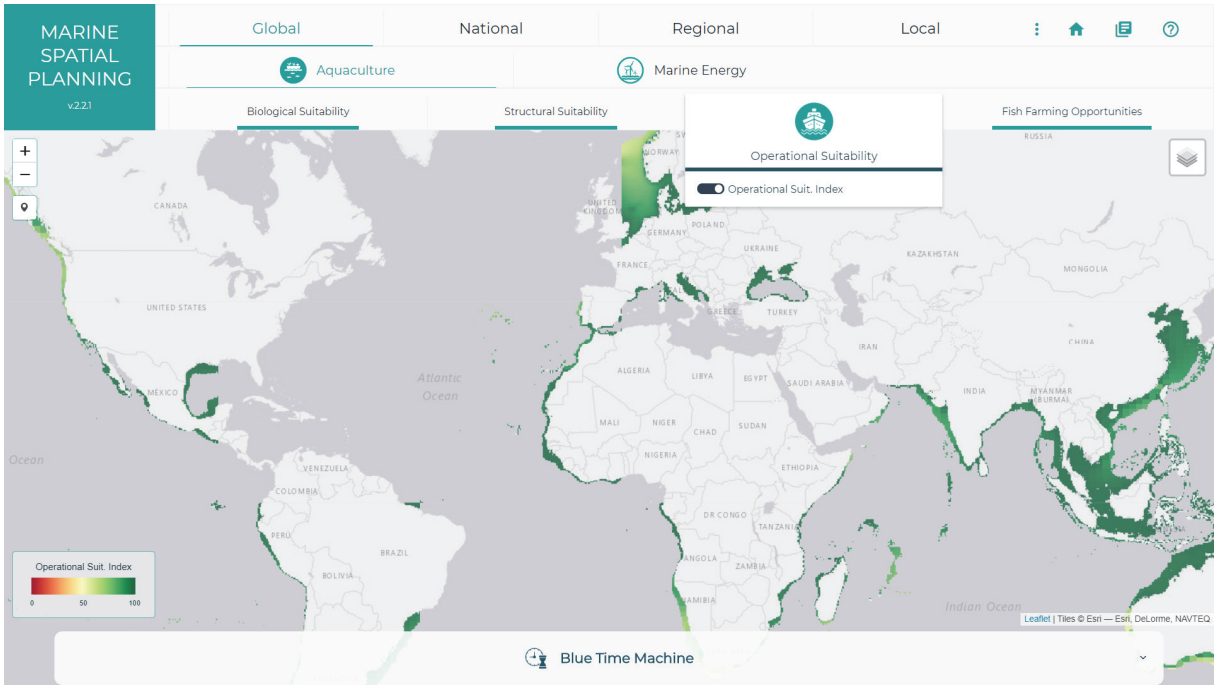

Figure 19. Operational suitability for aquaculture activities at global scale

Finally, the Fish Farming Opportunity map combines the biological, structural and operational aspects of the aquaculture activity worldwide, see Figure 20.

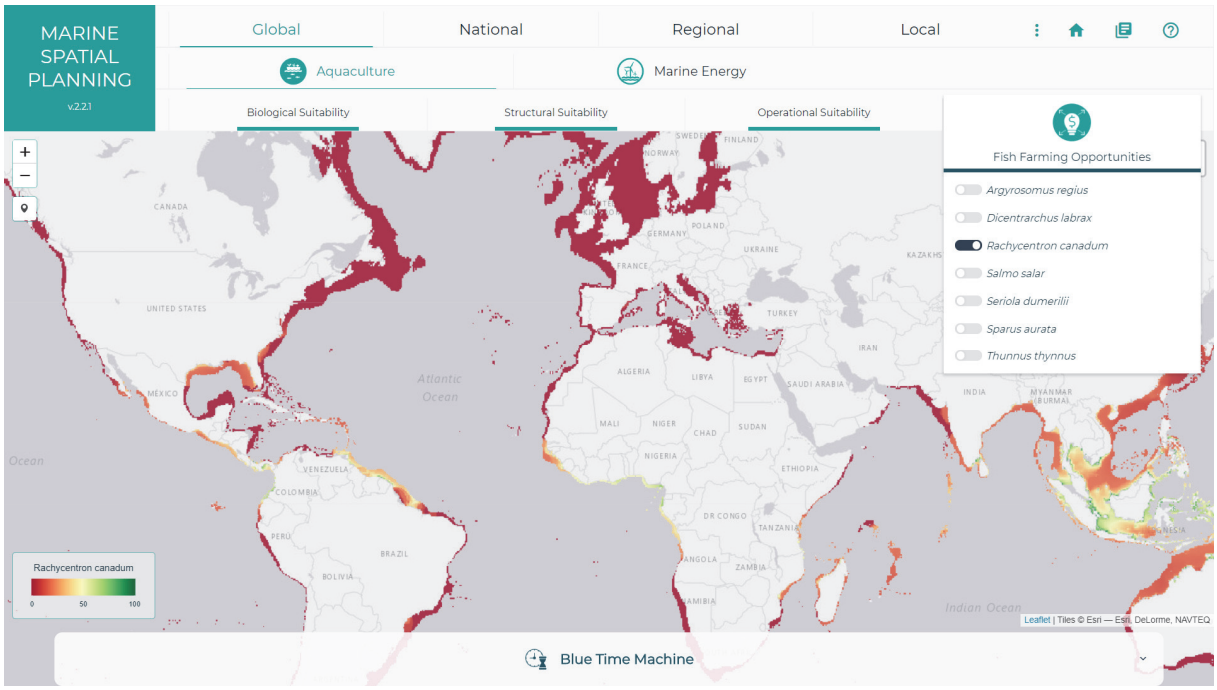

Figure 20. Fish farming opportunities for aquaculture activities at global scale

On the other hand, the **Marine Renewable Energy section** includes four sub-sections that provides information about four marine renewable energy suitability indexes: (1) energy resource (waves and wind), (2) structural, (3) operational and (4) distance to centers, and the result of combining all of them, MRE farming opportunities.

Energy resource suitability has been obtained by the mean of available energy, significant wave height, peak wave period and wind speed values. Wind and Wave exploitation have been evaluated based on the percentage of time the wind speed, waves and their available potential remain within the production threshold, providing the percentage of time a site could be harvested energetically, see Figure 21.

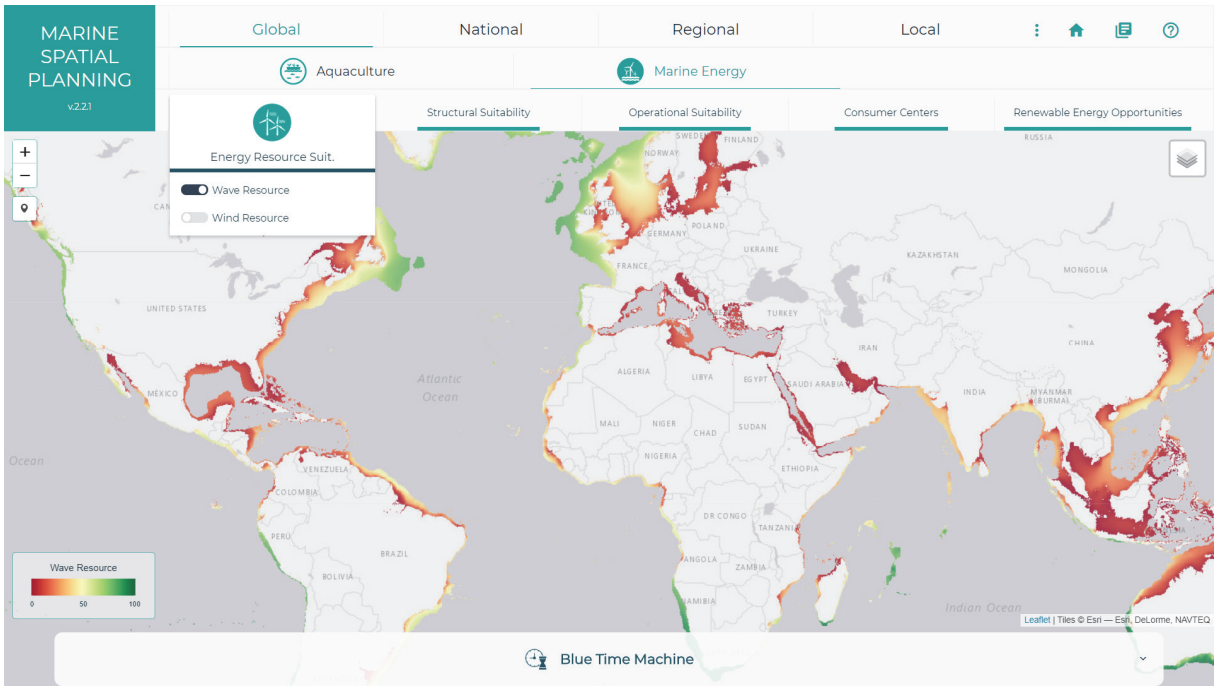

Figure 21. Wave energy resource suitability for marine renewable energy activities at global scale

Metocean variables, such as currents, waves and winds, were analyzed in order to evaluate their influence on design and structure, obtaining the structural suitability index. The metocean conditions have been evaluated according to the percentage of time that these variables met the established thresholds over the entire time series, see Figure 22.

