Joint European Research Infrastructure Network for Coastal Observatories

JERICO WP10

D10.1 - Report on Trials and Deployments

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TABLE OF CONTENTS

1. Document Description

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2. Executive Summary

This report provides details on field trials and deployments of Marine Sensing technology by a number of Jerico partners. The report will focus on the trials carried out by various project partners that have included potential new sensors as part of the deployments.

This document describes the various steps involved in the implementation of the call, giving an overview of the proposals that were accepted and indicating how they progressed and documenting the results. This report is closely aligned with Deliverable 3.4 which focuses on sensors which are in pre-operational mode. WP10 is looking at potential development of new physic-chemical and biological sensors which have been tested in the various field trials included in this report.

The objective is to examine the extent that existing technologies can be improved and new technologies can be tested and applied to benefit future coastal operational oceanographic systems in Europe's coastal seas. The Work Package focused on 6 key tasks within the emerging technologies area:

10.1 Monitoring Biological compartments and processes

10.2 Development of new physico-chemical sensors

10.3 Use of emerging Profiling technologies in coastal seas.

10.4 Use of Ships/vessels of opportunity in coastal oceanographic measurements

10.5 Ferry-box Quality Control algorithm development

10.6 Remote Sensing on suspended particulate matter

The various field trials are presented in this report with a focus on different observation platforms and different parameters which will be measured by the various sensors.
Each field trial was assessed using the following headings

- Rationale

- Focus on new trials and experiments
- Instrument set up
- Platform used
- Methodology
- Assessment of the success/failure of trial

3. Trials and Deployments

Introduction:

The Jerico Project is the first step of a pan-European coastal Infrastructure, open to all providers and users. Work package 10 is dedicated towards improvement of existing and emerging technologies on coastal observatories The WP description identified three issues which if addressed would result in a quality improvement of a European Observatory of coastal ecosystems.

- Dealing with the improvements and the development of tools and sensors,
- Dealing with the use and the development of platforms
- Dealing with the establishment of a sound implementation strategy for long-term coastal observatories.

A key element of the work package was to deploy and trial a number of sensing technologies on a variety of different platforms. This deliverable will describe the various deployments carried out by the relevant project partners. A number of trials and deployments were carried out under each task identified under the description of work.

The trails were carried out on platforms that facilitated the optimal deployment of the sensors including emerging profiling technology, gliders and ships of opportunity. Careful consideration was given in the case of each trial to the following:

1. Set of parameters being measured in the trial

2. Key monitoring locations for the trials

3. Sampling strategy both temporal and spatial within the trial sites

3.1. Software Testing and deployment for Monitoring of key biological compartments - WP10 Task 10.1

This trial was carried out by EPOC CNRS.

This task is linked to the set of software development work being completed as part of deliverable 10.2. The plan is to include any related trial data from this work package into this section once received from the partners.

3.1.1. Rationale for trial

Testing and deployment are two important phases when developing software. Software testing allows pointing out any defects and errors that may have been produced during the development of software. This phase aims to assure an effective performance of the software application. After a successful testing the software needs to be deployed under different circumstances. The main goals of the deployment phase include: 1) deploying the solution technology, 2) stabilizing the deployment and 3) transitioning the software to operations. Thus, the deployment phase may include some changes and enhancements.

3.1.2. Focus on new trials and experiments

SpiArcBase has been tested within a dataset of Sediment Profile Images (SPIs) coming from the Rhône river mouth in the Mediterranean Sea (Romero-Ramirez et al., 2013). We present here some of the results from the deployment phase obtained by analyzing Sediment Profile Images coming from the Arcachon Lagoon (French Atlantic Coast). The SPIs from the deployment phase come from an environment very different than the ones from the testing phase.

3.1.3. Instrument set up

Due to the depth of the sampling sites (see Table 1) a light-framed version of the sediment profile imager has been used as sampling tool (Fig. 1). The minimum weight of the standard version is about 300kgs whereas the light-framed version weights about 100kgs allowing for a deployment from smaller boats at shallower waters. Image acquisition is no longer completely automatic (like in the standard version); the profiler needs to be deployed by the operator when the sea-bottom is achieved (similar to a self-portrait mode on a camera). This particularity did not have any negative effect in our acquisition.

In order to consider a SPIs for analysis a good penetration of the prism needs to be achieved:

The sediment-water interface needs to be present on the image so that depths in the sediment can be computed for any found biogenic structure. This might be a problem when sediments are very muddy.

There is enough sediment present on the images, this means that as a minimum the whole apparent Redox Potential Discontinuity (aRPD) can be measured. This might be a problem for sanddy sediments.

Figure 1 Light-framed version of sediment profile imager during sampling acquisition at the Arcachon Lagoon.

3.1.4. Methodology

The Arcachon Lagoon is a macrotidal lagoon of around 180km² located in the south of the French Atlantic Coast. Its heterogeneous nature is translated among others by the size of its sedimentary particles; these can be classed from mud (particle size <63 microns) to coarse sand (more than 500 microns)(Blanchet, 2004). A total of 14 stations at the Arcachon Lagoon were sampled during spring 2011 (Fig. 2). SPI acquisition took place successfully only in 5 of the 14 stations because the penetration of the prism would not be enough at sandy sediments. A total of 57 images (Table 1) have been acquired and analysed with SpiArcBase.

Table 1. Depth, location and number of acquired SPIs at the successful stations.

Station	Depth [m]	Latitude N	Longitude W	SPIs
Lanton	4,5	44°41’862	1°05’087	12
L’ile	7,2	44°42’715	1°10'395	6
Courbey	6,7	44°40’544	1°11’857	12
Tort	2,5	44°42’732	1°06’268	14
Lège	7	44°44'161	1°09'619	13

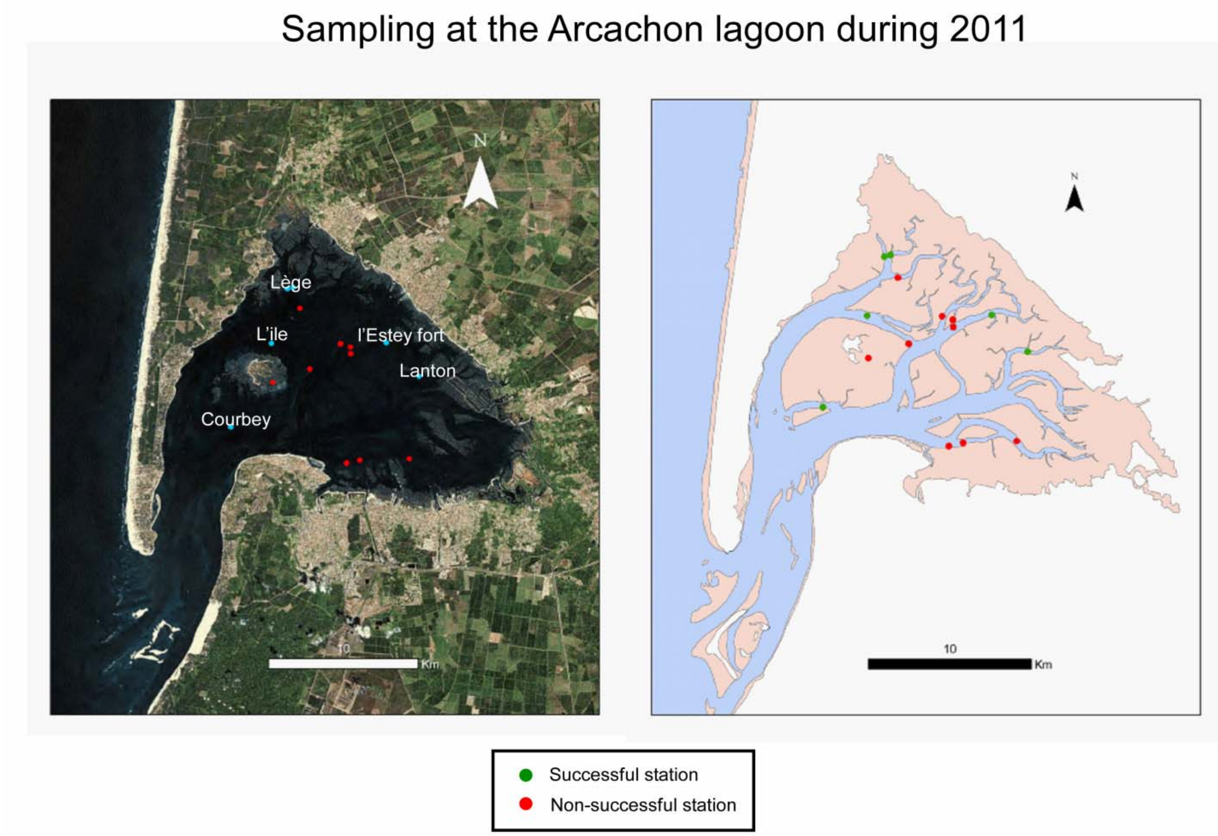

Figure 2 Sampled stations at the Arcachon Lagoon.

3.1.5. Assessment of the trial

SpiArcBase classified biogenic structures into: 1) biogenic structures at the sediment-water interface which includes tubes, feeding structures and epifauna and 2) biogenic structures in the sediment which includes oxic voids, associated to oxic voids, burrows and infauna. SpiArcBase also computed in an objective manner the apparent Redox Potential Discontinuity (aRPD) (Romero-Ramirez et al., 2013)

Taken into account those computed parameters (the biogenic structures found in a SPIs and the mean aRPD depth), SpiArcBase computes the Benthic Habitat Quality index (Nilsson and Rosenberg, 1997). This index provides a first assessment of the ecological status of the habitat quality. The BHQ index varies between 0-15, where 0 implies bad conditions and 15 excellent ones (Rosenberg et al., 2009).

An important step of this deployment phase included the verification of the results given by SpiArcBase with a benthic ecologist and a developer. This step was made image by image. An example of the analysis obtained by SpiArcBase on an image of each successful station is shown in Figure 20, 21 and 22. The image with the highest number of biogenic structures corresponds to Courbey station (Figure 22), whereas Lanton and Tort presented the lowest number (Figure 21). The average of each computed parameter has been calculated at each successful station (Table 2).

Table 2. Mean of extracted features from SPIs analyzed with SpiArcBase.

			Biogenic Structures		
Station	Mean BHQ	Mean aRPD [cm]	Mean number	Mean Surface [cm²]	Mean depth [mm]
Lanton	5,8	3,3	0,41	0,88	17,5
L'ile	4,6	2,1	0,83	1,71	15,6
Courbey	7,6	3,1	1,59	2,02	19,4
Tort	7,1	3,1	0,79	2,45	35,3
Lège	7,7	4,38	0,47	1,48	17,1

These results led to a satisfactory conclusion for this study. Enhancements of SpiArcBase were proposed and consequently developed, especially for the export mode of the analyzed images and its extracted parameters.

