Joint European Research Infrastructure network for Coastal Observatories

Conclusion report on FerryBox systems
D3.5

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1. Document description

REFERENCES

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2. Executive Summary

This report is a conclusion of the documented work that has been done in the context of JERICO work package 3 and parts of work package 4. It gives an overview of the several tasks that have been addressed in the following reports:

D3.1 Report on current status of Ferrybox

D3.4 Report on new sensor developments

D4.1 Report on existing calibration facilities

D4.2 Report on Calibration Best Practices

D4.4 Report on best practise in operation and maintenance

According to the JERICO Description of Work (DoW), the report addresses the Task 3.1 which deals about FerryBox systems. The related subtasks consider the current status (T3.1.1) and Best Practises for FerryBox systems (T3.1.2), the harmonization and merging of quality data (T3.1.3) and the testing of new sensors on board of FerryBox systems (T3.1.4). As the tasks of sensor calibration and Best Practises of operation and maintenance (T4.1 & T4.4) are also closely related to FerryBox, they will be also addressed here.

3. Introduction

FerryBox systems are cost-effective platforms tools supporting the collection of marine scientific and monitoring data. The concept evolved in Europe through the activities of EuroGOOS and the realisation that if a few of the 800 ferries operating in European waters could be fitted with “boxes” of scientific instruments, a valuable increase in observations of some key marine parameters could be achieved (Fischer et al., 2000; Fischer and Flemming, 1999). Ferryboxes would produce a high yield of reliable high-frequency high-quality data along repeated transects, improving on conventional monitoring strategies based on infrequent sampling.

Many technical problems (e.g. power availability, installation and storage space, long-term fouling) typical for fixed and isolated marine measuring systems such as buoys would not be a problem for Ferryboxes. As the measuring device would “come back to the operator”, servicing and calibration could be done directly in a nearby homeport. Moreover, the system and its components would be protected from the harsh marine conditions inside the ship’s hull and thus compared to devices deployed off shore the operating costs of Ferrybox systems would be significantly lower.

These ideas were developed and tested in the EU-FP5 FerryBox project (Petersen et al., 2007). That project included tests on nine different systems and clearly showed that the expectations of such systems were met. The key oceanographic parameters (water temperature, salinity, chlorophyll-fluorescence, dissolved oxygen and turbidity) were easily and consistently observed. It also showed that the basic measurements could be extended to provide information on a wider range of processes.

The instruments were stable and had low maintenance requirements once an appropriate installation had been developed. The period from 2000 onwards has seen a steady growth in the number of Ferryboxes and related deep-sea systems in operation around the world. The potential for considerable further growth has been widely recognised (Borges and Co-

Authors, 2010; Hydes et al., 2010).

The high resolution of Ferrybox systems in space and time can provide deeper insights into marine processes that can be used to better assess the ecosystem and the underlying physical-biogeochemical processes in the marine environment. Special events like intense short-term algal blooms, rarely detected by standard monitoring methods, can be studied in detail and related to variations in influencing factors such as temperature, wind and nutrient load. This information can be used for the further development of ecosystem models. Techniques to assimilate Ferrybox data into numerical models can be used to improve reliable forecasts (Grayek et al., 2011; Stanev et al., 2011). By combining remote sensing imagery with hydrodynamic model transports the 'one-dimensional' view along a ferry transect can be expanded into a 2D spatial view (Petersen et al., 2008; Volent et al., 2011).

Over the years, however, a general need for integration and harmonization of FerryBox activities in Europe was acknowledged especially after the end of the FerryBox project in 2005. Since then, several new FerryBox routes have been established while few were cancelled. Different methods of operation, maintenance and sensor calibration have been developed by the operating institutions. One of the key issues in JERICO, was to document, exchange and harmonize the FerryBox activities. This report will give an overview of the efforts documented in several project reports.

4. Main Report

4.1. Overview of existing FerryBox systems and calibration facilities

4.1.1. FerryBox systems

The FerryBox system is a well-established monitoring device, operated on ships of opportunity (SoO) since more than 20 years. Following on from the successful EU-FP5-FerryBox project (2002-2005), the community has expanded and kept in touch via the web site and conferences at 18-monthly intervals that have attracted attendance from around the globe (these were in Oslo, 2007; Southampton, 2008; Gothenburg, 2010; Hamburg/Geesthacht, 2011; Helsinki, 2013 and Tallinn, 2014). Information regarding on-going activities using Ferryboxes in European Waters can be found on the FerryBox web site - www.ferrybox.org. Details of the current status can be found in D3.1 Report on current status of Ferrybox and e.g. in Petersen (2014).