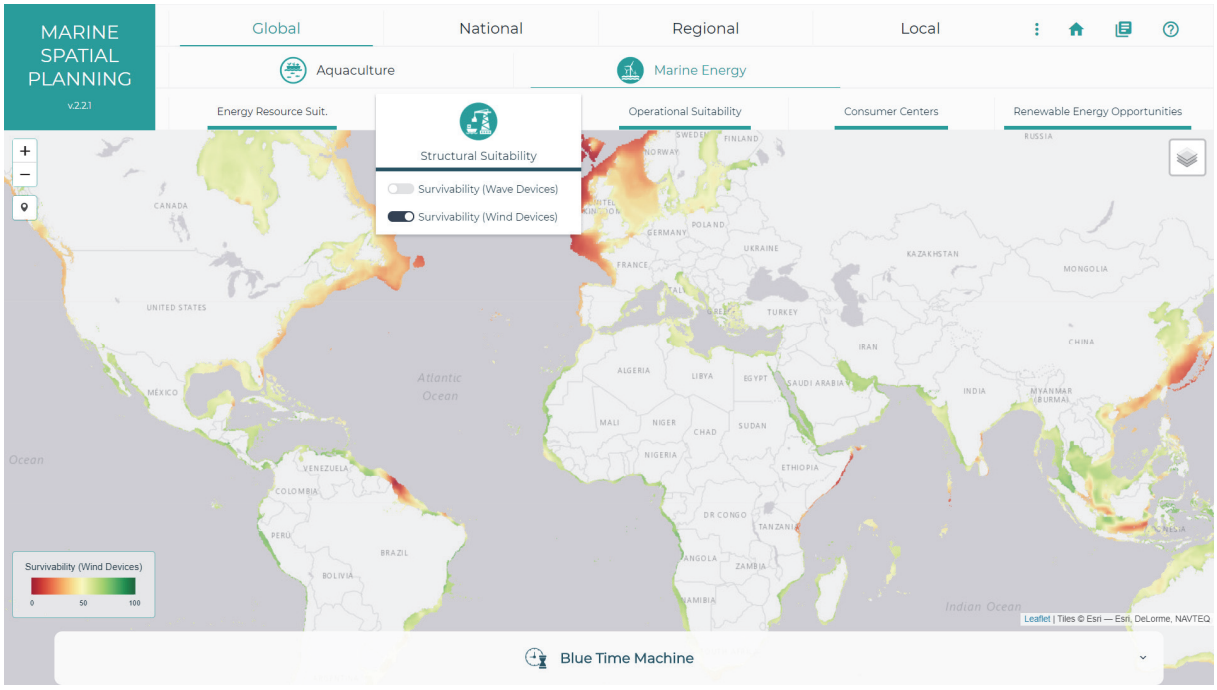

Figure 22. Wind structural suitability for marine renewable energy activities at global scale

The operational suitability provides information about the feasibility to conduct O&M activities considering distances to ports and site accessibility worldwide, see Figure 23.

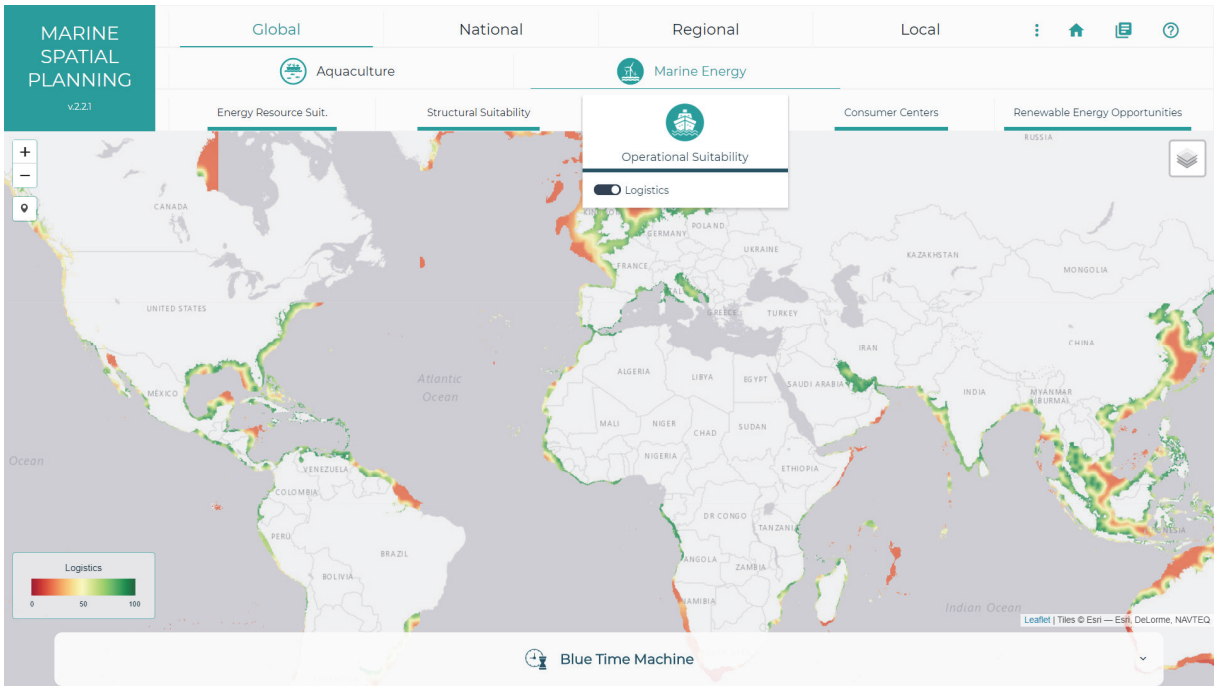

Figure 23. Operational suitability for marine renewable energy activities at global scale

The Consumer center suitability considers that the closer an offshore farm is to an energy substation, the lower the cost of installation and energy losses due to dissipation. The consumer center suitability worldwide is showed in Figure 24.

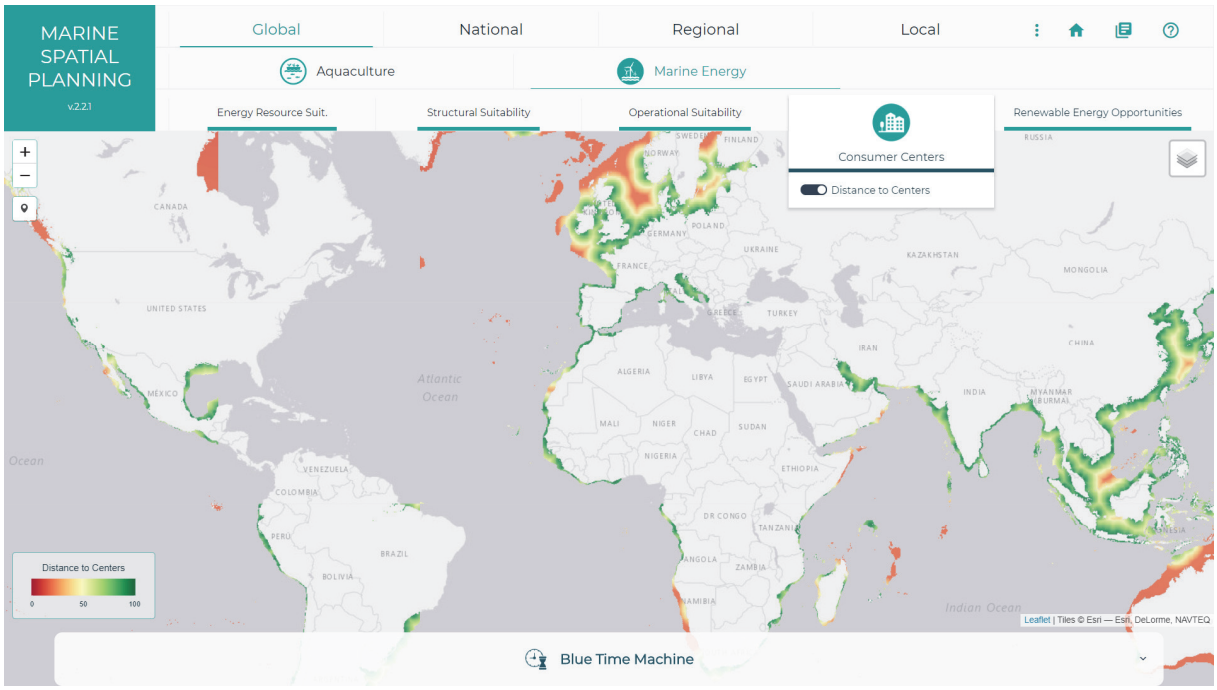

Figure 24. Consumer Center suitability for marine renewable energy activities at global scale

Finally, making use of the critical value method, the renewable energy opportunities were obtained by the integration of production, structural, operational and energy transport suitability indexes for waves and winds. As it can be seen from Figure 25 and Figure 26, wave and wind based renewable energy opportunities can be queried worldwide.

