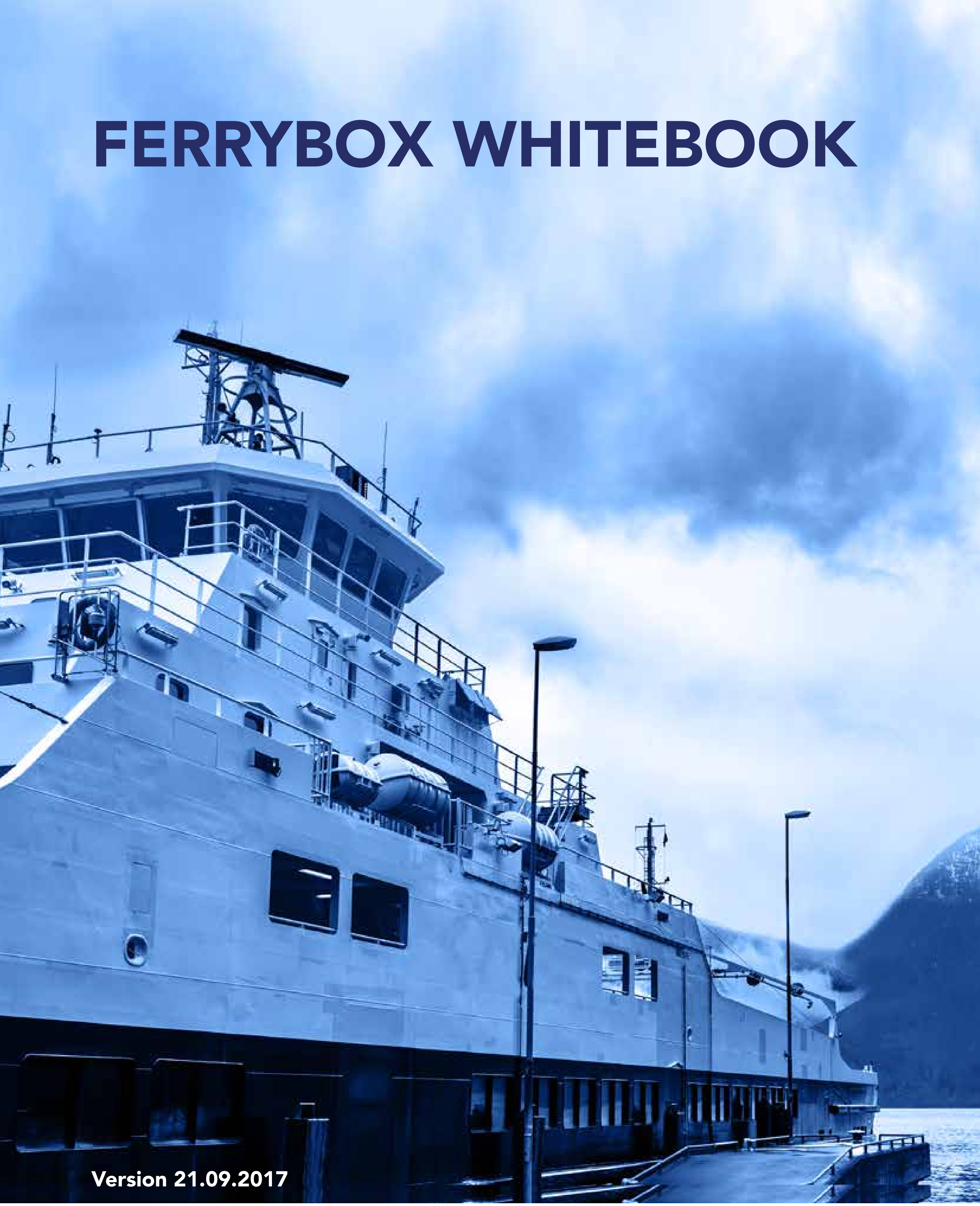
FERRYBOX WHITEBOOK



Version 21.09.2017

www.eurogoos.eu

EuroGOOS
European Global Ocean
Observing System

KNOWLEDGE OF THE OCEAN IS LIMITED

The EuroGOOS FerryBox Task Team is one of seven EuroGOOS Task Teams, operational networks of observing platforms promoting scientific synergy and technological collaboration among European ocean observing infrastructures. Jointly Task Team members make available European ocean data to the EuroGOOS Regional Operational Oceanographic System (ROOS) data portals across all European maritime regions, which in turn feed data to the European Marine Observation and Data Network (EMODnet) and Copernicus Marine Service (CMEMS).

FerryBox technology allows taking automated measurements aboard ships of opportunity. The core ocean parameters measured are temperature, salinity, turbidity, and chlorophyll-a fluorescence. In addition, non-standard sensors provide data on currents and sediment transport, pH, oxygen, nutrients, and algal species. Currently, FerryBox systems are installed on a network of European FerryBox contributors, mainly national marine research institutes and environmental agencies.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Whitebook presents a scientific and technical description on a newly developed instrument for automatic measurements of a series of environmental oceanographic parameters called FerryBox which supports monitoring of the water quality of coastal and offshore waters of European seas. Thus, a contribution to a future European Oceanographic Observation System (EOOS).

The principal idea is to use ships of opportunity like ferries on fixed routes to make automatic measurements of important oceanographic parameters. These measurements are made in a flow-through system where different sensor are applied to continuously measure parameters like water temperature, salinity, turbidity as a measure of the amount of suspended matter, and fluorescence as a measure of the amount of algae. The sustainability of the systems could be greatly enhanced by using automatic cleaning systems so that the effort for maintenance could be reduced. In comparison to other in situ measurement systems, the reliability and data availability of FerryBoxes is higher and maintenance costs are significantly lower. FerryBox systems have reached a state of matureness and the number of measured parameters is still increasing with focus on more biogeochemical variables. The systems are extended with new sensors and analyzers for e.g. algal composition, pH, carbon budget (pCO_2, alkalinity) and on some ferry routes nutrients like phosphate, nitrate and silicate. The Whitebook describes the technical details of such FerryBox systems in detail. Furthermore, the applications of the collected data for monitoring and scientific purposes is described for different water systems like the Baltic Sea, the North Sea, the Bay of Biscay and the Mediterranean Sea. To overcome the problem of spatial scale a strong connection has been built with satellite remote sensing, which can deliver images of certain parameters (e.g. chlorophyll-a, TSM etc.) of much larger areas.

Long term observations on fixed transects are a powerful mechanism to detect long-term trends in coastal and oceanographic waters. In the Baltic Sea, such time series are available for over 25 years and of great help in detecting long-term effects of eutrophication and their reduction. In other areas examples of riverine nutrient inputs can be shown. Furthermore, the continuous measurements, repeated along a certain transect within days or more often, are also very helpful to detect short-term events that can be detected by research cruises only occasionally due to the limited coverage in time.

The FerryBox time series can be further used for validation and improvement of physical models and the increasing number of biogeochemical variables will be very useful for further development and improvement of eco-system models. Real-time FerryBox data can be used for data assimilation to support and enable better estimates in operational models. Furthermore, the high spatial and temporal frequency of data by FerryBox systems can provide real-time information for nearby aquaculture and fishing operations including early warning indicators for e.g. toxic algal blooms.

With the introduction of new sensors for alkalinity and pH ocean acidification and the special behavior of the coastal ocean as a highly dynamic component of the global carbon budget can be followed in detail as the diverse sources and sinks of carbon and their complex interactions in these waters are still poorly understood.

As most FB systems are equipped with automated water sampler this makes it possible to get water samples from certain areas on a regular basis for subsequent lab analysis. First pilot studies highlighted the feasibility for both target and non-target exploratory screening of trace contaminants. Another application of water sampling could be the investigation of the steadily growing abundance of micro plastics in the oceans which might be possible after the development of suitable analytical techniques.

Compared with other marine monitoring and measuring systems FerryBoxes acquire very large amounts of data. Hence quality control, evaluation and processing of these data need to be highly automated, robust and reliable. Therefore, new procedures for data processing and evaluation have been developed for the increasing number of routinely operated FerryBoxes. The planned common European database in connection with the EuroGOOS ROOSes, EMODnet and Copernicus Marine Environment Monitoring Services (CMEMS) will help to make FerryBox data easily available and visible.

In a dedicated chapter, the estimated costs for installation and maintenance of such instruments are presented. Finally, a plea for support by the European Commission (DG Mare and DG Innovation) is made to be able to extend the current routes to e.g. other parts of the Mediterranean Sea and the Black Sea and to support the overall data system within the future European Ocean Observing System (EOOS).
A list of key messages derived from the whitepaper is summarized below:

- FB systems have evolved with a set of standard sensors to a mature observational system;
- FB systems allow cost-effective measurements with high resolution in space and time along a certain route;
- FB data may strongly support the validation of numerical ocean models;
- FB data can be used as ground truth measurements for satellite remote observations;
- New developments of biogeochemical sensors enable full insight into ocean acidification and the impact of coastal oceans on atmospheric CO_2;
- Continuous and long-term observations of the carbon cycle enable the detection of climate relevant changes in coastal and open ocean waters;
- FB systems enable discrete water sampling on certain positions for specific compounds (e.g. contaminants, micro plastics, etc.) without extra cost;
- A common European FB database including data quality control increases the availability of FB data and supports the activities of CMEMS and EMODnet;
- FB systems are still operated mainly by research money and suffer from unsustainable funding in the long term;
- New FB lines must be developed, especially in the Mediterranean and Black Sea;
- There is a further need for discussions with all potential stakeholders on which type of data products are needed to fulfill science or societal requirements e.g. for environmental assessments.

INTRODUCTION

Our knowledge of the ocean is limited by our observational ability and the ocean continues to be severely under-sampled. To better understand and manage the oceans and the coastal systems, there is a clear need for environmental data of high spatial and temporal resolution. Efforts within global and regional programmes are evolving to better coordinate observing efforts internationally. However, gathering the required ocean information can prove costly. Recent efforts have shown great promise in reducing this cost by taking advantage of ships of opportunity (SOOP) or volunteer observing ships (VOS) as mobile platforms for environmental data collection. The installed systems can integrate data from water quality and meteorological sensors with GPS information into a data stream that is automatically transferred from ship to shore. There are numerous advantages to the SOOP program: no ship costs, no energy restrictions, regular maintenance is possible, transects are sampled repeatedly and problems with biofouling of sensors can be better controlled. There is great potential for data coverage using ferries and cargo ships sailing a fixed route on a regular basis, especially in coastal regions.

Already in the 1930'ies observational systems were developed to be installed on ships-of-opportunity. Sir Alistair Hardy started collecting data on the distribution of zooplankton and fish larvae regularly in the North Sea using the newly developed Continuous Plankton Recorder (CPR), which was towed from research vessels as well as from voluntary ships. At the same time, the Norwegians used the "Hurtigruten" along the Norwegian coast to collect salinity and temperature data on a regular basis. A primary goal was to characterize water masses to support studies related to the distribution of commercial fishes and better understand their behavior. In the 1990'ies, the Finnish Institute of Marine Research (FIMR, now SYKE) initiated regular ferry-based observations on the distribution of algal blooms and nutrients within the Alg@line project (Rantajärvi *et al.*, 1998) in the Baltic Sea.

The first steps towards a European system of FerryBoxes was taken during an EU-funded project (2002-2005) helping to optimize the use of these systems for automated measurements and water sampling on ships of opportunity, e.g. merchant vessels and ferries. The core parameters measured were temperature, salinity, turbidity, and chlorophyll-a fluorescence. In addition, non-standard sensors were tested for observation of currents and sediment transport, pH, oxygen, nutrients, and algal species. Since those first steps the European FerryBox community has further increased the cooperation through the establishment of a FerryBox Task Team under EuroGOOS. Currently, FerryBox systems are installed on a network of European FerryBox contributors, mainly national marine research institutes and environmental agencies.

The FerryBox Task Team (http://eurogoos.eu/ferrybox-task-team/) is one of seven EuroGOOS Task Teams, enabling operational networks of observing platforms promoting scientific synergy and technological collaboration among European ocean observing infrastructures. Task Team members exchange open source tools, collaborate in areas of common interest, and jointly make European data available to the EuroGOOS Regional Operational Oceanographic system data portals across all European maritime regions, which in turn feed data to the European Marine Observation and Data Network (EMODnet) and Copernicus Marine Service (CMEMS).

In this report, the present status of FerryBox systems in Europe is presented. Different aspects regarding measurement technology, sensor development, data handling and management, costs and scientific achievements as well as use and applications of data for environmental assessments are presented and discussed.

The structure of the report is divided in three main units: in unit 1 the development of Ferry Box systems to date are described; unit 2 is about the applications and users of Ferry Box data, in unit 3 the indicative costs of a Ferry Box system is presented. In the Annex, more information about the EuroGOOS Ferry Box Task Team is given.

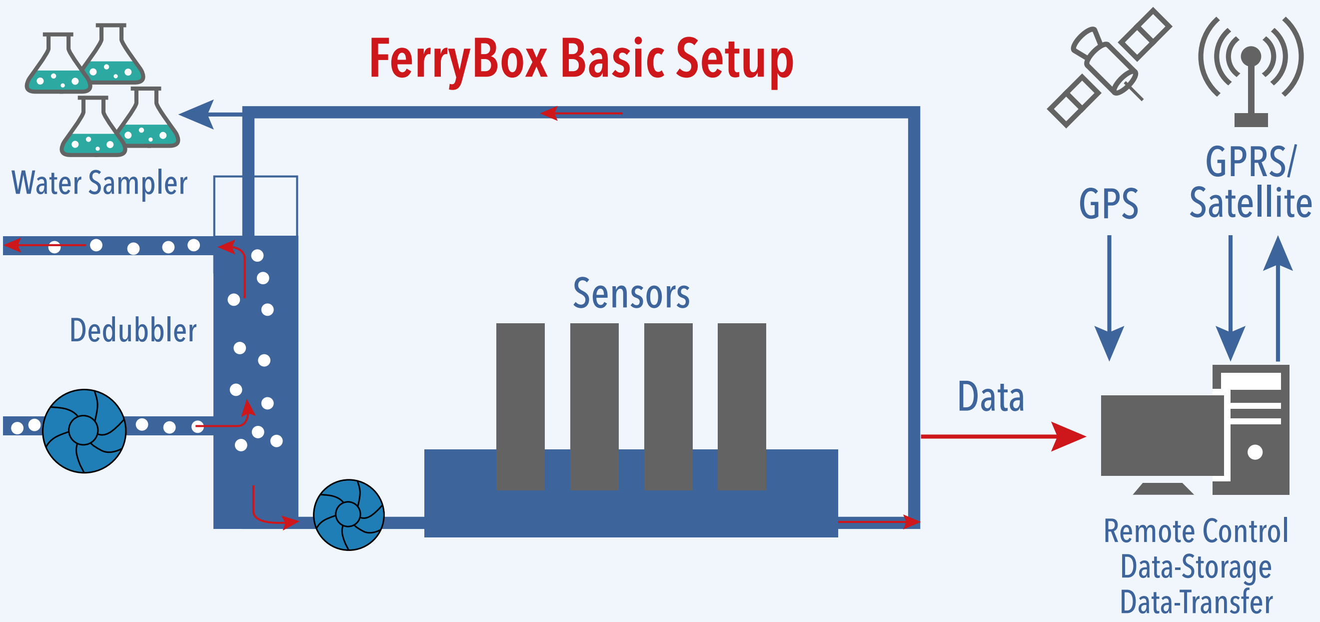
UNIT 1 – DEVELOPMENT OF FERRYBOX SYSTEMS TO DATE

Chapter 1: FerryBox systems

In general, all FerryBox (from now on FB) systems employ a similar design. There are differences in the design of the flow-through system, the degree of automation and biofouling prevention as well as the possibilities of supervision and remote control. The system consists of a water inlet from where the water is pumped into the measuring circuit containing multiple sensors. This inlet may be positioned at the sea chest or on an extra valve in the hull of the ship which is specially designed for the FerryBox's purpose. It is important to mention that the FerryBox should be positioned as close as possible to the inlet and that the seawater should not be influenced, for instance, by long residence times in the sea chest. An optional debubbling unit removes air bubbles, which may enter the system mainly during rough seas. Coarse sand particles, which may be introduced in shallow harbors and which settle and tend to block the tubes, are removed as well by the debubbler. A basic system includes sensors for temperature, salinity, turbidity and chlorophyll-a fluorescence, and a GPS receiver for position control. Many systems also include an inline water sampler and additional sensors, e.g., for oxygen, pH, pCO_2 or algal groups as well as meteorological instruments (air pressure, air temperature and wind). When nutrients are measured, a small amount of the water is filtered by a hollowfiber cross-flow filter module for automatic nutrient analysis.

For reliable, unattended operation, the system is controlled by a computer that also logs the data. Data are transmitted to shore via mobile phone connection or satellite communication. In some systems, biofouling is prevented by automatic cleaning of the sensors with tap water, and by rinsing with acidified water or water containing a detergent after each cruise, which is controlled by the position of the vessel. A schematic diagram of a FerryBox system is shown in Fig. 1.1. More details can be found in Petersen *et al.* (2003).

