



HiSEA DELIVERABLE 3.1

REVIEW OF THE STATE OF THE ART

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REQUIREMENTS**



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Acronyms:

API: Application Programming Interface
CAMS: Copernicus Atmosphere Monitoring Service
CMEMS: Copernicus Marine Environment Monitoring Service
CPBM: Coupled Physical-Biogeochemical Models
DAS: Data Aggregator System
DIAS: Data & Information Access Services
ECMWF: European Centre for Medium-Range Weather Forecasts
EMODnet: The European Marine Observation and Data network
EO: Earth Observation
GIS: Geographic Information System
HAB: Harmful Algae Bloom
IaaS: Infrastructure as a Service
IADAS: Integrated Autonomous Data Acquisition System
IMTA: Integrated Multi-Trophic Aquaculture
IMS: Integrated Management System
KPI: Key Performance Indicators
MFC: Monitoring and Forecasting Centre
MFS: Mediterranean Forecasting System
MSFD: Marine Strategy Framework Directive
NODC: National Oceanographic Data Center
OGC: Open Geospatial Consortium
OMI: Ocean Monitoring Indicators
OPeNDAP: Open-source Project for a Network Data Access Protocol
PORTS: Physical Oceanographic Real-Time System
POC: Particulate Organic Carbon
SME: Small and Medium-sized Enterprise
SST: Sea Surface Temperature
SYNOP: Surface synoptic observations
TAC: Thematic Assembly Centre
WMO: World Meteorological Organization





1 Introduction

HiSea, Information Services System at Sea for Ports and Aquaculture, intends to provide a service based on the organization of collection, aggregation, and analysis of many sources of data (model outputs, satellite imagery, *in situ* measurements, and crowdsourcing). Moreover, following users specifications, the system is able to “manage” the results (publish reports on the web, send an alert on the user’s smartphone, etc.).

For a sea professional user, the assembly of these procedures is called “Service”, an IT specialist called it “Integrated Management System”. A so system/service relies on IT tools (platforms, software, etc.) and it is the outcome of numerous scientific and technical results.

During the last decade, many projects have been developed and set up to support the ports and aquaculture industry. Several projects have recently been completed or are still in progress. In the first part of this document, these projects are addressed. The second part deals with a summarised revision of reusable tools and/or concepts. Monitoring coastal activities in sectors such as ports and aquaculture is based on high resolution descriptive data sets which include two main classes of data:

- Physical Environment data;
- Bio-geochemical (BGC) data.

For each of the three main sources of data exist:

- Model outputs;
- Satellite imagery;
- *In situ* measurements.

Considering a descriptive parameter, these data sets are well-defined in term of spatiotemporal characteristics:

- *in situ*-measurements give time series at a precise location (or path) with a small time step;
- satellite imagery give synoptic fields typically at a daily time step
- model outputs give two synoptic fields :
 1. analysis a few times a day
 2. Forecast at any required time step.

Once a situation is diagnosed as "potentially problematic", only forecasting models may indicate whether this situation will eventually evolve to a critical situation for supported activities. More "realistic" model simulations require taking into account valid external information. This is the reason why in-situ and satellite imagery are used to process an analytic situation (an Analysis) using a data assimilation method. Then the model will run using this analysis as Initial Conditions.





2 Projects inventory for Aquaculture

2.1 SAFI: Supporting our Aquaculture and Fisheries Industries

2.1.1 Description

SAFI, a 3 years FP7/EU project, was completed by October 2016. It was led by Argans in collaboration with aquaculture and fisheries stakeholders to jointly define the products to be developed, the useful indicators and the decision support services and tools that can be developed.

The objective of [SAFI project](#) was to exploit EO resources to support fishery and aquaculture industries in marine coastal regions. The service, based on the additive value brought by a network of SMEs, is adapted to each category of targeted users and, by making the best use of emerging EO products, aims to realize::

- Develop a service to assist aquaculture deployment (optimization of cages location w.r.t. to environmental and ecological context) and environmental monitoring during operations;
- Develop a service to support fishery by providing indicators of recruitments, abundances, and shell/fish locations (and its variability due to climate change);
- Set up a network of SMEs at different levels of expertise (and EO awareness) required by the service – and to build a consistent and marketable offer;
- Evaluate the capacity of exportation and acceptance of this service;
- Foster the use of Sentinel 2 and Sentinel 3 data.

The project finally led to the development, deployment and evaluation of an integrated web-GIS, broadcasting SAFI indicators (<http://www.safiservices.eu/>) to the various concerned user (industrials, public administrations in charge of fishery/aquaculture planning, EO service providers and general public) that will be feed by a service of EO high level data processing.

2.1.2 Data used

The project used Earth observation (EO) data from remote sensing and output model mainly provided by CMEMS/Copernicus and to promote the use of Sentinel 2 and Sentinel 3 data (<https://scihub.copernicus.eu/>).

The main used parameters were:

- Sea Surface Temperature (SST)
- Turbidity
- Water Transparency (Secchi depth)
- Chlorophyll-A concentration (Chla)
- Plankton size distribution





- Coloured Dissolved Matters (CDOM)
- Significant Wave Height
- Salinity
- Global currents

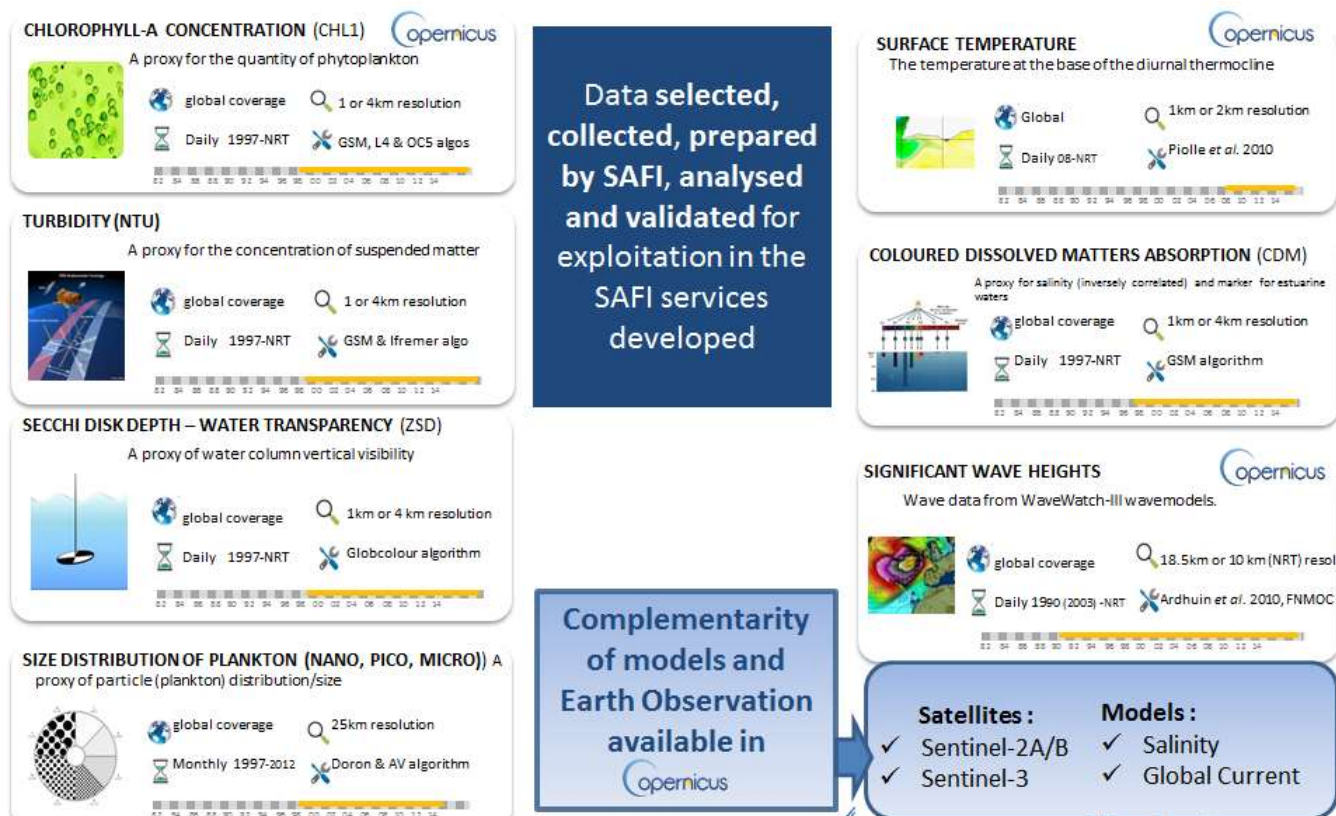


Figure 1 : Data collected within SAFI

2.1.3 Services/platform

The SAFI Decision Support Service (DSS) is designed to support users, managers, planners, and researchers in the aquaculture and fisheries sectors. The service is delivered via an interactive web-GIS online platform (<http://www.safiservices.eu>), the DSS offers users a range of functions for aquaculture and fisheries management and near-real-time environmental monitoring. Two levels of service have been developed:

- The [SAFI Mini-Web tool](#) (unrestricted access);
- The [SAFI Advanced tool](#) (earmarked for commercial development - contact us to gain access), with the functioning link to a Big Data processor (powered by [C-TEP](#)).



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821934



SAFI uses the [Coastal Thematic Exploitation Platform \(C-TEP\)](#). C-TEP is a data access service dedicated improving the efficiency of data-intensive research into our dynamic coastal areas. The C-TEP platform provides advanced tools and data management resources to easily process and manage large volumes of coastal data and make it easily accessible to users. C-TEP is an online service, funded by ESA, which will provide access to over 20 years of EO data, Near Real Time (NRT) EO data, non-space data, and multi-sensor processing tools.

2.1.4 Points of interest

A selection of pilot case studies has been implemented within C-TEP to demonstrate the processing power and tools and services which are available through the platform. (See [SAFI miniweb tool](#)).

The project is closed, but the service is still running. Therefore, some features of SAFI are reusable as starting points in the design of HiSea:

- Processing capacity in Sentinel data and other sensors processing (supply chains);
- Parameters rendering algorithms like Chla, Turbidity, suspended matters, CDOM;
- Index computation like optimal farming area selection;
- On-line service C-TEP via the user interface.

2.2 SMART: Sustainable Management of Aquaculture through Remote sensing Technology

2.2.1 Description

This two years ESA/innovator project has completed by mid of 2017 and was led by Argans (leader) with [BLUEFARM](#) as a sub-contractor.

The SMART project (<http://smart-eo.eu/>) aims at providing Earth Observation (EO) products and services to the aquaculture industry for planning, operation and impact monitoring. In the perspective of availability of Sentinel 2 and 3, and the outcomes of the Sentinel 2 preparatory workshops, SMART makes use of innovative joint exploitation of Medium (MR) and High Resolution (HR) optical missions (in particular, MERIS and Landsat) to better support coastal aquaculture (<http://smart-eo.eu/context-objectives>).

2.2.2 Data used

SMART makes use of innovative joint exploitation of MR and HR optical missions (in particular, MERIS/OLCI-like, Landsat, Sentinel 3 for MR, and Sentinel 2 for HR) to better support coastal aquaculture. The main used parameters were:

- Sea Surface Temperature (SST)
- Water Transparency (Secchi depth)
- Chlorophyll-A concentration (Chla)





- Coloured Dissolved Matters (CDOM)
- Global currents

2.2.3 Services

The novelty of the EO products comes from highly relevant new parameters (e.g. Particulate Organic Carbon - POC) which are derived owing to new algorithms that have been developed to assess the biomass productivity (carrying capacity) of a marine site (at short scale and/or on a statistical basis). Two types of application have been developed:

1. EO-derived tools for optimization, exploitation and monitoring of mussels farms;
2. estimation of pollution impact of fish farming.

Three levels of products/service improvements (which indicated a higher and higher level of sophistication) are sketched on the figure below (1st level in blue, 2nd level in orange and 3rd in green).

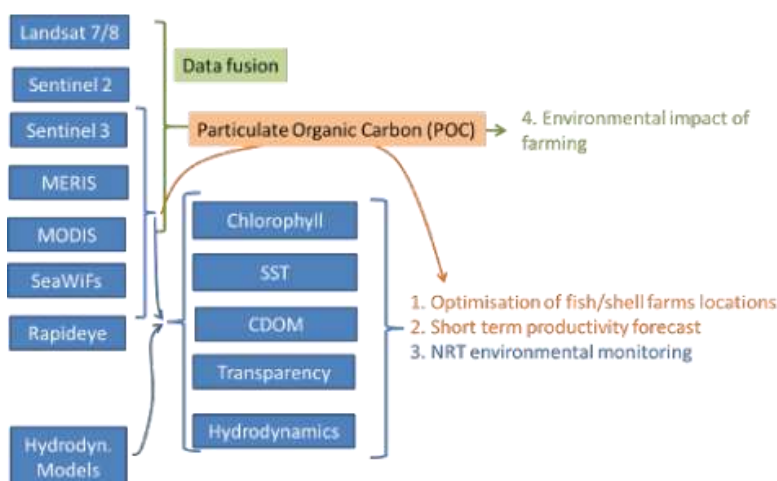


Figure 2 : Data fusion and new parameters estimate in SMART

2.2.4 Points of interest

The Smart project uses:

- numerous HR/MR satellite data
- Innovative algorithmic approaches
- Original fields of applications

SMART addresses a user community who has started only very recently to consider the use of EO information as a potential tool for aquaculture site selection. It may be important to apply [SMART BGC algorithms](#) in HiSea-Aquaculture applications.



2.3 AQUA-USERS: AQUAculture USers driven operational Remote Sensing information services.

2.3.1 Description

The EU-funded project AQUA-USERS (<http://www.aqua-users.eu/>) led by Deltares, provides the aquaculture industry with user-relevant and timely information based on the most up-to-date satellite data and innovative optical in-situ measurements. The key purpose is to develop an application that brings together satellite information on water quality and temperature with in-situ observations as well as relevant weather prediction and metocean data.

The application and underlying database will be linked to a decision support system that includes a set of user-determined) management options. Specific focus will be put on the development of indicators based on Earth observation data for aquaculture management including indicators for harmful algae bloom events. The methods and services developed within AQUA-USERS will be tested by the members of the user board, aquaculture companies and organizations representing different geographic areas and aquaculture production systems.

2.3.2 Data used

Satellite data

Within the project, water quality products will be derived from EO data (first ENVISAT MERIS, later Sentinel 3 OLCI from CMEMS/Copernicus) with algorithms specifically developed for the regions that host the aquaculture sites. Also, Sea Surface Temperature (SST) data and methods are examined and consolidated. Furthermore, methods for Harmful Algal Bloom (HAB) detection will be developed based on optical satellite information and supporting evidence.

Model outputs

Appropriate supporting information with excellent (spatio)-temporal coverage are obtained from hydrodynamic models. This dataset, complemented by measurements in the *in-situ* database is analysed using multivariate statistical analyses for the development of site-specific indicators for aquaculture suitability, and development of the decision support methodology, which will also comprise custom-made weighting functions

In-situ data

A pivotal part of the AQUA-USERS project is the collection and integration of in-situ data into the database and application. In close collaboration with the users, in-situ data are collected at the users' production sites. These data include WISP-3 measurements, Secchi depth, cell counts, concentrations of pigments, solids and coloured dissolved organic matter, data on phytoplankton composition, data on environmental physical conditions (temperature, oxygen levels et.) as well as the actual response of the aquaculture species (e.g. mortality, growth, yield, and fish behaviour). In addition, data from various sources are integrated into the database, including *Ferry*





box systems, weather forecasts and metocean data (e.g. wave height). An important aspect of this work is the development and application of methods for quality control of these data before they can be entered into the joint project database.

2.3.3 Services/Platform

The following snapshot shows the portal that provides access to the specialized datasets: <https://portal.aqua-users.eu/>



Figure 3 : AQUA-Users data portal

2.3.4 Points of interest

The merging of model outputs, satellite imagery and in-situ measurements is a complex operation. In HiSea project applications, it may be important to refer to the **merging calculation techniques** (Satellite & in-situ measurement) used in this project.

2.4 BlueBRIDGE: Building Research environments fostering Innovation, Decision making, Governance and Education to support Blue growth

2.4.1 Description

BlueBRIDGE (<https://www.bluebridge-vres.eu/>) supports capacity building in interdisciplinary research communities actively involved in increasing scientific knowledge about resource overexploitation, degraded environment and ecosystem. BlueBRIDGE aims at providing a more solid ground for informed advice to competent



authorities and at enlarging the spectrum of growth opportunities as addressed by the Blue Growth Societal Challenge.

BlueBRIDGE capitalizes on past investments and uses the proven [D4Science infrastructure](#). BlueBRIDGE has developed innovative services, the so-called Virtual Research Environments (VREs), in the following areas:

- Ecosystem approach to Fisheries - services for stock assessment and for the generation of unique identifiers for global stocks (See [Solutions for Ecosystem Approach to Fisheries](#));
- Aquaculture - services supporting the analysis of socio-economic performance in aquaculture (See [Solutions for Aquaculture](#));
- Maritime Spatial Planning - spatial planning services to identify aquaculture and fisheries infrastructures from satellite imagery and tools to visualize, analyse and report on a range of ecologically important seafloor features within marine protected areas (See [Solutions for Maritime Spatial Planning](#)).
- Education - tools to set up and deliver training courses in a cost-effective way (See [Solutions for Education](#)).

