D3.2
Evaluation of CMEMS catalogue for value adding

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348.

Project no.	776348
Project acronym:	CoastObs
Project title:	Commercial service platform for user-relevant coastal water monitoring services based on Earth Observation
Instrument:	H2020-EO-2017
Start date of project:	01.11.2017
Duration:	36 months
Deliverable title:	D3.2 Evaluation of CMEMS catalogue for value adding
Due date of deliverable:	Month 20

Organisation name of lead contractor for this deliverable: CNR

Author list:

Name	Organisation
Vittorio Ernesto Brando	CNR
Federica Braga	CNR
Marco Bracaglia	CNR
Rosalia Santoleri	CNR
Kathrin Poser	WI
Steef Peters	WI

Dissemination level		
PU	Public	X
CO	Confidential, restricted under conditions set out in Model Grant Agreement	
CI	Classified, information as referred to in Commission Decision 2001/844/EC	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

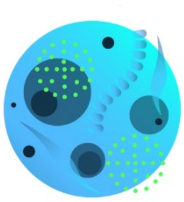
History			
Version	**Date**	**Reason**	**Revised by**
01	16/07/2019	Initial Draft	Vittorio Brando, Marco Bracaglia, Federica Braga
02	18/07/2019	Comments by co-authors	Steef Peters
03	??/07/2019	Internal Review	

Please cite as:

Brando, V.E., Braga, F., Bracaglia, M, Santoleri, L. , Poser, K., Peters, S. (2019). D3.2 Evaluation of CMEMS catalogue for value adding. CoastObs Project.

CoastObs Project

CoastObs is an EU H2020 funded project that aims at using satellite remote sensing to monitor coastal water environments and to develop a user-relevant platform that can offer validated products to users including monitoring of seagrass and macroalgae, phytoplankton size classes, primary production, and harmful algae as well as higher level products such as indicators and integration with predictive models.



phytoplankton

seagrass

harmful algal blooms

primary production

To fulfil this mission, we are in dialogue with users from various sectors including dredging companies, aquaculture businesses, national monitoring institutes, among others, in order to create tailored products at highly reduced costs per user that stick to their requirements.

With the synergistic use of Sentinel-3 and Sentinel-2, CoastObs aims at contributing to the sustainability of the Copernicus program and assisting in implementing and further fine-tuning of European Water Quality related directive.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 776348

Partnership

Water Insight BV. (WI)

The University of Stirling (USTIR)

Consiglio Nazionale Delle Ricerche (CNR)

Université de Nantes (UN)

HZ University of Applied Sciences (HZ)

Universidad de Vigo (UVIGO)

Bio-Littoral (BL)

Geonardo Environmental Technologies Ltd. (GEO)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

TABLE OF CONTENTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

FIGURES

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement No 776348

TABLES

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement No 776348

ABBREVIATIONS

List of abbreviations	
Abbreviation	**Explanation**
ADB	Autorità di bacino Distrettuale delle Alpi Orientali
ARPAV, ARPA Veneto	Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto
ARVI	Cooperativa de Armadores de Pesca del Puerto de Vigo
BOA	Bottom Of Atmosphere
BWD	Bathing Water Directive
CDOM	Coloured Dissolved Organic Matter
Chl-a	Chlorophyll-a
CMEMS	Copernicus Marine Environment Monitoring Service
CNR	Consiglio Nazionale Delle Ricerche
CRC	Comité Régional de la Conchyliculture
COREPEM	Comité Régional des Pêches Maritimes et des Elevages Marins des Pays de la Loire
DT	Delayed Time
EO	Earth observation
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FR	France
HAB	Harmful Algal Bloom
INTECMAR	Instituto Tecnolóxico para o Control do Medio Mariño de Galicia
IOP	Inherent Optical Properties
IT	Italy
L1	Level 1: Satellite data processed as Digital numbers or TOA Radiances
L2	Level 2: Satellite data processed as BOA Radiances, reflectances or basic geophysical product
L3	Level 3: Satellite data processed mapped onto a regular grid , a single snapshot, or daily combined products
L4	Level 4: Satellite data products for which a temporal averaging method and/or an interpolation procedure is applied to fill in missing data values
MERIS	MEdium Resolution Imaging Spectrometer
MFC	Monitoring and Forecasting Center
MODIS	Moderate Resolution Imaging Spectroradiometer
MSFD	Marine Strategy Framework Directive

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement No 776348

MSI	MultiSpectral Instrument
NASA	National Aeronautics and Space Administration
NL	Netherland
NOAA	National Oceanic and Atmospheric Administration
NRT	Near real time
OC	Ocean Colour
OCTAC	Ocean Colour Thematic Assembly Center
OLCI	Ocean and Land Colour Instrument
PAR	Photosynthetically Available Radiation
PC	Phycocyanin
PML	Plymouth Marine Laboratory
PO	Project officer
PO Mossel	Producentenorganisatie van de Nederlandse Mosselcultuur
PP	Primary productivity
PFT	Phytoplankton Functional Type
PSC	Phytoplankton Size Class
PUM	Product User Manual
QA	Quality assurance
QuID	Quality Information Document
REP	Reprocessing
Rrs	Remote Sensing Reflectance
RWS	Rijkswaterstaat
S2 or S-2	Sentinel-2
S3 or S-3	Sentinel-3
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SME	Small Medium Enterprise
SMIDAP	Syndicat Mixte pour le Développement de l'Aquaculture et de la Pêche en Pays de la Loire
SNR	Signal to Noise Ratio
SP	Spain
SPM	Suspended Particulate Matter
SST	Sea Surface Temperature
TAC	Thematic Assembly Center
TOA	Top of the Atmosphere
TSM	Total Suspended Matter
VIIRS	Visible Infrared Imager Radiometer Suite
WFD	Water Framework Directive
WP	Work package
WQ	Water Quality

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

1 Summary

CoastObs aims to develop a user-relevant platform that offers user-relevant innovative and higher- level information products and coastal monitoring services. These services aim to be fully automated, commercial, reliable and sustainable. The validated basic and innovative products will be flexibly combined into higher-level products to fit the users' information needs.

Both basic products and a set of innovative products are being developed in accordance with users' needs in order to provide them with useful information to monitor coastal water environments and deal with the main problems affecting the different study areas.

The scope of this document is to evaluate the CMEMS catalogue for use as part of the CoastObs service portfolio, by assessing the spatial coverage and the product accuracy in the four CoastObs study areas of the products available in the CMEMS catalogue.

The CMEMS operational products do not provide yet the necessary spatial coverage for near shore environments of the case study regions, due to the conservative masking used in the OCTAC production chains. Furthermore, the products are not as locally accurate as required by the users in the CoastObs case study areas, as the algorithm design and the accuracy assessment of these products are performed at basin scale.

The gap between what the Copernicus core service currently delivers and what users in the near-coastal areas addressed in this project require, still offers opportunities for the downstream services proposed by CoastObs. The development of user-required products within CoastObs, can also provide an opportunity for bottom-up feedback for the service evolution of CMEMS.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

2 Introduction

CoastObs develops a user-relevant platform that offers user-relevant innovative and higher-level information products and coastal monitoring services. These services aim to be fully automated, commercial, reliable and sustainable. The validated basic and innovative products will be flexibly combined into higher-level products to fit the users' information needs.

Work Package 3 is aimed at the development of a set of services and products based on the combination of Earth Observation (EO) data with in situ information. Both basic products and a set of innovative products are being developed in accordance with users' needs in order to provide them with useful information to monitor coastal water environments and deal with the main problems affecting the different study areas.

The scope of this document is to evaluate CMEMS catalogue for use as part of the CoastObs service portfolio, by assessing the spatial coverage and the product accuracy in the four CoastObs study areas of the products available in the CMEMS catalogue. Evaluation of the CMEMS products will form the basis material for communication to CMEMS and involved stakeholders and thus contribute to CMEMS evolution. This activity will be carried out in Task 6.5 "Interface with CMEMS" that will be concluded with a "Discussion document CMEMS core and downstream services" (D6.1) due on August 2020 (M33).

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement No 776348

3 The CoastObs case study areas

To demonstrate the multi-user approach of CoastObs, four case studies have been identified in coastal areas where various types of stake holders have indicated a need for better information on water quality.