Fig. 1.1.: Schematic diagram of a FerryBox flow-through system



Chapter 2: Links between FB operators and the shipping industry

So far two opportunities for interaction with the shipping companies have been observed. The first one is an educational opportunity to present data gathered during a ferryboat trip on line for the people on board. This has been realized by a Dutch company, TESO, together with the Royal NIOZ on board of one of their ships crossing the Marsdiep between den Helder and the island of Texel. This ferryline is transporting large number of tourists to the island in about 20 minutes. During the trip, the data measured on salinity, water temperature and currents are presented on line on a large screen with some explanation to the public (Fig. 2.1). The objective of this information is to explain simple oceanographic principles to the public.

Another example of interaction between shipping industry and scientific research is the cooperation with companies operating cruise liners. The Germany-based TUI Cruises were interested to present aboard of their first newly build vessel named *MeinSchiff3* scientific applications and supported the installation of a FerryBox and an air analyzer for measuring the concentration of mercury and the trace gases SO_2 and CO in the air. In an exhibition room besides different oceanographic instruments the data of the FerryBox are presented online on a big touch screen (Fig. 2.2) with additional information about oceanographic research.

Fig. 2.1: Picture of information screen on board Dutch ferry between Den Helder and Texel.

Fig. 2.2: Live presentation of FerryBox data on board cruise liner *MeinSchiff3* (TUI Cruises).

Fig. 2.3: Connection between outside and inside in new Ferry between Cuxhaven and Helgoland including temperature sensor.

A topic which would be of great benefit to potential and future FB operators would be the installation during construction of new ships of a water intake point and outflow including power supply within the bow. This would greatly facilitate the later installation of a FB system. The costs of such an installation during the construction would likely be very low. A hydrodynamical prototype needs to be built in cooperation with a shipyard. Recently during the construction of a new Ferry running between Cuxhaven to the Island of Helgoland an application for a later installation of a FB was made which greatly facilitated the on-board installation. (Fig. 2.3).

Chapter 3: FerryBox Data management

Since the beginning of FerryBox activities in the Baltic Sea in the 80s and on an European level with the FP5 project "FerryBox"(2003-2005) there has been an increasing number of FerryBox lines as well as ongoing activities on harmonization of operation (e.g. JERICO project). However, progress in visibility and accessibility of the FB data is much less even if there exist long-term FB data sets especially in the Baltic Sea and North Sea. These data sets are often only available upon request to the data originator and mostly based on files (ascii or NetCDF). At Helmholtz-Zentrum Geesthacht (HZG) all data are directly stored in a relational database with free internet access where user can download the data. There is a need to enhance the access to FB data both in real-time and in delayed mode. Only subsets (mainly T and S and partly oxygen and chlorophyll-a fluorescence) of real-time data were delivered to the MyOcean series of projects on a ftp server or nowadays to the EuroGOOS ROOSs through the Copernicus Marine Environment Monitoring Service (CMEMS) established in partnership with the ROOSs with no guaranty of the completeness of the aggregated data. In addition, within the CMEMS, the data are aggregated per day and per month to fulfil the need of operational oceanography users and the original very specific structure of FB data (one dataset for each performed transect) is getting lost. This makes it difficult to compare a set of transects on the same route in an easy way or create so called scatter plots from on transect over time. Moreover, it is quite complicated to get a comprehensive graphical overview of sampled FerryBox data in a certain area and at certain routes.

Therefore, there is a need to create a FerryBox portal that will provide access to the highest quality of European FerryBox data fed directly by providers in near real time and in delayed mode when the data have been processed. These data will be freely available to the operational and research communities.

A common European FB database of all FerryBox operators will also serve as a showcase for the joint FerryBox activities in Europe, increasing the visibility of the FB community and the accessibility of FerryBox data. 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. Password controlled access can be offered to have an individual access to his own data for quality assessment and further data processing (e.g. changing QF, correcting data etc.). A specific FerryBox database should be structured in such a way that FB data can be stored as a single transect with a high performance for data access and for different types of database queries. The FerryBox database (based on a SQL Oracle database) developed by HZG may act as an example which has been successfully operated over 10 years with high performance.

The Jerico-Next opens up new possibilities to support such a development. Further support could be provided by EuroGOOS and EMODnet. A schematic view of such a FerryBox data management tool is shown in figure 3.1. In a first step of the development of such a common database a selected number of parameters (T, S, Turb, DO, Chl-a …) of all FB routes in Europe would be delivered in real-time (RT) or near-real-time (NRT) to one central relational database. Data can be uploaded to the database either file structured (e.g. via ftp server) in near-real-time (at the end of one cruise) or in real-time by direct communication (e.g. via satellite communication) of a certain FB computer with the database (machine to machine communication). All data in the database should have been undergone a real-time quality control with agreed standards and flagging scheme of all operators according to the recommendations of the EuroGOOS Data Management, Exchange and Quality WG (DATAMEQ). Such a real-time control can be derived from first developments in the JERICO project (SMHI: Python routines, HZG: Labview routines) and MyOcean (NIVA). The internal structure of the database should retain the structure of single FerryBox transects. In combination with a web based pan-European data portal this ensures that all FB data are easy accessible and visible. Also, data that have been corrected in delayed mode should be made available to provide an integrated access to FB transects.

Such a database can act as a central and reliable provider for selectable subsets of FerryBox data which can be further delivered to or downloaded from other portals and initiatives such as the ROOSs, CMEMS INSTAC and EMODnet. For this purpose, a few download options should be provided:

1. A direct data download from the database keeping the transect structure;
2. Offering data per observed property between two users using the OGC SOS (Sensor Observation Service) web service for selectable time period;
3. Export of a subset of observed properties regularly in OceanSites NetCDF format on regular time intervals retaining the transect structure and downloadable using the OpenDAP web service.

For visualization as well as export of the data web services should be available offering the ability to include data or visualisation automatically into other web pages (see Fig. 3.1.).

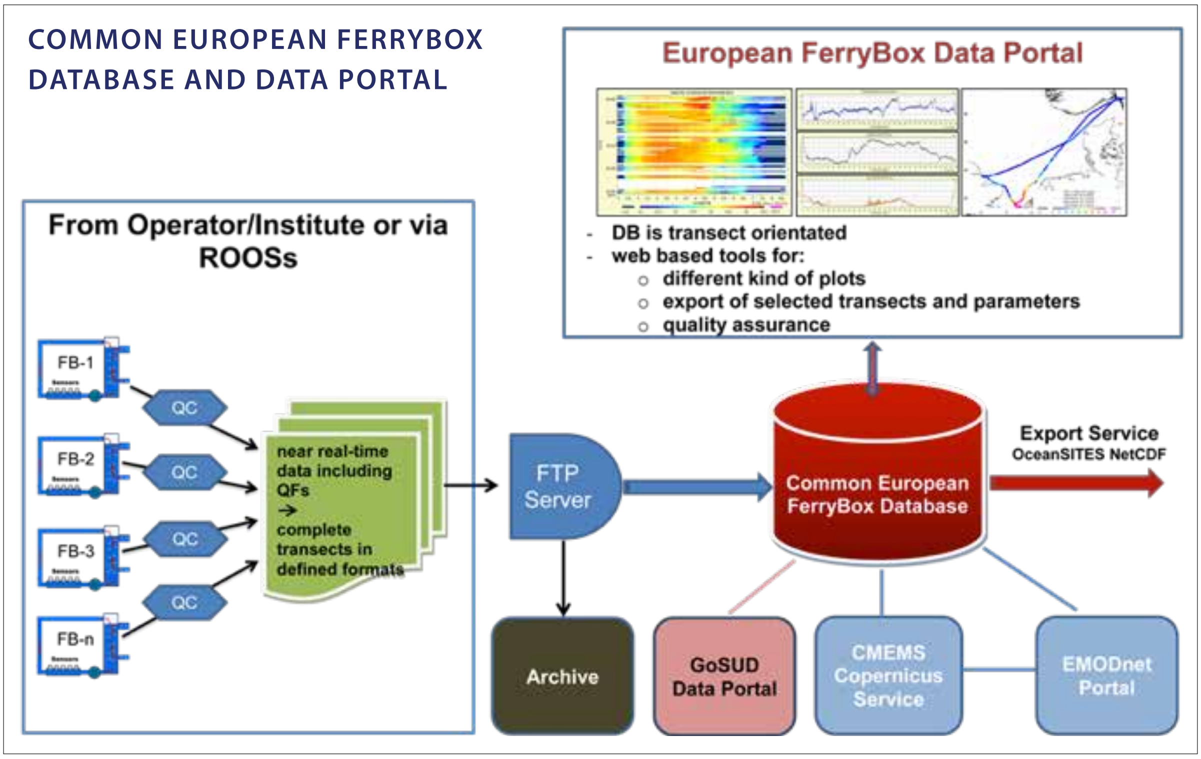


Fig. 3.1: Schematic diagram of a proposed European FerryBox database and connected data portal with an external backup with manage files on a ftp site e.g. a s a daily synchronisation between the FB ftp site and GOSUD site.

Chapter 4: Links between FerryBox systems and other (inter)national organizations, governance of FB systems

FB systems will be part of observational methods together with gliders, Euro Argo, radar hydrography, moorings, and satellite remote sensing. Altogether these observational techniques finally will be part of the EOOS (European Ocean Observation System).

It might be possible if the use of FB systems for monitoring the marine environment has been fully implemented that FB systems could be co-financed by the EU (such as EMODnet) as an EU–FB system.

Other organizations interested in FB systems could be JCOMM, ICES, EEA and the Global Ocean Observing System (GOOS) program of the IOC.

To fully cover the European waters one could imagine the following coverage of the European regional seas: Baltic Sea (3 FB lines), Arctic (Norway to Svalbard, 1 FB line), North Sea including Kattegat/Skagerrak (3 FB lines), English Channel (1 FB line), Irish Sea (1FB line), Atlantic coast (1 FB line), Mediterranean (3 FB lines), Black Sea (1-2 FB lines). This makes a total of ca. 15 FB lines and an investment volume of 1.5 to 2 Million €. Based on estimates on costs of maintenance another 1 million € annually would be needed.

EU member states would be asked to give support through their own marine monitoring institutions. Such EU based governance would help to run the system independent on national policies and would enhance the use of marine and coastal environmental data for future assessments within the Framework of i.e. the MSFD.

Chapter 5: Participating institutes, and groups; specific expertise

(Table of institutes and persons involved with their expertise from FerryBox website (www.ferrybox.org)

INSTITUTION	DESTINATION HARBOURS	NAME OF PLATFORM	OBSERVED PARAMETERS	PUBLIC AWARENESS WEBSITE	START OF OPERATION	END OF OPERATION	REPETITION RATE OF ROUTE
BCCR/UIB	Amsterdam - Bergen	M/S Trans Carrier	pCO_2, T, S, Trb, Chl-a, pCO_2	http://www.bjerknes.uib.no/	2005	Finished Sept 2009	weekly
Cagliari University	Toulon - Bastia	Mega Express 3	T, S, pH, Chl-a, SPMD, POCIS, silicon rubber, DGT, (DO and Trb)		2015	today	daily (October to May)
Cagliari University	Golfo Aranci - Livorno	Mega Express 3	T, S, pH, Chl-a, SPMD, POCIS, silicon rubber, DGT, (DO and Trb)		2015	today	daily (June to September)
CNRS-INSU/ Ifremer	Plymouth-Roscoff	MV Armorique	T, S, DO, chl-a, Trb, CDOM	http://abims.sb-roscoff.fr/hf/fbox.html	2010	today	daily
EMI	Tallinn - Mariehamn - Stockholm	Victoria I	T, S, Trb, Chl-a, CDOM	www.sea.ee	2006	today	daily
HCMR	Souda Bay - Peiraues	Olympic Champion	T, S, Trb, Chl-a, DO, pH	www.poseidon.hcmr.gr	2002-2003	today	daily
HZG	Cuxhaven - Harwich	Duchess of Scandinavia	T, S, DO, Chl-a, pH, Trb, nutrients	www.cosyna.de	2002	2005	6 - 7 times per week
HZG	Cuxhaven - Immingham	TorDania	T, S, DO, Chl-a, pH, Trb, nutrients	www.cosyna.de	2006	2012	3 - 4 times per week
HZG	Moss-Halden-Zeebrugge-Immingham	LysBris	T, S, DO, Chl-a, pH, Trb, nutrients, pCO_2	www.cosyna.de	2007	today	14 days
HZG	Büsum - Helgoland	MS Funny Girl	T, S, DO, Chl-a, pH, Trb	www.cosyna.de	2008	today	daily during summer time
HZG	Cuxhaven- Helgoland	MS FunnyGirl	T, S, DO, Chl-a, pH, Trb	www.cosyna.de	2009	today	3 times/week autumn &winter
HZG	Rotterdam-Immingham	Hafnia Seaways	T, S, DO, Chl-a, pH, Trb, pCO_2	www.cosyna.de	2013	2014	3 - 4 times per week

INSTITUTION	DESTINATION HARBOURS	NAME OF PLATFORM	OBSERVED PARAMETERS	PUBLIC AWARENESS WEBSITE	START OF OPERATION	END OF OPERATION	REPETITION RATE OF ROUTE
HZG	Gothenburg - Zeebrugge	Hafnia Seaways	T, S, DO, Chl-a, pH, Trb, pCO_2	www.cosyna.de	2014	Finished Feb 2015	3 - 4 times per week
HZG	Cuxhaven - Immingham	Hafnia Seaways	T, S, DO, Chl-a, pH, Trb, pCO_2	www.cosyna.de	2015	today	3 - 4 times per week
HZG	Mediteranean Sea / Canarian Islands	Mein Schiff 3	T, S, DO, Chl-a, pH	www.cosyna.de	2014	today	random routes
Ifremer	Portsmouth-Santander-Plymouth-Roscoff-Cork (Saint Malo)	MV Pont-Aven	T, S, DO, chl-a, Trb, CDOM	http://abims.sb-roscoff.fr/hf/fbox.html	2011	today	weekly
"IMGW PIB	MV Pont-Aven	T, S, DO, chl-a, Trb, CDOM	http://abims.sb-roscoff.fr/hf/fbox.html?execution=e1s3	2011	today	weekly	3 - 4 times per week
IMGW PIB (IMWM NRI)	Gdynia - Karlskrona	Stena Spirit	T, S, Trb, Chl-a, DO	http://www.baltyk.pogodynka.pl/	2008	today	every second day
(IMWM NRI)"	Gdynia - Karlskrona	KV TOR	T, S, Trb, Chl-a, DO		2011	today	3 - 4 times per week
IMR	Bergen-Kirkenes	MS Vesterålen	T,S, Chl-a fluorescence		2006	today	11 day roundtrip
IMR	Norwegian West Coast (Bergen)	MV Hascosay	T,S, Oxygen	http://www.scotland.gov.uk/Topics/marine/science/Research/Researchers/AEProgramme/oceanographic			Biodiversity
IMR	Norwegian West Coast (Bergen)	KV TOR	T,S, Oxygen		2011	today	Unregular trips surveying the western Norwegian Coast
INSTM	Tunis-Marseilles, Tunis-Genoa	Carthage	T,S,Chl-a, cond, pH, pCO_2, Oxygen,Trb, sound velocity		march 2016	today	
Marlab	Lerwick - Aberdeen	MV Hascosay	T, S, Trb, Chl-a	http://www.scotland.gov.uk/Topics/marine/science/Research/Researchers/AEProgramme/oceanographic			
MIO (CNRS/INSU)	Genova -Libyan harbours	Jolly Indaco	T, S	www.ciesm.org/marine/programs/partnerships.htm	5/1/10	5/1/11	2 times/month
MIO (HYMEX/CNRS/INSU)	Marseilles-Algiers	Niolon	T, S	www.hymex.org , www.ifremer.fr/transmed	2/1/12	today	2-4 times/month
MSI/TUT	Tallinn - Helsinki	MS Silja Europa	T, S, Chl-a, turb, (pCO_2); nutrients, Chl-a, phytoplankton (wkl sampl in spring-summer)	http://ferrybox.msi.ttu.ee	1997	today	daily
NIVA	Histhals, Stavanger, Bergen	MS Bergensfjord	T, S, Trb, Chl-a, nutrients (weekly samples)	www.ferrybox.no	2008	Finished 2013	3 times per week
NIVA	Sandefjord - Strømsstad	MS Oslofjord	T, S, Trb, Chl-a, nutrients (weekly samples)	www.ferrybox.no	2015	today	3 times per week
NIVA	36 locations from Bergen to Kirkenes	MS Trollfjord	T, S, Trb, pCO_2, Chl-a, pH, nutrients (weekly samples), irradiance, radiance, wind	www.ferrybox.no	2006	today	1 week
NIVA	Oslo, Kiel	MS Color Fantasy	T, S, Trb, Chl-a, CDOM, cyanobacteria, nutrients (weekly samples), irradiance, radiance	www.ferrybox.no	2008	today	daily
NIVA	Tromsø, Bjørnøya, Longyearbyen, Ny Alesund	MS Nordbjorn	T, S, Trb, Chl-a, nutrients (weekly samples), irradiance, radiance	www.ferrybox.no	2008	today	1 week
NIVA/MARLAB/Univ. Rhode Island	Hirtshals, Torshavn, Seydisfjord	MS Norrøna	T, S, Trb, Chl-a + ADCP, XBT	www.ferrybox.no	2008	today	
NOCS	Portsmouth-Bilbao	Pride of Bilbao	"auto: T, S, Chl-a, Trb, O2, pCO_2;	http://www.itameriportaali.fi/en/itamerinyt/levatiedotus/en_GB/levatiedotus/	1998		daily
NOCL	Birkenhead- Dublin	Lagan Viking	T, S, Chl-a, Trb		2006	2011	12 time/week
SMHI & SYKE	Gothenburg-Kemi-Oulu-(Husum)-Lübeck-Gothenburg	"Tavastland	T, S, Trb, Chl-a-fluorescence, Phycocyan-fluorescence, CDOM-fluorescence, DO, PAR, airPress, airTemp, pH, pCO_2 and CO_2 in air, RC (phytoplankton, salinity, chl a, CDOM).	http://on-line.msi.ttu.ee/lvferry/	2013	2013	3 times per week
SYKE	Helsinki - Stockholm	Silja Serenade	T, S, Chl-a, Turb, Phycocyan, nutrients, phytoplankton	http://www.itameriportaali.fi/en/itamerinyt/levatiedotus/en_GB/levatiedotus/	1998		daily
SYKE	Helsinki-Travemunde, Helsinki-Gdynia	Finnmaid	T, S, Chl-a, nutrients, Phycocyan, CDOM, TURB, nutrients, phytoplankton	http://www.itameriportaali.fi/en/itamerinyt/levatiedotus/en_GB/levatiedotus/	Finnpartner1998 - 2006, Finnmaid 2007-		daily
LIAE - MSI/TUT	Riga-Stockholm	MS Romantika	T, S, DO, Trb, Chl-a, phycocyanin (monthly samples nutrients, Chl-a, phytoplankton)	http://on-line.msi.ttu.ee/lvferry/	2013	2013	every second day

UNIT 2 – APPLICATIONS AND USERS OF FB DATA

Chapter 6: Regional and global long-term time series based on FB observations

FerryBoxes installed on ships of opportunity (SoO) provide data of selected tracks on a regular basis. Long-term time series on such a track can be used to detect events along these transects and to analyze processes.