2.4.2 Data used

BlueBRIDGE gives you seamless access to heterogeneous [datasets](#).

- Biological and Ecological List of Names and data
- Geo-referenced chemical and physical variables with global geospatial coverage
- Raster data

2.4.3 Services/Platform

BlueBRIDGE creates and delivers tailored data management services for the aquaculture sector and the fisheries, education and maritime spatial planning domains through collaborative web-based research environments, the so-called VREs, built on top of a hybrid-data infrastructure

VRE: Virtual Research Environments are web-based systems that can be accessed on-demand through a simple user interface. VREs provide users from different disciplines, institutions or even countries, with secure access to collaborative tools, services, data and computational facilities meeting their specific needs. The hardware setup and software deployment required to operate these facilities is translated into easy and intuitive operations for the VRE creator. ([More on VREs](#)) The key distinguishing features of a VRE are:

- It is a web-based working environment;
- It is tailored to serve the needs of a Community of Practice;





- It is expected to provide a Community of Practice with the whole array of commodities needed to accomplish the community's goal(s);
- It is open and flexible with respect to the overall service offering and lifetime;
- It promotes fine-grained controlled sharing of both intermediate and final research results by guaranteeing ownership, provenance, and attribution.

The BlueBRIDGE VREs are built on the [D4Science infrastructure](#). **D4Science** is a self-sustained hybrid data infrastructure executing around 60,000 models & algorithms per month and providing access to over a billion of records hosted in more than 50 worldwide repositories. Currently, D4Science serves over 2,700 users from multiple scientific domains (e.g. fisheries, biodiversity, ocean observation, etc.). The added value of D4Science is that it is a framework in which infrastructure resources (e.g. data and services) made available by different data infrastructures can be dynamically packaged to serve the needs associated with scientific or societal questions. All of this is completely transparent for the user.

2.4.4 Points of interest

HiSea will offer a support service dealing with the cloud. It might be important to check if the VRE concept may be used in the design of the HiSea platform.

2.5 IMPAQT: Intelligent Management Systems for Integrated Multi-trophic Aquaculture

2.5.1 Description

This 3 years H2020/EU project has started in May 2018 and is led by Marine Institute (IRL). Argans and Deltares are involved in that project.

The overall objective of IMPAQT (<https://impagtproject.eu/>) is to develop and validate in-situ a multi-purpose (inland, coastal and offshore productions), multi-sensing (heterogeneous sensors and new/emerging technologies) and multi-functional (advanced monitoring, modelling, data analytics and decision making) management platform for sustainable IMTA production. The high level ambition is to drive a paradigm shift in the European Industry by paving the way to both a more environmentally friendly and more efficient/higher yielding European Industry.

IMPAQT adopts a holistic approach addressing the complete system view. This comprises three main interacting subsystems: the autonomous data acquisition and communication system, the advanced IMTA model and the integrated management system. The high level overview of IMPAQT platform is depicted in Figure 4.



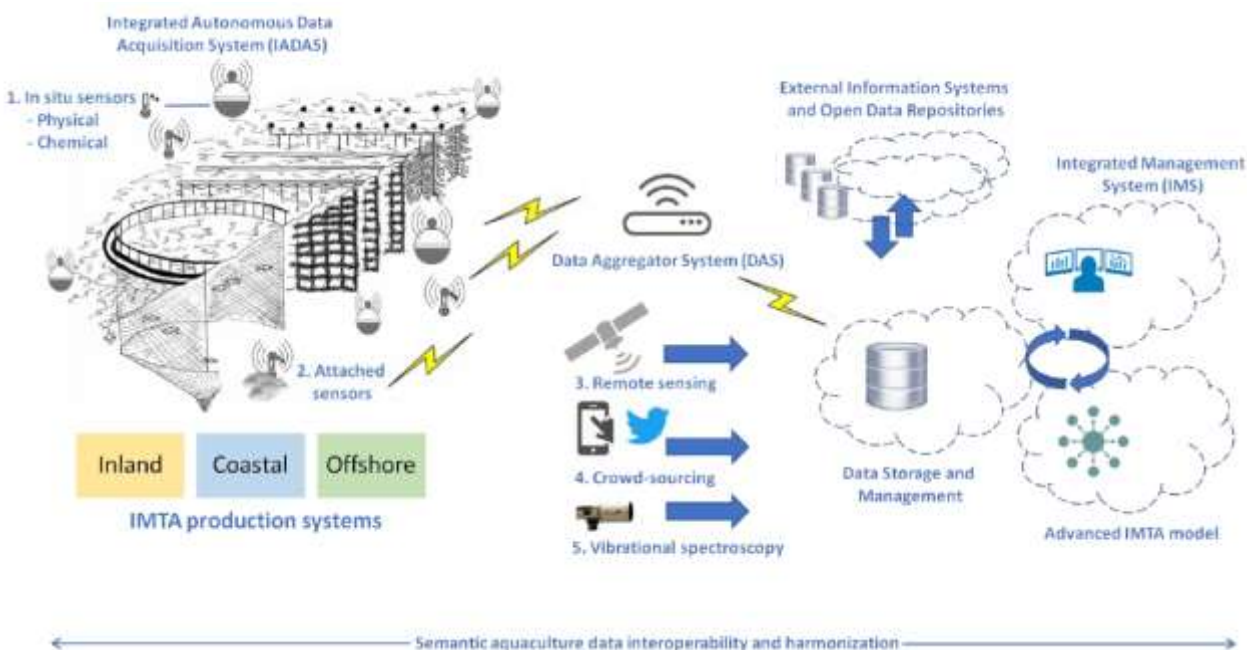


Figure 4 : High level overview of IMPAQT platform

2.5.2 Data used

IMPAQT will develop arrays of cross-selective sensors for detecting out-of-normal state conditions of Integrated Multi-Trophic Aquaculture (IMTA) farms. The *electronic tongue principle* will be adopted, where the recognition of compounds results from the pattern of signals produced by different receptors. To ensure the autonomy of the sensors in the field, a novel modular autonomous smart sensing unit, IADAS (Integrated Autonomous Data Acquisition System), will be developed. IMPAQT will also develop DAS, leveraging on the most promising emerging low power short/long range communication technologies and offering edge processing and autonomous behaviour in the field. Finally, the project will optimize a few other heterogeneous data sources for IMTA case, namely attachable biomechanical sensors, remote sensing algorithms and products, crowd sourced datasets and vibrational spectroscopy.

2.5.3 Services/Platform

IMPAQT comprises two (2) main interacting systems: a) Autonomous Data Acquisition and Communication System and b) IMTA Model and Integrated Management System.

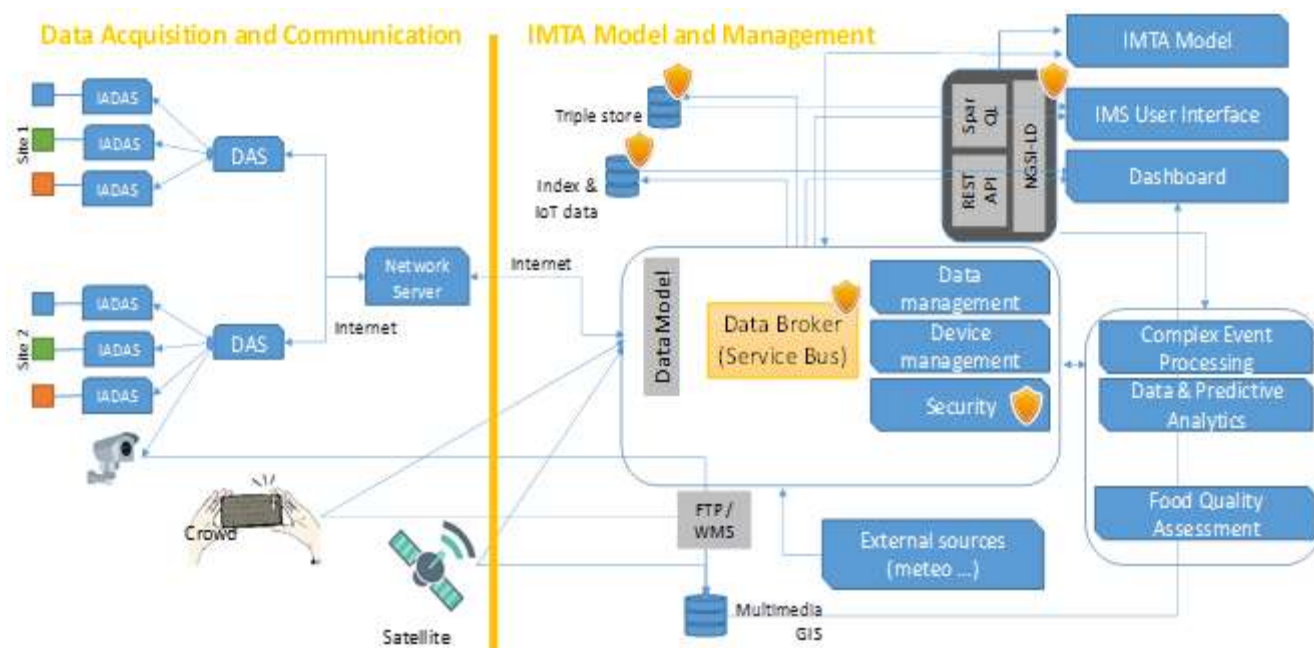


Figure 5 : Functional architecture of IMPAQT platform

The autonomous data acquisition and communication system comprises sensors connected to IADAS (e.g. in site deployed chemical and physical sensors, attached species sensors), together with other devices connected to DAS (e.g. cameras), as well as remote sensing products and crowd-sourcing applications connected directly to the cloud (i.e. IMTA Model and Integrated Management System).

IADAS is a modular autonomous smart sensing unit, incorporating the necessary technologies for the long term, autonomous deployment of sensors in the operational environment. It offers autonomy in terms of providing power and connectivity, as well as controlling the operation of sensor components. IADAS will provide a set of different sensor interfaces in order to be able to manage a wide number of sensors.

IMPAQT is characterized by distributed intelligence, incrementally from IADAS to DAS to IMS and IMTA model, depending on the specific requirements and needs of the deployment case.

2.5.4 Points of interest

It may be important to follow the progress of this project of marine farm equipment in **“in situ” data management** as part of the application of HiSea in Aquaculture.



2.6 ODYSSEA: Operating a network of integrated observatory systems in the Mediterranean Sea

2.6.1 Description

This 4.5 years H2020/EU project has started in June 2017 and is led by Democritus University of Trace (GR). Hidromod and Deltares are involved in that project. ODYSSEA (<http://odysseaplatform.eu/>) purpose is to develop, operate and demonstrate an interoperable and cost-effective platform that fully integrates networks of observing and forecasting systems across the Mediterranean basin, addressing both the open sea and the coastal zone.

Through ODYSSEA's end-user centered approach, in which the various groups of end-users and stakeholders, within and external to the Consortium, are being involved from Day 1 of the project in the design, development and operation of the platform, including identification of gaps in data collection and accessibility.

High priority gaps are being filled through multiple approaches that include developing a network of coastal observatories, deploying novel in-situ sensors at sea (i.e. micro plastic sensors), oceanographic modelling and integrating existing mobile apps for citizen scientist networks. By applying advanced algorithms to organize, homogenize and fuse the large quantities of data in common standard type and format as well as other types of formats, the ODYSSEA platform will provide both primary data and on-demand derived data services, including forecasts, from all Mediterranean countries through a single public portal to various end-user groups and stakeholders. End-user requirements will drive the creation of secondary data sets which the platform will provide as new and packaged services matching the specialized information needs of users.

2.6.2 Data used

The platform will collect its data from the many databases maintained by agencies, public authorities, and institutions of Mediterranean EU and non-EU countries, integrating existing earth observation facilities and networks in the Mediterranean Sea building on key initiatives such as Copernicus, GEOSS, GOOS, EMODNet, ESFRI, Lifewatch, Med-OBIS, GBIF, AquaMaps, Marine IBA e-atlas, MAPAMED and others with marine and maritime links.

ODYSSEA will improve accessibility to existing data as well as increase the temporal and geographic coverage of observational data in the Mediterranean

2.6.3 Services/Platform

In the framework of ODYSSEA an innovative platform capable to deliver data download and discovery (through a single access point to multiple databases such as CMEMS, EMODNET, SEADATANET, etc.) and user focused services capabilities.



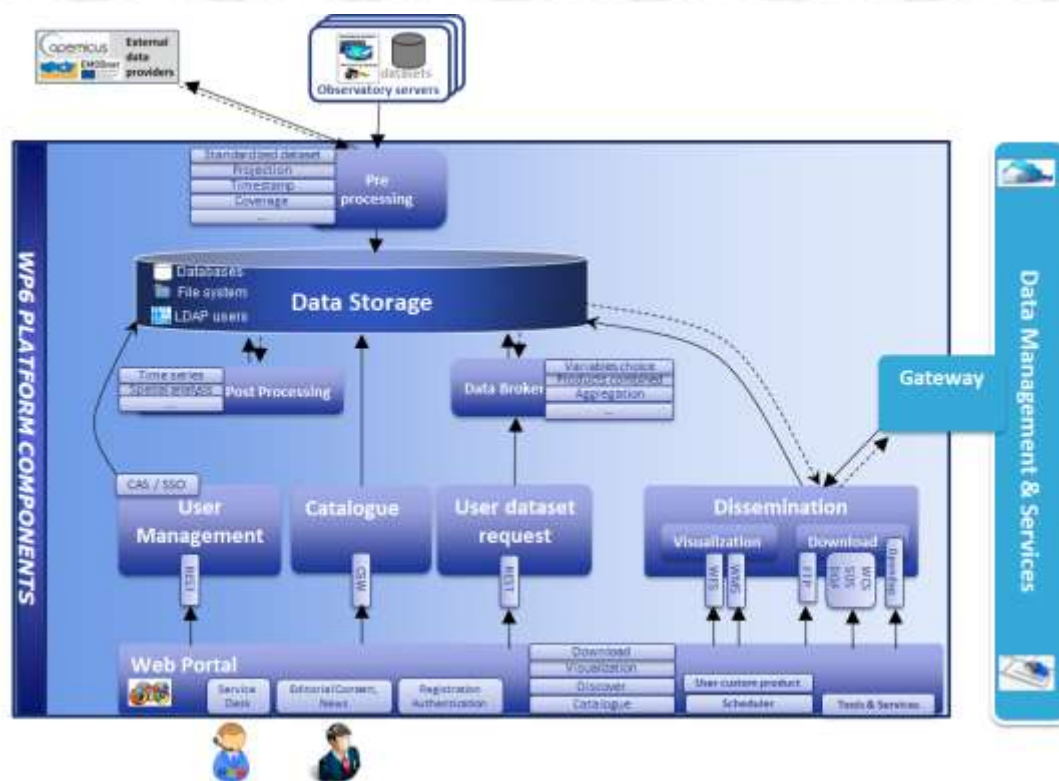


Figure 6 : ODYSSEA Platform general architecture

This platform will be complemented at the local (observatory) level by two other existing platforms:

1. [Delft-FEWS](https://oss.deltares.nl/web/delft-fews/home) an open data handling platform developed by Deltares to provide an easy and modular way of setting up an operational forecasting system (<https://oss.deltares.nl/web/delft-fews/home>);
2. [AQUASAFE](http://www.aquasafeonline.net/en/info.asp) an open source platform, developed by HIDROMOD, which aims to increase efficiency in operations management, providing real time information and integration with forecast and diagnostics tools. According to the concepts implemented in AQUASAFE this integration is achieved by the management of measured data (sensors, remote detection) and modeled data (water distribution, wastewater, receiving waters, meteorology, etc.) in a uniform way (<http://www.aquasafeonline.net/en/info.asp>).

These local platforms intend to provide:

- High resolution modelling results;
- Local personalized alarms, combining data from several sources (real or modelled);
- Automatic personalized scenario simulation processes, to assess management options in real time;
- Automatic reports of modelling results and/or measures, based on user predefined templates;
- A practical way to upload local modelling and locally acquired data to the ODYSSEA platform.