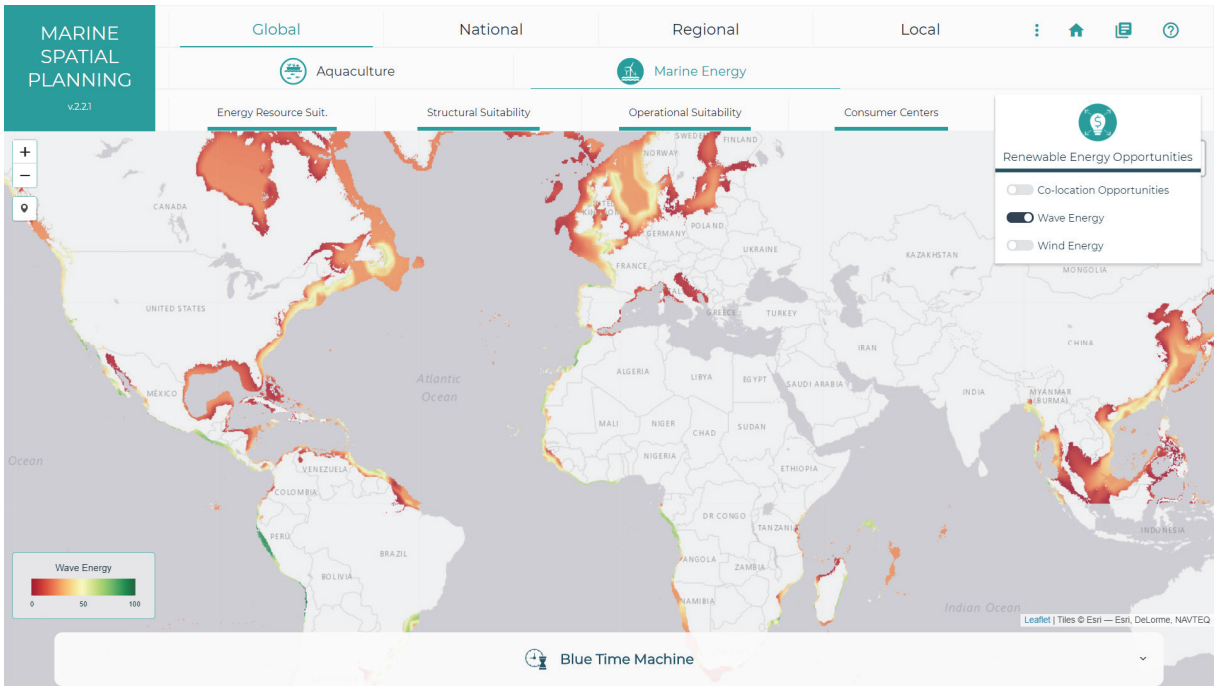

Figure 25. Wave marine renewable energy opportunities at global scale

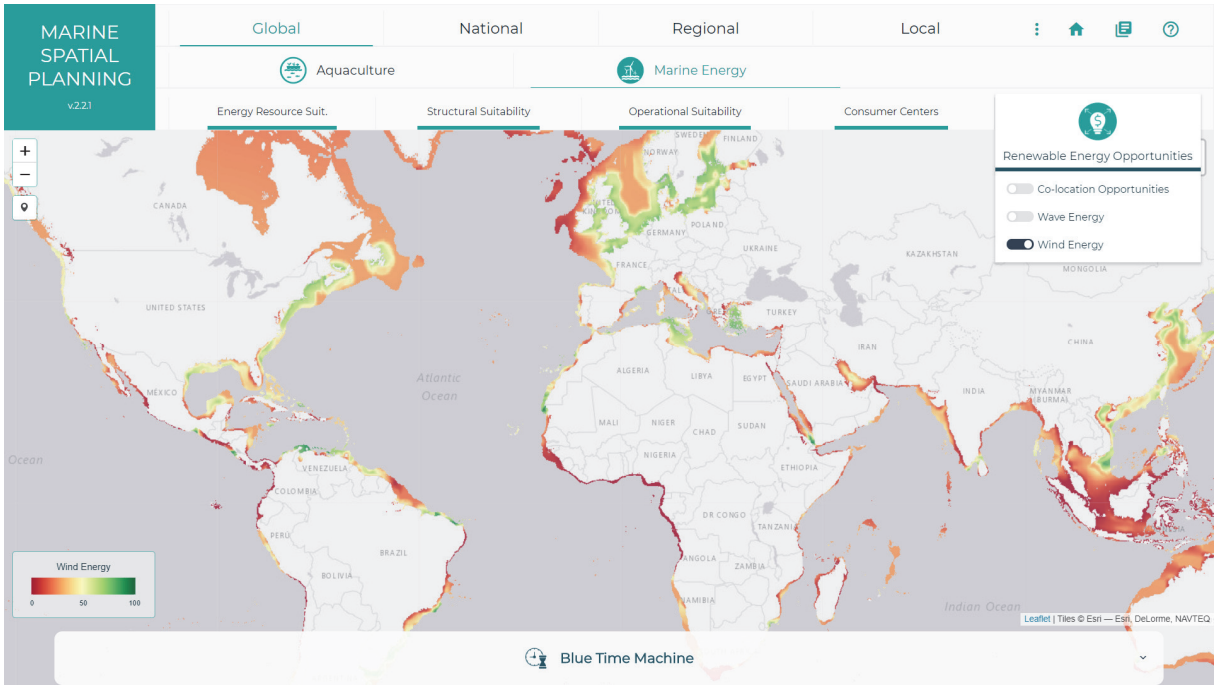

Figure 26. Wind marine renewable energy opportunities at global scale

Wind and wave based renewable energy opportunities were integrated in a final map named "Co-location opportunities", see Figure 27.

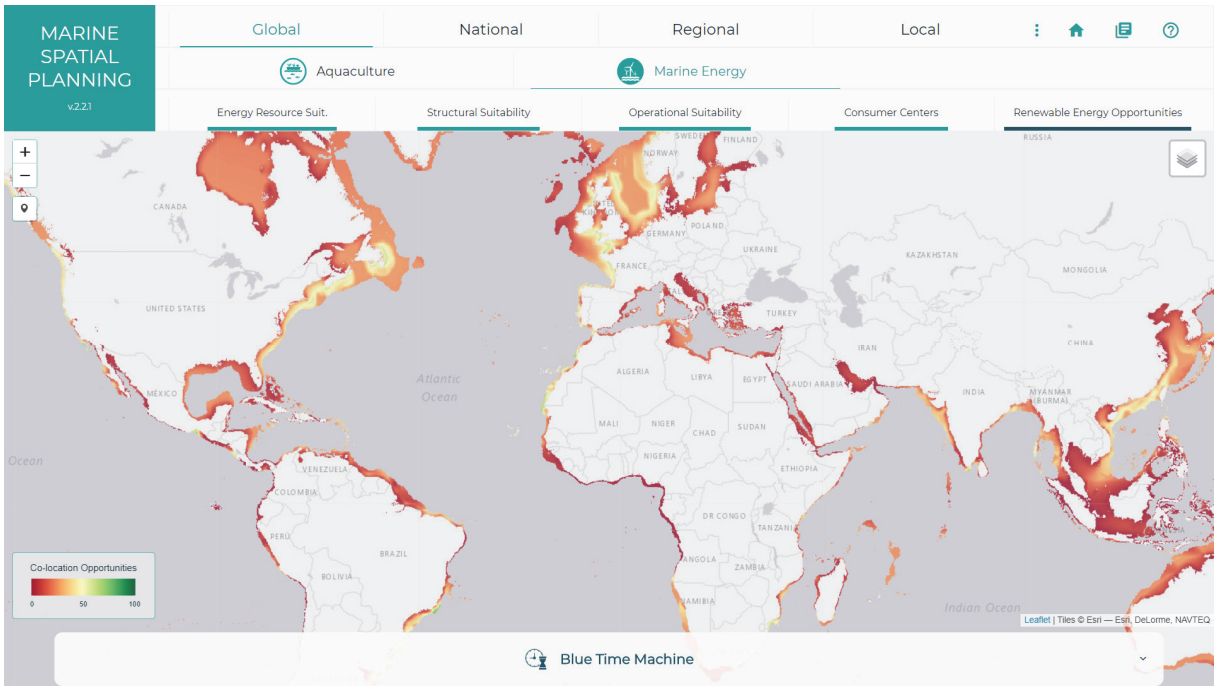

Figure 27. Marine renewable energy co-locations opportunities at global scale

Results from the ATLAS Project, entitled "Viability ATLAS for the development of offshore aquaculture in the Spanish coasts", financed by the Spanish Ministry for the Ecological Transition (MITECO), are also hosted at the MSP Platform. ATLAS project provides offshore aquaculture farming maps for the Spanish coasts at national and regional scales. While the RENAQUA DSS project provides the same suitability indexes (biological, structural and operational) and final fish farming opportunity map for 7 species, the ATLAS project provides the same suitability indexes and fish farming opportunity map for 15 species, see Figure 28.

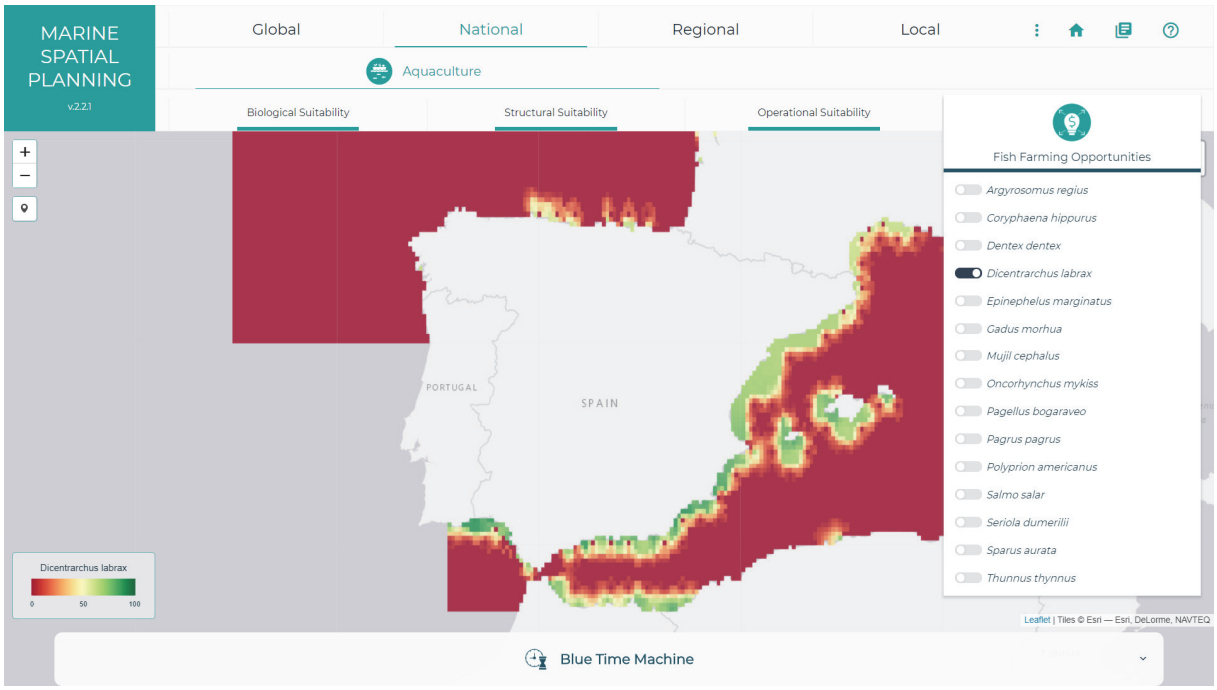

Figure 28. ATLAS – Fish farming opportunities for the Spanish coasts

ATLAS project was also implemented at regional scale at the Canary Islands and Balearic Islands, see Figure 29**¡Error! No se encuentra el origen de la referencia.**.

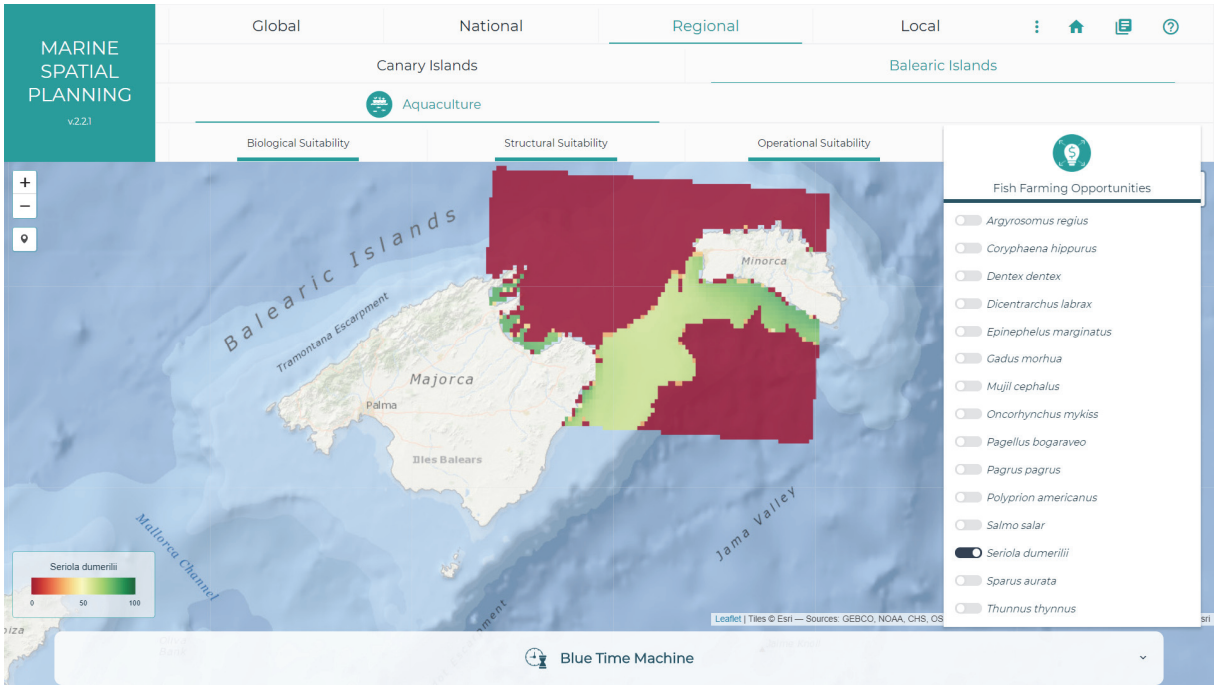

Figure 29. ATLAS – Fish farming opportunities for the Balearic Islands

The results from the analysis of co-location opportunities for renewable energies and aquaculture facilities in the Canary Archipelago undertaken by Weis *et al* (2018) is also available from the MSP Platform from the Regional scale navigation bar, see Figure 30.

