ODYSSEA

Operating a network of integrated observatory systems in the Mediterranean Sea

Project Deliverable Report

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Deliverable Title: Data Post-Processing Procedures

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Executive Summary

ODYSSEA intends 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.

To achieve this prime objective, a platform architecture must be defined, which can provide the following minimum requirements:

- collect data from external databases maintained by agencies, public authorities, and institutions of Mediterranean EU and non-EU countries;
- integrate 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;
- support the operation and execution of different simulation models (hydrodynamic, wave, water quality, ecology, statistics, etc.);
- support the integration of real time data being acquired by local sensors;
- provide data discovery and downloading services;
- provide user focused downstream services

This document aims to define the ODYSSEA collected and produced datasets and to set up guidelines for data post-processing procedures that could be included in the Platform. Data produced at ODYSSEA pilot Observatories, consisting of data from sensors, remote sensing and numerical models, together with data collected from external sources and synthesized within ODYSSEA platform are the focus of this deliverable. The processing procedures on these datasets, both at initial and further levels, are extensively discussed to guide WP7 partners who are responsible for algorithms. These guidelines could provide input into Deliverable D3.2 on Data Management Plan for collected Data, Deliverable 7.1 on Algorithms Requirements Specification Document, and Deliverables 7.2 and 7.3 on Algorithms applied on sample data and Reference Algorithms.

1 Introduction

ODYSSEA is a user-centred project aiming to make Mediterranean marine data easily accessible and operational to a broad range of multiple end-users operating in the Mediterranean Sea. To achieve this scope ODYSSEA is expected to:

- integrate existing Earth Observation systems into a single platform,
- offer on-demand derived data services for end-users and stakeholders,
- upgrade existing operational oceanographic capacities, by integrating novel sensors for emerging pollutants into existing static and mobile monitoring systems
- support EU policy implementation, especially Directives and Protocols related to coastal and marine environment,
- improve interoperability in monitoring, using datasets in multiple ways, providing a holistic view of the status and trends of the Mediterranean Sea,
- foster blue growth jobs creation, in the fields of operational oceanography, instrumentation, data management, early-warning systems, etc.
- open the participation to non-EU member Mediterranean states, particularly those along the North African coast and the Middle East coast.

Based on the above, ODYSSEA is a system bridging the gap between operational oceanographic capacities and the need for information on marine conditions by the community of end-users. The project aims to fulfill the following 10 specific objectives:

1. Develop the ODYSSEA platform to discover, integrate and process datasets obtained from an expanded range of existing observational platforms (Copernicus, EuroGOOS, EMODnet, etc),
2. Fill in data gaps and increase the spatial and temporal resolution of existing Earth Observing systems by establishing a series of ODYSSEA Observatories,
3. Develop a prototype 'chain' of models, linking models to existing databases, providing short- and long-term prognostic results, aiding users to manage risks and emergencies and providing data never previously reported,
4. Expand existing operational monitoring systems capacity, testing the integration of other sensors (e.g., novel sensors for emerging pollutants, such as micro-plastics, submarine cameras for benthic organisms and fish species recognition, classification and tracking and acoustic sensors for mammals and marine noise monitoring).

5. Emphasize on biological datasets utilizing and combining physico-chemical data to open, reliable biological data at Mediterranean scale, develop new biological datasets, model and assess the human impact on biological resources and provide stock assessment recommendations per stock and Observatory area,
6. Combine physico-chemical data, habitat types, biota etc. to allow the calculation of secondary indicators (e.g., eutrophication indices, pollution indices, MSFD descriptors, etc.) and export these indicators to end-users,
7. Link indicators to EU policies using the same datasets for different descriptors and indices of EU legislation (Water Framework Directive, Environmental Quality Standards Directive, Habitats Directive, Birds Directive, CFP, Barcelona Convention – MAP),
8. Develop a community of Mediterranean data users, by directly involving them on platform design, data collection and day-to-day operations,
9. Train and educate policy-makers and end-users on platform usage, demonstrate all new technologies (sensors, models, systems) and educate young scientists, engineers and entrepreneurs,
10. Improve professional skills and competences focusing on Northern Africa capacity building, link environmental technologies to marine policies and legislation, supporting new and qualified “jobs of the sea”.

2 ODYSSEA Data Description

Data in ODYSSEA are divided into:

a) Data at Mediterranean level, collected and integrated from existing databases operated by Earth Observation Systems and networks maintained by agencies, public authorities, research institutions and universities of Mediterranean EU and non-EU countries.

b) Data at Observatory level, collected by a set of sensors and systems and simulated by a series of high resolution numerical models, operating at each of the nine prototype ODYSSEA Observatories, focusing on serving local/regional end-users of any maritime sector.

Data at Mediterranean level may be divided in terms of their parameters into topics including meteorology, topography, bathymetry, hydrology, hydrography, geology, physics, chemistry, biology, biodiversity, climate change, etc. These data may be further divided into a) static/archived datasets, collected once or at long irregular intervals, such as bathymetry, geology, biodiversity, etc.; b) dynamic/forecasted datasets, collected and/or produced at short regular intervals (hourly, daily, etc.) continuously updated in databases, such as physical, optical, biophysical parameters (made available via sensors, satellites or models).

Data at Observatory level may be divided into data collected by a) in-situ sensors deployed at the sea surface, sea floor or operating continuously throughout the water column; b) satellites collecting physical, chemical, bio-optical parameters; c) numerical models simulating processes and producing data on physical, chemical, biological, bio-optical, etc, parameters.

Data from sensors deployed at each Observatory will be initially transferred at local storage/processing platforms as raw data (Level 0) and then to the central ODYSSEA platform for further processing. Increased effort is needed to make these data operational for end-users and exchangeable to other systems, as:

- Real-time quality checks (RTQC) and flagging are required to process these data;
- Secondary parameters derivation, parameters inter-relation, data visualization;
- Data harmonization to become interoperable;
- Hydrographic features and processes understanding.

Data from sensors will also be used by the high resolution numerical models during the calibration, validation and assimilation phases. Data from numerical models contain high resolution forecasts in a wide range of parameters over the area covered by each Observatory. Data from sensors and models need to be harmonized following SeaDataNet standards, to be interoperable and accessible to users of the platform.

Data from satellites will be collected to be combined with model results to improve forecasting capacity, especially at sea surface processes, such as eutrophication. Secondary indices combining data from sensors, models and satellites will be derived to aid the implementation of EU policies.

Overall, data from external databases at Mediterranean level will be mostly gridded data, with specific temporal and spatial resolution. Data at Observatory level collected from sensors will be mostly time-series (static), while the data collected from gliders and satellites and the data produced by models will be gridded, with spatio-temporal variability. This variability in the nature of data from different sources poses an important limitation in terms of post-processing, as different tools and processing methods are required.

3 The ODYSSEA Monitoring Systems

3.1 The Glider Systems

Buoyancy-driven gliders will be used as Autonomous Underwater Vehicles following a well-designed trajectory and oscillating throughout the water column. The Alseamar's SEA EXPLORER gliders will be used for these surveys. The systems can remain unattended at sea for several weeks to months without any need for maintenance. Alseamar will be responsible for operation and pilotage, in close collaboration with local Observatory leaders.

The gliders to be developed within the framework of ODYSSEA project will be carrying all appropriate sensors to simultaneously monitor a range of parameters, while regular surface communications with satellite will allow their movement to be controlled and data uploaded at near real-time mode.

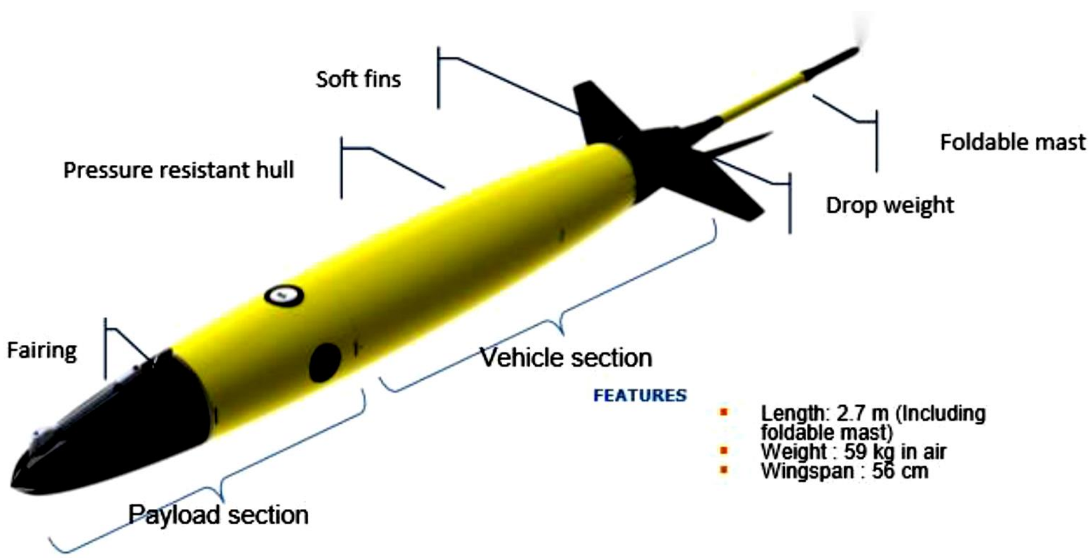

Figure 1. Alseamar's SEA EXPLORER glider system and its two basic components: the vehicle section and the payload section.

For ODYSSEA purposes Alseamar will built two vehicle sections and three payload sections. These systems will be used to monitor physical, chemical, biological and acoustical parameters at selected Observatory sites (Thracian Sea/North Aegean Trough, Israel coastline, Ah-Hoceima and Stora Gulf). More specifically, the autonomous multi-mission platform developed by Alseamar (SeaExplorer glider) will be utilized as an autonomous, long-endurance (up to 2 months), cost-effective system, capable of covering thousands of kilometers, carrying novel embedded sensors. Along its saw-tooth profile, the SEAEXPLORER surfaces regularly to establish a communications link for supervision and piloting (SPS, using GPS positioning) and data transmission. When in surface, theses gliders will be regularly piloted by iridium communication for mission update and real-time data downloading. Gliders will move at a speed of 1 knot, covering the whole water column.

3.2 Surface and Bottom Deployment Platforms

Develogic is developing a modular sensor platform to be used for static deployments from existing maritime facilities. It will consist of a flexible sensor system for real-time data transmission to the ODYSSEA platform. Standard parameters such as water temperature, conductivity/salinity, dissolved oxygen, turbidity and currents will be measured locally at the surface waters at each Observatory. At selected Observatories, the system will expand its current capacity to integrate a fluorometer, for the determination of chlorophyll-a concentration, and a submerged camera, for fish species image analysis. At selected Observatories a novel microplastics sensor will be integrated to monitor floating plastic particles with diameter less than 4 mm.

The Develogic static monitoring platforms consist of two systems: the Modular Seafloor Lander (MSL) deployed at the sea bottom, and the surface monitoring platform.

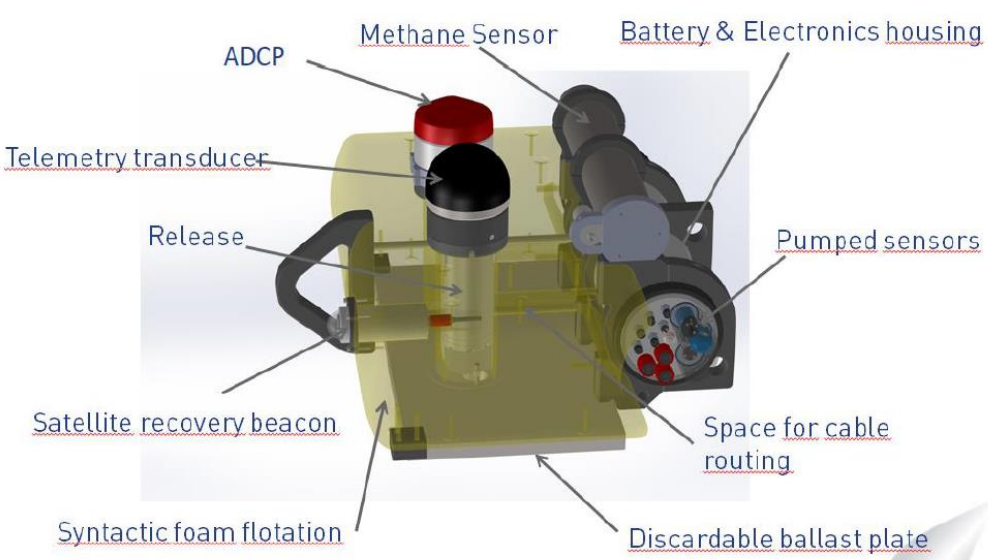

Figure 2. The Modular Seafloor Lander (MSL) and its components and configuration.

The MSL is an autonomous system with flexible configuration, capable to receive a broad range of sensors and operate at sea bottom (up to 250 m) during long-term deployments. The main novelties of this system are the hydro-acoustic data transfer from sea bottom to the sea surface and from there to land-based PC, the automatic recovery from sea bottom for system maintenance and the easy and controlled-descent at sea bottom. The system uses syntactic foam at its external housing producing the required buoyancy to lift the MSL system to sea surface using a remote mechanical release.

The surface systems will be customized to the needs of each Observatory and the mounting requirements of each end-user. For this reason, the systems are still under development. The basic configuration of surface platforms comprises of the housing, sensors and electronic systems and the customized-mounting. At the end of ODYSSEA, a broad range of surface systems will have been developed to serve the needs of end-users operating in the Mediterranean Sea.

4 Data collection and data transfer

4.1 Glider data collection

Sea gliders are small, autonomous underwater vehicles designed to glide the water column surface to a programmed depth (usually near the bottom) and back, while measuring a series of oceanographic parameters along a sawtooth trajectory (Eriksen et al., 2001). Sea gliders use small changes in buoyancy to effect vertical motion, and wings to convert the vertical motion to horizontal movement, thereby propelling themselves forward with very low power consumption (Klinck et al., 2012).

These systems are designed for missions in a range of several thousand kilometers and durations of many months. The glider is comprised of two parts: the vehicle, equipped with global positioning system for system navigation, and the payload, equipped with the various sensors, dedicated for monitoring.

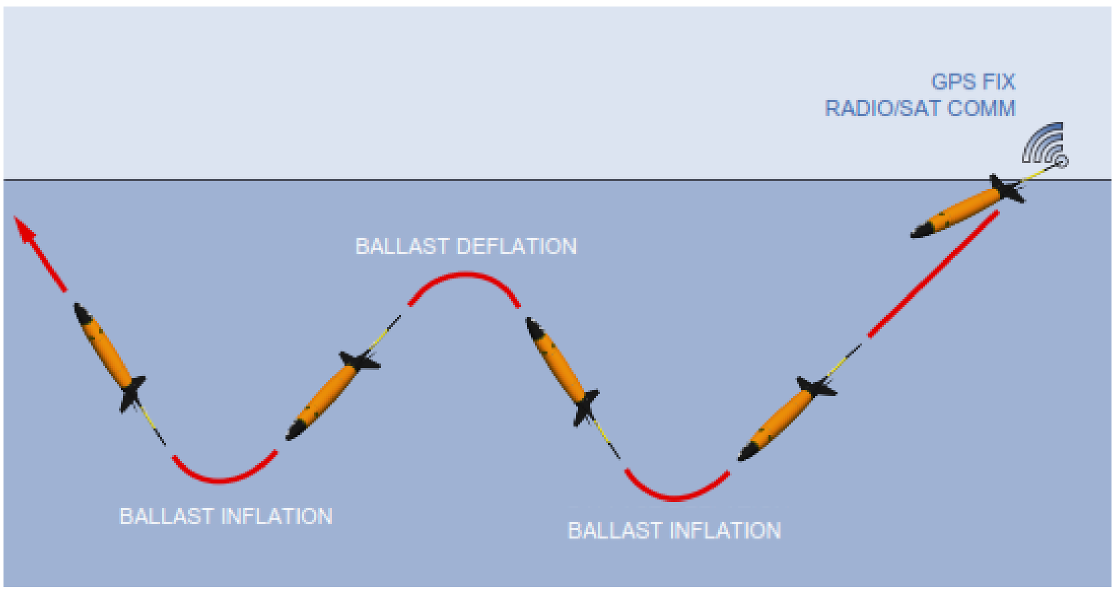

Figure 3. Glider underwater operation.

Alesamar's SEA EXPLORER will be used for the glider monitoring of oceanographic parameters at selected ODYSSEA Observatories. The system has long endurance, capable of covering up to a 1,200 km track and up to 60 continuous monitoring days at sea and it is powered by rechargeable batteries.

For this purpose, two vehicles and three payloads will be built. The three payloads are equipped with the following sensors:

1. GPCTD, DO, Chlorophyll-a, suspended particulate matter, turbidity and CDOM.

The SeaBird GPCTD is a modular, low-power profiling instrument dedicated for autonomous gliders, measuring pressure, temperature, conductivity and dissolved oxygen. The FlbbCD version combines the Flbb optical design with a CDOM fluorometer. The sensor measures phytoplankton abundance (chlorophyll-*a*), total particle concentration (backscattering) and dissolved organic matter (CDOM fluorescence). These data are combined and stored into a single data stream.

The GPCTD system is equipped with a pump, thus diminishing the effect of variable flushing rate affecting the response of conductivity and dissolved oxygen sensors observed in systems without pumps.

Chl-*a* fluorescence is a proxy for concentration of the pigment; excitation was at 470 nm with emission measured at 682 nm. Optical backscatter of particles (a proxy for particle concentration), may be determined from total backscatter minus the contribution from water, as the sensor measures at two wavelengths and has the capacity to report as b_{bp}(470) and b_{bp}(700). Data produced by b_{bp}(700) may be referred as particulate backscatter. The CDOM fluorometer operates at an excitation wavelength of 370 nm and emission wavelength of 460 nm, with the sensor having a sensitivity of 0.09 ppb.

All sensors will be factory-calibrated prior to deployments.

2. Passive acoustic monitoring system

Alseamar's underwater acoustic sensor will be used for passive acoustic monitoring. The sensor records underwater sounds at sampling rate of 48, 96 or 192 kHz and it is capable to perform marine mammal assessment, sonar ping detection, marine traffic monitoring, habitats health status, human noise mapping, etc. For the purposes of ODYSSEA project the marine mammal assessment/detection, the seabed acoustic characterization, the acoustic landscape and Habitats Health Status (HHS) assessment and the human noise mapping will be carried out.

Figure 4. Alseamar's passive acoustic monitoring sensor.

3. GPCTD and micro-plastics sensor

The micro plastic sensor is a new sensor to be integrated on the SeaExplorer and therefore the sensor must fit in the current SeaExplorer standard configuration. LEITAT will develop the system and its components. This will require: a) system upgrading from surface to underwater sensor through pressure adaptation; b) system resizing to fit in the gliders and the sensor platform; c) the use of external power supply; d) the removal of the peristaltic pump and the storage units (external components will be used); e) algorithms adaptation.

When operational, the system will be able to monitor micro-plastic particles with diameter less than 5 mm. Micro-plastic category include: a) particles of plastics that are purposefully manufactured to be of a microscopic size (cosmetics), and b) plastic fragments derived from the breakdown of larger plastic debris, both at sea and on land (e.g. from urban and industrial processes, clothing, tourism).

The ODYSSEA micro-plastic sensor can provide in-situ real-time automated data and for this reason the sensor will be integrated into both the Alseamar gliders and the Develogic surface and SeaLander platforms.

Outputs from the above-described sensor payloads are recorded in the glider's internal memory at a rate of approximately 0.5 Hz, or one sample every two seconds. Glider data will be transmitted via the Iridium satellite communication network at the end of each dive cycle. Data from both dive and climb profiles will be used, although climb profiles it is expected to be more highly resolved near the surface, as the glider ascents at a slower rate than descents.

