CADEAU Service
CMEMS Demonstration 32-DEM-L5

Final report on activities
September 2018 [T0+18]

Index

Executive summary

CADEAU is a downstream coastal service that aims to operationally produce a bulletin based on an integrated model downscaling of the regional Mediterranean Copernicus Marine Environment Monitoring Service. CADEAU focuses on nutrient dynamics, eutrophication and bathing water quality in coastal areas in support of the application of the EU Directives relative to the coastal and marine environment (WFD, UWWTD, BWD, MSFD). In particular, the products (publicly delivered through a dedicated web-portal) are designed to provide information on the space-time distributions of the major parameters related to water quality (nitrogen and phosphorus concentration, chlorophyll, temperature, dissolved oxygen, TRIX), with emphasis on the northern Adriatic region. The environmental monitoring data have been processed and assimilated into a high-resolution downscaling of CMEMS, based on the coupled MITgcm-BFM modeling system. The integrated results will be used to assess the impact of urban waste water treatment plants (with discharge points in or near the sea and rivers), the biogeochemical conditions and the evaluation of Good Environmental Status in the Adriatic Sea to meet the WFD/BWD/MSFD requirements, and the potential impact of bacterial pollution on shellfish farming.

CMEMS downstream service

The operational service consists of an annual bulletin reporting the marine environmental state and the water quality along the Italian northern Adriatic coast, which belongs to the CMEMS Mediterranean Sea region. The system is based on the high-resolution MITgcm-BFM model for the northern Adriatic Sea. The model is initialized and driven by the downscaling operational procedure of the nominal products (hydrodynamics and biogeochemistry) of the CMEMS Mediterranean Monitoring and Forecast Centre. Further, it integrates satellite data and the Italian water quality monitoring system by means of nudging algorithms. A dedicated webpage has been created by ISPRA, which describes the service and focuses on the usefulness and the integration of CMEMS information. The core of the present new service is the development of the project web-portal, which is hosted at ISPRA and provides the bulletin and the dedicated products. The accessibility of the service is free and there are statistics available to track traffic count.

CMEMS products

The products available through the web-portal include time series (2006-2017) of high-resolution maps of several variables. The navigable maps are guaranteed by the web-GIS tools. GIS maps are grouped per year and different labels identify the variables. It is always transparent for the user what kind of data he/she is visualizing and which data sets have been used (or assimilated) to produce it. The Service is able to provide the derived products as tools for decision for the implementation of measures in the overall environmental planning process. The derived products useful for the Water Framework Directive and Marine Strategy Framework Directive are shapefiles related to water quality parameters: Surface Temperature, Dissolved oxygen, Chl-a, NOx, NH4, PT, DIN, TRIX. The derived products useful to support the management of bathing waters are indexes developed to help the definition of the area of influence. These indexes help identifying which, among the main freshwater discharges with a risk of bacterial pollution, can produce an impact on bathing waters and areas dedicated to the aquaculture of *Mytilus galloprovincialis*. The shapefiles contain: indexes for the mean and the maximum relative impact of a source on a bathing water and the aquacultures plants, indexes relating the mean and maximum portion of a plume released

by a source impacting on a bathing water and indexes showing the cross-correlation between the *Intestinal Enterococci* and *E.coli in situ* data.

Targeted users

The targeted users of the services are:

- at national level, the Ministry of Environment and Ministry of Health, that may adopt the derived products as tools for decision support for the implementation of measures in overall environmental planning process set by UWWTD/BWD/WFD/MSFD;
- at regional level, the Regions (i.e., for our demonstration: Friuli Venezia Giulia, Veneto, Emilia-Romagna and Marche) and the regional environmental agencies, directly involved in the environmental management of coastal areas, and the tourism/fishery industry associations and stakeholders, with their fundamental economic revenues produced by tourism and seafood activities;
- at sub-regional level, the local municipalities, directly responsible for the bathing water quality of coastal areas and the citizen health.

First bulletin for the period 2006-2017

The first bulletin of this new CMEMS service is available in the section "Bulletin" on the web site: http://www.bio.isprambiente.it/cadeau/. The northern Adriatic Sea has been subdivided into seven areas, and all the variables have been elaborated for each of the seven areas. The analysis was performed by calculating the annual minimum, maximum and the annual average (2006-2017) for each variable for each of the subdivisions. Furthermore, the minimum, the average and the maximum for the ten-years period 2008-2017 have been drawn up for each subdivision.

1. General overview of the project

EU countries are requested to comply with many Directives with respect to coastal and marine environment (e.g., WFD, UWWTD, BWD, MSFD). Such Directives either specify threshold values to comply with, or prescribe environmental assessment procedures and actions to reach specific targets. CADEAU is a downstream coastal service that aims to routinely produce an annual environmental bulletin based on an integrated model downscaling of the regional Mediterranean Copernicus Marine Environment Monitoring Service (CMEMS). The service is applied to the northern Adriatic Sea, since it is one of the most sensitive areas along the Italian coastline where eutrophication and marine resources exploitation both influence and depend on the quality of the marine ecosystem. CADEAU focuses on nutrient dynamics, eutrophication and bathing water quality, impact on shellfish farming in coastal areas in support of the application of the EU Directives. In particular, the products (publicly delivered through a dedicated web-portal) are designed to provide information on the space-time distributions of the major parameters related to water quality (nitrogen and phosphorus concentration, chlorophyll “a”, temperature, oxygen). The Italian coastal monitoring dataset managed by ISPRA has been processed and integrated into a high-resolution downscaling of CMEMS, based on the coupled MITgcm-BFM modeling system. The integrated results are used to assess the impact of urban wastewater treatment plants (with discharge points in or near the sea and rivers), the biogeochemical conditions and the evaluation of Good Environmental Status in the Adriatic Sea to meet the WFD/UWWTD/BWD/MSFD requirements. The downstream service and the coastal derived products aim to provide a contribution for the assessment of good environmental status, for bathing water quality assessment, and shellfish farming management.

2. Development of the service (Task. 1)

2.1 Development of the operational model system (Sub-Task 1.1)

The operational service consists of an annual bulletin reporting the marine environmental state and the water quality along the Italian northern Adriatic coast, which belongs to the CMEMS Mediterranean Sea region. The system is based on the high-resolution MITgcm-BFM model for the northern Adriatic Sea (Cossarini et al., 2017) implemented at OGS. The model is initialized and driven by the downscaling operational procedure of the nominal products (hydrodynamics and biogeochemistry) of the CMEMS Mediterranean Monitoring and Forecast Centre. Further, it integrates satellite data and the Italian water quality monitoring system by means of nudging algorithms. Further improvements will include finer data assimilation techniques (3DVAR-BIO, Teruzzi et al., 2013).

2.1.1 Development of the integration between the MITgcm-BFM model, experimental data and the downscaling modeling system for the northern Adriatic Sea (Sub Task 1.1.1)

The numerical simulations are based on the MITgcm-BFM coupled hydrodynamic-biogeochemical model (Cossarini et al., 2017, Fig. 1). The modelling system is based on the MITgcm hydrodynamic and transport modules. The biogeochemical processes are included via the BFMcoupler package, and integrated in space and time by the MITgcm. Hydrodynamic and biogeochemical variables can be assimilated by using either native MITgcm modules, or assimilation schemes affecting the coupler, or both.

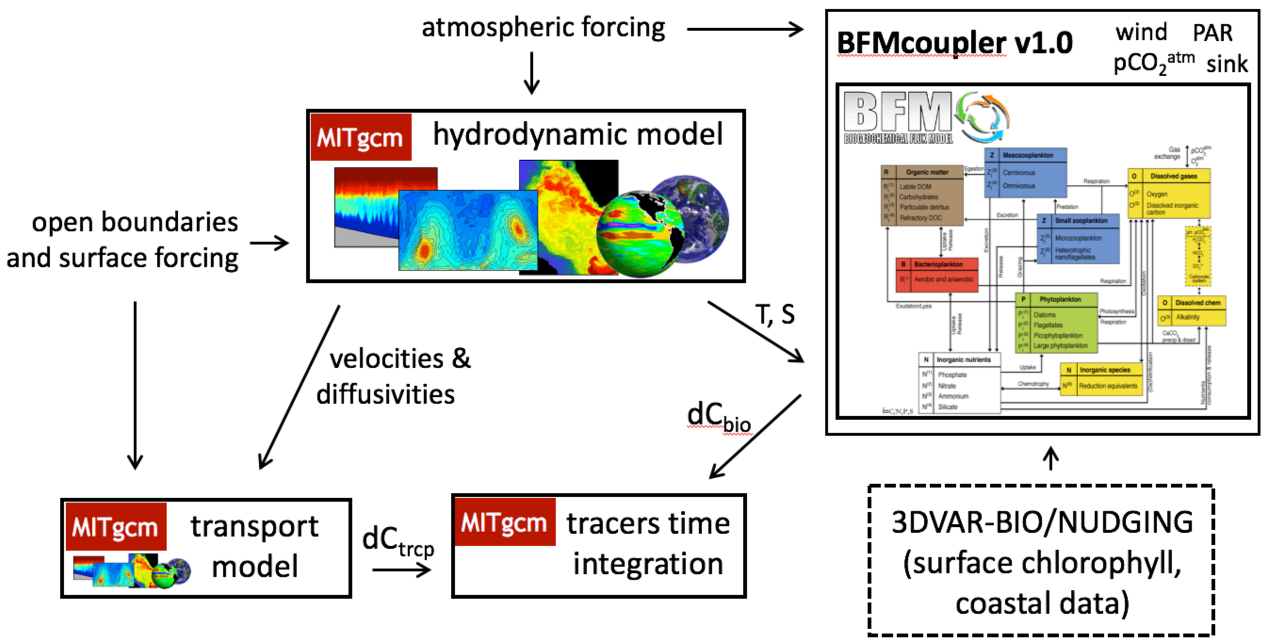

Figure 1. The MITgcm-BFM coupled hydrodynamic-biogeochemical model.

The model domain (northern Adriatic Sea) has been discretized with a horizontal resolution of 1/128° (850 × 600 m) and 27 unequally spaced vertical levels. The bathymetry adopted for the service spans north of latitude 43.5° N (Fig. 2) and explicitly considers the 19 major rivers flowing into the basin. Daily discharge rates are available for the Po, Isonzo and Timavo rivers. The other flow rates have been derived from up-to-date climatologies, modulated in order to have the maximum and minimum values in spring/autumn and summer/winter, respectively.

The meteorological forcing is obtained from the RegCM model developed at the Abdus Salam Centre for Theoretical Physics (ICTP) and from COSMO-LAMI model, run by the Emilia-Romagna Environmental Protection Agency (ARPA-EMR). The RegCM and the COSMO-LAMI datasets cover the 2006-2012 and the 2013-2017 time-periods, respectively (even if adopting different horizontal resolutions, 10 and 2.2 km). Both models include the meteorological parameters needed to drive the coupled model (air temperature, pressure and humidity, wind velocity, heat fluxes and precipitation).

Initial and open boundary conditions are derived from the CMEMS modelling system: we extracted the initial conditions for January 2006 and we processed the CMEMS dataset to obtain the daily open boundary conditions on the southern side of the domain.

Model resolution and set-up guarantee a proper simulation of the main basin and sub-basin scale features of the northern Adriatic Sea (Fig. 2), both from the hydrodynamic and biogeochemical point of view.

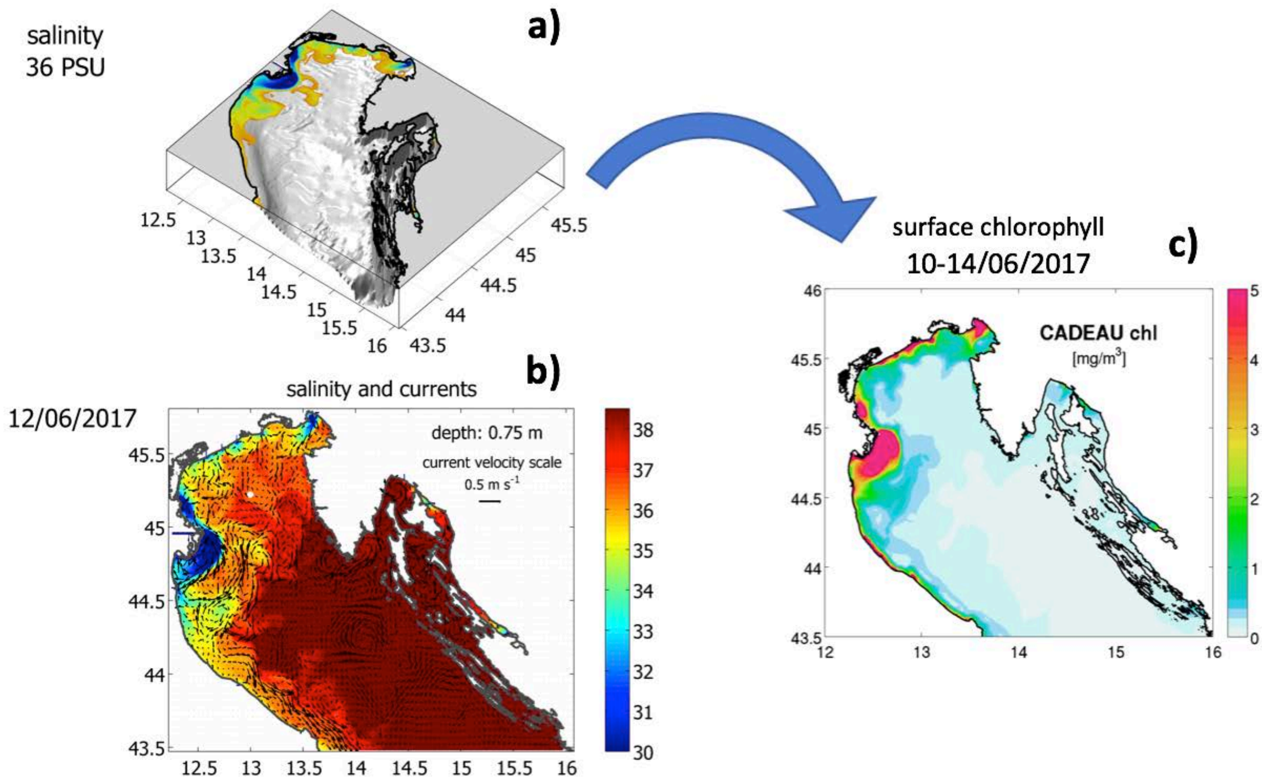

Figure 2. 3D (a) and surface (b) view of the salinity field in the northern Adriatic Sea. Plot c) shows the corresponding surface chlorophyll spatial variability.