Detection of events

Figure 6.1 shows as an example of continuous salinity data along a transect between England and Germany (Cuxhaven-Immingham) and an observed freshwater inflow (exceptional depletion of salinity) between 4.8° and 5.5° E in May 2008.

The evidence from data on nutrient concentrations, river discharge rates and drift simulations make a plausible case that the observed low-salinity patch was the result of high freshwater input by the River Rhine (Petersen *et al.* 2011).

Figure 6.2 illustrates the TS data from two transects (14th & 15th of August 2012) of HCMR's FB installed on a HS/Ferry travelling daily between Athens and Crete (Greece). The salinity minimum of the plots between 37 and 37.5 degrees N indicates the less dense Black Sea water mass that is pouring into the Aegean Sea through the Dardanelles straits. The right panel highlights the spatial distribution of the SSS on the 15th of August 2012 as produced by the operational POSEIDON Aegean Sea Model.

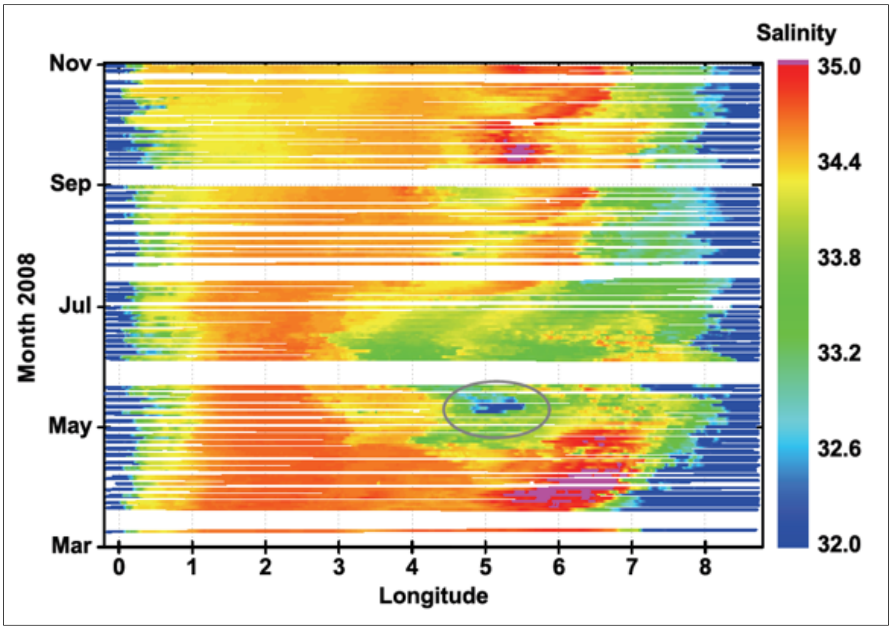


Fig. 6.1.: Pooled salinity data along the Immingham (UK) to Cuxhaven (DE) transect in 2008. The grey circle indicates the time period of a freshwater inflow.

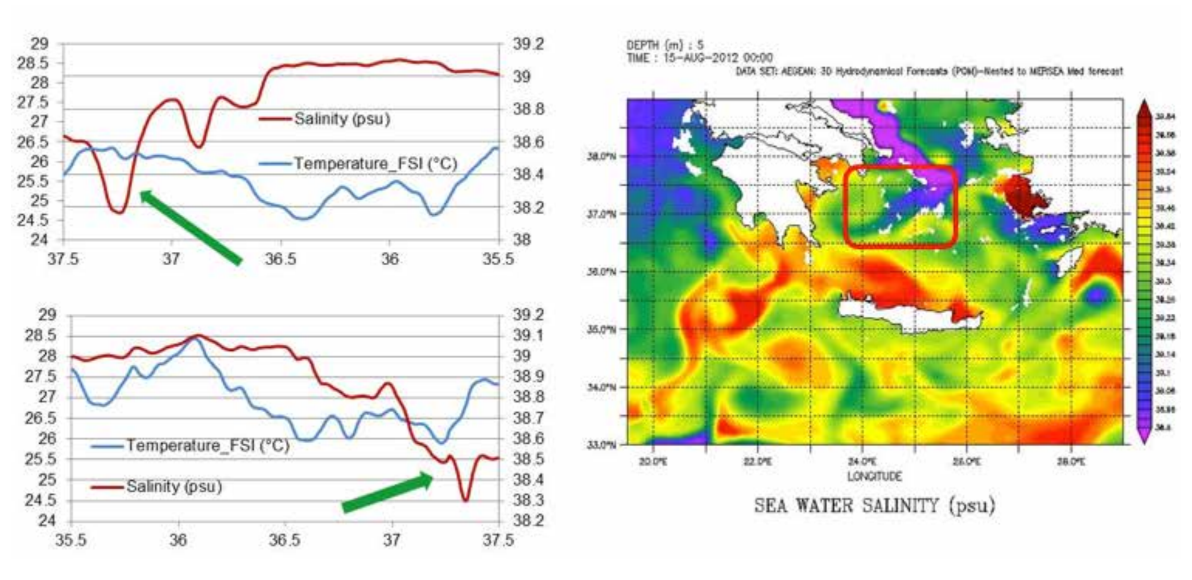


Fig 6.2.: Salinity data of two FB transects (14-15 August 2012) and the SSS output (15 August 2012) of the Operational POSEIDON Aegean Sea Model. The salinity minimum near the island of Milos is an indicator of Black Sea Water (BSW) flowing in the Aegean Sea. (left frames: left axes: temperature, right axes: salinity).

Investigation of processes

A continuous dataset on oxygen concentrations was recorded along the track from Harwich to Cuxhaven for several years. Oxygen anomalies were used in combination with wind fields to estimate the oxygen fluxes for the respective years during the growing seasons. Oxygen fluxes, in turn, were used to derive time series of carbon fluxes (carbon uptake) as an indicator for biological activity neglecting the small thermal component of the calculated oxygen anomaly. Figure 6.3 shows the calculated uptake of carbon during the growing sessions for the years 2002, 2004 and 2005.

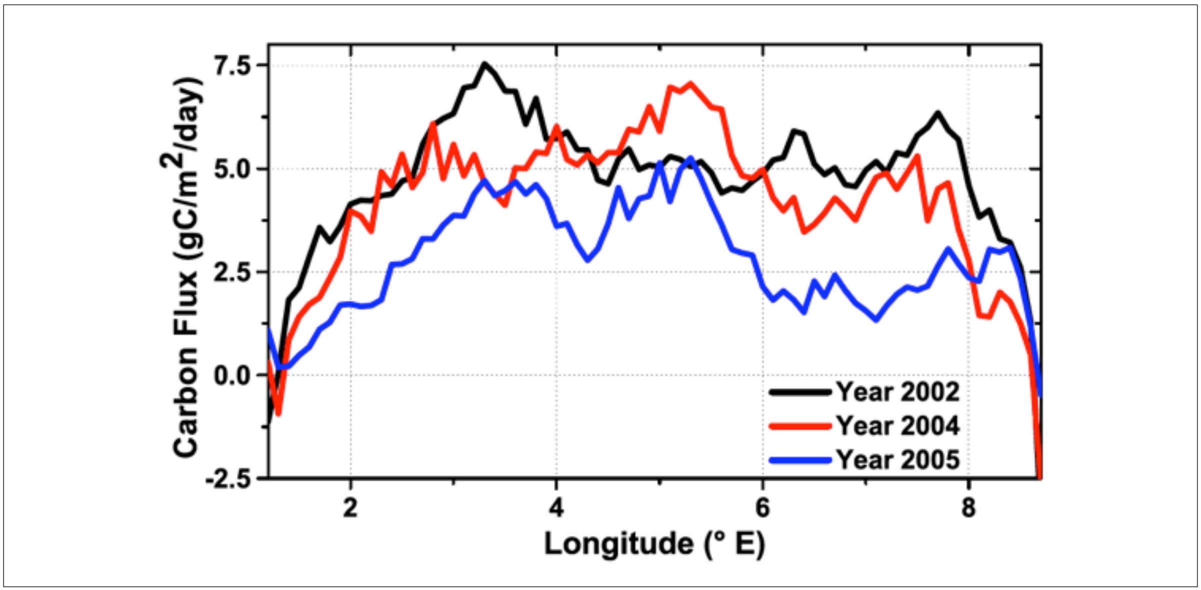


Fig.6.3: Uptake of carbon during growing season (March to October) calculated from average oxygen fluxes measured along the transect Harwich–Cuxhaven in 2002, 2004 and 2005.

These fluxes can be regarded as net productivities showing distinguished maxima along the transect as well as varying magnitudes in the different years (Petersen *et al*. 2011). The maxima suggest that these specific regions may act as important carbon sinks due to increased phytoplankton growth.

Coastal upwelling events

FerryBox technology has been used to study coastal upwelling events in the Gulf of Finland, Baltic Sea, which can supply large amounts of nutrients into the euphotic layer. Based on the introduced upwelling index and related criterion, 33 coastal upwelling events were identified in May-September 2007-2013 (Kikas and Lips, 2015). It was shown that the wind impulse needed to generate upwelling events of similar intensity differ between the two coastal areas whereas this difference is related to the average wind forcing in the area. Two types of upwelling events were identified – one characterized by a strong temperature front and the other revealing gradual decrease of temperature from the open to coastal area with maximum temperature deviation close to the shore (Fig. 6.4) during the July-August period.

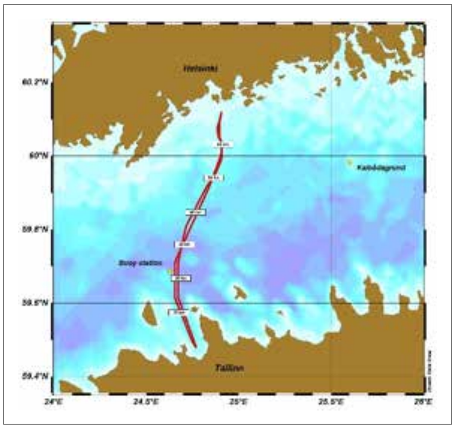
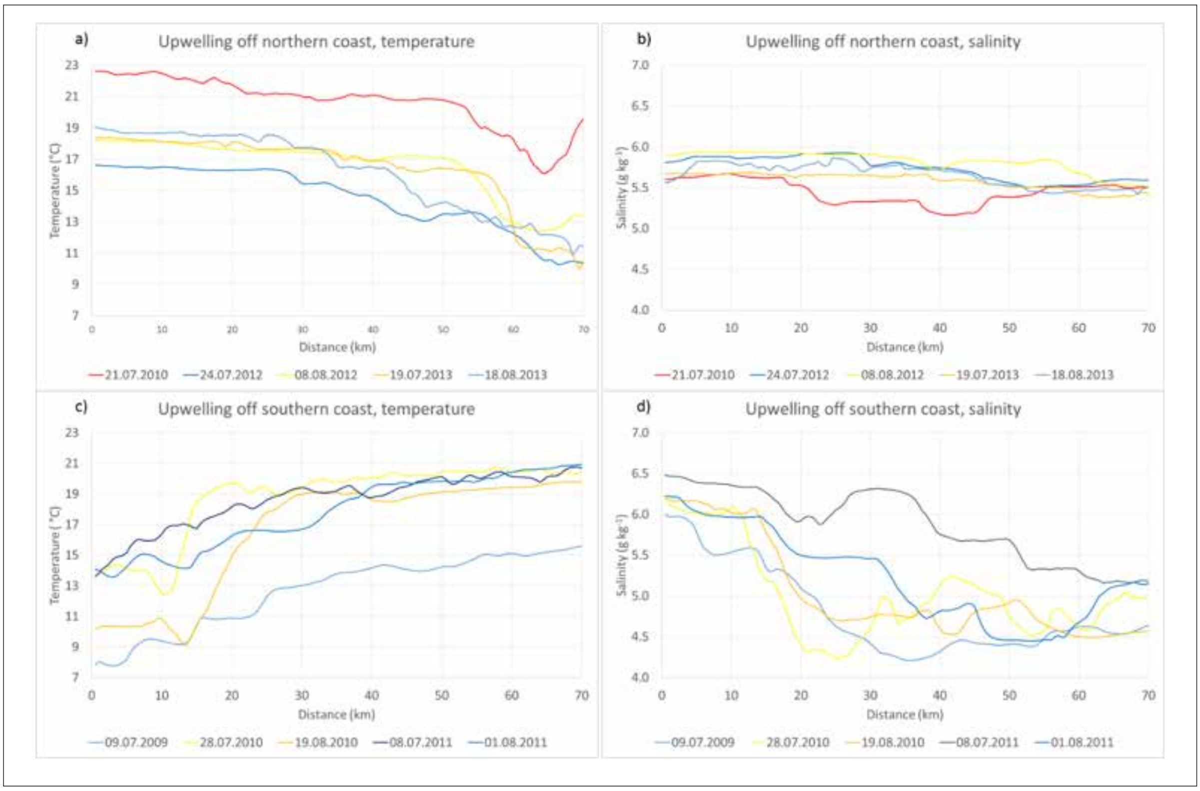


Figure 6.4 Map of the study area and transect (upper panel). Characteristic distributions of temperature and salinity along the ferry route Tallinn-Helsinki with coastal upwelling events off the northern coast (a, b) and off the southern coast (c, d); x-axis shows the distance from the Tallinn Bay (latitude 59.48 N) in km along the meridional transect. Monitoring large-scale climate variation and their effects.



The FerryBox lines from Oslo southwards (Oslo-Hirtshals/Fredrikshavn for 6 years, then Oslo-Kiel for 7 years) have so far provided 13 years of data measurements for the Oslo fjord and Skagerrak, and 7 years of data from Kattegat and the western Baltic (Fig. 6.5.a). Thus, a very good time series is developing which will prove to be an invaluable baseline for the studies of possible future climate change. For instance, the outflow of brackish water from the Baltic Sea (Fig. 6.5.a) can be monitored with much greater frequency and detail than feasible with research cruises, and future changes can be compared with the existing catalogue of data. Also, short-term events such as freshwater pulses from floods can be monitored, which is of increasing importance as the frequency of heavy rainfall is expected to increase. In the Oslo fjord, we find positive and negative correlations between chlorophyll and salinity depending on season (Fig. 6.5.b). These examples demonstrate the usefulness of continuous and long-term measurements along a transect based on FerryBox observations.