For these four areas, operational services are being set up for the members of the user group according to their product and service requirements. These services will be fully automated and be integrated into the users' operational data management systems. An overview of the four case study areas with details on the users and their interests is presented in Figure 1, Table 1.

The precise definition of these services will be part of the Service Level Agreements between the consortium partners and the users. Table 2 provides an overview of the expectations by the users on the improvements that will be provided by the CoastObs services in support of their activities and operations.

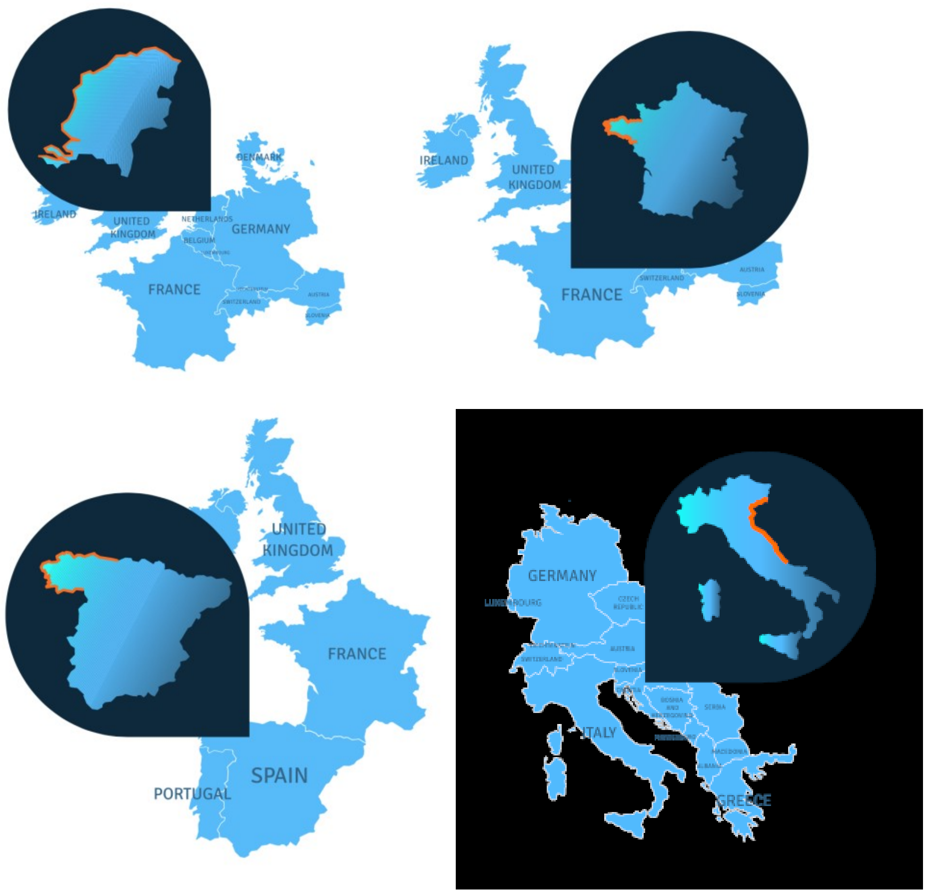


Figure 1 Overview of CoastObs case study areas.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

Table 1. Overview of CoastObs case studies

Dutch Coast case study	**Objectives**	• gain insight in spatial and temporal variation in food availability for mussels • monitor turbidity as a result of dredging fisheries and sand nourishment • monitor environmental status of the coastal waters, including eutrophication, PP, indicator species *phaeocystis*, and to provide data for reporting requirements
	Identified users and interests	• Mussel producers (M en M Padmos, WK Schot, Steketee, De Rooij, De Waal Padmos): • A mussel producer organisation (PO Mossel): • The national authorities responsible for water monitoring (Rijkswaterstaat): • Interests shellfish farmers: production improvement • Interest National Authority: improving monitoring efficiency
French Coast case study	**Objectives**	• gain insight in spatial and temporal variation of intertidal macrophytes (seagrass beds and macro-algae) and submerged seagrass beds; • retrieve European Directives variables (eg. biomass and areal extent) • develop an optical non-destructive method to estimate intertidal seagrass leaf biomass and epiphytes with a field spectroradiometer
	Identified users and interests	• Representatives of oyster producers (CRC), of fishermen (COREPEM), local associations (ADBVBB): maps of macrophytes and wild bivalves beds (oyster and mussels) for resources management • National agencies (AFB, AAMP): variables requested by the Water & Marine Strategy Framework Directives • UN as a scientific user →NDVI time-series of intertidal and submerged vegetation to understand the role of global warming vs. local anthropogenic pressures on vegetation dynamic
Spanish Coast case study	**Objectives**	• incorporate chlorophyll-a concentration from satellite ocean colour data into the prediction of bloom occurrence of Pseudo-nitzschia spp. abundance and dynamics in Galicia Area using the SVM models for early detection.
	Identified users and interests	• Cooperativa de Armadores de Pesca del Puerto de Vigo (ARVI) and Consello Regulador do Mexillón de Galicia: maps of Chlorophyll-a concentration, Sea Surface Temperature and primary productivity for resource management and HAB detection.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

Italian Coast case study	**Objectives**	• to gain insight in spatial and temporal variation of submerged macrophytes and their correlation to eutrophication and anoxic crises in the Lagoon of Venice; • to investigate the morphodynamics, coastal erosion in dynamic key areas, based on suspended sediment transport pathways.
	Identified users and interests	• The Regional Agency for Environmental Prevention and Protection in Veneto (ARPAV): primary producers (phytoplankton, macroalgae and seagrasses) and water quality parameters in the LV, both in operational monitoring and time-series analysis mode. • The Eastern Alps Hydrographic District: the historical analysis of coastal morphodynamics and on the mapping of river plumes. • CNR as a scientific user: suspended sediment products, which can support the assessment of sediment transport and dispersion processes to support marine spatial planning activities

3.1 Case study Dutch coast

The case study is focused on two areas: the Scheldt estuary and the Wadden Sea (Figure 2).

Waddenzee and Eems estuary is a highly dynamic and productive estuarine area, characterized by extensive tidal mud flats, saltmarshes, and deeper tidal creeks. It's also one of the largest coastal wetlands in the world and a biodiversity hotspot. Pressures such as eutrophication, increased sedimentation due to dredging, sea level rise and invasive species are causing ecosystem changes.

The Western Scheldt (Dutch: Westerschelde), is the estuary of the Scheldt river. Total productivity is elevate, both as primary (phytoplankton) and secondary production (e.g. zoo-plankton and shrimps) as well as production of higher trophic levels (e.g. benthic organisms and fish) that are significant due to the availability of large amounts of detritus. The intertidal mussel beds play a major role in the recycling of nutrients in this estuary.

Figure 2 Location of Dutch case study areas

3.2 Case study South Brittany

The French case study has two sites: Bourgneuf Bay, an intertidal seagrass meadow dominated by *Zostera noltei* and the subtidal seagrass beds dominated by the specie *Zostera marina* that is located in the Glénan Archipelago.

The intertidal case-study site is Bourgneuf bay (2°W, 47°N) a shellfish ecosystem located south of the Loire estuary on the French Atlantic coast. Z. noltei grows as monospecific stands in sandy muddy sediment, stretching out along the shoreline, in areas unoccupied by oyster-farming (Barillé et al. 2010). Even though the oyster activities do not seem to have a direct impact on seagrass in the Bay, it is a concern for oyster producers because of the close vicinity between this habitat and oyster farming-sites. The second site is a subtidal Zostera marina seagrass beds located in the Glenan archipelago (47° 43′ 01′′ N , 4° 00′ 00′′ O.) at nine miles from the coast, in South Brittany. This area of 35 km2, is characterized by numerous rocky islets and nine small islands, surrounding an enclosed shallow lagoon. The turbidity is low and the archipelago is protected by environmental regulations. The subtidal seagrass bed of Zostera marina covers an area of ca. 3km2 estimated by photo-interpretation.

3.3 Case study Galicia

The Galician coast, one of the most intensive areas of mussel production in the world, suffers from a frequent occurrence of a variety of harmful algal events. Coastal embayments like rias are physically complex systems and pose a challenge for the detection, monitoring and forecast of harmful algal events. Interest in monitoring HABs is considerable, mainly because of the economic and social importance of the extensive culture of mussels (Rodríguez et al., 2011), and the frequent occurrence of harmful algal events .