CMEMS products have been used to drive, validate and optimize the model through data assimilation techniques. For these purposes, we downloaded the following products:

MEDSEA_REANALYSIS_BIO_006_008

Copernicus Marine Service Mediterranean Sea biogeochemistry reanalysis products. This product has been used to build the initial conditions and boundary conditions (section at Lat 43.5°N) of the biogeochemical variables of the BFM model for the operational restarts and simulations of the northern Adriatic high-resolution reanalysis. The data have been interpolated from the 1/16° resolution of the CMEMS product to the 1/128° resolution of the present service.

MEDSEA_REANALYSIS_PHYS_006_004
Copernicus Marine Service Mediterranean Sea physics reanalysis products. This product has been used to build the initial conditions and boundary conditions (section at Lat 43.5°N) of the physical variables of the MITgcm transport model for the operational restarts and simulations of the northern Adriatic high-resolution reanalysis. The data have been interpolated from the 1/16° resolution of the CMEMS product to the 1/128° resolution of the present service.

OCEANCOLOUR_MED_CHL_L3_REP_OBSERVATIONS_009_073
Copernicus Marine Service Mediterranean Sea surface chlorophyll concentration from multi satellite observations reprocessed (ESA-CCI). This product has been used as input for the coastal high-resolution data assimilation implemented in the reanalysis run (Fig. 3).

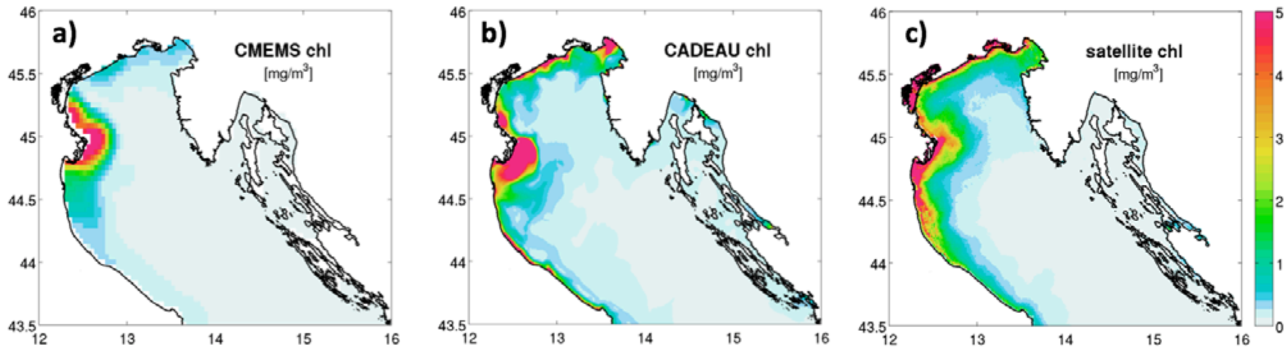

Figure 3. Improvement in model accuracy after increasing the resolution. Surface chlorophyll (10-14 June 2017): results of the CMEMS 1/24° model (a), of the CADEAU 1/128° model (b) and satellite data (c).

MEDSEA_ANALYSIS_FORECAST_BIO_006_014
Copernicus Marine Service Mediterranean Sea biogeochemistry analysis and forecast products. This product will be used to build the initial conditions and boundary conditions (section at Lat 43.5°N) of the biogeochemical variables of BFM model for the operational restarts of the annual updates. The data have been interpolated from the 1/24° resolution of the CMEMS product to the 1/128° resolution of the present service.

MEDSEA_ANALYSIS_FORECAST_PHY_006_013
Copernicus Marine Service Mediterranean Sea physics analysis and forecast products. This product will be used to build the initial conditions and boundary conditions (section at Lat 43.5°N) of the physical variables of the MITgcm model for the operational restarts of the annual updates. The data have been interpolated from the 1/24° resolution of the CMEMS product to the 1/128° resolution of the present service.

OCEANCOLOUR_MED_CHL_L3_NRT_OBSERVATIONS_009_040
Copernicus Marine Service Mediterranean Sea surface chlorophyll concentration from satellite observations. This product, presently based on MODIS-Aqua and NPP-VIIRS sensors, or its update featuring the Sentinel 3 data, will be used as input for the coastal high-resolution data assimilation implemented in the annual operational updates.

SST_MED_SST_L4_REP_OBSERVATIONS_010_021
Copernicus Marine Service Mediterranean Sea surface temperature from satellite observations (reprocessed Pathfinder V5.2 AVHRR data). The data are interpolated through an Optimal Interpolation algorithm. This product has been used for the assimilation of SST in the reanalysis run.

SST_MED_SST_L4_NRT_OBSERVATIONS_010_004
Copernicus Marine Service Mediterranean Sea surface temperature from satellite observations (merged-multisensor SST data remapped over the Mediterranean Sea at high and Ultra High spatial resolution, respectively 1/16° and 0.01°). This product will be used for the assimilation of SST in the operational updates.

OCEANCOLOUR_MED_CHL_L4_NRT_OBSERVATIONS_009_041
Copernicus Marine Service Mediterranean Sea surface chlorophyll concentration from multi satellite observations. This product is the update of the OCEANCOLOUR_MED_CHL_L3_NRT_OBSERVATIONS_009_040 observations, featuring the Sentinel 3 data. It will be used as input for the coastal high-resolution data assimilation implemented in the annual operational updates.

Integration of the numerical model and the experimental dataset

A preliminary processing of the experimental data consisted in mapping the sampling stations and the urban wastewater discharge points (Fig. 4) on the model grid. For each site, we selected the closest water point in the model domain, whether in the sea or in the rivers.

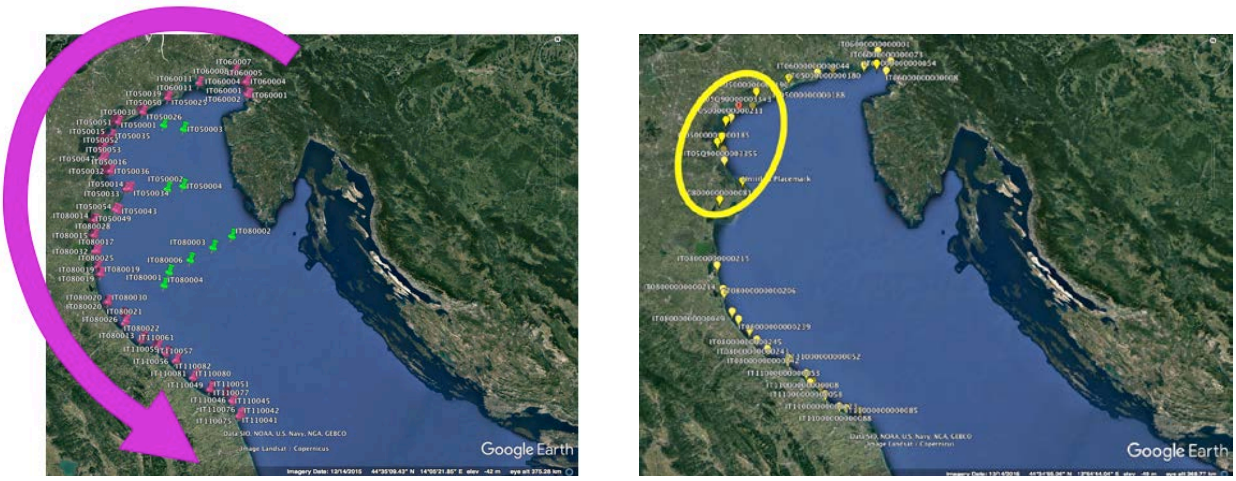

Figure 4. Spatial distribution of the sampling stations (left) and of the UWWTP discharge points (right).

The sampling data have also been analyzed to obtain a synoptic view of the dataset and to check the spatial and temporal distribution of the in-situ measurements. This step is essential for the implementation and tuning of the parameters used by the data nudging/assimilation schemes, which integrate the measurements into the numerical model. As an example, Fig. 5 gives a synthetic overview of the phosphate *in-situ* data. The stations are ordered by administrative divisions and, except for 9 open-sea points, their distribution follows the coastline in the counter clockwise direction, starting from the north. For each year, the measurements are averaged by temporal groups: a temporal group of measurements is defined as a set of "consecutive" measurements with a maximum tolerance of 3 days without records and belonging to a maximum temporal window of 7 days. The averaged measurements are assigned to the central time of each window.

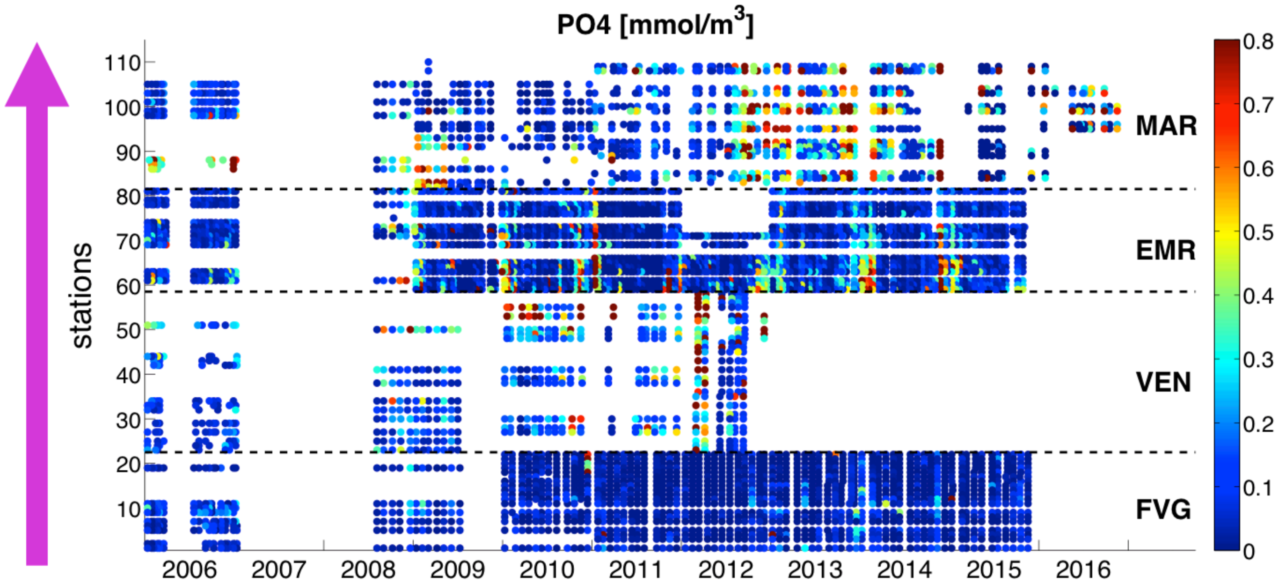

Figure 5. Spatial and temporal distribution of phosphate data, ordered as indicated by the purple arrow (see also Fig. 4). The four administrative regions considered in the project are Friuli Venezia Giulia (FVG), Veneto (VEN), Emilia Romagna (EMR) e Marche (MAR).

The UWWTP data are integrated in the model as local bottom sources of nutrients. We updated the model routines to include this new type of forcing for the biogeochemistry. Since discharge loads were not available for several treatment plants, we computed the average load (for population equivalent) and the average efficiency of the known systems, and we extended these (average) estimates to the other plants, for which only the population equivalent is known.
In particular, for the Chioggia case-study we also imposed 12 sources of tracer, with a first-order decay law that simulates Escherichia Coli bacteria (Chan et al., 2013). The reaction rate coefficient is defined as:

$$k(z,t) = \left(k_b + k_s S(z,t)\right)\theta^{T-20} + k_I I(t) e^{-e_t z}$$

where z is depth, t is time and the constants are set to k_b=0.8, k_s=0.017, k_I=0.086, e_t=0.5 (water characterized by higher transparency) and θ=1.07.
Fig. 6 shows a 3D view of the tracer concentrations in late winter 2017. These data have been processed to obtain the indexes described Section 3.1.2 of this report.

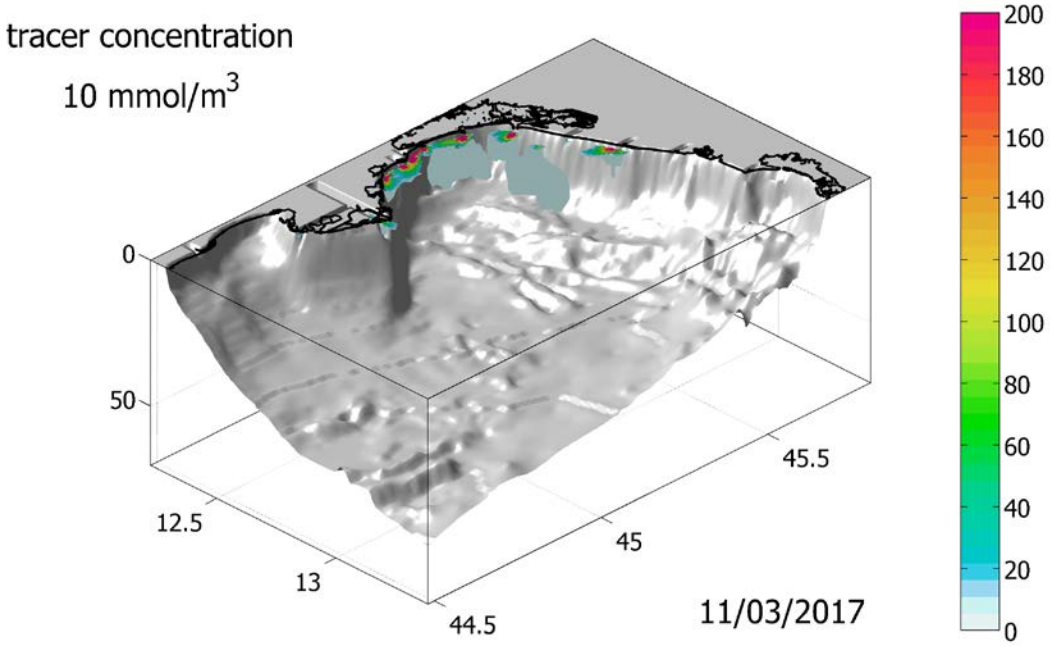

Figure 6. 3D view of the concentration of the 12 tracers considered in the Chioggia case study.

2.1.2 Finalization of the reanalysis run (Sub Task 1.1.2)

The reanalysis timespan covers the period 2006-2017, while the experimental data are available until 2016 (Fig. 7). Model results have been compared with in-situ data and proved to be in good agreement with data, even if some noticeable errors can be found (and have been corrected by adopting data assimilation techniques).