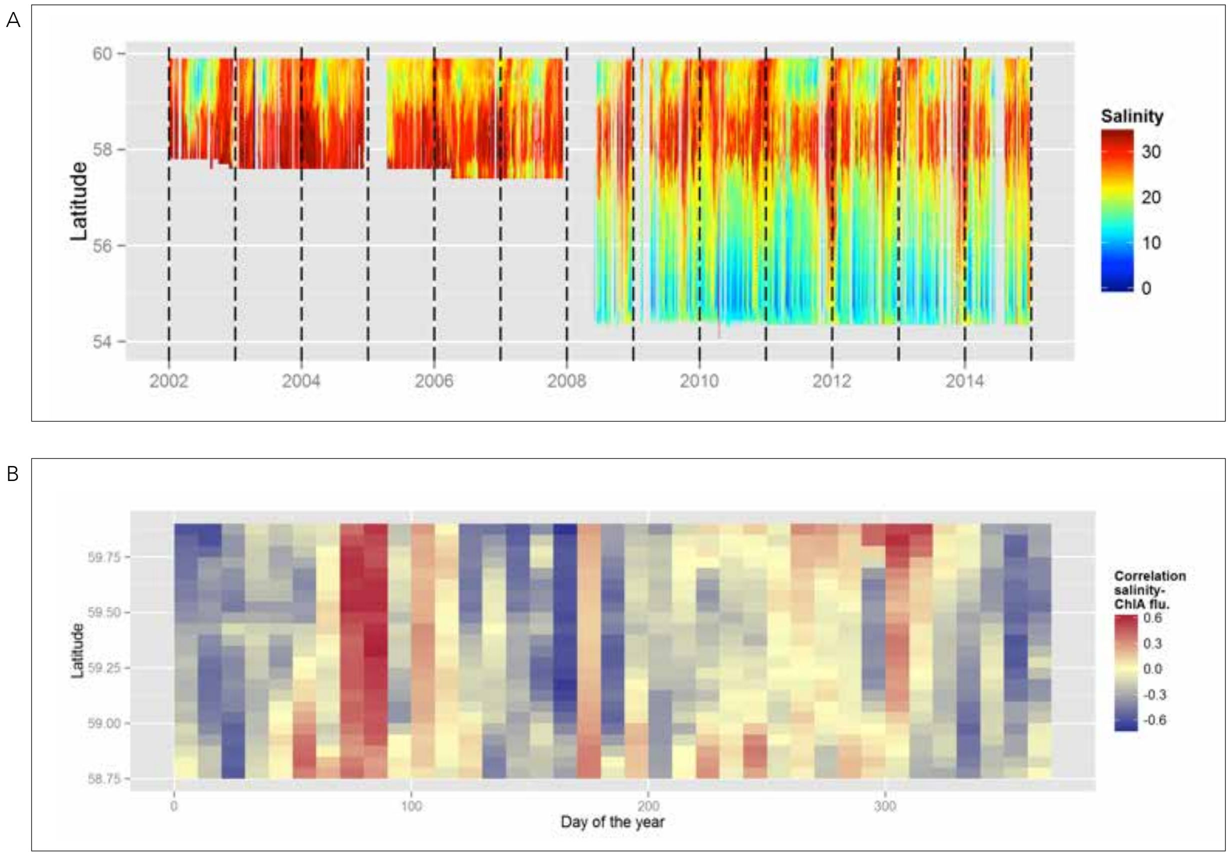


Fig. 6.5: (a) Salinity along the Ferrybox transects Oslo-Hirtshals/Fredrikshavn (2002-2007) and Oslo-Kiel (2008-2014). Means per day and 0.05 degree latitude. The pulses of fresh water in the Oslo fjord (latitude 59-60) in spring are evident as well as the outflow of fresh water from the Baltic (south of latitude 55.4). The plot is based on more than 4 million measurements.

(b) Correlations between salinity and chlorophyll A in the Oslo fjord. The colors show the correlation between the salinity deviance and chlorophyll A deviance (both corrected for latitude and season). The spring bloom in the end of March (ca. day 80) is positively correlated with high salinities, while the chlorophyll in winter and the summer bloom around day 140-200 is negatively correlated with salinity.

Chapter 7: FB measurements as ground truth for satellite observations

FerryBox data have for some years already been used in combination with satellite data both for validation and development of downstream services. It has been demonstrated that the biogeochemical data (BGC) collected by the traditional FB sensors as well as data from above surface mounted sensors for marine reflectance and Sea Surface Temperature (SST) are useful for this purpose. In addition to the direct use of the FB sensor data for validation, it is also possible to automatically collect water samples for more advanced analysis in the laboratory since the sensor data cannot measure all the Inherent Optical Properties (IOP) we need for validation of optical satellite products.

Traditional validation of optical satellite data is performed using fixed stations from research vessels or from fixed platforms, but the use of sensor data from a FB transect provides more data and hopefully more matchups. The water intake of the FB at 3-5 meters represents a depth where the main marine signal is reflected back to the satellite sensor in the coastal zone. The combination of FB data and satellite data has been explored already in the EU projects FerryBox and REVAMP, and in the ESA project VAMP. In the in situ component of the Copernicus program (CEMES) this has been further developed and in the two running EU-FP7 projects AquaUsers and HighROC new services are developed from the combination of satellite data and FB data.

The core sensor data on a typical FB installation are temperature, salinity, Chl-a fluorescence, and turbidity. The temperature measurement is of the bulk temperature on 3-5 meters and can be used in some cases, but since the satellite SST are sensing only the “skin” temperature this can give a wrong validation. It is then more common to use a deck mounted spectro-radiometer for SST measuring in the thermal part of the spectrum. Salinity data are mostly used as important information for understanding the different optical water masses when studying other optical sensor data (e.g. cDOM). Salinity sensor data could be used in combination with the Soil Moisture Ocean Salinity (SMOS) Earth Explorer satellite sensor, but this would only be valid for open sea since the geometric resolution of SMOS is relatively large so it will only be for more Atlantic FB (VOS) lines.

Chlorophyll-a fluorescence (Chl-a_FL) is a candidate for use towards satellite data, but the diurnal variation of the Chl-a_Fl are a challenge for direct validation of the satellite optical product Chl-a. But if one has a good understanding of the variability of the Chl-a_Fl /Chl a ratio this can give important information of the quality of the satellite products in the coastal areas (Case II waters). Taking this into account the Chl-a_Fl are a good proxy for the Chl-a, but it is optimal for Chl-a validation to take water samples for analysis of the Chl-a pigments and degradation products directly. This is also needed to establish the Chl-a_Fl/Chl-a ratio. The most obvious use is to develop downstream services for WFD combining data from the two platforms.

The satellite product Total Suspended Material (TSM) is directly coupled to the particle scattering and the core sensor turbidity in the FB systems is a very good candidate to use since the turbidity is strongly correlated to the backscattering. The sensor has of course to be very well calibrated and one must check the local or regional relationships of the TSM/Turbidity ratio which is performed by using water samples and laboratory analysis.

In the European network of FB the mentioned core sensors are installed on most of the ships so this should give a large dataset for validation if properly optimized for these applications. Some FB lines have installed more advanced BGC sensors as well as above water sensors, and some of them are already used in the validation like the above water radiance and irradiance sensors for estimating the water reflectance (Ocean Color). Control of the marine reflectance at the sea surface is the most important validation for the optical satellite data. This signal is the basis for all the optical satellite water products and if this is wrong for some reason like e.g. adjacency

effect of land on the marine signal (failure of atmospheric correction) the satellite water products will give erroneous values.
In figure 7.1 such a comparison is shown for the MEdium Resolution Imaging Spectrometer (MERIS) reflectance at the sea surface and the estimated marine reflectance from ship mounted TriOS Ramses sensor from the Barents Sea.

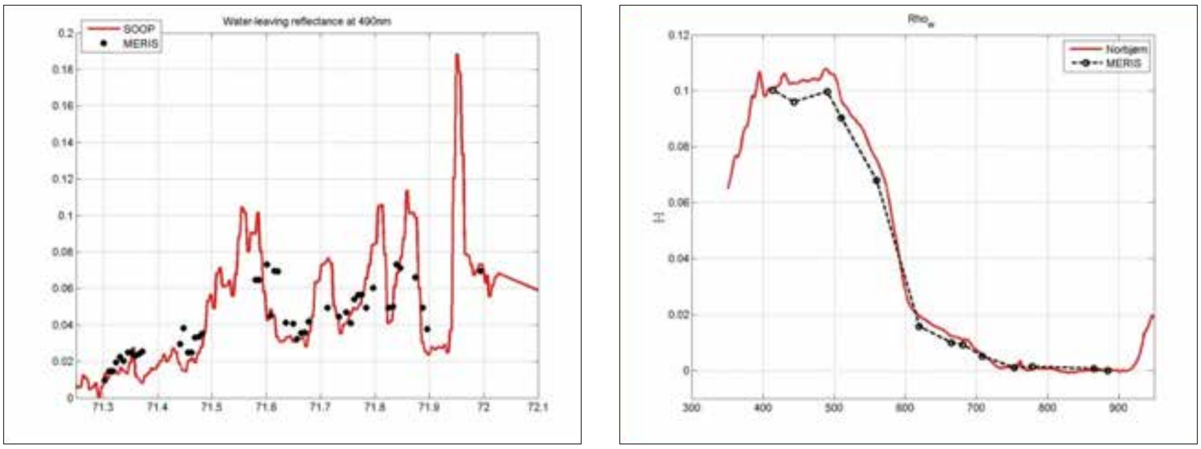


Figure.7.1. Marine reflectance (Rhow) as measured by MERIS and TriOS Ramses in the Barents Sea during a coccolithophore algal bloom. (a) Rhow at 490 nm from MERIS and the Ramses sensor along a transect (left) and (b) the reflectance spectrum close to the matchup time of MERIS on board M/V Norbjørn against wavelength(right); (left frame x-axis: longitude, y-axis: marine reflectance; right frame: x-axis: wavelength, y-axis: marine reflectance).

As part of ongoing sensor projects (EU and others) and initiatives by the FB partners, new sensors for the IOP of the water masses are being tested e.g. the integrating sphere measuring the absorption of particles and cDOM. This can be an important sensor for characterization of the absorption properties of the water constituents and can be more directly linked to the water IOP for testing bio-optical algorithms.

Even though core turbidity sensor data are well correlated to the TSM, it is important to implement some new sensors available that measure the backscattering at different and optimal satellite wavelengths. Some sensors are already on the market, but they need to be tested and validated in a flow-through system to address possible issues related to scattering of micro airbubbles.

For some coastal areas, the optical satellite algorithms (Chl-a) have problems connected to the high absorption of dissolved organic material (cDOM) since this has an absorption in the same part of the spectrum as the Chl-a pigments. Some FB systems have a cDOM sensor installed and they can be of high value for the interpretation and understanding why satellite products in some areas fail. The most used FB-installed cDOM sensor is based on fluorescence, but it should give a good proxy for the DOM that influences the algorithms. Satellite cDOM products have up to now not been very successful, but due to the increase of freshwater runoff into the sea and darkening of the coastal waters, this is an important scientific task to explore more and to better understand and monitor with FB and satellite data.

The European Copernicus programs involving the new environmental satellite like the Sentinels (primarily Sentinels 2 and 3) will benefit much from strengthening the connection of in situ data from FB for direct validation and downstream service developments.

A comparison between large scale RS (MERIS) observations and measurements on board FB lines is shown in Fig. 7.2. with a rather consistent agreement.

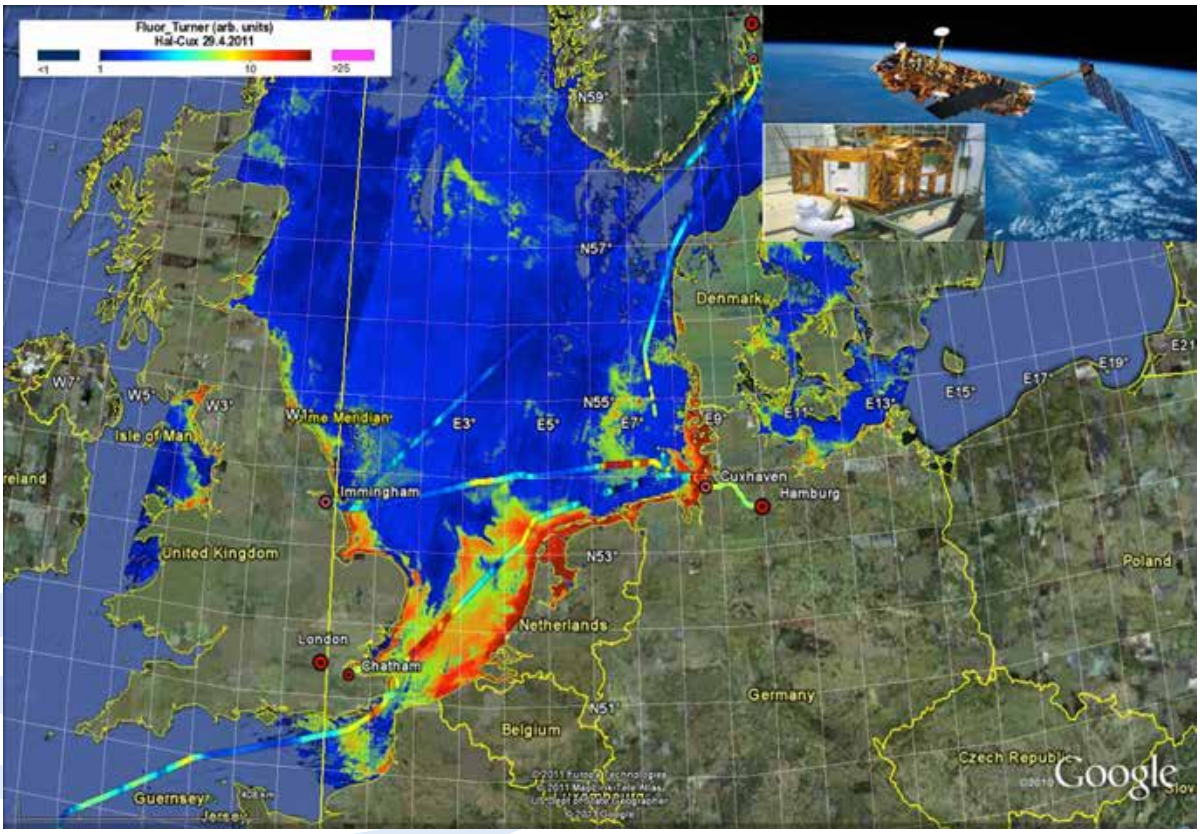


Fig.7.2. Comparison between large scale remote sensing (MERIS) picture of the North Sea with approximately simultaneous observations made with FB systems along a few routes (May 2011).

Chapter 8: Use of FB measurements for the fishing and aquaculture community

FB measurements can offer high frequency data, in particular in sea areas which are used by the fishing and aquaculture community and therefore may prevent interactions with e.g. harmful algal blooms or discharges of noxious compounds.

The coastal ocean is heavily used by aquaculture industries (finfish and shellfish), wild-caught fisheries, and maritime operations. This region is often strongly affected by anthropogenic activities (run-off, nitrogen inputs, ocean acidification, etc.), and also represent environmental extremes in microbe- and phytoplankton-mediated biogeochemical processes (eutrophication, oxygen minimum zones, and harmful algal blooms). The resilience and management of aquaculture and natural finfish and shellfish stocks are dependent on our understanding of these processes and, in some cases, early-warning measures to prevent potential negative socio-economic consequences.

For example, Norwegian coastal and fjord waters are spawning grounds for Atlantic cod which are harvested at a rate of ~0.5 million tons/year which accounts for about half of the global catch (FAO report, 2012). These coastal and fjord waters overlap with >1000 finfish aquaculture sites that produce >1 million tons/year of salmon (about half of global farmed salmon) (Norwegian Fisheries Directorate, 2014), much of which provides protein for other European countries. Both the wild Atlantic cod fishery and the salmon aquaculture are susceptible to environmental fluctuations in physical conditions (e.g., temperature, salinity, mixing), chemical conditions (e.g., nutrient concentrations, O_2, pH/CO_2, contaminants), and biological conditions (e.g., harmful/noxious algal blooms, presence of fish and shellfish parasites/viruses). Poor characterization and understanding of the temporal and spatial scales at which these biological and physiochemical conditions change in Norwegian coastal waters, in combination with uninformed management, could have potentially significant negative effects on the Atlantic cod fisheries and aquaculture operations.

FerryBox routes presently consist of commercial container and passenger ships that operate in key coastal regions including the Norwegian coast and fjords (in the example above), Baltic Sea, North Sea, and parts of the German, French, Spanish, and Greek coastlines. The high spatial and temporal frequency of presently collected data by FerryBox systems can provide real-time information for nearby aquaculture and fishing operations. Additionally, creating a useable and accessible knowledgebase in combination with further development of advanced biological and chemical sensors (see Chapters 6 and 8) will assist these industries in identifying and providing warning of adverse conditions and mitigate potential negative impacts.

An example of the monitoring activities using a FB system is shown in fig. 8.1. Another Hurtigruten ship is also equipped with a FB system, so that the frequency of measurements is increased by a factor of two.