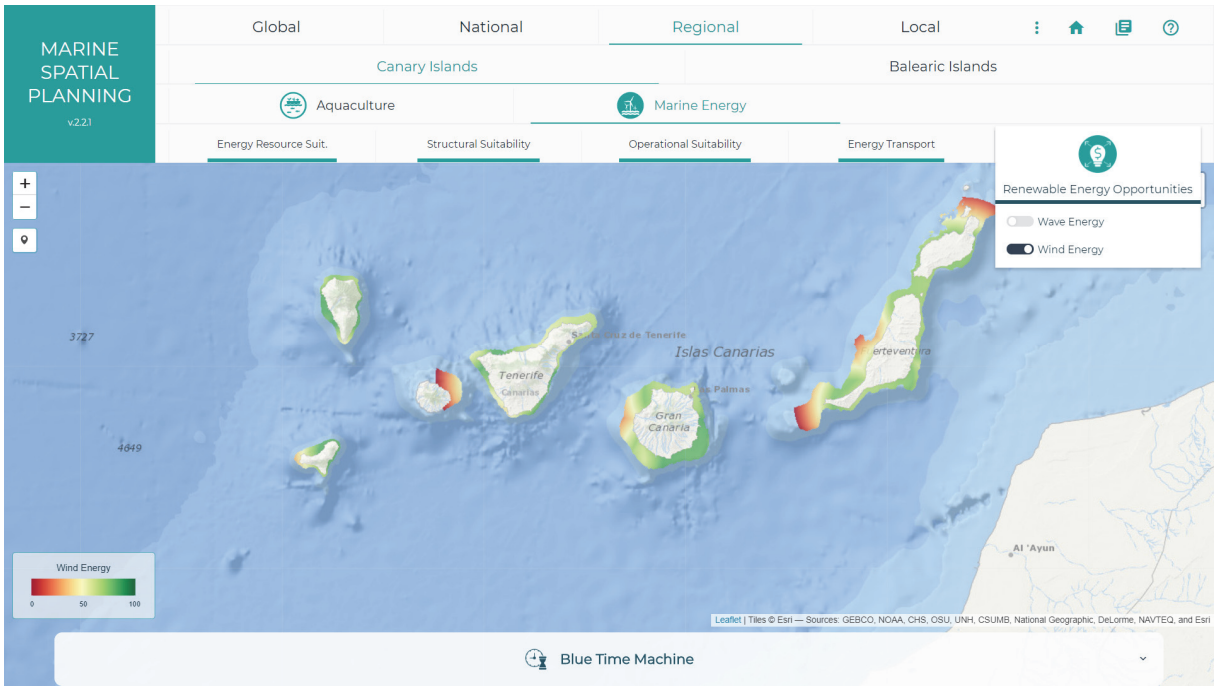

Figure 30. Wind renewable energy opportunities for the Canary Islands

3.3 SOCIOECONOMIC AND THEMATIC MAPPING

The socioeconomic and thematic mapping section, activated through the layers icon on the map, provides the visualization of socioeconomic and thematic maps in Europe, provided by EMODNet (http://www.emodnet.eu/), see Figure 31.

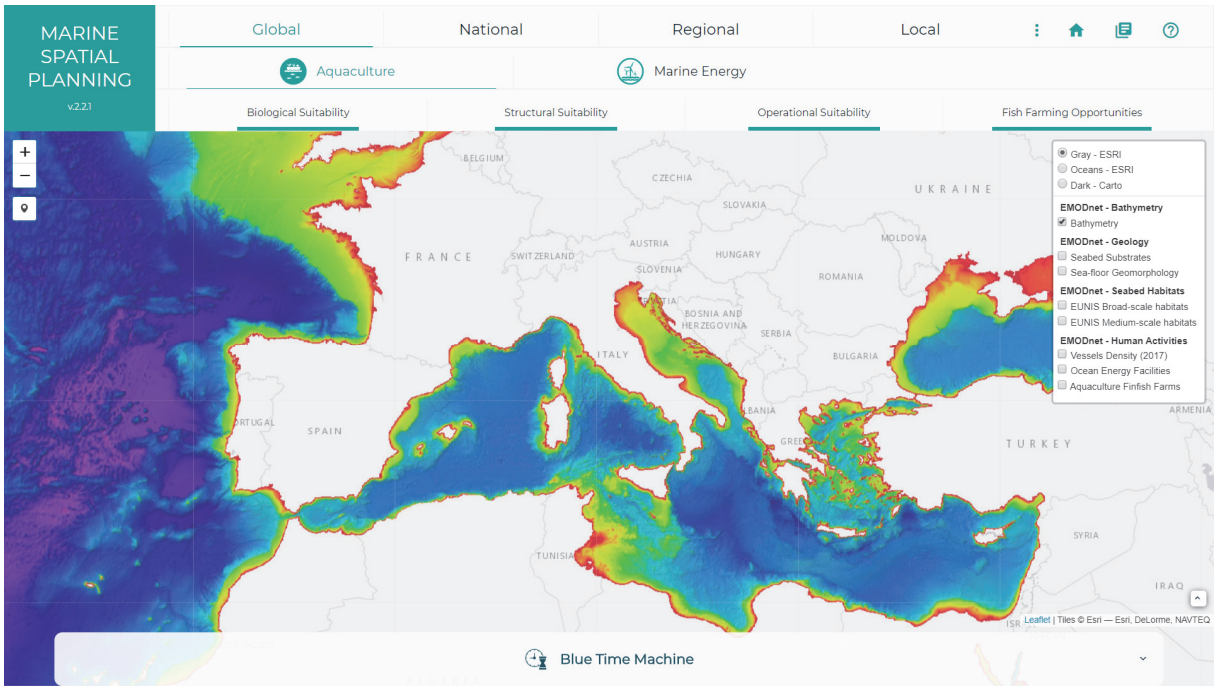

Figure 31. Socioeconomic and thematic mapping

The thematic mapping includes three subjects: bathymetry, geology and sea habitats. EMODnet geology provides access to seabed substrates, sea-floor geomorphology (see Figure 32), whereas EMODnet seabed habitats provides access to EUNIS broad and medium scales of habitats.

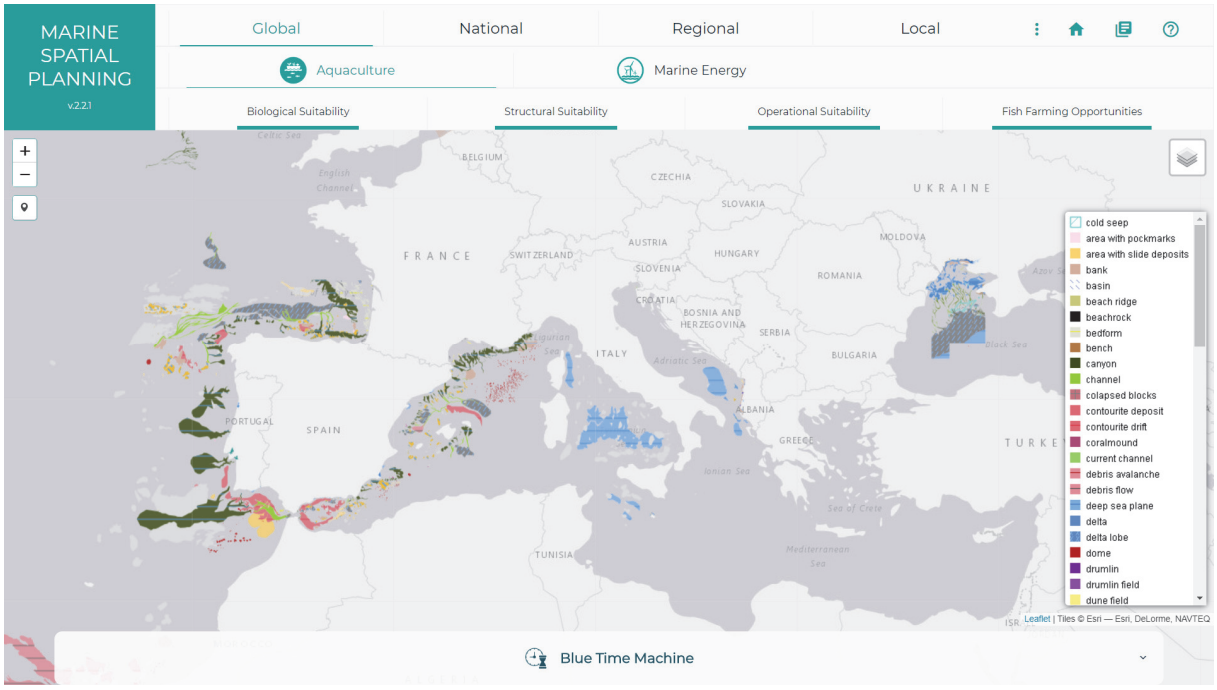

Figure 32. Sea-floor geomorphology mapping

The socioeconomic mapping provides visualizations about ocean energy facility locations, aquaculture finfish farm locations and vessel density in Europe, provided by EMODnet, see Figure 31.