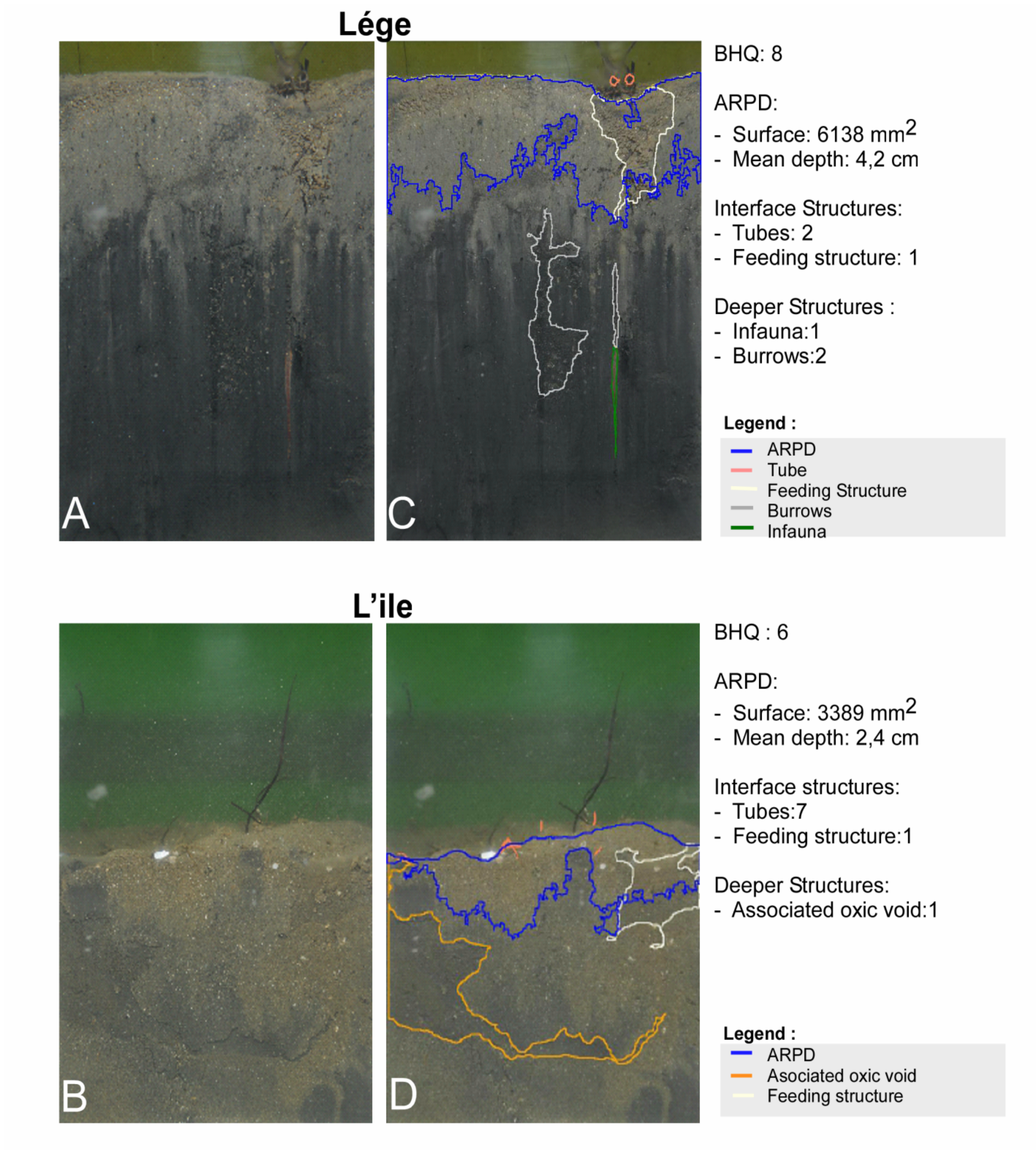

Figure 3 SPIs acquired at Lége et L'ile with a summary of extracted information. A and B) Original SPIs, C) and D) SPIs analysed by SpiArcBase

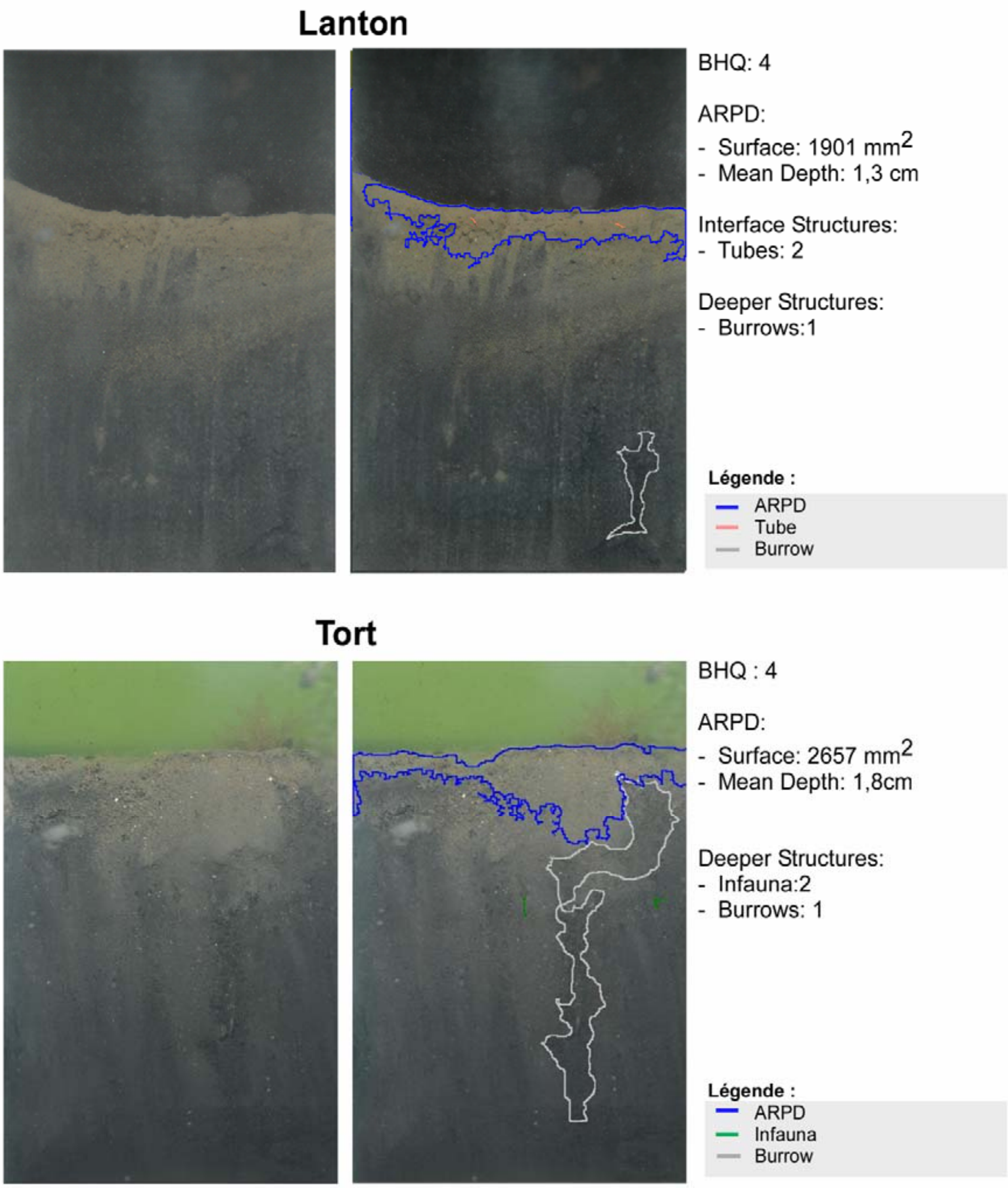

Figure 4 SPIs acquired at Lanton et Tort with a summary of extracted information. A and B) Original SPIs, C) and D) SPIs analysed by SpiArcBase

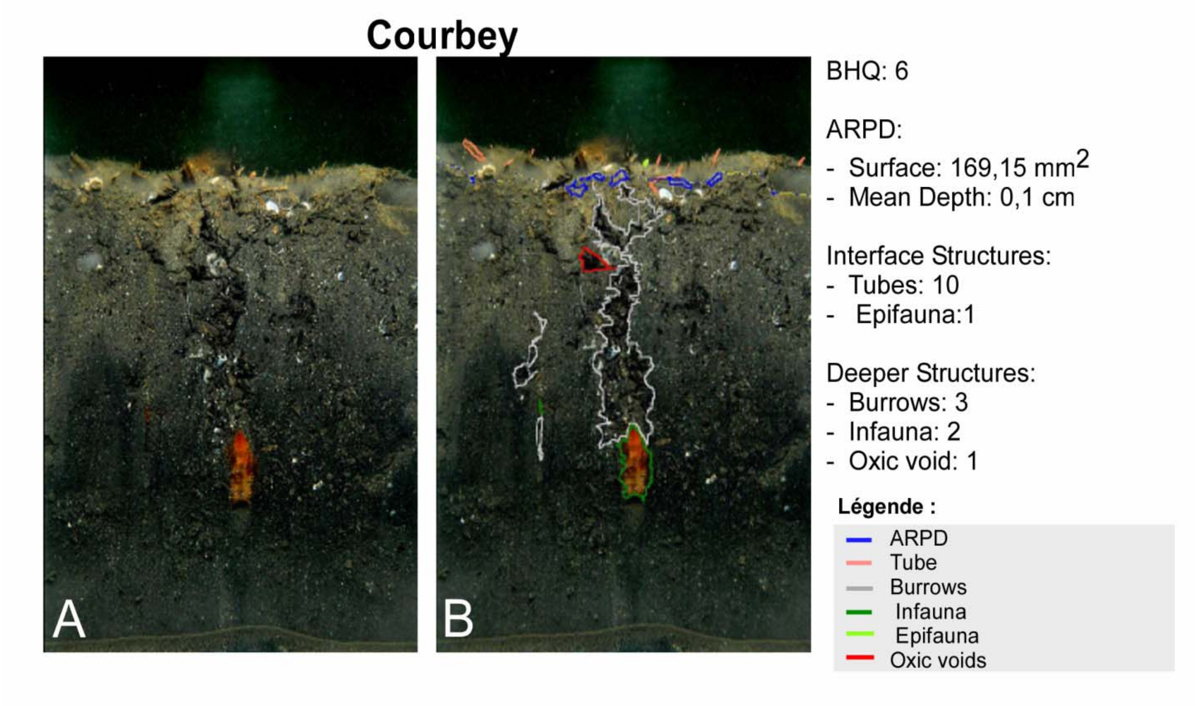

Figure 5 SPI acquired at Courbey with a summary of extracted information. A) Original SPI, B) SPI

A detailed report on the Software used in this field trial is presented in deliverable 10.2 for Workpackage 10.

3.2. Phycoerythrin fluorometry in autonomous monitoring systems - WP10 Task 10.2 Development of new physico-chemical sensors

This trial was carried out by the Finnish Environment Institute SYKE, Marine Research Centre

3.2.1. Background and Rationale

The detection of bulk phytoplankton biomass using online detection of Chlorophyll a (Chla) fluorescence has been carried out for 40 years. Despite the known variability in the ratio between Chla concentration and Chla fluorescence the method provide first order information on the distribution of phytoplankton biomass. The variability between Chla concentration and fluorescence is due to cell physiology, affecting fluorescence yield, and due to differences in the pigmentation of various phytoplankton taxonomic groups. chla fluorescence is a response of Chla pigments located in the Photosystem II in the cells, while Chla pigments located in Photosystem I do not contribute to fluorescence of living cells. In eukaryotic species, the distribution of Chl among photosystems is more or less equal, while in cyanobacteria most of the Chl is located in non-fluorescing Photosystem I. Thus the Chla fluorescence response of cyanobacteria is low and their distribution is poorly detected using *in vivo* Chla fluorometry.

Among other phytoplankton pigments, phycobilins show autofluorescence and their distribution can be tracked similarly to Chla . Operational monitoring of phycocyanin has been done in the Baltic Sea since 2005 (Seppälä et al 2007) and long time series exist also in other locations. Phycoerythrin fluorescence has not been recorded to similar extent, although the importance of this pigment has been known for a long time. While Chla is found in all phytoplankton species, the abundance of phycobilin pigments is restricted to few taxonomic groups only. Therefore they optimally also serve as a marker pigments for the abundance of those taxonomic groups, especially cyanobacteria.

