Fifth Framework Programme of the European Commission 1998-2002
Energy, Environment and Sustainable Development (EESD) Programme

FerryBox

From On-line Oceanographic Observations to Environmental Information

Final Report

Detailed Work Package Report (Section 3)

Contract number :	**EVK2-2002-00144**
Revision :	**2.0**

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Document Reference Sheet

This document has been elaborated and issued by the European FerryBox Consortium.

P 1	**GKSS**	**GKSS Research Centre** **Institute for Coastal Research**	**Coordinator**
P 2	**NERC.NOC**	**NERC.NOC – National Oceanography Centre** **Southampton University and National Environment Res. Council** formerly NERC.SOC – Southampton Oceanography Centre	
P 3	**NIOZ**	**Royal Netherlands Institute of Sea Research**	
P 4	**FIMR**	**Finnish Institute of Marine Research**	
P 5	**HCMR** (formerly NCMR)	**Hellenic Centre for Marine Research** (formerly National Centre for Marine Research)	
P 6	**NERC.POL**	**Proudman Oceanographic Laboratory**	
P 7	**NIVA**	**Norwegian Institute for Water Research**	
P 8	**HYDROMOD**	**HYDROMOD Scientific Consulting**	
P 9	**CTG** **(formerly CIL)**	**Chelsea Technology Group** **(formerly Chelsea Instruments Ltd.)**	
P 10	**IEO**	**Spanish Institute of Oceanography**	
P 11	**EMI**	**Estonian Marine Institute** (in cooperation with the Estonian Maritime Academy)	

The European FerryBox Project was co-funded by the European Commission under the Fifth Framework Programme of the European Commission 1998-2002 - Energy, Environment and Sustainable Development (EESD) Programme under contract no. EVK2-2002-00144.

Document Control Table

Project acronym:	FerryBox		Contract no.:	EVK2-2002-00144	
Deliverable No.:	Not applicable			Revision:	2.0
WP number and title:	FerryBox WP-1	Project Coordination and Management			
Work Package Manager:	Franciscus Colijn – GKSS Research Centre				
Work Package Team:	FerryBox Consortium				
Document title:	Detailed Work Package Report (Section 3)				
Document owner:	European FerryBox Project Consortium				
Document category:	Project Management Report – Detailed Work Package Report				
Document classification:	PU – Public				
Status:	Final				
Purpose of release:	Publication on the FerryBox report CD ROM and website				
Contents of deliverable:	Report on project work packages (Section 3)				
Pages (total):	21	Figures:	0	Tables:	0
Remarks:	For publication on the FerryBox report CD and website				
Main author / editor:	Franciscus Colijn	Leader FerryBox WP-1	GKSS		
Contributors:	FerryBox Team				
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Project website:	http://www.ferrybox.org				

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WP 1 Project Management and Coordination

During the last year of the project two major meetings were organised which all partners attended: the first meeting took place at the Spanish Institute of Oceanography (IEO) in Santander from 7 to 8 February 2005. The meeting was prepared by our local partner Dr. Alicia Lavin with colleagues and took place in a nice ambiance in the city of Santander. All Work Packages were discussed including the progress made as well as the missing parts. A relatively long session was held regarding the cost-benefit analysis of the FerryBox project.

This part was prepared jointly by the WP6 leader Klaus Pfeiffer and input from colleagues from the Chelsea Technology Group. Together they have taken the main responsibility for achieving the final draft of this deliverable, which will be of great interest to the scientific community and operational services. Details of the calibration procedures were discussed as well because they proved to be more complicated than previously thought.

The status of all other deliverables was checked and where needed discussions held to agree on the final form of the deliverables.

A part of the meeting was devoted to a discussion on the dissemination of the project results. It was agreed that presentations within a special workshop would be held during the ASLO conference in Santiago di Compostela in summer 2005, and that contributions at the EuroGOOS 2005 meeting should be presented including a plenary talk for improved visibility and outreach of the project; a contribution will also be given during the upcoming GSC-GOOS in Melbourne by the coordinator.

The level of dissemination of the project can be considered as very good: all partners have been extremely active in conference meetings and other fora, to present the objectives, goals and first results of the project. This was possible because several partners already had Ferryboxes in place at the very start of the project.

Apart from dissemination a discussion was held on the future of the FerryBox project and the continued funding by the European Community. Within the FP 6 Programme no further possibilities exist but within the Framework of GMES new options become available, which will be dealt with by the individual partners, referring to the results already obtained in the FerryBox project. A first list of potential manuscripts from the FerryBox project was compiled which will be used to follow the scientific achievements of this EU project.

