Joint European Research Infrastructure network for Coastal Observatory – Novel European eXpertise for coastal observaTories - **JERICO-NEXT**

Deliverable title	D4.4: First valorisation results for each region
Work Package Title	WP4
Deliverable number	D4.4
Description	First synthesis of JRAP results per region or key site of JERICO-RI
Lead beneficiary	Ifremer
Lead Authors	Puillat I (Ifremer)
Contributors	Leading contributor per site: A. Rubio (AZTI, Bay of Biscay), F. Artigas & A. Lefebvre (CNRS-LOG and Ifremer, Channel and North Sea), B. Karlson (SMHI, Kattegat-Skagerrak), J. Seppala (SYKE, Baltic Sea), A. Kink & L. Nizzetto (NIVA, Norwegian Sea), Berta & A. Griffa (CNR, Liguria to Ibiza Channel) and B. Moure (SOCIB, Liguria to Ibiza Channel), R. Nair (Adriatic Sea, OGS), G. Petihakis (HCMR, Cretan Sea). **Other Contributors are listed in chapter 3.**
Submitted by	Ingrid Puillat (Ifremer)
Revision number	V 1.4
Revision Date	3 Sept. 2019
Security	**Consortium Only until 30 August 2020**

The JERICO-NEXT project is funded by the European Commission's H2020 Framework Programme under grant agreement No. 654410

Project coordinator: Ifremer, France.

History			
Revision	**Date**	**Modification**	**Lead Author**
0.1	May-Aug. 2018	Gathering of Chapter 3 contributions	I. Puillat
0.2	Sept-Oct. 2018	Update of Chapter 3 with missing contributions	I. Puillat
0.3	Nov. 2018-Feb. 2019	Gathering information and brainstorming for Chapter 4	I. Puillat
0.4	Mar.-Jun.2019	Update of the constribution: last scientific analysis and revision of the document. Legends etc.	I. Puillat
1.0	10 June 2019	Version 1	I. Puillat
1.1	17-20 June 2019	Revision of the Executive summary,	A. L. King, I. Puillat
1.2	23 June 2019	Aknowledgements received	L. Laakso, I. Puillat
1.3	12 Aug. 2019	Revision for Channel and North Sea + consideration of the feedback from the STAC (received during the final General Assembly)	F. Artigas, I. Puillat
1.4	3rd Sept. 2019	Modification of the conclusion section and of the executive summary. References to the JERICO structure in PSS and IRS will be reported in D1.4	I. Puillat

Approvals				
	Name	**Organisation**	**Date**	**Visa**
Coordinator	Farcy	Ifremer	09 Sept 2019	PF
WP Leaders	Puillat	Ifremer	03 Sept. 2019	IP
WP Coleader	Grémare	CNRS-EPOC		

Table of contents

List of Figures

1. Executive Summary

WP4 of JERICO-NEXT aims to synthesize the project's activities in the other WPs and gather the contributions around applied Joint Research Activity Projects (JRAPs) selected to benefit of and highlight JERICO-NEXT activities. In order to fulfil this objective, methodologies developed or improved in WP3 were applied in the JRAPs;the provision of data assembled and distributed was undertaken according to the WP5 recommendations; dedicated topical approaches of the scientific strategy matured jointly with WP1&4 (Deliverable D4.1) were applied within the JRAPs, providing then in return essential input to the future road map of the research infrastructures. Indeed, six JRAPs were implemented to address different key environmental issues and/or policy needs such as those considered by the MSFD, and according to the 6 JERICO-NEXT scientific areas:

1- JRAP#1 on pelagic biodiversity
2- JRAP#2 on benthic biodiversity
3- JRAP#3 on chemical contaminant occurrence and related biological responses
4- JRAP#4 on hydrography and transport
5- JRAP#5 on carbon fluxes and carbonate system
6- JRAP#6 on operational oceanography and forecasting.

These JRAPs were not intending to implement similar actions at each JERICO-RI site but only to a selection of sites/regions according to the consortium interests and requirements from local to regional scales. Consequently, it is paramount to regionally synthesize the preliminary results after deployments in JRAPs, which is the purpose of this document.
The main document is organised according to the following regions and sites:

- Bay of Biscay (South East Bay of Biscay, Portuguese Margin and Nazaré Canyon, Girond Mud patch and Bay of Brest)
- Channel and North Sea
- Kattegat and Skagerrak Sea
- Baltic Sea
- Norwegian Sea
- Med. Sea: From Liguria to the Ibiza Channel
- Med. Sea: Northern Adriatic Sea
- Med. Sea: Cretan Sea.

Results for those regions are presented in chapter 3 after consideration of the regional or site specificities related to the most relevant scientific issues of the area and the most relevant societal and policy needs, respectively. As the project and the JRAPs were not a priori organised to fit with regional to local needs, the reader may identify a weak point in the way JERICO-NEXT is addressing scientific syntheses per region. Nevertheless, it is a preliminary work towards the regional structuration of the RI, as expected, and a significant effort was put forth to identify discrepancies in the level of regional integration, and the recommended way to progress on this issue is presented in Chapter 4.

Synthesis of main achievements per region of JERICO-RI

1) Bay of Biscay: SE BoB

- Involved JRAPs: JRAPs #1 3 4 6
- Progress in the study of coastal small scale and mesoscale features from the combined use of multiplatform in-situ and satellite data.
- Progress in the application of innovative techniques (developed in WP3) in this area for data-gap filling, data-blending, advanced Lagrangian diagnostics and performing observing system experiments (OSEs) and observing system simulation experiments (OSSEs).
- Success in the gathering of new high-resolution datasets from different surveys and actions in the area (ETOILE with MASTODON-2D moorings deployment and TNA BB-TRANS).
-

2) Bay of Biscay: Gironde and Bay of Brest

- Involved JRAPs: JRAP #2
- Success in gathering biological and biogeochemical observations on a major marine mudpatch located in a high energetic environment. New evidence on the major role of hydrodynamics in controlling benthic diversity and associated biogeochemical processes in this mudpatch.
- Success in deriving high resolution spatial maps of clam dredging pressure in the Bay of Brest and in using these maps to show the deleterious effect of this activity on benthic diversity hosted by maerl beds.
- Success in the field testing of several techniques and tools (e.g., Image acquisition via mobile platforms and sediment profiling, image processing via dedicated software, and O2 sediment microprofiling) developed within both JERICO-FP7 and JERICO-NEXT.

3) Bay of Biscay: Nazare Canyon

- Involved JRAPs: JRAPs #4 & 6
- Success in the implementation of a high-resolution model with data assimilation able to describe the energetic dynamics and coastal ocean impacts of this long submarine canyon.
- Progress in understanding the crucial importance of real-time monitoring infrastructures (fixed platforms, HF radars) to the characterization and operational forecasting of coastal ocean areas marked by the presence of submarine canyons, view the energetic and short spatial scale processes that are associated with these topographic features and the impacts canyons promote on larger domains of the coastal ocean.
- Progress in understanding the dominant processes of subinertial dynamics in the Nazare Canyon area of influence, contributing to define the main components of a real-time monitoring system for this area.

4) Channel and North Sea

- Involved JRAPs: JRAPs #1, 4, 5
- Successful implementation of innovative (semi-)automated techniques for the monitoring of phytoplankton dynamics and C cycle in the English Channel and the North Sea - an extended shelf system influenced by multiple sources of human pressure and contrasting hydrodynamical conditions
- Some of these methods were compared with traditional laboratory analysis which helped to better address the added value of innovative techniques in terms of improving the spatial and temporal resolution (both in surface and in the water column), making it possible to consider functional and, sometimes, even taxonomical characterization of phytoplankton communities composition as well as photo-physiology, at high resolution, in almost real-time.
- New insights into the seasonality of the spatial distribution of delta partial pressure of carbon dioxide (pCO_2) measured continuously on ships of opportunity at a regional scale in the North Sea, and the relation between marine sinks of CO_2 with high total chlorophyll a fluorescence.
- Automated techniques made it possible to characterize the size and functional composition of phytoplankton communities (from pico- to microphytoplankton) through the main bloom episodes including outburst of potential HABs as *Pseudo-nitszchia* spp. and *Phaeocystis globosa* (characterized as high or low red fluorescence nano-eukaryotes: Nano high and Low FLR) from the Eastern English Channel (EEC) towards the southern North Sea, in international cross-border (UK, FR, BE, NL) common research cruises, following the spatial and temporal succession of spring blooms.
- There is a need to increase the combined implementation of innovative and reference techniques both on current monitoring of discrete stations as well as in continuous automated measurements performed on cruises and ships of opportunity (as FerryBoxes), in order to increase the spatial and temporal resolution of the surveys of the different eco-hydrodynamic regions of the area.

5) Kattegat and Skagerrak

- Involved JRAPs: JRAPs #1, 3, 5, 6
- Harmful algae, phytoplankton diversity and abundance were observed in near real time at an aquaculture site on the Swedish west coast. In situ imaging flow cytometry combined with machine learning and wireless communications provided data every 20 minutes.
- Data from HF radar, FerryBox, research vessels and oceanographic buoys were used together with results from the 3D-NEMO Nordic ocean circulation model and remote sensing to describe the Kattegat-Skagerrak system.
- Data from a FerryBox system revealed the occurrence of strong concentration gradients reflecting progressive dilution along the South-North transect and highlighted harbours areas as hotspots for chemical compounds.
- Microbial molecular markers representing bacterial species and genes were used to identify hydrocarbon pollution or high nutrient loads.
- Barcoding of phytoplankton and bacteria revealed previously unknown diversity in the pelagic communities
- Carbon fluxes and carbonate system variability in the Skagerrak/Kattegat region is primarily driven by changes in salinity resulting from the balance of freshwater inputs from riverine and Baltic sources and saline waters from the Atlantic Ocean.

6) Baltic

- Involved JRAPs: JRAPs #1, 5, 6
- Different technologies for phytoplankton research have been successfully evaluated in the Baltic Sea. Operational monitoring of phycoerythrin fluorescence started after in-depth study during JRAP1, which identified different origins of this signal. To study filamentous cyanobacteria blooms, various sensors were tested and they were largely complementary. New absorption method seems to provide reliable estimates for Chlorophyll-a concentration, but still lacks automated maintenance procedures. Better understanding was obtained on the range of conversion factor between electron transport rate (measured with fluorescence induction) and carbon fixation rate, as well as of the reasons behind this variability.
- Carbonate system components of the Baltic Sea showed large seasonal variability indicating high impact of biological activity for pH and pCO_2. Alkalinity of the Baltic Sea is difficult to model from other carbonate system components and online sensors are required to understand its variability.
- The joint studies between different (multinational) research groups using different technologies provided good know-how exchange and should be encouraged. As well, multidisciplinary research efforts, including physics, chemistry, biology and modelling, should be encouraged, to gain knowledge on the environmental challenges more in detail.

7) Norwegian Sea

- Involved JRAPs: JRAPs #1, 3, 6
- The Norwegian Sea plays a major role as an area where potentially highly polluted waters from the North Sea mix with water transported from the North Atlantic Ocean. This water is then transported into the Arctic region. Analysis of the transport pathway of waterborne contaminants along the Norwegian coast was instrumental for assessing the spatial range of contaminants with different properties and address questions regarding exposure of the Arctic.
- 42 currently used pesticides in Europe, 5 artificial sweeteners and 11 pharmaceuticals and personal care products were targeted during the study. Several compounds were detected in the Norwegian Sea, including current use pesticides, artificial food additives and some pharmaceuticals. Their presence in this coastal area, and also in high-latitude more open waters, highlight the potential for these contaminants to undergo long range transport with marine currents.
- Seasonal variability in temperature in the coastal area (up to a 15 ˚C differential between summer and winter depending on latitude) is a large driving force on carbonate system variability, including a decrease in surface water fCO_2 due to lower wintertime temperatures as well as the uptake of atmospheric CO_2 as water cools during its northward journey from the North Atlantic to the Arctic Ocean.

- In addition, a focal point was the improvement of systems that provides knowledge for the transport of parasites and harmful algae in the Norwegian Sea coastal area. Here the observations by FerryBoxes, fixed stations as well as repeated transects were used to validate and improve numerical model simulations.

8) Mediterranean Sea: Ligurian to Ibiza channel

- Involved JRAPs: JRAPs #1, 4, 6
- Major investigation effort was led in the Liguro-Provencal area and the Catalan Margin to study the variability of the Northern current through the combination of independent and complementary observational platforms. The dynamics of the boundary currents were studied to identify the interplay between various forcings (remote, thermohaline and wind), the generation of mesoscale and submesoscale instabilities, and data blending and assimilation techniques were investigated.
- Major results have shown a clear correlation between hydrographic changes led by climatic interannual variability and the community composition of phytoplankton and zooplankton. The role of (sub)mesoscale processes have shown to modulate biochemical processes and to locally enhanced marine biomass productions/accumulation.
- The multiplatform observing system in the NW Mediterranean Sea, combined with growing centralized frameworks of data management and distribution, i.e. Copernicus Marine Environment Monitoring Service and SeaDataNet/SeaDataCloud, will provide the basis for an extended European coastal infrastructure.

9) Mediterranean Sea: Adriatic Sea

- Involved JRAPs: JRAPs #5 & 6
- During the project, important steps forward have been made on the development of capabilities to integrate new kinds of experimental data and oceanographic models to support ecosystem management. The implementation of an Adriatic oceanographic model assimilating surface current from coastal radar and temperature profiles from fishing vessels (FOOS fleet) has been developed and tested, providing encouraging results. Surface currents from coastal radars were integrated with results from drifter deployments to investigate zones of recruitment for small pelagic fishes, highlighting the role of remote areas in supporting the ecological role of these environments.
- One year of high frequency data of sea surface pCO_2 was successfully gathered at a fixed station in the northernmost Adriatic. Results highlighted how the biological CO_2 uptake during phytoplankton blooms was able to keep the central basin a strong CO_2 sink not only in winter, when low temperatures favor CO_2 dissolution, but through most of the year, even when temperatures raised above 25°C.
- The work carried on so far highlighted the potentiality of the area, where historical data and many observational systems are available to support both ecosystem management and advanced marine researches. On the other hand, they pointed out the need for integration of the existing facilities and observational systems also at a trans-border level to address the climate and ecological challenges facing this basin.

10) Mediterranean Sea: Cretan Sea

- Involved JRAPs: JRAPs #2 & 6
- An interesting case of how the additional assimilation of glider profiles and FerryBox observations used in the OSE experiment is beneficial for the Aegean Sea forecasting system in terms of reducing the system biases. This improved the sea surface salinity model bias over the south Aegean (north of Crete and south of 37°N).
- In the Cretan Sea, the vertical migration of mesopelagic organisms (macroplanktonic and micronektonic) was observed by acoustical means for almost 2.5 years in the epipelagic and mesopelagic layers. The observed organisms were categorized into four groups according to their migration patterns which appeared to occur at diel and seasonal scale. The variability of the migration patterns was inspected in relation to the physical and biological environmental conditions of the study area. Stratification of the water column does not act as a barrier for the vertical motion of the strongest migrants that move up to 400 m every day. Instead, changes in light intensity (lunar cycle, daylight duration, cloudiness) and the presence of prey and predators seem to explain the observed daily, monthly and seasonal.

This report clearly demonstrates how the consortium of the project is willing to progress on **monitoring strategie**s in several JERICO studies (besides the simulation experiments for transport studies, the analysis of search radius from contaminant sources and the use of covariance in highly relevant low-concentration persistent contaminants, use of multi-functional sensors, etc.); despite the **difficulty** and time-consuming activity of operating both fixed and mobile platforms working in the highly dynamic complex and densely utilised coastal areas. By progressing on the integration of scientific fields, it also shows the benefit of operating several platforms types (fixed & mobile, at sea, remote, & numerical). For instance, we can emphasize what deployments in JRAPs have proved:

* JRAP #1: interest in deploying complementary observing systems for algal blooms to get information interoperable at EU level.
* JRAP #2: success in monitoring highly dynamic benthic ecosystems.
* JRAP #3: possibility to successfully perform monitoring of contaminants in an interoperable manner.
* JRAP #4: the highly resolved low-cost sensor and mooring deployments for specific transport or contaminant studies, which shows the intent to be cost-efficient. The complementarity of remote + at sea and numerical systems.
* JRAP#5: coastal carbon fluxes and biogeochemical cycling: The relatively large variability of conditions keeps being a challenge for sensor developers, with necessary periodic calibration needs that are possible to tackle as shown.
* JRAP#6: makes a strong case of the need for in-situ data vs models, in particular for coastal processes.

A vision: a possible geographical structure of JERICO-RI per region and site

As a consequence, JERICO-RI already proved his capability to gather information and tools to qualify and quantify processes, their scales, related challenges and the possible solution to progress on. As a next step, in agreement with regional stakeholder, JERICO-RI should develop regional forum/center to share information (data and products), expertises, practices, solution and training in line with regional purposes to support scientists and regional stakeholders. This would support application of policies and regulations, based on applied collaborations between scientists and other stakeholders to tackle common societo, environmental and scientific questions from local to regional scales.

According to the monitoring purposes in regions and sites, the need of integration in scientific fields is diverse and JERICO-NEXT presented only a first steps. In the future, JRAPs, TNA & regions should engage with outermost regions where regional projects take place and could be liaised with JERICO RI to better connect these regions in the coastal observing RI landscape. Because of these considerations, the consortium progressed towards regional integrated coastal observatories and preliminary elements are presented in chapter 4.

A main lesson learned is that societal challenges and priorities at the regional level are important elements for the structuring of a coastal observing system. Therefore, a key challenge for the future is to improve **regionalisation of the observatories for a better understanding of region-specific processes and an improved fit-for-purpose** of the JERICO-RI (**see deliverable 1.2**). Furthermore, the observatories need to be **consolidated in terms of performance, reliability and variables** to optimally address and answer to key regional and pan-European environmental challenges. The two above-mentioned aspects are the integration challenge that ***the consortium wishes to tackle by implementing a regional structure of JERICO-RI***.

The structuring process will be challenging because coastal observatories are not operated by the same organisations and therefore may have differing objectives and means of operation (financial, logistical, etc.). Based on these differences, we have proposed that the coastal observing systems in JERICO-RI can be structured hierarchically in which all sizes and types of coastal observatories can function in JERICO-RI in an integrated and mutually beneficial way. This will be reported in deliverable D1.4. This way towards a regional structuring of JERICO-RI is included in the proposal for the 3rd project of the JERICO series of projects, JERICO-S3, selected for funding during 4 years and to start in early 2020. With regards to the WP4 of the present project, the final deliverable: D4.5 is in progress to report results of each of the six JRAP activities and will be available by Sept. 2019 on the JERICO-RI website.

2. Introduction

WP4 of JERICO-NEXT aims to synthesize the project's activities in the other WPs and gather the contributions around applied Joint Research Activity Projects (JRAPs) selected to benefit of and highlight JERICO-NEXT activities. In order to fulfil this objective, methodologies developed or improved in WP3 were applied in the JRAPs;the provision of data assembled and distributed was undertaken according to the WP5 recommendations; dedicated topical approaches of the scientific strategy matured jointly with WP1&4 (Deliverable D4.1) were applied within the JRAPs, providing then in return essential input to the future road map of the research infrastructures. Indeed, six JRAPs were implemented to address different key environmental issues and/or policy needs such as those considered by the MSFD, and according to the 6 JERICO-NEXT scientific areas:

1- JRAP#1 on pelagic biodiversity

2- JRAP#2 on benthic biodiversity

3- JRAP#3 on chemical contaminant occurrence and related biological responses

4- JRAP#4 on hydrography and transport

5- JRAP#5 on carbon fluxes and carbonate system

6- JRAP#6 on operational oceanography and forecasting.

These JRAPs were not intending to implement similar actions at each JERICO-RI site but only to a selection of sites/regions according to the consortium interests and requirements from local to regional scales. Consequently, it is paramount to regionally synthesize the preliminary results after deployments in JRAPs, which is the purpose of this document.

The main document is organised according to the following regions and sites:

- Bay of Biscay (South East Bay of Biscay, Portuguese Margin and Nazaré Canyon, Girond Mud patch and Bay of Brest)
- Channel and North Sea
- Kattegat and Skagerrak Sea
- Baltic Sea
- Norwegian Sea
- Med. Sea: From Liguria to the Ibiza Channel
- Med. Sea: Northern Adriatic Sea
- Med. Sea: Cretan Sea.

Results for those regions are presented in chapter 3 after consideration of the regional or site specificities related to the most relevant scientific issues of the area and the most relevant societal and policy needs, respectively. As the project and the JRAPs were not a priori organised to fit with regional to local needs, the reader may identify a weak point in the way JERICO-NEXT is addressing scientific syntheses per region. Nevertheless, it is a preliminary work towards the regional structuration of the RI, as expected, and a significant effort was put forth to identify discrepancies in the level of regional integration, and the recommended way to progress on this issue is presented in Chapter 4.

Durand Dominique, Puillat Ingrid, Karlson Bengt, Grémare Antoine, Nizzetto Luca, Rubio Anna, Laakso L, Mourre Baptiste (2016). JERICO-NEXT. Approaches to monitor European coastal seas. JERICO-NEXT-WP4-D4.1-V3.0. https://archimer.ifremer.fr/doc/00382/49331/

Puillat Ingrid, Karlson Bengt, Artigas Felipe, Grémare Antoine, Nizzetto Lucas, Rubio Anna, Laakso Lauri, Seppala Jukka, Mourre Baptiste (2016). JERICO-NEXT. Progress Report #1 JERICO-NEXT-WP4-D4.2-061216-V2.0. https://archimer.ifremer.fr/doc/00382/49333/

Puillat Ingrid, Karlson Bengt, Artigas Luis Felipe, Grémare Antoine, Nizzetto Luca, Rubio Anna, Laakso Lauri, Seppala Jukka, Mourre Baptiste (2017). JERICO-NEXT. Progress Report #2. JERICO-NEXT-WP4-D4.3-101217-V2.0. https://archimer.ifremer.fr/doc/00406/51702/

3. First valorisation results for each region

3.1. Bay of Biscay

Involved institutes: IFREMER, CNRS-LOG, AZTI, IH

Lead authors: Anna Rubio, Joao Vitorino (IH), Antoine Grémare (CNRS-EPOC)

Contributing authors: Felipe Artigas (CNRS-LOG), Ainhoa Caballero (AZTI), Luis Ferrer (AZTI), Alejandro Orfila (CSIC-IMEDEA), Guillaume Charria (IFREMER), Pascal Lazure (IFREMER)

Involved JRAPs: 1, 3, 4 and 6

3.1.1. *The Bay of Biscay (BoB) (SW Atlantic European margin)*

BoB is a complex region characterized by irregular bathy-topographical features (e.g. submarine canyons, and steep changes of the orientation of the coast) and a narrow shelf (Figure 3.1-1). Four subareas have been tackled during this period of JERICO-NEXT: The southeastern (SE) BoB, the Nazaré Canyon area (Portuguese margin), the Gironde and the French Brittany coastal areas.

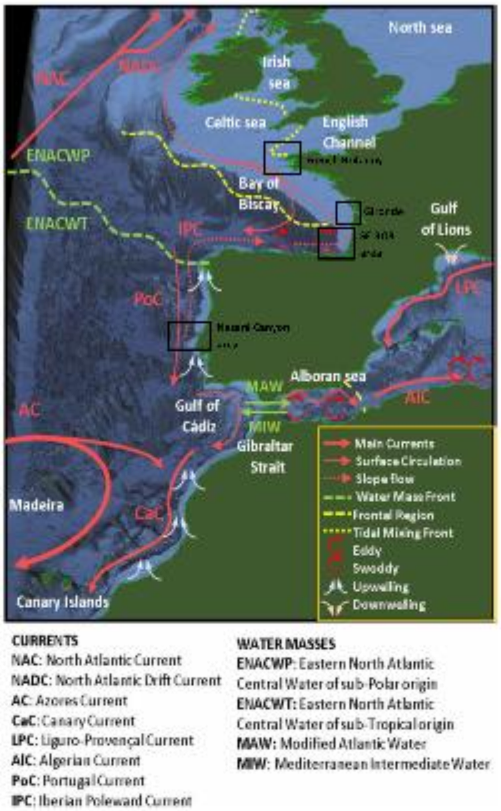


Figure 3.1-1 Main characteristics of the circulation in the IBIROOS area, from Sotillo et al. (2015). Overlapped are plotted the areas covered by the SE BoB, the Nazaré Canyon area (Portuguese margin), the Gironde and the French Brittany coastal observatories

Along the slope, the main feature of the circulation common to all the areas is the Iberian Poleward Current (IPC) which is intensified mostly in winter months. The extension of this current has been observed to reach as far north as the coast of Ireland (see for instance Sotillo et al., 2015). The IPC is one of the main along-slope flows that promote trans-boundary interactions along the Atlantic margin of Europe. At local scales other processes, like the intensification of the current or eddies generated through the interaction of the along-slope flow with the bathymetric irregularities, are key in the modulation of the exchanges between the coastal system and the open ocean.

Borja et al. (2019) have identified the following pressing issues that can compromise the ecological status of the Bay of Biscay: Pollution from hazardous substances (found in coastal locations close to urban and industrial areas); Eutrophication in some estuaries and bays in Northern Brittany and extended estuarine plumes spread in the continental shelf of the Bay of Biscay (occurrence of algal blooms); Decrease in biodiversity (different threatened or declining species, including sharks, skates and rays, seabirds, whales, diadromous, and commercial fish species); Existence of invasive species in the Bay of Biscay (Zorita et al., 2013) - due to growing maritime traffic and other activities (e.g., aquaculture), the number of exotic species is expected to increase; More and new research has to be done to fully understand and evaluate the impacts of climate change in the Bay of Biscay. In addition to those, other important local environmental problematics and needs have been identified from the analysis of recent activities and exchanges with stakeholders in each of the cited subareas.

3.1.2. *The SE BoB*

3.1.2.1. Specificities of the this region

Most relevant scientific questions from regional to local scales

The SE BoB is an area characterized by complex circulation patterns, thus, represents a particular challenge for the accurate monitoring and forecast of 4D transport patterns. Over the shelf, the circulation is driven mainly by winds, with seasonal variation in strength and direction (Solabarrieta et al. 2015). Over the slope, the IPC flows eastwards (northwards) along the Spanish (French) coast advecting warm surface waters in winter (Le Cann and Serpete 2009; Charria et al. 2013) (Figure 1). In summer, the flow is reversed and three times weaker than in winter (Solabarrieta et al. 2014). The generation of these eddies (the so-called SWODDIES) occurs mainly in winter, when the intensified IPC interacts with the abrupt bathymetry (Pingree and Le Cann, 1992). Teles-Machado et al. (2016) studied the generation of SWODDIES in the NW Iberian margin, by means of a 20-year high-resolution numerical simulation, and found a relationship between the formation of eddies, topographic features and the wind variability. A sudden decrease in southerly winds resulted in the development of instabilities in the IPC and generation of eddies, being the anticyclones (cyclones) formed mainly on the equatorward (poleward) side of the canyons and on the poleward (equatorward) side of promontories or capes (Teles-Machado et al., 2016). The effect of SWODDIES on the primary production has been previously investigated by different authors (Rodríguez et al., 2003; Fernández et al., 2004, Garcia-Soto et al., 2002; Caballero et al., 2014 and 2016). In several studies, the trapping of mesotrophic water from coastal areas by SWODDIES has been observed using satellite data, but has not been quantified (e.g., Caballero et al., 2014). In-situ measurements showed that the depth-integrated Chlorophyll-a (Chl-a) concentration was higher in the cores of anticyclonic eddies than in their periphery, influencing the plankton composition (Rodríguez et al., 2003; Fernández et al., 2004, Caballero et al., 2014). In contrast, lower Chl-a concentrations have been observed in the cores of cyclones (Garcia-Soto et al., 2002; Caballero et al., 2016).

At shorter time-scales, the variability is dominated by tides (mainly semidiurnal) and inertial waves (Rubio et al., 2011). The River Adour is the main source of continental water (Valencia et al., 2004), while the rivers along the Spanish coast (Nervión, Bidasoa, Deba, Urola, Oria and Urumea) show much lower runoff (Ferrer et al., 2009;). Seasonal runoff patterns are observed, with maximum runoff (over 1000m3.s-1 for the River Adour) during winter and spring and much weaker runoff in summer (mostly under $100m^3.s^{-1}$).

In JERICO-NEXT, for the SE BoB, we focused on several topics. One was the study of the role of the SWODDIES in the cross-shelf exchanges and on their observability using land-based and satellite remote-sensing data and more generally in the role of mesoscale processes in the physical-biological interactions. A second important focus was to study the internal waves' field thanks to the deployment of a Moving Vessel Profiler (MVP) and of 6 MASTODON-2D moorings (low cost thermistor chains) during the ETOILE survey.

The most relevant scientific questions in this specific area are listed in the following.

- How ocean processes affect the surface transports? Identification of the key processes for accurate transport estimates and study of their potential impact on the distribution of floating matter (plankton - or other pelagic organisms, marine litter, pollutants, etc.)
- How well these processes are observed by the existing systems? Can we suggest new approaches and elements to improve coastal observatories?
- How can we use observations to improve numerical models and how we can use both (models and data) to develop new tools for improving applications of operational oceanography to relevant societal needs?
- Study the presence and distribution of pollutants in the area and possible links with different current conditions. Pollutants like: PAHs; Organochlorine pesticides (DDT, HCB, HCHs), PCBs, PBDEs (polybrominated diphenyl ethers) and novel brominated flame retardants (several compounds).
- Characterize the mesoscale and sub-mesoscale phytoplankton distribution and links between the hydrological structure and the high-resolution spatial distribution of planktonic microorganisms.
- High frequency variability induced by tides such as due to internal tides.

Most relevant societal needs and policy needs (including agencies/users potential list)

In this area, human activities such as sport, artisanal and commercial (industrial) fishing, tourism, industry, offshore aquaculture and platforms, etc. are leading to an increasing human pressure which is also justifying the need to monitor and observe this area. Consequently, in addition to previously identified scientific questions, other important local environmental challenges and needs identified from the analysis of recent activities and exchanges with stakeholders in the SE area of the Bay of Biscay are:

- Sustainable Fisheries & Aquaculture activities (bivalve): (i) Integrated management of commercial fishing species (anchovy, hake, tuna…) and the understanding of the impacts that physical processes have in the recruitment, biomass and distribution of this species towards more accurate stock models; (ii) Biotoxin control for aquaculture (and depending on the installation activity impacts).
- Floating Marine Litter (FML) and plastic pollution: (i) Data for Lagrangian studies for source identification, hotspots detection and forecast; (ii) Integrated evaluation of FML impacts; (iii) Management of FML removal in coasts and open sea
- Hazards and coastal risks: (i) Extreme events forecast, floods and damage prevention; (ii) Adaptation measures to the erosion of the coastline; (iii) Historical and real-time data for navigation safety and contingency plan; (iv) Accurate wind and current high-resolution data for search and rescue operations.

3.1.2.2. Acquired data and archiving made

Data type	Sampling location/area	Sampling period	Institute responsible for data
Surface ocean currents from HF radar	SE BoB, hourly data	2009-present	AZTI
Slope Buoys (TS and currents from 10 to 150m)	Se BoB, hourly data	2006-present for Donostia buoy; 2006-2013 for Matxitxako buoy	AZTI
Glider data - BB-TRANS TNA campaign (TS, ADCP currents, turbidimeter, turbulence sensor…]	SE BoB, sampling depending on the sensors	15/05/2018 - 15/06/2018	AZTI, HZG (TNA Action) & CNR-ISMAR

ETOILE survey (ADCP, MVP, CTD, multi-spectral fluorometer (continuous recording, casts), automated flow cytometry, plastic sampling, MASTODON-2D moorings)	SE BoB, sampling depending on the sensors	07-08/2017	IFREMER, AZTI, CNRS-LOG

3.1.2.3. Collaboration with other international initiatives

LIFE LEMA - Intelligent marine Litter removal and Management for local Authorities (LIFE15 ENV/ES/000252) starting in September 2016. One of LIFE LEMA tasks will focus on the applications of transport characterization from HFRs and models (in coordination with JERICO-NEXT WP4 Task JRAP 6) to specific purposes related with FML

MyCoast project - A Coordinated Atlantic Coastal Operational Oceanographic Observatory. Interreg Atlantic Area, 2017-2020. There are many synergies with this project which will help to broaden the applications of standards and JERICO-RI data and products in the Atlantic Area

COCTO (Coastal Ocean Continuum in surface Topography Observations) funded by TOSCA/ROSES in the frame of SWOT altimetry mission - 2015-2018. Diagnostics developed in this project will be potentially used in the frame of JERICO-NEXT for comparisons between numerical experiments and *in situ* observations.

IBIROOS - Real-time observations collected by EUSKOOS are automatically sent to the regional node of EuroGOOS (via the focal point Puertos del Estado, Spain)

EMODNET - Real-time observations collected by EUSKOOS are automatically sent to the regional and platform nodes of EuroGOOS

EUROGOOS Coastal WG—Synergies between this group's (created in 2018) and JERICO-RI's efforts on mapping the global network of coastal observatories and in the design of the roadmap for its future development. It is for sure not related just to this subarea area but more generally to the whole JERCIO-RI.

3.1.2.4. Scientific progress so far

Coming back to the most relevant scientific questions asked here before, the JERICO-NEXT team working on the SE of the BoB, led several actions to progress ahead, using analysis of historical remote sensing data, recently acquired HF radar data, in situ observation thanks to gliders survey, cruise data and moorings. Efforts were driven on both the data acquisition with their traditional interpretation methods and on the methodologies to derive new data products applying these new analysis methods.

a- ***Towards a better characterisation and understanding of mesoscale processes and associated transport of matter: Eddy & upwelling induced cross-shelf export of high Chl-a coastal waters in the SE Bay of Biscay***

Study of winter anticyclonic eddies from the analysis of historical remote sensing data

Different remote sensing data were combined in the period 2011-2014 to characterise winter anticyclonic eddies in the SE BoB and to infer their effects on cross-shelf exchanges. The study focused in an anticyclonic eddy that develops in a period when typical along shelf-slope currents depict a cyclonic pattern. While the joint analysis of available satellite data (infrared, visible and altimetry) permitted the characterisation and tracking of the anticyclone properties and path, data from a coastal HF radar system enabled a quantitative analysis of the surface cross-shelf transports associated with this anticyclone. The warm core anticyclone had a diameter of around 50 km, maximum azimuthal velocities near

50 cm s-1 and a relative vorticity of up to -0.45 f. The eddy generation occurred after the relaxation of a cyclonic wind-driven current regime over the shelf-slope; then, the eddy remained stationary for several weeks until it started to drift northwards along the shelf break. The surface signature of this eddy was observed by means of high-frequency radar data for 20 consecutive days, providing a unique opportunity to characterize and quantify, from a Lagrangian perspective, the associated transport and its effect on the Chl-a surface distribution. The obtained results suggest that the eddy-induced recurrent cross-shelf export is an effective mechanism for the expansion of coastal productive waters into the adjacent oligotrophic ocean basin. See Rubio et al. 2018 for further detail.

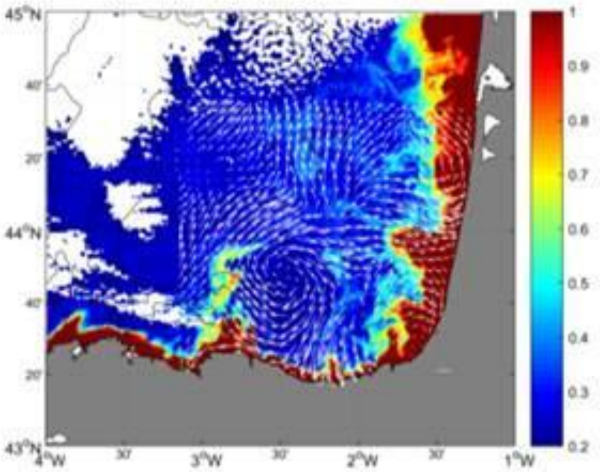


Figure 3.1-2 MODIS-Aqua derived Chl-a (mg m-3) and HFR hourly surface current vectors on the 21 December, eddy cross-shelf Chl-a rich waters export towards the open ocean can be observed. Isobaths (m): 200, 1000, 2000, 3000.

Study of upwelling process with HF radar and satellite imagery (visible and IR)

In another study also using historical data, upwelling processes along the oceanic eastern boundary of the SE BoB are studied using HF radar and satellite imagery for the period 2009- 2016. The results of this analysis are compared with those derived from the conventional way of estimating upwelling index in the area (wind forcing). This comparison is done in order to assess the agreement between the two methods and remote sensing techniques.

Under N-NE winds (Wind speeds ≥ 5 cm/s and a persistence of ~3 days) different intense upwelling processes during the period 2009-2016 have been identified. These events have been identified by different data: Wind, HF radar (HFR), Sea Surface Temperature (SST) and Chl-a data. During these events, westwards currents dominate along the French shelf. As a result of these currents, there is an offshore and southward transport of the coastal surface waters in the French shelf. This is translated in a cooling of surface waters and an instantaneous decrease of the Chl-a concentration in this area due to the advection. Actually, Primary Productivity might have been enhanced in the area of upwelling but the produced organic matter (chl a) was advected by currents. HFR is a useful tool to estimate the upwelling processes in the study area.

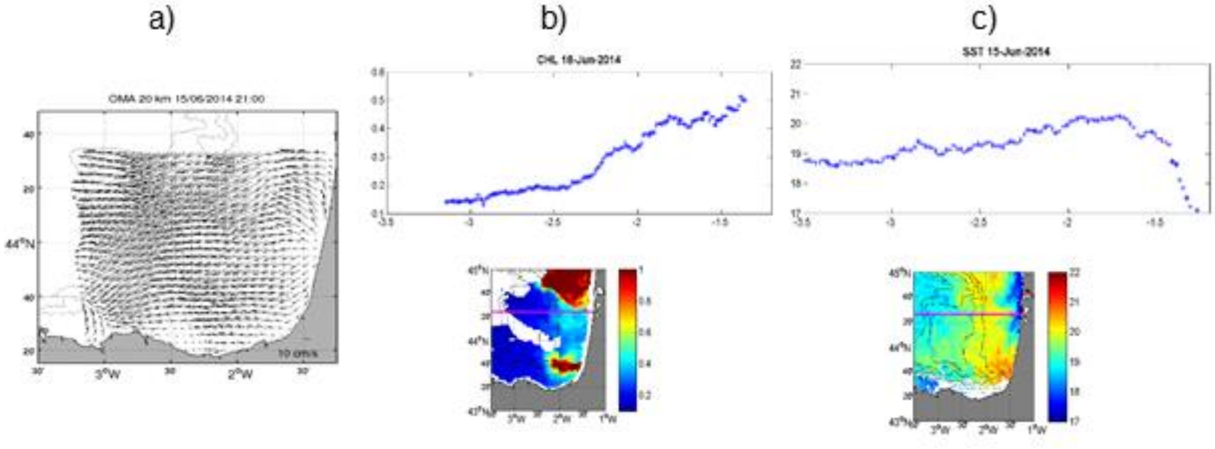


Figure 3.1-3(a) HFR Surface currents, (b) Chl-a and (c) SST satellite surface fields during an upwelling favourable period. In b and c the values for Chl-a and SST along the pink section superimposed to the satellite images are provided at the upper panels.

Mesoscale variability from HF radar and altimetry

To obtain and additional insight on the mesoscale dynamical features in the study area, we compare measurements from HF radar and altimetry within the SE BoB, over the period 2009-2015. The results provide an evaluation of the performance of different coastal altimetry datasets within the study area and a better understanding of the ocean variability contained in both data sets.

The variability of the radar and altimetry measurements are higher near the coast, and both observing systems detect the IPC and eddies, which are the main mesoscale processes within the area. The highest correlations between radar and altimetry take place in the slope, where the IPC affords a great part of the mesoscale variability. Example of four eddies detected by the HFR and the altimeter (even if the eddy core is not crossed by the altimeter track) is shown. Besides, the IPC intensifications are also detected by the HFR and altimetry in late autumn and winter, mainly in the nearest points to the coast between the isobaths 200 and 1000 m. From the joint analysis of Sea Level Anomaly (SLA) and HFR data series, four main IPC events lasting around 2-3 weeks are described. For the four events, HFR currents show a typical IPC spatial pattern, with poleward circulation along the slope intensified between the isobaths 200 m and 1000 m and SST positive anomalies along the slope (increase of 0.5-1 ºC). Please see Manso-Narvarte et al. 2018 for further details.

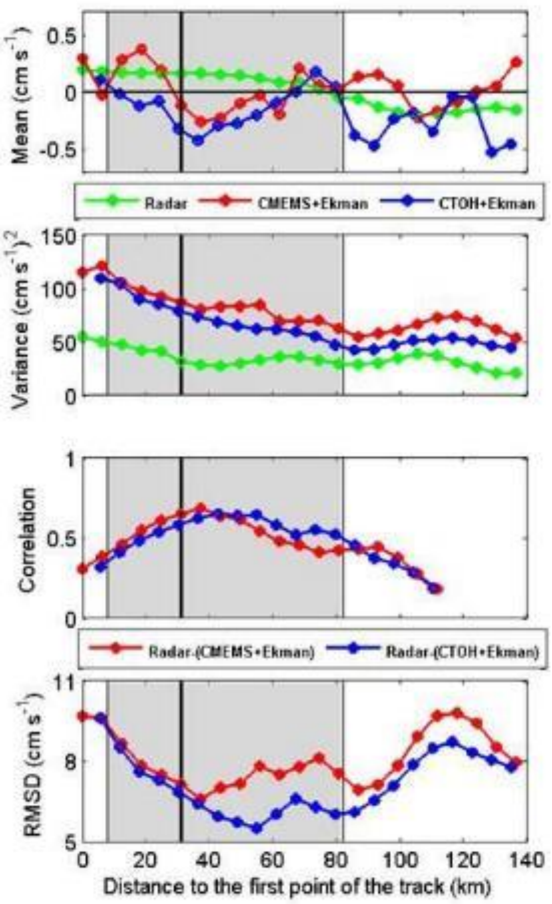


Figure 3.1-4Comparison between SLA-derived and HFR low-pass filtered current anomalie along Jason 2 348 track, showing that the highest agreement between both observing systems occurs over the slope (highlighted in grey). Two SLA products are used: CTOH-XTRACK product.

ETOILE Cruise Leg2.2 - mesoscale features and bio-phys coupling

In summer 2017, the area covering the CapBreton canyon (SE BoB) was surveyed in the framework of the ETOILE cruise. The main objective of this campaign was twofold: Leg 1 and leg1.2 were devoted to the study of internal tides in the area, while Leg 2.2 was designed to gather hydrographic and hydrodynamic data, as well as to determine the distribution of phytoplankton and floating marine litter. During Leg 2.2, besides the various remote sensing data available for this area, such as HF radar or satellite data, in situ hydrographic measurements were collected by a CTD and a Moving Vessel Profiler. Likewise, other parameters such as temperature, conductivity and in vivo chlorophyll fluorescence (total and per pigmentary/spectral phytoplankton group) were continuously recorded. Then, multi-spectral fluorescence casts, chlorophyll *a* and particulate suspended matter concentration, as well as marine floating litter abundance were sampled in selected stations. A saline frontal structure with high spatial variability was identified at 20-100 m depth at the edge of the continental shelf. This front separated the less saline coastal waters from the saltier open sea waters. Furthermore, the surface current displayed an anticyclonic circulation when encountering the saline front, showing coherence between the radar data and geostrophic currents derived from CTD data. The effect of these features in the distribution of floating marine litter and phytoplankton is discussed in detail in Dávila (2018). The distribution of marine litter seemed to be spatially correlated with positive surface relative geostrophic vorticity (not shown). The maximum concentrations were found located in the frontal zones at the periphery of cyclonic eddies. Concerning phytoplankton, a Deep Chlorophyll Maximum was observed at ~50 m depth, highly dominated by Brown Algae (Figure 3.1-5). When examining the vertical distribution of Brown algae it was found that their abundance was highly correlated with negative vorticity (corresponding areas with anticyclonic rotation), being this factor the most influencing one, modulating the fluid dynamical niche of phytoplankton. On the contrary, Green Algae were mainly influenced by salinity.

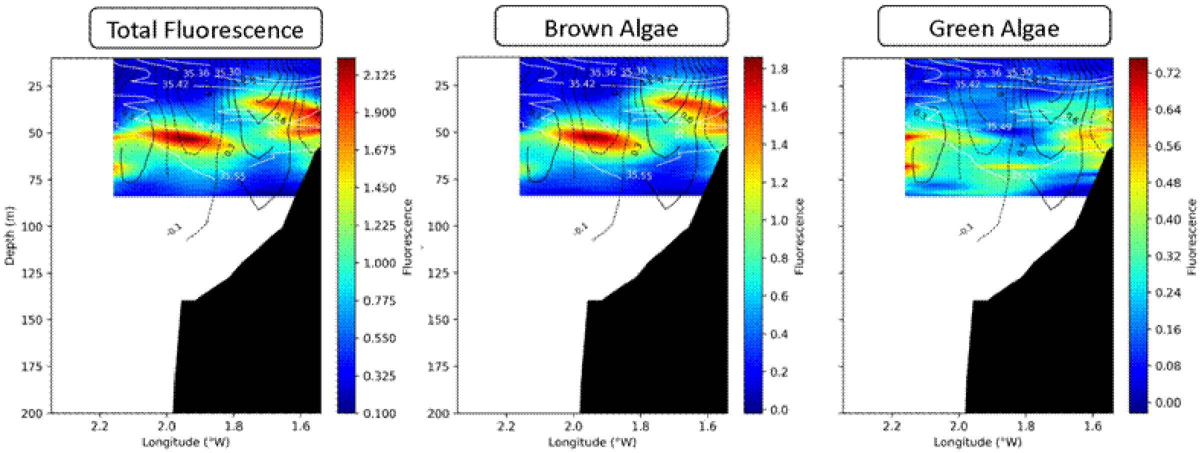


Figure 3.1-5 Cross sections of multi-spectral fluorescence (Fluoroprobe). Brown algae were correlated with areas of negative vorticity (or anticyclonic circulation; in black lines) whereas green algae seem to follow the depression of the halocline (in white lines).

Transport of contaminants: Passive samplers

Four passive samplers were deployed in two different sites of the south-eastern Bay of Biscay; three of them were collocated in the aquaculture facilities of Mendexa, whilst the fourth one was fixed to the buoy of Donostia. These devices accumulated, during weeks even months (see Table 1), the chemical contaminants present in the water such as organochlorine pesticides. After the recovery the samplers were sent back to NIVA for their processing and the processed data was sent back to AZTI for further analysis of the data (in progress). The passive sampler deployment on the fixed platforms delivered data that enabled the characterization of water contamination profile and the assessment of the main seasonal fluctuation. Results are displayed in Figure 3.1-6.

Table1. Date of deployment and retrieval of the passive samplers in the Donostia buoy and Mendexa longline.

DONOSTIA BUOY		MENDEXA LONGLINE	
DEPLOYED	RETRIEVED	DEPLOYED	RETRIEVED
10 MARCH 2017	5 DECEMBER 2017	21 FEBRUARY 2017	3 APRIL 2017
		21 FEBRUARY 2017	8 JANUARY 2018
		19 JUNE 2017	1 AUGUST 2017

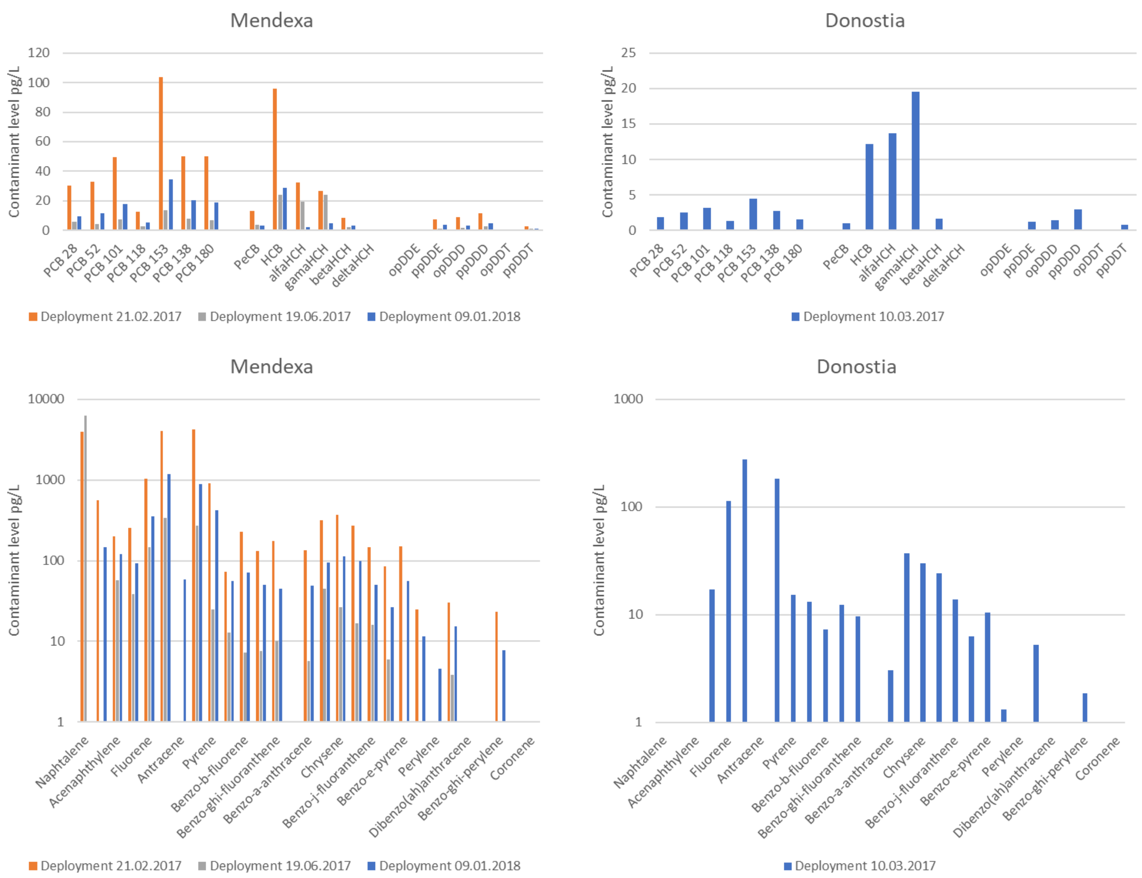


Figure 3.1-6 Results of the analyses of passive samplers deployed in the Bay of Biscay during 2017-2018.

Measurements provided consistent information on the contamination profile, with the relative proportion of different contaminants substantially maintained between locations and across deployments in different seasons.

The major axis of variability appears to be represented by time. In particular, looking at the results from Mendexa, winter and early spring concentrations appears to be higher than in summer for most compounds. This is an expected behaviour. The targeted contaminants are prevalently hydrophobic volatile substances with the atmosphere serving as major sources (Gioia et al., 2008; Lohmann et al., 2009). Lower temperatures favour partitioning of these compounds present as gases in the atmosphere, towards the water. Among the persistent organic pollutants (POPs) regulated under the Stockholm Convention (http://chm.pops.int/), PCBs were the most abundant group of contaminants. Among the group of chlorinated pesticides, Hexachlorobenzene was the must abundant contaminant in seawater. All congeners in the DDT group were below 10 pg/L, with a contamination profile dominated by methabolites such as p,p'DDE and p,p'DDD, reflecting therefore the influence of secondary sources (e.g. old burden of contaminants volatilizing from soils and depositing in seawater, or released from sediments) re-emitting "aged" pesticides.

b- Study of high frequency processes

ETOILE Survey - Internal waves

During the ETOILE field survey, a specific focus was drawn to investigate the field of internal waves in the SE Bay of Biscay thanks to deployment of a Moving Vessel Profiler (MVP) and of 6 MASTODON-2D moorings (low cost thermistor chains). The MVP was operated during 3.5 days along 10 round trips along a 44°N transect between depths of 20 m to 150 m. We spotted solitons, with amplitudes up to 29 m and propagating at 0.25 to 0.8 m.s-1, over the shelf at each internal tide. Supported by mooring data and SAR images we characterised the propagation of wave packets on a 24 km distance, including observations of polarity inversion and energy transfer between solitons. The comparison with the speeds calculated according to the KdV model was convincing, even if the limits from the equations and the Coriolis dispersion did not permit to get a perfect fit. The results of this analysis are synthesized in a Master 2 thesis (Gauthier, 2018) and a publication in an international journal is in progress.

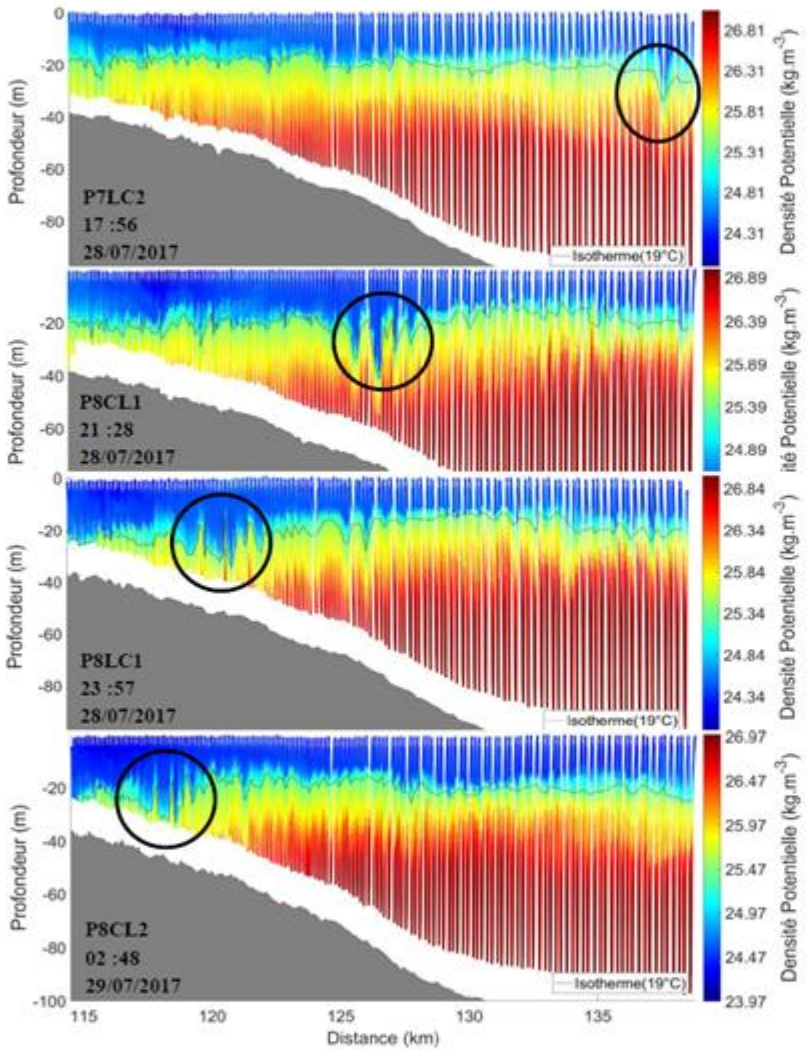


Figure 3.1-7 Propagation of soliton packets (as shown by the black circles) during 4 MVP transects completed in 8 hours.

c- Methodologies towards an operational observation of coastal hydrodynamics and associated transports

Facing recurrent problems of anthropogenic pollution, transport of harmful algae etc. researchers drove some effort during the past decade to develop or improve methodologies to better estimate transport and mixing. The work led in JERICO-NEXT focused on:

i) gap filling methods thanks to HF radar data,

ii) computation of blended data products for a better assessment of transport at higher resolution (presentation of 2 cases here after), and,

iii) development of forecasting modelling capacities thanks to assimilation of data.

The here below results illustrate this effort led in the SE Bay of Biscay thanks to the WP3 and WP4 of the JERICO-NEXT project.

Gap-filling methods (WP3, IMEDEA-CSIC, SOCIB, AZTI)

In the last years, the use of Lagrangian metrics to study mixing and transport properties has been growing in importance. A common condition among all the Lagrangian techniques is that complete spatial and temporal velocity data are required to compute trajectories of virtual particles in the flow. The increased availability of high-frequency continuous surface currents derived from HF radars, is providing new possibilities on the application of Lagrangian methods to these observations for understanding small-scale transport processes in the coastal ocean. However, hardware or software failures in the HFR systems can compromise the availability of data, resulting in incomplete spatial coverage fields or periods without data. In this regard, several methods have been widely used to fill spatiotemporal gaps in HFR measurements. Despite the growing relevance of these systems there are still many open questions concerning the reliability of gap-filling methods for the Lagrangian assessment of coastal ocean dynamics. In this context and within the WP3 T2.3, we have first developed a new methodology to reconstruct HFR velocity fields based on self-organizing maps (SOMs). Then, a comparative analysis of this method with other available gap-filling techniques is performed, i.e., open-boundary modal analysis (OMA) and data interpolating empirical orthogonal functions (DINEOFs). The performance of each approach is quantified in the Lagrangian frame through the computation of finite-size Lyapunov exponents, Lagrangian coherent structures and residence times. We determine the limit of applicability of each method regarding four experiments based on the typical temporal and spatial gap distributions observed in HFR systems unveiled by a K-means clustering analysis. Our results show that even when a large number of data are missing, the Lagrangian diagnoses still give an accurate description of oceanic transport properties. Please, see Hernandez-Carrasco et al. 2018, for further detail.

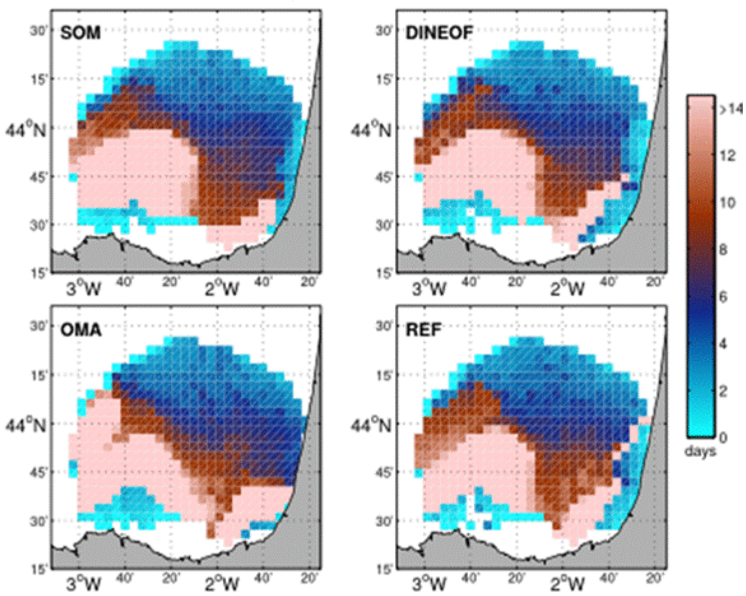


Figure 3.1-8 Snapshots (April 04, 2013 18:00) of Residence Times computed from the three filled and the reference HF Radar data for a scenario representing a decrease in bearing coverage in one of the antennas (more details in Hernandez-Carrasco et al.,2018)

Case 1: First experiments on data blending in the SE BoB (WP3, CNR, AZTI): model + HF radar

The combination of the data obtained from multiplatform observing systems is an interesting approach for a better understanding the three-dimensional coastal circulation. The application of data-blending methods to observations with complementary spatial coverage can be used for extending the information to the nearby areas or vertically through the water column. In the case of HF Radar, the combination with observations in the water column is especially interesting since it can broaden the application of this data to biological, geochemical and environmental issues, since plankton or pollutants can be located deeper in the water column and not only follow surface dynamics. In the framework of WP3 T3.2, the skills of two data blending methods applied to current velocity are compared in the SE BOB area: the DCT-PLS method proposed by Fredj et al. (2016) and the ROOI method proposed by Jordà et al. (2016). The former is based on a penalized least square (PLS) regression approach combined with a discrete cosine transform (DCT) method, so based on a purely statistical approximation. The latter is based on a reduced order optimal interpolation (ROOI) fed with spatial covariance matrix, which add physical information to the method.

To test the methods' skills, they have been applied to pseudo-observations of currents extracted from the IBI CMEMS model field (ATLANTIC-IBERIAN BISCAY IRISH- OCEAN PHYSICS REANALYSIS), simulating a real observatory configuration in the area. The outputs of the methods are compared with the IBI model data, which is also used as the synthetic 'truth'. The observations considered are a surface current field (simulating HF radar measurements) and at two locations with current velocity profiles over the slope (simulating data from two ADCPs collocated on two slope buoys).

For the ROOI method, different historical datasets have been tested to infer the spatial covariances (in order to be able to assess the performance of the method with more and less realistic cases): the IBI model data itself, as the ideal blending case where the model use for covariances is identical to the observations; a high resolution (HR) reanalysis product (GLOBAL OCEAN PHYSICS REANALYSIS GLORYS12V1), which provides similar results to IBI (but independent) ; and a low resolution (LR) reanalysis product (GLOBAL OCEAN PHYSICS REANALYSIS GLORYS2V4) that offer the most realistic and challenging scenario since the obtained covariances are more independent to the pseudo-observations obtained from IBI CMEMS model and the low resolution of the model grid is not resolving properly the mesoscale contained in the pseudo-observations. For the DCT-PLS method, the only input are the pseudo-observations obtained from the IBI CMEMS model.

First results were obtained for winter 2011, when the circulation is mainly driven by the slope current in eastward direction along the Spanish slope and northward along the French slope. Results are presented in terms of RMSDs between the outputs of the methods and the IBI 'truth' data. If we consider the LR reanalysis product, which is, as mentioned, the one that provides the most realistic case, it is shown that the ROOI method provides the best results for the U component if we consider the whole study area. Similar results using both methods are obtained for V and in general in the areas with high density of observations.

In conclusion, each method has its pros and cons. On the one hand, the advantage of the ROOI method is that physical information is used to carry out a more robust blending in areas where there is low density of observations. On the other hand, the disadvantage is that you need a good model for the covariance matrices, and therefore, the DCT-PLS method seems to be a good option if there is absence of a (good) model in the area.

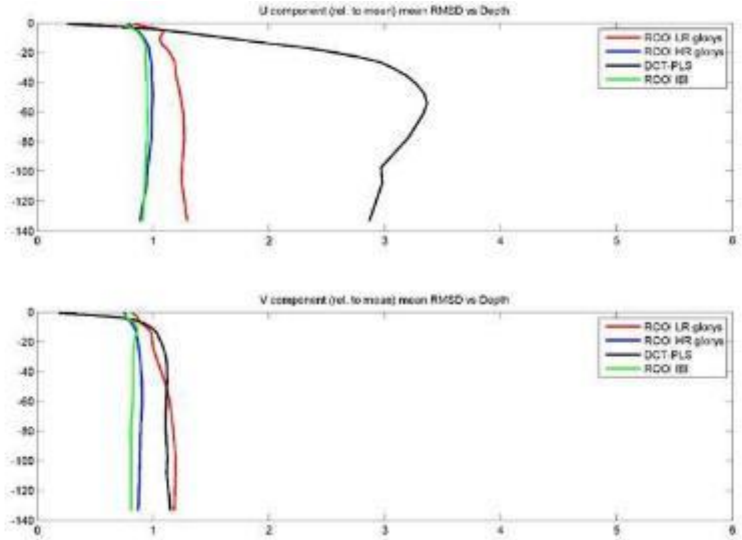


Figure 3.1-9 Mean RMSD relative to the mean current (of each grid point) for each depth (in meters). For component U (top) and component V (bottom). The results obtained using DCT-PLS and ROOI (using different datasets for the covariance matrices) are shown.

Case 2: Glider BB-trans TNA mission, first results of glider + HF radar data blending

The BB-TRANS mission took place from 17 May to 14 June 2018. A Slocum deep glider equipped with a CTD, ADCP, fluorescence-turbidity and MicroRide sensors, measured the water column of the south-eastern Bay of Biscay, from the surface to at a maximum depth of 1000 m. The aim of this mission was to acquire data along the water column and within the area covered by a coastal HF radar system and crossed simultaneously by altimeters on board two different satellites. **These measurements permit first to test different methodologies of data blending for deriving transport in the water column, together with surface currents obtained by the HF radar; and second, to evaluate the accuracy of coastal altimetry along-track data in the study area**. During the mission, besides de glider tracking that allowed to monitor the position and the data measured by the glider, surface current fields and derived Lagrangian Residual Currents (LRC), and surface LRCs (Figure 3.1-10) along with images from satellites, were used to change when necessary the next positions and setting of the glider, in a near real time. During the mission the glider flowed below the track of the Sentinel 3A's 257 track and Jason-3's track 248 several times. Hereafter is the preliminary analysis which is still in progress.

From the analysis performed up to now, both gliders crossed mesoscale eddies. For example, the shallow glider crossed an anticyclonic core around 26 May, while the deep glider passed close to the periphery during the same days. Around this date, a down-lifting of the seasonal thermocline is observed in the vertical profiles of the shallow glider (Figure 3.1-10.c, black square). The down-lifting was more evident in the salinity and density profiles (Figure 3.1-10.c) and had a clear impact in the fluorescence, whose Deep Chlorophyll Maximum reached deeper waters. Some days after, around 2-3 June, the deep glider arrived at the periphery of a cyclone. In this occasion, an up-lifting of the shallower isotherms (from surface to around 100 m depth) and a down-lifting of the intermediate isotherms (from around 100 to 400 m depth) is observed (not shown). The core of this cyclone was close to the position of the anticyclone mentioned before. Therefore, two hypotheses could be obtained from this inverse polarity of these mesoscale structures. First, both signals (in different dates) correspond to the same eddy but due to the interaction of the surface waters with the wind, it is not observed the same polarity of the eddy in the sea surface and in deeper waters (0-100 m). And second, these signals correspond to two different eddies that occupied the same place, in a time difference of a week. In order to test these last hypotheses, more analyses must be done for obtaining more conclusive results. These analyses will be also complemented with high resolution model data from the Atlantic-Iberian Biscay Irish - Ocean Physics Reanalysis, available in the Copernicus Marine environment monitoring service (http://marine.copernicus.eu).

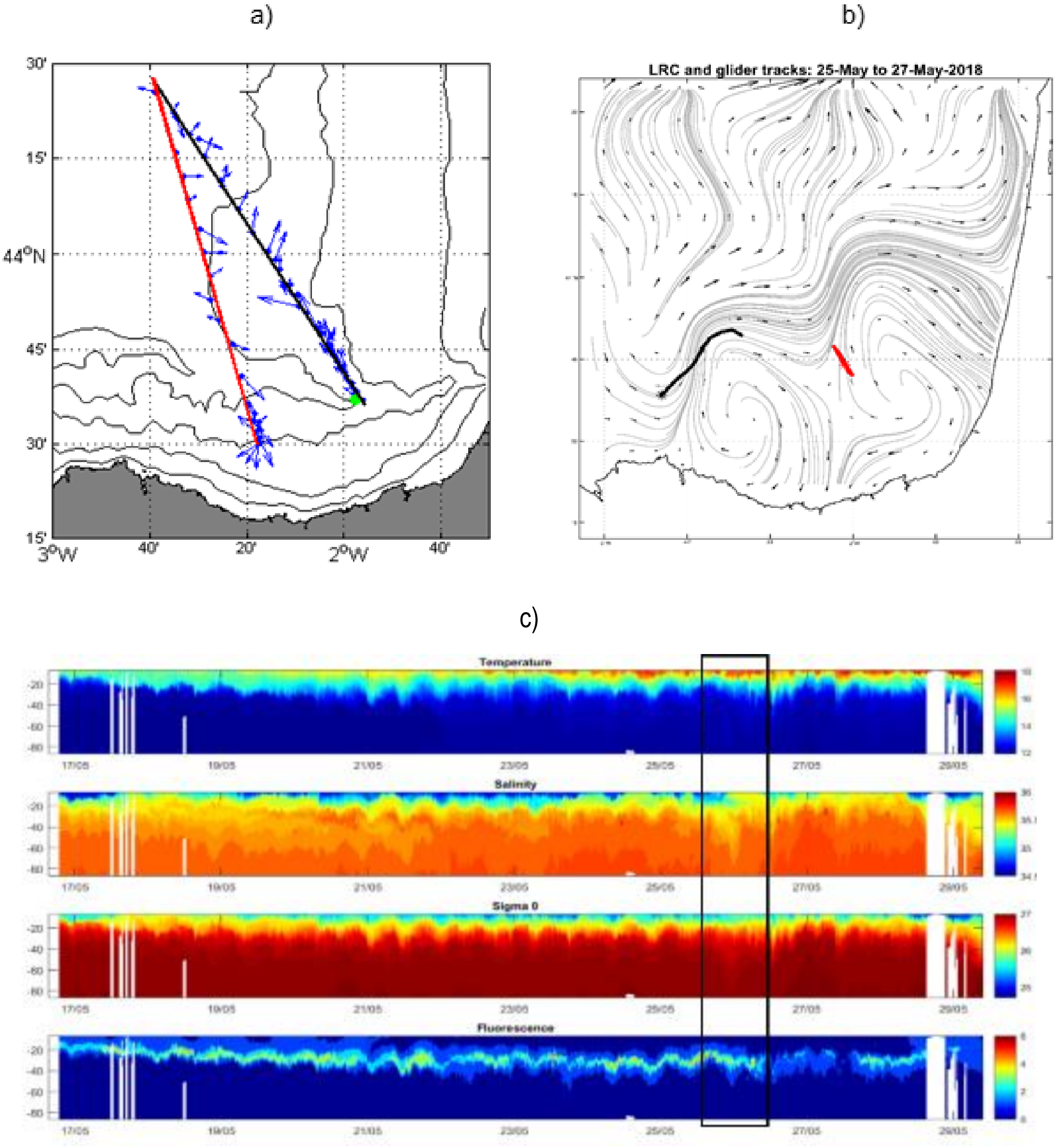


Figure 3.1-10 (a) Tracks of the two altimeters crossing the area during the mission (the black/red line represents the track of Jason 3/Sentinel 3A) and vertically integrated currents corresponding to the deep glider (blue arrows). (b) Lagrangian Residual Current maps estimated from the HFR data and corresponding to 25 to 27 May 2018 show well defined mesoscale structures in the area during the glider survey. The trajectories followed by the deep-glider (red line) and shallow-glider (black line) during this period are also shown (the asterisks indicate the beginning of the trajectory).(c)vertical potential temperature, salinity, density and fluorescence (panels from top to bottom) distribution along the shallow-glider tracks from the surface to 100 m depth. The black square delimits the signal of the eddy.

Improvement of forecasting capabilities thanks to Data assimilation (JRAP#6)

The ROMS domain used in the operational system covers the SE BoB, extending from 43.24º N to 44º N and from 3.4º W to 1.3º W, with a mean horizontal resolution of 670 m. Vertically, the water column is divided into 32 sigma-coordinate levels. The atmospheric forcing inputs used in ROMS are provided by MeteoGalicia (meteorological agency of Galicia). These data (with hourly and 12-km resolutions) are obtained using the Weather Research and Forecasting model (WRF). At present, the conditions applied to the open boundaries are estimated using the hourly outputs obtained by the Iberian-Biscay-Irish Monitoring and Forecasting Center, IBI-MFC, based on the Nucleus for European Modelling (NEMO). These outputs are used only at the boundary points to reduce the size of the input files with information of 3D temperature, salinity and currents. Furthermore, every Friday ROMS is initialized in all the domain with the updated data from NEMO, which include assimilation data of previous days. The objective of this new configuration is to correct the possible deviations of the model due to the non-use of data assimilation. In the very near future, the atmospheric forcing will be improved in spatial resolution from 12 km to 3 km. This will increase the variability of the results and allow to capture local phenomena such as gales. ROMS also includes a Lagrangian particle tracking module. This module is activated in the present configuration for the southeastern of the SE BoB and is running with currents at high-temporal resolution (one minute). Several floats are located at the sea surface to forecast the drift of algae blooms, especially towards the Mendexa region (a pilot aquaculture farm), marine litter or other type of pollution, and for search and rescue applications. **Here we show some examples of the forecast of the model, including currents, temperature and salinity fields and trajectories of some floats from initial fixed points in the domain.**

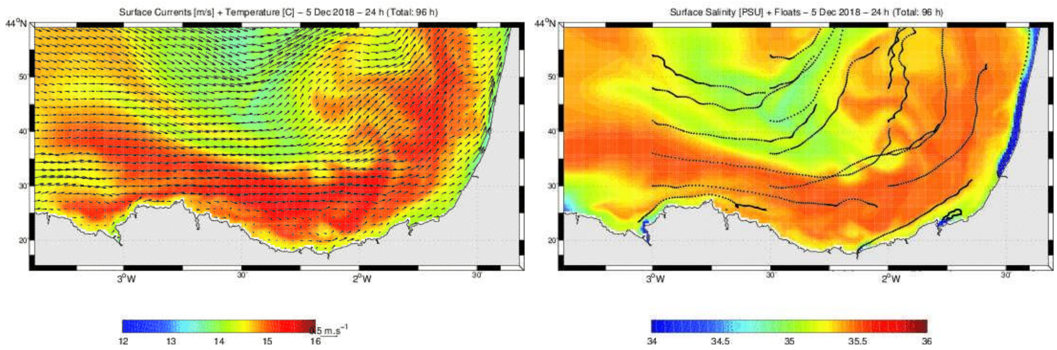
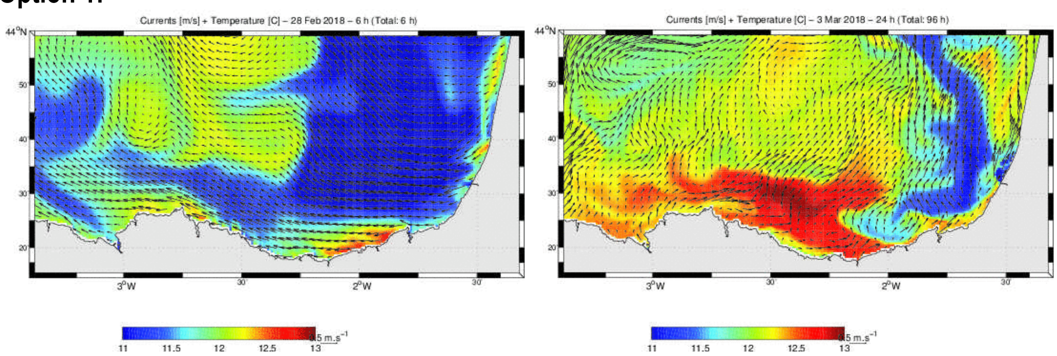


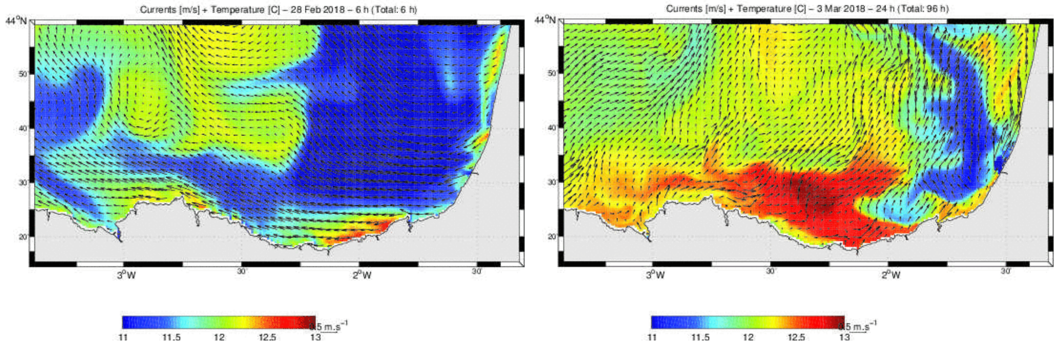
Figure 3.1-11 Examples of ROMS model operational outputs

For the SE BoB, we ran three different configurations, based on three different boundary condition options including: 1) sponge and nudging layers (with the same extension) near the open boundaries; 2) sponge layer without nudging layer; and 3) without sponge and nudging layers. Generally, option 1 and 2 provides the smoothest results, while option 3 can cause the model breaks down. Using these options, after several hours the model results begin to differentiate in a remarkable way. The recommendation is to use option 1 with an appropriate parameterization, but option 2 is also recommended in order to reduce the size of the input files. Here we show some examples of these options for the forecast between the beginning of 28 February 2018 and the end of 3 March 2018:

Option 1:



Option 2:



Option 3

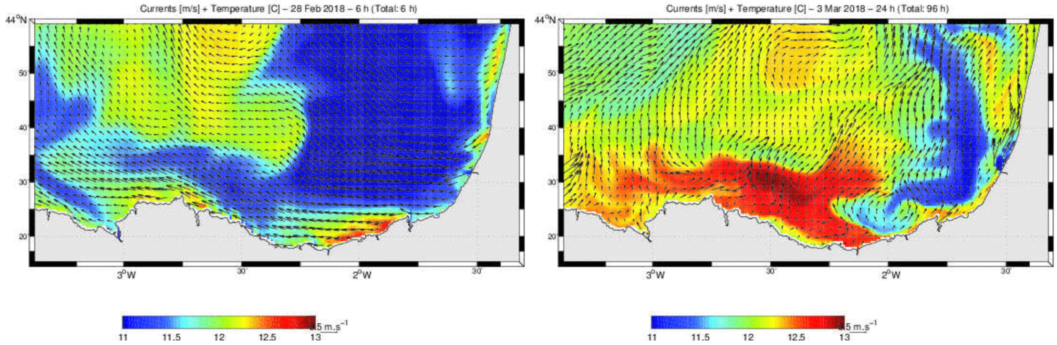


Figure 3.1-12. Examples of ROMS model operational outputs from three different configurations, based on three different boundary condition options

One experiment was carried out in collaboration with the European project LIFE LEMA, LIFE15 ENV/ES/000252 (http://lifelema.eu). Several small wooden boats and four surface drifting buoys were released during the ETOILE survey. The information obtained is being analysed and compared with outputs from numerical models (winds, waves and currents). Although the drift of these objects can be reasonably explained with a simple wind model (based only on the wind module and direction), waves and ocean currents will be used to try to obtain other drift models.

3.1.2.5. Synthesis and way forward

The SE BoB is an area characterized by complex circulation patterns and where relevant human activities linked to marine resources are concentrated, representing a particular challenge for the accurate monitoring and forecast of 4D transport patterns. In JERICO-NEXT, for the SE BoB, we focused on the study of coastal processes at different scales (from mesoscale to high frequency), on their role in the transport, water exchanges, physical-biological interaction and on improving their monitoring using in-situ, land-based and satellite remote-sensing data and advanced data processing methodologies. In addition to the study of eddy and upwelling induced cross-shelf export of high Chl-a coastal waters using historical data, mesoscale features and bio-physical coupling were also tackled by two devoted surveys: the ETOILE survey (leg 2.2) and the BB-TRANS cruises (JERICO-NEXT WP7).

The ETOILE survey focus was however the study of internal waves, and for that purpose, high-frequency measurements were performed thanks to deployment of a Moving Vessel Profiler (MVP) and of 6 MASTODON-2D moorings (low cost thermistor chains developed within JERICO-NEXT WP3). In an additional field action, four passive samplers were deployed in two different sites of the SE Bay of Biscay to characterize the chemical contaminants present in the water, such as organochlorine pesticides.

Finally, capitalizing technical developments undertaken in JERICO-NEXT WP3 and WP4 the application of new methodologies in the SE BoB allowed to progress towards an operational observation of coastal hydrodynamics and associated transports; like: new gap filling methods to enable Lagrangian estimations from HF radar data, new data blending techniques for a better assessment of transport at surface and subsurface layers, and, improved forecasting modelling capacities thank to assimilation of data.

Next steps on short term:

- Complete/publish the analysis of data from ETOILE survey Leg 2.2 - explore the vertical dimension (vertical currents have been also computed and we are analysing this with fluorometer data in the water column).
- Process and analyse data form the two gliders in the BB-trans survey
- Progress in collaboration with CNR, University of Jerusalem (E. Fredj, based only on observational data) and IEO (G. Jordà, using additional model data for covariances) on the application of data blending techniques in the SE BoB. Two methods have been tested for the area with reasonably good results, and offer further possibilities on the intercomparison of the methods' skills (WP3) or their use for planning future deployments in the area (JRAP4) and new products/application (WP3 / WP4) based on blended information (subsurface transports, gap filled data series)
- Analysis of the Passive samplers' data in the SE BoB in collaboration with L. Nizzetto (NIVA)
- The new ROMS configuration for the SE BoB is initialized in all the domain with the updated data from NEMO, which include assimilation data of previous days. The objective of this new configuration is to correct the possible deviations of the model due to the non-use of data assimilation. In the very near future, the atmospheric forcing will be improved in spatial resolution from 12 km to 3 km. This will increase the variability of the results and allow to capture local phenomena such as gales.

Next steps on mid and long term:

Among the lessons learned from the implementation of individual JRAP actions on of the most important is that **to conduct integrated studies we need data gathered in the same area with similar coverage and temporal scales, and models that solve the same processes**. So, the main work line to progress in the futures will be to gather additional and truly Integrated observations in the area by means of:

(i) the integration of additional sensors to the existing moorings and facilities to build a truly integrated multiplatform and multidisciplinary observing system.
(ii) the addition to the operational observations of data from satellite, additional regular sampling activities in the area and of one or more devoted oceanographic surveys for multidisciplinary process studies, cal/val
(iii) the capitalization of existent coastal facilities for experimentation in relation to the blue economy
(iv) Coupled biogeochemical modelling – DA for Physics, biogeochemical data for validation/assessment
(v) the capitalization of established transnational collaboration in operational oceanography related and scientific projects
(vi) the analysis and update of key drivers (key scientific questions, needs) and the development of tailored tools/products. For this it is very important to be in contact and even work in close collaboration to the stakeholders.

We need to solve the proper temporal and spatial scales (covering both coastal and open sea waters) and gather at the same time multidisciplinary info (like fluorometry, plastic sampling) which is not easy, and couple all this with info from physical-biogeochemical models.

3.1.3. *The Portuguese margin and the Nazaré Canyon*

3.1.3.1. Specificities of the this region

a- Most relevant scientific questions from regional to local scales

The complex circulation of the southern Portuguese margin and Gulf of Cadiz area that is revealed by the numerical modelling studies requires a more extensive support from observations. The processes described above link directly main features of the mid-North Atlantic circulation with coastal ocean processes and are crucial to understand the interactions between the North Atlantic basin, the Mediterranean Sea and the European and Northwest Africa coastal ocean areas.-

Further observational evidences and a better understanding of the processes are in particular required to:

- detail the topographic β-plume circulation offshore in the western Gulf of Cadiz area and understand how it interacts with major topographic features such as the Gorringe seamount (located 200km southwest Cape St Vicente)
- understand how the β-plume circulation interacts with the wind-driven circulation of the North Atlantic basin (a missing aspect in the cited studies)
- understand how the coastal ocean processes (e.g. the upwelling in the west Portuguese margin) connect with the Gulf of Cadiz circulation and impact the Western Mediterranean and the mid-Atlantic basin (e.g. through the westward “return” current of the β-plume circulation.
- Understand the impacts of this complex dynamics on the marine life and marine ecosystems in particular how it promotes species connectivity in this large geographical area and how it impacts migratory routes of pelagic fishes.

A real-time monitoring and operational forecast system (MONIZEE system) covering the complete coastal ocean area off Portugal (figure 1) was installed by Instituto Hidrografico in the course of the last few decades. The system is presently collecting a comprehensive data set that allows not only to support regional users (e.g. national and local authorities, port authorities, fishing and surfing communities) but also national commitments and international programs. The MONIZEE system as a whole already contributed to JERICO. In JERICO-NEXT we extended this contribution by focusing a subset of the global system – the Nazaré Canyon Observatory – which monitors the area of influence of the Nazaré Submarine Canyon, one of the largest submarine canyons of the European margin. This enabled us to address a particularly challenging area for numerical models, where the importance of the different components of the observing system to improve model simulations and forecast can be well stated, and at the same time to discuss some important aspects of the rich dynamics of the Portuguese coastal ocean area described above, giving particular emphasis to processes that have a transboundary impact.

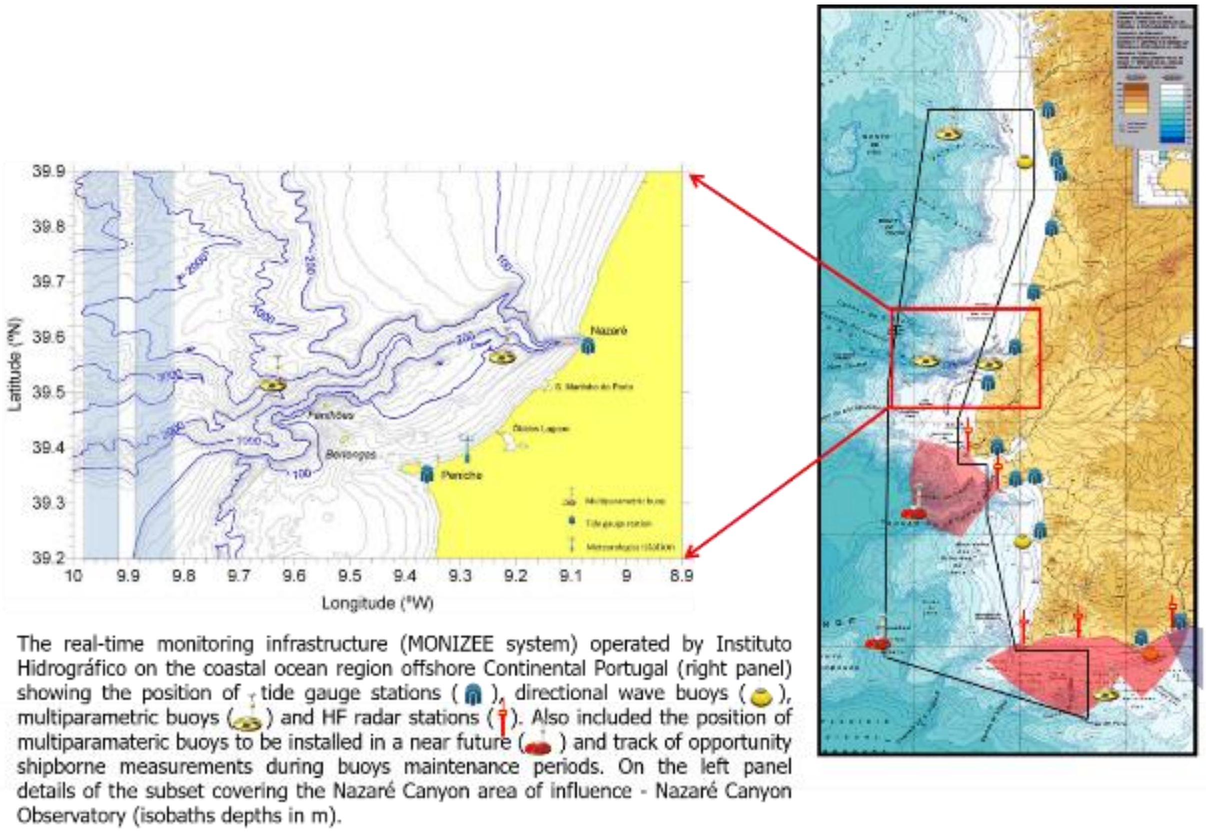


Figure 3.1-13 The real-time monitoring infrastructure (MONIZEE system) operated by Instituto Hidrografico in the Portuguese continental margin (right panel) and details of the Nazaré Canyon Observatory (left panel).

In JERICO-NEXT we focused in the area of influence of Nazaré Canyon (W Portugal) which is one key area in the shaping of several of the processes above mentioned. This is the largest submarine canyon of the European margin, extending for more than 200 km and cutting completely the continental shelf and slope. At local scales the Nazaré Canyon is responsible for a broad range of impacts on the coastal ocean which have direct effects on the coastal populations and the local economy. These include:

- Intensification and persistence of coastal ocean response to local wind forcing conditions (e.g. upwelling at canyon head)
- Energetic mixing promoted by bottom intensified internal tides in the middle part of the upper section of the canyon and affecting the Central Water and upper Mediterranean Water depths; this process can be responsible for a contribution to the shelf environment of saline waters with MW influence.
- "Capture" of the nearshore sedimentary transit associated with the littoral drift, with a key role for the sedimentary balance in the local coastal environment.
- Occurrence of high turbidity (flushing) events triggered by storms and leading to rapid exportation of sediments from the canyon head to the deep abyssal plain offshore
- Amplification of surface gravity waves in specific locations due to wave refraction by the canyon topography (in association with other processes) leading to the giant waves of Nazaré which since 2011 are promoting an international interest in the Nazaré area with strong impacts on the tourism sector.