The type and amount of phycobilin pigments vary between cyanobacterial groups. For this reason, the fluorescence wavelengths, and thus phycobilins, to be detected by fluorescence must be selected using preliminary information on fluorescence properties of species in study area. in addition to cyanobacteria, some other phytoplankton groups, like cryptophytes, dinophytes and red algae may contain phycobilins, limiting the specificity of phycobilin fluorometry for cyanobacteral detection.

The Baltic Sea suffer from regular summer blooms of filamentous cyanobacteria. These blooming species are known to have phycocyanin as their major phycobilin, and they do not contain any phycoeryhtrin. Subsequently, monitoring of phycocyanin fluorescence has been operational for 10 years to detect variability of these blooms (Seppälä et al 2007). During summer, picocyanobacteria (<2µm) are very abundant in the Baltic Sea as well. Though they never form actual blooms, they mey contribute to 30-80% of the total phytoplankton biomass during June-August. Their contribution to carbon fluxes and biogeochemical cycles may be even larger than their share of the biomass, as their growth and grazing rates are higher than those of larger phytoplankton groups. Phycoerythrin is the major pigment for open sea picocyanobacteria, and thus phycoeryhtrin fluorescence may be suitable tool to detect their abundance.

3.2.2. Trials and experiments

Though background studies have been carried out to demonstrate the possibilities of phycoerythrin fluorometry in the detection of picocyanobacteria in the Baltic Sea, the operational monitoring is not underway. In this study we tested the suitability of commercial phycoerythrin fluorometer for the detection of picocyanobacteria.

3.2.3. Instrument set-up

Unilux phycoeryhtrin fluorometer is a relatively small instrument with diameter of 26.5 mm and length of 105 mm. It weight 100 g and has pressure housing made from Acetal C. It has excitation at 530 nm and measure emission at 590 nm. Fluorescence data was logged at 1 sec interval, however, a moving average of 20 seconds is used in data analyses.

3.2.4. Platform used

The data presented is collected during a SUPREMO12-2 cruise in the Baltic Sea 11.-17.7. 2012. The cruise covered Gulf of Finland, northern Baltic Proper, Gulf of Bothnia and Archipelago Sea. Phycoerythrin fluorometer (Unilux, Chelsea Technologies Group) was installed in the flow-through system of RV Aranda in 2012 (Figure 1).

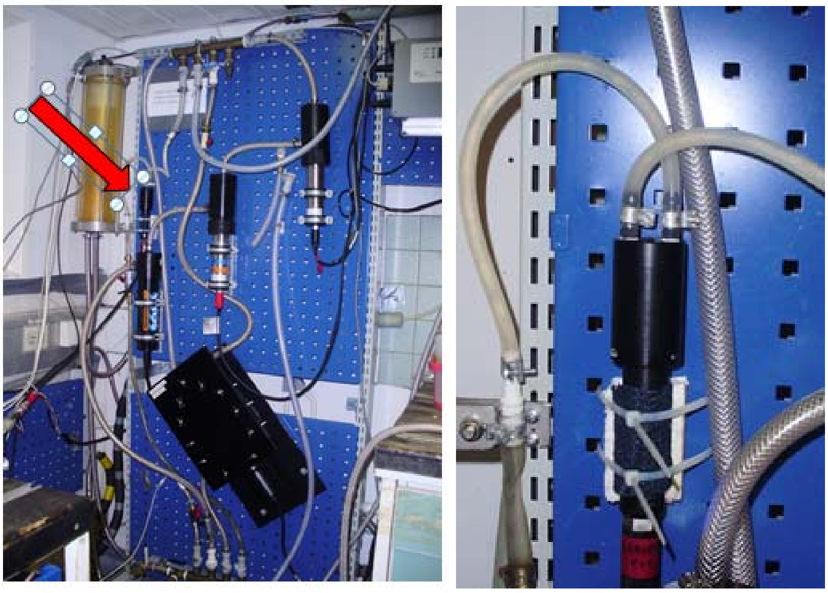

Figure 6 Phycoeryhtrin fluorometer installed in the flow-through system in RV Aranda. Left: red arrow showing the instrument, Right: closer look showing the flow-through cap.

3.2.5. Methodology

In addition to phycoerythrin fluorescence, discrete water samples were collected to analyze in vivo spectral fluorescence properties (Spectrofluorometry, Varian Cary Eclipse)of all phytoplankton pigments. Chla concentrations were measured using extraction methods. Some analyses were conducted from size-fractionated (total and <2 µm) water samples as well.

3.2.6. Assessment of the success/failure of trial

Altogether 24000 measurements of phycoerythrin fluorescence were recorded (at 20 sec interval) during the cruise. The spatial distribution of phycoeryhtrin fluorescence varied 7-fold (engineering units from 0.16 to 1.11) (Figure 2). The highest values were observed at the entrance to the Gulf of Finland and at the northern Baltic Proper. Values at the Gulf of Bothnia were very low.

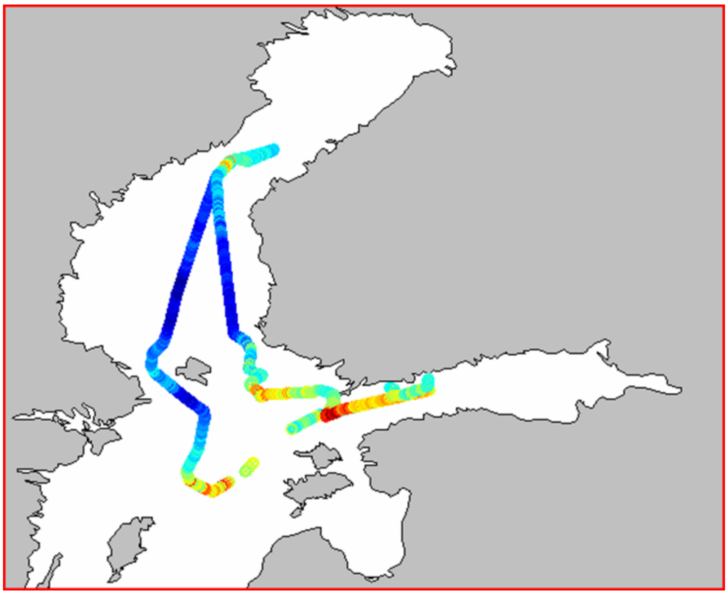

Figure 7. Variability of phycoeryhtrin fluorescence during trials. Low values are in blue, high values in red.

Spectral fluorescence excitation-emission analysis of water samples identified that the phycoeryhtrin peak (max excitation at 560 nm, max emission at 570 nm) in the Baltic Sea is located roughly at the wavelengths used in this instruments (Figure 3). Thus the instrument is optically suitable for the detection of Baltic Sea picocyanobacteria. In other sea areas, with more clear waters, other types of phycoerythrin (phycourobilin forms) may be more abundant and the suitability of the instrument for those conditions need to be tested separately.

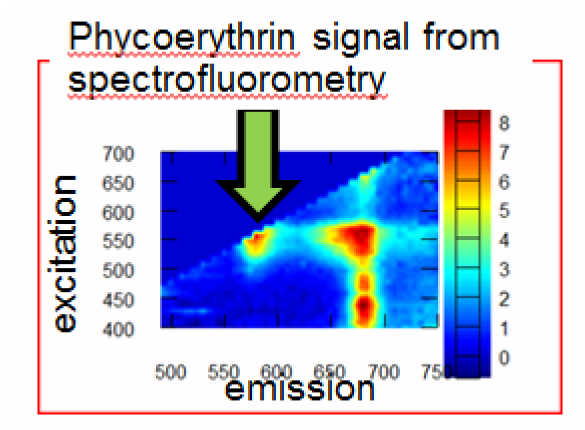

Figure 8 Spectral excitation-emission fluorescence matrix for phytoplankton community measured during the cruise. Besides Chl a fluorescence line at 680 nm, phycoerythrin peak is clearly visible at excitation 560 nm and emission 570 nm.

Fluorescence signal measured with in situ Unilux fluorometer in the flow-through system was compared with spectral excitation –emission fluorescence measurements, by integrating the fluorescence from the phycoerythrin peak (as seen in Figure 3). These two measurements showed similar patterns (Figure 4). The small deviations from linear relationship are most likely due to effect of sampling (not exactly same water volumes were measured) and due to spectral variations between instruments.

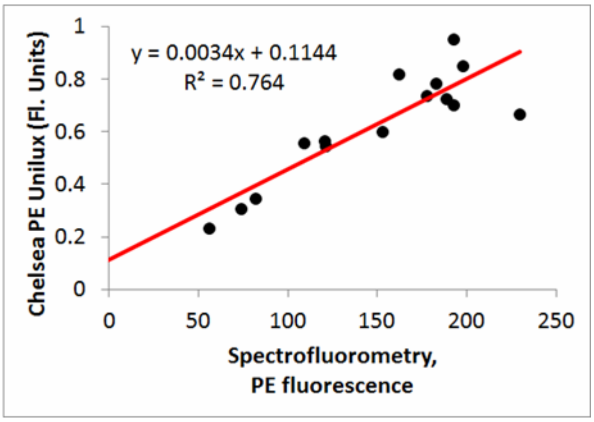

Figure 9 Relationship between phycoerythrin fluorescence as integrated from spectral excitation-emission fluorescence matrix and those measured from flow-through system.

The size-fractionated samples spectral excitation-emission fluorescence showed that >60% of the phycoeryhrin fluorescence signal originate from picoplankton (i.e. picocyanobacteria) (Figure 5). The remaining part of the phycoerythrin signal originates from larger cyanobacteria, cryptophytes, dinoflagellates and ciliate *Mesodiniunm rubrum,* which are the other phycoeryhtrin containing organisms in the study area.

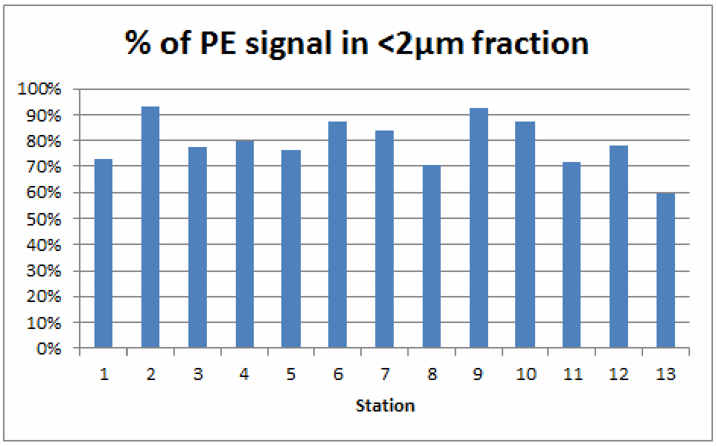

Figure 10 Contribution of picocyanobacteria (<2µm fraction) to the total phycoeryhtrin fluorescence, as measured with spectral excitation-emission fluorescence.

The results obtained show that phycoeryhrtin fluorometry is already suitable parameter to be included in the operational monitoring of the Baltic Sea. The tasks still to be conducted are related to primary calibration of instrument, and validation of field data. Especially we need to collect more detailed information on the phytoplankton species composition, for the species containing phycoerythrin, during phycoerythrin monitoring activities. luckily, other novel techniques, like FlowCAM and automated image regocnision toolpack in epifluorescence microscopy may be used to identify phycoerythrin containing species from the remaining species.