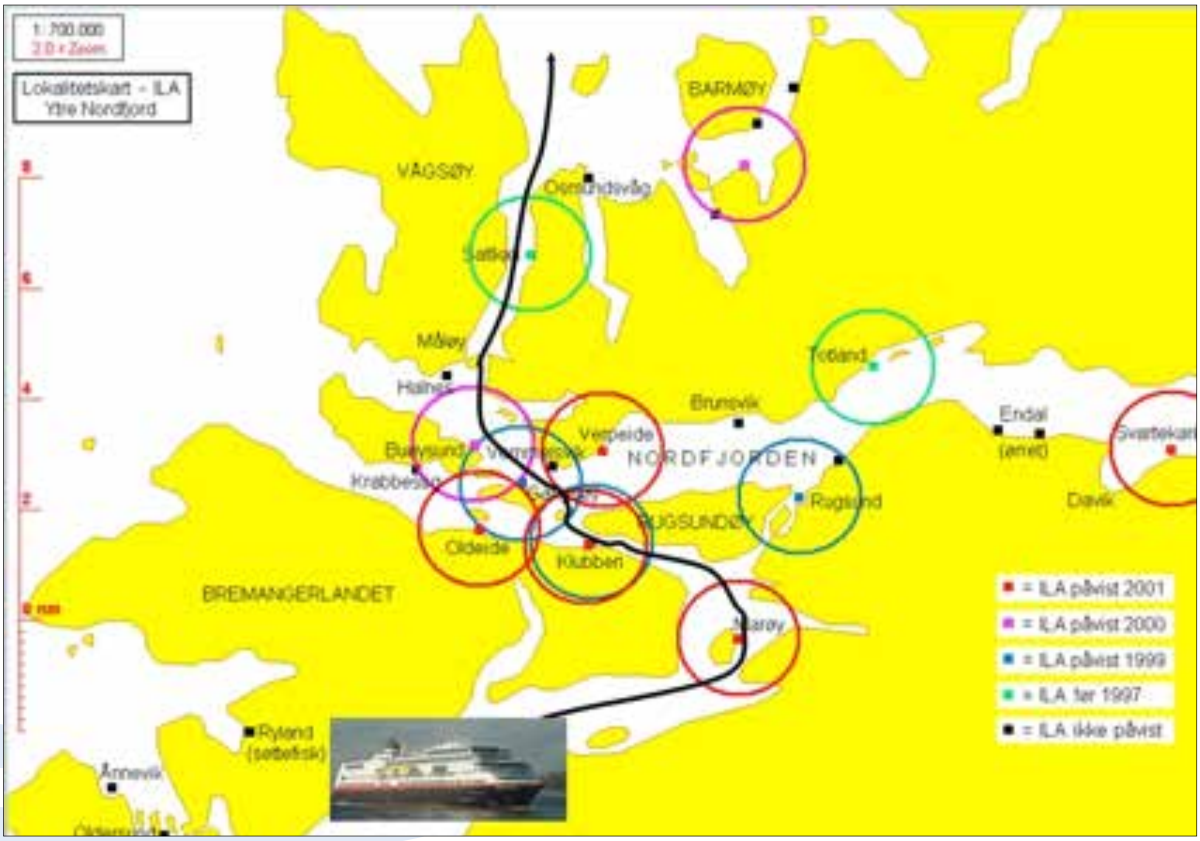


Fig. 8.1. Trollfjord FB line through Norwegian waters.

- M/S Trollfjord FerryBox line in black – map centered at ~61.9 deg N 5.1 deg E in Nordfjorden (western Norway). This site is visited every ~5 days by the Trollfjord FerryBox.
- Monitoring for water quality including harmful algal blooms, infectious salmon anemia (ILA), in addition to collecting observations for hydrography/circulation and predictive model validation
- The figure shows the proximity of the Trollfjord FerryBox track and location of salmon farm operations as indicated by square symbols. The color of the symbols and circles indicate the year in which infectious salmon anemia was first detected

Chapter 9: Use of FB data by the scientific community including the use of FB data by modelers

FB Measurements may be a very useful data set for the validation and testing of ecosystem and oceanographic models or as input for data assimilation exercises.

Model validation by FerryBox data

FerryBox data were used to compare model simulations applied to the North Sea with FB temperature and salinity data from a track along the southern North Sea over several years (Haller *et al*. 2015). Figure 9.1 shows the differences for temperature and salinity between model and in-situ data along the transect of the FerryBox for two different models (BSHcmod v4 and FOAM AMM7 NEMO). The simulation of water temperatures is satisfying; however, limitations of the models exist, especially near the coast in the southern North Sea, where both models are underestimating salinity, likely due to inadequate river climatology.

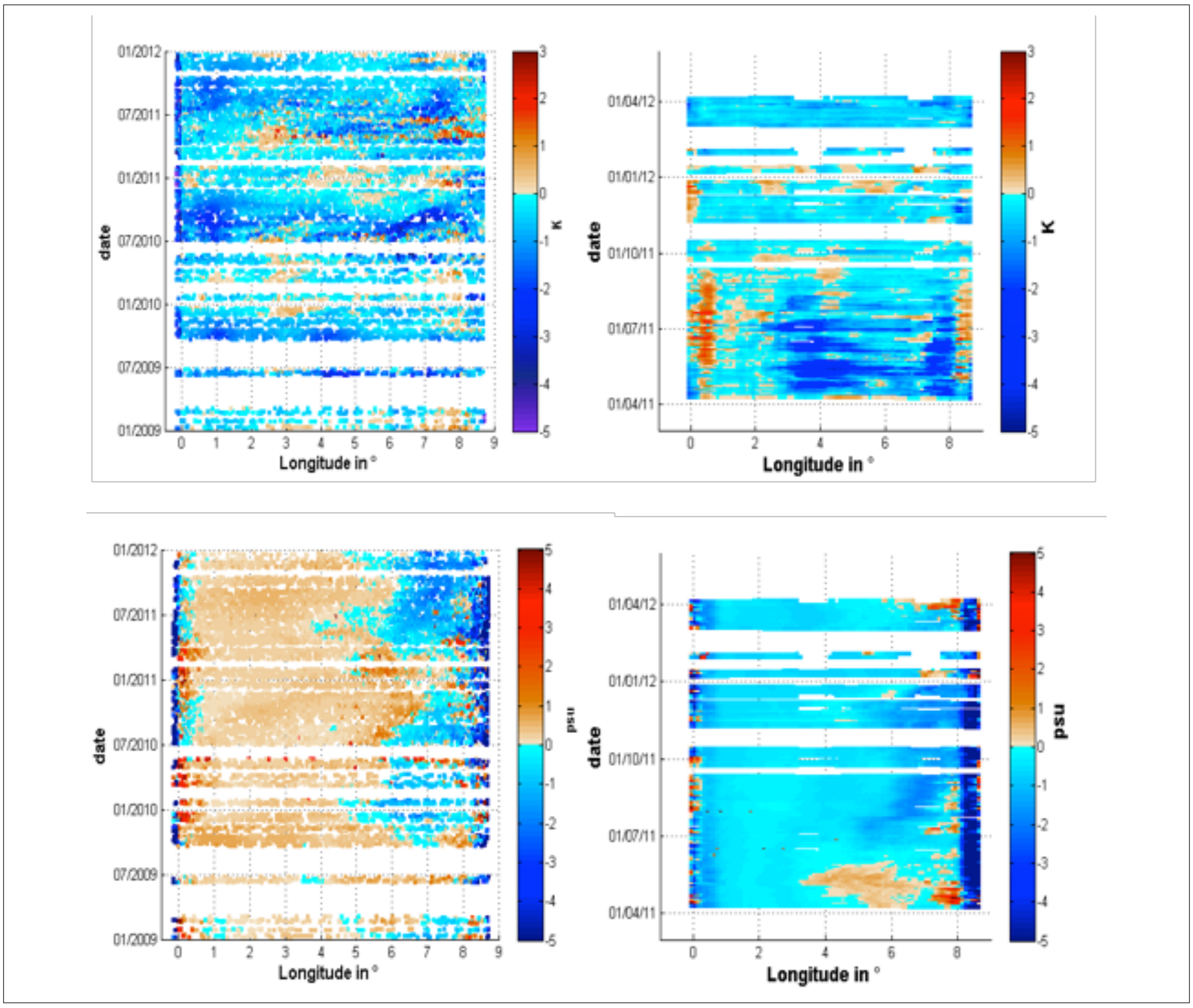


Fig. 9.1: Upper panels: Difference between model results and observed water temperatures for Immingham-Cuxhaven FB transect (left side BSH model-FB 2009-2011, right side AMM7 model -FB 2011-2012). On the left side is located the East England coast, on the right side the German Bight. Positive values indicate model overestimation.
Lower panels: Difference between model results and observed salinity for Immingham-Cuxhaven FB transect (left side BSH model-FB 2009-2011, right side AMM7 model-FB 2011-2012). On the left side is located the East England coast, on the right side the German Bight. Positive values indicate model overestimation.

The study results reveal weaknesses of both models, in terms of variability, absolute levels and limited spatial resolution. In coastal areas, where the simulation of the transition zone between the coasts and the open ocean is still a demanding task for operational modelling FerryBox data, combined with other observations with differing temporal and spatial scales serve as valuable tool for model evaluation and optimization. The optimization of hydrodynamical models with high frequency regional datasets, like the FerryBox data, is beneficial for their subsequent integration in ecosystem modelling.

Data Assimilation

The use of FerryBox data to improve the estimates of model data has been tested with data from a FerryBox in the North Sea (Grayek *et al.* 2011, Stanev *et al.* 2011). The figure 9.2 show the comparison of in situ data with a free run and a run for data assimilation with FerryBox data.

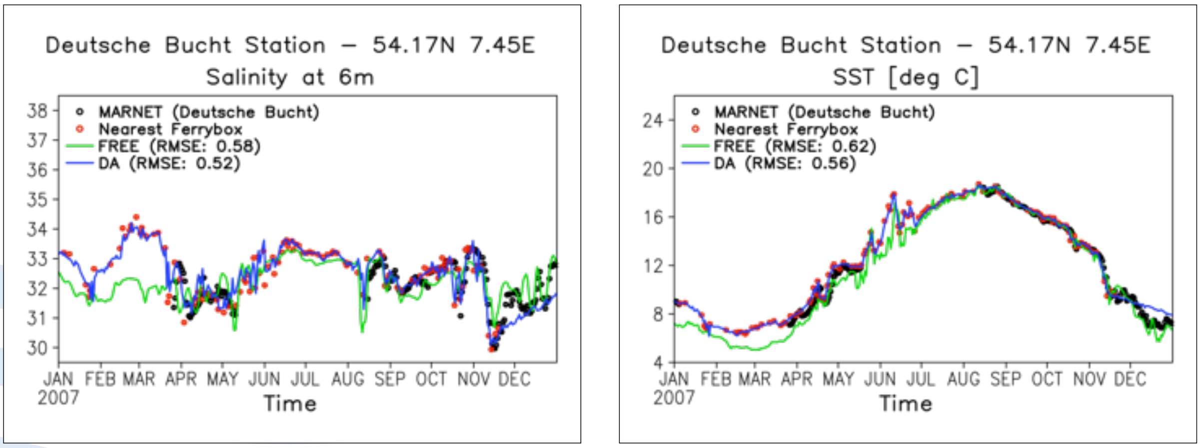


Fig.9.2: Comparison of in-situ measurements (dots) with the model output of a free run (FREE) and a run with data assimilation (DA).

The model is capable to simulate the surface temperature reasonably well, in particular in the offshore area of the German Bight. It was demonstrated that data assimilation significantly improves the performance of the model with respect to both SST and SSS. Although this improvement is mostly around the Ferry track, it is demonstrated that in general the skill is good over larger areas covered by the model solution.

A data assimilation exercise was conducted using the FerryBox temperature measurements along the route from Heraklion to Piraeus. In order to assess the impact of the FerryBox SST data in constraining the Aegean Sea hydrodynamic model, which is part of the operational POSEIDON forecasting system, the in-situ data were assimilated using an advanced multivariate assimilation scheme. 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.

Apart from the improvement of the SST error, the additional assimilation of daily 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 (sea surface height) RMS error. In the Cretan Sea, the model shows persistent error (5–6 cm) to the west of Crete (west Cretan passage), south of Crete and southeast of Santorini island (35° N 26° E). The introduction of SST data along the FB route Piraeus to Heraklion into the assimilation system is able to lower the SSH errors by 1–3 cm (G. Korres *et al,* 2014). Moreover, the correct representation of the dipole in the model simulations is also very important in terms of the ecosystem forecast (POSEIDON Biogeochemical Model) since an intense activity of the cyclone often results in the upwelling of nutrients from the deep Transient Mediterranean Water mass.

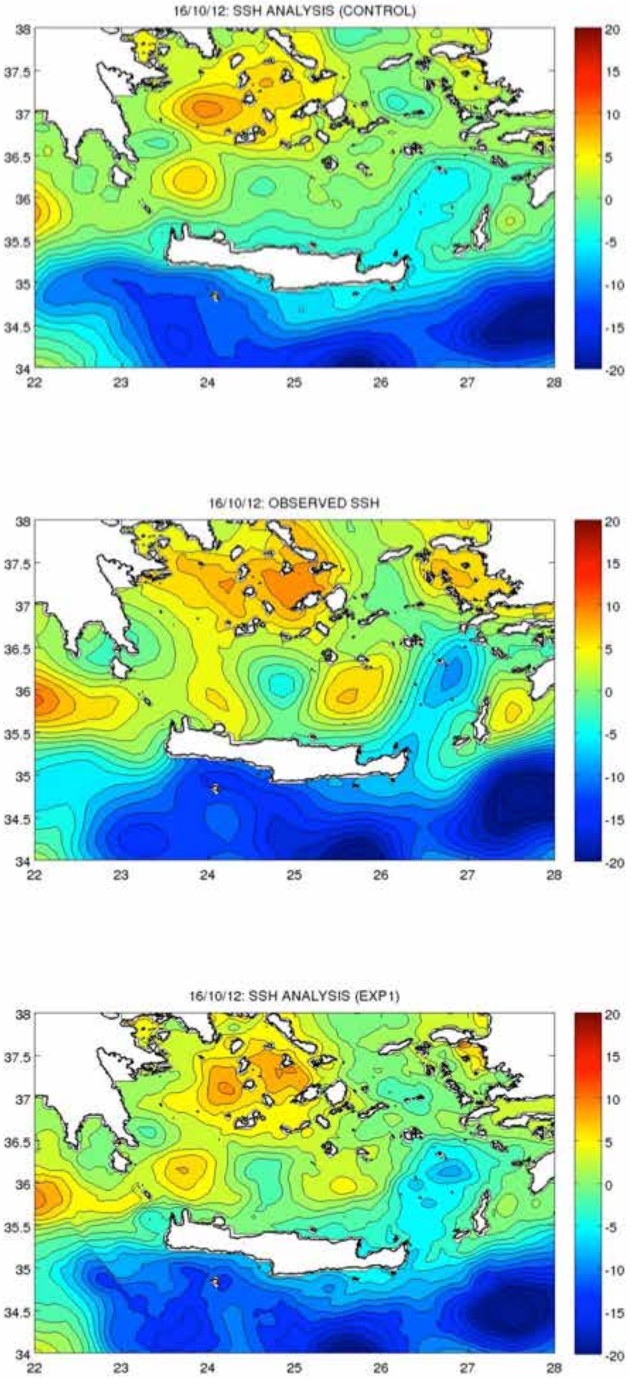


Fig. 9.3: SSH field (in cm) for 16 October 2012 corresponding to a) the analysis of CTRL experiment b) the satellite observations and c) the analysis of EXP1 experiment. The basin wide improvement of SSH (sea surface height) prediction through FerryBox SST (sea surface temperature) assimilation is depicted. X-axis in all frames: longitude, Y-axes: latitude.

Chapter 10: Use of FerryBox systems as an efficient alternative to current monitoring strategies

This contribution shows a comparison between FB systems and current monitoring strategies based on surveys, and fixed or moored stations.

FerryBox systems equipped with autonomous water sampling devices enable following the dynamic events in the marine environment (such as phytoplankton spring blooms) with high resolution in space and time. (Fig. 10.1) Based on data from the Gulf of Finland, the ratio of nitrogen to phosphorus consumption during the growth phase of the spring bloom was estimated and it was found to be close to the Redfield ratio (Lips *et al.*, 2014). The maximum phytoplankton carbon biomass was observed after the depletion of inorganic nitrogen from the surface layer, which coincides with the transition in the community dominance from diatoms to dinoflagellates. Since diatoms exhibit a relatively narrow and more distinct period of high biomass compared with dinoflagellates (Fig. 10.2), the conventional monitoring methods might overlook the period of diatom dominance in the Gulf of Finland. Thus, FB technology provides both, more accurate estimate of nutrient consumption, which could improve performance of biogeochemical models, and estimates of the state of marine environment by applying indicators based on species composition of phytoplankton community (e.g. diatom-dinoflagellate ratio).

The combination of FB systems with the Continuous Plankton Recorder (CPR, SAHFOS, UK) enables a direct link between species composition and environmental parameters, which currently is missing for most of the CPR lines. First attempts for a combination of both data sources are running.