The regional impacts of the Nazaré Canyon are presently largely unknown. However the canyon occurs along the northern flank of Estremadura Plateau a particularly sensible area for triggering of the (winter) Iberian Poleward Slope Current (IPC) and where substantial adjustment occurs in the Mediterranean Water flow. These are two of the main along slope flows that promote trans-boundary interactions along the Atlantic margin of Europe. Existing observations and ongoing numerical simulations indicate that the following processes could potentially affect the regional scale:

- Interaction between canyon circulation and the Iberian Poleward Slope Current near the canyon mouth potentially leading to changes in the expression of IPC along the Iberian margin north of Nazaré.
- Role of the canyon in the process of adjustment of the Mediterranean Water flow passing the Estremadura Plateau.
- Energetic mixing between the main core of Mediterranean Water and North Atlantic Deep Waters (NADW) below which occurs near the canyon mouth (1700m-2000m depth) and is promoted by bottom intensified internal tides; the plume of deep saline water that exits the canyon mouth can potentially be transported along the continental slope to other areas.
- Effects on the deep ocean of the high turbidity nepheloid layers exiting the canyon upper section during flushing events.

The most relevant scientific questions in this area are listed in the following:

- Improve the understanding of the physical oceanography of the Nazaré Canyon area of influence. Several observation sets already exist but the complexity of the area, the broad range of processes and the limitations of the observations (in space or in time) do not allow to build a comprehensive image from the observations alone. The work that is being developed in the framework of JERICO-NEXT aims to use a high resolution model with data assimilation to fully extract from the observations set this comprehensive image. This will be used to:
- Characterize the shelf/slope circulation in the area of influence of the Nazaré Canyon
- Evaluate the best strategies (in what regards the existent monitoring system as well as the available models) to characterize and forecast the physical conditions that affect such a complex area marked by abrupt topography and energetic processes.
- Show the adequacy of the high resolution model with data assimilation to reproduce and forecast the dominant subinertial processes in the area.
- How do long submarine canyons (such as Nazaré Canyon) affect the regional scale namely how canyon circulation interact with slope currents such as IPSC and MW and how mixing inside canyons followed by slope transport can modify getting insight on the processes of interaction between the canyon circulation and the slope processes (IPC, MW and NADW levels).

b- Most relevant societal needs and policy needs

In the case of the Portuguese margin (focusing Nazaré Canyon area) important regional problematics to which the OOS can provide support are:

- Need to monitor the coastal ocean environment as part of MSFD. The global monitoring system operated by Instituto Hidrográfico (in which the Nazaré Canyon observatory is inserted) is presently contributing to the Portuguese implementation of MSFD. Potential users: General Direction for the Sea Policy (DGPM) and the General Direction of Marine Resources (DGRM)
- Support to key areas in the fisheries sector strongly dependent on shelf/slope conditions (e.g tuna fish farms off the Southern Portuguese coast, offshore aquaculture areas). Potential users: at local level regional associations and operators and local Town Hall services for support to fishing activities, at national level the General Direction of Marine Resources (DGRM).
- Support to new economical areas linked to tourism (e.g. tourism associated with big wave surfing in Nazaré). Potential users: Local authorities such as Town Halls or local maritime authorities, event organizers.
- Support to the management of marine protected areas such as the Berlengas Islands Reserve (in the Nazaré Canyon area of influence) or the Gorringe Seamount (offshore the SW tip of Portugal). Potential users: Portuguese Institute for the Conservation of Nature and Forests (ICNF).
- Real-time environmental monitoring is required to support the nautical community in this area of heavy ship traffic resulting from the confluence of routes from North Europe, Mediterranean and Africa. The monitoring

system also has a key impact in supporting mitigation operations in case of accidents such as oil-spills. Potential users: ship operators, port authorities, the national authority for civil protection (ANPC), the Portuguese Navy.

- Operational capacity and scientific knowledge to support national, regional and local authorities during crisis at seas such as extreme weather events, oil-spill accidents or search and rescue operations. Potential users: at national level Civil Protection Authority, Portuguese Navy including the General Direction for the Maritime Authorities, at local levels: Town Halls.

3.1.3.2. Acquired data and archiving made

Data type	Sampling location/area	Sampling period	Institute responsible for data
Currents from 7m to about 80m depth	**Nazaré Canyon hourly data** Leixoes (NW Portugal area), hourly data Faro (Gulf of Cadiz area)hourly d, ata	**M1 since 2009** **M2 since 2010** Since 2010 Since 2015	IH
Water temperature at chosen depths from 3m to 200m	**Nazaré Canyon hourly data** Leixoes (NW Portugal), hourly data Faro (Gulf of Cadiz), hourly data	**M1 since 2009** **M2 since 2010** Since 2010 Since 2015	IH
Wave parameters M1 & M2 buoys	**Nazaré Canyon hourly data** Leixoes (NW Portugal) , hourly data Faro (Gulf of Cadiz), hourly data	**M1 since 2009** **M2 since 2010** Since 2010 Since 2015	IH
Meteorological Parameters (atmospheric pressure, air temperature, relative humidity, wind speed and direction at 3m height)	**Nazaré Canyon hourly data** Leixoes (NW Portugal), hourly data Faro (Gulf of Cadiz), hourly data	**M1 since 2009** **M2 since 2010** Since 2010 Since 2015	IH
Sea surface height	Nazaré Peniche Other áreas: 15 tide gauges along continental coast	Since 2010 Since 1960	IH

HF radar surface currents	**Nazaré Canyon Hourly data** Lisbon bay, houry data Southern margin (Gulf of Cadiz), hourly data	**05-20 October 2011** Since 2012 Since 2015	IH

Note: In bold the data sets used in Instituto Hidrográfico contribution to JERICO-NEXT JRAP#6

3.1.3.3. Collaboration with other international initiatives

GLOSS (Global Sea Level Observing System) - Data collected in selected tide gauges stations of the MONIZEE network (such as the one installed in Nazaré) are feeding this program of the United Nations.

ENAMTWS (Northeast Atlantic and Mediterranean Tsunami Warning System) - Data collected in selected tide gauges stations of the MONIZEE network (such as the one installed in Nazaré) are feeding this program of the United Nations established after the Asian heartquake and tsunami of 2014.

Global Telecommunication System (GTS) - Real-time observations collected by the MONIZEE system are automatically sent to GTS (via the focal point IPMA, Portugal).

IBIROOS - Real-time observations collected by the MONIZEE system are automatically sent to the regional node of EuroGOOS (via the focal point Puertos del Estado, Spain)

EMODET - Real-time observations collected by the MONIZEE system are automatically sent to EMODNET.

MyCoast project - A Coordinated Atlantic Coastal Operational Oceanographic Observatory. Interreg Atlantic Area, 2017-2020. There are many synergies with this project which will help to broaden the applications of standards and JERICO-RI data and products in the Atlantic Area

OCASO project - Coastal Environmental Observatory of the Southwest: INTERREG POCTEP 2015-2019. Development of synergies between partners in Spain and Portugal aiming the establishment of an operational oceanography transboundary structure for the southwestern Iberian area.

MarRisk project INTERREG POCTEP 2015-2019. Development of synergies between partners in Spain and Portugal aiming the consolidation of a knowledge infrastructure for the assessment of coastal risks affecting the area of North Portugal and Galicia (Spain) in a framework of climate change.

3.1.3.4. Scientific progress so far

A high resolution model with data assimilation based on the Harvard Ocean Prediction System (HOPS) was implemented for the Nazaré Canyon area of influence in the framework of JRAP#6. The model (LAM-HOPS) has a 300m horizontal resolution and 30 double-sigma vertical levels and was run with wind stress and air-sea heat flux forcing. A Shapiro filter scheme was used to incorporate sub-grid physics. A regional NEMO model (IBI_REANALYSIS_PHYS_005_002, with 9km horizontal resolution and 75 constant depth levels) was used to provide initialization and boundary conditions for the HOPS model. For the period covered by our cases studies daily mean fields are provided in a regular grid at 50 depth levels by the Copernicus Marine Environment Monitoring Service. A sequential Optimal Interpolation (OI) scheme was used in LAM-HOPS to assimilate profiles of T and S collected by CTDs or by currentmeters.

The high resolution HOPS model is being used both to improve our understanding of the subinertial processes that affect the complex area of influence of Nazaré Canyon as well as to assess how several components of the Nazaré Canyon Observatory MONICAN are contributing to improve the models ability to simulate and forecast this area.

Three scenarios (case studies) are presently being explored:

a. Evaluation of the add-value of currentmeter moorings (fixed platforms) using a comprehensive data set collected in June-July 2007 which included repeated CTD/VMADCP coverages of the global area and data from 3 currentmeter moorings at positions along the canyon axis and was complemented with MUR SST data.

b. Evaluation of the add-value of multiparametric buoys fixed platforms) using observations collected in March-April 2011 which included CTD/VMADCP/LowerADCP coverage of the canyon area of influence, 3 currentmeter moorings along the canyon axis and 2 multiparametric buoys at mid-shelf and upper slope near the canyon providing temperature at several depths and upper-100m currents.

Evaluation of the add-value of HF radar using data collected in a short period of test of the system which was held from 05 to 20 October 2011. The data set used in this scenario includes HF radar area and data from 2 multiparametric buoys (temperature and currents in upper 100m) and is complemented with MUR SST data.

We present here a first set of results from the first case study which is particularly suited to illustrate the complex interactions between the shelf and slope dynamics in this area of the Portuguese margin. This case study focusses the period from June to July 2007 that corresponded to the transition from downwelling conditions to upwelling conditions in this area. Two distinct phases of this transition period were covered by data collected onboard a research vessel (CTD and Vessel Mounted ADCP profiles) and data collected in 3 currentmeter moorings. The high-resolution model with data assimilation is used here, in each of these periods, to build a synoptic image of the oceanographic conditions from the essentially non-synoptic observations.

Figure 3.1-14 illustrates some of these aspects using the surface (10m depth) fields for 21 June 2007, corresponding to the decay phase of downwelling conditions and transition to upwelling (left panels) and for 06 July 2007 corresponding to the phase of upwelling conditions. On the top of this figure we present the Multiscale Ultrahigh Resolution (MUR) L4 analysis of sea surface temperature for these two days, which give us the regional SST distribution. Below we present the temperature and current fields obtained from the regional NEMO model and with the high-resolution HOPS model. The HOPS results were obtained with assimilation of the available CTD profiles.

The comparison between the two models puts in evidence the importance of using a high-resolution model to simulate (and forecast) the dominant physical processes in such a coastal ocean area characterized by important topographic effects. The smoothed version of the topography used in NEMO does not allow to reproduce important aspects of the shelf/slope circulation in the area. One of such aspects is the development of a large anticyclonic cell over the canyon at mid shelf which occurs during the transition from downwelling to upwelling conditions. The large and intense vortice that was obtained with HOPS assimilation runs for the 21 June 2007 is very similar to the anticyclonic cell in surface currents observed in October 2011 with an HF radar system under similar wind forcing conditions (Figure 3.1-14, bottom left panel).

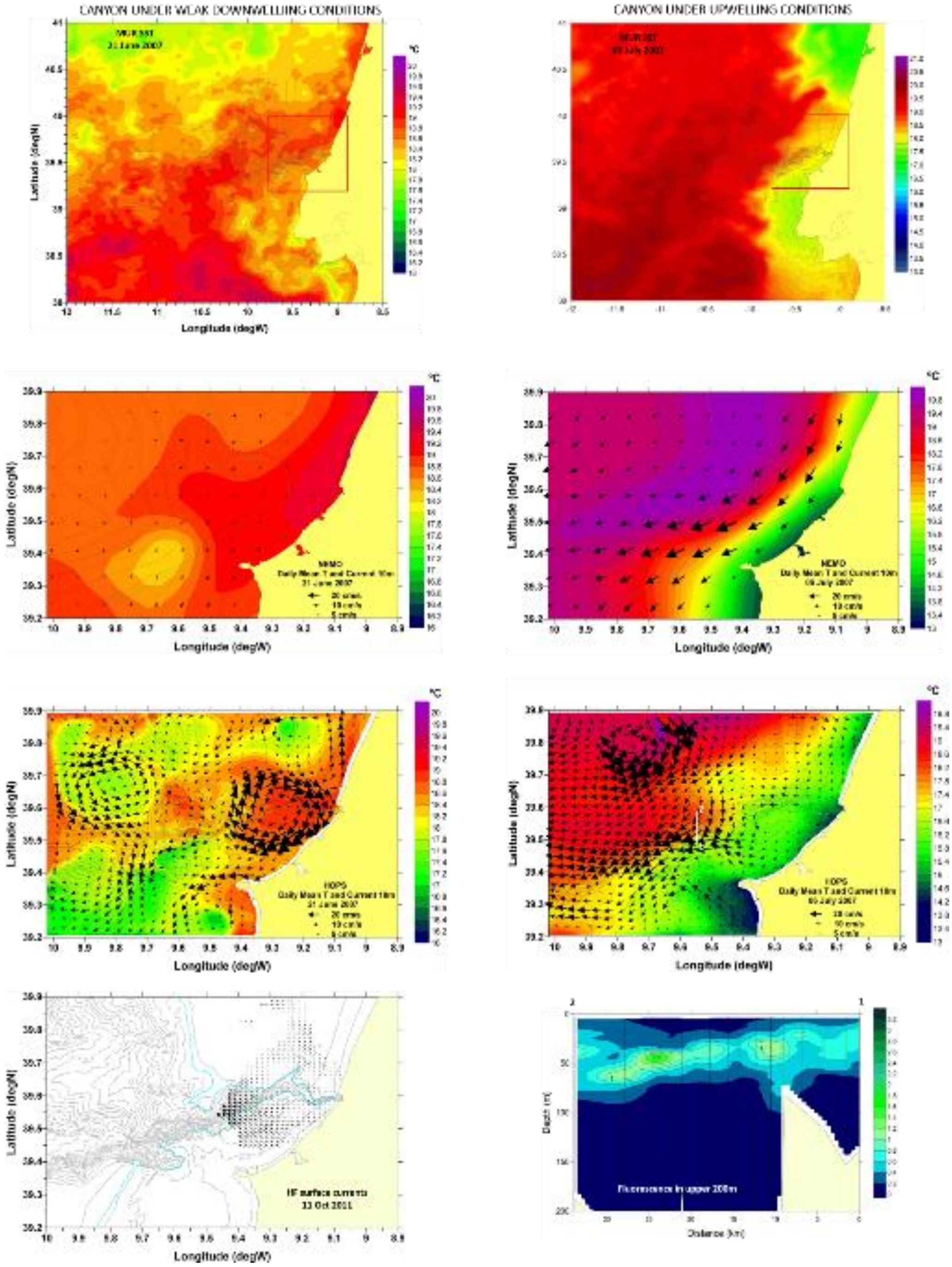


Figure 3.1-14 Surface temperature and subinertial currents in the area of influence of Nazaré Canyon during weak downwelling conditions (left panels) and upwelling conditions (right panels). The 3 upper set of figures refer to the numerical simulations conducted forthe period of June-July2007. The bottom left figure corresponds to the surface currents measured on the 11 October 2011 by a HF radar system during similar weak downwelling conditions. The bottom right panel shows the fluorometry measurements conducted along a section crossing the Nazaré Canyon mouth on the 05 July2007. Details are provided in the text.

A second aspect is observed during upwelling conditions (Figure 3.1-14, right panels) when northerly winds promote upwelling of cold (nutrient rich) subsurface waters along the coast and the development of a southward coastal jet. The high resolution HOPS runs show that canyon topography and the blocking associated with the shallow (30m depth) ridge between Cape Carvoeiro and the Berlengas and Farilhoes Islands both act to deflect the upwelling jet offshore, directing him towards the continental slope region in the northern flank of Estremadura Plateau (the large plateau of depth shallower than 200m that is located south of the domain). A potential biological impact of this process is suggested by the section of fluorometry covered on the 05 July 2007 across the canyon mount area (Figure 3.1-14, bottom right panel) and that depicts the deepening of high fluorometry values along the southern flank of Nazaré Canyon, presumably due to subsidence promoted by the imping jet.

Finally a common aspect evident in both related to the way the slope circulation interacts with the shelf domain in the Nazaré Canyon area of influence. The MUR SST regional fields show that in both cases warm oceanic water circulates around the Estremadura Plateau and extends inshore over the shelf north of Nazaré Canyon. This interaction is retrieved in the high resolution HOPS simulations, in which the northern boundary is located in the area where this inshore penetration occurs. For the periods of downwelling conditions both MUR SST and HOPS show that this warm oceanic water is feeding the poleward (downweling) current that develops along the coastal boundary. During the upwelling conditions both MUR SST and HOPS show that this inshore penetration warm oceanic water cuts the southward continuity of the coastal band of cold upwelled areas that extends along the coast northwards of Nazaré.

This intense interaction between the slope circulation and the shelf environment in the area of Nazaré Canyon does not only have an impact on the local coastal ocean conditions (and consequent impact on the local ecosystems) but can also impact the development of Iberian Poleward Current and change how this current influences regions further north such as the northwestern Portuguese and Spanish slopes and the northern Spanish slope on the Bay of Biscay. So by this transboundary process the interaction that takes place in Nazaré Canyon area (and the signature of the upwelled waters there) can have a potential impact in the conditions found on those remote regions of the eastern Biscay Bay.

Other processes acting on Nazaré Canyon can also promote a connection between the shelf and inner shelf environments offshore Nazaré and the deep ocean regions offshore. Two of the most expressive of these processes are illustrated in Figure 3.1-15. On the left of the figure we present a turbidity section along the Nazaré Canyon axis during the development of a high turbidity (flushing) event. Several of these events occur in Nazaré Canyon each year (mostly during winter) in association with periods of large waves associated with storms in the North Atlantic. These processes lead to an injection of bottom sediments from the inner shelf onto the canyon head and the subsequent rapid transport of sediments along the canyon axis to the abyssal area offshore from where they can subsequently disperse in the deep ocean area.

A second processes is illustrated in the right panel of Figure 3.1-15 which shows the salinity and currents fields at 2000m depth from an HOPS simulation with assimilation of CTD profiles collected in the area in April 2011. Internal tides promoted by the interaction of the barotropic tide with the Nazaré Canyon topography are focused at the bottom of the canyon. This process is particularly important in areas where the canyon as the steeper topography such as occurs near the canyon mouth. Here these bottom intensified tidal motions promote important mixing between the Mediterranean Water and the North Atlantic Deep Water below. A plume of high salinity waters at 2000m depth is seen in Figure 3.1-15 to emerge from the canyon mount and to continue along the slope, advected by the circulation at this depth. These changes can then influence other areas far from the canyon geographic location.

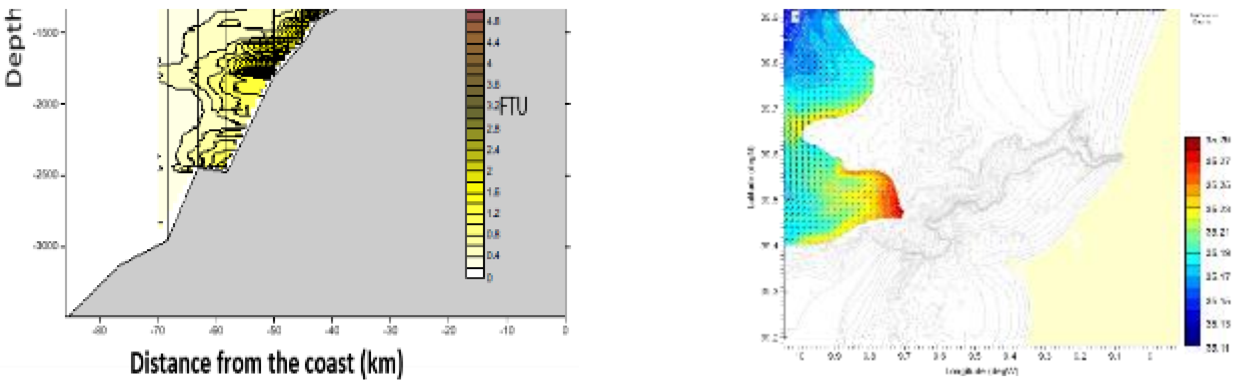


Figure 3.1-15 Two aspects of the interactions between the coastal ocean environment and the deep ocean promoted by Nazaré Canyon. On the left observation along-axis turbidity measurements revealing a high turbidity (flushing) event. On the right the salinity and current field at 2000m depth from a HOPS simulation with assimilation of CTD data for the period 15-22 April 2011. Details are provided on the text.

3.1.3.5. Synthesis and way forward

Synthesis and specific next steps

Knowledge Gaps

Several key questions remain to be clarified concerning the physical processes that affect the Portuguese coastal ocean area and the associated impacts (on the marine ecosystems, sediment transport and bottom sedimentary cover, contaminants dispersion, others). Among these some of the questions/gaps that require a transnational effort are:

- Shaping of IPC by connections with basin circulation and by interactions with the shelf circulation
- Role of boundary currents (IPC but also MW) in promoting biological connectivity along the global coastal ocean area that extends from NW Africa to the Northern Europe and linking the W Mediterranean and the mid-Atlantic basin
- Shaping of basin circulation features (Azores Current, but also by interactions in the coastal ocen area of Gulf of Cadiz
- Deep (and fast) connections of the North Atlantic regimes promoted by submarine canyons.

Technological Gaps

Several gaps can be identified in our present capacity for the monitoring of this coastal ocean area.

- To extended real-time monitoring to the complete water column: Presently the real time monitoring is based on multiparametric buoys and mainly focused on the upper water column depths (up to 200m depth) although standalone sensors are being installed at deeper levels. Several of the processes that affect this coastal ocean area, and particularly the main transboundary processes such as the IPC and MW, link surface layers with intermediate and even deep circulation.
- To complete HF radar coverage. Presently only about one third of the Portuguese coastal ocean area (continental margin) is covered by HF radar measurements.
- Optimization of surveys.

Numerical Modelling Gaps

- Assimilation models for the Portuguese margin area: several regional models are presently being used for the operational forecasting of the oceanographic conditions affecting the Portuguese area. None of these models however is an assimilation model capable of profiting from the

- Need for integration of biogeochemical modules in assimilation models.

Next steps (short-term)

In what concerns the specific objectives of IH contribution to JRAP#6 the short-term developments include:

- The completion of the 3 case studies mentioned previously. For case study 3 this will require to complete the implementation of a processing methodology for HF radar data and the implementation of the assimilation strategy for HF radar data.
- The completion of a two part paper exploring the data set and model simulations with data assimilation for the period June-July 2007 (expected to be complete by the beginning 2019).
- The conduction of an additional (forth) case-study aimed to assess the add-value of citizens data is being planned for the first months of 2019. This will involve a period of observations in Nazaré Canyon area.

In what regards the developments of the Portuguese coastal ocean capacities based on the observing system maintained by IH, the following short-term developments are envisaged:

- Increase the capacities in biogeochemistry and biological sampling using the multiparametric buoys network. This will include:
  - (a) Acoustical monitoring and marine mammal monitoring - IH is presently coordinating project SUBECO that aims to integrate hydrophones in the multiparametric buoys maintained by this institute. The near future development aims to extend this capacity to the complete network of multiparametric buoys providing marine mammal and ambient noise monitoring along the complete Portuguese coastal ocean area.
  - (b) Improve fluorometry and dissolved oxygen measurements - These parameters are already being collected by IH multiparametric buoys but sensors are installed at 3m below the surface and by this reason are rapidly affected by biofouling problems. Ongoing work aims to redefine measurements strategy and sensors type in order to extend the valid period for these measurements.
  - (c) Microplastics sampling – IH will start soon a monitoring program using the multiparametric buoys network. At the beginning this program will be developed in the framework of ongoing project AQUIMAR, using the analysis equipment that is presently being acquired as part of this project.
  - (d) Extend collaborative actions with groups involved in other aspects of biological sampling profiting from IH monitoring infrastructure (see "Future/Potential collaborations…" below).
- Extend HF radar coverage. Ongoing discussions with Spanish colleagues will potentially lead to the installation of one additional HF radar station that will allow the coverage of the northern Portuguese margin (linking with a station existent in the Spanish Galicia coast)
- Further development of modelling and operational forecasting capacities. Presently IH maintains an operational forecasting capacity for the Portuguese margin based on wave models (with several models going from basin scale models to regional and local area models) and circulation models (based in a non-assimilation HYCOM model operated in close connection with the Hydrographic and Oceanographic Service of the French Navy-SHOM). Short-term developments comprise:
  - (a) The implementation of HOPS both for the global Portuguese coastal ocean area as well as in high resolution domains for specific sub-areas of interest, which is view as a first step towards the implementation of an operational model with data assimilation for this global area. This works will be an extension of the work developed in JERICO-NEXT profiting from the know-how acquired in the assimilation strategies for fixed-platforms data and HF radar data or for the coupling with the regional NEMO model.
  - (b) The start of implementations and test of the biogeochemical module already implemented in HOPS model.
- Articulation of monitoring and forecasting capacities for the continental shelf area with remote sensing capacities. These developments will follow two main lines:

(a) The interaction between IH teams and remote sensing teams aiming to jointly explore the potential of the monitoring infrastructure to validate/calibrate remote sensing measurements and the impact of remote sensing products in the modelling/forecasting capacities.

(b) The articulation between IH monitoring and forecasting capacities for the Portuguese continental shelf and slope and capacities that are being developed at IH (in collaboration with other partners) for the bathymetric mapping of the inner shelf-littoral zone using satellite measurements. These developments are being conducted as part of IH contribution for Horizon 2020 project "*Coastal Waters Research Synergy Framework – Co-ReSyf".*

3.1.4. *Gironde Mud Patch and Bay of Brest*

Involved institutes: CNRS-UB, CNRS-UBO, IFREMER
Lead author: A. Grémare, Contributing authors: A. Carlier, J. Grall

3.1.4.1. Specificities of the this region

The West Gironde Mud Patch and the Bay of Brest are both located on the French Atlantic Coast. These are two coastal ecosystems, which are under tight continental influence and therefore under strong anthropogenic pressure.

Although located offshore because of the strong hydrodynamics of the Atlantic Ocean, the **West Gironde Mud Patch** is the main depository of particle input from the Gironde river-estuarine system. As such, it is potentially submitted to disturbances directly (e.g. sediment instability) or indirectly (e.g. chemical contamination) associated with sedimentation fluxes. Its bottom are harvested for both fishes (e.g. common soles) and invertebrates (e.g. Norway lobsters). Overall, the structuration and dynamics of sediments in the West Gironde Mud Patch also appear to be controlled by local hydrodynamics (e.g., major storms) and biological processes (e.g. bioturbation). The West Gironde Mud Patch is thus submitted to an interplay between natural and anthropogenic disturbances, which makes its monitoring within the Marine strategy Framework Directive especially challenging.

The Bay of Brest is a shallow semi-enclosed area connected to the Iroise Sea and submitted to a strong hydrodynamics (macrotidal regime). It exhibits a large panel of benthic habitats, some of which harboring a strong biodiversity (e.g. maerl beds). The Bay of Brest is a semi enclosed area, subject to a wide combination of disturbances, including heavy demersal fishing pressure, excessive nutrient inputs from watersheds and proliferation of invasive species. These perturbations are in strong interactions and do affect biodiversity and ecosystem functioning. The main examples of such impacts are: (1) the link between farming activities and biogeochemical cycles (i.e., N and Si), and (2) the effects of the proliferation of an exotic benthic suspension feeder (i.e., *Crepidula fornicata*) and benthic bivalve fisheries on the biodiversity and the ecological quality status of benthic habitats (e.g. maerl beds). Moreover, disturbances interact between each other in generating complex effects on ecosystem. Today, harmful algal blooms become recurrent in the Bay, preventing the fishery of the great scallop and forcing fishing activities to switch preys, which contributes to increase negative effects on maerl beds and associated benthic biodiversity.

a- Most relevant scientific questions from regional to local scales

The overall objective of JERICO-NEXT JRAP2 was to assess the links between: (1) disturbance nature and intensity and macrobenthic diversity, and (2) macrobenthoic diversity and cosystem functioning. An associated objective related to the first of this two points was to contribute to the calibration of the biotic indices currently used to infer ecological Quality Status from the analysis of the composition of benthic macrofauna.

JRAP 2 is composed of 4 research actions, which are associated with different combinations of geographical locations and disturbance sources. The first one is taking place in the West Gironde Mud Patch (see above) and is aiming at assessing the combined effects of continental inputs and ocean hydrodynamics on macrobenthic diversity and particulate organic matter mineralization. The second research action is taking place in the Bay of Brest and is aiming at assessing the effect of clam dredging on the structuration of maerl baeds and the macrobenthic diversity they host. The third action is also located in the Bay of Brest. It is aiming at assessing the effect of the invasive species Crepidula fornicata on macrobenthic diversity. The fourth research action is taking place in the Cretan Sea and is aiming at assessing the effects of a sewage output on macro- and microbenthic diversity. Interactions between the four resarch actions are insured by (1) the common necessity of assessing disturbance intensity at the right spatial and temporal scales, (2) homogeneity in the assessments of diversity and common use of some instruments/methodologies/tools developed within JERICO-NEXT and the former JERICO (e.g. ‚Pagure 2‘, Sediment Profile Imaging and Image analysis techniques, in situ sediment O_2 microprofiler), and (3) the use of a common field and data processing approaches to assess the main two objectives of JRAP 2 (see above).

Due to the geographical structuration of the present report, the following section will only deal with the first three research actions of JRAP 2 (i.e., those taking place in the West Gironde Mud Patch and in the Bay of Brest).

b- Most relevant societal needs and policy needs

The West Gironde Mud Patch and the Bay of Brest are both concerned by the application of the Marine Strategy Framework Strategy, which is aiming at preserving/improving the Ecological Quality Status of regional seas they are part of. The marine strategy framework directive is based on an ecosystem approach. It integrates both structural and functional descriptors including biodiversity (D1). Monitoring is a key step in the whole process of the Marine Strategy framework Directive. Its sound implementation is far from casual especially in: (1) offshore systems such as the West Gironde Mud Patch, where basic information required to define an optimal sampling strategy is still largely lacking, and (2) areas submitted to multiple (natural and anthropogenic) disturbances such as the West Gironde Mud Patch and the Bay of Brest. In both areas, an important societal need comes from the fishermen community who is worrying about the ecological state of targeted commercial species (common sole, Norway lobster, great scallop, variegated scallop, warty venus, European flat oyster). The bay of Brest is also concerned by the application of the Habitat Directive as it hosts a 'Natura 2000 at sea' area. Managers of this special area of conservation need to know the proliferation stage of invasive species, such as *Crepidula fornicate.*

3.1.4.2. Acquired data and archiving made

Overall 12 field cruises taking place within the framework of the three above mentioned research actions have been achieved between April 2015 and June 2018 (see **Table I**). Most analyses are still in progress and an additional, non initially planned) seasonal cruise will take place in the West Gironde mud Patch during January-February 2019. Further details will be provided action per action (see below).

***Table I**: Summary of the progress status of the different items constitutive of the three research actions taking place in the West Gironde Mud Patch and the Bay of Brest.*

Research Actions	**Field sampling**	**Analysis: Assessment of disturbance**	**Analysis: Macrofauna diversity and imaging profiles**	**Analysis: Functional parameters**	**Data analysis: Linking disturbance, diversity and functioning**
West Gironde Mud Patch: July 2010	3 sampled stations	Relying on AMORAD	Done	Done	Yet to be done
West Gironde Mud Patch: October-November 2016	8 sampled stations	Relying on AMORAD	Done	In progress	Yet to be done
West Gironde Mud Patch: August 2017	7 sampled stations	Relying on AMORAD	In progress	In progress	Yet to be done

West Gironde Mud Patch: January-February 2018	4 sampled stations	Relying on AMORAD	In progress	In progress	Yet to be done
West Gironde Mud Patch: April-May 2018	5 sampled statio	Relying on AMORAD	In progress	In progress	Yet to be done
West Gironde Mud Patch: Mapping May-June 2019	Not initially planned, In progress	Not appropriate	Yet to be done	Not appropriat e	Not appropriate
West Gironde Mud Patch January-February 2019	Not initially planned, shiptime required	Yet to be done	Yet to be done	Yet to be dor	Yet to be done
Bay of Brest: Dredging October 2015	10 sampled stations	Done	Done	Not appropriate	Yet to be done
Bay of Brest: Dredging January 2016	10 sampled stations	Done	Done	Not appropriate	Yet to be done
Bay of Brest: Dredging June 2016	10 sampled stations	Done	Done	Not appropriate	Yet to be done
Bay of Brest: Dredging September 2016	10 sampled stations	Done	Done	Not appropriate	Yet to be done
Bay of Brest: Dredging December 2016	10 sampled stations	Done	In progress	Not appropriate	Yet to be done

Bay of Brest: Dredging April 2017	10 sampled stations, Including SPI and benthic O2 flux	Done	In progress	In progress	Yet to be done
Bay of Brest: Invasive species April 2017	Cancelled due to bad weather conditions	Not appropriate	Not appropriate	Not appropriate	Not appropriate
Bay of Brest: Invasive species April 2018	30 „Pagure 2" profiles (3 areas*10 profiles per area)	Done	In progress	Not appropriate	Yet to be done

3.1.4.3. Collaboration with other international initiatives

-

3.1.4.4. Scientific progress so far

West Gironde Mud Patch.

The initially planned sampling strategy for seasonal field cruises consisted in the sampling of 10 stations located along two inshore-offshore transects (Figure 3.1-16). These two transects were indeed sampled during the first two seasonal cruises. Due to bad weather conditions, this was not possible to do so during the third and fourth seasonal cruises during which only the North transect was sampled. This led us to apply for additional shipping time to achieve another field cruise during January-february 2019. This application is currently under evaluation. Most of the analyses are still under progress.Some of the analyses of the October-November cruises are however completed, which already allows to pinpoint interesting preliminary results regarding the relative magnitude of spatial and temporal changes in: (1) main sediment characteristics, (2) macrobenthic diversity, and (3) sediment profile images. For all these parameters, the main driving factor of spatial changes seems to be the inshore-offshore gradients (see Figure 3.1-16 for macrobenthic diversity and sediment profile image characteristics) and there are no apparent differences between the two sampled transects. Moreover, the comparison with the data collected in July 2010 show: (1) no signficant differences in sediment granulometry and organic contents (data not shown) except at the very external end of the Northern transect, which was muddy in 2010 but sandy in 2016; but (2) conversely major differences in both benthic macrofauna composition (Figure 3.1-17A) and sediment profile image characteristics (Figure 3.1-17B) all along the Northern inshore-offshore transect. Our current working hypothesis is that temporal changes in the studied characteristics are the main parameters that should be put in correlation with the two disturbance sources constituted by continental inputs from the Gironde River and Ocean hydrodynamics. The analysis of the literature regarding the West Gironde Mud Patch suggests that this second source may be the major one in the case of major winter storms such as those, which took place during the 2013-2014 Winter. This led us to undertake an additional cruise devoted to the spatial mapping of the West Gironde Mud patch, which took place during May-June 2018.

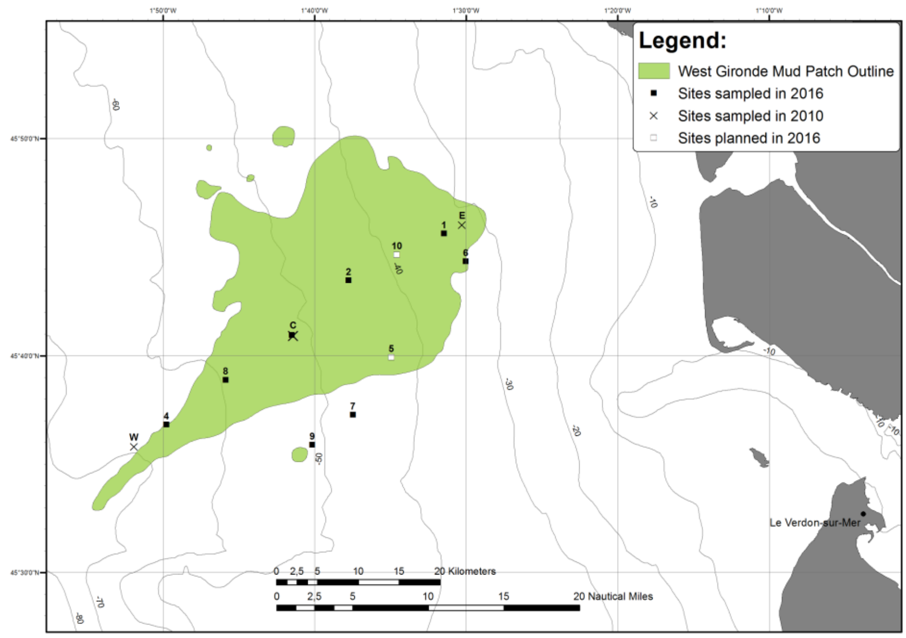


Figure 3.1-16: Map showing the sampling plan adopted for the West Gironde Mud Patch seasonal sampling cruises with the location of the stations that were successfully sampled during the July 2010 and October-November 2016 cruises. (see text for details)

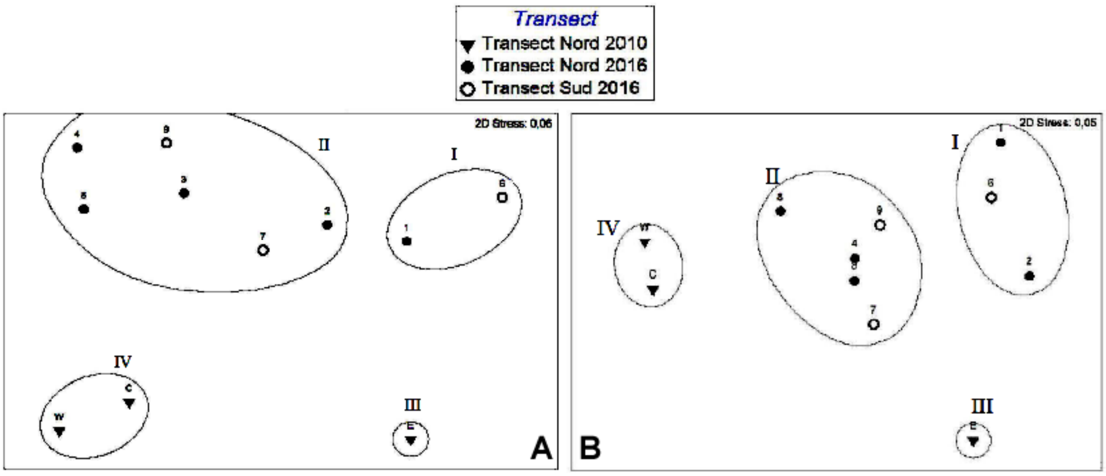


Figure 3.1-17 Non metric Multidimensional Scaling of benthic macrofauna compositions (A) and Sediment Profile Image characteristics sampled in July 2010 and October-November 2016 (B). Modified from Lamarque 2017.

Bay of Brest: Dredging.

The first challenge of this action was to quantify the disturbance caused by clam dredging at the appropriate (i;e., small enough) spatial and temporal scales. This was achieved based on the analysis of the data generated by the Automatic Identification System of fishing vessels system, which resulted in maps (i.e., one per fishing season) of dredging pressure with a 50m*50m spatial resolution. These maps are shown in Figure 3.1-18. They clearly put in evidence very high dredging pressure during 2015-2016.

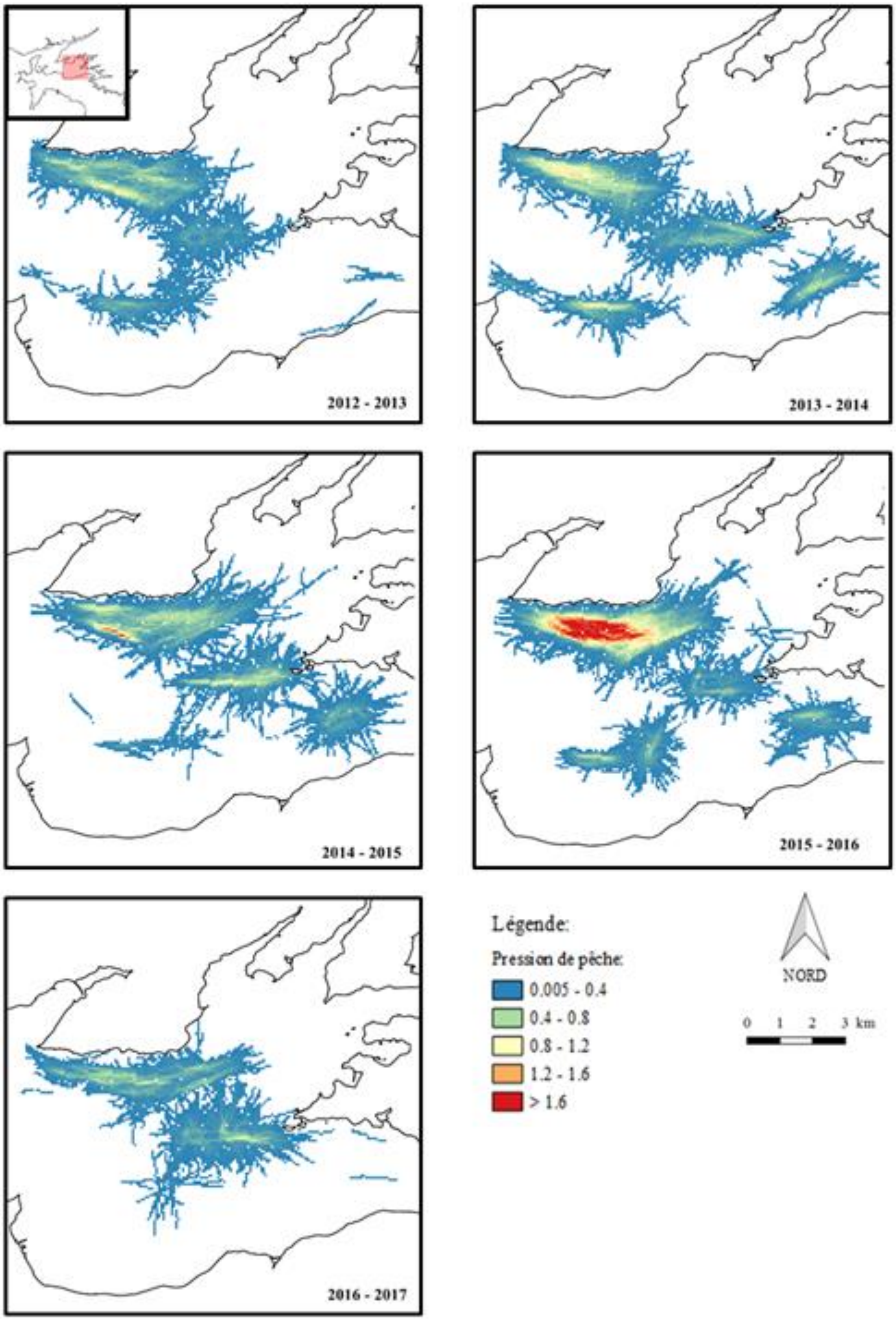


Figure 3.1-18 Maps showing the spatio-temporal changes in dredging intensity in the Bay of Brest between 2012 and 2017. Taken from Tauran (2018) based on data by Pantalos (2015) and then Grall and Le Garrec (2018)

Most of the sediment characteristics and macrobenthic diversity analyses have been done but some of them are still in progress. Already available data nevertheless clearly show major effects of dredging on sediment granulometry (diminution of fines, data not shown) and benthic macrofauna composition (Figure 3.1-19).

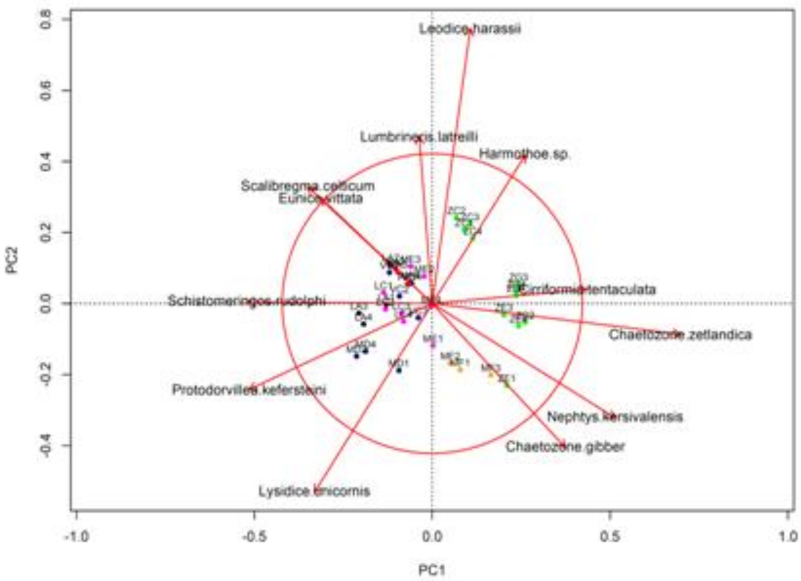


Figure 3.1-19 Results of the Principal Component Ordination of benthic macrofauna composition recorded during the January 2016 field cruise (Green= zero fishing, Orange= low, Red= medium, Blue= high, Purple= very high)

The results of the April 2017 field cruise on maerl characteristics have also been analysed based on the analysis of sediment cores and sediment profile images using the AVIExplore software developed within JERICO. Results show a clear impact on the vitality (data not shown) and the characteristics of maerl fragments (Figure 3.1-20).

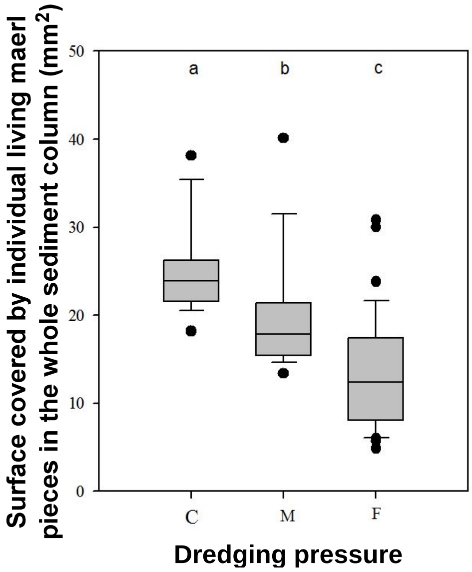


Figure 3.1-20 Box and whiskers plot showing the effect of cumulated dredging intensity on the mean surface of living maerl individual pieces. C: controls, M: Medium dredging pressure; F: High dredging pressure. The upper letters vindicate significantly differing groups (PERMANOVA, p<0.05)

Moreover, the multivariate analysis (multiple linear regressions used to link maerl characteristics and fishing pressure show that the characteristics of the maerl at the sediment surface are better explained by the dredging pressure during the preceding year, whereas the characteristics of the maerl within the whole sediment column are better explained by the historicity of dredging pressure, the most impacting year always being 2015-2016 (data not shown). This result pinpoints the importance in explicitly taking in consideration not only accumulation but also the historicity of disturbance when assessing its effects on biological communities.

Bay of Brest: Invasive species.

Little is known on the ecological impact of marine invasive species at regional scale, since scientific data are fragmented and very site-specific. In the case of Crepidula fornicata, previous studies suggest that the extent of biodiversity change in colonised areas depend on the biomass of C. Fornicata and on the observation scale (diversity increase at very small scale, but diversity homogenisation at embayment scale). Such data remain too limited to allow a generalisation of conclusions at regional (or maritime façade) scales. For the Bay of Brest, the scientific question is addressed at local scale and deals with the ecological impact of a benthic invasive species on the colonised benthic ecosystem. But the conclusions should be confronted to those derived from other colonised bays in order to draw more generic conclusion. For the Bay of Brest, the aim is to assess how the benthic biodiversity is influenced by the proliferation stage of this exotic species by submarine imagery (underwater video system ‚Pagure-2'). Diversity patterns of epifauna (macro- and megafauna) are described along a Crepidula biomass gradient. Since the stock of C. fornicata has declined in the Bay of Brest, changes of diversity are also investigated with respect to the vitality of Crepidula banks (alive vs. Dead). The field cruise corresponding to this action was initially planned to take place during spring 2017. It had to be cancelled due to bad weather conditions. Consequently, the 'Pagure-Next-2018' cruise has finally been achieved from 16th to 21th April 2018. The underwater video system 'Pagure-2' has been deployed over three different areas of the Bay of Brest, representing three different stage of Crepidula fornicata proliferation (high density live Crepidula bed; low density live Crepidula bed; dead Crepidula bed). In each area, an average of 10 imagery profiles (each 300 to 900m long) were achieved, and both continuous video and still images (every 10 sec) data were collected (Figure 3.1-21). This sampling strategy has been designed in order to assess the impact of the Crepidula fornicata on epibenthic biodiversity with respect to alive Crepidula biomass considered as the main disturbance factor (varying, over the 3 areas, from high live biomass to dead bed). In each area, some imagery profiles were also achieved on locations without Crepidula (live or dead). These were considered as reference sites. All analysis procedures are still under progress.

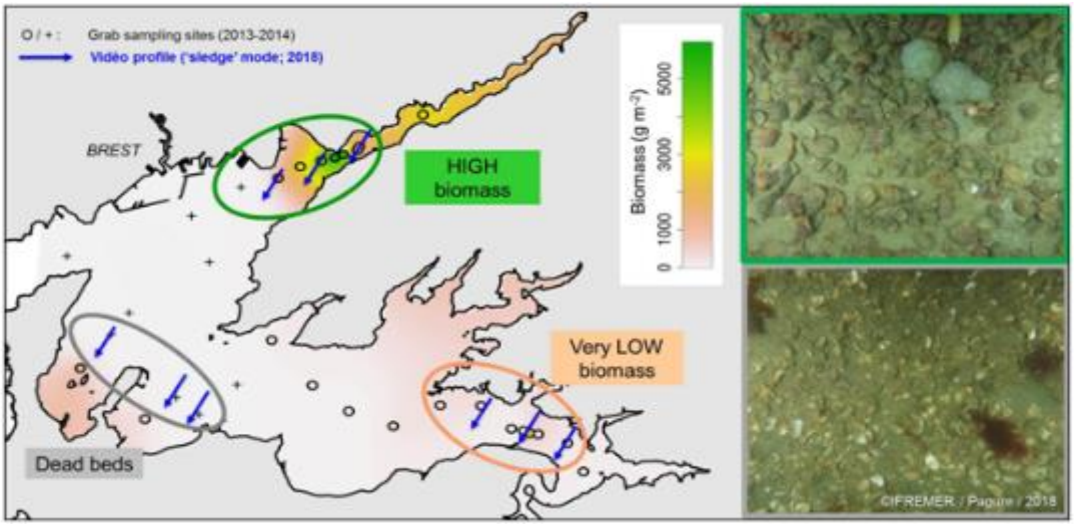


Figure 3.1-21 Overall sampling strategy and examples of images collected using ‚Pagure 2' during the April 2018 field cruise.

3.1.4.5. Synthesis and way forward

Synthesis and specific next steps (short-term)

West Gironde Mud Patch. Due to bad weather conditions, we were only able to sample 4 stations during our January-February 2018 cruise. This was not satisfactory and we thus decided to apply for shiptime in order to achieve an additional cruise in the very beginning of 2019, which was not initially planned and may somehow result in delay in data interpretation. Some of the already collected results suggest changes in the spatial delimitation of the West Gironde Mud Patch in relation with major storms (see above). In order to further document this point, another additional cruise, specifically dedicated to spatial mapping, was achieved during May-June 2018. This will allow for a direct comparison with available historical data (1987-1991). Our results already show major temporal changes in the composition of benthic macrofauna and sediment profile images. During next year, we will complement the analyses of all collected samples in order to tackle the two main scientific questions put forward by JRAP 2 (see above).

Bay of Brest Dredging. The analysis of AIS data have led to the quantification of dredging pressure at a very small spatial scale, which enhances the possibility of a sound crossing with biological data. Such a crossing has already been achieved for maerl vitality and structure, which has shown the importance of dredging historicity. During the next year we will finalize the analysis of benthic macrofauna composition and apply the same statistical approach to assess the effect of dredging on their spatio-temporal changes.

Bay of Brest Invasive species. At this stage, we have collected a sufficient amount of imagery data to assess the impact of *Crepidula* on the epibenthic biodiversity in the Bay of Brest. The 5 days-cruise led to 30 imagery profiles, representing ~8 hours of video and ~2500 high resolution photos. Extraction of relevant informations from videos and photos and interpretation of data will be achieved in 2019, between semestres 42 and 48.of the JERICONext project.Most of the imagery profiles were done over stations that were previously sampled for endofauna in 2013-2014. This should allow to compare trends of biodiversity change in the endofauna and in the epifauna compartments, under the same *Crepidula* influence.

Data integration and interpretation. The analysis of the interaction between disturbances, composition and functionalities of benthic communities ultimately relies on: (1) a sound assessment of disturbance intensities, and (2) the implementation of appropriate multivariate techniques. Point 1 is very well engaged for the two research actions taking place in the Bay of brest. In the case of the West Gironde Mud patch, it will be handled through an interaction with a French national project. It is essential that this project indeed provides expected inputs within the JERICO-Next time frame. As for point 2, the West Gironde Mud Patch and the Bay of Brest – dredging research actions have already shown the occurrence of major temporal changes in macrobenthic composition, which is a prerequisite for tackling the two main scientific questions put forward by JRAP 2. This is not the case yet for the Bay of Brest – Invasive species research action due to a delay in the achievement of its field cruise (see above). We already started using multivariate techniques for interpreting some of our results regarding the effect of dredging in the Bay of Brest. During next year, we will apply these approaches to the study of the questions put forward by all JRAP 2 actions.

3.1.5. *References for Bay of Biscay*

Barton, E.D., 1989. The poleward undercurrent on the eastern boundary of the subtropical North Atlantic. In “Poleward Flows along Eastern Ocean Boundaries”,S.J. Neshyba, Ch.N.K. Mooers, R.L.Smith, R.T. Barber (Eds.), 82-95

Borja, A., Amouroux,D. Anschutz,P., Gómez-Gesteira, M., Uyarra, M.C., Valdés, L. 2019. Chapter 5 - The Bay of Biscay, Editor(s): Charles Sheppard, World Seas: an Environmental Evaluation (Second Edition), Academic Press, 2019, pages 113-152, ISBN 9780128050682 , https://doi.org/10.1016/B978-0-12-805068-2.00006-1.

Caballero, A., Ferrer, L., Rubio, A., Charria, G., Taylor, B.H., Grima, N., 2014. Monitoring of a quasi-stationary eddy in the Bay of Biscay by means of satellite, in situ and model results. Deep Sea Res. Part II-Topical Studies in Oceanography, 509 doi: 10.1016/J.DSR2.2013.09.029.

Caballero, A., Rubio, A., Ruiz, S., Le Cann, B., Testor, P., Mader, J., Hernández, C., 2016. South-Eastern Bay of Biscay eddy-induced anomalies and their effect on Chlorophyll distribution. J. Mar. Syst., 162, 57-72, doi:10.1016/ j.jmarsys.2016.04.001.

Cabeçadas, G., M. J. Brogueira, C. Gonçalves, 2003. Intermediate water masses off south-southwest Portugal: chemical tracers. Journal of Marine Research, 61, 539-552.

Cachão, M., A. Oliveira, J. Vitorino, 2000. Subtropical winter guests, offshore Portugal. Journal of Nannoplankton Research, 22, 19-26.

Charria G., Lazure P., Le Cann B., Serpette A., Reverdin G., Louazel S., Batifoulier F., Dumas F., Pichon A., Morel Y., 2013. Surface layer circulation derived from Lagrangian drifters in the Bay of Biscay. J. Mar. Syst., 109-110: S60-S76.

Dávila, 2018. Influence of (sub)mesoscale processes on the distribution of organic and inorganic particles in the SE Bay of Biscay. MsC Thesis for the Marine Environment and Resources Erasmus Mundus master degree.

Fernández, E., Álvarez, F., Anadón, R., Barquero, S., Bode, A., García, A., García-Soto, C., Gil, J., González, N., Iriarte, A., Mouriño, B., Rodríguez, F., Sánchez, R., Teira, E., Torres, S., Valdés, L., Varela, M., Varela, R., Zapata, M., 2004. The spatial distribution of plankton communities in a Slope Water anticyclonic Oceanic eDDY (SWODDY) in the southern Bay of Biscay. J. Mar. Biol. Assoc. U.K., 84: 501-517.

Ferrer, L., Fontán, A., Mader, J., Chust, G., González, M., Valencia, V., Uriarte Ad, Collins, MB., 2009. Low-salinity plumes in the oceanic region of the Basque Country. Cont. Shelf Res., 29 (8): 970-984.

Fredj, E., Roarty, H., Kohut, J., Smith, M., and Glenn, S.: Gap Filling of the Coastal Ocean Surface Currents from HFR Data: Application to the Mid-Atlantic Bight HFR Network, J. Atmos. Ocean. Tech., 33, 1097–1111, https://doi.org/10.1175/JTECHD-15-0056.1, 2016.

Frouin R, A.F.G. Fiúza, I. Ambar, T.J. Boyd, 1990. Observations of a poleward surface current off the coasts of Portugal and Spain during winter. Journal of Geophysical Research 95(C1),679–691

Garcia-Soto, C., Pingree, R.D., Valdés, L., 2002. Navidad development in the southern Bay of Biscay: Climate change and swoddy structure from remote sensing and in situ measurements. J. Geophys. Res., 107, 3118, doi: 10.1029/2001JC001012.

Gauthier, V., 2018. Caractérisation de l'hydrodynamisme haute fréquence dans le Sud-Est français du Golfe de Gascogne à partir de mesures in situ. Rapport de stage Master 2 "Sciences de la Mer", université de Perpignan Via Domitia.

Gioia, R.; Nizzetto, L.; Lohmann, R.; Dachs, J.; Temme, C.; Jones, K. C.,, 2008. Polychlorinated Biphenyls (PCBs) in air and seawater of the Atlantic Ocean: Sources, trends and processes. Environmental Science & Technology, 42, (5), 1416-1422.

Haynes R, E.D. Barton, 1990. A poleward flow along the Atlantic coast of the Iberian Peninsula. Journal of Geophysical Research 95, 11425–11441.

Hernández-Carrasco, I., Solabarrieta, L., Rubio, A., Esnaola, G., Reyes, E., and Orfila, A.: Impact of HF radar current gap-filling methodologies on the Lagrangian assessment of coastal dynamics, Ocean Sci., 14, 827-847, https://doi.org/10.5194/os-14-827-2018, 2018.

Huthnance, J.M., 1984. Slope Currents and "JEBAR". Journal of Physical Oceanography, 14, 795-810.

Jia, Y., 2000. Formation of an Azores Current due to Mediterranean overflow in a modelling study of the North Atlantic. Journal of Physical Oceanography, 30, 2342-2358.

John, H.-C., E. Mittelstaedt, K. Schulz, 1998. The boundary circulation along the European continental slope as a transport veichle for two calanid copepods in the Bay of Biscay. Oceanologica Acta, 21(2), 307

Jordà, G., Sanchez-Roman, A., and Gomis, D. (2016). Reconstruction of transports through the Strait of Gibraltar from limited observations. Clim. Dynam, 1–15, doi:10.1007/s00382-016-3113-8

Le Cann B., Serpette A., 2009. Intense warm and saline upper ocean inflow in the southern Bay of Biscay in autumn-winter 2006-2007. Cont. Shelf. Res., 29 (8): 1014-1025.

Liu, Y., et al., 2012. Comparison of the XTRACK altimetry estimated currents with moored ADCP and HF radar observations on the West Florida Shelf, Advances in Space Research, 50, 8, 1085-1098;

Lohmann, R.; Gioia, R.; Jones, K. C.; Nizzetto, L.; Temme, C.; Xie, Z.; Schulz-Bull, D.; Hand, I.; Morgan, E.; Jantunen, L., 2009. Organochlorine Pesticides and PAHs in the Surface Water and Atmosphere of the North Atlantic and Arctic Ocean. Environmental Science & Technology, 43, (15), 5633-5639.

Manso-Narvarte, I., Caballero, A., Rubio, A., Dufau, C, Birol, F, in press. Joint analysis of coastal altimetry and high-frequency radar data: observability of seasonal and mesoscale ocean dynamics in the Bay of Biscay. Ocean Science, 14, 1265-1281, https://doi.org/10.5194/os-14-1265-2018, 2018

Pascual, A., et al., 2015. Assessing SARAL/AltiKa Delayed-Time Data in the Coastal Zone: Comparisons with HFR Observations, Marine Geodesy, DOI: 10.1080/01490419.2015.1019656;

Peliz, A., J. Dubert, D. B. Haidvogel, B. Le Cann, 2003. Generation and unstable evolution of a density-driven Eastern Poleward Current: The Iberian Poleward Current. Journal of Geophysical Research, 108 (C8), 3268. doi:10.1029/2002JC001443 .

Peliz A., J. Dubert, P. Marchesiello, A. Teles-Machado, 2007. Surface circulation in the Gulf of Cadiz: model and mean flow structure. Journal of Geophysical Research, 112(C11015), doi:10.1029/2007JC004159.

Pereiro, D., Souto, C., Gago, J. 2019. Dynamics of floating marine debris in the northern Iberian waters: A model approach, Journal of Sea Research,144, 57-66, doi: 10.1016/j.seares.2018.11.007.

Pingree, R.D., Le Cann, B., 1992. Three anticyclonic Slope Water Oceanic eDDIES (SWODDIES) in the southern Bay of Biscay in 1990. Deep-Sea Res. 39 (7/8), 1147–1175.

Relvas, P., E.D. Barton, 2002. Mesoscale patterns in the cape São Vicente (Iberian Peninsula) upwelling region. Journal of Geophysical Research, 107 (10), 3163, doi:10.1029/2000JC000456.

Roarty, H., et al., 2016, Growing network of radar systems monitors ocean surface currents, Eos, 97, doi:10.1029/2016EO049243

Roesler, C. J., et al. , 2013. Evaluating the use of high-frequency radar coastal currents to correct satellite altimetry, J. Geophys. Res. Oceans, 118, 3240–3259, doi:10.1002/jgrc.20220.

Rodríguez, F., Varela, M., Fernandez, E., Zapata, M., 2003. Phytoplankton and pigment distributions in an anticyclonic slope water oceanic eddy (SWODDY) in the southern Bay of Biscay. Mar. Biol., 143 (5), 995-1011.

Rubio A, Reverdin G, Fontán, A., González, M., Mader, J., 2011. Mapping near-inertial variability in the SE Bay of Biscay from HF radar data and two offshore moored buoys. Geophys. Res. Lett., 38 (19): L19607.Rubio, A., Caballero, A., Orfila, A., Hernández-Carrasco, I., Ferrer, L., González, M., Solabarrieta, L., and Mader, J.: Eddy-induced cross-shelf export of high Chl-a coastal waters in the SE Bay of Biscay, Remote Sensing of Environment, 205, 290 – 304, https://doi.org/doi.org/10.1016/j.rse.2017.10.037, 2018.

Santos, A.M.P., M.F. Borges, S. Groom, 2001. Sardine and horse mackerel recruitment and upwelling off Portugal. ICES Journal of Marine Science, 58, 589-596. doi:10.1006/jmsc.2001.1060.

Solabarrieta L., Rubio A., Castanedo S., Medina R., Fontán A., González M., Fernández V., Charria G., Hernández C. (2014). Surface water circulation patterns in the southeastern Bay of Biscay: New evidences from HF radar data. Cont. Shelf Res., 74, 60-76.

Solabarrieta, L., Rubio, A., Cárdenas, M., Castanedo, S., Esnaola, G., Méndez, F.J., Medina, R., Ferrer, L., 2015. Probabilistic relationships between wind and surface water circulation patterns in the SE Bay of Biscay. Ocean Dyn., 65 (9): 1289-1303.

Sotillo, M. G., S. Cailleau, P. Lorente, B. Levier, R. Aznar, G. Reffray, A. Amo-Baladrón, J. Chanut, M. Benkiran & E. Alvarez-Fanjul (2015) The MyOcean IBI Ocean Forecast and Reanalysis Systems: operational products and roadmap to the future Copernicus Service, Journal of Operational Oceanography, 8:1, 63-79, DOI: 10.1080/1755876X.2015.1014663

Teles-Machado, A., Peliz, A., McWilliams, J., Dubert, J., Le Cann, B. Circulation on the Northwestern Iberian Margin: Swoddies. 2016. Progress in Oceanography, 140, 116-133, doi:10.1016/j.pocean.2015.09.011.

3.2. Channel and North Sea

Lead authors: Felipe Artigas (CNRS-LOG) & Alain Lefebvre (IFREMER)
Contributors: H. Aardema (HZG), Y. Bozec (CNRS-SBR), H. Brix (HZG), P. Claquin (CNRS-BOREA), V. Créach (Cefas), R. de Blok (VLIZ-UGent), E. Debusschere (VLIZ), P. Fisher (HZG), J. Kromkamp (NIOZ), F. Lizon (CNRS-LOG), A. Louchart (CNRS-LOG), K. Möller (HZG), E. Poisson-Calillault (ULCO-LISIC), M. Rijkeboer (RWS), A. Veen (RWS), Y.G. Vonyova (HZG), J. Woschlaeger (HZG), G. Wacquet (CNRS-LOG)

Involved JRAPs: JRAP#1, 4, 5,
Contact persons: JRAP#1: Felipe Artigas
JRAP#4: Johannes.Schulz-stellenfleth
JRAP#5: Willy Petersen

Involved institutes:
JRAP#1: Phytoplankton dynamics and blooms

- Cefas: Véronique Créach (veronique.creach@cefas.uk)
- CNRS - LOG: Felipe Artigs (Felipe.Artigas@univ-littoral.fr); Fabrice Lizon (Fabrice.Lizon@univ-lille.fr), Arnaud Louchart (Arnaud.Louchart@etu.univ-littoral.fr), Guillaume Wacquet (Guillaume Wacquet@univ-littoral.fr); - BOREA : Pascal Claquin (Pascal.Claquin@unicaen.fr),
- IFREMER LER/BL Alain Lefebvre (Alain.Lefebvre@ifremer.fr); + LISIC ULCO Emilie Poisson-Caillault (Emilie.Poisson@univ-littoral.fr)
- VLIZ: Elisabeth Debusschere, Klaas Deneudt, Jonas Moltermans, Leynert Tiberghien +U. Gent Reinhoud de Blok
- RWS: Machteld Rijkeboer, Arnold Veen, Heidi Aardema; +Thomas Rutten Projects, SME sub-conractor of RWS (as NIOZ) NIOZ : Jacco Krokmap
- HZG: Klas Möller (klas.moeller@hzg.de); Jochen Wollschlaeger (Jochen.Wollschlaeger@hzg.de)

JRAP5 (carbon cycles) partners working in the area:

- NIVA: Kai Sorensen (kai.sorensen@niva.no) & Andrew King (andrew.king@niva.no)
- HZG: Wilhelm Petersen (wilhelm.petersen@hzg.de) & Yoana G. Voynova (yoana.voynova@hzg.de)
- AWI/HZG: Philip Fischer (philipp.fischer@awi.de) & Ingeborg Bussmann
- CNRS: Yann Bozec (bozec@sb-roscoff.fr), Thierry Cariou (cariou@sb-roscoff.fr), Eric Macé (mace@sb-roscoff.fr).

3.2.1. *Specificities of the this region*

3.2.1.1. Most relevant scientific questions from regional to local scales

General characteristics of the area

The North Sea – Channel – Celtic Seas represent two shallow epi-continental seas and a shelf area interconnected and affected by mega-tidal regimes, increasing West-East gradient of freshwater inputs, and Western and Northern intrusion of Atlantic waters. They consist in a succession of frontal zones, from continental margins to areas of tidal fronts varying at daily to seasonal scales and are more or less extended regions of freshwater influence where also important mixing by storms of different regimes and timing occur.

The dominant human activities are fishing, shipping, ports wind farms, oil and gas production and aggregate (sand) extraction. Together with eutrophication, they represent the main pressures that need to be addressed for the Water Framework and Marine Strategy Framework Directives

Therefore, there is a need to enhance the understanding of the dynamics of plankton diversity and especially the dynamics and determinism of algal blooms which ensure rich living resources, but which also could lead to harmful events (HABs), by combining data on phytoplankton distribution, abundance and diversity as well as primary productivity, with chemical and physical oceanographic data.

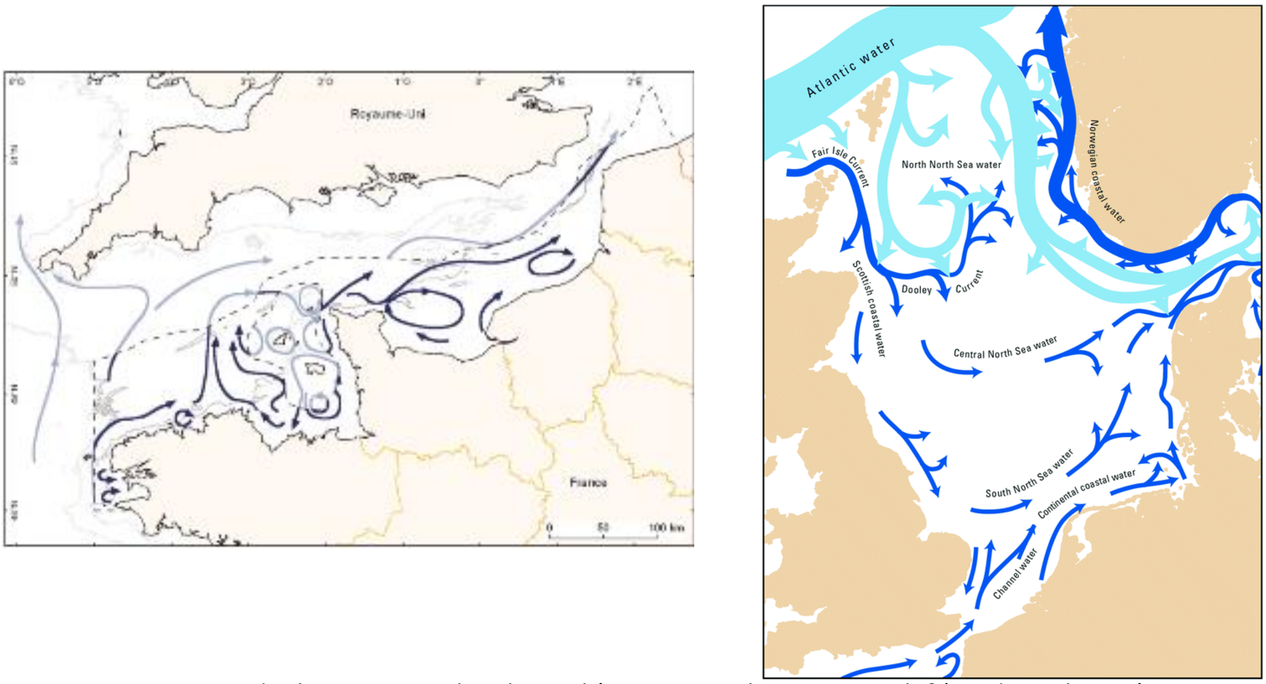


Figure 3.2-1 Residual Currents in the Channel (Lazure & Delmare, 2012; left) and North sea (OSPAR, 2000; right)

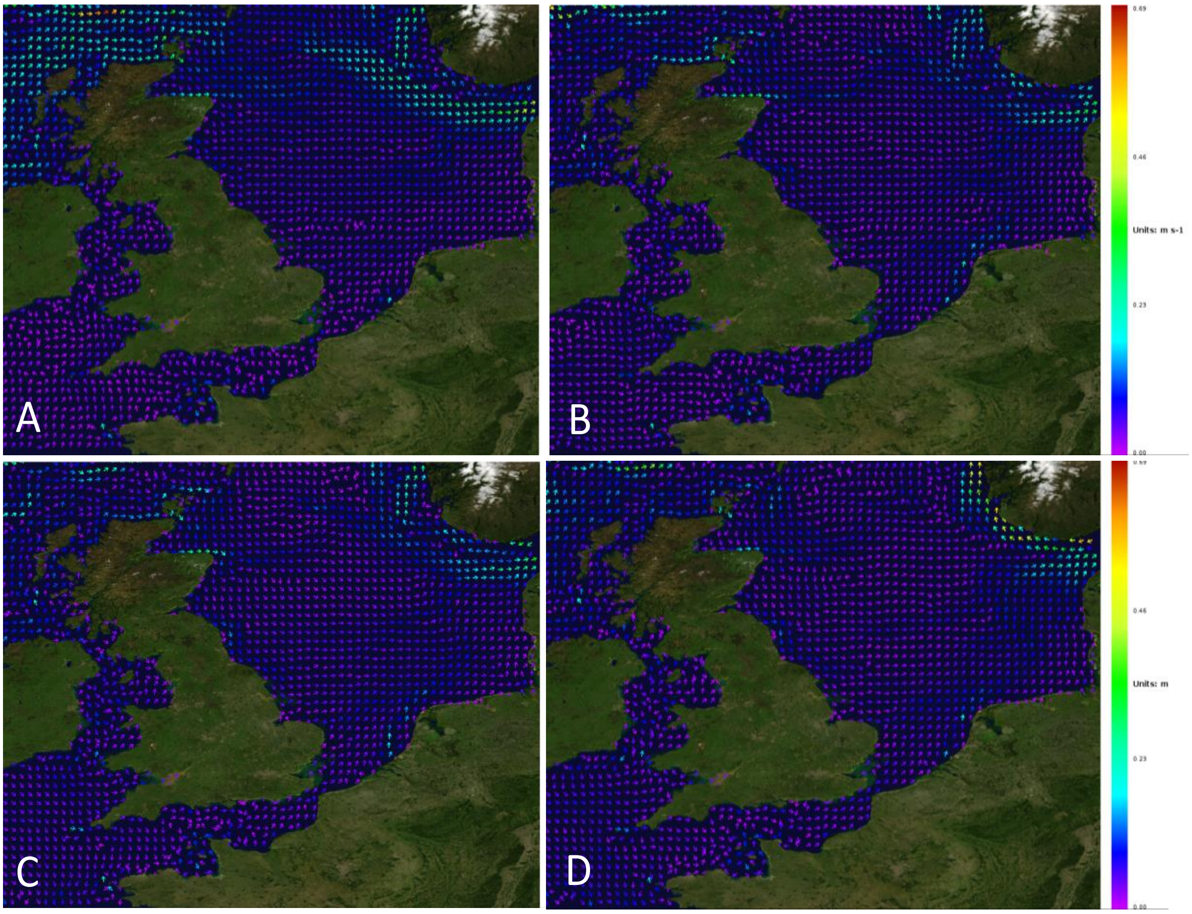


Figure 3.2-2 Monthly mean horizontal velocity (3D) of the Atlantic-European North West Shelf in December 2016 (A), March 2017 (B), June 2017 (C) and September 2017 (D). NORTHWESTSHELF_REANALYSIS_PHY_004_009 (downloaded 24/05/2019 from CMEMS)

Most relevant scientific questions and those targeted in JERICO-NEXT

Within the JERICO-NEXT project, we addressed phytoplankton dynamics (JRAP1) and Carbon fluxes (JRAP5) through the implementation of automated sensors for phytoplankton research vessels, Ferrybox systems and oceanographic observatories including instrumented fixed platforms and buoys. This field work was kept in connection with analytical developments, modelling and earth observation issues as presented in section 3.2.4.

Main scientific question JRAP1 addresses in this region:

One of the main questions that needs to be addressed by applying (semi-)automated temporal and spatial approaches, was to assess the temporal and spatial variability of phytoplankton distribution in these highly productive but changing, heterogeneous and vulnerable systems, from mesotrophic to eutrophic, in order to study what conditions trigger the outbursts of selected species/groups including noxious algae (HABs), what drive their export or lasting, what is the influence of connectivity amongst the different systems, and what is the role of short-term changes and patchiness.

JRAP#1 concerns the use novel automated and in part autonomous methods for observing/discriminating phytoplankton and harmful algal blooms, at the individual organisms/colonies level as well as considering the whole community, to determine the species/size-class/functional groups composition as well as phothosynthetic parameters. Tests, inter comparison and combination of several sensors are applied to observe and explain the development of algal blooms. An important objective is to set up recommendation on observational methods suitable for this trophic region.

These approaches, if sustained, could allow to study long-term changes in these areas, in response to environmental management of human pressures (in the frame of MSFD) and climate change.

There is a need in combining phytoplankton monitoring with environmental parameters in order to address also the following specific matters and questions:

- Impacts of nutrients inputs and ratios on phytoplankton biodiversity and productivity, including focus on HAB
- Dynamics of Phaeocystis globosa and other species or groups responsible of blooms
- Competition or synergy between Phaeocystis globosa and Pseudo-nitzschia
- Transboundary transport and advection of blooms especially in frontal systems in the whole Channel and North Sea system
- Occurrence of sporadic toxic blooms in mid-Channel waters
- Importance of extreme events (i.e., storms, floods) on phytoplankton dynamics
- Development of reference values, threshold and indicators
- Role of wind, tidal forcing and bathymetry for transport within the German Bight
- Small-scale spatial dynamics of phytoplankton in the eastern Channel and Southern North Sea submitted to multiple influence from Atlantic Waters and important estuarine loads (Seine, Thames, Schelde-Rhine)
- How the study of physiological parameters in vivo and in situ in the euphotic layer help to better understand phytoplankton dynamics in relation with its potential environmental controlling factors?
- How to manage to get more accurate GPP rates by integrating all physiological regulation and acclimation occurring in the water column? Can this approach change the map of phytoplankton dynamic in spatial sampling?

Main scientific question JRAP5 addresses in this region:

JRAP#5 aims at addressing the role and responses of the European Coastal Ocean and Marginal Seas in the global C-cycle, and to provide recommendations for a European integrated C-cycle monitoring. In practice, sea surface water pCO2-concentration and other relevant parameters are measured throughout EU utilizing fixed stations and Voluntary Observing Ships (VOS). The aim in this JRAP is to measure for one full year simultaneously, combine results and along with publishing the results, try to find best practices for observations, and standard operating procedures.

In this region, one objective is to connect the pCO2 measurements with phytoplankton outbursts (detected by total chlorophyll a in vivo fluorescence). One further goal would be to be able to discriminate main phytoplankton blooming groups in the area (like Phaeocystis globosa and diatoms in North Sea) together with water masses.

3.2.1.2. Most relevant societal needs and policy needs

Assessment of Good Environmental/Ecological Status for the MSFD, WFD,

- Assessment of the eutrophication status for the OSPAR Common Procedure and the Quality Status Report
- Definition of reference conditions or threshold for nutrients and phytoplankton (biomass, blooms frequency, composition)
- Evaluation of sediment fluxes and budget along the shelf, essential for coastal evolution (estuaries and shoreline)
- Reliable forecast of surface currents (e.g., for search and Rescue) and volume transports (important for biological and chemical models) within the German Bight
- Assessing carbonate system parameters on a seasonal and regional scale, to better understand/quantify the local carbon budgets and potential effect of coastal ocean acidification and effect of climate change on productivity
- Support to the management of marine protected areas.

- Real-time environmental monitoring which is required to support decisions from authorities, environmental managers and professionals when considering results from Institutes implementing monitoring programmes in the area of HAB.
- Strengthen the operational capacity and scientific knowledge to support national, regional and local authorities during HAB crisis.

3.2.2. *Acquired data and archiving made*

Data type	Sampling location/area	Sampling period	Institute responsible of the data
Phytoplankton including harmful algae - microscopy	Eastern English Channel	1992-2017 (weekly to monthly sampling frequency)	Ifremer*
Main physico-chemical parameters (T, S, Nutr, O2, Turbidity (or SSC)...)	Eastern English Channel	1992-2017(weekly to monthly sampling frequency)	Ifremer
High Frequency measurements from the MAREL Carnot instrumented station	Eastern English Channel	2004-2018 (measurement every 20 min)	Ifremer
High Frequency measurements from a Pocket Ferry Box and a Ferry Box	English Channel	2014-2018	Ifremer
High Frequency measurements from buoys (X3) with automatic collection for nutrients and phytoplankton	North Sea and Thames estuaries	2000-now	Cefas
Main physico-chemical parameters (T, S, Nutr, O2, Turbidity (or SSC)...)	Dutch Marine territories in the North Sea	1990 - now	Rijkswaterstaat
Continuous measurements with automated pulse-shape-recording flow cytometry, T, S, Fluorescence	North Sea - English Channel - Celtic Seas	2012-now	Cefas
Surface current measurements from three HF radar stations	German Bight	2010-2018	HZG
FerryBox data on the Cuxhaven-Immingham line	German Bight	2010-2017	HZG

(T, S, pH, turbidity, pCO2, O2, fluorescence)			
FerryBox data on the Büsum-Helgoland line (T, S, pH, turbidity,, pCO2, fluorescence, O2)	German Bight	2010-2018	HZG
FerryBox data from the Cuxhaven station (T, S, pH, turbidity, nutrients, fluorescence, O2)	German Bight/Elbe estuary	2010-2018	HZG
FerryBox data on the Roscoff-Plymouth line (T, S, pCO2, turbidity, fluorescence, O2)	English Channel	2011-2018	CNRS
FerryBox data on the Roscoff-Cork line (T, S, DO, chl-a, Trb, CDOM)	Celtic Sea	2014-2016	CNRS
HF data on the ASTAN buoy off Roscoff (SST, SSS, DO, Fluorescence, pCO2)	English Channel	2016-2018	CNRS
Automated pulse shape-recording flow cytometer (3 parallel sensors); Flowcam; Zooscan; Fluoroprobe, FRRF, pigment, nutrients, T, S, Chl a, NGS	English Channel, Southern bight of North Sea, Thames Estuary	2017-05-08 until 2017-05-12	VLIZ,CNRS-LOG, RWS
Automated pulse shape-recording FCM, flowcam, zooscan, nutrients, pigment, S, T, Chl a	Englisch Channel, Southern bight of North Sea, Thames Estuary	2018-04-16 until 2018-04-20	VLIZ
Automated pulse shape-recording flow cytometer, multi-spectral fluorometry	English Channel, Southern bight of North Sea, Thames Estuary	2014/09-10 2017/04-05	CNRS-LOG (U. Littoral)
FRRF profiler, PAR and Trios data	Englisch Channel, Southern bight of North Sea, Thames Estuary	2017/04-05-06 2018/04-07	CNRS-LOG-U.Lille

*Ifremer's data are submitted to QA/QC procedures within Quadrige2, Sismer and Coriolis data management systems. Most of these data are also transferred to EMODNET and to the ICES DOME databases.

3.2.3. *Collaboration with other international initiatives*

The JERICO-NEXT cruises organised by VLIZ in 2017 are in collaboration with the ESFRI initiative LifeWatch, and they involved CNRS-LOG, RWS and NIOZ.
PHYCO (2017) cruises were also part of preliminary cruises for the implementation of the Monitoring Programme of the MSFD in France.
The same sensors were also tested in other Regional areas as the Skagerrak-Kattegatt and the Baltic Sea (Aranda cruise, SMHI, SYKE, CNRS-LOG and CNRS-LOV) as well as in the Southern Bay of Biscay (IFRMER, AZTI and CNRS-LOG) and the Mediterranean Sea (CNRS-MIO).
The use of satellite data is an important building block for providing spatially coherent information on phytoplankton abundance and variability. Some JERICO-Next colleagues were also involved in the INTERREG "Channel" S-3 EUROHAB (2017-2021), working on Sentinel-3 satellite products for detecting Eutrophication and Harmful Algal Bloom events in the French-English Channel. Moreover, within the JMP-EUNOSAT project (Feb 2017 - Feb 2019) all countries around the North Sea have worked together towards joint monitoring and assessment of eutrophication for MSFD in the North Sea.

3.2.4. *Scientific progress so far*

3.2.4.1. Field measurements with automated systems in the North Sea

North Sea Ferry Box combined pCO_2, in situ in vivo fluorescence and hyperspectral spectrophotometry (HZG).

Different continuous measurements were performed in the Haiden-Zeebrugge-Immingham-Moss and the Cuxhaven-Helgoland-Immigham ferrylines, in the frame of both JRAP#1 and JRAP#5.
The goal was to be able to connect the pCO2 measurements with phytoplankton outbursts detected by total in vivo chlorophyll a fluorescence.

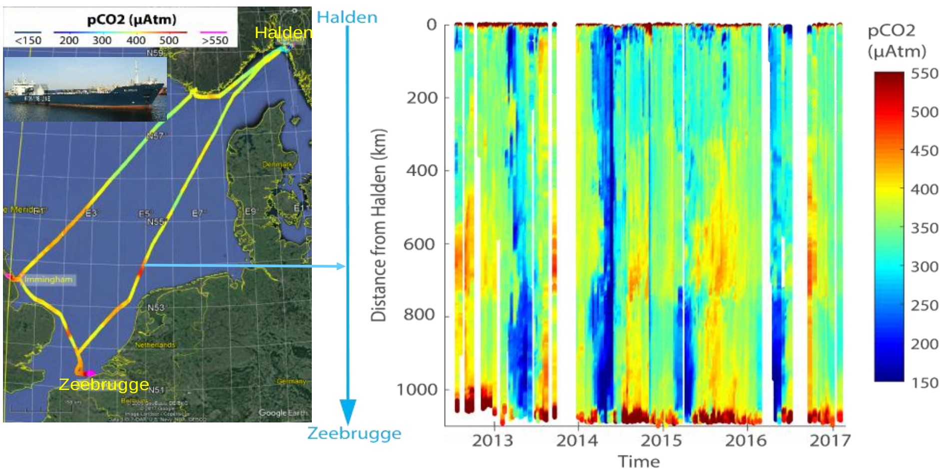


Figure 3.2-3 : Continuous recording of pCO2 from 2013 to 2017 in the central North Sea. FerryLine cruises

The difference of pCO_2 between the atmosphere and the sea surface (ΔpCO_2) reveals a distinct behavior of shallow well mixed regions and deeper, stratified areas in the summer:

- pCO_2 is undersaturated during spring along all routes and in autumn, in the region of the DoggerBank
- pCO_2 is supersaturated in summer in the English Chanel region and Dogger Bank and in autumn, in the Southern Central North Sea

Anomalies of pCO_2 and DO show similar patterns during spring, but differ in the spatial distribution during other seasons probably caused by different thermal behavior of pCO_2 and oxygen. Morevoer, the measurement of pCO_2 can be combined with dissolved oxygen measurements to potentially derive a time series of productivity estimates along these transects.

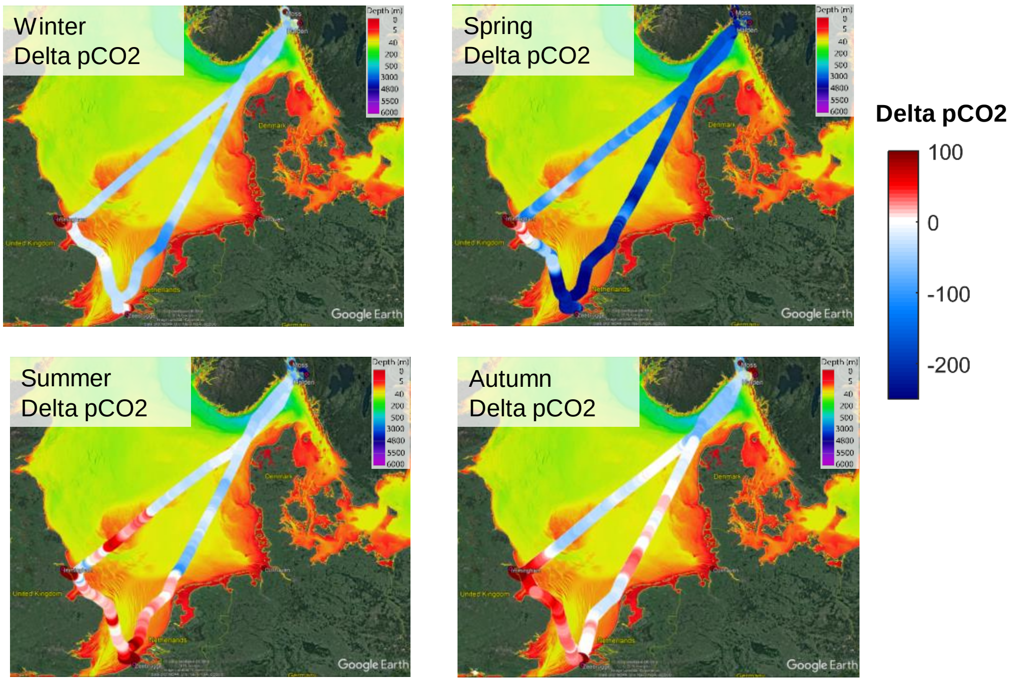


Figure 3.2-4 Continuous recording of delta pCO2 at four seasons in the central North Sea. Haiden-Zeebrugge-Immingham-Moss and Cuxhaven-Helgoland-Immigham ferrylines.