Typical descent speeds are as high as 0.3 m/s within the surface mixed layer and slowed to as little as 0.06 m/s near the upper 1-km depth. Typical ascent speeds range from 0.06 to 0.10 m/s. In the upper 150 m, typical vertical sampling resolution during ascent may be around 0.5 m and during descent 0.8-0.9 m.

4.2 MSL and Surface Platforms Sensor Systems

At both the MSL and the surface platforms the following set of sensors will be deployed.

Water temperature and conductivity data will be collected using the Aanderaa 4319B conductivity sensor, with the following the specifications:

For conductivity

- Range: 0-7.5 S/m
- Resolution: 0.0002 S/m
- Accuracy: 0.0018 S/m

For water temperature

- Resolution: 0,01ºC
- Accuracy: ±0,05ºC

Hydrostatic pressure will be measured using the Keller PAA-10LHXX pressure sensor having the following features:

- Range: 0-30 bars
- Resolution: 0,15 mbars
- Accuracy: <0.05%FS

Dissolved oxygen content will be measured using the Aanteraa 4531 sensor with the following features:

- Range: 0-800 µM
- Resolution: <1 µM
- Accuracy: <8 µM or 5% FS whichever is greater

Chlorophyll-a concentration will be measured using the Turner Designs type Cyclops 7F fluorometer with the following features:

- Detection limit: 0.03 µg/l
- Range: 0-500 µg/l

The MSL platform will also be equipped with the Aanderaa DCPS 5400 ADCP sensor, capable to measure currents up to 80 m depth, with a limited blanking zone of only 1 m, near the surface, and a cell size of 0,5 to 5 m. The three-dimensional current speed will be measured with accuracy of 3 mm/s or ±1% of reading. The system will have an integrated compass and an inclinometer for pitch and roll readings.

The MSL will also be equipped with a full HD video and still image camera. It is camera built in-house by Develogic consisting of full LED illumination, full HD video and still image recording. The system may follow a configurable recording schedule and then an MPEG image compression routine. Data will be stored internally at on SDXC storage cards capable to receive very large data packages.

Hydro-acoustic data will be collected using the Neptune Sonar hydrophone with a recording capacity up to 17TB stored internally on SDHC cards.

4.3 MSL and Surface Platforms Data Transfer

Static systems' operation and data collection principles is similar for both the surface and bottom deployments. However, different sensors will be deployed at each system and therefore data processing and analysis will be based on that. Data packages from MSLs collected by standard sensors will be transferred to sea surface by a hydro-acoustic modem. The hydro-acoustic modem is capable of transferring data at a range of 1,000 m from MSL deployment. From there, data may be stored at a laptop/tablet and via a surface modem to be transferred to the land-based station using a mobile phone network (if existing) or a satellite network. MSL remote access and data download is also possible in case a surface communication buoy is deployed to connect the MSL via the acoustic modem and iridium or mobile network to the remote user.

Figure 5. The Develogic surface modem for data transfer to remote user.

Similar approach will be followed for data collected by standard sensors for surface platforms. However, data collected by submarine cameras (full videos, photos) and acoustic sensors (hydrophone records) will probably be too large to be transferred through the above systems. These data will be internally stored and collected at regular time-intervals (about 6 months) when the MSLs are recovered for maintenance and servicing.

The data collected from MSLs and surface platforms are stored in files with standard csv format. This format is a simple file for tabular data easily imported in MS-Excel and ODV.

4.4 Data provided by Monitoring Systems

The data provided by all these systems and sensors deployed within the framework of ODYSSEA project are the following:

Table 1: Data provided by the Observatory systems

System	Sensor	Data
Glider payload 1	Acoustic sensor	Acoustic signal
Glider payload 2	GPCTD + DO	Conductivity, Temperature, Salinity, Density Dissolved Oxygen
	FLBBCD	Chlorophyll A Fluorescence (proxies of phytoplankton abundance) Backscattering (total particle concentration) CDOM Fluorescence (dissolved organic matter)
Glider payload 3	Microplastic	Microplastic particles per lt
MSL type A x1	Neptune Sonar Hydrophone	Acoustic signal
	ADCP	Current profiler
	Aanderaa 4531	Dissolved Oxygen, Temperature
	Aanderaa 4319B	Conductivity, Temperature, Salinity, Density
	Cyclops 7F	Chlorophyll A Fluorescence
MSL type B x1	Neptune Sonar Hydrophone	Acoustic signal
	ADCP	Current profiler
	Aanderaa 4531	Dissolved Oxygen, Temperature
	Aanderaa 4319B	Conductivity, Temperature, Salinity,Density
	Cyclops 7F	Chlorophyll A Fluorescence

	Microplastic	Microplastic particles per lt
Surface monitoring type A x1	Aanderaa 4531	Dissolved Oxygen, Temperature
	Aanderaa 4319B	Conductivity, Temperature, Salinity, Density
	Cyclops 7F	Chlorophyll A Fluorescence
	DW.CAM	camera and lights
	Microplastic	Microplastic particles per lt
Surface monitoring type B x1	Aanderaa 4531	Dissolved Oxygen, Temperature
	Aanderaa 4319B	Conductivity, Temperature, Salinity, Density
	Cyclops 7F	Chlorophyll A Fluorescence
	DW.CAM	camera and lights
Surface monitoring type C x5	Aanderaa 4531	Diluted Oxygen, Temperature
	Aanderaa 4319B	Conductivity, Temperature, Salinity, Density
	Cyclops 7F	Chlorophyll A Fluorescence

The following Table classifies the data to be collected by these systems, based on the Data_Typology and their associate Data_parameter presented at D13.1.

Table 2: Data association with sensors deployed at Observotories

Data Typology	Data Typology code	Data parameter	Data parameter code	System	Sensor
Biota abundance biomass and diversity	B070	Fauna abundance per unit area of the bed	FABD	Surface monitoring type A or B	DW.CAM Camera
Birds mammals and reptiles	B015	Cetacean abundance	CETA	Glider Payload 1	PAM-ASR1 acoustic sensor

				MSL	Neptune Sonar Hydrophone
Fish	B020	Fish abundance in water bodies	FAXT	Surface monitoring type A or B	DW.CAM Camera
		Fish morphology age and physiology	FATM	Surface monitoring type A or B	DW.CAM Camera
Anthropogenic contamination	H001	Acoustic noise in the water column	NOYS	Glider Payload 1	PAM-ASR1 acoustic sensor
		Litter abundance and type	LITT	Glider Payload 3 or MSL type B or Surface monitoring type A	Microplastic sensor
Human activity	H005	Human noise			
Currents	D030	Horizontal velocity of the water column	RFVL	MSL type A or B	DCPS 5400 ADCP
		Vertical velocity of the water column	LRZA	MSL type A or B	DCPS 5400 ADCP
Water column temperature and salinity	D025	Salinity of the water column	PSAL	Glider payload 1	GPCTD
				MSL type A/B	Aanderaa 4319B
				Surface monitoring type A/B/C	Aanderaa 4319B

		Temperature of the water column	TEMP	Glider payload 1	GPTCD
				MSL type A/B	Aanderaa 4319B or Aanderaa 4531
				surface monitoring type A/B/C	Aanderaa 4319B or Aanderaa 4531
		Electrical conductivity of the water column	CNDC	Glider payload 1	GPCTD
				MSL type A/B	Aanderaa 4319B
				surface monitoring type A/B/C	Aanderaa 4319B
		Density of the water column	SIGT	Glider payload 1	GPCTD
				MSL type A/B	Aanderaa 4319B
				surface monitoring type A/B/C	Aanderaa 4319B
		Concentration of dissolved organic matter in the water column	HMSB		CDOM du FLBBCD
Habitat	B050	Habitat characterisation	HBCH		Acoustic glider+ camera

Pigments	B035	Chlorophyll pigment concentration in the water column	CPWC		
Dissolved gases	C015	Dissolved oxygen parameters in the water column	DOXY		
Optical properties	D015	Optical backscatter	OPBS		
Suspended particulate material	G015	Concentration of suspended particulate material in the water	TSED		FLBBCD back
Positioning references and data management	Z005	Horizontal platform movement			
		Vertical spatial coordinates			

5 Remote Sensing Data at Observatory level

The remote sensing data will be mainly produced by the NASA Goddard Space Flight Center's Ocean Data Processing System (ODPS), by the European Space Agency (ESA) and by the Copernicus Marine Environment Monitoring Service (CMEMS). The temporal remote sensing resolution will be vary from daily to monthly, the spatial remote sensing resolution will be vary from 300m to 4km and the spectral remote sensing resolution will depend on each remote sensing mission and will be vary from the visible to the near-infra-red. Remote sensing data will be obtained from different remote sensing missions. Table 5 in Appendix 1 presents the available remote sensing datasets from various sensors and systems, their temporal and spatial resolution and the produced variables. Table 6 in Appendix 1 presents the datasets that will be extensively used during ODYSSEA project at Observatory level.

Level-1A data from NASA Goddard Space Flight Center will be obtained from Level-0 (L0) data files which contain the raw radiance counts (digital numbers) and refer to unprocessed instrument data at full resolution. Level-1A data files that are also unprocessed contain the sensor and raw radiance counts as well as spacecraft and instrument telemetry and calibration and navigation data. Remote sensing mission such as MODIS-Aqua where navigation data are not included, a separate geolocation data file will be generated from the Level-1A data files and will be used in order to define the geo-referencing parameters. This geolocation file will be then used as an input for the derivation of Level-1B (L1B) data. Level-1B data files contain the calibrated top-of-atmosphere radiances derived from Level-1A sensor counts by applying the sensor calibration. Atmospheric correction will be applied in order to convert the top-of-atmosphere radiance of Level-1B to normalized water-leaving reflectance of Level-2 data. Level-2 data files will contain the calculated geophysical values for each pixel (e.g. chlorophyll-α, bottom depth, etc.) derived from the Level-1B radiances by applying bio-optical algorithms (see Table 6 in Appendix 1). Level-2 data also will contain geolocation data and each Level-2 product will correspond exactly in geophysical coverage (scan-line and pixel-extend). Level-2 (L2) data products will be generated from Level-1A products using the SeaWiFS Data Analysis System (SeaDAS) and programming tools. Also, Level-3 remote sensing data will be used in cases where Level 2 remote sensing data are absent (e.g. cause to cloud coverage or not passage of the remote sensing sensor). No remote sensing data filling procedures will be developed.

According to CMEMS product user manual (PUM) for Sea Level SLA products (2017), the products that will be used by CMEMS Sea Level TAC (Thematic Assembly Centre) are the surface heights observations from the altimeters. The CMEMS SL-TAC produces two components: one REPROCESSING (REP) component and on Near-real-Time (NRT) component. The purpose of the NRT CMEMS component is the acquisition of altimeter data from various altimeter missions in a) near-real-time (IGDRs) or in short time critical (L2P STC for Sentinel-3A) i.e. within a few days at most and b) in fast delivery: real time (OGDRs) or near real time (L2P NRT for Sentinel-3A) and the validation and correction of these altimeter data sets (i.e edition and selection, update of corrections and homogenization, orbit error reduction) in order to produce each day along-track and gridded products. The Delayed Time or REP (for REPROCESSING) component of SL-TAC system is responsible for the production of processed remote sensing data in order to provide a homogeneous, inter-calibrated and highly accurate long time series of all altimeter data. REP products are more precise than NRT products.

CMEMS Ocean Colour Thematic Assembly Centre (OCTAC), products are currently used to monitor marine conditions and are acquired by the CMEMS MFCs for ecosystem model assimilation/validation. For Mediterranean Sea region, OCTAC delivers only two types of products: chlorophyll and optics. Chlorophyll is the phytoplankton chlorophyll concentration evaluated either via standard processing or via region-specific algorithms. Optics refers to any other variable retrievable from ocean colour sensors, and includes: IOPs (Inherent Optical Properties, such as absorption and scattering), diffuse attenuation coefficient of light at 490 nm (Kd490), secchi depth (transparency of water), spectral remote sensing reflectance (Rrs), coloured dissolved organic matter (CDOM), and the non-organic solid particulate matter (SPM). Following the CMEMS convention, the ocean colour products are further classified in Near Real Time (NRT) and reprocessed (REP). The NRT products are operationally produced every day and provide the best estimate of the ocean colour variables at the time of processing. A first version of this product is generated soon after the satellite passage, by using climatological ancillary data (meteorological and ozone data for atmospheric correction, and attitude and ephemerides for data geolocation). These versions of NRT products are available within 24 hours from the satellite acquisition. The REP products, instead, are consistent multi-year time series produced by using a consolidated and consistent input dataset, with a unique processing software configuration. Therefore, these represent a much more solid data set for long-term analyses. For NRT products, presently the entire OCTAC relies on the available ocean colour sensors: MODIS-Aqua and NPP-VIIRS (from NASA) and Sentinel-3A OLCI (from EUMETSAT).

The product level can be Level-3 (L3) or Level-4 (L4). L3 are the daily composite products as obtained by merging all the ocean satellite passages and they can be of any spatial resolution, typically 1, 4, 9, and 25 km. L4 are those products for which a temporal averaging method or an interpolation procedure is applied to fill in missing data values. Temporal averaging is performed on 8-days and monthly bases. The interpolation procedure currently used spans from Optimal Interpolation to DINEOF procedure.

The CMEMS Ocean Sea Ice Thematic Center (OSI TAC) is responsible for the collection, processing, qualification and distribution of sea surface temperature (SST), surface winds and sea ice (SI) data products derived from radiometers (infra-red and microwave), scatterometers and Synthetic Aperture Radar (SAR) satellite missions. The OSI TAC is in charge of the near-real time (NRT) and delayed mode (REP) processing of SST, Sea Ice and Wind observations, (regionally and globally), required for CMEMS modelling and data assimilation and for applications.

The SST component of the OSI TAC is distributed to L3 and L4 level products (PUM for Level 4 SST products over the Mediterranean and Black Seas, 2015). The L3S data correspond to supercollated (merged-multisensor) L3P SST data remapped over the Mediterranean at high (HR=1/16°) and ultra-high (UHR=1/100°) spatial resolution, representative of night SST values (00:00 UTC). The L3S data are produced selecting only the highest quality input data from input L2P images within a short temporal window (local nightime), to avoid diurnal cycle and cloud contamination. Consequently, the L3S processing is run daily, but L3S files are produced only if valid SST measurements are present on the area considered. The L4 data correspond to daily gridded optimally interpolated satellite estimates of the SST over the Mediterranean Sea, at high (HR=1/16°) and ultra-high (UHR=1/100°) spatial resolution, representative of night SST values (00:00 UTC). L4 data are produced daily and reprocessed after one month to guarantee the maximum quality in the archived datasets (using a symmetrical temporal window in the interpolation algorithm). If no L3S data for the same day are present, the L4 is produced combining a first guess field with available L3S data from previous days.

Sentinel-3 mission will mainly used in order to study the sea surface topography, sea and land surface temperature, and ocean and land surface colour with high accuracy and reliability to support ocean forecasting systems, environmental monitoring and climate monitoring. The Sentinel-3 satellite carries multiple instruments to measure sea-surface topography, sea- and land-surface temperature, and ocean- and land-surface colour. Level 2 refers to derived geophysical variables. This will have required processing to remove the atmospheric component of the signal, as well as the application of algorithms to measurements to generate other products. The timeframe of the delivery of products can be near real-time (NRT) which delivered less than 3 hours after data acquisition, slow time critical (STC) which delivered within 48 hours after data acquisition and non-time critical (NTC) which typically delivered within 1 month after data acquisition. Level-2 (L2) data products will be generated using the Sentinel Application Platform (SNAP) and programming tools.

The instrument responsible for taking sea (and land) surface temperature measurements on Sentinel-3 is the Sea and Land Surface Temperature Radiometer (SLSTR). The SLSTR products (Level-1B and Level-2 measurement, annotation and auxiliary datasets) will be generated separately in two instrument views and at two resolutions, depending on optical channels: 500 m resolution for solar reflectance bands and 1 km resolution for thermal infrared bands.

The Sentinel-3 Ocean and Land Colour Instrument (OLCI) is a programmable, medium-spectral resolution, imaging spectrometer operating in the solar reflective spectral range (400 nm to 1 040nm). The OLCI instrument measures reflected solar radiation from the Earth's surface and clouds simultaneously in 21 spectral bands. OLCI products are available at two spatial resolutions: full Resolution (FR) at approximately 300 m and reduced resolution (RR) at approximately 1.2 km. The OLCI products Level-2 water product provides water and atmospheric geophysical parameters computed for full and reduced resolution. Each product provides:

- water-leaving reflectance (Rxxx) for all bands except those dedicated to measurement of atmospheric gas.

- ocean colour products such as algal pigment (*chl_oc4me* and *chl_nn*, in two separated files), total suspended matter (*TSM_NN*) concentrations and transparency characterisation based on the diffuse attenuation coefficient (*KD490_M07*).
- neural network water-inherent optical properties such as coloured dissolved material (CDM) absorption (*ADG_443_NN*).
- atmosphere by-products such as photosynthetically active radiation (PAR), aerosol optical depth /aerosol angstrom exponent (gathered in one file and noted respectively as T865 and A865) and integrated water vapour (IWV) column.

The main Sentinel-3 Radar Altimetry (SRAL) products are the sea surface height, the significant wave height and the wind speed at the sea surface. The main application of the Sentinel-3 topography mission is the study of ocean topography including mean sea level, wave height, wind speed over the surface, sea-ice, ocean currents, Kelvin and Rossby waves, eddies and tides. In the Sentinel-3 SRAL mission, there are two main modes of operation: high resolution mode commonly called synthetic aperture radar (SAR) and low resolution mode (LRM). The SRAL mission is always operated at high resolution mode. Low resolution mode is back-up mode only. A Level-2 SRAL/MWR complete product contains three data files: a "reduced" (Red) data file, containing a subset of the main 1 Hz Ku band parameters, a "standard" (Std) data file containing the standard 1 Hz and 20 Hz Ku and C-band parameters and an "enhanced" (Enh) data file containing the standard 1 Hz and 20 Hz Ku and C-band parameters, the waveforms and the associated parameters necessary to reprocess the data (at least in LRM mode).

The Ocean Colour Climate Change Initiative OC-CCI project is providing ocean colour essential climate variable (ECV) data, with a focus on case 1 waters, which can be used, for example, in climate change prediction and assessment models. OC-CCI aims to produce the highest quality data, perhaps not containing the very latest data, which may be adjusted in the light of recalibration or assessment. According to the product user guide Ocean Colour Climate Change Initiative (OC_CCI) (2017),the basic input data are typically calibrated level 1 or level 2, so OC-CCI is ultimately dependent on the controlling agency for the quality of the radiometric and spectral calibration, and does the best possible with that limitation. The dataset is created by band-shifting and bias-correcting MERIS, MODIS and VIIRS data to match SeaWiFS data, merging the datasets and computing per-pixel uncertainty estimates. The physical variables that exist in OC-CCI are: Remote sensing reflectance, Chlorophyll-a, estimated using a blended combination of OC3, OCI (OC4+CI) and OC5 algorithms, QAA total absorption, QAA absorption due to detrital and dissolved matter, QAA backscatter due to particulate matter, attenuation coefficient and water class memberships. Chlorophyll-a in the OC-CCI products has units of mg m^{-3}, and is provided as daily products with a horizontal resolution of ~4 km/pixel. Furthermore, the root-mean-square (RMS) uncertainty and the bias in the log10 chlorophyll-a concentration are provided, based on comparison with match-up in-situ data. The OC-CCI products also include daily composites of remote-sensing reflectance (Rrs) at the sea surface, at a resolution of ~4 km/pixel. R_{rs} values are provided for the standard SeaWiFS wavelengths (412, 443, 490, 510, 555, 670nm) with pixel-by-pixel uncertainty estimates for each wavelength. The attenuation coefficient at 490nm for downwelling irradiance, which is an apparent optical property, is one of the OC-CCI products. It is provided at daily resolution and spatial resolution of ~4 km/pixel. The OC-CCI product includes inherent optical properties (IOP) with resolution of ~4 km: the total absorption and particle backscattering coefficients, and, additionally, the fraction of detrital & dissolved organic matter absorption (adg) and phytoplankton absorption (aph). The backscattering coefficient reported is particle backscattering (bbp), and does not include the contribution to total backscattering from water. Uncertainty estimates (RMSD and bias) are reported for the components of absorption (aph and adg) but not for a_{tot} or bbp. Sentinel-3 mission will mainly used in order to study the sea surface topography, sea and land surface temperature, and ocean and land surface colour with high accuracy and reliability to support ocean forecasting systems, environmental monitoring and climate monitoring. The Sentinel-3 satellite carries multiple instruments to measure sea-surface topography, sea- and land-surface temperature, and ocean- and land-surface colour. Level 2 refers to derived geophysical variables. This will have required processing to remove the atmospheric component of the signal, as well as the application of algorithms to measurements to generate other products. The timeframe of the delivery of products can be near real-time (NRT) which delivered less than 3 hours after data acquisition, slow time critical (STC) which delivered within 48 hours after data acquisition and non-time critical (NTC) which typically delivered within 1 month after data acquisition. Level-2 (L2) data products will be generated using the Sentinel Application Platform (SNAP) and programming tools.