During the EUROGOOS 2005 Meeting in Brest in June 2005 again very good circumstances for dissemination were encountered. Within the EUROGOOS community there is very extensive operational interest in our FerryBox project, not at least due to the current general secretary Dr. Hans Dahlin. The option to hold a plenary talk was well taken and presented by Dr. Wilhelm Petersen. Not only were the oceanographic community, also the operational modellers and forecast people impressed by what so far has been achieved.

Immediately after the EUROGOOS Meeting in Brest, a meeting of the ICES/IOC steering group on GOOS took place at IFREMER in Brest. Here again the group was informed about the main results and conclusions of the FerryBox project. The coordinator presented the state of the art of the project, which fits very well into other observational projects financed by the EU.

During the final phase of the project the activities both on board of the ferries were continued to extent our observational series. However main emphasis was on analysing the data and considers the applications which were planned.

The final workshop took place in Helsinki from 18 to 20 October 2005 at the new building of the Finnish Institute for Marine Research. The group was welcomed by the director of the Institute Eva-Maria Poutanen who mentioned that the FerryBox consortium was the first group to visit the new institute.

At this meeting all Work Package leaders presented the results of their groups. Moreover, several general items such as publication strategy, contributions for the Cost Benefit Analysis, future projects relevant for FerryBox, the list of draft publications, the outreach of the project and the final report to the EU were discussed.

A special acknowledgement goes to the general secretary of EUROGOOS who attended the meeting in full (Dr. Hans Dahlin), and gave several suggestions and comments on the results of the EU project.

At the close of the meeting the tasks to be fulfilled were compiled and work loads distributed over the partners.

A very positive conclusion of the consortium is that all partners irrespective of further funding will continue measurements with their own systems and that a clear wish has been formulated to inform each other on a regular basis in the years to come. Therefore the project website will be further maintained.

WP 2 Operation and Metrology of the FerryBox Systems

Task 2-1 Functionality of the FerryBox Systems

The 2nd "FerryBox year" in which all Ferryboxes should be in operation continued in November 2004 until the end of the project. On some ferry lines the second year was less successful than the first year from various reasons. Good results with high yield of reliable data could be obtained on the routes in the Baltic, Skagerrak, North Sea and Atlantic. A detailed description about the availability and quality assurance of the sampled data can be found in the deliverable D-2-3 which was updated for the second year. (ref. Annex).

The measures for data quality assurance are still an outstanding problem which could not be completely solved during the project. Thus a lot of data still do not fulfil the anticipated quality standards.

The actual status on the Ferryboxes on the different routes is as follows:

In the Baltic Sea the two lines (Helsinki – Travemünde, Helsinki – Tallinn) were in operation during the whole year. Calibrations of temperature, salinity and fluorescence measurements have been carried out for the operational equipments on a regular basis. Monthly calibration reports have been sent to CTG.

On the second route (Helsinki – Tallinn) the system on the new boat operated well. In December a broken salinometer and temperature sensor failed. In January all sensors were taken off for annual calibration. From February until mid of April 2005 the ice conditions only allowed to switch on the system occasionally.

The Ferrybox in Skagerrak have been in operation during the whole FerryBox year and the recovered reliable data are in average between 85% and 93 % for the standard parameters. The Ferrybox system for Skagerrak was out of operation from January to April 2005 due to docking times of the ferry and refitting and reinstallation of the system on a new location of the ferry.

On the route in the Southern North Sea the system runs stable since September 2003. Main gaps occurred due to docking times in January and problems with the outlet pump in computer problems and a broken salinometer in February and March 2005 resulting in missing salinity data in that time. The installed database system (Oracle) was further developed and reinstalled on a much faster hardware (Linux system). All data from the database can be graphical plotted via internet access. In addition registered users can download selected data. The graphic tools were supplemented by a scatter plot, which allows to plot the data of a whole time period along the transect (position vs. time) with colour mapped dots. End of October 2005 the ferry company cut the operation of ferry route out and Ferrybox system had to be removed.