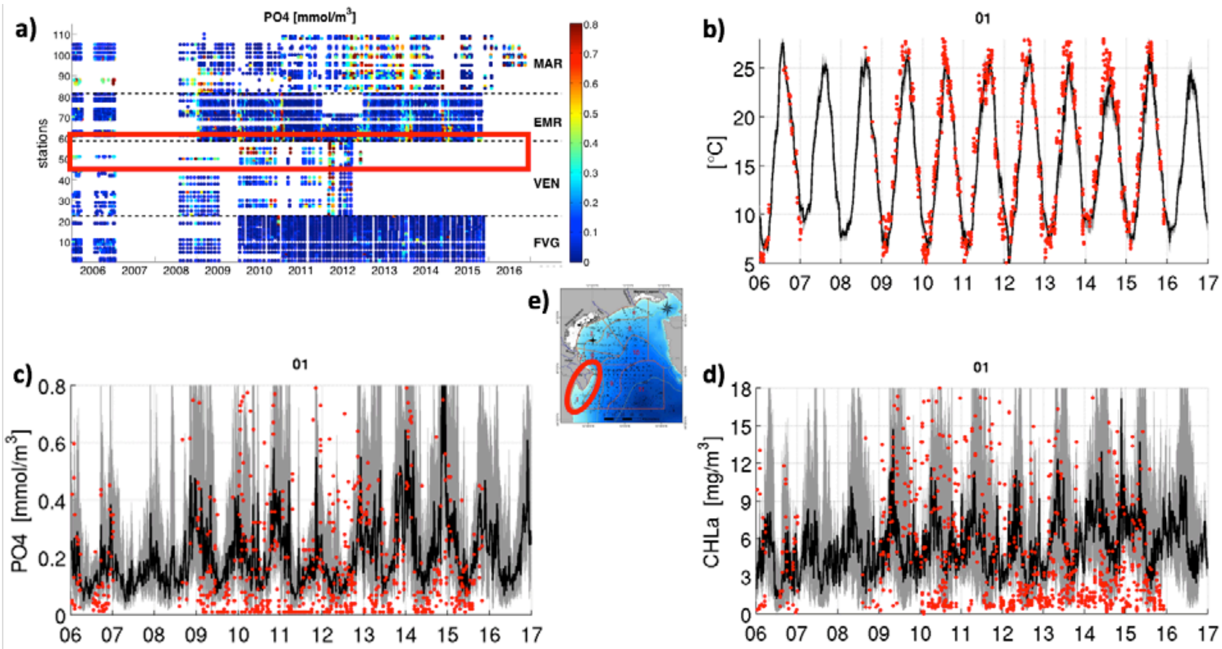

Figure 7. Comparison of model results (black lines) with the experimental dataset (red dots) in the surroundings of the Po river mouth (area highlighted by the red ellipse in plot e). Selected dataset (a) and temperature (b), phosphate (c) and chlorophyll-a (d) time series in the period 2006-2016.

We corroborated model results by comparing them against the climatologies computed by Solidoro et al. (2009). Also in this case, the seasonal cycle is reproduced satisfactorily and the spatial and temporal variability of model results is consistent with the observations (Fig. 8).

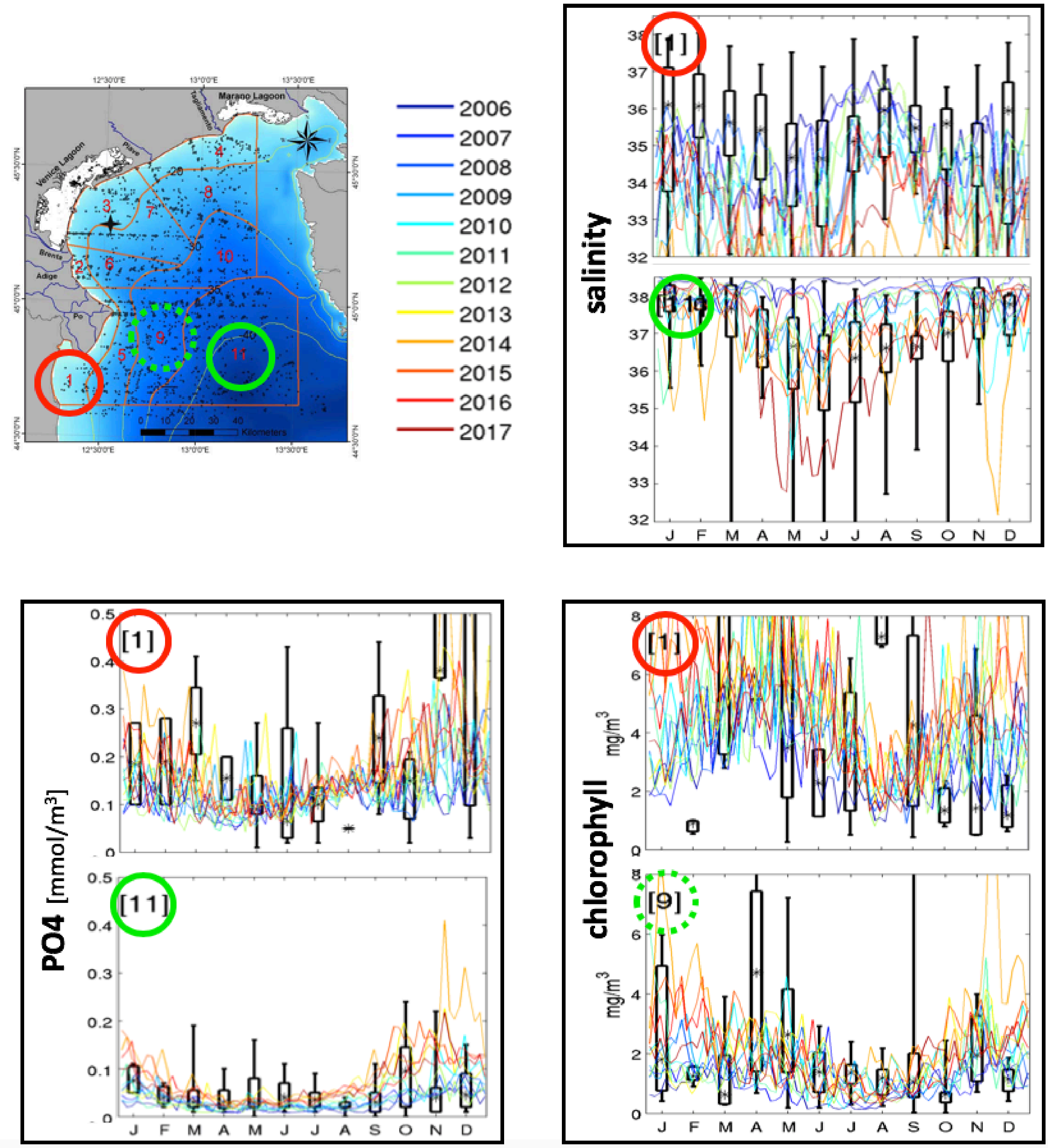

Figure 8. Comparison between model results (colored lines) and the climatologies reported in Solidoro et al. (2009) (box plots), for salinity, phosphate and chlorophyll. The three areas considered are shown by the colored circles in the top-left map.

Inaccuracies and biases in model output have been corrected by applying nudging algorithms, both for in situ and satellite data. The tendency for temperature, salinity or a generic tracer *T* in each grid point of the domain is modified through the following equation:

$$\frac{dT}{dt} = \frac{dT}{dt} - \frac{M_{rbc}}{\tau_T}(T - T_{rbc})$$

where M_{rbc} is a 3-D mask (no time dependence) with values either 0 or 1. When M_{rbc} is 1, relaxing timescale is $1/\tau_T$. Where it is 0 there is no relaxing. The value relaxed to is a 3-D (potentially varying in time) field given by T_{rbc}.

Fig. 9 shows an example for SST. The underestimation of temperature, especially in the northernmost part of the basin in spring (plot a) is corrected by satellite data. In situ data are represented by the colored dots, the size of which is proportional to the amount of experimental data in that station during that period.

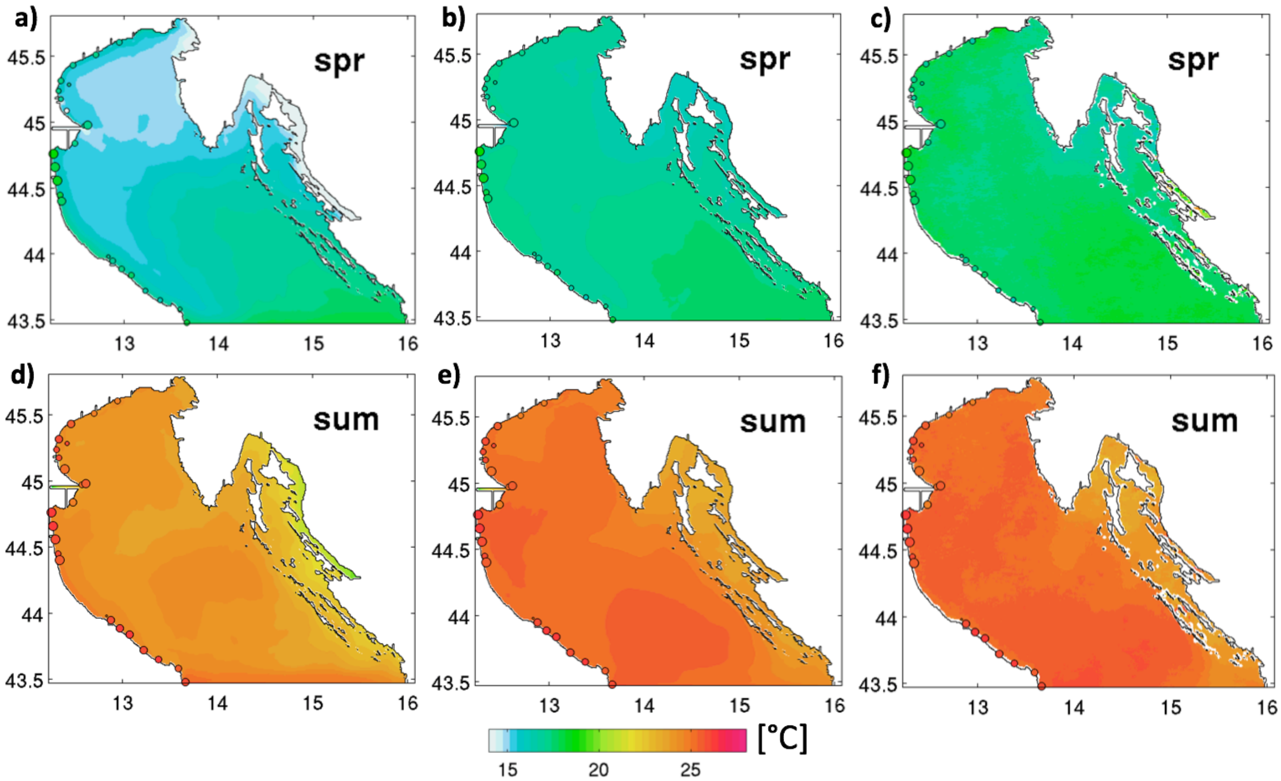

Figure 9. Sea surface temperature in spring (upper plots) and summer (lower plots) 2012. Model results without SST assimilation (a, d), with SST assimilation (b, e) and CMEMS satellite data (c, f). The dots represent the experimental dataset: the size of the dots is proportional to data abundance in the selected period.

Fig. 10 shows the same results focusing on the temporal variability and considering the spatial average over the domain.

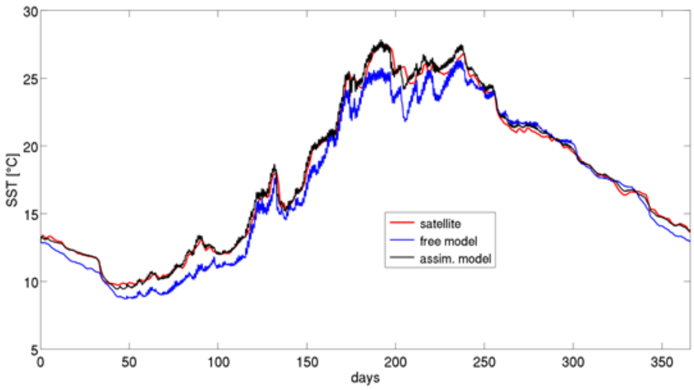

Figure 10. SST (spatial average) in 2012: comparison between model without assimilation (blue), with assimilation (black) and satellite data.

The same approach has been used also for nutrients. Fig. 11 shows the effect of assimilating in situ data on nutrient concentration. The major effects are confined to the coastal area and the result is a remarkable improvement in the model data comparison.

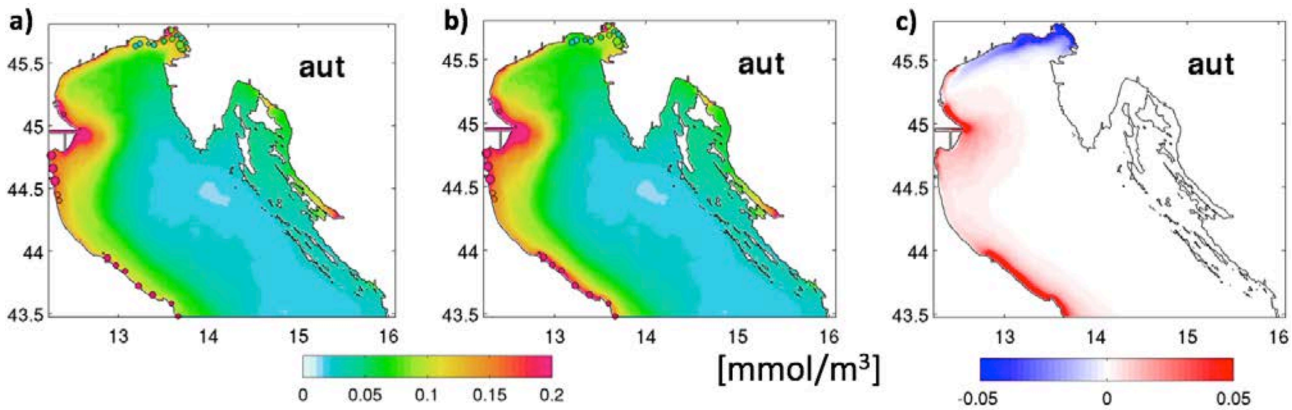

Figure 11. Comparison between model phosphate (surface, monthly average) and experimental data (dots) in autumn 2012. The size of the dots is proportional to data abundance in the selected period. Model without assimilation (a), with assimilation (b) and related anomaly (c).

It must be pointed out that also experimental data are affected by uncertainties and the sampling interval can be too coarse to evaluate properly the variability of the system. Fig. 12 shows an example of the effects of the correction of the nutrient fields on chlorophyll concentration.