Moreover, in research cruises, it was possible to test hyperspectral measurements to discriminate main phytoplankton blooming groups in the area: *Phaeocystis globosa* and diatoms.

FerryBox systems are a mature tool to continuously measure carbon related parameters like pH and pCO_2 along large sections of the southern and central North Sea. Data sets provide a detailed picture of the carbon dynamics in surface waters in different regions and at different seasons. The combination with automated sensors for phytoplankton discrimination represents the next step of integration between C cycle and phytoplankton dynamics.

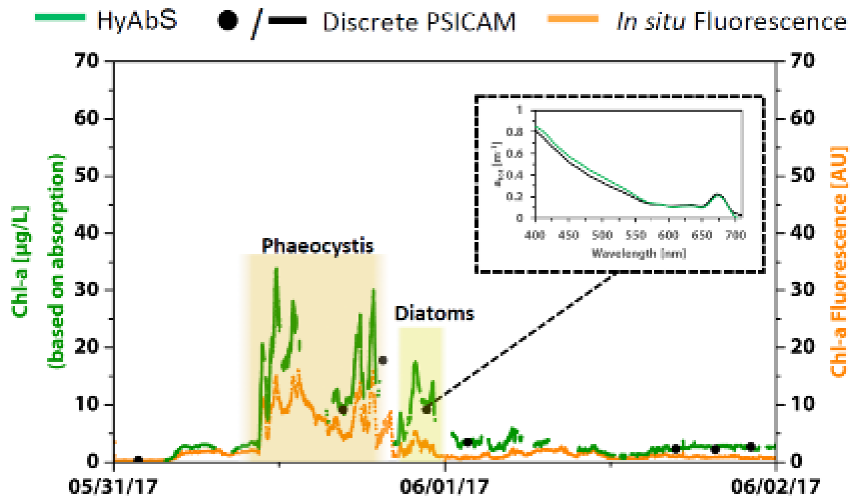
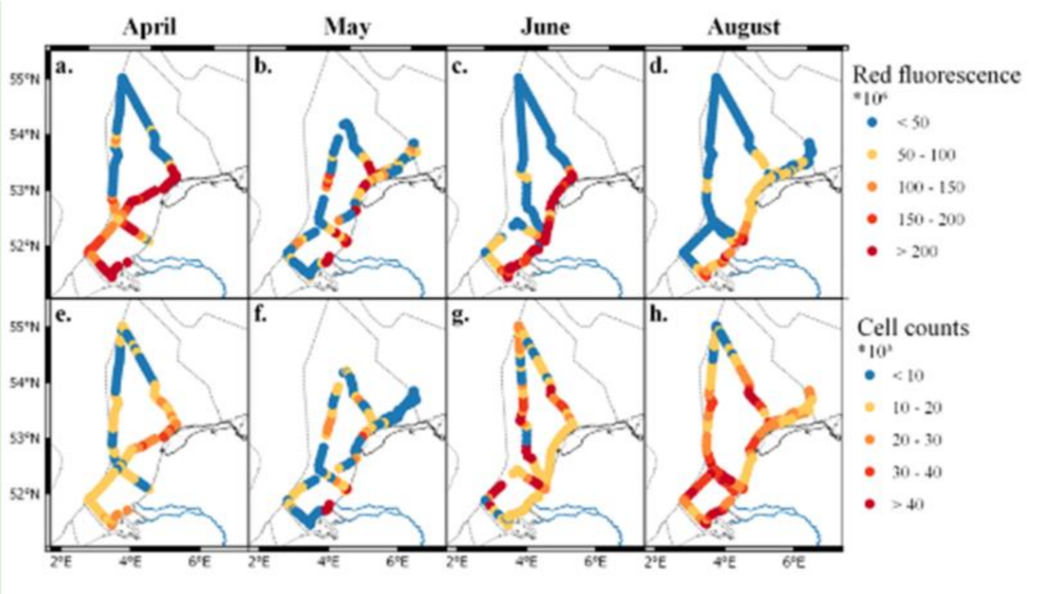


Figure 3.2-5 Continuous recording of in vivo chlorophyll a fluorescence and chl a with the Hyperspectral Absorption sensor (HYAbs). Discrete measurements with a PSICAM. RV "Heincke"

North Sea Seasonal phytoplankton dynamics (abundance and primary productivity (RWS, NIOZ)

In the frame of regular monitoring of the Dutch part of the southern North Sea, RWS operated, in collaboration with NIOZ, a field test of automated pulse shape-recording flow cytometer (PSFCM, Cytosense) and a Fast Repetition Rate fluorometer (FRRF) instruments., in preparation of routine monitoring as part of a Ferrybox system between Norway and the Netherlands.

Four seasons were sampled in 2017 (Aardema et al., 2018). Phytoplankton total abundance, red fluorescence and community composition showed high spatial heterogeneity in the Dutch North Sea from April to August 2017 (Fig. 3.2-5, Aardema et al., 2018). The relative abundance of picophytoplankton was generally higher offshore and in the northern part of the area.The pico-red group was always dominant even though they contributed less to total red fluorescence. The pico-Synechococcus group showed a strong numerical presence offshore in April and in most of the Dutch North Sea in June. The nano-red group was often a dominant group, both terms of cell abundance as well as for their contribution to total red fluorescence. The nano-cryptophytes were never abundant interms of abundance, but contributed to the total red fluorescence in the northern offshore regions. Notwhistanding microphytoplankton represented always less than 10% of the total cell numbers, they sometimes dominated the total red fluorescence, mostly in coastal regions (Figure 3.2-6; Aardema et al., 2018). Photosyhsiological parameters were addressed and gross primary productivity was estimated: it ranged from minimum values in June to peak productivities recorded in the coastal zone in May (Figure 3.2-7). Average GPP was highest in April (when spatial heterogeneity in GPP was low) and lowest in August (Aardema et al., 2018).



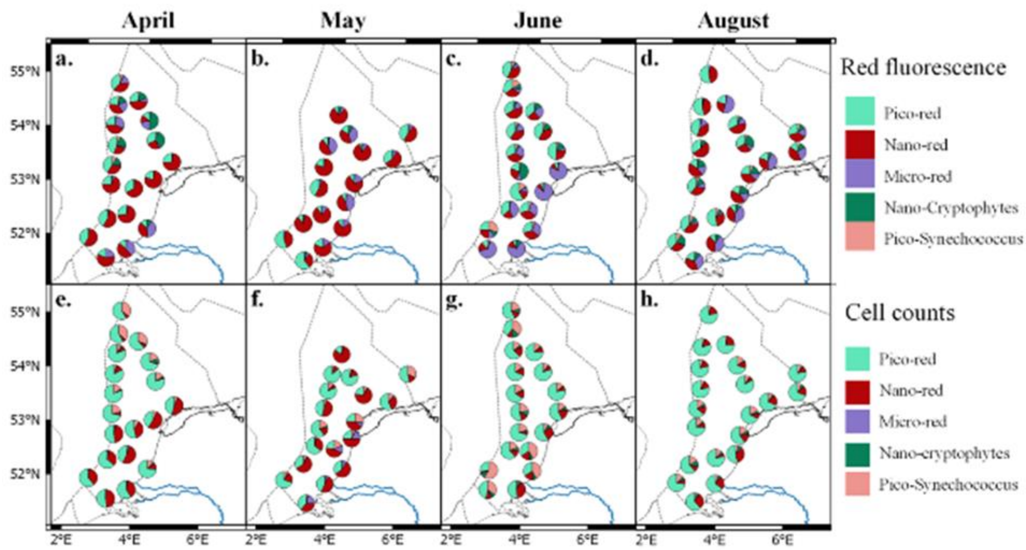


Figure 3.2-6 Use of automated Flow Cytometry to address phytoplankton functional/size groups spatial and temporal distribution in the S. North Sea (RWS cruise, Aardema et al., 2018). From top to botoom : Total Red Fluorescence (proxy of chl a, 10), Cell counts, Contribution of each of the 5 cytometry classes to total reed fluorescence and to total cell counts.

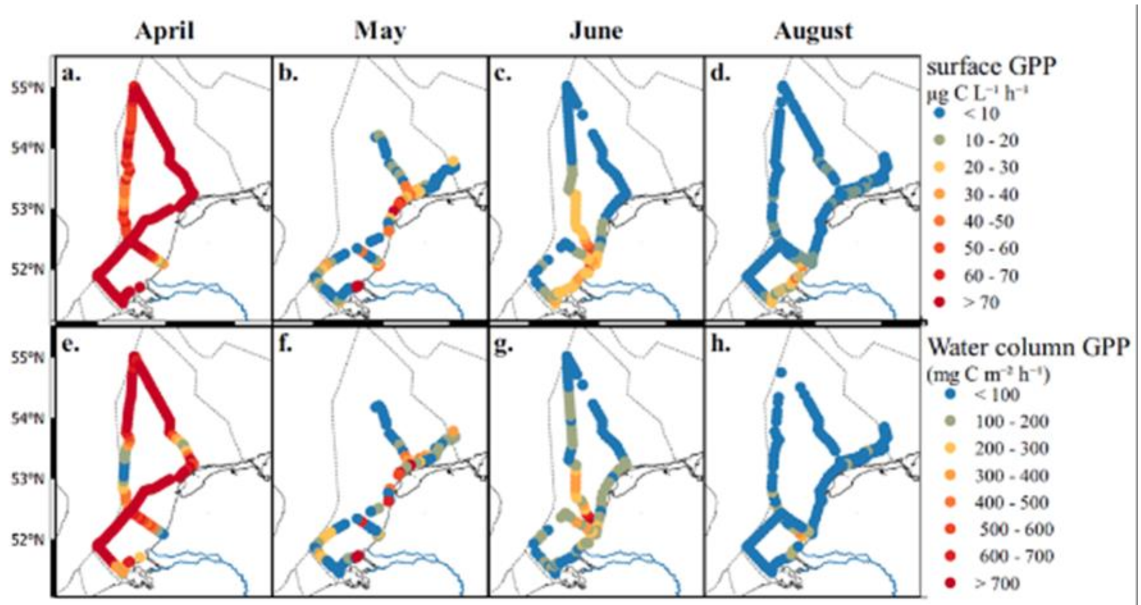


Figure 3.2-7 Estimations of seasonal surface and water column Gross Primary Productivity of phytoplankton from continuous and discrete measurements with a Fast Repetition Rate fluorometer (FRRf). in the S. North Sea (RWS cruise, Aardema et al., 2018)

3.2.4.2. Field measurements with automated systems from the western English channel to the southern North Sea

Phytoplankton spring blooms from the eastern English Channel to the southern North Sea (CNRS-LOG, VLIZ, IFREMER, RWS)

Three research cruises (PHYCO - CNRS-LOG, Lifewatch-VLIZ and RWS), from April 20 to May 19, 2017).were carried out from eastern English Channel to the southern North Sea at an interval of one week, in order to follow the progression towards the North of the Phaeocystis globose bloom from late April to mid May 2017. In addition, three pulse shape-recording FCM were used in parallel during the JERICO-NEXT - LifeWatch cruise of VLIZ in early May 2017. Each FCM captured the same trend in the total phytoplankton concentration. We aimed at quantifying the spatial dynamics of phytoplankton in the southern North Sea based on abiotic measurements and phyto- and zooplankton measurements by different sensors (automated FCM, FlowCAM, pigments, NGS, Zooscan), and investigating the spatial distribution of the phytoplankton communities from picophytoplankton to microphytoplankton.

The multi-spectral fluorometer Fluoroprobe (bbe Moldaenke) revealed the heterogeneity of 4 phytoplankton spectral groups: BlueGreen algae (phycocyanin containing), Brown algae, *Phaeocystis globosa* (thanks to the implementation of a dedicated fingerprint for Haptophytes; Houliez et al., 2012) and Cryptophytes (Phycoerythrin containing). It was possible then to estimate the absolute and relative contribution of each group to the total chlorophyll *a* equivalent. *P. globosa* was dominant in the brackish coastal waters except in the Thames estuary and the Bay of Seine, where brown algae (mainly diatoms) dominated. Highest concentrations of chlorophyll *a* were reported around brackish waters from the Bay of Somme to the Dutch estuaries.

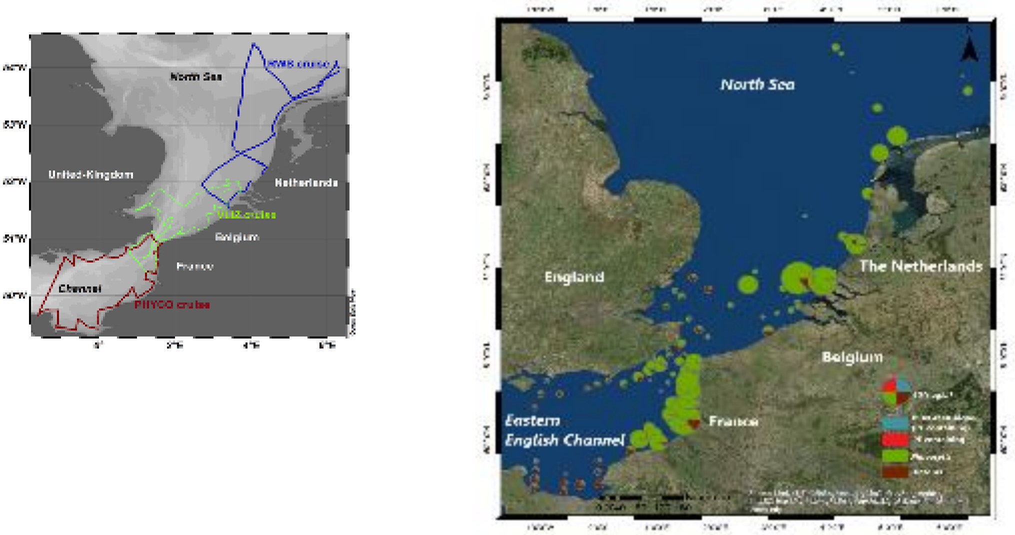


Figure 3.2-8: Chlorophyll a equivalents (total and per group, right) addressed by multispectral groups (Fluoroprobe bbe Moldaenke) : Haptophytes, brown algae, phycocyanin and phytcoerythrin) assessed from the eastern English Channel to the North Sea during the 2017 spring bloom cruises: PHYCO-"Côtes de la Manche" R.V. (CNRS-LOG), Lifewatch-"Simon Stevin" R.V. (VLIZ) and "Zirfaea" R.V. (RWS).

The high frequency of acquisition performed by automated pulse shape-recording flow cytometers made it possible to detect and characterise the patchiness of phytoplankton groups (here, two potential HAB micro-algae, *Phaeocystis globosa* and *Pseudo-nitzschia spp*., Figure 3.2-9) at sub-mesoscale from the eastern English Channel to the southern North Sea.

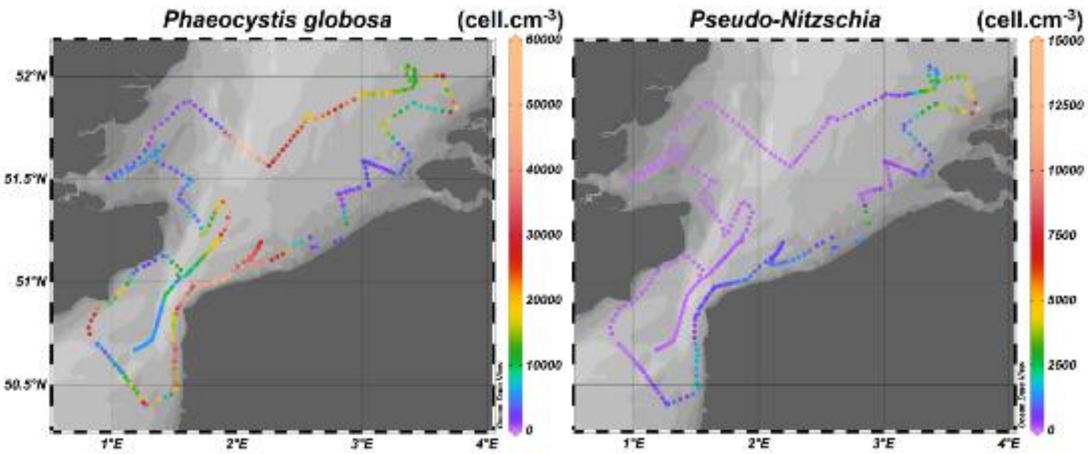


Figure 3.2-9 : Spatial distribution of Phaeocystis globosa and Pseudonitzschia spp. characterized from the eastern English Channel to the southern North Sea, during the Lifewatch- VLIZ -cruise (May 2017).

Recent work on vocabulary standardization made it possible to discriminate at least six phytoplankton groups: *Synechococcus*, Eukaryotic Picophytoplankton (Picoeukaryotes), Eukaryotic Nanophytoplankton (Nanoeukaryotes), Coccolithophores, Cryptophytes and Microphytoplankton. However up to 13 groups could be discriminated in spring 2017, including different phases of the *Phaecosytis globosa* life forms (within the Red Nanoeukaryotes) and the genus *Pseudo-nitzschia.*

Through the three spring cruises (Figure 3.2-10), waters under direct brackish influence were dominated by nanophytoplankton groups (and microphytoplankton), whereas offshore waters and other coastal waters were dominated by pico-eucaryotes, *Synechococcus*-like (and Nano-SWS coccolitophore-like). As already noticed in previous high frequency cruises (Bonato et al., 2015), eukaryotic nanophytoplankton groups were dominant in the eastern English Channel, especially in the brackish waters (i.e. "Coastal flow") as well as off most French, English, Belgian and Dutch estuaries, whereas eukaryotic picophytoplankton groups were mostly dominant along the English coast and offshore the southern North Sea. Sharp variations and amplitudes of the abundance and the total red fluorescence (proxy of chlorophyll *a*) occured often and quickly along the cruise. Despite, a dominance of eukaryotic nanophytoplankton in terms of abundance, the contribution of microphytoplankton of the total red fluorescence was the highest (Figure 3.2-11).

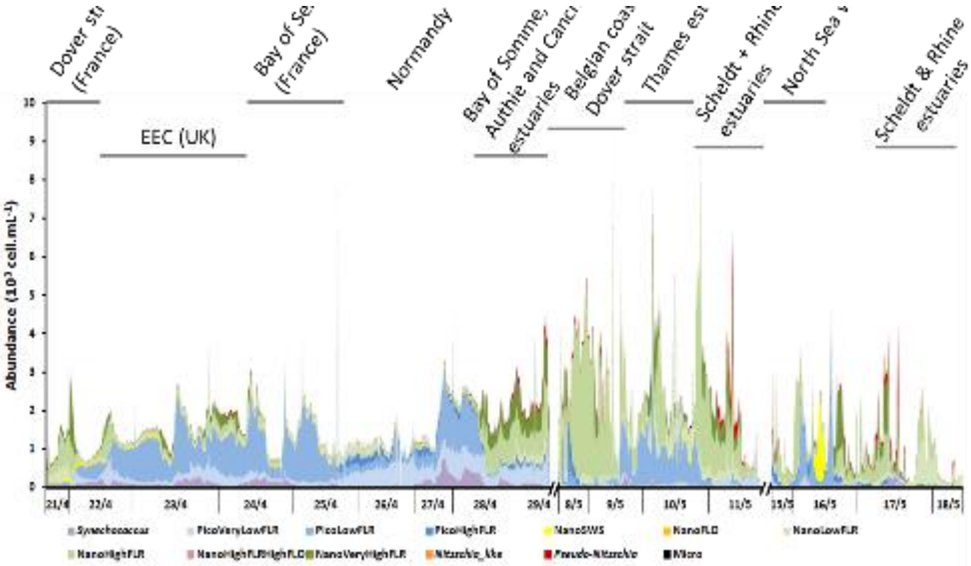


Figure 3.2-10 Continuous recording of phytoplankton functional groups by automated pulse shape-recording flow cytometry during the spring bloom development from South to North: PHYCO (CNRS-LOG), Lifewatch (VLIZ) and RWS cruises (April-May 2017)-Louchart et al., in prep.

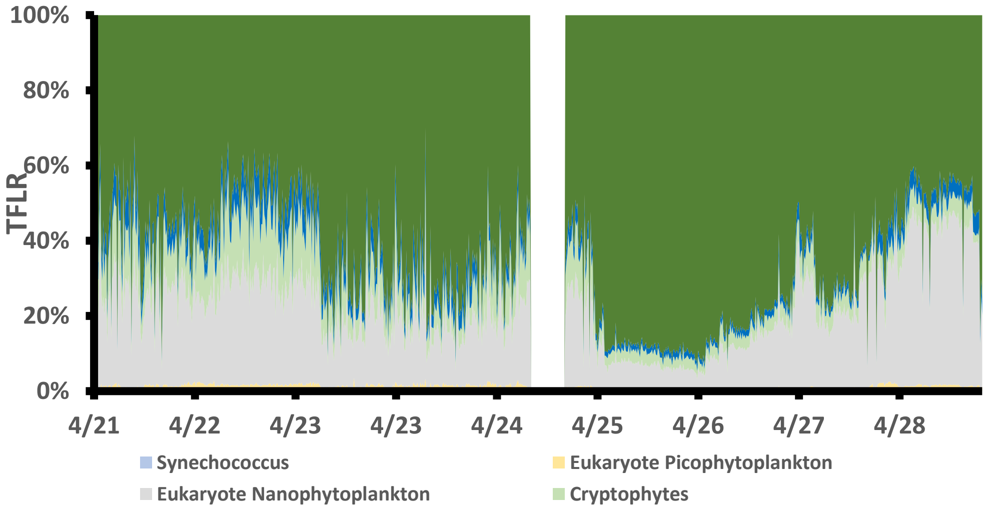


Figure 3.2-11 Continuous recording of phytoplankton functional groups by automated pulse shape-recording flow cytometry expressed ias a cumulative % of total red fluorescence (TFLR) as a proxy of total chorophyll a (phytoplankton biomass), during the PHYCO (CNRS-LOG) cruise in the eastern English Channel.

Phytoplankton Photosynthesis in the English Channel

Four 2017 joint JERICO-NEXT cruises were a unique opportunity to create a reference database about vertical profiles of the new FRRF machine of Chelsea group (Ltg) and compare results gathered with different light excitation protocols (using or not 3 different wavelengths) of measurements and GPP (Gross Primary Production) computations in very contrasted waters in the area. The first task was to compare protocols and algorithms of GPP computation for different waters dominated by different phytoplankton groups: picophytoplankton, diatoms and/or *Phaeocystis globosa* in the eastern English Channel and the southern Bight of the North Sea; and cyanobacteria / diatoms / dinoflagellates in the Baltic Sea (see section 3.4).

As an example of contrasted waters investigated by the FRRF profiler, the figure 3.2.11 shows a map of the euphotic depth (depth of 1% of surface light intensity) computed with PAR measurements during the early May Lifewatch-VLIZ cruise. The euphotic depth varied from 1m to 18m in such a restricted area.

.

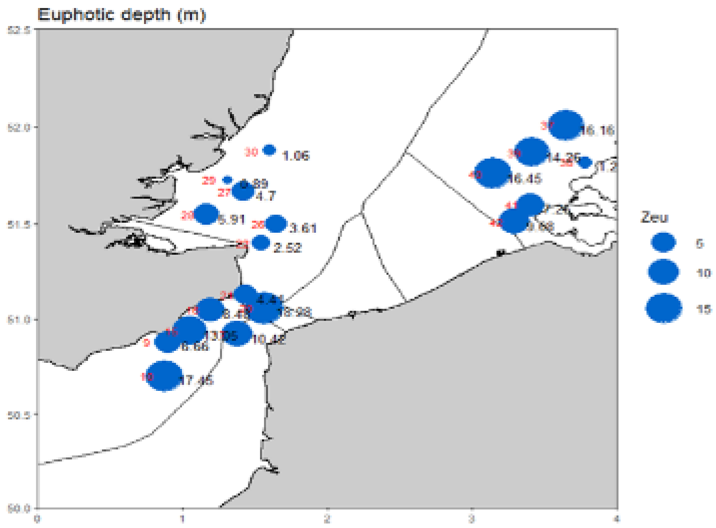


Figure 3.2-12 . Spatial variation of euphotic depth (m-1) computed from FRRF PAR sensor during theLifewatch-VLIZ cruise in April 2017 where FRRF profiles have been made during the day

The FRRF measurements were related to changes into taxon physiology on which is superimposed a variability due to fast photoregulation, photoacclimation occuring at more or less daily time scale and stress due to high light and low nutrient concentrations. In 2017 more than 125 FRRF profiles were performed in mixed waters as well as in stratified waters off the Thames, Schelde and Rhine estuarine waters, in parallel to light quality measurements (red-blue and green light ratio).

The figure 3.2.12 display a vertical FRRF profile for a mixed water column performed during the VLIZ cruise, that can be compared with the profiles realized in stratified waters of the Baltic Sea (see § 3.4.4, and Figure 3.4-5). We can notice on the two figures that the CV (%) for each physiological microalgae parameter are lower in most mixed waters of eastern English Chanel and North sea than in Baltic Sea waters. However, these parameters in mixed waters are globally greater than expected for such a station in the middle of the Strait of Dover (English Channel). The coefficients of variation (CV) varied from 16 to 65 % at station BY15 of the Baltic Sea and from 10 to 45 % at station n° 20 in the Strait of Dover. However, greater CV values are not observed for the same parameters between the two contrasted systems. Effective quantum yield displayed a greater vertical variation (a factor 2) in the Strait of Dover than in stratified waters of Baltic Sea. It is the opposite for the Reaction Center II (RCII) concentrations between the two systems.

Such results are related to different species and hydrological structure of the water column but could also be related to different photo-acclimation processes occurring in the light gradients.

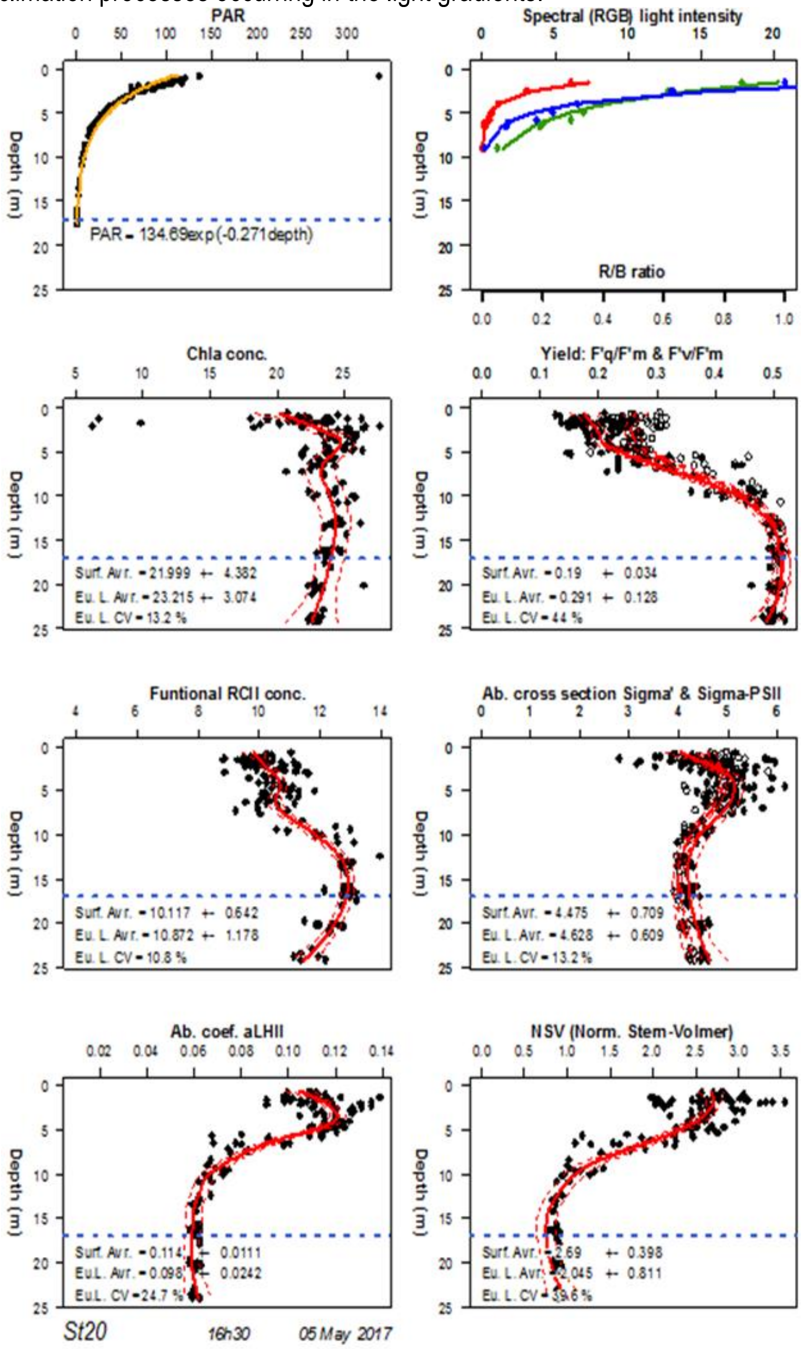


Figure 3.2-13: FRRF vertical profile performed during the VLIZ cruise in the middle of the Strait of Dover (may 5 2017, 4h30 p.m.), displaying light intensity and quality (λ for blue, green and red wavebands); the effective and pseudo-maximum PSII quantum yield (YPSII and F'v/F'm rel. unit), absorption cross section of PSII (σ ' and σ PSII in nm2.PSII-1), photoinhibition (NSV rel. unit), reaction centre concentration (RCII in nmol PSII.m-3), absorption coefficient of PSII light harvesting (aLHII in m-1) with Euphotic Depth (blue line) and Chla (mg.m-3) vertical profiles. CV mean coefficient of vertical variation (%) are computed across the euphotic layer (EU. L.), parameter averages (Avr.) are computed for surface layer (between 1

and 3 m) and for the euphotic layer. Red lines are vertical tendency and confidence intervals (95%) obtained by LOESS model with R.

In conclusion, a detailed study of these FRRF profiles needs to be carried out in order to compare vertical regulation and or photoacclimation processes of phytoplankton for contrasted waters columns/ecosystems: from permanently stratified waters, occasionally stratified and mixed water columns in order to better understand physiological plasticity of phytoplankton in relation with stability factors of waters, taxonomy, nutrient concentrations, light intensity and quality all along the water column.

On the other hand, a FRRF was also implemented in the SMILE buoy (CNRS-BOREA, IFREMER) and tests were carried out during 2017 and 2018, making it possible to study the daily changes in photosynthetic parameters and estimated gross primary productivity in a site submitted to important (Seine River, local rivers) estuarine inputs.

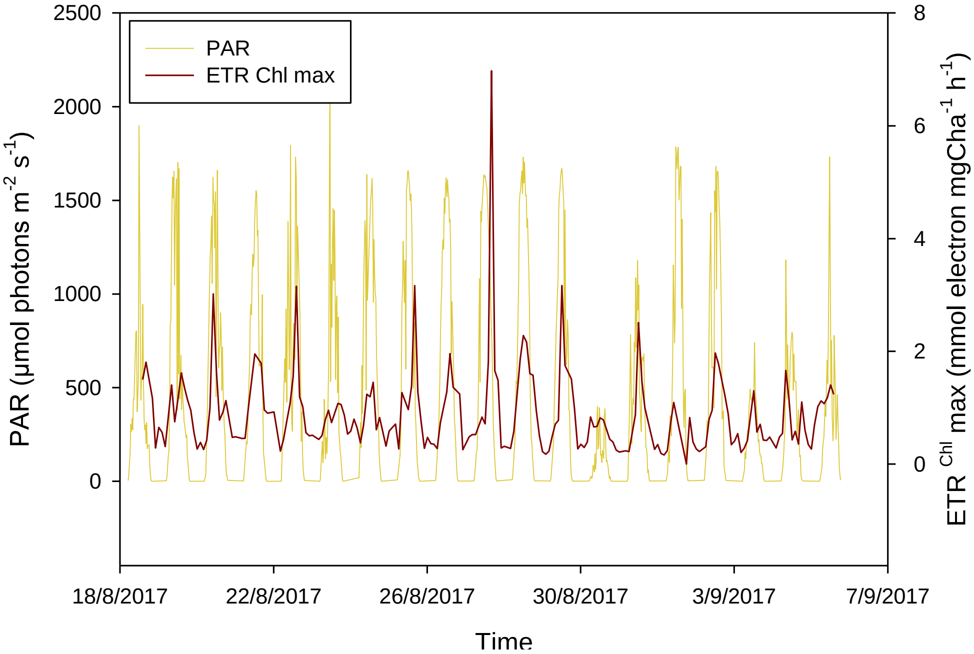


Figure 3.2-14: Continuous recording of Photosynthetic Available Radiation and Maximum Photosynthetic Capacity (ETR^{chl} max) in the SMILE Buoy during summer 2017. Bay of Seine.

Phytoplankton spatial distribution at high resolution, from the Western Channel to the North Sea (Cefas, CNRS-LOG, CNRS-SBR, IFREMER)

Between 2010 and 2015 (JERICO-FP7), air-sea fluxes of CO2 in the Western English Channel were addressed (CNRS-SBR) based on FerryBox systems installed onboard the Armorique and Pont-Aven Ferrys. These ferries mainly covered the Roscoff-Plymouth and Roscoff-Cork lines. Several papers by Marrec et al. (2013, 2014, 2015) demonstrated the importance of thermal fronts in the differentiation of various water masses in the area and their impact on regional air-sea CO2 fluxes.
During the JERICO-NEXT project, only one line (Roscoff-Plymouth) was still running and mainly during Summer. In parallell, a Buoy was implemented with automated sensors (the ASTAN buoy off Roscoff) to assess the impact of tidal, diurnal and seasonal biogeochemical process on air-sea CO2 fluxes in the area and compare those results to the one obtained in the previous 5 years with the Ferryies. The data (SST, SSS, DO, Fluorescence, pCO2) collected at the ASTAN buoy during the given period allowed us to assess the impact of local (tidal, diurnal, and short-scale processes) on the regional air-sea CO2 flux assessment. We identified a third nearshore water mass much more biologically

productive than the 2 waters masses (homogeneous vs stratified) identified in previous studies between Roscoff and Plymouth by Marrec et al. (2014). Statistical analysis by wavelet analysis on the high-frequency data allowed us to identified key seasonal pattern on the control of air-sea CO2 fluxes on the near-shore versus offshore water masses.
Automated systems for phytoplankton automated observation were implemented into fisheries cruises leaded by Cefas or IFREMER, in order to optimize the assessment of phytoplankton dynamics in such productive areas from the Celtic Seas to the Noprth Sea (trhough the English Channel). Indeed, in many commercially important species of fish, the timing and location of spawning is thought to be closely coupled to blooms in phytoplankton populations (Brander, 1994; Chambers and Trippel, 1997). This makes good sense for the fish: the main source of larval food is zooplankton, which in turn thrive in waters rich in their main food source, phytoplankton (James et al. 2003).

The western English Channel (WEC) and eastern Celtic Sea (ECS) contain a relatively high diversity of planktivorous pelagic fish species including sardine, sprat, horse mackerel, mackerel, herring and anchovy (Wallace and Pleasants 1972; Coombs et al. 2005), which spend part of their life cycle in the area. Sardine, sprat and herring are found here throughout the year including during spawning time (Bréchon et al. 2013), and their larvae and juveniles use the relatively shallow waters as nursery grounds. Whilst the main spawning area for horse mackerel and mackerel is further west (off the shelf edge), after hatching, the larvae drift onto the shelf into the coastal waters of the region (Jansen et al. 2015).

As a part of a multidisciplinary studies carried on for several years in Celtic Sea, Western Channel and North, JERICO-NEXT contribution in 2017 focused on determining the contribution of the different phytoplankton functional types alongside with physical, biogeochemical parameters and other biological compartments including zooplankton, fish, and mammals. Figure 3.2-14 & 3.2-15 showed the difference of temperature, salinity, turbidity and oxygen during the survey and the abundance and the relative contribution of the functional types of phytoplankton (Figure 3.2-14).
The measurements were carried on the RV Cefas Endeavour using a 4H-Jena FerryBox and a Cytosense automated pulse shape-recording flow cytometer (Cytobuoy b.v., Worden, NL) which were also been implemented into two surveys: same area as in Figures 3.2-14 & 3.2-15 in Western Channel and Celtic Sea and in North Sea on the eastern coast of England.

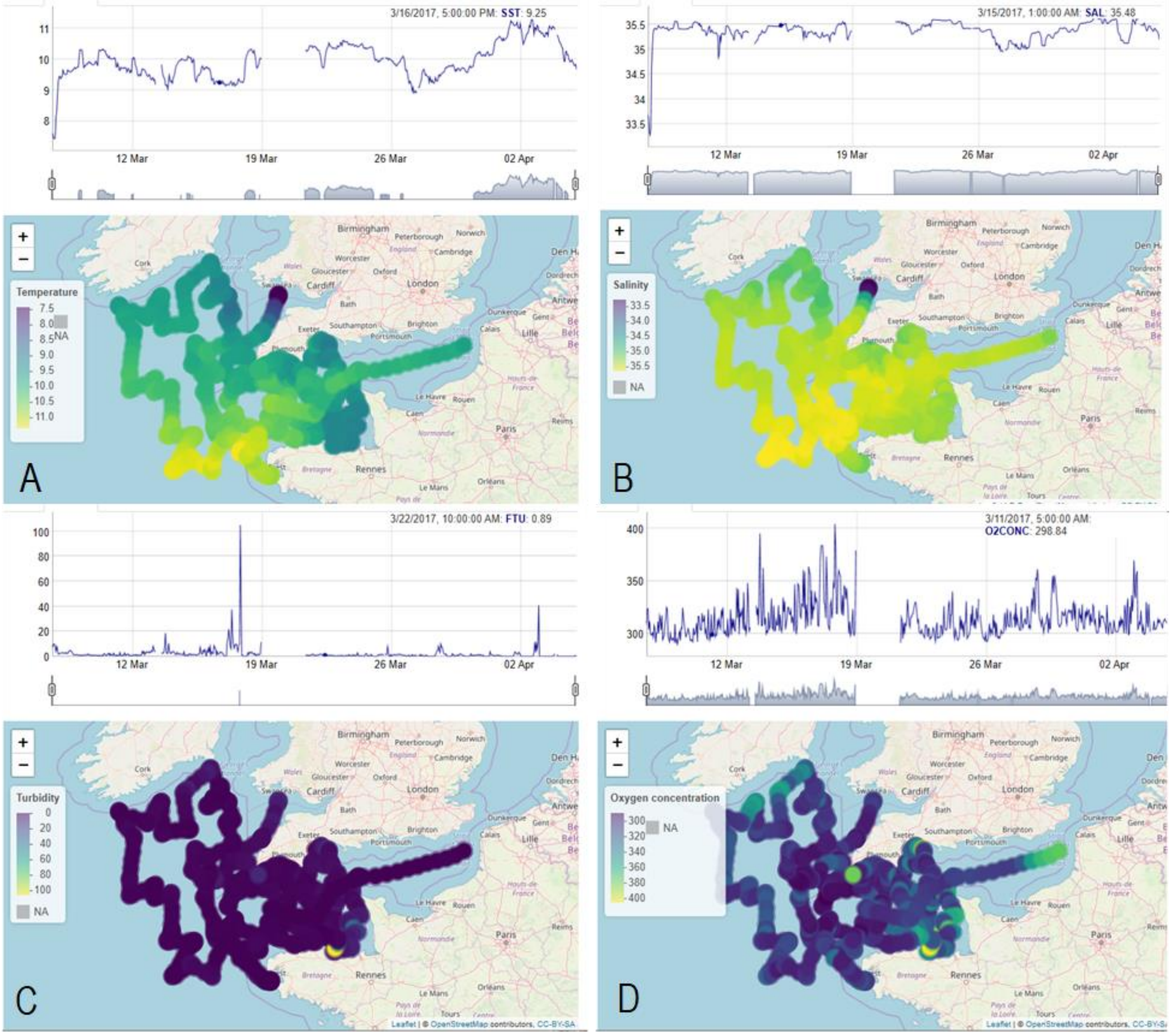


Figure 3.2-15: Salinity (A), Temperature (B), Turbidity (C), Oxygen concentration (D) during the The International Bottom Trawl Survey in March 2017.

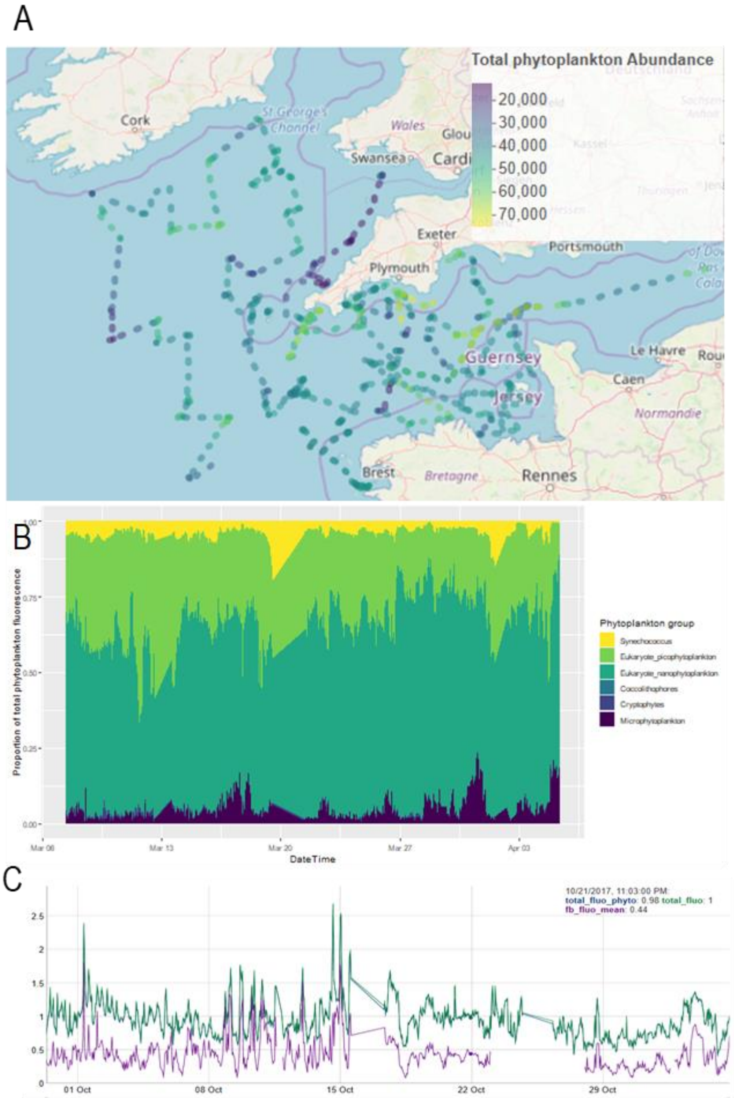


Figure 3.2-16: Abundance (A), and relative contribution of the functional types (B) to the total fluorescence (C) of phytoplankton during the The International Bottom Trawl Survey in March 2017.

Automated phytoplankton monitoring was also implemented during some French fisheries cruises as the CAMANOC cruise (mid-September-mid-Ocober 2014) from Celtic Seas and Western English Channel (WEC) to the Eastern English Channel (EEC) and the Bay of Seine (BOS). Continuous recording evidenced thermo-haline structures as fronts and gradients conditioning the distribution of phytoplankton groups defined by automated pulse shape-recording flow cytometry. As an example, Synechococcus spp. (picocyanobacteria) abundance showed great patchiness by and between frontal systems (Figure 3.1-14). At the opposite size class, microphytoplankton showed also higher abundance by the thermal front (Louchart *et al.*, submitted).

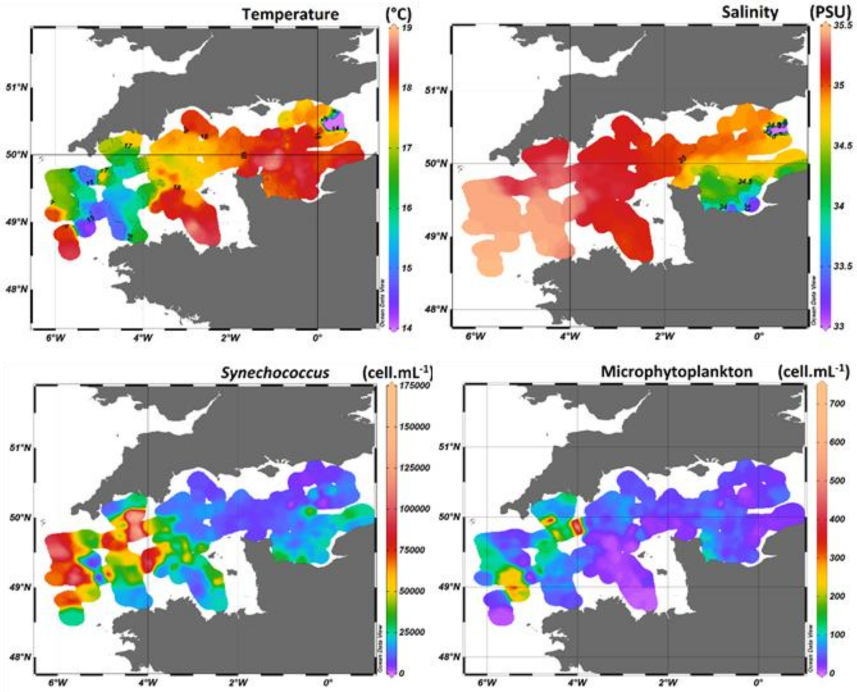


Figure 3.2-17 Spatial distribution of temperature (A), salinity (B), Synechococcus-like (picocyanobacteria; C) and microphytoplankton (D) addressed by automated pulse shape-recording flow cytometry during the CAMANOC cruise (IFREMER, September-October 2014).

Moreover, the spatial distribution of microphytoplankton taxa was also addressed by automated image acquisition (FlowCAM) within the CAMANOC fisheries cruise at some discrete stations from the Western to the eastern English Channel (central part) and the Bay of Seine. Three geographical areas were highlighted by applying the Partitioning Around Medoids (PAM) algorithm on taxa abundance (Figure 3.2-18): the Western English Channel (WEC) essentially characterized by diatoms (mainly of genus Guinardia, Leptocylindrus and Rhizosolenia), the Eastern English Channel showing high abundance of dinoflagellates (*Prorocentrum*) and haptophytes (*Phaeocystis globosa*), the Bay of Seine where the highest abundance of diatoms was detected (*Chaetoceros*, *Leptocylindrus* and *Pseudo-nitzschia*). These estimations were consistent with the variability of microscopic counts but total numbers were underestimated (mainly because of the presence of colonies which are considered as one single particle).

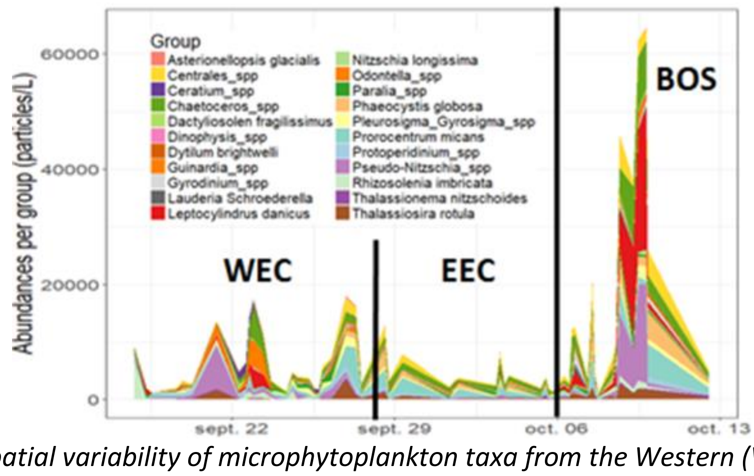


Figure 3.2-18: Spatial variability of microphytoplankton taxa from the Western (WEC) to the Eastern English Channel (EEC) and the Bay of Seine (BOS), addressed in discrete samples by FlowCAM image acquisition, during the CAMANOC cruise (IFREMER, September-October 2014)

3.2.4.3. Development or update of numerical and modelling tools for automated measurement systems

Development of a numerical tool with R software.

- Development of R tools were made to manage data from Pocket Ferry Box or Ferry Box with other sources (on board data, additional devices,...) (Figure 3.2-19)

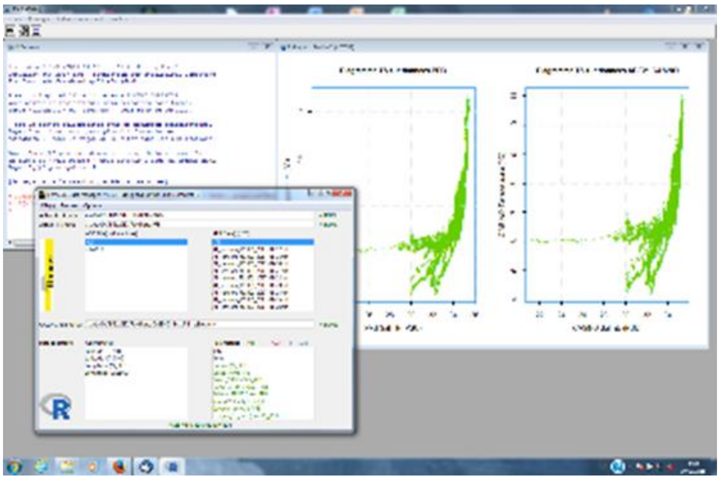


Figure 3.2-19. Screenshot for the Ferry Box Data Management (FBDataM) R interface. Example of Temperature / Salinity diagrams from the Pocket Ferry Box and from the Seabird 21 (RV "Thalassa" Genavir/Ifremer).

- Moreover, developments of R data processing interface were achieved in order to generate statistical diagnostics and propose a synoptic view of the main hydrological parameters, phytoplankton biomass and spectral groups (Figure 3.2-16) collected during Ferry Box equipped cruises.
- Finally, the development of an Unsupervised spectral classification of environmental status and of the dynamics of phytoplankton blooms in the eastern English Channel.

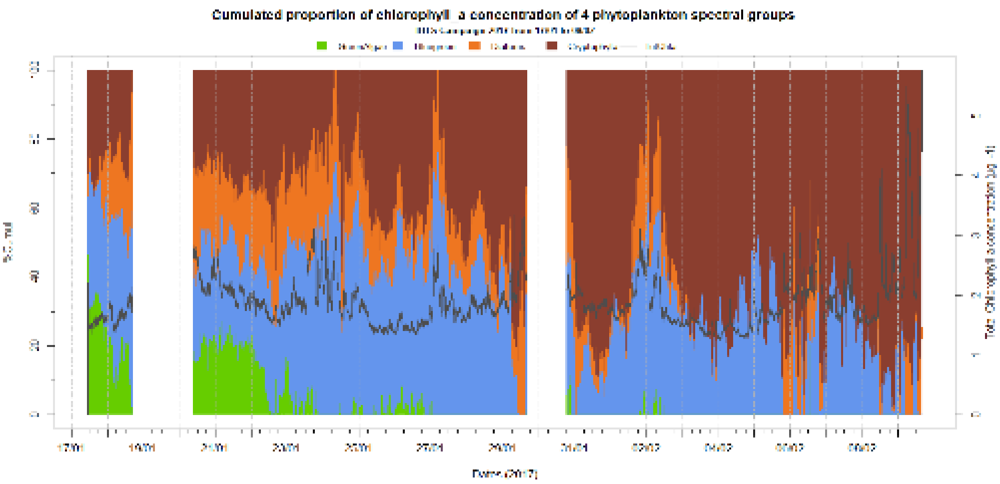


Figure 3.2-20: Time series of chlorophyll-a concentration as estimated by the Algae Online Analyser (bbe) (eq. µg Chla. l-1) (right axis) and relative proportion of each spectral groups: Green, Blue-Green, Brown and Cryptophyta in AOA total chlorophyll-a fluorescence (%) (left axis) during the IBTS 2017 cruise (Ifremer) on the RV Thalassa. Figure generated via the FBDataM R interface.

High Frequency Technology

In order to strengthen the monitoring capacities (High Frequency, mesoscale approach) in the English Channel and North Sea (and also in other marine areas), the RV Thalassa (Ifremer/Genavir) was first equipped with a Ferry Box (FB, 4H-Jena) at the end of 2017. This implementation follows a test phase which has been engaged in 2014 with the implementation of a Pocket Ferry Box (PFB) combined with a flow cytometer and a spectral fluorometer during the DYMAPHY 2012 (Lefebvre and Poisson-Caillault, 2019) and CAMANOC 2014 cruises (Louchard et al., In prep.) then during the following IBTS and CGFS cruises.

The whole implementation procedure (including installation, quality control and assurance,…) is now available (in French) following https://doi.org/10.13155/59685.

In 2018, the RV Thalassa sailed ~245 days and the Ferrybox was running 229 days (Operational ratio: 93%)

Considering the Thalassa's path in 2018, it is noteworthy that all European cruises are renewed year after year since 20 years at the same period on the same transect, and it will bring a huge FB data set in the coming years (Figure 3.2-21).

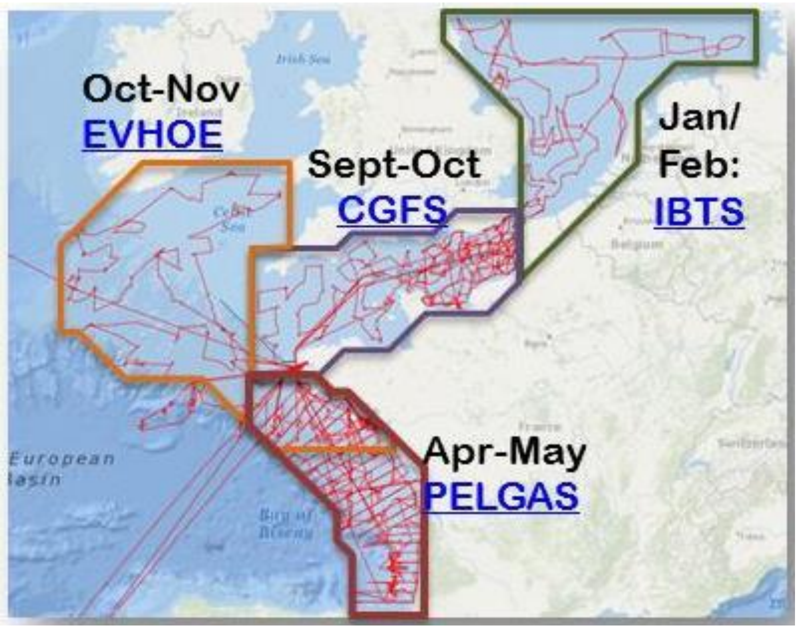


Figure 3.2-21 Main RV Thalassa's path in 2018 – Overview of the potential Ferry Box database available over the long term.

In 2018, a special technical cruise onboard the RV Thalassa (ESSTECH 2018) was planned in April in order to control and to validate High Frequency results from the Ferry Box and the Pocket Ferry Box when compared to in situ conventional results. Water samples collected from the outlet of the FB and the PFB and from a Niskin bottle were analysed and compared using spectrophotometry (chlorophyll-a concentration), HPLC (pigment content) and phytoplankton counts (inverted microscopy, phytoplankton identification and abundance).

Main physico-chemical parameters measured both by the FB and the PFB were also compared (Figure 3.2-22).

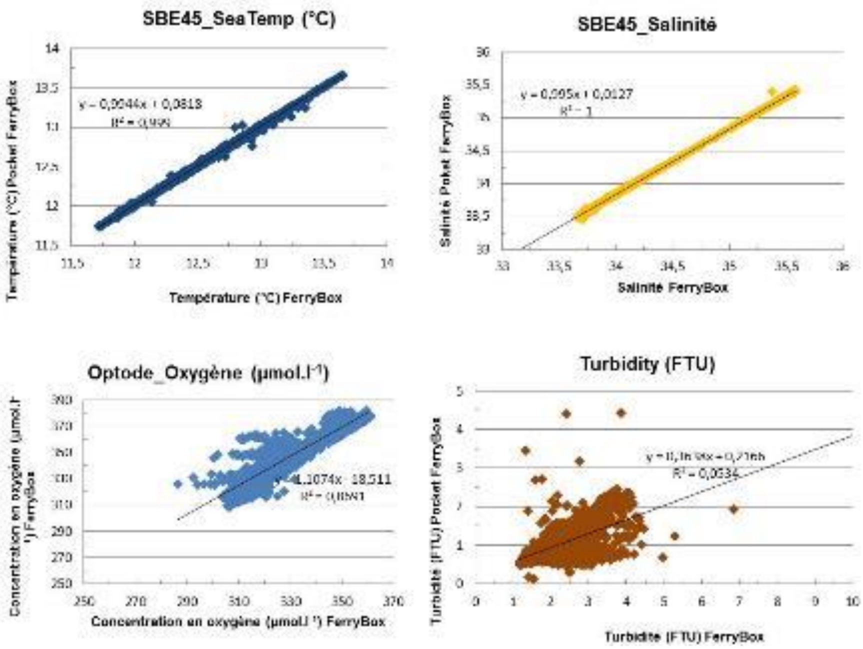


Figure 3.2-22 Comparison of the main physico-chemical parameters measured by the Ferry Box and the Pocket Ferry Box during the ESSTECH 2018 cruise onboard the RV Thalassa.

The same comparison was also applied to the multi-spectral fluorometer data (Algae Online Analyzer – AOA, bbe, Moldaenke) (Figure 3.2-23). The Cryptophyta spectral groups gives the worst results whereas the Brown (Diatoms) and Green results are coherent. Nevertheless, whereas the qualitative dynamics of the signal is comparable, some discrepancies appeared from the quantitative point of view.

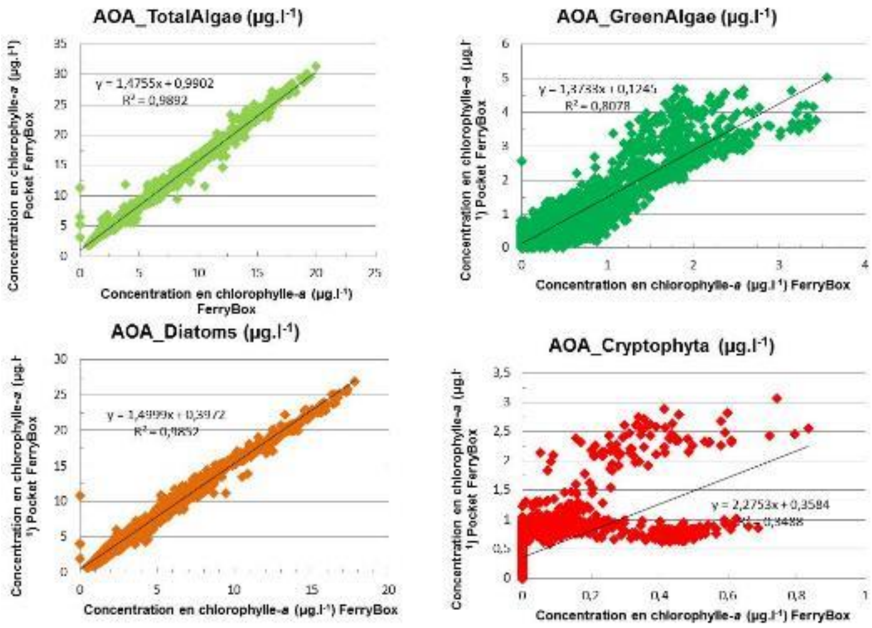


Figure 3.2-23 Comparison of the spectral fluorometer (Algae Online Analyzer) results from the Ferry Box and the Pocket Ferry Box during the ESSTECH 2018 cruise.

FB and PFB Data analysis using spectral classification (uHMM tool) allows to discriminate several ecoregions with specific physico-chemical and biological signatures (Figure 3.2-24). The classifier allows to define in near real-time these regions based on a specific combination of a multi-parameter database in the spectral space: Groups 1 to 5 correspond to typical coastal, intermediate and offshore waters. They are automatically identified without any *a priori* knowledge from the expert.

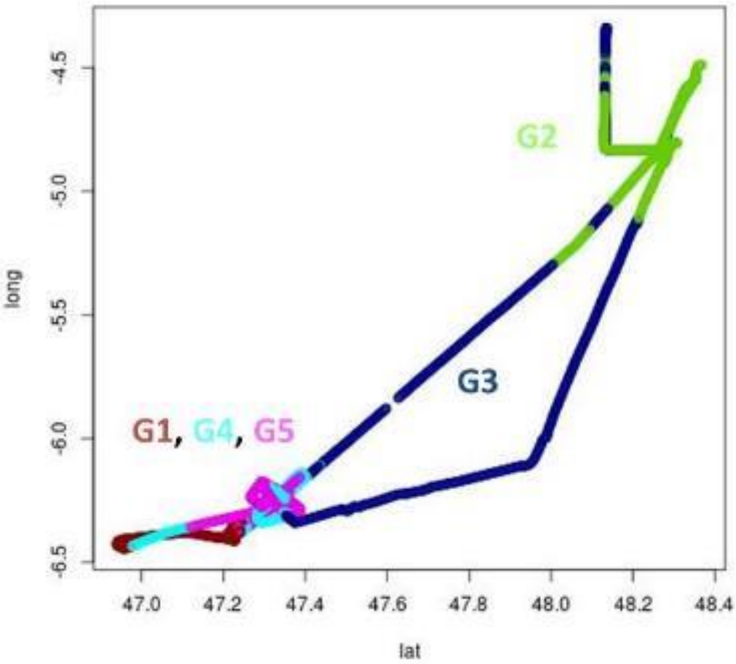


Figure 3.2-24 Characterization of different ecoregions (G1 to G5) from Ferry Box Data during the ESSTECH 2018 cruise using spectral classification (uHMM tool).

Update of modelling tool ECO-MARS3D

In order to better assess the English Channel ecosystem dynamics, we initiate lately in the project a modelling activities. The objectives were to update the model considering new knowledge gained through in situ sampling strategy and to propose some development considering some HAB genera (*Pseudonitzschia*, *Karenia* and *Phaeocystis*). A first task was to update the French ECO-MARS3D model for the recent years (2011 to 2018) in order to use it every future year to compute maps of classical eutrophication descriptors. This model based on the IFREMER's MARS3D hydrodynamical code (Lazure and Dumas 2008) uses a regular grid with 4x4 km meshes and 30 sigma levels covering the Bay of Biscay, the English Channel and the southern part of the North Sea, up to the Rhine estuary. Up to now, the validation of the biogeochemical art has been done on the 2000-2010 period only (Ménesguen et al., Ocean modelling, accepted). The main deliverables will be yearly maps of DIN and DIP winter means, 90th percentile of total surface chlorophyll and 10th percentile of summer bottom dissolved oxygen. A second task was to use the computed dilution plumes of the 45 most important French rivers to compute the expected DIN and DIP marine distributions. Thanks to a statistical relationship between usable nutrients (i.e. DIN and DIP respecting the Redfield ratio, equal to 16), local turbidity, depth of mixed surface layer and residence time, the expected 90th percentile of chlorophyll will be computed. Putting a linear approximation of this relationship in a Simplex method will finally allow computing the set of lowest reductions to recommend DIN and DIP concentrations of each French river, in order to reach everywhere the GES for total marine chlorophyll.

3.2.4.4. Satellite products

JRAP#1 strategy was also completed through the use of remote-sensing data to provide an effective mesosccale water-quality monitoring systems (Gohin et al., 2002, 2008). We expect a better surveillance of the coastal waters in term of eutrophication risk and HAB identification by using satellite data. Complementary to *in situ* data, we used daily interpolated multi-sensor OC5 Chl-a for assessing the concentration and trend of the phytoplankton biomass (Figure 3.2-25).The seasonal distribution of Chl-a and its change over time were observed from both in situ and satellite observations at stations characteristic of the coastal waters from the northern Bay of Biscay to the eastern English Channel (Gohin et al., in rev.).

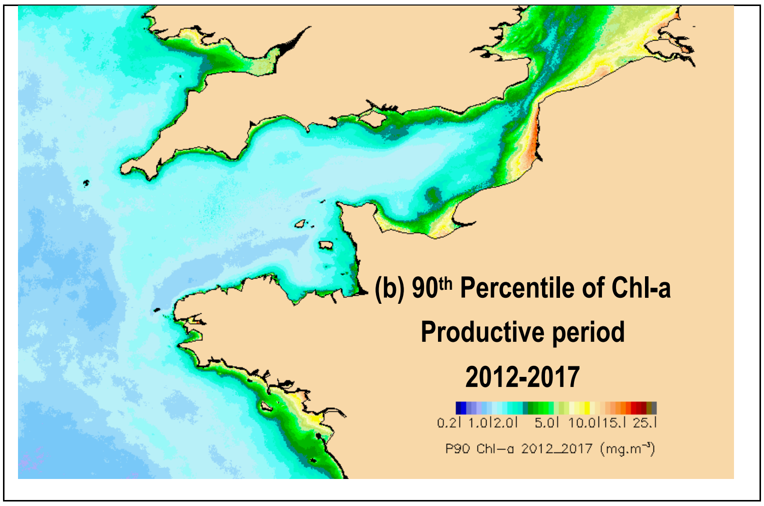


Figure 3.2-25: Satellite products of the 90th percentile of Chlorophyll-a during the period 2012-2017 in the English Channel and southern bight of the North Sea (Gohin et al., in rev.)

3.2.4.5. Characterization of phytoplankton diversity, productivity and dynamics

Synoptic view of hydrological and biological conditions in the English Channel

Based on numerical developments, a proof-of-concept to characterize simple phytoplankton communities using high resolution measurement devices when coupled to an optimized numerical methodologies for data processing (spectral clustering) was proposed by Lefebvre and Poisson-Caillault (2019). The following objectives have been reached:

(1) Considering numerical methodological development issues, we tested the performance of several unsupervised classification methods (Figure 3.2-18) in order to propose the most optimized one to comply with label-specific environmental conditions as a way to discriminate phytoplankton spectral groups and associated hydrological conditions;

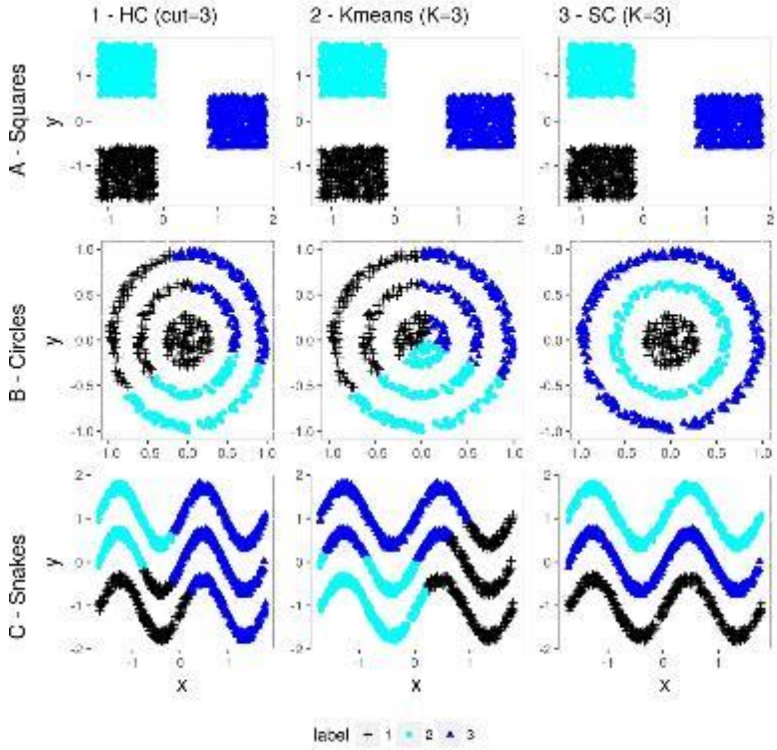


Figure 3.2-26 Comparison of the performance of clustering algorithms (1-Hierarchical Clustering, 2-Kmeans, 3-Spectral Clustering) on artificial data differently structured in the classification space: (A) three compact square-shape clusters, (B) three clusters with one disk surrounded by two circles and then (C) three streamers with point-to-point connectivity

(2) From an ecological viewpoint, we characterized high resolution spatio-temporal variability of phytoplankton spectral fluorescence in a temperate, well-mixed open coastal system (Figure 3.2-27). We also studied the relationships between multi-spectral fluorescence and major abiotic variables in order to evaluate the usefulness of such techniques to identify environmental conditions, eco-regions, and the main factors controlling phytoplankton structure, as well as direct and indirect effects of blooms events on ecosystems, making a link with eutrophication and HAB issues. Considering the complex hydrodynamics of the studied area and the specificity of such an environment partly dominated by the Prymnesiophyceae *Phaeocystis globosa* in spring, we verified that there were (i) a high spatio-temporal variability of phytoplankton spectral fluorescence and total chlorophyll a (chl a) concentration, and (ii) a strong difference in phytoplankton fluorescence signatures between UK and French waters;

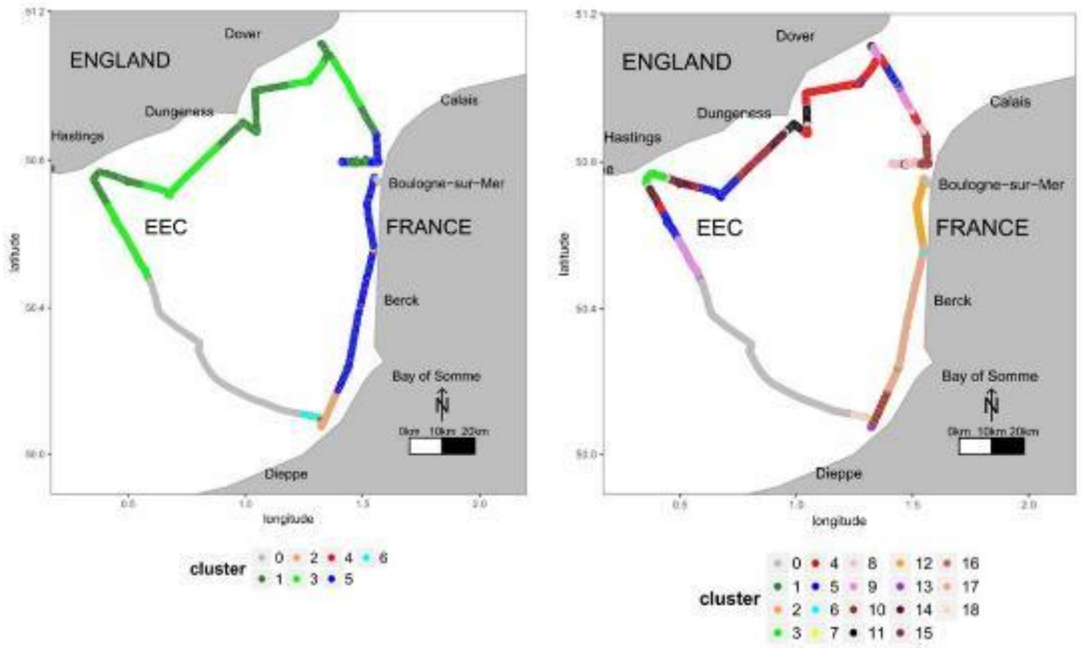


Figure 3.2-27 Temporal and spatial view of the resulting clusters of Leg 2 by spectral clustering for K=6 (left hand side) and K=18 clusters (right hand side)

(3) From a technical viewpoint, we identified advantages and drawbacks of multi-spectral fluorometry, using a limited number of phytoplankton spectral groups, as a preliminary approach.

3.2.5. *Synthesis and way forward*

3.2.5.1. Synthesis and specific next steps

The North Sea-Channel area is a shelf system submitted to multiple sources of human pressure and contrasted hydrodynamical conditions (i.e. well mixed to temporary to permanently stratified areas, frontal systems) which makes it logical to have an international interdisciplinary approach at fine spatial and temporal resolution. The way to achieve this, is to combine i) innovative and reference techniques both on current monitoring of discrete stations as well as ii) in continuous automated measurements. The formers are performed on weekly to monthly basis in coastal areas or on dedicated cruises in the whole or part of the English Channel-North sea area whereas the last are performed in cruises and ships of opportunity as ferrylines, in order to increase the spatial and temporal resolution of the surveys of the different eco-hydrodynamic regions of the area. Moreover, the combination of both continuous recording addressing spatial gradients in ships of opportunity and high-frequency measurements in fixed platforms and moorings, together with automated analytical tools, helps to improve our understanding of phytoplankton diversity and dynamics. It also improves understanding the triggering, extension and timing of phytoplankton blooms, and their relation to hydrodynamics, nutrients and C cycle, trophic interactions and anthropic pressure.

The implementation of innovative (semi-)automated techniques was effective. It was possible to compare these measurements with traditional laboratory analysis and to define the added value of these innovative techniques in terms of improving the spatial and temporal resolution (both in surface and in the water column), making it possible to consider functional and, sometimes, even taxonomical characterization of phytoplankton communities composition and photo-physiology at high resolution in almost real-time.

Some specific issues were addressed classified into two main categories (see below).

- A first set of considerations deals with strictly technological aspects (e.g., (1) the fact that some data need to be expressed in terms of cell abundance (which remains difficult for colonial species); (2) exchanges on the size and concentration resolution of optical techniques compared to classical microscopy analysis when assessing planktonic diversity, and (3) the fact that optical methods are complementary to imaging approaches in meeting OSPAR/HELCOM objectives when implementing the MSFD.

- A second set of questions deals with the nature of the technological conclusions originating from achieved work and their dissemination within an outside the JERICO-NEXT community. It was first underlined that due to the high diversity of tested/compared optical tools, clear recommendations have to be formulated towards potential scientific users. As for now, it appears that such recommendations would be context-dependent and that relevant information is already available on the JERICO-RI website and through a (still) limited number of publications. Moreover, newt steps clearly will include : (1) a strong interest/necessity of developing interactions with the remote sensing community, (2) discussion with the modelling community dealing with eco-hydrodynamic models and (3) to address clear recommendations on “what type of sensors to be implemented and where for resolving which questions”. This of course applies for all regions considered within the JERICO-Next project.

3.2.5.2. Specific developments for the future

At local or regional scale:

- According to the implementation made within JERICO-NEXT, it appears that a combination of sensors is requested to deal with phytoplankton dynamics in a determined area (depending on hydrodynamics, exposure, local issues)
- Morever,there is a need in applying common operational procedures in a common area for implementing automated sensors as pulse shape-recording flow cytometry, imaging in-flow, multi-spectral and variable fluorescence to address the dynamics of phytoplankton functional groups, physiology and estimated primary productivity.
- Some sensors can be implemented in an automated way on Reseach Vessels or ships of opportunity, some are still requesting the intervention of operators, which can be a remote process combined with non-specialist intervention in the platform.
- Automated machine learning and classification products were released
- There is a need to consider the vertical component of light and physiology in order to address properly the integrated primary productivity
- There is a need to couple phytoplankton dynamics and estimated productivity to pCO2 and O2 continuous recording systems (in order to address the main groups that are responsible for C uptake), as well as with nutrients automated sensors, in order to better address limitation issues for phytoplankton and, when possible, with also zooplankton estimates, in order to also approach the top-down control and the trophic connectivity with higher trophic levels.

At a larger scale:

- There is a need to improve the operability (procedures, data analysis, data vocabulary) and discrimination (classification tools) of automated techniques addressing phytoplankton dynamics & diversity (at low or high taxonomical and/or functional levels) and productivity, as well as their inclusion into general or specialized data bases, across the whole North sea and Channel scale.
- There is a need to improve the discrimination of taxa (images) and/or functional groups (automated flow cytometry, multi-spectral fluorometry) as well as the assessment of primary productivity from physiological photosynthetic parameters estimated *in situ*
- Even in “well mixed systems”, the vertical dimension needs to be addressed as well as the benthic-pelagic coupling

- A combination of physical/hydrodynamics, chemical and biological sensors in defined areas and platforms (fixed stations, ferry lines, research cruises) across the whole English Channel-North Sea systems is requested for better interpretations of the results gathered by automated phytoplankton sensors.
- We need to move towards a better assessment of the meaning of phytoplankton functional groups (through the definition and characterization of functional traits) and their contribution to primary productivity, for better integration into models, indicators assessment and calculations, as well as remote sensing products.
- Data flows need to be organised from raw sensor observations to analytical platforms and, further, to integrated coherent spatially resolving information products on the English Channel and North Sea, starting from basic parameters (physical, nutrients, light climate/ Kd, chlorophyll) to more in-depth understanding of phytoplankton abundance, biomass, functional/taxonomical diversity, size distribution, processes: primary production and carbon cycling, and consequences for higher trophic levels, including zooplankton. The integrated product should provide a good overview for MSFD, the scientific community and policy makers on trends in the English Channel and North Sea and likely causes and effects in the future.

3.2.6. *References for the Channel and North Sea*

Aardema, H. M., Rijkeboer, M., Lefebvre, A., Veen, A., and Kromkamp, J. C.: High resolution *in situ* measurements of phytoplankton photosynthesis and abundance in the Dutch North Sea, Ocean Sci. Discuss., https://doi.org/10.5194/os-2018-21, in review, 2018.

Bonato S., Christaki U., Lefebvre A., Lizon F., Thyssen M. & Artigas L.F. (2015) High spatial variability of phytoplankton assessed by flow cytometry, in a dynamic productive coastal area, in spring: the eastern English Channel. Estuarine Coastal and Shelf Science, 154: 214-223

Brander K.M., 1994. The location and timing of cod spawning around the British Isles. *ICES Journal of Marine Science*, 51: 71–89, doi.org/10.1006/jmsc.1994.1007

Bréchon A., Coombs S.H., Sims.D.W., Griffiths A.M. 2013. Development of a rapid genetic technique for the identification of clupeid larvae in the Western English Channel and investigation of mislabelling in processed fish products. *ICES Journal of Marine Science*, 70: 399–407, https://doi.org/10.1093/icesjms/fss178.

Chambers R.C., Trippel E.A., 1997. Early Life History and Recruitment in Fish Populations. Chapman and Hall, London.

Coombs S.H., Halliday N.C, Southward A.J., Hawkins S.J. Distribution and abundance of sardine (Sardina pilchardus) eggs in the English Channel from Continuous Plankton Recorder sampling, 1958-1980. Journal of Marine Biology, 85: 1243-1247.

Gohin, F., Druon, J. N., and Lampert, L., 2002. A five channel chlorophyll concentration algorithm applied to SeaWiFS data processed by Seadas in coastal waters, International Journal of Remote Sensing, 23, 1639-1661 doi:10.1080/01431160110071879.

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

Houliez E., Lizon F., Thyssen M., Artigas L.F., Schmitt F.G. (2012) Spectral fluorometric characterization of Haptophyte dynamics using the FluoroProbe : an application in the Eastern English Channel for monitoring Phaeocystis globosa. Journal of Plankton Research, 34(2), 136–151.

James A., Pitchford J.W., Brindley J. 2003. The relationship between plankton blooms, the hatching of fish larvae, and recruitment. Ecological modelling, 160: 77-90.

Jansen T, Finlay Burnset F. 2015. Density dependent growth changes through juvenile and early adult life of North East Atlantic Mackerel (Scomber scombrus). Fisheries Research, 169: 37-44

Lazure P., Desmare S. 2012. Caractéristiques et Etat Ecologique de la Manche-Mer du Nord, Etat physique et chimique, Caractéristiques physiques, Courantologie. IFREMER. 9 pp.

Lefebvre A., Caillault-Poisson E., 2019. High resolution overview of phytoplankton spectral groups and hydrological conditions in the eastern English Channel using unsupervised clustering. Marine Ecology Progress Series. Volume 608, page 73-92, https://doi.org/10.3354/meps12781

Marrec P., Cariou T., Latimier M., Macé E., Morin P., Vernet M., Bozec Y. 2014. Spatio-temporal dynamics of biogeochemical processes and air–sea CO2 fluxes in the Western English Channel based on two years of FerryBox deployment. Journal of Marine Systems, 140: 26-38.

Van Leeuwen S., Mills D., Van der Molen J. 2015. Stratified and non-stratified areas in the North Sea: Long-term variability and biological and policy implications. Journal of Geophysical, 120: 4670-4686.

Wallace P.D., Pleasants, C.A. 1972. The distribution of eggs and larvae of some pelagic ¢sh species in the English Channel and adjacent waters in 1967 and 1968. International Council for the Exploration of the Sea (CM Papers and Reports), CM1972/J: 8, 4pp

3.3. Kattegat Skagerrak

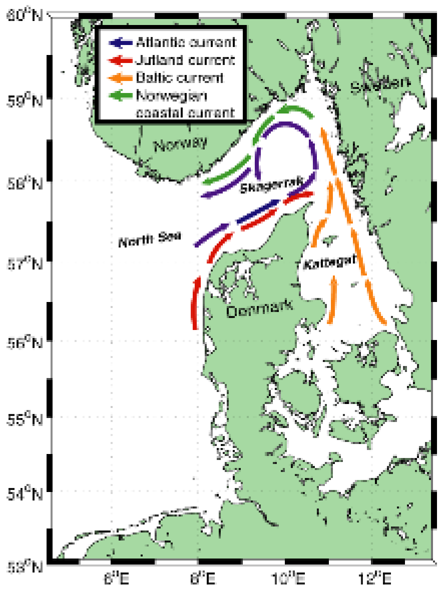
Involved institutes: SMHI, NIVA and HZG, NORCE,
Authors:
SMHI: Bengt Karlson, Lars Arneborg and Lars Axell and Michael Brosnahan (WHOI, subcontractor to SMHI)
NIVA: Andrew King, Richard Bellerby, Wenche Eikrem, Luca Nizzetto, Marit Norli and Kai Sørensen
NORCEIRIS: Elisa Ravagnan and Catherine Boccadoro
HZG: Wilhelm Petersen, Yoana G. Voynova, Martina Gehrung

Involved JRAPs:
JRAP1: Pelagic biodiversity
JRAP 3: Chemical contaminant occurrence and related biological responses
JRAP 5: Carbon fluxes and carbonate system
JRAP 6: Operational oceanography

3.3.1. *Specificities of the this region*

3.3.1.1. Most relevant scientific questions from regional to local scales

General characteristics of the area



The Skagerrak-Kattegat forms a transition area between the North Sea and the Baltic Sea. In winter ice sometimes forms in the coastal areas and occasionally also offshore. The region is dynamically very active as it contains the outflowing of brackish surface water from the Baltic Sea. As a result, strong stratification due to surface and bottom salinity differences forms, which is enhanced by temperature during part of the year. Unlike the Baltic Sea, tides are important, but less than in the North Sea. The frontal zone between the brackish coastal zone and the North Sea water changes position on short time scales due to winds, tidal currents, and the in- and outflows through the Danish Straits. The currents in the region are affected by the atmospheric forcing as well as the baroclinic structure in the ocean, which makes current forecasts difficult even using high-resolution state-of-the-art ocean models.

The area is affected by eutrophication due to high riverine nutrient input. Also, nutrient input from the catchment area of the Baltic Sea influences the Skagerrak-Kattegat. Eutrophication is observed due to increased primary production and reduced Secchi depth. Other examples of eutrophication include harmful algal blooms and low bottom oxygen, especially in areas with reduced water mixing. Low oxygen conditions cause mortalities of benthic organisms. High biomass algal blooms can occasionally cause fish mortalities. There are also low biomass algal blooms of biotoxin producing species. The toxins may accumulate in filter feeders such as bivalves. The development of harmful algal blooms is a result of several physical, chemical and biological processes, which are not fully understood. There is a need to resolve the natural temporal and spatial variability using high frequency sampling to investigate the factors that trigger and limit the timing, variability, and spatial extent of phytoplankton blooms in the area.

Climate change is likely to affect the Skagerrak-Kattegat area in several ways. An increase in temperature may affect the biogeography of many organisms. In JRAP #1 the phytoplankton are in focus, especially harmful algae. Changes in temperature will likely affect winds and stratification and also riverine input of nutrients and dissolved organic matter. The combustion of fossil fuels also causes changes in the ocean carbonate system, potentially leading to ocean acidification:

-Increase in atmospheric CO_2 and equilibration with ocean – increased ocean pCO_2 and decreased pH (should apply to all regions)
-Freshwater input and decrease in buffering capacity for fjord and river outlets
-Seasonal low omega-aragonite/calcite in wintertime in Skagerrak that can affect calcifying organisms

The Skagerrak-Kattegat also represents an interesting case study to assess emissions and transport of anthropogenic pollutants. Through the Danish Straits, Baltic Sea water masses receiving agricultural runoff and wastewater from some of the most populated regions of Europe drain into this area. The Baltic is recipient of a complex cocktail of industrial and agricultural contaminants. The presence of steep gradients in water quality parameters along the Kattegat-Skagerrak (including salinity, temperature, and biology) represents a unique opportunity to investigate spatial range of marine contaminants in relation to physical descriptors. In addition, this specific case study was used here to explore co-linearity between contaminant distribution and distribution of sensitive microorganisms in the water column.

The Jutland current brings water from the southern North Sea to the Skagerrak. Litter from the Southern North Sea end up on islands and beaches along the Swedish Skagerrak coast. This may be the most visible environmental problem in the eye of the public. A large effort on cleaning litter is made to reduce problems for wildlife, tourism and recreational activities. Also, micro-plastics pollution is a problem, both from local sources and from advection from far away.

Most relevant scientific questions and those targeted in JERICO-NEXT

- Eutrophication – phytoplankton biomass, structure of phytoplankton communities, oxygen conditions
- HAB - biotoxin producing algae and fish killing algae
- Climate changes -
- Transport of pollutants – oil,
- Litter and microplastics (not addressed in JERICO-NEXT)

3.3.1.2. Most relevant societal needs and policy needs (including agencies/users potential list)

As in most populated coastal regions, it is of great importance for society to be able to simulate drift trajectories of oil spills by making short-term ocean forecasts, and also for Search and Rescue operations. Ecosystem services and blue growth are important, e.g. fisheries, tourism and aquaculture. The EU Marine Strategy Framework Directive and the EU Water Framework Directives govern monitoring of e.g. biodiversity, invasive species, food webs and eutrophication. Directives about food and hygiene govern monitoring of food such as mussels and oysters and also the content of algal toxins in the bivalves. The Swedish Agency for Marine and Water Management governs the national Swedish marine monitoring programs while the National Food Agency governs monitoring of biotoxins in bivalves and the occurrence of harmful algae. Regional monitoring is through the Water Quality Association of the Bohus Coast and the monitoring program of the coast of Halland. The Norwegian Environment Agency (Miljødirektoratet) monitors water quality including ocean acidification; Inner and outer Oslofjord research councils also have an interest in water quality in the Skagerrak; Some aquaculture operations are located in southern Norway, but the bulk is found along the West and Northern Coasts.

The Water Framework Directive (WFD) establishes requirements for good surface water chemical status which are defined in terms of compliance with environmental quality standards (EQSs) established for chemical substances at European level. Prioritization mechanism for hazardous substances include monitoring. This area is of particular interest for the monitoring point of view as it connects different coastal regions with very different characteristics. Because of this, this particular area has been under special focus for JRAP #3 on contaminants.

3.3.2. *Acquired data and archiving made*

Data type	Sampling location/area	Sampling period	Institute	Data repository
Temperature and wave height and direction, sampling every hour	Väderö buoy, Sweden	2015-2018 (start in 2005)	SMHI	Swedish National Oceanographic Data Centre at SMHI
HF radar data on surface currents and waves	Eastern Skagerrak	2015	SMHI	Swedish National Oceanographic Data Centre at SMHI
Ferrybox data, many parameters including salinity, temperature, chlorophyll fluorescence, turbidity, cDOM fluorescence, etc.	Skagerrak-Kattegat, Oslo-Kiel transect	2015-present (start in 2001)	NIVA	Submitted to EMODNET
Phytoplankton including harmful algae - microscopy	Tångesund, Sweden	August to Oct. 2016	SMHI NIVA	Swedish National Oceanographic Data Centre at SMHI and EMODnet
Phytoplankton including harmful algae – Imaging Flowcytobot	Tångesund, Sweden	August to October 2016	SMHI	Swedish National Oceanographic Data Centre at SMHI, EMODnet and EcoTaxa
Bio-optical data – chl. fluorescence	Tångesund, Sweden	August to October 2016	SMHI	Swedish National Oceanographic Data Centre at SMHI
Salinity, temperature and currents	Tångesund, Sweden	August to October 2016	SMHI	Swedish National Oceanographic Data Centre at SMHI
Inorganic nutrients	Tångesund, Sweden	August to October 2016	SMHI	Swedish National Oceanographic Data Centre at SMHI
Metabarcoding of phytoplankton	Tångesund, Sweden	August to October 2016	SMHI	Samples are not yet fully analysed. Data on 16S rDNA has been analysed, data on 18S rDNA are pending.