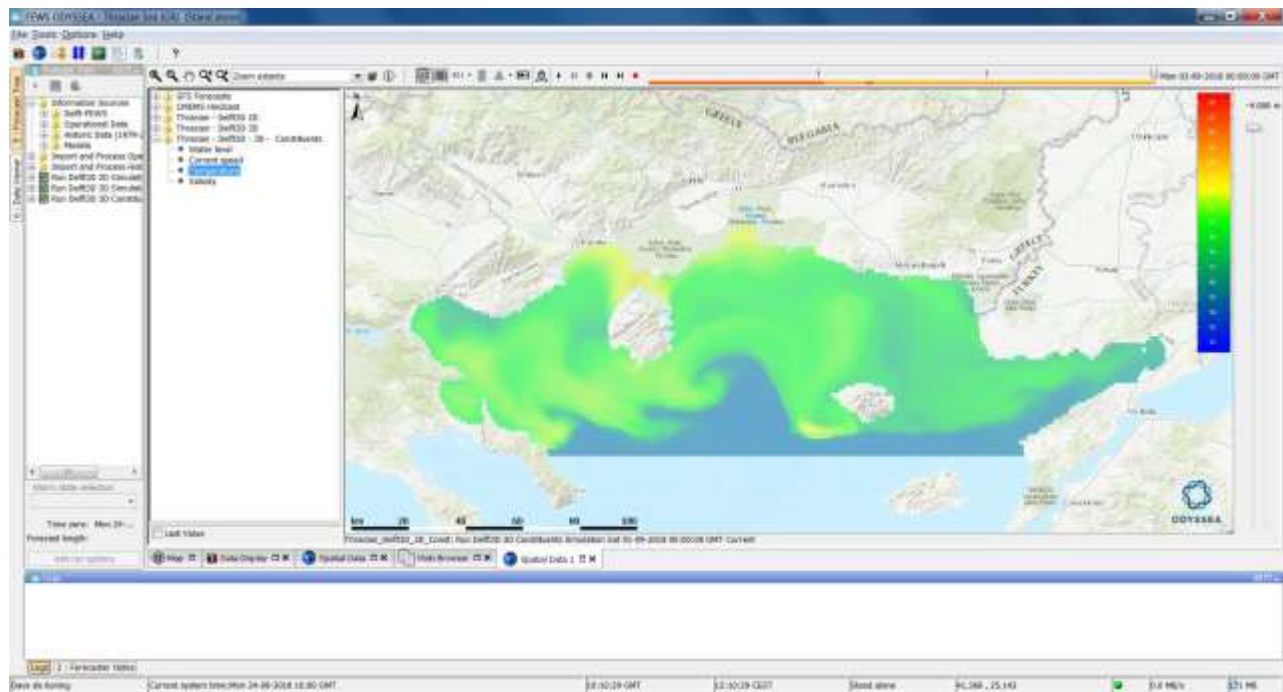


Figure 7: User-friendly visualization displays in Delft-Fews.

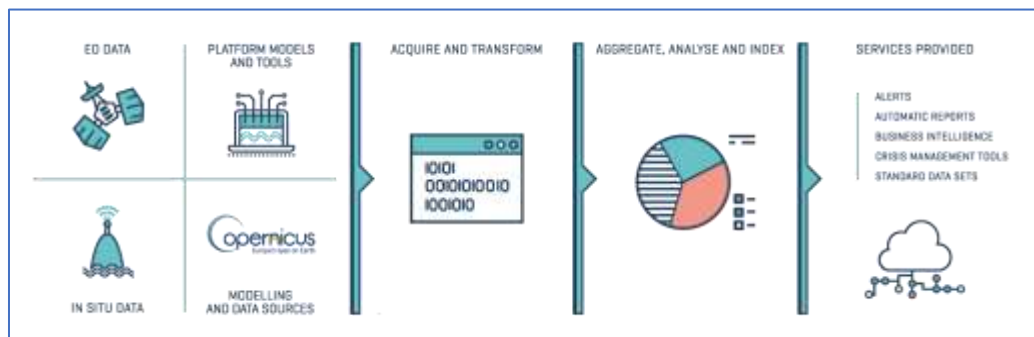


Figure 8 : AQUASAFE dataflow

2.6.4 Points of interest

The setup of the HiSea platform will make use of numerous new technologies. It may be important to follow the progress of this project during the successive phases of the development of the ODYSSEA platform as part of the applications of HiSea.



3 Strategic programs

3.1 Blue-Growth

The [Blue Growth Strategy](#) is the long term management strategy towards more sustainable growth and jobs in the blue economy in the marine and maritime sectors. It has launched initiatives in many policy areas related to Europe's oceans, seas and coasts, facilitating the cooperation between maritime business and public authorities across borders and sectors, and stakeholders to ensure the sustainability of the marine environment (European Commission, 2017).

The 'blue' economy represents roughly 5.4 million jobs and annually generates a gross added value of almost €500 billion. However, further growth is possible in several areas, such as aquaculture, coastal tourism, marine technology, ocean energy, and seabed mining which are highlighted within the strategy. Additionally, part of the strategy is to focus on essential components to provide knowledge, legal certainty and security in the blue economy; i) marine knowledge to improve access to information about the sea; ii) maritime spatial planning to ensure an efficient and sustainable management of activities at sea; iii) integrated maritime surveillance to give authorities a better picture of what is happening at sea (European Commission, 2017).

3.2 Marine knowledge 2020

Knowledge is an engine for sustainable growth in the interconnected global economy and therefore a key element to achieve smart growth in the European Union in line with the "Europe 2020" strategy. Improving knowledge of the seas and oceans is one of the three cross-cutting tools of the EU's integrated maritime policy. Marine knowledge can also help achieve the other two tools – better spatial planning and integrated maritime surveillance. The creation of marine knowledge begins with an observation of the sea and oceans. Data from these observations are assembled, then analysed to create information and knowledge. Subsequently, the knowledge can be applied to deliver smart sustainable growth, to assess the health of the marine ecosystem or to protect coastal communities. The magnitude of future changes in oceanic systems, their impact on human activity and the feedback on the ocean from these changes in human behaviour cannot be forecast without understanding the way the system works now and how it worked in the past. Knowledge is necessary to achieve a good environmental status of marine waters, in accordance with the Marine Strategy Framework Directive, the environmental pillar of the integrated maritime policy. Knowledge is a key component of the EU's plan to integrate marine and maritime research and a contribution to the Digital Agenda (European Commission, 2010)¹. Three objectives have been established in order to improve marine knowledge:

1. reduce operational costs and delays of those who use marine data;
2. increase competition and innovation amongst users and re-users of marine data by providing wider access to quality-checked, rapidly-available coherent marine data;

¹ https://ec.europa.eu/maritimeaffairs/policy/marine_knowledge_2020





3. Reduce uncertainty in knowledge of the oceans and seas and therefore provide a sounder basis for managing future changes (European Commission, 2010).

3.3 The Marine Strategy Framework Directive

The Marine Strategy Framework Directive (MSFD) aims to achieve a Good Environmental Status (GES) of all EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend. It is the first EU legislative instrument related to the protection of marine biodiversity, as it contains the explicit regulatory objective that "biodiversity is maintained by 2020", as the cornerstone for achieving GES. In order to achieve GES by 2020, each Member State is required to develop a strategy for its marine waters (or Marine Strategy). In addition, because the Directive follows an adaptive management approach, the Marine Strategies must be kept up-to-date and reviewed every 6 years (European Commission, 2019).

3.4 Integrated Coastal Management (ICM)

Coastal zones are among the most productive areas in the world, offering a wide variety of valuable habitats and ecosystem services that have always attracted humans and human activities. The beauty and richness of coastal zones have made them popular settlement areas and tourist destinations, important business zones and transit points. Currently, more 200 million European citizens live near coastlines, stretching from the North-East Atlantic and the Baltic to the Mediterranean and the Black Sea.

Because the well-being of populations and the economic viability of many businesses in coastal zones depend on the environmental status of these areas, it is essential to make use of long-term management tools, such as integrated coastal management, to enhance the protection of coastal resources whilst increasing the efficiency of their uses. A sectoral approach lead to disconnected decisions that risk undermining each other, to inefficient use of resources and missed opportunities for more sustainable coastal development (European Commission, 2016).

Integrated coastal management (ICM) ICM aims at the coordinated application of the different policies affecting the coastal zone and related to activities such as nature protection, aquaculture, fisheries, agriculture, industry, offshore wind energy, shipping, tourism, development of infrastructure and mitigation and adaptation to climate change. It will contribute to the sustainable development of coastal zones by the application of an approach that respects the limits of natural resources and ecosystems, the so-called 'ecosystem-based approach'. ICM covers the full cycle of information collection, planning, decision-making, management and monitoring of implementation. It is important to involve all stakeholders across the different sectors to ensure broad support for the implementation of management strategies (European Commission, 2016).





4 Project inventory for ports

4.1 AQUASAFE PORTS

4.1.1 Description

[AQUASAFE PORTS](#) is capable to deliver user-focused services integrating different data sources and manage different models to deliver accurate and reliable information, readily available, easily understandable and with high resolution to fit seamlessly users' operation, planning, and management requirements. The data may be obtained from classic sampling or be acquired in real time. Models may be executed in diagnostic mode, to simulate scenarios, or periodically in forecast mode. This methodology allows a real time management of the necessary data to characterize water quantity and quality with a high space and time continuity. AQUASAFE PORTS works as an integral element for models, external data sources and real time data systems, allowing:

- Modelling results available in real time, through the integration of near real time data or other external data source with models, without human intervention;
- The anticipation of problematic situations through the creation of personalized alarms, combining data from several sources (real or modelled);
- The launch of automatic personalized scenario simulation processes, to assess management options in real time;
- Automatic report generation of modelling results and/or measures, based on user predefined templates;
- A practical way to use modelling results through the know-how of current users.

AQUASAFE PORTS also provides tailor-made solutions, being compatible with (or easily adaptable to) several models (meteorology, waves, hydrodynamics, water quality, etc.) and databases. It also includes the possibility to customise interfaces according to the profiles of different users.

4.1.2 Data used

- Meteorology
- Wave
- Hydrodynamic outputs
- Water quality

4.1.3 Services /Platform

The figure below shows an Example of a personalized AQUASAFE dashboard.



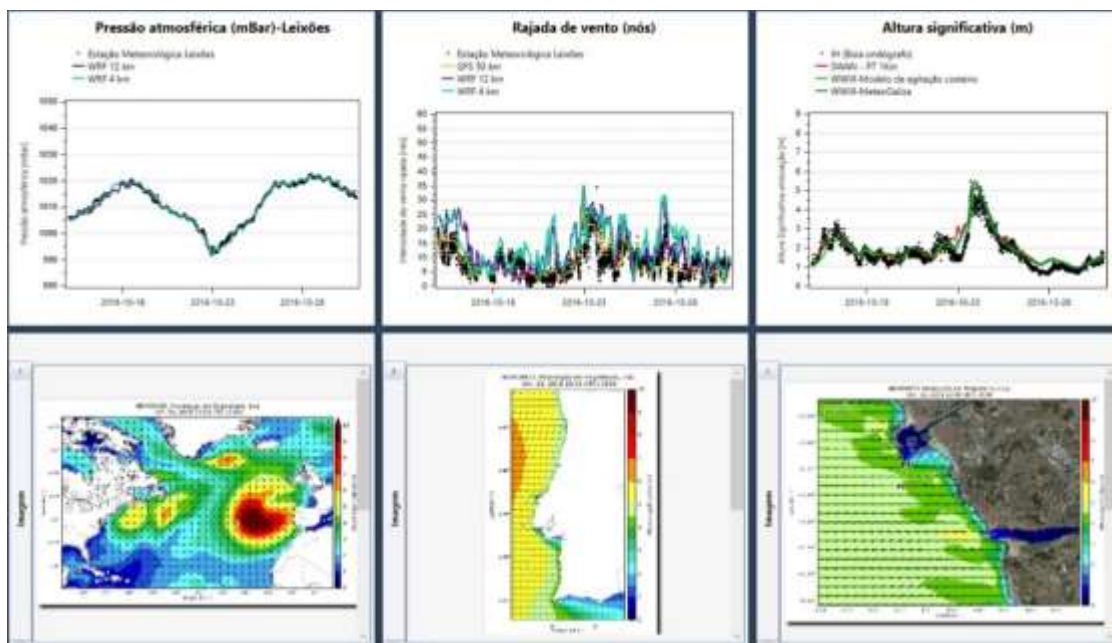


Figure 9: Example of a personalized AQUASAFE dashboard

AQUASAFE PORTS is supported by AQUASAFE Platform which is designed to let the user customize his own service by selecting what data he wants to see and how he wants to see it.

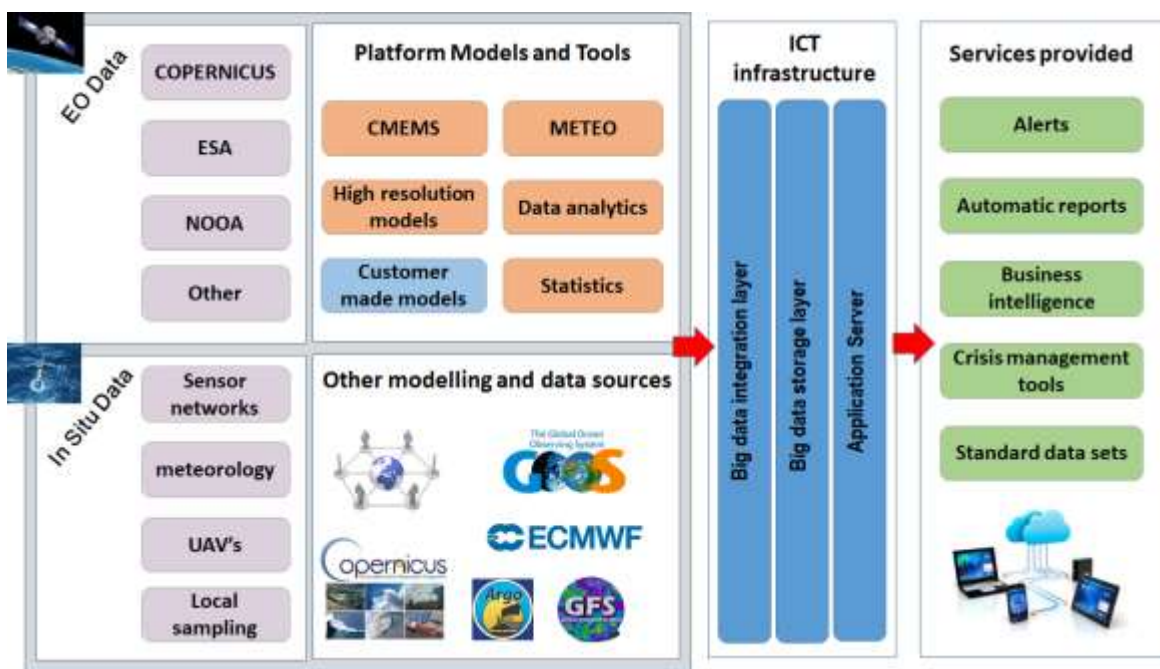




Figure 10: Generic AQUASAFE platform concept

4.2 PORTS (NOAA): Physical Oceanographic Real-Time System

4.2.1 Description

PORTS (https://tidesandcurrents.noaa.gov/ports_info.html) is an integrated system of sensors concentrated in seaports that provide commercial vessel operators with accurate and reliable real-time information about environmental conditions. NOOAPORTS measures and disseminates observations, predictions and nowcast/forecast for water levels, currents, bridge air gap, salinity and meteorological parameters (e.g., winds, waves, atmospheric pressure, visibility, air and water temperatures).

PORTS is a service of the Center for Operational Oceanographic Products and Services (CO-OPS). CO-OPS collects and analyses, and communicates oceanographic information

4.2.2 Data used

Several data are used in this project as showed in **Error! Reference source not found..**

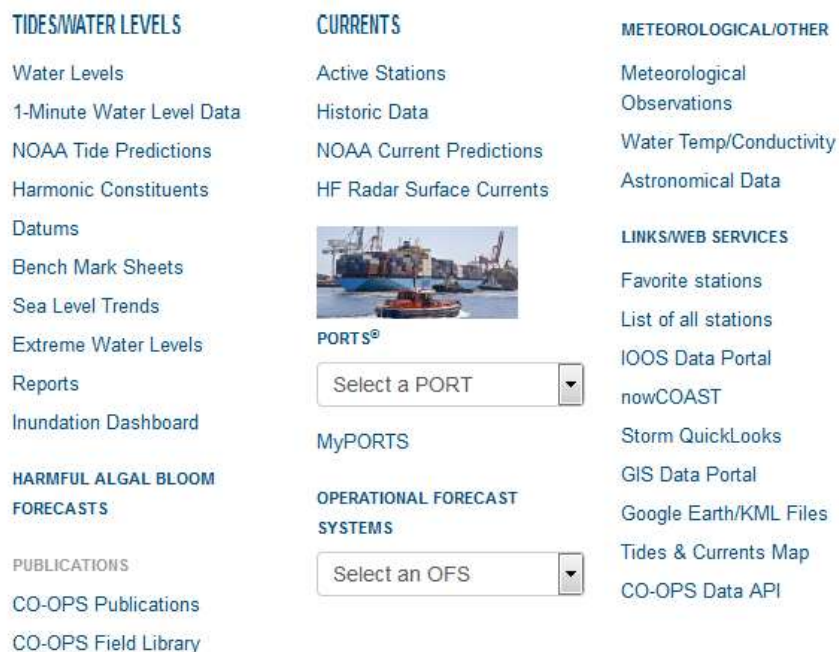


Figure 11 Data, Analyses and Publications that make up the Physical Oceanographic Real-Time System (PORTS®).