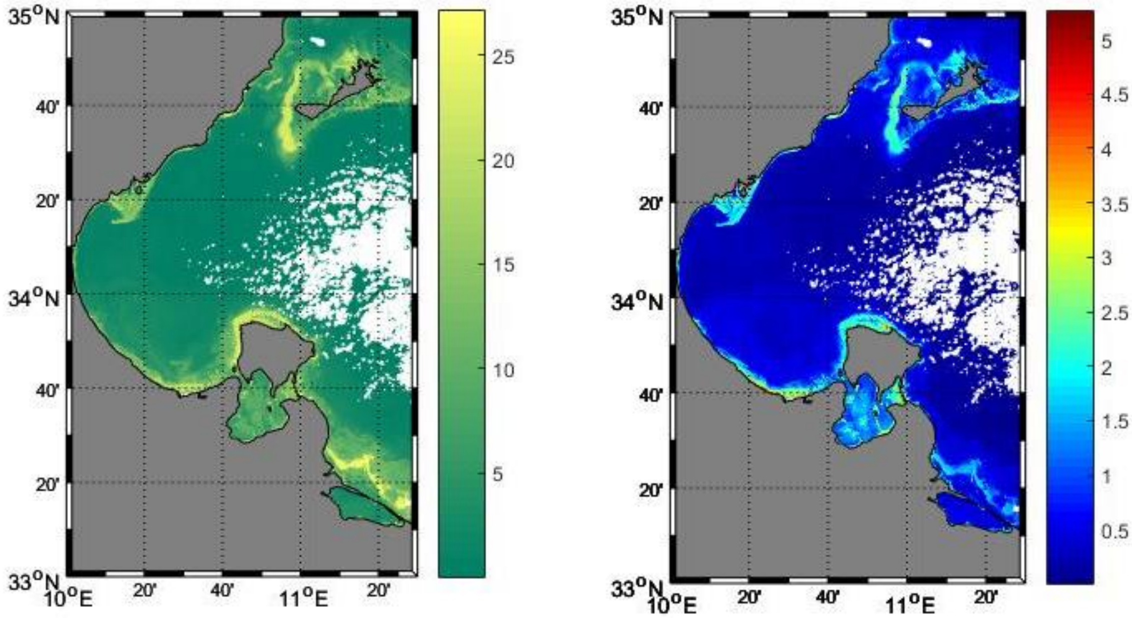

Figure 6. Chlorophyll-a (in µg/l) distribution (left panel) and CDOM (in µM) distribution (right panel) over Gabes Gulf using Sentinel 3 Level 2 data.

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6 ODYSSEA Observatory Data Quality Control

Data post-processing collected by gliders, MSLs and surface platforms will follow and apply the main procedures for Quality Control proposed by SeaDataNet and adopted by CMEMS IN SITU TAC. These processes will ensure common standards, consistency and reliability of data to be distributed among existing platforms and data providers, as well as to external end-users.

Data Quality Control procedures will allow:

- the detection of missing data;
- the detection of errors made during the transfer or re-formatting;
- the detection of duplicates;
- the detection of outliers (spikes, out of scale data, vertical instabilities, etc.); and
- the assignment of a quality flag to each numerical value in order not to characterize the observed data points.

Initial real time quality control (RTQC) in ODYSSEA will consist of:

- A series of automatic checks will be performed on raw data: date and time, position, and range checks.
- Date and time of an observation will be valid when:
  - Year 4 digits – this can be tuned according to the data
  - Month between 1 and 12
  - Day in range expected for month
  - Hour between 0 and 23
  - Minute between 0 and 59
- Latitude and longitude values will be valid when:
  - Latitude in range -90 to 90
  - Longitude in range -180 to 180
- Position must not be on land to be valid:
  - Observation latitude and longitude located in ocean
- Regional range test should satisfy that:
  - Observed parameter values are within the expected extremes encountered in particular regions.

Detailed analysis of RTQC per platform based on SeaDataNet recommendations and CMES procedures is provided at Appendix 1.

Scientific RTQC in ODYSSEA will consist of:

- Checks on raw file header details (check for header file test in Table 1 of Appendix 1),
- Ensure station/glider positions not on land (check for position on land test in Table 1 of Appendix 1),
- Automatic range checking for each parameter (check for parameter range test in Table 1 of Appendix 1),

- Check units supplied for each parameter (check for parameter units test in Table 1 of Appendix 1),
- Check no data points below bottom depth on glider data (check Minmax test in Table 1 of Appendix 1),
- Check for spikes in time-series data collected by MSLs and surface platforms (check for spikes test in Table 1 of Appendix 1),
- Check for spikes in glider data (check for spikes test in Table 1 of Appendix 1),
- Check for duplicates (check duplicates profiles/data test in Table 1 of Appendix 1).

Checks for data collected by biogeochemical sensors will follow the RTQC myOcean Manual (Jaccard et al., 2012). Such tests refer to DO, CDOM and Chl-*a* sensors and include the biofouling detection test, the parameter relationship test, the DO vs Chl-*a* data test, the T/S vs fluorescence test and the day/night test.

More details on biogeochemical RTQC is provided in Table 3 of Appendix 1.

Quality flagging will take place based on the standards introduced by SeaDataNet (L201) and followed by Copernicus INSITU TAC, as:

Quality Code	Meaning	Comment
0	**No QC was performed**	**Data should not be used without a quality control made by the user**
1	**Good data**	**All real-time QC tests passed**
2	**Probably good data**	**These data should be used with caution**
3	**Bad data that are potentially correctable**	**These data are not to be used without scientific correction**
4	**Bad data**	**Data have failed one or more of the tests**
5	**Value changed**	**Data may be recovered after transmission error**
6	**Below detection limit**	
7	**In excess of quoted value**	
8	**Interpolated value**	**Missing data may be interpolated from neighboring data in space or time**

9	**Missing value**	
A	**Incomplete Information**	

7 ODYSSEA Observatory Filling Data Gaps Process

Data collected by glider, MSLs and surface platforms at ODYSSEA Observatories will be related to CMEMS data reported for adjacent cells. Using data during the recording period, a linear (or multi-linear) regression model will relate observations collected at specific locations (end-user facilities) and adjacent CMEMS cells, for the same parameter. This regression model will be utilized to fill data gaps in periods platform sensors (on gliders, MSLs, surface systems) malfunction and/or regular maintenance and servicing takes place. Such procedure has been proposed by McPhaden and McCarty (1992) to fill in ADCP data gaps.

8 Glider data post-processing

8.1 Post-processing on Payload 1 – CTD, Chl-a and bio-optics

Major challenges for gliders include sensor validation and collected data interpretation. In ODYSSEA there will be three levels in glider data processing:

- Level 0, storage of exactly the same data as produced by the glider (raw data).
- Level 1, contains the processed glider data through the following procedures: quality checks and flagging (as described above), dividing data into transects along glider's trajectory, correction/interpolation of geographic coordinates, unit conversion, secondary parameters derivation (e.g., salinity based on conductivity, density based on temperature, salinity, pressure, speed of sound based on temperature, etc.), data filtering and correction.
- Level 2, contains data post-processed below level 1 to derive vertical profiles, and gridded data presented as (x-z) transects.

Initial Level 2 data post-processing includes the extraction of relations among the collected parameters, the derivation of flow and hydrographic structures and fields, as well as data inter-relations with observations collected by satellites and numerical models results.

Further analysis of the above-described CTD, DO and Chl-*a* glider data aims to examine physical/biological, physical/bio-optical and physical/particle interactions through the various levels of data processing.

The ODYSSEA data processing levels for glider data are described in detail below:

- Level 0 contains glider raw data converted from binary to netCDF files, without any additional processing; all data samples are the glider sensors measurements collected during the mission (errors included) stored in the form of time-series. These files represent the source for all the following processing steps. Variables names will be the same stored in the glider; a standard name is added as variable's attribute whenever is available. These glider data will be stored at the local Observatory system and transferred to ODYSSEA platform.
- The standard glider files names are in the following format:
  File Name: seaSSS.M.pld1.raw.Y.gz

  where: seaSSS represents the vehicle identification number (ex: sea007, sea015 …); M is the mission number (ex: 1, 34, 403); Y is the YO number (ex: 1, 23, 654).

  Inside the file, the first line explains the data present at each column:

  e.g., PLD_REALTIMECLOCK represents the GPS real time synchronized at each surfacing (in dd/mm/yyyy hh:mm:ss.sss);

  NAV_RESOURCE represents the navigation state (from glider) ex: 115 for surfacing, 116 transmitting, 110 inflecting down, 100 going down, 118 inflecting up, 117 going up;

  NAV_LONGITUDE and NAV_LATITUDE represent the fact that new values are not collected when the glider is underwater (in Degrees minutes decimals);

  NAV_DEPTH represents the depth the glider operates (in dbar);

  FLBBCD_CHL_COUNT represents the Raw Chlorophyll (in counts);

  FLBBCD_CHL_SCALED represents the scaled Chlorophyll (in ug/l);

  FLBBCD_BB_700_COUNT represents the raw backscattering (in counts);

  FLBBCD_BB_700_SCALED represents the scaled backscattering (in m-1/sr-1);

  FLBBCD_CDOM_COUNT represents the raw CDOM (in counts);

  FLBBCD_CDOM_SCALED represents the scaled CDOM (in ug/l);

  GPCTD_CONDUCTIVITY represents the water Conductivity (in mS/m);

  GPCTD_TEMPERATURE represents the water temperature (in °C);

  GPCTD_PRESSURE the barometric pressure above the glider (in dBar);

  GPCTD_DOF represents the sampling frequency (in Hz).

- For the generation of Level 1 data, the following analysis will take place:
  - Initial data cleaning for the removal of outliers and any error measurements. QC/QA procedures will be applied on data through a sequence of range tests, gradient tests, spike tests and stationary tests.

- Interpolation of reference coordinates (in time and position will be made) to extract the projected trajectories between points of geolocation.
- General sensor processing and sensor lag and thermal lag corrections (if needed) will be carried out.
- Calculation of water salinity based on conductivity, pressure and temperature data, using standard methods.
- Calculation of water potential density based on salinity, temperature and pressure.
- Calculation of speed of sound based on water temperature.
- The WET Labs FlbbCD provides algorithms to convert raw counts to chlorophyll (in mg/m^3).
- Raw time series of temperature, conductivity, pressure, and chlorophyll fluorescence collected on the descending legs of each dive will be processed with **a low-pass filter or a three-point median filter** to remove the noise from signal and reject obvious outliers.
- Time shift-to-alignment for all collected variables will be carried out, as the response time per sensor varies.
- Backscatter measurements will be obtained from the glider at an angle of 117 degrees. This angle allows the implementation of a volume - scattering function to **estimate the backscatter coefficient** through the spectral slope γ, as suggested by Boss and Pegau (2001). The derivation of γ refers to the linear regression between log(λ) and log(b_{bp}(λ)) at λ = 550 nm and 880 nm, respectively. This index characterizes the slope of the particle size distribution for particles with diameter lower than 10 µm (Loisel et al., 2006).

PLD_REALTIMECLOCK	NAV_RESOURCE	NAV_LONGITUDE	NAV_LATITUDE	NAV_DEPTH	FLBBCD_CHL_COUNT	FLBBCD_CHL_SCALED	FLBBCD_BB_700_COUNT
26/06/2017 13:41:09.944	117	640.062	4.307.333	8.845			
26/06/2017 13:41:10.118	117	640.062	4.307.333	8.845	53	0.0968	101
26/06/2017 13:41:10.319	117	640.062	4.307.333	8.845	51	0.0726	97
26/06/2017 13:41:11.118	117	640.062	4.307.333	8.845			
26/06/2017 13:41:11.450	117	640.062	4.307.333	8.845	50	0.0605	101
26/06/2017 13:41:12.119	117	640.062	4.307.333	8.845			
26/06/2017 13:41:12.569	117	640.062	4.307.333	8.845	52	0.0847	93
26/06/2017 13:41:13.118	117	640.062	4.307.333	8.845			
26/06/2017 13:41:13.698	117	640.062	4.307.333	8.845	50	0.0605	100
26/06/2017 13:41:13.990	110	640.062	4.307.333	8.675			
26/06/2017 13:41:14.119	110	640.062	4.307.333	8.675			
26/06/2017 13:41:14.819	110	640.062	4.307.333	8.675	55	0.1210	97
26/06/2017 13:41:15.119	110	640.062	4.307.333	8.675			
26/06/2017 13:41:15.940	110	640.062	4.307.333	8.675	49	0.0484	112
26/06/2017 13:41:16.118	110	640.062	4.307.333	8.675			
26/06/2017 13:41:17.069	110	640.062	4.307.333	8.675	47	0.0242	99
26/06/2017 13:41:17.119	110	640.062	4.307.333	8.675			

Figure 7. Glider sample data at level 1.

- At Level 2, the following analysis will take place:
  - Interpolation/binning of Level 1 data will be implemented to reach a unique long/lat pair for each profile.
  - Using the change in pressure, recorded by the CTD sensor, quasi-vertical profiles will be derived from glider data. Each profile will be represented by the median time and its

geographic position (as recorded by GPS). These resulting profiles may be **treated as ship-born CTDs**.

- Using these consecutive profiles **transects (x-z)** for all collected parameters along the glider trajectories will be drawn.
- The actual 3-dimensional vehicle trajectory analysis, **revealing indirectly the structure of local currents**. Especially, between one surfacing and the next, a comparison of the dead-reckoned displacement with the GPS-measured distance traveled over ground may yield an estimate of the current velocity averaged temporally over the interval between surfacings and vertically over the depth of the dives. These the "dead-reckoned" currents derived indirectly by combining the pre- and post-dive latitude and longitude of the glider, along with glider pitch, heading, and vertical velocity data (Davis et al., 2003). In shallow water this measurement is usually sufficient to describe the general characteristics of the background circulation. In deeper water it enables computation of absolute (i.e., unambiguous with respect to a reference layer) geostrophic velocity profiles (Hodges and Fratantoni, 2009). The largest source of error following this method for currents calculation is the calibration of the glider compass. Error estimation and "dead-reckoned" currents data will be assessed using data from nearby ADCP stations.

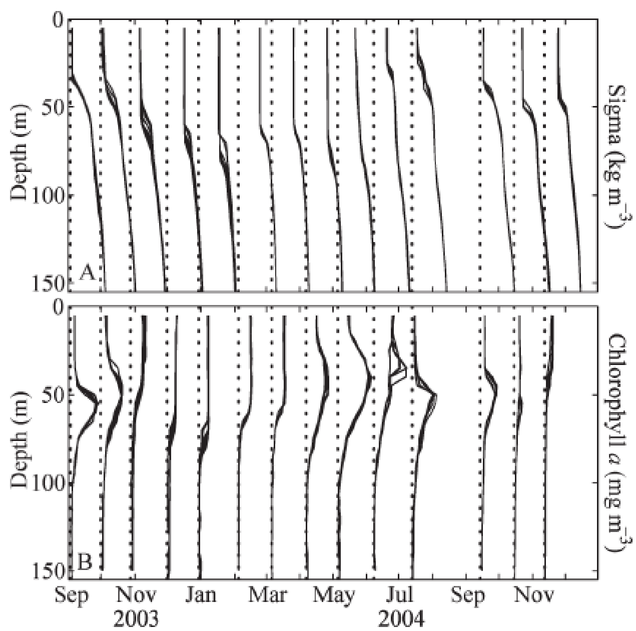

Figure 8. Temporal change in the profiles of a) sigma-density and b) Chl-*a* as derived from long-term glider monitoring (after Perry et al., 2008).

Data post-processing on Level 2 glider data will include:

- **Extraction of typical monthly-mean and monthly-median profiles** for each collected parameter, derived from data collected during long–term deployments. Such analysis could be used to identify the variability at seasonal and inter-annual level. Monthly median profiles will be created by firstly binning profile data from each descent-ascent pair into 10 m bins. The analysis will produce at each position a single, smoothed profile at 5 m depth resolution. From this collection of profiles, the monthly median values along the water column will be computed.
- From the set of typical monthly-mean and monthly-median profiles, a set of time-depth profiles will be created. From the temporal change of these profiles and the location of the maximum vertical gradient in water density, **the depth of the pycnocline can be estimated.**
- Time-depth plots of median profiles for water temperature, salinity, density, dissolved oxygen, Chl-a and particulate optical backscatter coefficients will be developed along each transect from surface to bottom.
- T-S plots and x-z transects for each individual parameter will be developed to **visualize their patterns and derive the hydrographic characteristics of water masses at each depth level.**
- **Secondary parameters,** as the potential energy anomaly (ϕ, J/m^3) and Brund-Vaisala frequency (BFV, s^{-1}) to assess water column mixing/stratification conditions will be employed. Particle size distribution will be assessed through the spectral slope γ.
- **The standard ODV software** will be used for derivation, interpolation and visualization of the above data. The file format chosen to store glider data is NetCDF, a widely used format within the oceanographic community.

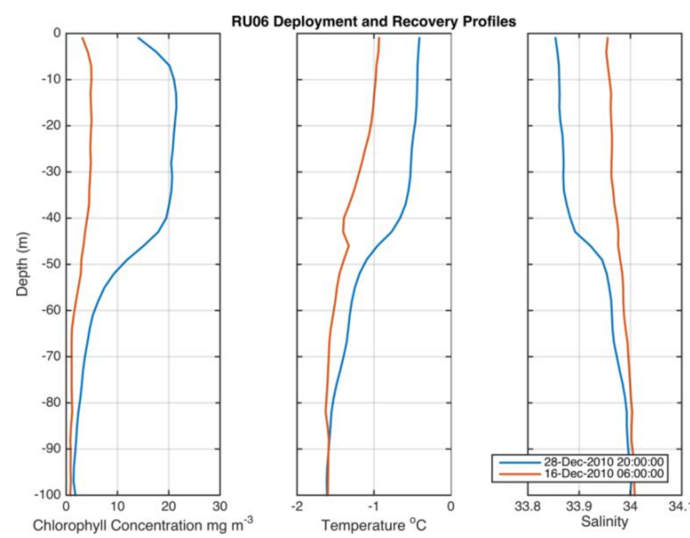

Figure 9. Depth deployment and recovery profiles of chlorophyll fluorescence, temperature, and salinity recorded by glider.