Salinity, temperature and oxygen, chl. fluorescence	Koster fjord, Sweden	2018 (some data from 2014-)	SMHI	Swedish National Oceanographic Data Centre at SMHI
Chemical contaminants Polycyclic Aromatic Hydrocarbon (PAHs	Oslo-Kiel Transect	January 2017	NIVA	Data quality process ongoing
DNA biomarker	Oslo-Kiel Transect	January 2017	IRIS	Data quality process ongoing
Chemical contaminants Currently Used Pesticides	Oslo-Kiel Transect	January 2017	NIVA	Data quality process ongoing
Chemical contaminants Artificial Sweeteners	Oslo-Kiel Transect	January 2017	NIVA	Data quality process ongoing
Chemical contaminants Pharmaceuticals and Personal care products	Oslo-Kiel Transect	January 2017	NIVA	Data quality process ongoing
Passive sampler Analysis of PCBs, Organochlorine Pesticides, Brominated flame retardants	Tångesund oceanographic buoy	August 2016 – July 2017	SMHI	Data quality process ongoing

3.3.3. *Collaboration with other international initiatives*

The work on effects of climate change is in part a result of collaboration with the CoClime project (Co-development of CLimate services for adaptation to changing Marine Ecosystems) which was initiated by JPI-climate http://www.jpi-climate.eu/nl/25223446-Co_CliME.html

The work on Harmful Algal Blooms is in part a result of the IOC HAB programme http://hab.ioc-unesco.org and of collaboration in the ICES-IOC Working group on Harmful Algal Bloom Dynamics, WGHABD http://www.ices.dk/community/groups/Pages/WGHABD.aspx

The European FerryBox community have also contributed to the JERICO-NEXT work in the Kattegat-Skagerrak www.ferrybox.org

3.3.4. *Scientific progress so far*

JRAP #1 Pelagic biodiversity - Biodiversity of plankton, harmful algal blooms and eutrophication
Bengt Karlson Wenche Eikrem and Marit Norli

Some results from a harmful algal bloom study in the Skagerrak

Phytoplankton diversity and abundance and the role of physical oceanographic process for the development of harmful algal blooms were studied at an aquaculture site at Tångesund in Sweden August to October 2016. The Imaging Flow Cytobot, an automated *in situ* microscope, was used to investigate the plankton community with high frequency at six depths. An example of results is shown in Figure 3.3-1 where the distribution of the toxin producing alga *Lingulodinium polyedrum*, is shown. Weekly water sampling for analysis of phytoplankton, nutrients and chlorophyll were also made. Some of the samples were analysed using electron microscopy to verify the identity of selected species. An instrumented oceanographic buoy was used to observe physical conditions and chlorophyll fluorescence. Also ADCP:s and moored CTD-rigs were used. In addition, three cruises were carried out to investigate geographic distribution from the coast towards the central Skagerrak. Ferrybox data from the NIVA Oslo-Kiel route and temperature data from the SMHI Väderö buoy also contributed to the study. Results show the importance of physical forcing of water exchange for the distribution of harmful algae. In Fig. 3.3.4 some of the results from the observations of the physical oceanographic parameters from the Tångesund study is shown. ADCP and CTD rigs were deployed inside and outside the fjord system. Wind forced upwelling at the outer coast was also reflected inside th fjord. This was seen as high salinities near surface and also as a replacement of the phytoplankton community. Scientific articles based on the results from the harmful algal bloom study along the Swedish Skagerrak coast in autumn 2016 are in preparation. The study has resulted in three master theses at the University of Gothenburg (Markowska, 2017, Wester Kringstad 2017 and Zhang 2017).

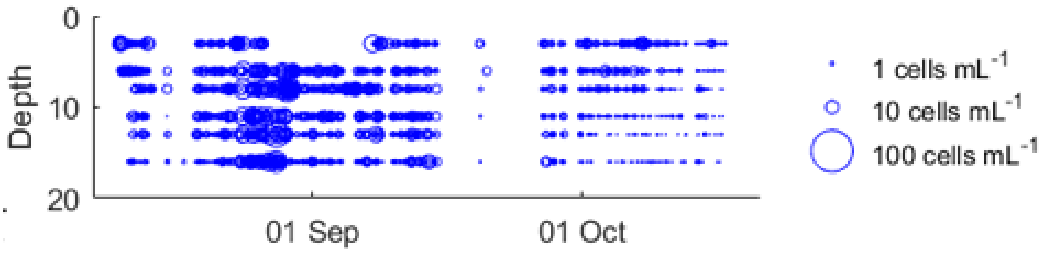


Figure 3.3-1 The abundance of Lingulodinium polyedrum at Tångesund, Sweden August to October 2016. Results from Imaging Flow Cytobot with high temporal resolution at six depths.

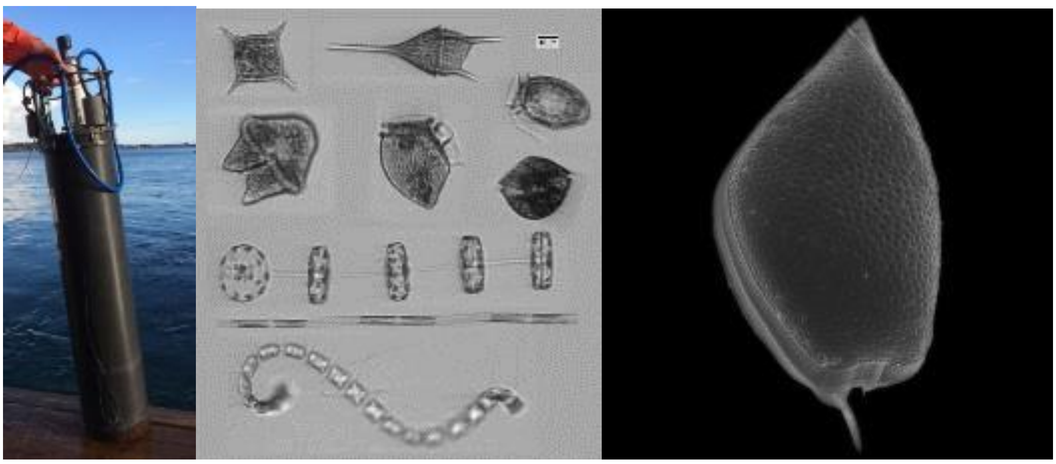


Figure 3.3-2 Left: the Imaging Flow Cytobot, middle: images from the IFCB and right: a scanning electron micrograph of Prorocentrum micans (photo Wenche Eikrem.)

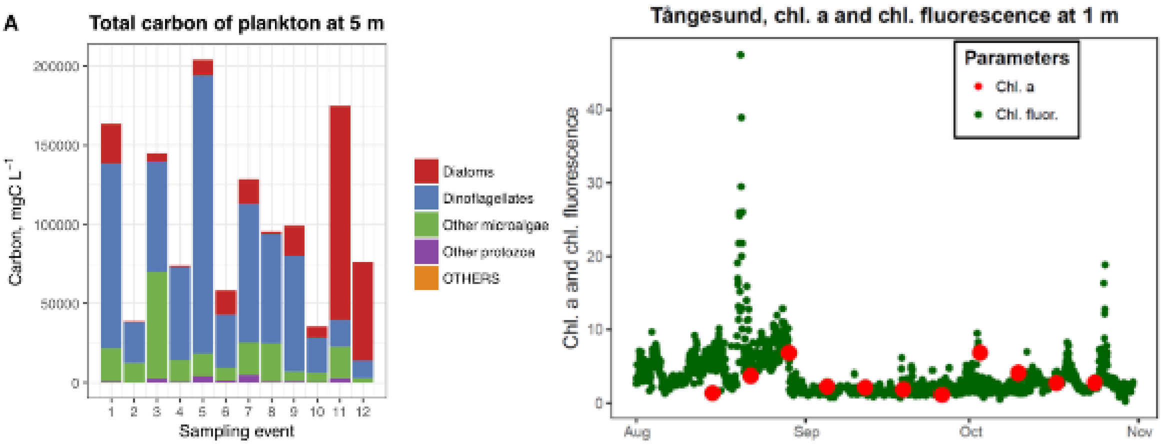


Figure 3.3-3 Left: the biomass of major groups of phytoplankton based on microscopy, Right: Chlorophyll fluorescence and chlorophyll from water samples from Tånggesund. Right: electron microscope photo of Prorocentrum micans.

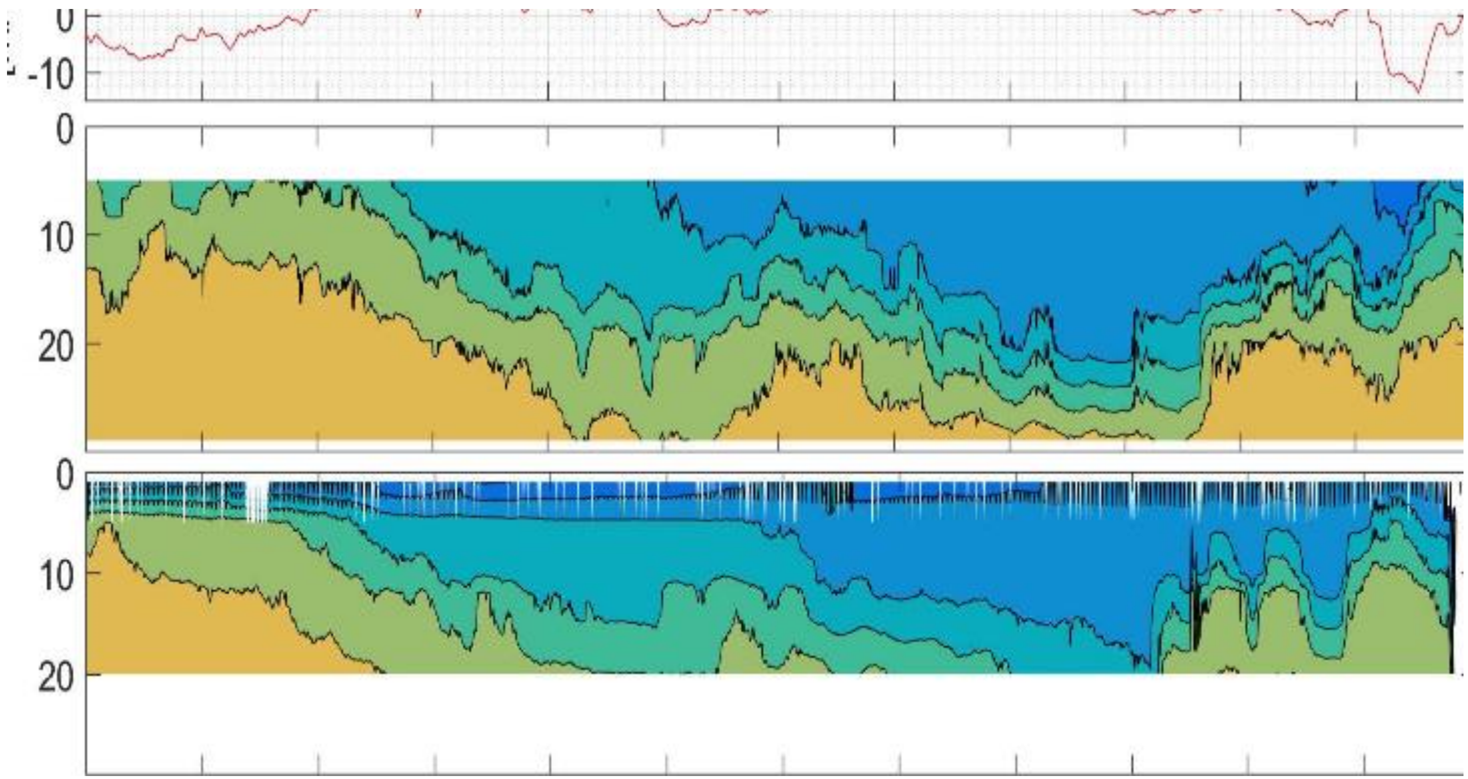


Figure 3.3-4. From the top: a – Observed northward wind component [m/s] from the station Måsekär; b – Time series of salinity at the station M1 in Kråke fjord; c – CTD mooring salinity data from Tångesund merged with the salinity data from the SMHI buoy in Tångesund; d – ADCP data from Kråke fjord; positive velocities [m/s] are directed northward (into Tångesund) and negative, southward (blue). From Markowska, 2017. Only data from August 2016 is illustrated, data from the period

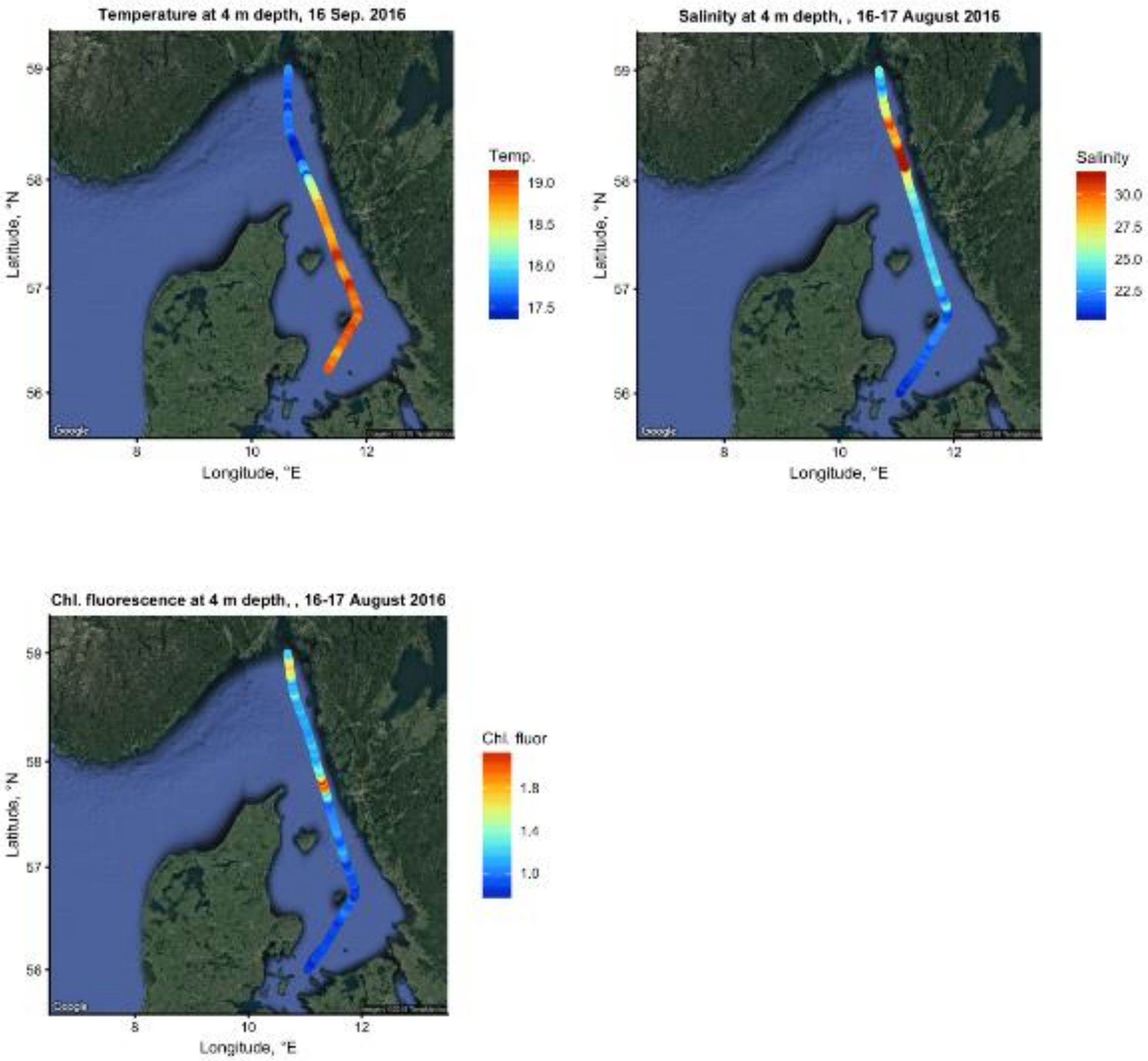
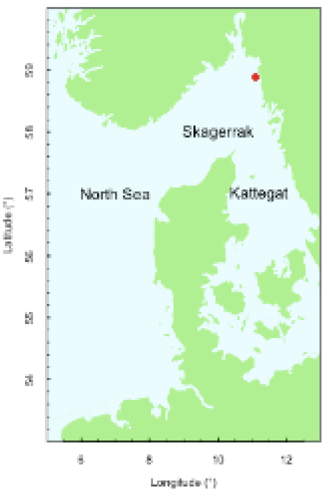


Figure 3.3-5 The Ferrybox system on merchant vessel Color Fantasy was used for observing salinity, temperature and chlorophyll fluorescence at 4 m depth. Data from NIVA.

Results from the Koster fjord buoy

Data from year 2018 from the coastal oceanographic buoy in the Koster fjord, operated by SMHI in cooperation with the University of Gothenburg, are shown in Figure 3.3-6. The buoy was deployed from June to end of November. Data was compared with results from the regional monitoring programme of the Water Quality Association of the Bohús Coast. The buoy data illustrate the high natural variability that is not captured with a monthly monitoring program. This is evident especially in the salinity data and in the data on chlorophyll and chlorophyll fluorescence. Anti fouling devices on the buoy worked well which resulted in a high quality data set.



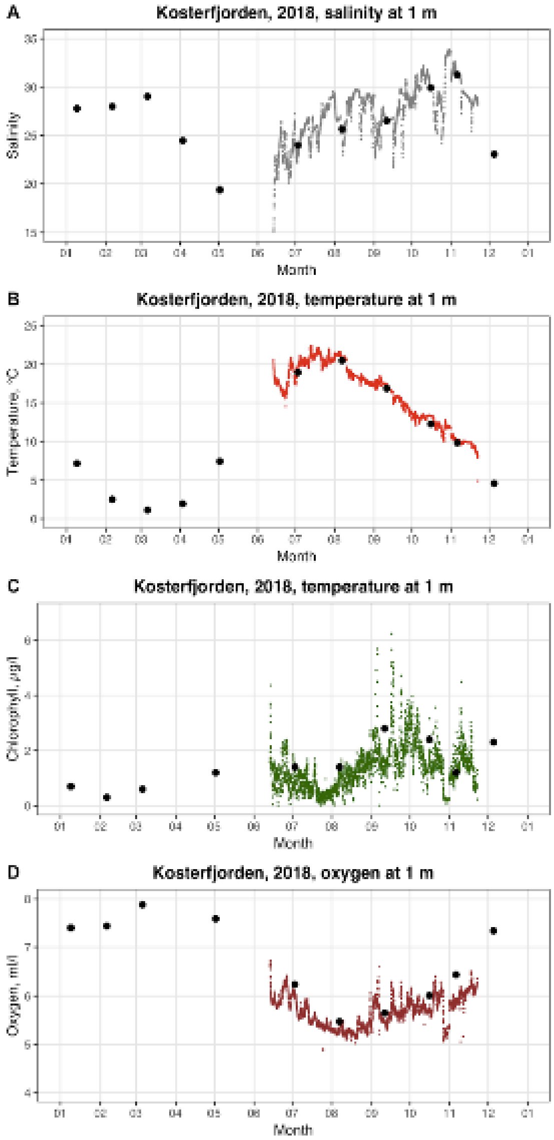


Figure 3.3-6 Left: location of Koster fjord buoy, middle: image of the parts above water and right: results from the oceanographic buoy deployed in the the Koster fjord, Sweden, hourly data are shown. Black markers represent data from the regional monitoring program with manual monthly sampling.

JRAP #3 Occurrence of chemical contaminants in Northern coastal waters and biological responses
Luca Nizzetto, Catherine Boccadoro and Elisa Ravagnan

Already available results from chemical analyses of samples collected through the Color Fantasy FerryBox include: PAHs, DNA biomarker, Artificial Sweeteners and current use pesticides. Results for the single deployment of a passive sampler at Tångesund are also available for PCBs, organochlorine pesticides and brominated flame retardant.

All data from the FerryBox system revealed, as expected, the occurrence of strong concentration gradients reflecting progressive dilution along the South-North transect and highlighted harbours area (Oslo and Kiel as hotspot for some compounds.

The left part of Figure 3.3-7 shows the distribution of Polycyclic Aromatic Hydrocarbon (PAHs) in the Danish Straits, Kattegat, Skagerrak and Oslo Fjord transect. PAHs are compounds released from crude oil contaminations or different type of combustions. They can be both emitted directly to water or to the atmosphere. Airborne PAHs can be deposited to surface water. On land airborne PAHs can be accumulated in soil and vegetation for variable amount of time. They are persistent in soil and can be transported to marine water through runoff (Figure 3.3-8).

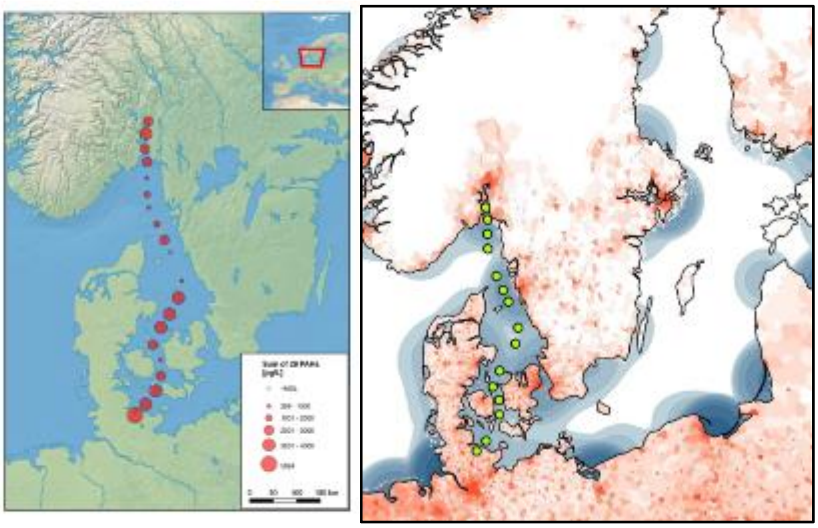


Figure 3.3-7 Left: The distribution of the sum of 29 PAHs (left). Right: Aggregated and Weighted Distances (AWD) from wastewater discharge points. AWD are synthetic proxy of the influence of coastal wastewater discharging points at the selected sampling location. This value maximized the correlation between Saccharine concentrations and AWDs (p<0.05) providing a Spearman correlation coefficient of 0.8.

Results from the analyses of pesticides currently used highlights a strong dependence between concentrations and salinity, demonstrating the origin of these substances from agricultural and riverine runoff and Baltic waters.

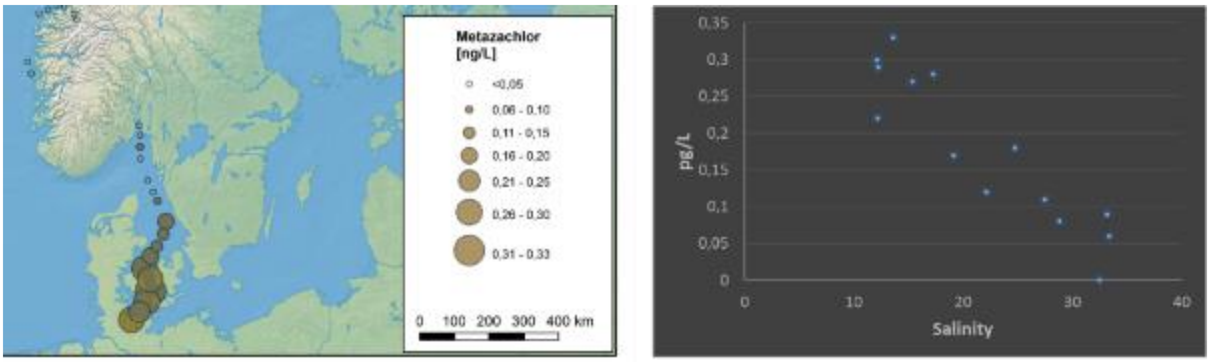


Figure 3.3-8 Distribution of the pesticide Metazachlor and relationship with salinity

Along the same transect microbial molecular markers have been analysed from samples taken in correspondence with PAHs samples. These markers represent bacterial species and genes used to identify hydrocarbon pollution or high nutrient loads. The chosen markers respond better in typical marine waters with elevated salinity, less well in brackish waters as near Kiel harbour where the salinity is extremely low (around 13 PSU).
Molecular markers signalling hydrocarbon contamination give the same distribution pattern as the sum of 29 PAHs (Figure 3.3-7), higher in the close proximity of the harbours and in the middle of the Kattegat area, due to intense

marine traffic. This correspondence demonstrates the potential use of these markers as early warning for hydrocarbon presence.

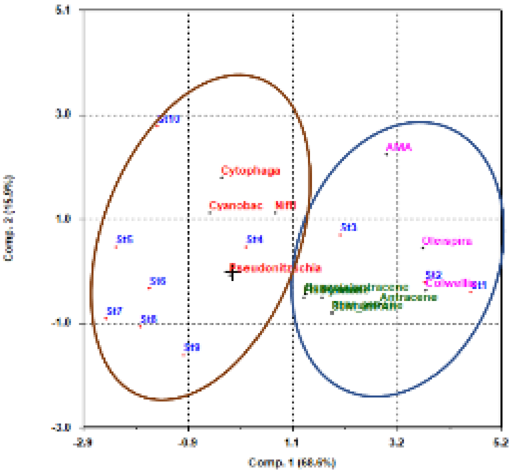


Figure 3.3-9: on the left, a PCA analysis including the 20 stations, the main PAHs and the molecular markers selected: it is evident a clear division between the first part of the transect (St1-10) from Oslo to the centre of the Kattegat and the second part of the transect (St11-20) representing the Danish straights and the Kiel harbour. It should be noted that circa 12 hours have passed between the two semi-transects sampling. Station 20 in the Kiel harbour is separated from the other because of his strong influence from the freshwater influx from the Kiel canal. On the right, the 10 station of the first half-transect separate quite clearly in the ones influenced by hydrocarbons and oil-markers (St1-3 along the Oslo fjord) to the more "marine stations" influenced more by the nutrient-markers, while station 4 shows influence of both type of pollutions.

Artificial sweeteners also provided interesting insights. Their distribution could be linked the distribution of wastewater discharge points along the costs using a spatial model frame that take into consideration source intensity (e.g. human population size at each discharge point) and aggregated and weighted (AWD) distances of sampling points from multiple discharge points using a spatial function (kernel density function) dependent on the search radius (Figure 3.3-8 right part). Compounds with different persistence, and therefore, different ability of travelling far from sources, had concentrations that were correlated to AWD under certain values of the kernel function search radius (e.g. more persistent compounds correlated to AWD calculated with larger search radius). This relatively simple model approach is of great importance for the design of monitoring aimed maximizing information (e.g. capturing maximum monitoring data variability) while minimizing sampling effort.

JRAP #5 Coastal carbon fluxes and biogeochemical cycling

Richard Bellerby, Andrew King and Kai Sørensen

Carbon fluxes and carbonate system variability in the Skagerrak/Kattegat region is primarily driven by changes in salinity resulting from the balance of freshwater inputs from riverine and Baltic sources and saline waters from the Atlantic Ocean, seasonal variability in ocean temperature (~15 ˚C differential between summer and winter), and photosynthetic activity that draws down inorganic C. Based on calculations using a number of assumed constants, the magnitude of change driven by changes in ocean temperature and photosynthetic activity was found to be on the order of +/- 100 µatm fCO_2 during spring/summer, respectively, which represents about a +/-25% change in surface ocean fCO_2 in the region. Surface waters are generally low in pCO_2 and high in pH and aragonite saturation relative to waters >50 m depth. The annual CO_2 sink/source is also partially dependent on mixed layer depth and water depth. Generally, regions with deeper mixed layer depth and water depth serve as CO_2 sinks whilst shallower regions allow for surface return of respired CO_2 (i.e. Emeis et al., 2015). The northern Skagerrak, with relatively deep water depth, is a very strong summertime C sink with very strong N-S gradients (Bozec et al., 2005).

Yoana G. Voynova, Wilhelm Petersen and Martina Gehrung

Continuous high frequency measurements of total alkalinity and pCO_2 could help elucidate the regional and/or seasonal changes in carbonate system parameters. Recently, the installation of a high-frequency total alkalinity sensor on a cargo vessel passing through the Skagerrak two times a week has provided a detailed picture of the regional variabilities in total alkalinity in relationship to salinity (see Figure 3.3-10 below). We aim to verify and extend the timeframe of our preliminary alkalinity measurements, and relate them to other carbonate system parameters such as pH and pCO2, thereby obtaining a time series for the surface waters in the Skagerrak region. In addition, CDOM and chlorophyll fluorescence, as well as dissolved oxygen should provide an estimate of local primary production, but could also help track (along with salinity) regional water masses, which could in turn impact alkalinity.

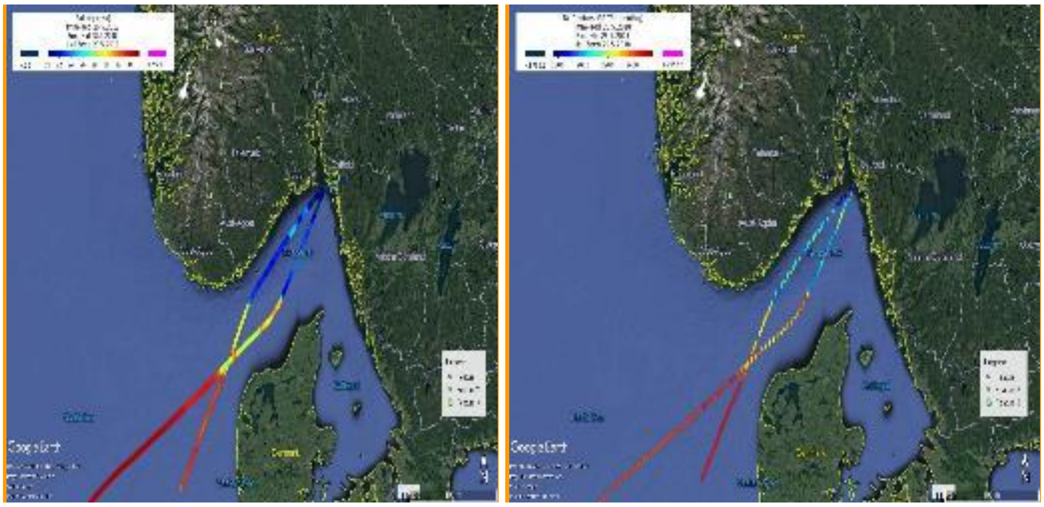


Figure 3.3-10 Salinity and total alkalinity (umol kg-1) for the Skagerrak region near Norway. The parameters were measured using a FerryBox in combination with a Contros HydroFIA TA

JRAP#6 Operational oceanography and coastal forecasting

Lars Axell and Lars Arneborg

Two High-Frequency (HF) radars were deployed and operated on the Swedish west coast during autumn 2014 to late December 2015 (leased from CODAR). Due to a necessary change of frequency of the HF radars, the best quality from the system was acquired during the last ten months of operations (March to December 2015). Radial velocities from the two HF radar stations were used to calculate eastward and northward current components, which were subsequently assimilated into the ocean model NEMO-Nordic (Hordoir et al., 2015; Pemberton et al., 2017) which is currently the operational ocean forecasting model at SMHI. The data assimilation methods tested were 3D EnVar (Axell and Liu, 2016) and 4D EnVar (Axell and Liu, 2017). Figure 3.3-11 shows the monthly mean current for March 2015 according to (middle left) HF radar data and (right) NEMO-Nordic using 4D EnVar. To improve the results further requires more development work on data assimilation as well as coupling to a wave model.

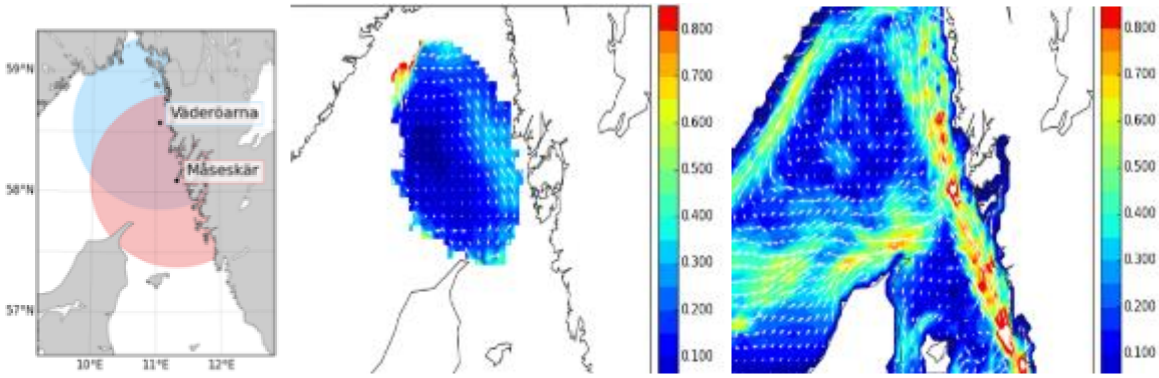


Figure 3.3-11 Location of HF radar antennas (left), monthly mean current in the Skagerrak according to HF radar data (middle) and NEMO-Nordic model (right) using 4D EnVar data assimilation.

The forecast system (model plus data assimilation) was also used in 3D mode (3D EnVar) to assimilate available in situ standard stations of salinity and temperature, to validate against the measurements in the coastal water outside Tångesund (3.3.1, not included in the data assimilation). The validation shows a good model representation of the highly variable coastal stratification. As work in progress, these model data are used as outer boundary conditions for a coastal zone model, which will be validated against current and stratification data in Tångesund and in the fjord system inside Tångesund. This model system will be used to extend the current data for the Tångesund region, to connect the occurrence of harmful toxins in the Tångesund mussel farm with advection of water past the farm from the open sea or from the inside the fjord system.

3.3.5. *Synthesis and way forward*

3.3.5.1. Synthesis and specific next steps

During the project a multiplatform system has been used for near real time observations of the Kattegat-Skagerrak. Data produced were used together with model results and remote sensing data. Ferrybox systems have been used to collect data almost continuously. New development includes observations of the carbonate system with novel sensors and collection of samples for analyses of contaminants. An advanced multiparameter ocean observing system was deployed next to an aquaculture site in a Swedish fjord. In situ imaging flow cytometry was successfully used to describe the phytoplankton community at the species or genus level with a focus on harmful algae with a high frequency. HF radar was used to observe ocean currents and sea state during one year. The data was assimilated into a 3D physical oceanographic model. A HF radar system has been established in Norway. An offshore oceanographic buoy in Sweden continues to produce data since year 2005. Two newer coastal buoys are operational in Swedish fjords.

3.3.5.2. Specific developments for the future

An aim is to set up a multiplatform ocean observation and prediction system for the Kattegat-Skagerrak-East North Sea area. The system would involve Sweden, Norway, Denmark and Germany. One goal would be to produce warnings and predictions based on near real time data for harmful algae, oil spills. Collecting long term data on eutrophication, microplastics, climate change related parameters including plankton biomass and biodiversity, would be another aim. Stationary Ferrybox systems are cost efficient platforms for measuring many parameters in near real time. They have a very high value, especially in strategic locations in currents. Islands, wind mills and oil/gas platforms are useful for locating these systems. They have shown their value e.g. at Helgoland, Germany and at Utö, Finland. At present there are systems in development in the Kattegat-Skagerrak area. One is located at the mouth of the Oslo fjord. The island of Väderöarna in the Baltic Current along the Swedish Skagerrak coast is a potential location.

3.3.6. *References - Kattegat-Skagerrak area*

Aksnes, D.L., Nicolas Dupont, Arved Staby, Øyvind Fiksen, Stein Kaartvedt and Jan Aure (2009). Marine Ecology Progress Series. Coastal water darkening and implications for mesopelagic regime shifts in Norwegian fjords Vol. 387, pp. 39-49

Artioli, Y., J. C. Blackford, G. Nondal, R. G. J. Bellerby, S. L. Wakelin, J. T. Holt, M. Butenschön, J. I. Allen, 2014. Heterogeneity of impacts of high CO2 on the North Western European Shelf. Biogeosciences10(6):9389-9413.

Bozec Y., H. Thomas, K. Elkalay and H.J.W. de Baar (2005). The continental shelf pump for CO2 in the North Sea-evidence from summer observation. Marine Chemistry, 93, 131-147.

Capuzzo, E., Stephens, D., Silva, T., Barry, J., & Forster, R. M. (2015). Decrease in water clarity of the southern and centralNorth Sea during the 20th century. Global Change Biology, 21, 2206–2214. http://doi.org/10.1111/gcb.12854

Emeis, K.-C., et al. 2015. The North Sea — A shelf sea in the Anthropocene. Journal of Marine Systems 141:18–33.

Frigstad, H., T. Andersen, D. O. Hessen, E. Jeansson, M. Skogen, L-J. Naustvoll, M.W. Miles, T. Johannessen, R.G.J. Bellerby(2013) Long-term trends in carbon, nutrients and stoichiometry in Norwegian coastal waters: Evidence of a regime shift Original Research Article Progress in Oceanography, Volume 111, Pages 113–124.

Hordoir R, Axell L, Höglund A, Dieterich C, Fransner F, Gröger M, Liu Y, Pemberton P, Schimanke S, Andersson H (2019) Nemo-Nordic 1.0: a NEMO-based ocean model for the Baltic and North seas-research and operational applications. Geoscientific Model Development 12:363-386

Karlson, B. (editor) (2006) Monitoring the pelagic system in the Skagerrak. Forum Skagerrak report. 67 pp. http://extra.lansstyrelsen.se/havmoterland/SiteCollectionDocuments/Publikationer/forum-skagerrak/monitoring-pelagic-system.pdf

Markowska N (2017) A study of the circulation of water in the Stigfjorden area based on model and observations. Master Thesis, University of Gothenburg, Gothenburg, Sweden, 78 pp.

Müller, J. D., Schneider, B. and Rehder, G. (2016), Long-term alkalinity trends in the Baltic Sea and their implications for CO2-induced acidification. Limnol. Oceanogr., 61: 1984-2002. doi:10.1002/lno.10349

Wester Kringstad K (2017) Phytoplankton pigments and biomasses. Master Thesis, Univeristy of Gothenburg, Gothenburg, Sweden, 58 pp.

Zhang K (2017) Harmful Dinophysis spp. bloom dynamics at the Swedish West Coast - The influence of hydrographic, biological and meteorological variables on the abundance of Dinophysis spp. Master Thesis, University of Gothenburg, Gothenburg, Sweden, 43 pp.

3.4. Baltic Sea

Involved institutes: SYKE, SMHI, FMI, CNRS

Lead author: Jukka Seppala

Participants:

Jukka Seppälä, Pasi Ylöstalo, Timo Tamminen, Suvi Rytövuori, Jani Ruohola, Anne-Mari Lehto, Petri Maunula, Sirpa Lehtinen, Seppo Kaitala (SYKE)

Lauri Laakso, Sami Kielosto, Martti Honkanen, Jan-Victor Björkqvist (FMI)

Bengt Karlson, Anna Wännstrand-Wranne, Johannes Johansson (SMHI)

Luis Felipe Artigas, Fabrice Lizon, Arnaud Louchart, Lars Stemmann (CNRS)

Involved JRAPs: JRAP1, 5 and 6

3.4.1. *Specificities of the this region*

3.4.1.1. Most relevant scientific questions from regional to local scales

General characteristics of the area

The Baltic Sea is a brackish and coastal basin with several specialties, compared to other European coastal seas (Leppäranta and Myrberg 2009) . The salinity of the Baltic Sea varies from fresh water in river mouths up to 10 psu in the surface waters of Danish straits (and further up to 32-33 psu at the bottom waters of Danish straits). The low salinity and salinity gradient have consequences to the physics, chemistry and biology of the Baltic Sea. Besides the seasonal thermocline, there is a permanent halocline separating water with higher salinity, originating from the North Sea, and less-saline surface water affected by riverine inputs. The halocline, usually found at 40-80 meters, works as barrier reducing the atmospheric forcing. Occasional intrusions of high saline water from the North Sea affect the deep water salinity, halocline, and eventually biogeochemistry of the whole sea.

Nutrient load to the Baltic Sea is relatively large and consequently several Baltic subareas suffer from eutrophication (Andersen et al. 2015). The main symptoms of eutrophication are increased algal production, decrease of water clarity, changes in the species composition and algal blooms. As a result of eutrophication, combined with limited water exchange and reduced mixing, there are large anoxic bottom areas in the Baltic Sea. Internal loading of phosphorus from anoxic areas feed algae production in addition to anthropogenic nutrient loads. Among the algal blooms, the spring bloom shows the highest biomass. Spring blooms consist of diatoms and dinoflagellates, their relative dominance depending especially on the stratification, mixing and ice conditions. It is notable, that these two major spring bloom groups have different effects on elemental fluxes. During summer, blooms of filamentous cyanobacteria are frequent phenomena. Blooming species are able to fix atmospheric nitrogen, further adding to the eutrophication of the sea and they are largely uneatable to major grazers affecting the elemental fluxes. In addition to load of nutrients, large amounts of dissolved organic matter enter to the Baltic Sea, affecting the bacterial processes and autotrophy/heterotrophy balance.

Low tolerance to brackish waters limits the distribution of many marine organisms in the Baltic and also affects their growth rate and size. The species richness of bottom fauna and macroalgae is relatively low in the Baltic and additionally the anoxic conditions hamper the dispersal of several benthic animals. Yet another stress factor to marine fauna of the Baltic Sea is due to pollutants. Due to limited water exchange and considerable amount of human activities and industry, several pollutants are accumulating in the fauna, affecting even the fisheries.

Specific conditions of the Baltic Sea, makes it very vulnerable to climate change related changes (Reusch et al. 2018). It is expected that climate change will affect directly the temperature and salinity of the Baltic Sea and thereby mixing and stratification influencing also air-sea and surface-bottom fluxes. Increase of river discharges are expected, accompanied with increased load of dissolved organic matter, increasing also the brownification. Potential decrease of ice cover will also impact the stratification and mixing. All these changes will affect the marine life, with impacts not yet known.

Most relevant scientific questions and those targeted in JERICO-NEXT

The key scientific questions in the Baltic include:

- How marine biology is coupled to physical and chemical processes and how the elemental cycles are driven by physical and biological processes?
- How the state of the Baltic Sea is affected by the climate change and other human activities? What are the ecosystem effects of unwanted perturbations (e.g. anoxic bottoms, algae blooms, invasive species, microplastics, pollution) and how to secure ecosystem health, ecosystem services and sustainable blue growth?
- Whether the countermeasures to reduce eutrophication and pollution have an effect
- Improve understanding on the functioning of marine ecosystems and biogeochemistry, by coupling observations, experimentation and modelling
- What is the socio-economic importance of marine environment?

The specific scientific questions primarily targeted in JERICO-NEXT JRAPs included

- How to improve monitoring of pelagic biology, especially phytoplankton, using emerging technologies (JRAP1)
- Relative importance of biological and chemical/physical variables for air-sea carbon fluxes, and how do these vary spatio-temporally (JRAP5)
- Study how physical processes affect the spatiotemporal distribution of phytoplankton (JRAP6)

.

3.4.1.2. Most relevant societal needs and policy needs (including agencies/users potential list)

The Baltic Sea provides various ecosystems services, and is actively exploited for commercial activities including traditional marine uses and blue growth initiatives, and the value of its biodiversity is intrinsic. The overall societal and policy needs, for state-of-art and future monitoring of the Baltic Sea, are mainly driven by HELCOM and EU policies, which strongly guide the national policies. It is clear that to improve the assessment of the state of the Baltic Sea, the data need to be collected by relevant methods and spatiotemporal scales, and the data need to be easily accessible. Within HELCOM the Baltic coastal states collaborate very strongly, and share a HELCOM COMBINE database used in the holistic assessments. The actual research vessel based monitoring is done using harmonized methodologies, developed in joint workshops. It is obvious that similar harmonization round is needed for operational observations, allowing the cost-efficient and seamless combination of data from multiple sources.

3.4.2. *Acquired data and archiving made*

Data type	Sampling location/area	Sampling period	Institute responsible for data
Flow through measurements (sampling depth -5 m) for pCO_2, pH, temperature, salinity, O_2, fluorescence of Chlorophyll, phycocyanin and CDOM, turbidity, spectral fluorescence, FRRF fluorometry. Meteorological parameters (T, WS, WD, solar radiation etc). Surface waves.	Utö Atmospheric and Marine Research Station	April 2017-May 2018, good coverage until begining of May (pump broke)	FMI, SYKE

Campaigns to measure extracted Chlorophyll, spectral absorption and fluorescence, primary production (C-14), alkalinity and DIC.			
Flow through measurements (sampling depth -5 m) for pCO_2, temperature, salinity, Fluorescence of Chlorophyll, phycocyanin and CDOM. turbidity In addition water samples are collected for analysis of several parameters.	Ferrybox in ferry Silja Serenade; Helsinki-Mariehamn-Stockholm	April 2017-May 2018; not good coverage due to technical issues and ice season	FMI, SYKE
Flow through measurements (sampling depth -3 m) for pCO_2, temperature, salinity, O_2, Fluorescence of Chlorophyll, phycocyanin, and CDO turbidity). Meteorological parameters (air temperature, air pressure, solar radiation-PAR). In addition, water samples are collected for analysis of several parameters.	Ferrybox in ferry Tavastland; Kemi-Lübeck	April 2017-May 2018; in the beginning not good coverage, good coverage since October	SMHI
Flow through measurements (sampling depth -5 m) for temperature, salinity, Fluorescence of Chlorophyll, phycocyanin, phycoerythrin, and CDOM. turbidity, weekly cell counts for phycoerythrin containing species (2016). In addition water samples are collected for analysis of several parameters.	Ferrybox in ferry Finnmaid; Helsinki-Travemunde	May - September 2016 & 2017	SYKE
Continuous flow through measurements (sampling depth - 5 m) measurements of Chlorophyll and phycocyanin, fluorescence, salinity and temperature. Continuous recording with CytoSense (automated flow cytometer), Fluoroprobe (multi-spectral fluorometer). Casts of Fluoroprobe, FRRF (photosynthetic parameters) and UVP5 (in situ imaging). Discrete	ARANDA cruiser	July 2017	SMHI CNRS LOG

measurements of CytoSense, PhytoPAM (photosynthetic parameters) and FlowCAM at different depths.			

3.4.3. *Collaboration with other international initiatives*

The work in JRAP5 within the Baltic Sea is collaborating with a Blue Baltic project Bonus-Integral, in which FMI and SMHI are both partners. The aim of Bonus-Integral is to develop carbonate system observations at the Baltic Sea towards an integrating indicator of ecosystem status. The data QC procedures in JRAP5 follow the recommendations of ICOS-OTC (Integrated Carbon Observing System - Ocean Thematic Center), in line with CMEMS quality flagging and SOCAT-database protocols. Development and testing of new technologies for phytoplankton research benefit from collaboration with RI-H2020 project AQUACOSM, in which SYKE is having a leading role in developing new integrated online monitoring systems for experimental studies.

3.4.4. *Scientific progress so far*

Baltic Sea studies have included:

- studies on which optical methodologies are best suited to detect changes in the phytoplankton biomass, taxonomy and productivity (JRAP#1)
- intensive measuring period to record the variability in air-sea C-fluxes and to understand which are the contributions of physico-chemical vs. biological controls of these fluxes (JRAP#5)
- contribute to the operational modelling of waves and provide first insight how the wave action modifies the biology, especially phytoplankton abundance, of the open sea areas (JRAP#6)

Phycoerythrin fluorescence in the Baltic Sea

Phycoerythrin is a red pigment, especially suited for harvesting the green light that penetrates deepest in the Baltic Sea. Phycoerythrin is thus very valuable pigment for species staying at deeper water layers, but frequently observed also throughout the upper water column. Especially picocyanobacteria, often dominating the phytoplankton community in the Baltic Sea during summer months, are rich of phycoeryhtrin. Phycoeryhtrin fluorescence cannot be used, however, as a proxy for picocyanobacteria alone because some other groups (cryptophytes, some dinoflagellates, ciliate *Mesodinium rubrum*) may have high phycoerythrin content as well.

In 2016 we started operational monitoring of phycoerythrin fluorescence using ferrybox system onboard cargo vessel Finnmaid. We compared the performance of two different fluorometers, Unilux (Chelsea Technologies Group LTD) and microFlu-Red (Trios GMBH). The instruments provided comparable results with slight differences in their LOD and LOQ. We performed various validation measurements in laboratory, using weekly samples collected from Finnmaid. We counted phycoerythrin containing cells using epifluorescence microscopy and flowCAM and did additional spectral measurements from different size-fractions. Details of the study are given by Rytövuori 2017.

Phycoeryhrin fluorescence showed clear seasonal and spatial structures (Figure 3.4-1). During the early summer the signal was related to abundance of *Mesodinium rubrum*, while in late summer it was closer related to picocyanobacteria. Occasional increases of phycoerythrin fluorescence were observed due to upwelling, which is explained by uplift of phycoerythrin rich deeper phytoplankton populations. Based on these measurements, it seems clear that phycoerythrin fluorescence originates from various organisms, their pigment content vary and simple correlation methods are not well suited to analyse the abundance of phycoerythrin containing cells. However, the spatio-temporal variability of phycoeryhtrin fluorescence can be explained by succession of different phycoerythrin containing organisms, thus providing insight in pelagic phytoplankton biodiversity and functionality. The follow-up measurements in 2017-2019 have resulted in rather similar records of phycoerythrin fluorescence, indicating especially that *Mesodinium rubrum* plays an important role in the post-spring bloom phytoplankton populations (see also Lips and Lips 2017).

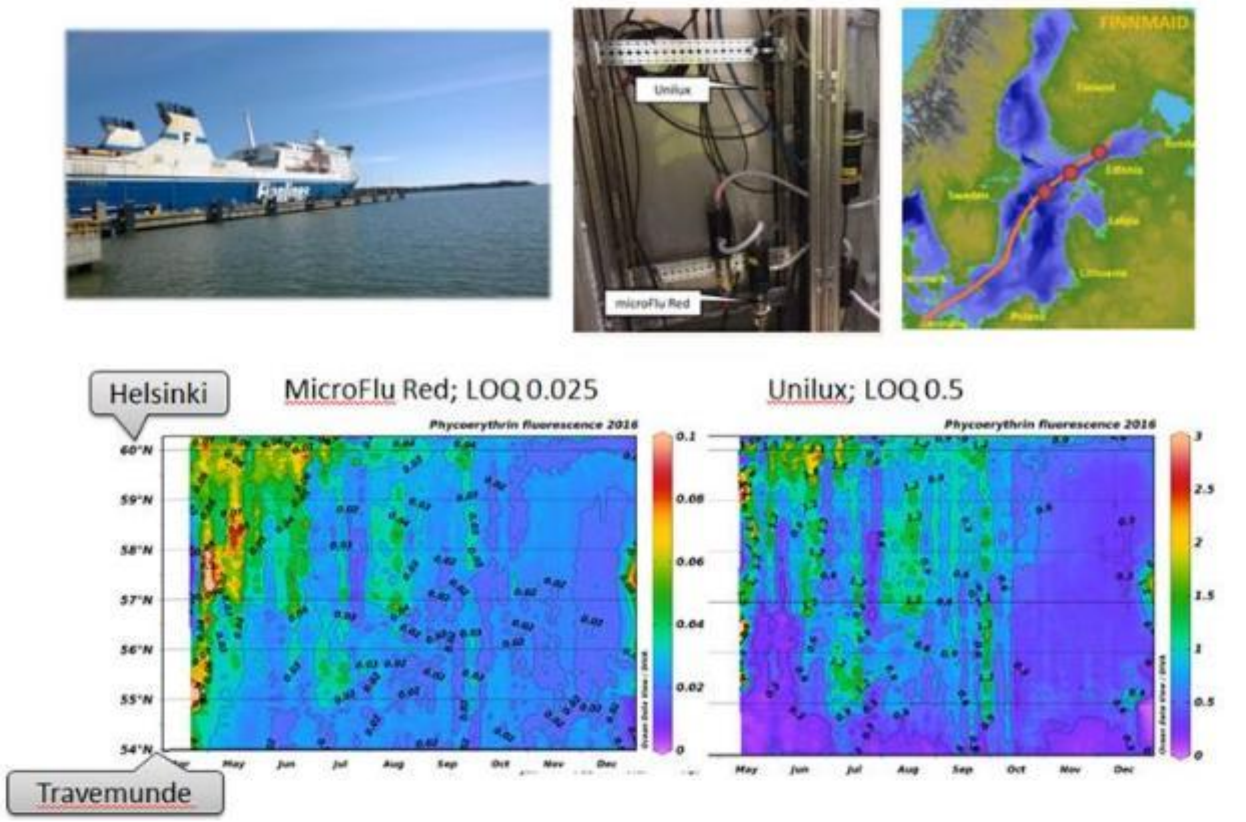


Figure 3.4-1 Spatiotemporal variability in phycoerythrin fluorescence, as measured using two commercial fluorometers installed in ferrybox system onboard ferry Finnmaid commuting between Helsinki and Travemunde.

Multi-instrument comparison for phytoplankton research

In a study carried out in July 2017, the distribution, biomass and biodiversity of phytoplankton were investigated in the Baltic Sea and the Kattegat-Skagerrak. In addition phytoplankton physiological parameters and production were measured from the surface to 35 m depth by an FRRF profiler (the euphotic layer was always lower than this depth).The nitrogen fixing cyanobacteria were in focus. Ocean colour satellite remote sensing images provided a high horizontal resolution of surface accumulations. Flow-through systems on a research vessel and on two merchant ships were used to investigate the near surface distribution based on fluorescence properties of the organisms. The vertical distribution was investigated by water sampling and microscopy, as well as using in situ imaging of cyanobacteria colonies (UVP5 instrument), multi wavelength fluorometry (Fluoroprobe) and by analysing samples using automated flow cytometry (CytoSense). Horizontal and vertical small-scale variability was substantial (Figures 3.4.2 & 3). The different cyanobacteria had dissimilar distribution, and all the filamentous cyanobacteria taxa were absent in the Kattegat-Skagerrak. The FRRF profiler reveal the fine vertical structure of quantum efficiency of photosynthesis and several physiological phytoplankton parameters (Figure. 3.4.4). FRRF measurements are related to taxon physiology on which is superimposed a variability due to fast photoregulation, photoacclimation occuring at more or less daily time scale and stress due to high light and low nutrient concentrations. In the case of the Baltic Sea all these processes can occuring. A detailed study of these profiles will be made in comparison with the contrasted waters/ecosystems sampled with the FRRF profiler during the 4 JericoNext cruises realized in 2017. Such a comparison will allow to compare permanently stratified, occasionally stratified and mixed water column in order to better understand physiological plasticity in relation with stability factors of waters, taxonomy, light intensity and quality all along the water column. The FRRF physiological parameters will also allow to compare the phytoplankton productivity computed, the JVPSII index (a volumetric electron flux), across the euphotic layer (ex in Figure 3.4.5), instead of potential phytoplankton production based on sub-surface water measurements (between 3 and 5 m). The figure 3.4.5 display a classical shape of the vertical profile of the JVPII index for different excitation light colors; i.e. a decreasing shape as the light intensity in the water column. We will see in the next part of this report an opposite case of vertical FRRF profile, for the mixed water columns of the English Channel. Such a study highlights the need for multi-method approaches when investigating harmful algal bloom dynamics.

Figure 3.4-2 Left: Two nitrogen fixing cyanobacteria: Nodularia spumigena and Aphanizomenon flos-aquae, middle: satellite image of cyanobacteria bloom 14 July 2017 (OLCI sensor, Sentinel 3A, processed by SMHI) and right: composite of 7 days of observations of surface

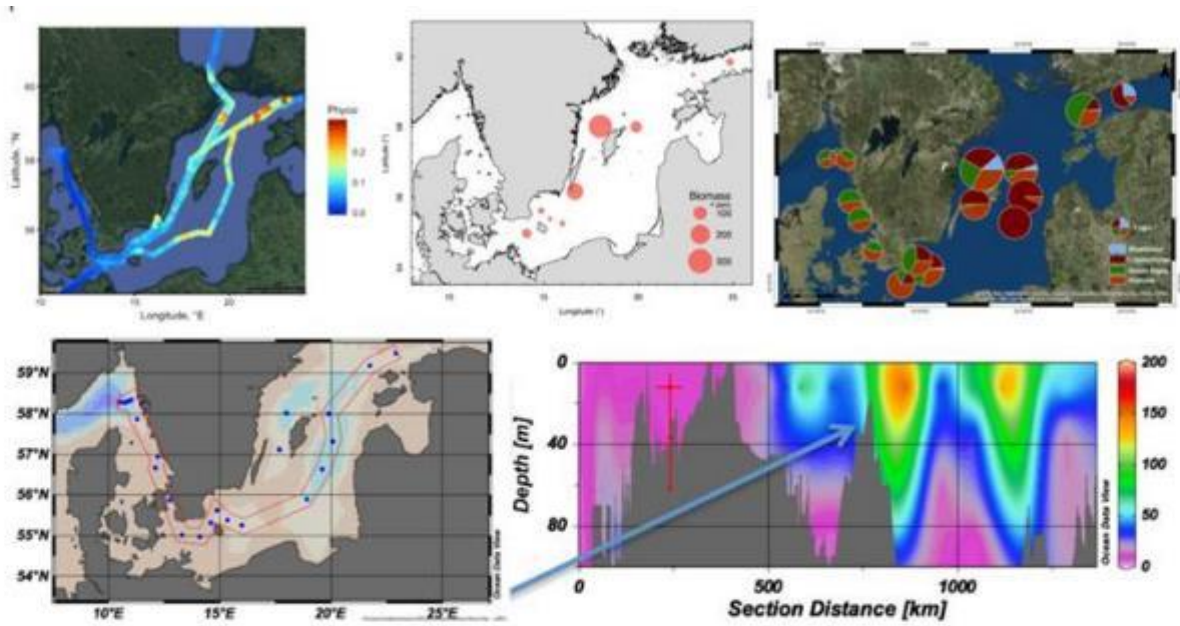


Figure 3.4-3 Preliminary results from research cruise 10-17 July 2017. Top left: Phycocyanin fluorescence, a proxy for cyanobacteria biomass from R/V Aranda and from ferrybox system on merchant vessel Tavastland during the same week, top middle: the biomass of Nodular spumigena based on microscopy, top right: the distribution of phytoplankton pigments groups based on multi wavelength fluorescence, bottom left: stations visited, red frame illustrates which stations were used for bottom right: the distribution of Nodularia spumigena – like cyanobacteria colonies based on in situ imaging with the UVP5.

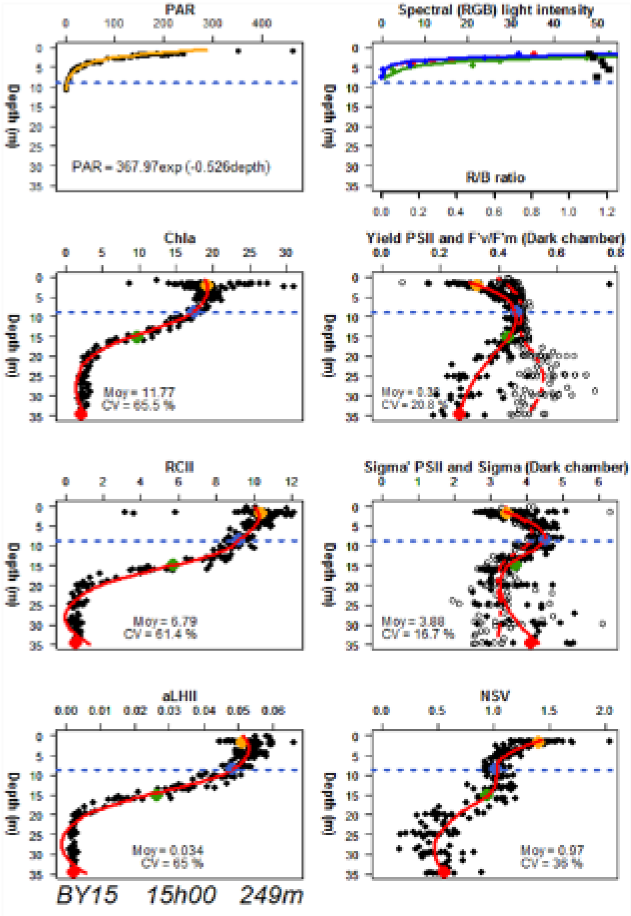


Figure 3.4-4 One of the 14 FRRF vertical profile realized during the Aranda cruise: station BY15, displaying light intensity and quality (λ for blue, green and red wavebands); the effective and pseudo-maximum PSII quantum yield (YPSII and F'v/F'm rel. unit), absorption cross section of PSII (σ ' and σ PSII in nm2.PSII-1), photoinhibition (NSV rel. unit), reaction centre concentration (RCII in nmol PSII.m-3), absorption coefficient of PSII light harvesting (aLHII in m-1) with Euphotic Depth (blue line) and Chla (mg.m-3) vertical profiles. CV mean coefficient of vertical variation (%).

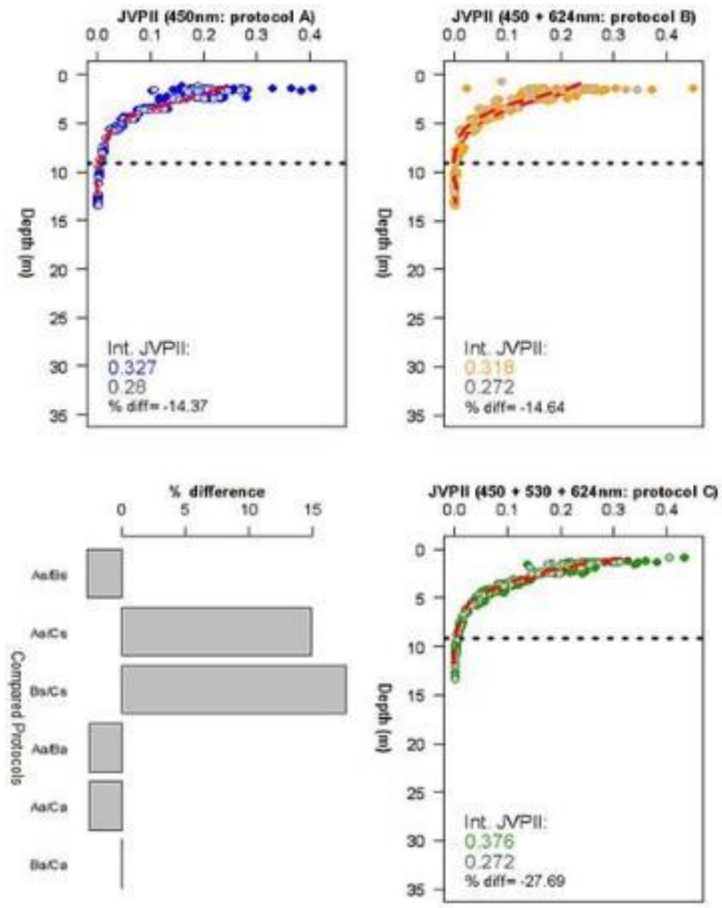


Figure 3.4-5 Vertical profiles of the JVPSII parameters (volumetric electron flux), a productivity index of GPP (Growth Primary Production), computed according to Oxborough et al, 2012) with 3 protocols and 2 algorithms that are compared here in % difference (bar plot).

Detection of cyanobacterial blooms in the Baltic Sea

Finnish Environment Institute carries out operational detection of cyanobacterial blooms in the Baltic Sea using ferrybox monitoring of phycycyanin fluorescence (Seppälä et al 2007) and by analysing satellite ocean colour (Kahru et al 2007). These are supplemented by less frequent water sampling, e.g. using research vessels, information from Coastal Guard and by citizen observations. The results are used to assess the state of the water basins and also to inform authorities and public on the algae bloom situations (Figure 3.4.6).

One of the most intensive blooms of filamentous cyanobacteria in the Baltic Sea was observed in 2018. The work carried out during JERICO-NEXT largely supported the algae bloom state reporting at the Finnish Environment Institute. First, the online automated QC protocols (developed in WP3) allowed the real-time use of algae fluorescence records from ferrybox systems. Secondly, the multi-sensor observations at Utö station provided exceptional possibilities to follow bloom dynamics using optical sensors and Imaging FlowCytobot.

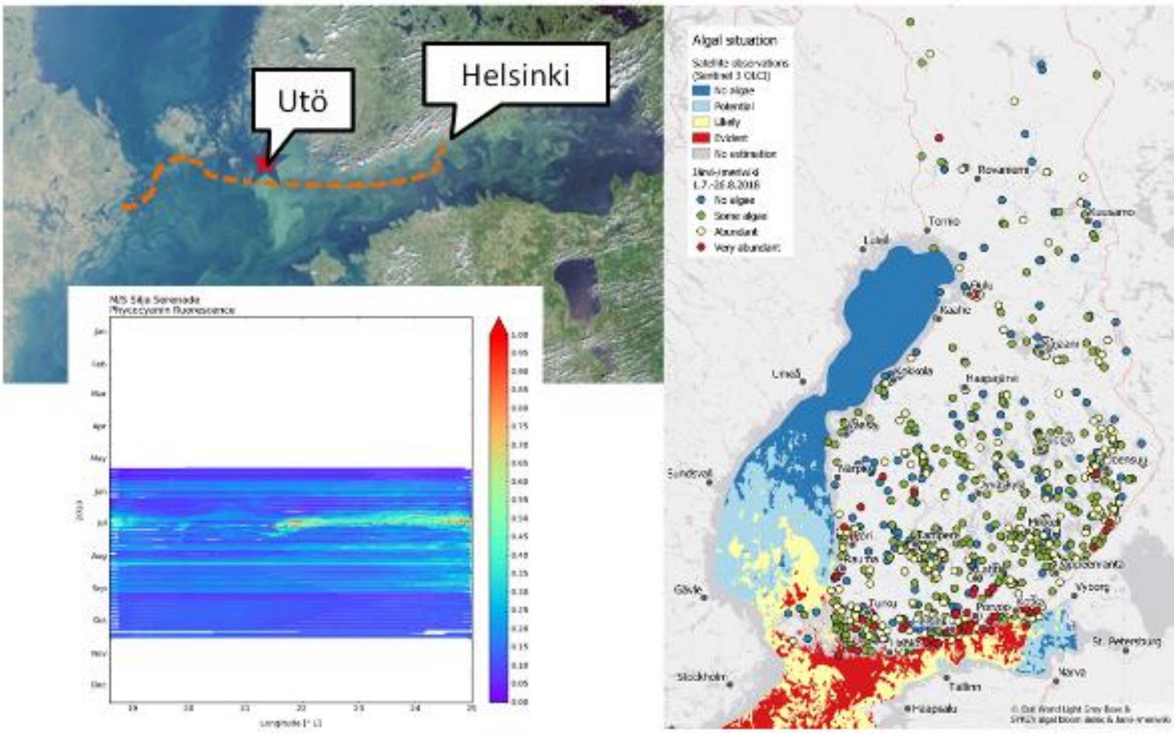


Figure 3.4-6 Cyanobacterial bloom as seen in satellite image, 16 July 2018 (Source: ESA Copernicus Sentinel Data and SYKE). Location of Utö station and route of ferry Silja Serenade are shown (Upper left). Variability of phycocyanin fluorescence along route of Silja Serenade, as proxy of abundance of filamentous cyanobacteria (Lower, left). Algae situation in Finland in 2018, as collected from multisource information and in the sea areas largely supported by operational observations (Right).

Imaging FlowCytobot (IFCB) has been used in Utö station in 2017-18. IFCB takes samples at 20 minute intervals, and produces images of the phytoplankton cells. For the cyanobacterial bloom period in 2018, the classifiers for the major bloom forming species (*Aphanizomenon flosaquae* and *Dolichospermum* spp.) were done following Sosik and Olson (2007). Images were analysed using Random Forest based image processing algorithm (Sosik and Olson 2007) and further the biomass of these major species were calculated using observed dimensions of filaments. *Nodularia spumigena*, typically dominant species during these blooms was observed only in very small quantities. This data collected allow us to analyse how different species are affected by rapid shifts in the environmental conditions, how the community succession develops, which species co-occur and which not. In addition, such high-frequency biomass data allow validation of optical devices. In Figure 3.4-7 we show how the bulk phycocaynin fluorescence is related to the biomass of filamentous cyanobacteria. Such validation allows analysing how the optical signatures develop during the bloom, and which technologies are best suited in bloom detection. So far such comparisons are done using few samples analysed by traditional microscopy, making the detection of seasonal trends complex. Data in Figure 3.4-7 shows tight coupling of phycocyanin fluorescence and biomass of filamentous cyanobacteria, with slight shifts showing higher biomass-spesific fluorescence during the early bloom (maybe due to highly pigmented cells).

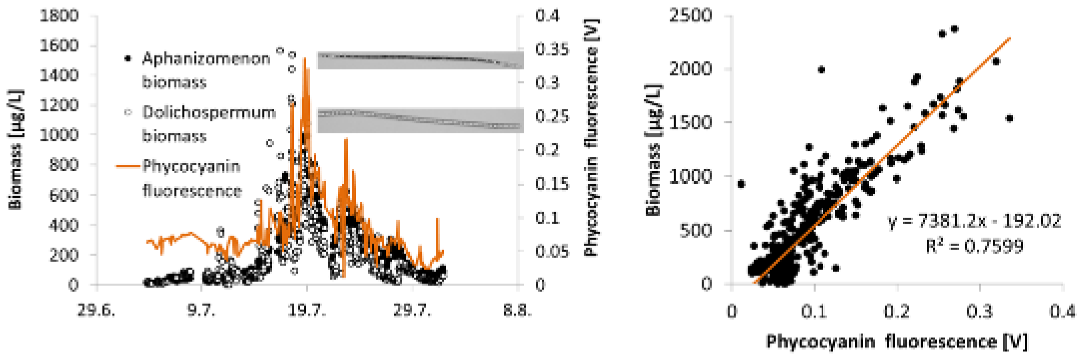


Figure 3.4-7. Development of cyanobacterial bloom at Utö station (Baltic Sea). Biomass of major bloom forming filamentous cyanobactreia are measured using Imaging FlowCytobot. Phycocyanin fluorescence (Trios MicroFlu-Blue) is used as a proxy of filamentous cyanobacteria abundance (Left). Relationship between phycocyanin fluorescence and total biomass of filamentous cyanobacteria, as estimated with Imaging FlowCytobot (Right).

Tests with emerging optical sensors for phytoplankton research

Operational observation of phytoplankton mostly relies on Chlorophyll fluorescence though experimentally various sensors have been tested. One major drawback in Chlorophyll-a fluorescence is the fluorescence quenching due to high light intensities; as such this is an important protection mechanism in algae, but it complicates the use of fluorescence intensity as a proxy of chlorophyll concentration. It is well known that absorption methods do not suffer from such phenomena and variability between Chlorophyll-a in vivo light absorption and concentration is much less than for fluorescence. The draw-back so far has been methodological issues in measuring online absorption. These drawbacks are partly relaxed in commercial integrating cavity spectrophotometer (OSCAR, Trios Gmbh). The first results from Utö station, spring 2017, indicate that the absorption-based estimation of Chlorophyll-a (in this phase, simply calculated as peak height of Chlorophyll a absorption band at 676 nm) is highly correlating with analytical measurements of Chlorophyll-a concentration. In turn, fluorescence based measurements show decline in response during sunny conditions. Lack of automated system for cleaning and calibration still prevent the large scale use of absorption based technique.

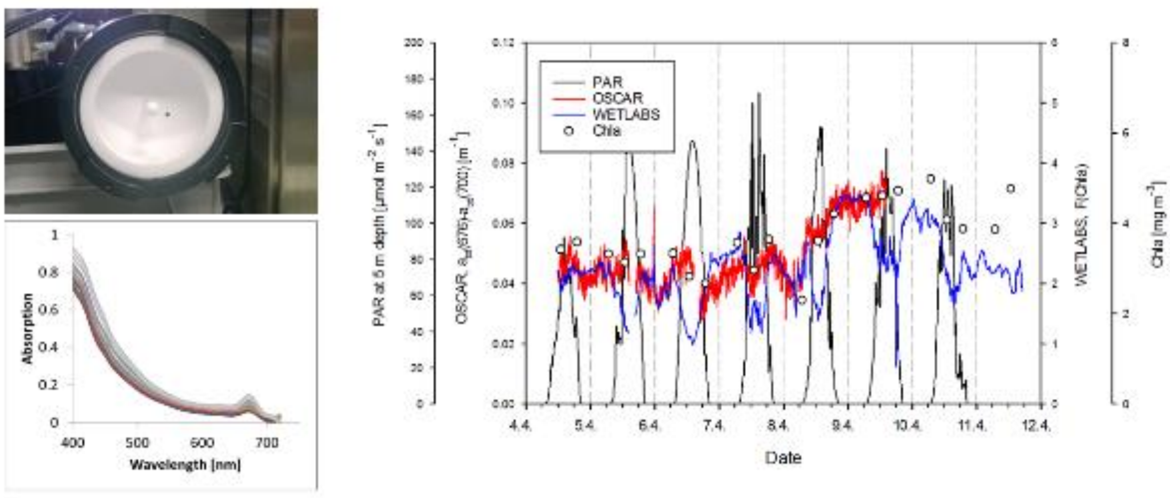


Figure 3.4-8. Intergarting cavity spectrophotometer Oscar (Upper Left), some absorption spectra collected at Utö station in April 2017 (Lower Left) and continuous measurement of light (PAR, black line), Chlorophyll a fluorescence with WETLABS fluorometer (blue line), showing decrease of fluoresce at noon,

proxy of Chlorophyll a concentration calculated from the absorption red peak of the OSCAR spectrophotometer (red line) and laboratory measurements of Chlorophyll a (open circles) (Right).

Measuring phytoplankton primary production using fluorescence induction technique is complicated as there is unknown reason for variability in the conversion factor between electron transport rate (measured with e.g. FRRF fluorometer) and carbon fixation rate (measured using carbon isotope). Part of the variability reported in literature might be due to different techniques used in different studies. In Utö station, in 2017, we studied the variability of the conversion factor during four one-week campaigns. The observed variability was from 4 to 18 (mol e- (mol C)$^{-1}$). In spring the variability was much less than during other seasons and close to the theoretical minimum value of 4. Values higher than 4 indicate that part of the light energy gained by primary reactions of photosynthesis are used for other processes than carbon fixation. Our results indicate that the observed variability in the conversion factor is not related to the time of the day (i.e. light), but rather to phytoplankton community composition and maybe also to availability of nutrients (Figure 3.4-9).

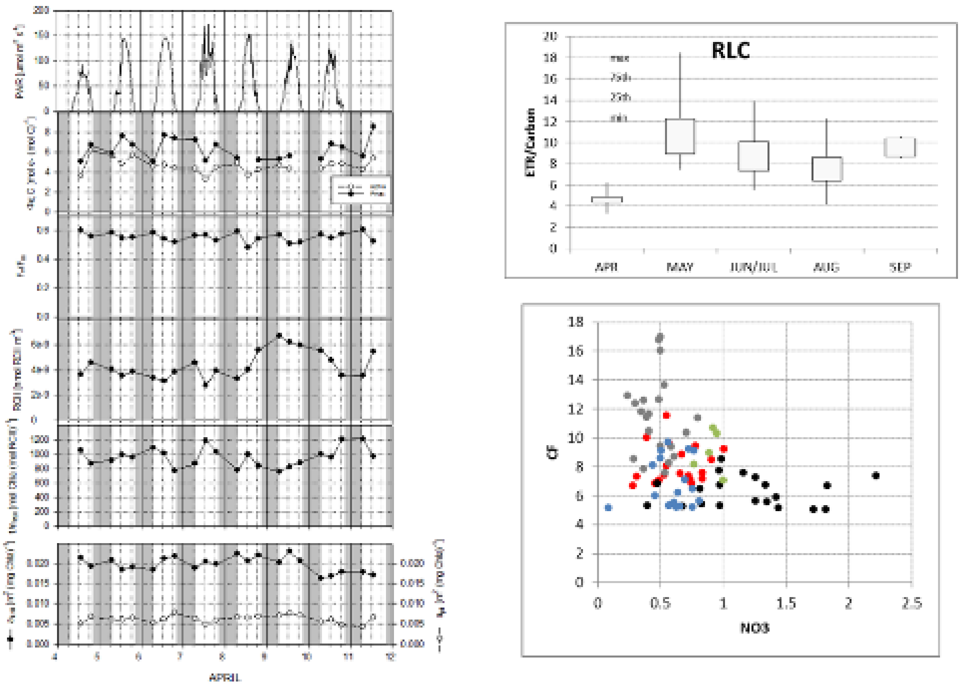


Figure 3.4-9 Fluorescence induction measurements during the intensive measurement period at Utö, in April 2017 showing values of Irradiance, conversion factor between electron transport rate and rate of carbon fixation, efficiency factor for photosystem II, number of reaction centers, size of reaction centers and absorption cross-section (from top to down, Left). Conversion factor varied seasonally (Upper Right) and was partly related to the amount of inorganic nutrients, thus physiological state of cells (Lower Right).

pCO$_2$ measurements and air sea C- fluxes

There is a gap in knowledge about the marine carbonate system in the Baltic Sea and the air-sea interchanges of carbon dioxide are essential for the understanding of climate change and its effects. In JRAP#5 we made continuous pCO$_2$ and pH measurements at Utö Atmospheric and Marine Research Station from April 2017 to April 2018 (Figure 3.4.6). In addition we measured a suite of other relevant variables (see 3.4.2), including also periodic samplings for alkalinity and DIC, as well as primary production.

In addition to fixed point measurements, pCO2 systems were installed on two ferrybox platforms. Cargo vessel Tavastland, a ship commuting between Travemunde and Kemi - thus covering the Baltic Sea including the Gulf of Bothnia every week, is part of the long term SMHI marine observing system. Passanger ferry Silja Serenade commutes between Helsinki and Stockholm daily, and is maintained by SYKE, while FMI took part in installing the carbonate system measurements onboard.

C-flux studies at Utö started by improvements of eddy covariance method (Honkanen et al 2018). The study compared two closed-path gas analyser setups, the other equipped with a drier and virtual impactor. The study shows that the measuring site is capable of monitoring air-sea CO_2 fluxes.

Dynamics and covariance of carbonate system measurements at Utö are currently analysed (Figure 3.4.6). Spring bloom in 2017 was moderate and pCO2 was at 200µatm at minimum. This period was showing a maximum of pH , around 8.4. The net autotrophic conditions remained until August-September, and in-water pCO2 values were lower than atmospheric ones. The period from autumn until spring 2018 was showing net heteotrophy with pCO2 values peaking at 700 µatm, pH showing a minimum at 7.9, and with low Chlorophyll values. The first order variability in pCO_2 and pH is related to biological activity. On top of that, smaller variability is due to effects of temperature on gas solubility, due to mixing events and transport of different water masses. The detailed analyses how these different components affect carbonate system is under scrutiny.

During four week-long campaigns in spring and summer in 2017, seawater pH and pCO_2 were measured by continuous measurement equipment (Figure 3.4.7). Alkalinity and DIC were measured using discrete water samples. Samples were taken three times a day at 7am, 1pm and 7pm local time. Additional details of the study are given in Lehto (2019). Measured values of carbonate system components support earlier results in the Baltic Sea. Alkalinity and DIC were strongly correlated. Also, both components correlated tightly with salinity. As for pH and pCO_2, those were clearly inversely related. Seawater pCO_2 was below the atmospheric content of CO_2 during the spring and summer until mid-August. In other words, the sea acted as a carbon sink. Additional measurements are needed to get data from all the seasons.

CO_2 system calculations and modeling are performed with CO2calc software (Robbins ym. 2010) designed for conditions in oceans. Large catchment area with DOM-rich river runoffs, hydrographical features, eutrophication and large seasonal changes makes Baltic Sea difficult to model. Best results were obtained when modelling was performed by including one of alkalinity or DIC and one of pH or pCO2. Even then, modelling results should be used with caution. As an example of modelling results, pCO_2 was systematically too low compared to measured values. Bias ranged from -40 to -138 ppm, mean prediction error was 12–42 %.of model results (Figure 3.4.8). Therefore, it would be best to measure all the four components to get the most accurate picture of the inorganic carbon system. Model could be improved for Baltic Sea conditions by taking account organic alkalinity and correct estimate for borates.

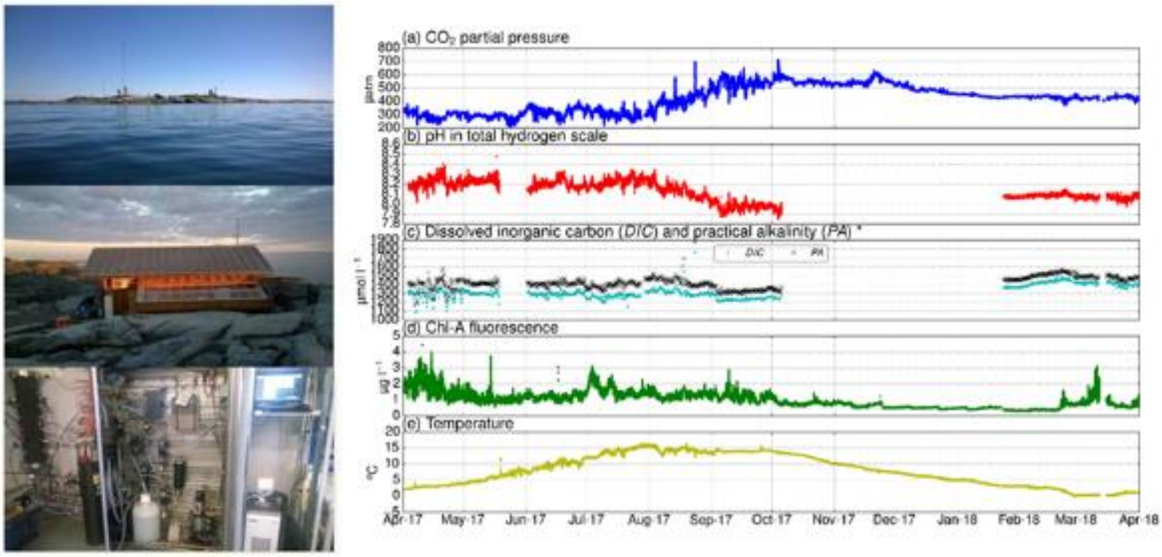


Figure 3.4-10 Utö Atmospheric and Marine Research Station (left), and measured variability in pCO2, pH, Chlorohyll fluorescence and temperature, and estimated DIC and alkalinity

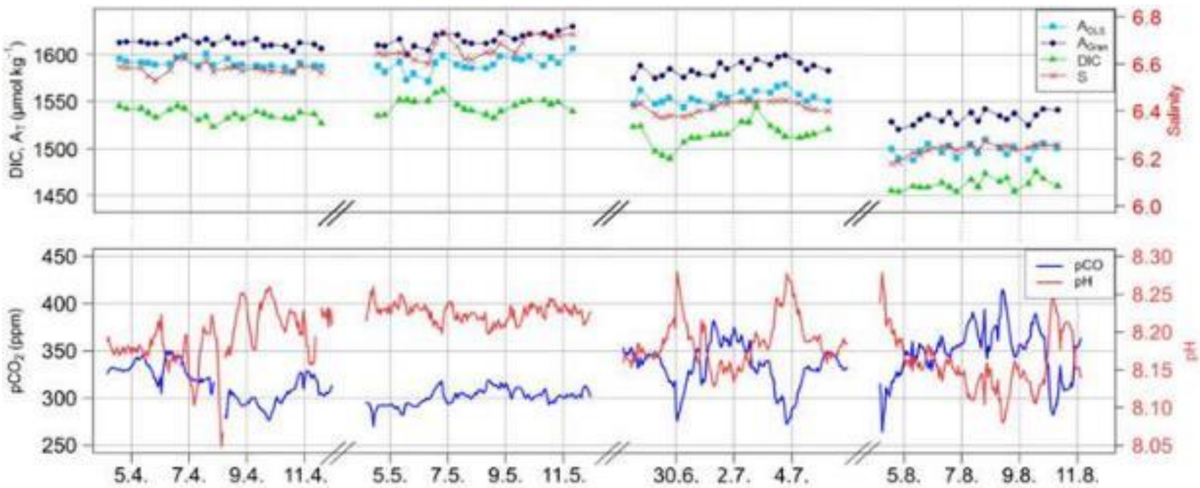


Figure 3.4-11 Inorganic Carbon System in Utö during four measurement campaigns in 2017. Gran method (blue) and ordinary least square -method (light blue) of alkalinity, dissolved inorganic carbon (green) and salinity (red) are shown in the upper diagram. Down are pH (red) and pCO2 (blue). Note the scales for salinity and pH in the right side.

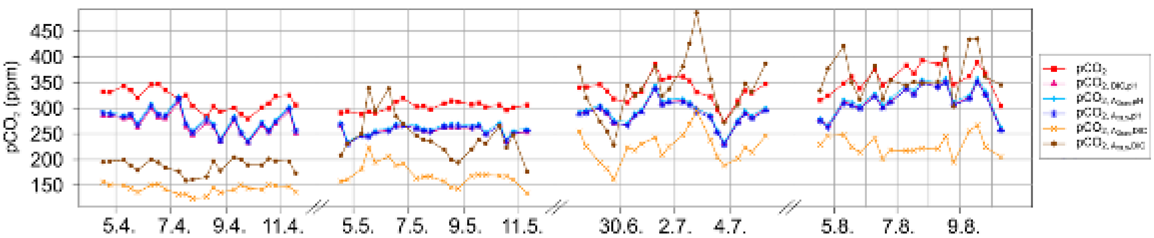


Figure 3.4-12 Results of measured (red squares) and modelled pCO_2 in Utö during the measuring campaigns in 2017. Pink triangles indicate pCO_2 modelled by DIC and pH measurements, light blue

diamonds by A_{Gran} and pH measurements, blue stars by A_{OLS} and pH measurements, yellow x-marks by A_{Gran} and DIC measurements and brown circles by A_{OLS} and DIC measurements.

Regarding the spatial variability in pCO2, the data from the ferrybox and the pCO2 system is merged in a phyton based program, Ferrybox Tools, in order to calculate pCO2 from xCO2, salinity and temperature. The toolbox can export data and make maps in scatter and time series format.

The aim for the measuring period has been to get pCO2 data from the ferrybox in the Gulf of Bothnian, since this is the first longer period of pCO2 measurements in this area. The transect in the Baltic Proper will be interesting to analyze and to compare with the ferrybox line Finnmaid, that also measure pCO2, partly at the same transect. The first results show a clear salinity dependence with lower pCO2 values in the Bothnian bay, where the salinity is below 4 psu.

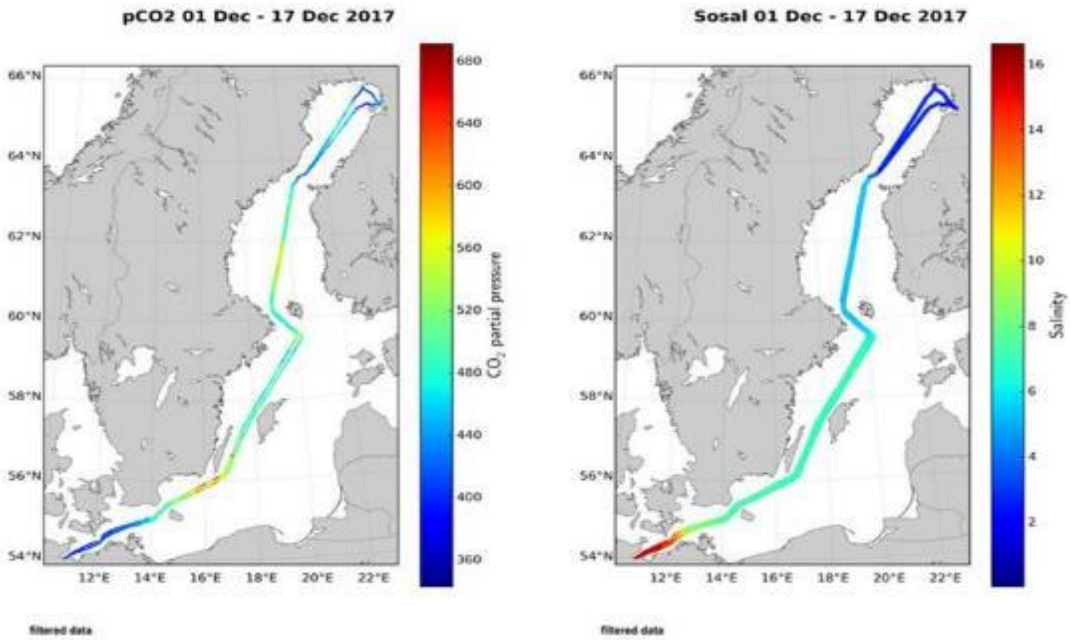


Figure 3.4-13 pCO2 (µatm) and salinity measurements from Tavastland during December 2017.