4.2.3 Services/Platform

[MyPORTS](#) is an application designed to let the user customize his own PORTS[®] page by selecting what data he wants to see from any PORTS[®].

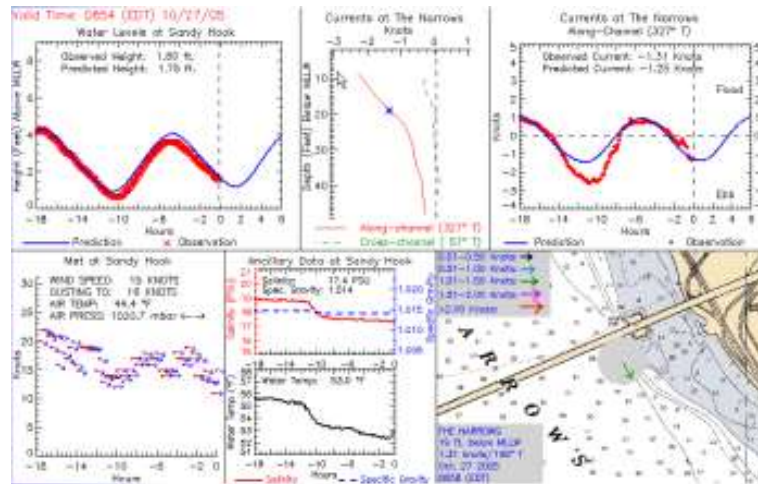


Figure 12 : An example of PORTS composite data display.

4.3 Port of the future

This project is led by Deltares. The growing number of port development projects recognizes the need to shift economies and social structures towards more sustainable models. The development of a new or extended port layout requires adequate attention to several aspects that guarantee both sustainable port growth and a healthy ecosystem functioning. There is a need for innovative solutions for port development which are in harmony with the ecosystem and which are robust or adaptable under change. Through an integrated and ecosystem-based approach, port development can be realized in an inclusive way, providing an economic, environmental and social vital port: the “Port of the Future” concept.



Figure 13: Port of the Future concept

4.4 SAMPA projects

In the framework of the SAMPA series of projects (<http://sampa-apba.puertos.es/>) a tailor-made software application entitled SAMPA-CMA, was developed to provide customized access to metocean information. <http://marine.copernicus.eu/usecases/met-ocean-conditions-port-management/>

The SAMPA project aims to provide, among other things, to know more accurately and in advance the ocean-meteorological conditions (wind, currents, waves and sea level) of the Strait of Gibraltar and the Bay of Algeciras, in order to more accurately forecast the storms and minimize the associated risks. The advances developed for Algeciras, a pilot port of installation of these new improvements associated with SAMPA, could be in the future implanted in other Spanish ports. The project consists of 3 main modules:

- Implementation of a permanent measurement system (oceanographic buoys, sea level stations, meteorological stations and current meters).
- Development of a prediction system based on numerical models (atmosphere, currents, waves, sea level, and trajectory of discharges)
- Implementation of an early warning system based on the detection of adverse situations and the publication/sending of warnings to the different users of the port community.

SAMPA project is being extended to the entire Spanish port system through SAMOA project. SAMOA's main objective is to provide each Port Authority with personalized ocean-meteorological information adapted to their needs. The service consists of various modules (improved instrumentation and new prediction systems), which are accompanied by value-added systems that allow better exploitation of it.

4.5 Corealis



Port operators need to comply with increasingly stricter environmental regulations and societal views for sustainability. A sustainable land-use strategy in and around the port and a strategic transition to new, service-based, management models that improve capacity and efficiency are paramount. They are key enablers for ports that want to keep pace with the ocean carriers needs and establish themselves as trans-shipment hubs with a 'societal license to operate'; for ports whose land strategy, hinterland accessibility and operations are underpinned by circular economy principles.

COREALIS proposes a strategic, innovative framework, supported by disruptive technologies, including Internet of Things (IoT), data analytics, next generation traffic management and emerging 5G networks, for cargo ports to **handle upcoming and future capacity, traffic, efficiency and environmental** challenges. It respects the limitations that many European ports are facing concerning the port land, intermodal infrastructure and terminal operation. It proposes beyond state of the art innovations that will **increase efficiency and optimize land-use**, while being financially viable, respecting circular economy principles and being of service to the urban environment. Through COREALIS, ports will minimize their environmental footprint to the city, they will **decrease disturbance** to the local population through a significant **reduction in the congestion around the port**. They will also be a pillar of economic development and **business innovation**, promoting local start-ups in disruptive technologies of mutual interest. COREALIS innovations are keys both for the **major deep sea European ports** in view of the mega-vessel era, but also relevant for **medium sized ports with limited investment funds** for infrastructure and automation.

4.6 Port of the Future Serious Game

The [Port of the Future Serious Game](#) aims at raising awareness for the current policy-making challenges of ports, so as to support the port stakeholders in achieving sustainable development. The game applies a fictional but realistic environment, autonomous scenarios, a set of measures and a qualitative set of indicators that provide information on the effects for society, natural environment and economy. By introducing real-world challenges associated with port development and going through a decision making process for selecting sustainable measures, the stakeholders can experience aspects of sustainable port development first hand through the serious game.

The Port of the Future Serious Game can also facilitate policy-making in ports with respect to socio-economic development, considering the natural requirements and the impact of sustainable design on balanced growth. For these reasons, the game can be played by a wide range of players including port authorities, planners, managers, policymakers, private companies, NGOs, scientists, nature developers, scientist, students and citizens. The procedure of the game can be summarized as follows.



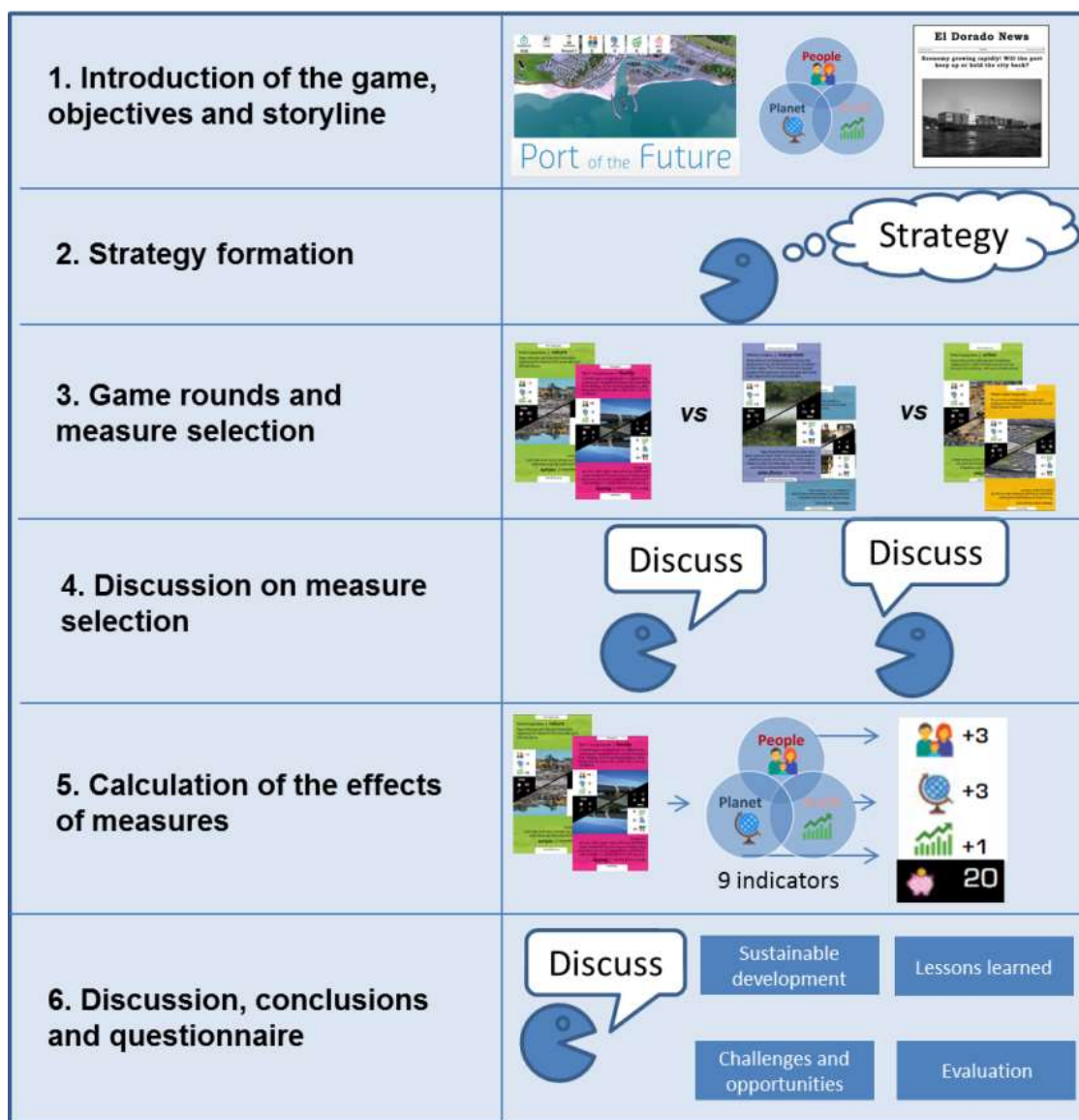


Figure 14: Port of the Future Serious Game scheme.

The aim is to move away from the traditional port and to reach the “Port of the Future” vision. To achieve that, a team of up to five players chooses appropriate policy measures in four rounds. Different scenarios will be played to investigate the wide range of possible impacts and to trigger the debate among the players by creating constructive conflicts between them during the negotiation and decision-making process. This is expected to demonstrate that successful policy-making in ports can only be achieved when the stakeholders work in close collaboration with each other.



HiSea and Corealis may create extra value by incorporating some elements in each other's work etc. or at least disseminating the progress/results of each of the projects with each other.

4.7 Water management by the port authority of Valencia

The Port Authority of Valencia (APV) manages under the same umbrella three ports of the Valencian Community, which are: Gandía, Sagunto and Valencia. For these, the APV measures and controls an array of different parameters in relation to water quality, sampled from a set of specific areas defined in each of the three ports in order to comply with current regulations and guarantee their commitment with the environment.

This section will describe the methodology used by the Port Authority in matters of water quality management, areas and points of study within the ports and the variables studied.

Although the HiSea project focuses on the Port of Valencia, Gandía and Sagunto have been included as the exact same methodology is used in their facilities.

4.7.1 Water quality

- QUALITY OF WATER BODIES IN THE PORT FACILITY

The Water Framework Directive (2000/60/EC) states that Member States must protect, improve and regenerate all bodies of surface water with the aim of achieving good surface water status at the latest 15 years after the date of the entry into force of the Directive. The WFD goes on to say that Member States shall protect and enhance all artificial or heavily modified bodies of water, as is the case in the ports of Valencia, Sagunto, and Gandía, with the aim of achieving good ecological potential.

In 2013, ROM 5.1.13 was published on the quality of coastal waters in port areas, prepared by State Ports, which contains the standards and protocols for analysis and assessment of the sheltered waters in the Ports of Valencia, Sagunto, and Gandía.

- AREAS OF STUDY

Regular sampling campaigns are conducted at least every 6 months to monitor water quality in the three ports managed by the Port Authority of Valencia, and which are reported to the Regional Government for validation and control:

- Port of Valencia
- Port of Sagunto
- Port of Gandía

The areas of study include both intra-port waters (mass of water heavily modified by the presence of ports), as well as a control station representative of the extra-port waters (mass of coastal water) in each port. The sampling points used in each of the port facilities are shown in the images below:





Figure 15: The sampling points used in each of the port facilities

- DETERMINATION OF THE PORT AQUATIC MANAGEMENT UNITS (PAMU)

In order to assess the environmental quality of port waters following the criteria established in ROM 5.1-13 “Quality of coastal waters in port areas”, the Port Aquatic Management Units (hereinafter PAMU) have been delimited and typified as a management instrument for the water environment in the port service area (PSA). In this context, these PAMUs are the basic units for the management of port water quality, and have been created according to the following aspects:

- Uses and activities that are developed in the PSA
- Physical and hydro-morphological characteristics
- Hydrodynamic conditions.

All PAMUs have been typified as:

CATEGORY	CLASS	TYPE
Coastal waters	Heavily modified waters	CM3: Mediterranean coastal waters with low renewal rate

The PAMUs for each port are listed below:



Figure 16: The PAMUs for each port

- VARIABLES STUDIED

For each PAMU, the monitoring of the quality of the intra-port waters has been carried out based on the indicators considered for the evaluation of environmental quality in ROM 5.1.13, which are the following:

- Quality indicators of CF sediment: Organic Quality Index (ICO)
- Indicators of biological water quality: phytoplankton (concentration of chlorophyll a) and benthic invertebrates (BOPA)
- Indicators of QF water quality indicators: turbidity, oxygen saturation, total hydrocarbons, faecal contamination and nutrients
- Chemical quality of water and sediment: priority substances and other pollutants

The variables analysed both in situ and in the laboratory during 2016 are shown below:

SAMPLE	IN SITU MEASUREMENTS	ANALYSIS IN LABORATORY	SAMPLE POINTS
Water column	Chlorophyll a Temperature Salinity Dissolved Oxygen Turbidity Total hydrocarbons	Faecal conatimation: E. coli and intestinal enterococci. Nutrients: nitrates, nitrites, ammonium and phosphates	PORT OF VALENCIA: PV1, PV2, PV3, PV4,PV5, PV9 and PV0.
			PORT OF SAGUNTO: PS1, PS2, PS3 and PS0.
			PORT OF GANDÍA: PG1, PG2, PG3 and PG0.
Sediment	Potential Redox	Total organic carbon Kjeldahl Nitrogen Total phosphorus Benthic invertebrates (BPOA)	PORT OF VALENCIA: PV2, PV3, PV4,PV5, PV9 and PV0.
			PORT OF SAGUNTO: PS1, PS2, PS3 and PS0.
			PORT OF GANDÍA: PG1, PG2, PG3 and PG0.



SAMPLE	ANALYSIS IN LABORATORY	SAMPLE POINTS
Water column	Compounds of tributyltin (TBTs), 1,2-Dichloroethane, Alachlor, Aldrin, Arsenic, Atrazine, Cadmium, Chlorphenvinphos, Chloroalkanes C10-13, Chlorpyriphos, Copper, Chromium VI, Total DDT, Di (2-ethylhexylphthalate (DEPH), Dichloromethane, Dieldrin, Brominated diphenyl ethers, Diuron, Eduosulfan, Endrin, Hexachlorobenzene, Hexachlorobutadiene, Hexachlorocyclohexane, Isodrin, Isoproturon, Mercury, Nickel, P,P'-DDT, Lead, Selenium, Simazine, Terbutilazine, Carbon tetrachloride, Tricloromethane (chloroform) Trifluralin, Zinc.	PORT OF VALENCIA: PV5
	Compounds of tributyltin (TBTs), 1,2-Dichloroethane, Arsenic, Cadmium, Chloroalkanes C10-13, Copper, Chromium VI, Total DDT, Di (2-ethylhexylphthalate (DEPH), Dichloromethane, Brominated diphenyl ethers, Hexachlorobenzene, Hexachlorobutadiene, Mercury, Nickel, P,P'-DDT, Lead, Selenium, Terbutilazine, Carbon tetrachloride, Trichloromethane, Zinc	PORT OF SAGUNTO: PS3
		PORT OF GANDIA: PG3
	Nonphenolol, Octogeneal	PORT OF VALENCIA: PV1, PV2, PV3, PV4,PV5, PV9 and PV0.
		PORT OF SAGUNTO: PS1, PS2 and PS3
		PORT OF GANDIA: PG1, PG2 and PG3
Sediment	Cadmium, Lead, Copper, Nickel, Zinc, Arsenic, Mercury, Chromium VI, Polychlorinated Biphenyls (PCBs), Tributyl Tin Compounds (TBTs), HAPs	PORT OF VALENCIA: PV5
		PORT OF SAGUNTO: PS3
		PORT OF GANDIA: PG3

Figure 17: The variables analysed both in situ and in the laboratory during 2016.

In situ continuous readings of the various hydrological variables were taken throughout the water column with the aid of a high-precision CTD oceanographic profiler (an SBE 19Plus V2). A laboratory accredited by ENAC, the Spanish National Accreditation Body, carried out the laboratory tests.