3.4 Case study Adriatic Sea coast

The Italian case study is composed of two adjoining sites: The North Adriatic Sea and the Venice lagoon.

The North Adriatic Sea is a shallow (~35 m) and semi-enclosed regional sea and its hydrodynamics are influenced by meteorological forcings (winds and tides). It is considered to be one of the most productive regions of the Mediterranean. The largest phytoplankton blooms occur in its surface layers in late winter and in summer. The area alternates between case 1 and case 2 water types. Case 2 conditions are mainly due to the effects of local winds, which resuspend bottom sediments, and due to the discharge from the Po River and other rivers to the north, which are sources of terrestrial particulate and dissolved matter. The Venice lagoon is a very shallow coastal environment with a mean depth of 1 m, connected with the sea through three inlets (Lido, Malamocco, Chioggia) to the North Adriatic Sea and it is influenced by freshwater from the land and tides of the NAS. A succession of different environments from the mainland to the sea characterizes the complex morphology of the lagoon that has a total surface of ca. 550 km^2. Water quality, storm surge and high tides, both natural and anthropogenic are the main problems.

Table 2. Overview of expectations by Users of how CoastObs can improve or support their activities

User	Geographic area of interest	Expectation of how CoastObs can improve or support their activities
Rijkswaterstaat (RWS)	Wadden Sea including ~5km outside the Wadden islands, Eastern and Western Scheldt estuary, The entire Dutch coast	Insight into system dynamics 1. Spatial variability of WQ parameters 2. Temporal variability of WQ parameters 3. Statistics, long term change, anomalies
Producentenorganisatie van de Nederlandse Mosselcultuur (PO Mossel)	Eastern Scheldt estuary & Wadden Sea	Assess effects of environmental activities in and around culture plots. Notably, magnitude of turbidity as a result of dredging fisheries and scale effects of sand nourishment around culture plots.
M en M Padmos + WK Schot + Mosselkweek Steketee-Bom, De Waal	Eastern Scheldt estuary & Wadden Sea	Mussel farmers working on production improvement and anticipation of ecosystem dynamics: trough better insight in patterns of food quality and food quantity and in possible contra-

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

Padmos, De Rooij mosselkweek		productive effects from environment (e.g. effects of sand nourishment) in and around culture plots.
Syndicat Mixte pour le Développement de l'Aquaculture et de la Pêche en Pays de la Loire (SMIDAP)	Bourgneuf bay and Loire estuary	To produce maps of chlorophyll a, SPM, temperature, toxic microalgae to help understanding growth and risks of cultivated bivalves. To obtain water quality indicator for shellfish ecosystem To produce suitability maps to optimize the best locations for growing mussels and to understand mussels mortality events To obtain data about historical analysis of coastal accretion
Comité Régional des Pêches Maritimes et des Elevages Marins des Pays de la Loire (COREPEM)	Bourgneuf bay and Loire estuary	To produce maps of wild oyster reefs/mussel beds for their management for their exploitation by professional To produce maps of macroalgae spatial distribution to monitor the resource collected by professional To produce interannual time-series map of seagrass beds to analyze possible interactions with professional handfishing
French Agency of Biodiversity	Bourgneuf bay and Loire estuary Glenan Island	To get phycocyanin, phytoplankton phenology , chlorophyll-a concentration, and productivity maps for the Glenans and Bourgneuf Bay to better understand the functioning of pelagic food web in relation with the management of basking shark populations. To produce maps of seagrass beds in relation with anthropogenic pressures To produce SPM maps to analyse anthropogenic pressures (e.g. dredging) Would like to count marine mammals in the sea and the stranded ones Would like to count birds In Bourgneuf bay, to get maps of the reefs of honeycomb worm Detailed maps of shores: discriminate species To detect variations of the coastline, tidal flat bathymetry In fact, this agency is interested beyond the two

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

		study sites and would be interested to extend it to all Marine Protected Areas of the whole French coastal areas, but also in the French overseas territories
Comité Régional de la Conchyliculture (CRC)	Bourgneuf bay and Loire estuary	To produce maps of wild oyster reefs/mussel beds that are considered as a resource, but which contribute at the same time to the trophic competition with cultivated conspecifics. To produce maps of macroalgae spatial distribution to help optimize field sampling strategies (when macroalgae are present the biomass of wild oysters is low and known) To produce interannual time-series map of seagrass beds to analyze possible interactions with aquaculture
Cooperativa de Armadores de Pesca del Puerto de Vigo (ARVI)	Galician coasts	To produce maps of Chlorophyll-a concentration, Sea Surface Temperature and primary productivity for their management for their exploitation by professional.
Consello Regulador do Mexillón de Galicia	Galician coasts	We hope that the data provided by CoastObs will improve the models we are developing in the aforementioned projects.
Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto (ARPA Veneto)	Venice Lagoon and northern Adriatic Sea	Supporting environmental applications such as monitoring water quality, pollution, algal bloom, episodes of anoxia.

Autorità di bacino Distrettuale delle Alpi Orientali (ADB)	Northern Adriatic Sea coasts	Providing raw/processed data from remote sensing and data processing able to strengthen knowledge on some specific aspects currently linked to traditional monitoring only, especially within internal waters. That is: 1. Indicators/indices relevant for drought risk assessment (linked to soil moisture, vegetation stress, ...) 2. Indicators for coastal erosion as impact of reduced sediment transport (due to hydromorphological pressures on internal waters) and as impact of storm surges. 3. indicators/indices linked to quantitative/qualitative parameters describing water flow and - secondly - quantitative/qualitative parameters linked to ecological status (which would be primarily useful to environmental agencies in charge for status classification) Providing data/models/tools to gain information on water scarcity, through the measure of its potential impacts on detectable parameters.
CNR –ISMAR	Mediterranean and Black Seas	Improve the availability of satellite data to be used for model initialization, validation and data assimilation.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

4 Relevant products in the CMEMS catalogue

4.1 The Ocean Colour data-streams in the CMEMS catalogue

This section aims to summarize the organization of the Ocean Colour data-streams in the CMEMS catalogue. The following text in italic is an excerpt from Volpe et al 2019:

"The Copernicus Marine Environment Monitoring Service (CMEMS) is one of the six services of the Copernicus program. It provides regular and systematic reference information on the physical state, variability and dynamics of the ocean, ice and marine ecosystems for the global ocean and the European seas. CMEMS delivers both satellite and in-situ high-level products prepared by Thematic Assembly Centres (TACs) and modelling and data assimilation products prepared by Monitoring and Forecasting Centres (MFCs).

The Ocean Colour Thematic Assembly Centre (OCTAC) builds and operates the European ocean colour operational service within CMEMS providing global, Pan-European and regional (Arctic Ocean, Atlantic Ocean, Baltic Sea, Black Sea, and Mediterranean Sea) ocean colour (OC) products based on earth observation from OC missions (Le Traon 2015, Von Schuckman 2016; 2017).

The OCTAC bridges the gap between space agencies, providing ocean colour data, and all users who need the added-value information not available from space agencies. Presently, the OCTAC relies on current and legacy OC sensors: MERIS (MEdium Resolution Imaging Spectrometer) from ESA, SeaWiFS (Sea-viewing Wide Field-of-view Sensor) and MODIS (Moderate Resolution Imaging Spectroradiometer) from NASA, VIIRS (Visible Infrared Imager Radiometer Suite) from NOAA, and most recently the Copernicus Sentinel 3A OLCI (Ocean and Land Colour Instrument) sensor.

Starting from the Level-2 (L2) data downloaded from space agencies, the OCTAC generates Level-3 (L3) and Level-4 (L4) products in near-real time (NRT) and delayed time (DT) modes. Within CMEMS, L3 products refer to the single snapshot, or daily combined products, mapped onto a regular grid, while L4 are products for which a temporal averaging method and/or an interpolation procedure is applied to fill in missing data values. The NRT products are operationally produced daily to provide the best estimate of the ocean colour variables at the time of processing. These products are generated soon after the satellite swaths are available together with climatological ancillary data, e.g., meteorological and ozone data for atmospheric correction, and predicted attitude and ephemerides for data geolocation. In the DT processing, the updated ancillary data made available from the space agencies are used to improve the quality of the NRT data. NRT and DT data streams hence are designed to fulfil the operational oceanography specific requirements for near real time availability of high quality satellite data with a sufficiently dense space and time sampling (e.g., Le Traon et al., 2015). Generally, once a year, the full data time series undergoes a reprocessing (REP) to ensure most

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

recent findings to be consistently applied and back propagated to all data. REP products are multi-year time series produced with a consolidated and consistent input dataset and processing software configuration, resulting in a dataset suitable for long-term analyses and climate studies (Von Schuckman et al., 2017, Sathyendranath et al., 2017 and references therein).