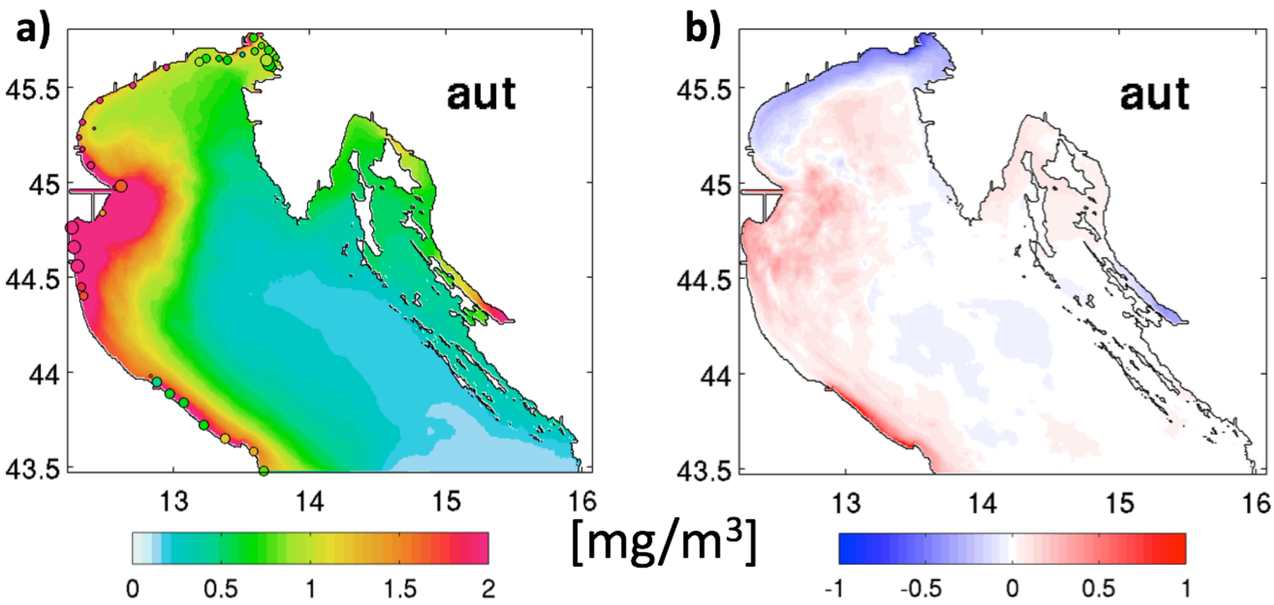

Figure 12. Effect of nutrient assimilation on surface chlorophyll. Surface values after assimilation (a) and anomaly (assimilated minus non-assimilated, b).

2.1.3 Production of the nutrient dynamics and eutrophication derived products (Sub Task 1.1.3)

The new modeling system described in paragraph 2.1.1 was used to generate several derived products of nutrient dynamics and eutrophication:

- ✓ maps of concentration of nitrate, phosphate, ammonia;
- ✓ maps of concentration of biomass of primary producers (chlorophyll "a");
- ✓ maps of eutrophication index (TRIX).

In the web-portal (see paragraph 2.3) the derived products are all available. Some examples are reported in Fig. 13, 14, 15, 16.

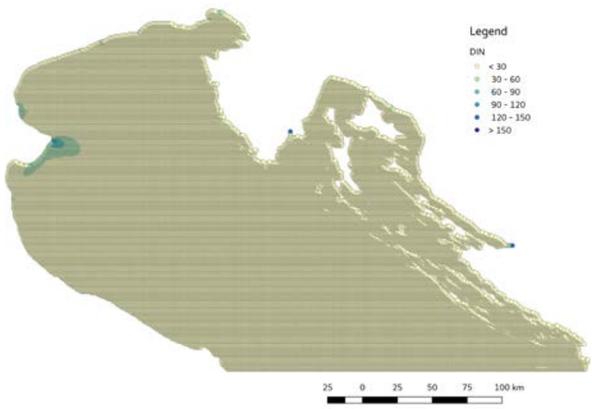

Figure 13. Dissolved Inorganic Nitrogen, monthly mean, March 2014.

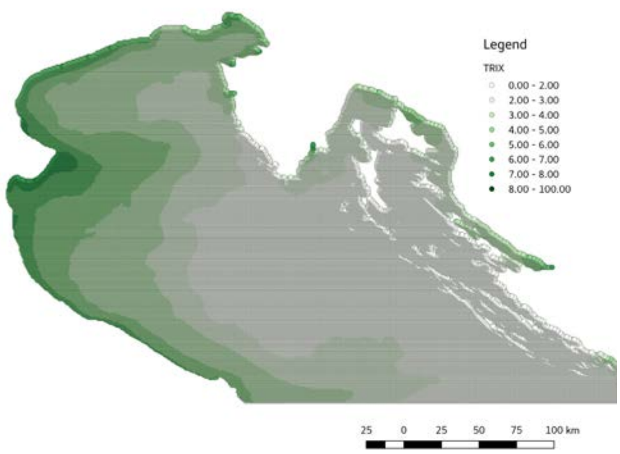

Figure 14. TRIX, May 2012.

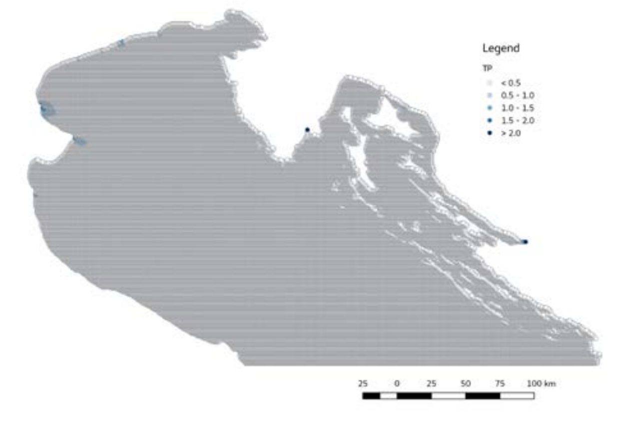	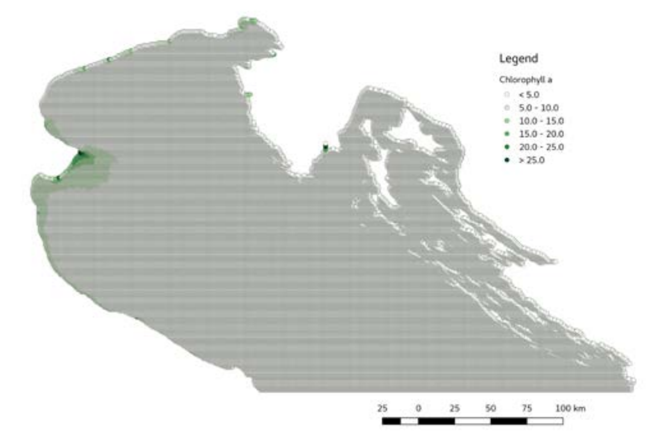
Figure 15. Total Phosphorous, monthly mean, October 2017.	**Figure 16**. Chlorophill “a”, 90 percentile, 2006.

2.1.4 Encountered issue

The main issues were related to the relevant amount of missing data in the EIONET *in situ* dataset (Fig. 5). This shortage of data led to several problems both in the corroboration and in the assimilation phase.
As regards the corroboration of the model output, we mitigated this issue by comparing our results not only with the available data, but also with the climatologies computed by Solidoro *et al*. (2009), as shown in Section 2.1.2, Fig. 8. Both comparisons led to satisfactory results.
As regards the assimilation, the largest data gaps did not allow its computation for some sites and some periods (e.g., 2007 in all areas, after 2013 in the Veneto Region). In the other cases, we simplified the dataset by merging the 110 coastal stations into 40 clusters of stations, reducing the number of the assimilation points, on the one hand, but increasing the amount and temporal coverage of the data, on the other hand. By so doing, the assimilation process became more solid and led to good performances, despite some residual mismatches related to data uncertainty (Fig. 11 and 12).
Another encountered issue was related to the changing of produ\
cts for the acquacolture management plants. Initially, the service had to provide products which showed correlation between organic matter/primary producers and mussels, clams weight and size. After the Workshop in Venice, the stakeholders asked to perform another kind of product, more connected to the hygienic sanitary quality status of the waters. The aquaculture managers, often have problems with bacterial pollution and when happen, they are forced to close the aquaculture plants. In order to avoid the decreasing of benefits from the production, it is more interesting the application of an index for the identification of bacteria pollution. For this reason it has been changed the plan of work established at the beginning of the project.

2.2 Creation of the web page introducing the service

A dedicated webpage has been created by ISPRA, which describes the service and focuses on the usefulness and the integration of CMEMS information.

This page (http://www.bio.isprambiente.it/cadeau/) contains:

- ✓ a link to the official web page of the CADEAU service in English;

- ✓ the ISPRA and OGS logos visible at the top of the page;
- ✓ the CMES User Uptake label visible;
- ✓ the description of the project;
- ✓ the CMEMS Region definition;
- ✓ the CMEMS area of benefit definition and sub-categories;
- ✓ the name of the service;
- ✓ a link to the official service web page;
- ✓ a section with the CADEAU news;
- ✓ email to help visitors if they need more information about the service (cadeau@isprambiente.it);
- ✓ the Copernicus Marine Service Desk email to help visitors if they need more information about CMEMS.

The webpage shows the information and the link to the products in the CMEMS catalogue used in the service:

- ❖ MEDSEA_REANALYSIS_BIO_006_008 - CMEMS Mediterranean Sea biogeochemistry reanalysis products.
- ❖ MEDSEA_REANALYSIS_PHYS_006_004 - CMEMS Mediterranean Sea physics reanalysis products.
- ❖ OCEANCOLOUR_MED_CHL_L3_REP_OBSERVATIONS_009_073 - CMEMS Mediterranean Sea surface chlorophyll concentration from multi satellite observations reprocessed (ESA-CCI).
- ❖ MEDSEA_ANALYSIS_FORECAST_BIO_006_006 - CMEMS Mediterranean Sea biogeochemistry analysis and forecast products.
- ❖ MEDSEA_ANALYSIS_FORECAST_PHYS_006_001 - CMEMS Mediterranean Sea physics analysis and forecast products.
- ❖ OCEANCOLOUR_MED_CHL_L3_NRT_OBSERVATIONS_009_040 - CMEMS Mediterranean Sea surface chlorophyll concentration from satellite observations.

The webpage contains the track traffic count. At 25/09/2019 the numbers are: 351 web hits / 191 visitors.

2.3 Development of the web-portal (Sub-Task 1.2)

Sub-task 1.2 is dedicated to the development of the service web-portal. The web-portal is hosted at ISPRA and it provides the bulletin and the dedicated products. The accessibility of the services is free and there are statistics available to track traffic count. At the 25/09/2018, the numbers are: 137 portal hits / 98 visitors.
The products available through the web-portal include time series (2006-2017) of high-resolution maps of several variables. The navigable maps are guaranteed by the web-GIS tools. GIS maps are grouped per year and different labels identify the variables. It is always transparent for the user what kind of data he/she is visualizing and which data sets have been used (or assimilated) to produce it. Once a map or a set of maps have been selected, a sidebar will be available for users with the years and the covered period (2006-2017) printed on it. By moving a cursor on such side-bar, web-GIS will show maps of the year selected by the cursor. Such functionality will allow the user to easily navigate through different years comparing different layers. Fig. 17 shows the structure of the CADEAU portal. It is possible through the "download data" section to download all parameters for marine waters quality and indexes for Aquaculture and Bathing waters (see

paragraph 3) available in shapefile. In the web-GIS section it is possible to view the layers of all variables with the associated specific scales.

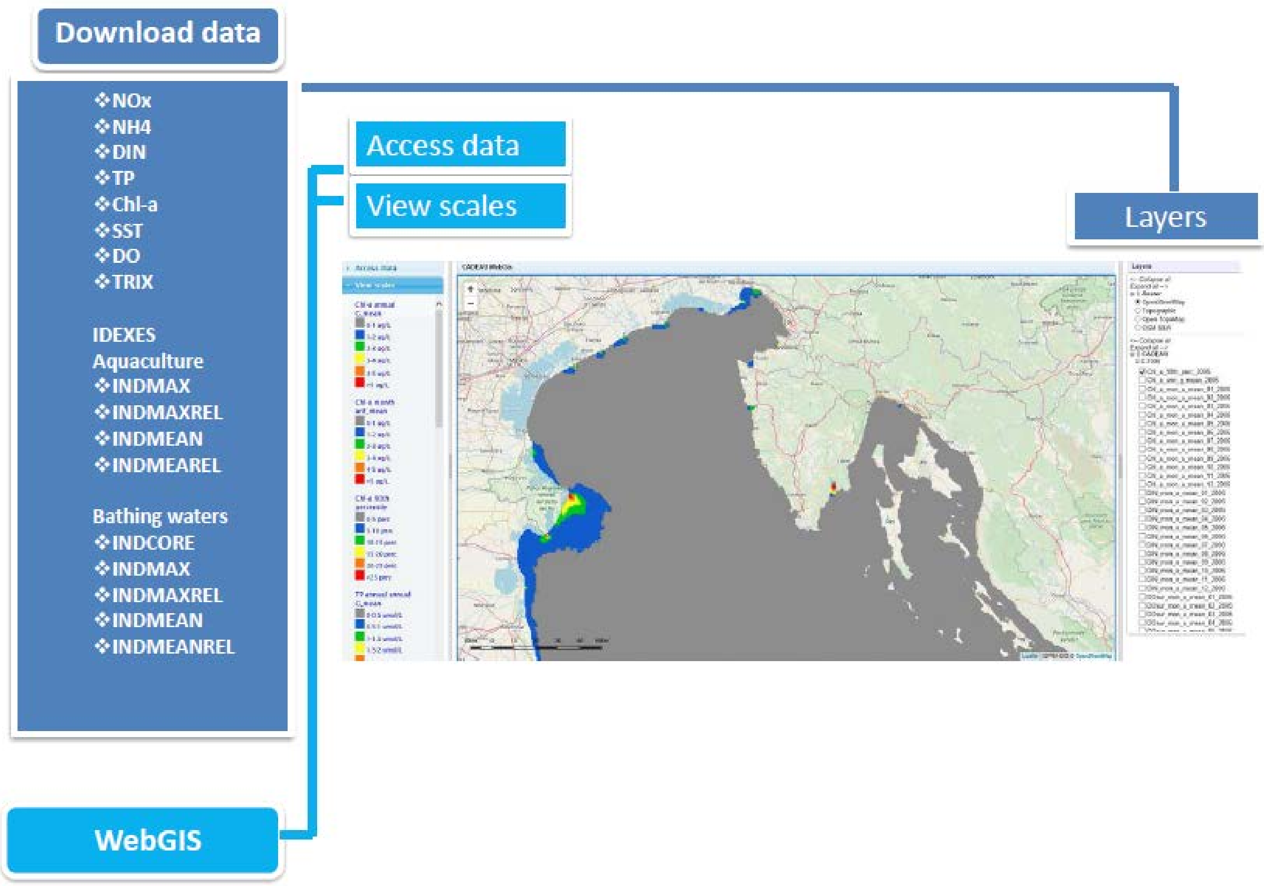

Figure 17. Structure of the CADEAU portal.