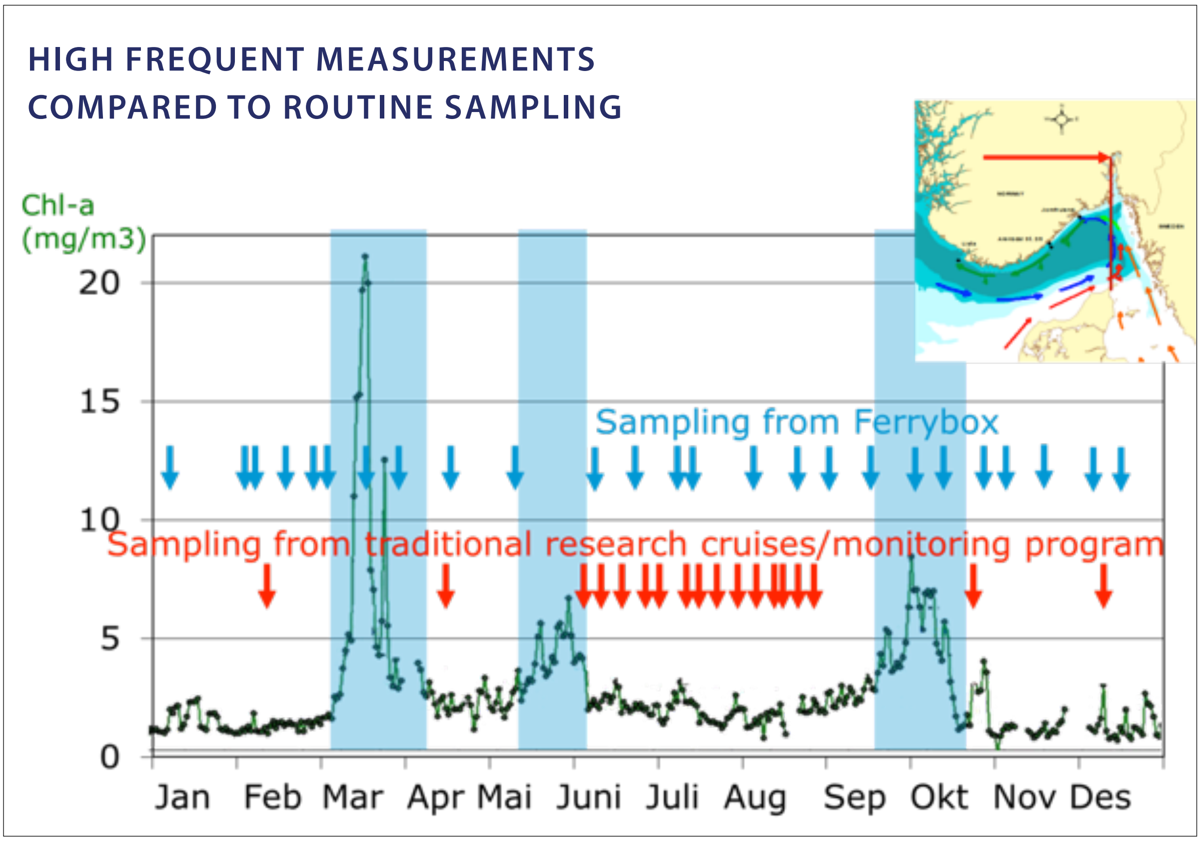

HIGH FREQUENT MEASUREMENTS COMPARED TO ROUTINE SAMPLING

Fig. 10.1: Comparison of FB sampling and sampling from a traditional monitoring program, showing misfit between natural blooms and observation frequency.

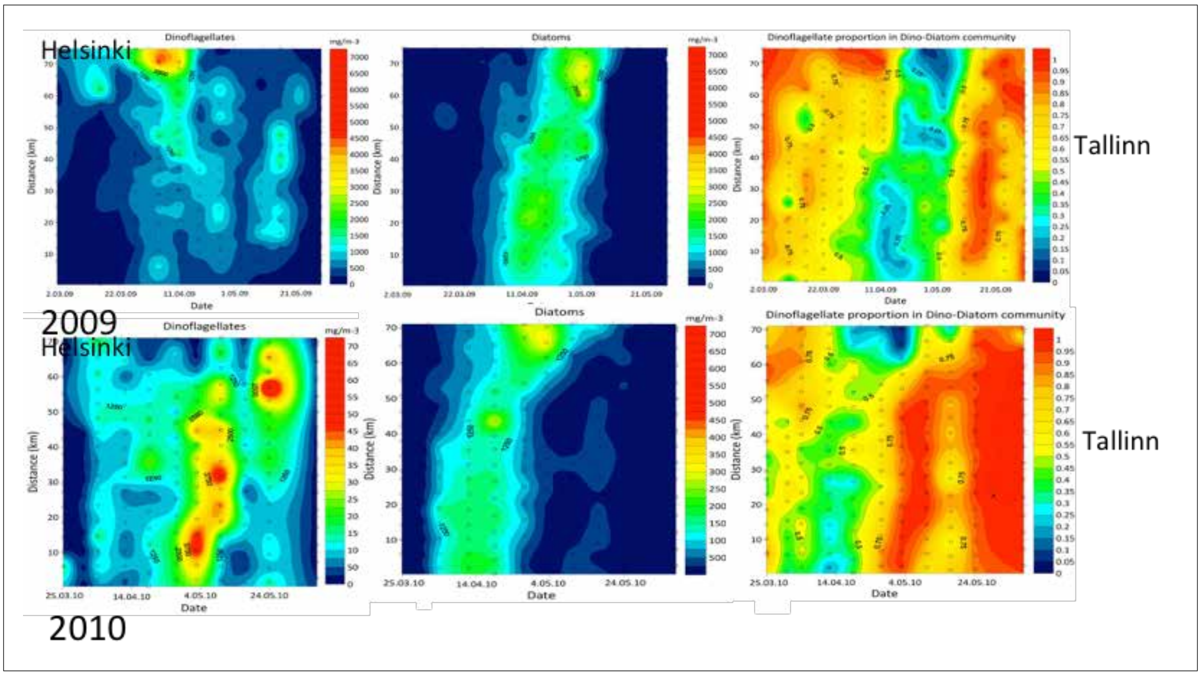


Fig. 10.2: Temporal variation of the horizontal distribution of the carbon biomass of diatoms and dinoflagellates based on microscopical counts and the proportion of dinoflagellates in the diatom–dinoflagellate community along the ferry route from Tallinn to Helsinki in the springs of 2009 and 2010. The sampling sites are indicated as white dots. (Lips *et al.*, 2014).

Chapter 11: Development of new sensors for (coastal) oceanographic observations (Innovation)

FerryBox flow-through systems offer good possibilities to extend the system of standard parameters with other, or even new, sensors as long as they are suitable for unattended operation over a longer time period. If appropriate, new sensors are available for unattended use in FerryBoxes, the scope of marine research could widen considerably. This is even possible if these new instruments are not so robust or still in a prototype stage because they are operated in a protected environment inside the vessel. To obtain reliable estimates on the ecological state of the sea, newly developed sensors for more biologically relevant parameters are especially important, and would be of special interest regarding the requirements of the Marine Strategy Framework Directive (MSFD) in Europe. At present, there are many new in-situ technologies suitable for application in FerryBoxes under development. However, the range of commercially available and reliable instruments is still limited. Mature and suitable bio-geochemical sensors for unattended long-term operation for chlorophyll-a fluorescence, dissolved oxygen, pCO_2 and pH are commercially available. Existing methods for pH include glass electrodes, solid state sensors and spectrophotometric detection. Of the three, the glass electrodes are the least reliable in terms of accuracy and drift. Other instruments such as chemical analysers for nutrients are offered as well; however, these still suffer from long-term instabilities and tedious efforts for maintenance including calibration and quality assessment.

Biological observations: phytoplankton biomass and species composition

Important parameters, for examining the ecosystem at the first trophic level include the amount of biomass and the community structure of the algae. However, such measurements are not easy to implement in autonomous systems. For example, the quantitative assessment of biomass derived from chlorophyll-a poses a particular problem. Chlorophyll-a fluorometers measuring chlorophyll-a fluorescence are commonly used and easy to operate. However, the fluorescence signal is only a proxy for chlorophyll-a and even less accurate to estimate the algal biomass. The fluorescence yield and the conversion factors are strongly dependent on the phytoplankton species composition and the physiological status of the cells as well as light conditions (see also Chapter 3). Other problems arise in the case of cyanobacteria. Chlorophylls and carotenoids are present in virtually all algae, while phycobilin pigments are the main pigments in cyanobacteria and red algae. Thus, in vivo fluorescence of chlorophyll-a showing low fluorescence yield is not appropriate to measure concentrations of cyanobacteria. Instead, the fluorescence of phycobilin pigments (e.g. phycoerythrin) can be used (Seppälä *et al.* 2007) but still suffer from high variability of fluorescence yield (Simis *et al.* 2012).

Alternatively, to the fluorescence of chlorophyll-a, algal concentration can also be measured by the absorption of their pigments. As absorption is less influenced by the physiological status such a measurement may be more reliable than the fluorescence signal. However, the absorption signal is distorted by interference from and scattering of other particles. New developments using integrating spheres with extreme long light pathways overcome these obstacles.
The main advantage is that the higher particle concentration does not disturb the absorption measurements. Very recently, Wollschläger *et al.* (2013) demonstrated the applicability of such instruments in an FB system although the long-term stability has to be improved. Furthermore, using the fingerprints of the complete absorption spectra these spectra can be used for differentiation between different algae groups.

Flow cytometry (Dubelaar and Jonker 2000) may be a promising complementary method for getting information about the community structure of algae, including pico- and nano-phytoplankton. First applications in underway systems have been demonstrated earlier by Zubkov *et al.* (2000) and very recently by Thyssen *et al* (2015).

For monitoring of algae species and in particular harmful algae bloom (HAB) taxa, cost effective monitoring methods are needed. Conventional methods like light microscopy at the species or genus level require broad taxonomic expertise and are time-consuming. New technology based on nucleic acid biosensors for the detection of microbial organisms, and molecular sensors have been introduced as a novel technology for the monitoring of phytoplankton (Metfies *et al.* 2005). A semi-automated rRNA biosensor for the detection of up to 14 target species for the detection of HABs has been described by Diercks-Horn *et al.* (2011). Further development shall result in a fully-automated system including filtration.

Another important parameter is primary production. This is a measurement that is hard to make with autonomous systems but important for the assessment of the functioning of the ecosystem. Pulsed-amplitude-modulation fluorometry such as FRRF (Fast-Repetition-Rate-Fluorometry) provides an alternative to laboratory ^{14}C uptake methods obtaining seasonal and annual primary production estimates (Melrose *et al.* 2006). However, signals generated by in-situ FRR fluorescence can exhibit a strong taxonomic (adaptive) component (Suggett *et al.* 2009). Until now, this method has not been used in underway systems on a routine basis due to the complicated interpretation of the data.

Nutrient measurements

In addition to the light conditions the availability of nutrients controls the algae growth, thus nutrient data are another important biologically relevant parameter showing great gaps in operational monitoring. With the exception of nitrate, nutrients can only be measured with wet-chemical analysers with the required sensitivity in the ocean. In particular, nitrate can be determined by UV absorption, but with detection limits (~1µmol) not suitable for surface waters in the open ocean (Frank *et al.* 2014). Most commercially available nutrient analysers developed for laboratory use require substantial and consistent maintenance and are not optimized for long-term unattended operation. Promising new developments based on sequential injection analysis (SIA) and optimized for long-term unattended operation with regular internal calibration checks (Frank *et al.* 2006) may be commercially available in the near future.

Carbonate system measurements

In the case of the inorganic carbonate system a quantitative assessment of the impact of biology and mixing on sea surface pCO_2 measurement of additional inorganic carbon parameters is of great interest in order to have a better understanding of the role of the ocean for the uptake and storage of anthropogenic CO_2, as well as of the degree of ocean acidification (see also Chapter 13). In the meantime, there are different reliable pCO_2 measuring systems on the market. With respect to understanding inorganic carbonate system dynamics at least two components of the carbonate systems have to be measured. Besides pCO_2 this can be high precision pH, total alkalinity (T_{Alk}), carbonate (CO_3^{2}-) or total dissolved inorganic carbon (DIC). With the exception of DIC there are different developments for autonomous sensors under development or already commercially available (pH, T_{alk}).

For precise quantification of the carbon budget the right combination of parameters is essential. Thus, the combination of pH with pCO_2 would be less helpful in that pH provides essentially the same information as pCO_2 due to the strong anti-correlation of pH – pCO_2 and subsequent error propagation. In particular, data of either or total dissolved inorganic carbon (DIC) need to be sampled in addition to high precision data of pCO_2 or pH. Currently, efforts are being made to develop high-frequency, automated in situ carbon sensor technologies to determine T_{Alk}. First instruments already exist for the measurement of T_{Alk} or DIC with the required accuracy and precision (± 1 µmol kg^{-1}). Very recently a combined automated instrument and optimized for underway measurements measuring high precision pH (accuracy ±0,003) and T^{alk} (accuracy ±1.1 µmol kg−1) by spectrophotometric detection has been presented (Aßmann *et al.* 2011, Aßmann 2012).

A similar instrument for underway measurements, but solely for alkalinity, has been published by Wang *et al.* (2013). Most spectrophotometric pH sensors are only applicable at higher salinities > 20. A special development for measuring pH in fresher water such as the Baltic Sea has been published by Hakonen *et al.* (2013).

Microplastics and contaminants

A different issue which could be investigated by means of SOOPs is the steadily growing abundance of microplastics in the oceans (Andrady, 2011). The lipophilic character of these particles results in high enrichment of e.g. persistent organic pollutants (POPs) which subsequently can be ingested by marine biota. After development of suitable techniques, continuous sampling along fixed routes could be used to investigate this issue on a global scale.

Another way around using the particular absorbing characteristics of plastics is the use of so-called passive samplers for monitoring waterborne POPs or other organic pollutants (Vrana *et al.* 2005). For example, Allan and Harman (2013) proposed a strategy of actively towed aquatic passive sampling devices through water in the same way CPRs are operated. In a similar way, such samplers could be used in flow-through systems such as FerryBoxes. First attempts are started in Norway (pers. communication Kai Sørensen) and will be extended to vessels in the North Sea.

Circulation and physical oceanography

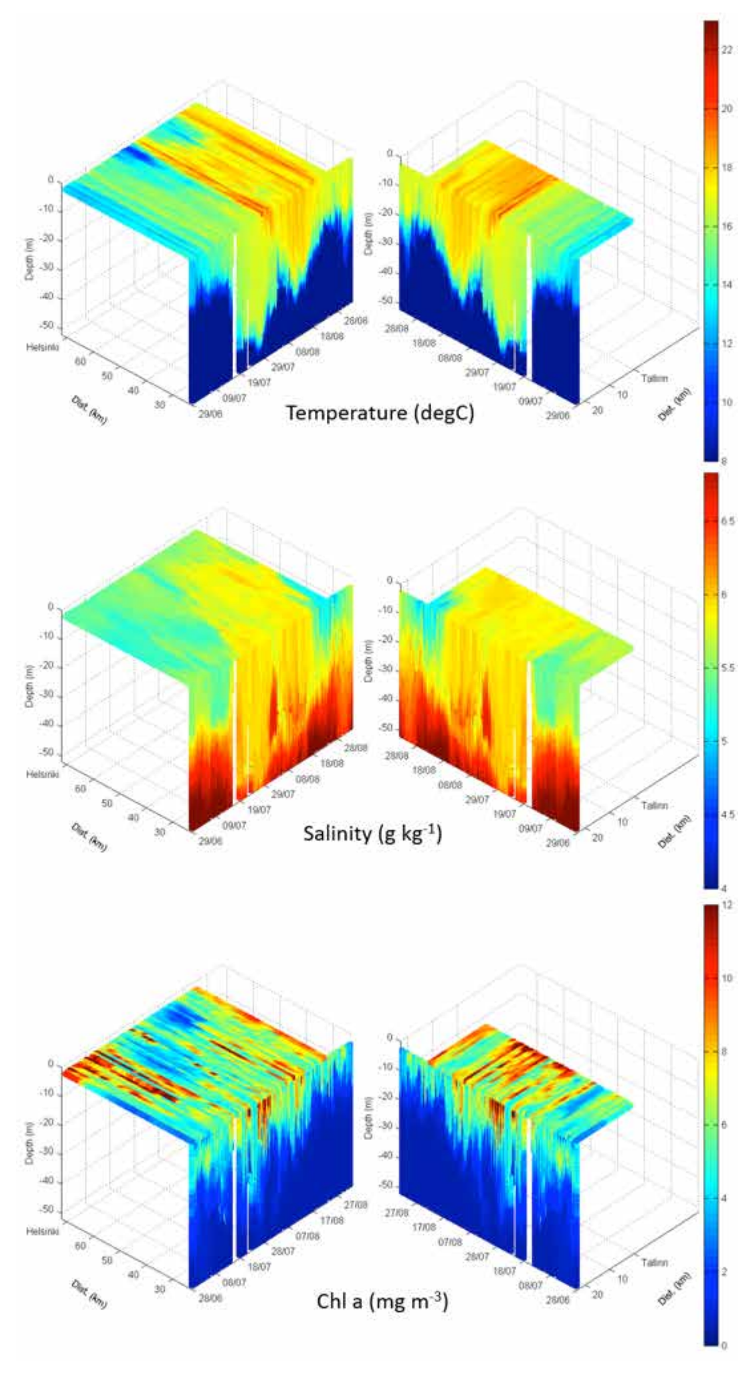
In the majority, only surface waters are sampled with FerryBox systems. Moreover, profiling instruments such as ADCPs (Acoustic Doppler Current Profiler) can enable observations through the water column (Send *et al.* 2009, Buijsman & Ridderinkhof, 2007, Rossby *et al.* 2010). Very recently a new project has been started in Chile measuring the upwelling processes along the Chilean coast with an ADCP aboard of a cargo ship (Aiken & Ramirez, 2013). The main issue is the comparatively high speed of the vessel in comparison with the measured currents, and the uncertainty of the positioning system. In the future, new global positioning systems with higher spatial resolution may overcome these problems. For getting at least the information about the vertical distribution of temperature and salinity, a combination of FerryBox measurements can be combined with traditional expendable bathy thermographs XBTs (Fuda *et al.* 2000, Korres *et al.* 2009).

The availability of sensors measuring physical parameters is clearly much better than for biological and chemical parameters. Therefore, only temperature, salinity and density as important physical components are mentioned here with emphasis on the other sections in this chapter.

Chapter 12: Integration between different observational methods and FerryBox (HF Radar, moorings, gliders, Euro-Argo, etc.)

Apart from FB systems a suite of other observational methods and instruments are commonly used in oceanography. Sometimes these methods may offer possibilities to integrate measurements e.g. surface measurements from FB systems with vertical observations with a scanfish, a mooring or an Argo float or glider. Here we present one example of FB measurements and a mooring in the Baltic Sea.