Within CMEMS, observations from multiple missions are processed together to ensure homogenized and inter-calibrated datasets for all essential ocean variables. Combining the observations from different platforms results in higher coverage as compared with those of the single sensors. Moreover, the multi-sensor product allows non-expert users to access a robust and less ambiguous source of information.

Currently in the OCTAC, the NRT and DT multi-sensor L3 and L4 products are derived from MODIS-AQUA and NPP-VIIRS data, while REP includes observations from SeaWiFS, MODIS-AQUA, MERIS and NPP-VIIRS. Global REP products are derived from two datasets: the OC-CCI (Climate Change Initiative, www.esa-oceancolour-cci.org) funded by the European Space Agency and the Copernicus-GlobColour initially developed by Globcolour Project (www.globcolour.info) and then updated and produced in the framework of CMEMS. OLCI is foreseen to be included into the NRT/DT multi-sensor products in 2019 and in the REP when the quality of the data will be deemed suitable."

Further than the multi-sensor datasets, currently the single sensor S3A OLCI data is processed at 1 km resolution in NRT/DT (Le Traon et al., 2017). OLCI datasets at 300 m resolution from S3A and S3B will be included in the CMEMS catalogue for all regions by the end of 2020. CMEMS is also planning to include in the service-catalogue in 2020 new high resolution Ocean Colour products for coastal waters application based on Sentinel2/MSI data to further contribute to the implementation of environmental policies implementation and the sustainable use of marine resources in the coastal domain.

4.2 Relevant products of the CMEMS catalogue for CoastObs

For each ocean region, the OCTAC delivers two types of products: CHL and OPTICS. CHL is composed of two datasets: the phytoplankton chlorophyll concentration (Chl-a) and the Phytoplankton Functional Types; whereas OPTICS refers to other variables retrieved from ocean colour sensors, and includes: Inherent Optical Properties (IOPs), such as absorption and scattering; the diffuse attenuation coefficient of light at 490 nm (Kd490); Secchi depth (transparency of water); spectral Remote Sensing Reflectance (Rrs); photosynthetically available radiation (PAR); Coloured Dissolved Organic Matter (CDOM); and the Suspended Particulate Matter (SPM).

The OCTAC regional products provide higher accuracy than standard OC data available from space ground segments thanks to the regionalization of processing chains that takes into account the bio-optical characteristics of each regional sea for production and data validation (e.g., D'Alimonte and Zibordi, 2003; Brewin et al 2018; Kajiyama et al., 2018; Pitarch et al., 2016; Volpe et al., 2007; 2019). Moreover, the approach is to produce a

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement No 776348

blended product with the appropriate chlorophyll algorithm being applied depending on the water types present in a pixel (Kajiyama et al., 2018; Le Traon et al., 2017; Volpe et al., 2019).

The products of the CMEMS OCTAC catalogue of interest for this report are from two regions: the Mediterranean Sea for the Venice lagoon and the Northern Adriatic Sea, and the Atlantic Ocean for Dutch, French and Spanish study sites (Table 3). The remainder of this section will summarize the approaches for the processing chains in the two regions. Details on all products in the CMEMS catalogue are provided in the Product User Manual (PUM) and in the Quality Information Documents (QuIDs).

Table 3: relevant products of the CMEMS OCTAC catalogue for this report

region	L3/ L4	NRT/ REP	Product name	notes
MED	L3	NRT	OCEANCOLOUR_MED_OPTICS_L3_NRT_OBSERVATIONS_009_038	
MED	L4	NRT	OCEANCOLOUR_MED_OPTICS_L4_NRT_OBSERVATIONS_009_039	
MED	L3	REP	OCEANCOLOUR_MED_OPTICS_L3_REP_OBSERVATIONS_009_095	
MED	L3	NRT	OCEANCOLOUR_MED_CHL_L3_NRT_OBSERVATIONS_009_040	
MED	L4	NRT	OCEANCOLOUR_MED_CHL_L4_NRT_OBSERVATIONS_009_041	
MED	L3	REP	OCEANCOLOUR_MED_CHL_L3_REP_OBSERVATIONS_009_073	
MED	L4	REP	OCEANCOLOUR_MED_CHL_L4_REP_OBSERVATIONS_009_078	
ATL	L3	REP	OCEANCOLOUR_ATL_OPTICS_L3_REP_OBSERVATIONS_009_066	
ATL	L3	REP	OCEANCOLOUR_ATL_CHL_L3_REP_OBSERVATIONS_009_067	
ATL	L4	REP	OCEANCOLOUR_ATL_CHL_L4_REP_OBSERVATIONS_009_091	
ATL	L3	NRT	OCEANCOLOUR_ATL_CHL_L3_NRT_OBSERVATIONS_009_036	
ATL	L4	NRT	OCEANCOLOUR_ATL_CHL_L4_NRT_OBSERVATIONS_009_090	
ATL	L3	NRT	OCEANCOLOUR_ATL_OPTICS_L3_NRT_OBSERVATIONS_009_034	
ATL	L4	NRT	OCEANCOLOUR_ATL_OPTICS_L4_NRT_OBSERVATIONS_009_092	

4.2.1 The Atlantic Ocean Products

In the Atlantic Sea, the same operational processing chain is operational for the NRT/DT and the REP data production. Rrs spectra over the common set of SeaWiFS wavelength are produced by the Plymouth Marine Laboratory (PML) with a processing chain based on the OC-CCI processor version 4 (hereafter CCIv4). SeaWiFS, MODIS-AQUA data and VIIRS data were derived with l2gen, while MERIS data are processed with the POLYMER. CCI v4 is based on the NASA reprocessing R2018.0 for SeaWiFS, MODIS and VIIRS (Brewin et al 2018).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

In the Atlantic Sea, the regional chlorophyll algorithm is OC5CCI, a combination of OCI (Hu, Lee & Franz, 2012) and OC5 (Gohin, F., et al., 2008.). OC5CI was selected after a calibration exercise and sensibility analysis of the existing algorithms that analysed the quantitative performance against in situ data for several algorithms (OC3, OC4, OCI, OC5CI, OC5, Brewin et al 2018).

4.2.2 The Mediterranean Sea Products

In the Mediterranean Sea, two different processing chains are operational : one for the NRT/DT and one for the REP data production. The input of both processing chains is the spectral Rrs downloaded from upstream data providers. Hence, in both cases, the atmospheric correction is not part of these processing chains. The output of both chains, i.e. Chl-a and Kd490, are consistently retrieved with the same algorithms from common set of wavelengths corresponding to the SeaWIFS bandset.

The NRT/DT chain involves the pre-processing of L2 data from different sensors with different wavelengths that are then merged together over a common set of wavelengths. More detail on the multi-sensor approach are provided in Volpe et al 2019. For the REP processing, Rrs spectra over the common set of SeaWIFS wavelength are produced by the Plymouth Marine Laboratory (PML) using the OC-CCI processor (www.esa-oceancolour-cci.org) merging MERIS, MODIS-AQUA, SeaWiFS and VIIRS data, as described earlier.

In the Mediterranean Sea , the blended chlorophyll product is based on two algorithms: for Open Ocean waters (Case I), the MedOC4, an updated version of the regionally parameterized Maximum Band Ratio (Volpe et al., 2007, 2019) , while for optically complex waters (Case II domain) the ADOC4 algorithm (D'Alimonte and Zibordi, 2003) is used.

4.2.3 Standard flagging in the OCTAC processing chains

Within the OCTAC processing chains, in the passage from L2 to L3 single sensor data, quality flags provided by Space Agencies are applied to mask data that could be affected by large source of uncertainties, due to both environmental and instrumental conditions. The flags applied to SeaWiFS, MODIS and VIIRS data are those of the standard processing from NASA (https://oceancolor.gsfc.nasa.gov/atbd/ocl2flags/), while for OLCI the suggested flags are provided by EUMETSAT (https://www.eumetsat.int/website/wcm/idc/idcplg?IdcService=GET_FILE&dDocName=PDF_S3_PN_OLCI_L2M_001&RevisionSelectionMethod=LatestReleased).