The sampling levels, the sampling methods and the analysis methods used to study the variables are gathered in the following tables:

- Sample levels vary from:

SAMPLE LEVEL	Water column profile	Integrated in the water column	Surface	Sediment
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- Sampling methods vary from:

SAMPLING METHOD	SBE 19plus V2 multi-parameter profiler	SBE 43 sensor fitted to an SBE 19plus V2 multi-parameter profiler	Sensor Seapoint fitted to an SBE 19plus V2 multi-parameter profiler	Cyclops-7 sensor fitted to an SBE 19plus V2 multi-parameter profiler	Hydrographic hose	Sterile bottle	Cyclops-7 sensor (ultraviolet) fitted to a multiparameter profiler	Draga Van Veen
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- Analysis methods vary from:

ANALYSIS METHOD	Thermometry	Conductimetry	Polarographic method	Nephelometry	Fluorometry	Spectrophotometry UV-VIS	ISO 78992/ ISO 9308-1	Chromatography CG/MS
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ANALYSIS METHOD	ISO 78992/ ISO 9308-1	Chromatography CG/MS	Inductive coupling plasma spectrometry (ICP/MS)	IR spectroscopy	Volumetric titration	Spectroscopy	Optical Microscopy
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4.7.2 Measuring technics at Port of Valencia

The *in-situ* water sampling methods in the ports managed by the Port Authority of Valencia are carried out with a number of different instruments which are placed on the day in the specific sampling points of each port. Once the sampling is complete, they are retrieved until the following campaign. The *in-situ* methods used are:

- SBE 19plus V2 multi-parameter profiler;
- SBE 43 sensor fitted to an SBE 19plus V2 multi-parameter profiler;
- Sensor SeaPoint fitted to an SBE 19plus V2 multi-parameter profiler;
- Cyclops-7 sensor fitted to an SBE 19plus V2 multi-parameter profiler;
- Cyclops-7 sensor (ultraviolet) fitted to a multi-parameter profiler

Others instruments used:

- Hydrographic hose (*Nutrients, PCBs, TBTs, Nonphenolol, Octogeneal, Biocides, Heavy Metals, VOCs, Organochlorines, Trihalomethanes Chloroform, Phthalates, Chloroalkanes, Ethers*)
- Van Veen Grab (*Cadmium, Lead, Copper, Nickel, Zinc, Arsenic, Mercury, Chromium VI, PCBs, TBTs, PAHs, TOC, Kjeldahl Nitrogen, Total phosphorus, Benthic invertebrate fauna*)
- Sterile bottle (Faecal pollution)



4.8 Environmental Management System (EMS) for ports

The best way to address the environmental management of an industrial site is to engage an International Standard procedure ISO (International Organization for Standardization). [ISO 14000](#) is a family of standards related to environmental management aiming to help organizations in minimising how their operations (processes, etc.) negatively affect the environment. ISO 14000 Standard is based on the establishment of an [Environmental Management System \(EMS\)](#). An EMS includes a monitoring program of the environment. An EMS is based on continual improvement for evaluating process efficiency and/or improving process output. In developing a monitoring program of a port environment, four main stages can be identified:

1. Recognize the particular environmental challenges and legislative/policy drivers;
2. Determine what information is already available and in what format;;
3. Develop a system to utilize existing data and to incorporate and integrate new information;
4. Select prudent monitoring methods to fill knowledge deficiency.

It is important to prioritize and focus on the port's main environmental issues. A recommended practice is to develop a baseline monitoring program that is flexible enough to allow integration and merging of a variety of data types, providing crucial background on a range of key environmental parameters, supplemented when necessary with complementary and more specific environmental parameters monitoring.

Basic hydrographic parameters such as currents, tidal movement, waves, temperature and salinity profiles are very useful to understand pollutant distribution in the water column and sediments. Also beneficial are data gathered on local meteorological conditions, which can provide an important insight into possible atmospheric dispersion patterns within and beyond the port area.

For water quality, there is an increasing number of multi-parameters monitoring systems that can provide reliable and very useful data on a variety of environmental parameters. The data can feed directly into the port's environmental database for instant accessing.

For supporting the management of dredging plans as well as investigating sediment contamination trends, it may be important to collect sediment samples both inside and outside its boundaries. The latest can provide an indication of the nature of the seabed or what the sediment contains by way of contaminants or its ecological composition.

There is evidence to suggest that the monitoring of microbenthic and pelagic organisms such as fish can provide powerful tools for assessing aquatic environments but the lack of standards and guidelines for assessing the general quality of the environment within ports and harbours is a problem not only for ecological monitoring but also for the general water and sediment quality.





5 Data currently used in those projects

5.1 Introduction

HiSea aims to provide a co-designed service offering high resolution water quality data at sea used in different coastal activities in sectors such as ports and aquaculture. The **HiSea** downstream service retrieves and pre-processes the Copernicus Service products, including model outputs, satellite imagery and in-situ measurements. Complementary dataset and in-situ measurements are downloaded from external providers. Near real time data are locally acquired together with local high resolution models forecasts. The proposed service provides an operational system for the demonstration services which produces enhanced information using data fusion algorithms. The high resolution models would be fed with data through data assimilation module. The operational service would provide information that will be used in the daily activities of the operational system in place.

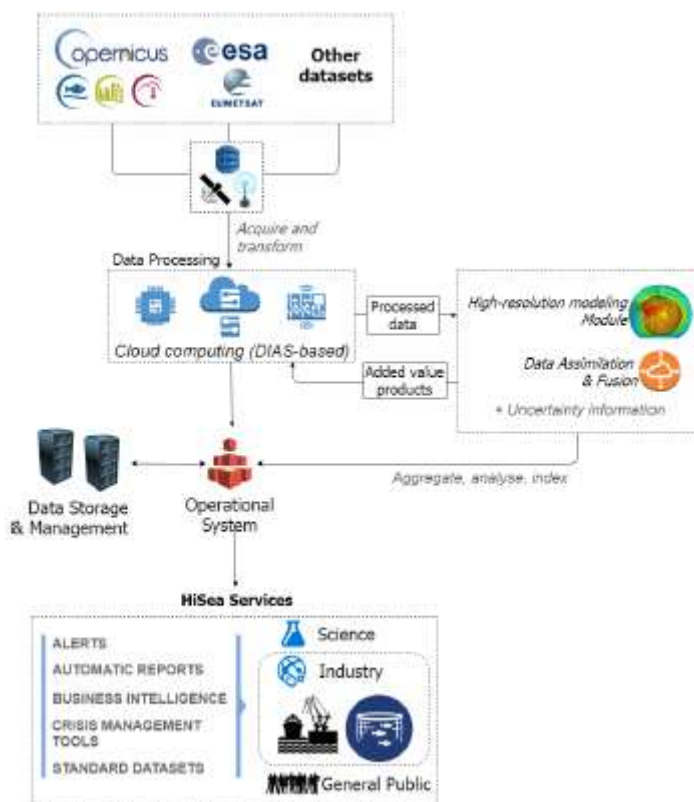


Figure 18 : HiSea general concept

A privileged data provider is the Copernicus Marine Environment Monitoring Service (CMEMS) and the Copernicus portal through its different services. In this context the **Copernicus Marine Environment Monitoring Service** (CMEMS) and the **Copernicus Atmosphere Monitoring Service** (CAMS) play a relevant role.



5.2 Physical Environment data

The information produced by HiSea service is based (or derived from) on measured and forecast data from oceanographic (waves, currents, water levels, sea temperature, salinity, chlorophyll, etc.) and meteorological (wind, precipitation, air temperature, etc.) parameters.

Data are acquired from external providers (CMEMS, Other Copernicus services, NOAA, ECMWF, local institutions, etc.) while forecasts may either be acquired from external providers or produced by HIDROMOD (mostly from high resolution models).

Regarding the oceanographic parameters, Copernicus Services are the main external providers contributing with data (used both to produce user fitted information and to validate high resolution models) and forecasts. Regarding the meteorology, due to the still high costs of ECWMF, NOAA's GFS is the main external provider.

Beyond these two fundamental sources, the system also integrates data from several other external providers (wave buoys, tide gauges, radar, satellite, meteorological stations) and forecasts (mostly for high resolution meteorological models but also for oceanographic regional or local models). The data source acronyms employed hereafter are

- IS: *In Situ*;
- MO: Model;
- RS: Remote Sensing.

In the following text, Copernicus Service products will be indexed_c (Copernicus), other provider's products indexed_e (external) and HiSea partner's products indexed_i (internal)

5.2.1 In-situ data

Time series of *In Situ* parameters are essential for understanding the processes controlling hydrodynamic processes in the coastal ocean. Moreover IS data have an essential role in the calibration/validation of others sources of data (as remotely data, or inferred parameters from Satellite data) and in improving model performances *via* data assimilation. The table below summarises the available physical environment *in situ* data.

The weather and oceanic data are called "[metocean](#)" data. *Metocean data* are generally remotely transmitted to a *Supervisory Control and Data Acquisition* (SCADA). A SCADA system is a control system architecture that uses computers, networked data communications and graphical user interfaces for high-level process supervisory management. Hereafter, a summary of metocean *in-situ* data we may be retrieved at CMEMS and other centres.





Table 1: Physical environment In situ data

	Weather data	Oceanic data
Parameters	<ul style="list-style-type: none"> - Air Temperature and Heat Index - Barometric Pressure - Humidity - Precipitation - Solar Radiation and Photosynthetically Active Radiation - Wind Speed and Direction 	<ul style="list-style-type: none"> - Temperature - Salinity - Current - Waves - Tide - Agitation
Instruments	<ul style="list-style-type: none"> - multi parameters weather sensors - Radar, Lidar 	<ul style="list-style-type: none"> - Probes (T, S.) - Current meter & profiler - Wave buoys - Gliders - Tide gauges - High frequency radars
Data providers	SYNOPS : surface SYNOptic observations WMO/SYNOP core data	CMEMS/Copernicus EMODnet SeaDataNet

Table 2: Physical environment In situ data summary (Var. Par.: Various Parameters)

Parameter	Data Source	Product identifier
SYNOPS atmosphere	IS_e	https://donneespubliques.meteofrance.fr/?fond=produit&id_produit=90&id_rubrique=32
Ocean Var. Par.	IS_c	INSITU_MED_NRT_OBSERVATIONS_013_035
Ocean Var. Par.	IS_e	EMODnet-Physics

5.2.2 Satellite data

Typical oceanic data which can be obtained by satellite remote sensing technics:

- **Swell:** Satellite synthetic aperture radar (SAR) observations can provide a global view of ocean swell fields when using a specific “wave mode” sampling.
- **Ocean Surface Wind:** Two types of satellite microwave instruments measure ocean surface winds, the passive microwave radiometer and the active microwave scatterometer.
- **Surface current:** Satellites provide a wide range of data that can be used to generate surface ocean current maps at different time and space scales depending on the techniques used.



- **Transparency:** can be related as a measure of the depth of light penetration into the water. Water transparency depends on the number of particles in the water. Particles can be inorganic (e.g. **sediment from erosion**).
- **Ocean turbidity:** The scattering particles that cause the water to be turbid can be composed of many things, including **sediments**.
- **Secchi depth:** helps to measure the clarity of the water.

The table below summarises the available physical environment satellite data.

Table 3: Physical environment satellite data

	Weather data	Oceanic data	Wave data
Parameters	- Ocean surface wind	- SST - turbidity	- wave height - wave direction
Instruments	- Remote sensing +model interpolation	- AVHRR, Pathfinder, MODIS... - Ocean colour sensors (i.e. OLCI, MODIS, VIIRS)	- SAR - Altimeter
Data providers	CMEMS/Copernicus See also CMEMS/WIND-TAC	CMEMS/Copernicus	CMEMS/Copernicus See also CMEMS/WAV-TAC

Table 4: Physical environment CMEMS satellite data products summary.

Parameter	Data Source	Product identifier
Sea Surface Temp.	RS_c	SST_MED_SST_L4_NRT_OBSERVATIONS_010_004 SST_GLO_SST_L4_NRT_OBSERVATIONS_010_001
Ocean Surface Wind	RS_c	WIND_GLO_WIND_L3_NRT_OBSERVATIONS_012_002 WIND_GLO_WIND_L4_NRT_OBSERVATIONS_012_004
Turbidity	RS_c	OCEANCOLOUR_MED_OPTICS_L3_NRT_OBSERVATIONS_009_038
Waves	RS_c	WAVE_GLO_WAV_L3_SWH_NRT_OBSERVATIONS_014_001 WAVE_GLO_WAV_L3_SPC_NRT_OBSERVATIONS_014_002



5.2.3 Models outputs

Hereafter, we draw a distinction between “*model*” and “*modelling software*” (a coastal ocean hydrodynamics calculation code). A model is an *application* of modelling software over a regional/local oceanic coastal area. More often, modelling *software* (current, wave, sedimentary transfer, ecosystem, water quality) are assembled in a *Modelling System Software*.

5.2.3.1 Hydrodynamic modelling

The physical (numerical) modelling ranges from simple one-dimensional (1D) to full 3D with high-order turbulence closure schemes. Numerical modelling of the coastal areas clearly requires flexible and optimized models of significant dynamical complexity. Regarding physical environment data, HiSea applications will have to consider two types of model outputs:

- Data from forecasting models running in Operational Centres (external sourcing) on an oceanic region at a medium resolution (i.e.: hereafter the Mediterranean Sea). These models ensure to follow the evolution of the oceanic region of interest and give boundary conditions for High Resolution modelling.
- Data from an application of a Modelling System Software on a local area around the site of interest (internal sourcing).

The Copernicus Marine Service for global ocean analysis and forecast system at 1/12 degree is providing 10 days of 3D global ocean forecasts daily updated. The time series starts on December 27, 2006 and is aggregated in time in order to reach a two full years’ time series sliding window. This product includes daily mean files of temperature, salinity, currents, sea level, mixed layer depth and ice parameters from the top to the bottom over the global ocean (cf. Table 4)

It also includes hourly mean surface fields for sea level height, temperature and currents (cf. Table 6) and waves solution products for all globe (cf. Table 12).

For Iberian-Biscay-Irish region (cf. Figure 19), the Ocean Analysis and Forecasting system, daily run by Puertos del Estado provides a 5-day hydrodynamic forecast including high frequency processes of paramount importance to characterize regional scale marine processes (i.e. tidal forcing, surges and high frequency atmospheric forcing, fresh water river discharge, etc.). A weekly update of IBI downscaled analysis is also delivered as historic IBI best estimates. The system is based on an eddy-resolving NEMO model application run at 1/36° horizontal resolution (cf. cf. Table 7 and

Table 8).

For the Mediterranean Sea region (cf. Figure 19) the physical component of the Forecasting System (Med-Currents) is a coupled hydrodynamic-wave model implemented over the whole Mediterranean Basin. The model horizontal





grid resolution is $1/24^\circ$ (ca. 4 km) and has 141 unevenly spaced vertical levels. The hydrodynamics are supplied by the Nucleolus for European Modelling of the Ocean (NEMO v3.6) while the wave component is provided by Wave Watch-III; the model solutions are corrected by a variational data assimilation scheme (3DVAR) of temperature and salinity vertical profiles and along track satellite Sea Level Anomaly observations (cf. Table 9).

Apart from these Global/Regional models local high resolution models may be implemented using as initial and boundary conditions these Global/Regional models. In the framework of HiSea two water modelling systems will be available: **Delft3D** (developed by Deltares) and **MOHID** (developed by Hidromod)... Both models are capable to simulate storm surges, tsunamis, detailed flows and water levels, waves, sediment transport and morphology.

Other coastal-ocean hydrodynamic modelling software such as Telemac, Mars, ROMS, DHI Mike or HYCOM (just to mention some) may also be used for this purpose.