3. Demonstration, documentation and involvement of the users community (Task. 2)

3.1 Demonstration of the service (Sub-Task 2.1)

In the framework of the EU Directives related to coastal and marine environment, Member States have to arrange environmental management plans within a Common Implementation Strategy coordinated by European Commission.
For this reason, we implemented an operational service which consists of an annual bulletin reporting the marine water quality state along the Italian northern Adriatic coast, which belongs to the CMEMS Mediterranean Sea region.

The bulletin includes three different kind of products:

1. **Supporting the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD)**
   - marine quality parameters:
     - ✓ Surface Temperature
     - ✓ Dissolved oxygen

- ✓ Chl-a
- ✓ NOx
- ✓ NH4
- ✓ PT
- ✓ DIN
- ✓ TRIX

2. Supporting the Bathing Water Directive (BWD)

- ➢ Indexes for the potential impact of bacterial pollution on a bathing water.

3. Supporting the aquaculture management

- ➢ Indexes for the potential impact of bacterial pollution on shellfish farming.

3.1.1 Implementation of the service supporting the Water framework Directive and Marine Strategy Directive

During the past 20 years, national and local environmental authorities enforced measures (i.e., activities to improve environmental status) focused on changing the intensities of predominant pressures, achieving some good results. But much remains to be done. WFD and MSFD pose challenging problems in order to define what is a "Good Environmental / Ecological /Chemical Status", and the identification and definition of specific measures in terms of concrete actions has proved to be even more difficult.
According to the Water Framework Directive in 2014, the Mediterranean Geographical Intercalibration Group - *Coastal waters - BQE "phytoplankton*" established the thresholds values of the ecological quality classes for the "Phytoplankton" Organic Quality Element (EQB) for the different types of water bodies WFD (Directive 2000/60 / EC) present in the Italian coastal marine waters (Report "Water Framework Directive 3rd Intercalibration Phase, Mediterranean Geographical Intercalibration Group - Coastal waters – BQE "phytoplankton", November 2014). (Table 1, Fig. 18).

Tab.1.Threshold values according to the Directive 2000/60/EC.

Boundaries Type I	TRIX	Chl-a annual *G_Mean* µg/L	Chl-a *90th percentile** µg/L	TP annual *G_Mean* µmol/L
Reference Conditions	-	1.40	3.93	-
H/G	4.25	2.0	5.6	0.26
G/M	5.25	**5.0**	14.0	**0.55**
M/P	6.25	12.6	35.2	1.15
P/B	7	25.0	70.1	2.00

Boundaries Type II A Adriatic	TRIX	Chl-a annual *G_Mean* µg/L	Chl-a *90th percentile** µg/L	TP annual *G_Mean* µmol/L	Chl-a EQRs actual	Chl-a EQRs normalized
Reference Conditions	-	0.33	0.87	-	1	1
H/G	4	0.64	1.7	0.26	0.52	0.82
G/M	5	**1.5**	4.0	**0.48**	0.22	0.61
M/P	6	3.5	9.3	0.91	0.09	0.40
P/B	7	8.2	21.7	1.71	0.04	0.19

Boundaries Type II A Tyrrhenian	TRIX	Chl-a annual *G_Mean* µg/L	Chl-a *90th percentile** µg/L	TP annual *G_Mean* µmol/L	Chl-a EQRs actual	Chl-a EQRs normalized
Reference Conditions	-	0.32	0.78	-	1	1
H/G	4	0.48	1.2	0.35	0.66	0.84
G/M	5	**1.2**	2.9	**0.76**	0.27	0.62
M/P	6	2.9	7.1	1.63	0.11	0.40
P/B	7	7.3	17.6	3.51	0.04	0.18

Type **threshold value G/M**	Chl-a (µg/L) annual *G_Mean*	Chl-a (µg/L) *90th percentile**	TP (µmol/L) annual *G_Mean*
Type III W Adriatic	**0.64**	1.7	**0.26**
Type III W Tyrrhenian	**0.48**	1.2	**0.35**

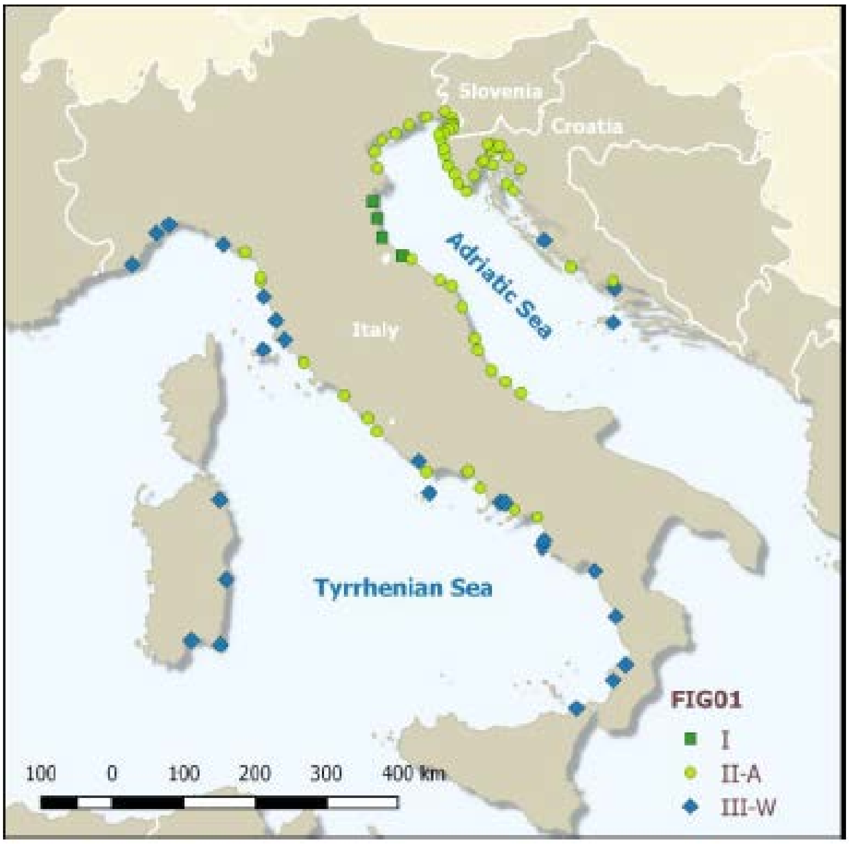

Figure 18. Typing of marine coastal waters according to the Directive 2000/60/EC. Type I (very influenced by the contribution of fresh water), Type II A (moderately influenced by the contribution of fresh water), Type III W (no influenced by the contribution of fresh water).

The Marine Strategy Framework Directive (Directive 2010/56/EC) for the assessment of the marine quality status uses 11 descriptors. Among these, the Descriptor 5 is related to Eutrophication. The parameters that the Member States have to take into account are:

- D5C1: nutrient concentrations in micromoles per liter (µmol/l),
- D5C2: chlorophyll a concentrations (biomass) in micrograms per liter (µg/l),
- D5C3: bloom events as number of events, duration in days and spatial extent in square kilometers (km^2) per year,
- D5C4: photic limit as depth in meters (m),
- D5C5: oxygen concentration in the bottom of the water column in milligrams per liter (mg/l).

The Service is able to provide the majority of parameters listed above (Surface Temperature, Dissolved oxygen, Chl-a, NOx, NH4, PT, DIN, TRIX), which are useful for both Directives (Directive 2000/60/EC and Directive 2010/56/EC).

3.1.2 Implementation of the service supporting the Bathing waters Directive (BWD)

The EU Directive 2006/07/EC on Bathing Waters highlights the importance of prevention in the managing of bathing areas. This is mainly based on a tool called "Profile" of the bathing water. The Profile contains a section dedicated to the description of the area of influence, defined as the area containing all the pressures with a possible negative impact on the bathing water quality.
In order to support the management of bathing waters, indexes have been developed to help the definition of the area of influence. These indexes help in identifying which among the main freshwater discharges with a risk of bacterial pollution can produce an impact on a bathing water. The indexes have been developed for the use case of the Chioggia Municipality. Fig. 19 shows the discharge points considered in the use case. These include the main river mouths and the main urban waste water treatment plants in the area. Overall, 12 potential sources of bacterial pollution have been considered (Fig. 20). Passive tracers were released from the potential sources of impact. These tracers take into account the bacterial decay due to salinity, temperature, solar radiation and turbidity. Furthermore, they were considered as different tracers, hence, in a given point it is possible to differentiate between the pollution due to one source from the one induced by another one.

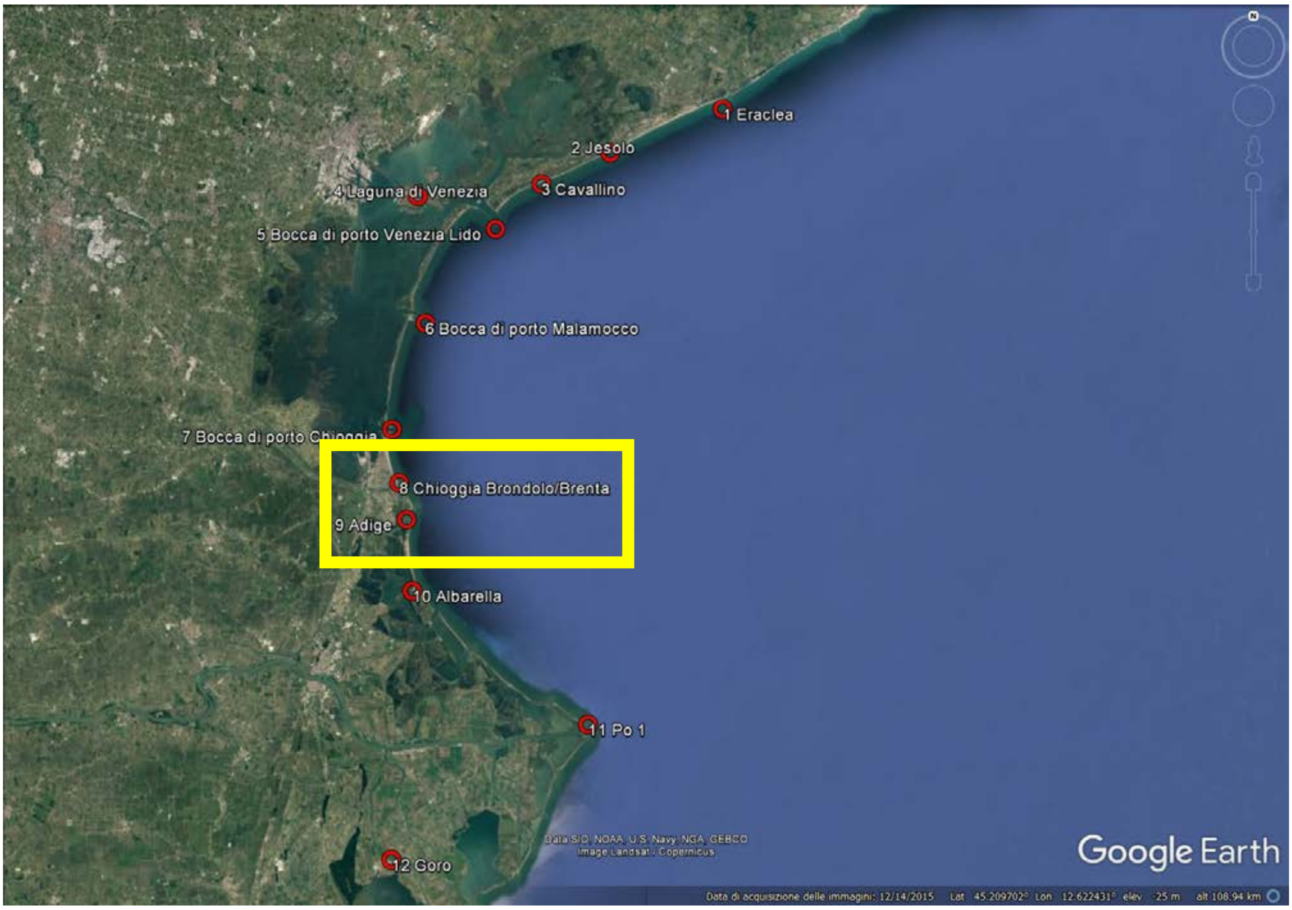

Figure 19. Potential sources of bacterial pollution for the Chioggia use case. The yellow rectangle shows the coastal area managed by the Chioggia Municipality.

The Municipality of Chioggia manages 11 bathing water areas (Figure 20). Their profiles highlight the potential risk of bacterial pollution originating from the Venice lagoon inlets of Chioggia, the Brenta and Adige river mouths and the Chioggia Brondolo urban waste water treatment plant (with differences in the profiles due to the proximity of each bathing water to the different sources).

Figure 20. Bathing waters managed by the Chioggia Municipality.

The indexes allow to evaluate the potential bacterial pollution that can be induced by each of the 12 sources. In order to describe the different impacts that can be induced, different indexes have been developed. A first group of indexes quantify the portion of outflow from a source that can potentially impact on a bathing water. The indexes can also differentiate in which conditions this impact can happen. A second group of indexes relates *in-situ* measurements of bacterial pollution to the plume presence. These indexes show which sources should be investigated to identify the cause of past pollution events. In order to evaluate the potential pollution through the indexes a few data must be considered.

The concentration of *Escherichia coli* in untreated waste waters is about $10^7/10^8$ UFC/100ml (http://www.aqp.it/portal/page/portal/MYAQP/SERVIZI/Servizio%20di%20depurazione/La%20disinfezione%20delle%20acque%20reflue).

Considering the threshold of 500UFC/100ml provided in the Directive for bathing waters of quality at least sufficient (in Italy the Decree 30 March directly enforce the banning of bathing in this condition), in case of total by-pass of a urban waste water treatment plant (waste water are not treated at all) even if the plume reaches a bathing water with a concentration of 10^{-5} with respect to the one at the source, it can produce an impact on the bathing water quality.

Furthermore, in Italy the D.lgs 152 2006 suggests a threshold not higher than 5000UFC/100ml for the concentration of E. coli in the outflows of urban waste water treatment plants (plants with a population equivalent of at least 2000 people). This second threshold is ten times the threshold of 500UFC/100ml. Hence, even in normal working conditions a bathing water impacted by only one tenth of the concentration at the source may be affected by pollution.
Table 2 shows the index for the mean relative impact of a source on a bathing water. The index is evaluated comparing the tracer value in the closest wet grid cell to the bathing water (summing up all vertical levels) and the tracer value at the source point (specific vertical level). Values in the class “high” indicate that a source can impact a bathing water even in standard conditions.

Table 2. Mean relative impact on bathing waters. (Data in the period 2006-2017).