A known issue with the NASA L2 standard flags is that the Stray Light (SL) flag masks also affects data acquired near the coastlines and estuaries (Barnes et al.,2019). The SL flag is designed to mask all the pixels that can be affected by the adjacency effect of clouds and lands. Indeed, for measurements performed over pixels close to the shore, the light reflected by the land surface can be forward scattered into the sensor field of view, and this can result in an abnormal increase of the reflectance in the near-infrared (NIR). A similar issue is related to the application of the ANNOT_DROUT flag to OLCI processing that leads to over-masking of pixels in optically complex waters. The current evolution of the OCTAC processing chains aims to address the shortcoming of the conservative flagging and masking implemented by the agencies to increase the near-shore coverage.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

5 Data availability and the local accuracy of the CMEMS products

In this section, the data availability and the local accuracy of the CMEMS products is presented. For the four study areas, the available data from the relevant CMEMS product was extracted to evaluate the spatial coverage by mapping the number of valid pixels for a calendar year and the median Chl-a value for the pixels that exceeded a threshold of 50 valid observations per calendar year. The product accuracy of the products in the CMEMS catalogue was based on local reference data collected by CoastObs partners or provided by stakeholders. A pairwise match-up analysis was performed between the in situ data from local monitoring programs and the median Chl-a value extracted from a 3x3 pixel box around the monitoring location, but only in correspondence of at least 3 valid pixels.

5.1 Case study Dutch coast

For the Wadden Sea area, the number of available pixels for 2018 in the Chl-a dataset for from OCEANCOLOUR_ATL_CHL_L3_NRT_OBSERVATIONS_009_036 reaches a maximum of ~70 valid observations from 5 km offshore towards the North Sea. Within the Wadden sea there are only a few pixels reaching ~50 valid observations, as shown also for the Chl-a median field for 2018 (Figure 3). For the Scheldt Estuary area, the maximum of ~80 valid observations from 5 km offshore towards the North Sea, but very little data within the Western and Eastern Scheldt Estuary (Figure 4).

The matchup analysis was performed for the time series 2002- 2017 of in situ samples collected by Rijkswaterstaat using CMEMS product OCEANCOLOUR_ATL_CHL_L3_REP_OBSERVATIONS_009_067, and with data collected from loggers in 2018 using CMEMS product OCEANCOLOUR_ATL_CHL_L3_NRT_OBSERVATIONS_009_036. The location of the sampling stations and of the logger yields enough data in the Wadden Sea, but no co-located data for the Scheldt Estuary. For both the samples collected at the stations and the logger measurements, the OCTAC Chl-a products consistently underestimated the in situ counterparts and also show a low R2 (Figure 5).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

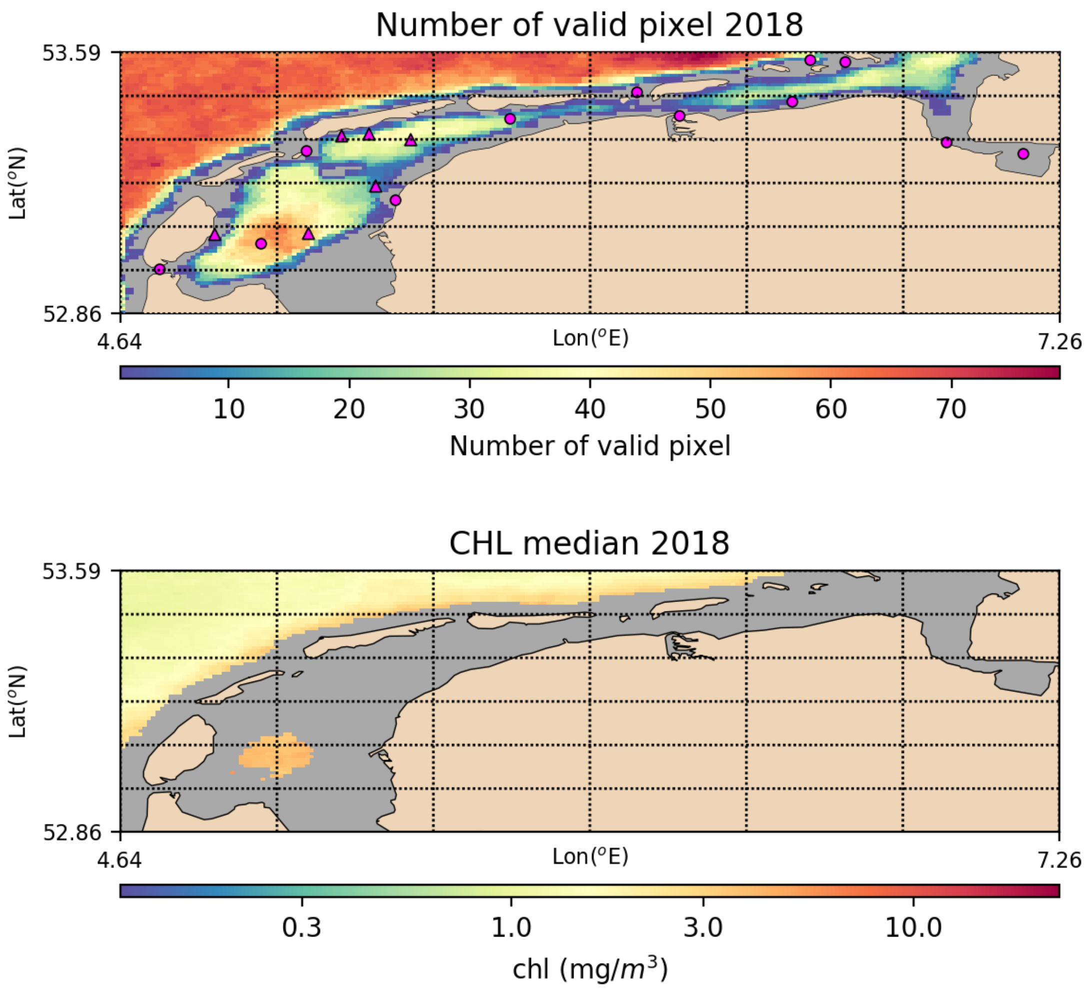


Figure 3 Data availability and median Chl-a concentration in the CMEMS data for the Wadden Sea in 2018. Top: number of valid pixels with location of the in situ data (triangles are stations and circles are logger locations) for the Wadden Sea; Bottom: median Chl-a concentration for 2018 computed from the CMEMS data (only for number of valid pixels>50). Grey indicates messing values.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