3.3. Fast-repetition rate fluorometry in autonomous monitoring systems - WP10 Task 10.2 Development of new physico-chemical sensors

This trial was carried out by the Finnish Environment Institute SYKE, Marine Research Centre.

Key Personnel: **Stefan Simis, Susanna Nenonen, Pasi Ylöstalo, Mika Raateoja**

3.3.1. Rationale

Primary production measurements of marine phytoplankton using the benchmark technique of 14C uptake are increasingly less common due to the necessity for sea-going laboratories, cost of consumables and trained technicians, and increasing legislative obstacles in using radioisotopes in several countries. Methods to assess photosynthetic parameters and contributing to modelled primary production, which are based in optics are increasingly sought. Examples of such methods are pulsed-amplitude fluorometry (PAM) and fast-repetition rate fluorometery (FRRf). These methods do not generate waste, can be automated and without the need for supervision they offer significant cost-reductions and increased spatiotemporal coverage. FRRf instruments are more costly than PAM but offer a stricter interpretation of photosynthetic parameters. FRRf uses inducible fluorescence to infer electron transport rate for photochemistry at a high time-resolution. It is now believed that a quantum-calibrated FRRf can be used to directly assess gross primary production in terms of fixed Carbon, provided that samples are first acclimated to darkness which allows their full capacity for photochemistry to be measured with the fluorometer (Oxborough et al. 2012, Silsbe et al. in prep).

The estimation of gross photo primary production from FRRf is based on interpreting the fluorescence response to progressively emerging light stress upon the photosynthetic machinery of the phytoplankton assemblage. This stress leads the phytoplankton to exhibit various photo-protective measures and eventually – after the full photo-protective capacity has been exhausted – photo-inhibitory responses. This so-called rapid light curve (RLC) approach is comparable to the collection of P-I (photosynthesis-irradiance) curves with incubators for 14C uptake rate measurements. The result of the RLC measurement with an FRRf is a model of the electron transport rate rather than Carbon uptake.

Within the scope of future MSFD monitoring there is room to consider emerging methods to enhance the efficacy of monitoring efforts. Particularly, activities that allow better upscaling of in situ measurements to large spatial coverage by remote sensing or through ecosystem models are of significant interest in current and future indicator development. Also, methods that allow deeper insight into core indicator responses will continue to be developed. It is therefore expected that optical methods/models to assess marine primary production such as FRRf will rapidly mature in the coming years, to be implemented in regular monitoring practices.

Recently, the EU FP7 project PROTOOL resulted in the first FRRf specifically designed for flow through systems and commercially available as the FFL-40 (Photon Systems Instruments, Czech Republic). This instrument is also the first system designed to follow the optimal optical configuration for phytoplankton communities with a strong cyanobacteria component (Simis et al. 2012), using blue and amber excitation and a narrow emission detection band. The system has built-in support for pumps, valves, temperature control, dark acclimation, and an API for inclusion in an existing sensor platform, such as the FerryBox. The first instrument in this series was delivered to SYKE in April 2013.

3.3.2. Trials and experiments

Here we focus on the implementation and data handling of the first commercially built FFL-40 unit, on MS Finnmaid, a ship-of-opportunity in the Algaline network. During the implementation trial, we focus on the following aspects:

Integration of the FRRf with existing systems

Measurement protocols

Software development for instrument control, synchronization, and data handling

Field tests on the sensitivity of the FRRf during summer 2013

We report here on the first field tests done in summer 2013, the subsequent definition of measurement protocols, and efforts to implement the FRRf measurements in a ferrybox environment. The final effort is still ongoing during spring/summer 2014.

3.3.3. Instrument set-up

The FFL-40 is installed together with a refrigerated water sampler (ISCO 6712) alongside the existing flow-through system in which temperature, salinity, chlorophyll-a fluorescence, phycocyanin fluorescence (in summer) and a separate water sampler are controlled and geolocated using GPS.

As a first implementation activity, a data logging and processing environment was developed for the FFL-40, in the Python language. The instrument is equipped with its own web server and the manufacturer supplies an API for communication with the instrument, for which a wrapper was written. A sampling script further synchronized the start of the FRRf measurement protocol with water sampling, based on predefined sampling station locations, and only outside defined harbour areas. The developed data logging software also implements storage of the FFL-40 results in a local database along with metadata of geoposition, timestamp, and water sample identifiers. The software can run on a FerryBox host computer alongside existing FerryBox software used in Alg@line.

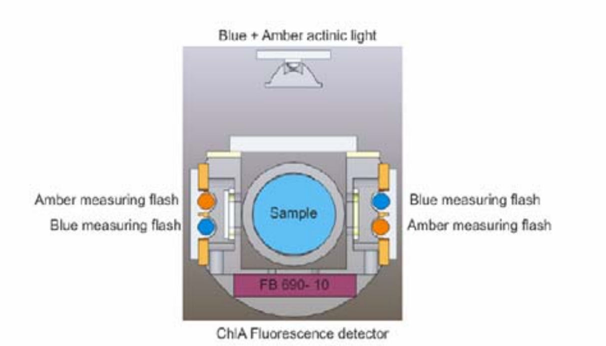

Figure 11 FFL-40 installed in the MS Finnmaid ferrybox and Optical configuration of the FFL-40

3.3.4. Platform used

MS Finnmaid is a roll-on roll-off cargo vessel with two round-trips per week between Helsinki (Finland) and Travemünde (Germany). Occassionally the ship also visits St Petersburg (Russia) or Gdansk (Poland). The ferrybox on Finnmaid is equipped with a washing system that activates in predefined harbour areas. The ferry was visited every 1-2 weeks to collect water samples and to clean the instruments. Besides the ferrybox sensors, Finnmaid was also equipped with an Rflex hyperspectral reflectance unit (http://sourceforge.net/projects/rflex/) which can be used to derive the penetration of sunlight in the sea, a parameter that is required to model primary production from the FFL-40 FRRf results. Here we report only on the implementation period which was supported through Jerico, as analysis of the combined FRRf and Rflex data is not yet completed (and pending further automation).

The software environment developed for the FFL-40 connects to the web server that is part of the FFL-40, and for which an API is provided by the manufacturer, implemented in java. The API functions are called in the Python wrapper through the jpype package. The API supports the loading of pre-programmed measurement protocols, starting/stopping measurements, among other functions. The wrapper also retrieves unprocessed measurement results from the FFL-40 server over SFTP using the

Paramiko package, and inserts both raw and fitted values into the results database through the SQLAlchemy ORM package for Python. LocalDB was chosen as a database in the test setup, although other options are supported. A database, if none is existent, is created on startup. GPS NMEA strings are decoded from the same serial stream as provided to the regular ferrybox environment, to geolocate all measurements. Water samples can be requested after a user-defined date threshold and are taken at programmed stations. In between these stations, measurements continue until the next station is predicted (from gps speed and heading) to come up before the time it takes to complete one measurement protocol. When water samples are not requested, the FFL-40 is triggered continuously.

3.3.5. Methodology

When the measurement start command is sent to the FFL-40, valve switching stops the flow of seawater through the measurement and circulation reservoirs and routes it around the latter for temperature control. The sample is recirculated for 5 seconds between the reservoirs, following every light step. This keeps temperature of the sample regulated in both reservoirs, and prevents settling of particles in the reservoirs. Both reservoirs are exposed to the same actinic light level.

The core of the FRRf measurement is the rapid light curve (RLC), a series of fluorescence induction curves obtained against an increasing background illumination (actinic light). Because the ferry travels throughout the diurnal cycle of the phytoplankton, it is important to assess the photoacclimation state during each measurement. The approach implemented to accommodate this is shown in **Erreur ! Source du renvoi introuvable.**. Each protocol contains two RLCs, each taking only 5 minutes, separated by an assessment of non-photochemical quenching at low, medium, and high actinic light levels and a dark acclimation period. Each RLC is set up with a close to symmetrical increase/decrease in the actinic light dose, so that light acclimation established during the RLC can also be assessed. Throughout the measurement protocol, blue and amber excitation flash trains are alternated, and separated approximately 5 seconds apart.

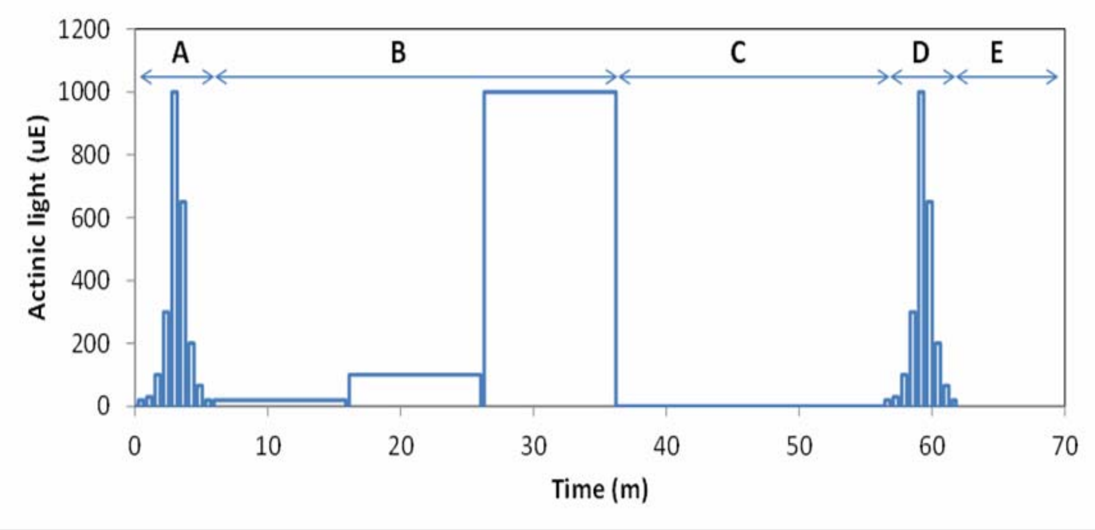

Figure 12 Protocol for FRRf deployment on MS Finnmaid in 2014.

The protocol contains two identical rapid light curves (RLC, periods A and D in graph) with an increasing and subsequently decreasing actinic light dose (5 minutes per step) allowing to assess light acclimation first during the RLC (within A or D), and secondly before (A) and after (D) dark acclimation. Each light step under A and D lasts 5 minutes. Period B is a long (10 minutes) exposure to each of three actinic light intensities to assess non-photochemical quenching in the sample. C is 20-minute period of dark acclimation prior to the second RLC. The system is flushed under period E.

A result set for a single sample is depicted in **Erreur ! Source du renvoi introuvable.**, showing the fitted values of minimum and maximum fluorescences (F_0, F_m), the quantum yield of charge separation (F_v/F_m) at photosystem II (PSII) and the average absorption cross-section of PSII (σ_{PSII}), all for both blue and amber excitation light. In the example shown, non-photochemical quenching was minimal at the start of the measurement, because the two RLCs (A/D in **Erreur ! Source du renvoi introuvable.**) are highly similar and F_v/F_m was at the same level as obtained during the dark acclimation period (C).