The layered structure of the Baltic Sea, with the seasonal thermocline and the halocline situated at different depths, is a challenge to be accurately described by numerical models, especially at the scales relevant for phytoplankton dynamics. In many cases, a proper validation of model results is difficult due to the absence of observational data with the required resolution and coverage in time and space. In order to fill this gap a number of autonomous devices, including moored profilers, FerryBoxes, and a glider, in combination with research vessel based instruments are applied (see e.g. Fig 10.1). The analysis showed that in these conditions, the horizontal wavenumber spectra of temperature variance in the surface layer as well as in the seasonal thermocline had slopes close to -2 between the lateral scales from 10 to 1 km (the internal Rossby radius of deformation is 2-5 km in the Gulf of Finland). It suggests that the geostrophic sub-mesoscale processes could contribute considerably to the energy cascade in this stratified sea basin. Furthermore, we suggest that the sub-mesoscale processes could play a major role in feeding surface blooms in the conditions of coupled coastal upwelling and downwelling events in the Gulf of Finland. (Lips *et al.*, 2016).



Temperature (degC)

Salinity (g kg^{-1})

Chl a (mg m^{-3})

Fig. 12.1. Temporal changes in horizontal and vertical distributions of temperature (°C), salinity (g kg-1) and chlorophyll a content (mg m-3) in the Gulf of Finland measured by the FerryBox system between Tallinn and Helsinki and the autonomous buoy profiler at station AP5 from 29 June to 31 August in 2012. The FerryBox data are split into two parts at the position of the buoy profiler AP5. X-axis shows the distance along the ferry route from a starting point off Tallinn harbour.

Chapter 13: Need for environmental data from FerryBox systems

There is a general need for environmental data from coastal seas and oceans. This need has much to do with the political aspirations of the EU as promoted by EuroGOOS and the EEA. The scientific use of FB data has been taken into account by most of the FB operators. However, the establishment of a mechanism to use the FB data within a political framework has not yet been reached.

For MSFD a series of environmental data are needed to describe the state of the environment, for which data can probably be delivered by FB systems. As long as the detailed definitions for these indicators have not been fixed, it is difficult to promote the FB data for this specific purpose.

In general, coastal marine waters are final receptors of potentially thousands of chemical contaminants of anthropic origins originated from direct wastewater effluent, riverine inputs, atmospheric depositions or any other form of direct emission directly to the marine water. Descriptor 8 of the MSFD introduces actions aimed at monitoring chemical pollution in marine waters. Building a realistic perception of exposure and risk for the definition of environmental quality standards will require a huge and costly monitoring effort. Whether the infrastructural and methodological platform to allow such an effort to take place in a cost-effective way exists or not, is still debated.

First pilot studies (Brumovsky *et al.* 2016) also highlighted a high degree of feasibility for both target and non-target exploratory screening of trace contaminants in small volumes water samples (e.g. 1 to 4 L). Results beyond expectations were achieved by combining already-in-place standard automatic water samples on FerryBox with state-of-the art liquid chromatography-mass spectrometry instrumentation. Advances in the performance of mass spectrometer sensitivity and accuracy drove to dramatically lower the limit of detections during the last few years. Thanks to this it was recently shown that a range of contaminants of emerging concern, including several pharmaceuticals and antibiotics of human and veterinary use as well as synthetic food additives such as artificial sweeteners, could be detected in FerryBox originated samples even at sub-part-per-trillion levels starting from samples of few L of marine waters.

These results open a perspective for the use of the FerryBox, not only as a support for the definition and implementation of regulation, but also as a powerful tool to carryout investigative scientific research in terms of discovery of new marine contaminants, and contaminant fate model calibration and validation.

The needs for the future extension of the use of FB systems were an FB reference handbook which contains details on installation and maintenance of FB systems, include technical details about available sensors, their calibration and a flow-through cleaning system to avoid biofouling. (see further next chapter on data management). Further suggestions for the contents of a FB reference handbook have been made.

Another suggestion is the writing of a guideline, where FerryBox information is considered to be information derived from automatic flow-through systems implemented on board ships of opportunity. The observations are either original or in validated form, and may be aggregated temporally and spatially to a specific level. The data must include a distinct time and position. In the case of aggregated information, these may be estimates. Data need to follow rules and parameters need to be clearly defined and follow rules from the SeaDataNet and Copernicus initiatives. Quality assurance and control are needed to use FB data for environmental assessments.

The contents of the data and ancillary information should adhere to the Formatting Guidelines for Oceanographic Data Exchange (http://ocean.ices.dk/formats/GETADE_Guidelines.aspx) prepared by the IOC's Group of Experts on the Technical Aspects of Data Exchange (GETADE) and available from RNODC Formats.

Any additional information of use to secondary users which may have affected the data or have a bearing on its subsequent use should also be included. For additional information on quality control procedures, metadata requirements for particular parameters and collection instrumentation, see UNESCO (1996).

Chapter 14: Role of FB data in climate change research: ocean acidification and impact of (coastal) oceans for CO_2 uptake from the atmosphere

Coastal oceans play a disproportionately important role in the global carbon cycle referenced to their volume and surface area. As conduits of organic carbon from land to the open ocean, they perform an important role in regulating carbon fluxes to the atmosphere through sequestration of carbon to the sediments. Addition of nutrients, following land-use changes, through the addition of fertilizers and industrial run off have changed the function of coastal regions. This has led to increases in productivity that has modified the carbon cycle. Concomitantly, increases in atmospheric, through fossil fuel combustion is leaving a signature in the ocean in the form of ocean acidification. Reductions in seawater pH and omega, and increases in CT and pCO_2 are now beginning to become visible even in highly variable carbonate systems of the coastal ocean. (cf. Chapter 9).

The coastal and shelf regions are areas of high importance regarding food security. They harbour a multitude of different ecosystems, often with high biodiversity but anchored on a few keystone species. With increasing ocean acidification, this diversity is being challenged with thresholds approaching for many species – the loss of which could mean changes in the productivity and function of ecosystems.

In order to develop prognoses for change and thus facilitate effective management and adaptive procedures for these changes, it is necessary to understand the present functioning of the coupled ecosystem-carbonate system. FerryBox measurements allow for this understanding through their ubiquitous nature catching the highly frequent interplay between, *inter alia*, productivity, respiration, ocean climate, and human pressures. Repeat section measurements enable the forcing and feedbacks between seasonal productivity and e.g. pH on scales relevant to understanding the phenology and succession of coastal ecosystems and their influence on the air-sea fluxes of CO_2.

Instrumentation for monitoring the carbonate system in coastal waters is now available after many years of development. Routine measurements of underway spectrophotometric pH, carbonate ion proxy, total alkalinity and pCO_2 are possible (Chapter 9). Many techniques transferred from open ocean technologies. However, it is often not practical to transfer proven technologies as the coast and shelves have different challenges. None of these more important that when attempting to monitor in highly turbid environments. Here optical methods are compromised.

UNIT 3 – INDICATIVE COSTS

Chapter 15: Operational and investment costs of systems including maintenance

In this chapter the costs of FB systems, depending on the choice of sensors, are estimated and how much maintenance is needed to obtain reliable data, including the initial costs of installation.

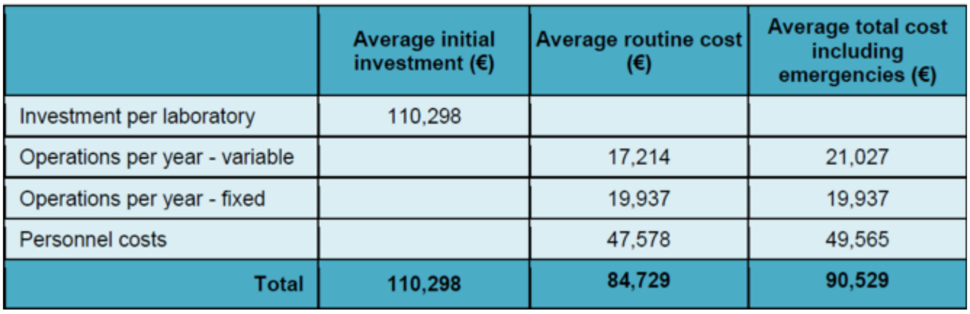
Analysis of costs for FerryBox systems

The different systems described under FerryBoxes include commercial systems and custom-made systems installed on ships of opportunity and research vessels. In the FP7 project JERICO (www.jerico-fp7.eu) the cost was compiled using questionnaire replies returned from JERICO project partners. Based on questionnaires costs have been estimated for FerryBox systems (JERICO deliverable D4.5). The results of this analysis are shown below:

Summary of costs related to Investments

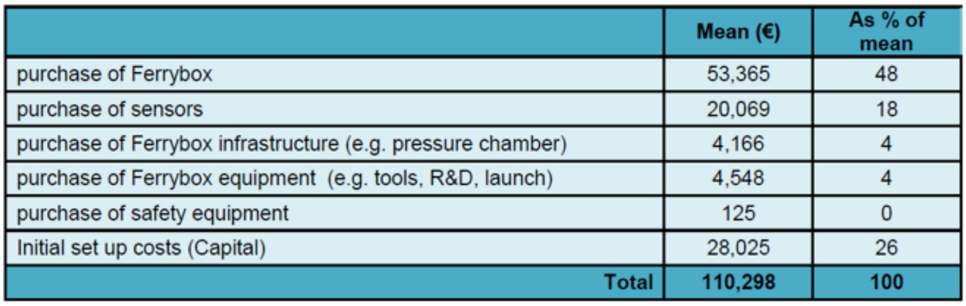
The average initial investment per FerryBox is € 110,298 (Table 15.1) although there is a wide range in the investment made. The cost of purchasing the system, and other capital costs, dominate the initial investment (Table 15.2). The average annual routine running cost is €84,729 and the average annual total cost (routine plus emergency) for operating a FerryBox system is €90,529 due to the additional variable and personnel costs associated with responding to emergencies (Table 15.1). The amount of money spent on non-routine operations is much smaller for FB systems than for fixed platforms. Personnel costs (€49,565) account for 55% of the total running costs with variable costs (€21,027) and fixed costs (€19,937) accounting for 23% and 22% respectively (Table 15.1). The personnel costs equate to an annual average of 125 days for total operations.

Table 15.1.: Summary of initial investment and annual running costs per FerryBox system.



	Average initial investment (€)	Average routine cost (€)	Average total cost including emergencies (€)
Investment per laboratory	110,298		
Operations per year - variable		17,214	21,027
Operations per year - fixed		19,937	19,937
Personnel costs		47,578	49,565
Total	**110,298**	**84,729**	**90,529**

Table 15.2.: A breakdown of the investment associated with running FerryBox systems.

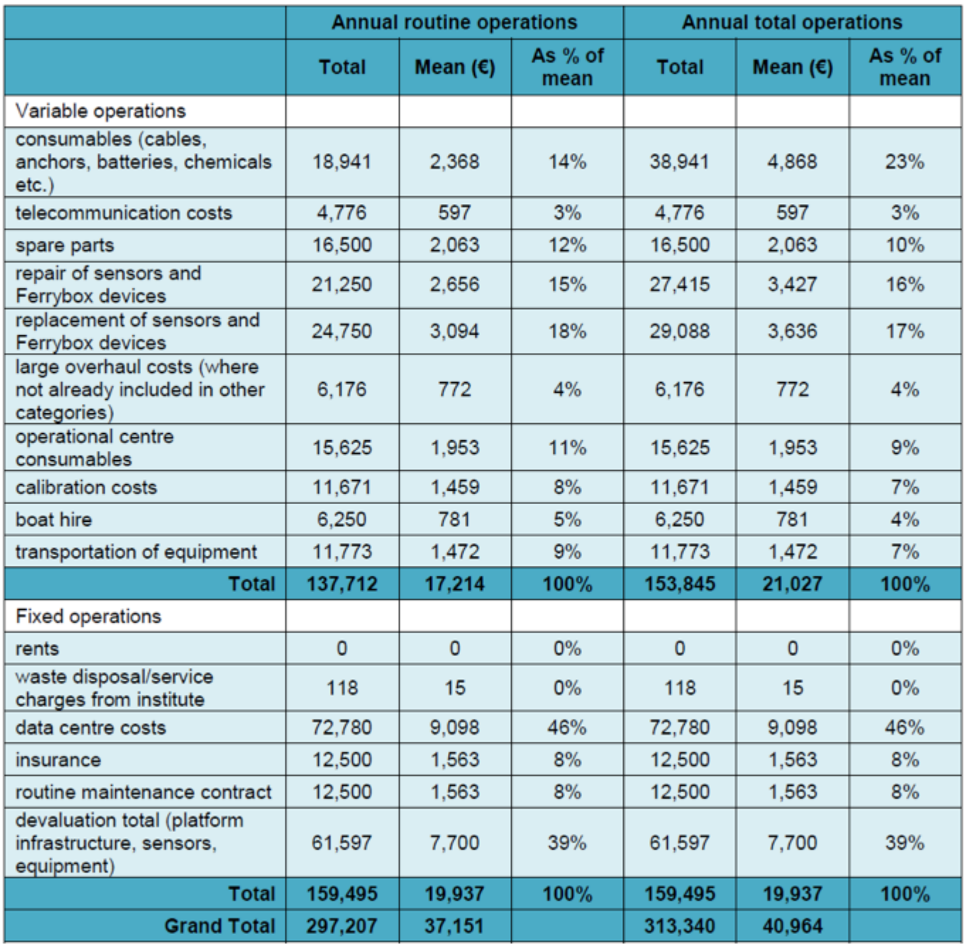


	Mean (€)	As % of mean
purchase of Ferrybox	53,365	48
purchase of sensors	20,069	18
purchase of Ferrybox infrastructure (e.g. pressure chamber)	4,166	4
purchase of Ferrybox equipment (e.g. tools, R&D, launch)	4,548	4
purchase of safety equipment	125	0
Initial set up costs (Capital)	28,025	26
Total	**110,298**	**100**

Summary of costs related to Operations

Consumables, repair, replacement and calibration of sensors, spare parts account for 73% of the variable operating costs of a FerryBox system (Table 15.3). Fixed operational costs are dominated by data centre and devaluation (Table 15.3).

Table 15.3.: The annual routine and total operations costs associated with running FerryBox systems.

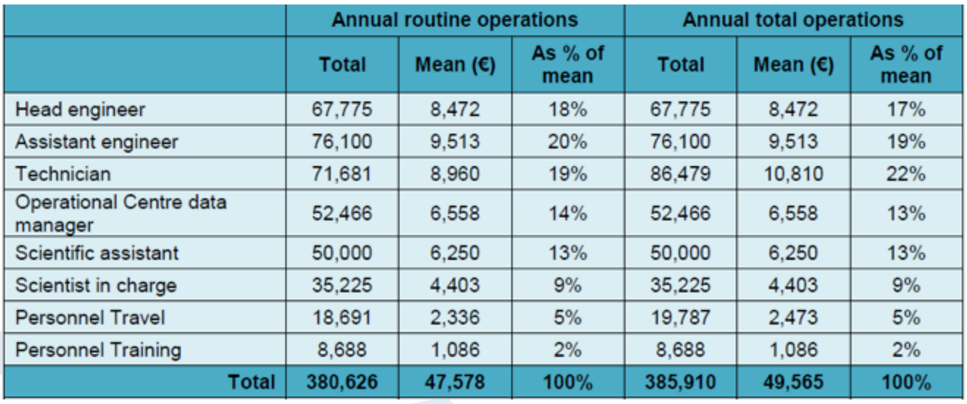


	Annual routine operations			Annual total operations		
	Total	Mean (€)	As % of mean	Total	Mean (€)	As % of mean
Variable operations						
consumables (cables, anchors, batteries, chemicals etc.)	18,941	2,368	14%	38,941	4,868	23%
telecommunication costs	4,776	597	3%	4,776	597	3%
spare parts	16,500	2,063	12%	16,500	2,063	10%
repair of sensors and Ferrybox devices	21,250	2,656	15%	27,415	3,427	16%
replacement of sensors and Ferrybox devices	24,750	3,094	18%	29,088	3,636	17%
large overhaul costs (where not already included in other categories)	6,176	772	4%	6,176	772	4%
operational centre consumables	15,625	1,953	11%	15,625	1,953	9%
calibration costs	11,671	1,459	8%	11,671	1,459	7%
boat hire	6,250	781	5%	6,250	781	4%
transportation of equipment	11,773	1,472	9%	11,773	1,472	7%
Total	**137,712**	**17,214**	**100%**	**153,845**	**21,027**	**100%**
Fixed operations						
rents	0	0	0%	0	0	0%
waste disposal/service charges from institute	118	15	0%	118	15	0%
data centre costs	72,780	9,098	46%	72,780	9,098	46%
insurance	12,500	1,563	8%	12,500	1,563	8%
routine maintenance contract	12,500	1,563	8%	12,500	1,563	8%
devaluation total (platform infrastructure, sensors, equipment)	61,597	7,700	39%	61,597	7,700	39%
Total	**159,495**	**19,937**	**100%**	**159,495**	**19,937**	**100%**
Grand Total	**297,207**	**37,151**		**313,340**	**40,964**	

Summary of costs related to Personnel

Personnel costs (€49,565) account for 55% of the total annual running costs of €90,529 for FerryBox systems. Engineer and technician costs account for over half of the annual routine and total operations costs (Table 15.4).

Table 15.4.: A breakdown of the annual routine and total personnel costs associated with running FerryBox systems.