In the Wadden Sea the new flow system had major problems with biofouling causing improper flow rates and bad data especially for of the salinometer and turbidity sensor. The re-installed ADCP runs well without any maintenance. In January 2005 the ferry went out of service. Given the large problems with biofouling combined with the planned new ferry with a moonpool coming into service in June 2005, the sensors were not reinstalled on this system. However, there was a long delay in the delivery of this new ferry and no further observations are available after mid January 2005

In the Irish Sea a still had problems with effective maintenance as the Ferrybox could only visited once a fortnight. The used ferry operated on different routes. Two route from Birkenhead to Belfast (on north and one south of Isle of Man and one route from Birkenhead to Dublin. Reliable data were only obtained for salinity and temperature. The chlorophyll-a fluorescence and turbidity sensor delivered data of unknown quality:

On the route to the Isle of Wight (Solent) the system installed on the ferry Red Falcon was removed from service in October 2004. Work on this ferry line was not continued in 2005 due to lack of manpower.

On the ferry from Portsmouth to Southampton in the Atlantic the data return in 2005 was as good as in 2004. Extensive calibration and validation procedures were carried out during the whole year. In December 2004 a turbidity senor and an Aanderaa Oxygen Optode was added to the standard set of sensors. In June 2005 a system for measuring the partial pressure of carbon dioxide was added. Major problems with biofouling (coating with brown slime) on the fluorescence and turbidity sensors where detected from early July until late September.

Inter-calibration work was continued with IEO in the Bay of Biscay:

In the Mediterranean Sea the new Ferrybox was out of operation since November 2004. From November 2004 until April 2005 the ferry-boat was servicing another line from Patras to Venice. From April 2005 until November 2005 problems with the Ferrybox as well as still shifting the operation of the ferry between Piraeus to Heraklion and Patras to Venice on a non anticipated pattern did not allow the recording of reliable data on this route. Thus no data are available on this route in the 2nd FerryBox year.

Task 2-2 Metrology

The task 2-2 (metrology) still suffered on the partial insufficient acceptance by the partners and the lack of qualified man power. Some of the partners sent calibration forms to CTG on a monthly basis. But the reporting was far from complete and the evaluations of the calibrations forms were not completed at the end of the project. In addition changes of the involved stuff at the responsible partner (CTG) and lack of pressure to the partners operating a Ferrybox did not completely close this task.

Inter-calibration of the different Ferrybox systems continued with the turbidity sensor. After testing the stability of turbidity Formazin standards by NIVA a certified stock solution were shipped around to all partners. NIVA send Formazine standards to the partners which used this for calibration and checking the sensors. For some of the partners the diluted Formazin solution was send back to NIVA for control. FIMR, NERC.NOC, NERC.POL, GKSS and HCMR participated in this.

In autumn 2005 NIVA conducted an inter-comparison of chlorophyll-a analysis in the lab. Seven of the FerryBox partners participated on this experiment.

The use of a solid-state standard for checking changes in the calibration of the chlorophyll sensor has been intensively tested at NOC together with CTG. At GKSS a solid state standard from the manufacturer (Turner Design) was used. From the test with the Turner standard it turned out that minimal change in the positioning of the standard caused huge shifts in the data. Thus these data could not be used quantitatively in order to correct drifts of the fluorometer.

Task 2-3 Reporting of Quality Controlled Data

At the end of project the partners have reported their quality controlled data in a common data format together with a comprehensive set of meta-data as defined in WP-3. All data will be end-controlled and merged to a common data set (see WP-3 below for further details).

Task 2-4 Trials of Non-standard Sensors

The results of testing non-standard sensors on certain ferry lines have been reported by several partners and are described in detail in deliverable D-2-4.

For investigations on water and sediment transport an ADCP proved to be a very valuable and long-term stable instrument with low effort on maintenance.

The applicability of oxygen and pH sensors as well as of nutrients analysers has been shown. These data extend the information on biological processes although especially for nutrient analysers the effort for maintenance increases notably. It turned out that the commercially available devices to investigate algal characteristics have to be further developed in order to use them for routine analysis.

WP 3 Management of FerryBox Data

This work package encompassed the activities regarding management and handling of the large amount of data and information produced within the FerryBox project. Therefore a Project Data and Information Management Plan ("FerryBox DIMP" – deliverable D-3.1) was established and implemented which harmonises processing and exchange of data and information among the project partners.

One of the main goals was elaborating a common format, a joint data inventory and unified meta-data contents for effective data assembly and exchange which ought to be compliant with technology and affiliated guidelines and standards in Europe. The project partners agreed on a simple and easy to handle data format allowing effective data exchange as well as further use of the data acquired by the different Ferrybox systems and operators. This format is also easy to use of the data by third parties as well as for import to and export to/from almost arbitrary user applications.

All data produced by the project reveal certain common standards such as being uniquely time and space referenced (e.g. UTC time, WGS-84 coordinates given in decimal degrees). Each data value is controlled by a commonly agreed quality control procedure (in WP 2) and marked with the standard BODC (plus, optionally, individually defined) data flags.