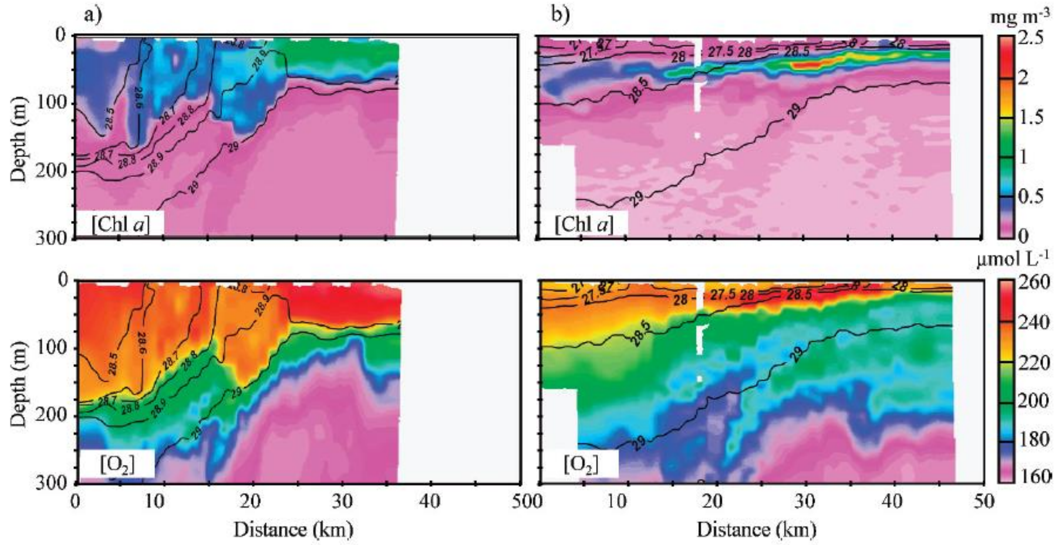

Figure 10. Chl-a concentration and DO content glider data along its transect (after Niewiadomska et al., 2008).

Interrelation of Level 2 glider data with other observations and model results will include:

- **Glider data will be related to satellite data** (e.g., Satellite altimetry from TOPEX-POSEIDON, SST from MODIS-Aqua and Chl-*a* from SeaWiFS) collected for the same period and area as the glider. Mesoscale features as eddies and frontal zones may be revealed by this analysis. Sea glider data averaged over the first 10 m depth will be compared to SST and Chl-*a* satellite-derived data. Linear correlation models will be applied to assess the strength and statistical significance between Sea Glider and satellite-derived Chl-*a* data.
- **The mixed-layer depth (MLD),** defined as the deepest depth where density-increase with respect to the surface value remains less than 0.03 kg m^{-3} will be determined for each glider profile. In case the density increase from the surface reference to the deepest sampled by the glider depth remains below 0.03 kg m^{-3}, then the MLD is considered to be deeper than this depth.
- **The euphotic layer depth (ELD)** will be derived, based on Chl-*a* profiles using the relationship proposed by Morel and Berthon (1989) and extended by Morel and Maritonera (2001).
- The **pycnocline presence and strength** (based on density gradient recorded by the glider) will be reported and associated to Chl-*a* and particulate backscatter.
- Spring and summer stratification is a key parameter to eutrophication and the analysis may lead to **pre-bloom and bloom processes understanding and forecasting**. Autumn pycnocline erosion may also lead to sub-surface Chl-*a* maximum (Deep Chlorophyll Maximum, DCM). CDOM and Chl-*a* relations will be tested.

- MLD and DCM values will be correlated to extract patterns of spatial and temporal variability.

Further, glider data will be combined to results from numerical models (ODYSSEA high resolution local/regional models) and CMEMS prognostic fields:

- Physical/biological and bio-optical analysis and Physical/particles study will involve the impact of local currents, waves, tidal oscillations and meso-scale features prevailing in the area the glider operates. Physical forcing may explain the phytoplankton and suspended particles distribution in the water column and within the horizontal plane.
- Chl-*a* time-series using potential density as vertical coordinate rather than depth may reveal the diurnal isopycnal heaving taking place within the water column.
- Anomalies and fluctuations as micro-structures and filament structures detected in the temperature, salinity, DO, CDOM, Chl-*a* etc. fields will be revealed.
- Differences in day-night Chl-*a* concentration changes will be examined to understand the phytoplankton diel cycle. This is apparent as Chl-*a* concentration increases in daylight hours due to phytoplankton growth, while decreases in the night due to grazing, respiration and natural death.
- Combining temperature and Chl-*a* glider data with PAR data obtained from the CMEMS data (satellite observations and numerical models forecasts) **the marine primary production (PP, in g C m^{-2} d^{-1}) will be estimated and forecasted**.

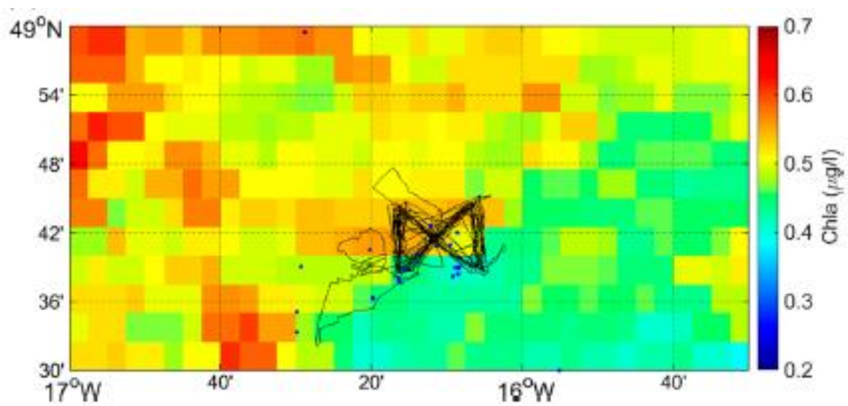

Figure 9. Modis aqua chlorophyll map showing location of study site and track of glider (black line, after Hemsley et al., 2015).

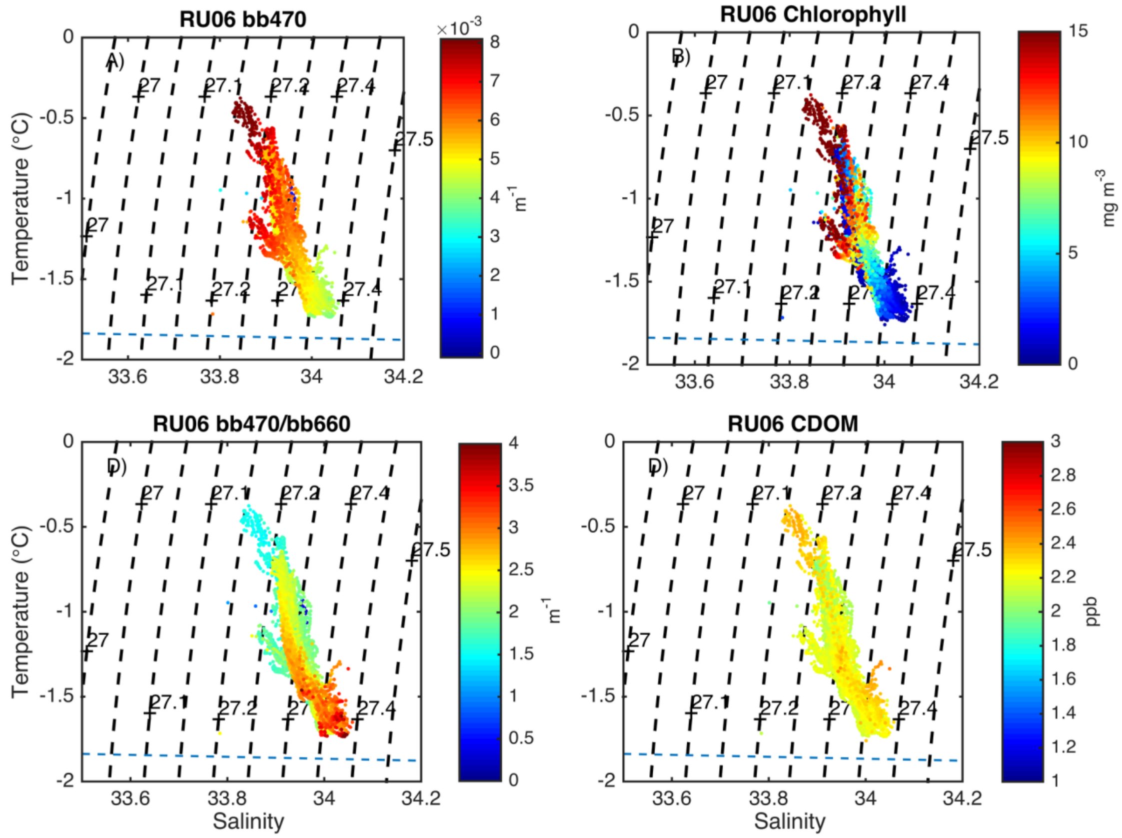

Figure 10. Bio-optical properties in temperature-salinity space (after Schofield et al., 2015).

8.2 Post-processing on Payload 2 – Passive Acoustic Monitoring

PAM analysis marine mammal assessment will aim to:

1. echolocate marine mammals and report on their presence and data to the relevant ODYSSEA Observatory;
2. estimate marine mammals' species, density and size, based on the Inter-Pulse Interval (IPI);

Since sound propagates efficiently in water, the detection range of marine mammals' signals can be quite large, exceeding 100 km in favorable conditions for low-frequency calls. After glider recovery collected echosounder signals will be post-processed as follows:

1. Data will be screened by experienced ODYSSEA acoustic data analysts (AUTH scientific team).
2. The real-time echolocation will be verified using specialized software (Matlab routines). Marine mammals' densities at specific time periods and areas of the monitored Observatories will be assessed.

Alseamar's underwater acoustic sensor for passive acoustic monitoring will be mounted on the SeaExplorer at selected Observatories. The acoustic sensor will record echolocation clicks (to include non-whistling animals, e.g. *Phocoena phocoena*) and save them in databases. Preprocessing of the data will include high-pass filtering to eliminate low frequency noise, e.g. due to engine noise.

The static hydrophone mounted on the Seafloor Lander at each Observatory will record echolocation clicks and burst pulses from odontocetes. Echolocation clicks of odontocetes will be studied via a spectrographic analyser and interclick interval measurements to differentiate them from burst pulses. Appropriate sound analysis software will be used for displaying and quantifying spectral and temporal aspects of recorded sounds (e.g. Avisoft-SASLab Pro, PAMGuard software) (Bailey et al. 2010; Gillespie et al. 2008. We will extract information such as the number of clicks likely to come from odontocetes, the average click rate (the number of positive clicks divided by the total recording time), the click intensity (the mean number of positive clicks during minutes with clicks) (Au & Hastings 2008). The techniques incorporated to examine time- and frequency- domain characteristics will be linear prediction coding (LPC) and fast Fourier Transform (FFT). The degree of correct identification of sound on species level will depend on the species present in the study area.

8.3 Post-processing on Payload 3 – Micro-plastics

This glider payload will be equipped with the newly developed micro-plastics sensor, capable to detect suspended plastic particles along gliders transect. Micro-plastic particles consist of polyethylene, polystyrene, polypropylene or polyamide particles with diameters in the range of 0.5–5 mm.

The developed by LEITAT within ODYSSEA project micro-plastics sensor consist of an optical transducer, allowing imaging acquisition using excitation sources (UV light) and a control board, including processor for data acquisition, processing and conversion to transmission format. System operation involves the flow of water, as the glider moves, through a transparent channel to the optical sensor. A dedicated electronic control board will be developed responsible for data storage, data formatting, data transmission and communication with the glider to allow data integration with the rest of the sensors.

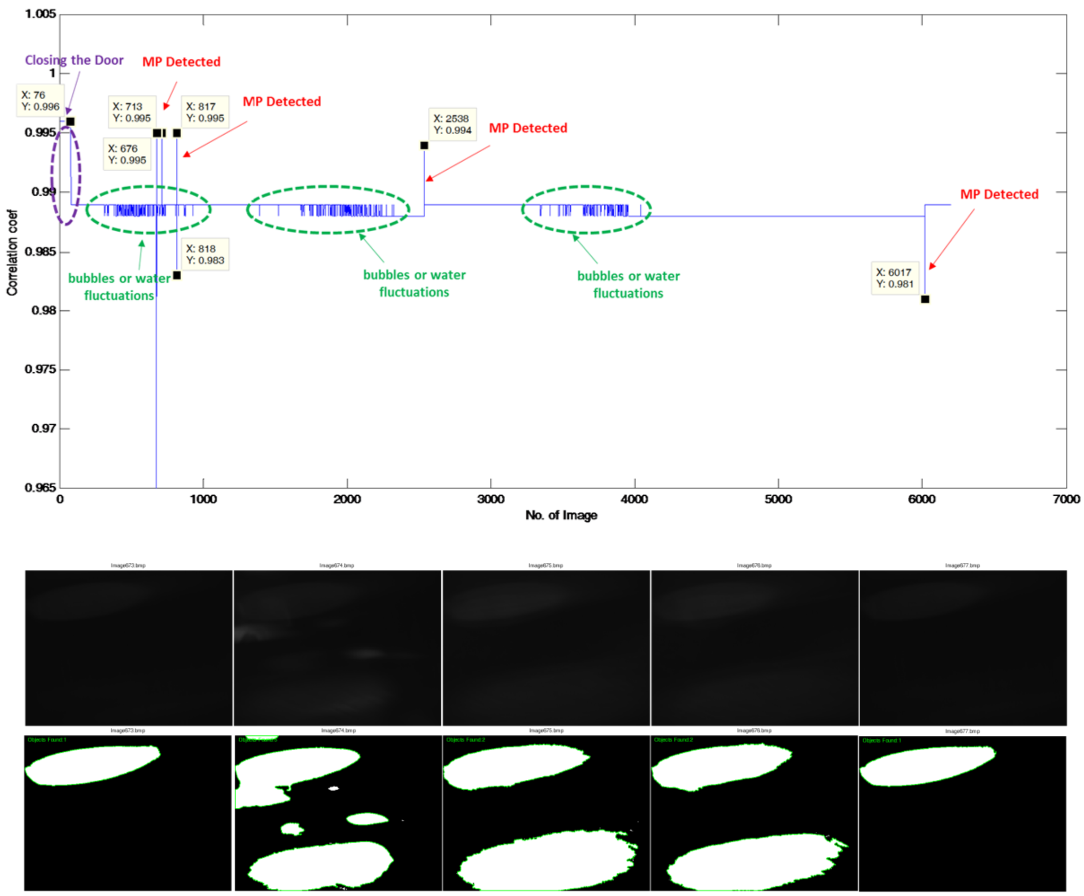

Figure 11. Detected microplastic particles (Real image—up /Processed image—below).

Reported data refer to micro-plastics concentration in the water column (in mg/l) with a rate of a few minutes, depending on the memory and energy requirements of the system.

Sensor data will be post-processed in the dedicated electronic board before their transmission to land-based station. Additional processing will be needed to join sensor data with other inputs like: GPS coordinates, time stamp, water temperature, etc.

9 MSL and Surface Platforms Data Post-processing

MSLs and Surface Platforms will collect oceanographic data in the form of time-series; therefore, parameters measured over time at regular time-intervals. The following post-processing will take place on standard oceanographic variables (temperature, conductivity, pressure, dissolved oxygen, chlorophyll-a, etc.):

- Level 0, storage of raw data as produced by the MSLs and surface platforms. These data will be stored at local Observatory level and then transferred to ODYSSEA platform.
- Level 1, contains the processed time-series data for quality flagging, quality checks and quality control (as previously described). ODYSSEA will follow and apply all automatic quality controls that have been applied by the CMEMS INSITU TAC level. Visual inspection of time-series data will also take place to detect anomalous values, mostly spikes. These procedures are defined by parameter, elaborated in coherence with international agreements, as the SeaDataNet, and documented in the CMEMS Catalogue. Other procedures include the unit conversion and data filtering and correction.
- Level 2, contains data post-processed below level 1 to derive secondary parameters (e.g., salinity based on conductivity, density based on temperature, salinity, pressure, speed of sound based on temperature, etc.).

Data post-processing on Level 2 MSL and surface time-series data will include:

- **Extraction of typical weakly-mean, monthly-mean and annual-mean data** for each collected parameter, derived from data collected during long–term deployments. Such analysis could be used to identify the variability at seasonal and inter-annual level and identify hidden trends. Level 2 time-series may be filtered and smoothed to omit noise and meaningless fluctuations. Fourier and harmonic analysis on these series may show the cyclic influence of external factors (e.g., tides).
- Time-depth plots of water temperature, salinity, density, dissolved oxygen, Chl-a and currents will be developed at each location.
- T-S plots and Chl-*a* - DO plots will be developed to **visualize their patterns and derive the hydrographic characteristics of water masses at each time interval.**
- **Secondary oceanographic parameters** will be employed.

The standard ODV software will be used for derivation, interpolation and visualization of the above data. The file format chosen to store MSL and surface platforms' data is NetCDF, a widely used format within the oceanographic community.

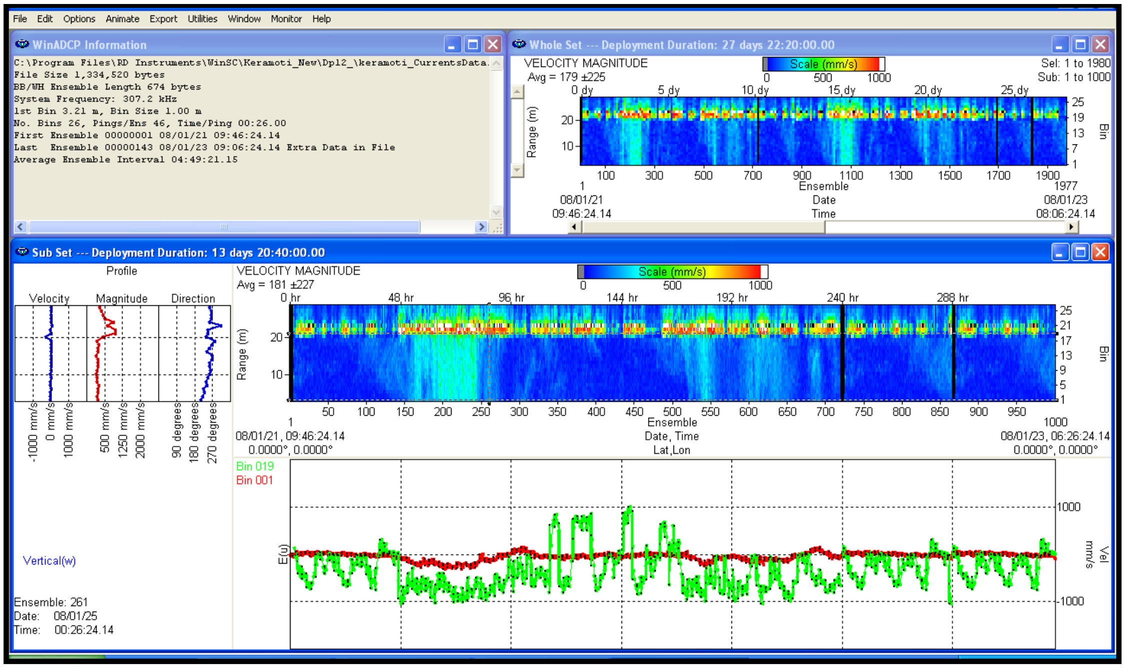

Figure 12. ADCP current data plotted as time-series.

