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FERRYBOXES WITHIN EUROPE:

STATE-OF-THE-ART AND INTEGRATION IN THE EUROPEAN OCEAN OBSERVATION SYSTEM (EOOS)

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Abstract

The development and use of FerryBox systems as a cost-effective instrument for continuous observations of the marine environment has been well established since more than 15 years. The systems have evolved to maturity and are since widely used around the coastal ocean of Europe. The availability of newly developed sensors allows the extension of FerryBox measurements to more biogeochemical parameters which are of interest for the requirements of the Marine Strategy Framework Directive (MSFD).

The FerryBox community initially formed from the partners of an EU funded FerryBox project provides mutual exchange of experience and is now organized within EuroGOOS as a so called FerryBox Task Team (www.ferrybox.org). Within the EU funded infrastructure projects JERICO and JERICO-NEXT the technical harmonization as well as the developing of best practise guides for FerryBox systems have been a step further to high quality environmental data products. Within JERICO-NEXT it has been decided to build up a common FerryBox database and data portal in order to make the FerryBox data more available and visible. Furthermore this database will be function as a close link to the Copernicus Marine Environmental Monitoring Services (CMEMS) and the EMODnet portal.

Keywords: FerryBox, EuroGOOS Task Team, ships of opportunity, operational oceanography

1. Introduction

The development and use of FerryBox systems as a cost-effective instrument for continuous observations of the marine environment has been well established since more than 20 years (Petersen 2014). The systems have evolved to maturity and are since widely used around the coastal ocean of Europe. The availability of newly developed sensors allows the extension of FerryBox measurements to more biogeochemical parameters which are of interest for the requirements of the Marine Strategy Framework Directive (MSFD). The FerryBox community initially formed from the partners of an EU funded FerryBox project provides mutual exchange of experience and is now organized within EuroGOOS as a so called FerryBox Task Team (www.ferrybox.org).

This contribution will give an overview about the FerryBox network in Europe including examples of application as well as the status of the European FerryBox database/data portal and the connection to the European Marine data services.

2. Ferrybox Task Team

Since about two years EuroGOOS has organized its activities in working groups and so-called Task Teams (TT). Within this context a FerryBox TT has been established. The TT is responsible for the organisation of the activities of the TT, such as compiling a whitebook on the achievements of the FerryBox community, on the organisation of a recurrent workshop once every 1.5 years to show new applications and technical innovations of FerryBox systems and e.g. collecting data of regular FerryBox routes into an European wide data system, including making data available for all kind of users. Within the TT many activities to extend the possibilities of FB systems to collect other oceanographic parameters as current standard ones like salinity, temperature, turbidity, fluorescence, oxygen, carbon dioxide and dissolved inorganic macronutrients. New sensors are under testing like high precision pH, algal species composition with flowcytometry and molecular analysis. The TT is regularly documenting its activities at the EuroGOOS headquarter and attending meetings with other EuroGOOS TTs.

Within the EU funded infrastructure projects JERICO and JERICO-NEXT the technical harmonization, as well as the developing of best practise guides for FerryBox systems, have been a step further to high quality environmental data products.

Meanwhile FerryBoxes or similar systems are used worldwide. Through the years, some 30 ships are involved in FerryBox monitoring of sea surface parameters. A map of the routes currently operating FerryBoxes in Europe is shown in Fig. 1.

Fig. 1. FerryBox routes from different institutions in Europe in 2016.

3. Ferrybox data base and data portal

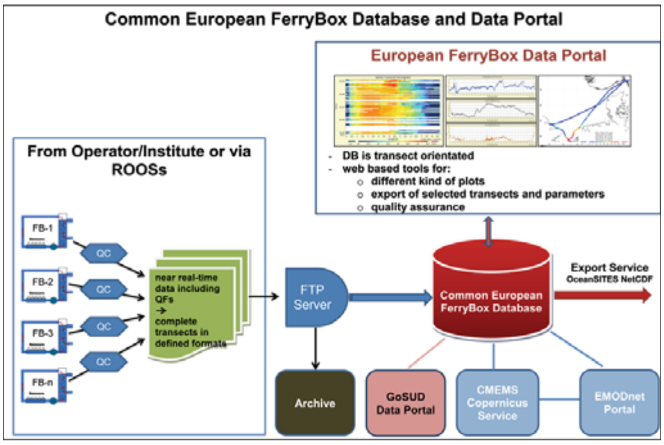

Fig. 2. Schematic diagram of the European FerryBox database and data portal.

During the last FerryBox workshop in 2016 it was decided that a separate European FerryBox portal will be developed, housing a FerryBox database. This portal will provide free access to the highest quality of European FerryBox data, fed directly by FerryBox users in near real-time or in delayed mode, once the data have been processed. Furthermore, this common European FB database of all FerryBox operators will also serve as a showcase for the joint FerryBox activities in Europe and will increase the visibility of the FB community.