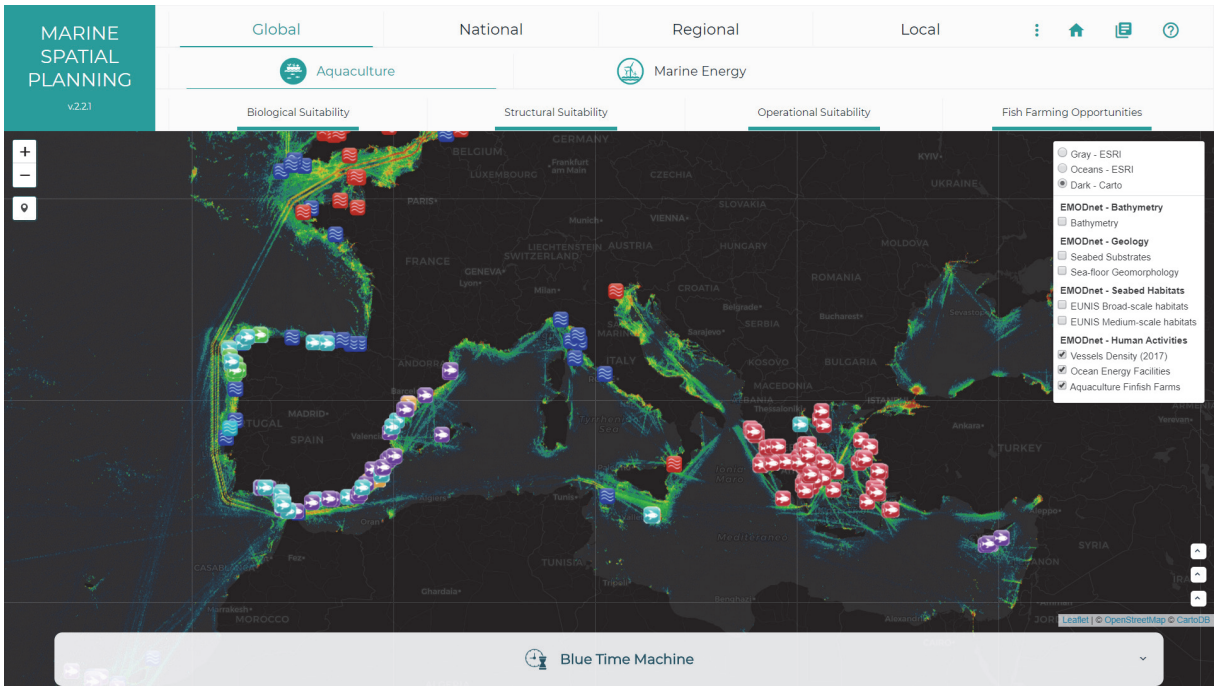

Figure 33. Human activities mapping

3.4 THE BLUE TIME MACHINE

The Blue Time Machine, activated through the bottom navigation bar, offers a digital representation of the past, present and future conditions, including climate change, through three main sections:

1. Data Hub
2. Blue Growth
3. Tools

As it can be seen from Figure 34, the Blue Time Machine provides a temporal line with four periods of time: past, present, short term forecast and climate change. End user could also select between Data Hub, Blue Growth and Tools.

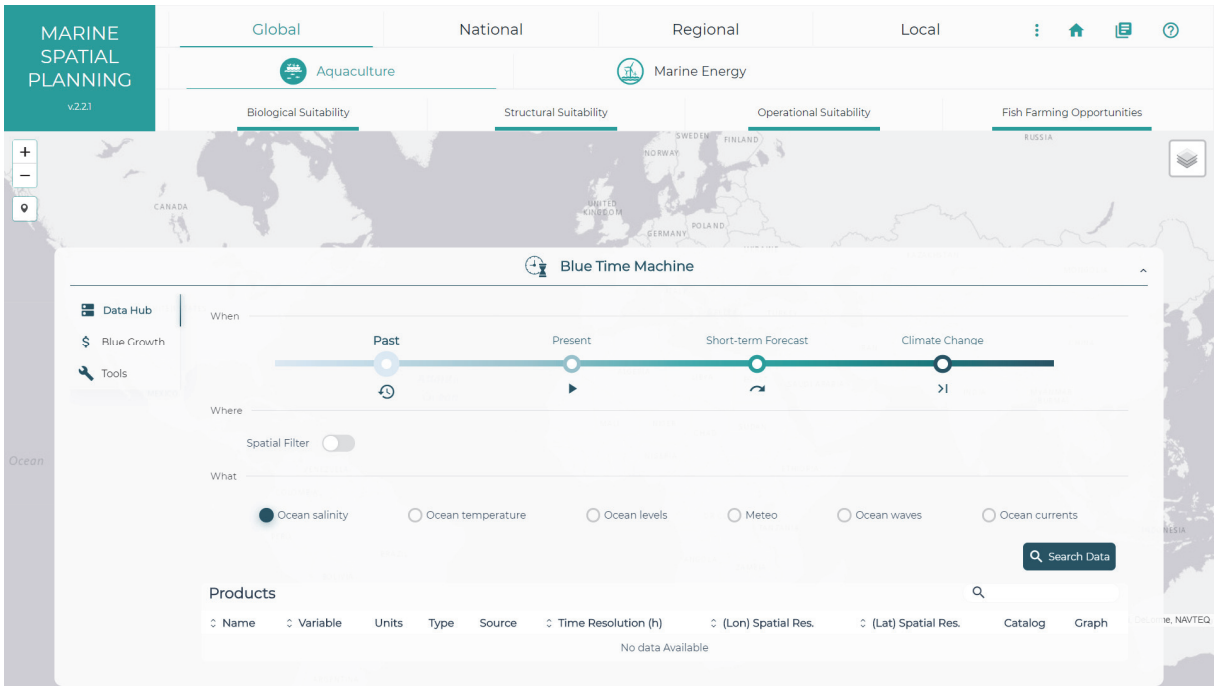

Figure 34. The Blue Time Machine

<u>DataHub</u>

The DataHub is a metocean products discovery User Interface. The User Experience is based on three aspects that allow defining the search of metocean data: “When”, “Where” and “What” should be searched.

- When – one temporal period must be selected among four: past, present, short-term forecast and climate change.
- Where – a spatial filter could be applied for searching products in a given longitude and latitude.
- What – end users select the type of variable to request the search

The search in the Data Hub provides a list of products with their main metadata fields for the past, short-term forecast and climate change periods. For instance, Figure 35 shows the results for the short-term forecast, in which the Products are listed with the following fields: name, variable, units, type source, time resolution, spatial resolutions and links to the Catalogue and Graphs.

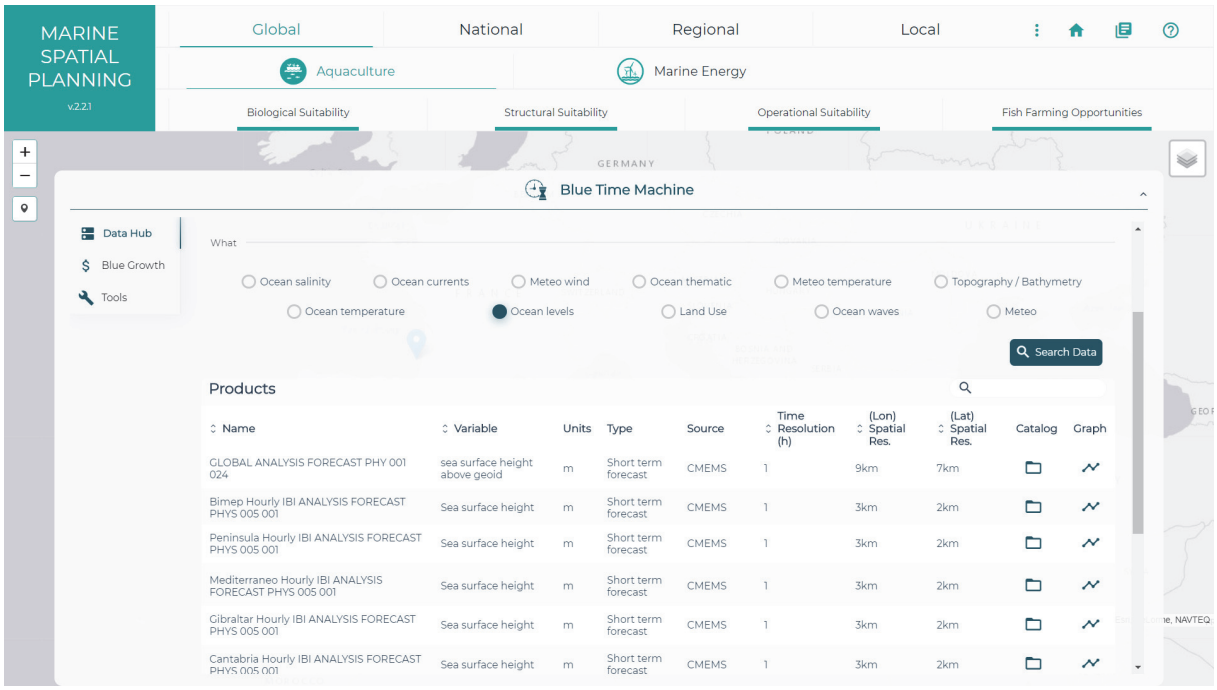

Figure 35. Data Hub – access to Short-term forecast query

The link to the catalogue opens a new tab pointing to the product hosted in the THREDDs Data Server (TDS), see Figure 36 . The TDS provides interoperability protocols to access the metocean products.

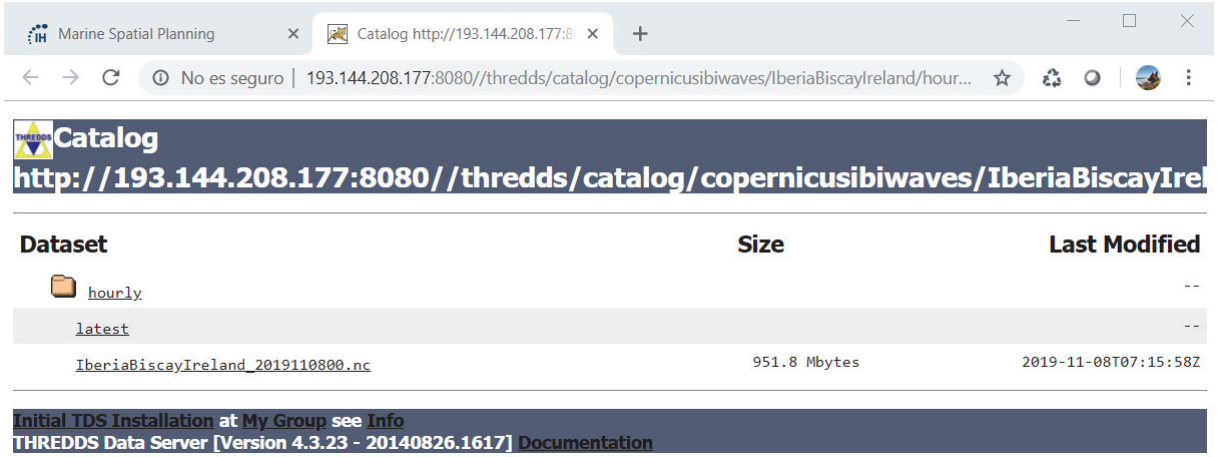

Figure 36. Data Hub – access to the catalogue

The link to the Graph allows to visualize charts of the data sets for a given longitude and latitude, see Figure 37.