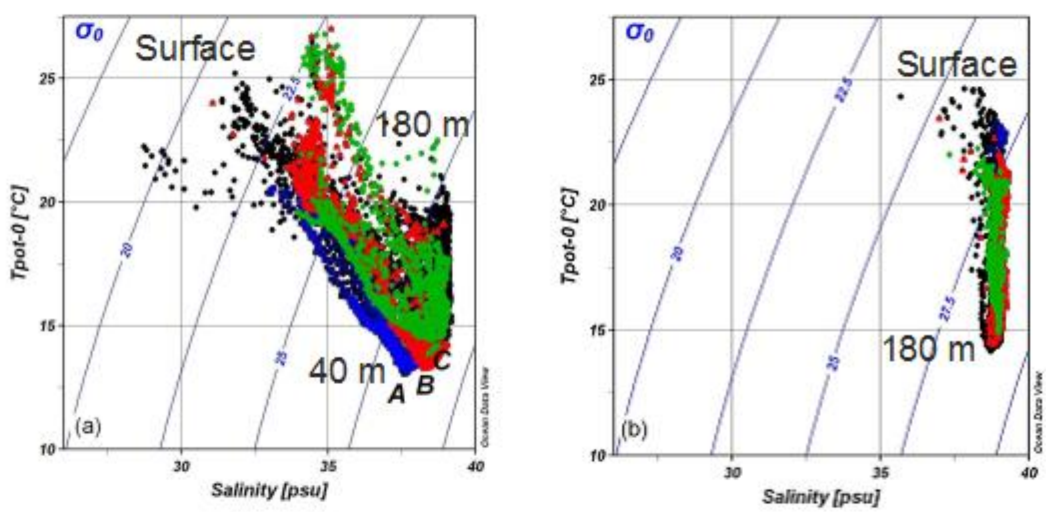

Figure 13. T/S plots from profiled data.

Interrelation of Level 2 MSL and surface platform data with other observations and model results will include:

- **MSL and surface platform data related to satellite data** (e.g., SST from MODIS-Aqua and Chl-*a* from SeaWiFS) collected for the same period and area as the platform. Mesoscale

features as eddies and frontal zones may be revealed by this analysis. Linear correlation models will be applied to assess the strength and statistical significance between MSL and satellite-derived SST and Chl-*a* data.
- **Pre-blooming and blooming processes understanding and forecasting**. CDOM, DO and Chl-*a* relations will be tested.

Further, MSL and surface platforms data will be combined to results from numerical models (ODYSSEA high resolution local/regional models) and CMEMS prognostic fields:

- Physical/biological and bio-optical analysis and Physical/particles study will involve the impact of local currents, waves, tidal oscillations and meso-scale features prevailing in the area the glider operates. Physical forcing may explain the phytoplankton and suspended particles distribution at the surface in the broader area.
- Chl-*a* time-series in relation to nutrient, salinity and optical parameters time-series will be correlated to reveal hidden relations.
- Temporal anomalies and fluctuations detected in the temperature, salinity, DO, CDOM, Chl-*a* etc. fields will be revealed.
- Differences in day-night Chl-*a* concentration changes will be examined to understand the phytoplankton diel cycle. This is apparent as Chl-*a* concentration increases in daylight hours due to phytoplankton growth, while decreases in the night due to grazing, respiration and natural death.

Combining temperature and Chl-*a* MSL and surface data with PAR data obtained from the CMEMS data (satellite observations and numerical models forecasts) **the marine primary production (PP, in g C m^{-2} d^{-1}) will be estimated and forecasted**.

Special post-processing procedures will be performed at Observatory level, using the underwater cameras recording sessile benthic as well as mobile animals and assessing the structure of the local assemblages. These camera stations can be baited with crushed fish (e.g. European pilchard *Sardina pilchardus*) as it has been shown that adding bait increases the number of carnivorous fish sampled, while it does not decrease the abundance of herbivores (Cappo et al. 2003; Langlois et al. 2010). For the estimation of species richness, diversity, coverage and abundance, the fauna will be recorded and identified to the lowest possible taxonomic level with the use of quantitative photographic and video analysis along with selected in situ samplings that will enhance taxonomic precision. These methods have advantages over other common sampling procedures as they are non-destructive, fast, objective, repeatable and less laborious (Bianchi et al. 2004).

The photographic samples will be analyzed using the specialized software photoQuad which is an advanced image processing software system dedicated to ecological applications. This software has the capacity to study the sessile communities, integrating various methods for the estimation of species area, percentage coverage or presence/absence information (Trygonis & Sini 2012). The video samples will be analyzed either by performing a visual assessment of the video tracks, using Final Cut software

(Santín et al. 2017), or of images extrapolated from them every 10s in order to avoid overlaps (Bo et al. 2014). The extrapolation will be done by using DVDVideoSoft, a free internet software, and the surface of each video frame will be quantified with the ImageJ software. The researcher who will extract data from the video samples will endeavor to track unique mobile individuals and count them only once. Alternatively, if possible, automatic video analysis methods will be used to facilitate the laborious process (Spampinato et al. 2012).

Develogic's underwater acoustic sensor for passive acoustic monitoring will be mounted on the MSL at selected Observatories. The acoustic sensor will record echolocation clicks (to include non-whistling animals, e.g. *Phocoena phocoena*) and save them in databases. Preprocessing of the data will include high-pass filtering to eliminate low frequency noise, e.g. due to engine noise.

The static hydrophone mounted on the Seafloor Lander at each Observatory will record echolocation clicks and burst pulses from odontocetes. Echolocation clicks of odontocetes will be studied via a spectrographic analyser and interclick interval measurements to differentiate them from burst pulses. Appropriate sound analysis software will be used for displaying and quantifying spectral and temporal aspects of recorded sounds (e.g. Avisoft-SASLab Pro, PAMGuard software) (Bailey et al. 2010; Gillespie et al. 2008). We will extract information such as the number of clicks likely to come from odontocetes, the average click rate (the number of positive clicks divided by the total recording time), the click intensity (the mean number of positive clicks during minutes with clicks) (Au & Hastings 2008), and other useful features such as cepstral coefficients (Halkias & Ellis 2006). The techniques incorporated to examine time- and frequency- domain characteristics will be linear prediction coding (LPC) and fast Fourier Transform (FFT). The degree of correct identification of sound on species level will depend on the species present in the study area. Additionally, whenever possible using direct and surface reflection arrivals (and bottom reflection arrivals in areas with flat bottom topography) we can succeed in the localization of sounds, thus proceed in assessing the number of odontocetes present (Aubauer et al. 2000; Halkias & Ellis 2006).

10 Remote Sensing Data Post-processing

Satellites and *in situ* measurements are essential to interpret the biogeochemical processes at the ocean surface and the deeper layers. Satellites can 'see' only the upper surface layer so the combination of remote sensing data with *in situ* observations can lead to a better biogeochemical estimation of the entire water column. Glider data can be used for the study of regional and global temporal and spatial phenomena occur in the ocean. Other critical aspects of the use of glider data are the calibration and validation of remote sensing data, the improvement of the remote sensing algorithms and the validation of global biogeochemical and bio-optical models. Remote sensing and glider data information can be useful to the design of a data management system in a marine environment and can have many applications in the marine ecosystem as the detection and the monitoring of a harmful algal bloom.

The following parameters, available from remote sensing observations, are commonly used to detect the presence of algal blooms (Gordon and Clark, 1980): a) chlorophyll-a concentration (Chl-a), b) chlorophyll-a concentration anomalies (usually taken with respect to 2-3 months means, c) sea surface temperature (SST) and d) optical characteristics (absorption, backscattering). Additionally, different ocean colour remote sensing algorithms used to monitor HABs as a) reflectance classification algorithms, which derive qualitative estimates in a known marine area (Siswanto et al., 2013; Moore et al., 2012), b) reflectance band-ratio algorithms, which relate the remotely sensed water reflectance directly to surface concentrations of optically significant water constituents (empirical algorithms) (Balch et al., 2005) and c) spectral band difference algorithms, where the spectral difference quantifies the absorption feature (Hu et al., 2012; Matthews et al., 2012). Algal taxa blooms can be coccolithophores, *Trichodesmium* sp., *Sargassum* sp., dinoflagellate as *Karenia brevis* etc and can cause surface events. Many indices used to predict and monitor an algal bloom event. Fluorescence line height (FHL) is uses to determine chlorophyll-a concentration and can be described by equation 1:

$$FHL = L_F - [L_R + \frac{\lambda_R - \lambda_F}{\lambda_R - \lambda_L}(L_L - L_R)] \qquad [1]$$

where λ_F, λ_L, λ_R are respectively the central wavelength of fluorescence peak and two baseline wavelengths. L_F, L_L, L_R are respectively the radiances in fluorescence peak and two baseline bands.

The MERIS maximum chlorophyll index (MCI), measuring the radiance peak at 700-710 nm in water-leaving radiance, indicates the presence of a high surface concentration of chlorophyll *a* against a scattering background (Eq.2). The index is high in ‘red tide’ conditions (intense, visible, surface, plankton blooms) and is raised when aquatic vegetation is present.

$$MCI = L_{709} - L_{681} - 0.389(L_{753} - L_{681}) \qquad [2]$$

In Eq.2, L_{865} represents Level 1 radiances (as measured at the satellite) at a wavelength of 865 nm, and similarly for other wavelengths, and the factor 0.389 represents the wavelength ratio (709–681)/(753–681).

The Floating Algal Index (FAI) is a measure of the height of the NIR peak relative to a baseline value that is linearly interpolated from adjacent bands in the red and short wave in-frared (SWIR) wavelengths (Eq.3;Eq.4), where RRC is the Rayleigh corrected top-of-atmosphere reflectance λ(SWIR), λ(NIR), and λ(RED) are the wavelengths of the SWIR, NIR, and red bands, respectively.

$$FAI = R_{RC}(NIR) - R'_{RC}(NIR) \qquad [3]$$

$$R'_{RC}(NIR) = R_{RC}(RED) +]R_{RC}(SWIR) - R_{RC}(RED)]\frac{\lambda(NIR) - \lambda(RED)}{\lambda(SWIR) - \lambda(RED)} \qquad [4]$$

Following Wynne et al. (2010), the Cyanobacteria Index (CI) is calculated by Eq.5 and Eq.6. A positive CI is indicative of elevated densities of cyanobacteria and a high CI is associated with higher density of cyanobacteria.

$$CI = -SS(681) \qquad [5]$$

$$SS(681) = nLw(681nm) - nLw(665nm) - [nLw(709nm) - nLw(665nm)] * \frac{(681-665)}{(709-665)} \qquad [6]$$

According to Ahn & Shanmugam (2008), the red tide index (RI) is built by normalizing the deducted and combined ratio Lw(510)/Lw(555) nm with the absolute values of water-leaving radiance at 443 nm (Eq. 7). This allows a good separation of red tides from other dominant optical types. RI values vary from −1 to +1. A red tide index value of −1 means absence of harmful algal bloom (HAB) and close to +1 indicates the highest possible of HABs.

$$RI = \frac{[L_w(510)/L_w(555) - L_w(443)]}{[L_w(510)/L_w(555) + L_w(443)]} \qquad [7]$$

Amin et al. (2008, 2009a, 2009b) proposed the Red Band Difference (RBD) index and the Karenia Brevis Bloom Index (KBBI), which are specifically designed to detect *Karenia brevis*. (Amin et al., 2008). RBD and KBBI are expressed by Eq.8 and Eq.9 respectively, where the spectral region is 667-681 nm.

$$RBD = nL_w(\lambda_2) - nL_w(\lambda_1) \qquad [8]$$

$$KBBI = \frac{nL_w(\lambda_2) - nL_w(\lambda_1)}{nL_w(\lambda_2) + nL_w(\lambda_1)} \qquad [9]$$

As it is mentioned before glider optical data can be used to calibration and validation of remote sensing data.

11 Data Use for Models Calibration and Validation

Data from gliders, MSL and surface platforms will be used for the calibration of numerical models. ADCP data from MSL platforms will be used to calibrate and validate the hydrodynamic models; similarly, temperature and salinity data from gliders, MSL and surface systems will also be used for hydrodynamic models' calibration and validation. Chlorophyll-*a*, CDOM and DO data collected by gliders, MSLs and surface platforms will also be used to calibrate and validate the biogeochemical models.

A series of model calibration and validation criteria will be used, as:

a) The Root Mean Square Error (RMSE) and the Scatter Index (SI) of the modelled and observed values of each parameter. RMSE is defined as:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} \left(y_i - \hat{y}_i \right)^2}{N}} \qquad [10]$$

where y_i are the observed time-series; $\hat{y}_i$ the corresponding model values; and N is the total number of dataset. The parameter RMSE should be as close to 0.0 as possible for reliable model performance. The Scatter Index is defined as the ratio of the RMSE normalised by the mean of the observed values, expressed as:

$$SI = \frac{RMSE}{average\,observed\,value} \times 100 \qquad [11]$$

SI should be as close to 0.0 as possible.

b) The validity could also be tested through scattergrams, which are graphs of the modelled versus measured values. Best match occurs when all points fall on a 1:1 slope line. Deviation from that line is measured by fitting through the points a straight regression line of the following equation:

$$y_i = \gamma\,\hat{y}_i \qquad [12]$$

If this slope γ is less than 1.0, then the model underestimates the observed data. If the slope γ is greater than 1.0, the model overestimates the observed values. Another parameter that evaluates the accuracy of the agreement is the squared correlation coefficient R^2, which shows whether data scatter is around the best fit line. The closer R^2 is to 1.0 the less the points are scattered around the straight line. R^2 is defined as:

$$R^2 = \frac{ssr}{sst} \qquad [13]$$

where $ssr = \sum_{i=1}^{N} (\hat{y}_i - \overline{y})^2$ and $sst = \sum_{i=1}^{N} (y_i - \overline{y})^2$ where $\overline{y}$ is the mean observed value.

c) Finally, model's performance under extreme conditions could be tested using the detection rate (DR) and the false alarm rate (FAR) parameters. DR is defined as the ratio between the number of modeled episodes in which the parameter exceeds a threshold value, and the number of the observed extreme episodes, while FAR as the ratio of false alarms predicted by the model to the total number of observed episodes.

d) The standard Taylor diagram (Taylor 2001) will be used to evaluate the fidelity and robustness of ODYSSEA numerical model results. On this diagram three statistical parameters are displayed; the correlation coefficient (r), as:

$$r = \frac{\frac{1}{N}\sum_{n=1}^{N}\left(O_n - \widehat{O}\right)\left(S_n - \widehat{S}\right)}{\sigma_{O}\sigma_{S}} \quad [14]$$

the centered Root Mean Squared Difference (cRMSD), as:

$$cRMSD = \sqrt{\frac{1}{N}\sum_{n=1}^{N}\left[\left(O_n - \widehat{O}\right)\left(S_n - \widehat{S}\right)\right]^2} \quad [15]$$

and the ratio of the standard deviations of the observed and simulated data (σ_o, σ_s), where O_n and S_n represent the observed and the simulated values, respectively; Ô and Ŝ the corresponding observed and simulated mean values; and N the number of measurements.

12 Data Use for Models Assimilation

With the availability of a wide array of data sources on biogeochemical variables such as chlorophyll-a, suspended particulate matter, and water temperature amongst others, the information provided from the multi-functional monitoring module of each ODYSSEA Observatory can be used in conjunction with the modelling efforts. Remote sensing products and derived information, generally, possess a higher spatial resolution than in-situ monitoring due to the satellite's ability to cover large swaths of the globe with each of the passes over areas of interest. However, this information is generally ascribed a lower quality value than direct monitoring efforts due to the various degradations resulting from the acquisition and processing phases required to develop biogeochemical variables from the data. Therefore, while both can be used in an assimilation framework, higher reliability on the quality, accuracy, and precision of in-situ data allows this information to be weighted relatively higher than those for remote sensing when developing the covariance matrices in the Data Assimilation (DA) process.

Biogeochemical models such as Delft3D link biogeochemical variables such as phytoplankton and nutrients, light and temperature with growth functions and system dynamics. Particularly in light limited systems such as turbid waters in delta zones, it might be beneficial to give extra attention to optics, and optical properties derived from either the in-situ or remotely sensed data. This can be approached by better characterisation of the in light climate modules, and/or directly calculation of primary production by incorporating optical properties. Brewin's (2017) introduction clearly illustrates how incorporating blooms (high biomass) dynamics, and knowledge (from the models) such as spatial nutrient (e.g. Si) limitations can help to characterise primary production, and therefore stresses the crucial role that DA can play. Data assimilation can be utilized for the automated calibration of models or for state-updating. Automated calibration allows for the utilization of optimization functions through estimation and calibration methods such as Shuffled Comples Evolution (SCE), Simplex, or Conjugate Gradients, in order to find an optimal solution to parameterization problems. Through such applications, constraints can be placed on the parameters of interest as well as positive or negative correlations for multi-parameter assessments in order to ensure rational outcomes. Such methods have been widely applied and are fully explained in areas such as hydrology (Vrugt et al. 2005; Madsen, 2003; Confesor & Whittaker, 2007), hydrodynamics (Garcia et al. 2015), groundwater (Franssen & Kinzelbach, 2009), and biogeochemical models (Rose et. Al. 2007) with many papers describing the optimization functional utilized as well as shortcoming and benefits to each. Muleta (2011) explores the responsiveness of the object function to automated calibrations and describes the goodness of fit within model simulation in depth while provide methods to do so.

Alternatively, state updating is a form of data assimilation where an already calibrated model can take advantage of monitoring information in order to edge the model in the proper direction through an evaluation of the variable values given through the simulation and also the data product corresponding to the model's variable and time step. Either of two data assimilation methods, Ensemble Steady State Kalman Filter (EnSSKF) and Ensemble Kalman Filter (EnKF), can be applied to the biogeochemical model via a step-wise assimilation process of the selected ODYSSEA Observatory data products. These products include those related to chlorophyll-a concentrations, suspended solid concentrations, and light attenuation coefficients, but may vary from Observatory to Observatory. This will mostly depend on the data availability within each Observatory, with considerations on the spatial and temporal resolution of said data sets, as well as the primary objective functions of the model outputs and how such variables can relate to the automated calibration or active state updating of modelling exercises. The assimilation methodologies, EnKF and EnSSKF, can be utilized and currently exist within OpenDA1, a Data Assimilation module which is capable of connecting to a variety of models via a black-box wrapper. A pre-existing platform such as OpenDA would allow the modellers and observatory groups to take advantage of to take advantage of pre-existing coding of these assimilation methods, thereby allowing for a focus on the data assimilation component of this project rather than developing coding of existing mathematical constructs. With the collaboration of the relevant modelling team, the modelling expertise can be utilized to effectively map the variables from the data products into the modelling realm, assuring consistency between data products and modelling parameters; ensuring conservation of mass and elements. Recently, OpenDA has been successfully applied to optimise and assimilate model applications for ocean, shelf sea and inland hydrodynamics, water quality and biogeochemistry such as for example by Zijl et al. (2013, 2015); Loos et al. (2013). Besides, van Velzen et al. (2016) recently applied OpenDA to assimilate Sea Surface Height (SSH) with NEMO.

Currently, different variational and Kalman filtering approaches exist and have been widely applied to various types of hydrodynamic and biogeochemical models. We propose to start with a traditional EnKF for an easier implementation and its simplicity. Asynchronous filtering (Sakov et al., 2010) will be applied to reduce the impact on performance of the repeated initialisation, i.e. the assimilation times are decoupled from the observation times. Through the initial application of the EnKF to the model space, an enhanced covariance matrix will be developed, relating the model outputs and affiliated uncertainties. This first phase covariance matrix will then be used as an initializing element in the later optimization application where EnSSKF, which increase the efficiency of the assimilation methodology, will be explored.