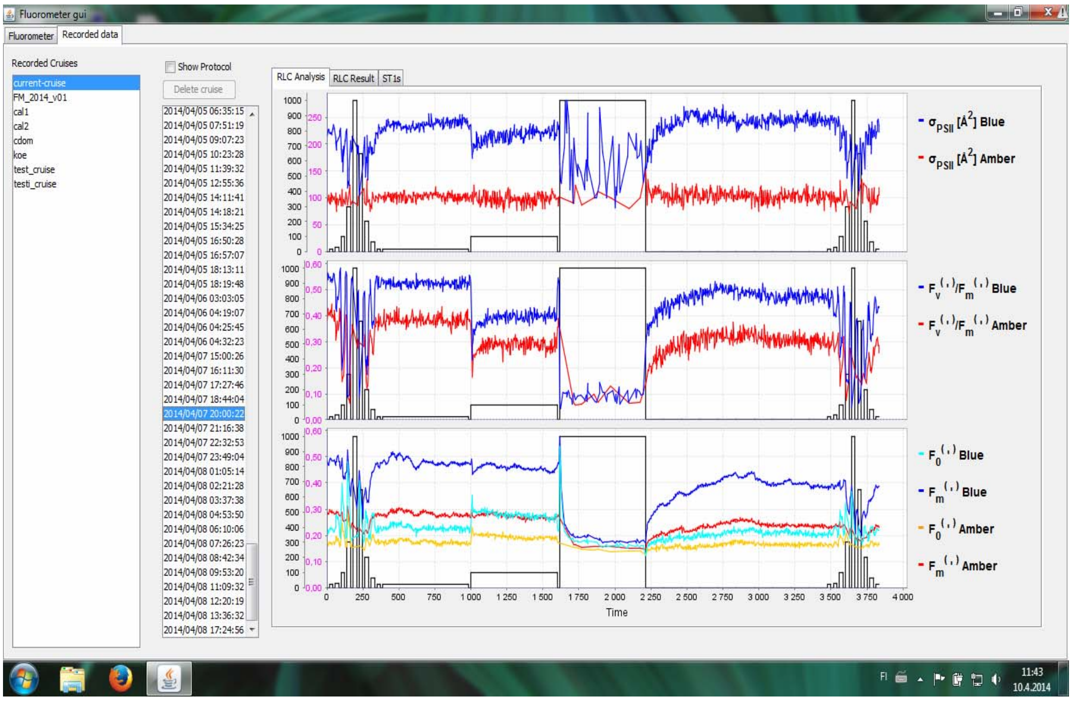

Figure 13 Screenshot of the web GUI of the FFL-40 for a single measurement

3.3.6. Assessment of the success/failure of trial

A simplified protocol was used in summer 2013 to assess whether instrument sensitivity is sufficient to delineate patterns in phyptolankton productivity. This consisted of 10 light steps of 30 seconds each, with 15 FRRf induction curves measured during each light step. The light levels increased from 10 to 1000 µmol quanta m^{-2} s^{-1}. Between each light step, a dark period of 10 s was used, during which 4 FRRf induction curves were measured. The entire protocol lasted approximately 10 minutes.

Fitting of each induction curve is performed by the instrument server, but as an exercise we investigated the raw measurement data to determine any measurement artefacts. The image below shows how the resulting fitted parameters and consequently, the estimates of primary Productivity parameters, are dependent on the recorded signals. By default, all light levels are included in the fitting routines. However, at the highest light intensities, strongly quenched fluorescence signals can introduce noisy data in the fits, and these may be better left out (**Erreur ! Source du renvoi introuvable.**).

Four transects of MS *Finnmaid* in the summer of 2013 (16-17 Jul, 17-18 Jul, 9-10 Aug, and 11-12 Aug) were used to investigate the sensitivity of the instrument to capture the spatial variability in productivity parameters. The diurnal behavior of both the alpha and Pm productivity parameters is obvious from the results of the first transect shown in **Erreur ! Source du renvoi introuvable.** The ambient light environment dictates the light-acclimative state and light harvesting efficiency of the phytoplankton community. It

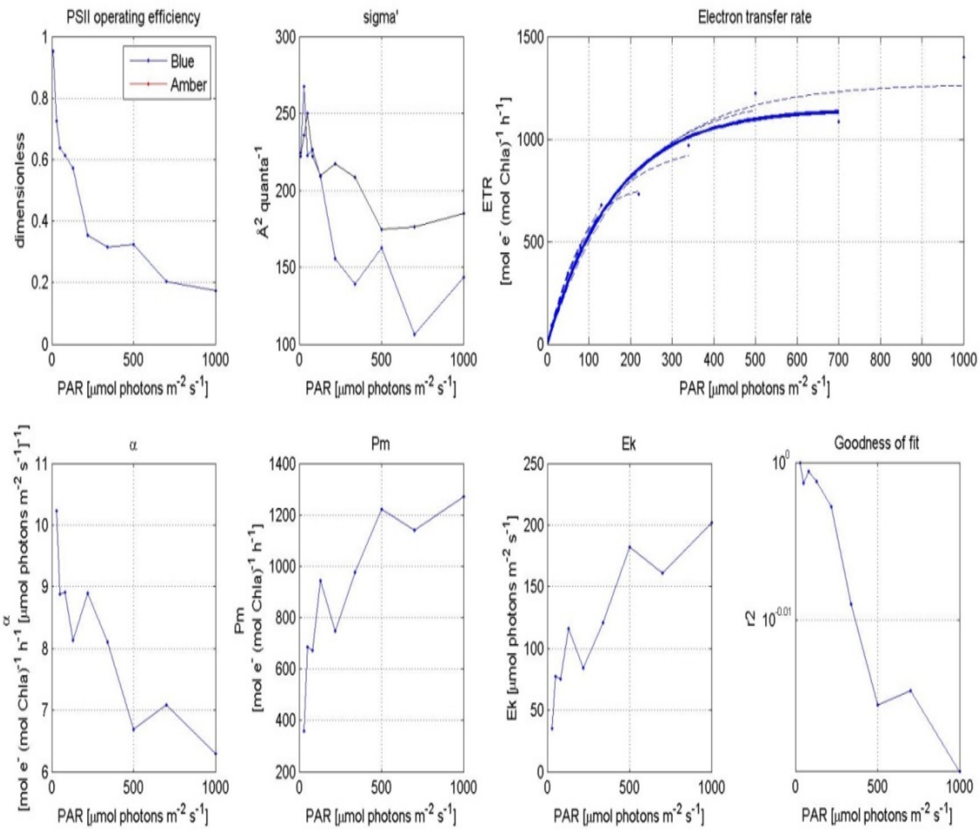

Figure 14 Variations of the fitted RLC depending on the actinic light interval included in the fits.

should be noted that the Reflex light measurements will be better suited to explain variations in the light environment compared to the sun angle used to illustrate light conditions here, however these results are still pending.

3.4. **Report on trials and deployment (NERC) - WP10 Task 10.2.3 Carbon Development of new physico-chemical sensors**

This trial was carried out by NERC.

3.4.1. ***Rationale***

The ocean is directly affected by the accumulation of CO_2 in the atmosphere as it results in a change in the carbonate-system equilibrium leading to a reduction in seawater pH. This chemical change in the sea water has become known as ocean acidification and is a high priority to scientists in order to calculate how much of the CO_2 in our oceans comes from man's activities.

The aim is to develop an accurate and precise autonomous *in situ* pH sensor for long term deployment on remote platforms. The system is based on the spectrophotometric approach implemented on a simple micro-fluidic platform with low power and reagent consumption. A robust optical set up is achieved with the use of a custom-made polymeric flow cell coupled to a three wavelength LED. The measurement is made close to *in situ* temperature (+0.2 °C) in the continuous flow of the ship's underway seawater supply.

In order to understand the dynamics of the oceanic carbonate system high precision pH measurements are required (<0.002 pH units). This report covers a microfluidic spectrophotometric pH system developed by Rerolle (Rerolle et al. 2013) based on the colorimetric method from Clayton and Byrne using Thymol blue as the pH indicator (Clayton and Byrne, 1993).

3.4.2. ***Instrument Setup***

The pH system uses a microfluidic design that includes an absorption cell and a static serpentine mixer that has been fabricated in PMMA poly(methylmethacrylate). The absorption cell is 10 mm long with a volume of 5 µL connected via two optical fibres (600 µm diameter, Thorlabs, USA). A tri-coloured LED is used as a light source with wavelengths of 435 nm and 596 nm, corresponding to the absorption maximum of the Thymol blue indicator forms HI^- and I^{2-}, and a wavelength of 750 nm to monitor the sample turbidity. The detector is a linear array photodiode spectrophotometer (HR4000, Ocean Optics). Fluidics is controlled using two syringe pumps (Harvard Apparatus Nanomite, Kent, uk) via four micro-solenoid valves (LFNA1250125H, Lee Products Ltd, UK) which are mounted on top of the microfluidic chip.

3.4.3. *Methodology and Platform Used*

The pH sensor was deployed on RRS Discovery cruise D366 as part of the Ocean Acidification Research Programme. The automated pH system was operated continuously over a period of a month on an underway water system which had an intake at approximately 5 m deep. The cruise covered coastal shelf waters on the northwest European Shelf and part of the Bay of Biscay, as shown in Figure 1. Surface seawater pH along this transect ranged from between pH 7.995 and pH 8.21 with the highest values in the north sea (north of the UK) due to high phytoplankton biomass and primary productivity resulting in the uptake of DIC. The lowest values were measured in the sea north east of Ireland due to DIC production as a result of the remineralisation of organic matter.

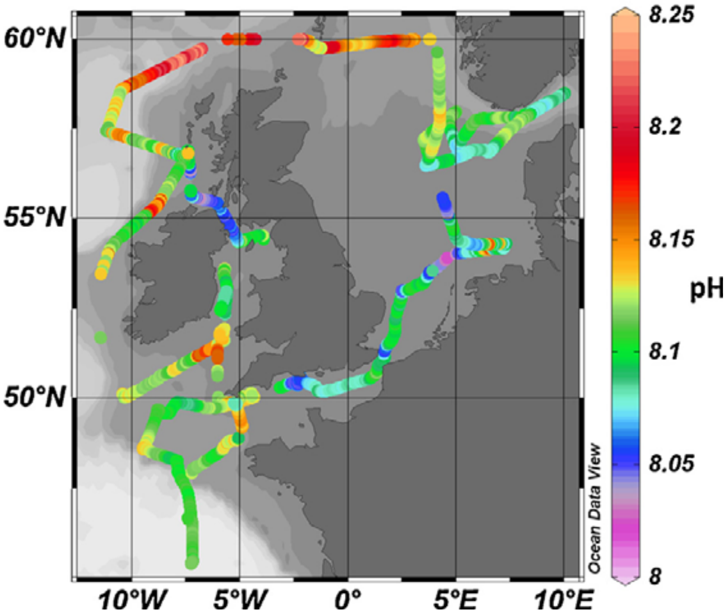

Figure 15 Map of surface water pH_{tot} in European shelf waters determined during research cruise D366. (From Rérolle, 2013.)

3.4.4. *Assessment of the success/failure of trial*

Using the pH sensor a new set of surface sea water pH data was measured in the northwest European shelf waters highlighting the relationship between pH values and biological activity along the transect. Measurements were taken through the summer months of 2011 and it was found that biological activity was the main control of pH distribution.

The performance of the pH system was evaluated using certified TRIS buffer at 25.02 ± 0.01 °C. The short term precision was 0.001 pH unit (n = 20) and accuracy within the range of a certified Tris buffer (0.004 pH units). One of the main advantages of using the microfluidic system was that over a month deployment only 30 µL of indicator was consumed which is a major advantage for long term deployment of these type of systems using a ferrybox or a mooring buoy.

The cruise report was published in 2013 (Rerolle, V. M. C.; Floquet, C. F. A.; Harris, A. J. K.; Mowlem, M. C.; Bellerby, R. R. G. J.; Achterberg, E. P., Development of a colorimetric microfluidic pH sensor for autonomous seawater measurements. Anal Chim Acta 2013, 786, 124-131.)