Associated with the measured data a comprehensive data documentation (meta-data) was agreed which is in line with international requirements and standards. For parameter definitions this uses the BODC parameter dictionary. This is considered as important for future use of the data and also as a contribution European standardisation in marine and oceanographic data. Both the data and meta-data formats and contents are easily adaptable to almost all other types of time and geo-spatially referenced data. A comprehensive guideline document was elaborated and implemented therefore (deliverable D 3-2) which will become public after the end of the project. These guidelines may also stipulate other users for future applications in FerryBox data, and, even more generally, in oceanographic data production, documentation and quality control.

At the end of the project all operators of Ferrybox systems assembled and documented their data for incorporation in a joint data inventory (the so called "Final FerryBox Data Set"). For the final assembly and as final consistency control of the merged individually produced data sets some software has been developed by HYDROMOD. The data collection will be published after the end of the project's funded phase on a DVD together with a short documentation on its contents. The FerryBox data are freely available for interested users for scientific purposes. In addition the British Oceanographic Data Centre (BODC) acts as a data custodian. BODC will include these data into their data repositories and can also make them available through their data services.

The work package incorporated also a series of individual activities conducted by the project partners for improving and optimising their individual data handling and management means for their Ferrybox systems. Such comprised for instance functionality upgrading of user controls, on-line data retrieval and transmission to shore as well as improvements in automated pre- and post-processing. Also a variety of adaptations were done to produce or export the data from individual systems and applications in compliance with the project data management and assembly guidelines depicted above.

Further activities in this work package were dedicated to transferring and making the data available for various individual applications such as web-based services or websites. Also the related information technology developments of the FerryBox website, web pages and Internet data services were clustered under this work package (refer to the WP 6 on exploitation and dissemination for further details).

Within this work package also technologies for online data transfer and data availability/publishing in real- or quasi-real-time have been substantially developed further. Nowadays on several ferries on-line web access through ship-to-shore satellite communication links for control of the Ferrybox systems and to displays status information and actual measurements is installed. A series of websites of the respective institutes enable on-line access to the FerryBox data and thereof derived data products (see WP 6 for details).

Database storage routines have been also developed as well as guidelines for the handling of FerryBox data. Furthermore the standardisation of the data handling, processing and retrieval systems considerably advanced throughout the project.

WP 4 Scientific Analysis of Ferrybox Data

Objectives

The key project objectives in WP 4 were to provide a scientific support for the principle that Ferryboxes can deliver information of immediate scientific value, based on a coordinated approach which can quantify environmental variability on a European scale. During the last reporting period the work within the work package was concentrated on the conclusion of the 3 scientific areas (1) Eutrophication including plankton productivity and variability in productivity in relation to physical and biogeochemical constraints. (2) Transport of sediments (and associated contaminants) over long and short spatial and temporal scales. (3) Determination of the stability and transport of water masses. It implemented and tested the procedures and software developed in WP-2 and WP-3.

The work was structured to provide a basis for the calibration and validation of the associated models developed in WP-5. In turn the data collected by the *Ferryboxes* was compared to data collected using research ships, remote sensing satellites and moored instruments on buoys. The observations presented in deliverable D-4-3, 4, 5 are based on standardised reports which seek to systematically compare ecosystem and physical events to in the Baltic, Skagerrak, North Sea, Irish Sea, English Channel, Bay of Biscay Aegean Sea and the eastern Mediterranean.

Actions in WP in months 25-36 covered all the majors areas of work planned for this work package - (1) Defining the different regions of water sampled by the Ferryboxes; (2) Using the Ferrybox data to better understand the process controlling eutrophication and (3) sediment transport; (4) Comparing data from Ferrybox to that collected by other systems.

Regional Hydrography

Identifying marine waters with different sources and properties

Representatives from all the partner institutions attended a meeting organised by NOCS and hosted by NIOZ in February 2004 to develop a systematic basis for distinguishing the differences between the Ferrybox routes and observations. These ideas were further discussed at the FerryBox Science Conference held at NOCS in October 2004. The procedure has now been applied to compare the data from the different routes for the two FerryBox years 2003 and 2004 where this data is available. It is proving to be an effective way of summarising the data as it enables the display of significant difference between the years such as the higher temperatures seen in the Bay of Biscay in 2003 and in the Gulf of Finland in 2004 and the shift in fresh water inputs in the Bay of Biscay between 2003 and 2004.