[1] https://www.openda.org/

13 Post-processing on Model Results

A series of coupled numerical models will be applied at all ODYSSEA Observatories, and will be daily operated to produce analytical, high-resolution (spatial and temporal) short-term forecasts (up to next five days). More specifically:

- The meteorological model WRF will produce at each grid cell hourly data of wind speeds, wind direction, air temperature, relative humidity, total solar radiation, sensible and evaporative heat fluxes and rainfall rates;

- The hydrodynamic model Delft-3D Flow will produce at each grid cell hourly data of three-dimensional currents, sea level, water temperature, salinity, density.

- The wave model Deltf-3D Wave will produce at each grid cell hourly data of significant wave height, wave direction, period,

- The biogeochemical model Delwaq will produce at each grid point hurly data of algae, dissolved nutrients (NO_3, NH_4, PO_4, Si, TIC), electron-acceptors (SO_4, SUD), particular and detrital organic matter, dissolved oxygen, BOD, pH, Coliform bacteria, and many more added gradually in the system (e.g., inorganic suspended solids, heavy metals).

- The oil spill model MEDSLICK II will produce estimates of hypothetical oil spill dispersions based on scenarios developed by Observatory managers.

- The mussel farm model (developed by DUTH) will produce forecasted parameters on shellfish growth (length, weight) and reproduction rates based on data produced by hydrodynamic and biogeochemical data and models (water temperature, salinity, particulate matter concentration, chlorophyll-a concentration, etc.

These models will be daily run at local Observatory platforms and simulated data and forecasts will be stored at different directories and files.

Daily, a file should be developed containing all model forecasts, produced by all numerical models, and this file should then be transferred to the central ODYSSEA platform for further processing.

14 Data Post-processing for Indicators Derivation

14.1 Eutrophication Risk Indicators for environmental assessment within MSFD

Eutrophication is the result of nutrients enrichment, primarily in nitrogen and/or phosphorus compounds, entering a waterbody and modifying its 'pristine' seasonal cycle, allowing a greater annual primary production of organic material and potentially leading to the accumulation of algal biomass. Eutrophication may lead to harmful algal blooms (HABs), decrease in water transparency, elimination of seagrasses and depletion of dissolved oxygen at bottom waters. Stoichiometric changes lead to plankton species shifts (from diatoms to dinoflagellates) and dominance of small size plankton (nanoplankton) and gelatinous zooplankton. MSFD refers to the adverse effects of eutrophication including losses in biodiversity and ecosystem degradation affecting the sustainable provision of goods and services.

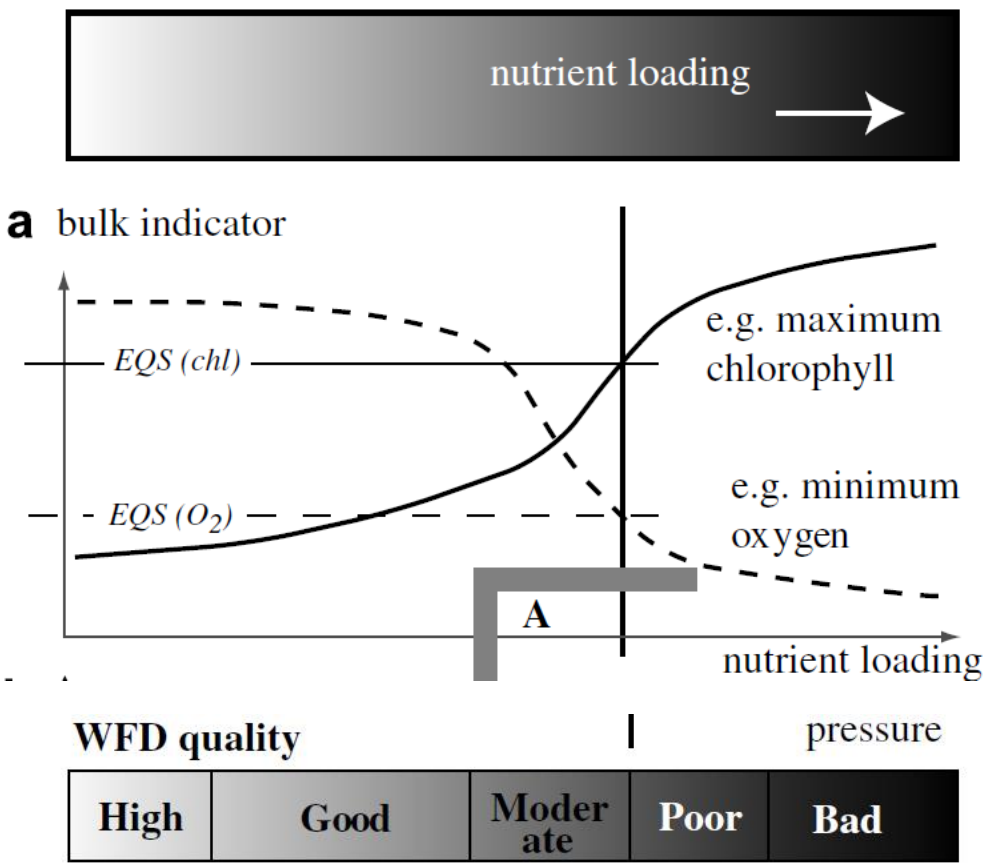

Figure 14. Identifying undesirable disturbance in the context of eutrophication (after Tett et al., 2007).

Many methods have been developed to assess eutrophication using 'secondary symptoms', as low dissolved oxygen content, submerged aquatic vegetation loss, frequent algal blooms occurrence, and indicators as TRIX (Vollenweider et al., 1998), TWQI (Giordani et al., 2009) and others. Simple indicators and their associated thresholds are:

- Winter (November-February) nitrate concentration: threshold defined as above 20 µM for coastal waters;
- Spring-summer (March-September) chlorophyll concentration: threshold defined as above 15 µg l^{-1} for coastal waters;
- Summer oxygen (May-September) concentration: threshold defined as below 5 mg l^{-1} for coastal waters.

Ferreira et al. (2011) reviewed the eutrophication assessment tools and indicators (Table 4).

Table 4. Indicators for eutrophication assessment.

Method Name	Biological indicators	Physico-chemical indicators	Nutrient load related to impairments	Integrated final rating
TRIX[b]	Chl	DO, DIN, TP	no	yes
EPA NCA Water Quality Index[a]	Chl	Water clarity, DO, DIN, DIP	no	yes
ASSETS[e]	Chl, macroalgae, seagrass, HAB	DO	yes	yes
TWQI/LWQI[c]	Chl, macroalgae, seagrass	DO, DIN, DIP	no	yes
OSPAR COMPP[g]	Chl, macroalgae, seagrass, phytoplankton indicator species	DO, TP, TN, DIN, DIP	yes	yes
WFD[f]	phytoplankton, Chl, macroalgae, benthic invertebrates, seagrass,	DO, TP, TN, DIN, DIP, water clarity	no	yes
HEAT[d]	Chl, primary production, seagrass, benthic invertebrates, HAB, macroalgae	DIN, DIP, TN, TP, DO, water clarity	no	yes
IFREMER[h]	Chl, seagrass, macrobenthos, HAB	DO water clarity, SRP, TP, TN, DIN, sediment organic matter, sediment TN, TP	no	yes
STI[i]	Chl, Primary Production	DIN, DIP	no	no

Eutrophication indicators that could be computed in ODYSSEA platform to assess the environmental state of the marine systems are shown in Table 4 of Appendix I.

Additionally, Tett et al. (2007) proposed a set of indicators that could also be used in the frame of ODYSSEA to assess the marine environmental status. These indicators are the Secchi disk depth, the water column chl-*a* concentration, the pelagic and benthic chl-*a* concentrations, the mean and maximum chl-*a* concentrations during growth season, the frequency of HABs, the mean and minimum dissolved oxygen concentration at deep water under pycnocline presence.

These indicators will be valuable for fish-farm managers, mussel-farm operators and policy-makers.

14.2 Aquaculture Sitting Indicators

Aquaculture is one of the fastest growing food-producing sectors, supplying approximately 40% of the world's fish food, expanding at an annual rate of 9% (Englehaupt, 2007). Regulations and international oversight for the aquaculture industry are extremely complex, with several agencies attempting to regulate aquaculture practices, including site selection, pollution control, water quality, feed supply, and food safety. Environmental concerns and issues related to the impacts of aquaculture on the coastal environment, especially in the vicinity of areas with touristic interest, create the need for the transfer of aquaculture activities towards more exposed offshore waters. In parallel, Myrseth (1991) reported that profits of offshore aquaculture are slightly higher than nearshore. Under these conditions the sitting and design of aquaculture farm depends highly on waves and hydrodynamics prevailing in the area.

On-site observations and numerical model results (hindcasts and reanalysis datasets) will be able to provide indicators capable to aid the design and sitting of aquaculture (fish and mussel) farms at offshore as well as at nearshore locations. Linfoot et al. (1990) explained that the cage-design factors in offshore aquaculture should consider (a) economic factors, especially operating costs; (b) biological factors, especially the minimisation of exposure to disease, stress and allowing adequate water exchange; (c) engineering factors.

Pèrez et al. (2003) presented a novel method for offshore wave climate characterization and aquaculture sitting selection. Wave time-series, expressed as the significant wave height H_S, the peak wave period T_P and the prevailing direction of wave propagation, as well as their statistical parameters, are important factors on the design and sitting of aquaculture farms. Other descriptors include the wave energy spectra and the wave directional spectra, which show the distribution of energy and wave direction as a function of wave period. Extreme wave analysis following the Probability over Threshold method (POT), the estimation of the probability distribution function and return period analysis for extreme events will be carried out. Suitability maps for fish and mussel farms based on average and extreme wave heights will be developed. All the above-discussed descriptors could be estimated based on historic results of wave numerical models (e.g., CMEMS reanalysis datasets).

Stevens et al. (2008) reviewed the criteria related to flow and wave impact on the design and sitting of offshore mussel farms. Based on these, the effective energy transfer from the combined effect of waves and currents on farm structure could be estimated. The drag forces acting on the submerged part of the aquaculture structure due to water flow impact are given by:

$$F = \frac{1}{2} C_d \rho A U^2 \quad [16]$$

where ρ is the water density, A is a measure of structure's area, C_d is the drag coefficient and U is the mean velocity. Historical data on mean velocity U and water density ρ may be collected from existing CMEMS reanalysis products. Short-term forecasted data may be provided by the respective CMEMS products and at ODYSSEA Observatories by the high-resolution ODYSSEA prognostic numerical models.

Historical water flow data will enable to analyse the orientation of flow aiding in the design and respective orientation of the submerged structures, as structures aligned with the flow will experience a lower drag force, as downstream elements are contained within the wake produced by those upstream. Other design parameters as the spacing of cages in the case of fish aquaculture or the spacing of cylinders in longline mussel farming are dependent on the magnitude and orientation of these drag forces.

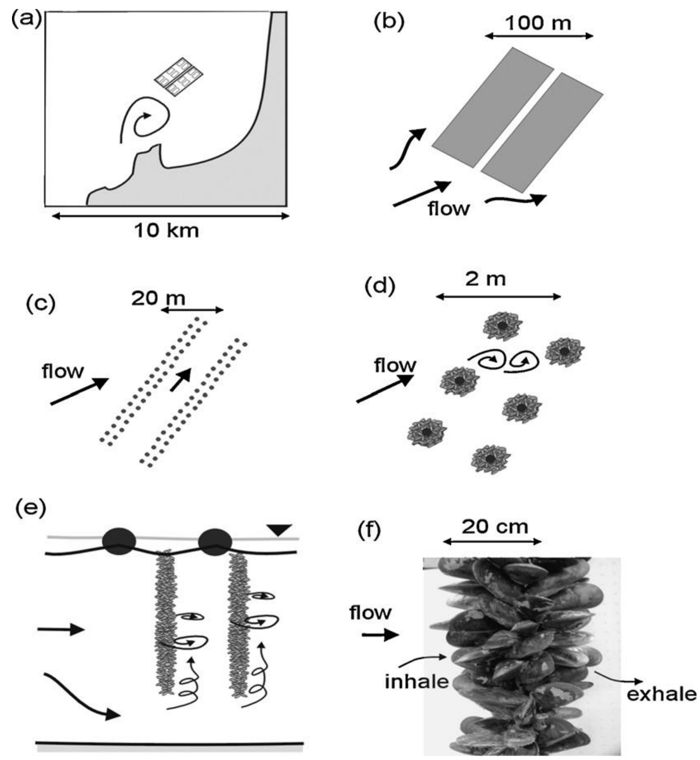

Figure 15. Impact of flow on aquaculture farms (after Stevens et al. 2008).

The impact of the oscillating wave forces on the stationary submerged part of an aquaculture farm consist of both drag and inertial components which are commonly described by the Morison equation (Morison et al., 1950).

$$F = F_d + F_a = \frac{1}{2} C_d \rho A u^2 + C_m \rho V \frac{\partial u}{\partial t} \quad [17]$$

where u is the instantaneous wave-induced velocity, V is cage displaced volume, C_m is an added mass coefficient and $\partial u / \partial t$ is local acceleration. Wolfram and Naghipour (1999) suggested values for $C_d = 1.7$ and $C_m = 2.0$.

Another issue related to aquaculture farms sitting is the interaction of the tide-driven stratified water column with the sloping bed. This effect produces large relatively slow-moving oscillations of the isotherms within the water column. These waves induce rapid temperature and velocity changes and thus affect the fish and mussels of respective farms. On-site measurements and numerical model results will be able to provide data of these parameters throughout the water column.

These indicators will be valuable for fish-farm managers, mussel-farm operators and policy-makers.

14.3 Wave Power Potential Indicators

The capacity to estimate the wave power at each location of the Mediterranean Sea is directly linked with the potential to harness this wave energy by any appropriate Wave Energy Converter device. Presently wave energy is considered as one of the renewable sources with the greatest potential to develop over the next decades (Cruz, 2008).

Results from the high-resolution wave models in terms of significant wave heights, periods and directions will be used to assess the gross wave energy at each pilot Observatory area. For any given wave depth, the wave power per crest length, P, can be approximated as:

$$P \approx \rho g \frac{(H_{mo})^2}{16} C_g(T_e, d) \qquad [18]$$

where ρ is the water density (to be calculated based on the state equation using the hydrodynamic model results for water temperature and salinity, kg/m^3), H_{mo} is the significant wave height, d is the water depth (m) and C_g is the velocity of wave energy propagation (group celerity, m/s). C_g may be calculated from:

$$C_g = \left[1 + \frac{4\pi d}{\lambda \sinh\left(\frac{4\pi d}{\lambda}\right)} \right] g T_e \tanh\left(\frac{2\pi d}{\lambda}\right) \qquad [19]$$

where λ is the wavelength (m) calculated from:

$\lambda = \frac{g T_e^2}{2\pi} \tanh\left(\frac{2\pi d}{\lambda}\right)$ and $T_e = \alpha T_p$ where T_e is the energy period and T_p is the peak period (a=0.9).

Wave power roses will be produced based on wave model results to lead to the estimation of wave power intensity (in kW/m of wave-crest length) per directional sector of 22°. Results will be reported on monthly, seasonal, annual and inter-annual basis. Long-term averages and maximum values will be computed at each Observatory based on the CMEMS Reanalysis datasets. Maps of wave energy/power distribution throughout the whole computational grid on historic and forecasted basis will be developed.

These indicators will be valuable for renewable energy consultants, harbor authorities, oil and gas rig managers, fish-farm managers, mussel-farm operators and policy-makers.

14.4 Offshore Jacket Platform Stress Indicators

Jacket platforms act as base for overall structure which is used to extract hydrocarbon from oceans. Jacket platforms are optimised to achieve maximum reliability by using minimum material. Safety factors for their design should take into consideration inherent uncertainties in load and resistance. Loads include the environmental loads, the dead and the live loads on the platform. Environmental loads mostly refer to loads induced by the impact of waves, winds and currents. Live load refer to the weights of consumable supplies and fluids in pipes and tanks. Dead loads refer to the weight of the solid structure.

Lighter jacket platforms may be designed at coastal waters where environmental load-to-gravity load ratio is low. Heavier Jackets will result where environmental load to gravity load is higher and load and resistance uncertainties are high (exposed to deep offshore waters and dynamic loadings).

The critical part in structural design of jacket platforms is the appropriate evaluation of environmental load and resistance factors. To estimate environmental loads long-term and reliable metocean data (combined meteorological and oceanographic data) is needed. Based on ISO and API design codes jacket platforms should be checked against a wave and a current load of 10,000 years return period. Reliability analysis should be based on the Bayesian probability of failure and the probability of survival estimation. In case the probability of failure leads to a return period less than 10,000 year, then modifications in the design for the strengthening of jacket platform is required.

Environmental loads vary significantly due to uncertainty of wind, wave and current. Jacket platforms are inherently more sensitive to waves than current and winds (Chakrabarti, 1987). Long-term statistics of these metocean parameters requires data on the number of individual storms. Extreme value distributions as Weibull and Gumbel may be fitted on these wave storm data to reach parameters as scale, location and shape. Maximum current speeds occur concurrently to maximum wave heights accounting for approximately 10% of the wave-induced forces. The impact of the winds depends on the size and shape of platforms structural elements however this wind force represents approximately 5-10% of the wave force.

Different methods for finding the response of offshore Jackets subjected to random ocean forces have been widely published (Birades et al. 2003; Stahl et al. 1998). SHELL estimates environmental load factors as

$$W = \alpha H_{\max}^2 + bH_{\max} cV_C^2 + dV_C + e \qquad [20]$$

where W = environmental load effects, H_{max} = variable annual maximum wave height, V_c = variable current speed, and a, b, c, d and e are coefficients.

Long-term historical wind, wave and current data may be collected from existing CMEMS reanalysis products. These data could be used to compute the environmental loads on the jacket platforms at any Mediterranean Sea location.

Short-term forecasted wind, wave and currents data may be provided by the respective CMEMS products and at ODYSSEA Observatories by the high-resolution ODYSSEA prognostic numerical models.

These indicators will be valuable for platform engineers and designers, oil and gas rig managers, safety operators and policy-makers.

Indicative ODYSSEA products and their methodology to derive, presently based on CMEMS datasets is analysed at Appendix II of this report.

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16 Appendix I

Table 1. Scientific RTQC applied on raw datasets collected by physical sensors.

Performed Test	Description of Actions	Alert	Correction
File header test			
Position on land	Check long/lat for positions on land	Automatic check	Quality flag edited in file
Date check	Check that sampling date corresponds to date of file and name of file	Automatic check	Quality flag edited in file
Parameter range check	Check that data in parameters fall within pre-defined range (Table 2)	Automatic check	Quality flag edited in file
Ascending immersion check	Check that data in PRESSURE and DEPTH increase	Automatic check	Quality flag edited in file
Duplicate level check	Check that data/profiles are not duplicated	Automatic check	Quality flag edited in file
Minmax test	Check that glider PRESSURE and DEPTH data do not exceed minimum/maximum reference values	Automatic check	Outlier(s) elimination, extraction and concatenation of corrected data
Spike Check	For glider data, check spikes on profiles, e.g., when DT/DZ > 0.5 and/or DP/DZ > 1.5	Automatic check	Outlier(s) elimination, extraction and concatenation of corrected data

Table 2. Automatic range checking for each parameter

No	Parameter	Units	Range	
			Lower limit	Upper limit
1	Water temperature	°C	-5	+45
2	Conductivity	S/m	0	8
3	Salinity	Psu	0	50
4	Pressure	bars	0	30
5	Current Speed	m/s	0	10
6	Current Direction	deg	0	360
7	Chlorophyll-a	µg/l	-0.1*	100
8	Dissolved Oxygen	µM	0	900
9	CDOM	ppb	0	500

* Small negative values of Chl-*a* could also occur, ascribed mainly to instrumental and electronic "noise" of the fluorescence sensors, e.g. a small drift in calibration can cause retrieval of small negative values (-0.1 to 0 µg/l) when the real Chl-*a* concentration is close to zero.