As of January 2015, a total of 23 Ferrybox systems are in use in European coastal waters, while operators who are partners in the JERICO project run 16 of these. In addition FerryBox systems are operated on research vessels by CEFAS, HZG, MUMM, RIKZ, IMR and NERC/NOC. The numbers of JERICO Ferrybox systems located in each region are: 7 in the North Sea; 5 in the Baltic; 2 in the Atlantic; 1 in the Mediterranean. An overview is shown in Figure 1.

The core FerryBox parameters found in every system are:

- Water temperature,
- Salinity,
- Chlorophyll-a fluorescence,
- Turbidity.

In **Fehler! Verweisquelle konnte nicht gefunden werden.** the most important parameters that are measured on European FerryBox routes are listed concerning the absolute numbers.

Table 1 : Overview of biogeochemical and physical parameters measured on FerryBox systems, operated on European FerryBox routes.

Parameter	Number of installed sensors
Water temperature	23
Salinity	23
Turbidity	17
Chlorophyll-a	18
Dissolved oxygen	9
pH	5
CDOM	5
Nutrients	9
Phytoplankton (water samples)	5
pCO2	5

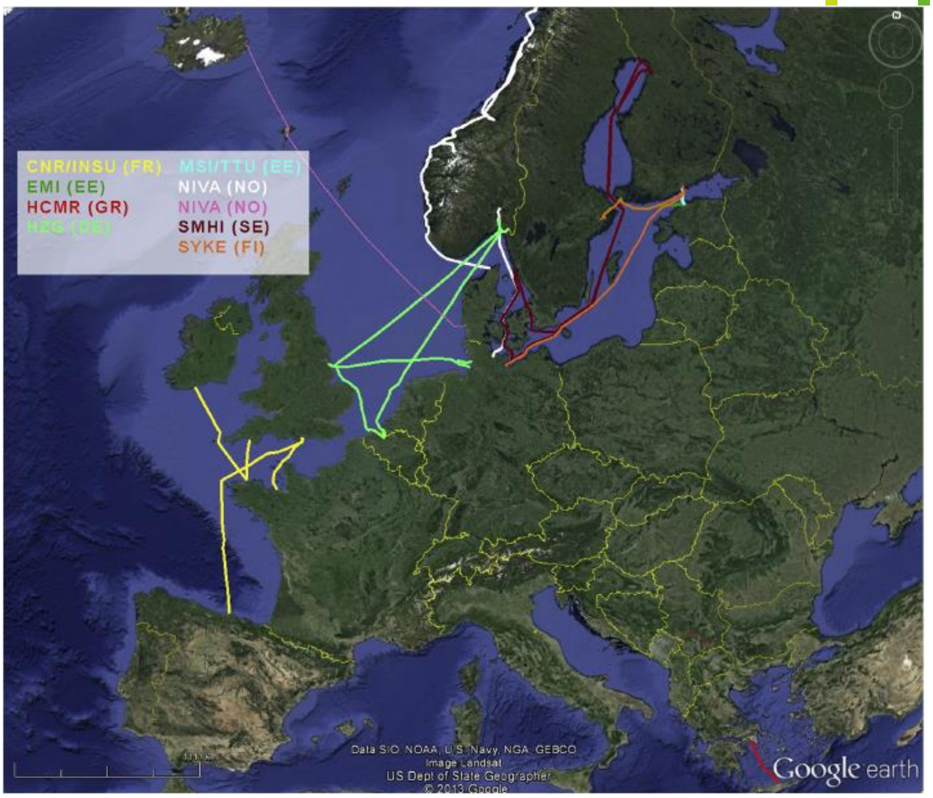

Figure 1 : FerryBox routes currently operating in European coastal waters (effective end of 2014)

Details are given of the methods used by the operators to access data from their systems and the regularity with which this is done. Nearly all users have some form of automated data transmission system from ship to shore. This is done in near real time either by cooperating with the ship's own data transmission systems such as Inmarsat or using a user installed systems based on Orbcomm or Iridium. Other systems use less regular transfer of data done when the ship is in port using mobile phone connection (GPRS or UMTS).