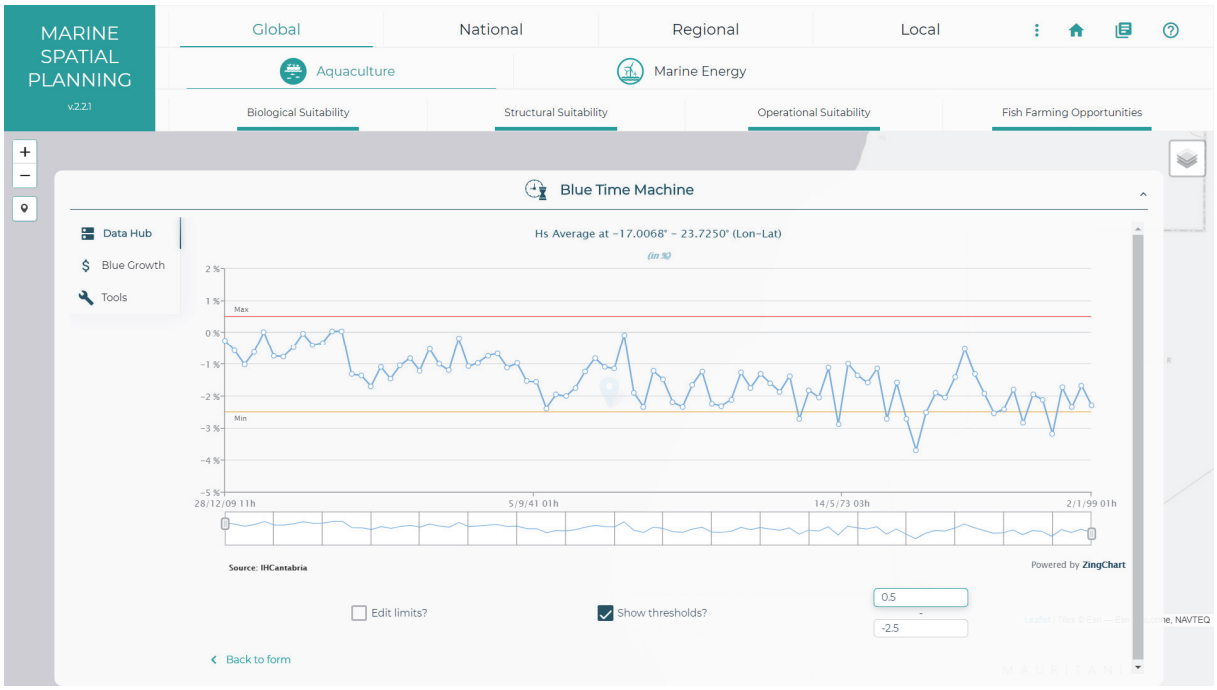

Figure 37. Data Hub – access to climate change charts

The past, short-term forecast and climate change products are derived from numerical modelling and store as data cubes, coverages with several dimensions in netCDF format. On the other hand, the “present” products are mainly obtained from sensors that provide information in near real time. In this case, the data hub provides access to metocean data from buoys, tidal gauges and HF Radars. As it can be seen from Figure 38, the search provides a list of sensors sorted by distance from the given longitude and latitude.

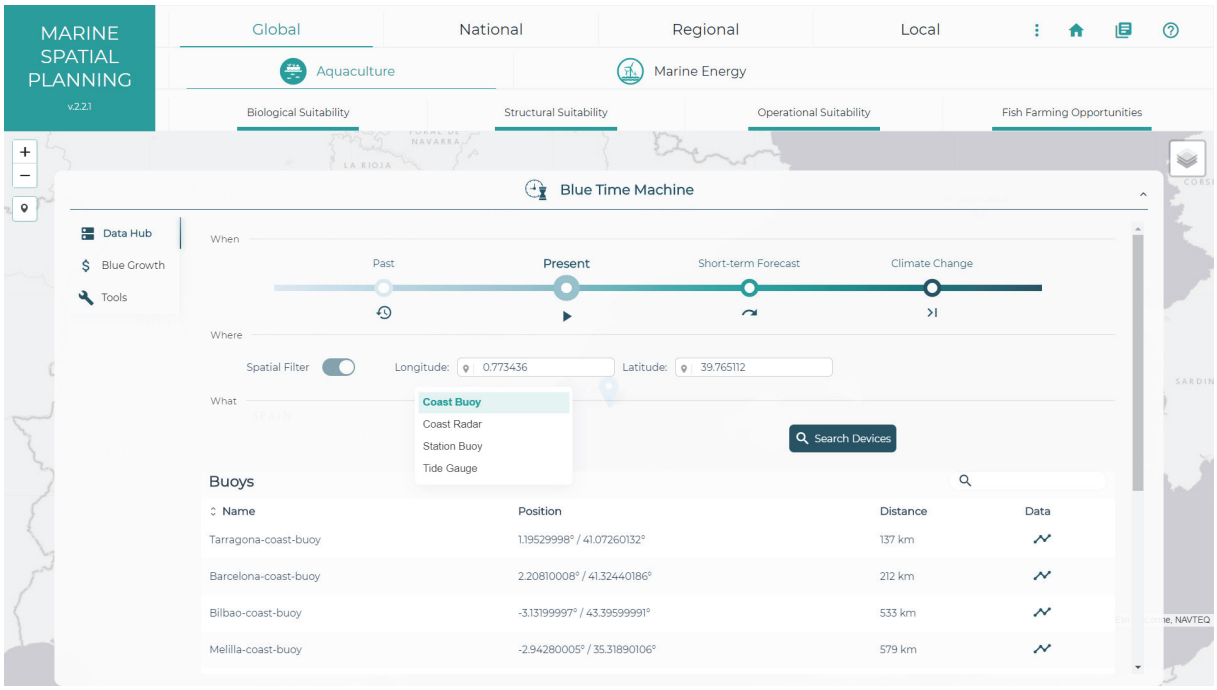

Figure 38. Data Hub – access to near real time metocean data “present”

The list of sensors provides information about the devices: name, location, distance and access to the latest data sets collected, see Figure 39.

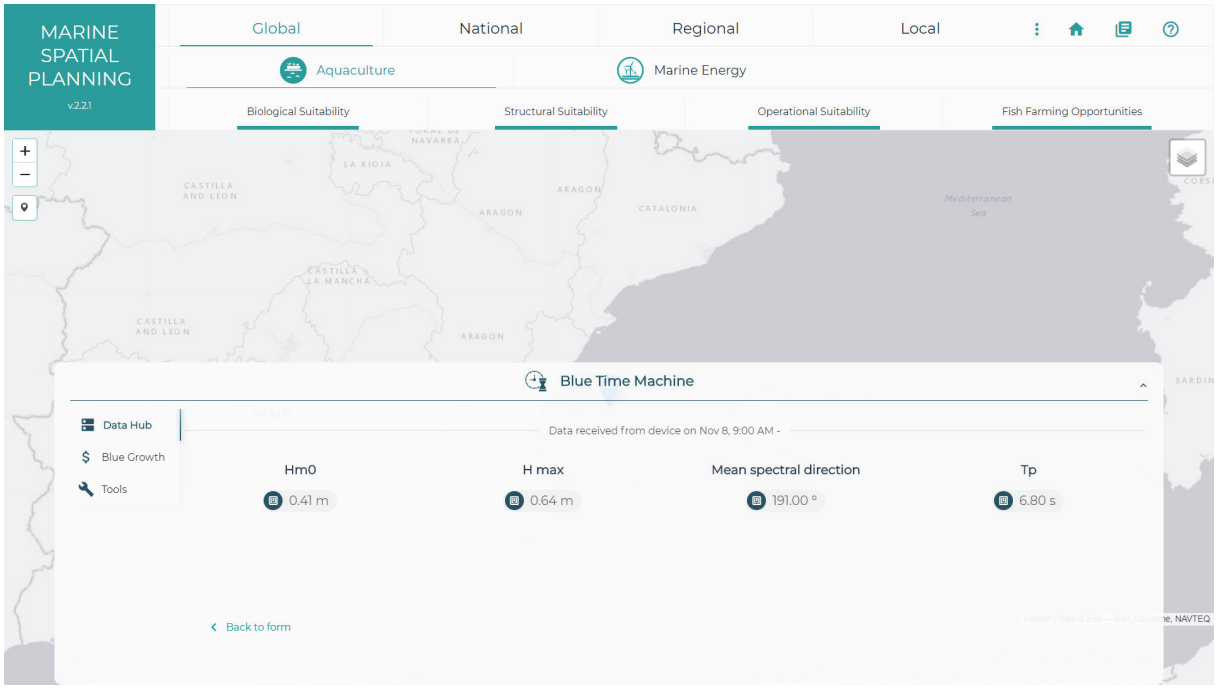

Figure 39. Data Hub – real time metocean data “present”

Blue Growth

The Blue Growth section focuses on providing tailored information to the economic sectors, aquaculture and marine renewable energy. In this sense, it keeps the same structure and user experience, as the Data Hub, defining "When", "Where" and replaces "What" for a selector of sectors (aquaculture and MRE) that allows to include the "Feature" of interest.

Whereas past and climate change periods provide information for strategic decisions, present and short-term forecast focus on operability and maintenance.

Figure 40 shows the UI for querying the MRE suitability and Figure 41 shows the results of querying the biological suitability under climate change scenarios.