3.5. Emerging technology: profiling technology, inter-comparison with mature technology WP10 Task 10.3 Use of emerging Profiling technologies in coastal seas.

This trial was carried out by OGS (Istituto Nazionale di Oceanografia e di Geofisica Sperimentale)

Key Personnel – Rajesh Nair

3.5.1. Rationale

To be effective, coastal observatories have to provide comprehensive observations of the coastal marine system. This means that measurements of state variables need to be made not only at and above the sea surface but, more importantly, below it, also. Usually, however, it is customary practice to obtain this required water-column information by regularly visiting and sampling multiple locations, including those of key observatory elements, according to some prearranged sampling plan. Measurements are usually made using manually deployed automatic measuring devices - a hydrological probe or fluorometer, for example - and/or by analysing suitably collected water samples either on-site or later in a land-based laboratory. The obvious drawback to this way of operating is the lack of sufficient temporal resolution and the inability to track rapid changes in water column properties at the scales necessary to follow evolving phenomena of interest.

In situ profiling sensor systems can help to integrate indispensable information on water column characteristics in the coastal seas. So far, however, such profiling technologies have chiefly emerged as buoy-based systems, chiefly because buoys have historically been the mainstay of many marine observing networks. Despite their utility, the use of similar systems has not spread widely. Some of the reasons for this are that they are quite expensive, tend to be power-hungry, and often require continuous and regular maintenance, thus adding to operational costs.

There is therefore a clear need to find low-cost alternative solutions to fill this evident technological gap. Instrumented coastal profiling floats could offer one such solution. As profiling sensor packages, they offer many advantages. They are relatively cheap, more self-contained, require little maintenance, can transmit data in real-time, and are easy to handle. At their current state-of-the-art, such floats may not pack many sensors presently but it is to be expected that this situation will certainly change in future. Considering all these factors, testing the possibility of using a tethered float as a substitute for a profiling buoy was thought to be well worth evaluating.

3.5.2. Focus on new trials and experiments: the Adriatic Sea Experiment

As part of a field evaluation of moored profiling technology, an inter-comparison of temperature and salinity profiles obtained using two kinds of moored profiling CTD systems, an autonomous buoy-mounted profiler and a tethered profiling float, was planned in the northern Adriatic Sea in the Eastern Mediterranean (Figure 1). The experiment called for deploying an nke ARVOR-C tethered profiling float, that was provided by IFREMER, alongside one of the Mambo-type profiling buoys operated by the OGS in the area. It was set to start in October 2012 but the designated Mambo buoy was severely damaged in early November 2012 by a very bad weather event and had to be brought ashore for repairs. However, it was possible to salvage the buoy's controller and profiling apparatus. These were inspected in the laboratory, tested, and then mounted on another buoy operating in the same area during the last week of April 2013. The operation of the salvaged systems on the new buoy was closely monitored during the following months until November 2013 when the experiment was finally initiated.

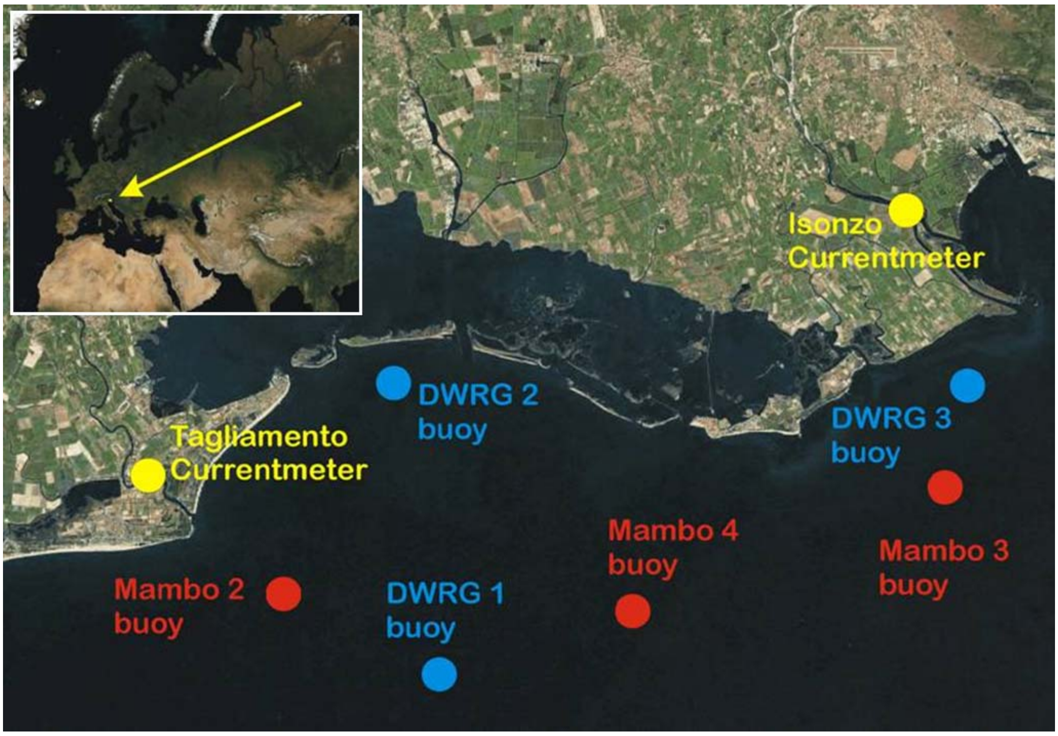

Figure 16: The area where the Adriatic Sea Experiment was carried out showing the different elements of the OGS monitoring network there; the tethered ARVOR-C profiling float used in the Experiment was tethered close to the indicated Mambo 3 buoy.

3.5.3. Instrument set up

The MAMBO monitoring buoy essentially consists of the following principal elements:

- an anchored buoy composed of a toroidal steel float with a superstructure, ballast, anchors, an electrical power supply system and signalling devices;
- a measurement module comprising an on-board controller, a meteorological station mounted on the superstructure, and a profiling system constituted by a winch and a multi-parametric hydrological probe;
- A Nortek AquaPro acoustic Doppler current profiler (1MHz).

The superstructure consists of an aluminium tripod tower bearing two flat triangular stands which function as supports for instrumentation and other accessories; the lower one contains the winch and wire-guide of the profiling system, the controller and a voltage stabilizer while the upper one holds the meteorological station and signalling devices. The profiling system is composed of two main elements:

- the winch;
- an Idronaut Ocean Seven 316 multi-parametric hydrological probe.

The winch, possessing an internal slip-ring, consists of a motorized drum wound with a coaxial cable (25 meters of 7 mm or 200 meters of 3.2 mm cables) which is directed down to the level of the sea-surface while in operation by two pulleys and a cable-guide. The position and angle of inclination of the upper pulley, directly in front of the winch, can be adjusted manually. The winch can support a load of about 20 kg, and its velocity - ranging from 0.5 to 15 cm/s - can be regulated in steps of 0.5 cm/s. The Idronaut probe provides measurements of various standard hydrological parameters: conductivity, temperature, pressure, salinity, pH and dissolved oxygen. It is parked at a depth of 10 m when not in use, and is supplied with a passive anti-fouling system.

The nke ARVOR-C float mounts a SBE 41/41CP CTD module which, when turned on during its ascent phase, samples temperature (T), conductivity (C), and pressure continuously at a rate of 1 Hz. The module is manufactured by Sea-Bird Electronics, Inc., and incorporates their trademark pump-controlled, T-C ducted flow configuration to minimize salinity spiking caused by mismatch of temperature and conductivity measurements. The pump is normally turned off between profiles. The indispensable anti-fouling protection necessary to ensure high-quality data includes anti-foulant devices to minimize bio-fouling of the module’s conductivity cell, a U-shaped flow path, and a programmable pump cutoff setting to switch off the integral pump as the float approaches the sea surface. The U-shaped flow path prevents oils and contaminants from being ingested as the float breaks through the surface skin of the sea. It also prevents water from flowing through the system due to waves or currents while the float is at the surface transmitting the data it has collected.

3.5.4. Platform used

To keep the ARVOR-C float in place, a modular tethering frame was built ad hoc. The frame (Figure 2) consisted of a series of interconnected tubes describing a tetrahedron with a flotation device at each of the base vertices. The float (Figure 3) was attached to a wire running down from the vertex at the top of the structure using a carefully-constructed mechanism that permitted it to move up and down along the cable with changing buoyancy. The wire was ballasted at the bottom to keep it vertical as far as possible despite the motion of the overlying frame at the sea surface.

Figure 17 (a) A close-up of the tethering frame with the float attached to it.(b) The nke ARVOR-C float being readied in the workshop.

3.5.5. Methodology

The tethering frame bearing the ARVOR-C float was to be moored close to the chosen Mambo profiling buoy (Figure 4). The float was to be programmed to profile once an hour so as to be able to provide data in concomitance with the transmissions of the profiles from the buoy which took place every three hours. The data from the two systems were to be supplemented with those from intermittent CTD casts that were to be carried out whenever possible during the period of the deployment.

Figure 18 A view of the float tethering frame at sea.

3.5.6. Assessment of the success/failure of trial

The float with its frame was deployed on 07 November 2013. The float broke free on 15 November under very bad weather conditions, and was recovered. The frame was found to be intact but the supporting wire had snapped, and the fastening mechanism was broken. The mechanism was repaired and the wire was replaced with a stronger one. Other small structural modifications were carried out to render the whole system more robust. The profiles made by the float during its time at sea were downloaded. Subsequently, the unit was re-programmed and re-deployed on 10 January 2014 despite the continuing bad weather. On 17 January, the same thing happened again. This time, the float was recovered and sent back to IFREMER after downloading all its stored data. The buoy controller had failed, too, for some reason, during both periods, so no buoy profiles were available for comparison. Notwithstanding the several setbacks, the trial can be considered a partial success. When the float was operational, it did profile regularly, holding its position. It is clear that the tethering frame needs more work, in terms of both the design as well as the kinds of materials that were used, in order to make it able to weather really harsh sea conditions. The information gathered during the sea trial that was performed has provided valuable insights on the nature of the problems to be faced, and has helped to formulate new ideas for the further development of the system.

3.6. Ships of opportunity/Next Generation fishing vessel probes - WP10 Task 10.4

This Trial was carried out by IFREMER

Next Generation fishing vessel probes

Considerable progress was reported for the Italian Fisheries Operational Oceanographic System (FOOS) where equipping fishing vessels with sensors (e.g. temperature, salinity, catch weight and net drum rotations) is becoming a mature and well understood technology. The focus is shifting towards making useful products for fishermen from the data collected from sensors on board fishing vessels.

3.6.1. Rationale

Faced to the lack of data to assess precisely the spatial distribution of catches and fishing effort and for the environmental characterization of the fishing area, Ifremer has been implemented the Recopesca project. The project consists in fitting out fishing vessels representative of the whole fishing fleet with sensors on the fishing gears and aboard the vessel itself. These sensors record data on fishing effort (and at mid-terms catches) and physical parameters such as depth, temperature, salinity or turbidity. Recopesca aims at setting up a network of sensors, for scientific purposes, to collect data allowing improving resources assessment and diagnostics on fisheries, as well as environmental data required for an ecosystem approach to fisheries.

Moreover, the local environmental conditions and their variability, especially on the continental shelf, are often insufficiently sampled, mostly because of the specific conditions: low depth, significant current (especially tidal current), various human activities (professional and recreational) making vulnerable the measure devices. Thus, even for basic parameters such as temperature or salinity, most of the available measures are limited to oceanographic campaigns.