Operative wave modelling

We compared surface flowthrough Alg@line measurements from M/S Silja Serenade in the Baltic Sea to wave model data from the third generation wave model WAM (Figure 3.4-14). The wave model data were extracted based on the time and position of the ship. In this case study we use data from summer 2015 as we have quality-assured wave model data available for the whole year.

The temperature, salinity and turbidity measured by the ferry box showed some variations that can reasonably be attributed to wind and wave induced mixing. The amount of chlorophyll seemed to be dominated by other factors. The estimated turbulence of braking waves at the surface was found to be highly variable, with maximum values being 25 times the mean value. The added contribution was mostly concentrated to the top layer ($z < 1$ m) of the sea.

The relative contribution of the Langmuir turbulence (compared to the wind shear) was also determined, but was found to be small. This is in slight contrast to previous preliminary results by Tuomi (2014). However, there are many uncertainties involved with the estimation of the Langmuir number. Since the Langmuir turbulence is capable of enhancing the mixing deeper than turbulence by breaking surface waves, a more in-depth study into this phenomenon is recommended as future research.

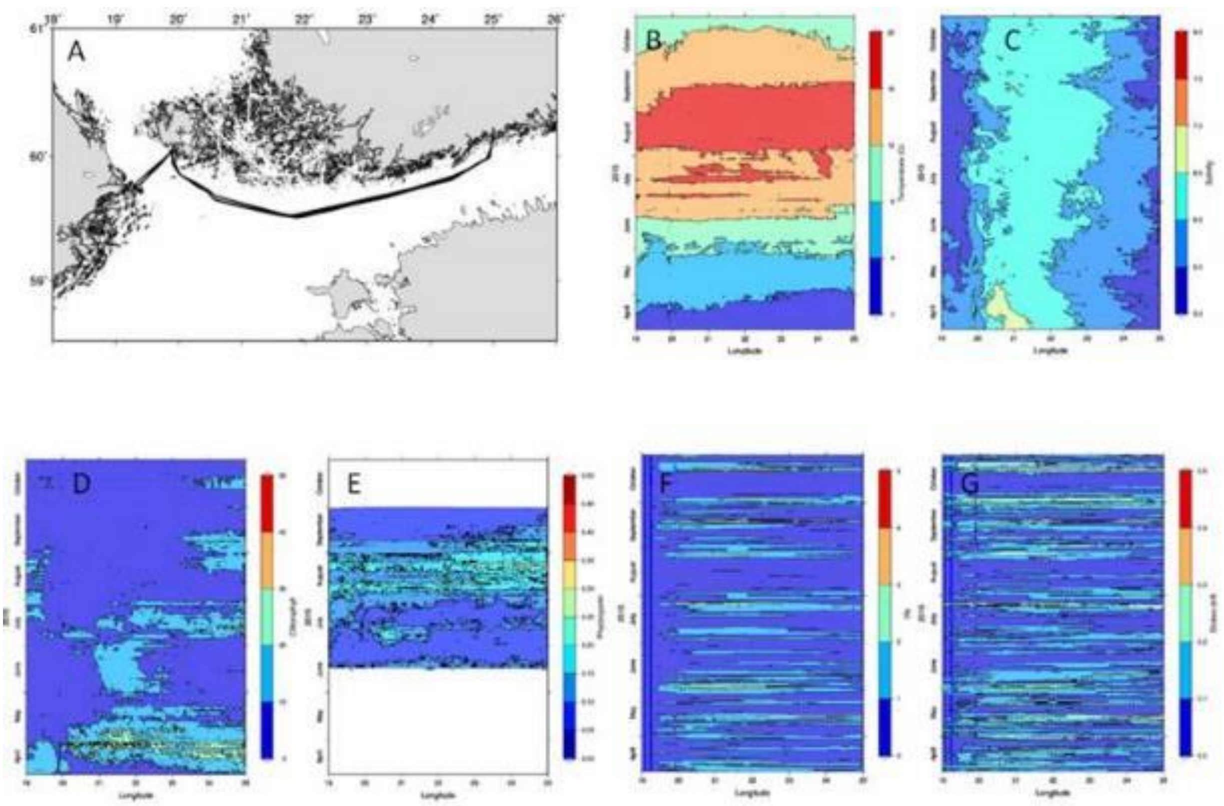


Figure 3.4-14 The route of Silja Serenade in the Baltic Sea with its stop in Mariehamn in between the ports of Helsinki and Stockholm (A). Temperature (B), salinity (C), Chlorophyll a fluorescence (D), phycocyanin fluorescence (E) measured by Silja Serenade. The significant wave height (F) and surface Stokes drift (G) at the ship track of Silja Serenade from the WAM results.

3.4.5. *Synthesis and way forward*

3.4.5.1. Synthesis and specific next steps

Data collection for JRAP#1 and JRAP#5 lasted until April 2018, while the modelling work for JRAP#6 was conducted in May 2018. For JRAP#1 data manuscripts are already in preparation for phycoerythrin and instrument comparison parts. One master thesis was published on phycoerythrin data (Rytövuori 2017). In JRAP#5, one paper (Honkanen et al. 2018) and one master thesis (Lehto 2019) have been published. Additional manuscripts on diurnal cycle of the CO_2 system and how environmental conditions affect cyanobacterial blooms are under preparation. The additional scientific papers are planned for

- description cyanobacterial bloom dynamics, based on multiplatform detection systems
- evaluation of the variability - and reasons behind – in the conversion factor from electron transport rate, as measured with FRRF technique, to carbon fixation.
- assessment of spectral absorption and fluorescence methods in describing the shifts in phytoplankton community composition,
- more holistic analysis, between site and between technology, protocols and computation algorithms for FRRF profiler parameters,
- between site and between technology comparisons in estimating carbonate chemistry variables.

It is expected that the results obtained for the Baltic Sea will provide insight on:

- monitoring gaps
  - e.g. which sea areas, seasons, subsystems (e.g. benthic systems) and variables need to be included to fine tune the C-flux estimates,
- technology gaps
  - e.g. which technologies would be essential to understand the spatiotemporal occurrence of phytoplankton blooms and their connection to physics and chemistry.
  - A specific question: are the integrated values of physiological parameters across the euphotic layer (via FRRF profiler) well correlated or explained by physico-chemical parameters than sub-surface values of these parameters?
- collaboration gaps
  - e.g. how to improve observations and fill in the gaps by advancing the multi-institutional, multinational, multisectoral collaboration.
  - Multinational collaborations are good opportunity to test hypothesis in various ecosystems; to build new database such like with the vertical FRRF profiles; to better understand photoacclimation plasticity in various ecosystems.
- knowledge gaps
  - e.g. what seem to be major unknows in C-fluxes.

One of the key concerns is that how the harmonize methodologies, to get fully comparable datasets for Baltic Sea. Another cost-efficient issue is, how to connect private sector data and public data. It would also be important to improve visibility and usability of operational oceanography data, services and products and to connect better with modelling and satellite communities. An important issue is also improving the scientific use of operational data, alone or in combination of other data, this effectively involves making the data more easily available.

3.4.6. *References for the Baltic Sea*

Andersen J.H., J. Carstensen, D. J. Conley, K. Dromph, V. Fleming-Lehtinen, B. G. Gustafsson, A. B. Josefson, A. Norkko, A. Villnäs and C. Murray, 2017. Long-term temporal and spatial trends in eutrophication status of the Baltic Sea. Biological Reviews 92. 135-149. https://doi.org/10.1111/brv.12221.

Honkanen M., J.-P. Tuovinen, T. Laurila, T. Mäkelä, J. Hatakka, S. Kielosto, and L. Laakso, 2018. Measuring turbulent CO2 fluxes with a closed-path gas analyzer in marine environment, Atmos. Meas. Tech. Discuss., 11, 5335-5350 https://doi.org/10.5194/amt-11-5335-2018.

Kahru M., O.P. Savchuk and R. Elmgren, 2007. Satellite measurements of cyanobacterial bloom frequency in the Baltic Sea: interannual and spatial variability. Mar Ecol Prog Ser 343: 15-23.

Lehto, A-M (2019) Modelling inorganic carbon system in Utö Baltic Sea. MSc Thesis. University of Helsinki. http://urn.fi/URN:NBN:fi:hulib-201905131931.

Leppäranta M. and K. Myrberg, 2009. Physical oceanography of the Baltic Sea. Springer-Verlag, Berlin-Heidelberg-New York, 378 pp.

Lips I. and U. Lips, 2017. The importance of *Mesodinium rubrum* at post-spring bloom nutrient and phytoplankton dynamics in the vertically stratified Baltic Sea. Front. Mar. Sci. 4, https://doi.org/10.3389/fmars.2017.00407.

Oxborough K., M. C. Moore, D, Suggett, T. Lawson, H. G. Chan and R. J. Geider, 2012. Direct estimation of functional PSII reaction centre concentration and PSII electron flux on a volume basis: a new approach to the analysis of Fast Repetition Rate fluorometry (FRRf) data. Limnol Oceanogr Meth 10: 142–154.

Reusch T. B. H., J. Dierking, H. C. Andersson, E. Bonsdorff, J. Carstensen, M. Casini, M. Czajkowski, B. Hasler, K. Hinsby, K. Hyytiäinen, K. Johannesson, S. Jomaa, V. Jormalainen, H. Kuosa, S. Kurland, L. Laikre, B. R. MacKenzie, P. Margonski, F. Melzner, D. Oesterwind, H. Ojaveer, J. C. Refsgaard, A. Sandström, G. Schwarz, K. Tonderski, M. Winder and M. Zandersen , 2018. The Baltic Sea as a time machine for the future coastal ocean. Science Advances 4, no. 5, eaar8195. DOI: 10.1126/sciadv.aar8195.

Robbins L., M. Hansen, J. Kleypas, S. Meylan, 2010. CO2calc: A User Friendly Carbon Calculator for Windows, Mac OS X and iOS (iPhone). U.S. Geological Survey Open-File Report 2010–1280 17.

Rytövuori S., 2017. Detection of picocyanobacteria and other algae containing phycoerythrin pigment in the Baltic Sea. MSc Thesis, University of Helsinki, *in Finnish*. http://urn.fi/URN:NBN:fi:hulib-201705174155.

Seppälä J., P. Ylöstalo, S. Kaitala, S. Hällfors, M. Raateoja and P. Maunula, 2007. Ship-of-opportunity based phycocyanin fluorescence monitoring of the filamentous cyanobacteria bloom dynamics in the Baltic Sea. Estuarine, Coastal and Shelf Science, 73, 489-500.

Sosik H.M. and R.J. Olson, 2007. Automated taxonomic classification of phytoplankton sampled with imaging-in-flow cytometry. Limnol Oceanogr Methods 5: 204-216Tuomi, L., 2014. On modelling surface waves and vertical mixing in the Baltic Sea. Ph.D. thesis University of Helsinki.

3.5. Norwegian Sea

Lead author: Luca Nizzetto, Andrew King (NIVA)
Involved institutes: NIVA, HZG
Participants: Ian Salter (FAMRI, associated partner), Dominique Durand (COVARTEC), Henning Wehde (IMR)
Involved JRAPs: JRAP 3 (Luca Nizzetto), JRAP6 (Henning Wehde)

3.5.1. *Specificities of the region*

3.5.1.1. Most relevant scientific questions from regional to local scales

General characteristics of the area

The Norwegian Sea covers ~1.1 million km^2 and is situated between the coast of Norway (to the east) and the Iceland and Greenland Seas (to the west/northwest). It serves as a physical and biogeochemical connection between the North Atlantic Ocean and the Arctic Ocean. A large fraction of northward heat and biogeochemical transport from the north Atlantic into the Norwegian Sea occurs via the North Atlantic Current (NAC), passing through the Faroe-Shetland Channel (Nilsen and Falck, 2006). Because of this circulation, biogeochemical processes occurring in the Norwegian Sea can affect the flux of nutrients and organic matter northward to the productive regions of the Barents Sea and Arctic Ocean. On larger spatial and temporal scales, biogeochemical processes in the Norwegian Sea proper ultimately determine preformed nutrient content of North Atlantic Deep Water formation water masses in the vicinity of the Lofoten Basin, a region that accounts for over half of global deep water formation.

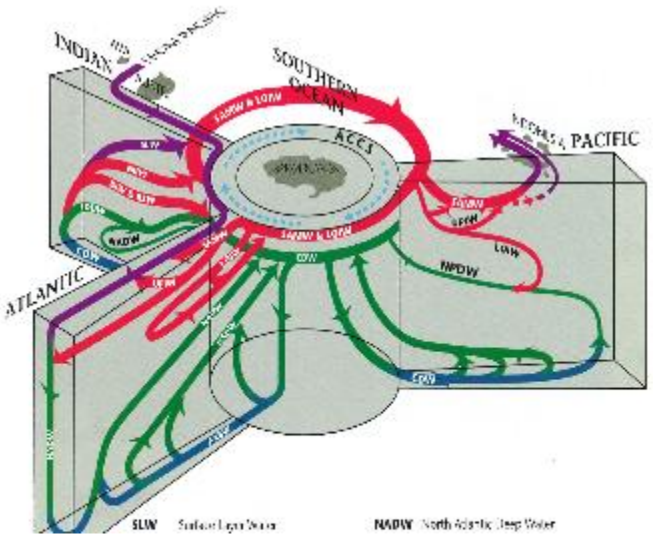


Figure 3.5-1 A three-dimensional schematic of global interbasin flow with typical vertical meridional sections for each ocean and their connections in the Southern Ocean. North Atlantic Deep Water formation in the Norwegian Sea is one of several major deep water formation processes. Reproduced from Gordon (1991).

High spring and summertime phytoplankton primary production (Rey, 2004) and zooplanktonic secondary production (Melle et al., 2004) support massive pelagic and demersal fisheries (Loeng and Drinkwater, 2007). Along coastal Norway, for instance, is a main spawning area for the prolific haddock and cod stocks that spend their adult years in the Barents Sea (Loeng and Drinkwater, 2007). Within the lowest trophic level, phytoplankton catalyse biological productivity by fixing inorganic nutrient elements, including carbon and nitrogen, and provide nutrition for higher trophic levels. Phytoplankton production also constitutes a substantial fraction of organic matter exported to the continental shelf and deep sea (Eppley and Peterson, 1979). Deep mixing during winter and subsequent stratification in the spring results in a nutrient-rich and relatively shallow sunlit surface layer. Several patterns have emerged regarding nutrient and phytoplankton dynamics in the Norwegian Sea. Springtime stratification and bloom timing has been linked to the North Atlantic Oscillation (NAO), presumably through variability in large scale climate, hydrology, and wind forcing (Skogen et al., 2007). And recently, a long-term decline in wintertime $Si(OH)_4$ (-16-22%) and NO_3 (-7%) inventories between 1990-2010 was reported (Rey, 2012), potentially linked to long-term variability in poleward transport of North Atlantic waters.

The eastern Norwegian Sea along Norway is composed of fjord ecosystems and coastal areas. Fjords are ubiquitous geological features in high latitudes, and characteristic of the Norwegian coastline. They are important marine ecosystems as local hotspots of productivity and C burial (Smith et al., 2015), provide nursery grounds for heritage fisheries like herring and cod, and are a cornerstone of the Norwegian aquaculture, tourism industry, and recreation. The ecosystem functions and services that fjords provide can, however, be adversely affected by a wide variety of human activities like pollution, habitat deterioration, over-exploitation of marine resources, and in the longer term, climate change driven warming and OA (Millennium Ecosystem Assessment, 2005; Solomon et al., 2007). Major changes in fjord and coastal ecosystems have been observed over the last few decades in southern/western Norway, with changes in the composition and phenology of plankton communities, loss of kelp forest, increased growth of fouling algae, and large fluctuations and declining trends in recruitment of near-shore fish populations (Johannessen et al., 2011; Trannum et al., 2012; Moy & Christie, 2012). A pronounced darkening of Norwegian fjords due to increased input of riverine organic matter has also been observed (Aksnes et al., 2009). Climate change has been identified as a major driver behind these changes through alterations in oceanic forcing and runoff from land (Harley et al., 2006).

The Norwegian Sea has an important role as a transitional area linking the European marginal seas as the North Sea to the Arctic. The North Sea and and European coastal areas in general are recipients of many antropogenic chemical contaminants The Norwegian Atlantic Current (NAC) and the Norwegian Coastal Current (NCC) are believed to be important conveyors of these contaminants towards high latitudes. Previous monitoring carried out using JERICO-RI infrastructures has shown that the North Sea water presents detectable levels of many chemical pollutants including, industrial chemicals, pesticides, personal care products, artificial food additives and pharmaceuticals (Brumowsky et al., 2015). The efficiency at which these water pollutants are transported along the NAC and NCC was never accessed before.

Most relevant scientific questions and those targeted in JERICO-NEXT

-Impact of climate variability and climate change on security and risk management of marine ecosystem services including aquaculture and fisheries

-Climate change effects on biodiversity and eutrophication

-Land-ocean interactions and influence of terrestrial inputs on coastal ecosystem

-Transport of anthropogenic C and chemical contaminants to Arctic

3.5.1.2. Most relevant societal needs and policy needs (including agencies/users potential list)

The coastal Norwegian Sea faces a number of issues linked to the growth of the aquaculture industry and resource exploitation (e.g., oil extraction, fish harvesting), but also faces major environmental and societal challenges including: climate change, ocean acidification, contaminant transport, and preservation of ecosystem services. Many of these challenges are linked to the WFD and MSFD discussed in previous chapters, and these issues are dealt with at a national level (Norwegian Environment Agency) at the regional level with local authorities and county governments. Further details of major environmental issues are listed below:

- increased finfish aquaculture operations in fjords that is managed by the Norwegian government; how to maximize production without causing a complete industry collapse and ecosystem deterioration?

- linked to aquaculture operations and eutrophication due to land-use changes, some deep fjord waters have been stratified and deoxygenated resulting in fish kills and hydrogen sulphide production (nuisance)

- climate change and ocean acidification effects on ecosystem structure and function at multiple trophic levels

- local input of chemical pollutants and transport of pollutants from Europe to the Arctic
- impact of physical environment on aquaculture
- Impact of aquaculture operations on ecosystem
- linking JERICO-NEXT to the established aquaculture traffic light system in Norway
- linking to ICES Ecosystem approach work

3.5.2. *Acquired data and archiving made (to be moved to appendix)*

Data type	Sampling location/area	Sampling period	Institute	Data repository
Chemical contaminants – from FerryBox survey	Norwegian Sea – Route: Bergen Kirkenes	08-25 August 2016	NIVA	Submitted to EMODnet Chemistry
Chemical contaminants – from FerryBox survey	Norwegian Sea – Barents Sea Route: Tromsø-Longyearbyen	21-23 June 2016	NIVA	Submitted to EMODnet Chemistry
FerryBox data, many parameters including salinity, temperature, chlorophyll fluorescence, turbidity, cDOM fluorescence, etc.	Norwegian Sea - Bergen-Kirkenes	2015-present (start in 2005)	NIVA	NIVA, European FerryBox Database, Copernicus, and EMODnet Physics
FeryBox data, many parameters including salinity, temperature, chlorophyll fluorescence, turbidity, cDOM fluorescence, etc.	Norwegian Sea - Tromsø-Longyearbyen	2015-present (start in 2008)	NIVA	NIVA, European FerryBox Database, Copernicus, and EMODnet Physics
Contaminant-Chemical data from surveys	Norwegian Sea	1970´s	IMR	IMR
Ferrybox data, many parameters including salinity, temperature, chlorophyll fluorescence	Norwegian Sea - Bergen-Kirkenes	2006-present	IMR	IMR

3.5.3. *Collaboration with other international initiatives*

-

3.5.4. *Scientific progress so far*

JRAP#3: Occurence of Chemical Contaminants :

Within JRAP#3 we have conducted two cruises using the FerryBox platform (Bergen-Kirkeness and Tromsø-Longyearbyen routes). The Norwegian Sea is a key conveyor belt for contaminants originated in high source-density regions of the North Sea towards the Arctic. Analysis the transport pathway of waterborne contaminants along this transect is instrumental to assess the spatial range of contaminants with different properties and address question regarding exposure to the Arctic. These challenges are both relevant for the MSFD, for the Arctic Monitoring and Assessment Programme (AMAP) and for the Stockholm Convention on persistent organic pollutants.

The monitoring conducted within JRAP 3 included a transect between Tromsø to Longyearbyen in the Svalbard archipelago. This was necessary to address questions regarding the function of the Norwegian Sea current system as a vector of contaminants to the Arctic environment. During the sampling campaign we have collected data for a number of contaminants including: 42 currently used pesticides in Europe, 5 artificial sweeteners and 11 pharmaceuticals and personal care products. Data on pharmaceuticals and personal care products are currently under quality check. Concerning currently used pesticides, several compounds were detected in the Norwegian Sea, displaying elevated spatial range and potential for Arctic contamination (Figure 3.5-2).

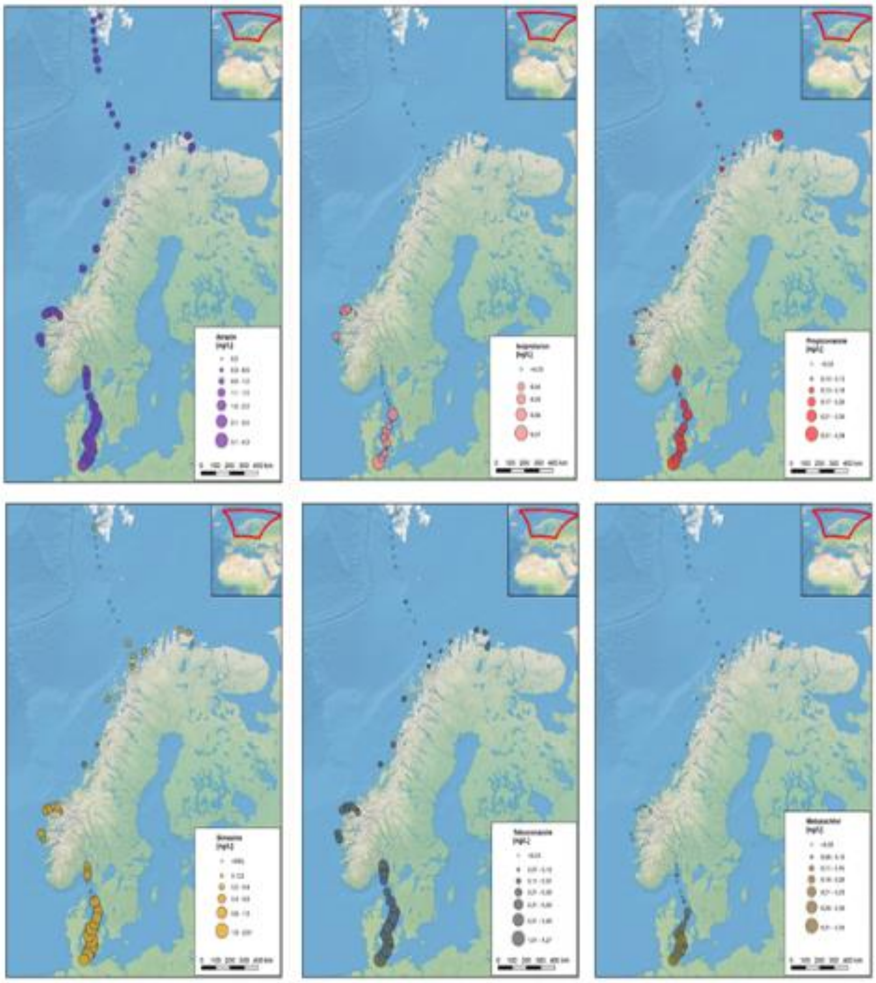


Figure 3.5-2 Distribution of selected current use pesticides

Pesticides are used mainly in agriculture and reach coastal areas through surface runoff and riverine transport. Their distribution in more coastal areas such as the Kattegat and Skagerrak region showed, as expected, a strong dependence on salinity.

Among them Atrazine, an extremely persistent and water soluble herbicide banned in Europe for Agricultural use in 2003 (Bethsass and Colangelo, 2013) and included among priority substances in the EU WFD and MSFD is found to be ubiquitous along the monitored transect. Levels in the Norwegian Sea and Barents Sea were lower than in areas directly affected by land-based sources, such as the Kattegat and Skagerrak. However, no progressive decline with distance from anthropic areas was observed, suggesting long range Atlantic transport being a relevant contributor to Atrazine in the region. These results highlight the large potential for long range transport of Atrazine through marine currents. Atrazine detected in this area could potentially reflect sources in remote locations, such as North and Central America, where these herbicides is still in use.

Other pesticides such as Simazine (also included in the MSFD priority list) and Tebuconazole and Propiconazole (not included in the MSFD priority list) were frequently detected in the region but their distribution reflected coastal emission hotspots.

Artificial sweeteners are artificial additives extensively used in food and soft drink industry. They are emitted to the environment through wastewater after passing human and wastewater treatment metabolisms, to a large extent, unaffected. They generally are highly soluble and persistent. For this reason, they have been suggested as markers of wastewater contamination in the environment. Of 5 analyzed artificial sweeteners only Sucralose was detected ubiquitously along transects. Sucralose is a large production sweetener. It is characterized by extreme environmental persistence and solubility. The result shown here suggests this substance as an ideal oceanographic marker of potential anthropic influence from wastewater. To our knowledge this is the first time Sucralose is measured in open Atlantic water. Measured concentrations were in the order of ng/L even in open European and Arctic waters, making Sucralose possibly the most abundant anthropogenic substance in the oceans.

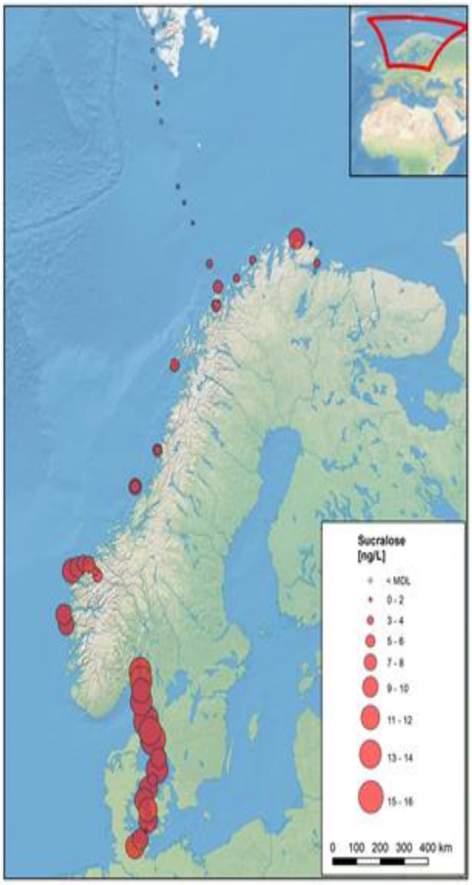


Figure 3.5-3 Distribution of Sucralose

JRAP #5 Coastal carbon fluxes and biogeochemical cycling
Richard Bellerby, Andrew King and Kai Sørensen (NIVA)

Carbon fluxes and carbonate system variability in the Norwegian Sea, as with other coastal regions, are partially driven by changes in freshwater inputs from riverine and ice melt sources from land and saline waters from the Atlantic Ocean in the south. Freshwater input into the Norwegian Sea typically transits through fjords that ubiquitously line the Norwegian coast (Figure 3.5-4). Low salinity periods occur mostly during spring/summer when snow and ice accumulated on land during winter melts and flows into the fjords and the sea. Regions with especially strong impacts of freshwater input include southwestern Norway, near Trondheim and Trondheimsfjord (~66 deg N), and some regions in southern (<64 deg N) and northern Norway (~69-70 deg N) (Figure 3.5-3 & 5.4). Seasonal variability in temperature (up to a 8-10 ˚C differential between summer and winter depending on latitude) is also a large driving force on carbonate system variability (Figure 3.5-4) including a decrease in surface water fCO_2 due to lower wintertime temperatures as well as the uptake of atmospheric CO_2 as water cools during its northward journey from the North Atlantic to the Arctic Ocean. Photosynthetic activity during spring and summer algal blooms draws down dissolved inorganic C and results in annual minima in surface water fCO_2. The spring bloom typically progresses from south in early March and then to north with an offset of ~weeks.

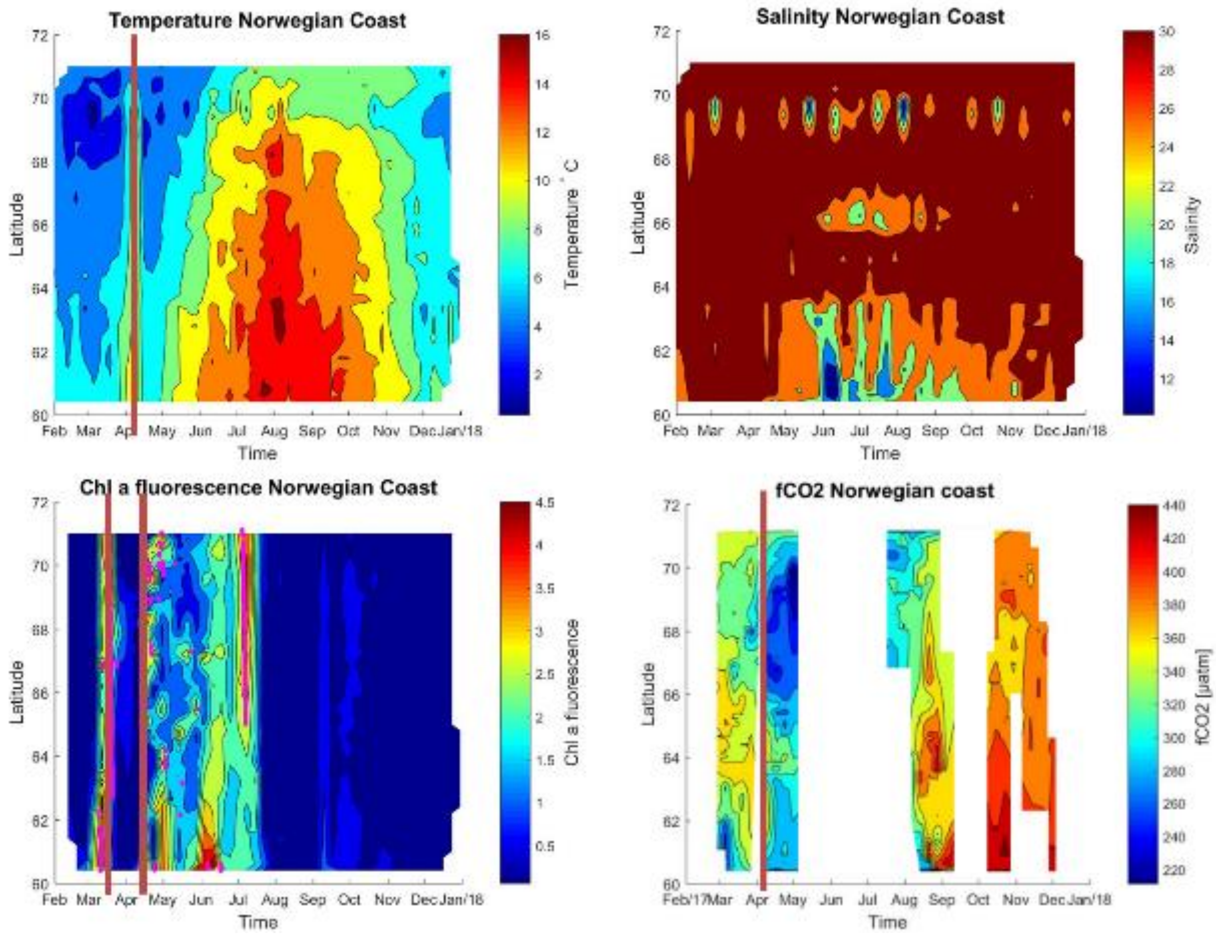


Figure 3.5-4: Temperature, salinity, chl a fluorescence, and fCO2 data collected from M/S Trollfjord FerryBox from Feb 2017-Dec 2017 along the Norwegian coast from ~60 deg N to 71 deg N. Red linesIindicate time periods where data quality was flagged as suspicious.

JRAP#6 Operational oceanography and forecasting

Main focal point of interest for the operational oceanography in the Norwegian Sea and their coastal areas is the provision of near real time information on ocean circulation and transport of potential harmful pollutants/ substances/algae/parasites towards the needs of the aquaculture and oil/gass industry and to serve as decision base for the governmental decision on extending the industrial activities. One of the main steps in the recent years was the development of the so called ´traffic light system´ providing the knowledge base for decision makers to decide on the increase/maintaining/reduction of aquaculture production in 13 regions along the Norwegian coast (see Figure 3.5-5). This development is of highest interest and is based on the model estimates of the so called NorKyst800 model (Norwegian Coast 800) which is strongly dependant on near real time provision of the Jerico-Next observational infrastructure.

.

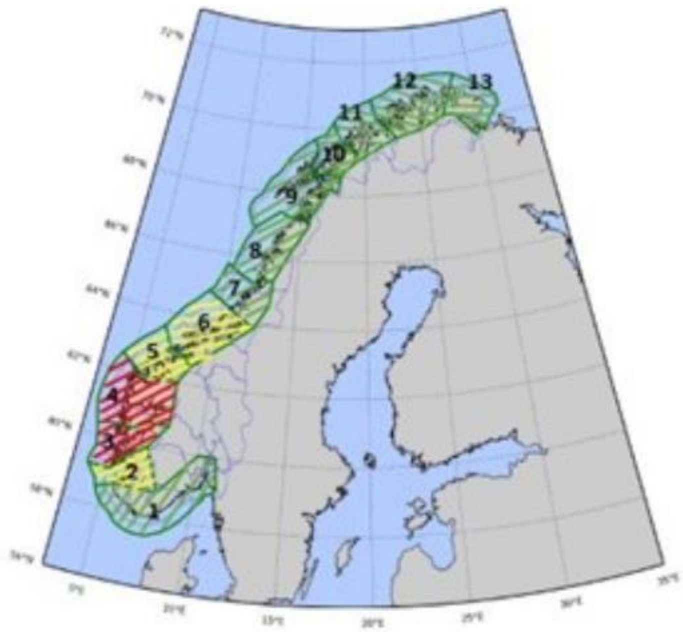


Figure 3.5-5: Distribution of the 13 production areas along the Norwegian coast with the results for the year 2017. Green colour means that the production can be increased, Yellow, that the production can be maintained and red that the production has to be reduced

The NorKyst-800 (Norwegian Coast 800m) is a numerical, high-resolution, ocean modelling system. The main motivation for establishing NorKyst-800 was the potential to provide environmental information for all coastal areas in Norway as input to applications regarding oil spills, drift of floating objects ("man-over-board"), spread of harmful algae and salmon lice etc. This model relies substancially on the provision of JERICO-NEXT observations in terms of model validation that is crucial for the improvement of the estimates.

3.5.5. *Synthesis and way forward*

3.5.5.1. Synthesis and specific next steps

The coastal Norwegian Sea is an immense coastline with countless islands and fjords - small and large alike. There are clearly regions that are more sensitive to environmental issues than others (e.g., Lofoten Islands), and regions that have historically and at present are experiencing high levels of anthropogenic impacts (e.g., fjords with large aquaculture operations, southern Norway where population is higher). The coastal Norwegian Sea also experiences periods of high flow of freshwater and watershed constituents (nutrients, dissolved organic matter, pollutants) in certain regions - this is not only source terms for freshwater and its constituents, but the buoyancy effect of freshwater in coastal regions can dramatically affect water column stratification and circulation.

Because of the interdependence between biological, chemical, and physical variables in the coastal ocean of the Norwegian Sea, observations of multiple ocean disciplines must be integrated with the corresponding terrestrial/watershed disciplines. Further, due to seasonality and large regional variability, observations should also ideally be temporally and spatially coordinated in order to maximize the value of observations and level of understanding.

3.5.6. *References for the Norwegian Sea*

Aksnes, DL, Dupont, N, Staby, A, et al., 2009. Coastal water darkening and implications for mesopelagic regime shifts in Norwegian fjords. Mar. Ecol. Prog. Ser. 387:39-49.

Bethsass J., Colangelo, A., European Union Bans Atrazine, While the United States Negotiates Continued Use, International Journal of Occupational and Environmental Health, 2013, Volume 12, 2006 - Issue 3

Brumowsky, M.; Becanova, J.; Kohoutek, J.; Thomas, H.; Petersen, W.; Sørensen, K.; Nizzetto, L., 2016, Exploring the occurrence and distribution of contaminants of emerging concern through unmanned sampling from ships of opportunity in the North Sea. Journal of marine systems, 162, 47-56

Eppley, R.W. and Peterson, B.J., 1979. Particulate organic-matter flux and planktonic new production in the deep ocean. Nature, 282(5740): 677-680.

Gordon, A., 1991. The role of thermohaline circulation in global climate change. In: Lamont–Doherty Geological Observatory 1990 & 1991 Report, Lamont–Doherty Geological Observatory of Columbia University, Palisades, New York, pp. 44–51.

Harley, CDG, Hughes, AR, Hultgren, KM, et al., 2006. The impacts of climate change in coastal marine systems. Ecol Lett 9:228−241.

Johannessen, T, Dahl, E, Falkenhaug, T, Naustvoll, LJ, 2011. Concurrent recruitment failure in gadoids and changes in the plankton community along the Norwegian Skagerrak coast after 2002. ICES J Mar Sci doi: 10.1093/icesjms/fsr194.

Loeng, H. and Drinkwater, K., 2007. An overview of the ecosystems of the Barents and Norwegian Seas and their response to climate variability. Deep-Sea Research Part Ii-Topical Studies in Oceanography, 54(23-26): 2478-2500.

Melle, W., Ellertsen, B. and Skjoldal, H.R., 2004. Zooplankton: the link to higher trophic levels. In: H.R. Skjoldal and R. Sætre (Editors), The Norwegian Sea ecosystem. Tapir Academic Press, Trondheim, pp. 559 p.

Millennium Ecosystem Assessment, 2005. Ecosystems and human well-being: synthesis. Washington, DC: Island Press. ISBN 1-59726-040-1.

Moy, F, Christie, H, 2012. Large-scale shift from sugar kelp (Saccharina latissima) to ephemeral algae along the south and west coast of Norway. Mar Biol Res 8:309−321.

Nilsen, J.E.O. and Falck, E., 2006. Variations of mixed layer properties in the Norwegian Sea for the period 1948-1999. Progress in Oceanography, 70(1): 58-90.

Rey, F., 2004. Phytoplankton: the grass of the sea. In: H.R. Skjoldal and R. Sætre (Editors), The Norwegian Sea ecosystem. Tapir Academic Press, Trondheim, pp. 97–136.

Rey, F., 2012. Declining silicate concentrations in the Norwegian and Barents Seas. Ices Journal of Marine Science, 69(2): 208-212.

Skogen, M.D., Budgell, W.P. and Rey, F., 2007. Interannual variability in Nordic seas primary production. Ices Journal of Marine Science, 64(5): 889-898.

Smith, RW, Bianchi, TS, Allison, M, et al., 2015. High rates of organic carbon burial in fjord sediments globally, Nature Geoscience, doi:10.1038/ngeo2421

Solomon, S., Qin, D., Manning, M., et al., 2007. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Trannum, HC, Falkenhaug, T, Omli, L, et al., 2012. Fact sheet from the Coastal Monitoring Programme (TA-2905) 4 pp. In Norwegian.

3.6. Mediterranean Sea: Summary of circulation as a common introduction for JERICO-NEXT work in that sea.

The Mediterranean Sea is a semi-enclosed basin characterized by a multiscale circulation including basin scale processes (exchange through the various straits and thermohaline circulation), mesoscales and sub-mesoscale processes (closely related to air-sea fluxes at the sea surface). The Mediterranean Sea can be divided into several sub-basins interconnected among each other and JERICO-NEXT focuses on the investigation of the following areas: Ligurian Sea, Adriatic Sea, Aegean/Cretan Sea, Ibiza Channel, Tyrrhenian Sea, and Algero-Tunisian basin (**Erreur ! Source du renvoi introuvable.**):

Figure 3.6-1 Map of the Mediterranean Sea. In yellow the areas of investigation involved in JERICO-NEXT.

The North Western Mediterranean is a specific region playing a key role for the hydrology and biogeochemistry of the whole basin due to (1) the deep convection that redistribute organic and inorganic matters all over the water column, and (2) the subsequent intense spring bloom that represents the most important biological process of the basin at the origin of carbon exports (MerMex group, 2011). It is one of the most dynamic region in the Mediterranean Sea.

At the basin scale the Western Mediterranean has a cyclonic circulation involving waters of relatively recent Atlantic origin (AW) in the surface layer and Levantine Intermediate Water (LIW) in the layer below. Inside the cyclonic gyre circulation, surface cooling and evaporation due to cold and dry northern winds and preconditioning of the water column (Levantine Intermediate Water uplifting) are important in winter in the Gulf of Lion resulting in the apparition of warmer and denser new deep water (Testor et al., 2018). In addition, intense winds produce colder and fresher water in the shelf of Gulf of Lion which overflow occasionally the shelf edge and cascade through the canyons (De Madron et al., 2013).

The intensity of the vertical mixing in winter will condition the nutrients supply which will trigger the biomass production during the spring period. Due to the dynamic system and the presence of boundary currents in the north and in the south, the western basin can be characterized by different bio-regions based on the chlorophyll-a (Chl-a) seasonality (D'Ortenzio et D'Alcala, 2009; Mayot et al., 2017). These bio-regions range from "high bloom" and "intermittently bloom" in the Gulf of Lion and Ligurian Sea to "no bloom" region in the Algerian basin. This spatial clusterization determines the carbon biological pump efficiency and the carbon sequestration (Kessouri et al. 2018) which plays a crucial role in the climate, since oceans have absorbed, and still absorbs about a quarter of anthropogenic CO_2 emissions (Le Quéré et al., 2018), limiting the increase in atmospheric carbon dioxide (CO_2) but increasing ocean acidity (Gattuso and Hansson, 2011).

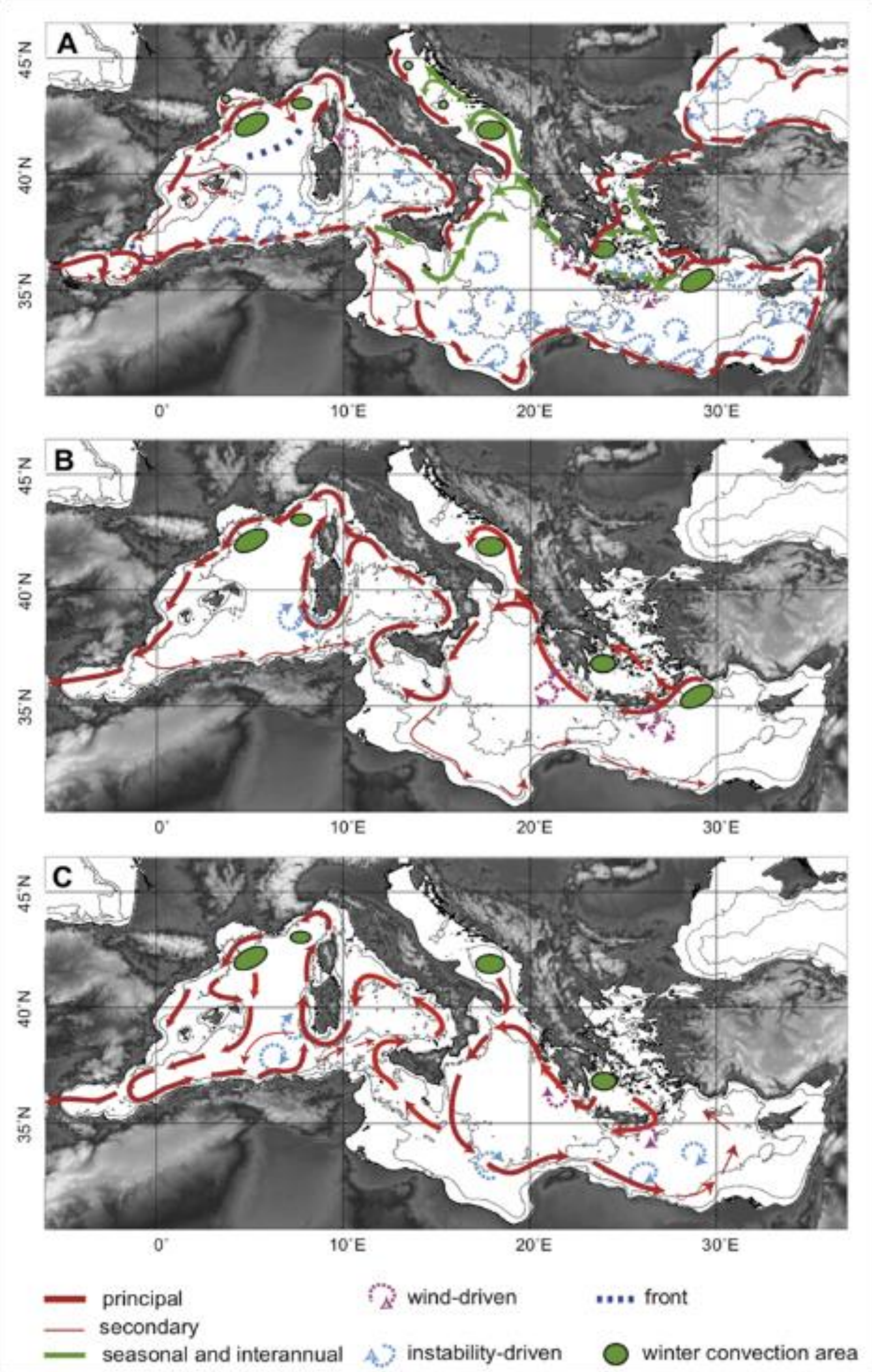


Figure 3.6-2 (A) Circulation of surface water masses, redrawn from Millot and Taupier-Letage (2005a). (B) Circulation of intermediate water masses, and (C) represents circulation of deep water masses. The thin lines represent the 1000-m and 2000-m isobaths (MerMex group, 2011)

3.7. From the Ligurian Sea to the Ibiza Channel (NW Mediterranean Sea)

Involved JRAPs: 1, 4, 6

Authors: M. Berta, A. Griffa, L. Coppola, L. Stemmann, M. Thyssen, G.Grégori, I. Pairaud, E. Jansen, S. Ciliberti, G. Coppini, S. Marini, A. Molcard, C. Quentin, B. Mourre, J. Tintoré, J. Allen, A. Ribotti, B. Zakardjian, I. Puillat

3.7.1. *Specificity of the region*

3.7.1.1. Most relevant scientific questions from regional to local scales

General characteristics of the area

The circulation in the northwestern Mediterranean Sea is cyclonic and characterized by an intense boundary current, the Northern Current (NC) (Millot et al., 1999). It is formed in the Genoa Gulf by the junction of the Western Corsica Current (WCC) and the Eastern Corsica Current (ECC) flowing out of the Tyrrhenian Sea through the Corsica channel. This cyclonic gyre is closed to the south by the current associated with the presence of a density front crossing the basin from west to east, the North Balearic Front (NBF). It constitutes an important dynamic barrier between the surface waters of the northern and southern parts of the Western Mediterranean (Mancho et al., 2006), which in fact have very different physical functioning. The general circulation of the NC is affected by seasonal variability as well as synoptic processes (Albérola et al. 1995). Even though the NC variability affects marine and coastal activities across the whole NW Mediterranean Sea, so far it has been investigated in a few specific locations of the basin (coastal and offshore sites nearby Nice and Marseille, such as Sammari et al., 1995, Conan and Millot, 1995).

Shelf water cascading produce occasionally in winter dense and cold water cascading over the shelf edge through canyons in the Gulf of Lion and the Catalan-Margin. This shelf water cascading produces a large supply of organic material to deep water column and responsible to intense resuspension layer which could reach the Ligurian Sea during intense and very cold winter (Canals et al., 2006; Puig et al., 2013). Outside these periods, gales, particularly from the East, reduce the residence time in the Gulf of Lion of coastal waters strongly influenced by the Rhône and produce a transfer of biogenic elements and contaminants to the Catalan coastal zone (Mikolajczak et al., 2019).

Changes in the Western Mediterranean are often concentrated in the Ibiza Channel, which with its narrow width (80 km at narrowest point) and sill (800 m), governs an important inter-basin exchange of water masses. As with other restricted “choke points” in the global ocean, for example Drake Passage in the Southern Ocean (Meredith et al., 2011) and the Fram and Denmark Straits in the North Atlantic, dynamic processes in the Ibiza Channel exert a controlling influence on the exchange of water volumes. It is important to monitor and characterise the variability of these exchanges (Send et al., 2010); SOCIB has been doing this with gliders since 2011. Heslop et al. (2015), showed autonomous ocean gliders in the Ibiza Channel (Western Mediterranean Sea) show variations in the transport volumes of water over timescales of days-weeks, as large as those previously only identifiable as seasonal or eddy driven. High frequency variation in transports of water masses has critical implications for ocean forecasting. Eddies are a persistent feature in the seasonal cycle of the Balearic Sea, formed within the sub-basin or further north, both cyclonic and anticyclonic ‘blocking’ eddies of variable size (30 – 80 km) have been observed in the Ibiza Channel. The anticyclonic ‘blocking’ eddies are frequently associated with cold cores of Western Mediterranean Intermediate Water (WIW), leading to the suggestion that this water mass plays a determining role in the Ibiza Channel transports (Pinot et al., 2002; Pinot and Ganachaud, 1999). WIW is a cold winter produced water mass formed in the Gulf of Lion, Balearic and Ligurian Seas (Conan and Millot, 1995; Salat and Font, 1987, Vargas et al., 2012), during strong winter cooling events that cause a mixing and cooling of the surface AW to a buoyancy equilibrium between AW and LIW.

As a consequence, a major investigation effort was led in the Ligurian Sea, in the Gulf of Lion and the Catalan Margin to study the variability of the NC, the interactions between physical and biogeochemical processes and their impact on the biomass of plankton and marine particles through the combination of independent and complementary observational platforms deployed in this sub-region. Major results have shown a clear correlation between hydrographic changes led by climatic inter-annual variability and the community composition of phytoplankton and zooplankton (Howes et al. 2015, Auger et al., 2014, Vandromme et al., 2011, Garcia-Comas et al., 2011). The role of mesoscale processes have been shown (Falkowski et al., 1991) to be important to locally enhanced marine productions/accumulation, and above that, the submesoscale and hourly processes modulate and generate large variability that has to be integrated (Levy et al., 2001; Thyssen et al., 2009). More downstream from the NC, the Balearic Sea is a particularly challenging region for ocean operational forecasting systems due to the complexity of the topography and of the ocean dynamics from coastal area to open sea. In particular, the Ibiza Channel (IC) is a circulation “choke” point in the western Mediterranean, governing the meridional water mass exchanges between the adjacent sub-basins. The circulation is highly variable under the influence of multiple ocean processes (basin-scale circulation, sub-basin scale recirculation, mesoscale activity, shelf-slope exchanges, water mass spreading and mixing), and strongly affects the local ecosystem (e.g. Atlantic Bluefin tuna spawning). A mixed multi-platform / multidisciplinary observing and modelling approach is used to investigate ocean processes in that area.

High resolution observations of biochemical processes contribute to fill the gap in biogeochemical datasets and models. Targeted observations of physical and biochemical properties at the edge of coastal and open waters help to understand the influence of coastal activities and urban sewages on the open sea fertilization. Moreover winter storms and dense water convection events fuel nutrients to the surface layers and trigger phytoplankton blooms. These processes are still poorly understood both from a physical and biological point of view due to the impracticability of sea operations during such severe weather conditions. This issue could be overcome through the coordination and networking of the arising remote sensing and automated platforms with the historical observational sites in the area. Bridging the gap between physical and biochemical observations contributes to understand processes and conditions enhancing primary production that in turn is channeled to the higher trophic layers sustaining the proliferation of pelagic fishes (such as anchovies and sardines) and marine mammals. In fact, this aspect is particularly important for the Ligurian Sea being in the heart of the Pelagos Sanctuary for Mediterranean Marine Mammals, marine protected area established since 1999, extending about 90.000 km2 in the northwestern Mediterranean Sea between the Liguro-Provencal coast and the Island of Sardinia, encompassing Corsica and the Archipelago Toscano.

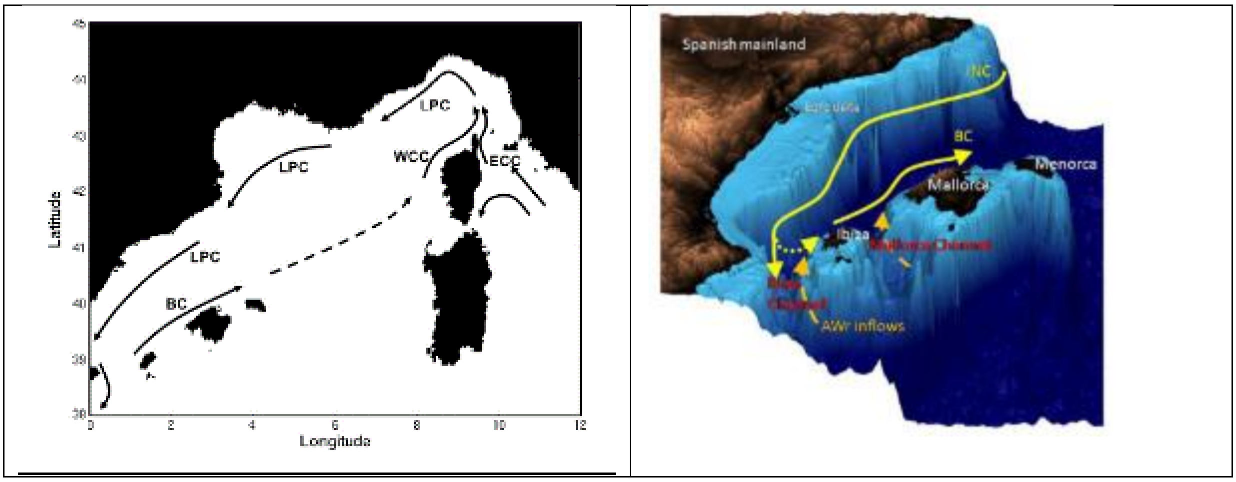


Figure 3.7-1 Left Schematic view of the major ocean circulation features in the NW Mediterranean Sea (Birol et al. 2010), Rigth: a focus on the Balearic Sea and in the Channel of Ibiza

Most relevant scientific questions and those targeted in JERICO-NEXT

Main scientific questions for the area relates to:

a) dynamics of the boundary currents with objective to identify the interplay between various forcings (remote, thermohaline and wind), and generation of mesoscale and submesoscale instabilities.

b) impact of transport on the biological component (such as, phytoplankton, larvae, jellyfishes and shrimps) and on pollutants (such as oil, chemicals, and micro/macroplastic).

c) influence of coastal activities and urban sewages on the open sea fertilization and pollutant impact

JERICO-NEXT focus is on items a) and b) from Ligurian Sea to Balearic Sea and moreover on the meridional water mass exchanges through the Ibiza Channel circulation choke point. It also investigates how winter storms and dense water convection events trigger phytoplankton blooms.

To reach these objectives, the methodology is based on analysis of HF radar data, deployment of in situ observing systems (gliders, ferrybox and low cost MASTODON-2D moorings upgraded in the framework of WP3), modeling, data assimilation and analysis.

How? Particularly within JERICO-NEXT, JRAPs 1, 4, 6 drew effort to:

1) Reconstruct the three dimensional transport in the Ligurian current to study the connection between surface and water column currents and dynamics. Investigate the usage of HF radar data to infer subsurface information on transport. Analyze the impact of blending HFR data with complementary velocity datasets, in particular (but not only) through data assimilation in numerical models.

2) Deploy low cost in situ mooring (MASTODON-2D) for temperature monitoring

3) Evaluate the capacity of regional ocean models to represent the here above processes and the improvement provided by the assimilation of coastal observations

4) Collect new biogeochemical datasets (phytoplankton functional diversity, …) from automated and innovative sensors and couple with models through high resolution observations of biogeochemical stocks and processes in coastal and open sea areas.

3.7.1.2. Most relevant societal needs and policy needs (including agencies/users potential list)

The NW Mediterranean Sea is characterized by densely populated coasts, which exert increasing pressure and disturbance on **Marine Protected Areas (MPA)** that are of great importance for **conservation of biodiversity**. MPAs are located along the coast next to important ports and industrial areas and extend also to pelagic areas, the suitable habitat for marine mammals. It is therefore crucial for a correct managing of the coastal activities, conducive of a sustainable blue growth, to understand how ocean currents and their transport trigger primary productivity, affect the distribution of larvae and eggs of marine species as well as to understand how currents spread **harmful chemical pollutants** and **plastic debris**.

Investigation of physical and biological properties in the NW Mediterranean Sea provide useful information for the **management of sustainable fisheries** through modelling sharpness, i**ntroducing phytoplankton size and functional traits within global biogeochemical** models. Biophysical observations also contribute to the understanding of **recurrent harmful algal blooms or massive jellyfishes beaching** which affect touristic activities along the coast.

Moreover monitoring ocean currents at sea also play a key role for **navigation route planning** and safety. In fact, route recommendations typically rely on weather forecasts due to the limited spatio-temporal resolution of the oceanographic forecast products. The availability of coastal observatories and high-resolution ocean forecast products including observations assimilation would find application for optimal ship routing.

Potential users include Environmental Agencies, Life Guard, Port Authorities, Regional and local authorities.

3.7.2. *Acquired data and archiving made*

Data type	Sampling location/area	Sampling period	Institute
Surface current measurements from HF radar network	Ligurian Sea (La Spezia)	August 2016-ongoing	CNR-ISMAR
Hydrographic cruise and glider test (DASPO experiment)	Ligurian Sea (La Spezia)	February 2017	CNR-ISMAR
Drifter experiment within the radar field (DOUBLE RADAR)	Ligurian Sea (La Spezia)	March 2018	CNR-ISMAR
HF radar (MOOSE)	Ligurian Sea (Toulon)	B. Zakardjan please check and add dates	MIO
Glider section (MOOSE T00)	Ligurian Sea (Nice-Calvi)	L.Coppola	CNRS/DT-INSU/LOV
Glider section (MOOSE T02)	Gulf of Lion (Marseille-Minorca)	P. Testor	CNRS/DT-INSU/LOCEAN
Surface phytoplankton functional groups from automated flow cytometry CHROME project	Tunisian Plateau/Tyrrhenian/Ligurian/Western Mediterranean Gulf of Tunis/Bay of Marseille	March 2016 October 2016-January 2017	CNRS MIO/INSTM
Surface temperature/salinity/fluorescence CHROME project	Tunisian Plateau/Tyrrhenian/Ligurian/Western Mediterranean Gulf of Tunis/Bay of Marseille	March 2016 October 2016-January 2017	INSTM/MIO
Phytoplankton functional groups fluorescence/TSG OSCAHR	Ligurian sea	October/November 2015	CNRS MIO
Zooplankton and phytoplankton together with hydrological and biogeochemical variables in the coastal zone	Ligurian sea	Weekly between 2013 and 2014, data available at http://www.obs-vlfr.fr/data/view/	CNRS/SU/LOV
HF radar surface currents	Ibiza Channel	June 2012-ongoing	SOCIB
Glider temperature and salinity sections 39N	Ibiza Channel	January 2011-ongoing	SOCIB

Fixed mooring surface currents, temperature and salinity, sub-surface currents	Ibiza Channel	October 2013-ongoing	SOCIB
Bentic Images for biodiversity assessment (Advance TNA project)	Balearic Sea. Barcelona Coast	November 2018- February 2019	OBSEA-UPC
Fluorescence with and without antifouling techniques (Foulstop TNA project)	Balearic Sea. Barcelona Coast	November 2018- February 2019	OBSEA-UPC

3.7.3. *Collaboration with other international initiatives*

For the Ligurian Sea, CNR-ISMAR and MIO-CNRS are collaborating in the framework of two Interreg Projects (Italy-France Maritime): IMPACT and SICOMAR-PLUS. The projects deal with applications regarding transport of pollutant and biological quantities and with maritime security. Environmental agencies (e.g. Italian ARPA), Life Guards and Regional and local authorities participate to the projects. There is a strong interplay with JERICO-NEXT in terms of infrastructures and applications.

In particular, in the framework of these projects the HF radar infrastructure in Ligurian Sea will be potentiated, leading to a network from the Italian Tyrrhenian coast up to the French Toulon area.

CNR-ISMAR has an ongoing collaboration with the Jerusalem College of Technology regarding blending of HFR data with other current measurements in the water column from coastal observatories (e.g. ADCP and gliders).

CNR-ISMAR has an ongoing collaboration with the CMRE-NATO (Centre for Maritime Research and Experimentation) in La Spezia for monitoring the Ligurian Sea dynamics through targeted sea campaigns and remote sensing of the area (such as satellite altimetry and HFR). ISMAR and CMRE cooperated in the experiment LOGMEC 2017 and the two institutions will cooperate for the next cruise in the Ligurian Sea in fall-winter 2018.

CMCC participated also to LOGMEC 2017, contributing in the experimental phase and modeling activities. CMCC and CMRE collaboration will continue also in 2018.

In the framework of the JRAP1, CNRS MIO has collaborated with the INSTM (C. Sammari, S. B. Ismail) under the AMIDEX CHROME project. The OSCAHR cruise (A. Doglioli, G.Gregori) was supported by the MIO “Axes Transverses” program (AT-COUPLAGE), by FEDER fundings (PRECYM flow cytometry platform) and by the following projects: CHROME (PI M. Thyssen, funded by the Excellence Initiative of Aix-Marseille University – A*MIDEX, a French “Investissements d’Avenir” program), SeaQUEST (PI O.Ross, funded by the UE FP7 people), AMICO (PI C. Pinazo, fundedby Copernicus – MEDDE French Ministry MDE), and BIOSWOT (PI F. d’Ovidio, funded by TOSCA/CNES).

The CNRS MIO has integrated the pan European SEADATACLOUD project for the leading of the standardised vocabulary and interoperability of phytoplankton functional groups datasets from flow cytometry (https://www.bodc.ac.uk/resources/vocabularies/vocabulary_search/F02/). All collected datasets will enter the CYTOBASE database (example for the CHROME project: https://chrome.mio.univ-amu.fr/?page_id=938; soon available) build for the purpose to include the standard vocabulary and the interoperable metadata adapted system. The collected CHROME data sets will be part of the CNRS TOSCA CYTOSAT project, in collaboration with the LOG.

Further datasets have been collected thanks to a collaboration with the MERMEX DEWEX project (2013) lead by LOMIC/OOB (P. Conan), the MERMEX-CHARMEX PEACETIME project (2017), led by the LOV (C. Guieu).

Coastal monitoring in Villefranche Sur Mer is operated and funded by the SOMLIT network (CNRS) and the link to the open sea area is operated through gliders and HF radars which are managed by the national observing system MOOSE funded by CNRS. The standalone and cabled mooring deployed respectively in the DYFAMED (Nice) and the MEUST (Toulon) sites are included in the EMSO Ligurian node (EMSO ERIC).

CNR had already established and still active long-term cooperation with CNRS in Villefranche Sur Mer in the field of operational oceanography and joint monitoring activities carried out within the European project FixO3 and within the worldwide system of long-term, open-ocean reference stations measuring dozens of essential ocean variables (EOVs) and monitoring the full depth of the ocean from air-sea interactions down to the seafloor. Cooperation also concerns the optimization of the monitoring in-situ campaigns and the exchange of expertise as well as the reciprocal access to infrastructures within trans-national activities of many European projects (i.e., JERICO-FP7, FixO3).

SOCIB closely collaborates with Spanish and European partners through participation in the projects CMEMS-InSitu, ERIC Euro_Argo, EMODnet Medsea Check Point, PRE-SWOT, ABACUS, IBISAR, PlasticBusters, among others. It participates in international initiatives such as EuroGOOS, MonGOOS and GODAE Ocean View. It is also actively involved in the US Office of Naval Research CALYPSO program, with close collaborations in particular with Woods Hole Oceanographic Institution, Scripps Institution of Oceanography or University of Washington.

OBSEA-UPC participates with Spanish and European institutions and networks like EMSO-ERIC or JERICO-RI were the observatory works as test site and in-situ measurement place with a time dataset series since 2009. Obsea-UPC is also associated partner of EMODnet where all data acquired by the Observatory is public on-line.

3.7.4. *Scientific progress so far*

3.7.4.1. Reconstruction of three dimensional transport in the Ligurian current (JRAP 4)

Current circulation and transport in the Ligurian Sea have been studied in the framework of JRAP 4 using data from HF radars (HFR) complemented by data from gliders, drifters, and vessel-mounted instrumentation. At present, there are two JERICO-NEXT HFR systems, (yellow coverage in Figure 3.7-2), one in the La Spezia area (CNR-ISMAR) and the other in the Toulon area (MIO-CNRS).

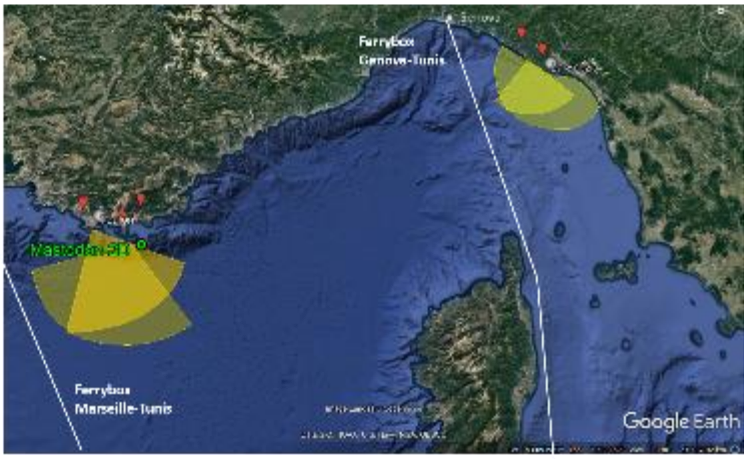


Figure 3.7-2 In yellow the HF radar coverage in the Ligurian Sea presently part of Jerico-NEXT. Red pins are the HFR antennas. In green the thermistor line Mastodon-2D upgraded by Ifremer within JERICO-NEXT. White lines are the flow cytometer samplings along ferry routes collected by MIO-CNRS.

Currents and transport at the ocean surface have been computed by HFR data, showing the complexity of variability at seasonal and synoptic scales. Examples of results from the La Spezia area are shown in Figure 3.7-3. Monthly averages shows a seasonal reversal of the current, that flows predominantly northwestward during winter and predominantly southeastward in the summer. Synoptic variability can overrule this seasonal tendency, as shown by the examples of direct wind response.

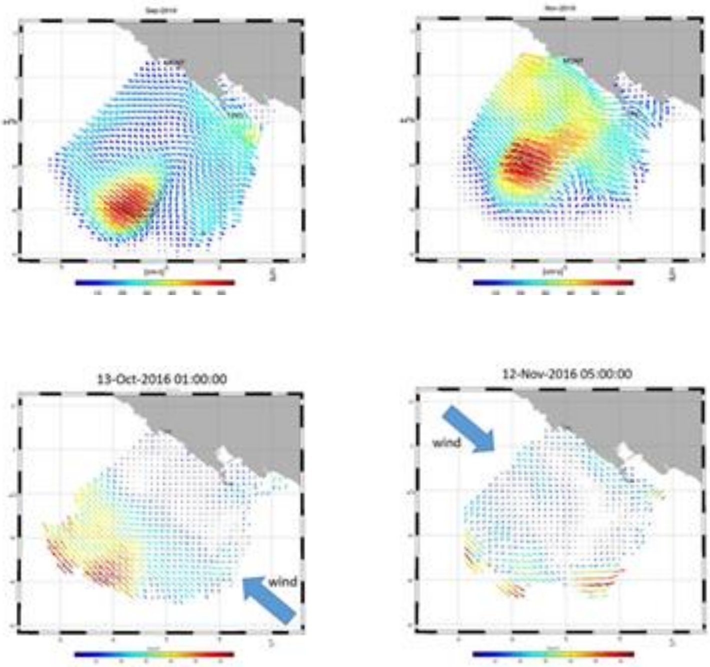


Figure 3.7-3 Surface currents from HF radar in La Spezia area. Top panels show monthly averages, while bottom panels show hourly maps.

While HFR data can provide unprecedented spatial and temporal coverage of surface velocity, for many applications is very important to have information also on subsurface transport. This problem has been approached in synergy with WP 3.2, where methodologies to analyze and blend velocity data at the surface and in the water column have been developed, and then applied to the JRAP 4 data sets. A combination of HF radar dataset and glider section near Toulon provide an example of 3D vision of the NC pathway indicating the velocity, direction and vertical structure in the Ligurian Sea (Figure 3.7-4) This integration of dataset is possible through the MOOSE network where lagrangian and eulerian platforms are combined and sustained to observe the variability of the NC during seasons and during extreme events (eg. deep water convection).

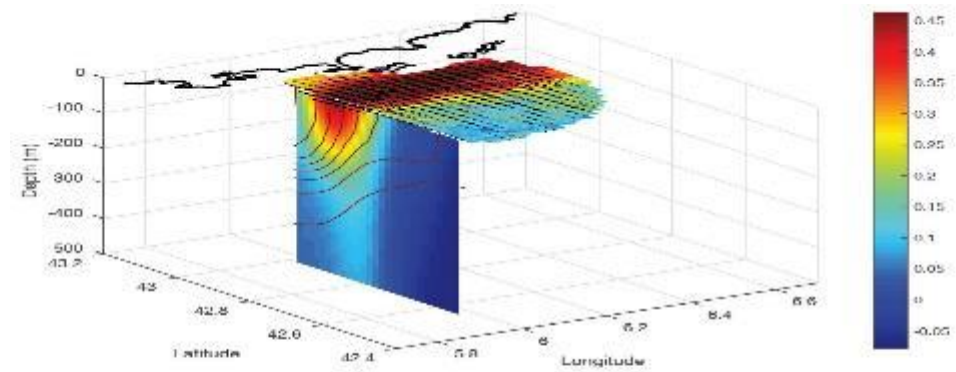


Figure 3.7-4 An example of HF radar surface currents combined with glider geostrophic derived velocities (m/s) in 19-22 January 2013 revealed the intensity and pathway of the North Current near Toulon in 3D (Zakardjan et al., personal communication).

A preliminary study aimed at separating the wind induced current in the upper layers from the geostrophic current has been carried out using an historical data set in the Toulon area including HFR data at the surface and geostrophic velocities from glider data in the water column (Berta et al., 2018). As a further step, the blending of various velocity data set is presently under investigation. A DCT-PLS method (Fredj et al. 2016) has been tested, in collaboration with Prof. E. Fredj from the Jerusalem College of Technology, at first using outputs from the GLAZUR hydrodynamic model, following an OSSE approach, and then the actual observations. The preliminary results are positive and encouraging, as shown by the examples in Figure 3.7-5, in terms of reconstruction of the 3D velocity in the water column. Other methodologies will also be investigated in collaboration also with AZTI. The blending experience will be useful also in preparation to actual model data assimilation, providing sensitivity to the type of data and treatment.

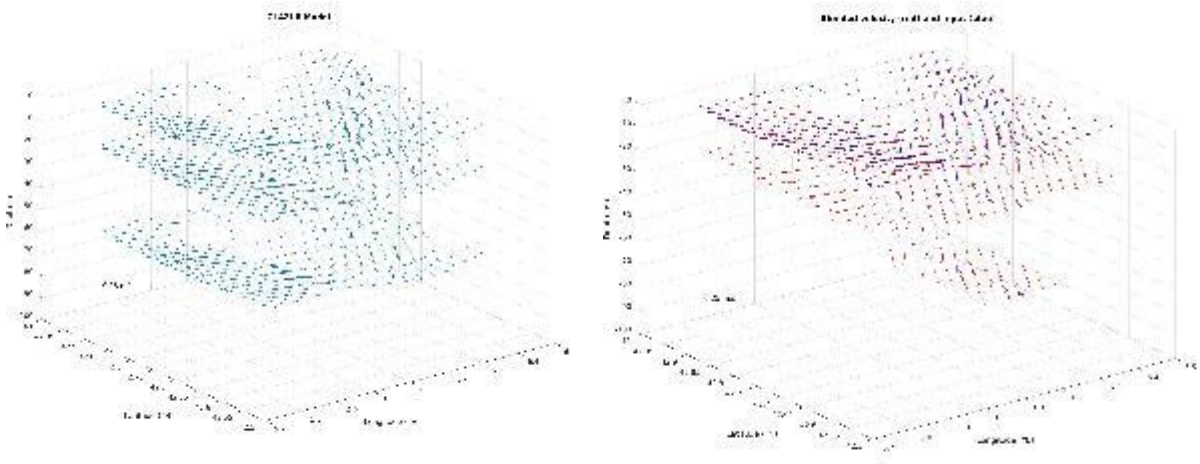


Figure 3.7-5 . In the left panel 3D currents from model output used as ground truth for testing the blending method. In the right panel 3D current blending (red arrows) starting from selected model currents information at the surface and along a section (blue arrows)

The results discussed above provide the basis for applications regarding transport of pollutant and biological quantities, which will be carried out in synergy with the INTERREG projects, using chemical and biological quantities. Examples of biological applications have already been performed in the Adriatic Sea (Sciascia et al., 2018) and they are discussed in the "Adriatic Sea'' Section. Additional in situ observations are available from targeted mooring deployment within JERICO-NEXT and historical buoys datasets available from collaboration with other projects focusing on the Ligurian Sea:

3.7.4.2. Deployment of low cost in situ mooring (MASTODON-2D) for temperature

MASTODON-2D: thermistor lines upgraded by Ifremer within JERICO-NEXT and deployed in September-October 2017 off the Provence coast (between Marseille and Toulon). The depth of the lines goes down to 120-200m and stays 5-10m below the surface. This device represents a low cost and easy to deploy autonomous system continuously monitoring the water column temperature and was able to record an intense and long-lasting (>10 day) upwelling event (Figure 3.7-6).

Each thermistor line contains around ten Temperature-Pressure captors which are spaced every 10-20 meters from subsurface buoy depending on the Mastodon-2D line length, and had a sample period of 5 minutes. On the figures 'Mastodon B' and 'Mastodon A', each line represent the temperature of one captor during the deployment period (1 month), hottest temperature (purple and red lines) corresponding to subsurface water. The figures highlight a stratification with water temperature higher than 18 °C on a 20 meters thick water layer from the 22nd to the 31st of August, followed by a net colding event that resulted in an almost homogeneous column water 10°C colder. These observations are typical signature of upwelling event, that long more than 10 days in the Cassidaigne area (Mastodon B), whereas Hyeres area got warmer earlier (Mastodon A). On the Mastodon A, the subsurface temperature exhibited between September 3 and September 13 large oscillations revealing the rôle played by the (sub)mesoscale processes in relaxation. These results represent two different upwelling relaxation situations, which will contribute to a better understanding when analysed in parallel with sea surface satellite data and 3D hydrodynamic model results.

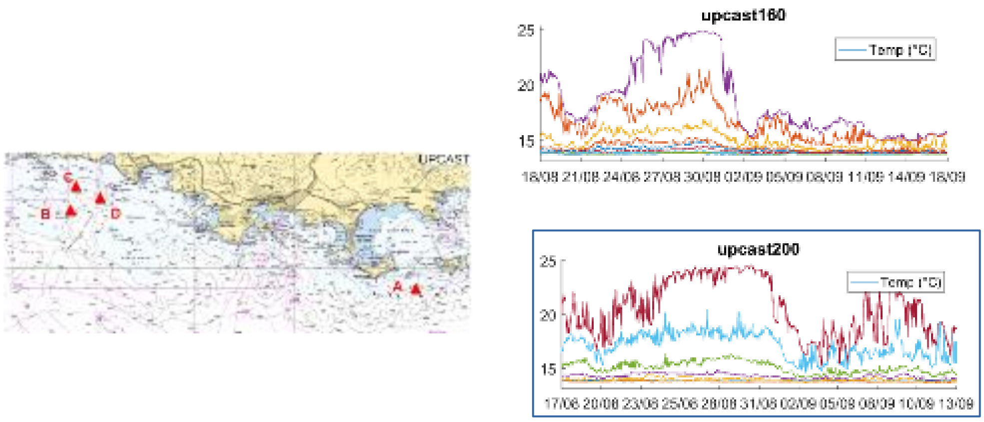


Figure 3.7-6 In the left panel a picture of the MASTODON-2D line. In the middle panel the map showing the deployment sites and in the right panels an example of the sea surface temperature drop (purple lines) recorded by two thermistor lines during an upwelling event.

3.7.4.3. Capacity of regional ocean models to represent targetted processes and improvement provided by the assimilation of coastal observations (JRAP 6)

Ligurian Sea

At CMCC, the aforementioned HFR system in the La Spezia area (CNR-ISMAR) has been assimilated into the AIFS-EnSRF data assimilation system. The goal of this experiment is to assess the impact of the HFR data on the modeling of transport.

To evaluate the transport of passive tracers, the AIFS-EnSRF system is interfaced with the Lagrangian model of Jansen (2016). This is a Python model capable of modeling 2D and 3D particle transport, integrating the advection equation using the 4th order Runge-Kutta method with a 30-minute time step. Two runs were performed from January to February 2017: a control run assimilating ARGO temperature and salinity profiles as usual; and an HFR run assimilating ARGO and the HFR data from the La Spezia system. As no actual drifter data was available in this period and area, the impact assessment is performed using the trajectories of virtual drifters. The drifters are released at regular distance within the radar coverage for both runs, allowing a comparison of their trajectories with and without HFR assimilation.

Figure 3.7-7 shows the results of the virtual drifter simulation for a one-week period. It can be seen that the HFR assimilation has a significant impact on the virtual drifters, making the smoothed out trajectories of the control run more realistic.

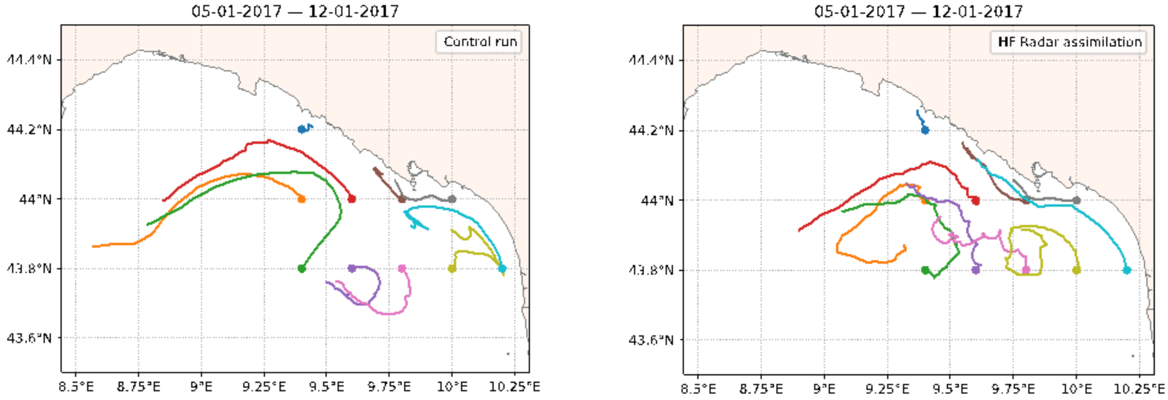


Figure 3.7-7 Virtual drifter trajectories modelled by the AIFS-EnSRF system without (left) and with HFR assimilation. The starting locations of the virtual drifters are indicated by the closed circles.

In order to test future instrument deployments and new observation types, an OSE/OSSE infrastructure was developed based on the AIFS model. Following the recommendations of Halliwell (2014), the AIFS-EnSRF assimilation system is paired with another NEMO-based model at very high resolution. This twin model uses the SURF relocatable model (Trotta, 2016) at 1/64° horizontal resolution to provide synthetic observations for the AIFS-EnSRF system.

The system is validated by performing an OSE and OSSE for the same period. Where the OSE assimilates normal ARGO profiles, the OSSE assimilates profiles extracted from the SURF nature run at the same time and location of the ARGO. The behaviour of the system in the OSE and OSSE is then compared to establish that the synthetic observations are sufficiently similar to the real observations. An example of the profiles used in the assimilation is shown in Figure 3.7-8.

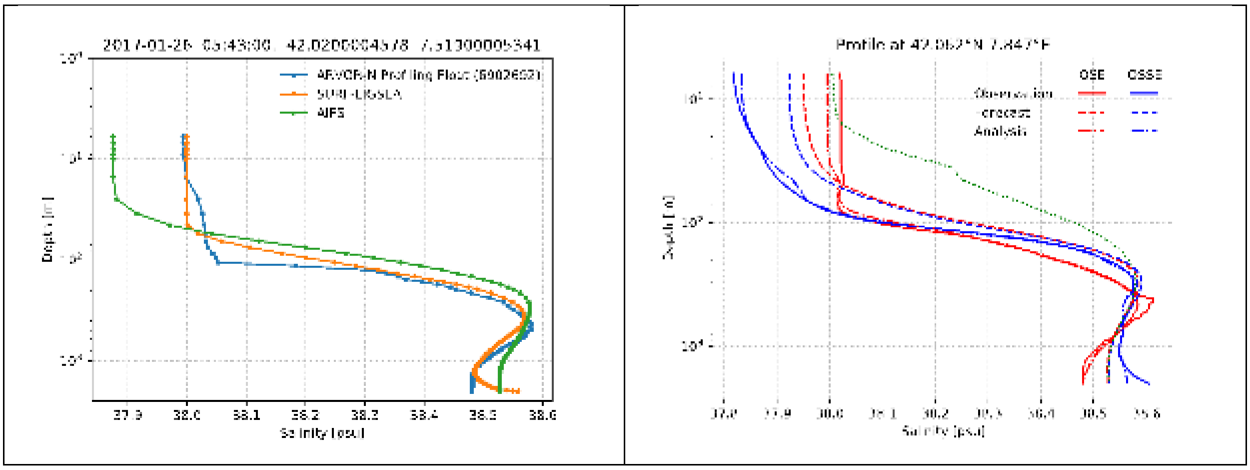


Figure 3.7-8 Comparison of a salinity profile from AIFS, ARGO and the SURF nature run (left). The right panel shows what happens during the assimilation cycle in the OSE (red) and OSSE (blue).

Aggregated results for the full period are shown in Figure 3.7-9. Differences found between the OSE and OSSE experiments are of the order of 10% or less. The only significant differences are observed for salinity near the surface, where the synthetic observations are further from the model than the real observations. Below approximately 3m depth also salinity shows good agreement between the OSE and OSSE.

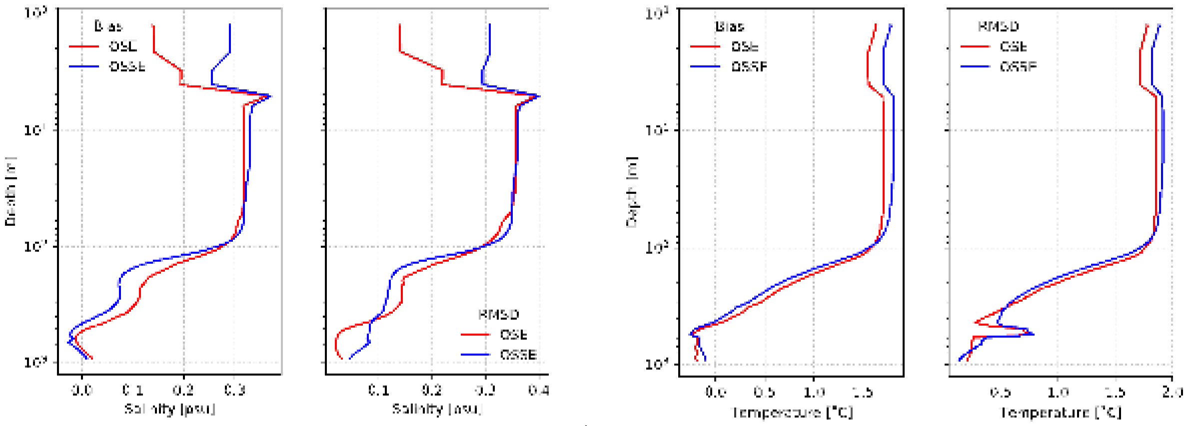


Figure 3.7-9 Combined results for salinity (left panels) and temperature (right panels) for the full period of the OSE/OSSE calibration experiment. For the OSE (OSSE) the model is compared to the real (synthetic) observations in terms of bias and RMSD.

Ibiza Channel

The high-resolution WMOP model developed at SOCIB (Juza et al., 2016, Mourre et al., 2018) has been assessed using observations from fixed mooring, HF radar and glider data in the Ibiza Channel, providing insights into the surface hydrographic variability, surface circulation and water mass transports. Moreover, in the framework of JERICO-NEXT JRAP-6, a series of Observing Systems Experiments (OSEs) has been performed to evaluate the impact of the assimilation of HF radar observations in the model.

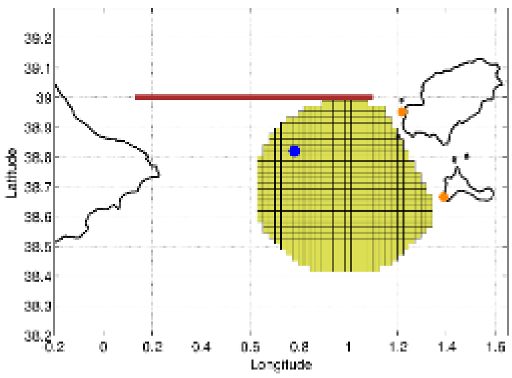


Figure 3.7-10 Observational network in the Ibiza Channel: HF radar antenna locations (orange dots), HF radar total surface currents coverage (yellow area), glider transect (red line) and fixed mooring (blue dot).

I. *Surface hydrographic variability*

The sea surface temperature (SST) at the fixed mooring location is marked by a strong seasonal cycle, with a good agreement between observations and simulations. Minima (around 13.5ºC) are found in February-March, while maxima (up to 28.3ºC) are reached in July-August. The WMOP_hindcast SST is colder than in observations, especially in summer-fall. The SST interannual variability is captured by all datasets. Concerning the sea surface salinity (SSS), the observation values oscillate around 38 from October 2013 to July 2015 and in spring 2016; strong SSS decreases are observed in fall 2015 and summer-fall 2016 due to inflows of fresh AW from south (as depicted by the HF radar in section 4.2.). Strong discrepancies in magnitude and phase are found between observations and models. The WMOP_hindcast SSS is in good agreement with the observations in 2013-2014, but the strong decrease in 2015 is not reproduced and the simulated SSS is overestimated. The SSS magnitude and variability in WMOP_forecast and MED-MFC are closely linked due to the regular restart. Some of the low salinity events (due to the AW inflows) are reproduced in these two simulations. Additionally, the WMOP_forecast and MED-MFC SSS are more variable at daily/weekly/monthly time scales than the observations and WMOP_hindcast.

II. *Surface circulation and variability*

Empirical Orthogonal Functions (EOF) analysis has been performed for daily mean surface currents from June 2012 to August 2014 both for observational data and model outputs within the HF radar coverage area. The temporal mean of the HF radar observations shows a southeastward flow in the middle of the IC (~0.7ºE), recirculating eastwards and then flowing northwards at the east forming and joining the Balearic Current in the northern shelf of the Balearic Islands. WMOP_hindcast reproduces the observed mean circulation but with a too strong and too large northward flow. This northward meridional current dominates the mean circulation in MED-MFC in the whole eastern part of the IC.