Furthermore this database will be function as a close link to the Copernicus Marine Environmental Monitoring Services (CMEMS) and the EMODnet portal. Moreover web-based tools can be used by each FerryBox operator in a similar way to track the activity and the status of his own FerryBox. Fig. 2 shows the proposed design of such a FerryBox data portal and data base.

4. Scientific Ferrybox applications

In this chapter a few examples of FerryBox developments and scientific applications are shown.

4.1 Carbon cycle

Knowledge of seasonal and spatial variability in seawater pH is important for several reasons. pH is one of four key measureable variables of the seawater carbonate system. It is closely tied to availability of CO_2 in seawater which is the primary substrate for photosynthesis by marine phytoplankton and macroalgae. pH has also been shown to directly or indirectly affect physiology and development of various marine organisms from bacteria to larval fish, with low pH conditions generally associated with negative effects. The saturation state of aragonite and calcite is pH dependent and this has implications on abiotic carbonate dissolution/formation as well as biomineralization of calcium carbonate by calcifying organisms like coccolithophores, pteropods, bivalves, and corals. Improving our observations and understanding present day spatial and temporal variability in pH variability is critical for detecting long-term changes in pH, such as the projected decrease in ocean pH due to ocean acidification caused by anthropogenic fossil fuel burning which is projected to decrease the pH by ~0.3-0.4 by 2100.

NIVA developed an underway spectrophotometric pH sensor (Fig. 3) that pairs with FerryBox systems that can precisely and accurately determine seawater pH under operating conditions to <0.003 pH (Reggiani *et al.* 2016). The Sensor has been applied along the Norwegian coast. The observed seasonal range in pH from ~8.05-8.30 (winter to spring/summer) in coastal waters above ~66 °N is comparable to the projected average global change due to ocean acidification by year ~2050-2070.

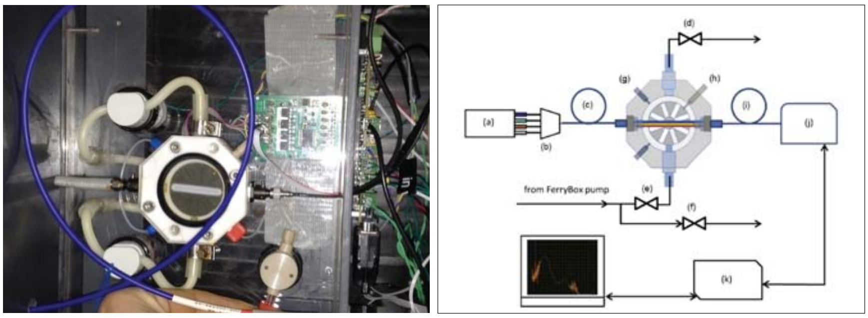

Fig. 3. Automated spectrophotometric high precision pH sensor developed at NIVA for FerryBox applications.

4.2 Phytoplankton Monitoring

Algaline project has been using FerryBox systems on commercial ferries in monitoring the state of the Baltic Sea, and especially to follow the development phytoplankton blooms, since 1993 (Kaitala *et al.* 2014). Phytoplankton abundance is followed using chlorophyll a fluorescence, which is validated using weekly of semiweekly collected discrete samples and analytical laboratory measurements of chlorophyll a concentration. SYKE is currently reviewing different approaches to overcome difficulties in the validation, which arise due to the variability in the chlorophyll a specific fluorescence, i.e. ratio between chlorophyll a fluorescence and concentration.

Spatio-temporal response surfaces, done using kriging methods, are currently explored to minimize prediction errors. In addition they work towards harmonization of primary calibration of field fluorometers, which will provide traceability for fluorescence records.

Phycocyanin fluorometers have been used in the Baltic Sea since 2005 to track the abundance of filamentous cyanobacteria containing occasionally large amounts of this blue-green pigment. Summer blooms occur frequently at different parts of the Baltic Sea, depending on the nutrient status, temperature and mixing conditions. These blooms include often toxic species and they have consequences for biogeochemical cycles as filamentous cyanobacteria species are able to fix atmospheric nitrogen, they may leek fraction of fixed nitrogen to be used by other species and thus causing fertilization of open sea, and they are largely inedible for zooplankton. Phycoerythrin is a red pigment, especially suited for harvesting the green light that penetrates deepest in the Baltic Sea. Phycoerythrin is thus very valuable pigment for species staying at deeper water layers, but frequently observed also throughout the upper water column. Especially Baltic picocyanobacteria, often dominating the phytoplankton community during summer months, are rich of phycoeryhtrin. Phycoeryhtrin fluorescence cannot be used, however, as a proxy for picocyanobacteria alone because some other groups (cryptophytes, some dinoflagellates, ciliate Mesodinium rubrum) may have highphycoerythrin content as well. Fig. 4 shows as an example of phycocyanin fluorescence as proxy of the filamentous cyanobacteria blooms and phycoerythrin fluorescence as proxy of the picocyanobacteria and sporadic occurrence of other phycoerythrin containing species) along the route Travemuende - Helsinki. The high phycoerythrin fluorescence during spring was mostly related to abundance of M. rubrum, while in the summer the values indicate more the distribution of cryptophytes and picocyanobacteria.