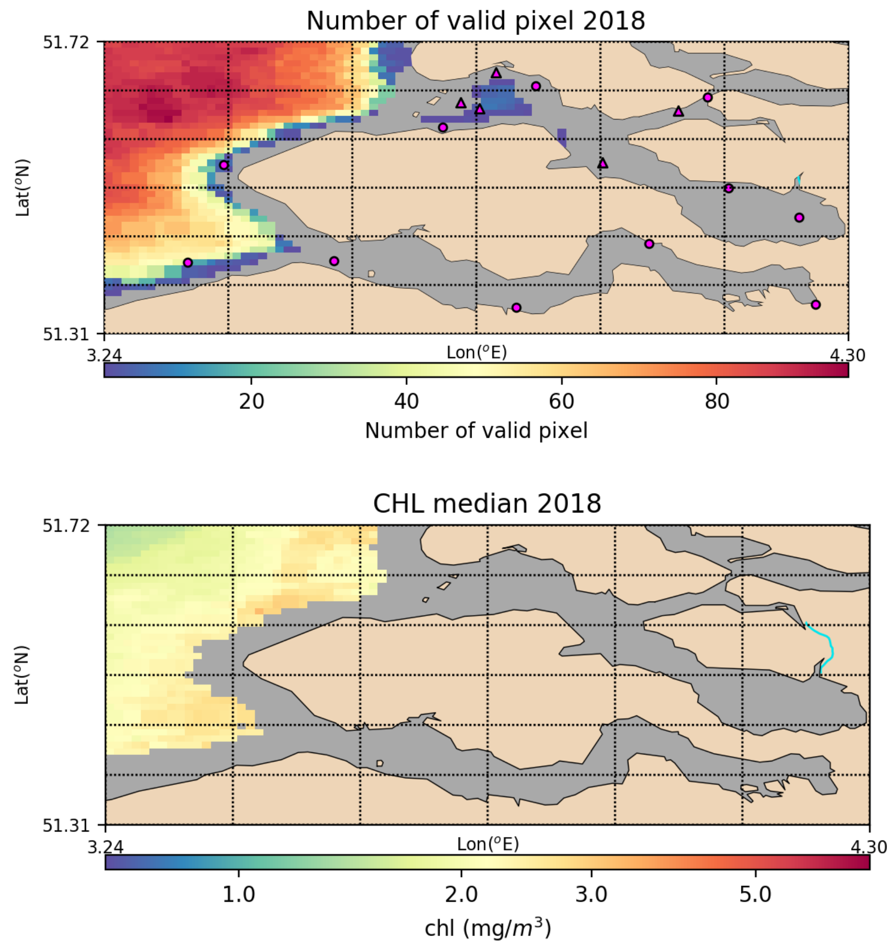
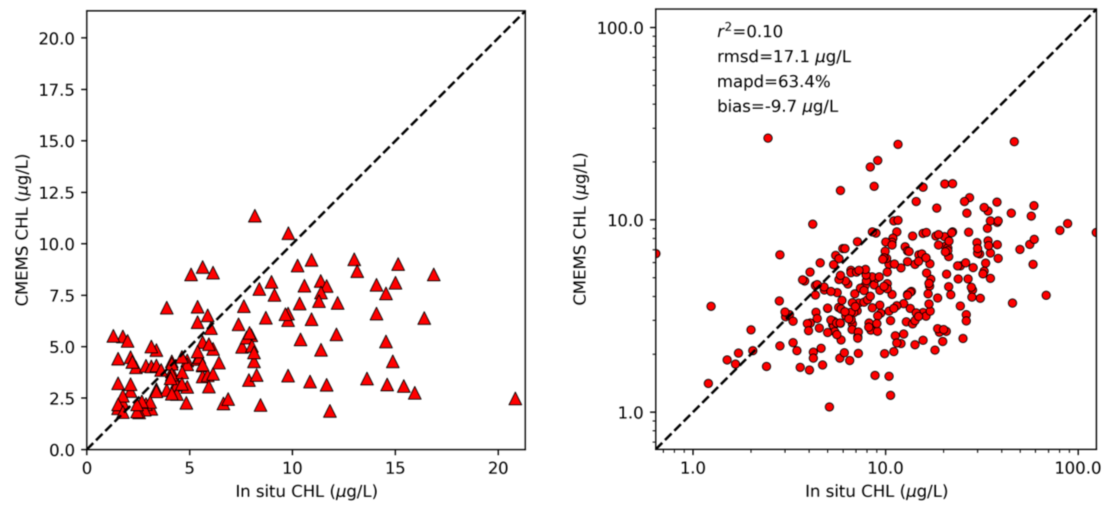


Figure 4 Data availability and median Chl-a concentration in the CMEMS data for the Scheldt Estuary in 2018. Top: number of valid pixels with location of the in situ data (map triangle mark stations and circles mark logger locations) for the Scheldt Estuary; bottom: median Chl-a concentration for 2018 computed from the CMEMS data (only for number of valid pixels>50). Grey indicates messing values.



This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement No 776348

Figure 5 Matchup analysis for Chl-a concentration with the CMEMS satellite data for the Wadden Sea. Left: matchup with data from water quality stations (2002-2017); right: matchup with data from water quality loggers (2018)

5.2 Case study South Brittany

For the Bourgneuf Bay and Loire Estuary area, the number of available pixels for 2018 in the Chl-a dataset for from OCEANCOLOUR_ATL_CHL_L3_NRT_OBSERVATIONS_009_036 reaches a maximum of ~120 valid observations from 5 km offshore towards the Atlantic Ocean (Figure 6). No data is available within the Loire Estuary, as shown also for the Chl-a median field for 2018, it means that the area corresponding to our inter-tidal case-study is masked out and then, no matchup analysis was performed.