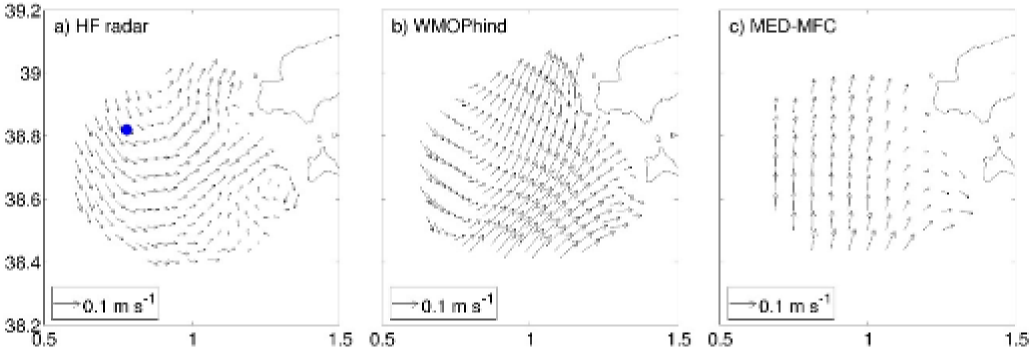


Figure 3.7-11 : June 2012-August 2014 surface velocity averages from (a) HF radar; (b) WMOP_hindcast; and (c) MED-MFC. The blue dot indicates the location of the fixed mooring

The two first EOF modes of the observed surface current explain 42% of the total variance. The first one corresponds to surface meridional currents. The simulated spatial patterns are relatively in good agreement with the HF radar structure. The second EOF is dominated by zonal surface velocities in both observations and models. Lana et al. (2016) have shown that these observed meridional and zonal velocity patterns are the responses to meridional and zonal winds, respectively. The associated temporal components highlight the high temporal variability of the two modes at both daily and monthly time scales, both in observations and models, as well as discrepancies in magnitude and phase. The correlation with the HF radar is higher in WMOP_hindcast than in MED-MFC.
The Hovmöller diagrams along the zonal section at 38.7ºN highlight the meridional circulation patterns across the channel and their variability at both high and low frequencies. The southward flow (negative values) to the west and the northward flow (positive values) to the east are reproduced in WMOP_hindcast, as well as strong events such as the inflow in June 2012 and the outflow in January 2015. The velocities from HF radar and WMOP_hindcast have the same order of magnitude and similar time scales of variability. WMOP_forecast has stronger velocities, is more variable and closer to the MED-MFC outputs due to the weekly restart to the MED-MFC fields. Although large discrepancies with the HF radar are found, the inflow event in fall 2016 is present in both WMOP_forecast and MED-MFC. The surface geostrophic velocities from altimetry are much less variable and represent a continuous inflow in the eastern part of the channel around 1ºE. Only the strongest events seem to be captured by the altimetry (inflow in June 2012, January and fall 2016, outflow in January 2015).
The mean kinetic energy of WMOP_hindcast is of the same order of magnitude of the HF radar energy, while WMOP_forecast generates strong kinetic energies, even larger than its parent model (MED-MFC in the second period). The altimetry kinetic energy remains lower than the kinetic energy monitored by the HF radar for any period.

III. ***Water mass transports***

In agreement with Pinot et al. (2002) and Heslop et al. (2012), the glider monthly climatology over 2011-2015 shows that the total southward transport across the IC (associated with the NC) is larger in winter and early spring (maximum of 1.2 Sv in April) while in summer, it strongly decreases until 0.5 Sv in July. The northward transport is less subject to a seasonal cycle, varying from 0.25 Sv in fall-winter to 0.45 Sv in summer. Consequently, the net flow has a marked seasonal cycle remaining negative throughout the year.

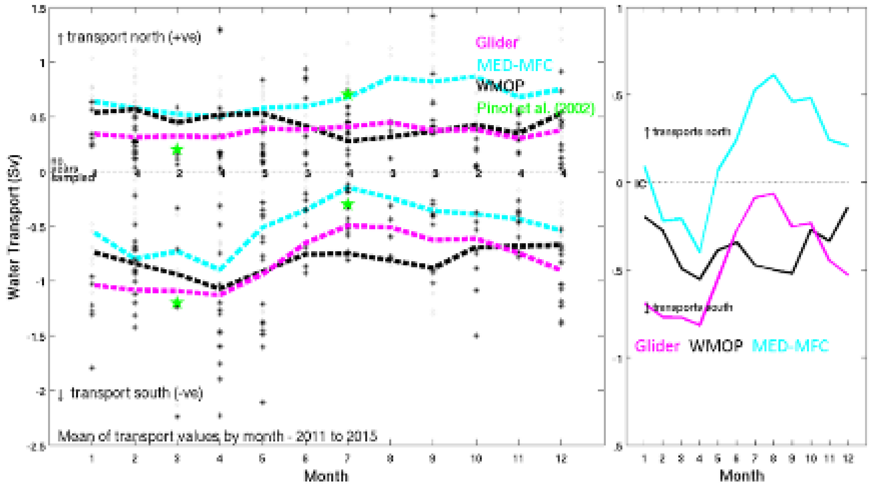


Figure 3.7-12: Left panel: monthly climatology over 2011-2015 of northward (inflow) and southward (outflow) transports through the IC from gliders (magenta), WMOP_hindcast (black) and MED-MFC (cyan). Right panel: same for net flow.

WMOP_hindcast is able to reproduce the inflow and outflow variability, but the seasonal cycle of the total net transport is not well represented due to the too strong NC in summer. The MED-MFC represents the seasonal cycle of the southward transport but it reproduces a too strong northward transport leading to a positive net flow from May to December.

The observed daily/weekly transports per water mass during the glider missions from 2011 to 2015 show the typical water masses of the western Mediterranean (recent and modified surface AW, WIW, LIW and WMDW) as well as their high frequency variability transports. Although discrepancies in magnitude and phase with the observations are found, WMOP_hindcast is able to generate and propagate WIW, formed in the Northwestern Mediterranean, during the winters 2011, 2012, and 2013, and to reproduce the strong outflow (NC) event in winter-spring 2015 and the important inflow of fresh AW in November-December 2015. Very few WIW quantities are found in the MED-MFC transports across the IC. This model deficiency is probably related to the circulation error highlighted in the region (Juza et al., 2015).

IV. ***Impact of HF radar data assimilation***

The one-month period selected for the simulation experiments is 20 September - 20 October 2014, due to the availability of a data set of 14 drifters deployed in the HF radar coverage area, which can be advantageously used as independent data for the validation of the experiments. Three 30-day simulations were produced, namely GNR, HFR and NO_ASSIM. **GNR** assimilated data from satellite SLA, SST and Argo profiles. **HFR** assimilated the same observations plus HFR daily mean total velocity data, and **NO_ASSIM** did not assimilate any data.

The assimilation scheme employed is a Multimodel Local Ensemble Optimal Interpolation (EnOI). It is a variant of the EnOI, which has been widely used and represents a good cost-effective alternative compared to more complex methods as Ensemble Kalman Filter (EnKF) or 4Dvar, allowing to use a large ensemble size and domain localization. The WMOP DA system consists here of a sequence of analyses (model updates given a set of observations) generated every 3 days and model forward simulations between the analyses. A domain localization of 200 km was used. More details of the method employed can be found in Hernandez-Lasheras and Mourre 2018.

As a first step, we verify that the assimilation of HF radar data allows to improve the representation of surface velocities in the area covered by the radar, without degrading the improvements in terms of SLA, SST and T-S profiles provided by the GNR simulation.

Then, the 14 surface drifters deployed in the HF radar coverage area during the study period were used as independent data for the evaluation. Real trajectories were compared to virtual trajectories generated from the model simulations, starting from the observed positions of the drifters every day. Results show how HF radar DA leads to an improvement of the Lagrangian prediction capabilities. Overall, considering all drifters and starting days, after 48 hours, the average separation distance is reduced from 26km to 20km in GNR compared to NO_ASSIM, and further reduced to 13km thanks to HF radar data assimilation. Notice that the average travel distance of the drifters in two days is approximately 27km. In addition, the dimension of the radar observation area (for total currents) is around 60km. Another important aspect if that the improvement obtained in terms of surface currents and in trajectory prediction capabilities is achieved even beyond the radar footprint. This can be seen in the simulations starting after 5 Oct, for which the majority of the drifters are outside the radar area but still providing better results after HF radar data assimilation.

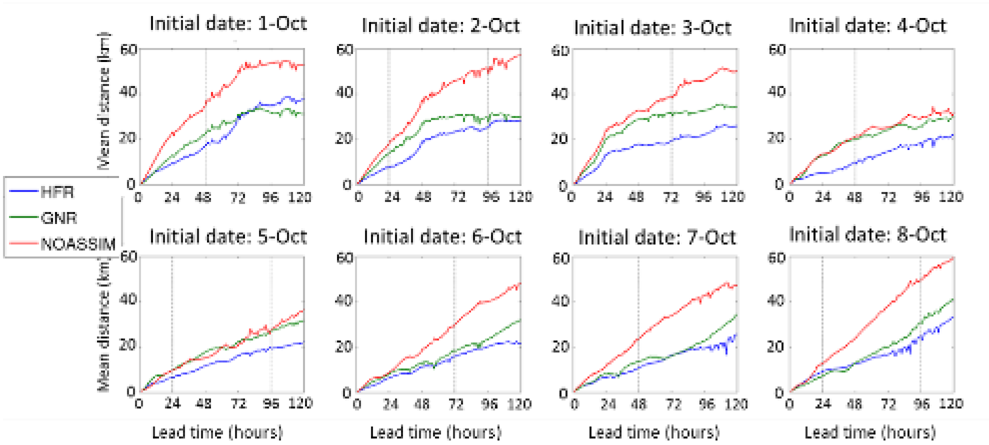


Figure 3.7-13 Evolution of the mean distance between drifters and virtual model particles over the 5 days lagrangian simulation period prorated over the 14 drifters for each simulation (NO ASSIM, GNR, HFR). Each panel shows the results for a specific starting date. Y-axis express the mean distance in km. X-axis express the forecast lead time in hours. Dashed vertical lines indicate the analysis dates.

3.7.4.4. Collect new biogeochemical datasets (phytoplankton functional diversity, …) from automated and innovative sensors (JRAP 1)

In the frame of the task 3.1., and in order to circumvent the gap in time series of mesoscale phytoplankton observation, the A*MIDEX CHROME project aimed to cover at basin scales phytoplankton functional groups thanks to the combination of both automated hydrological sensors, pulse shape recording flow cytometry and ships of opportunity. This experience allowed for the first time in the Mediterranean, to implement on a Ferry (the Carthage) a Cytosense (Cytobuoy, N.L.) coupled to a Ferrybox® belonging to the Tunisian INSTM institute (A*midex-CHROME Project). For the first time, the phytoplankton has been monitored at high resolution (every hour) for more than 4 months, on a transect between Marseille/Genova and Tunis, across the Western Mediterranean Sea.

The collected data sets from the CHROME project included JERICO-NEXT best practices and followed Subtask 3.1.2 sampling advices (WP3 of JERICO-NEXT) in order to analyse both picophytoplankton up to microphytoplankton, and covers one transect in late early spring 2016, and the late autumn-early winter period 2016-2017. The successful installation of the flow cytometer for more than 4 months on a ship of opportunity without remote control, with a 48 hours way and back crossing duration, and settled in the high vibration conditions of the frontal part of the ship, is an important result (Figure 3.7-14). The period of installation spanned 32 crossings between Tunis and Marseille and Tunis and Genova. The flow cytometer sampling frequency was of 1/30' for an average 20 hours crossing, leading to 30-35 samples each time. An amount of 1091 samples were validated that could combine with the ferrybox datasets.

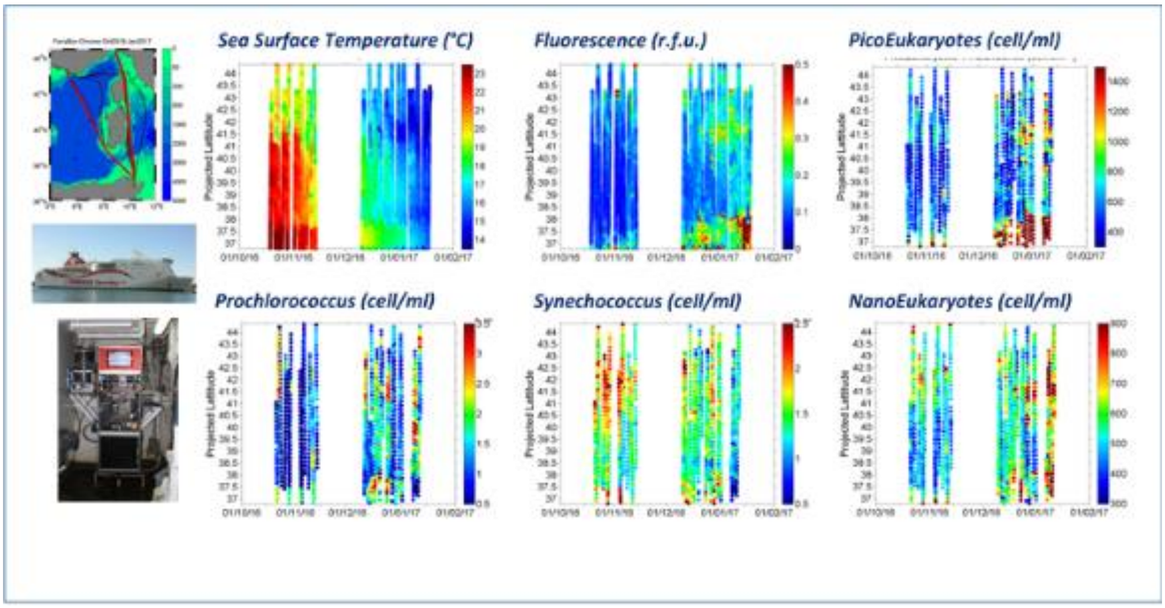


Figure 3.7-14 Ferry routes during the 4 months sampling with the Cytosense flow cytometer in the frame of the CHROME project.

The results collected illustrate the sea surface temperature decline with season and north south gradient, in contrast to the opposite increase of fluorescence. The abundances of pico-nanophytoplankton functional groups evidence the singular responses of each size class to the seasonal changes. Microphytoplankton are not illustrated. Furthermore, this unique dataset enable to follow the strait of Bonnifacio (41.5°N, on the way Tunis-Genova) production pulses observed after wind driven upwelling's that could not have been observed otherwise (Courtesy P. Marrec et al.). The collected data will be available for the JERICO consortium through the Seadatanet portal.

3.7.5. *Synthesis and way forward*

3.7.5.1. Synthesis and specific next steps

While HFR data provide unprecedented spatial and temporal coverage of surface velocity, for many applications is very important to have information also on subsurface transport. This problem has been approached in JERICO-NEXT, where methodologies to analyze and blend velocity data at the surface and in the water column have been developed in WP4 and applied to the Ligurian Sea in WP4. Results are very promising as blended data are in agreement with simulated ones. Investigation in blending of various velocity data set is still progressing beyond JERICO-NEXT. The blending experience will be useful also in preparation to actual model data assimilation, providing sensitivity to the type of data and treatment.

The assimilation of HF Radar data in a hydrodynamics model significantly improved the definition of the trajectory of drifting material and supports the need to use HF radar data in an operational use of forecasting systems. In addition thanks to availability of high quality and high resolution HF radar, a novel implementation of data assimilation scheme, based on Ensemble Kalman Filter approach, has been developed with the scope to improve ocean forecasting. An OSE/OSSE infrastructure for the Adriatic Sea and the NW Mediterranean has been tested within T3.7 and further applied to complex case studies such as the OSE in the Ligurian Sea and the FOOS in the Adriatic Sea. Results demonstrate the good attitude of the Adriatic-Ionian Forecasting System coupled to Ensemble Square Root filter to improve the quality of the ocean fields and predictability. It represents a first step towards operational OSE/OSSE system for designing future coastal observatories in the Mediterranean Sea and to evaluate the impact of future observations in our operational systems (from regional to coastal scales). Using the numerical setup implemented in the Balearic Sea, OSSEs will also be implemented in the Ibiza Channel area to evaluate and quantify the impact of an additional HF radar antenna located on the Spanish peninsula, which would allow to provide surface current observations over the whole length of the Channel.

The results discussed above provide the basis for applications regarding transport of pollutant and biological quantities that will be carried out in synergy with the INTERREG projects, using chemical and biological quantities. Examples of biological applications have already been performed in the Adriatic Sea as published in the JERICO-NEXT special issue of Ocean Science journal (Sciascia et al., 2018) and they are discussed in the “Adriatic Sea” Section. In addition, the complete coverage in the Ligurian Sea will be drastically improved in the next few years as part of two Interreg projects (IMPACT and SICOMAR-PLUS, see Section “Collaboration with other international initiatives”), extending from the Corsica Channel to Toulon by 2021 (pink coverage in Figure 3.7-15).

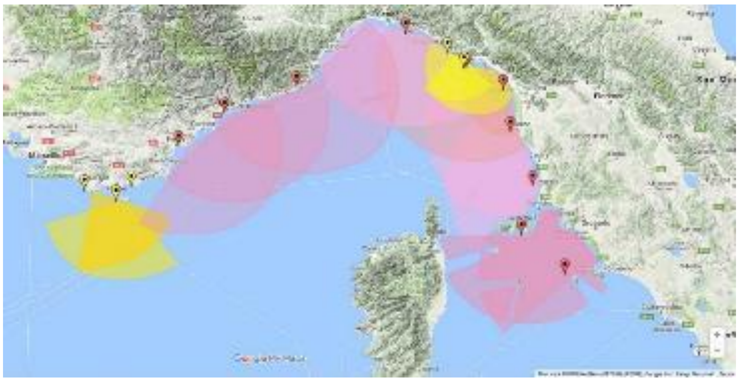


Figure 3.7-15 HF radar coverage in the Ligurian Sea. Systems that are presently part of Jerico-NEXT are shown in yellow (CNR-ISMAR and MIO-CNRS). The pink coverage indicates the expected coverage by year 2021, including systems by Regione Toscana-Consorzio LaMMA thatare not presently part of JERICO-NEXT

The incoming HFR network will cover the location nearby Toulon and the long-term mooring in the Corsica Channel (active since 1985), providing water column physical properties. The surface currents provided by the HFR radar network will be combined also with the other bio-physical observational datasets from historical platform in the Ligurian Sea: The coastal site in Villefranche sur Mer within SOMLIT and COAST-HF networks, the open sea DYFAMED site, the W1M3A marine observatory, the Nice-Calvi glider transect, the ferrybox transects between Marseille/Genova and Tunis, and the EMSO Ligurian node.

The physical and biological observing network proposed within JRAP1 and JRAP4, which includes some long-term monitoring systems (such as HF radar and historical moorings) as well as targeted deployment of specific monitoring devices (such as Mastodon-2D and ferryboxes), will be used to monitor sea dynamics, transport of biochemical properties (including plastics), as well as species behavior and distribution, therefore providing fundamental information for the management of coastal and marine activities. The multiplatform observing system in the NW Mediterranean Sea, combined with growing centralized frameworks of data management and distribution, i.e. Copernicus Marine Environment Monitoring Service and SeaDataNet/SeaDataCloud, will provide the basis for an extended European coastal infrastructure. More specifically, with regard to investigation on pelagic phytoplankton biodiversity and distribution, the collected datasets, in addition to the CHROME data sets directly included in the JERICO-NEXT consortium, will be part of a large and coherent database following the Seadatacloud standards, in order to fill the requirement for modeling and remote sensing. Still a lot of contribution to the database building and standardization procedures are required, that should be part of the priorities in the next future. The successful deployment of such a complete sensor that is automated flow cytometry (in terms of size ranges resolution, precision and robustness) should open the way to equipping other ships of opportunity in the Mediterranean. As an example, the Aegean ferrybox could install automated biological sensors as the flow cytometer. The vessel moving platforms have to be strengthened by fixed platforms to ensure temporal high resolutions datasets in selected highlighted and typical areas, as well to be available for monitoring pulsed environmental events that are not always covered by moving vessels. Those automated high resolution sensors generate huge amount of data that need often some expert processing before use, and do not always fit standards and dedicated open access databases. SeadataCloud project included researchers that triggered the qualifications of flow cytometry vocabulary to make those future datasets available for end-users. Almost done, it is now another challenge to automate the analysis of output raw files and create the workflow until the database.

3.7.5.2. Specific developments for the future

Investigation on pelagic phytoplankton biodiversity and distribution, (JRAP 1)

A testing and calibration facility in MIO: Outbreaking technologies for sensitive biogeochemical and chemical automated and high resolution analysis are expanding (nutrients, trace metals, single cell and cellular staining). They do require dedicated areas for testing and validation, as well as strong data ingesting systems. The Sea Water Sensing Laboratory @ MIO Marseille (AMU-CNRS) aims to pump sea water to benches where sensors under validations can be improved and calibrated in laboratory conditions. Furthermore, the SSL@MM will be a reference point for trace metal and biological clean pumping were mercury and phytoplankton functional groups will be continuously monitored.

During JERICO-FP7, a new sampling and analysis protocol was established to investigate the whole plankton variability (from bacteria to jellyfish) by using imaging sensors. These techniques have been successfully applied both at high frequency and combining instruments (Romagnan et al., 2015, Romagnan et al., 2016)

An automated video system mounted on fixed and drifting platforms:

We envision further developments of the multiplatform observing system in the NW Mediterranean Sea by installing on fixed and drifting platforms automated video monitoring systems (GUARD-1, developed by CNR-ISMAR, Fig. Guard) capable to disclose remarkable information on biodiversity, non-indigenous and commercial fish species for ecological applications in accordance with the monitoring approach supported by the EC Marine Strategy Framework Directive.

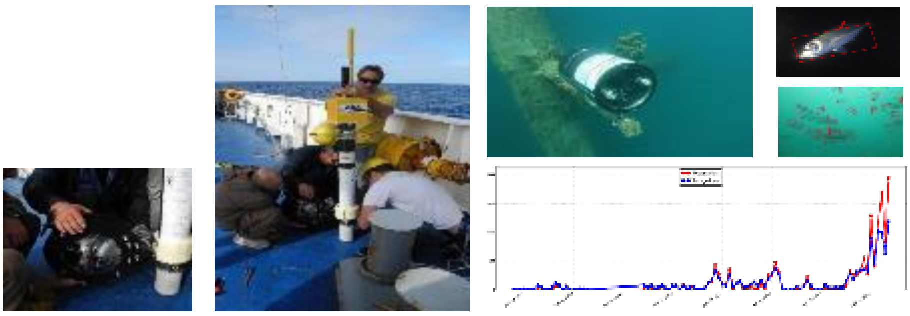


Figure 3.7-16 Pictures of the GUARD-1 on a float and on a fixed platform. Comparison between the recognised (blue line) and the observed (red line) fish daily abundance time-series. Some examples of automated fish recognition results (red boxes).

A data distribution platform

This platform is specific to deliver a compact and comprehensible access to all the coastal observational products from available infrastructures operating in the Ebro shelf and along the Catalan margin (see details in the Annex 4).

Synergetic integration of in situ and remote sensing products in the coastal margin.

The Mediterranean region, with approximately 40% of the annual time free of clouds (see fig.), is a privileged region to give a good support to cal/val activities of remote sensing products for ongoing and future missions, and more importantly, to develop a synergetic exploitation of in situ and remote sensing products in the coastal margin. Specifically we will develop the following points associated with the setup of the CASABLANCA site in mid and end 2019:

- The AERONET-c node will allow to reduce the noise of collocated satellite colour estimates using the data fusion methodologies (Olmedo et al., 2016) and to apply triple-collocation methodologies (Horeau et al. 2018) to estimate the amplitude of the true ocean color signal. Main Seasonal Trend decomposition will be obtained by applying Loess (STL) procedure (Piles et al. 2019).
- The CASABLANCA mooring in combination with the 2d fields from the Ebro HF radar will allow to develop a full 3-d validation of the operational models. Test on the range of validity of recent techniques to derive high resolution surface velocity fields from infrared and microwaves sensors (Isern-Fontanet, et al., 2017) will be undertaken locally in the CASABLANCA sites and for the rest of HF radars sites. An assessment tool for decision taken in case of emergencies will be developed to integrate the in situ and modelling from both eulerian and lagrangian metrics and validation will be carried out in collaboration with the Spanish SAR agency developing regular SAR exercise in the CASABLANCA site.

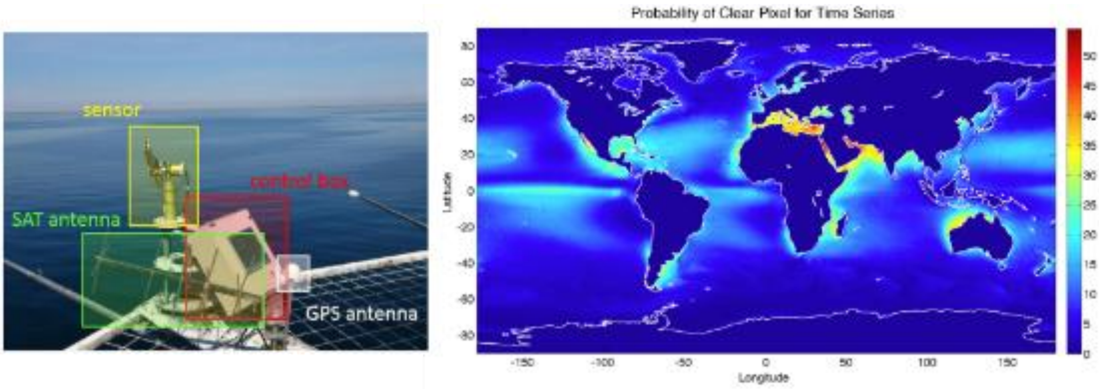


Figure 3.7-17 Probability of clear pixel for the time series (1982-2011) of SST Pathfinder 9 km frontal database from University of Rhode Island (URI). Left) AERONET-C installation on a ol platform

.

3.7.6. *References for Ligurian Sea to the Ibiza Channel*

Albérola, C., C. Millot, and J. Font, 1995. On the seasonal and mesoscale variabilities of the Northern Current during the PRIMO-0 experiment in the western Mediterranean Sea. Oceanol. Acta, 18, 163–192.

Astraldi, M. and G. P. Gasparini, 1992. The seasonal characteristics of the circulation in the North Mediterranean Basin and their relationship with the atmospheric-climatic conditions. J. Geophys. Res., 97, 9531–9540.

Auger, P.A., C. Ulses, C. Estournel, L. Stemmann, S. Somot, and F. Diaz, 2014. Interannual control of plankton communities by deep winter mixing and prey/predator interactions in the NW Mediterranean: Results from a 30-year 3D modeling study. Prog. Oceanogr. 124, 12-27.

Berta, M., L. Bellomo, A. Griffa, M. Magaldi, A. Molcard, C. Mantovani, G.P. Gasparini, J. Marmain, A. Vetrano, L. Béguery, M. Borghini, Y. Barbin, J. Gaggelli, and C. Quentin, 2018. Wind induced variability in the Northern Current (North-Western Mediterranean Sea) as depicted by a multi-platform observing system. Ocean Sci., 14, 689-710, https://doi.org/10.5194/os-14-689-2018.

Birol F., M. Cancet, and C. Estournel, 2010. Aspects of the seasonal variability of the Northern Current (NW Mediterranean Sea) observed by altimetry. Journal of Marine Systems 81(4): 297-311. DOI:10.1016/j.jmarsys.2010.01.005.

Conan, P. and C. Millot, 1995. Variability of the Northern Current off Marseilles, Western Mediterranean Sea, from February to June 1992. Oceanol. Acta, 18, 193–205.

Falkowski, P. G. and J. LaRoche, 1991. Acclimation to spectral irradiance in algae. Journal of Phycology, 27: 8-14. doi:10.1111/j.0022-3646.1991.00008.x

Fredj, E., H. Roarty, J. Kohut, M. Smith, and S. Glenn, 2016. Gap Filling of the Coastal Ocean Surface Currents from HFR Data: Application to the Mid-Atlantic Bight HFR Network. J. Atmos. Oceanic Technol., 33, 1097–1111, doi: 10.1175/JTECH-D-15-0056.1

Garcia-Comas, C., L. Stemmann, F. Ibanez, L. Berline, M.G. Mazzocchi, S. Gasparini, M. Picheral, and G. Gorsky, 2011. Zooplankton long-term changes in the NW Mediterranean Sea: Decadal periodicity forced by winter hydrographic conditions related to large-scale atmospheric changes? Journal of Marine Systems 87, 216-226.

Guillén J., L. Arin, J. Salat, P. Puig, M. Estrada, A. Palanques, G. Simarro, and J. Pascual, 2018. Coastal oceanographic signatures of heat waves and extreme events of dense water formation during the period 2002-2012 (Barcelona. NW Mediterranean). Scientia Marina 82(4), 189-206.

Hernandez-Lasheras, J. and B. Mourre, 2018. Dense CTD survey versus glider fleet sampling: comparing data assimilation performance in a regional ocean model west of Sardinia. Ocean Sci., 14, 1069-1084, https://doi.org/10.5194/os-14-1069-2018.

Heslop, E.E., S. Ruiz, J. Allen, J.L. López-Jurado, L. Renault, and J. Tintoré, 2012. Autonomous underwater gliders monitoring variability at “choke points” in our ocean system: A case study in the Western Mediterranean Sea. Geophysical Research Letters, 39.

Horeau N., M. Portabella, W. Lin, J. Ballabrera-Poy, and A. Turiel, 2018. Error characterization of sea surface salinity products using triple collocation analysis. IEEE transactions on Geosciences and Remote Sensing, 56, 9, 5160-5168. DOI: doi.org/10.1109/TGRS.2018.2810442

Howes, E.L., L. Stemmann, C. Assailly, J.O. Irisson, M. Dima, J. Bijma, and J.P. Gattuso, 2015. Pteropod time series from the North Western Mediterranean (1967-2003): impacts of pH and climate variability. Mar Ecol Prog Ser 531, 193-206.

Isern-Fontanet J., J. Ballabrera-Poy, A. Turiel, E. García-Ladona, 2017. Remote sensing of ocean surface currents: a review of what is being observed and what is being assimilated. Nonlinear Processes in Geophysics, 24, 613-643. DOI: 10.5194/npg-24-613-2017.

Juza, M., B. Mourre, J.-M. Lellouche, M. Tonani, and J. Tintoré, 2015. From basin to sub-basin scale assessment and intercomparison of numerical simulations in the Western Mediterranean Sea. J. Mar. Syst., 149, 36-49, doi:10.1016/j.jmarsys.2015.04.010.

Juza, M., B. Mourre, L. Renault, S. Gómara, K. Sebastián, S. Lora, J.P. Beltran, B. Frontera, B. Garau, C. Troupin, M. Torner, E. Heslop, B. Casas, R. Escudier, G. Vizoso, and J. Tintoré, 2016. SOCIB operational ocean forecasting system and multi-platform validation in the Western Mediterranean Sea. Journal of Operational Oceanography, 9, s155-s166.

Kessouri, F., C. Ulses, C. Estournel, P. Marsaleix, F. D’Ortenzio, T. Severin, et al. 2018. Vertical mixing effects on phytoplankton dynamics and organic carbon export in the western Mediterranean Sea. Journal of Geophysical Research: Oceans, 123. https://doi.org/10.1002/2016JC012669

Lana, A., J. Marmain, V. Fernández, J. Tintoré, and A. Orfila, 2016. Wind influence on surface current variability in the Ibiza Channel from HF Radar. Ocean Dynamics, 66, 483-497.

Lévy M., P. Klein, and A.M. Treguier, 2001. Impact of sub-mesoscale physics on production and subduction of phytoplankton in an oligotrophic regime. Journal of marine research 59 (4), 535-565

Mourre, B., E. Aguiar, M. Juza, J. Hernández-Lasheras, E. Reyes, E. Heslop, R. Escudier, E. Cutolo, S. Ruiz, E. Mason, A. Pascual, and J. Tintoré, 2018. Assessment of high-resolution regional ocean prediction systems using multi-platform observations: Illustrations in the Western Mediterranean Sea. In “New Frontiers in Operational Oceanography”, E. Chassignet, A. Pascual, J. Tintoré and J. Verron, Eds, GODAE Ocean View, 663-694, doi: 10.17125/gov2018.ch24

Olmedo E., J. Martínez, M. Umbert, N. Hoareau, M. Portabella, J. Ballabrera, and A. Turiel, 2016. Improving time and space resolution of SMOS salinity maps using multifractal fusion. Remote Sensing of Environment, 180, 246-263. DOI: 10.1016/j.rse.2016.02.038

Piles M., J. Ballabrera-Poy, and J. Muñoz-Sabater, 2019. Dominant Features of Global Surface Soil Moisture Variability Observed by the SMOS Satellite. Remote Sensing 2019, 11, 95; doi:10.3390/rs11010095

Pinot, J.M., J.L. López-Jurado, and M. Riera, 2002. The CANALES experiment (1996-1998). Interannual, seasonal, and mesoscale variability of the circulation in the Balearic Channels. Progress in Oceanography, 55, 335-370.

Ribó M., P. Puig, A. Palanques, and C. Lo Iacono, 2011. Dense shelf water cascades in the Cap de Creus and Palamós submarine canyons during winters 2007 and 2008. Marine Geology, 175-188. doi:10.1016/j.margeo.2011.04.001

Romagnan, J.B., L. Aldamman, S. Gasparini, P. Nival, A. Aubert, J.L. Jamet, and L. Stemmann, 2016. High frequency mesozooplankton monitoring: Can imaging systems and automated sample analysis help us describe and interpret changes in zooplankton community composition and size structure - An example from a coastal site. Journal of Marine Systems 162, 18-28.

Romagnan, J.B., L. Legendre, L. Guidi, J.L. Jamet, D. Jamet, L. Mousseau, M.L. Pedrotti, M. Picheral, G. Gorsky, C. Sardet, and L. Stemmann, 2015. Comprehensive Model of Annual Plankton Succession Based on the Whole-Plankton Time Series Approach. Plos One 10.

Sammari, C., C. Millot, and L. Prieur, 1995. Aspects of the seasonal and mesoscale variabilities of the Northern Current in the western Mediterranean Sea inferred from the PROLIG-2 and PROS-6 experiments, Deep-Sea Res., 42, 893–917.

Sciascia, R., M. Berta, D.F. Carlson, A. Griffa, M. Panfili, M. La Mesa, L. Corgnati, C. Mantovani, E. Domenella, E. Fredj, M.G. Magaldi, R. D'Adamo, G. Pazienza, E. Zambianchi, and P.-M. Poulain, 2018. Linking sardine recruitment in coastal areas to ocean currents using surface drifters and HF radar. A case study in the Gulf of Manfredonia, Adriatic Sea. Ocean Sci., 14, 1461–1482, https://doi.org/10.5194/os-14-1461-2018.

Thyssen, M., N. Garcia, and M. Denis, 2009. Sub meso scale phytoplankton distribution in the North East Atlantic surface waters determined with an automated flow cytometer. Biogeosciences, 6, 569-583, https://doi.org/10.5194/bg-6-569-2009.

Vandromme, P., L. Stemmann, L. Berline, S. Gasparini, L. Mousseau, F. Prejger, O. Passafiume, J.M. Guarini, and G. Gorsky, 2011. Inter-annual fluctuations of zooplankton communities in the Bay of Villefranche-sur-mer from 1995 to 2005 (Northern Ligurian Sea, France). Biogeosciences 8, 3143-3158.

3.8. Northern Adriatic Sea

Involved institutes: CMCC, CNR, OGS, IRB

Authors:
CNR: Carolina Cantoni, Roberta Sciascia, Maristella Berta, Annalisa Griffa
CMCC: Stefania Ciliberti
OGS: Rajesh Nair
IRB-CIM: Martin Pfannkuchen (associated partner)

Involved JRAPs: JRAP6, and JRAP5

3.8.1. *Specificity of the region*

3.8.1.1. Most relevant scientific questions from regional to local scales

General characteristics of the area

The Northern Adriatic (NA) is the northernmost basin of the Mediterranean Sea. It is characterized by a shallow depth (<100 m) and a marked seasonal and interannual variability of both meteoceanographic and biogeochemical parameters. The general circulation is cyclonic with a flow towards the northwest along the eastern side and a return flow towards the southeast along the western side (Figure 3.8-1). This pattern is often dominated by local cyclonic gyres that vary in intensity according to the season in response to changing winds and thermal fluxes during the year (Poulain PM et al., 2001). During winter, when favourable meteorological conditions occurs, the area is a site of dense water formation that, from the NA shelf flows southward and contribute to the ventilation of the deep layers of the Eastern Mediterranean basin (Carniel et al, 2016; Cantoni et al., 2016).

Figure 3.8-1: The northern Adriatic Sea showing the potential site for regional integration, indicated by NA, comprising a core (Zones 1 and 2) and boundary areas.

The NA receives terrestrial fresh water input from surface runoff, karstic seeps and more importantly several rivers along the Italian, Slovenian and Croatian coast; the most important is the Po River, which drains large, intensely cultivated and highly industrialized inland areas and delivers to the sea huge amounts of dissolved and particulate materials, including anthropogenic contaminants. The Po River is the largest freshwater input into the Mediterranean (Poulain PM et al., 2001). The interactions between the river water masses and the circulation processes significantly influence the biomass and composition of plankton in this area. The Adriatic Sea has been for decades the site of extensive eutrophication phenomena, anoxic / hypoxic events and formation of mucilaginous aggregates detrimental for fishing activities and tourism (Giani et al., 2012).

All these factors make this area very sensitive to meteorological forcings and vulnerable under a climate change scenario. The Adriatic Sea plays an important role in air-sea CO_2 sequestration mechanism impacting the carbon budget and the acidification of the Mediterranean basin (Luchetta et al.2010),

In addition, this area is strongly influenced by anthropogenic pressure: the intense maritime traffic coupled with rising temperatures exposes this sub-basin to the invasion of alien species and to ecological and biogeochemical modifications (Giani et al., 2012).

Most relevant scientific questions and those targeted in JERICO-NEXT

To support the management of the ecosystem and progress on a forecasting system, JERICO-NEXT actions mainly focused on modelling and data assimilation in JRAP6 and on the development of capability to study transport and retention of larvae thanks to analysis of HF radar data as well as oceanographic and fishery data. JERICO-NEXT actions (JRAP5) have also enabled a significant step forward in the study of global change in this area, and its impacts on CO_2-air flows.

3.8.1.2. Most relevant societal needs and policy needs (including agencies/users potential list)

The Northern part of the Adriatic Sea (hereafter indicated by NA) in the Eastern Mediterranean basin is a trans-boundary region comprising coastal zones of three different nations, Italy and Croatia, mainly, and a small section belonging to Slovenia. The zones are quite densely populated and are important contributors to the relevant national economies, hosting important marine-related resources and industrial activities. They are also intimately linked to the local cultural and social systems. An integrated coastal observation system in the NA is urgently required to deal with many pressing issues affecting it. These include climate-change effects on land-sea and air-sea fluxes, transport and dispersal of pollutants, eutrophication, the rise in jellyfish and harmful algal blooms, coastal erosion, water quality and environmental status criticalities, maritime traffic, and civil protection. Such a system would be a concrete instrument for building the formal framework necessary for the implementation of a shared ICZM protocol in the region that could possibly serve as a building block for a similar protocol for the rest of the Adriatic Sea in the future.

3.8.1.3. Acquired data and archiving made

At the PALOMA station, in the central area of the Gulf of Trieste, one year of high quality operational sea surface pCO2, salinity, temperature and dissolved oxygen data, were gathered in the framework of JRAP5. The intense observation period took place from April 2017 to April 2018, simultaneously in all the different European sites studied within this JRAP activity. Data were acquired, post processed and quality controlled following ICOS-MSA standards and were archived on CNR-ISMAR server and made available according to the JERICO-NEXT data policy.

In the Gulf of Manfredonia, historical HF Radar data acquired in 2013-2015 were used to compute surface current as part of the VA component of JERICO-NEXT.

3.8.2. *Collaboration with other international initiatives*

The whole Northern Adriatic is a marine “macro-site” belonging to the LTER-Italy, LTER-Europe and LTER International network. (https://deims.org/92fd6fad-99cd-4972-93bd-c491f0be1301). Most of the fixed observatory already belongs to Research Infrastructures (RI), which are now at various stages of development, but all already officially recognized in the panorama of IR European countries: Danubius-RI, EMBRC-ERIC, LTER-RI, ICOS-RI, LifeWatch ERIC and DiSSCo-RI.

Among them, the PALOMA station, already collaborating in JERICO-NEXT JRAP-5, is the first Mediterranean marine station officially admitted to the ICOS-RI network.

3.8.3. *Scientific progress so far*

The work led in the framework of JERICO-NEXT in the northern Adriatic Sea mostly stands in the application of the Adriatic-Ionian Forecasting System (AIFS) with i) HF-data assimilation after specific development in Task 3.7 (WP3), and ii) assimilation of fish and oceanographic data (FOOS system) thanks to the JRAP6 activities, as described hereafter. In addition, HF Radar data were also analysed to investigate biological retention zone (action to relate to JRAP4) and thanks to the JRAP5 activity, sea-surface pCO_2 was continuously measured over a yearly cycle to assess the sensibility of air-sea CO_2 fluxes in response to physical ad biological controls.

Adriatic Ionian Forecasting System: AIFS (CMCC)

The Adriatic-Ionian Forecasting System (AIFS) is a NEMO-based model for the central Mediterranean Sea. It uses a horizontal resolution of 1/45˚ (approximately 2km) and 121 vertical levels. Data assimilation in this system is performed using a Python implementation of the Ensemble Square Root Filter (EnSRF) of Whitaker and Hamill (2002). The filter is coupled to the model in offline mode.

The ensemble for the EnSRF is generated from a 12-year historical run (2003-2014). Using the restart files of the nominal model, perturbations are added by sampling the daily average fields for 3 days from each year. These days are spaced 14 days apart and centered on the nominal date. The mean over all days is subtracted from the fields and replaced by the fields of the nominal model. Each day then becomes the perturbation for one ensemble member. The perturbed fields are temperature, salinity and the zonal and meridional velocities. The system is herein referred as AIFS-EnSRF.

The system is capable of assimilating temperature and salinity from a variety of sources (among others ARGO and the FOOS fishery observatory). In the context of JERICO-NEXT the system has been developed specifically to allow the assimilation of radial HFR velocities, as part of task 3.7, in WP3. Its application is led in WP4, JRAP6. The assimilation of radial as opposed to zonal/meridional velocities allows more data to be used (specifically: areas covered by only a single antenna) and allows a more accurate representation of the uncertainty.

Main activities were:

- Numerical simulations and evaluation of Adriatic Ionian Forecasting System model performances
- Adriatic Ionian Ensamble Square Root Filter model setup assessment
- OSE in the Western Adriatic and impact of coastal observations on model performance

Assimilation of HFR data in the Gulf of Manfredonia with AIFS-EnSRF

The HFR data in the Gulf of Manfredonia are used to perform data assimilation experiments with the AIFS-EnSRF system at CMCC. These experiments focus on February and March of 2014, a period in which also a series of drifters had been deployed within the HFR coverage. Three experiments have been performed, varying the uncertainty on the HFR data and the frequency of assimilation. In experiments 1 and 2 the assimilation of HFR is performed daily at midnight only, while in experiment 3 the assimilation is performed hourly. Experiments 1 and 3 assume an uncertainty of 1 cm/s for the HFR data, while experiment 2 used 0.5 cm/s. The results are summarized in Figure 3.8-2. The AIFS-EnSRF system with daily assimilation of HFR at midnight shows a significant improvement in the description of the zonal (u) component of the drifter movement, independent of the assumed uncertainty. The meridional (v) component shows very little improvement with daily assimilation. Moving to hourly assimilation of HFR the meridional component shows a significant improvement compared to the drifter trajectories, while the results for the zonal component remain approximately the same. A possible explanation of this effect lies in the topology of the antenna network, which constrains the zonal component more than the meridional component. The meridional component therefore benefits more from the increased amount of HFR data assimilated with hourly assimilation.

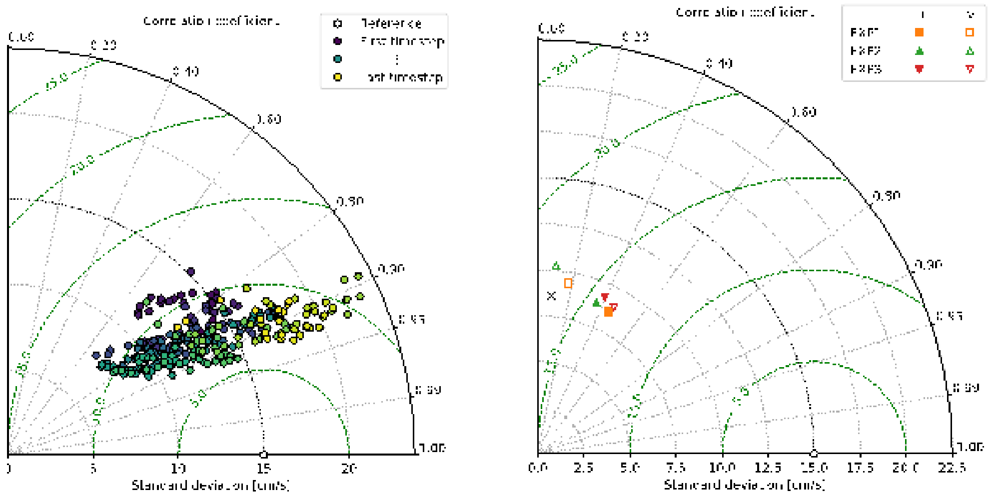


Figure 3.8-2 Taylor diagrams showing the performance of the AIFS-EnSRF system with HFR data assimilation. The left panel shows the agreement of the model with the radial velocity just before assimilation for each (hourly) timestep. The right panel shows the comparison of the three experiments performed to the independent drifter data. AIFS without HFR data assimilation is represented by the cross.

Assimilation of FOOS data in Ancona area with AIFS-EnSRF

Finally, the AIFS-EnSRF system has been used to assimilate data from the Fishery & Oceanography Observing System (FOOS) established by CNR-ISMAR in Ancona (Martinelli, 2016). The FOOS consists of a fleet of seven vessels operating in the Adriatic Sea, equipped with sensors that record temperature and salinity during the haul of the fishing nets. The resulting in-situ measurements span a depth range of roughly 0—150m. For the period of January-February 2017, the FOOS temperature data is assimilated into the AIFS-EnSRF system at daily frequency. In this period no salinity data was available. Figure 3.8-3 shows an example of the assimilation of two typical profiles.

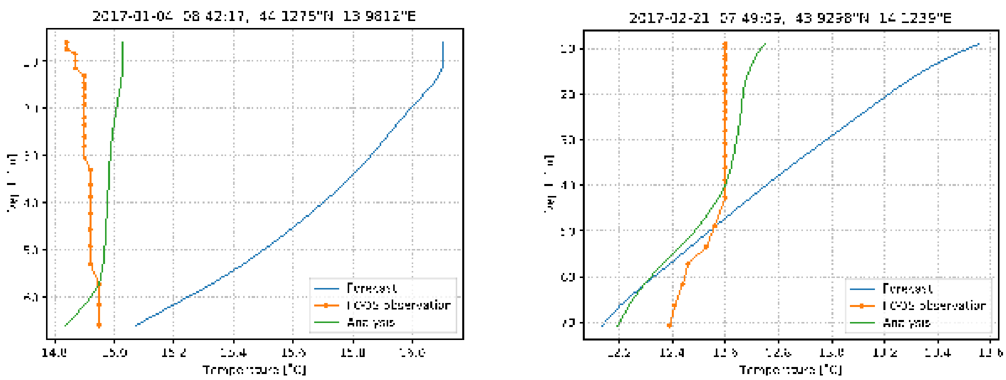


Figure 3.8-3 Assimilation of two typical profiles from the FOOS dataset. The FOOS observation is shown, as well as the AIFS-EnSRF forecast and analysed values.

Aggregated results for the entire period are shown in Figure 3.8-4. It is known that the system exhibits a warm bias, especially at depth the assimilation of FOOS temperature observations manages to reduce the bias by around one degree. For the deeper layers the effect of the assimilation persists, while closer to the surface the performance is more variable. This is most likely due to the fact that at depth the sea is more stable, which means the corrections not only have a greater reach in time, but also in space.

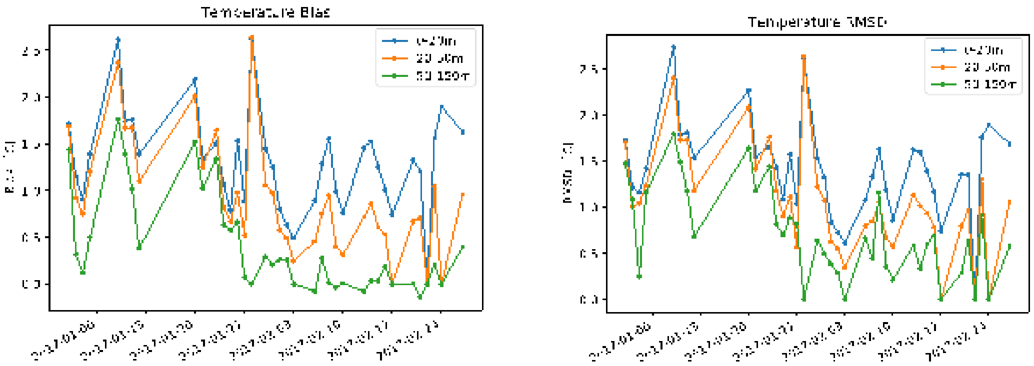


Figure 3.8-4: Evolution of bias and RMSD of the AIFS-EnSRF system compared to the FOOS profiles, just before assimilation. It can be seen that, especially at the deeper layers, the assimilation has a beneficial effect on the model.

Analysis of HF radar data in the Gulf of Manfredonia

HFR data in the Gulf of Manfredonia (Corgnati et al., 2018) have been used by CNR-ISMAR together with drifter data and otolithes analysis (Sciascia et al., 2018) to investigate recruitment of small pelagic (sardines). The Gulf of Manfredonia is an important nursery area for sardines and an important question from the fishery and ecological management point of view is whether the nursery is supported by local spawning or by spawning from remote areas in the North and Central Adriatic. Radar data were used to compute retention properties inside the Gulf, while historical and targeted drifter data provided information on connectivity between the remote spawning areas and the Gulf. The results indicate that the average residence time in the Gulf of Manfredonia is relatively short (< 10 days) compared to the typical passive pelagic larval duration (30-50 days). Therefore the larvae nursery in the Gulf of Manfredonia seems more likely supported by remote spawning areas.

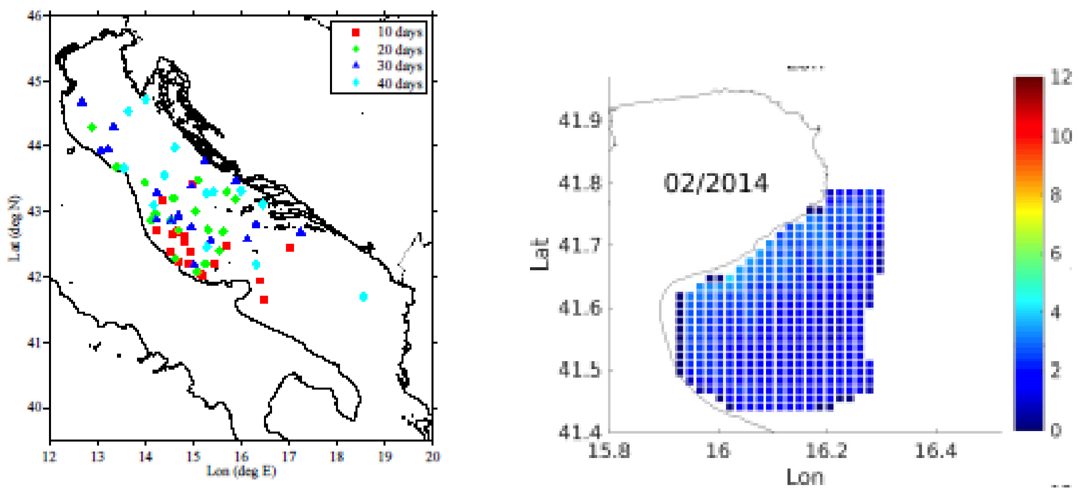


Figure 3.8-5 Left panel: historical drifter locations at 10 days, 20 days, 30 days, and 40 days before entering the Gulf of Manfredonia. Right panel: bootstrap estimates of average residence times (in days) of virtual particles advected in the HF radar velocity field and released within the boundaries of the Gulf of Manfredonia (example for February)..

Sensitivity of air-sea C-fluxes to biological and physical controls in the Gulf of Trieste

The PALOMA elastic beacon, managed by CNR-ISMAR (Figure 3.8-6), since 2012 has been equipped with autonomous instrumentation to quantify and study air-sea CO_2 fluxes. The station is visited monthly to collect discrete samples of pH and total alkalinity the main biogeochemical parameters (Cantoni et al 2012). In the framework of JERICO-NEXT project, JRAP5, one year of high quality data were acquired from April 2017 to April 2018, post processed and quality controlled following ICOS-OTC standards. The comparison between discrete samples continuous measurements of pCO_2 and dissolved oxygen (Fig. 3.8.5) fulfilled the ICOS requirements and the station was successfully labelled as ICOS class I station.

Surface pCO_2 values exert the main control over air-sea CO_2 fluxes: when atmospheric pCO_2 values exceeds the marine ones, the seas can adsorb atmospheric CO_2 acting as CO_2 sinks, when the situation is the opposite, they release CO_2 to the atmosphere, acting as a CO_2 source. Seawater temperature and the balance between photosynthesis and respiration are the main forcings driving marine pCO_2 variability: the low temperatures, increasing CO_2 solubility, decrease pCO_2, photosynthesis, removing dissolved inorganic carbon, also decrease pCO_2 values. High temperatures and the prevalence of respiration over photosynthesis determine the opposite effect.

Considering 400 µatm as average atmospheric concentration, the offshore area of the N. Adriatic (Zone 1, Figure 3.8-1) was an atmospheric CO_2 sink from January 2017 to the end of July and from mid-November to the beginning of April 2018. During August 2017 the area acted as a CO_2 source while in Autumn (from 15/09 to 07/11) values were mostly in equilibrium with the atmosphere (Figure 3.8-1(a)).

The wintry season (from 01/01 to 27/03) was characterized by low biological activity, as evidenced by the oxygen saturation mostly in equilibrium with the atmosphere (100 % ± 5 %). Under these conditions, the low seawater temperature (between 10.5°C and 7.5°C) can be considered as the main driver of the low pCO_2 (down to 300 µatm) observed.

In late spring –early Summer (from 11/05 to 08/06) pCO_2 remained below 350 reaching the minima annual values (283.7 µatm), even if seawater temperatures ranged between 16.4°C and 25.2°C. Oxygen oversaturation (up to 130 %) indicated the onset of intense phytoplankton blooms trigged by riverine nutrient loads (salinity down to 31 psu, NO_3 4.03) hence biological CO_2 fixation had a major role in keeping pCO_2 values low.

Throughout summer (from 30/07 to 20/08) riverine nutrient loads decreased (NO_3 0.47 µM) and the slight oxygen oversaturation (100%<DO<110%) indicated the lack of intense phytoplankton blooms able to strongly decrease CO_2 concentrations. Seawater temperature increased furtherly (up to 30 °C) leading to higher pCO_2 values that remained above 400 µatm for the whole period, reaching values as high as 474 µatm at the end of the month.

During fall, the high frequency measurements highlighted the occurrence of two steep pCO_2 increases (on 29/09 and on 22/10), both coupled with a sharp decline of oxygen saturation. They could be ascribed to the outbreak of bottom waters (Cantoni et al., 2012), segregated during summer and enriched in CO_2 by organic matter remineralisation.

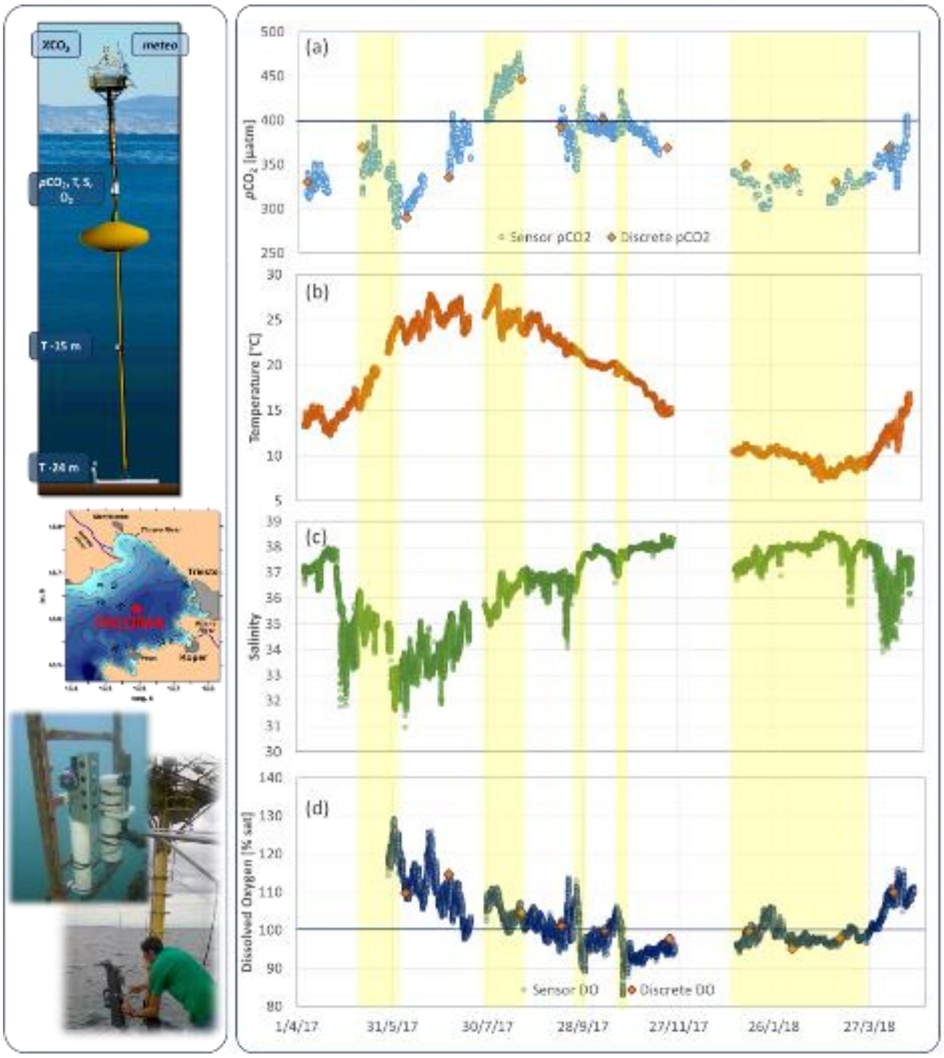


Figure 3.8-6 : Left: schematic of the PALOMA elastic beacon (CNR-ISMAR), its location and the experimental activity. Right: Data acquired at 3m avg. depth during JRAP5 high intensity measurement activity. (a) CO2 partial pressure (pCO2), squares are values calculated from discrete pH and total alkalinity samples, (b) Temperature, (c) Salinity, as PSU, (d) Dissolved oxygen as % sat, squares are values calculated from discrete DO samples (Winkler method). Events discussed in the text are highlighted in yellow.

3.8.4. *Synthesis and way forward*

Synthesis and specific next steps

During the project, important steps forward has been done on the development of capabilities to integrate new kind of experimental data between them and within oceanographic models to support ecosystem management. The Adriatic Ionian Forecasting System (AIFS) has been implemented with a data assimilation module capable of assimilating temperature acquired during the haul of the fishing nets from the FOOS fleet, as well as radial velocities from HFR radar. Several data assimilation experiments showed a significant improvement of the results encouraging further studies. The analysis of HFR data were integrated with results from drifter deployments to investigate the role of the Gulf of Manfredonia in the recruitment of small pelagic: results highlighted the role also of remote areas in supporting the ecological role of this gulf. A first elaboration of the high frequency sea surface CO_2 data acquired during the project highlighted how intense phytoplankton blooms were able to keep the North Adriatic a strong CO_2 sink even with seawater temperatures above 25°C. In the next months, a further data elaboration is foreseen, to allow a better comparison with the CO_2 data gathered in other European sites.

The work carried on so far highlighted the potentiality of the area, where historical data and many observational systems are available to support both ecosystem management and advanced marine researches. On the other hand, they pointed out the need for integration of the existing facilities and observational systems also at a trans-border level to address the climate and ecological challenges facing this basin.

3.9. References for the Northern Adriatic Sea

Cantoni C., Luchetta A., Chiggiato J., Cozzi S., Schroeder K., Langone L., 2016. Dense water flow and carbonate system in the southern Adriatic: A focus on the 2012 event. Marine Geology, 375, 15-27

Cantoni, C., Luchetta, A., Celio, M., Cozzi, S., Raicich, F., Catalano, G., 2012. Carbonate system variability in the Gulf of Trieste (North Adriatic Sea). Estuar. Coast. Shelf Sci. 115, 51–62.

Carniel S., Bonaldo D., Benetazzo A., Bergamasco A., Boldrin A.,.Falcieri F.M., Sclavo M.,Trincardi F.,Langone L., 2016. Off-shelf fluxes across the southern Adriatic margin: Factors controlling dense-water-driven transport phenomena. Marine Geology, 375, 44-63.

Corgnati, L. P., C. Mantovani, A. Griffa, M. Berta, P. Penna, P. Celentano, L. Bellomo, D.F. Carlson, R. D'Adamo, 2018: Implementation and Validation of the ISMAR High-Frequency Coastal Radar Network in the Gulf of Manfredonia (Mediterranean Sea). IEEE Journal of Oceanic Engineering,44,2, 424-445.

Giani M., Djakovac T., Degobbis D., Cozzi S., Solidoro C., Fonda Umani S. 2012. Recent changes in the marine ecosystems of the northern Adriatic Sea. Estuarine, Coastal and Shelf Science, 115, 1-13

Haynes R and E.D. Barton, 1990. A poleward flow along the Atlantic coast of the Iberian Peninsula. Journal of Geophysical Research 95, 11425–11441

Luchetta, A., Cantoni, C., Catalano, G., 2010. New observations of CO2-induced acidification in the northern Adriatic Sea over the last quarter century. Chemistry and Ecology 26, 1-17.

Martinelli M., S. Guicciardi, P. Penna, A. Belardinelli, C. Croci, F. Domenichetti, A. Santojanni, S. Sparnocchia, 2016. Evaluation of the oceanographic measurements accuracy of different commercial sensors to be used on fishing gears. Ocean Engineering, 111, 22-33.

Poulain PM., Kourafalou V.H., Cushman-Roisin B. (2001) Northern Adriatic Sea. In: Cushman-Roisin B., Gačić M., Poulain PM., Artegiani A. (eds) Physical Oceanography of the Adriatic Sea. Springer, Dordrecht

Sciascia, R., Berta, M., Carlson, D. F., Griffa, A., Panfili, M., La Mesa, M., Corgnati, L., Mantovani, C., Domenella, E., Fredj, E., Magaldi, M. G., D'Adamo, R., Pazienza, G., Zambianchi, E., and Poulain, P.-M. 2018. Linking sardine recruitment in coastal areas to ocean currents using surface drifters and HF radar. A case study in the Gulf of Manfredonia, Adriatic Sea. Ocean Sci., 14, 1461–1482.

Whitaker J. S. and Hamill T. M., 2002. Ensemble Data Assimilation without Perturbed Observations. Monthly Weather Review, 130, 7 1913-1924.

3.10. Cretan Sea

Lead Partner: HCMR
Involved Partners: HCMR, CNRS??
Authors: Christos Arvanitidis (HCMR) <arvanitidis@her.hcmr.gr> , Christina Pavloudi (HCMR) <cpavloud@hcmr.gr>, George Petihakis (HCMR)
Involved JRAPs: JRAP2 and JRAP6

3.10.1. *Specificity of the region*

3.10.1.1. Most relevant scientific questions from regional to local scales

General characteristics of the area

The Cretan Sea plays an important role in the dynamics of the Eastern Mediterranean circulation and has been considered as heat, salt, and dissolved oxygen reservoir with high temperature and salinity in its intermediate and deep layers. It is also the poorer in nutrients and richer in oxygen, among the principal basins of the Mediterranean Sea (e.g. Souvermezoglou and Krasakopoulou, 2000; www.mongoos.eu/data-center). It is also an area of intermediate and/or deep-water formation, dominated by multiple scale circulation patterns and intense mesoscale variability (e.g. Georgopoulos et al., 2000). The deep-water mass formation in the Cretan Sea has the potential to transfer CO2 into the deep layers, however, there is a sparseness of carbonate system data, to understand its role as source or sink of CO2 and the existing AT-S relationships for the Mediterranean do not reproduce efficiently the AT levels observed in the Aegean Sea (Krasakopoulou et al., 2015 and references therein).
The Cretan Sea (as the rest of the Eastern Mediterranean Basin is considered to be an ultra-oligotrophic system. The dominance of the multivorous food web in the Cretan Sea is a dissimilarity with most areas of the Mediterranean Sea where the microbial food web generally dominates (Siokou-Frangou et al., 2010 and references therein).

As the Cretan Sea is deeply oligotrophic and bentho-pelagic coupling is the most important factor in controlling benthic macrofauna composition and dynamics. Probably the most important part in this process is the so-called "*microbial loop*". This loop accelerates the rates at which the organic material produced or precipitating on the surface layers of the waters is reaching the depths of the bathyal benthic habitats. Coastal expression of the very oligotrophic Cretan Sea ecosystem is modulated by the moderate to small riverine inputs and the rural activities in the Northern Crete. The Cretan Sea, according to its river discharges, is qualified as having open ocean characteristics (Ludwig et al., 2009 and references therein).

Northern Crete is not so densely populated, e.g. the largest city in the area which is Heraklion has around 300,000 inhabitants. However, the whole area is under a huge touristic pressure as more than three million people are arriving each year. Thus, the influence of the tourists in the local economy, as well as in the local environment, cannot be neglected and has not been properly accounted for.

Most relevant scientific questions and those targeted in JERICO-NEXT

- Seasonal variability of the Black Sea waters inflow through the Dardanelles straits - Interaction with the existing hydrodynamic state of the North Aegean
- Contribution of the mesoscale activity to the general circulation of the Aegean Sea
- Seasonal and interannual variability of the cyclonic and anticyclonic flow pattern that dominates the upper thermocline general circulation of the Cretan Sea
- Intermediate and deep water mass formation in the Cretan Sea - Contribution to the Eastern Mediterranean deep waters - Connection with the Eastern Mediterranean Transient
- Protection of marine environment from oil spill accidents, taking into account the future plans for oil drilling activities in the area (societal need)
- Support for handling coastal erosion problems, which are really critical in specific areas such as the Northern part of Crete (societal need)

- Sewage outputs in the Cretan Sea influence the composition of natural communities.

3.10.1.2. Most relevant societal needs and policy needs (including agencies/users potential list)

The societal needs in this area are more urgent than never, specifically because of the economic crisis. The society (both local and at national level) needs healthy and productive oceans, made up by seas in which both the physical and chemical environment are maintained in their normal conditions for this area and that the biodiversity and ecosystems function in such a way in which the ecosystem services are continuously delivered to the ocean and to the society. The societal demand also extends to the blue growth and the creation of jobs through the sustainable exploitation of the oceanic resources.

A plethora of relevant policies have been established over the years. The most important policies that need continuous and uninterrupted implementation are:

- The Habitats Directive (92/43/EEC)
- The Water Framework Directive (WFD: 2000/60/EC)
- The Marine Strategy Framework Directive (MSFD: 2008/56/EC)
- The Maritime Spatial Planning Directive (MSP: 2014/89/EU)

On the top of the above, one would add the Sustainable Development Goals (SDGs), which are a collection of 17 global goals set by the United Nations General Assembly in 2015.

However, if we: (a) take into account all the marine environmental legislation to which Greece is either an individual signatory party or a member of the EU as the signatory party of the international Treaties, Conventions, Commissions, etc; (b) map this legislation against the national one which ratifies the international legislation to the Greek law system; then the result is a very complex network of interlinked parts of various legislations that can be termed as “horrendogram”, after Boyes and Elliott (2014).

This picture, however, is further aggravated by the ministries, and other national and regional authorities which are involved in the implementation of this complex legislation system.

A short list of the potential agencies involved might include:

- State authorities at all levels: ministerial, regional, local
- Environmental management authorities
- Law enforcement authorities
- Fisheries and agriculture regulating agencies
- Port authorities
- National Park and MPA agencies
- Research Centres and higher education establishments

A short list of the potential users / stakeholders might include:

- Scientists and researchers
- Educators at all levels
- Students at all levels
- Diving club owners and professional trainers
- Fishermen and aquaculture units owners
- Entrepreneurs, activated in tourism
- Hotel owners and relevant professionals and workers
- Coastal development contractors, engineers and workers
- Ship makers, designers, owners, relevant professionals
- Coastal navigation and transport contractors, entrepreneurs and relevant professionals

- Environnemental managers (e.g. MPA managers)
- Military (naval) personnel
- Engineers and professionals working on energy
- Policy implementors
- Policy makers

3.10.2. *Acquired data and archiving made*

Data type	Sampling location/area	Sampling period	Institute
Physical and biochemical parameters (temperature, salinity, currents, Chlorophyll-A fluorescence, dissolved oxygen, turbidity, pH, CO2) from six oceanographic moorings.	Aegean and Ionian Seas	Jun. 2000-ongoing	HCMR
Physical and biochemical parameters (temperature, salinity, Chlorophyll-A, dissolved oxygen, nutrients)	Cretan Sea (Aegean)	Oct. 2016 – ongoing	HCMR
Macro- and microorganismic benthic communities collected in the Cretan Sea	Cretan Sea (Aegean)	Oct. 2016 – ongoing	HCMR
Temperature, Salinity and Dissolved oxygen from ARGO floats	Aegean Sea	Nov. 2013 – ongoing	HCMR
Temperature, Salinity, Dissolved Oxygen, Chlorophyll-A fluorescence, pH, Turbidity from Ferry Box system	Piraeus – Heraklion (Aegean Sea)	Aug. 2012- Dec. 2014, Oct. 2017 - ongoing	HCMR

3.10.3. *Collaboration with other international initiatives*

HCMR participates to the Copernicus Marine Environment Monitoring Service (CMEMS) through the operation of the Mediterranean Insitu Thematic Assembly Center (MED Insitu TAC) and the provision of the Mediterranean forecasting products for the sea state conditions.

HCMR is a member of the Euro-Argo ERIC and it has been assigned the responsibility of the Argo float deployments in the Aegean and Ionian Seas for the continuous monitoring of physical and biochemical conditions.

HCMR is a member of the EMSO ERIC and participates also in the EMSO Link project (H2020), contributing to the continuous recording of the sea bed conditions through the deployment and operation of a cable observatory off the Pylos area (South Ionian) at 1650 meters depth.

HCMR is also a member of the LifeWatch ERIC and it is charged with the development and operation of the national node of the electronic infrastructure on the biodiversity and ecosystem research.

3.10.4. *Scientific progress so far*

Progress held in JRAP6

The Aegean Sea high resolution hydrodynamic model has been assessed with and without data assimilation (inter-comparison is still ongoing) and a series of sensitivity experiments have been performed so far in order to understand the role of various forcing mechanisms in model performance.

The Aegean Sea forecasting component consists of a high resolution (1/30o) general circulation model of the Aegean Sea area nested within the Copernicus CMEMS with the latest version of Med-currents forecasting system, a data assimilation module based on the extended Kalman filter approach (Singular Evolutive Kalman filter with error covariance localization and partial evolution of the correction directions) that produces analyses on a weekly basis and a multivariate set of in-situ and satellite observations used for assimilation and model validation.

The main focus of this report is to assess the predictive skill of the system when run without data assimilation (model free run) and to assess a series of sensitivity runs aiming to improve the skill of the forecasting system. As such potential improvements we consider here the modification of the Dardanelles open boundary condition (Dardanelles Straits inflow/outflow is a key factor for the hydrodynamics and hydrology of the North Aegean Sea), the inclusion of wave dissipated energy to the TKE of the Aegean Sea hydrodynamic model and the testing of an alternative atmospheric forcing at 1/20 horizontal resolution from a WRF model setup over the Mediterranean Sea.

Considering the observational data set over the Aegean Sea we may refer to the continuous operation of 4-5 fixed station buoys (E1M3A, Athos, Pylos, Saronikos and recently Mykonos buoy station), periodic deployment and multi-year operation of Argo floats (some of them equipped with oxygen sensors), an HF Radar system measuring the surface currents over the Lemnos plateau (Zervakis et al., 2011), a Ferrybox system measuring foundation SST and SSS along the track from Piraeus to Heraklion Crete (Korres et al., 2014) and a gliders measuring module consisting of two “sea explorer” gliders that are operational since November 2017.
The HF Radar and the Ferrybox observational systems have been both considered and assessed in the framework of JERICO-FP7 project (2011-2015). The HF Radar system has stopped operating in Dec 2012 (it is expected to re-operate after a major upgrade in 2019) while the Ferrybox is again operational after a 3-year period (2015-2017) of inactivity. On the other hand, a series of pilot glider missions have been performed since November 2017 with the glider observation module (two “sea explorer” gliders) operating in the Cretan Sea. The acquired T/S observational data were used in OSE experiments (data assimilation experiments with and without Ferrybox recordings and gliders profiles) of the Aegean Sea modelling system described below.

As already said, a series of sensitivity runs (described briefly below) have been performed with the Aegean Sea model in order to improve our scientific knowledge in what is still missing in the Aegean Sea modelling approach. These runs involve the integration of the model in “free run” mode (without data assimilation) for the whole 2014. To assess model performance, simulation results for 2014 (daily outputs of the model) are inter-compared with temperature profiles from Argo floats operating in the geographical domain of the Aegean Sea model (some of these floats have been deployed in the framework of the Greek Argo program) and several type of satellite observations (satellite altimetry, foundation SST and skin temperature SST).

Aegean Sea model sensitivity with respect to the Dardanelles Straits boundary condition
The Dardanelles inflow/outflow has been implemented into the Aegean Sea model using an open boundary condition parameterization approach based on the results of the Maderich et al. (2015) that used a chain of simple linked models is used to simulate the seasonal and interannual variability of the Turkish Straits System. The original dataset of Maderich et al. (2015), consists of daily values, for the period 1969 - 2009, for the exchange (inflow and outflow) between Aegean Sea and the Turkish Straits system with respective values for salinity and temperature. The above data set is used to setup a daily climatology of volume inflow and outflow along with corresponding values for temperature and salinity. A further correction to the temperature of the outflowing waters to the Aegean Sea is introduced by considering foundation SST satellite measurements in the area close to Dardanelles Straits. The new open boundary condition drastically decreases the model bias (approximately -0.5^{o}C for the new scheme versus -1.3^{o}C for the control run) and RMS error in the area over the Lemnos plateau (northeastern Aegean Sea).

Aegean Sea model sensitivity with respect to the wind waves dissipated energy
The energy flux from the wind waves to the Aegean Sea hydrodynamics (wave dissipation due to white capping and depth induced breaking) has been parameterized as a source term in the TKE of the Mellor-Yamada turbulence closure scheme (Janssen, 2012) in the Aegean Sea hydrodynamic model. One year model integration results show a slight decrease of SST Bias and RMS error with respect to SEVIRI skin surface temperatures which becomes more pronounced during the summer period.

Aegean Sea model sensitivity to the meteorological forcing
The sensitivity of the Aegean Sea model to the surface (momentum, heat and water fluxes) boundary conditions has been studied for one year period (2014) using atmospheric forcing parameters (gridded fields of net shortwave radiation, downward longwave radiation, cloud coverage, precipitation, air temperature and relative humidity at 2m and x-y components of wind velocity at 10m) from two different atmospheric forecasting systems. The atmospheric models used in this sensitivity study is the Weather Research and Forecasting (WRF), version 3.6.1 (Skamarock et al., 2008) and the ETA atmospheric model (standard POSEIDON atmospheric forecasting system) both running at 1/20 horizontal resolution over the Mediterranean Sea and both initialized and forced at their open boundaries with 1200 UTC 0.5° × 0.5° spatial resolution Global Forecast System (GFS) data (National Centre for Environmental Predictions - NCEP).

The two atmospheric data sets/models (WRF vs ETA) drive the Aegean Sea model sea surface height (SSH) in a very similar way although the SSH RMS errors corresponding to WRF run are slightly lower with respect to the ETA run after August 2014 and up to the end of the run (Dec 2014). A noticeable improvement of WRF forcing with respect to ETA forcing experiment is evident during the summer period for both the foundation SST and the temperature of the 5-30m layer. For the latter, the basin averaged improvement during the summer period is 0.5oC or can be even higher. Below this depth the two experiments show very similar behavior.

OSE experiments in the Aegean Sea
Two major experiments have been performed over a 9-month period (31 Oct 2017 – 17 July 2018) with the Aegean Sea forecasting system to test the impact of the inclusion of additional insitu observations made on a quasi-operational basis within the South Aegean Sea in the estimation of the Aegean Sea hydrodynamic state: the control run where the standard set of satellite and insitu observations (satellite SSH and foundation SST, Argo T/S profiles) are assimilated into the model on a weekly basis and an OSE experiment where glider profiles and Ferrybox SST and SSS observations are taken into account on the daily scale. It is found that the Aegean Sea state is best represented when both the standard SSH, foundation SST and Argo T/S profiles observations, the glider data and the Ferrybox surface observations are assimilated together in the forecasting system through the usage of a properly tuned localized version of the SEEK filter (Korres et al., 2014].

An interesting case of how the additional assimilation of glider profiles and Ferrybox observations used in the OSE experiment is beneficial for the Aegean Sea forecasting system in terms of reducing the system biases can be seen through its effect on the sea surface salinity model bias over the south Aegean (north of Crete and south of 37^{o}N) presented in Figure 3.10-1 for the control run and the OSE experiment. During the period April – July 2018 (days 49 – 141 in Figure 3.10-1, the forecasting system control run in the south Aegean presents a significant bias with respect to Ferrybox SSS observations. This amounts to 0.238 psu (with the model being fresher than the observations) although between November – December 2017 the average bias was 0.085 psu. The result can be partially verified through the glider surface salinity observations in the south Aegean and the two buoys (E1M3A and Heraklion coastal buoy) SSS time series over the same period. We argue that this significant SSS bias after April 2018 is mainly due to meteorological forcing (decreased evaporation rates) used to drive the hydrodynamic model. In the OSE experiment the SSS bias reduces to -0.009 psu for the first period (Nov – Dec 2017) and to 0.01 psu from April 2018 until the end of the run. It is interesting to mention that the RMS error (corresponding to the OSE run) of Ferrybox SSS misfits over the south Aegean is 0.196 psu which is again lower than the figure corresponding to the control run (0.247 psu).

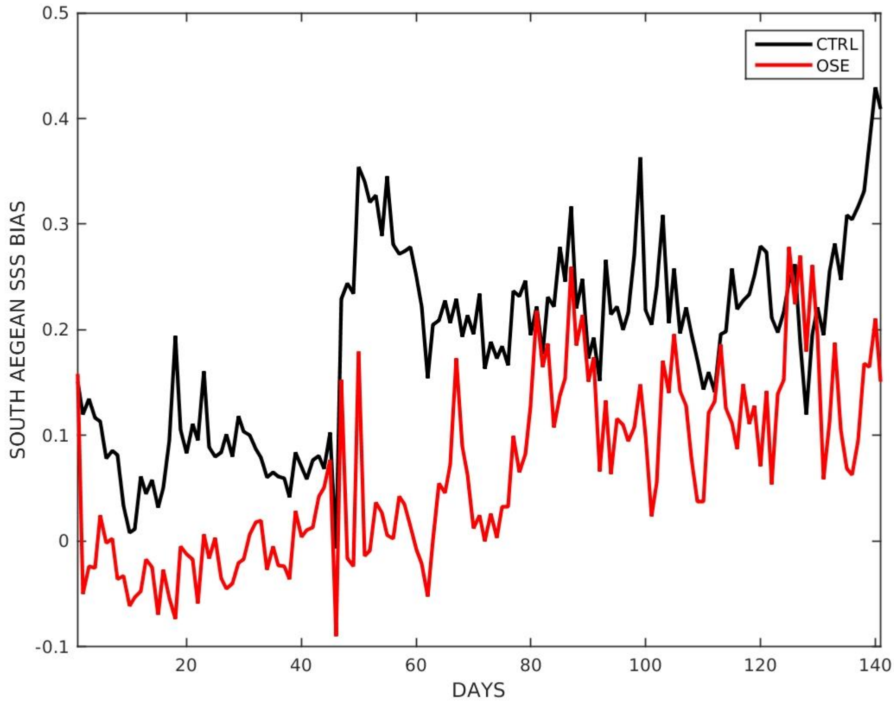


Figure 3.10-1 Sea surface salinity bias (defined here as obs-model) for the south Aegean Sea corresponding to the control run (black curve) and the OSE experiment. SSS observations are due to the Ferrybox operating during the period 31 Oct 2017 – 17 Jul 2018.

Progress held in JRAP2

The first Cretan Sea sampling cruise (JRAP#2) was conducted in October 2016 and the second Cretan Sea sampling cruise was conducted in July 2017 with the R/V Philia. Processing of the samples collected for estimation of environmental parameters (e.g. temperature, nutrients, granulometry etc.) from both the cruises has been completed. Processing of the samples collected for assessment of macrobenthic diversity at the Cretan Sea sampling stations from the 1st sampling cruise has also been completed. The processing of the samples from the 2nd sampling cruise will be completed in summer of 2019. The analysis of the biodiversity patterns and their correlation with those of the environmental parameters will be complete in the next months.

Processing and analyses of the sediment samples collected from the Cretan Sea and the West Gironde mud patch for microbial community assessment will be completed in summer of 2019. The first MiSeq sequencing run with samples from the 1st Cretan Sea cruise has been performed and the analysis of the results is ongoing. For the first time, blocking primers were used to prevent the amplification of microorganisms other than bacteria, e.g. fungi. The complete processing of the samples from both the Cretan Sea and the West Gironde mud patch will be completed in the next months.

3.10.5. *Synthesis and way forward*

3.10.5.1. Synthesis and specific next steps (short term)

The exercise carried out so far in the framework of the infrastructure project JERICO-NEXT has demonstrated the need for well-designed and coordinated multi-disciplinary research. In order to make progress on our current knowledge and provide compelling science-based knowledge and advise for policy and ultimately for the sustainable use of the resources of the Cretan Sea, we have to deploy all of our weaponry available towards common goals: from the systems dealing with the industrial monitoring of the physical and chemical properties of the marine environment to the conventional monitoring of the biota, the biodiversity and ecosystem functioning, including the molecular level of the biological organization. Only through such an aggressive approach we may collect the appropriate amount of data and information in order to properly model our oceanic systems and provide prognosis for their evolution with time, their deviations from their normal ranges as a result of the major drivers of change: (a) pollution and eutrophication; (b) over-harvesting of the ocean's invertebrate and plant stocks; (c) physical alterations to coastal and marine habitats; (c) invasions of exotic species; (d) global climate change, including increased ultraviolet radiation and rising temperatures.

Such an approach results in synthetic knowledge, which is necessary because not only represents more components of our geological, physical, chemical and biological marine environment but it is also relevant to many of the economic drivers of our societies. Only this type of synthetic knowledge can assist us in a global and holistic approach of economy, society and environment, towards our sustainable development goals, as defined by the United Nations General Assembly in 2015 for the year 2030. However, the data and information produced by such an approach may quickly become vast and unmanageable in many levels (e.g. storage, analysis, interpretation).

Therefore, our first next steps should include:

a) To carefully design and develop integrative observatories, in which the existing oceanographic, biodiversity and genomic ones are combined and benefit from each other, e.g. in terms of technology;
b) To develop smart monitoring strategies which take into account not only the performance of our gears and analytical workflows but also the framework imposed by the relevant legislation and by the societal expectations for blue growth and job creation;
c) By using the further development of the JERICO-NEXT as a case of a Research Infrastructure, to intensify the collaboration of the European Research Infrastructure Consortia (e.g. EMSO, EuroARGO, LifeWatch, EMBRC) focusing on the marine environment in order to accelerate the performance of both JERICO-NEXT and the ERICs involved over the entire life-cycle of their research performance. The latter means from the conception of the research idea and the formulation of the scientific hypothesis to be tested all the way to the collection, storage, analysis, interpretation and dissemination of the results and knowledge acquired.

3.10.5.2. Specific developments for the future

In the framework of the National Road Map for Research Infrastructures call, HCMR proposal HIMIOFoTS (National Infrastructure for Marine Research and Water Resources) was rated first and is currently in the implementation phase. The main objectives of the National Roadmap for Research Infrastructures are:

- To support the decision-making process in compliance with strategic priorities in research, aiming to enhance the effectiveness of investment planning for research infrastructures, at national and regional levels
- To support the development of an evidence-based national strategy in the framework of international negotiations, linked to EU priorities and, where appropriate, the European Strategy Forum on Research Infrastructures.

The aim of HIMIOFoTS is to develop an integrated national research infrastructure for the observation, forecasting and innovation for the oceans and internal waters. HCMR is the coordinator while POSEIDON operational system is the backbone around of which existing and future systems will be centered. In particular, the activities include:

- **Observing component**, besides POSEIDON the RI will include the national nodes of EMSO and EuroArgo ERICs, the coastal zone laboratory of the Univ. of Athens, the oceanographic research infrastructure of the Univ. of Aegean with the fleet of drifters, the national network of observation of rivers and lakes (DANUBIUS nodes) operated by HCMR and the National Technical University (both are DANUBIUS partners) as well as the testing facilities like flume tanks. In particular for the coastal part we plan to establish another FerryBox line in the North Aegean for the monitoring of Black Sea Waters, deploy new coastal ARGO floats and sustained glider sections as well as upgrade our monthly insitu program with more variables and better vertical resolution.

- **Forecasting component**, numerous operational models for the ocean the water cycle and the weather etc. in various resolutions. In addition existing climatic modells will be upgraded. Significant effort is foreseen towards the development of fully operational end to end fine scale models in coastal areas with significant interest.
- **Data center**, given that HCMR has a significant experience on operational data - it is the in Situ TAC of the Copernicus Marine Service for the Mediterranean - it will host and operate the integrated data center ensuring the efficient flow to mainstream aggregators.
- **Governing**, development of necessary structure in terms of governance with management board and relevant committees (technical, scientific, etc) as well as appropriate policies like access, services etc and business plan.

In addition to HIMIOFoTS important developments are:

1. The running project ROSACE (Radiometry for Ocean Colour SAtellites Calibration & Community Engagement) the objectives of which is to study and to propose a preliminary design for the infrastructure that will be used for the system vicarious calibration (SVC) of the Copernicus ocean colour radiometry (OCR) missions for upcoming decades, i.e., the Ocean and Land Colour Imager (OLCI) sensors aboard the Sentinel3 satellite series, and the Multi-Spectral Imager (MSI) sensors onboard the Sentinel2 satellite series. In addition to the BOUSSOLE buoy, a second buoy is proposed in the Cretan Sea next to the E1-M3A station. The main reason for choosing the particular site, besides the oceanographic characteristics (oligotrophy, flow regimes, depth etc) are the existing operational infrastructures in conjunction to the HIMIOFOToS expected outcomes (Integrated National RI).
2. The AQUACOSM and EMBRC research facilities at HCMR in CRETE. Both are in close collaboration with POSEIDON (and HIMIOFoTS) with many supporting activities either way.
3. In the short term roadmap, both fixed stations (E1-M3A & HCB) and the FerryBox systems are in the process to be included in the ICOS OCEAN.

3.11. References for Cretan Sea

Boyes S.J. and M. Elliott, 2014. Marine legislation – The ultimate 'horrendogram': International law, European directives & national implementation. Marine Pollution Bulletin 86, 39–47.

Georgopoulos, D., G. Chronis, V. Zervakis, V. Lykousis, S. Poulos and A. Iona, 2000. Hydrology and circulation in the Southern Cretan Sea during the CINCS experiment (May 1994–September 1995), Progress in Oceanography, 46(2–4), 89–112.

Janssen, P.A.E.M., 2012. Ocean wave effects on the daily cycle in SST. JGR, Vol. 117, C11.

Korres G., M. Ntoumas, M. Potiris and G. Petihakis, 2014. Assimilating Ferry Box data into the Aegean Sea model. Journal of Marine Systems, 140, 59–72.

Krasakopoulou E., C. Frangoulis, S. Psarra, A. Lagaria, L. Giannoudi and G. Petihakis, 2015. Carbonate system variables at the POSEIDON-E1-M3A site (S. Aegean Sea, Eastern Mediterranean), in: 11th Panhel. Symp. Oceanogr. & Fish., 857–860, [online] Available from: https://okeanos-dspace.hcmr.gr/bitstream/handle/123456789/1372/PanhellSympOceanFish11(857-860)2015..pdf?sequence=1.