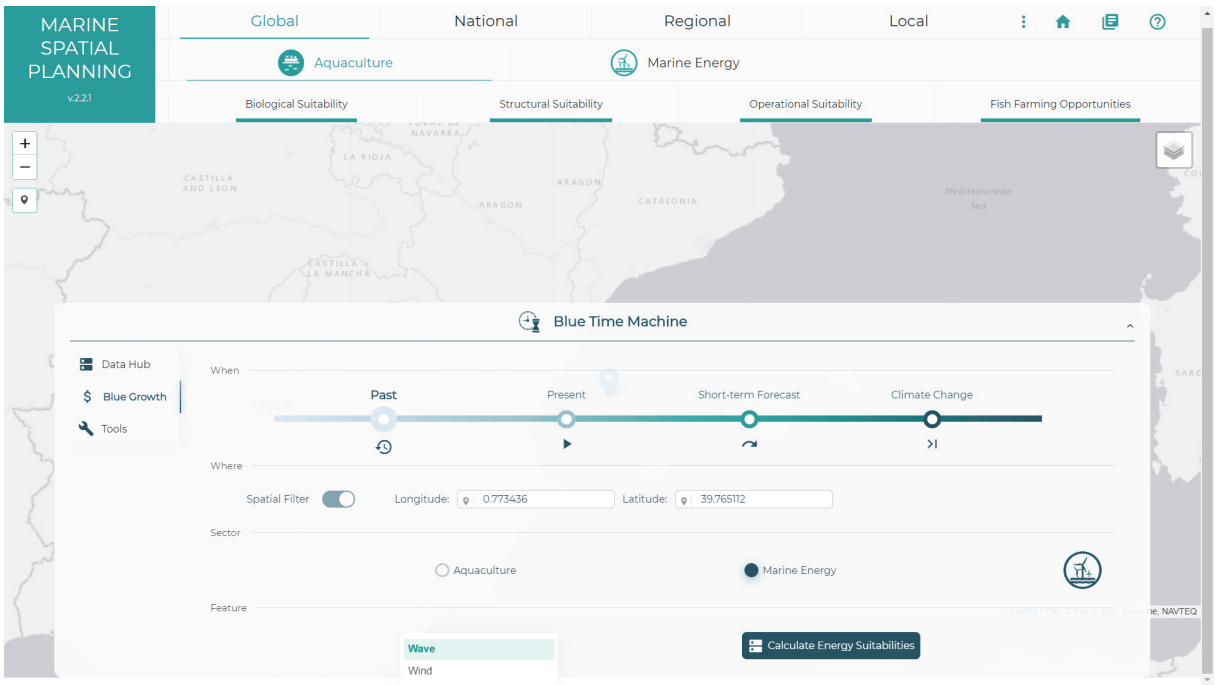

Figure 40. Blue Growth – Marine Renewable Energy Suitability

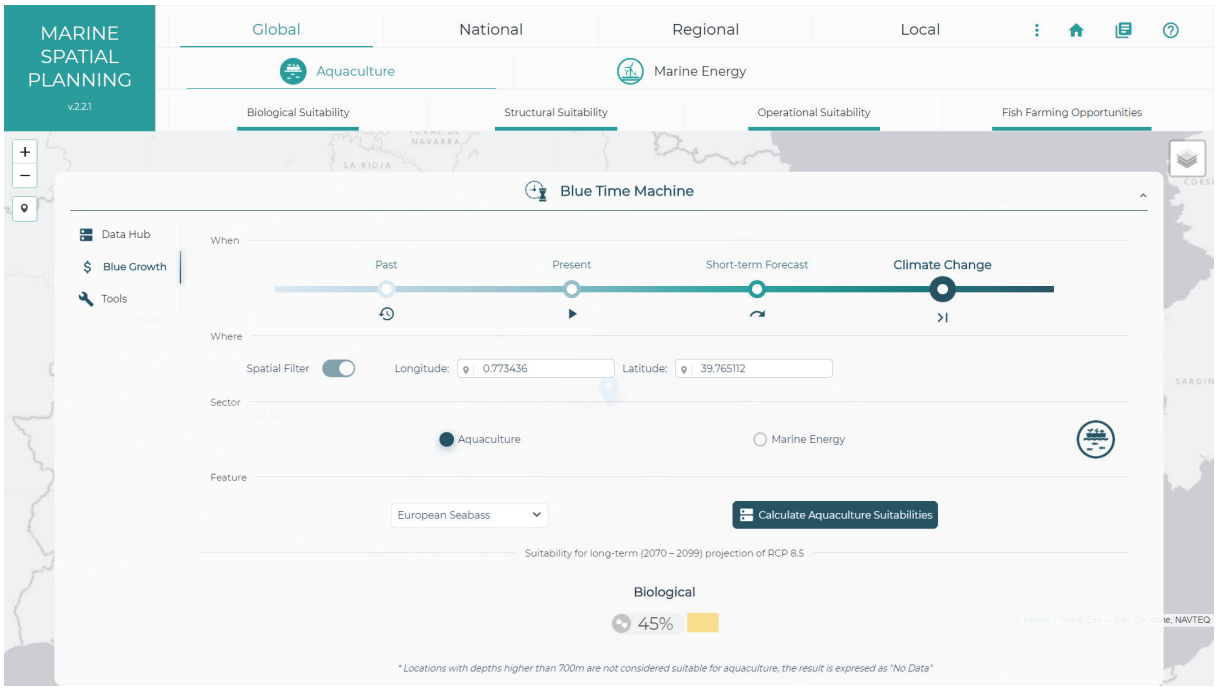

Figure 41. Blue Growth – Biological suitability under climate change scenarios

Figure 42 shows the UI for querying the short-term O&M and Figure 43 shows the results obtained, in which end users could modify thresholds, chart settings and interact with chart options trough right click over the chart (zoom in-out, download pdf, export image, export xls, print chart, etc.).

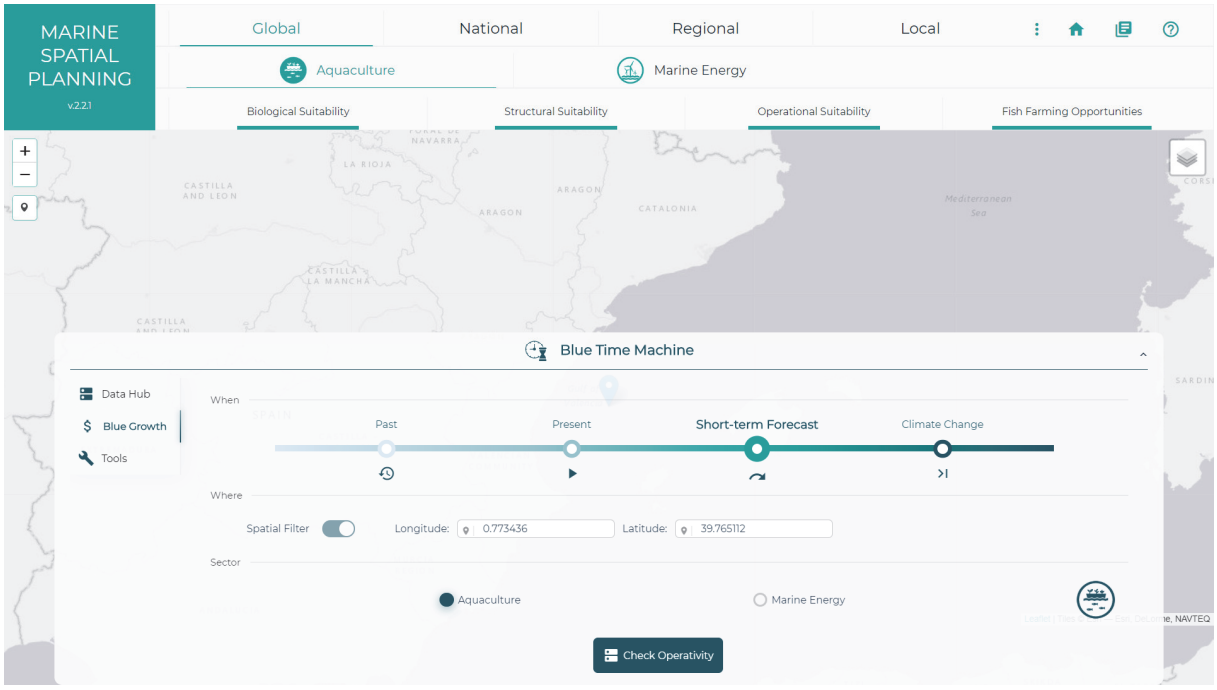

Figure 42. Blue Growth – Short-term forecast O&M

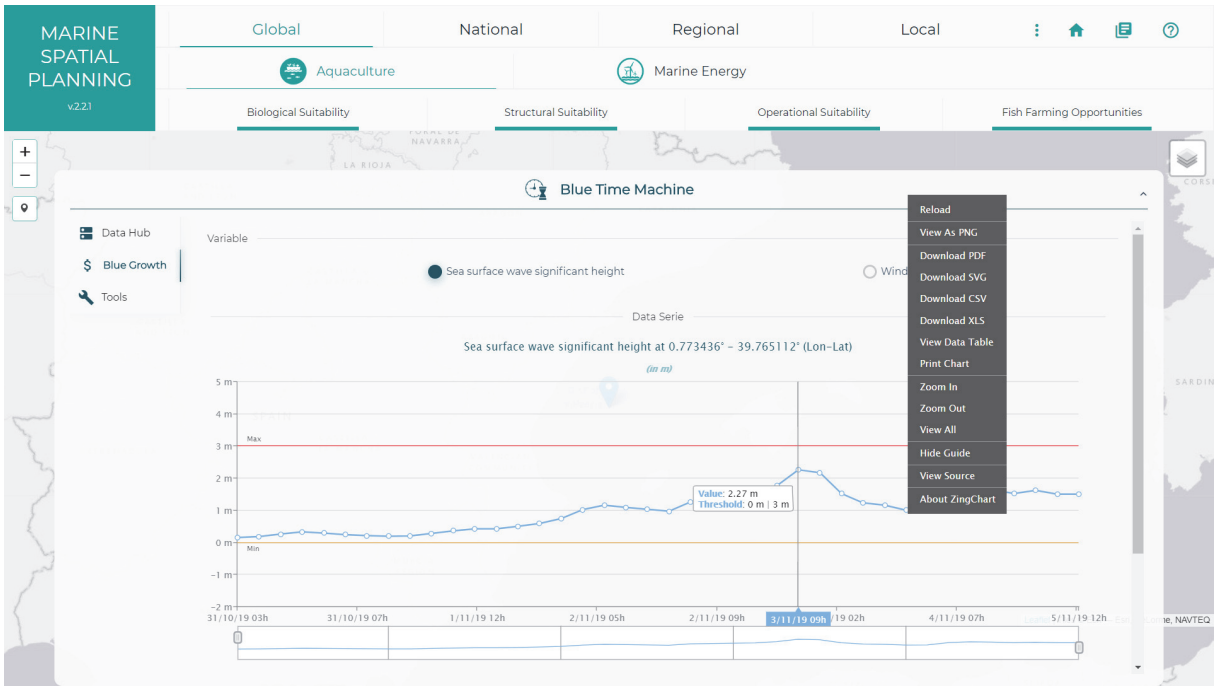

Figure 43. Blue Growth – Short term forecast operability thresholds

<u>Tools</u>

The aim of the tools section is to provide the highest degree of freedom to analyse CMEMS products and other metocean data sources for MSP activities. While the Data Hub and Blue Growth sections query data sets stored in the System, the tools analyse on the fly the metocean products.

Three tools have been designed and developed: Biological Suitability Tool, Wave Energy Suitability Tool and Wind Energy Suitability Tool. All of them make use of metocean data from reanalysis and allow users to set-up new configurations to perform the analysis on the fly.