Once received ashore some of these data are immediately displayed publicly in raw form on the operators own website. This allows easy access to the data for all concerned. It also enables the operators to control the system when two ways communications are in place and to regularly monitor the functioning of the system without the need for special facilities or being in a specific location.

One major focus of development in JERICO is to move forward with automatic data checking in real-time. In particular, this is needed for any data that are being fed into MyOcean data base. At HZG real time data control following the recommendations of MyOcean and the EuroGOOS DATA-MEQ group (Data Management, Exchange and Quality Working Group) are looking into near real time quality control for in-situ data (RTQC). These measures will include checking housekeeping parameters such as flow rate, speed of the ship and statistical information (e.g. variance, frozen (unchanging) values etc.) to achieve appropriate quality flagging of the near real time data transferred to MyOcean. This will be done prior to full quality control of the data. More details to data quality assessment can be found in JERICO deliverable D10.3.

Recommendations on the FerryBox installation

- One of the first steps when planning the installation of a Ferrybox system is to approach the shipping company. As in any business relationship, the first contact will be important for the outcome of the collaboration. Contacts should span different levels of the hierarchy. Environmental concerns and IMO regulations with respect to “green” ships mean that many companies are interested in helping when approached. “Web-displays” of data from the systems can be of interest for the company to help promote a good image. Keeping in mind the stability of contacts on board, it is an important advantage if the crew are not changed too often.
- Ship type and its primary use (ferries or cargo ships) will influence where and how easily a Ferrybox can be installed and operated. The water inlet must be ahead of outlets for black and grey water from the ship (sewage and other contamination). Newer ships may provide more and easier possibilities for installing cabling either through appropriate trunking or the existence of ”spare cable runs”. Also on newer ships, where assistance is available from the shipping company, access to the ship’s system signals may be possible (e.g. navigation, gyro etc.). The way the ship behaves at sea may also influence the placement of the Ferrybox installation on board. In the FerryBox community, experience has been gained over many years, so practical advice on different matters can be provided.

- The choice of the route also determines the technical solution needed for any given installation. The main purpose of the Ferrybox installations (monitoring or research) dictates the frequency with which a route needs to be repeated. Short repeat rates of hours to a few days are useful where biological processes are of dominant interest to every few weeks if the main target is changes in the CO_2 system. Long routes will reduce the possibilities to service the system. Short port calls make the servicing difficult and staff may need to travel with the ship to do the work. It is an important factor that the ship stays on the same route long enough for a valid data set to be obtained.

- Adequate space around the system for working and servicing is an important advantage. Too small a space will decrease the ability to service the system and reduce its reliability. The ability to inspect for leakage inside the ship is absolutely critical. Accessibility to the area of the ship where the system is or will be installed is important since heavy parts and/or bulky items may have to be transported during installation or maintenance/replacement activities. Finally, availability of facilities such as fresh water, power and internet/cable runs is necessary.

- There are some more technical aspects to be considered like:
    - water inlet
    - pumping system, valves and pipes
    - choice of FerryBox system
    - electrical considerations, power consumption

Advances in FerryBox activities: Data transfer

At a global and EU level, a number of initiatives now exist which potentially provide an overarching framework for Ferrybox operations and which also need the data collected by Ferrybox systems. At the first workshop of JERICO Dominique Durand (NIVA) gave an overview about the role of JERICO in Operational Ocean Observations, infrastructure projects and related EU initiatives. The role of FerryBox systems in EU project MyOcean has been shown and explained in Jaccard et al. (2011).

The Ferrybox data is acquired from vessels through various sources (mostly ftp servers). Any format of data can be imported, such as ASCII text files or MyOcean netCDF files. After the import and before export to the MyOcean FTP server, all data go through a Quality Control (QC) check - a defined procedure of checking and QC flagging. The netCDF format of metadata, data variables and QC flagging is set by OceanSITES v1.1.