Table 3. Scientific RTQC applied on raw datasets collected by biogeochemical sensors.

Performed Test	Description of Actions	Alert	Correction
Frozen Profile Test on glider data	Subtract two consecutive profiles for Chl-*a* and DO to get the absolute difference profiles - Derive the maximum, minimum and mean of absolute differences for Chl-*a* and DO – Failure if: max(deltaChl)<0.3 µg/l; min(deltaChl)<0.001 µg/l; mean(deltaChl)<0.02 µg/l; max(deltaDO)<9 µM; min(deltaDO)<0.03 µM; mean(deltaDO)<0.6 µM.	Failed data flagged as "Bad" data (Flag = 4).	Check actions for data gaps.
Parameter Relationship Test	Based on the fact that different biogeochemical parameters have a cause-effect relation. Check the scatter plot of Chl-*a* and DO. Test failed if: VChl > Threshold_Chl AND VDO< Threshold_DO, where Threshold_CHL = 5µg/L, and Threshold_DO = 90%. This test is only for oxygen saturation (not concentration).	Failed data flagged as "Bad" data (Flag = 4).	Check actions for data gaps.

Table 4. Eutrophication indicators within the MSFD framework.

Indicator	Parameters	Formula	Assessment
EPA	Chlorophyll-*a* (µg/l)		Poor > 20; Fair 5-20, Good 0-5;
TRIX	Chl-*a*, DO, DIN, TP	$TRIX = \frac{\log(Chl - \alpha \times aD\%O \times DIN \times TP) - (-1.5)}{1.2}$	2-4 Oligotrophic; 4-5 Mesotrophic; 5-6 Eutrophic; 6-8 Hyper-trophic
TWQI	Ph, Ma, DO, Chl-*a*, DIN, DIP	Transform measured variables into quality values (QVs).	Good QV100 = 6; Bad QV0 = 30
WFD	summer Chl concentration mean, max and 90th percentile annual data		Bad >14; Poor 10.5-14; Moderate 7-10.5; Good 3.5-7; High 0-3.5
EI	NO_3, NO_2, NH_3, PO_4, Chl-*a*	$EI = 0.297C_{PO_4} + 0.261C_{NO_3} + 0.296C_{NO_2} + 0.275C_{NH_3} + 0.214C_{Chl-a}$	(a) less than 0.04: High quality; (b) 0.04–0.38: Good; (c) 0.38–0.85: Moderate; (d) 0.85–1.51: Poor; (e) greater than 1.51: Bad.

Table 5. Remote sensing data available at Mediterranean and Observatory level.

Organisation	Remote Sensing Mission	Data Record Period	Processing Levels	Spatial Resolution	Temporal Resolution	Remote Sensing Variables	Data Format Type
Ocean Biology Processing Group (OBPG)/NASA's Goddard Space Flight Center	Aquarius	2011-08-25 to 2015-06-07	L1,L2		daily	Sea Surface Salinity (SSS)	hdf
			L3	1 deg	daily,rolling 7-day period, rolling 28-day period, monthly, seasonal, annual, cumulative	Derived Surface Density, Volumentric Soil Moisture, Sea Surface Salinity, Wind Speed	hdf
	CZCS	1978-10-30 to 1986-06-22	L1,L2	825m	daily	Normalized water-leaving radiance at 443, 520, 550, 670 nm, aerosol optical thickness, chlorophyll-a concentration	netcdf
			L3	4km, 9km	daily, 8-day composite, monthly, rolling 32-day composite, annual, entire mission	Remote sensing reflectance at 443, 520, 550, 670 nm, diffuse attenuation coefficient at 490 nm, chlorophyll-a concentration, aerosol optical thickness at 670 nm	netcdf
	MERIS	2002-04-29 to 2012-04-08	L1,L2		daily	chlorophyll-a concentration	hdf
			L3	4km, 9km	daily, 8-day composite, monthly,annual composite, entire mission composite	remote sensing reflectance, chlorophyll-a concentration, diffuse attenuation coefficient at 490 nm, photosynthetically	hdf, netcdf

						active radiation, pic, poc, IOPs	
	MODIS Aqua	2002-07-04 to PRESENT	L1,L2	1km	daily	sea surface temperature, chlorophyll-a concentration, IOPs, remote sensing reflectance at several wavelengths	hdf, netcdf
			L3	4km, 9km	daily, rolling 3-day quick-look composite, 8-day composite, annual composite, entore mission composite	sea surface temperature, chlorophyll-a concentration, IOPs, remote sensing reflectance at several wavelengths	netcdf
	OCTS	1996-11-01 to 1997-06-29	L1,L2	3.5 km	daily	chlorophyll-a concentration, IOPs	hdf, netcdf
			L3	9km	daily, 8-day composite, monthly, annual composite, entire mission composite	remote sensing reflectance, chlorophyll-a concentration, diffuse attenuation coefficient at 490 nm, photosynthetically active radiation, IOPs, aerosol optical thickness	netcdf
	SeaWiFS	1997-09-04 to 2010-12-11	L1,L2	4.5 km	daily	chlorophyll-a concentration, IOPs	hdf, netcdf
			L3	9km	daily, 8-day composite, monthly, rolling 32-day composite, annual composite, entire mission composite	remote sensing reflectance, chlorophyll-a concentration, diffuse attenuation coefficient at 490 nm, photosynthetically active radiation, IOPs, aerosol optical thickness	netcdf

Copernicus Marine Environment Monitoring Service (CMEMS)	Jason-1, Jason-2, Jason-3, HY-2A, Saral/Altika, Cryosat-2, T/P, ENVISAT, GFO,, ERS1/2	2014-03-24 to PRESENT	L3	7km, 14km	daily, biannually,pluri-annual-mean	sea surface height	netcdf
		1993-01-01 to PRESENT	L4	0.12 deg	daily, biannually,pluri-annual-mean	sea surface height	netcdf
	MODIS-Aqua,NPP-VIIRS	2013-01-01 to PRESENT	L3	1km	daily	chlorophyll-a concentration,remote sensing reflectance, diffuse attenuation coefficient	netcdf
		2013-01-01 to PRESENT	L4	1km	daily, weekly	chlorophyll-a concentration	netcdf
		2013-05-01 to PRESENT	L4	1km	weekly, monthly	diffuse attenuarion coefficient	netcdf
	SeaWiFS, MODIS-Aqua, MERIS	1997-09-04 to 2015-08-31	L3, L4	1km, 4km	daily, weekly	chlorophyll-a concentration, remote sensing reflectance, diffuse attenuation coefficient	netcdf
	ATS_NR_2P, AMSRE, SEVIRI, TMI, AVHRR_METOP_A, GOES, AVHRR17_G, AVHRR17_L, AVHRR18_G, AVHRR_18L, MODIS_A, MODIS_T, NAR17_SST, NAR18_SST	2010-08-20 to PRESENT	L3	0.01 deg, 0.02 deg	daily	sea surface temperature	netcdf

	AVHRR	1981-11-01 to 2015-12-31	L4	0.01 deg, 0.04 deg	daily	sea surface temperature	netcdf
	MetOp, Oceansat	2012-03-12 to PRESENT	L3	0.12 deg	daily	ocean wind	netcdf
		2012-11-15 to PRESENT	L4	25 km	daily (6 hourly mean)	ocean wind	netcdf
	MetOp	2007-05-16 to 2012-04-16	L4	25 km	monthly	ocean wind	netcdf
European Organization for the Exploitation of Meteorological Satellites (EUMESAT)	Sentinel-3A (S3A)	2016-02-2016 to PRESENT	L0, L1A (SRAL),L1B (SLSTR, OLCI, SRAL), L2 (OLCI)	Full: 300m Reduced: 1200m	Near-Real-Time(NRT,3 h after obs), Short-Time-Critical (STC, 48 h after obs), Non-Time-Critical (NTC, 30 d after obs)	altimetry (sea surface height, significant wave height, wind speed at the sea surface), ocean colour, sea surface temperature	netcdf
	Sentinel-3A (S3A) - OLCI	2016-02-16 to PRESENT	L1B	Full/Reduced	NRT/NTC	calibrated Top Of Atmosphere radiance values at 21 spectral bands	netcdf
			L2	Full/Reduced	NRT/NTC	water leaving reflectance, diffuse attenuation coefficient at 490 nm, absorption coefficient of coloured detrital and dissolved material at 443nm, Photosynthetically Active Radiation, chlorophyll, total suspended matter, aerosol load, Integrated Water Vapour column	netcdf
	Sentinel-3A (S3A)- SLSTR	2016-11-17 to PRESENT (NRT)	L1B	1km at nadir (TIR), 500m (VIS).	NRT	Radiances and Brightness Temperatures, sea surface temperature	netcdf

		2017-01-19 to PRESENT (NTC)	L1B	1km at nadir (TIR), 500m (VIS).	NTC	Radiances and Brightness Temperatures, sea surface temperature	netcdf
	Sentinel-3A (S3A) - SRAL	2017-03-06 to	L1A Unpacked L0		NTC	sea surface height	netcdf
		2017-03-06 to	L1A Unpacked L0		STC	sea surface height	netcdf
		2016-12-13 to	L1B		NRT	sea surface height	netcdf
		not began	L1B		NTC	sea surface height	netcdf
		2016-12-13 to	L1B		STC	sea surface height	netcdf
		2017-04-12 to	L1B stack echoes		NTC	sea surface height	netcdf
		2017-04-12 to	L1B stack echoes		STC	sea surface height	netcdf
		2016-12-13 to	Corrected Sea Surface Height		NRT	sea surface height	netcdf
		2016-12-13 to	Corrected Sea Surface Height		STC	sea surface height	netcdf
		2016-12-13 to	SRAL Altimetry Global	300 m, 7 km	NRT	altimeter range, sea surface height,wind speed,	netcdf

						significant wave height, sea ice	
		2017-01-19 to	SRAL Altimetry Global	300 m, 7 km	NTC	altimeter range, sea surface height,wind speed, significant wave height, sea ice	netcdf
		2016-12-13 to	SRAL Altimetry Global	300 m, 7 km	STC	altimeter range, sea surface height,wind speed, significant wave height, sea ice	netcdf
	Jason-3 (POSEIDON-3)	2016-02-12 to	Operational Geophysical Data Record		NRT/NTC	wave height, ocean surface wind speed	netcdf
		2016-02-12 to	Operational Geophysical Data Record		NRT/NTC	sea surface height anomaly, ocean surface wind speed	netcdf
	ASCAT (Metop)	2007-01-01 to 2014-03-31	L2	12.5 km	NRT	ocean surface wind (available coastal winds), soil moisture	netcdf
		2007-01-01 to 2014-03-31	L2	25 km	NRT	ocean surface wind, soil moisture	netcdf
	AMI-SCAT	2016-08-25 to	L2	25 km		ocean surface wind	netcdf
	POSEIDON-3 (Jason-2)	2008-07-04 to			continious	sea surface height, significant wave height and ocean surface wind speed	netcdf
	POSEIDON-3B (Jason-3)	2016-02-12 to		50 km		sea surface height, significant wave height and ocean surface wind speed	netcdf
	OSCAT	2013-09-18 to 2014-02-21				ocean surface wind	netcdf
	RAPIDSCAT	2015-05-19 to		25 km, 50 Km	NRT	ocean surface wind	netcdf

	SEAWINDS	1999-01-01 to 2009-12-31	L2	25 km, 50 km		ocean surface wind	netcdf
	AVHRR	2011-06-28 to	L2P	1 km		sea surface temperature	netcdf
		2008-11-21 to	L3C	0.05 deg	12 hours synthesis	sea surface temperature	netcdf
	IASI (Metop)	2014-12-11 to	L2P	12 km to 40 km		sea surface temperature	netcdf
		2011-03-24 to	L2P			sea surface temperature	netcdf
AVISO+ Satellite Altimetry Data	multimission	1993-01-01 to PRESENT		0.25 deg, 6-7 km	monthly, seasonally	sea surface height	netcdf
	multimission	2009-09-01 to PRESENT			NRT each day	wave height, wind speed	netcdf
	multimission	1993-01-01 to 2012-12-31		1/60˚, 1/16˚		mean sea surface, global tide	netcdf
CERSAT INFREMER MEDSPIRATION	merged	2010 to 2017	L2P, L4	0.01 deg	daily	sea surface temperature	netcdf

Table 6. Remote sensing datasets to be used within the frame of ODYSSEA at Observatory level.

Organisation	Remote Sensing Mission	Data Record Period	Processing Levels	Spatial Resolution	Temporal Resolution	Remote Sensing Variables	Data Format Type
Ocean Biology Processing Group (OBPG)/NASA's Goddard Space Flight Center	CZCS	**1978-10-30** to **1986-06-22**	L1,L2	825m	daily	Normalized water-leaving radiance at 443, 520, 550, 670 nm, aerosol optical thickness, chlorophyll-a concentration	netcdf
			L3	4km, 9km	daily, 8-day composite, monthly, rolling 32-day composite	Remote sensing reflectance at 443, 520, 550, 670 nm, diffuse attenuation coefficient at 490 nm, chlorophyll-a concentration, aerosol optical thickness at 670 nm	netcdf
	MERIS	2002-04-29 to 2012-04-08	L1,L2		daily	chlorophyll-a concentration	hdf
			L3	4km, 9km	daily, 8-day composite, monthly.	remote sensing reflectance, chlorophyll-a concentration, diffuse attenuation coefficient at 490 nm, photosynthetically active radiation, pic, poc, IOPs	hdf, netcdf
	MODIS Aqua	2002-07-04 to PRESENT	L1,L2	1km	daily	sea surface temperature, chlorophyll-a concentration, IOPs, remote sensing reflectance at several wavelengths	hdf, netcdf
			L3	4km, 9km	daily, rolling 3-day quick-look composite, 8-day composite.	sea surface temperature, chlorophyll-a concentration, IOPs, remote sensing reflectance at several wavelengths	netcdf

	SeaWiFS	1997-09-04 to 2010-12-11	L1,L2	4.5 km	daily	chlorophyll-a concentration, IOPs	hdf, netcdf
			L3	9km	daily, 8-day composite, monthly, rolling 32-day composite.	remote sensing reflectance, chlorophyll-a concentration, diffuse attenuation coefficient at 490 nm, photosynthetically active radiation, IOPs, aerosol optical thickness	netcdf
	Jason-1, Jason-2, Jason-3, HY-2A, Saral/Altika, Cryosat-2, T/P, ENVISAT, GFO,, ERS1/2	2014-03-24 to PRESENT	L3	7km, 14km	daily, biannually,pluri-annual-mean	sea surface height	netcdf
		1993-01-01 to PRESENT	L4	0.12 deg	daily, biannually,pluri-annual-mean	sea surface height	netcdf
	MODIS-Aqua,NPP-VIIRS	2013-01-01 to PRESENT	L3	1km	daily	chlorophyll-a concentration,remote sensing reflectance, diffuse attenuation coefficient	netcdf
		2013-01-01 to PRESENT	L4	1km	daily, weekly	chlorophyll-a concentration	netcdf
Copernicus Marine Environment Monitoring Service (CMEMS)		2013-05-01 to PRESENT	L4	1km	weekly, monthly	diffuse attenuarion coefficient	netcdf
	SeaWiFS, MODIS-Aqua, MERIS	1997-09-04 to 2015-08-31	L3, L4	1km, 4km	daily, weekly	chlorophyll-a concentration, remote sensing reflectance, diffuse attenuation coefficient	netcdf
	ATS_NR_2P, AMSRE, SEVIRI, TMI, AVHRR_METOP	2010-08-20 to PRESENT	L3	0.01 deg, 0.02 deg	daily	sea surface temperature	netcdf

	_A, GOES, AVHRR17_G, AVHRR17_L, AVHRR18_G, AVHRR_18L, MODIS_A, MODIS_T, NAR17_SST, NAR18_SST						
	AVHRR	1981-11-01 to 2015-12-31	L4	0.01 deg, 0.04 deg	daily	sea surface temperature	netcdf
	MetOp, Oceansat	2012-03-12 to PRESENT	L3	0.12 deg	daily	ocean wind	netcdf
		2012-11-15 to PRESENT	L4	25 km	daily (6 hourly mean)	ocean wind	netcdf
	MetOp	2007-05-16 to 2012-04-16	L4	25 km	monthly	ocean wind	netcdf
	Sentinel-3A (S3A)	2016-02-2016 to PRESENT	L0, L1A (SRAL),L1B (SLSTR, OLCI, SRAL), L2 (OLCI)	Full: 300m Reduced: 1200m	Near-Real-Time(NRT,3 h after obs), Short-Time-Critical (STC, 48 h after obs), Non-Time-Critical (NTC, 30 d after obs)	altimetry (sea surface height, significant wave height, wind speed at the sea surface), ocean colour, sea surface temperature	netcdf
European Organization for the Exploitation of Meteorological Satellites (EUMESAT)	Sentinel-3A (S3A) - OLCI	2016-02-16 to PRESENT	L1B	Full/Reduced	NRT/NTC	calibrated Top Of Atmosphere radiance values at 21 spectral bands	netcdf
			L2	Full/Reduced	NRT/NTC	water leaving reflectance, diffuse attenuation coefficient at 490 nm, absorption coefficient of coloured detrital and dissolved material at 443nm, Photosynthetically Active Radiation, chlorophyll, total suspened matter, aerosol load,	netcdf

						Integrated Water Vapour column	
		2016-12-13 to	L1B		NRT	sea surface height	netcdf
		not began	L1B		NTC	sea surface height	netcdf
		2016-12-13 to	L1B		STC	sea surface height	netcdf
		2017-04-12 to	L1B stack echoes		NTC	sea surface height	netcdf
		2017-04-12 to	L1B stack echoes		STC	sea surface height	netcdf
		2016-12-13 to	Corrected Sea Surface Height		NRT	sea surface height	netcdf
		2016-12-13 to	Corrected Sea Surface Height		STC	sea surface height	netcdf
		2016-12-13 to	SRAL Altimetry Global	300 m, 7 km	NRT	altimeter range, sea surface height, wind speed, significant wave height, sea ice	netcdf
		2017-01-19 to	SRAL Altimetry Global	300 m, 7 km	NTC	altimeter range, sea surface height, wind speed, significant wave height, sea ice	netcdf
		2016-12-13 to	SRAL Altimetry Global	300 m, 7 km	STC	altimeter range, sea surface height, wind speed, significant wave height, sea ice	netcdf

17 Appendix II

Product BATHY1S	Depth Correction
Variables	Bathymetry Topography
Product(s)	EMODNET Bathymetry Aster Topography
Datasets Involved	
Observations/Model	Numerical Model (DTM)
Processing level	L1
Formulae	Krigging Interpolation or other algorithm
Reanalysis	NO
Hindcast	NO
Forecast	NO
Geographical Coverage	From 5.5625°W to 36.25°E; From 30.17°N to 45.9375°N
Period	Present
Spatial Resolution	EMODNET: 0.00208 deg X 0.00208 deg ASTER: 0.000277 deg X 0.000277 deg
Temporal Resolution	None
Update Frequency	None
Interpretation	The product is expected to improve the bathymetry provided by EMODnet, especially at the coastal zone where most problems have been encountered. Bathymetry and coastal topography will be combined to upgrade the horizontal resolution of the final file.
Problems expected	The produced bathymetric file should be validated against data from existing maps to assess the capacity of applied algorithms.
Potential end-users	Users from all marine and maritime sectors