	Mean relative impact											
	Eraclea	Jesolo	Cavallino	Laguna di Venezia	Bocca di Porto Venezia Lido	Bocca di porto Malamocco	Bocca di porto Chioggia	Chioggia Brondolo (Brenta)	Rosolina Mare (Adige)	Isola Albarella	Foce Po	Goro
IT005027008001	0.00003	0.00001	0.00004	0.00062	0.00057	0.00211	0.07702	0.00061	0.00005	0.00002	0.00000	0.00000
IT005027008002	0.00004	0.00001	0.00011	0.00109	0.00155	0.00337	1.33861	0.00166	0.00009	0.00004	0.00000	0.00000
IT005027008003	0.00004	0.00001	0.00012	0.00103	0.00159	0.00307	0.21690	0.00330	0.00010	0.00004	0.00000	0.00000
IT005027008004	0.00004	0.00001	0.00011	0.00090	0.00144	0.00256	0.13620	0.00508	0.00009	0.00004	0.00000	0.00000
IT005027008010	0.00002	0.00001	0.00005	0.00041	0.00061	0.00106	0.02855	0.00775	0.00007	0.00003	0.00000	0.00000
IT005027008005	0.00002	0.00001	0.00007	0.00045	0.00082	0.00109	0.01347	0.09928	0.00013	0.00005	0.00000	0.00000
IT005027008006	0.00001	0.00000	0.00006	0.00032	0.00072	0.00074	0.00664	0.22966	0.00015	0.00005	0.00000	0.00000
IT005027008007	0.00002	0.00001	0.00008	0.00041	0.00093	0.00096	0.00657	0.16021	0.00040	0.00009	0.00000	0.00000
IT005027008011	0.00003	0.00001	0.00018	0.00101	0.00204	0.00238	0.00855	0.05473	0.00150	0.00022	0.00000	0.00000
IT005027008008	0.00001	0.00000	0.00007	0.00038	0.00071	0.00084	0.00333	0.02618	0.00214	0.00029	0.00000	0.00000
IT005027008009	0.00001	0.00000	0.00007	0.00038	0.00071	0.00084	0.00333	0.02618	0.00214	0.00029	0.00000	0.00000

Legend

Relative potential impact	Impatto relativo potenziale	Min	Max
Remote	Remoto	0	10^{-5}
Very Low	Molto scarso	10^{-5}	10^{-4}
Low	Scarso	10^{-4}	10^{-3}
Moderate	Moderato	10^{-3}	10^{-2}
Fair	Discreto	10^{-2}	10^{-1}
High	Alto	10^{-1}	...

Table 3 shows the index for the maximum of the relative impact of a source on a bathing water. The index is evaluated comparing the tracer value in the closest wet grid cell to the bathing water (summing up all vertical levels) and the tracer value at the source point (specific vertical level). Values in the class “high” indicate that a source can impact a bathing water even in standard working conditions but in peculiar hydrodynamic conditions.

Table 3. Maximum of the relative impact on bathing waters. (Data in the period 2006-2017).

	Maximum relative impact											
	Eraclea	Jesolo	Cavallino	Laguna di Venezia	Bocca di Porto Venezia Lido	Bocca di porto Malamocco	Bocca di porto Chioggia	Chioggia Brondolo (Brenta)	Rosolina Mare (Adige)	Isola Albarella	Foce Po	Goro
IT005027008001	0.01773	0.00309	0.00810	0.10892	0.03686	0.11166	0.59353	0.08176	0.02524	0.02400	0.00002	0.00000
IT005027008002	0.02530	0.00451	0.01480	0.16143	0.06215	0.16580	1.91915	0.13524	0.04165	0.04631	0.00004	0.00000
IT005027008003	0.02386	0.00452	0.01755	0.15439	0.06715	0.16723	1.19593	0.17015	0.04934	0.04869	0.00004	0.00000
IT005027008004	0.02202	0.00433	0.01455	0.14231	0.05623	0.16945	1.41898	0.20418	0.04191	0.04540	0.00005	0.00000
IT005027008010	0.01346	0.00267	0.00541	0.08117	0.02921	0.09074	0.47667	0.23112	0.03765	0.03210	0.00003	0.00000
IT005027008005	0.01355	0.00258	0.00785	0.08417	0.03293	0.08992	0.28791	0.57719	0.04798	0.03386	0.00005	0.00000
IT005027008006	0.00895	0.00159	0.00737	0.04696	0.02438	0.05634	0.16479	1.21898	0.04295	0.02956	0.00004	0.00000
IT005027008007	0.01096	0.00211	0.00895	0.06235	0.02948	0.06852	0.18232	0.75182	0.10644	0.04275	0.00010	0.00000
IT005027008011	0.01674	0.00299	0.02464	0.11220	0.05301	0.13258	0.19429	0.23579	0.15895	0.08786	0.00021	0.00000
IT005027008008	0.00993	0.00194	0.01078	0.06205	0.02667	0.07103	0.11665	0.26258	0.22608	0.12883	0.00018	0.00000
IT005027008009	0.00993	0.00194	0.01078	0.06205	0.02667	0.07103	0.11665	0.26258	0.22608	0.12883	0.00018	0.00000

Legend

Relative potential impact	Impatto relativo potenziale	Min	Max
Remote	Remoto	0	10^{-5}
Very Low	Molto scarso	10^{-5}	10^{-4}
Low	Scarso	10^{-4}	10^{-3}
Moderate	Moderato	10^{-3}	10^{-2}
Fair	Discreto	10^{-2}	10^{-1}
High	Alto	10^{-1}	...

Table 4 shows the index relating the portion of a plume released by a source impacting on a bathing water. Values greater than “very low” indicate a potential impact in extreme operating conditions (e.g., total by-pass). The plume is defined as the total quantity of tracer related to a certain source, present in a fixed moment in the whole computational domain. The idea of considering the whole plume is due to the fact that when a total by-pass happens, the pollution affects the sea for a few days.

Table 4. Mean plume impact on bathing waters. (Data in the period 2006-2017).

	Mean plume impact											
	Eraclea	Jesolo	Cavallino	Laguna di Venezia	Bocca di Porto Venezia Lido	Bocca di porto Malamocco	Bocca di porto Chioggia	Chioggia Brondolo (Brenta)	Rosolina Mare (Adige)	Isola Albarella	Foce Po	Goro
IT005027008001	0.00000	0.00000	0.00000	0.00003	0.00003	0.00026	0.02546	0.00009	0.00001	0.00000	0.00000	0.00000
IT005027008002	0.00000	0.00000	0.00000	0.00005	0.00010	0.00042	0.51529	0.00028	0.00001	0.00001	0.00000	0.00000
IT005027008003	0.00000	0.00000	0.00001	0.00005	0.00010	0.00038	0.06564	0.00058	0.00002	0.00001	0.00000	0.00000
IT005027008004	0.00000	0.00000	0.00000	0.00004	0.00009	0.00031	0.03457	0.00093	0.00001	0.00001	0.00000	0.00000
IT005027008010	0.00000	0.00000	0.00000	0.00002	0.00004	0.00012	0.00734	0.00145	0.00001	0.00000	0.00000	0.00000
IT005027008005	0.00000	0.00000	0.00000	0.00002	0.00005	0.00014	0.00333	0.01967	0.00002	0.00001	0.00000	0.00000
IT005027008006	0.00000	0.00000	0.00000	0.00002	0.00005	0.00010	0.00154	0.04667	0.00003	0.00001	0.00000	0.00000
IT005027008007	0.00000	0.00000	0.00000	0.00002	0.00006	0.00012	0.00146	0.03173	0.00007	0.00001	0.00000	0.00000
IT005027008011	0.00000	0.00000	0.00001	0.00005	0.00012	0.00027	0.00168	0.01065	0.00027	0.00003	0.00000	0.00000
IT005027008008	0.00000	0.00000	0.00000	0.00002	0.00004	0.00010	0.00064	0.00496	0.00039	0.00004	0.00000	0.00000
IT005027008009	0.00000	0.00000	0.00000	0.00002	0.00004	0.00010	0.00064	0.00496	0.00039	0.00004	0.00000	0.00000

Legend

Relative potential impact	Impatto relativo potenziale	Min	Max
Remote	Remoto	0	10^{-5}
Very Low	Molto scarso	10^{-5}	10^{-4}
Low	Scarso	10^{-4}	10^{-3}
Moderate	Moderato	10^{-3}	10^{-2}
Fair	Discreto	10^{-2}	10^{-1}
High	Alto	10^{-1}	...

Table 5 shows the index for the maximum portion of a plume released by a source impacting on a bathing water. Values greater than "very low" indicate a potential impact in extreme operating conditions (e.g., total by-pass) and with peculiar hydrodynamic conditions.

Table 5. Maximum of the plume impact on bathing waters. (Data in the period 2006-2017).

	Maximum plume impact											
	Eraclea	Jesolo	Cavallino	Laguna di Venezia	Bocca di Porto Venezia Lido	Bocca di porto Malamocco	Bocca di porto Chioggia	Chioggia Brondolo (Brenta)	Rosolina Mare (Adige)	Isola Albarella	Foce Po	Goro
IT005027008001	0.00062	0.00049	0.00021	0.00220	0.00249	0.00937	0.10785	0.01209	0.00307	0.00274	0.00000	0.00000
IT005027008002	0.00089	0.00073	0.00051	0.00326	0.00363	0.01264	0.93113	0.01783	0.00507	0.00528	0.00000	0.00000
IT005027008003	0.00085	0.00073	0.00060	0.00312	0.00338	0.01216	0.31253	0.02027	0.00600	0.00556	0.00000	0.00000
IT005027008004	0.00081	0.00070	0.00050	0.00288	0.00283	0.01055	0.22325	0.02432	0.00510	0.00518	0.00000	0.00000
IT005027008010	0.00051	0.00043	0.00018	0.00164	0.00147	0.00514	0.06428	0.02680	0.00458	0.00366	0.00000	0.00000
IT005027008005	0.00048	0.00042	0.00027	0.00170	0.00166	0.00415	0.03639	0.05803	0.00584	0.00386	0.00000	0.00000
IT005027008006	0.00031	0.00026	0.00023	0.00095	0.00123	0.00238	0.02029	0.12365	0.00523	0.00339	0.00000	0.00000
IT005027008007	0.00039	0.00034	0.00031	0.00126	0.00148	0.00290	0.02188	0.07364	0.01119	0.00528	0.00000	0.00000
IT005027008011	0.00063	0.00048	0.00085	0.00227	0.00228	0.00636	0.01756	0.03251	0.01865	0.00939	0.00000	0.00000
IT005027008008	0.00038	0.00031	0.00037	0.00125	0.00115	0.00304	0.01016	0.03172	0.02376	0.01153	0.00000	0.00000
IT005027008009	0.00038	0.00031	0.00037	0.00125	0.00115	0.00304	0.01016	0.03172	0.02376	0.01153	0.00000	0.00000

Legend

Relative potential impact	Impatto relativo potenziale	Min	Max
Remote	Remoto	0	10^{-5}
Very Low	Molto scarso	10^{-5}	10^{-4}
Low	Scarso	10^{-4}	10^{-3}
Moderate	Moderato	10^{-3}	10^{-2}
Fair	Discreto	10^{-2}	10^{-1}
High	Alto	10^{-1}	...

Table 6 shows the cross-correlation between the Intestinal Enterococci *in-situ* data and the quantity of tracer in the closest wet grid cell of a bathing water. The closest to 1, the closest the correlation. In order to better identify the relation between the plume presence and high bacterial contamination, only bacterial concentration higher than 20% of the threshold in the Decree 30/03/2010 are taken into account, all the other data are set to 0 (i.e., values >= 40 UFC/100ml).

Table 6. Cross correlation between the *in-situ* measures of Intestinal Enterococci bacterial pollution (according to the monitoring related to the Directive) and the quantity of tracer present in the bathing water closest grid cell in the same moment. (Data in the period 2006-2017). Colors highlight values in the range 0.5/0.6 – 0.6/0.7 – 0.7/0.8 – 0.8/0.9 – 0.9/1.0.

Cross-correlation between Intestinal Enterococci data and the plume presence												
	Eraclea	Jesolo	Cavallino	Laguna di Venezia	Bocca di Porto Venezia Lido	Bocca di porto Malamocco	Bocca di porto Chioggia	Chioggia Brondolo (Brenta)	Rosolina Mare (Adige)	Isola Albarella	Foce Po	Goro
IT005027008001												
IT005027008002												
IT005027008003												
IT005027008004	0.53	0.53	0.53	0.53	0.53	0.82	0.96	0.97	0.84	0.84	0.87	0.94
IT005027008010	0.42	0.42	0.42	0.42	0.42	0.59	0.85	0.55	0.47	0.47	0.56	0.63
IT005027008005	0.16	0.16	0.2	0.17	0.24	0.25	0.57	0.82	0.18	0.18	0.19	0.3
IT005027008006	0.51	0.49	0.5	0.49	0.51	0.58	0.22	0.83	0.22	0.27	0.19	0.47
IT005027008007	0.32	0.49	0.27	0.5	0.56	0.24	0.19	0.9	0.3	0.13	0.13	0.13
IT005027008011	0.38	0.8	0.32	0.66	0.7	0.3	0.24	0.76	0.31	0.24	0.25	0.43
IT005027008008	0.58	0.58	0.58	0.58	0.58	0.71	0.58	0.94	0.36	0.3	0.3	0.32
IT005027008009	0.21	0.51	0.25	0.35	0.51	0.23	0.24	0.95	0.38	0.23	0.23	0.24

Table 7 shows the cross-correlation between the E. Coli *in-situ* data and the quantity of tracer in the closest wet grid cell of a bathing water. The closest to 1 the closest the correlation. In order to better identify the relation between the plume presence and high bacterial contamination, only bacterial concentration higher than 20% of the threshold in the Decree 30/03/2010 are taken into account, all the other data are set to 0 (i.e., values >= 100 UFC/100ml).

Table 7. Cross correlation between the *in-situ* measures of E. Coli bacterial pollution (according to the monitoring related to the Directive) and the quantity of tracer present in the bathing water closest grid cell in the same moment. (Data in the period 2006-2017). Colors highlight values in the range 0.5/0.6 – 0.6/0.7 – 0.7/0.8 – 0.8/0.9 – 0.9/1.0.