The MyOcean Ferrybox data is provided both as “latest” and as monthly netCDF files. Final archiving of data to be used for example to meet the needs of the Marine Strategy Framework Directive (MSFD) should be linked to the European Marine Observation and Data Network (EMODNet). EMODNet has the potential to link existing and developing European observation systems, by providing a common data management structure across European data centres. This should facilitate long-term and sustainable access to the high-quality data on bathymetry, biological, chemical and physical parameters.

Advances in FerryBox activities: Quality control

Within the structure of the JERICO Project the development of common quality control efforts is shared across the three work packages WP3 (Harmonizing Technological Aspects), WP4 (Harmonizing Operation and Maintenance Methods) and WP5 (Data Management and Distribution).

With respect to the operation of Ferryboxes (WP3) the focus is on the physical-practical activities needed to provide a validation pathway for the measurements that will be reported in the meta data set, such as:

- the use of pre- and post-calibration of instruments either in the home laboratory or by the instrument manufacturer e.g. pCO_2
- validation of measurements through the contemporaneous collection of samples of

water which are then analysed in the home laboratory for the same parameter as is measured automatically in the Ferrybox system, e.g. salinity)

- use of inter-laboratory calibration exercises to cross check between laboratories e.g. annual workshop on chlorophyll-fluorescence instruments organised by SYKE within the work of JERICO. Production of the fully QC'd delayed-mode data activities will be aided by WP5 Task 5.2. This task will also manage the necessary interaction between JERICO and SeaDataNet II.

A basic dichotomy exists in reporting of the near real time data (MyOcean) and the delayed mode data (SeaDataNet) in terms of the time allowed for quality control and the capacity of the receiving system to accept QC-related-meta-data. In the case of MyOcean the capacity is limited while in the case of SeaDataNet the capacity tends to be infinite. In the first case MyOcean sets the limits. In the second case agreement has to be reached between data producers and data users on what meta data is actually needed for a data set to be valid (validate-able) and useful.

For the final reporting of delayed mode data, reporting should follow the best practice being set by global expert activities. The Ocean Data Standards Report is recommending splitting data flagging in two parts. The primary layer must be simple and strictly limited to data quality with unambiguous definitions of flags. It should offer quick access to quality information to assess the fitness for purpose of the data. The second layer provides information justifying the quality flag applied at the primary level and information on data processing history. It applies to all instances where quality flags are used to inform the users of the quality of oceanographic and meteorological data. There are five primary data quality flags, similar to the MyOcean and SeaDataNet flags. The idea is the flag order is monotonic to aid a user. The MyOcean data quality flags are shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Table 2 : MyOcean data quality flags.

Code	Meaning
0	no QC was performed
1	good data
2	probably good data
3	bad data, but correctable
4	bad data
5	value changed
6	below detection limit
7	in excess of quoted value

4.1.2. Existing calibration facilities

The objective of work package 4 was to improve the performance of JERICO observatories and the overall quality of products delivered by project partners. The first steps consist on a survey of the existing calibration facilities amongst JERICO partners to evaluate common practises depending on measuring methods, financial and personnel possibilities. The details are given in D4.1 Report on existing facilities. Differences between the facilities are outlined and discussed as well as possible future steps.

In general, most institutes have some kind of funding (ideally both by institute budget and project funding). However, there are differences in the estimated total amount of the annual budget, ranging roughly from 5000 to 50000 €. The majority does have project and budget funding and also have some funds for upgrading the infrastructure. However, only 4 out of 15 institutes have a constant funding which is rather important, considering that sensor calibration is a routine work. So this is thought to be an issue for improvement.

A second important issue is that some institutes have no dedicated staff for calibration work, even though this is supposed to be crucial for reliable routine sensor calibration. However, half of the partners declared dedicated staff with a clear hierarchy and chain of responsibility, acknowledging the importance of such structure.

The overall reliability shows a wide spread between institutes which can show only features of general calibration issues and institutes which reach highest reliability.

The second part of our analyses on existing calibration facilities evaluates the calibration routines and system for different sensor types. We distinguish between physical, optical and chemical sensors. The JERICO partners have been asked to fill in for each parameter separately. The main topics of this part of the questionnaire are details of the calibration routine like calibration interval, used instruments, field calibration, quality audits etc.