Figure 19: Area covered by IBI 3D (left) and MedSea (right)

Table 5: Data information for the product Global Ocean $1/12^\circ$ - daily mean sea surface parameters

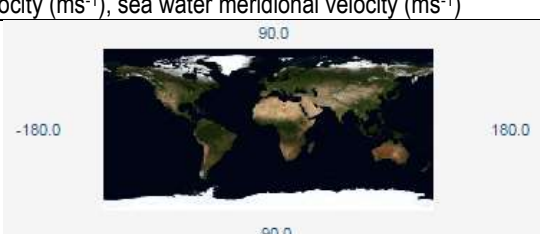
Data Information	
Provider	Copernicus Marine Service (CMEMS)
Product identifier	GLOBAL_ANALYSIS_FORECAST_PHY_001_024
Downloaded Variables	Sea surface height above geoid (m), sea water potential temperature (K), sea water salinity, sea water zonal velocity (ms^{-1}), sea water meridional velocity (ms^{-1})
Geographical coverage	
Areas	Global-ocean
Spatial resolution	0.083 degree
Vertical coverage	From -5500 m to 0 m
Temporal resolution	Daily mean
Temporal coverage	From 2006-12-27T00:00:00Z, still going
Update frequency	Daily



Table 6: Data information for the product Global Ocean 1/12° - hourly mean sea surface parameters

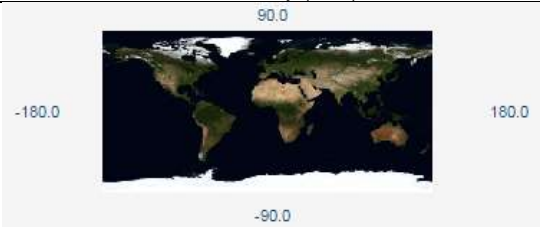
Data Information	
Provider	Copernicus Marine Service (CMEMS)
Product identifier	GLOBAL-ANALYSIS-FORECAST-PHY-001-024-HOURLY-T-U-V-SSH
Downloaded Variables	Sea surface height above geoid (m), surface: sea water potential temperature (K), sea water zonal velocity (ms^{-1}), sea water meridional velocity (ms^{-1})
Geographical coverage	
Areas	Global-ocean
Spatial resolution	0.083 degree
Temporal resolution	Hourly mean
Temporal coverage	From 2006-12-27T00:00:00Z, still going
Update frequency	Daily

Table 7: Data information for the product IBI 1/36° - 3D fields


Data Information	
Provider	Copernicus Marine Service (CMEMS)
Product identifier	IBI_ANALYSIS_FORECAST_PHYS_005_001_DAILY
Downloaded Variables	Eastward sea water velocity (ms^{-1}), northward sea water velocity (ms^{-1}), sea surface height above sea level (m), sea water potential temperature (K), sea water salinity
Geographical coverage	
Areas	NE Atlantic
Spatial resolution	0.028 degree
Vertical coverage	From -5500 m to 0 m
Temporal resolution	Daily mean
Temporal coverage	From 2013-01-01 T00:00:00Z, still going
Update frequency	Daily



Table 8: Data information for the product IBI 1/36° - sea surface parameters


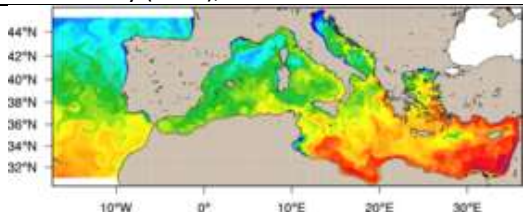
Data Information	
Provider	Copernicus Marine Service (CMEMS)
Product identifier	IBI_ANALYSIS_FORECAST_PHYS_005_001_HOURLY
Downloaded Variables	Eastward sea water velocity (ms^{-1}), northward sea water velocity (ms^{-1}), sea surface height above sea level (m), sea water potential temperature (K)
Geographical coverage	
Areas	NE Atlantic
Spatial resolution	0.028 degree
Temporal resolution	Hourly mean
Temporal coverage	From 2013-01-01 T00:00:00Z, still going
Update frequency	Daily

Table 9: Data information for the product MEDSEA 1/24° - 3D fields

Data Information	
Provider	Copernicus Marine Service
Product identifier	MEDSEA_ANALYSIS_FORECAST_PHY_006_013
Downloaded Variables	Sea surface height above geoid (m), sea water potential temperature (K), sea water salinity, sea water zonal velocity (ms^{-1}), sea water meridional velocity (ms^{-1})
Geographical coverage	
Areas	Mediterranean-sea
Spatial resolution	1/24° degree
Temporal resolution	hourly mean
Temporal coverage	From 2018-02-19 T00:00:00Z, still going
Update frequency	Daily

5.2.3.2 Weather models

Regarding meteorological data, HiSea applications may consider two types of model outputs:

- Data from forecasting models running in Meteorological Centres ([external sourcing](#)): a class of global or sub-area weather models at a medium resolution. These models ensure to follow the evolution of the weather situation and give boundary conditions for High Resolution modelling.
- Data from an application of a *High-Resolution Weather Calculation Code* over a mid-wide coastal area around the site of interest ([internal sourcing](#)). Such model outputs may be used as forcing to a local hydrodynamic model.

Presently at Global/Regional level the NOAA GFS (*cf. Table 10*) is most probably the widest used product (it is free). ECMWF is a similar European product available but, although it may provide more accurate forecasts for Europe, it is still paid and, for this reason, it has more limited use.

Presently other competitive, higher resolution, free access product is also available for Europe. The German Weather Service (DWD) run operationally the forecast model ICON all over Europe and North of Africa (*cf. Table 11*), four times a day, ranging from 180 h (00 and 12 UTC runs) to 120 h (06 and 18 UTC runs) of forecast, all this, with a horizontal resolution of nearly 13 km.

Table 10: Data information for the product Global Forecast System (GFS)

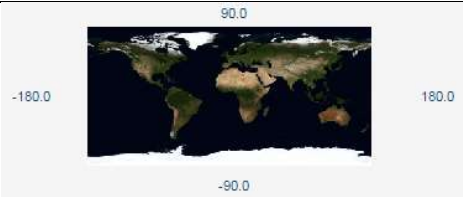
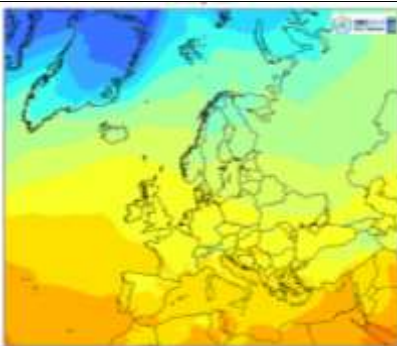
Data Information	
Provider	National Centers for Environmental Prediction (NCEP)
Product identifier	gfs.tCCz.pgrb2.0p50.fFFF, gfs.tCCz.pgrb2.0p25.fFFF
Downloaded Variables	wind velocity X (ms^{-1}), wind velocity Y (ms^{-1}), atmospheric pressure (Pa), solar radiation (Wm^{-2}), air temperature ($^{\circ}\text{C}$), relative humidity (%), precipitation (mm), wind modulus (ms^{-1}), wind direction ($^{\circ}$), wind gust (ms^{-1}), cloud cover, downward long wave radiation (Wm^{-2})
Geographical coverage	
Areas	Global-ocean
Spatial resolution	0.50 and 0.25 degree
Vertical coverage	Values at 10 meters high
Temporal resolution	3 Hourly mean
Temporal coverage	(0.50 degree) From 199-01-01 T00:00:00Z, still going (0.25 degree) From 2015-02-14 T00:00:00Z, still going
Update frequency	Daily



Table 11: Data information for the product ICON (DWD)

Data Information	
Provider	Deutscher Wetterdienst (DWD)
Product identifier	ICON-EU
Downloaded Variables	wind velocity X (ms^{-1}), wind velocity Y (ms^{-1}), atmospheric pressure (Pa), air temperature ($^{\circ}\text{C}$), relative humidity (%), precipitation (mm), wind gust (ms^{-1}), cloud cover, downward long wave radiation (Wm^{-2})
Geographical coverage	
Areas	Europe
Spatial resolution	~13 km
Vertical coverage	Values at 10 meters high
Temporal resolution	1 Hourly
Temporal coverage	No historic data
Update frequency	4 times day

Other products may also be available via the *National Meteorological Offices* of Europe States or private/public institutions. Some examples are:

- ARPEGE (https://donneespubliques.meteofrance.fr/?fond=produit&id_produit=130&id_rubrique=51). ARPEGE is an operational forecasting global model at Météo-France. ARPEGE implements a variational assimilation method of observed data providing 0.5° (global) and 0.1° (Europe) resolution forecasts.
- AROME (https://donneespubliques.meteofrance.fr/?fond=produit&id_produit=131&id_rubrique=51). AROME is a specific high resolution weather model developed and running at Meteo-France providing 0.025° for France (cf. Figure 20).

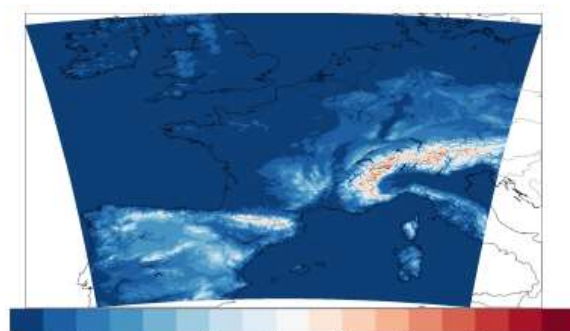


Figure 20 : AROME model calculation domain.

Apart from these several institutions are presently running local high-resolution models mostly based on MM5 or WRF.

5.2.3.3 Wave models

A wave model on an oceanic region at a medium resolution may be used to get boundary conditions for High resolution modelling. From CMEMS there are available wave products both at global level (GLOBAL_ANALYSIS_FORECAST_WAV_001_027), IBI region level (IBI_ANALYSIS_FORECAST_WAV_005_005) and Mediterranean Sea level (MEDSEA_ANALYSIS_FORECAST_WAV_006_017).

Table 12: Data information for the product Global Ocean Waves 1/12° - 3 hours instantaneous

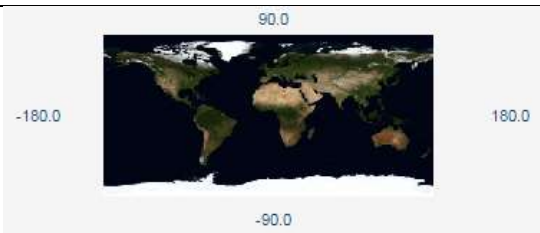
Data Information	
Provider	Copernicus Marine Service (CMEMS)
Product identifier	GLOBAL_ANALYSIS_FORECAST_WAV_001_027
Downloaded Variables	Spectral significant wave height (m), spectral moments (-1,0) wave period (s), wave principal direction at spectral peak (°), mean wave direction (°) and wave period at spectral peak / peak period (s)
Geographical coverage	
Areas	Global-ocean
Spatial resolution	0.083 degree
Vertical coverage	surface
Temporal resolution	3 hours instantaneous
Temporal coverage	From 2006-03-01T00:00:00Z, still going
Update frequency	Daily



Table 13: Data information for the product IBI Waves 1/12° - 3 hours instantaneous


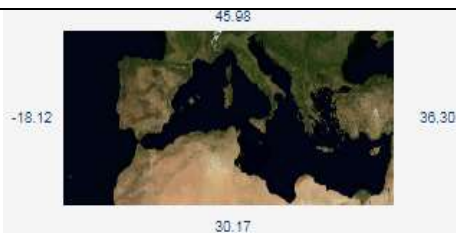
Data Information	
Provider	Copernicus Marine Service (CMEMS)
Product identifier	IBI_ANALYSIS_FORECAST_WAV_005_005
Downloaded Variables	Spectral significant wave height (m), spectral moments (-1,0) wave period (s), wave principal direction at spectral peak (°), mean wave direction (°) and wave period at spectral peak / peak period (s)
Geographical coverage	
Areas	NE Atlantic
Spatial resolution	0.1 degree
Vertical coverage	surface
Temporal resolution	Hourly-mean
Temporal coverage	From 2015-01-01T00:00:00Z, still going
Update frequency	Daily

Table 14: Data information for the product IBI Waves 1/24° - hourly instantaneous

Data Information	
Provider	Copernicus Marine Service (CMEMS)
Product identifier	MEDSEA_ANALYSIS_FORECAST_WAV_006_017
Downloaded Variables	Spectral significant wave height (m), spectral moments (-1,0) wave period (s), wave principal direction at spectral peak (°), mean wave direction (°) and wave period at spectral peak / peak period (s)
Geographical coverage	
Areas	Mediterranean Sea
Spatial resolution	0.042 degree
Vertical coverage	surface
Temporal resolution	Hourly instantaneous
Temporal coverage	From 2017-01-01T00:00:00Z, still going
Update frequency	Daily



5.2.4 Spanish Port System as example

5.2.4.1 Public Body State Ports (OPPE) Service

<http://www.puertos.es/es-es/oceanografia/Paginas/portus.aspx>

The Public Body State Ports of Spain has developed and maintains systems for measuring and forecasting the marine environment with the fundamental objective of providing the Spanish Port System with the ocean-meteorological data essential for its design and operation, which allows it to reduce costs and increase the efficiency, sustainability and safety of port operations. Benefits of this activity are not limited to the port environment, but also seek to be a service open to society and other institutions.

The system consists of measurement networks (buoys, tide gauges and high frequency radars), prediction services (waves, sea level, currents and water temperature) and climatic sets, which describe both the current maritime climate and its scenarios for change in the 21st century.

5.2.4.2 State Meteorological Agency (AEMET) service

<http://www.aemet.es/en/portada>

The object of AEMET is the development, implementation and provision of meteorological services under the jurisdiction of the State and support for the exercise of other public policies and private activities, contributing to the safety of people and goods, and the welfare and sustainable development of Spanish society.

As a National Meteorological Service and State Meteorological Authority, AEMET's basic objective is to contribute to the protection of lives and property through the adequate prediction and monitoring of adverse meteorological phenomena and as a support for social and economic activities in Spain through the provision of quality meteorological services. It is responsible for the planning, management, development and coordination of meteorological activities of any nature within the state, as well as the representation of this in international organizations and fields related to Meteorology.

Among others, its services are focused on:

- Meteorological observation in Spain, and data archive.
- Monitoring and forecasting of weather hazards.
- Weather forecasting at State, regional, provincial, district and local levels.
- Specific meteorological support for the National Defence and for air and maritime navigation.
- Information and specialist advisory services for the mass media and the general public.
- Development and exploitation of numerical models for weather and climate prediction.
- Meteorological and climate-related studies and products for applications of social and economic interest.
- Observation, monitoring and evaluation of atmospheric processes with regards to structure and to radiation processes and chemical composition.

5.2.5 Data assimilation

Data assimilation is the process by which observations of a real system are incorporated into a computer model. The purpose of data assimilation is to improve the predictive power of models. Data assimilation was initially developed in the field of numerical weather prediction.





5.2.5.1 Data assimilation methods

Historically, there are two major classes of methods. The first ones consider the model as a very strong constraint. In the second class, an error rate is introduced in the model dynamics. This distinction is not necessary. Some of the main aspects on which it is based are used to clarify the issue.

Among the first-class methods are the variational methods and their derivatives. The model dynamics is assumed as a strong constraint. If the model trajectory may be described by the mathematical relationship (which gives a forecast):

$$\frac{\partial X}{\partial t} = AX + F \quad (1)$$

Where X is the parameter vector of the model. F is a determinist forcing. Then, the assimilation procedure is mostly based on a modification of the initial conditions before integrating the model during a temporal window. On this basis, this degree of freedom may be combined with an alteration of one or more of the model parameters (e.g. The non-solar heat flux at the sea surface).

In the second class, it is assumed that the model does not depict the wholeness of physical reality (limited constraint). In practice, we write the new form of (1):

$$\frac{\partial X}{\partial t} = AX + F + v \quad (2)$$

Where v is a perturbation of the forcing F . Then, v is considered as a Gaussian random variable: i.e. the average is unknown, but the covariance matrix may be assessed. This statistical approach (X is currently a random variable) is the fundamental of the Kalman filter and its derivative. The reality of the dynamics is estimated from a deterministic forecast of X using eq. (1) and statistical information on the model trajectory (from an observation X_{obs}) and an associated error.

This distinction between the two classes of methods vanishes in case a variational method may consider an external forcing among the degree of freedom. Two ways to combine model, data and errors:

1. Sequential assimilation incorporates the whole available information in a temporal window. At a time t , the data are merged with the forecasts (the model outputs from eq. 1). Thus, we get synoptic estimates of relevant variables: The *Analysed Fields*. Variational methods, Kalman filter, Optimal Interpolation (OI) are based on sequential assimilation.
2. Extended assimilation incorporates external information as soon as one set of data is available.

Uncertainty of the prediction can't be ignored. It may come from two distinct origins:

- the incomplete model dynamics
- The data errors.

The main quality criterion that can be used is the variance of the estimated error.

A four-dimensional variational data assimilation scheme (4D-Var) was developed to obtain optimal states of the ocean (including the atmosphere) using multi-time-level observations from the modelled dynamics and physics. 4D-Var aims at obtaining optimal input parameters (e.g., initial conditions, model error, lateral boundary conditions, empirical constants, etc.) by globally adjusting a model solution to all available observations over an interval of time (i.e., the assimilation period). 4D-Var involves an iterative process, which normally takes a few to





several tens iterations, to minimize a cost function that measures the square distance between the model solutions and the observations using the model as a constraint (*i.e.*, constrained minimization). A backward run of the adjoint model is required to provide the gradient information into the minimization process.

The 3D-Var method provides a suboptimal solution to the model states using only one-time- level observation. This assimilation scheme is thus less robust in time but requires less computational power. The forms of ED-Var and 4D-Var cost functions are given [here](#).

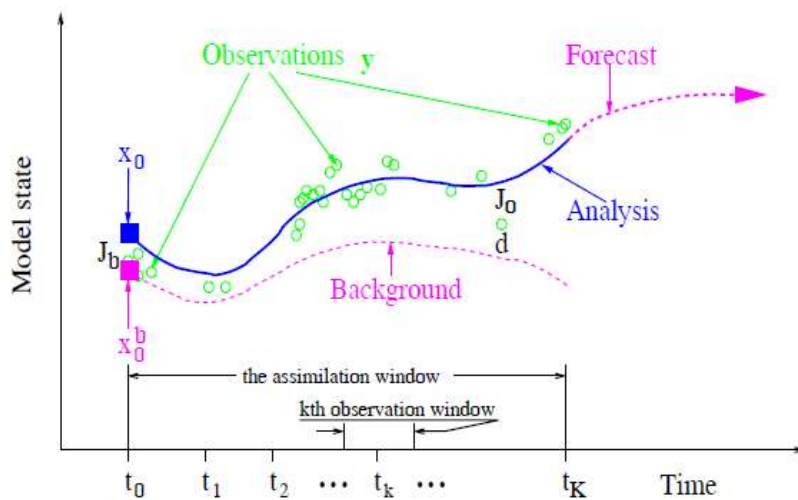


Figure 21 : A graphical illustration of the 4Dvar data assimilation method



5.3 Biogeochemical (BGC) data

A BGC model in the coastal ocean is a mathematical formulation of the dominant biogeochemical processes at the interface of oceanic and terrestrial environments in a specific oceanic region. The NPZD model is a simplification of an extremely complex ecosystem. The currently most elaborated biogeochemical models include several groups of phytoplankton, zooplankton and bacteria. Specific models are now also developed to answer a specific scientific question such as, the development of harmful algal blooms. The relative simplicity of NPZD (B) models make them appealing tools for most regional studies and notably for initial investigations on physical-biological dynamics. A quantitative comparison of BGC models outputs to various fields of data may now be accessible.