	Annual routine operations			Annual total operations		
	Total	Mean (€)	As % of mean	Total	Mean (€)	As % of mean
Head engineer	67,775	8,472	18%	67,775	8,472	17%
Assistant engineer	76,100	9,513	20%	76,100	9,513	19%
Technician	71,681	8,960	19%	86,479	10,810	22%
Operational Centre data manager	52,466	6,558	14%	52,466	6,558	13%
Scientific assistant	50,000	6,250	13%	50,000	6,250	13%
Scientist in charge	35,225	4,403	9%	35,225	4,403	9%
Personnel Travel	18,691	2,336	5%	19,787	2,473	5%
Personnel Training	8,688	1,086	2%	8,688	1,086	2%
Total	**380,626**	**47,578**	**100%**	**385,910**	**49,565**	**100%**

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

After one and a half decade FerryBox observational systems have been developed into a stage of maturity. Major achievements are the development of suitable flow through systems with a wide range of different sensors for salinity, temperature, chlorophyll fluorescence, oxygen and turbidity. A major achievement has been the development of a flushing system to prevent biofouling within the FB systems. Therefore, technical details of the FB systems such as flow through volumes, clogging of the water flow, collection of data and storing them are all now well developed and with a high degree of maturity.

A further extension with new sensors is underway such as pCO_2, pH, algal composition, and potential toxic species. Molecular biological techniques are helping to solve the problem of diverse phytoplankton composition. However, there is still a need to further extend the capabilities to perform biological measurements.

Installation of a new system on board a ship of opportunity still is a very laborious task. There is a strong need for a standardized type of connection so that in principle every ship would be available for a FB system. In this regard, it is recommended to make tests and develop prototypes for such a standard connection.

Compared with other marine monitoring and measuring systems FerryBoxes acquire very large amounts of data. Hence quality control, evaluation and processing of these data need to be highly automated, robust and reliable. Therefore, new procedures for data processing and evaluation have been developed for the increasing number of routinely operated FerryBoxes. The planned common European database in connection with the EuroGOOS ROOSes, EMODnet and Copernicus Marine Environment Monitoring Services (CMEMS) will help to make FerryBox data easily available and visible to the whole community.

Overall, the following conclusions and recommendations can be summarized from the present White Book:

- FB systems have evolved with a set of standard sensors to a mature observational system;
- FB systems allow cost-effective measurements with high resolution in space and time along a certain route;
- FB data may strongly support the validation of numerical ocean models;
- FB data can be used as ground truth measurements for satellite remote observations;
- New developments of biogeochemical sensors enable full insight into ocean acidification and the impact of coastal oceans on atmospheric CO_2;
- Continuous and long-term observations of the carbon cycle enable the detection of climate relevant changes in coastal and open ocean waters;
- FB systems enable discrete water sampling on certain positions for specific compounds (e.g. contaminants, micro plastics etc.) without extra cost;
- A common European FB database including data quality control increases the availability of FB data and supports the activities of CMEMS and EMODnet;
- FB systems are still operated mainly by research money and suffer from unsustainable funding in the long term;
- New FB lines must be developed, especially in the Mediterranean and Black Sea;
- There is a further need for discussions with all potential stakeholders on which type of data products are needed to fulfill science or societal requirements e.g. for environmental assessments.

REFERENCES

Introduction

Rantajärvi, E., Olsonen, R., Hällfors, S., Leppänen, J.-M., Raateoja, M., 1998. Effect of sampling frequency on detection of natural variability in phytoplankton: unattended high frequency measurements on board the ferries in the Baltic Sea. J. Mar. Sci. 55, 697–704.

Chapter 1

Petersen W., Schroeder, F., Bockelmann F.-D. (2011): FerryBox - Application of continuous water quality observations along transects in the North Sea. Ocean Dynamics 61:1541–1554.

Chapter 6

Kikas, V. and Lips, U.: Upwelling characteristics in the Gulf of Finland (Baltic Sea) as revealed by FerryBox measurements in 2007–2013, Ocean Sci. Discuss., 12, 2863-2898, doi:10.5194/osd-12-2863-2015, 2015.

Chapter 8

FAO. 2012. Atlantic cod species fact sheet. http://www.fao.org/fishery/species/2218/enFisheries Directorate Norway. 2014. http://www.fisheries.no/aquaculture/Aquaculture/#.VTj61iGqrQA

Chapter 9

Grayek, S., Staneva, J., Schulz-Stellenfleth, J., Petersen, W., Stanev, E.V., 2011. Use of FerryBox surface temperature and salinity measurements to improve model based state estimates for the German Bight. J. Mar. Syst. 88, 45–59.

Haller, M., Janssen, F., Siddorn, J., Petersen, W., and Dick, S. (2015): Evaluation of numerical models by FerryBox and fixed platform in situ data in the southern North Sea. Ocean Sci., 11, 879-896, www.ocean-sci.net/11/879/2015/

Stanev, E. V., Schulz-Stellenfleth, J., Staneva, J., Grayek, S., Seemann, J., Petersen, W. (2011): Coastal observing and forecasting system for the German Bight – estimates of hydrophysical states, Ocean Sci., 7, 569-583.

Chapter 11

Allan, I; Harman, C.P.; Ranneklev, S.B.; Thomas, K.V.; Grung, M. (2013) Passive sampling for target and nontarget analyses of moderately polar and nonpolar substances in water Environmental Toxicology and Chemistry ISSN 0730-7268. Vol 32 No 8 s 1718 - 1726 doi: 10.1002/etc.2260

Andrady, A. L. (2011). Microplastics in the marine environment. Marine pollution bulletin, 62(8), 1596-1605.

Aßmann, S., Frank, C., and Körtzinger, A. (2011): Spectrophotometric high-precision seawater pH determination for use in underway measuring systems, Ocean Sci., 7, 597-607, doi:10.5194/os-7-597-2011

Buijsman, M.C., Ridderinkhof, H., 2008. Long-term evolution of sand waves in the Marsdiep inlet. I: high-resolution observations. Cont. Shelf Res. 28, 1190–1201.

Diercks-Horn, S., Metfies, K., Jäckel, S., & Medlin, L. K., 2011. The ALGADEC device: a semi-automated rRNA biosensor for the detection of toxic algae. Harmful Algae 10(4), 395-401.

Frank, C., Schroeder, F., Ebinghaus, R., Ruck, W., 2006. A fast sequential injection analysis system for the simultaneous determination of ammonia and phosphate. Microchim. Acta 154, 31–38.

Frank, C., Meier, D., Zielinski, O., Voß, D. (2014): Computation of nitrate concentrations in coastal waters using an in situ ultraviolet spectrophotometer: behavior of different computation methods in a case study a steep salinity gradient in the southern North Sea. Methods in Oceanography 9, 34 - 43, DOI: 10.1016/j.mio.2014.09.002

Fuda, J., Millot, C., Taupierletage, I., Send, U., Bocognano, J., 2000. XBT monitoring of a meridian section across the western Mediterranean. Sea Deep Sea Res. 47 (1),2191–2218.

Hakonen, A., LG Anderson, J Engelbrektsson, S Hulth, B. Karlson (2013) A potential tool for high-resolution monitoring of ocean acidification, Analytica chimica acta, pp. ? 2013

Korres, G., Nittis, K., Hoteit, I., Triantafyllou, G., 2009. A high resolution data assimilation system for the Aegean Sea hydrodynamics. J. Mar. Syst. 77, 325–340.

Melrose, D.C., Oviatt, C.A., O'Reilly, J.E., Berman, M.S., 2006. Using autonomous FRRF measurements on SOOPs can significantly improve global GPP estimates. Mar. Ecol. Prog. Ser. 311, 37–46.

Metfies, K., Medlin, L., 2005. Ribosomal RNA Probes and Microarrays: Their Potential Use in Assessing Microbial Biodiversity. Methods Enzymol. 395, 258–278.

Rossby, T., Flagg, C., Donohue, K., 2010. On the variability of Gulf Stream transport from seasonal to decadal timescales. J. Mar. Res. 68, 503–522.

Send, U., *et al.*, 2009. A global boundary current circulation observing network. In: Hall, J., Harrison, D.E., Stammer, D. (Eds.), Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol 2). ESA Publication WPP-306, Venice, Italy (21–25 September 2009).

Seppälä J, Ylöstalo P, Kaitala S, Hällfors S, Raateoja M, Maunula P 2007. Ship-of-opportunity based phycocyanin fluorescence monitoring of the filamentous cyanobacteria bloom dynamics in the Baltic Sea. Estuar Coast Shelf Sci 73(3–4), 489–500. doi: 10.1016/j.ecss.2007.02.015

Simis, S.G.H., Huot, Y. Babin, M. Seppälä, J., Metsamaa L., 2012. Optimization of variable fluorescence measurements of phytoplankton communities with cyanobacteria. Photosynth Res 112,13–30

Suggett, D.J.,Moore, C.M., Hickman, A.E., Geider, R.J., 2009. Interpretation of fast repetition rate (FRR) fluorescence: signatures of phytoplankton community structure versus physiological state. Mar. Ecol. Prog. Ser. 376 (1–19), 2009.

Thyssen, M., Alvain, S., Lefèbvre, A., Dessailly, D., Rijkeboer, M., Guiselin, N., Creach, V., Artigas, L.-F.: 2015. High-resolution analysis of a North Sea phytoplankton community structure based on in situ flow cytometry observations and potential implication for remote sensing. Biogeosciences 12, 4051—4066. doi: 10.5194/bg-12-4051-2015

Vrana, B., Mills, G.A., Allan, I.J., Dominiak, E., Svensson, K., Knutsson, J., Morrison, G., Greenwood, R., 2005. Passive sampling techniques for monitoring pollutants in water. Trends Anal. Chem. 24, 845–868.

Wang, Z.A., Chu, S.N., Hoering, K.A., 2013. High-frequency spectrophotometric measurements of total dissolved inorganic carbon in seawater. Environ. Sci. Technol. 47, 7840–7847.

Wollschläger, Jochen; Grunwald, Maik; Röttgers, Rüdiger; Petersen, Wilhelm (2013). “Flow-through PSICAM: a new approach for determining water constituents absorption continuously”. Ocean Dynamics 63(7): 761-775. doi: 10.1007/s10236-013-0629-x

Zubkov, Mikhail V.; Sleigh, Michael A.; Burkill, Peter H., 2000. Assaying picoplankton distribution by flow cytometry of underway samples collected along a meridional transect across the Atlantic Ocean. Aquatic Microbial Ecology 21, 13-20.

Lips, I., Rünk, N., Kikas, V., Meerits, A., Lips, U. 2014. High-resolution dynamics of spring bloom in the Gulf of Finland, Baltic Sea. J. Mar. Syst. 129, 135-149.

Lips, U., Kikas, V., Liblik, T., and Lips, I.: Multi-sensor in situ observations to resolve the sub-mesoscale in the stratified Gulf of Finland, Baltic Sea, Ocean Sci. Discuss., doi:10.5194/os-2016-5, in review, 2016.

Chapter 13

Brumovsky, M.; Becanová, J.; Kohoutek, J.; Thomas, H.; Petersen, W.; Sørensen, K.; Sáňka, O.; Nizzetto, L. (2016) Exploring the occurrence and distribution of contaminants of emerging concern through unmanned sampling from ships of opportunity in the North Sea, Journal of Marine Systems. doi: 10.1016/j.jmarsys.2016.03.004

ANNEX 1: EUROGOOS FERRYBOX TASK TEAM

Terms of Reference

1. Develop the European FerryBox network and assist the standardization of FerryBox operations, data and applications, including:
   - All applications of FerryBox Systems (physical, chemical, biological parameter etc…)
   - Common procedures on operation, quality control and data handling of FerryBox systems (link to best practice in EU projects JERICO and JERICO-NEXT)
   - Implementation of new upcoming probes and sensor systems
   - Applications in combination with other technologies (including satellites, fixed platforms, gliders, numerical modelling…)
   - To include R/V's which are operating thermosalinographs

2. Act as the European component in the global community using ships of opportunity (e.g. JCOM-SOT), incorporate links with ICOS

3. Ensure the integration of FerryBox networks in the European Operational Oceanographic Services and contribute to the development of the European Ocean Observing System (EOOS)

4. Ensure data availability via the EuroGOOS ROOS data portals including data quality procedures

5. Foster dialog between operators and end-users on:
   - Data structure, format and dissemination (interoperability of datasets)
   - Quality control procedures
   - Validation procedures
   - Technological solutions

6. Be a framework for operators to:
   - Operating a common website
   - Share success stories and difficulties
   - Provide and exchange open source tools (data analysis, applications…)
   - Promote scientific synergies for key questions
   - Fill gaps and looking for complementarity with other technologies or modelling products
   - Promote joint proposals through networking (e.g. create synergies between different local consortium INTERREGs…)

Work plan

AC: Achieved
IP: In progress
ST: Short term Actions (<1-2 years)
MT: Mid-term Actions (> 2 years)

Setting up /promotion of the FerryBox group

ACTION	TERM	WHO/TOR/…?
ToR and roadmap (this document)	AC	HZG, NIVA
Create LOGO (based on existing FB community logo?)	IP	HCMR, HZG
Core group definition, adding strategic members	IP	HZG, NIVA
Upgrading and/or updating existing webpage (www.ferrybox.org)	AC, IP	HZG
EMODnet Phase 3: promoting FerryBox activities in the context • Coordination • To fill gaps in key places • Supporting funding of existing systems	ST	EuroGOOS Task Team
Seek funding for joint/coordination activities Prepare a COST ACTION proposal	ST	EuroGOOS FB Task Team, FB community
Identify other funding possibilities for network activities (H)	IP	FB community
White paper: Status and achievement of FerryBox activities	IP	FB Task Team
Reporting FerryBox Task Team activities	ST	HZG, NIVA

Towards providing a framework to FerryBox users

ACTION	TERM	
Optimize website for the group Subtasks: • Information about existing FB lines (routes, parameters, instruments etc.) • Organization of the information in the webpage (news, links with key webpages…) • Define topics	IP AC IP IP	HZG, EuroGOOS
FerryBox workshops every 1.5 years	ST	FB Task Team,
Other participation in between (for example in JCOMM, EGU…)	IP	FB community

Towards common European recommendations (first ideas, not completely discussed)

ACTION	TERM	WHO
Reporting on existing European and national projects (work plan, results…)	ST	FB Task Team
Intensify contacts with other groups operating SoOPs (ICOS, JCOMM-SOT …)	IP, ST	FB Task Team, HZG
Identify existing activities in other countries outside Europe	ST	
Template for key research questions around the use of FerryBox systems	ST	
Complete the inventory (data management procedures, applications, stakeholders achieved, which kind of founding…)	ST	
How to recover the need from the different kind of users (workshops…) – related to the format	ST	
Identify specific added value of FerryBox products that can be useful for specific stakeholders	ST	
How to coordinate FerryBox activities/measurements to address long-term environmental change	MT and beyond	

In this **FerryBox whitebook** the achievements, users and needs for FerryBox systems are presented.

The EuroGOOS FerryBox Task Team is one of seven EuroGOOS Task Teams, operational networks of observing platforms promoting scientific synergy and technological collaboration among European ocean observing infrastructures. Jointly Task Team members make available European ocean data to the EuroGOOS Regional Operational Oceanographic System (ROOS) data portals across all European maritime regions, which in turn feed data to the European Marine Observation and Data Network (EMODnet) and Copernicus Marine Service (CMEMS).

FerryBox technology allows taking automated measurements aboard ships of opportunity. The core ocean parameters measured are temperature, salinity, turbidity, and chlorophyll-a fluorescence. In addition, non-standard sensors provide data on currents and sediment transport, pH, oxygen, nutrients, and algal species. Currently, FerryBox systems are installed on a network of European FerryBox contributors, mainly national marine research institutes and environmental agencies.

www.ferrybox.org

FERRYBOX WHITE PAPER. EUROGOOS PUBLICATION 2017
W. PETERSEN AND F. COLIJN, HZG, EDS.

WITH CONTRIBUTIONS FROM:
K. SØRENSEN (NIVA), A. KING (NIVA), S. KAITALA (FMI), U. LIPS (MSI), E. STANEV (HZG), G. KORRES (HCMR), H. WEHDE (IMR) AND G. BREITBACH (HZG).

EUROGOOS

EUROPEAN GLOBAL OCEAN OBSERVING SYSTEM

EuroGOOS identifies priorities, enhances cooperation and promotes the benefits of operational oceanography to ensure sustained observations are made in Europe's seas underpinning a suite of fit-for-purpose products and services for marine and maritime end-users. EuroGOOS is a pan-European network operating within the Global Ocean Observing System of the Intergovernmental Oceanographic Commission of UNESCO (IOC GOOS).

Working hand in hand with partners in the European ocean research and observation community, EuroGOOS is promoting the integration of scientific knowledge and innovation for different users spanning science, policy, industry and society. The EuroGOOS Regional Operational Oceanographic Systems deliver analysis and forecasts of Europe's regional seas and feed quality-assured data to pan-European data portals (e.g. Copernicus Marine Service and EMODnet). EuroGOOS working groups and networks of marine observing platforms (Task Teams) enhance synergy and deliver strategies, priorities and standards, towards an integrated European Ocean Observing System (EOOS).

EuroGOOS AISBL

231 Avenue Louise, 1050 Brussels, Belgium
Tel: +32 2 238 37 90
Email: eurogoos@eurogoos.eu
www.twitter.com/EuroGOOS
www.eurogoos.eu