Ludwig W., E. Dumont, M. Meybeck and S. Heussner, 2009. River discharges of water and nutrients to the Mediterranean and Black Sea: Major drivers for ecosystem changes during past and future decades?, Progress in Oceanography, 80(3–4), 199–217.

Maderich V., Y. Ilyin, and E. Lemeshko, 2015. Seasonal and interannual variability of the water exchange in the Turkish Straits System estimated by modelling. Mediterranean Marine Science, 16, 2.

Siokou-Frangou, I., Christaki, U., Mazzocchi, M. G., Montresor, M., Ribera d'Alcalá, M., Vaqué, D. and Zingone, A., 2010. Plankton in the open Mediterranean Sea: a review, Biogeosciences, 7(5), 1543–1586.

Skamarock W.C., J.B. Klemp, J. Dudhia, D.O. Gill, D.M. Barker, M.G. Duda, X.Y. Huang, W. Wang and J.G. Powers, 2008. A description of the Advanced Research WRF version 3. NCAR Technical Note:NCAR/TN-475 + STR, Mesoscale and Microscale Meteorology Division, National Centre for Atmospheric Research, Boulder, CO, USA.

Souvermezoglou E. and E. Krasakopoulou, 2000. Chemical oceanography in the Cretan Sea: Changes associated to the transient, Mediterranean Marine Science, 1(2), 91–103.

Zervakis V., G. Korres, Z. Kokkini, E. Tragou and T. Karambas, 2011. DARDANOS: A WERA system for monitoring the Dardanelles outflow in the Aegean, Rapp. Comm. Int. Mer Medit. 39, 201.

4. Some elements towards a regional integrated coastal observation

The purpose of this chapter is to gather preliminary information from local/regional observation sites to establish a medium to long term vision of the development of the European coastal observation. The objective was to survey JERICO-NEXT partners involved in WP4 to get their opinion in a concerted way. This action is useful to understand local, regional and national priorities and visions and thus to brainstorm the consortium to progress on establishing a roadmap for the future as expected in WP1 (Deliverable 1.4, task 1.6).

To reach this objective the following questions were asked for each site:

a) Two priority scientific/societal questions that a regionally integrated coastal system could investigate in this region?
b) What are the observation systems [like FB lines, Glider endurance lines, cable obs., buoys or set of buoys, HF radars, sustained periodic cruises (notion of time series), and set of manual sampling stations sustained in a period way] that are already delivering a time series of data in an operational way toward sustained data infrastructures (national or EU data infrastructure) and that can support investigation on these priority questions?
c) We need to consider modelling to progress toward an operational JERICO-RI, because models need data and because models are delivering complementary information. What are the models/configuration that are able to deliver more synoptic information on this region or that would benefit from in situ observation in the area?
d) What are the missing parameters or systems that should be added to improve these observations and/or toward a better integration in a 5 year time scale?
e) What products could be developed as prototype (firstly) built on EXISTING operational data flows ? [Products here means merging of in situ + model+ sat (or 2 of the 3) or only one, but with objective to answer expressed scientific needs / societel/policy needs, and that could be transferred to CMEMS for instance or produced by X in the future in an operational way.]
f) What products could be developed at longer term if some data flows not yet operationally flowing to EU/national channels would become interoperable in a way such they are flowing to these channel? (and thus what are the data flows needed to become interoperable?

Here after are the results.

4.1. Bay of Biscay

4.1.1. *SE Bay of Biscay*

a) Two Priority scientific/societal questions that a regionally integrated coastal system could investigate in your region

Scientific:
(a) Characterize the IPC three-dimensional variability, a current connecting transboundary regions along the continental slope and can be an important mechanism for transport of active and passive particles (plankton -invasive species, jellyfish-, pollutants - marine litter, plastics)
(b) Study the mechanisms that drive the IPC variability (including teleconnections with the North Atlantic circulation: NOA, EA) and the generation of mesoscale eddies in the area, for improving forecasts
(c) Improve the monitoring and understanding of upwelling processes and river plumes dynamics, associated secondary circulation, filaments (coastal-open ocean exchange), frontal areas and their impacts in the coastal ocean productivity.

Societal:
(a) Integrated management of commercial fishing species
(b) Floating Marine litter and plastic pollution.
(c) Hazards and coastal risks, and adaptation measures to the erosion of the coastline in a climate change context

As explained previously, Borja et al. (2018) have recently identified a number of pressing issues that can compromise the status of the Bay of Biscay. To be able to solve Bay of Biscay some management and governance challenges in coming years, these authors highlight a number of important steps like: Obtaining data with a better spatial and temporal resolution for a continuous monitoring of the ocean, developing coordinated spatial planning, expanding the Marine Protected Areas network, promoting sustainable fishing and encouraging the collection of data to support the management of mixed fisheries.

In addition to those, other important regional environmental problematics and needs identified from the analysis of recent activities and exchanges with stakeholders in the SE area of the Bay of Biscay are:

Integrated management of commercial fishing species (anchovy, hake, tuna…). JERICO-NEXT has done specific efforts for understanding the impacts of physical processes in Chl-a and phyto. But further work is needed for:

- understand physical drivers of recruitment, biomass and distribution of this species towards more accurate stock models
- Biotoxin control for aquaculture (and depending on the installation activity impacts): understand the main drivers: adequate sampling strategy (vertical sampling), numerical modelling? Machine learning?

Floating Marine litter and plastic pollution. A recent paper (Pereiro et al. 2018) points to high residence times in the SE Bay of Biscay, where the concentration of floating debris would be, on average, 2.1 times higher than in the north-western Iberian coastal waters. JERICO-NEXT has allowed a first trial experiment to study the processes that affects FML distribution in the area (through ETOILE survey) and for the improvement of data and models for Lagrangian studies for source identification. But further work is needed for:

- hotspots detection and forecast, Integrated evaluation of FML impacts, Management of FML removal in coasts and open sea. Integrated observations (in-situ sampling, videometry by the use of IR cameras in river mouths).

Hazards and coastal risks. *JERICO-NEXT has not contributed to this thematic, due to lack of near-shore monitoring.* Further work is needed for:

- Historical and real-time data for navigation safety and contingency plan and search and rescue operations (Data from JERICO-NEXT are useful but not demonstration) – NEED FOR SPECIFIC PRODUCTS
- Extreme events forecast, floods and damage prevention, Adaptation measures to the erosion of the coastline (climate change context). shore monitoring based on videometry.

b) *What are the observation system [like FB lines, Glider endurance lines, cable obs., buoys or set of buoys, HF radars, sustained periodic cruises (notion of time series), and set of manual sampling stations sustained in a period way] that are already delivering a time series of data in an operational way toward sustained data infrastructures (national or EU data infrastructure) and that can support investigation on these priority questions?*

system name	national/regional IR name where the system belongs	parameters (related to the priority question here above)	contact person (name, institute, email)	data infrastructure
Bilbao station	www.euskoos.eus	WAV/ATM/CUR/SST	jmader@azti.es	EMODnet, INSTAC
Pasaia station	www.euskoos.eus	WAV/ATM/SST	jmader@azti.es	EMODnet, INSTAC
Donostia buoy	www.euskoos.eus	WAV / SST / SSS / CUR / ATM	jmader@azti.es	EMODnet, INSTAC
HF radar	www.euskoos.eus	CUR	jmader@azti.es	EMODnet, soon in

				INSTAC and SeaDataNet
Water quality network (quarterly surveys)	www.azti.es http://www.uragentzia.euskadi.eus	C,T,pH, dissolved oxygen, nutrients, chl-a, transparency, suspended solids, turbidity, transmittance, metals, pesticides, PAHs.	jmader@azti.es	http://www.uragentzia.euskadi.eus/y76baWar/fillFilters.do
Sustained fisheries cruises (annual surveys BIOMAN in spring since 1987, and JUVENA in Autumn since 2003)	www.azti.es	Zooplankton biomass and size structure/-Fish abundance and distribution /Birds and mammals /Macro-litter	jmader@azti.es	
Bilbao Vizcaya buoy	Puertos del Estado	WAV/ATM/CUR/SST		EMODnet, INSTAC
Recopesca	Coriolis	C,T	guillaume.charria@ifremer.fr	Coriolis CMEMS
ARCACHON B13 buoy	ILICO/COAST-HF	C, T, fluorescence, turbidity	nicolas.savoye@u-bordeaux.fr	Coriolis CMEMS
PELGAS field cruises	Ifremer, yearly cruises programmed since 2000 at least.	CTD fluo?		Coriolis/SISMER

c) We need to consider modelling to progress toward an operational JERICO-RI, because models needs data and because models are delivering complementary information. What are the models/configuration that are able to deliver a more synoptic information on this region or that would benefit from in situ observation in the area?

model name/config	ref person for a future collaboration	types (hydrodyn, biogeo etc)	possible contribution: need of specific data to assimilate and/or capability to deliver some specific information (drifting of matter, transport…)
IBI CMEMS	http://marine.copernicus.eu/services-portfolio/access-to-products/	HYDRO- BIOGEO	Data assimilation,need data for model assessment, operational delivery of 1 week

	Marcos Sotillo <marcos@puertos.es>		forecasts
ROMS - AZTI	jmader@azti.es	HYDRO	High resolution simulations of the SE corner, need data for model assessment
SYMPHONIE - BOBSHELF	Ayoub Nadia <nadia.ayoub@legos.obs-mip.fr>	HYDRO	Data assimilation, High resolution simulations of the SE corner, need data for model assessment
CROCO/BOB MARS3D/BACH	sebastien.theetten@ifremer.fr, guillaume.charria@ifremer.fr?	HYDRO	High resolution hindcast available (1km 2000-2012 / 4km 1958-2010)
MARS3D/MARC	Jean.Francois.Le.Roux@ifremer.fr	HYDRO	High resolution simulations (2.5km 2006-2019 + 500m AGRIF zoom Adour 2010-2018)

d) What are the missing parameters or systems that should be added to improve these observations and/or toward a better integration in a 5 year time scale?

system name/or missing system	national/regional IR name where the system belongs	missing parameters (related to the priority question here above)	name of the person suggesting
Radar HF (Landes)	Coriolis	u,v (surface circulation)	guillaume.charria@ifremer.fr
Buoy in Adour river plume	ObservatoireAdour/CoastaHF	T,C,u,v, turbidity, chl-a, O2	damien.sous@mio.osupytheas.fr

e) What products could be developed as prototype (firstly) built on EXISTING operational data flows?

Products here means merging of in situ + model+ sat (or 2 of the 3) or only one, but with objective to answer expressed scientific needs / societel/policy needs, and that could be transferred to CMEMS for instance or produced by X in the future in an operational way.

- Merging in-situ (radar HF) + altimetry → Use HF radar data time series to improve the MDT estimation in the coastal area and improve the coastal SLA (in line with COMBAT CMEMS SE evolution project) and also as an approximation to compute subsurface currents by the use of data blending methods (e.g. Jordà et al. (2016))

- In-situ moorings (CTD+ADCP data 0-200m) + HF radar + Satellite (visible+IR) to monitor upwelling and MLD dynamics, drift and synamics of passive tracers (like Floatting Marine Litter), and for model assessment and validation for monitoring and forecasting Adour, Loire and Gironde river plumes and impacts in the coastal zone

f) What products could be developed at longer term if some data flows not yet operationally flowing to EU/national channels would become interoperable in a way such they are flowing to these channel? (and thus what are the data flows needed to become interoperable?

- Products related to integrated coastal management using Lagrangian approaches for particle dispersion with application to other quantities (data from cytometers, or biogeochemical buoys in river plumes/estuary areas (Adour, Loire, Gironde), ferrybox, moorings,data from water quality campaigns, drifters,environmental DNA..)
- The availability of real time data on currents in the French continental shelf (HF radar Landes antena, Buoy in Adour river plume) could be used with several of the aforementioned methods to expand geographically the area with information on surface/subsurface currents for transport estimation, residence times, FML hotspots…
- Reanalysis of in-situ and satellite data tailored for the coastal zone, taking into account also data from recurrent campaigns in the area for integrated management of commercial fishing species.
- Improved and geographically extended currents : Potential to merge info from long range HF-radars and data from upcoming satellite mission (SKIM)

Plans for the future (mid to long-term)

Among the lessons learned from the implementation of individual JRAP actions on of the most important is that **to conduct integrated studies we need data gathered in the same area with similar coverage and temporal scales, and models that solve the same processes**. So, the main work line to progress in the futures will be to gather additional and truly Integrated observations in the area by means of:

(i) the integration of additional sensors to the existing moorings and facilities to build a truly integrated multiplatform and multidisciplinary observing system.
(ii) the addition to the operational observations of data from satellite, additional regular sampling activities in the area and of one or more devoted oceanographic campaigns for multidisciplinary process studies, cal/val
(iii) the capitalization of existent coastal facilities for experimentation in relation to the blue economy
(iv) Coupled biogeochemical modelling – DA for Physics, biogeochemical data for validation/assessment
(v) the capitalization of established transnational collaboration in operational oceanography related and scientific projects
(vi) the analysis and update of key drivers (key scientific questions, needs) and the development of tailored tools/products. For this it is very important to be in contact and even work in close collaboration to the stakeholders.

We need to solve the proper temporal and spatial scales (covering both coastal and open sea waters) and gather at the same time multidisciplinary info (like fluorometry, plastic sampling) which is not easy, and couple all this with info from physical-biogeochemical models.

Integration of additional sensors and data to the existing moorings and facilities

We will need to ensure the existence of a complete and operational network of current/waves/hydrography observation at different scales combining HF radar, moorings, and other more coastal technologies like videometry (coast-land integration and along-shelf and cross-border connectivity) and also completing the multidisciplinary character of the observatory.

Additional facilities that could be added to this end:

- Additional moorings or sensors in existing moorings like: automatic optical sensors for monitoring phytoplankton, zooplankton, marine mammals.
- A sustained program of biodegradable drifting buoys (e.g. CARTHE buoys) and Gliders or AUVs (AZTI's ITSAS DRONE, equipped with an acoustic sensor and a weather station, first test/mission are expected for 2019).
- Videometry stations KOSTASystem (http://www.kostasystem.com/) for the study of dynamics on the surfing zone, extreme events, coastal flooding, and floating marine litter.
- Use of innovative genetic tools in the following work lines for routine surveys: Community composition: environmental DNA (multiple targets: bacteria, phyto, sea mammals, birds); Metagenomics microbial community; Population genetics (in fishes); Population structure (size/age) in fishes.

Another two important aspects will be: (1) To establish synergies between coastal observatories and coastal/land observatories - we should look collaboration/complementarities with DANUBIUS RI. Also, this is an interesting issue concerning plastics where river surveys are key to monitor the arrival of FML (OSPAR river surveys on floating marine litter, MFSD); (2) To work towards multiplatform integration: multiplatform approach integrating HF radar/x-band/videometry (to be discussed further application to slick detection, and plastics …), and data blending techniques to generate new data products.

Integration between in-situ and land-based remote systems and satellite oceanography

The use of improved and integrated ocean observations of currents as a ground truth is key for the testing/designs and cal/val activities liked to the new or potential new satellite missions (e.g. SWOT or phase-A SKIM mission). Also new data products can arise from multiobs approaches, combining different satellite observations (e.g GlobCurrent project). The HF radar system in the Se BoB is especially interesting for comparison / combination with satellite data since it is a relatively low-frequency system within the HF band, which offers data in a wide spatial coverage and with closer spatial resolution to that of satellite products. In addition to altimetry, SAR and other products from satellite (IR, visible) an interesting line is working on the automatic detection of plastics from satellite.

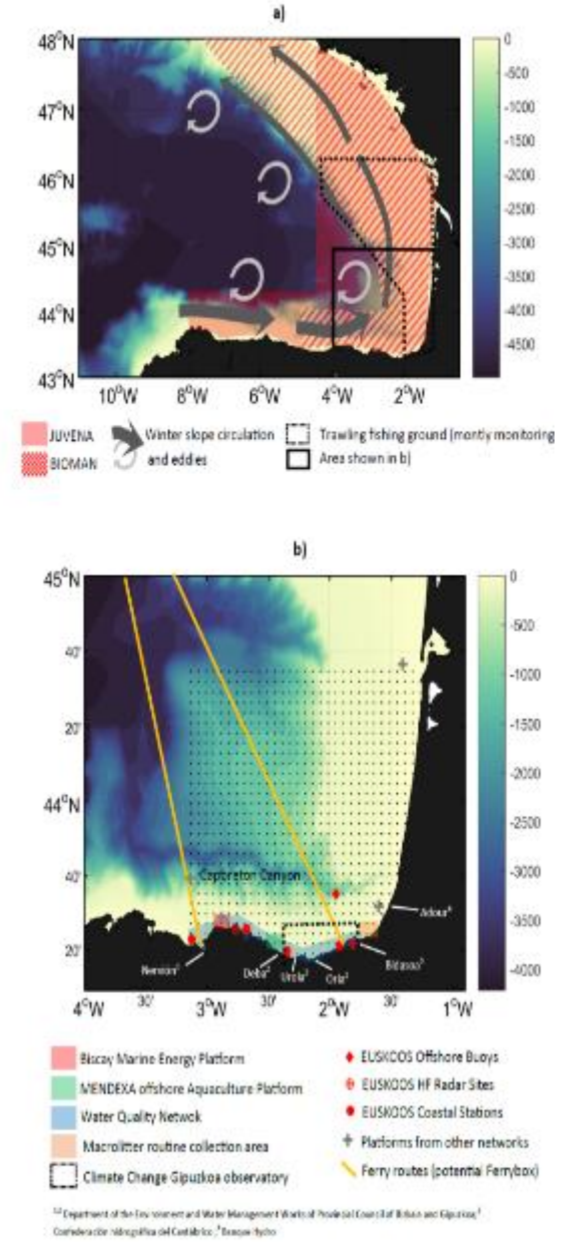


Figure 4.1-1 SE Bay of Biscay EUSKOOS (www.euskoos.eu) coastal observatory, main operational elements, routine surveys and experimental facilities.

<u>Integration of additional regular sampling activities and historical data for process studies/cal/val</u>

There is a huge potential in the joint use of data from additional regular sampling activities in the area (with multidisciplinary observations: pollutants, plankton, mammals, marine litter…) for process studies, cal/val and application of models and operational products. One possibility is the capitalization of the existing systematic fisheries assessment surveys to complete the operational multidisciplinary observations of the SE BoB observatory. These surveys could be used to work in the optimization of the sampling strategy and the integration of new methodologies/observing technologies. AZTI works in two sustained fisheries cruises (performing annually BIOMAN in Spring since 1987, and JUVENA in Autumn since 2003), and participates in monthly monitoring onboard trawling fishery vessels (among others) which provide different data like: phytoplankton biomass and biodiversity, zooplankton biomass and size structure, fish abundance and distribution, birds and mammals, macro-litter and microplastics, seagrass and macroalagal cover. In addition, AZTI performs routine monthly Coastal Water monitoring and offshore aquaculture monitoring surveys (see next section)

Capitalization of existent coastal facilities for experimentation in relation to the blue economy sectors

In the case of the SE BoB, two infrastructures in the fields of renewable marine energies and aquaculture are currently operating and seem key actors/users for the development and future expansion of the observatory (see Figure 4.1-1 for location).

- **Mendexa Offshore Aquaculture and Experimental** facility - AZTI has an offshore experimentation area to test different solutions for offshore marine aquaculture. This experimental area is located on the coastal strip between Ondarroa and Lekeitio on beds 50 m deep, within an area declared as of Interest for Marine Aquaculture by the Basque Government.
- **Biscay Marine Energy Platform**, S.A., or BiMEP, is an infrastructure for testing prototypes of ocean energy collectors and auxiliary equipment on the open sea. Operating since June 2015, BiMEP provides technology developers a site with suitable wave and wind resources for testing the technical and economic viability of different concept designs, offering security before advancing to the full-scale commercial phase (it is led by the Energy Agency of the Basque Government)

Other interesting activities carried within the observatory coverage that could be linked for future expansion of the users/uses of data/models and applications of the SE BoB observartory are:

-The **Water Quality Network** with 32 stations in estuaries (E-stations) and 19 in coastal waters (L- stations) where seasonal sampling is carried out controlling different physic-chemical variables (see Figure 1b for location and Figure 2 for details in the network)

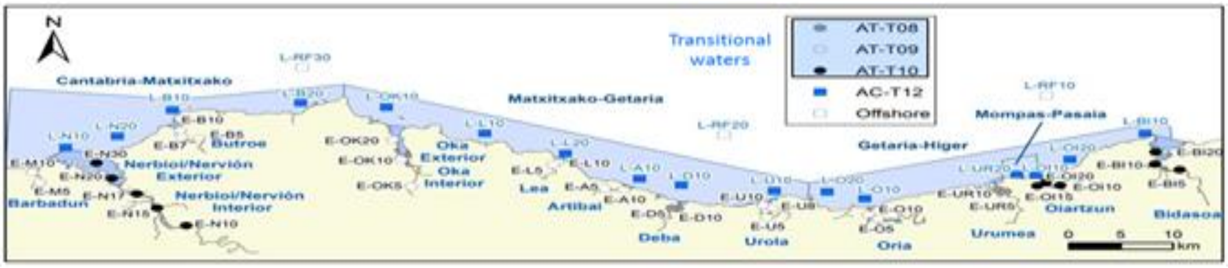


Figure 4.1-2 SE Bay of Biscay coastal Water quality network.

-The upcoming activities of the **Fundación de Cambio Climático de Gipuzkoa** (see Figure 1b for the area covered by the observatory). This recently created entity will focus its activity on three axes of action: the creation of an observatory to measure and analyse the conditions of global warming in the territory, the impulse of the Circular economy promoting the recycling industry and the green economy, and the Energy transition through the promotion of renewable energies.

Existence of established transnational collaboration in OO related and scientific projects

- The Basque Coast Scientific Interest Group ("Groupement d'Intérêt Scientifique Littoral Basque") is a flexible and cross-border partnership tool, created in 2013, bringing together local administrations (Communauté d'Agglomération Pays Basque, Département des Pyrénées Atlantiques, Diputación Foral de Gipuzkoa), research organizations (AZTI, Université de Pau et Pays de l'Adour) and private companies (Rivages Pro Tech, centre de R&D littoral de Suez Eau France, Casagec) from the SE BoB. The members work collectively to build and implement research and transfer projects matching societal needs of the Basque Coast in terms of coastal management. The collaborations are aimed at developing new research, with a view to improving scientific knowledge on the one hand, and helping operational decision-making on the other. The organization is a flexible body, so research partnerships are also formalized with other communities and scientific institutions depending on the needs of the projects. Collaborations are ongoing with IFREMER, the Adour Garonne Water Agency, CEREMA, the University of Bordeaux (EPOC), the Basque Government, the New Aquitaine Region, etc.

- Concerning **marine litter** in the SE BoB, several projects have allowed the collection of FML data and experience on this specific issue and to capitalize the results of this projects is key for future developments. One of them is the demonstration project **LIFE LEMA (LIFE 15 ENV/ES/000252)**, ongoing until September 2019. LIFE LEMA aims at defining a holistic management plan for local authorities, that includes the development and testing of technologies, to address FML. The experience gained focuses on: the application and developments of methodologies for FML collection, analysis and characterization; the analysis of the environmental factors behind the concentration of marine litter on beaches (Granado et al., 2019) and offshore (Declerck et al., 2019); the transference of knowledge and tools to the administration; citizen science and the communication and dissemination on the floating marine litter and plastics issue in scientific and general public forums. In addition to LIFE LEMA, other two ongoing project coordinated by AZTI have to be highlighted: LITTER (Department of Environment, Regional Planning, Agriculture and Fisheries of the Basque Government Framework Programme, 2017-2019) and BLUENET (recently funded EMFF Project 2019-2020); the former devoted to map the abundance of plastics in coastal areas of the SE BoB and develop lab protocols to facilitate the analysis of plastic samples; the latter, to define a management plan for abandoned, lost and otherwise discarded fishing gears for the SE BoB.

Other running projects to be highlighted are:

- **MyCOAST**(Atlantic Area Transnational Programme 2014-2020, led by AZTI) main aim is to fill the gap between the large-scale products and the end-users whilst addressing a transnational handling of the coastal observatories in the Atlantic region. The resulting synergy will allow deploying and capitalizing innovative and standardized tools in the risk management systems applied mainly to extreme weather events leading to flooding, maritime safety and coastal pollution.
- **COMBAT** (66-SE-CMEMS-CALL2 2018-2020, led by AZTI) main objective is to improve the interface between coastal monitoring and modelling systems by including a 7 year-long HFR data set in the computation of a new coastal MDT. Besides the benefits explained before of a coastal MDT, the combined use of altimetry and HFRs is an arising possibility, in line with the increasing number of HFR systems being installed along the European (Rubio et al. 2017, Fig. 2) and world ocean coasts (Roarty et al., 2016) for the improved observation and characterization of the coastal processes and transports..
- **IBISAR** (UU-CMEMS call, led by SOCIB) proposes to further develop, improve and validate in the IBI coastal area (including the SE BoB) an existing prototype of Environmental Data Server (EDS) skill assessment (SA) service initially developed by RPS Ocean Science, which provides real-time met-ocean product ranking for emergency responders and SAR operators.
- **LIFE-IP INTEMARES -** Integrated, Innovative and Participatory Management for N2000 network in the Marine Environment (LIFE15 IPE/ES/000012). The main objective of the INTEMARES project is to implement the PAF for Natura 2000 in the Spanish marine Natura 2000 network and ensure that, upon completion, Spain has a consolidated network of marine Natura 2000 sites managed in a demonstrative, effective and integrated way, with the active participation of the sectors involved and with research as a basic tool for decision-making. Starting in 2019, a specific action (in which AZTI is expecting to participate) will work for the **integration of the CapBreton and adjacent canyons area** in the network of Natura2000 sites. As in other submarine canyons of the Atlantic, the presence of habitats and species of corals and sponges of high biological value, but whose distribution and state of conservation is unknown, is to be expected. We must also add that in the areas surrounding the areas of submarine canyons of Cabo Matxitxako, previous studies have detected high concentrations of sightings of cetaceans and birds, which is indicative of complex ecosystems, with a high concentration of biodiversity.

4.1.1. *The Portuguese margin and the Nazaré Canyon*

a) 2 Priority scientific/societal questions that a regionally integrated coastal system could investigate in your region

1) Slope intensified flows (IPC, MW) and connectivity between European Margin, Mediterranean Sea and NW African margin: (a) Forcing and modulation by interactions with coastal ocean dynamics (e.g. upwelling, canyon circulations) and deep ocean circulation, (b) role on long-distance transport of contaminants and biological species,
2) Shaping of North Atlantic circulation structures (e.g. Azores Current) by adjustment processes occurring in the South Portuguese (Gulf of Cadiz) coastal ocean area.
3) Impacts of extreme weather on coastal populations, maritime traffic and coastal erosion; nearshore wave amplification.
4) Climate Change effects focusing rapid deep ocean impacts promoted by long submarine canyons
5) W Iberian Upwelling and connections with the Canary Upwelling System.

b) What are the observation systems [like FB lines, Glider endurance lines, cable obs., buoys or set of buoys, HF radars, sustained periodic cruises (notion of time series), and set of manual sampling stations sustained in a period way] that are already delivering a time series of data in an operational way toward sustained data infrastructures (national or EU data infrastructure) and that can support investigation on these priority questions?

system name	national/regional IR name where the system belongs	parameters (related to the priority question here above)	contact person (name, institute, email)	data infrastructure
MONICAN1 Multiparametric buoy 30km offshore Nazaré (W Portuguese coast) Water depth:1800m hourly data	MONIZEE system (national IR) Nazaré Canyon Observatory	Meteo, Waves, Water column T & currents, near surface O2,Fluor Oil spill alert	Joao Vitorino Instituto Hidrografico joao.vitorino@hidrografico.pt	IH IBIROOS, EMODNET,GTS
MONICAN2 Multiparametric buoy 6km offshore Nazaré (W Portuguese coast) Water depth:90m Hourly data	MONIZEE system (national IR) Nazaré Canyon Observatory	Meteo, Waves, Water column currents, near surface T, O2,Fluor, Turb	Joao Vitorino Instituto Hidrografico joao.vitorino@hidrografico.pt	IH IBIROOS, EMODNET,GTS
RAIA Multiparametric buoy 30km offshore Porto (NW Portuguese coast) Water depth:1800m Hourly data	MONIZEE system (national IR) RAIA observatory	Meteo, Waves, Water column Currents, near surface T, O2,Fluor	Antonio Jorge da Silva Instituto Hidrografico jorge.silva@hidrografico.pt	IH IBIROOS, EMODNET,GTS

FARO Multiparametric buoy 30km offshore Faro (S Portuguese coast) Water depth:1800m Hourly data	MONIZEE system (national IR) OCASO observatory	Meteo, Waves, Water column Currents, near surface T, O2,Fluor	Carlos Fernandes Instituto Hidrografico santos.fernandes@hidrografico.pt	IH IBIROOS, EMODNET,GTS
LEIXOES wave buoy 12km offshore Leixoes (NW Portuguese coast) Water depth:90m Hourly data	MONIZEE system (national IR)	Waves and Sea Surface Temperature.	Rita Esteves Instituto Hidrografico rita.esteves@hidrografico.pt	IH IBIROOS, EMODNET,GTS
SINES wave buoy 12km offshore Sines (SW Portuguese coast) Water depth:90m Hourly data	MONIZEE system (national IR)	Waves and Sea Surface Temperature.	Rita Esteves Instituto Hidrografico rita.esteves@hidrografico.pt	IH IBIROOS, EMODNET,GTS
FARO wave buoy 12km offshore Leixoes (S Portuguese coast) Water depth:90m Hourly data	MONIZEE system (national IR)	Waves and Sea Surface Temperature.	Rita Esteves Instituto Hidrografico rita.esteves@hidrografico.pt	IH IBIROOS, EMODNET,GTS EMODNET,GTS,IBIROOS
LISBON BAY HF radar facility Coverage C. Roca-C. Espichel and to about 70km offshore. (W Portuguese coast) Hourly data	MONIZEE system (national IR)	Surface currents Nearshore Waves Tsunami detection (ongoing development)	Carlos Fernandes Instituto Hidrografico santos.fernandes@hidrografico.pt	IH IBIROOS,EMODNET
ALGARVE HF radar facility Coverage: complete S Portuguese margin (C. S. Vicente-Guadiana River mouth and to about 70km offshore). Hourly data	MONIZEE system (national IR) OCASO observatory	Surface currents Nearshore Waves Tsunami detection (ongoing development)	Carlos Fernandes Instituto Hidrografico santos.fernandes@hidrografico.pt	IH IBIROOS, EMODNET
Coastal Tide gauge network 17 stations along the	MONIZEE System (national IR)	Sea surface height	Dora Carinhas, Instituto Hidrográfico dora.carinhas@hidro	IH IBIROOS, EMODNET

Portuguese continental coast			grafico.pt	
Program of regular CTD, Lowered ADCP, Vessel Mounted ADCP observations during buoys maintenance and transits.	MONIZEE System (national IR)	P, T, S (C), Nef, Fluor. Current profiles	Joao Vitorino Instituto Hidrografico joao.vitorino@hidrografico.pt	To be included in data set sent to IBIROOS, EMODNET

c) We need to consider modelling to progress toward an operational JERICO-RI, because models needs data and because models are delivering complementary information. What are the models/configuration that are able to deliver a more synoptic information on this region or that would benefit from in situ observation in the area?

model name/config	ref person for a future collaboration	types (hydrodyn, biogeo etc)	possible contribution: need of specific data to assimilate and/or capability to deliver some specific information (drifting of matter, transport…)
HOPS_PT	Joao Vitorino Instituto Hidrografico joao.vitorino@hidrografico.pt	HYDRODYN (end 2019) (BIOGEO-end 2020)	Assimilation of data collected by the MONIZEE system and remote sensing data
HYCOM PT area	Luis Quaresma Instituto Hidrográfico luis.quaresma@hidrografico.pt	HYDRODYN	Operational forecasts. Data is being used to validation of operational model
WW3 multiple scenarios	Luis Quaresma José Paulo Pinto paulo.pinto@hidrografico.pt	WAVE Models	Operational forecasts for global, regional and local scenarios. Data is being used to model validation
IBI_ANALYSIS_FORECAST	CMEMS	HYDRODYN	Data can be used in model validation and assimilation
MEDSEA_ANALYSIS_FORECAST	CMEMS	HYDRODYN	Data can be used in model validation and assimilation
MOHID	Francisco Campuzano	HYDRODYN	Data is already being used in model validation

d) What are the missing parameters or systems that should be added to improve these observations and/or toward a better integration in a 5 year time scale?

system name/or missing system	national/regional IR name where the system belongs	missing parameters (related to the priority question here above)	name of the person suggesting that (or ref person to talk to) + email@
Additional sensors in multiparametric buoys	MONIZEE system	Real-time salinity in water column (in development) Acoustic monitoring (in development) Improved O2 and Fluorometry sensors at several depths pCO2/pH Near bottom currents (in implementation) Nutrients Low Cost Contaminant Samplers (first samplers installed in framework of AQUA-GAPS Program - contact Froppes Smedes - RECETOX) Microplastic sampler Larvae Traps (Program already started and Phytoplankton Samplers	Inês Martins marina.martins@hidrografico.pt Luis Quaresma luis.quaresma@hidrografico.pt Joao Vitorino /Inês Martins Instituto Hidrografico joao.vitorino@hidrografico.pt marina.martins@hidrografico.pt Carla Palma / Carlos Borges Instituto Hidrografico carla.palma@hidrografico.pt carlos.borges@hidrografico.pt Partner: Marina Cunha University of Aveiro - (Portugal) marina.cunha@ua.pt Potential partner: Vanda Brotas-University of Lisbon (Portugal)
HF radar covering Nazaré area and the northern Portuguese margin	MONIZEE system	Extend the spatial coverage of HF radar surface currents	Carlos Fernandes Instituto Hidrografico santos.fernandes@hidrografico.pt
Ferry Box Lines	MONIZEE system	Continuous surface sampling profiting	Joao Vitorino

profiting maintenance of fixed platforms		regular missions for maintenance of MONIZEE platforms	Instituto Hidrografico joao.vitorino@hidrografico.pt
AUV observations	Potential partner: LSTS (Underwater Systems and Technology Laboratory)	Articulation of MONIZEE observations with potential AUV missions in Portuguese coastal ocean area and nearby deep ocean	
Glider sections	Several potential partners to be contacted	Articulation of MONIZEE observations with potential glider missions in Portuguese coastal ocean area and nearby deep ocean	
Citizens Science	Articulate MONIZEE monitoring with observations conducted by groups of non-specialists (e.g. fisheries communities, divers, nautical communities)	T,S profiles collected during regular operations in coastal ocean areas.	Joao Vitorino Instituto Hidrografico joao.vitorino@hidrografico.pt

e) What products could be developed as prototype (firstly) built on EXISTING operational data flows ?

Products here means merging of in situ + model+ sat (or 2 of the 3) or only one, but with objective to answer expressed scientific needs / societel/policy needs, and that could be transferred to CMEMS for instance or produced by X in the future in an operational way.

1) Integrated 3D maps of the oceanographic conditions prevailing on sectors of the Portuguese coastal ocean area on specific time windows. These combine (a) Surface currents from HF radars, (b) Water column measurements (temperature (salinity), current) collected by multiparametric buoys, (c) CTD+Lowered ADCP + Vessel mounted ADCP measurements collected during fixed-platform maintenance periods, (d) satellite imagery. These can also be complemented with model fields for the same period of time.

2) The long term time series collected by the MONIZEE system provides key information to support studies of the variability at different time and spatial scales of the Portuguese coastal ocean area as well as to identify trends and long-term variability associated with North Atlantic regimes (NAO, decadal and multidecadal variability). These long term time series can be used to build a number of Ocean Monitoring Indicators that could eventually integrate CMEMS OMI catalogue.

3) High resolution hindcasts, nowcasts and forecasts for specific sectors of the Portuguese coastal ocean area. These products would be obtained from high resolution models that are coupled to the global and regional models (such as CMEMS NEMO) but that (a) use more realistic local meteorological forcing and local coastal inputs and (b) assimilate all the available observations that are being collected in those coastal ocean areas by the MONIZEE system. These 3D fields can provide support to a broad range of studies that develop in those coastal ocean areas.

4) The data collected by the MONIZEE system is specifically indicated in the legislation that translates the European MSFD to the Portuguese legal framework as one of the two contributions of Instituto Hidrografico. In this regard a number of products are planned to be developed in order to present this data in a way more suitable to the needs of the Portuguese MSFD. This could include the integration of observations, modelling and complimentary data such as remote sensing data and the development of statistics and indicators that are best fitted to this purpose.

5) Products for real-time support of marine traffic exploiting AIS to put available to the ships the combination of real-time observations of the systems that are present in the areas they are crossing (such as multiparametric buoys measurements of winds, waves, currents or surface currents from HF radars) and forecast products for the next few days.

6) Operational products aimed to support port authorities are presently being developed at IH in the framework of projects SAGA (national funded projet) and MARISK (INTERREG). These products use the real-time measurements provided by the available multiparametric buoys, wave buoys, HF radars and coastal tide gauges that integrated MONIZEE and combined then with forecasts of waves and currents for the selected areas.

7) Several products tailored to specifically support the surfing community are already now being provided by Instituto Hidrografico. These products combine real-time data and model forecast and are being defined and tuned by a close discussion with that community. A similar approach is to be followed to the identification of the best products to be developed to support wither the local fishing community, the local touristic operations (such as diver operators) and the local authorities.

f) What products could be developed at longer term if some data flows not yet operationally flowing to EU/national channels would become interoperable in a way such they are flowing to these channel? (and thus what are the data flows needed to become interoperable?

1) Products directed to support connectivity studies/assessments putting together physical observations (from buoys, HF and regular CTD/VMADCP surveys), biological observations (larvae traps and phytoplankton measurements in buoys and during surveys, also potentially available FerryBox systems, gliders AUVs), model integrations (Hydrodynamics+Biogeo), remote sensing images.

2) Products specifically tailored to support environmental agencies. For example presently the Portuguese Environmental Agency is using data collected by some of the MONIZEE monitoring systems to support studies on coastal risks. More specific products can be developed by integrating the MONIZEE observations with high resolution numerical modelling maps and with data collected by remote sensing in order to deliver to this type of agencies a more focused support. These types of products are envisaged to support areas such as coastal risks or management of marine protected areas.

3) Nearshore products: The development presently ongoing in satellite bathymetry of the littoral areas can allow a number of new products showing realistic assessment's or forecast for the conditions the nearshore environment. Such products can support for example studies of littoral 2.

4) Acoustic mapping products – Acoustical monitoring using the multiparametric buoys is presently in development at Instituto Hidrografico. Once operational this data can be exploitet to reveval the presence of marine mammals in the areas of the buoys or to characterize underwater noise affecting these areas. Products can be developed integrating this data and other environmental data such as for example temperature/salinity data (buoys or remote sensing) and AIS data.transport of sediments and coastline evolution.

Plans for the future (mid to long-term)

Integration of additional regular sampling activities and historical data for process studies/cal/val

- Conduction of a program of regular shipborne sampling activities covering the complete Portuguese coastal ocean area profiting the periods of maintenance of the multiparametric buoys network (2 periods each year).
- Integration of ferry-box systems onboard the vessels used for maintenance of MONIZEE system. A first evaluation of the feasibility of installation of such systems onboard the hydrographic vessels operated by IH (two 70m long vessels and two 32m long vessels) was already conducted.
- Articulation with autonomous platforms and integration of gliders as part of MONIZEE monitoring activities– Several contacts were initiated with partners that have expertise in the operation of gliders (such as SOCIB, in the framework of JERICO-NEXT, or PLOCAN) and it is envisaged the future acquisition of this type of system to integrate the MONIZEE monitoring system. A close collaboration is also being held with the group of robotics of the Faculty of Sciences of University of Port with several field actions aimed to test the monitoring capacities of AUVs/UAVs and the assimilation of AUV data. We plan to extend this collaboration, namely to the development and installation of communication modules between autonomous vehicles and the multiparametric buoys.

Existence of established transnational collaboration in OO related and scientific projects

The monitoring capacities installed in the framework of the MONIZEE system are presently contributing to transnational regional observatories such as: the **RAIA Observatory** in the NW Iberian area (through the cooperation between the Galician area/North Spain and North Portugal) and the **OCASO observatory** (regions of Algarve-South Portugal and South Spain).

MyCOAST project (Atlantic Area Transnational Programme 2014-2020, led by AZTI). IH is participating in this project which main aim is to fill the gap between the large-scale products and the end-users whilst addressing a transnational handling of the coastal observatories in the Atlantic region.

OCASO project - Coastal Environmental Observatory of the Southwest. INTERREG POCTEP 2015-2019. Development of synergies between partners in Spain and Portugal aiming the establishment of an operational oceanography transboundary structure for the southwestern Iberian area.

MarRisk project INTERREG POCTEP 2015-2019. Development of synergies between partners in Spain and Portugal aiming the consolidation of a knowledge infrastructure for the assessment of coastal risks affecting the area of North Portugal and Galicia (Spain) in a framework of climate change.

Future/potential collaborations with scientists/research centers or infrastructures

Several collaborative efforts are envisaged to address global problems relevant to the eastern North Atlantic area and, in particular, the European Atlantic margin. These include:

- Collaborative effort in the assessment of species connectivity and migration patterns. Such collaborative efforts could be conducted using already existent capacities, using for example the data collected by multiparametric buoys, other fixed platforms and HF radars along the area from Western Mediterranean to the northern European margin. This type of studies should put together as potential partner, partner responsible for main infrastructures such as SOCIB, AZTI and IH (from the JERICO-NEXT community), NOC and PLOCAN (from the EMSO community) and potential partners in Morocco as well as partners involved in the studies of species connectivity/migrations (e.g. tuna tagging studies, larval traps partners – University of Aveiro, Portugal) .
- Collaborative effort in the study of the interactions between the mid-Atlantic circulation (Azores Current) and the European coastal ocean processes. Aspects related to the forcing mechanisms for the Iberian Poleward slope

Current along the European margin and interactions of the IPC with coastal dynamics could be addressed by a joint effort of partner maintaining monitoring infrastructures along the European margin (such as IH and AZTI from the JERICO-NEXT community) and in the Atlantic basin (such as IFREMER for the Azores node of EMSO). Aspects related with the interactions between the Azores Current and the Mediterranean Water in the Gulf of Cadiz area and the shaping of Azores Current could be addressed by partners maintaining monitoring infrastructures in the Gulf of Cadiz and W Mediterranean (such as IH and SOCIB from the JERICO-NEXT community) and partners with Atlantic basin infrastructures that cover different geographical areas of influence of the Azores Current (such as IFREMER for the Azores node of EMSO and PLOCAN for the Canary Current node of EMSO).

- Collaborative efforts in the study of deep connections promoted by submarine canyons could be envisaged joining partners that are monitoring areas of influence of large canyon systems, either from the JERICO-NEXT (IH for the Nazaré Canyon and AZTI for the Gouf de Capbreton canyon), from the EMSO community (CNRS/IFREMER for the Var canyon in the Ligurian sea, IPMA for the future installation of a bottom module near the Setubal canyon offshore Portugal) or from other communities (e.g CSIC-Spain with is monitoring the Cap de Creus canyon).
- In areas of support to industry the capacities installed as part of MONIZEE can potentiate the development of collaborations with port operators (in part already ongoing), with oil and gas companies (several prospection actions were developed in recent years along the Portuguese continental margin), with the marine energy sector (e.g. products to support offshore wind farms such as the WindFloat Atlantic that will be installed by EDP) or with tuna farms and future offshore aquaculture projects that could installed in the area.

4.2. Channel and North sea

a) *2 Priority scientific/societal questions that a regionally integrated coastal system could investigate in your region ?*

Functioning of coastal zones as a sink for CO2.

- Matter fluxes and budgets in the North Sea and its subregions, especially related to carbon (inorganic, organic, SPM).
- Anthropogenic effect on matter fluxes and budgets of the coastal sea, exemplified in the North Sea, with special focus on carbon (inorganic, organic, SPM).
- Connexion between pCO2 and estimated primary productivity from coupled photosynthetic measurements
- Connexion between major pCO2 variability and changes in phytoplankton taxonomical/functional diversity addressed at high spatial and temporal resolution
- Considering the link to the higher trophics. How the physical lower trophic levels are impacting the higher trophic levels, following an Integrated ecosystem approach.

This could be achieved through combining existing and planned in situ and remote sensing observations, for instance, high resolution time-series of plankton (phyto and zoo) and particles (marine snow) from stationary underwater observatories by implementation of imaging systems.

Consequences of anthropogenic nutrients inputs with superimposed global change on eutrophication direct (development of microalgae, harmful algal blooms, including biodiversity and dynamics aspects) **and indirect effects** (oxygen deficiency, fish and benthos kills).

Variability of water clarity, hydrological and sediment patterns and phytoplankton outbursts (water turbidity, light composition, sediment fluxes, phytoplankton biomass and productivity) **from short time scales** (hourly, diurnal, fortnightly tidal) **to long time scales** (yearly to decades):

- Interactions between turbidity and phytoplankton blooms: what drives what, a seasonal control dependency? Can we estimate OM quality (fresh and refractory) from SSC and/or satellite measurements coupled to discrete analysis?
- More detailed identification of errors in transport models (e.g., errors in wind forcing, bottom roughness or bathymetry).
- Coupling/comparing current measurements and models to hydrological and phytoplankton continuous recording, in order to disentangle the influence of hydrology on the distribution of phytoplankton abundance and diversity as well as on photosynthetic parameters.
- Development of optimized numerical methodologies for high-resolution data processing (up to the implementation of Genuine User Interface).
- Relative contribution of natural forcing, extreme events and human activities on turbidity/water clarity and sediment fluxes on the Western Channel/Southern North Sea system: coupling monitoring networks (LF/HF), satellite and 3D numerical model results.

To solve the specific spatio-temporal dilem in primary production studies:

- To solve daily temporal variation of photosynthesis of a community in a given water column and in the same time, the spatial variation of this process across the ecosystem in a small range of time.
- To compute and compare daily production rates for different area of an ecosystem integrating all physiological variability in horizontal and vertical dimensions (increasing effective quantum efficiency at a DCM for exemple).
- In such strategy, the question of calibration between carbon and electron flux is also an opened question because: How to manage and calibrate the different measurement protocols and algorithms (excitation light colors, Sigma and aLHII algorithms of the new FRRF) to compare FRRF GPP rate estimations obtained with different machines: a profiler in the water column under the sun as light source and a laboratory sensor on board using LED as light source ?

b) What are the observation systems [like FB lines, Glider endurance lines, cable obs., buoys or set of buoys, HF radars, sustained periodic cruises (notion of time series), and set of manual sampling stations sustained in a period way] that are already delivering a time series of data in an operational way toward sustained data infrastructures (national or EU data infrastructure) and that can support investigation on these priority questions?

system name (First year of implementation - last year of implementation or + if ongoing)	national/regional RI name where the system belongs	parameters (related to the priority question here above)	contact person (name, institute, email)	data infrastructure
MAREL Carnot buoy	IR-ILICO / COAST-HF	T, S, O2, Fluo, N03, P, Si, Turb	Alain LEFEBVRE	Coriolis
REPHY / SRN monitoring program (1992 - +)	IR-ILICO / PHYTOBS	T, S, Turb, Chloro, O2, SM, DIN, P, Si, microphyto abundances	Alain LEFEBVRE alain.lefebvre@ifremer.fr	Quadrige2
REPHYTOX	/	HAB species abundances, PSP-DSP-ASP toxins concentrations in shellfish	Alain LEFEBVRE alain.lefebvre@ifremer.fr	Quadrige2
IGA Gravelines monitoring program (1975 - +)	/	T,S, Chloro, DIN, P, Si, microphyto and zooplancton abundances	Elvire Antajan elvire.antajan@ifremer.fr	Quadrige2
IBTS (2007- +), CGFS (2014 - +) ecosystemic cruises (low resolution strategy)	/	T,S, Chloro, DIN, P, Si, microphytopl. and zooplancton abundances	Arnaud AUBER arnaud.auber@ifremer.fr Franck COPPIN franck.coppin@ifremer.fr	Sismer, Quadrige2
Ferry Box onboard the RV "Thalassa": IBTS, CGFS cruises (high resolution strategy) (2017 - +)	/	T, S, spectral Fluo (4 phytopl. groups), Turb, O2, pH	Alain LEFEBVRE alain.lefebvre@ifremer.fr Brieuc CRENAN brieuc.crenan@ifremer.fr	Coriolis

SOMLIT PhytOBS ZooNet	IR-ILICO IR-ILICO En cours de mise en route	T, S, Turb, Chloro, O2, SM, DIN, P, Si, POC, NOC, micro/nano/pico/ Phytoplankton diversity/abundance Zooplankton diversity/ abundance	Nicolas SAVOYE n.savoye@epoc.u-bordeaux1.fr Pascal CLAQUIN pascal.claquin@unicaen.fr Maud LEMOINE Maud.Lemoine@ifremer.fr Jean-Louis JAMET jean-louis.jamet@univ-tln.fr Laure MOUSSEAU laure.mousseau@obs-vlfr.fr	BDD SOMLIT BDD RESOMAR – Pelagos BDD RESOMAR - Pelagos
PHYCO and ECOPEL Manche cruises	JERICO, CPER MARCO and DCSMM HP (French MSFD Pelagic Habitats)	T, S, Turb, Chloro, O2, SM, DIN, P, Si, POC, NOC, DOC, CDOM, pigments, micro/nano/pico/ Automated phytoplankton observation (functional diversity, photosynthetic parameters). Optical parameters Phytoplankton diversity/abundance Zooplankton diversity/ abundance	Felipe ARTIGAS Felipe.Artigas@univ-littoral.fr	BDD RESOMAR - Pelagos (to be confirmed)
Satellite OC data (source IFR / RBINS / Copernicus?)		Chla, Turbidity, SSC		
(SMILE/SCENES station 2015 - +)	IR ILICO/COAST HF	T, S, Turb, Fluo, O2, SSC	Romaric VERNEY romaric.verney@ifremer.fr	Coriolis
Buoys + Monitoring Cruises	MARNET	T, S, O2, pH, currents (ADCP)	BSH	NOOS, CMEMS
FerryBox lines (Denmark-Faroe-Iceland (NIVA/HAV), Netherlands-Norway	NorSOOP	S, T, chl, turbidity, cDOM, O2, pCO2, pH, nutrients, flow cytometry,	Andrew King, NIVA, andrew.king@niva.no	Institutional, European FB Database, NOOS, EMODnet

(NIVA/RWS)		contaminants, microplastics, radiance/irradiance, met, etc.		
Continuous plankton recorder	CPR Survey	"Plankton" :)	Marine Biological Association UK, cprsurvey@mba.ac.uk	Institutional?
Ecosystem survey cruises North Sea ecosystem cruise pluss several repeated transects IBTS Include the link to the ICES fishery science/ quota/assessment work	IMR	S, T, chl, nutrients zooplankton Establish link to the higher trophic levels.	Henning Wehde IMR Henning Wehde	Norwegian Marine Data Centre
Southern Norway research cruises	Norwegian Environmental Agency	S, T, O2, nutrients, chl, hard bottom, etc.	Camilla With Fagerli, NIVA, camilla.with.fagerli@niva.no	Institutional, governmental
FerryBox lines Southern North Sea: -Cuxhaven-Immingham -Norway-Netherlands/Belgium- England -Büsum-Helgoland (German Bight)	COSYNA (HZG)	S, T, chl, turbidity, cDOM, O2, pCO2, pH, alkalinity, nutrients, etc.	Wilhelm Petersen (wilhelm.petersen@hzg.de) Yoana Voynova (yoana.voynova@hzg.de)	European FB Database, COSYNA + CMEMS and EMODnet
Stationary FerryBox Elbe Estuary (Cuxhaven)	COSYNA (HZG)	S, T, chl, turbidity, cDOM, O2, pCO2, pH, nutrients, etc.	Wilhelm Petersen (wilhelm.petersen@hzg.de) Yoana Voynova (yoana.voynova@hzg.de)	COSYNA + CMEMS and EMODnet
Cabled Observatory (Underwater node) Helgoland	COSYNA (AWI)	S, T, chl, turbidity, currents (ADCP), Plankton, Particles	Philip Fischer (philip.fischer@awi.de), Klas Möller	COSYNA

& Underwater Plankton and Particle Observatory		(Marine snow)	(klas.moeller@hzg.de)	
Buoy-operated underwater nodes with vertical profiler	COSYNA (HZG)	S, T, chl, turbidity, currents (ADCP), Can be expanded to other quantities	Holger Brix (holger.brix@hzg.de)	COSYNA
HF Radar (German Bight)	COSYNA (HZG)	Currents	Jochen Horstmann (jochen.horstmann@hzg.de)	COSYNA
High frequency measurements from buoys	Cefas (Defra)	Turbidity,fluorescence, nutrients, phytoplankton, temperature, salinity, PAR (above and below water)	Naomi.greenwood (naomi.greenwood@cefas.co.uk)	Cefas data HUB, NOOS, EMODnet physic
Ferrybox on RV regular cruises (MPA, fisheries, nutrient)	Cefas (Defra)	Fluorescence Temperature Salinity Turbidity Fe/Fm Diversity phytoplankton (Flow cytometry)	Kate collingridge (Kate.collinridge@cefas.co.uk) Veronique.creach(veronique.creach@cefas.co.uk)	Cefas data HUB
Lifewatch cruises	VLIZ	T, S, Turb, Chloro, O2, SM, DIN, P, Si. Automated phytoplankton observation (functional diversity, photosynthetic parameters). Pigments. Phytoplankton diversity/abundance Zooplankton diversity/ abundance	Elisabeth Debusschere elisabeth.debusschere@vliz.be	VLIZ database
Zirfaea Dutch cruises	RWS	T, S, Turb, Chloro, O2, SM, DIN, P, Si. Automated phytoplankton observation (functional diversity, photosynthetic parameters).	Machteld.Rijkeboer machteld.rijkeboer@rws.nl	RWS database

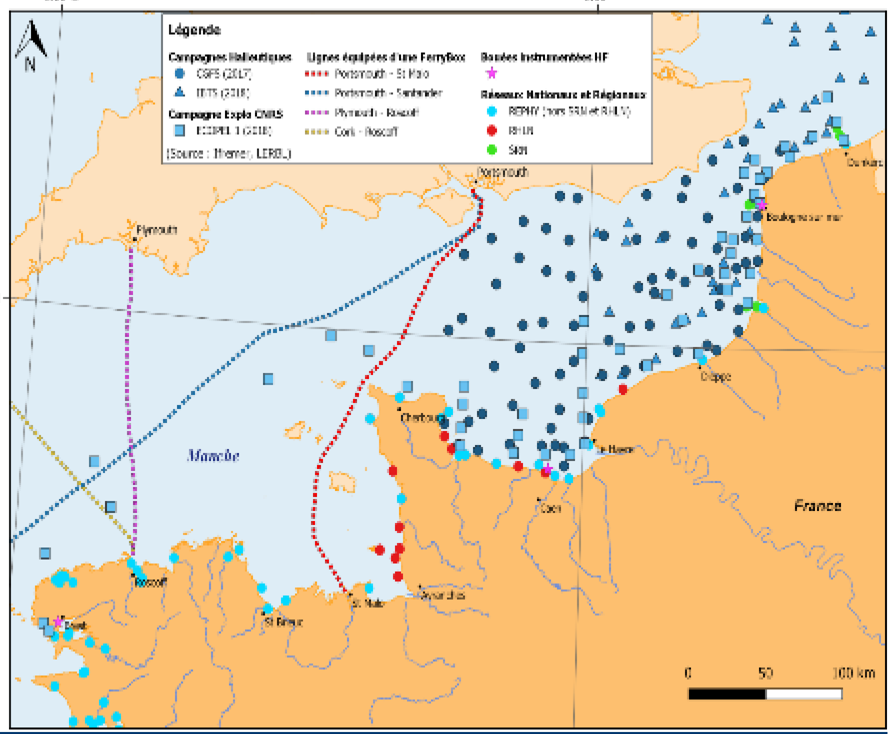


Figure 4.2-1 Location of the main sampling stations (from low to high resolution strategy) in the eastern English Channel and southern bight of the North Sea

c) We need to consider modelling to progress toward an operational JERICO-RI, because models needs data and because models are delivering complementary information. What are the models/configuration that are able to deliver a more synoptic information on this region or that would benefit from in situ observation in the area?

model name/config	ref person for a future collaboration	types (hydrodyn, biogeo etc)	Possible contribution: need of specific data to assimilate and/or capability to deliver some specific information (drifting of matter, transport…)
Roms (NorthSea 800)	Jon albretsen, IMR	Hydrodynamic	Hydrodynamic, IBM Lagrangian
Norwecom	Morten Skogen, IMR	Hydrodyn and biogeoch	Hydrodynamics, T, S, Chlorophyll, N, P Cycles
EcoMARS3D English Channel - Atlantic (MANGA) (see description below)	Alain LEFEBVRE / Martin PLUS, Ifremer	Hydrodyn - biogeoch	Hydrodyn ; T,S, Chloro, N and P cycles, turb, phytopl. biomass, including some HAB
COHERENS RBINS			

ERSEM North Sea	Phil Wallhead/NIVA	Biogeochemical (stochiometric, multiple plankton sizes)	Assimilate data and deliver forecasts of biology (plankton and smaller) and chemistry
FVCOM North Sea	Andre Staalstrom/NIVA	Hydrodynamical	Assimilate data; currents, transport
MEPS Numerical Weather Prediction model (North Sea)	Ole Vignes, Met NO (o.vignes@met.no); Met NO and SMHI cooperation	Weather	Assimilate data, forecast weather
NorShelf ROMS (North Sea)	Johannes Röhrs, Met NO, johannesro@met.no	Hydrodynamical	Assimilate data, circulation, hydrography
Three dimensional hydrodynamic model (GETM) and particle tracking model (GITM)	John Aldridge (john.aldridge@cefas.co.uk)	Hydrodynamical	Assimilate data; currents, transport
ERSEM	Luz garcia (luz.garcia@cefas.co.uk)	Biogeochemical	Food web data assimilation
- NEMO (circulation model used in CMEMS) - SCHISM (unstructured grid model to bridge gap between coastal and regional scale) - WAM (wave model used in CMEMS)	johannes.schulz-stellenfleth@hzg.de	Hydrodynamical Biogeochemical	Simulations of standard hydrodynamical parameters (currents, water levels, S, T, sea state, mixing), suspended matter and biogeochemical parameters (e.g. primary production, oxygen, ...). OSSEs and assimilation (e.g., HF radar …)
Delft3D / DFLOW-FM	anouk.blauw@deltares.nl	Coupled 3D physical-biochemical model	Currents, water levels, Salinity, Temperature, mixing/ stratification, suspended matter, light climate, nutrients, chlorophyll-a, phytoplankton species composition (groups), primary production

d) What are the missing parameters or systems that should be added to improve these observations and/or toward a better integration in a 5 year time scale?

system name/or missing system	national/regional IR name where the system belongs	missing parameters (related to the priority question here above)	name of the person suggesting that (or ref person to talk to) + email@

HF radar (missing)	Missing!	currents	alexei.sentchev@univ-littoral.fr
MOW station ?	RBINS		
Interoperable utomated sensors for phytoplankton observation in existing automatyed observing platforms and systems	Coast-HF (IR ILICO) Research Vessels Ferry Lines- Commercial vessels	Phytoplankton functional groups (size-classes, pigmentary groups, cytometric groups, etc.), light, photosynthetic parameters.	felipe.artigas@univ-littoral.fr

e) What products could be developed as prototype (firstly) built on EXISTING operational data flows ?
[Products here means merging of in situ + model+ sat (or 2 of the 3) or only one, but with objective to answer expressed scientific needs / societal/policy needs, and that could be transferred to CMEMS for instance or produced by X in the future in an operational way.]

North Sea eutrophication "index": chl *a* from *in situ,* feeding into ocean color satellite validation, which then is incorporated in biogeochem models (also nutrients, T, microscopy, cytometry, light, currents, from *in situ*) to predict times/locations of eutrophication?

Phytoplankton blooms-focusing on HABs in the Channel and North Sea : chl *a* and phytoplankton abundance/biomass from *in situ* addressed both by reference methods (microscopy and pigments) and by automated high spatial and temporal resolution methods (automated flow cytometry, imaging, multi-spectral approaches) feeding into ocean color and ocean Phytoplankton Functional Types satellite validation, which then is incorporated into biogeochem models (adding nutrients, T, light, currents, from *in situ*) to predict starting and decaying timing and location of phytoplankton blooms and HABs. Detection of changes in ecological status of pelagic habitats and calculation of PH indicators for MSFD

Weather prediction (North Sea): if JERICO-RI in situ + satellite observations are in place for MEPS weather prediction model

Development of an Environmental status prediction system based on an innovative, optimized open source digital system implementing semi-supervised classification coupling deep-learning and spectral classification constraint methodologies. The added value are (i) to propose the best up-to-date IA numerical methodologies to process the so complex (non linearity, missing data, autocorrelation etc.) and huge environmental database and (ii) to integrate multi-sensor and multi-parameter data (from in situ data to Ocean Colour and modeling). The objectives are to develop this system in order to predict environmental changes (physical and chemical parameters and phytoplankton biomass) in response to natural and anthropogenic forcing and in (near) real time, to define functional schemes of phytoplankton blooms in contrasting ecosystems and sediment pathways and fluxes, to develop a prediction and warning system, to be able to adapt in (near) real time sampling strategies (for Monitoring and Research purposes).

f) What products could be developed at longer term if some data flows not yet operationally flowing to EU/national channels would become interoperable in a way such they are flowing to these channel? (and thus what are the data flows needed to become interoperable?

Homogeneisation of sensors (inter operable automated phytoplankton observation) and corresponding data flows from extended international automated measurements in the Channel and North Sea in different automated observation platforms (FerryBoxes, Fisheries cruises, moorings and fixed stations, research cruises and monitoring).

4.3. Kattegat Skagerrak

a) *Priority scientific/societal questions that a regionally integrated coastal system could investigate in your region (5 lines max)?*

b) Climate change effects - land-sea fluxes, sea-air fluxes, biodiversity, eutrophication and HABs
c) Contaminants - e.g. transport of oil, other pollutants, litter and microplastics
d) Maritime safety (observations and modelling), e.g. wave height, ice, man over board etc.
e) Safe sea food - observations of Harmful algae and non-indigenous species, warnings of HAB (observations and modelling)
f) Marine spatial planning (renewable energy, marine natural resources)

With regards to climate change effects on land-sea fluxes and eutrophication/HABs:
The forcing factors for HAB are not known in enough detail to produce models predicting HAB. This is especially true for low biomass, biotoxin-producing species. The distribution of phytoplankton at or near the pycnocline is not known. It is likely that HAB develop here. Presently, we do not have a high-resolution 3D modelling system for the fjords and archipelagos as well as the open sea outside. Such a system, combined with a particle tracking model, could be used to track particles backwards to determine the origin of harmful blooms. In a longer perspective, these particles could be given properties representative for the algae they represent.

In addition, climate change is expected to increase the input of dissolved organic matter (DOM) from land and CO_2 from the atmosphere into the region. The increase in DOM over the last decades have already been observed through ocean darkening of the region (Frigstad et al., 2013; Capuzzo et al., 2017) that has potentially affected phytoplankton and benthic algal production (Capuzzoet al., 2017), as well as mesopelagic regime shifts (Aksnes et al., 2009). The projected impact of climate change and ocean acidification include significant reductions in surface ocean pH (0.3-0.4) and saturation state of calcium carbonate (surface -1 to -3) , with very high seasonal and regional variability, and consequential changes in primary production and sedimentation (Artioli et al., 2014).

b) What are the observation systems [like FB lines, Glider endurance lines, cable obs., buoys or set of buoys, HF radars, sustained periodic cruises (notion of time series), and set of manual sampling stations sustained in a period way] that are already delivering a time series of data in an operational way toward sustained data infrastructures (national or EU data infrastructure) and that can support investigation on these priority questions?

Operational oceanographic observations systems in the Kattegat-Skagerrak area in January 2019:

1. Oceanographic buoy Väderöarna, Sweden
2. Multi-parameter oceanographic buoy Kosterfjorden, Sweden
3. Multi-parameter oceanographic buoy Gullmarsfjorden, Sweden
4. Multi-parameter oceanographic buoy Koljöfjorden, Sweden
5. FerryBox system Oslo-Kiel
6. FerryBox system Immingham - Moss - Halden - Ghent
7. FerryBox system Strömstad - Sandefjord
8. FerryBox system Bergen - Hirtshals
9. FerryBox system Goteborg - Immingham
10. Several water level stations along the coasts
11. Regular monitoring cruises with research vessels (mostly monthly)
    a. Sweden - National Monitoring Program
    b. Sweden - Regional monitoring programs (Bohus coast and Coast of Halland)
    c. Sweden - biotoxin producing algae monitoring (at aquaculture sites)
    d. Norway - monthly sampling along Torungen - Hirtshals transect
    e. Norway - Inner Oslo Fjord
    f. Norway - Inner Oslo Fjord

g. Norway - coastal monitoring program
h. Norway - HAB monitoring (mainly at aquaculture sites)
i. Denmark - National monitoring program (maily coastal)
j. Denmark - HAB monitoring program (mainly at aquaculture sites)

12. Manual sampling from land: Flødevigen bay, three times per week (phytoplankton, HAB, salinity, temperature, chlorophyll).
13. Manual sampling of HAB from land: Three locations along the Swedish coasts, weekly April to June.
14. Manual sampling of HAB from land: Several locations along the Norwegian coast, weekly March to October.
15. Fixed stations along Norwegian coast - salinity and temperature

An integrated Eastern North Sea-Skagerrak-Kattegat real time observation and forecasting system would be very useful for society and an important tool for scientists. The aim would be to provide real time data and forecasts and also to contribute to long term monitoring related to climate change and eutrophication. The system would include the following components:

1. Instrumented oceanographic buoys (or other fixed platforms) positioned in strategic locations:
    a. The Baltic current - Swedish coast
    b. The Norwegian coastal current
    c. The Jutland current (Denmark)
    d. German bight
2. Ferrybox systems with long term funding
    a. Oslo-Kiel
    b. Gothenburg-Fredrikshavn
    c. Strömstad - Sandefjord
    d. Bergen - Hirtshals
    e. Bergen - Netherlands
3. Instrumentation would include sensors for:
    a. Carbonate system
    b. Automated in situ microscopes for observing phytoplankton diversity and abundance including harmful algal blooms
    c. Automated water sampling for molecular biological analysis of plankton diversity and of genes coding for selected functionality (e.g. toxin production)
    d. Bio-optical data, e.g multi wavelength fluorescence and absorption for phytoplankton biomass
    e. Sensors for contaminants, e.g. oil, PAH, microplastics
    f. ADCP:s - currents
    g. Waves
    h. Salinity, temperature
    i. Nutrients
4. Sensors for low oxygen conditions, e.g. in the Laholm bay (Sweden) and selected fjords in Denmark, Norway and Sweden.
5. Coupled remote sensing - in situ observations
6. 3D-physical model coupled to advection of oil, litter, microplastics etc. (existing)
7. 3D-physical model coupled to biogeochemical model (existing)
8. 3D-physical model coupled to individual based models of phytoplankton (in early development)
9. A data distribution system covering all data types
10. A system for informing authorities, industry and the public about results in near real time.

Table. Overview of existing infrastructures.

System name	National/regional RI name where the system belongs	Parameters (related to the priority question here above)	Contact person (name, institute, email)	Data infrastructure	Operational?	Level of financial sustainability? (low, med, high, unknown)
FerryBox (M/S Color Fantasy (NIVA), M/S Color Hybrid (NIVA), M/S Norrona (NIVA/HAV), M/S Transfighter (NIVA/RWS), and NIVA Research Station)	NorSOOP	S, T, chl, turbidity, cDOM, O2, pCO2, pH, nutrients, flow cytometry, contaminants, microplastics, radiance/irradiance, met, etc.	Andrew King, NIVA, andrew.king@niva.no	Institutional, European FB Database, NOOS, EMODnet	yes	Medium (at least 5 years)
FerryBoxes HZG (M/S Lys Bris, M/S Magnolia Seaways)	COSYNA	S, T, chl, turbidity, cDOM, O2, pCO2, pH, AT	Wilhelm Petersen, HZG, wilhelm.petersen@hzg.de, Yoana Voynova HZG, yoana.voynova@hzg)	Institutional, European FB Database, NOOS, EMODnet	yes	Medium (at least next 5 years)
Wave buoy	Väderöarna	Wave height and direction, temperature	Anna Willstrand Wranne, SMHI anna.wranne@smhi.se	Institutional, NOOS, EMODnet	yes	high
Multi parameter oceanographic buoys	Koster fjord and Gullmar fjord	S, T, chl, turbidity, O2, pCO2, current speed and direction	Anna Willstrand Wranne, SMHI anna.wranne@smhi.se	Institutional, NOOS, EMODnet	yes	medium
Multi parameter	Koljö fjord	S, T, chl, turbidity, O2,	Per Hall, per.hall@gu.s	?	yes	unknown

oceanographic buoy		pCO2, current speed and direction	e			
HF radars	n/a	Current speed/direction	Kai Christensen, Met Norway, kai.h.christensen@met.no	Institutional, building links with EuroGOOS HF radar TT and Copernicus	yes	Low, institutional, pending Norwegian Research Council funding
Cruises in the Swedish National Marine Monitoring Program	SMHI	Phyoplankton, zooplankton, S, T, O2, nutrients, chl etc.	Göran Nilsson, goran.nilsson@smhi.se	Institutional, governmental, Swedish Oceanographic Data Centre at SMHI	yes	High
Cruises in the regional monitoring program for the Bohus Coast, Sweden	SMHI and the Water Quality Association of the Bohús Coast	Phytoplankton,, S, T, O2, nutrients, chl etc.	Göran Nilsson, goran.nilsson@smhji.se	Institutional, governmental, Swedish Oceanographic Data Centre at SMHI	yes	High
Cruises in the regional monitoring program of the coast of Halland, Sweden Cruisess in regional monotoring programme Skagerrak	County administration board of Halland IMR	Phyoplankton, zooplankton, S, T, O2, nutrients, chl etc. Phyoplankton, zooplankton, S, T, O2, nutrients, chl etc	bo.gustavsson@lansstyrelsn.se Tone Falkenhaug,Henning Wehde IMR	Institutional,overnmental, Swedish Oceanographic Data Centre at SMHI Institutional IMR	Yes yes	High High
National monitoring and research cruises in Oslofjord and Skagerrak research cruises	Norwegian Environmental Agency	S, T, O2, nutrients, chl, hard bottom, phytoplankton etc.	Camilla With Fagerli, NIVA, camilla.with.fagerli@niva.no	Institutional, governmental	yes	Medium, depends on funding every ~3 years
VOS	ICOS Norway	S, T, O2, pCO2	Are Olsen, University of	ICOS carbon portal website	yes	On ESFRI roadmap

			Bergen, are.olsen@uib.no			

c) We need to consider modelling to progress toward an operational JERICO-RI, because models needs data and because models are delivering complementary information. What are the models/configuration that are able to deliver a more synoptic information on this region or that would benefit from in situ observation in the area?

NB: strong links between in situ (at least FerryBox) and remote sensing validation/algorithms; for forecasting there is strong assimilation of in situ and remote sensing observations into models.

Model name/config	**Ref person for a future collaboration**	**Types (hydrodyn, biogeo etc)**	**possible contribution: need of specific data to assimilate and/or capability to deliver some specific information (drifting of matter, transport...)**
NEMO-Nordic	Lars Arneborg, SMHI	3D physical oceanographic model - currents, salinity, temperature, stratification	Salinity, temperature, current speed and direction, vertical profiles and surface
NEMO-Nordic - SeaTrackweb	Lars Arneborg, SMHI	3D physical oceanographic model coupled to model for advection of oil, algal blooms, litter, microplastics etc	Observations of oil, algal blooms, litter, microplastics etc.
NEMO-Nordic-SCOBI	Lars Arneborg, SMHI	3D physical oceanographic model coupled to biogeochemical model	Inorganic nutrients, pCO2, pH, phytoplankton biomass (chl. a), biomass of phytoplankton functional groups, HAB, oxygen, water transparency, irradiation
MEPS Numerical Weather Prediction model	Ole Vignes, Met NO (o.vignes@met.no); Met NO and SMHI cooperation	Weather	Assimilate data, forecast weather
ERSEM North Sea	Phil Wallhead/NIVA	Biogeochemical (stoichiometric, multiple plankton sizes)	Assimilate data and deliver forecasts of biology (plankton and smaller) and chemistry
FVCOM North Sea	Andre Staalstrom/NIVA	Hydrodynamical	Assimilate data; currents, transport
NorShelf ROMS	Johannes Röhrs, Met NO, johannesro@met.no	Hydrodynamical	Assimilate data, circulation, hydrography

d) What are the missing parameters or systems that should be added to improve these observations and/or toward a better integration in a 5 year time scale?

System name/or missing system	National/regional IR name where the system belongs	Missing parameters (related to the priority question here above)	Name of the person suggesting that (or ref person to talk to) + email@
Ferrybox system crossing the Kattegat (mouth of the Baltic) Gothenburg-Fredrikshavn	Swedish Marine Observation System (MOS, SMHI)	Salinity, temperature, current speed and direction, observations of oil, algal blooms, litter, microplastics etc. Inorganic nutrients, pCO2, pH, phytoplankton biomass (chl. a), biomass of phytoplankton functional groups, HAB, oxygen, water transparency, irradiation	Bengt Karlson, bengt.karlson@smhi.se
Baltic Current multiparameter oceanographic buoy (may be combined with other fixed platform e.g. stationary Ferrybox on island Väderöarna)	Swedish Marine Observation System (MOS, SMHI)	As above. Today there is a wave buoy at this location.	Bengt Karlson, bengt.karlson@smhi.se

e) What products could be developed as prototype (firstly) built on EXISTING operational data flows ?
Products here means merging of in situ + model+ sat (or 2 of the 3) or only one, but with objective to answer expressed scientific needs / societel/policy needs, and that could be transferred to CMEMS for instance or produced by X in the future in an operational way.

Suggested products are:

Eutrophication "index": chl from in situ, feeding into ocean color satellite validation, which then is incorporated in biogeochem models (also nutrients, T, microscopy, cytometry, light, currents, from in situ) to predict times/locations of eutrophication? Same can be done for HABs? See Atlantos HAB bulletins

Plastics/contaminants/oil "index": in situ observations (but need to consolidate and ensure methodological harmonization) + circulation models to predict water quality, for example, for a certain size range of microplastics and a subset of contaminants. Presumably most plastics/contaminants coming from rivers, "local" sources for oil.

f) What products could be developed at longer term if some data flows not yet operationally flowing to EU/national channels would become interoperable in a way such they are flowing to these channel? (and thus what are the data flows needed to become interoperable?)

-

4.4. Baltic Sea

a) 2 Priority scientific/societal questions that a regionally integrated coastal system could investigate in your region

Q1. How the state of the Baltic Sea is affected by the climate change and other human activities. What are the ecosystem effects of unwanted perturbations (e.g. anoxic bottoms, algae blooms, invasive species, microplastics, pollution) and how to secure ecosystem health, ecosystem services and sustainable blue growth. Whether the countermeasures to reduce eutrophication and pollution have an effect.

Q2. How to improve the understanding on the functioning of marine ecosystems and biogeochemistry, e.g. how marine biology processes are coupled to physical and chemical processes and how these drive biogeochemical cycles

b) *What are the observation systems [like FB lines, Glider endurance lines, cable obs., buoys or set of buoys, HF radars, sustained periodic cruises (notion of time series), and set of manual sampling stations sustained in a period way] that are already delivering a time series of data in an operational way toward sustained data infrastructures (national or EU data infrastructure) and that can support investigation on these priority questions?*

system name	national/regional RI name where the system belongs	parameters (related to the priority question here above)	contact person (name, institute, email)	data infrastructure
Ferrybox Silja Serenade	FINMARI (Finnish Marine Research Infrastructure)	Continuous T, S, O2, pCO2, pH, Chla, CDOM, Phycocyanin, turbidity, water samples for any lab analysis (e.g. nutrients)	Jukka Seppälä, SYKE jukka.seppala@ymparisto.fi	National database, EmodNET & CMEMS (bottle data so far, continuous data soon)
Argo floats	FINMARI (Finnish Marine Research Infrastructure)	Temperature and salinity used to support operative oceanography	Laura Tuomi, FMI	EuroArgo
Coastal CTD-profiling stations (manual)	FINMARI (Finnish Marine Research Infrastructure)	Temperature and Salinity	Laura Tuomi, FMI	SEADATACLOUD
Ferrybox Finnmaid	FINMARI (Finnish Marine Research Infrastructure), ICOS	Continuous T, S, O2, pCO2, pH, Chla, CDOM,Phycocyanin, phycoerythrin, turbidity, methane, nitrous oxide, DIC-stable isotopes, water samples for any lab analysis	Jukka Seppälä, SYKE jukka.seppala@ymparisto.fi Gregor Rehder, IOW	CMEMS & EmodNET, ICOS

		(e.g. nutrients)		
Ferrybox Silja Europa	Collaboration with FINMARI	Continuous T, S, Chla, Phycocyanin, turbidity, water samples for any lab analysis (e.g. nutrients)	Urmas Lips TTU urmas.lips@taltech.ee	??
Utö Observatory	Finnish Marine Research Infrastructure (FINMARI); In addition, ICOS-ERIC (atmospheric GHG-observations at Utö) ACTRIS-PP (aerosol observations at Utö)	Continuous T, S, O2, pCO2, pH, Chla, CDOM,Phycocyanin, turbidity, Imaging flowcytobot, water samples for any lab analysis (e.g. nutrients), ADCP, ice, profiling buoy (T,S,Chla, phycocyanin), weather, CO2 fluxes etc.	Lauri Laakso FMI Lauri.laakso@fmi.fi	National database so far
Keri observatory	Estonian Environmental Observatory	??	Urmas Lips TTU urmas.lips@taltech.ee	??
Glider		??	Urmas Lips TTU urmas.lips@taltech.ee	??
Glider	FINMARI	Temperature and Salinity, Chla, CDOM O2	Laura Tuomi, FMI	

c) *We need to consider modelling to progress toward an operational JERICO-RI, because models needs data and because models are delivering complementary information. What are the models/configuration that are able to deliver a more synoptic information on this region or that would benefit from in situ observation in the area?*

model name/config	ref person for a future collaboration	types (hydrodyn, biogeo etc)	possible contribution: need of specific data to assimilate and/or capability to deliver some specific information (drifting of matter, transport…)
NEMO-LIM3	Laura Tuomi / FMI	Hydrodynamic, sea level and ice model	Vertical and surface properties of Sea water; currents; turbidity, solar light penetration depth

WAM	Laura Tuomi / FMI	Wave model	Wave observations, meteorological data
ERGOM-HBM -> updated to ERGOM-NEMO in 2019?	Laura Tuomi / FMI IOW	hydrodynamics and marine biogeochemistry	Discrepancies between models and observations from coastal observatories, VOS-lines, profiling buoys, Argo-floats, Gliders analysed, to optimise
FICOS	Laura Tuomi / FMI Elina Miettunen /SYKE	operative ecosystem model for Archipelago Sea to estimate effects of nutrient loads on Finnish coastal areas	Regional Jerico-RI observations (coastal observatories, VOS-lines, profiling buoys, Argo-floats, Gliders) are used for validation and improving the current modelling framework

d) *What are the missing parameters or systems that should be added to improve these observations and/or toward a better integration in a 5 year time scale?*

system name/or missing system	national/regional IR name where the system belongs	missing parameters (related to the priority question here above)	name of the person suggesting that (or ref person to talk to) + email@
Coastal Buyo network	FINMARI	Regional extension	jukka.seppala@ymparisto.fi
Sedimentation	FINMARI	C-fluxes to benthos	jukka.seppala@ymparisto.fi
Pelagic biology	FINMARI	Algae diversity, algae production, zooplankton abundance, at various locations	jukka.seppala@ymparisto.fi
Biogeochemistry	FINMARI	Extension of carbonate system measurements, extension of nutrient measurements	jukka.seppala@ymparisto.fi
Benthic processes	FINMARI	Benthic lander, with biogeochem sensors	timo.tamminen@ymparisto.fi

e) *What products could be developed as prototype (firstly) built on EXISTING operational data flows ?*

Products here means merging of in situ + model+ sat (or 2 of the 3) or only one, but with objective to answer expressed scientific needs / societel/policy needs, and that could be transferred to CMEMS for instance or produced by X in the future in an operational way.

Products:

1. 4-D Maps of algae distribution and physics in Northern Baltic/Gulf of Finland, from operational observations and thus data feeding to regional model developments and regional satellite cal/val (i.e. harmonized transnational measurements from various platforms)

2. Regional model validations allowing for more accurate simulation of anthropogenic pressures
3. Testing algorithms for satellite observations of CDOM and cyanobacterial blooms, harmonized validation data

f) What products could be developed at longer term if some data flows not yet operationally flowing to EU/national channels would become interoperable in a way such they are flowing to these channel? (and thus what are the data flows needed to become interoperable?

Products: Carbonate system models, Carbon flux models

1. Improve FIOCS model, extend the current Gulf of Finland domain to cover also the central part of the gulf and the Estonian coast.
2. Improve NEMO-LIM3-model to get more realistic estimates of the light penetration depth, affecting heat flux estimation
3. Improved harmful algae bloom detection

4.5. Norwegian Sea

a) 2 Priority scientific/societal questions that a regionally integrated coastal system could investigate in your region.

1) The impact of climate variability on on land-sea fluxes, on eutrophication/HABs and thus on security and risk management of marine ecosystem provisioning services aquaculture and fisheries.
2) Changes in aquatic biodiversity across the region (eDNA type monitoring)
3) Prevalence of HAB blooms

b) What are the observation systems [like FB lines, Glider endurance lines, cable obs., buoys or set of buoys, HF radars, sustained periodic cruises (notion of time series), and set of manual sampling stations sustained in a period way] that are already delivering a time series of data in an operational way toward sustained data infrastructures (national or EU data infrastructure) and that can support investigation on these priority questions?

system name	national/regional RI name where the system belongs	parameters (related to the priority question here above)	contact person (name, institute, email)	data infrastructure	Operational	Level of financial sustainability? (low, med, high, unknown)
FerryBoxes (Bergen-Kirkenes (NIVA/IMR), Denmark-Faroe-Iceland (NIVA/HAV), Tromsø-Svalbard (NIVA))	NorSOOP	S, T, chl, turbidity, O2, pH, pCO2, cDOM, nutrients, radiance/irradiance, flow cytometry, etc.	Andrew King, NIVA, andrew.king@niva.no	Institutional, ROOS's, EMODnet INSTAC	yes	Medium (at least 5 years)
IMR cruises - Svinøy-NW and Gimsøy-NW sections	n/a	S, T, chl, nutrients (need to confirm)	Henning Wehde henningw@hi.no	Norwegian Marine Data Centre	yes	med-high
Station M buoy (? 300km offshore)	Previously Norwegian Environmental Agency Ocean Acidification monitoring program	S, T, O2, pCO2	Ingunn Skjelvan, NORCE, insk@norceresearch.no	SOCAT (Surface Ocean CO2 Atlas), Norwegian Marine Data Centre	yes	Medium
Gliders	NorGliders	S, T, O2, chl, turbidity,	Ilker Fer, University of	Institutional, Norwegian	yes	unknown

		acoustics	Bergen, Ilker.Fer@uib.no	Marine Data Centre		
VOS	ICOSNorway ICOS-RI	S, T, O2, pCO2	Are Olsen, University of Bergen, are.olsen@uib.no	ICOS carbon portal website	yes	ERIC
Argo floats	NorArgo/EurArgo-ERIC	P, S, T, O2, chl, pH, nitrate	Kjell Arne Mork, Institute for Marine Research, kjell.arne.mork@hi.no	Institutional, Coriolis Data Centre	yes	ERIC
HF radars	n/a	Current speed/direction	Kai Christensen, Met Norway, kai.h.christensen@met.no	Institutional, building links with EuroGOOS HF radar TT and Copernicus	yes	unknown
Multidisciplinary Cabled observatory	LoVE EMSO-ERIC (in discussion)	S, T, chl, passive and active acoustics, turbidity, cameras	Espen Johnsen espen.johnsen@imr.no / Geir Pedersen, NORCE, gepe@norceresearch.no	Institutional (IMR)	yes	Research Council Infrastructure

System name (Faroe Island)	national/regional RI name where the system belongs	parameters (related to the priority question here above)	Contact person (name, institute, email)	data infrastructure	Operational ?	Level of financial sustainability? (low, med, high, unknown)
Moorings	tbc	Currents, T, S	hav@hav.fo	Institutional		
RV-based hydrographic transects	tbc	S, T, O, Fl	hav@hav.fo	Institutional		

Vessel based Surveys	ICOS-Denmark pend. (Carbonate)	S, T, Chl, Nutrients, zooplankton, fish larvae, fish eggs	hav@hav.fo	Institutional ICOS/AMAP		
Fixed Time-series	n/a	T, S, O, Chl, Nutrients, phytoplankton, zooplankton, DNA	hav@hav.fo	ICES-IROC (S, T); Institutional (O, Chl, Nutrients,Phyto, Zoo, DNA)		
Vessel-based pelagic fish surveys	ICES	T, S, Chl, Zooplankton biomass, Blue-Whiting, Herring, Atlantic Mackrel	hav@hav.fo	PG-NAPAS		
Vessel-based demersal fish surveys	ICES	T, S, O, Flu, zooplankton biomass, ground-fish biomass (incl. Cod, herring)	hav@hav.fo	Institutional		
Fixed Station Sea-bird Monitoring	tbc	Population and migration estimates		tbc		

c) We need to consider modelling to progress toward an operational JERICO-RI, because models needs data and because models are delivering complementary information. What are the models/configuration that are able to deliver a more synoptic information on this region or that would benefit from in situ observation in the area?

NB: strong links between in situ (at least FerryBox) and remote sensing validation/algorithms; for forecasting there is strong assimilation of in situ and remote sensing observations into models.

model name/config	ref person for a future collaboration	types (hydrodyn, biogeo etc)	possible contribution: need of specific data to assimilate and/or capability to deliver some specific information (drifting of matter, transport…)
MEPS Numerical Weather	Ole Vignes, Met NO	Weather	Assimilate data, forecast

Prediction model	(o.vignes@met.no); Met NO and SMHI cooperation		weather
ERSEM Norwegian Sea	Phil Wallhead/NIVA	Biogeochemical (stoichiometric, multiple plankton sizes)	Assimilate data and deliver forecasts of biology (plankton and smaller) and chemistry
FVCOM Fjords in Norwegian Sea	Andre Staalstrom/NIVA	Hydrodynamical	Assimilate data; currents, transport
NorShelf ROMS	Johannes Röhrs, Met NO, johannesro@met.no	Hydrodynamical	Assimilate data, circulation, hydrography
NORCOAST Norwecom	Jon Albretsen IMR jon.albretsen@hi.no Morten Skogen IMR Morten.Skogen@hi.no	Hydrodynamical, IBM Bio	Hydrography, higher trophic levels Bio, Biogeochemical

d) What are the missing parameters or systems that should be added to improve these observations and/or toward a better integration in a 5 year time scale?

system name/or missing system	national/regional IR name where the system belongs	missing parameters (related to the priority question here above)	name of the person suggesting that (or ref person to talk to) + email@
FB	NorSOOP/EuroGOOS/BISE (Biodiversity Information System for Europe)/EU-BON	eDNA based biodiversity estimates	
Buoys	EuroGOOS	Nutrient sensors (fluxes on/off shelf)	
Fixed time-series (Skopun)	ICOS/EuroGOOS	pCO2 / pH / O2 / Flu	
Ecosystem Approach	ICES IMR	Impact physics, biogeo on large ecosystems	Per Arneberg/Henning Wehde

e) What products could be developed as prototype (firstly) built on EXISTING operational data flows ? [Products here means merging of in situ + model+ sat (or 2 of the 3) or only one, but with objective to answer expressed scientific needs / societel/policy needs, and that could be transferred to CMEMS for instance or produced by X in the future in an operational way].

Suggested products are:

Eutrophication "index": chl from in situ, feeding into ocean color satellite validation, which then is incorporated in biogeochem models (also nutrients, T, microscopy, cytometry, light, currents, from in situ) to predict times/locations of eutrophication? Same can be done for HABs?