Cross-correlation between E. Coli data and the plume presence												
	Eraclea	Jesolo	Cavallino	Laguna di Venezia	Bocca di Porto Venezia Lido	Bocca di porto Malamocco	Bocca di porto Chioggia	Chioggia Brondolo (Brenta)	Rosolina Mare (Adige)	Isola Albarella	Foce Po	Goro
IT005027008001	0.19	0.65	0.73	0.99	0.68	0.2	0.98	0.98	0.98	0.98	0.19	0.19
IT005027008002	0.65	0.86	0.96	0.86	0.94	0.51	0.92	0.85	0.85	0.85	0.36	0.4
IT005027008003	0.29	0.55	0.3	0.6	0.66	0.54	0.31	0.53	0.52	0.52	0.55	0.31
IT005027008004	0.59	0.43	0.6	0.53	0.76	0.82	0.61	0.57	0.31	0.22	0.21	0.21
IT005027008010	0.58	0.32	0.2	0.33	0.39	0.34	0.18	0.53	0.09	0.03	0.01	0.01
IT005027008005	0.12	0.12	0.13	0.13	0.18	0.21	0.14	0.69	0.13	0.13	0.03	0.1
IT005027008006	0.34	0.66	0.51	0.74	0.73	0.38	0.28	0.54	0.1	0.11	0.07	0.07
IT005027008007	0.63	0.48	0.42	0.46	0.48	0.2	0.09	0.55	0.11	0.05	0.08	0.05
IT005027008011	0.54	0.78	0.29	0.6	0.64	0.24	0.18	0.71	0.21	0.2	0.22	0.19
IT005027008008	0.21	0.8	0.26	0.45	0.22	0.25	0.22	0.34	0.23	0.21	0.2	0.13
IT005027008009	0.21	0.8	0.43	0.61	0.65	0.39	0.37	0.24	0.06	0.09	0.08	0.07

3.1.3 Implementation of the service supporting the aquaculture

Initially, the foreseen products in support of aquaculture activities were all related to nutrients availability and identification of areas with favorable environmental conditions. During the workshop in Venice (June 2018) all the stakeholder interested to aquaculture products stated that their main interest is on the identification of bacterial pollution that could ruin their harvests and also permanently lower the quality of the aquaculture plants with consequent higher costs and less revenues from the activity. Listening at all the topic in the workshop their manifested interest to the indexes developed to help the management of bathing waters. Hence, it was decided to modify the originally planned products for aquaculture and to evaluate the same indexes developed for bathing waters for mussels aquaculture plants (only Mytilus galloprovincialis) in the study area (Fig. 21).

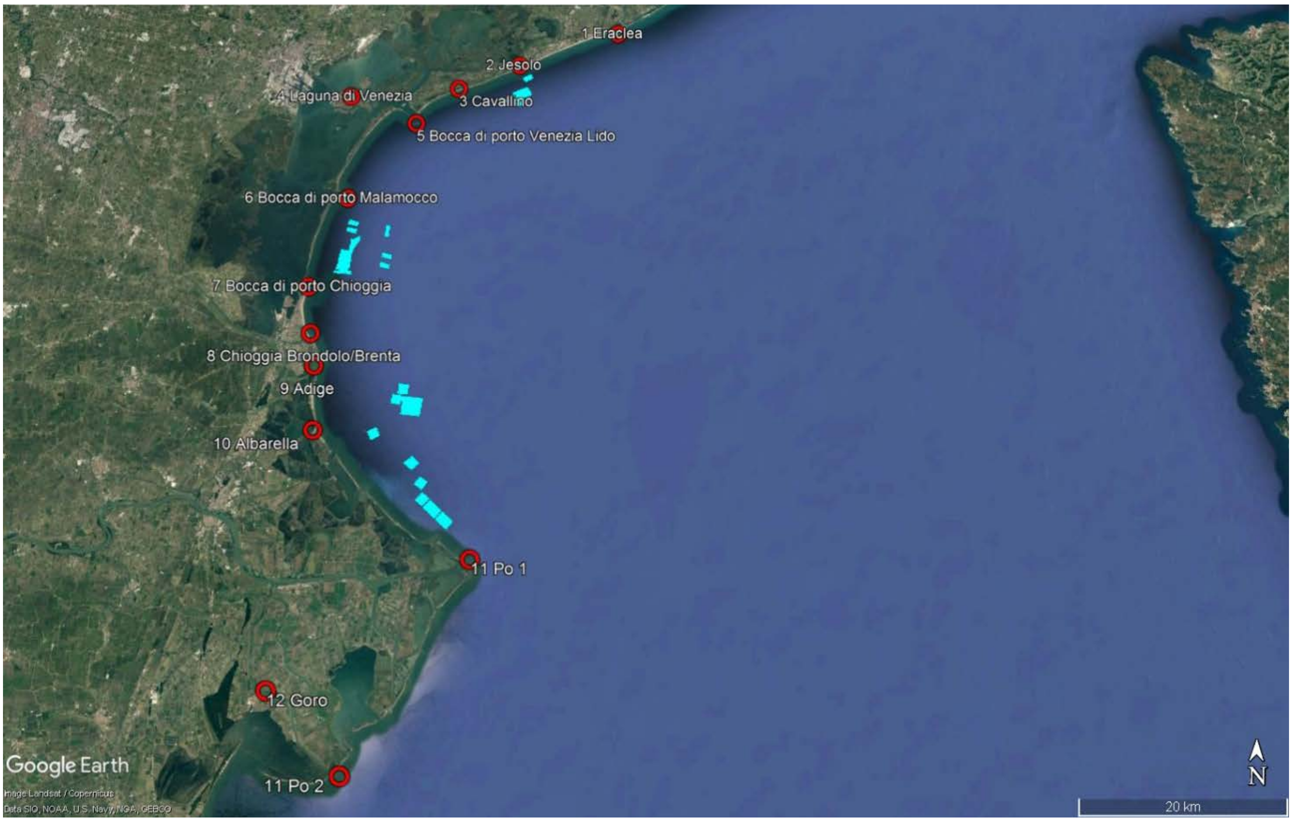

Figure 21. Potential bacterial pollution sources (in red) and areas dedicated to the aquaculture of Mytilus galloprovincialis (in cyan).

Each plant occupies an area including several grid points of the CADEAU model. Hence a total of 114 points were selected in order to evaluate the indexes. Considering that past monitoring data are not available for this additional products, only the indexes on the potential relative impact (mean and maximum) and potential plume impact (mean and maximum) were evaluated.
Fig. 22 shows an example for the mean relative impact for the source number 8 (Chioggia Brondolo urban waste water treatment plant) on the aquaculture plants. All the results for the 11 potential sources and the 4 different indexes are available on the CADEAU geoportal.

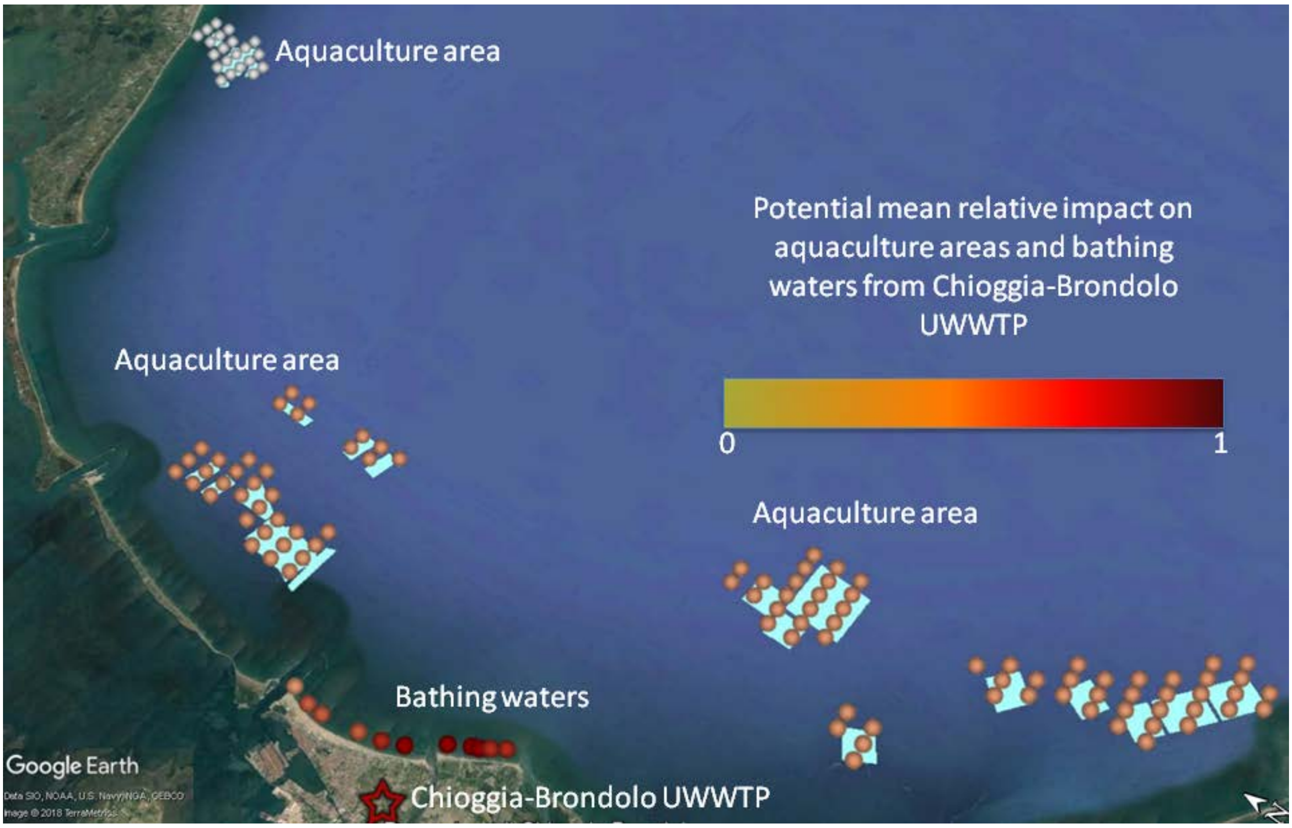

Figure 22. Index of mean relative impact for the source number 8 (Chioggia Brondolo urban waste water treatment plant, red star) on the aquaculture plants of *Mytilus galloprovincialis* (in cyan) and on bathing waters.

3.2 Documentation and involvement of the users community (Sub-Task 2.2)

3.2.1 Presentation of promotional activities

Outreach activities have been implemented in order to show to the potential final users the usefulness of the project and to gather their feedbacks in order to improve the service. **A Workshop was organized in Venice on the 5th of June 2018**. Institutions, bathing water managers and shellfish farmers were invited with the aim to guarantee the diffusion of results and transferability of the proposed solution in other contexts.

The participant at the Workshop were 60 people, they covered several categories: 35 % scientist, 20 % policy makers, 30% private sector, 5 % NGO, 10 % citizens. The national Copernicus User forum has also participated to the Workshop in order to further spread project results in the Copernicus Users community and to give further input.

During the meeting two round tables were organized both for the discussion of the bathing water concerns and for the shellfish farming problems in order to receive feedbacks to improve the services and products. The output and the presentation of the Workshop are available in the section "other documents" on the web site: http://www.bio.isprambiente.it/cadeau/ and in the ISPRA website: (http://www.isprambiente.gov.it/en/ispra-events/cadeau-project-product-and-services-from-copernicus-marinice-service-to-support-european-directive-for-coastal-environment?set_language=en).

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Other activities were carried out in order to promote the CADEAU service, below some events where the projects and their output were presented:

- ✓ **Copernicus Marine Week 2017, Brussels, 25-29 September 2017**
  Poster: The CADEAU directive-oriented downstream coastal service: integration of national water quality data and a model downscaling of the Mediterranean CMEMS
- ✓ **European Geosciences Union General Assembly (EGU) 2018, Wien, 8-13 April 2018**
  Poster: The CADEAU directive-oriented downstream coastal service: integration of the Italian water quality dataset and a model downscaling of the Mediterranean CMEMS
- ✓ **Italian National Copernicus User Forum, Workshop Copernicus "Monitoraggi e controlli ambientali", Rome, 18 October 2018**
  Oral presentation: Sviluppo di servizi di downstream orientati al supporto all'applicazione delle Direttive Europee sul mare; caso di studio in area alto-adriatica (Progetto CADEAU)
- ✓ **JONSMOD 2018, Florence, 17-19 October 2018**
  Oral presentation: Integration of the Italian water quality dataset and a model downscaling of the Mediterranean CMEMS: the CADEAU coastal service

3.3 User Uptake benefits

The targeted user of the services are:

- ➢ at national level, the Ministry of Environment and Ministry of Health, that may adopt the derived products as tools for decision support for the implementation of measures in overall environmental planning process set by UWWTD/BWD/WFD/MSFD;
- ➢ at regional level, the Regions (i.e., for our demonstration: Friuli Venezia Giulia, Veneto, Emilia-Romagna and Marche) and the regional environmental agencies, directly involved in the environmental management of coastal areas, and the tourism/fishery industry associations and stakeholders, with their fundamental economic revenues produced by tourism and seafood activities;

- at sub-regional level, the local municipalities, directly responsible for the bathing water quality of coastal areas and the citizen health.

During the Workshop in Venice all these categories participated. The main feedbacks of the Workshop were:

Water quality products

- ✓ The relatively high resolution (~750 m) was very appreciated.

Bathing waters products

- ✓ The 3 indicators were very appreciated.
- ✓ Need to provide them also as annual average.
- ✓ Possibility to validate the indicators using data of E. Coli and Enterococci at the discharge effluent (Veneto Regional Agency will provide them).

Shellfish farming products

- ✓ The temperature has negative effects on growth and on the reproductive cycle of mussels, it could be more useful evaluate the correlation between the temperature and the areas of shellfish farming than between primary producers (chl "a") and mussels size.
- ✓ Need to test the 3 indicators also to evaluate the potential bacteria impact on shellfish farming.
- ✓ Wave data analysis of storm surges. Heavy storms could increase the risk of damaging directly the farms and determine the loss of the product, which is the true capital of the aquaculture farm.
- ✓ Statistics concerning users of the service has been provided, in particular with regard to unique visitors of the web-portal and actual end users of the service.
- ✓ This information is contained in a dedicated page of the web portal and is produced both in spreadsheet format and graphical format and it is available on the website.

3.4 Publication of the first bulletin for the period 2006-2017

The first bulletin of this new CMEMS service is available in the section "Bulletin" on the web site: http://www.bio.isprambiente.it/cadeau/. The northern Adriatic Sea has been subdivided into 7 areas. All the variables have been elaborated for the seven areas (Fig. 23). The analysis was performed by calculating the annual minimum, maximum and the annual average (2006-2017) for each variable for each of the subdomains. Furthermore, the minimum, the average and the maximum for the ten-years period 2008-2017 has been drawn up for each subdivision. Regarding the Trophic conditions along the coasts represented by the TRIX index, they are reported in the bulletin only for the year 2012 and the coastal zones (1, 2, 3, 4 and 5). Some examples are reported in Fig. 24.