Calibration routines differ strongly depending on the measuring method and platform. Thus, instruments are often calibrated before deployment when installed e.g. on a glider. Other instruments offer the possibility to be calibrated more regularly, e.g. every 2-4 weeks. This seems to be the case for Ferrybox systems. So instruments are calibrated in most cases on occasion. It should be considered to come back to the calibration of sensors depending on what is recommended for that type of sensor.

During the first 18 months JERICO has significantly advanced on the calibration issues through a series of activities, which proved to be particularly successful. Thus, the devoted to calibration sections during the common between WP3 & WP4 workshops in Hamburg, Rome and Palma, the exercises the dedicated workshops for calibration practices for sensor categories (optical, chemical etc.) in Helsinki, Brest and Villefrance and the TNA actions, gave the opportunity to discuss and exchange information on calibration issues across observing platforms. Calibration techniques, problems and challenges for FerryBox, Fixed Platforms and Gliders were thoroughly examined acknowledging commonalities and most importantly differences. Furthermore, dedicated workshops to calibration practices for sensor categories (optical, chemical etc.) were organized. One workshop was held on the 9th of February 2012 at SYKE focusing on optical sensors (Chl-a and turbidity).

4.2. Best practises

4.2.1. Calibration Best practises

The term *calibration* is defined as an operation that establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurements uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication (JCGM, 2012).
Sometimes, however, the word *calibration* is misused to describe the process of altering the performance of an instrument to ensure that the values it indicates are correct within specified limits (e.g. adjusting an instrument until its reading agrees with that of another instrument). Strictly this is adjustment - defined as the operation of bringing a measuring instrument into a state of performance suitable for its use - and not calibration, although the nature and magnitude of the adjustment is often determined by a pre-adjustment calibration, sometimes known as an *as found* calibration (NPL, 2014).

The sensor calibration is a sensitive task and strongly dependent on the sensor type. Thus, the calibration of different sensor types has been addressed separately in D4.2 Report on Calibration Best Practices. The main report of D4.2 is divided in four chapters, i.e.

- Physical sensors,
- Optical sensors,
- Chemical sensors,
- Oxygen sensors.

In principal, the calibration of each sensor needs a high level of

- Experienced personnel
- Regular training of personnel
- Sensitive and careful handling of sensor calibration facilities
- Regular sensor calibration before (and after) deployment

Some general advices for calibration, which are independent from the sensor type, can be formulated:

- The proper calibration of sensors requires expertise, specialized equipment and procedures, dedicated staff, and most of all experience. If these resources are lacking in-house, it is better to send the sensors to the manufacturer for calibration or avail of an external provider of similar services.

- All the elements of the reference measuring systems must be maintained to within declared specifications by monitoring their performances regularly, adhering to recommended usage and upkeep practices, and scheduling servicing with a manufacturer immediately when laboratory quality assurance procedures indicate a developing problem.

- Sensors should be visually inspected prior to calibrating.

- The temperature calibration bath should be allowed to settle at a calibration set-point for a sufficient period of time (an hour or more) before sampling is initiated. The stability of the bath should be continuously monitored during the sampling interval.

- The calibrated sensors should be checked at least at a few calibration set-points prior to releasing them for duty.

- Proper field maintenance is the key to successful calibrations. Poorly maintained instruments often need to be subjected to long and complicated procedures in order to restore them to a condition that would permit a proper calibration to be performed.

- Calibration laboratories should be able to show proof of their competences by, for example, attending or organizing inter-laboratory comparisons whenever it is possible.

4.2.2. Maintenance Best practises

During a FerryBox maintenance procedure, several tasks have to be carried out to keep the system in good condition.

- The FerryBox pipes and valves should be inspected visually on contamination (i.e. biofouling) and leakages. If needed, they are cleaned mechanically by a tissue and distilled water. During the maintenance, the whole system is additionally washed with freshwater and the bottles of chemicals are checked for refilling.

- Manual cleaning (e.g. ethanol, deconex and tissue paper) and checking of the optical instruments is performed weekly at Alg@line ships. The calibration of the pH sensor (glass electrode) is controlled by buffer solutions. The fluorescence sensor is checked by a solid fluorescence standard, which at least will be an indicator for the drift of the sensor. Occasionally, e.g. once per year, stainless steel pipeline is acid washed (10% HCl).