However, in practice, only a small fraction of the biological compartments are available through *in situ* observations compared to the large diversity of marine organisms. Remote-sensing instruments (SeaWiFS, MODIS, MERIS and now the European Sentinel constellation) provide synoptic data sets of a proxy of surface phytoplankton biomass that can be efficiently used to provide strong constraints on CPBMs. BGC data can be divided into three main groups:

1. *in situ* observations (e.g. profiling probes, buoys, underwater gliders);
2. remote sensing data (e.g. satellite passive & active radiometers, aircraft imaging);
3. BGC model outputs.

In situ measurements provide time series and/or vertical profiles of biochemical tracers while the remotely sensed data sets provide synoptic information at (or near) the sea surface. Satellite sensors can provide very significant information on processes at the ocean surface on a daily time scale but low-level information on the vertical structure of biogeochemical processes.

5.3.1 In situ measurements

Time series are critical for understanding the processes which control biogeochemical cycles in the coastal ocean. The most classical biochemical tracers are:

- Chla (chlorophyll-a concentration);
- NO₃ (nitrate concentration);
- POC (Particulate Organic Carbon concentration);
- SIL (silicate concentration).
- O₂ (dissolved Oxygen)

The measuring technics may be based on a wide range of mooring systems deployed with multi-parameters **probes** and on **gliders** which are autonomous vehicles equipped with different sensors. Both are presently an important component of our observational capability (see Niewiadomska et al., 2008). These platforms can resolve time scales of minute to days and can provide a broad spatial context. Spatial variability and rates of ecosystem productivity may be assessed with sensors on gliders but the number of state variables that can be recorded



autonomously is limited because many sensors are prone to biofouling. Fouling limits in generally the acquisition of *in situ* measurements. Note that there is a lack of reference materials and certified standards for biogeochemical measurements.

5.3.2 Satellite data

Satellite data represent the largest available data set in terms of extension and frequency. As an example, reliable satellite Sea Surface Chlorophyll (SSC) estimations are available at both the spatial and temporal resolutions which are needed for oceanographic biogeochemical modelling. Some attempts were made to distinguish the relative contribution of chlorophyll by the different phytoplankton groups. For instance, PHYSAT is empirically based on reflectance anomalies (<http://log.cnrs.fr/Physat-2>) while Alvain et al. (2012) used radiative transfer simulations in addition to *in situ* measurements to understand the organization of the signals used in PHYSAT.

A variety of ecosystem indicators can be derived from satellite sensors (see Table 15).

Table 15 : The most commonly measured qualitative parameters of water by means of remote sensing.

Water Quality Parameter	Abbreviation	Units	Optical Activity
chlorophyll- <i>a</i>	CHL- <i>a</i>	mg/L	Active
Secchi Disk Depth	SDD	m	Active
Temperature	T	°C	Active
Colored Dissolved Organic Matters	CDOM	mg/L	Active
Total Organic Carbon	TOC	mg/L	Active
Dissolved Organic Carbon	DOC	mg/L	Inactive
Total Suspended Matters	TSM	mg/L	Active
Turbidity	TUR	NTU	Active
Sea Surface Salinity	SSS	PSU	Active
Total Phosphorus	TP	mg/L	Inactive
Ortho-Phosphate	PO ₄	mg/L	Inactive
Chemical Oxygen Demand (COD)	COD	mg/L	Inactive
Biochemical Oxygen Demand	BOD	mg/L	Inactive
Electrical Conductivity	EC	µs/cm	Active
Ammonia Nitrogen	NH ₃ -N	mg/L	Inactive

[CMEMS/OC-TAC](#) delivers two sets of products, CHL and OPTICS:

- CHL is the phytoplankton chlorophyll concentration. For the global and each of the regional seas, OC-TAC selected the state-of-the-art product algorithm based on optical characteristics of the basin and round robin procedure. For the regional seas, daily chlorophyll fields are produced by applying two different algorithms for open ocean (Case I) and coastal waters (Case II). The data are then merged into a single chlorophyll field providing a regional product with an improved accuracy of estimates in coastal waters.
- OPTICS products include all other variables retrieved from ocean colour sensors:
 - Inherent Optical Properties (IOPs), such as absorption and scattering;
 - The diffuse attenuation coefficient of light at 490 nm (Kd490);
 - *Secchi depth* (transparency of water);
 - spectral Remote Sensing Reflectance (Rrs);



- photosynthetically available radiation (PAR);
- Coloured Dissolved Organic Matter (CDOM)
- Suspended Particulate Matter (SPM).

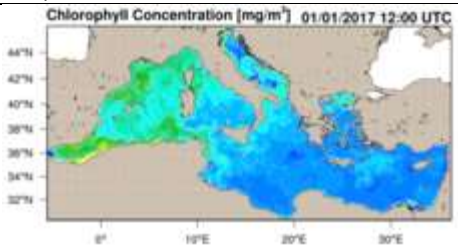
In situ-Satellite data merging:

Satellite data represent the largest available data set. However, as they are limited to surface waters, Lavigne et al. (2012) proposed a merging method to fill this gap. It consists firstly in adjusting the fluorescence profile to impose a zero chlorophyll *a* concentration at depth. Secondly, each point of the fluorescence profile is then multiplied by a correction coefficient, which forces the chlorophyll-*a* integrated content measured on the fluorescence profile to be consistent with the concomitant ocean colour observation.

5.3.3 CMEMS products

The biogeochemical analysis and forecasts for the Mediterranean Sea at 1/24 degree ([MEDSEA ANALYSIS FORECAST BIO_006_014](#)), produced by means of the [MedBFM](#) model system (i.e. the physical-biogeochemical OGSTM-BFM model coupled with the [3Dvar](#)-BIO assimilation scheme) provides, daily means of CHL, PHYC, O₂, NO₃, PO₄ and PP with a 0.042 degree x 0.042 degree spatial resolution.

Table 16: Data information for the product Mediterranean Analysis Forecast bio

Data Information	
Provider	Copernicus Marine Service
Product identifier	MEDSEA_ANALYSIS_FORECAST_BIO_006_014
Downloaded Variables	Chlorophyll (mg m^{-3}), phytoplankton (mol m^{-3}), oxygen (mmol m^{-3}), nitrate (mmol m^{-3}) and phosphate (mmol m^{-3})
Geographical coverage	
Areas	Mediterranean-sea
Spatial resolution	1/24° degree
Temporal resolution	daily mean
Temporal coverage	From 2017-01-01 T00:00:00Z, still going
Update frequency	twice weekly



HiSea partners Deltares and Hidromod also have the ability to run local high resolution models either based on [D water-quality](#), Water quality and Aquatic Ecology modelling suite or [MOHID](#) models. A variety of algae growth and nutrient dynamics models have also been incorporated into the sub-model of D-Water Quality *D-Ecology*.

Apart from those other coastal ocean BGC models are also available. Some examples of these are for instance:

- DMI/ERGOM: The ecosystem model ERGOM provides a mathematical description of the main biogeochemical processes including photosynthesis, grazing, respiration, mortality, mineralization, nitrification and denitrification. ERGOM is nitrogen-based and has nine state variables. [DMI/ERGOM](#) is the coupling with a version of the DMI North Sea - Baltic Sea ocean circulation model [HBM](#) in high spatial resolution.
- The OPATM-BFM biogeochemical model is composed of a tracer transport model implemented in OPA ocean circulation model ([OPA² Tracer Model](#)) coupled with a Biogeochemical Flux Model ([BFM](#)) which accounts for more than fifty variables. The BFM is a carbon-based model that reproduces the nutrients cycles with variable C:N:P:Si ratios within the food web compartments. Primary account for possible multi-limitation related to nutrient concentrations.
- The European Seas Regional Ecosystem Model ERSEM is a refined NPZD³ model. It incorporates a higher complexity of plankton community, a microbial loop, a variable nutrient stoichiometry, variable carbon and chlorophyll ratios and a comprehensive description of benthic biochemical and ecological processes. [ERSEM](#) is routinely coupled to a wide variety of hydrodynamic models such as [GOTM](#), [NEMO](#) and [FVCOM](#) using a coupling interface called [FABM](#) which enables ERSEM to be run as a simple box model or more realistically in 1-3 dimensional space at scales ranging from local, and coastal via regional to global applications.
- In France, IFREMER proposes the ECO-MARS3D model. This model is coupling a biology module to the [MARS3D](#) physics model. It allows modelling the nutrient and plankton concentrations in the Bay of Biscay and the Channel.
- The Model for Adaptive Ecosystems in Coastal Seas ([MAECS](#)) resolves the dynamics of nutrients, phytoplankton, zooplankton, dissolved organic matter, and detritus. MAECS is coupled to the physical General Estuarine Transport Model [GETM](#). MAECS is the ecosystem module of the German [COSYNA](#) (Coastal Observation System for Northern and Arctic Seas) system:

5.3.4 Models outputs

A BGC model results from the coupling of a biochemical model with a “physical” (in our case, a “hydrodynamic”) model. Marine ecosystem models are typically made of a set of ordinary differential equations that express the time rate of change of a set of state variables that represent different components of the ecosystem: Nutrients (**N**), Phytoplankton (**P**), Zooplankton (**Z**), Detritus (**D**), Bacteria (**B**), etc. These state variables vary in response to source and sink terms that represent growth, mortality for the living components and sinking out of the model domain. Marine ecosystem models vary widely in complexity, ranging from simple NPZ models to more elaborated models

² Acronym for “Océan PAralléliisé”) : an Ocean General Circulation Model (OGCM)

³ Nutrients (**N**) Phytoplankton (**P**) Zooplankton (**Z**) Detritus (**D**) modelling





that include multiple N,P,Z and other components (*) that allow the representation of multiple forms of N and multiple groups or size classes of phytoplankton, zooplankton and detritus. The first issue in working out an NPZ* model is the choice of transfer functions, *i.e.* the functional forms linking the various state variables to each other. The choice of functional formulations remains a critical step to build a realistic model. The parameterization of the model (the choice of coefficients such as the grazing rate of zooplankton on phytoplankton, or remineralization rate, etc.) is a strong determinant of the “dynamics” displayed by the model. Nonlinear versions and more complex model formulations are usually integrated over time using numerical methods.

Relatively simplified model formulations like NPZD are often employed in coupled three-dimensional (3D) model applications in marine systems as they require a relatively modest computational effort. Through numerous applications, these types of models have been shown to be capable of representing first-order variability in ecosystem dynamics and biogeochemical cycling.





6 DIAS: Data & Information Access Services

6.1 General Information

The common sense of DIAS is to allow users to discover, manipulate, process, and download Copernicus data and information. There are five competitive DIAS providers (CREODIAS, MUNDI, ONDA, WEKEO, and SOBLOO), which can be used in a cloud-based fashion. Each DIAS provider provides storage and computing capabilities. With help of them, it is possible to gain a full set of Copernicus data and information, an ability to process and combine data sets with data from other sources, and analysis ready information on the frontend for users. The DIAS providers should also provide access to the following information:

- ✓ Copernicus Sentinel Data from
 - **Sentinel-1** that provides an all-weather, day-and-night supply of imagery of earth's surface.
 - **Sentinel-2** that provides high resolution optical imagery for agricultural and forestry applications.
 - **Sentinel-3** that provides high accuracy optical, radar and altimetry data for marine and land applications.
 - **Envisat**, which is a polar orbiting satellite, which provided measurement of the atmosphere, ocean, land, and ice.
 - **Landsat-8**, which provides seasonal coverage of the global landmass.
- ✓ Information products from Copernicus six operational services together with cloud-based tools (pay-per-use and Open Source):
 - **Copernicus Atmosphere Monitoring Service (CMAS)** provides continuous data and information on atmospheric composition.
 - **Copernicus Marine Environment Monitoring Service (CMEMS)** provides regular and systematic reference information on the physical and biogeochemical state, variability and dynamics of the ocean and marine ecosystems.
 - **Copernicus Land Monitoring Service (CLMS)** provides geographical information about land cover and its changes, land use, vegetation state, etc.
 - **Copernicus Climate Change Service (C3S)** provides authoritative information about the past, present and future climate.
 - **Copernicus Security Service (CSS)** improves the surveillance of borders and maritime, and the support to EU external actions.
 - **Copernicus Emergency Management Service (CEMS)** consists of mapping and an early warning component to manage natural disasters, man-made emergency situations, and humanitarian crises.
- ✓ Additional commercial satellite or non-space datasets (dependent on DIAS provider)





- ✓ Premium offers in terms of support and priority

6.2 DIAS Similarities

The common base of the DIAS is the data and information that is coming from the above-mentioned Copernicus Sentinel sources. In terms of free-accessible data, the difference between the providers is only marginal. All providers offer a marketplace, where services can be accessed. Differences should theoretically only be found in custom services or sources from commercial satellites. In order to use those services, virtual machines can be rented from the DIAS provider. On these virtual machines, an own infrastructure can be set up, which is then a cloud-based infrastructure. The advantage is, that data must not be downloaded, because it is already inside the cloud environment. This enables to improve latency issues and to prevent redundant operations (e.g. downloads). Another advantage of having virtual machines is the option to setup a containerized infrastructure that is foreseen in HiSea.

In the following, the competitive DIAS providers are introduced.

- CREODIAS: a consortium managed by CreoTech, of 6 partners (e.g. CloudFerro, Sinergise, etc.) launched this service to provide Copernicus data. CREODIAS supports data from the sources of Sentinel-1, Sentinel-2, Sentinel-3, and Envisat. In addition to that, historical archives of Landsat-5, Landsat-7 and Landsat-8 are also available. CREODIAS already supports a lot of sources, but a roadmap for future sources is currently not available.
- A consortium led by Airbus with 4 additional partners (Orange, Capgemini, CLS and Vito) launched the DIAS service SOBLOO to provide Copernicus data. At the moment, most of all relevant sources are provided (i.e. Sentinel-1, Sentinel-2, and Sentinel-3) and also the Copernicus services CMEMS, CLMS, CEMS, CAMS, and C3S are already supported. Additional commercial sources, such as Landsat-8 are also planned for the future, but with no time statement.
- A consortium of 9 partners (e.g. Atos, T-Systems, DLR, etc.) led by Atos, launched this service to provide Copernicus data. Now, this provider supports only data from Sentinel-1, Sentinel-2, Sentinel-3 and Landsat-8. The integration of EnviSat is still missing. But the consortium is still active, as there is another integration of new sources still continuing for 2nd quarter 2019. It is planned to add a new collection of COSMO-SkyMed data. Amongst others, they are also offering services and tools in their marketplace, such as Open Telekom Cloud, Wildlife Monitoring, and toolboxes for Sentinel and geospatial data visualisation.
- A consortium of 4 partners led by Serco, launched this service to provide Copernicus data. At the moment, ONDA provides the full package of free services and supports data acquisition from Sentinel-1, Sentinel-2, Sentinel-3, Envisat and Landsat-8. Amongst others, they are also offering services and tools in their marketplace, such as earth surface deformation, or “Earth Starts Beating” applications, which provides an interactive visualization of Copernicus Sentinels missions. The future sources, planned for 2019 are Earth Observation Missions Sentinel-5P, SUOMI NPP, Envisat MERIS, and Envisat AATSR. Also, for June 2019 In Situ measurement such as Coriolis datasets, Lucas Project Database, ARGO floats data and MyOcean in situ TAC. The last Copernicus Service CEMS is also planned in June 2019.





- A consortium consisting of the partners EUMETSAT, ECMWF, and Mercator Ocean launched the DIAS services to provide Copernicus data. Unfortunately, the documentation on the project website is not specific enough to carry out detailed information about the specific satellites where they get the data from. But it seems that only data from Sentinel-1, Sentinel-2, Sentinel-3 and Envisat are available now. Landsat-8 seems to be missing. A roadmap for future sources is also not accessible.