Aquaculture "index": chl, T, pCO2/pH from in situ, validating satellite SST, and incorporation into physical/biogeochem models to inform salmon aquaculture operators of good/bad times; this has probably been started in H2020 TAPAS and maybe in other work (e.g., IMR with salmon lice)

Weather prediction: if JERICO-RI in situ observations are in place for MEPS weather prediction model

f) What products could be developed at longer term if some data flows not yet operationally flowing to EU/national channels would become interoperable in a way such they are flowing to these channel? (and thus what are the data flows needed to become interoperable?

Biodiversity estimates from sequencing seems like an obvious candidate but feasibility and standardization must be checked firstly.

4.6. From the Ligurian Sea to the Ibiza Channel (NW Mediterranean Sea)

a) *Priority scientific/societal questions that a regionally integrated coastal system could investigate in your region?*

There is an important set of different human activities (e.g. fishing, tourism, aquaculture and fishing farms,..) and coastal infrastructures (including a nuclear power plant) highly sensible to potential effects of climate change (intensification of storms, flooding events, sea level rise) which requires the sustainability of long term coastal monitoring. Eutrophication, harmful algae blooms and pollutants sources associated to big cities and rivers discharges (e.g. chemical, plastics) may benefit of real time multiparameter monitoring as early warning systems.

More specifically: observation and/or monitoring of:

- Freshwater and contaminants inputs from major Mediterranean Rivers (Ebro, Rhone and Po) sensitive to extreme events (flash flooding) or Impact of extreme events (floods and storms) on the source to sink transfer of particulate matter (sediment, organic matter, contaminants).Coastal - open sea continuum: North Current creates front/barrier between coastal and open sea water impacting at sub-mesoscale biogeochemical signatures, primary productivity and geographical distribution of biological communities;
- Water quality monitoring in MPAs (Gulf of Lions) for hydrological and biogeochemical parameters, impact of anthropogenic activities (trawling, wind farms, dredging, …)
- Shelf water cascading events in the Gulf of Lion and Catalan margin influencing the organic matter and contaminants inputs to deep water, the nepheloid resuspension layer and finally the benthic species diversity
- Impact of big cities on the water eutrophication and sediment pollution
- Impact of high energy events (storms, river floods, dense water formation…) on the hydrodynamics, turbidity and sediment transport, nutrients, pollutants discharge and morphological seabed changes.

b) What are the observation systems [like FB lines, Glider endurance lines, cable obs., buoys or set of buoys, HF radars, sustained periodic cruises (notion of time series), and set of manual sampling stations sustained in a periodic way] that are already delivering a time series of data in an operational way toward sustained data infrastructures (national or EU data infrastructure) and that can support investigation on these priority questions?

system name	national/regional IR name where the system belongs	parameters (related to the priority question here above)	contact person (name, institute, email)	data infrastructure
Network of 6 HF coastal buoys	COAST-HF/ILICO	T, S, Fluo, O2, Turbidity	G. Charria IFREMER guillaume.charria@ifremer.fr I. Pairaud (ivane.pairaud@ifremer.fr) F. Bourrin CEFREM fbourrin@univ-perp.fr	GDAC CORIOLIS SEANOE/ODATIS EMODNET
4 Fixed coastal sites	SOMLIT/ILICO PHYTOBS/ILICO	T, S, Fluo, O2, nutrients, pH, phytoplankton,...	L.Mousseau IMEV mousseau@obs-vlfr.fr P.Raimbault MIO patrick.raimbault@mio.osu	SOMLIT database QUADRIGE database

			pytheas.fr M. Lemoine IFREMER maud.lemoine@ifremer.fr P. Conan (OOB) pascal.conan@obs-banyuls.fr T. Leredde (Geosciences) Yann.Leredde@gm.univ-montp2.fr	
Fixed observatory DYFAMED (mooring & surface buoy)	EMSO	T,S,O2,currents, sediment traps	L.Coppola coppola@obs-vlfr.fr	CORIOLIS, SEANOE/ODATIS, EDMONET
Fixed observatory LION (mooring & surface buoy)	MOOSE/ILICO	T,S,O2,currents	P.Testor testor@locean-ipsl.upmc.fr	CORIOLIS, SEANOE/ODATIS, EDMONET
Fixed observatory ALBATROSS (mooring)	EMSO	T,S,O2,currents	D.Lefevre dominique.lefevre@mio.osupytheas.fr	CORIOLIS, SEANOE/ODATIS, EDMONET
Fixed observatory BILLION (mooring)	MOOSE/ILICO	T,S,O2,currents, sediment traps	X.Durrieu de Madron demadron@univ-perp.fr	CORIOLIS, SEANOE/ODATIS, EDMONET
Gliders sections	MOOSE/ILICO	T, S, Fluo, O2, CDOM, Turbidity, Current velocity & direction, particle size	L. Coppola IMEV coppola@obs-vlfr.fr F. Bourrin CEFREM fbourrin@univ-perp.fr	GDAC CORIOLIS SEANOE/ODATIS EMODNET
HF radars	MOOSE/ILICO	Current velocity, direction	B. Zakardjan MIO Bruno.Zakardjian@mio.osupytheas.fr C. Quentin MIO celine.quentin@mio.osupytheas.fr	SEANOE/ODATIS
HF radars	TirLig system	surface Current velocity direction	annalisa.griffa@sp.ismar.cnr.it carlo.mantovani@sp.ismar.cnr.it	thredds cathalogue feeding GEO portal and EMODNET.

			brandini@lamma.rete.toscana.it taddei@lamma.rete.toscana.it	planned also in CMEMS-INSTAC
Mooring	Corsica Channel Mooring	water column current velocity and temperature/salinity (data retrieved every 6 months) GUARD1 installation planned in spring 2019	anna.vetrano@sp.ismar.cnr.it katrin.schroeder@ismar.cnr.it mireno.borghini@sp.ismar.cnr.it	
imaging system	GUARD1/ DEEPEYE	megafauna video monitoring and automatic recognition	simone.marini@sp.ismar.cnr.it	now project user (ADVANCE) within JERICO-NEXT TNA. OBSEA observatory
cruise transect	Corsica-Capraia	CTD, LADCP, oxygen, turbidity, chla, nutrients	anna.vetrano@sp.ismar.cnr.it katrin.schroeder@ismar.cnr.it mireno.borghini@sp.ismar.cnr.it	CTD data in SEADATANET
Rivers monitoring	MOOSE/ILICO	Suspended particulate matter Nutrients metals	W. Ludwig (CEFREM) ludwig@univ-perp.fr P.Raimbault MIO patrick.raimbault@mio.osupytheas.fr	SEDOO Database
PUDEM	Catalan observatory	Monthly surveys of T, S, SCC, Ch-la profiles (0 - 35m)	jorge@icm.csic.es, emilio@icm.csic.es	local IT
CASABLANCA	Catalan observatory	V profiles (0-160 m), CTD,O2,Turbidity, pH (bottom) planned end	emilio@icm.csic.es	local IT

		2019		
Obsea-UPC - Fixed Coastal Site: seaflor and surface buoy	Catalan Observatory	T , S, CDOM, Turbidity, Current velocity & direction.	joaquin.del.rio@upc.edu	Emodnet and local IT
Ibiza Channel Monitoring Line	SOCIB observing system	Continuous Glider Occupation, T, S, Fluo, O2, Turbidity Seasonal Ship Occupation, T, S, Fluo, O2, Nutrients, Turbidity, Current velocity & direction	jallen@socib.es	
Ibiza Channel Buoy	SOCIB observing system	T, S, Fluo, O2, Meteo,	ealou@socib.es	
Ibiza Channel HF Radar	SOCIB observing system	Wave Height, surface current speed, direction	ereyes@socib.es	
Mallorca Channel Monitoring Line	SOCIB observing system	Continuous Glider Occupation, T, S, Fluo, O2, Turbidity Seasonal Ship Occupation, T, S, Fluo, O2, Nutrients, Turbidity, Current velocity & direction	jallen@socib.es	
Palma Bay Buoy	SOCIB observing system	T, S, Fluo, O2,pH, Meteo,	ealou@socib.es	

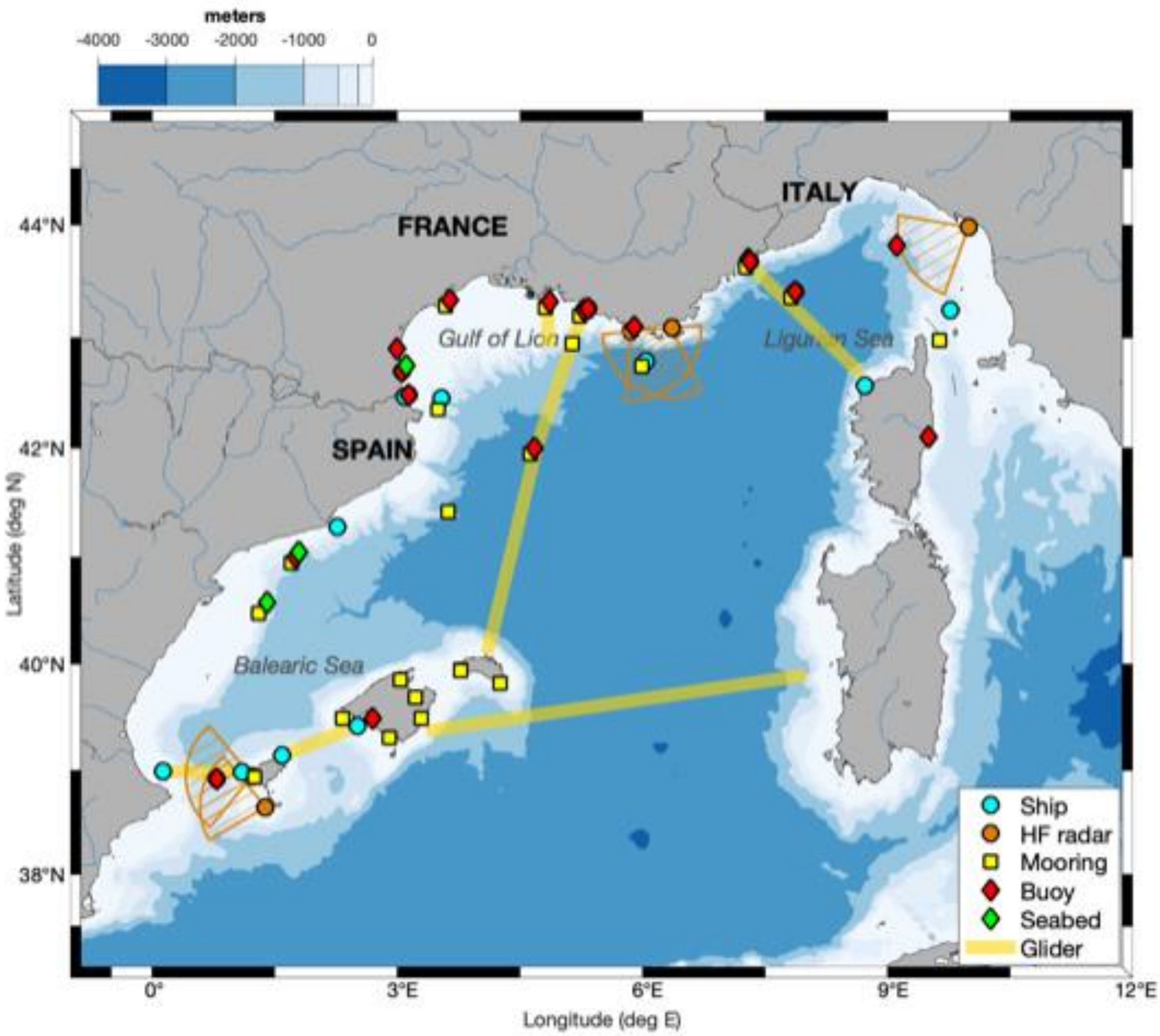


Figure 4.6-1 Observing system in the NW Med. Sea

c) We need to consider modelling to progress toward an operational JERICO-RI, because models need data and because models are delivering complementary information. Models and data assimilation are essential tools for the integration of multiplatform observations. *<u>What are the models/configuration that are able to deliver a more synoptic information on this region or that would benefit from in situ observation in the area?</u>*

model name/config	ref person for a future collaboration	types (hydrodyn, biogeo etc)	possible contribution: need of specific data to assimilate and/or capability to deliver some specific information (drifting of matter, transport…)
SYMPHONIE	C. Estournel claude.estournel@aero.obs-mip.fr	hydrodynamic	MOOSE-GE data for improvement of initial state. Can deliver transport of the NC, trajectories (surface for microplastics e.g or 3D with specific behaviours e.g.

			larvae)
ECO3M-S	C. Ulses caroline.ulses@aero.obs-mip.fr	biogeochemical model	Can deliver 3D biogeochemical fields and 2D fluxes (PP, export..)
MARS3D/MENOR	pierre.garreau@ifremer.fr	Hydrodynamics operational modelling	NW-MED configuration Resolution 1km Results and figures available through ftp : https://marc.ifremer.fr/resultats/temperature_et_salinite/modele_mars3d_mediterranee Possibility to plug on-line a lagrangian tool : http://www.ichthyop.org
WMOP	Baptiste Mourre bmourre@socib.es	Hydrodynamics	Western Med configuration, 2km,high-resolution atmospheric forcing, operational and hindcast, data assimilation, Lagrangian trajectory module
WMED	Roberto Sorgente Roberto.sorgente@cnr.it	Hydrodynamics operational model	Western Med configuration, 3,5km (1/32° horizontal resolution), the domain is: 003°-016 °E of longitude; 36.5-44.5 °N of latitude, atmospheric forcing, it delivers operational a daily 5-days forecast of the 3D ocean characteristics (temperature, salinity, etc.) and circulation http://www.seaforecast.cnr.it/forecast/index.php/en/forecast/western-mediterranean/ http://www.seaforecast.cnr.it/g3o/index.php/en/the-forecasting-systems/

d) What are the missing parameters or systems that should be added to improve these observations and/or toward a better integration in a 5 year time scale?

system name/or missing system	national/regional IR name where the system belongs	missing parameters (related to the priority question here above)	name of the person suggesting that (or ref person to talk to) + email@
Zooplankton biodiversity	ILICO	Zooplankton	L.Stemmann

		genomics	F.Not
Contaminants	ILICO (MOOSE)	Contaminants (metals coming for rivers)	D. Aubert
Sediment pollution. Algal blooms	ICM-CSIC	Heavy metals, CHLA, Nutrients, phytoplankton	Albert Palanques albertp@icm.csic.es
Coastal-Deep basin links	Catalan Margin Hydrochanges	Deep Currents, CTD, turbidity	Pere Puig ppuig@icm.csic.es
Autonomous imaging device for macro and mega fauna monitoring	OBSEA (already active under the ADVANCE JERICO-NEXT TNA Project) Corsica Channel mooring	Biodiversity quantification and monitoring. Macro and mega fauna temporal dynamics (daily, seasonal, annual)	Simone Marini (simone.marini@sp.ismar.cnr.it)

e) What products could be developed as prototype (firstly) built on EXISTING operational data flows ?
Products here means merging of in situ + model+ sat (or 2 of the 3) or only one, but with objective to answer expressed scientific needs / societel/policy needs, and that could be transferred to CMEMS for instance or produced by X in the future in an operational way.

1- 3D transport by marine currents
Applications: transport of pollutants, plastics and plankton (phytoplankton, larvae, jellyfish, HABs...) useful for ecosystem managements, fisheries, pollution mitigation.
Obtained combining current velocity data from HF radars, gliders, current meters and models, using blending and assimilation techniques. Synergy with altimetry data to extend toward the open sea, and use of specific model zooms to extend toward near coast/land where is needed
2- Shelf retention maps
Applications: ecosystem management, fisheries, marine safety.
Obtained from current velocity data from HF radar and models, releasing virtual Lagrangian particles and evaluating their residence time in selected shelf areas.
3- Marine response to climate change and extreme events
Applications: ecosystem management, fisheries, marine safety, climate change
Obtained from HF radar and models in coastal areas, characterizing wave response and current response including convergence/divergence and vertical transport. Where available these data should be integrated with biogeochemical data to characterize ecosystem response

f) What products could be developed at longer term if some data flows not yet operationally flowing to EU/national channels would become interoperable in a way such they are flowing to these channel? (and thus what are the data flows needed to become interoperable?

All the products above will be first computed in e) using the present data flow, and then expanded in f) using the extended data coverage expected in the near future (example HF radar data coverage in Italian and French coast). In particular for product 3) “Marine response to climate change and extreme events” the ecosystem response in term of macro and mega fauna and flora could be monitored using a “smart” autonomous imaging system (GuardOne) equipped for real time communication:

4.7. Northern Adriatic Sea (NA)

a) *2 Priority scientific/societal questions that a regionally integrated coastal system could investigate in your region ?*

The NA is the most productive area of the Mediterranean (from primary production to commercial fish). Early measurable ecological reactions to climate change are expected to be observable in a shallow, confined marine ecosystem with a good record of long term observations like the NA. The large and heavily used collection surface for the combined freshwater input in the confined NA marine ecosystem along with a densely populated coastline represents a strong anthropogenic pressure on this marine area. It is thus an area under severe anthropogenic pressure, and the NA is expected and observed to undergo measurable and rapid changes. The observation and monitoring of the consequences of this pressure as well as of the effectiveness of management measures is a societal obligation. A sustainable management of this ecosystem and its resources towards stability and resilience requires a multinationally coordinated and integrated observation system. More precisely, key parameters like the observation of invasive, toxic or endangered species and their relation to physical and chemical parameters/models are a prerequisite for management and forecast.

As a summary priority could be set

- To investigate the impact of extreme meteorological events on the ecosystem and on the water exchange within this area.
- To investigate the effect of river flooding and sediment transport at basin scale
- To set up forecasting systems that would support sustainable fisheries, sustainable exploitation of resources
- To investigate the role of environmental and biological forcings on the capability of the Northern Adriatic to adsorb and sequester CO_2 under a climate change scenario

b) What are the observation systems [like FB lines, Glider endurance lines, cable obs., buoys or set of buoys, HF radars, sustained periodic cruises (notion of time series), and set of manual sampling stations sustained in a period way] that are already delivering a time series of data in an operational way toward sustained data infrastructures (national or EU data infrastructure) and that can support investigation on these priority questions?

The Adriatic Sea is home to a number of active coastal observing initiatives involving many different systems that are providing measurements of oceanographic and bio-geochemical parameters extending over the whole trophic web from pico- to meso-plankton. However, the particularities of the NA region of the Adriatic in terms of both location (transnationality) and relative denseness of coverage (relative spatial resolution) by observational elements makes it an ideal site for a first attempt at trans-boundary integration.

system name	national/regional IR name where the system belongs	parameters (related to the priority question here above)	contact person (name, institute, email)	data infrastructure
Oceanographic Buoy MAMBO_1 (45°41'55.00"N :13°42'28.02"E)	MAMBO_OGS / ICOS RI	Air: Wind Sp., Dir., Temp, Hum, Press. Sea(1.5m): C, T, D, O2, pH, PCO2 Sea (10m) C, T, D, O2, pH, Turb., Fluor. Sea (17m bottom) C, T, D, O2, pH.	Fabio Brunetti, OGS, fbrunetti@inogs.it	National Ocean. Data Center (at OGS) CMEMS in situ TAC EMODNET SeaDataNet

Oceanographic Buoy MAMBO_2 (45°36'09.60"N :13°09'02.40"E)	MONITORAGGIO - FVG	Air: Wind Sp., Dir., Temp, Hum, Press. Sea: C, T, D, O2, pH, Turb., Fluor, ADCP	Fabio Brunetti, OGS, fbrunetti@inogs.it	Civil Protection Data Center. National Ocean. Data Center (at OGS). CMEMS in situ TAC EMODNET SeaDataNet
Oceanographic Buoy MAMBO_3 (45°38'38.40"N :13°30'40.80"E)	MONITORAGGIO - FVG	Air: Wind Sp., Dir., Temp, Hum, Press. Sea: C, T, D, O2, pH, Turb., Fluor, ADCP	Fabio Brunetti, OGS, fbrunetti@inogs.it	Civil Protection Data Center. National Ocean. Data Center (at OGS). CMEMS in situ TAC EMODNET SeaDataNet
Oceanographic Buoy MAMBO_4 (45°35'40.08"N :13°20'37.73"E)	MONITORAGGIO - FVG	Air: Wind Sp., Dir., Temp, Hum, Press. Sea: ADCP	Fabio Brunetti, OGS, fbrunetti@inogs.it	Civil Protection Data Center. National Ocean. Data Center (at OGS). CMEMS in situ TAC EMODNET SeaDataNet
Directional Waves Buoy DWRG1_1 (45°33'55.80"N :13°14'54.06"E)	MONITORAGGIO - FVG	Wave Height, Direction, Spectra	Fabio Brunetti, OGS, fbrunetti@inogs.it	Civil Protection Data Center. National Ocean. Data Center (at OGS). CMEMS in situ TAC EMODNET SeaDataNet
Directional Waves Buoy DWRG1_2 (45°41'58.00"N :13°12'33.02"E)	MONITORAGGIO - FVG	Wave Height, Direction, Spectra	Fabio Brunetti, OGS, fbrunetti@inogs.it	Civil Protection Data Center. National Ocean. Data Center (at OGS). CMEMS in situ TAC EMODNET SeaDataNet
Directional Waves Buoy DWRG1_3 (45°41'17.58"N :13°31'17.28"E)	MONITORAGGIO - FVG	Wave Height, Direction, Spectra	Fabio Brunetti, OGS, fbrunetti@inogs.it	Civil Protection Data Center. National Ocean. Data Center (at OGS). CMEMS in situ TAC EMODNET SeaDataNet
Current and flow bottom station with	MONITORAGGIO - FVG	ADCP	Fabio Brunetti, OGS,	Civil Protection Data Center.

real time data Isonzo River (45°45'41.76"N :13°29'46.04"E)			fbrunetti@inogs.it	National Ocean. Data Center (at OGS). CMEMS in situ TAC EMODNET SeaDataNet
Current and flow bottom station with real time data (45°39'18.41"N :13°05'06.13"E)	MONITORAGGIO - FVG	ADCP	Fabio Brunetti, OGS, fbrunetti@inogs.it	Civil Protection Data Center. National Ocean. Data Center (at OGS). CMEMS in situ TAC EMODNET SeaDataNet
HF Radar (45°44'28.38"N :13°40'10.06"E)	Radar - BIO	Surface Current Maps. Wave Maps.	Davide Deponte, OGS, ddeponte@inogs.it Nydia Catalina Reyes Suarez nreyessuarez@inogs.it	National Ocean. Data Center (at OGS).
Manual Sampling Station (monthly) C1 - LTER (45°42'3.43"N :13°42'35.87"E)	C1 - LTER	PROFILE: C, T, D 4 DEPTHS: O2, Nutrients (NO3, NO2,NH4,PO4,SiO4) Total Alkalinity, pH, Particulate Organic Carbon, Total Particulate Nitrogen, Chlorophill a, Dissolved Organic Carbon, Chromophoric DOM, Bacteria, Cyanobacterial and Viral abundance, Picoeukariotes. MIcrophyto -, Microzoo - , Mesozoo - plankton.	Michele Giani mgiani@inogs.it Marina Cabrini mcabrini@inogs.it	National Ocean. Data Center (at OGS).
Dynamic pylon PALOMA (45°37,097 N;	CNR / ICOS-RI	Air: Wind Sp., Dir., Temp. Sea: C, T, D, O2,	carolina.cantoni@ts.ismar.cnr.it	ICOS-RI, CNR-RMM, EMODNET

13°33,913 E)		pCO2		
PALOMA station (45°37,097 N; 13°33,913 E)	CNR / ICOS-RI	PROFILE: C, T, D 4 DEPTHS: O2, Nutrients (NO3, NO2,NH4,PO4,SiO4) Dissolved Organic Carbon, Dissolved organic nitrogen	carolina.cantoni@ts.ismar.cnr.it; anna.luchetta@ts.ismar.cnr.it	CNR database - ICOS-RI
Dynamic pylon S1-GB (44° 44.3097 N; 12° 27.1588 E)	CNR	Air: Wind Sp., Dir., Temp, Hum, Press solar radiation. Sea: C, T, D, O2	mariangela.ravaioli@bo.ismar.cnr.it, francesco.riminucci@bo.ismar.cnr.it	CNR-RMM, EMODNET
Buoy E1 (44° 08.595 N; 12° 34.206 E)	CNR	Air: Wind Sp., Dir., Temp, C, T, D, O2, Sea: C, T, D, O2,	mariangela.ravaioli@bo.ismar.cnr.it, francesco.riminucci@bo.ismar.cnr.it	CNR-RMM, EMODNET
"Acqua Alta" Oceanographic tower (45° 18.830'N ; 12° 30.530'E)	CNR	Air: Wind Sp., Dir., Temp, Hum, Press solar radiation. Sea: C, T, D, O2, Wave Height, Direction, tide, underwater imaging system monitoring jellyfish swarms	mauro.bastianini@ismar.cnr.it	CNR-RMM EM
Oceanographic buoy RV001 (45°04'38.0"N 13°36'40.0"E)	IRB/CMR	Air: Temp, Pressure, Humidity, Wind speed, Wind direction, Wind gusts, precipitation Sea: Temperature, Dissolved Oxygen, Salinity, Chlorophyll a concentration, Light scattering.	pfannkuchen@cim.irb.hr	*Public interface:* *http://faust.izor.hr/autodatapub/plutaca1_prikaz#*
Monthly, research vessel supported	*IRB/CMR*	*Depth profile CTD probe (Seabird)*	*pfannkuchen@cim.irb.hr*	*IRB/CMR*

sampling (45°04'38.0"N 13°36'40.0"E)		*Niskin sampling at surface, 1m, 5m, 10m, 15m, 20m, 25, and bottom depth. Phytoplankton community composition and abundance (Zooplankton not for all years) Temperature, Salinity, Alkalinity, Ph, Chlorophyll content, dissolved oxygen, Nutrient salts (NO3, NO2,NH4,PO4,SiO4) .*		
Monthly, research vessel supported sampling 45° 0'0.00"N 12°49'48.00"E	*IRB/CMR*	*Depth profile CTD probe (Seabird) Niskin sampling at surface, 1m, 5m, 10m, 15m, 20m, 25, and bottom depth. Phytoplankton community composition and abundance (Zooplankton not for all years) Temperature, Salinity, Alkalinity, Ph, Chlorophyll content, dissolved oxygen, Nutrient salts (NO3, NO2,NH4,PO4,SiO4) .*	*pfannkuchen@cim.irb.hr*	*IRB/CMR*
Monthly, research vessel supported sampling 45° 2'60.00"N 13°18'36.00"E	*IRB/CMR*	*Depth profile CTD probe (Seabird) Niskin sampling at surface, 1m, 5m, 10m, 15m, 20m, 25, and bottom depth. Phytoplankton community composition and abundance*	*pfannkuchen@cim.irb.hr*	*IRB/CMR*

		(Zooplankton not for all years) Temperature, Salinity, Alkalinity, Ph, Chlorophyll content, dissolved oxygen, Nutrient salts (NO3, NO2,NH4,PO4,SiO4) .		
Monthly, research vessel supported sampling 44°45'36.00"N 12°45'0.00"E	*IRB/CMR*	*Depth profile CTD probe (Seabird) Niskin sampling at surface, 1m, 5m, 10m, 15m, 20m, 25, and bottom depth. Phytoplankton community composition and abundance (Zooplankton not for all years) Temperature, Salinity, Alkalinity, Ph, Chlorophyll content, dissolved oxygen, Nutrient salts (NO3, NO2,NH4,PO4,SiO4) .*	*pfannkuchen@cim.irb.hr*	*IRB/CMR*
Monthly, research vessel supported sampling 45° 1'48.00"N 13° 9'0.00"E	*IRB/CMR*	*Depth profile CTD probe (Seabird) Niskin sampling at surface, 1m, 5m, 10m, 15m, 20m, 25, and bottom depth. Phytoplankton community composition and abundance (Zooplankton not for all years) Temperature, Salinity, Alkalinity, Ph, Chlorophyll content, dissolved oxygen, Nutrient salts (NO3,*	*pfannkuchen@cim.irb.hr*	*IRB/CMR*

		NO2,NH4,PO4,SiO4) .		
Monthly, research vessel supported sampling 45° 1'12.00"N 12°59'24.00"E	*IRB/CMR*	*Depth profile CTD probe (Seabird) Niskin sampling at surface, 1m, 5m, 10m, 15m, 20m, 25, and bottom depth. Phytoplankton community composition and abundance (Zooplankton not for all years) Temperature, Salinity, Alkalinity, Ph, Chlorophyll content, dissolved oxygen, Nutrient salts (NO3, NO2,NH4,PO4,SiO4)* .	*pfannkuchen@cim.irb.hr*	*IRB/CMR*

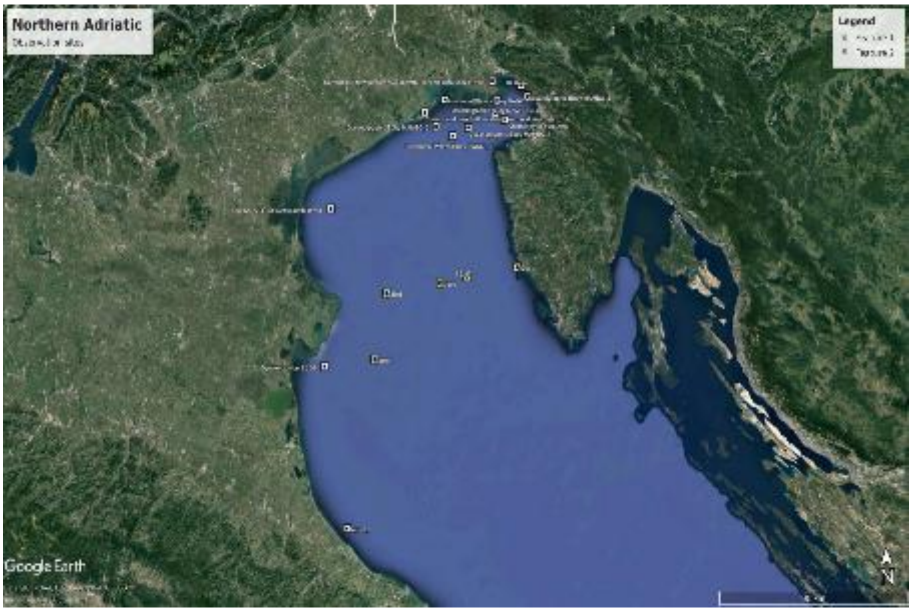


Figure 4.7-1 Map of the Northern Adriatic Sea, with the positions of the fixed stations and the area where data are acquired by the FOOS. The gray arrows indicate the schematic circulation in the area.

c) We need to consider modelling to progress toward an operational JERICO-RI, because models needs data and because models are delivering complementary information. What are the models/configuration that are able to deliver a more synoptic information on this region or that would benefit from in situ observation in the area?

The OGS develops and maintains several ocean and ocean-biogeochemical coupled models that have been tuned for providing a synoptic description of the space-time distributions and variabilities of major physical and biogeochemical parameters in the North Adriatic Sea.

model name/config	ref person for a future collaboration	types (hydrodyn, biogeo etc)	possible contribution: need of specific data to assimilate and/or capability to deliver some specific information (drifting of matter, transport…)
ROMS (Regional Ocean Modeling System) coupled with NPDZ	Alessandro Coluccelli (UNIVPM – Università Politecnica Marche), Aniello Russo (NATAO-STO-CMRE)	Oceanographic model coupled with a bio-geochemical model	need of bio-geochemical data to validate models
KASSANDRA forecasting system	Christian Ferrarin (CNR-ISMAR)	Oceanographic operating system for sea and wave level prediction	need of sea and wave level data to validate models
MOLOCH model	Silvio Davolio (CNR-ISAC)	Meteorological model	need of meteorological data to validate models

d) What are the missing parameters or systems that should be added to improve these observations and/or toward a better integration in a 5 year time scale?

For the OGS:
- Continuous monitoring of riverine inflows at selected sites;
- Completion of the HF radar system, currently under development;
- Integration of HF radar data in operational numerical models;
- Additional in-situ monitoring locations for pH and other marine carbonate system variables, dissolved oxygen, and possibly nutrients;
- Sustenance of an ongoing long time-series of selected physical/biological/biogeochemical variables;
- Harmonization of measurements with monitoring networks being run by other local agencies/bodies;
- Development of observational capabilities for biology.
-

system name/or missing system	national/regional IR name where the system belongs	missing parameters (related to the priority question here above)	name of the person suggesting that (or ref person to talk to) + email@
Central NA 45°15'15.52"N 12°58'36.47"E		Continuous CTD, nutrients, Oxygen, Chl depth profile, Currents	Martin *Pfannkuchen* *pfannkuchen@cim.irb.hr*
Southern gyre border *45° 1'12.00"N*		Continuous CTD, nutrients, Oxygen, Chl	Martin P*fannkuchen* *pfannkuchen@cim.irb.hr*

12°59'24.00"E		depth profile, Currents	
Fixed Coastal site, S1-GB Po Delta (44° 44.3097 N; 12° 27.1588 E)	CNR-ISMAR	CTD casts (C, T, D, DO)	mariangela.ravaioli@bo.ismar.cnr.it, francesco.riminucci@bo.ismar.cnr.it
Fixed Coastal site, E1 Emilia-Romagna coast (44° 08.595 N; 12° 34.206 E)	CNR-ISMAR	CTD casts (C, T, D, DO)	mariangela.ravaioli@bo.ismar.cnr.it, francesco.riminucci@bo.ismar.cnr.it
Fixed Coastal site, "Acqua Alta" Oceanographic tower Gulf of Venice (45° 18.830'N ; 12° 30.530'E)	CNR-ISMAR	CTD casts (C, T, D, DO)	mauro.bastianini@ismar.cnr.it

-

e) What products could be developed as prototype (firstly) built on EXISTING operational data flows ?
[Products here means merging of in situ + model+ sat (or 2 of the 3) or only one, but with objective to answer expressed scientific needs / societel/policy needs, and that could be transferred to CMEMS for instance or produced by X in the future in an operational way.]

- A gap analysis to assess present operational and R&D prediction capabilities for the NA region relative to some traceable user requirements;
- A handbook setting down the attributes for standard observational data (e.g., variables, including topographic, hydrological, meteorological, ecological, etc. data; space-time resolution; and accuracy) needed for multi-disciplinary model forcing, verification, validation, and data assimilation in the NA region;
- A handbook setting down the standard attributes (e.g., space-time resolution, accuracy, forecast horizons, and timeliness) for operational prediction and analysis of selected core variables (temperature, salinity, density, currents, chlorophyll, some nutrients) in the NA region that can be traced back to user requirements;
- A suite of preliminary model skill assessment metrics for the NA region involving the mentioned core variables which will form the basis for uncertainty estimates of predictions, tradeoff studies between alternative observing system networks, and validation studies;
- A set of flexible and adaptive standard model data formats for the NA region;
- Design and implementation plan for a distributed, "one-stop shopping" data portal and archival system for prediction input and output data for the NA region.
- QC NRT procedures to validate in situ data;
- Algorithms for the satellite sea colour data interpretation (eg Chlorophyll and turbidity);
- Procedures to validate modeling forecasts;
- Advanced information services dedicate to disseminate observation and forecast sea data to the population and institutions (eg "Informare System" for the Emilia-Romagna Coast, www.informare-er.it).

f) What products could be developed at longer term if some data flows not yet operationally flowing to EU/national channels would become interoperable in a way such they are flowing to these channel? (and thus what are the data flows needed to become interoperable?

- An overall Systems Engineering (SE) design and management scheme for the NA regional observational network;
- A "concept of operations" framework linking the NA regional network's prediction and analysis component with national and European observing systems with the aim of defining roles and responsibilities and mutually beneficial partnerships;

- Improved cyberinfrastructure, including a standards-based data portal and archiving system built to leverage both untapped information resources and other existing infrastructure at the local level, for the NA region;
- Thematic model evaluation environments, data assimilation schemes, and Observing System Experiments (OSEs)/Observing System Simulation Experiments (OSSEs) to assist in overall system development and performance evaluation of the NA regional observing network;
- A forum for the NA region to maintain periodic group communications on a face-to-face basis for fostering research and operational partnerships.

4.8. Cretan Sea

a) 2 Priority scientific/societal questions that a regionally integrated coastal system could investigate in this region?

Local level: Black Sea water effect on thermohaline circulation of the Aegean Sea
Regional level: intermediate and deep-water formation coupling with the biochemical functioning of the Eastern Mediterranean
Regional level: marine environmental indicator development (still in infancy in Mediterranean and Black Seas) for MSFD
Global level: climate change effect on marine productivity via the pressures of warming, acidification, nutrient-oxygen dynamics in an area with no terrestrial inputs

*b) What are the observation systems [like FB lines, Glider endurance lines, cable obs., buoys or set of buoys, HF radars, sustained periodic cruises (notion of time series), and set of manual sampling stations sustained in a period way] that are **already** delivering a time series of data in an **operational** way toward **sustained** data infrastructures (national or EU data infrastructure) and that can support investigation on these priority questions?*

system name	national/regional RI name where the system belongs	parameters (related to the priority question here above)	contact person (name, institute, email)	data infrastructure
Poseidon Ferrybox (PFB)	POSEIDON Monitoring, Forecasting and Information System for the Greek Seas	C, T, Turb,Fchl, O2	Petihakis George,HCMR, gpetihakis@hcmr.gr	Copernicus Emodnet Seadatanet
Poseidon Coastal Buoys (Athos, Saronikos, HCB, Mykonos)	POSEIDON Monitoring, Forecasting and Information System for the Greek Seas	C, T, D,currents, waves, meteo	Leonidas Perivoliotis, HCMR, lperiv@hcmr.gr	Copernicus Emodnet Seadatanet
Poseidon Open sea Buoys (E1M3A, Pylos)	POSEIDON Monitoring, Forecasting and Information System for the Greek Seas	C, T, D, O2, Fchl, Turb,currents, waves, meteo	Leonidas Perivoliotis, HCMR, lperiv@hcmr.gr	Copernicus Emodnet Seadatanet
Poseidon Gliders	POSEIDON Monitoring, Forecasting and Information System for the Greek Seas	C, T, D, O2	Leonidas Perivoliotis, HCMR, lperiv@hcmr.gr	Copernicus Emodnet Seadatanet
PYLOS cabled obs	EMSO-ERIC node	C,T,D,currents, pCO2,, camera	Petihakis George,HCMR, gpetihakis@hcmr.gr	Copernicus Emodnet Seadatanet

HF Radar	POSEIDON Monitoring, Forecasting and Information System for the Greek Seas	currents	Korres Gerasimos gkorres@hcmr.gr	Copernicus Emodnet Seadatanet
Sustained periodic cruises (E1M3A, HCB)	POSEIDON Monitoring, Forecasting and Information System for the Greek Seas	C, T, D, nutrients, plankton	Petihakis George,HCMR, gpetihakis@hcmr.gr	Copernicus Emodnet Seadatanet
Argo floats	EuroArgo ERIC	C, T, D, O2	Gerasimos Korres, HCMR, gkorres@hcmr.gr	Copernicus Emodnet Seadatanet

c) We need to consider modelling to progress toward an operational JERICO-RI, because models needs data and because models are delivering complementary information. What are the models/configuration that are able to deliver a more synoptic information on this region or that would benefit from in situ observation in the area?

model name/config	**ref person for a future collaboration**	**types (hydrodyn, biogeo etc)**	**possible contribution: need of specific data to assimilate and/or capability to deliver some specific information (drifting of matter, transport…)**
Princeton Ocean Model	Korres Gerasimos, gkorres@hcmr.gr	Hydrodynamic (POM) - various spatial scales	Operational with assimilation schemes embedded
Low trophic level (LTL) ecosystem model	Tsiaras Kostas, ktsiaras@hcmr.gr	Biogeo (ERSEM type) coupled to above hydrodynamic - various spatial scales	Operational with assimilation schemes embedded
Fish model	Tsiaras Kostas, ktsiaras@hcmr.gr	IBM model fully 2-way coupled to hydro and biogeo models.	Operational
Aquaculture model	Tsiaras Kostas, ktsiaras@hcmr.gr	Adaptation of the above LTL model	Service offered to the aquaculture sector. Next steps to operationalise it.
Bivalve model	Tsiaras Kostas, ktsiaras@hcmr.gr	DEB model coupled to the above LTL model	Towards a service for the Aquaculture sector
Search and Rescue model	Korres Gerasimos, gkorres@hcmr.gr	Hydrodynamic / Drifting	The service is offered to the national emergency

			system
Oil Spill model	Leonidas Perivoliotis, lperiv@hcmr.gr	Oil spill evolution and tracking	Partner of REMPEC with the mandate to provide forecast and contingency plan for the Aegean/Ionian seas.

d) What are the missing parameters or systems that should be added to improve these observations and/or toward a better integration in a 5 year time scale?

system name/or missing system	national/regional IR name where the system belongs	missing parameters (related to the priority question here above)	name of the person suggesting that (or ref person to talk to) + email@
Poseidon Ferrybox at Cretan Sea (PFB)	POSEIDON Monitoring, Forecasting and Information System for the Greek Seas	Nutrients, pH, pCO2, DIC, AT, DOC, particulate matter, PFTs	
Poseidon Coastal Buoys (Athos, Saronikos, HCB, Mykonos)	POSEIDON Monitoring, Forecasting and Information System for the Greek Seas	O2, pH, pCO2, Fchl, Turb, Nutrients, particulate matter, PFTs, Zooplankton, Sound	
Poseidon Open sea Buoys (E1M3A, Pylos)	POSEIDON Monitoring, Forecasting and Information System for the Greek Seas	Nutrients, pH, pCO2, particulate matter, PFTs, Zooplankton, Sound	
Poseidon Gliders	POSEIDON Monitoring, Forecasting and Information System for the Greek Seas	Nutrients, particulate matter, PFTs	
PYLOS cabled obs	POSEIDON Monitoring, Forecasting and Information System for the Greek Seas	Methane	
HF Radar	POSEIDON Monitoring, Forecasting and Information System for the Greek Seas	Validation with drifters	
Sustained periodic cruises (E1M3A, HCB)	POSEIDON Monitoring, Forecasting and Information System for the	pH, DIC, AT, PFTs, DOC, particulate matter,	

	Greek Seas		
Sustained periodic cruises (Saronikos, Pylos, Mykonos, Athos)	POSEIDON Monitoring, Forecasting and Information System for the Greek Seas	C, T, D, nutrients, pH, DIC, AT, plankton, DOC, particulate matter,	
Argo floats	POSEIDON Monitoring, Forecasting and Information System for the Greek Seas	Nutrients, pH, pCO2, particulate matter, camera	
Drifters fleet	POSEIDON & UoAegean	T, S, pH, currents	
Poseidon Ferrybox in North Aegean Sea	POSEIDON / HIMIOFoTS	C, T, Turb, Fchl, O2, pH, pCO2, Nutrients, DIC, AT, DOC, particulate matter, PFTs	
Moored platform nearby E1M3A	ROSACE	Ocean Colour	

e) What products could be developed as prototype (firstly) built on EXISTING operational data flows ?
[Products here means merging of in situ + model+ sat (or 2 of the 3) or only one, but with objective to answer expressed scientific needs / societel/policy needs, and that could be transferred to CMEMS for instance or produced by X in the future in an operational way.]

Product that could be developed and transferred to CMEMS: Advanced QC based on neighbour test (comparison with nearby sensor measuring the same variable) and multivariate test (rate of change test of an associated variable). These tests are described in the latest QARTOD reports. It appears that no system is conducting these tests in real time. They could be applied not only using a combination of in situ and satellite data flows but also, within a supersite context, among several in situ sensors located nearby.

Product: optimum sampling spatiotemporal resolution (and thus the optimum deployment-investment strategy) based on model data assimilation adding progressively different data sources

f) What products could be developed at longer term if some data flows not yet operationally flowing to EU/national channels would become interoperable in a way such they are flowing to these channel? (and thus what are the data flows needed to become interoperable?

Product : pH, pCO2, DIC, AT, air-sea flux of CO2 fields from in situ observations

Associated data flow to become operational: pH, pCO2, via in situ sensors (NRT) and pH, DIC, AT, via sampling-lab analysis (delayed mode)

Product: phytoplankton geographical distributions and PP by taxon or functional type from in situ data. Further product in combination with satellite data.

Associated data flow to become operational: phytoplankton diversity via observations of phycoerythrin fluorescence (NRT), (imaging) flow cytometry, sampling-lab analysis (delayed mode).

Product: zooplankton biomass and secondary (zooplankton) production.

Associated data flow to become operational: zooplankton biomass via ADCP backscatter data (NRT) and via sampling-lab analysis (delayed mode)

Product: zooplankton geographical distributions and secondary (zooplankton) production by taxon or functional type from in situ data.

Associated data flow to become operational: zooplankton diversity via in situ imaging (NRT) and via sampling-lab analysis (delayed mode).

Product: Particulate matter export fluxes from in situ measurements. Further product in combination with estimations from satellite.

Associated data flow to become operational: Particulate matter data from water column and sediment traps below euphotic zone (delayed mode).

Product: Ocean sound data from in situ measurements.

Associated data flow to become operational: Ocean sound data from in situ data (NRT).

5. Conclusions

5.1. Synthesis of main achievements per region of JERICO-RI

5.1.1. *Bay Of Biscay*

5.1.1.1. SE BoB

- Involved JRAPs: JRAPs #1 3 4 6
- Progress in the study of coastal small scale and mesoscale features from the combined use of multiplatform in-situ and satellite data.
- Progress in the application of innovative techniques (developed in WP3) in this area for data-gap filling, data-blending, advanced Lagrangian diagnostics and performing observing system experiments (OSEs) and observing system simulation experiments (OSSEs).
- Success in the gathering of new high-resolution datasets from different surveys and actions in the area (ETOILE with MASTODON-2D moorings deployment and TNA BB-TRANS).

5.1.1.2. Gironde and Bay of Brest

- Involved JRAPs: JRAP #2
- Success in gathering biological and biogeochemical observations on a major marine mudpatch located in a high energetic environment. New evidence on the major role of hydrodynamics in controlling benthic diversity and associated biogeochemical processes in this mudpatch.
- Success in deriving high resolution spatial maps of clam dredging pressure in the Bay of Brest and in using these maps to show the deleterious effect of this activity on benthic diversity hosted by maerl beds.
- Success in the field testing of several techniques and tools (e.g., Image acquisition via mobile platforms and sediment profiling, image processing via dedicated software, and O2 sediment microprofiling) developed within both JERICO-FP7 and JERICO-NEXT.

5.1.1.3. Nazare Canyon

- Involved JRAPs: JRAPs #4 & 6
- Success in the implementation of a high-resolution model with data assimilation able to describe the energetic dynamics and coastal ocean impacts of this long submarine canyon.
- Progress in understanding the crucial importance of real-time monitoring infrastructures (fixed platforms, HF radars) to the characterization and operational forecasting of coastal ocean areas marked by the presence of submarine canyons, view the energetic and short spatial scale processes that are associated with these topographic features and the impacts canyons promote on larger domains of the coastal ocean.
- Progress in understanding the dominant processes of subinertial dynamics in the Nazare Canyon area of influence, contributing to define the main components of a real-time monitoring system for this area.

5.1.2. *Channel and North Sea*

- Involved JRAPs: JRAPs #1, 4, 5
- Successful implementation of innovative (semi-)automated techniques for the monitoring of phytoplankton dynamics and C cycle in the English Channel and the North Sea - an extended shelf system influenced by multiple sources of human pressure and contrasting hydrodynamical conditions

- Some of these methods were compared with traditional laboratory analysis which helped to better address the added value of innovative techniques in terms of improving the spatial and temporal resolution (both in surface and in the water column), making it possible to consider functional and, sometimes, even taxonomical characterization of phytoplankton communities composition as well as photo-physiology, at high resolution, in almost real-time.
- New insights into the seasonality of the spatial distribution of delta partial pressure of carbon dioxide (pCO_2) measured continuously on ships of opportunity at a regional scale in the North Sea, and the relation between marine sinks of CO_2 with high total chlorophyll a fluorescence.
- Automated techniques made it possible to characterize the size and functional composition of phytoplankton communities (from pico- to microphytoplankton) through the main bloom episodes including outburst of potential HABs as *Pseudo-nitszchia* spp. and *Phaeocystis globosa* (characterized as high or low red fluorescence nano-eukaryotes: Nano high and Low FLR) from the Eastern English Channel (EEC) towards the southern North Sea, in international cross-border (UK, FR, BE, NL) common research cruises, following the spatial and temporal succession of spring blooms.

There is a need to increase the combined implementation of innovative and reference techniques both on current monitoring of discrete stations as well as in continuous automated measurements performed on cruises and ships of opportunity (as FerryBoxes), in order to increase the spatial and temporal resolution of the surveys of the different eco-hydrodynamic regions of the area.

5.1.3. *Kattegat and Skagerrak*

- Involved JRAPs: JRAPs #1, 3, 5, 6
- Harmful algae, phytoplankton diversity and abundance were observed in near real time at an aquaculture site on the Swedish west coast. In situ imaging flow cytometry combined with machine learning and wireless communications provided data every 20 minutes.
- Data from HF radar, FerryBox, research vessels and oceanographic buoys were used together with results from the 3D-NEMO Nordic ocean circulation model and remote sensing to describe the Kattegat-Skagerrak system.
- Data from a FerryBox system revealed, as expected, the occurrence of strong concentration gradients reflecting progressive dilution along the South-North transect and highlighted harbours areas (Oslo and Kiel) as hotspots for some chemical compounds.
- Microbial molecular markers representing bacterial species and genes were used to identify hydrocarbon pollution or high nutrient loads.
- Barcoding of phytoplankton and bacteria revealed previously unknown diversity in the pelagic communities (see deliverable D3.8).
- Carbon fluxes and carbonate system variability in the Skagerrak/Kattegat region is primarily driven by changes in salinity resulting from the balance of freshwater inputs from riverine and Baltic sources and saline waters from the Atlantic Ocean.

5.1.4. *Baltic*

- Involved JRAPs: JRAPs #1, 5, 6
- Different technologies for phytoplankton research have been successfully evaluated in the Baltic Sea. Operational monitoring of phycoerythrin fluorescence started after in-depth study during JRAP1, which identified different origins of this signal. To study filamentous cyanobacteria blooms, various sensors were tested and they were largely complementary. New absorption method seems to provide reliable estimates for Chlorophyll-a concentration, but still lacks automated maintenance procedures. Better understanding was obtained on the range of conversion factor between electron transport rate (measured with fluorescence induction) and carbon fixation rate, as well as of the reasons behind this variability.

- Carbonate system components of the Baltic Sea showed large seasonal variability indicating high impact of biological activity for pH and pCO_2. Alkalinity of the Baltic Sea is difficult to model from other carbonate system components and online sensors are required to understand its variability.
- The joint studies between different (multinational) research groups using different technologies provided good know-how exchange and should be encouraged. As well, multidisciplinary research efforts, including physics, chemistry, biology and modelling, should be encouraged, to gain knowledge on the environmental challenges more in detail.

5.1.5. *Norwegian Sea*

- Involved JRAPs: JRAPs #1, 3, 6
- Norwegian Sea plays a major role as an area where potentially highly polluted waters from the North Sea mix with water transported from the North Atlantic Ocean. This water is then transported into the Arctic region. Analysis of the transport pathway of waterborne contaminants along the Norwegian coast was instrumental for assessing the spatial range of contaminants with different properties and address questions regarding exposure of the Arctic.
- 42 currently used pesticides in Europe, 5 artificial sweeteners and 11 pharmaceuticals and personal care products were targeted during the study. Several compounds were detected in the Norwegian Sea, including current use pesticides, artificial food additives and some pharmaceuticals. Their presence in this coastal area, and also in high-latitude more open waters, highlight the potential for these contaminants to undergo long range transport with marine currents.
- Seasonal variability in temperature in the coastal area (up to a 15 ˚C differential between summer and winter depending on latitude) is a large driving force on carbonate system variability, including a decrease in surface water fCO_2 due to lower wintertime temperatures as well as the uptake of atmospheric CO_2 as water cools during its northward journey from the North Atlantic to the Arctic Ocean.
- In addition, a focal point was the improvement of systems that provides knowledge for the transport of parasites and harmful algae in the Norwegian Sea coastal area. Here the observations by FerryBoxes, fixed stations as well as repeated transects were used to validate and improve numerical model simulations.

5.1.6. *Ligurian to Ibiza channel*

- Involved JRAPs: JRAPs #1, 4, 6
- Major investigation effort was led in the Liguro-Provencal area and the Catalan Margin to study the variability of the Northern current through the combination of independent and complementary observational platforms. The dynamics of the boundary currents were studied to identify the interplay between various forcings (remote, thermohaline and wind), the generation of mesoscale and submesoscale instabilities, and data blending and assimilation techniques were investigated.
- Major results have shown a clear correlation between hydrographic changes led by climatic interannual variability and the community composition of phytoplankton and zooplankton. The role of (sub)mesoscale processes have shown to modulate biochemical processes and to locally enhanced marine biomass productions/accumulation.
- The multiplatform observing system in the NW Mediterranean Sea, combined with growing centralized frameworks of data management and distribution, i.e. Copernicus Marine Environment Monitoring Service and SeaDataNet/SeaDataCloud, will provide the basis for an extended European coastal infrastructure.

5.1.7. *Adriatic Sea*

- Involved JRAPs: JRAPs #5 & 6
- During the project, important steps forward have been done on the development of capabilities to integrate new kind of experimental data between them and within oceanographic models to support ecosystem management. The implementation of an Adriatic oceanographic model assimilating surface current from coastal radar and temperature profiles from fishing vessels (FOOS fleet) has been developed and tested, providing encouraging results. Surface currents from coastal radars were integrated with results from drifter deployments to investigate zones of recruitment for small pelagic, highlighting the role of remote areas in supporting the ecological role of these environments.
- One year of high frequency data of sea surface CO2 partial pressure was successfully gathered at a fixed station in the northernmost Adriatic. Results highlighted how the biological CO2 activity during phytoplankton blooms was able to keep the central basin a strong CO2 sink not only in winter, when low temperatures favor CO2 dissolution, but through most of the year, even when temperatures raised above 25°C.
- The work carried on so far highlighted the potentiality of the area, where historical data and many observational systems are available to support both ecosystem management and advanced marine researches. On the other hand, they pointed out the need for integration of the existing facilities and observational systems also at a trans-border level to address the climate and ecological challenges facing this basin. During the project, important steps forward have been made on the development of capabilities to integrate new kinds of experimental data and oceanographic models to support ecosystem management. The implementation of an Adriatic oceanographic model assimilating surface current from coastal radar and temperature profiles from fishing vessels (FOOS fleet) has been developed and tested, providing encouraging results. Surface currents from coastal radars were integrated with results from drifter deployments to investigate zones of recruitment for small pelagic fishes, highlighting the role of remote areas in supporting the ecological role of these environments.
- One year of high frequency data of sea surface pCO_2 was successfully gathered at a fixed station in the northernmost Adriatic. Results highlighted how the biological CO_2 uptake during phytoplankton blooms was able to keep the central basin a strong CO_2 sink not only in winter, when low temperatures favor CO_2 dissolution, but through most of the year, even when temperatures raised above 25°C.
- The work carried on so far highlighted the potentiality of the area, where historical data and many observational systems are available to support both ecosystem management and advanced marine researches. On the other hand, they pointed out the need for integration of the existing facilities and observational systems also at a trans-border level to address the climate and ecological challenges facing this basin.

5.1.8. *Cretan Sea*

- Involved JRAPs: JRAPs #2 & 6
- An interesting case of how the additional assimilation of glider profiles and FerryBox observations used in the OSE experiment is beneficial for the Aegean Sea forecasting system in terms of reducing the system biases. This improved the sea surface salinity model bias over the south Aegean (north of Crete and south of 37°N).
- In the Cretan Sea, the vertical migration of mesopelagic organisms (macroplanktonic and micronektonic) was observed by acoustical means for almost 2.5 years in the epipelagic and mesopelagic layers. The observed organisms were categorized into four groups according to their migration patterns which appeared to occur at diel and seasonal scale. The variability of the migration patterns was inspected in relation to the physical and biological environmental conditions of the study area. Stratification of the water column does not act as a barrier for the vertical motion of the strongest migrants that move up to 400 m every day. Instead, changes in light intensity (lunar cycle, daylight duration, cloudiness) and the presence of prey and predators seem to explain the observed daily, monthly and seasonal.

This report clearly demonstrates how the consortium of the project is willing to progress on **monitoring strategie**s in several JERICO studies (besides the simulation experiments for transport studies, the analysis of search radius from contaminant sources and the use of covariance in highly relevant low-concentration persistent contaminants, use of multi-functional sensors, etc.); despite the **difficulty** and time-consuming activity of operating both fixed and mobile platforms working in the highly dynamic complex and densely utilised coastal areas. By progressing on the integration of scientific fields, it also shows the benefit of operating several platforms types (fixed & mobile, at sea, remote, & numerical). For instance, we can emphasize what deployments in JRAPs have proved:

* JRAP #1: interest in deploying complementary observing systems for algal blooms to get information interoperable at EU level.
* JRAP #2: success in monitoring highly dynamic benthic ecosystems.
* JRAP #3: possibility to successfully perform monitoring of contaminants in an interoperable manner.
* JRAP #4: the highly resolved low-cost sensor and mooring deployments for specific transport or contaminant studies, which shows the intent to be cost-efficient. The complementarity of remote + at sea and numerical systems.
* JRAP#5: coastal carbon fluxes and biogeochemical cycling: The relatively large variability of conditions keeps being a challenge for sensor developers, with necessary periodic calibration needs that are possible to tackle as shown.
* JRAP#6: makes a strong case of the need for in-situ data vs models, in particular for coastal processes.

5.2. A vision: a possible geographical structuration of JERICO-RI per region and site

JERICO-RI already proved his capability to gather information and tools to qualify and quantify processes, their scales, related challenges and the possible solution to progress upon. As a next step, in agreement with regional stakeholder, JERICO-RI should develop regional forum/center to share information (data and products), expertises, practices, solution and training in line with regional purposes to support scientists and regional stakeholders. This would support application of policies and regulations, based on applied collaborations between scientists and other stakeholders to tackle common societo, environmental and scientific questions from local to regional scales.

According to the monitoring purposes in regions and sites, the need of integration in scientific fields is diverse and JERICO-NEXT presented only a first steps. In the future, JRAPs, TNA & regions should engage with outermost regions where regional projects take place and could be liaised with JERICO RI to better connect these regions in the coastal observing RI landscape. Because of these considerations, the consortium has proposed a vision towards regional integrated coastal observatories, which is presented in chapter 4.

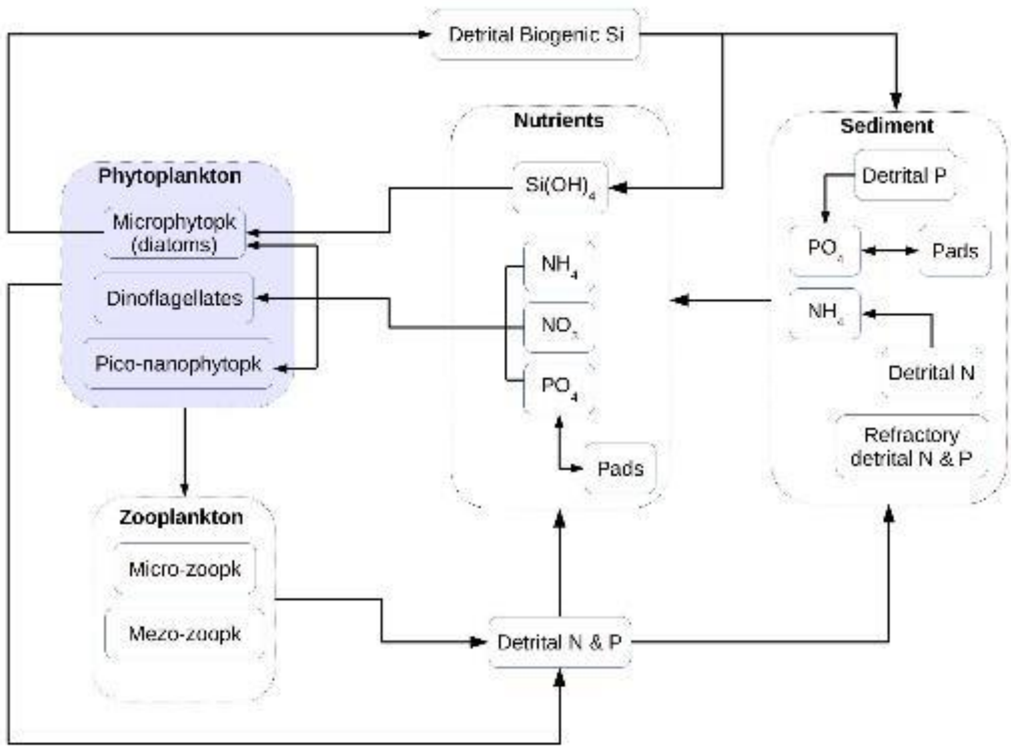
From JERICO-NEXT and WP4, a main lesson learned is that societal challenges and priorities at the regional level are important elements for the structuring of a coastal observing system. Therefore, a key challenge for the future is to improve **regionalisation of the observatories for a better understanding of region-specific processes and an improved fit-for-purpose** of the JERICO-RI. Furthermore, the observatories need to be **consolidated in terms of performance, reliability and variables** to optimally address and answer to key regional and pan-European environmental challenges. The two above-mentioned aspects are the integration challenge that ***the consortium wishes to tackle by implementing a regional structure of JERICO-RI***.

The structuring process will be challenging because coastal observatories are not operated by the same organisations and therefore may have differing objectives and means of operation (financial, logistical, etc.). Based on these differences, we have proposed that the coastal observing systems in JERICO-RI can be structured hierarchically in which all sizes and types of coastal observatories can function in JERICO-RI in an integrated and mutually beneficial way. This will be reported in deliverable D1.4 and the way towards a regional structuring of JERICO-RI is included in the proposal for the 3rd project of the JERICO series of projects: JERICO-S3 to be funded and to start in early 2020. With regards to the WP4 of the present project, the final deliverable: D4.5 is in progress to report results of each of the six JRAP activities and will be available by Sept. 2019 on the JERICO-RI website.

6. Annexes

6.1. Annex 1: Modelling with ECOMARS 3D in Channel and North Sea

The biochemical model ECOMARS is fully coupled with the hydrodynamic model MARS-3D (Model for Applications at Regional Scale). A detailed description of the MARS-3D model is available in Lazure and Dumas (2008). The biochemical model is an extension of the NPZD model type (Nutrients-Phytoplankton-Zooplankton-Detritus), aiming to simulate the production of main primary producers as well as the fluxes of limiting elements such as nitrogen (N), phosphorus (P) and silicon (Si). In order to approach the community composition and the phenology of the phytoplankton compartment, the model simulates 3 different classes: microphytoplankton, pico-nanophytoplankton and dinoflagellates.



ECOMARS 3D conceptual model. Boxes represent state variables and arrows stand for the N, P, Si fluxes between state variables.

Grazers are split into two groups, microzooplankton and mesozooplankton which graze on all size classes regarding the former and only on microphytoplankton and dinoflagellates regarding the
latter. Although heterotrophic bacteria biomass is not explicitly described in the model, the biogeochemical cycles are closed by equations of mineralization of particulate organic matter (detritus). Grazing on bacteria is not taken into account except for autotrophic bacteria that are included in the pico-nanophytoplankton.

Other modules are available (or sometimes currently under development) and can be coupled to the generic ECOMARS model:

- Macrophytes (in particular green macroalgaes)
- Seagrass beds
- Some toxic microalgae (*Pseudo-nitzschia*, *Alexandrium, Karenia* … genus for example)
- diagenesis in sediment

All the model equations have been previously detailed in several papers: Loyer et al. (2001) and Huret et al. (2013) for the biogeochemical cycling and the planktonic network, Plus et al. (2003, 2015) for the seagrass module, Ménesguen et al. (2006) for the green macroalgae. All equations and parameters can be consulted on the MARS-3D technical documentation (IFREMER-Dyneco, 2012) available here : http://www.ifremer.fr/docmars/html/index.html.

A sediment module could be coupled to the hydrodynamic and biogeochemical model (then named ECOMARS3D-MUSTANG). These hydrodynamics and sediment dynamics coupled models are already deployed in the Bay of Biscay, and could be implemented in the same configuration as the biogeochemical cycle along the next 5 years, which would allow to explore the sediment fluxes and interactions between sediment dynamics and biogeochemical processes and ultimately eutrophication issues.

A similar modelling platform is also implemented by DELTARES and RBINS (to be confirmed for biogeochemical processes), which hence would provide a diverse source of information and hence provide confidence indicators in final products.

6.2. Annex 2: more about circulation in the Ibiza Channel /AW

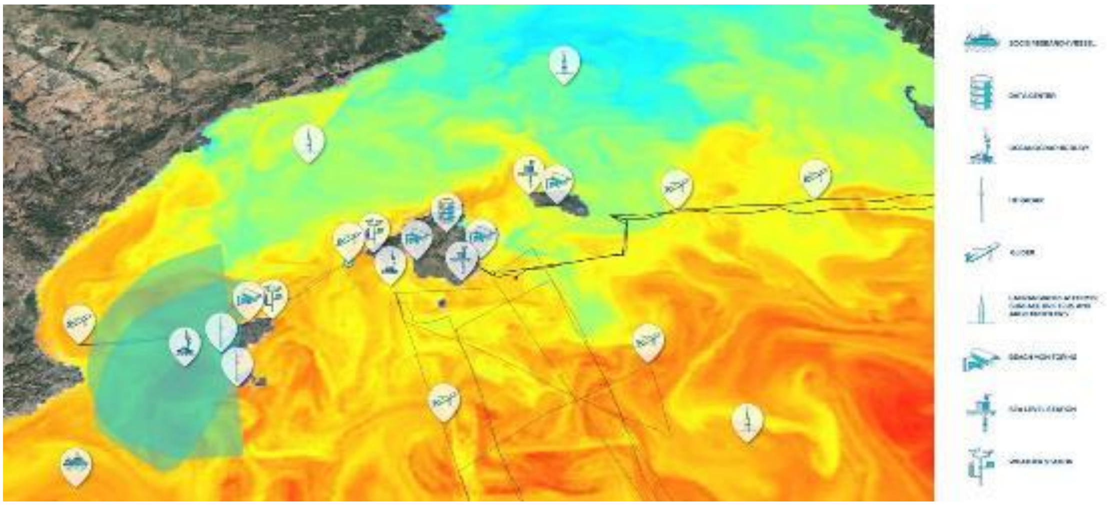
On the western side of the Ibiza Channel the Northern Current (NC), part of the cyclonic circulation, flows south out of the Balearic Sea sub-basin, whilst on the eastern side, AW of the most recent Atlantic origin (warmer and fresher) flows in from the Algerian sub-basin to the south. The AW inflows, which occur both through the Ibiza and to a lesser extent through the Mallorca channel, form the warm fresh core of the Balearic Current (BC) that flows northeast along the north coasts of the Balearic Islands. This exchange has a seasonal cycle, for example the previously observed seasonal range of transports for the NC has been determined as stronger in winter, 1.2 – 1.5 Sv (1 Sv = 10^6 m^3 s^{-1}), and weaker in summer, 0.5 – 0.3 Sv (Pinot et al., 2002). In spring these flows can be interrupted by 'blocking' eddies which divert the NC (northeast) to follow and join the path of the BC along the northwest coast of the Balearic Islands, reducing the N/S exchange in the Ibiza Channel (Pinot et al., 2002; Pinot and Ganachaud, 1999). Conversely, the AW inflows have been observed to strengthen in late spring/early summer (Pinot et al., 2002).

An index to link winter atmospheric conditions in the Gulf of Lion (WIW production) to regional circulation scenarios has been proposed (Monserrat et al., 2008). For the AW inflows, it has been suggested that they strengthen in response to the seasonal weakening of the NC and/or as a result of mesoscale activity to the south of the Balearic Islands (Pinot et al., 2002; Pinot and Ganachaud, 1999), however the strength, timing and location of AW inflows are known to influence the spawning grounds of migratory pelagic fish (Sabatés et al.; 2007, Alemany et al., 2010).

6.3. Annex 3: SOCIB Products and Services for the NW Mediterranean

SOCIB has developed a range of products and ocean data visualisation tools, in line with the observing and modelling facilities, with the support of the Data Center Facility. In order to continue SOCIBs development and to gain more users, to deliver data to new users, and to increase our utility to society, SOCIB recently undertook a product review and from this developed a sector-focused Products and Services Strategy.

The analysis enabled SOCIB to identify 10 key user sectors (***example Table 1***), groups of users with common data interests and needs, that are important to the region (economically/societal benefit) and for which SOCIB can provide data of value (e.g. value to decision making), both observed variables (e.g. wave height) and derived/value added variables (e.g. predicted wave height, divergence/convergence zones, spawning habitat mapping of top predator fish species). Multiplatform data integration through data assimilation in the SOCIB regional model is an important element in this approach. The importance of taking a sector-based approach is that end users are identified, products can be created that combine data streams and knowledge to fulfil user needs, with the participation of user groups (alpha testing), and potential users can be notified of product availability (marketing). The identification of user sectors also enables the defence of core funding requirements through the prioritisation of societal needs by national and local government stakeholders.



The 10 sectors and end users that are now core to the SOCIB products strategy:

1. Marine and coastal research (academia, government policy makers and responsible, NGOs)
2. Marine sports (recreational sailing, sports sailing/regattas, surfing, diving)
3. Beach and coastal communities (citizens, tourists)
4. Coastal protection, planning and governance (government environmental managers, beach and coastal planners, energy company managers)
5. Sustainable marine ecosystems (fisheries managers, fisheries scientists, commercial fishermen, recreational fishermen, sustainability managers)
6. Integrated coastal zone and ocean management (ICOM managers, MPA managers, marine managers, water quality operators)
7. Ports and Shipping (port managers, port pilots, ferry companies/captains, shipping companies/captains, cruise companies/captains)
8. Maritime safety (SAR operators, coastguard, oil spill response managers, maritime emergency managers, navy & national security agency)
9. Education and kids (school kids/teachers, higher education kids/ teachers, society)
10. Sustainability of islands and climatic change (government policy, sustainability managers)

Table: *SOCIB's list of products, by user sector.(here after)*

Products by Sector

SOCIB	Description	Assoc. Facilities	Type	Availibility
1 - Marine and coastal research	**scientists, government researchers, marine policy managers and implimenters, NGOs**			
SOCIB API Browser	Web based search interface for all SOCIB data (model and observational, excepting GIS vector based data)	DCF	met-ocean data catalogue	Web
DAPP	Viewer for current and historical missions mobile platforms - ship, glider, Argo, drifters, turtles - with access to visualisations of data. Jwebchart (engineering data), profiles viewer (ocean profiles), plots of variables.	DCF	met-ocean visualisation	Web
THREDDS Catalogue	Web and standards based access portal to SOCIB observational and model data	DCF	met-ocean data catalogue	Web
Lw4nc2	Application to display gridded data both observational and forecasting - HF Radar, WMOP	DCF	met-ocean visualisation	Web
Profiles viewer	Interactive viewer for data profiles - Argo, Ship, Glider - accessible through DAPP and SOCIB website	DCF	met-ocean visualisation	Web
Jwebchart	Interactive viewer of timeseries dataset from netcdf files, linked to THREDDS, used in DAPP and other tools	DCF	met-ocean visualisation	Web
WMOP forecast visualisation	Web page with access to ocean forecas imagest, by variable and regions. With Timeseries of model output of variables along key sections and validation of WMOP and SAPO-IB against various in situ platforms	DCF	met-ocean visualisation	Web
SAPO-IB wave forecast visualisation	Web page with wave forecast and real-time data	MF	met-ocean visualsation	Web
Fixed station viewer	Web page with interface for viewing fixed stations data (link is one example)	FSF, DCF	met-ocean visualsation	Web
Glider Toolbox	MATLAB/Octave scripts to manage data collected by a glider fleet, including data download, data processing and product and figure generation, both in real time and delayed time. Used by other institutes (10 - 20)	DCF	technology / software	Web
HR Radar QC reports generator code	A python command line tool to create the monthly reports of the HF Radar managed by SOCIB.	DCF	technology / software	Web
Leaflet Time Dimension Tool	Tool for visualising trajectories and gridded data, in use by other Institutes	DCF	technology / software	Web
HF Radar reports	Monthly validation report for HF Radar data	HFR	QC information	Web
Seaboard (platform)	Interface for various visualisations of meteo and ocean and model data (see seaboards below and also used as base for new tools)	DCF	technology / software	Web
SOCIB R/V Seabeard	Seaboard implimnetation for R/V data for cruises (onboard visualisation in real time of key datasets)	DCF	met-ocean visualsation	Web
SOCIB API	API fo machine to machine system integration for data access	DCF	technology / software	Web
2 - Marine sports	**recreational sailing, sports sailing/regattas, surfing, diving**			
Dive App	Web based application providing forecast and data for divers - planning/decision making	FSF, MF, DCF, P&S	Descision support tool	unknown
3 - Beach, coastal communities & tourists	**citizens, tourists**			
Beach Lifeguard App	Mobile app and parallel website bringing together the information on sea/met conditions required by beach lifeguards on a daily basis in their work, and over the longer team for seasonal analysis	MF, DCF, P&S	Descision support tool	2018
Hotel Seaboard	Seaboards for hotel partners displaying marine and met forecasts and beach images for tourists staying in hotels - online and hotel screens	BMF	met-ocean visualsation	Web
4 - Coastal protection, planning and governance	**Local, regional and Balearic environmental and emergency response managers, beach and coastal planners and environmental managers**			
Beach data viewer	Web based GIS map and data viewer for historical beach data in the Balearics - information on 877 beaches in the Balearic region	BMF	met-ocean visualsation	Web
Sa Costa	Balearic coastal sensitivity index	BMF	Descision support tool	Web
GIS Catalogue	Web based catalogue for all GIS/vector based datasets	BMF	met-ocean data catalogue	Web
Coastal Environmental Sensitivity Atlas	Book/Atlas - Coastal Environmental Sensitivity Atlas of the Balearic Islands (NEW 2015 EDITION) providing key information on Balearic coastline for planning, protection and governance	BMF	Descision support tool	Book
5 - Sustainable marine ecosystems	**fisheries managers, fisheries scientists, commercial fishermen, recreational fishermen, sustainability manages**			
Ocenography for Sustainable Fisheries Tool	Web based interactive maps displaying key ocean variables, forecasts & derived features for ecosystem assessment and management	P&S	met-ocean-model visualsation	2018
Blue Fin tuna larval index	Used to assess Eastern spawning stock biomass of bluefin tuna (Thunnus thynnus), integrating habitat and environmental variability from operational oceanography data sources. ICCAT endorsed into the 2017 assessment.	BFT	Descision support tool	ICCAT Only
Albacore tuna larval index	Used to assess Eastern spawning stock biomass of Mediterranean stock of Albacore (Thunnus alalunga), integrating habitat and environmental variability from operational oceanography data sources. ICCAT endorsed into the 2017 assessment.	BFT	Descision support tool	ICCAT Only
Blue Fin tuna larval survival index	Used to assess the effect of oceanographic variability into the bluefin tuna stock recruitment relationship in the Mediterranean. Under evaluation by the ICCAT SCRS.	BFT	Descision support tool	ICCAT Only
6 - Integrated coastal zone and ocean management	**ICOM managers, MPA managers, marine managers other, water quality**			
Indicators for ICZM	Book - System of Indicators for Integrated Coastal Zone Management (ICZM) in the Balearic Islands	SAIS	Descision support tool	Book
7 - Ports and Shipping	**port managers, port pilots, ferry, shipping and cruise companies/captains**			
Meteo Tsunami Forecast (BRIFS)	Balearic Rissaga Forecasting System (BRIFS) - predicting extreme sea level oscillations from meteotsunamis Ciutadella harbour	MF	Descision support tool	Online
8 - Maritime safety	**Search and Rescue, coastguard, oil spill response, maritime emergency managers**			
Sorerento Seaboard	Seaboard to illustrate the type of data available for SAR services (e.g. Sorrento), as when required - created for specific emergency	DCF	Descision support tool	Web
Lagrangian tool	Forecast of particle trajectory within WMOP, forward and backwards in time	MF	Descision support tool	On request
9 - Education and kids	**school kids/teachers, higher education kids/ teachers, society**			
Follow the Glider	Educational tool on gliders, how function and what they observe, for school kids and teachers	O&E	Educational Tool	Web
MedClic	Online descriptions of facilities and observations for school kids and teachers	O&E	Educational Tool	Web
10 - Sustainability of islands and climatic change	**government policy, sustainability managers**			
No specific products				
CROSS-SECTOR				
SOCIB Mobile Apps	Application to view data and forecasts for iOS and Android	DCF	met-ocean visualsation	Web

6.4. Annex 4: Observation systems Ligurian sea and Gulf of Lion:

A coastal time series in the Bay of Villefranche sur Mer was established in 1957 and weekly sampling for hydrology, biogeochemistry and plankton collection. The coastal site is part of the national observing network SOMLIT.

An open sea time series (DYFAMED) was established, in 1991, 52 km offshore in the central water where hydrology, biogeochemistry and plankton is recorded each month.

The W1M3A marine observatory, based on the ODAS ITALIA 1 buoy and on a close-by sub-surface mooring, was established in 2000 and further upgraded since 2008 providing meteorological and oceanographic measurements. The observatory is permanently moored in the center of the Ligurian Sea, 40 nm from the coast on a 1200 deep sea bed. It was part of the FixO3 project and it is within the global network of reference ocean station called OceanSITES.

Glider transects from Nice to Calvi are carried on since 2008 and connect the coastal and open sea sites. Time series and gliders sections are part of the national integrated observing system MOOSE established since 2010.

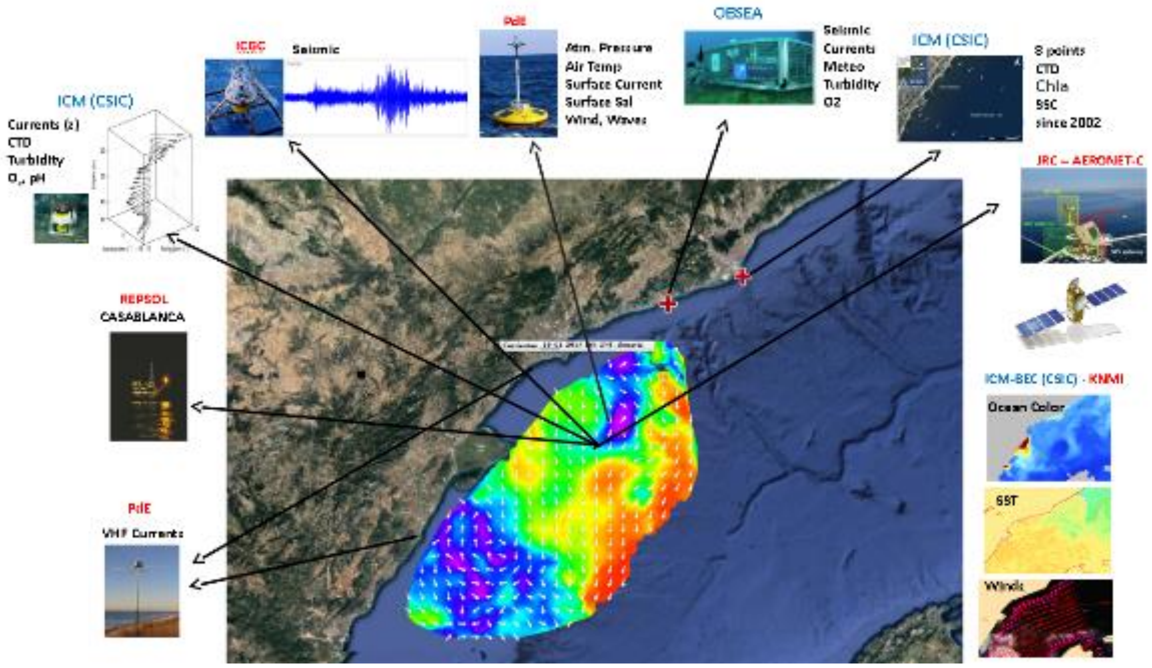
In addition, an EMSO standalone mooring has been deployed at 2300 m depth since 1988. This site is included in the EMSO Ligurian node.

6.5. Annex 5: Catalan Coast Observation System: J del Rio (UPC) and Emili Garcia (CSIC)

The Catalan Coastal Observation System is an initiative to promote the coordination of a comprehensive set of observational efforts in the Catalan margin, from the Cap de Creus to the Ebro shelf, with contributions of several institutions (see the figure). Initially it will be composed by:

- PUDEM (ICM-CSIC) regular monitoring just in front of Barcelona. Provides data from 8 points distributed in two transects since 2002-2015 and reduced to 5 stations from 2005-present with measurements of CTD, Chla, and SCC (0 - 35m)
- OBSEA (IUPC) site composed of a submarine observatory south of Barcelona with observations on T.S CDOM, turbidity, acoustics, seismometry, underwater images, meteo and velocity, at 20 m depth and with a surface buoy.
- CASABLANCA site (ICM-CSIC), close to the CASABLANCA oil platform that will be operational by the end 2019 composed by a mooring providing vertical profiles of velocity and benthic measurements at 160 m of CTD, Turbidity, O2, pH.
- CASABLANCA-AERONET-C node (joint collaboration JRC/ICM-CSIC) installed on the CASABLANCA oil platform, consisting on a multispectral radiometer on visible range that will be operational by mid 2019
- a met-ocean buoy operated by Puertos del Estado equipped with a atmospheric station and monitoring sea surface variables close to the CASABLANCA oil platform
- three HFR radar antennas operated by Puertos del Estado covering the Ebro shelf area

a point of measure of seismic activity (OBS) operated by the Catalan Institute of Cartography and Geology



6.6. Annex 7: The Northern Adriatic Coastal and shelf observatory (CNR)

The Northern Adriatic (NA) is an area with an ongoing network of fixed and moving platforms, with a proven extensive observational capability, providing measurements of oceanographic and biogeochemical parameters, covering the whole trophic web, from pico to meso plankton. The observational system, covering the whole Adriatic basin, has been already partially integrated thanks to previous national and international Projects, while the NA sub basin could therefore represent an ideal zone to be considered as a JERICO3 supersite.

Possible Involved partners:
CNR-ISMAR (Institute of marine Sciences), in Bologna, Trieste and Venezia
CNR-IRBIM (Institute for Biological Resouces and Marie Biotechnologies) in Ancona (previously ISMAR)
OGS
CMCC
Institute Ruder Boskovich (Croatia)

The observing system

	MAMBO (*)	**PALOM A**	**Acqua Alta**	**S1-GB**	**E1**	**Tele-Senigallia**
Type of structure	Oceanog. buoy	Dynamic pylon	Oceanog. platform	Dynamic pylon	Oceano g. buoy	Pylon
Continuous measurements						

Meteor ologicalparam. (air T, wind speed and direction, solar radiation, humidity, …)	x	x	x	x	x	x
pCO_2	x	x				
pH	x	x				
Pressure	x	x	x	x	x	x
Temperature	x	x	x	x	x	x
Salinity	x	x	x	x	x	x
Dissolved oxygen	x	x	x	x	x	x
Clorophyll-fluorescence	x		x	x	x	x
CDOM				x	x	x
Turbidity	x		x	x	x	x
Nitrate					x	
Currents speed-direction			x	x	x	x
Waves height			x			
Hydrophone		x				x
Discrete sampling						
Chemical parameters	x	x	x	x	x	x

Zooplancton	x	x	x	x	x	x
Phytoplancton	x		x	x	x	x
Microbiology	x		x			x
Benthic Foraminifera				x	x	

(*) Possible collaboration with OGS

Tab 1: Data gathered at the proposed fixed observatories in the Northern Adriatic sea

Fixed stations

CNR (ISMAR and IRBIM) operates five main oceanographic fixed stations in the NA (Tab 1) that acquire meteorological, physical and biogeochemical parameters, transmitted and published on line in real time. All the stations operated by CNR in the Adriatic, have been integrated in the RMM network (Meteo Marine Network http://www.ismar.cnr.it/prodotti/condivisione-dati/rete-meteomarina) that provides real-time interoperable and Qality Controlled open data.

Moving platforms

Since 2003, CNR-IRBIM of Ancona (formerly known as CRN-ISMAR) is running a program aimed at using Italian fishing vessels as Vessels Of Opportunity (VOOs) for the collection of scientifically useful datasets. In 2013, a new "Fishery & Oceanography Observing System" (FOOS) was conceived. Nowadays, new sensors for the collection of oceanographic and meteorological data allow the FOOS to collect more parameters, with higher accuracy, and to send them directly to a data center in near real time. Furthermore, the FOOS is a multifunction system able to collect data from the fishing operation and to send them to an inland data center, linking physical and biological data. http://www.ismar.cnr.it/infrastructures/observational-systems/adri-fishery-observing-system/index_html?set_language=en&cl=en

Ecological and biogeochemical time series

Continuous measurements at the fixed stations are integrated by monthly acquisition of discrete samples for chemical and biological analysis (Tab 1) contributing to the continuation of long time series (10-20 years) in the stations' area. Annual and/or biannual measurement campaigns are carried out on physical, chemical, biological and biogeochemical parameters in the water column and sediment.

Remote sensing and modelling

The data gathered in the area could be easily integrated by remote sensing and physical/ecological models, with the involvement of colleagues from UnivPM.

Integration of the coastal observation infrastructures and inclusion in a wider context

The whole Northern Adriatic is a marine "macro-site" belonging to the LTER-Italy, LTER-Europe and LTER International network. (https://deims.org/92fd6fad-99cd-4972-93bd-c491f0be1301). Most of the fixed observatory already belong to Research Infrastructures (RI), which are now at various stages of development, but all already officially recognized in the panorama of IR European countries: Danubius-RI, EMBRC-ERIC, LTER-RI, ICOS-RI, LifeWatch ERIC and DiSSCo-RI.

Among them, the PALOMA station, already collaborating in JERICO-NEXT JRAP-5, is the first Mediterranean marine station officially admitted to the ICOS-RI network.

Involved Projects/ Collaborations:

The proposed observational activity is already supported by national and international projects that could operate in collaboration with a JERICO3 proposal to sustain and improve the project results and their diffusion.
ADRIREEF, INTERREG Italy-Croatia;
Ariel, INTERREG Adonio; Project coordinator CNR IRBIM
Dory, INTERREG Italy-Croatia – Standard +;
EAFIR INTERREG Italy-Croatia;
ECOOS, INTERREG Italy-Croatia, project coordinator CNR ISMAR;
ICOS-RI, Integrated Carbon Observing System https://www.icos-ri.eu/
INFORMARE PON-FESR, project coordinator Consorzio ProAmbiente (Tecnopole Bologna CNR) Italy E.R. Region.
ITACA, INTERREG Italy-Croatia
PRIZEFISH, INTERREG Italy-Croatia;
SOUNDSCAPE, INTERREG Italy-Croatia
Watercare, INTERREG Italy-Croatia; project coordinator CNR IRBIM

References/links
MAMBO meteoceanographic buoy Web: http://nettuno.ogs.trieste.it/mambo/
PALOMA dynamic pylon Web: http://www.ts.ismar.cnr.it/node/84
Acqua Alta oceanographic tower (Norther Adriatic). Web: http://www.ismar.cnr.it/infrastrutture/piattaforma-acqua-alta
E1 meteoceanographic buoy Web: http://e1.bo.ismar.cnr.it/perl/e1_home.pl
S1-GB dynamic pylon Web: http://s1.bo.ismar.cnr.it/perl/s1_home.pl
Tele–Senigallia pylon (Central Adriatic). Web: rmm.an.ismar.cnr.it

Document prepared by:
Referents – Contact persons: Carolina Cantoni, Michela Martinelli, Lucilla Capotondi, PierLuigi Penna
Working Group: Carolina Cantoni, Michela Martinelli, Lucilla Capotondi, PierLuigi Penna, Mariangela Ravaioli, Caterina Bergami, Francesco Riminucci, Mauro Marini, Mauro Bastianini, Alessandra Pugnetti, Giuseppe Stanghellini
Institutions:
CNR -ISMAR (Institute of marine Sciences), in Bologna, Trieste and Venezia
CNR-IRBIM (Institute for Biological Resouces and Marie Biotechnologies) in Ancona (previously ISMAR)

7. Acknowledgements

Authors are very grateful for the support and contributions received from:

CIM at IRB, Croatia, Dr. Martin Pfannkuchen, Contribution to the Adriatic part
MSI at Taltech University, Estonia, Dr. Urmas Lips: Contribution to the Baltic part
Utön Ilves ltd, Finland, Ismo Willström, for maintaining observations at Utö Atmospheric and Marine Research Station.