- Some sensor flow cuvettes are designed for using high-pressure air to clean the sensor optics. NIVA uses such a system. In every harbour the pressurized air blows on the optics preventing biofouling to attach to the optics. For the Norwegian routes this means 1 – 4 cleanings per day. Additional manual cleaning is needed, though.

- As an integral part of all operational coastal observation programmes, the functioning and quality of sensors needs to be followed. Log-books and control charts should be used to trace the performance and maintenance of instruments and to provide evidence for quality assurance and auditing.

4.2.3. Operation Best practises

- System flushing

During autonomous operation, the system should be periodically washed with acidified water.
Either it is washed during the harbour stay of the vessel or, in case of a FerryBox system installed on a fixed platform or random routes (e.g. research vessels etc.) once a day. The used acid depends on the occasion.

- Water samples

Water samples collected by automatic water samplers should be used to validate the sensor data on a FerryBox.
Depending on the stability of the sensor a frequency of the validation can be established. It is important to validate the water samples taken by the automatic samplers. The holding time for the samples can be longer than in an ordinary laboratory set up, even if they are stored dark and cold.

- Power supply / power consumption

An uninterruptible power supply in true-line or online mode is strongly recommended. It not only provides a power backup if the ship mains should drop, it also regulates the input power and acts as a filter against spikes.

The power consumption of a system must be known before its installation. A typical installation will work well with 16A/220V AC, if a pump is included. The core sensor system may need less than 1A. Power requirements will increase in complex systems that for example include robotic samplers and low temperature (-80 ˚C freezers).

- Data from ship system

It is recommended to include also the data flow from the ship´s systems into the FerryBox system, i.e. the GPS signal and additional data like wind speed, gyro etc.

4.3. Strategies for future new developments

Many of the partners already test new or prototype instruments on a non-operational basis, yet the results of tests are often not widely known. In D3.4 Report on new sensor developments, the performance of new sensors has been assessed, as it is one of the main issues of sub-tasks 3.1.4 and 3.3.4 of JERICO WP3.

The range of instruments includes those measuring carbonate parameters (e.g. pH and pCO_2) sensors that provide a role in measuring ocean acidification, fluorometers for the measurement of primary productivity using the variable fluorescence technique, automated nutrient analysers, submersible flow cytometers and water samplers, spectroradiometers and absorption meters. Advances in existing sensors due to their miniaturisation or improved resolution are also assessed there.
The various sensor developments are presented with a focus on different observation platforms and the parameter, which will be measured by the sensor.

The listed sensor developments are addressed in a manner adopted from GROOM (2014) as follows:

- Scientific relevance
- Applied methods
- Implementation on platform
- Data quality control
- Outlook for possible improvements

So, beside the methods applied to each new sensor type, each sensor has also been classified according to the actual level of its implementation, i.e. if implementation on the platform is in a pre-operational or operational mode. New potential sensor developments have been addressed in WP 10 deliverable. In **Fehler! Verweisquelle konnte nicht gefunden werden.**, the descriptions of sensor developments in D3.4 have been summarized.

Table 3 : Overview of sensor development at JERICO partner institutes.

	Scientific relevance	Applied methods	Implementation on platforms	Data quality control
Phytoplankton – ft-PSICAM	Phytoplankton acts as a primary producer, basis of the marine food web	Sample in a diffuse light field set up in an integrating tube or sphere, optical path length is increased by reflective walls	The ft-PSICAM is designed to be connected to a FerryBox, sensor has been tested on ship cruises,	Calibration as for conventional PSICAM
Phycocyanin fluorescence sensor for cyanobacteria	Cyanobacteria blooms occur in mainly in fresh water and in brackish water. In the Baltic Sea surface accumulations of cyanobacteria is a recurrent phenomenon in summertime.	Fluorescence	Sensors are applicable for use in FerryBox and other systems	Calibration of the sensor was made using a culture of the picoplanktonic cyanobacteria *Synechococcus*
pH sensors (from HZG, NIVA, SMHI, ULPGC, NERC)	The pH of seawater is one of the key parameters of the carbon cycle and the CO_2 system in ocean and atmosphere	Spectrophotometric absorbance measurements employing an indicator dye; application of Durafets (ion sensitive field effect transistor based pH sensors); fluorescent probe DHPDS The ratio between red and green fluorescence varies due to pH	System is very portable and much smaller than comparable systems. No water bath is needed; tested on research cruises and beside FerryBox on regular cruise line	Comparisons with glass electrode measurements, water sample checks or pH calculated from carbonate parameters
Alkalinity	Part of the biogeochemical cycles and the carbonate system	Closed-cell titration method and acid-base indicator dye	Pre-operational tests have been performed, fully-autonomous device is currently new on market	Cross-validation with other carbonate variables
pCO2 (NIVA)	Key requirement for ocean acidification studies	Gas separation (membrane based) from the water phase and successive detection by high temperature ceramic solid state instead of IR detection	Underway measurements with such a system have been already performed	Carbon system determination is achieved through parallel monitoring of pH and pCO_2 (or TA and DIC); comparisons with water samples