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement No 776348

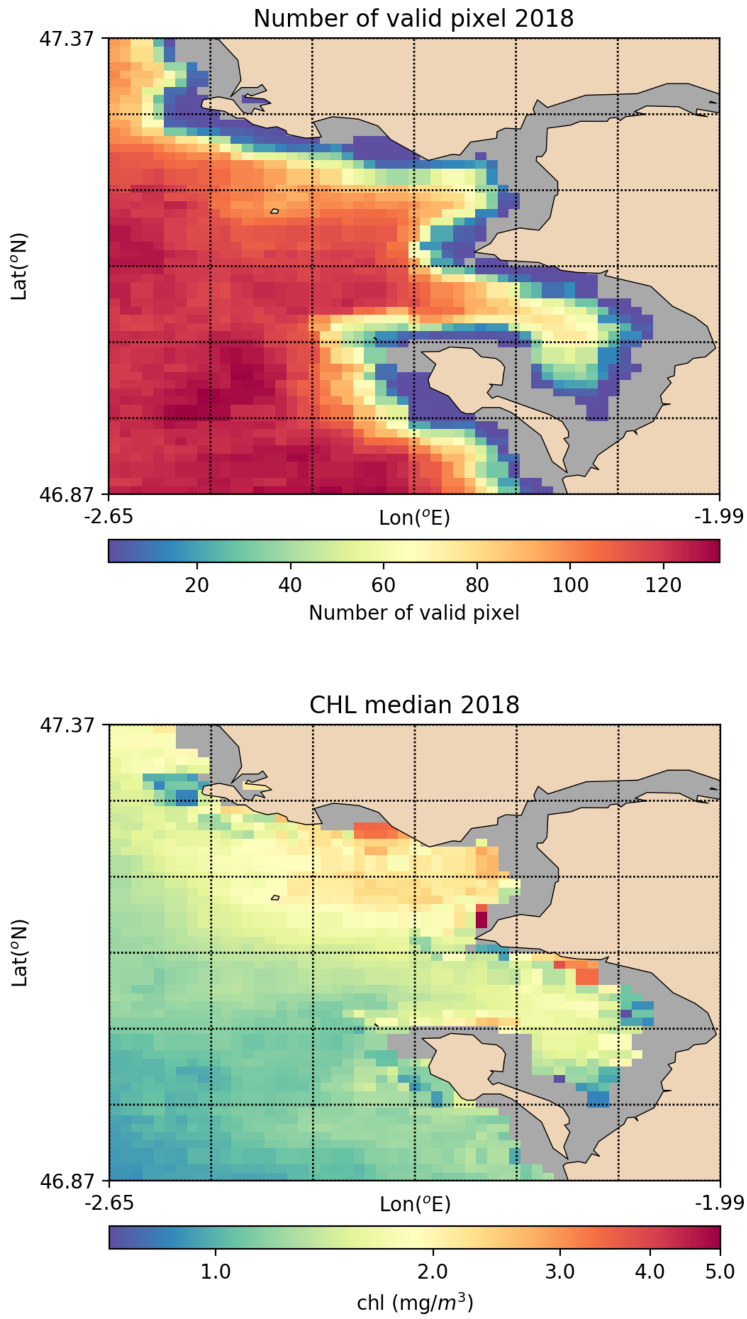


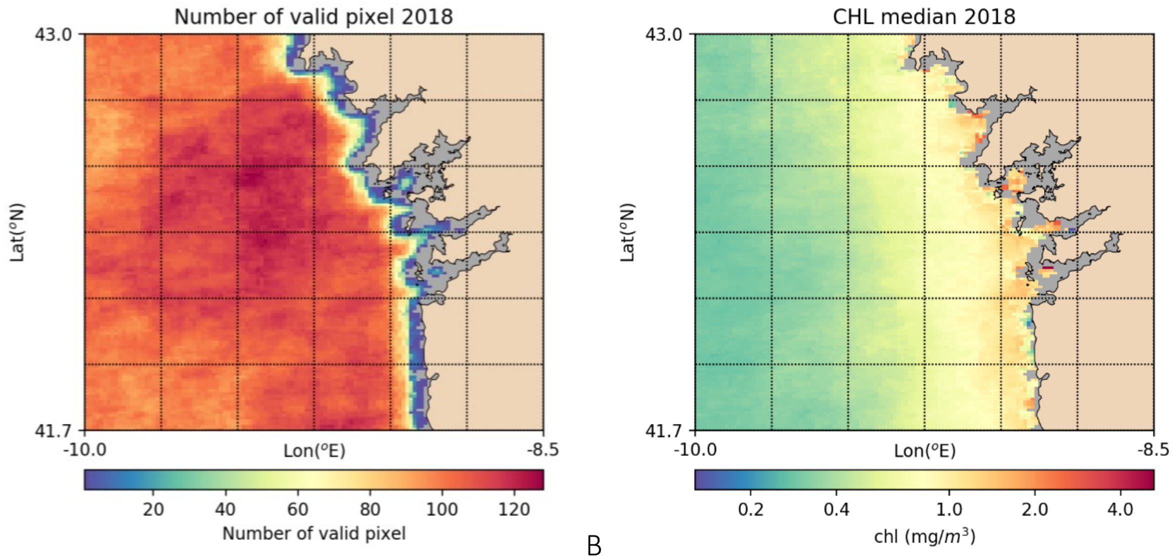
Figure 6 French case study: number of valid pixels and median Chl-a concentration in the CMEMS data for south Britanny in 2018. Grey indicates messing values.

5.3 Case study Galicia

For the Galicia case study area, the number of available pixels for 2018 in the Chl-a dataset from OCEANCOLOUR_ATL_CHL_L3_NRT_OBSERVATIONS_009_036 reaches a maximum of

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

~120 valid observations from ~10 km offshore towards the Atlantic Ocean (Figure 6). Very limited data is available within the rias, as shown also for the Chl-a median field for 2018 and for the detailed maps focused on the Rias (Figure 7). Hence the matchup analysis performed using Chl-a data from the weekly monitoring programme of INTECMAR yielded no suitable co-located data.



A

B

Figure 7 Data availability and median Chl-a concentration in the CMEMS data for the Galicia Coast in 2018. A: number of valid pixels for the Rias de Vigo; B: median Chl-a concentration for 2018 computed from the CMEMS data (only for number of valid pixels>50). Grey indicates messing values.

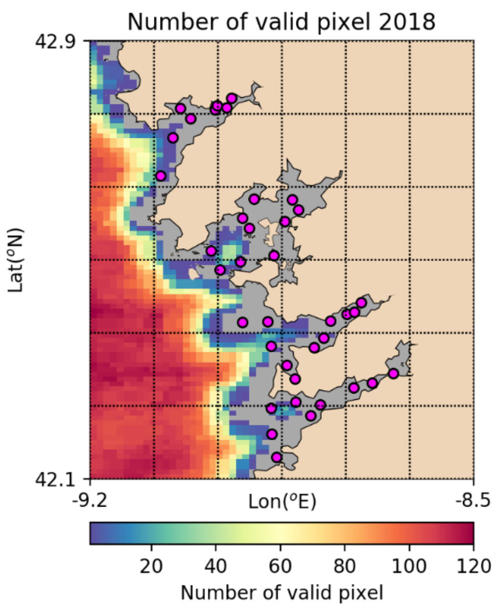


Figure 8 number of valid pixels for the Rias de Vigo number of valid pixels with location of the in situ data. Grey indicates messing values.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

5.4 Case study Adriatic Sea coast

For the Italian case study area, the number of available pixels for 2018 in the Chl-a dataset from OCEANCOLOUR_MED_CHL_L3_NRT_OBSERVATIONS_009_040 reaches a maximum of ~140 valid observations from ~10 km offshore towards the open waters (Figure 9). Very limited data is available within the Venice Lagoon, as shown also for the Chl-a median field for 2018. The matchup analysis was performed using Chl-a data from the monitoring programme of ARPAV (2002- 2017) for the CMEMS product OCEANCOLOUR_MED_CHL_L3_REP_OBSERVATIONS_009_073. The OCTAC Chl-a products consistently overestimated the nearshore in situ counterparts and also show a low R2 (Figure 10)

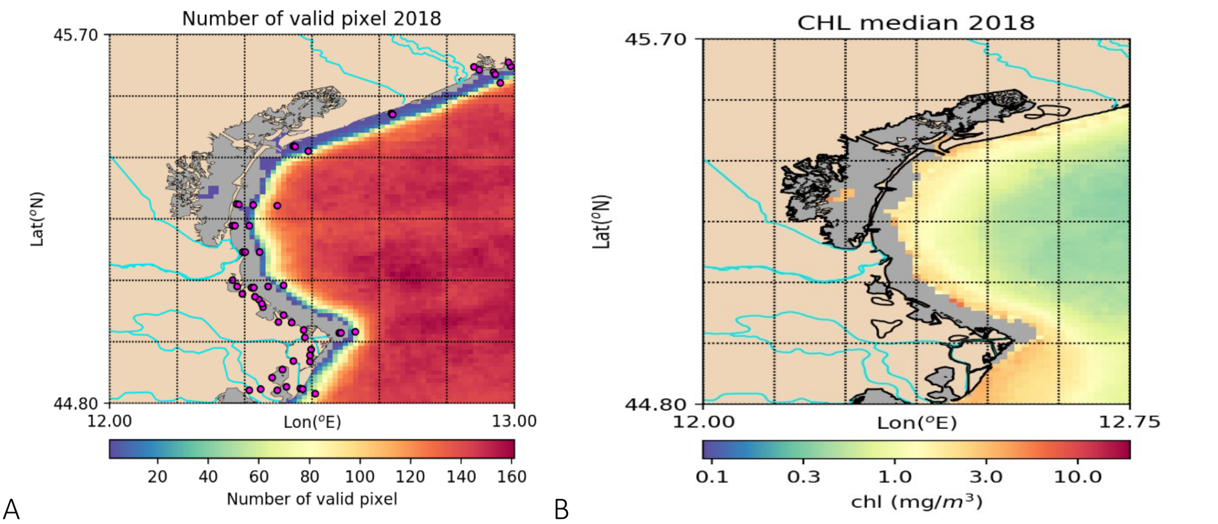
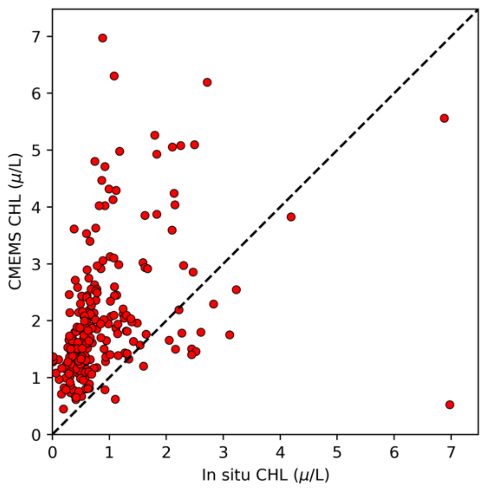


Figure 9 Data availability and median Chl-a concentration in the CMEMS data for the Northern Adriatic Sea and the Venice Lagoon in 2018. A: number of valid pixels with location of the in situ data for the Northern Adriatic Sea; B: median Chl-a concentration for 2018 computed from the CMEMS data (only for number of valid pixels>50). Grey indicates messing values.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

Figure 10 Matchup analysis for Chl-a concentration with the CMEMS satellite data for the Northern Adriatic Sea and the Venice Lagoon. Data from water quality stations (2002-2017).

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement No 776348

6 Implications of the findings

The overall aim of CoastObs is to develop a commercial downstream service platform for monitoring and reporting of coastal water quality based on Earth observation. One of CoastObs major objective is to make several scientifically mature information products derived for ENVISAT/MERIS in the last decade (primary production, HAB-indicators, phytoplankton functional groups, combined EO and optical in situ monitoring) available as operational information products recalibrated to Sentinel 3 (and Sentinel 2 if the spectral band-set and SNR allows).