Recopesca is a concrete achievement of participative approach: scientists and fishermen team up to give to the voluntary fishermen a role of scientific observer. It provides an innovative tool to collect data. The collected data can be used by both fisheries scientists and physicists, who dispose of information for areas non- or little-accessible till now.

3.6.2. Instrument set up, platform used and Methodology

Recopesca constitutes an innovative tool to collect data and contributes to supply the existing information systems. It must be considered as a means and not as a goal in itself.

The physical environmental data of Recopesca are used for operational oceanography studies or hydrodynamics models. They represent an important perspective of vertical profiles even near the coast and on large areas.

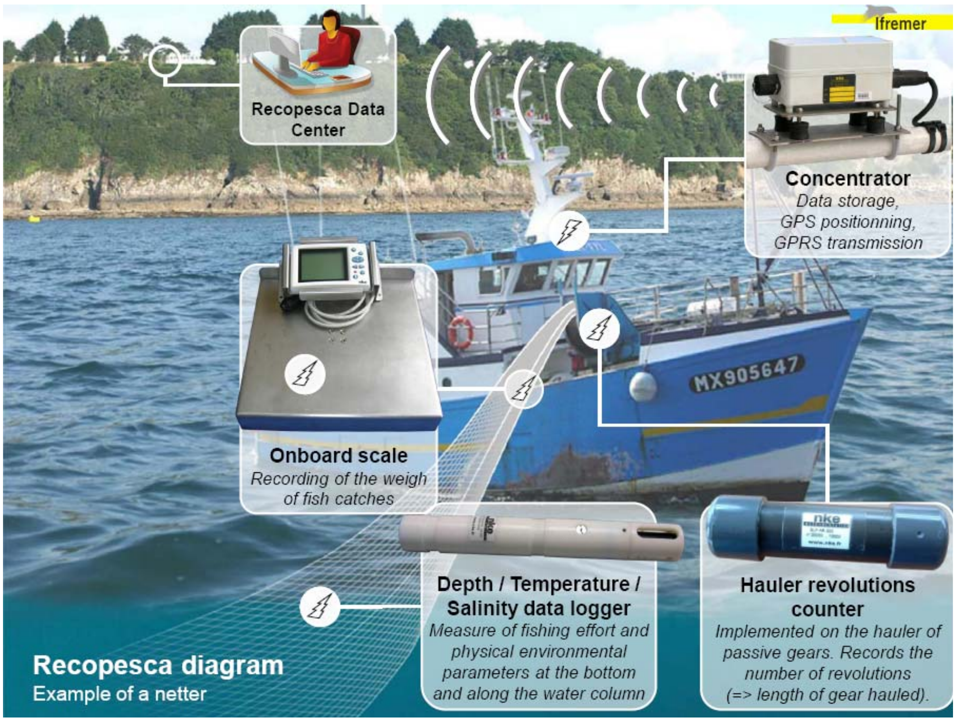

Figure 14 Recopesca Diagram – example of a netter

The fisheries data (activity, fishing effort and catches), resulting from direct measures, and no more from fishermen's declarations or estimation by survey, supply the Fisheries Information System of Ifremer. Moreover, the association of the different Recopesca sensors and devices allows linking fishing effort and catches at the finest scale of the fishing operation. Through the FIS, the fisheries Recopesca data can contribute to the whole fisheries research projects, especially in the framework of an ecosystem approach to fisheries, and assessments. They are complementary with log-books and VMS data.

The Recopesca observations are restricted to limited regions with a good temporal frequency. It allows a seasonal to annual monitory depending of fishing activities of the basic hydrological parameter. It gives a description of the whole water column, from the surface to the bottom. It allows a first monitoring of the bottom temperature which is of great importance for the analysis of the benthic ecosystem and the repartition of demersal and benthic fishes.

3.6.3. Assessment of the success/failure of trial

The Italian FOS has been upgraded in FOOS: Fishery & Oceanography Observing System. The FOOS is a multifunction system able to collect data from the fishing operation and send them to an inland data center, but also to send back to the fishermen useful information (forecasts etc..) through an electronic logbook with an ad hoc software embedded. In addition to other sensors and the capability to record catch data, the FOOS incorporates part of the Recopesca system (TD and CTD recorders and an ad hoc modified version of the NKE hub).

The FOOS implementation allowed a spatial extension of the monitored area and the installation on various kind of fishing vessels such as coupled pelagic trawlers, bottom trawlers, purse seiners etc. This point is of particular interest because of the multiplicity of fishing gears used in the Mediterranean and the variety of target species. The possibility to collect more parameters such as chlorophyll proxies and oxygen would be very useful both for the possibility to put these indicators in relation to fish biomass and for the opportunity to implement oceanographic daily observations, allowed by fishing fleets, already well known as vessels of opportunity. The real challenge is to be able to produce probes with a limited cost, accurate and able to be mounted on fishing gears.

We invite the reader to consult **Jerico deliverable 10.4 "Report on potential new sensors for ships of opportunity, including fishing vessels".**

3.7. Ferrybox QA algorithim - WP10 Task 10.5

3.7.1. Rationale

The huge amounts of FerryBox data require a reliable real-time data quality control and adequate data storage and data handling tools (e.g. relational databases, web-based visualization tools). In task 10.5 algorithms for optimizing the FerryBox data-processing are developed in order to facilitate the utilization of the data e.g. by models through data assimilation.

At HZG real-time flagging algorithms are developed according to MyOcean/SeaDataNet flagging scheme and to the recommendations of the DataMEQ group (EuroGOOS). Date are checked for spikes, frozen values, global range etc. Subsequently these qualified data are transferred to a MyOcean ftp site in near real-time. Currently these flagging algorithms are limited to physical parameters (S, T, Turb, DO). For delayed mode algorithms are partly available in MatLab code (Mark Hartman, Southampton) for use also by other partners. Next steps will be to develop common criteria for all FerryBox data, to make the checks more specific (e.g. including regional climatology) and also to include more biological parameters such as chlorophyll-a etc.

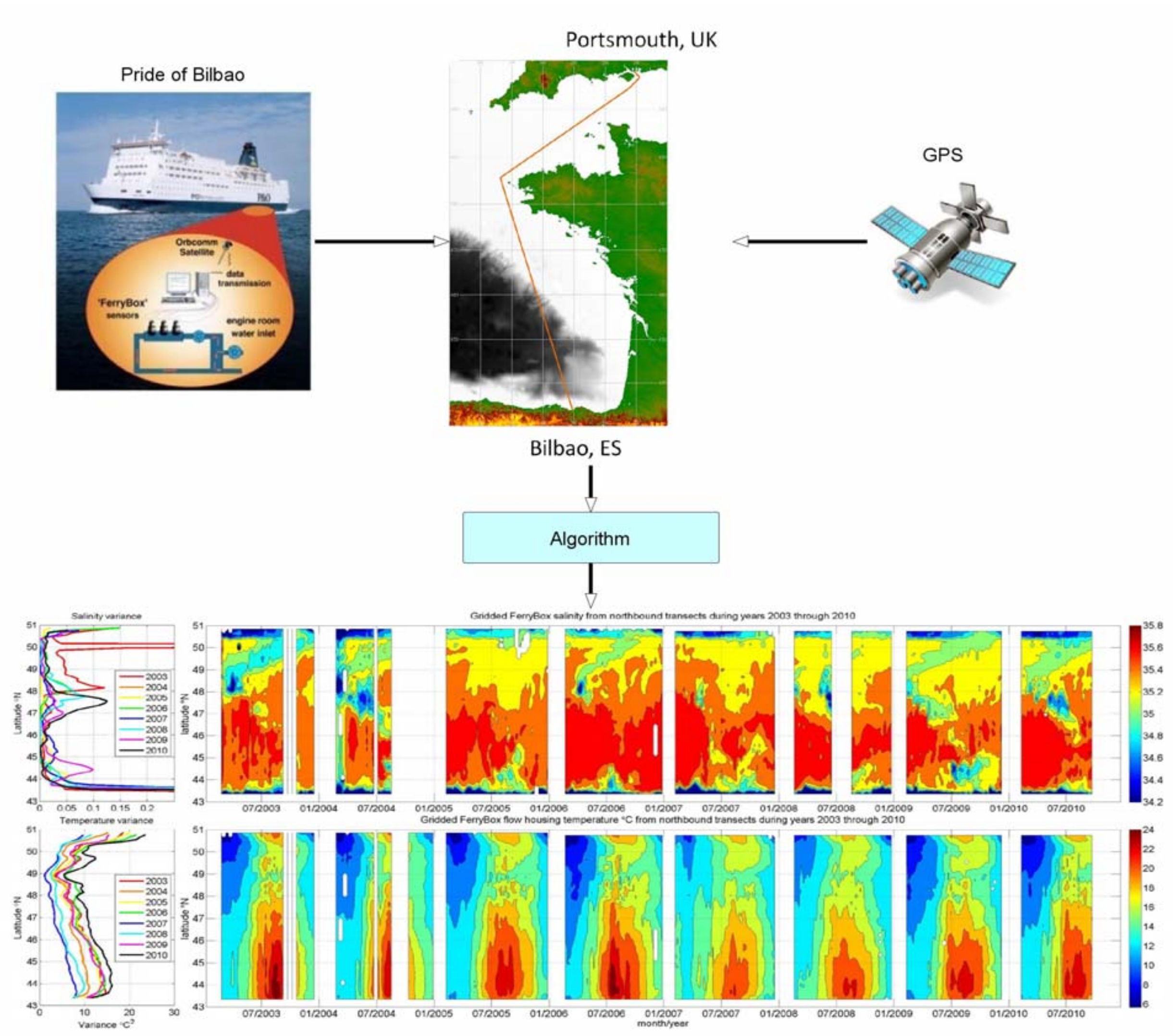

Figure 15 Schematic of Ferry Box system Algorithim application.

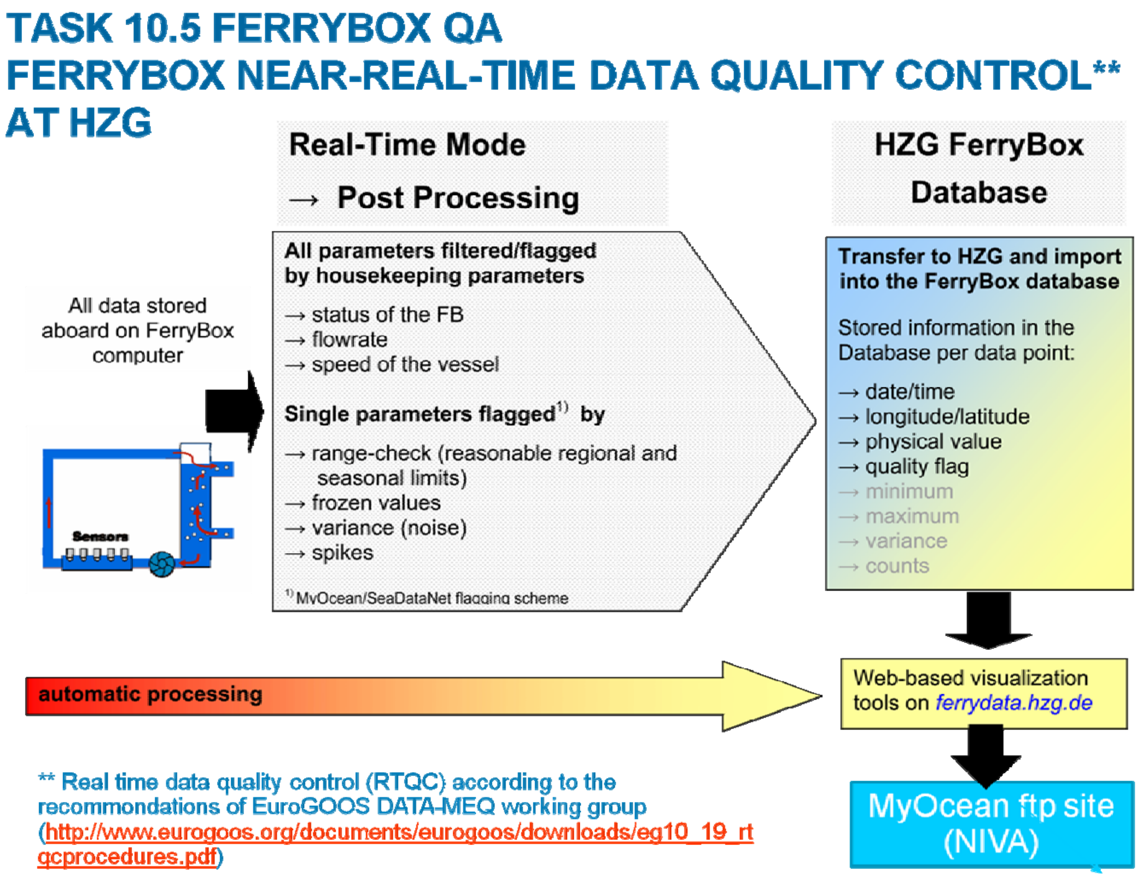

Figure 16 Schematic of Ferry Box real-time data flow and quality control.