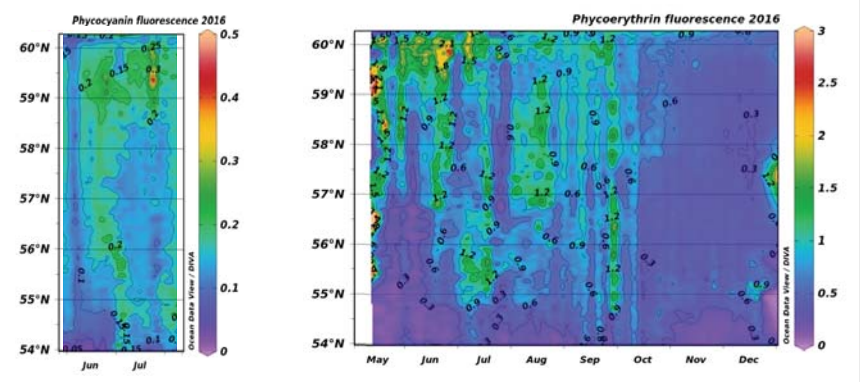

Fig. 4. Phycocyanin fluorescence (left panel) and phycoerythrin fluorescence (right panel) along the route Travemuende - Helsinki.

4.3 Data Assimilation

Operational monitoring and forecasting of marine environmental conditions is a necessary tool for the effective management and protection of the marine ecosystem. It requires the use of multi-variable real-time measurements combined with advanced physical and ecological numerical models. Towards this, a FerryBox system was installed and operated in the route Piraeus–Heraklion. This route is by large traversing the Cretan Sea being the largest and deepest basin (2500 m) in the south Aegean Sea. The analysis of FerryBox SST and SSS *in situ* data revealed the presence of important regional and sub-basin scale physical phenomena, such as wind-driven coastal upwelling and the presence of a mesoscale cyclone to the north of Crete. In order to assess the impact of the FerryBox SST data in constraining the Aegean Sea hydrodynamic model which is part of the POSEIDON forecasting system, the *in situ* data were assimilated using an advanced multivariate assimilation scheme based on the Singular Evolutive Extended Kalman (SEEK) filter, a simplified square-root extended Kalman filter that operates with low-rank error covariance matrices as a way to reduce the computational burden. Thus during the period mid-August 2012–mid January 2013 in addition to the standard assimilating parameters, daily SST data along the ferryboat route from Piraeus to Heraklion were assimilated into the model. Inter-comparisons between the control run of the system (model run that uses only the standard data set of observations) and the experiment where the observational data set is augmented with the FerryBox SST data produce interesting results (Korres *et al.* 2014). Apart from the improvement of the SST error, the additional assimilation of daily of FerryBox SST observations is found to have a significant impact on the correct representation of the dynamical dipole in the central Cretan Sea and other dynamic features of the South Aegean Sea, which is then depicted in the decrease of the basin wide SSH RMS error.

4.4 Integration with other observational platforms

The value of FerryBox data is increased when the FerryBoxes are part of observational networks including other platforms such as moored profilers, gliders, ARGO floats, and research vessel based instruments. For instance, in the stratified Gulf of Finland (Baltic Sea) a FerryBox system on board the Tallinn-Helsinki ferry has been combined with a moored profiler and measurements using a research vessel (see Lips *et al.*, 2016). Simultaneous high-resolution measurements in the surface layer and through the water column allowed to link the horizontal and vertical variability. The results of statistical analysis of FerryBox and Scanfish data suggest that the ageostrophic sub-mesoscale processes (with a spatial scale comparable or less than the internal Rossby radius of deformation which is 2-5km in the Gulf of Finland) could considerably contribute to the energy cascade in this stratified sea basin. Furthermore, a major role of sub-mesoscale processes in feeding surface blooms in the conditions of coupled coastal upwelling and downwelling events in the Gulf of Finland has been suggested (Lips *et al.*, 2016).

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References

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

Lips, U., Kikas, V., Liblik, T., Lips, I. (2016). Multi-sensor in situ observations to resolve the sub-mesoscale features in the stratified Gulf of Finland, Baltic Sea. *Ocean Science*, 12 (3), 715–732.10.5194/os-12-715-2016.

Petersen, W., FerryBox Systems (2014): State-of-the-Art in Europe and Future Development, *Journal of Marine Systems*, DOI: 10.1016/j.jmarsys.2014.07.003

Reggiani E.R.; King, A.L.;, Norli, M.; Jaccard P.; Sørensen, K.; Richard G.J. Bellerby, R.G:J. (2016): FerryBox-assisted monitoring of mixed layer pH in the Norwegian Coastal Current; *Journal of Marine Systems*