In addition to delivering L1 or L2 satellite data by ESA and EUMETSAT, Copernicus also provides six core thematic services, one of which is the Copernicus Marine Environmental Monitoring Service (CMEMS). CMEMS delivers a core information service free of charge to all users including service providers or end-users from the commercial sector or from the R&D sector. The focus areas of CMEMS are maritime safety, coastal and marine environment, marine resources, and weather, seasonal forecasting and climate activities. CMEMS provide Rrs, Chl-a and IOP data at 1km resolution for Sentinel 3 OLCI and for multi-sensor products (Le Traon 2017, et al., Garnesson et al., 2019; Volpe et al., 2019,). The data is served aggregated as daily, weekly and monthly products (Level 3) and is also served as optimally interpolated products (Level 4) to overcome cloud cover in subsequent oceanographic analyses (Le Traon et al 2015, Volpe et al 2018). The operational OCTAC Chl-a products are based on a blend of Case1 and Case2 algorithms to reduce uncertainties in all the application domain (e.g. Volpe et al 2019). These products may serve as basis for the production of CoastObs products required by the users such as PP, PSC and other higher level products.

A major aspect of CoastObs is to increase the efficiency of deriving products from L1 or L2 satellite data. The availability of suitable pre-processed input data from the Copernicus Core services (i.e. CMEMS) would be beneficial for the success of this project. Alas, as demonstrated with the analysis of the CMEMS catalogue in this report, In, the CMEMS operational products do not provide yet the necessary spatial coverage for near shore environments of the case study regions, due to the conservative masking proposed by the space agencies and implemented in the OCTAC production chains. Furthermore, the products accuracy at the local scale of the CoastObs case study areas, is lower than documented by OCTAC for the regional scale, as the algorithm design and the accuracy assessment of these products are performed at basin scale.

The addition to the CMEMS catalogue of the Sentinel 3 OLCI datasets at 300m resolution, currently planned for late 2020, should address some of these shortcomings. For the near future, the upstream for the CoastObs service will be directly sourced from the L1 or L2 satellite data and provided by the agencies (i.e. EUMETSAT for Sentinel3 OLCI) and not the preprocessed and value-added regional products available in the CMEMS catalogue.

Therefore, there is a gap between what the core service currently delivers and what users in the near-coastal areas addressed in this project require, which still offers opportunities for downstream services as proposed by CoastObs. The progress beyond the state of the art will be centred on algorithm developed for optically complex waters, implemented on Sentinel 3 bands, and tuned locally for the case study areas if needed. The development of user

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

required products within CoastObs, can also provide an opportunity for bottom-up feedback for the service evolution and aspiration of CMEMS coastal activities.

The Task 6.5 “Interface with CMEMS” will be the conduit for this two-way communication and it will be concluded with a “Discussion document CMEMS core and downstream services” (D6.1) due on August 2020 (M33). Moreover this activity will contribute to project’s white paper on the topic of cross fertilization between the value adding industry (potential of value adding to CMEMS products from the SME perspective) and CMEMS (further refining CMEMS portfolio in coastal waters to enhance uptake and increase liaisons with users at large and SMEs).

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 776348

7 References

Barillé L., Robin M., Harin N., Bargain A., Launeau P., 2010. Increase in seagrass distribution at Bourgneuf bay (France) detected by spatial remote sensing. Aquatic Botany 92, 185-194.

Barnes, B. B., Cannizzaro, J. P., English, D. C., & Hu, C. (2019). Validation of VIIRS and MODIS reflectance data in coastal and oceanic waters: An assessment of methods. Remote sensing of environment, 220, 110-123.

Brewin,R, S. Pardo, T. Jackson, M. Grant, B. Taylor , 2018 CMEMS-OCTAC: Qualitiy information Document for the Atlantic and Arctic Observation Products , http://marine.copernicus.eu/services-portfolio/access-to-products/?option=com_csw&view=details&product_id=OCEANCOLOUR_ATL_CHL_L4_REP_OBSERVATIONS_009_091

D'Alimonte, D. and Zibordi, G.: Phytoplankton determination in an optically complex coastal region using a multilayer perceptron neural network, IEEE T. Geosci. Remote, 41, 2861–2868, https://doi.org/10.1109/TGRS.2003.817682, 2003.

Garnesson, P., Mangin, A., Fanton d'Andon, O., Demaria, J., and Bretagnon, M.: The CMEMS GlobColour chlorophyll a product based on satellite observation: multi-sensor merging and flagging strategies, Ocean Sci., 15, 819-830, https://doi.org/10.5194/os-15-819-2019, 2019.

Gohin, F., Saulquin, B., Oger-Jeanneret, H., Lozac'h, L., Lampert, L., Lefebvre, A., Riou, P., and Bruchon, F.: Towards a better assessment of the ecological status of coastal waters using satellite-derived chlorophyll-a concentrations, Remote Sensing of Environment, 112, 3329-3340, 10.1016/j.rse.2008.02.014, 2008.

Hu, C., Z. Lee, and B.A. Franz (2012). Chlorophyll-a algorithms for oligotrophic oceans: A novel approach based on three-band reflectance difference, J. Geophys. Res., 117, C01011, doi:10.1029/2011JC007395.

Kajiyama T., D. D'Alimonte, and G. Zibordi, "Algorithms merging for the determination of Chlorophyll-a concentration in the Black Sea," IEEE Geoscience and Remote Sensing Letters, 2018. [Online]. Available: https://-www.doi.org/¬10.1109/¬LGRS.2018.2883539

Le Traon, P.-Y., Antoine, D., Bentamy, A., Bonekamp, et al.: Use of satellite observations for operational oceanography: recent achievements and future prospects, J. Oper. Oceanogr., 8, s12– s27, https://doi.org/10.1080/1755876X.2015.1022050, 2015.

Le Traon, P. Y., Ali, A., Alvarez Fanjul, E., Aouf, L., Axell, L., Aznar, R., et al. (2017). The copernicus marine environmental monitoring service: main scientific achievements and future prospects. Mercator. Ocn. J. 56, 101. doi: 10.25575/56

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776348

Pitarch, J., Volpe, G., Colella, S., Krasemann, H., and Santoleri, R.: Remote sensing of chlorophyll in the Baltic Sea at basin scale from 1997 to 2012 using merged multi-sensor data, Ocean Sci., 12, 379-389, 10.5194/os-12-379-2016, 2016.

Rodríguez, G. R., Villasante, S., & do Carme García-Negro, M. (2011). Are red tides affecting economically the commercialization of the Galician (NW Spain) mussel farming?. Marine Policy, 35(2), 252-257.

Sathyendranath, S., Brewin, R. J. W., Jackson, T., Mélin, F., and Platt, T.: Ocean-colour products for climate-change studies: What are their ideal characteristics?, Remote Sens. Environ., 203, 125–138, https://doi.org/10.1016/j.rse.2017.04.017, 2017.

Volpe, G., Santoleri, R., Vellucci, V., Ribera d'Alcalà, M., Marullo, S., and D'Ortenzio, F.: The colour of the Mediterranean Sea: Global versus regional bio-optical algorithms evaluation and im- plication for satellite chlorophyll estimates, Remote Sens. En- viron., 107, 625–638, https://doi.org/10.1016/j.rse.2006.10.017, 2007.

Volpe, G., Colella, S., Forneris, V., Tronconi, C., and Santoleri, R.: The Mediterranean Ocean Colour Observing System – system development and product validation, Ocean Sci., 8, 869–883, https://doi.org/10.5194/os-8-869-2012, 2012.

Volpe, G., Buongiorno Nardelli, B., Colella, S., Pisano, A., and Santoleri, R.: An Operational Interpolated Ocean Colour Prod- uct in the Mediterranean Sea, in: New Frontiers in Operational Oceanography, edited by: Chassignet, E. P., Pascual, A., Tintorè, J., and Verron, J., GODAE OceanView, 227–244, 2018.

Volpe, G., Colella, S., Brando, V. E., Forneris, V., Padula, F. L., Cicco, A. D., ... & Santoleri, R. (2019). Mediterranean ocean colour Level 3 operational multi-sensor processing. Ocean Science, 15(1), 127-146.

von Schuckmann, K., Le Traon, P. Y., Alvarez-Fanjul, et al. The Copernicus Marine Environment Monitoring Service Ocean State Report, J. Oper. Oceanogr., 9, s235–s320, https://doi.org/10.1080/1755876X.2016.1273446, 2016.

von Schuckmann, K., Le Traon, P.-Y., Smith, N., Pascual, A., Brasseur, P., Fennel, K., Djavidnia, S et al. Copernicus Marine Ser- vice Ocean State Report, J. Operat. Oceanogr., 11,, S1–S142, https://doi.org/10.1080/1755876X.2018.1489208, 2018.