3.8. Remote sensing of suspended particulate matter concentration, inter-comparison with smart buoy and benthic lander (RBINS-OD Nature) - WP10 Task 10.6

This trial was carried out by the Royal Belgian Institute of Natural Sciences.

3.8.1. *Background and rationale*

The dynamics of suspended particulate matter (SPM) control processes such as sediment transport, deposition, re-suspension, primary production and benthic communities. Automated tripods or other platforms allow recording of continuous time series of SPM concentration near the bottom at specific sites and are the only method to detect the effects of extreme events (storms) on the SPM dynamics. On the other hand, large synoptic scenes of surface SPM concentrations may be retrieved from satellites. Time series of in situ SPM concentration and satellite imagery are valuable data sources for the analysis of suspended sediment transport in coastal areas. Still, shortcomings remain, with satellite imagery suffering from a low temporal resolution and only related to surface data, whilst in situ measurements have a limited spatial resolution.

Both data can be combined when the vertical variation and the temporal SPM concentration heterogeneity is known. Up to now SPM concentration is measured near the seabed (tripods) and at the surface (remotely). The missing link is the in situ concentration at the surface.

3.8.2. *Focus on new trials and experiments*

The existing gap will be tackled by using a sensor buoy. This configuration will increase the number of match-ups (satellite picture at the same time as in situ measurements), and will allow to establish a relation between surface SPM concentrations, measured in situ (buoy) and remotely (satellite) on one hand, and between the in situ measured SPM concentrations at the surface (buoy) and near the bottom (tripod) on the other hand.

3.8.3. *Instrument set up*

A Campbell Scientific OBS5+ sensor was chosen, capable of monitoring suspended sediment concentration, temperature and pressure. It is a rugged stand-alone system with integrated logger and internal battery powered. A Zebratech Hydro Wiper system was attached to the sensor to avoid bio-fouling as much as possible. The sensor is installed in a stainless steel frame hanging at a depth of about 1.5m. Suspended sediment concentration is measured in NTU, which can easily be transformed in SPM concentration in g/l afterwards.

3.8.4. *Platform used*

In close cooperation with DAB Vloot, the owner of the navigation buoys, the AW-buoy at a distance of about 6 km from the Zeebrugge harbor (51°22.42’N 3°7.05’E - see Figure 1) was selected. The AW buoy (in water depths of ~10 m) was also chosen as it is in the direct proximity of the benthic tripod frame location MOW1 (51°22.04’N 3°6.95’E, measurements since 2005 and continuous since 2009).

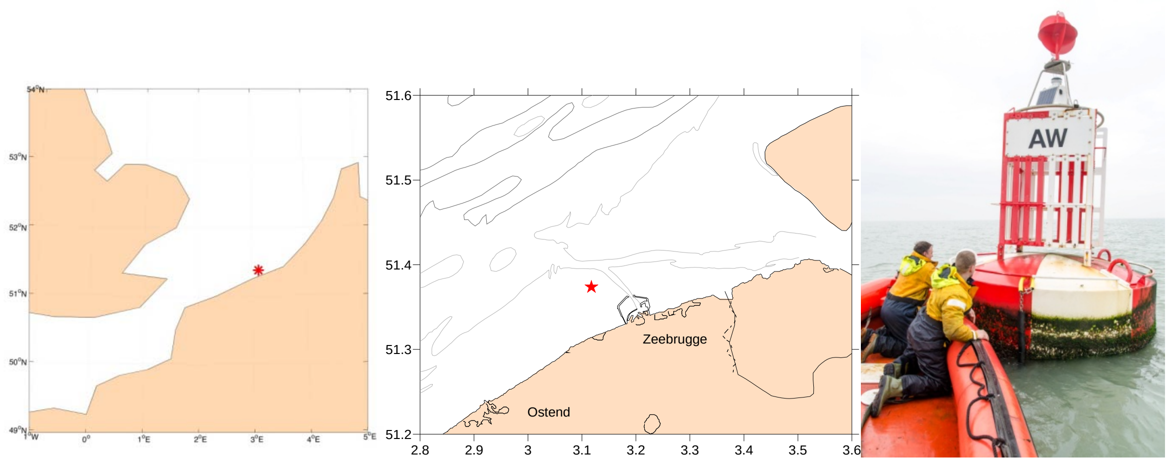

Figure 17 Location of the OBS-5 sensor, attached to the AW-buoy (left and middle). Picture of AW buoy with sensor attached using D-ring (right)

3.8.5. *Methodology*

Both in situ and in lab sensor calibrations were performed (Task 2.2), together with burst sampling over long enough time guaranteeing qualitative SPM concentration data (Task 2.1). The OBS5+ measures in bursts of 10 s at 25 Hz, every 10 minutes. The large data and battery capacity, together with the sampling scheme permits measurement periods up to several months.

3.8.6. *Assessment of the success/failure of trial*

The turbidity sensor has been collecting data since end of September 2013 and has witnessed several interesting events (see figure 2).

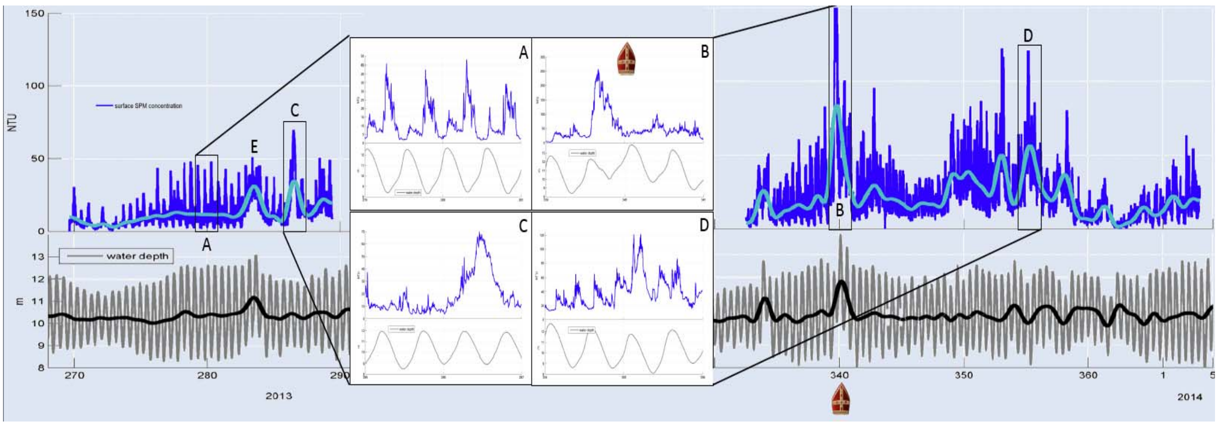

Figure 18 Time series of SPM (in NTU) and water depth (in m) at AW buoy. A, B ("Sinterklaasstorm"), C and D show details of events during the deployment.

Tidal forcing, without wind forcing, typically results in 2 SPM concentration peaks per tidal cycle - one peak around high water (HW) and one around low water (LW). Concentrations vary between 0.5 and 50 NTU, with higher value ranges during spring tides (>3.6 m tidal amplitude) and the smaller ranges during neap tides (<3.6 m tidal amplitude). As shown in A (spring tide conditions and low wind conditions), the peak around high water is much lower (4 x) than around LW, and is 1 hour behind. For all SPM peaks (A), one observes that there is an immediate increase followed by a gradual decrease. In B, a storm ("Sinterklaasstorm") is characterized with highest SPM concentrations recorded so far (up to 250 NTU). This storm was a SW storm (waves up to 3.5 m) followed by a N storm (swell waves up to 5 m). The first part deals with highest concentrations, whereas the NTU values decrease under swell wave conditions. However, for period E similar swell wave conditions were recorded and the set-up is 1 m less, but the concentrations remain relatively low. Time period C corresponds to a SSW wind forcing enhancing the flood current and as a result, a short-term increase (up to 70 NTU) is recorded. Note that this meteorological condition implies higher concentrations than those under swell event E, even though the waves are 2 times higher during E. A possible explanation is the vertical mixing of the water column that is less during swell waves, and this in combination with a coastal set-up. Under W-SW-SSW wind forcing, increased flood currents (no associated set-up) tend to better mix the water column. Further, land breeze also increases surface SPM concentration, as shown from day 350 onwards. This wind direction typically induces a coastal set-down. Another explanation is the offshore-directed drift (residual transport) of SPM away from the high-turbidity zone.

The overall conclusion of the first trial is that an optical backscatter sensor instrumented on a surface buoy is a valuable tool towards better understanding SPM dynamics in the high-turbidity area in front of the Belgian coast. Continuous time-series of suspended particulate matter (SPM) concentration near the surface covers a wide range of hydro-meteo conditions. Data analysis reveals that wind forcing is the dominant controlling factor for subtidal SPM dynamics, together with the lunar phases (i.e. spring-neap cycles). Wind direction and speed are responsible for (1) waves, (2) residual flows, and (3) coastal set-up or set-down.

Continuous data give the full picture of SPM concentration variation in the study area, whereas other sensors or platforms (such as satellites, ships) under sample this variability.

4. Conclusions

The deliverable presents detailed descriptions of the methodologies and results of a broad range of field trials and experiments which were designed to highlight the state of the art in coastal observation infrastructure and networks by looking to improve or adapt existing technologies and to trial emerging new technologies for the benefit of costal operational oceanography.

Based on the reports on the trials carried out above the following areas require further consideration by the Jerico Consortium:

- Suitability of the technology to particular applications
- The most appropriate platform to deploy the technology from
- Operational readiness of the technology
- Research and development opportunities (highlighting current gaps)

A workshop was held on October 16th to 18th 2013 at the Villefranche observatory to outline progress on emerging technologies within the JERICO FP7 project (Work-package 10). A particular focus of the workshop was to invite researchers outside the project consortium to:

- Learn of technology developments within JERICO and
- Present results of their own experiments and technology development

The workshop was a mixture of invited talks and practical demonstrations of some of the technologies involved. There were a total of 24 invited talks and 2 additional practical demonstrations.

All the trials included in this deliverable were underway at the time of the workshop and the workshop presented a valuable opportunity for the Jerico partners to exchange knowledge and know how relating to the best practice in the field deployments and trials being carried out.

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