Product EUTRO1R	Trophic State Index (TSI Indicator)
Variables	Chl-*a* Total Phosphorus (TP) Secchi Disk Depth (SDD)
Product(s)	MEDSEA_REANALYSIS_BIO_006_008 OCEANCOLOUR_GLO_OPTICS_L4_NRT_OBSERVATIONS_009_083
Datasets Involved	mass_concentration_of_chlorophyll_a_in_sea_water (CHL) – monthly (mg/m^3) mole_concentration_of_phosphate_in_sea_water (PO4) – monthly (mmol/m^3) ZSD - Secchi depth of seawater derived from MERIS and MODIS data - (8- days and monthly) – m
Observations/Model	Numerical Model
Processing level	L4
Formulae	$TSI_{Chl-a} = 9.81 \ln(Chl-a) + 30.6$ $TSI_{TP} = 14.42 \ln(TP) + 4.15$ $TSI_{SD} = 10(6 - \frac{\ln SD}{\ln 2})$ $\overline{TSI} = (TSI_{Chl-a} + TSI_{TP} + TSI_{SD}) / 3$
Reanalysis	YES
Hindcast	NO
Forecast	NO
Geographical Coverage	From 5.5625°W to 36.25°E; From 30.17°N to 45.9375°N
Period	1999-2015
Spatial Resolution	0.06 deg X 0.06 deg
Temporal Resolution	Monthly-mean
Update Frequency	Annual

Interpretation	TSI < 40, Oligotrophic waters 40 < TSI < 50, Mesotrophic waters 50 < TSI < 70, Eutrophic waters, >70, Hypertrophic waters
Problems expected	
Potential end-users	Aquaculture sitting consultants, scientists, policy-makers

Product EUTRO2R	TRophic IndeX (TRIX Indicator)
Variables	Chl-*a* *a*D%O Dissolved Inorganic Nitrogen (DIN) Total Phosphorus (TP)
Product(s)	MEDSEA_REANALYSIS_BIO_006_008
Datasets Involved	mass_concentration_of_chlorophyll_a_in_sea_water (CHL) – monthly (mg/m^3) mole_concentration_of_dissolved_molecular_oxygen_in_sea_water (O2) - monthly (mmol/m^3) mole_concentration_of_phosphate_in_sea_water (PO4) - monthly (mmol/m^3) mole_concentration_of_nitrate_in_sea_water (NO3) - monthly (mmol/m^3)
Observations/Model	Numerical Model
Processing level	L4
Formulae	$TRIX = \frac{\log(Chl - \alpha \times aD\%O \times DIN \times TP) - (-1.5)}{1.2}$ TRIX for Mediterranean Sea (after Vollenweider et al., 1998).
Reanalysis	YES
Hindcast	NO
Forecast	NO
Geographical Coverage	From 5.5625°W to 36.25°E; From 30.17°N to 45.9375°N
Period	1999-2015
Spatial Resolution	0.06 deg X 0.06 deg
Temporal Resolution	Monthly-mean

Update Frequency	Annual
Interpretation	0 < TRIX < 4, High Trophic Status, Oligotrophic 4 <= TRIX < 5, Good Trophic Status, Mesotrophic 5 <= TRIX < 6, Bad Trophic Status, Eutrophic 6 <= TRIX < 10, Low trophic Status, Hyper-trophic
Problems expected	The calculation of Dissolved Oxygen saturation (%) requires the following steps: Step1 – Calculate Cp as: =((EXP(7,7117-1,31403*LN(G1+45,93)))*G2*(1-EXP(11,8571-(3840,7/(G1+273,15))-(216961/((G1+273,15)^2)))/G2)*(1-(0,000975-(0,00001426*G1)+(0,00000006436*(G1^2)))*G2))/(1-EXP(11,8571-(3840,7/(G1+273,15))-(216961/((G1+273,15)^2)))) /(1-(0,000975-(0,00001426*G1)+(0,00000006436*(G1^2)))) Where G1 is water temperature (in deg Celsius) and G2 is pressure (1 atm at sea surface) Step 2 – DO% = (100 X DO (in mg/l))/Cp Step 3 – Calculate *a*%DO = abs(100 – DO%)
Potential end-users	Aquaculture sitting consultants, scientists, policy-makers

Product EUTRO3R	Efficiency Coefficient (EffCoeff)
Variables	Chl-*a* *a*D%O Dissolved Inorganic Nitrogen (DIN) Total Phosphorus (TP)
Product(s)	MEDSEA_REANALYSIS_BIO_006_008
Datasets Involved	mass_concentration_of_chlorophyll_a_in_sea_water (CHL) mole_concentration_of_dissolved_molecular_oxygen_in_sea_water (O2) mole_concentration_of_phosphate_in_sea_water (PO4) mole_concentration_of_nitrate_in_sea_water (NO3)
Observations/Model	Numerical Model
Processing level	L4
Formulae	$Eff.Coeff.=Log_{10}\dfrac{(Chl-a\times aD\%O)}{(DIN\times TP)}$ (after Giovanardi and Vollenweider, 2004)
Reanalysis	YES
Hindcast	NO
Forecast	NO
Geographical Coverage	From 5.5625°W to 36.25°E; From 30.17°N to 45.9375°N
Period	1999-2015
Spatial Resolution	0.06 deg X 0.06 deg
Temporal Resolution	Monthly-mean
Update Frequency	Annual
Interpretation	The Efficiency Coefficient expresses the degree of “nutrients utilization”. Thus, low values would indicate low, and vice versa, high values high nutrient utilisation.

Problems expected	The calculation of Dissolved Oxygen saturation (%) requires the following steps: Step1 – Calculate Cp as: =((EXP(7,7117-1,31403*LN(G1+45,93)))*G2*(1-EXP(11,8571-(3840,7/(G1+273,15))-(216961/((G1+273,15)^2)))/G2)*(1-(0,000975-(0,00001426*G1)+(0,00000006436*(G1^2)))*G2))/(1-EXP(11,8571-(3840,7/(G1+273,15))-(216961/((G1+273,15)^2)))) /(1-(0,000975-(0,00001426*G1)+(0,00000006436*(G1^2)))) Where G1 is water temperature (in deg Celsius) and G2 is pressure (1 atm at sea surface) Step 2 – DO% = (100 X DO (in mg/l))/Cp Step 3 – Calculate *α*%DO = abs(100 – DO%)
Potential end-users	Aquaculture sitting consultants, scientists, policy-makers

Product EUTRO4R	Eutrophication Risk
Variables	TRIX values
Product(s)	EUTRO2
Datasets Involved	TRIX
Observations/Model	Modeled Data Processing
Processing level	L4
Formulae	Due to the hypothesis of normality for single TRIX distributions, it is possible evaluate the probability of exceeding a prefixed TRIX point value, e.g. L = 6, conventionally chosen as lower limit for a "bad" trophic status $z = \frac{L - \overline{x}_i}{s_i}$ where x_overbar and s_l are the mean and standard deviation TRIX-values, respectively.
Reanalysis	YES
Hindcast	NO
Forecast	NO
Geographical Coverage	From 5.5625°W to 36.25°E; From 30.17°N to 45.9375°N
Period	1999-2015
Spatial Resolution	0.06 deg X 0.06 deg
Temporal Resolution	Monthly-mean
Update Frequency	Annual
Interpretation	The Efficiency Coefficient expresses the degree of “nutrients utilization”. Thus, low values would indicate low, and vice versa, high values high nutrient utilisation.
Problems expected	
Potential end-users	Aquaculture sitting consultants, scientists, policy-makers

Product EUTRO5H	Trophic State Index (TSI Indicator)
Variables	Chl-*a* Total Phosphorus (TP) Secchi Disk Depth (SDD)
Product(s)	MEDSEA_ANALYSIS_FORECAST_BIO_006_014 OCEANCOLOUR_GLO_OPTICS_L4_NRT_OBSERVATIONS_009_083 OCEANCOLOUR_MED_CHL_L4_NRT_OBSERVATIONS_009_041
Datasets Involved	mass_concentration_of_chlorophyll_a_in_sea_water (CHL) – (daily and 8-daily from satellite data or daily from numerical model) – (mg m^{-3}) mole_concentration_of_phosphate_in_sea_water (PO4) – (daily) – (mmol m^{-3}) ZSD - Secchi depth of seawater derived from MERIS and MODIS data - (8- days) – (m)
Observations/Model	Numerical Model - Satellite
Processing level	L4
Formulae	$TSI_{Chl-a} = 9.81 \ln(Chl-a) + 30.6$ $TSI_{TP} = 14.42 \ln(TP) + 4.15$ $TSI_{SD} = 10(6 - \frac{\ln SD}{\ln 2})$ $\overline{TSI} = (TSI_{Chl-a} + TSI_{TP} + TSI_{SD}) / 3$
Reanalysis	NO
Hindcast	YES
Forecast	NO
Geographical Coverage	From 5.5625°W to 36.25°E; From 30.17°N to 45.9375°N
Period	2016 - Present
Spatial Resolution	0.042 deg X 0.042 deg
Temporal Resolution	Daily-mean or 8-Daily-mean

Update Frequency	Daily or 8-Daily
Interpretation	TSI < 40, Oligotrophic waters 40 < TSI < 50, Mesotrophic waters 50 < TSI < 70, Eutrophic waters, >70, Hypertrophic waters
Problems expected	
Potential end-users	Aquaculture sitting consultants, Fish farm managers, mussel farms operators, scientists, policy-makers

Product EUTRO6H	TRophic IndeX (TRIX Indicator)
Variables	Chl-*a* *a*D%O Dissolved Inorganic Nitrogen (DIN) Total Phosphorus (TP)
Product(s)	MEDSEA_ANALYSIS_FORECAST_BIO_006_014 OCEANCOLOUR_MED_CHL_L4_NRT_OBSERVATIONS_009_041
Datasets Involved	mass_concentration_of_chlorophyll_a_in_sea_water (CHL) – (daily and 8-daily from satellite data or daily from numerical model) – (mg m^{-3}) mole_concentration_of_dissolved_molecular_oxygen_in_sea_water (O2) – (daily) – (mmol m-3) mole_concentration_of_phosphate_in_sea_water (PO4) – (daily) – (mmol m^{-3}) mole_concentration_of_nitrate_in_sea_water (NO3) – (daily) – (mmol m^{-3})
Observations/Model	Numerical Model - Satellite
Processing level	L4
Formulae	$TRIX = \frac{\log(Chl - \alpha \times aD\%O \times DIN \times TP) - (-1.5)}{1.2}$
Reanalysis	NO
Hindcast	YES
Forecast	NO
Geographical Coverage	From 5.5625°W to 36.25°E; From 30.17°N to 45.9375°N
Period	2016 - Present
Spatial Resolution	0.042 deg X 0.042 deg
Temporal Resolution	Daily-mean or 8-Daily-mean
Update Frequency	Daily or 8-Daily

Interpretation	2 < TRIX < 4, High Trophic Status, Oligotrophic 4 <= TRIX < 5, Good Trophic Status, Mesotrophic 5 <= TRIX < 6, Medium Trophic Status, Eutrophic 6 <= TRIX < 8, Low trophic Status, Hyper-trophic
Problems expected	The calculation of Dissolved Oxygen saturation (%) requires the following steps: Step1 – Calculate Cp as: =((EXP(7,7117-1,31403*LN(G1+45,93)))*G2*(1-EXP(11,8571-(3840,7/(G1+273,15))-(216961/((G1+273,15)^2)))/G2)*(1-(0,000975-(0,00001426*G1)+(0,00000006436*(G1^2)))*G2))/(1-EXP(11,8571-(3840,7/(G1+273,15))-(216961/((G1+273,15)^2)))) /(1-(0,000975-(0,00001426*G1)+(0,00000006436*(G1^2)))) Where G1 is water temperature (in deg Celsius) and G2 is pressure (1 atm at sea surface) Step 2 – DO% saturation = (100 X DO (in mg/l))/Cp
Potential end-users	Aquaculture sitting consultants, Fish farm managers, mussel farms operators, scientists, policy-makers

Product EUTRO7F	TRophic IndeX (TRIX Indicator)
Variables	Chl-*a* *a*D%O Dissolved Inorganic Nitrogen (DIN) Total Phosphorus (TP)
Product(s)	MEDSEA_ANALYSIS_FORECAST_BIO_006_014
Datasets Involved	mass_concentration_of_chlorophyll_a_in_sea_water (CHL) – (daily) – (mg m^{-3}) mole_concentration_of_phosphate_in_sea_water (PO4) – (daily) – (mmol m^{-3}) ZSD - Secchi depth of seawater derived from MERIS and MODIS data - (8- days) – (m)
Observations/Model	Numerical Model
Processing level	L4
Formulae	$TSI_{Chl-a} = 9.81\ln(Chl-a) + 30.6$ $TSI_{TP} = 14.42\ln(TP) + 4.15$ $TSI_{SD} = 10(6 - \frac{\ln SD}{\ln 2})$ $\overline{TSI} = (TSI_{Chl-a} + TSI_{TP} + TSI_{SD}) / 3$
Reanalysis	NO
Hindcast	NO
Forecast	YES
Geographical Coverage	From 5.5625°W to 36.25°E; From 30.17°N to 45.9375°N
Period	Present – 5 Days
Spatial Resolution	0.042 deg X 0.042 deg
Temporal Resolution	Daily-mean
Update Frequency	Daily

Interpretation	TSI < 40, Oligotrophic waters 40 < TSI < 50, Mesotrophic waters 50 < TSI < 70, Eutrophic waters, >70, Hypertrophic waters
Problems expected	Secchi Disk Depth data are extracted from remote sensing optical measurements. There do not exist operational forecasts for SDD. When the ODYSSEA Observatory models are operational SDD will be predicted operationally.
Potential end-users	Aquaculture sitting consultants, Fish farm managers, mussel farms operators, scientists, policy-makers

Product EUTRO8F	TRophic IndeX (TRIX Indicator)
Variables	Chl-*a* *a*D%O Dissolved Inorganic Nitrogen (DIN) Total Phosphorus (TP)
Product(s)	MEDSEA_ANALYSIS_FORECAST_BIO_006_014
Datasets Involved	mass_concentration_of_chlorophyll_a_in_sea_water (CHL) – (daily) – (mg m^{-3}) mole_concentration_of_dissolved_molecular_oxygen_in_sea_water (O2) – (daily) – (mmol m-3) mole_concentration_of_phosphate_in_sea_water (PO4) – (daily) – (mmol m^{-3}) mole_concentration_of_nitrate_in_sea_water (NO3) – (daily) – (mmol m^{-3})
Observations/Model	Numerical Model - Satellite
Processing level	L4
Formulae	$TRIX = \frac{\log(Chl - \alpha \times aD\%O \times DIN \times TP) - (-1.5)}{1.2}$
Reanalysis	NO
Hindcast	NO
Forecast	YES
Geographical Coverage	From 5.5625°W to 36.25°E; From 30.17°N to 45.9375°N
Period	Present – 5 Days
Spatial Resolution	0.042 deg X 0.042 deg
Temporal Resolution	Daily-mean
Update Frequency	Daily
Interpretation	2 < TRIX < 4, High Trophic Status, Oligotrophic

	4 <= TRIX < 5, Good Trophic Status, Mesotrophic 5 <= TRIX < 6, Medium Trophic Status, Eutrophic 6 <= TRIX < 8, Low trophic Status, Hyper-trophic
Problems expected	The calculation of Dissolved Oxygen saturation (%) requires the following steps: Step1 – Calculate Cp as: =((EXP(7,7117-1,31403*LN(G1+45,93)))*G2*(1-EXP(11,8571- (3840,7/(G1+273,15))-(216961/((G1+273,15)^2)))/G2)*(1- (0,000975-(0,00001426*G1)+(0,00000006436*(G1^2)))*G2))/(1- EXP(11,8571-(3840,7/(G1+273,15))-(216961/((G1+273,15)^2)))) /(1- (0,000975-(0,00001426*G1)+(0,00000006436*(G1^2)))) Where G1 is water temperature (in deg Celsius) and G2 is pressure (1 atm at sea surface) Step 2 – DO% saturation = (100 X DO (in mg/l))/Cp
Potential end-users	Aquaculture sitting consultants, Fish farm managers, mussel farms operators, scientists, policy-makers

Product WAVE1H	Offshore Wave Power
Variables	Significant Wave Height Wave Period Water Depth
Product(s)	MEDSEA_HINDCAST_WAV_006_012
Datasets Involved	sea_surface_wave_significant_height (SWH) sea_surface_wind_wave_mean_period (WW) sea_surface_wave_mean_period_from_variance_spectral_density_inverse_frequency_moment (MWP) sea_surface_wave_mean_period_from_variance_spectral_density_second_frequency_moment (MWP) sea_surface_wave_from_direction (VMDR)
Observations/Model	Modeled Data Processing
Processing level	L4
Formulae	For cells with water depth higher than half the wavelength, λ, then wave power in kW per meter of wave front length: $P = 0.49 * H_{mo}^2 * T_e$
Reanalysis	NO
Hindcast	YES
Forecast	NO
Geographical Coverage	From 18.125°W to 36.2917°E; From 30.1875°N to 45.9792°N
Period	Feb 2006 – Dec 2015
Spatial Resolution	1/24 deg X 1/24 deg
Temporal Resolution	Monthly-mean
Update Frequency	Annual
Interpretation	
Problems expected	The wavelength λ_o at deep waters is computed from:

	$$\lambda_0 = \frac{gT^2}{2\pi}$$ where is the sea_surface_wind_wave_mean_period (WW) and g is the gravitational acceleration (9.81 m/s^2). The energy wave period T_e is obtained as integrated by-product, computed based on the moments of the wave spectrum, as: $$T_e = \frac{m_{-1}}{m_0}$$ where m_{-1} is the Spectral moments (-1,0) wave period [s] (VTM10) and Spectral moments (0,2) wave period [s] (VTM02). Wave power is integrated over wave direction increments of 22^o.
Potential end-users	Aquaculture sitting consultants, Fish farm managers, mussel farms operators, port authorities, sea-planes sitting, marine renewables sitting consultants, oil and gas platform operators, maritime sector, scientists, engineers, policy-makers

Product WAVE1F	Offshore Wave Power
Variables	Significant Wave Height Wave Period Water Depth
Product(s)	MEDSEA_ANALYSIS_FORECAST_WAV_006_011
Datasets Involved	sea_surface_wave_significant_height (SWH) sea_surface_wind_wave_mean_period (WW) sea_surface_wave_mean_period_from_variance_spectral_density_inverse_frequency_moment (MWP) sea_surface_wave_mean_period_from_variance_spectral_density_second_frequency_moment (MWP) sea_surface_wave_from_direction (VMDR)
Observations/Model	Modeled Data Processing
Processing level	L4
Formulae	For cells with water depth higher than half the wavelength, λ, then wave power in kW per meter of wave front length: $P = 0.49 * H_{mo}^2 * T_e$
Reanalysis	NO
Hindcast	NO
Forecast	YES
Geographical Coverage	From 18.125°W to 36.2917°E; From 30.1875°N to 45.9792°N
Period	Aug 2016 – present
Spatial Resolution	0.042 deg X 0.042 deg
Temporal Resolution	Hourly-instantaneous
Update Frequency	Daily
Interpretation	
Problems expected	The wavelength λ_o at deep waters is computed from:

	$$\lambda_0 = \frac{gT^2}{2\pi}$$ where is the sea_surface_wind_wave_mean_period (WW) and g is the gravitational acceleration (9.81 m/s^2). The energy wave period T_e is obtained as integrated by-product, computed based on the moments of the wave spectrum, as: $$T_e = \frac{m_{-1}}{m_0}$$ where m_{-1} is the sea_surface_wave_mean_period_from_variance_ spectral_density_inverse_frequency_moment (MWP) and sea_surface_wave_mean_period_from_variance_spectral_density_ second_frequency_moment (MWP). Wave power is integrated over wave direction increments of 22°, defined by sea_surface_wave_ from_direction (VMDR).
Potential end-users	Aquaculture sitting consultants, Fish farm managers, mussel farms operators, port authorities, sea-planes sitting, marine renewables sitting consultants, oil and gas platform operators, maritime sector, scientists, engineers, policy-makers