FerryBoxes are a valuable tool for testing new developed sensors, as conditions are easy to handle for new developed devices; only minor energy and space restrictions, shelter from the elements and easy integration in data processing tools. There has been considerable development of new sensors that measure components of the carbonate system, thus research addressing ocean acidification and eutrophication will benefit from this progress. Especially, new sensors for pH monitoring are established on FerryBox routes. They provide better accuracy, higher salinity range (important for Baltic Sea monitoring) and more compact designs for easier installation on autonomous systems. Also, a new generation of pCO_2 sensors has been described.

Until lately, the Total Alkalinity has not been measured autonomously but more often has been calculated from other components of the carbonate cycle. It will be soon possible to measure the Total Alkalinity directly with the described device, which can be easily combined with pH measurement devices.

5. Conclusions

The main goal of JERICO work package 4 is the improvement of performance in regard to observatories and the overall quality of products, which are delivered by project partners. The first step consisted on a survey of the existing calibration facilities amongst JERICO partners to evaluate common practises depending on measuring platforms, financial and personnel possibilities. Differences between the facilities are outlined and discussed as well as possible future steps.

Close cooperation towards harmonisation between calibration facilities is needed even more, as calibration costs are a significant part of the regular platform maintenance. Thus, it becomes more than evident that scientific operational centres around Europe maintaining calibration facilities must follow the successful example of JERICO, ESONET and EuroSITES. During JERICO, calibration exercise workshops have been held to exchange and discuss calibration strategies and best practises (in Helsinki and in Brest 2012).

In a further step, several calibration best practise advices have been formulated, partly depending on sensor type. Some advices are valid for all sensor types. These advices are documented in deliverable D4.2.

The most important points of the calibration of sensors are in general:

- Experience of personnel
- Regular training of personnel
- Sensitive and careful handling of sensor calibration facilities
- Regular sensor calibration before (and after) deployment.

The optimal operation practises and the maintenance routines are essential for a successful operating of a FerryBox system. There is considerable expertise among European partners who run FerryBox systems since more than a decade. Some useful advises have been brought together in the JERICO deliverables D3.1 and D4.4. They have been summarized in this deliverable. The maintenance and operation Best practises include:

- Flushing of the FerryBox systems on a regular basis underway and in harbour
- Regular sampling of water probes
- Ensure constant power supply
- Data flow of Ship systems (GPS, Wind, Gyro etc.)
- The FerryBox pipes and valves should be inspected visually on each maintenance
- Manual cleaning if needed
- Functioning and quality of sensors needs to be followed on quality charts etc.

Further recommendations on Best practices can be found in JERICO deliverable D4.4.

In D3.4, an overview has been given about the status of sensor developments for offshore observing platforms. Several new promising developments are deployed on platforms in a test mode; some sensors are already in pre-operational mode.

- There has been considerable development of new sensors that measure components of the carbonate system, thus research addressing ocean acidification and eutrophication will benefit from this progress.
- New sensors for pH monitoring are established on FerryBox routes. They provide better accuracy, higher salinity range (important for Baltic Sea monitoring) and more compact designs for easier installation on autonomous systems.
- A pCO_2 sensor with a new detection principle (ceramic solid state detector) has been described.

- A Total Alkalinity sensor will be available soon, which could then be combined with pH measurement devices for better understanding of carbonate system in the oceans. It will be possible to measure the Total Alkalinity directly with the described device.

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