The **Biological Suitability Tool** provides the following degree of freedom of freedom for the analysis:

- end users can select any location worldwide,
- end users can select the metocean thresholds from 15 species or provide the salinity and temperature thresholds for a new specie, and
- end users can select the period of time to perform the analysis among the last 5, 10, 15, 20 years, or the whole data series.

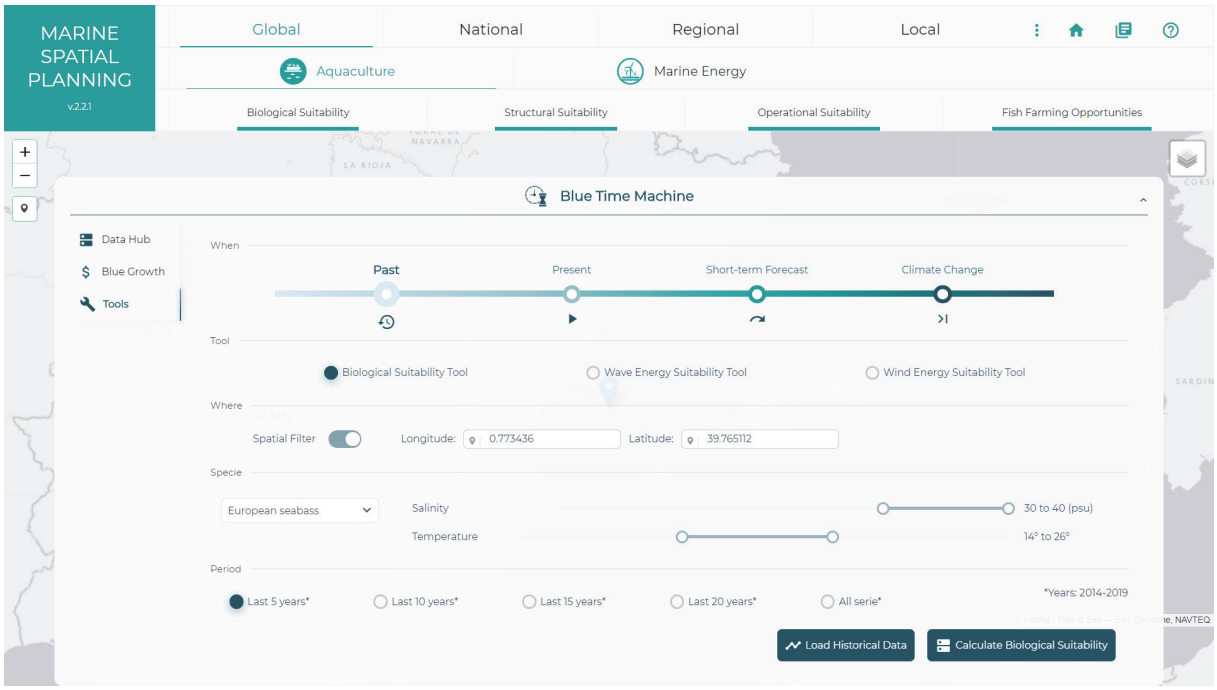

Figure 44. Tools – Biological Suitability Tool

The **Wave Energy Suitability Tool** provides the following degree of freedom for the analysis, see Figure 44:

- end users can select any location worldwide,
- end users can select the metocean thresholds from wave height, peak period and available energy flux.
- end users can select the period of time to perform the analysis among the last 5, 10, 15, 20 years, or the whole data series.

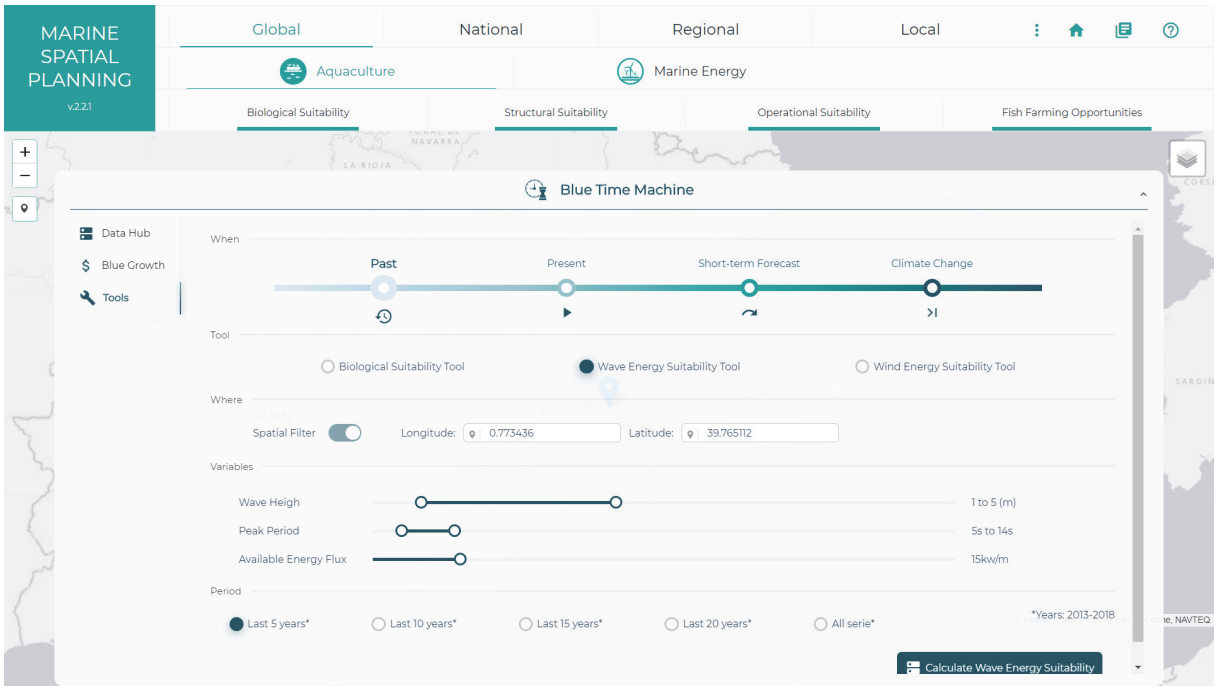

Figure 45. Tools – Wave Energy Suitability Tool

The **Wind Energy Suitability Tool** provides the following degree of freedom for the analysis, Figure 46, see Figure 45:

- end users can select any location worldwide,
- end users can select the metocean thresholds from maximum wave height and available potencial.
- end users can select the period of time to perform the analysis among the last 5, 10, 15, 20 years, or the whole data series.

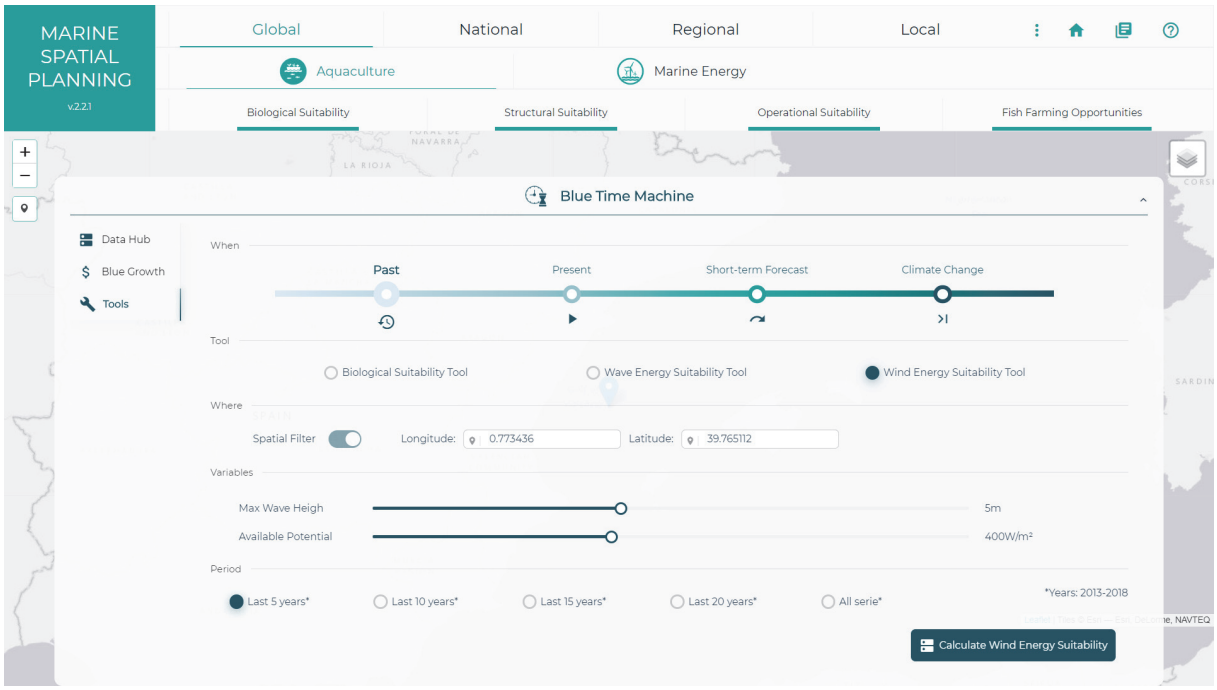

Figure 46. Tools – Wind Energy Suitability Tool

3.5 INTEROPERABILITY

The above sections provide a guide to access and use the MSP Platform from any standard Web browser (Chrome, Firefox, etc.). However, stakeholders with technical and analytical skills also require to access to the Service through interoperability protocols.

The Interoperability protocols of the RENAQUA Service act as a broker between two different applications so that they can communicate with each other, which enable to expose MetOcean operational data and services to any potential user. The RENAQUA interoperability Services try to facilitate the participation of Technical Implementation Units (TUI) from different sectors, who will exploit/consume the RENAQUA products to perform analytical testing of new technologies, numerical models, etc. In particular, interoperability protocols, following the Open Geospatial Consortium (OGC), were implemented as a service, for example: Web Map Service (WMS), Web Coverage Service (WCS). Other interoperability protocols such as OpenDap, NetCDF Markup Language (NCML) and NetCDFSubset, ftp or http were also implemented for those end users with less GIS expertise.

The reception of data from external sources (CMEMS, Puertos del Estado, NOAA, IMETEO, etc) required the development of flexible, stand-alone modules that enabled to migrate the

required information to the same store in operational mode. The Service collects the information from very different Data Providers with diverse data structures and formats (NetCDF, GRIBs, ASCII). The whole diversity of data sets are integrated in a common and standardized data format. Once the information is standardized, the RENAQUA Service provides communication protocols for data access.

The interoperability services are mainly provided through three APIs,

- Sensors API. It provides an interface to access observations collected by *in situ* sensors.
- Data Hub API. It provides an interface to access metocean operational products from numerical modelling.
- Process API. It provides access to programming interfaces that allow the request of analytical processes.