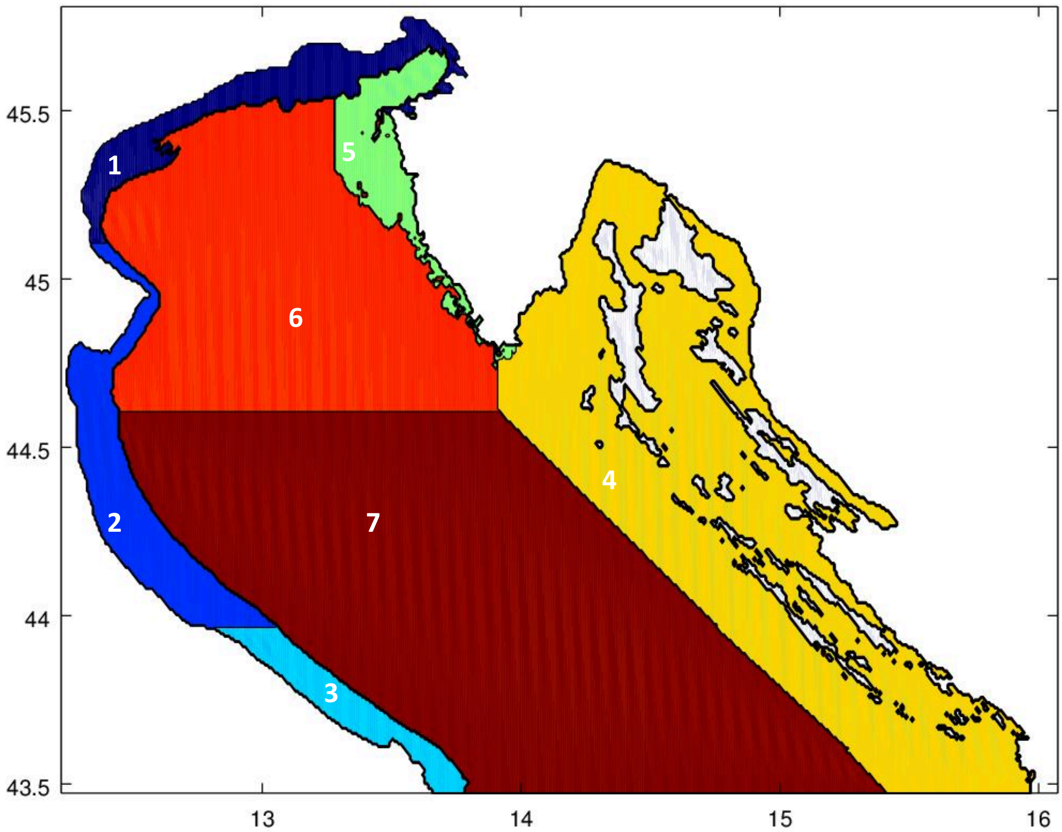
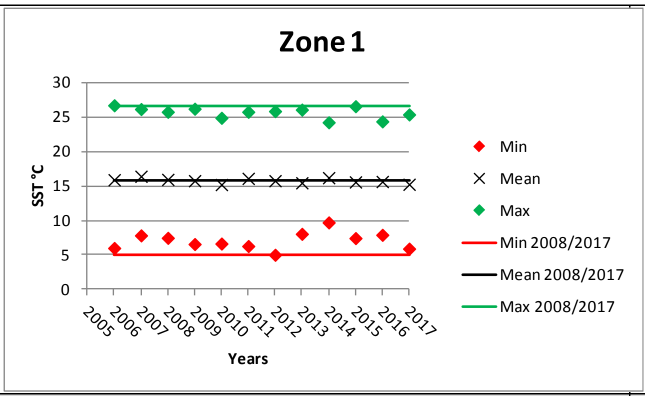
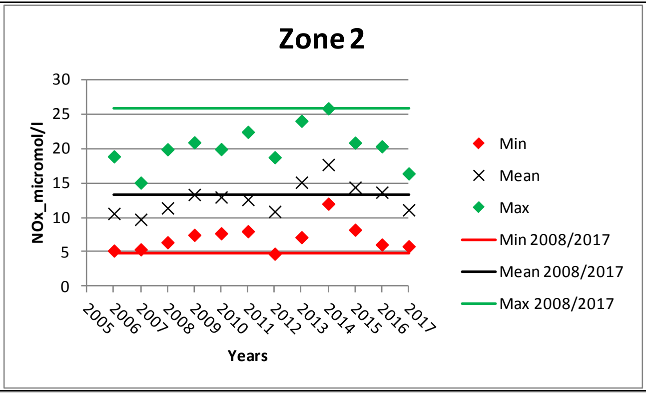


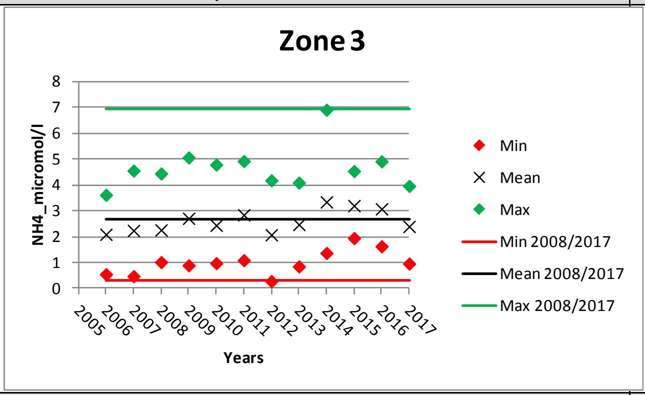
Figure 23. Seven subdivisions of the northern Adriatic Sea.



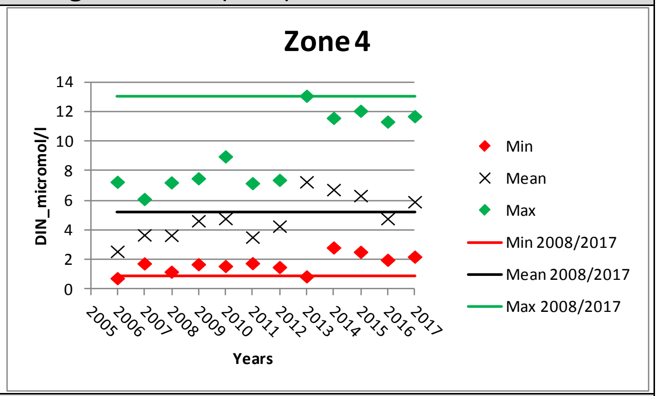
Sea Surface Temperature



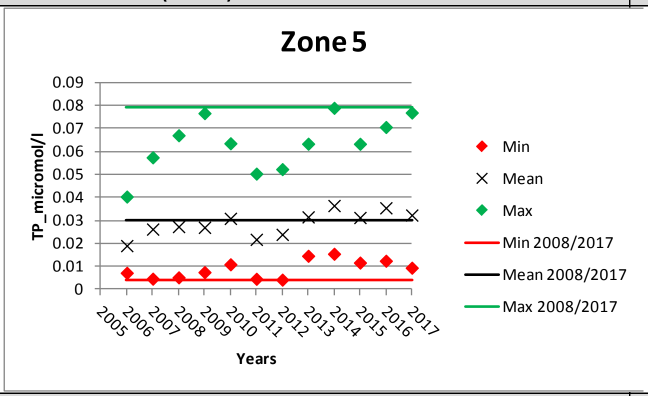
Nitrogen Oxides (NOx)



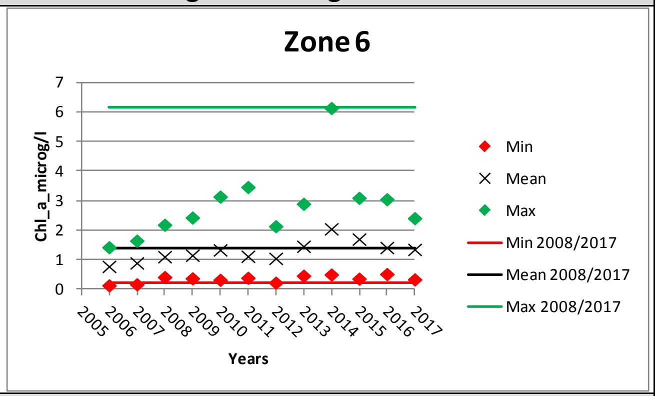
Ammonium (NH4)



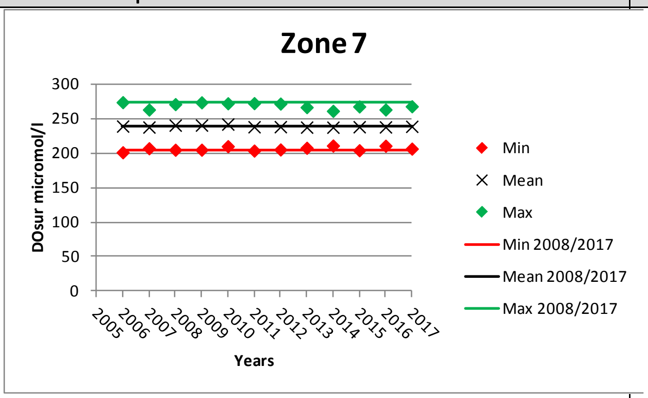
Dissolved Inorganic Nitrogen



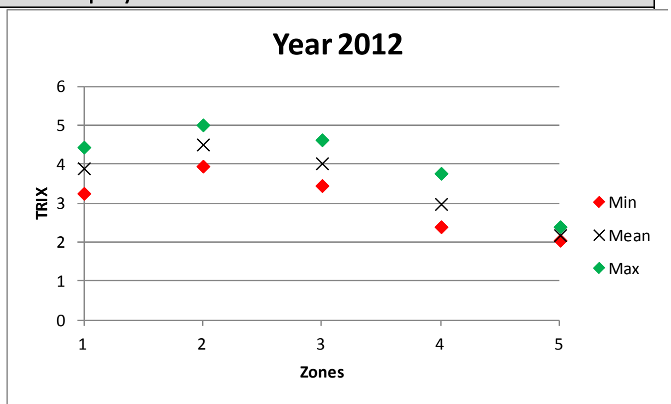
Total Phosphorus



Chlorophyll a



Surface Dissolved Oxygen



TRIX

Figure 24. Extraction of some elaborations from the bulletin, which is fully available in the website: http://www.bio.isprambiente.it/cadeau/.

3.5 Publication of the socio-economic analysis of the service supporting the BWD

In the section "other documents" of the website, it has been uploaded the report on the socio-economic analysis of the service supporting the Bathing water Directive. The report provides a quantifiable socio-economic understanding of the value of Chioggia bathing waters. The bathing closures (temporary banning of bathing in a bathing water) and the classification of bathing areas as "scarce" can generate a loss of economic value also related to the change of bathing tourist destinations. Taking into account the value of WTP calculated by Phillips *et al.*, (2018) in euro (€10,00) we computed the bathing water economic value of the Chioggia bathing water areas during the year 2017 (€ 12.350.000). The tourist presence in each bathing water was evaluated by estimating a daily economic value for the different months of the bathing season. Through the analysis of these data, we estimated the economic loss value for each day of bathing closure.

4. Maintenance and Operational annual updates of the services (Task.3)

The bulletin presents an environmental characterization of the current state of the northern Adriatic Sea coastal waters and will be yearly updated in alignment with the annual release of new data provided by the ISPRA monitoring network. The current state is assessed through the analysis and discussion of the derived products produced by a coastal reanalysis run for the period 2006-2017, while following updates are based on an analysis and hindcast run of the previous year. The reanalysis is performed by means of the MITgcm-BFM high-resolution modeling system developed by OGS, which assimilates the water quality and emission data provided by the ISPRA monitoring network on the Italian Adriatic coastline. The high-resolution model is forced at its boundary by the last version of the CMEMS physics and biogeochemical reanalysis products. At least three updates will be foreseen in 2019, 2020 and 2021. The service will be maintained and regularly kept up to date at least until the end of March 2021, also taking in account the changes in the CMEMS products catalogue to ensure a coherent alignment with the CMEMS platform.

5. Assessment and User requirements on CMEMS Products and future help from CMEMS User Uptake

5.1 Assessment and User requirements on CMEMS used products

In general, all the CMEMS products used in the CADEAU simulations proved to be suitable for a high-resolution downscaling experiment. Both the model and satellite data have adequate accuracy and spatial and temporal resolution. Anyway, the downscaling ratio is rather large (more than 5: from ~4.0 km to ~750 m) and can lead to some problems at the boundary between the CMEMS Mediterranean model and the CADEAU model (e.g., spurious reflections). Nonetheless, these occasional problems did not affect substantially the model results.

5.2 Suggestion on future help from CMEMS User Uptake

The Service could be further developed by extending the products for the Chioggia Municipality Use Case to the whole computational domain (Italian Regions: Marche, Emilia Romagna, Veneto, Friuli Venezia Giulia; Slovenia, Croatia). This would require further founds to improve the modeling system and to held appropriate workshops with local communities. Actually, we had already received requests from some of these communities (Veneto and Friuli Venezia Giulia).

Furthermore, in order to make it easier to access data and consult downstream products for the final user, it could be useful to create a CMEMS work unit to follow and help the development of web sites for downstream products, in order to make them more homogeneous. Finally, the web structure used to access CMEMS products could be doubled, in order to create a similar structure for the publication of results from User Uptake Services.

6 References

Chan S.N., Thoe W., Lee J.H.W., 2013. Real-time forecasting of Hong Kong beach water quality by 3D deterministic model, Water Research, 47, 4, 1631-1647, 10.1016/j.watres.2012.12.026.

Cossarini G.; Querin S.; Solidoro, C.; Sannino G. Lazzari P.; Di Biagio V.; Bolzon G. 2017. Development of BFMCOUPLER (v1.0), the coupling scheme that links the MITgcm and BFM models for ocean biogeochemistry simulations. Geosci. Model Dev., 10, 1423–1445.

Melli V., Angiolillo M., Ronchi F., Canese S., Giovanardi O., Querin S., Fortibuoni T. 2017. The first assessment of marine debris in a Site of Community Importance in the north-western Adriatic Sea (Mediteranean Sea). Marine Pollution Bulletin 114 (2017) 821-830.

Phillips P., Twigger-Rossa C., Cotton I., Gianferrara, E. Orr P., Cherchi F., Wyles K., Boschoff J.,Haydon P. 2018. The value of bathing waters and the influence of bathing water quality: Final Research Report. www.gov.scot/Publications/2018/08/2921/0. ISBN: 9781787811317.

Solidoro, C., M. Bastianini, V. Bandelj, R. Codermatz, G. Cossarini, D. Melaku Canu, E. Ravagnan, S. Salon, and S. Trevisani (2009), Current state, scales of variability, and trends of biogeochemical properties in the northern Adriatic Sea, J. Geophys. Res., 114, C07S91, doi:10.1029/2008JC004838.

Teruzzi A., Dobricic S., Solidoro C., Cossarini G., 2014. A 3-D variational assimilation scheme in coupled transport-biogeochemical models: Forecast of Mediterranean biogeochemical properties. Journal of Geophysical Research: Oceans, 10.1002/2013JC009277.