6.2.1 CREODIAS

[CREODIAS](#) platform is a cloud infrastructure adapted to the processing of big amounts of EO data, including an EO Data storage cluster and a dedicated **IaaS** cloud infrastructure for the platform's users. The EO Data repository contains many Copernicus Services data. The infrastructure and the services offered are optimized for use of EO data and support scientific, operational and commercial applications

Data sets

CREODIAS data repository contains full data sets (time and spatial coverage) of Sentinel 2, 3 and 5P, ESA/Landsat and Envisat/Meris, Sentinel 1 GRD and partial – covering Europe – repository of Sentinel 1 SLC with 6 months' worth of SLC data of the whole Earth. <https://discovery.creodias.eu/dataset>

Platform

The platform consists of *CREODIAS Repository*, *CREODIAS Processing* platform and *Platform as a Service tool*. The EO Data can be accessed *via* many interfaces including *S3 object interface* compatible with Amazon S3 standard, REST/API or standard POSIX-type file access:

- **Amazon S3** (Amazon Simple Storage Service) is a "simple storage service" offered by Amazon Web Services (AWS) that provides object storage through a web service interface. Amazon S3 provides storage services through Web services (REST, SOAP, and BitTorrent).
- **REST** ([REpresentational State Transfer](#)) is a software architectural style that defines a set of constraints to be used for creating Web services.
- **POSIX** (Portable Operating System Interface) is a family of standards specified for maintaining compatibility between operating systems.

Local storage is based on a **Ceph** solution. Ceph is a free-software storage platform, implements *object storage* on a single distributed computer cluster, and provides interfaces for object-, *block*- and file-level storage. Ceph implements distributed object storage using the Reliable Autonomic Distributed Object Store (**RADOS**), a reliable, self-contained, and distributed object storage engine.

CREODIAS processing covers a full set of virtual resources with several operating systems:

- VM – Virtual Machines
- virtual storage volumes
- virtual networks
- VPN concentrators (Virtual Private Network)





Resources are connected with 100 GBit/s SDN network switching.

Software-Defined Networking (**SDN**) technology is an approach to *cloud computing* that facilitates network management and enables programmatically efficient network configuration in order to improve network performance and monitoring.

The Browser allows visualization and basic processing of selected data collections

The SPARQL interface provides extended search capabilities linking metadata of all products stored in the repository with various information from the Internet.

Data Access Interfaces

Available Data Access Interfaces:

- [Object Data Access API](#) (SWIFT/S3) : access EO data by sending HTTP requests
- *Filesystem Interface* : CREODIAS makes the EO Data repository contents available directly through a POSIX filesystem interface (filesystem interface is not recommended for processing chain applications and direct object access should be used whenever possible)
- *EO Data Processing/Access HUB*: The EO Data Access Hub provides a complete set of mechanisms to access EO Data as dynamically generated OGC standard web services. The Hub itself is completed by front-ends to search, discover browse and download EO Data and to configure custom Web Service layers (EO Browser, Mosaic Generator, WMS Configurator)
- *HTTP Download*: Most of the data indexed in the CREODIAS catalogue (Locations: Local, Cached, Orderable) can be downloaded by users with the CREODIAS Platform acting as a proxy.
- *Proxy to External Copernicus Services*: Some Copernicus Services (Location: External) are accessible as standalone web services that cannot be mirrored or otherwise copied to the CREODIAS Platform.

IaaS services: <https://creodias.eu/general-information>

- *Computing Services*
 - Virtual Machines
 - Dedicated Server Virtual Machine
 - Containers – Docker Swarm and Kubernetes.
- Storage related service
- Data related services
- Virtual networking services
- Additional services
 - Orchestration service to ease and simplify virtual infrastructure deployment and management
 - Engineering support and consulting, project implementation and Third Party on-boarding





6.2.2 SOBLOO

Through a secure cloud computing architecture, [SOBLOO](#) will provides broad access to Copernicus data, Earth Observation commercial imagery, Mobile data, **and IoT** and geolocated databases. The [Internet of things \(IoT\)](#) refers to the concept of extending Internet connectivity beyond conventional computing platforms such as personal computers and mobile devices, and into any range of traditionally "dumb" or non-internet-enabled physical devices and everyday objects. SOBLOO is based on a double approach:

1. a DIY component (*Do It Yourself*), with APIs that are compatible with Open Geospatial Consortium (OGC) standards and tools for processing data on the fly of the geospatial domain available to users
2. a *Kubernetes* platform that allows to "Dockerise" applications in the tenants made available to our customers in the SOBLOO cloud. "

Data sets

[Global Data Offer](#)

- Satellite : Sentinel 1, sentinel 2 Sentinel 3 Sentinel 7p
- Copernicus core services : [CAMS](#), [CMEMS](#), [CLMS](#), [CEMS](#), [C3S](#)
- Thematic Products

Platform:

[Managed Applications](#) is an offer of management services and cloud applications. SOBLOO offers a modular approach that allows choosing the applications the user may manage himself and those he wants to entrust to SOBLOO. User may choose specific applications, *Middleware*, OS and databases that he wants to operate. SOBLOO guarantees availability, security and performance.

Managed Applications provides *services à la carte*, relying on a large catalogue of operating systems, Middlewares and databases as well as software and management tools.

Managed services can be ported to the various Orange infrastructure offers as well as the main public clouds (AWS, Azure).

- Management of changes, incidents, Flexible Engine versions (security rules, the evolution of virtual machines, etc.) is handled by the "Managed Applications" service.
- The Console and Flexible Engine reporting in the Cloud Store are read-only.
- The user delegates to Orange Business Services the responsibility for certain management tasks in his Managed environment.

IaaS services: <https://sobloo.eu/cloud-services>

SOBLOO IaaS (Infrastructure as a Service) solution allows managing a user virtual infrastructure from an online console.

- A smart elastic service with auto-scaling functionalities.





- The ability to manage one or multiple regions and easily implement your high availability strategy.
- Open and documented APIs will allow you to easily administrate your platforms and gain agility.
- 100% digital access to your infrastructure: rights management, monitoring, management of your resources and network parameters, ...
- A pay-per-use model without commitment

6.2.3 MUNDI

Mundi (www.mundiwebservices.com) integrates a large scope of EO and non EO data. This collection is regularly enriched with new sources. It combines real-time EO data from Copernicus with data from several other sources to provide easy cloud functions for users. The advanced access to satellite data is provided in pre-formatted COG files that improves the processing times and reducing the relative costs. In addition to the provision, the platform and its data is secured by a robust and scalable hybrid cloud platform.

Data sets (<https://mundiwebservices.com/marketplace>)

- Satellites: Sentinel-1, Sentinel-2, Sentinel-3, Landsat-8 (USGS)
- Copernicus core services: CMEMS, CLMS, EMS
- Thematic products: Grassland Monitoring, Web WorldWind, CybeleTechFarm Explorer, COSMO-SkyMed (Q2 2019)

Platform

Mundi is using the Open Telekom Cloud, which is based on OpenStack. Open Telekom Cloud is a public cloud instance which fulfils all relevant security requirements and regulations for operation of secure IT services. There, all services are accessible and can be used to get individual results. The self-developed project infrastructure that is hosted in the Mundi Infrastructure within virtual machines. Those virtual machines can be configured to the own needs. Therefore, it enables users to install Docker with Docker Swarm or Kubernetes. Other advanced tools, such as OSGEO GDAL and ESA SNAP Toolbox are provided as Docker container in the Mundi Marketplace. The Mundi tenant cloud also provides:

- Elastic Cloud Service-through virtual network computing console
- Elastic Volume Service in block level storage capacities or an Object Storage Service that offer a highly simplified access mechanism and a high-level of scalability
- Load balancing for distribute traffic on multiple elastic cloud server and balances loads
- Map reduce service offers a range of tools that allows big data analysis.
- Databases: MySQL, PostgreSQL, SQL Server





IaaS services

Mundi services allow managing a user virtual infrastructure from tools and from console. In the following, the tools and other opportunities are described that can be used within the tenants.

- Mundi Jupyter Notebook is an interactive tool to manipulate and store data in the Mundi Storage. It supports over 40 programming languages
- Cloud Optimized Geotiff is a regular GeoTIFF file, aimed at being hosted on an http file server. HTTP GET range requests enable to get only the needed parts of a file
- Free tools
 - Discovery to search, view and select data in area of interest
 - Download of selected data
 - Service Catalogue to explore and select different data sources
- Advanced tools
 - WPS Processing
 - Time Series data to detect temporal variations
 - Geometry control
 - Thematic algorithms and pipelines ready to use
- Advanced tools - Open Source
 - Orfeo Toolbox (OTB) for remote sensing, including a fast image viewer, apps callable from Bash, Python or QGIS, and a C++ API
 - ESA SNAP for EO processing and analysis

6.2.4 ONDA

[ONDA \(www.onda-dias.eu\)](http://www.onda-dias.eu) enables users to host data and build applications in their cloud. ONDA provides means to access EO satellites Data and geospatial information. For this, they provide a full availability of all Copernicus data, customizable solutions for diverse requirements and levels of expertise, innovative data access technology allowing users to easily extract only needed information from complex data sets.

Data sets

- Satellites: Sentinel-1, Sentinel-2, Sentinel-3, Envisat, Landsat-8
- Copernicus core services: CMEMS, CLMS, CAMS
- Thematic area: land, hazards, geology, and oceans





Platform

ONDA offers 3 types of virtual machines in their cloud environment.

- General Purpose instances have memory to CPU ratios suitable for most general purpose applications and come with fixed performance.
- Computing-Intensive instances have proportionally more CPU resources than memory and are well suited for scale out compute-intensive applications and High Performance Computing (HPC) workloads.
- Memory intensive instances offer larger memory sizes for memory-intensive applications, including database and memory caching applications.

Memory-Intensive instances offer larger memory sizes for memory-intensive applications, including database and memory caching applications.

IaaS

ONDA provides easy access to their IaaS that is flexible and scalable. Advanced API service allows users to easily access any low level component of the product through ENS (*Elastic Node Server*) without the need for a full download. ENS is an Open Source software providing a simple and scalable front-end to one or more Data Storages for use with client Computing Instances.

ENS extends traditional File or Object Storages by exposing not only standard Directories and Files but breaking them down further in a logical tree of Nodes up to the tiniest piece of information. The ENS Nodes can be located, queried and accessed semantically via their names disregarding their physical formats and locations.

See the [API - User Guide](#) :

NFS support files / tools should be installed (package nfs-common on debian, nfs-utils on centos/fedora).

A local directory should be created on system /local_path.

Accessing ENS filesystem is possible after having mounted it and used the following command:

sudo mount -t nfs4 -o nfsvers=4.1 ens.onda-dias.eu:/ /local_path

Where:

1. *-t nfs4: the mount type is NFS version 4*
2. *-o nfsvers=4.1: to force the use of NFS version 4.1 (recommended)*
3. */local_path: the local mount directory path*

All data are then available under /local_path.

The end user can execute all basic commands supported by a classic filesystem on /local_path, as ls, cp, cat.

To unmount the ENS filesystem, type the following command: sudo umount /local_path

Another option to retrieve metadata of selected data is the OData API. A query syntax of that is e.g.

[https://catalogue.onda-dias.eu/dias-catalogue/Products?\\$search='copernicus-land'](https://catalogue.onda-dias.eu/dias-catalogue/Products?$search='copernicus-land'). The difference to ENS is that the OData API is accessible from other platforms through the internet with help of the https protocol. But the direct access to products low level components is only restricted to ENS.





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ANNEX I: Summary of available data portals





Name	URL	Geographic scope	Description	source
World Ocean Database	http://www.nodc.noaa.gov/OC5/WOD/pr_wod.html	Global	Physics, Chemistry, Biology	<i>MSP Data Study</i>
Ocean Tracking Network	http://oceantrackingnetwork.org	Global	Biology	<i>MSP Data Study</i>
GEBCO	http://www.gebco.net	Global	Bathymetry	<i>MSP Data Study</i>
GLOSS	http://www.glosssealevel.org	Global	Physics (sea level)	<i>MSP Data Study</i>
Permanent Service for Mean Sea Level (PSMSL)	http://www.psmsl.org/	Global	Physics	<i>Columbus</i>
Sea Level Station Monitoring Facility	http://www.ioc-sealevelmonitoring.org/	Global	Physics	<i>Columbus</i>
JCOMMOPS	http://www.jcommops.org/board	Global	Diverse	<i>Columbus</i>
RAM legacy stock assessment database	http://ramlegacy.org/	Global	Biology	<i>Columbus</i>
Ocean Biogeographic Information System (OBIS)	http://www.iobis.org/	Global	Biology	<i>Columbus</i>
Fisheries and resources monitoring system	http://firms.fao.org/firms/en	Global	Biology	<i>Columbus</i>
iMarine gateway	https://i-marine.d4science.org/	Global	Biology	<i>Columbus</i>
AquaMaps	http://www.aquamaps.org	Global	Biology	<i>Columbus</i>
World Register of Marine Species (WORMS)	http://www.marinespecies.org	Global	Biology	<i>Columbus</i>
EMODnet	http://www.emodnet.eu	European	Physics, Chemistry, Biology, Geology, Bathymetry, Human Activities	<i>MSP Data Study</i>
SeaDataNet	http://www.seadatanet.org	European	Physics , Chemistry, Biology, Geology, Bathymetry	<i>MSP Data Study</i>
Copernicus Marine Service (CMEMS)	http://marine.copernicus.eu	European	Physics (data and models)	<i>MSP Data Study</i>





European Atlas of the Sea	http://ec.europa.eu/maritimeaffairs/atlas/maritime_atlas/	European	Mostly Human Activities	<i>MSP Data Study</i>
PANGAEA	https://www.pangaea.de/about/	European	Physics, Chemistry, Biology, Geology	<i>MSP Data Study</i>
Marine Operational Ecology Data Portal	http://portal.marineopec.eu/	European	model simulated ecosystem	<i>Columbus</i>
European Marine Life	http://www.european-marine-life.org/	European	Biology	<i>Columbus</i>
EEA Database	http://www.eea.europa.eu/data-andmaps	European	Diverse	<i>MSP Data Study</i>
Eurostat Database	http://ec.europa.eu/eurostat/data/database	European	Economic value of human activities	<i>MSP Data Study</i>
INSPIRE Geoportal	http://inspiregeoportal.ec.europa.eu	European	Diverse	<i>MSP Data Study</i>
ESPON 2013 Database	http://database.espon.eu/db2/home	European	Human activities	<i>MSP Data Study</i>
MAPAMED	http://www.mapamed.org	Mediterranean	Marine protected areas	<i>MSP Data Study</i>
Mediterranean Marine Data	http://www.mediterraneanmarinedata.eu	Mediterranean	Physics, Chemistry	<i>MSP Data Study</i>
Adriatic Atlas	http://atlas.shapeipaproject.eu	Mediterranean	Human activities, Physics, Chemistry, Biology, Geology, Bathymetry	<i>MSP Data Study</i>
AdriPlan Data Portal	http://data.adriplan.eu/	Mediterranean	Human activities, Physics, Chemistry, Biology, Geology, Bathymetry	<i>MSP Data Study</i>
THAL-CHOR WebGIS	http://www.mspscygr.info/#	Mediterranean	Human activities	<i>MSP Data Study</i>
ADRIBLU	http://mapserver.arpa.fvg.it/adriblu/map.phtml	Mediterranean	Human activities	<i>MSP Data Study</i>
Oceanographic Data Portal	data.ifremer.fr	Mediterranean, Atlantic and North Sea	Physics, Chemistry, Biology, Geology, Bathymetry, Human Activities	<i>MSP Data Study</i>





Coriolis	http://www.coriolis.eu.org/	Mediterranean and Atlantic	Physics	<i>MSP Data Study</i>
Oceanographic Mediterranean and Black Sea Data Management	http://isramar.ocean.org.il/perseus_data/	Mediterranean and Black Sea	Physical, Chemistry and Biology	<i>Columbus</i>
COCONET	http://coconetgis.ismar.cnr.it/	Mediterranean and Black Sea	Marine protected areas and wind energy potential	<i>Columbus</i>
PEGASO	http://pegasosdi.uab.es/geoportal/	Mediterranean and Black Sea	Human activities	<i>Columbus</i>
NODC	http://nodc.ogs.trieste.it/nodc/	Mediterranean	Biology, Chemistry, Physics	<i>Columbus</i>
DORIS	http://doris.ffessm.fr/	Mediterranean and more	Biology	<i>Columbus</i>
Physical Oceanography Institute of the University of Malta	http://ioi.research.um.edu.mt/capemalta/stations@malta/INDEX/	Mediterranean	Physics	<i>Columbus</i>
Cyprus Coastal Observing and Forecasting System	http://www.oceanography.ucy.ac.cy/cycofos/	Mediterranean	Physics (data and models)	<i>MSP Data Study</i>
SINAnet	http://www.mais.sinanet.isprambiente.it/ost/	Mediterranean	Diverse	<i>MSP Data Study</i>
POSEIDON	http://www.poseidon.hcmr.gr	Mediterranean	Physics	<i>MSP Data Study</i>
Spanish Harbours Authority	http://www.puertos.es/eses/oceanografia/Paginas/portus.aspx	Mediterranean and Atlantic	Physics (data and models)	<i>MSP Data Study</i>
Balearic Islands Coastal Observing and Forecasting System	http://www.socib.es	Mediterranean	Physics (data and models)	<i>MSP Data Study</i>