This material is compiled in Deliverable D4.3-5 and Hydes et al (paper 2). In the southern Bay of Biscay IEO (Gonzalez- Pola et al., paper 7) have used the geographical coincidence of a Ferrybox route in the south-eastern corner of the Bay of Biscay with a standard hydrographical section and satellite data. The different time series have been compared to analyse the capability of the systems to provide long-term high-resolution high-quality hydrographical time-series of the upper ocean. The inter-comparison exercise is based mainly in the Sea Surface Temperature (SST) as it is a well understood parameter dominated by a strong seasonal signal. The work demonstrates the ability of Ferrybox systems to capture information on local short-scale features which may be lost with other sampling systems.

In the English Channel NOCS (Kelly-Gerreyn et al., paper 4) used the detailed time series from the Ferrybox in conjunction with data for French river run off to identify for the first time that French Atlantic coast rivers are a major source of lower salinity waters which are frequently observed in the English Channel in summer and may be connected to the enhanced growth of nuisance algae in some years (Kelly Gerreyn et al., paper 5).

Eutrophication

A key contribution to this work is the development of a numerical indicator to summarise the data, which can be used by organisations such as the European Environment Agency as a management tool. This is based on work by FIMR (Fleming and Kaitala, 2005). The "*Fleming and Kaitala Procedure*" has been tested by other FerryBox partners. A simple numerical index is calculated to describe the magnitude of the spring bloom in different regions and this is compared to the amounts of nutrient present at the end of winter (Hydes et al., paper 3).

In general the expected general relationship between plankton biomass and nutrient load does exist. However, data from the Baltic shows how widely the index and its relationship to concentrations of nutrients can vary from year to year. This provides a challenge, to extend the analysis to see if the reasons for these variations can be found in the available data sets.

It also suggests that a degree of caution should be observed when trying to make judgements on the basis of data from a single year. In the Bay of Biscay and English Channel it has been possible to link bloom activity to specific hydrographic features (Kelly-Gerreyn et al., paper 5).

In the Baltic cyanbacterial blooms are problem of specific interest. EMI have analysed Ferrybox data collected in years 1997-2004 to determine the main factors controlling the intensity and species composition of cyanobacterial blooms in the Gulf of Finland (Lips & Lips paper 10). This has demonstrated that the difference between bloom and non-bloom years can explained predominantly by differences in amounts of photosynthetic active radiation and upwelling intensity. The changes in these two parameters can explain 46% of the variation in cyanobacterial bloom intensities. FIMR have evaluated the occurrence of cyanobacteria in relation to nutrients and salinity and temperature in the Baltic Sea using Alg@line data along the route Helsinki –Travemünde for the years 1997-2002 (Kaitala et al., paper 13). This has allowed specific organism relationships to be determined. For example *Aphanizomenon* tends to dominate at lower temperatures and so is more abundant in spring than *Nodularia*. High abundances tends be found in spring with a maximum density in the Gulf of Finland in June/July. While in summer higher temperatures over 15ºC and minimum concentrations of phosphate and nitrate are associated with the maximum abundance of *Nodularia*.

Sediment Transport

The main focus of the work of NIOZ has been on the use of Ferrybox data in particular the application of ADCP (Acoustic Doppler Current Profiler) based methods to determine controls of sediment transport. The Texel – Den Helder ferry across the Marsdiep tidal inlet is equipped with a vessel-mounted ADCP. Observations on currents and backscatter are used to obtain insight in the current field and suspended sediment concentration in the tidal inlet that forms the connection between the western most tidal basin of the Wadden Sea and the adjacent North Sea. The long duration and, especially, the high frequency of the observations (the ferry crosses the inlet each 30 minutes every day between 06.00 and 22.00 hrs) make the observations in principle suitable for such studies.

These studies found problems with the model commonly used to relate backscatter to suspended sediment concentration. A new model was developed that takes account of acoustic backscatter enhanced by coherence in the particles' spatial distribution as a result of turbulence-induced sediment fluctuations. This is based on a theoretically derived relationship (Merckelbach, 2005, paper 1a) which has been tested against field surveys to used calibrate the ferry observations (Merckelbach & Ridderinkhof, 2005, paper 1b). The calibrated data has identified that the greatest fluxes of sediment occur in spring and early summer. This suggests that biological processes may influence the magnitude of this net flux (Ridderinkhof & Merckelbach, paper 1c).

Comparison to other Systems

Data from buoys, satellites and research ships can be used in conjunction with Ferrybox data. Combination of the Ferrybox data with those from remote sensing and from research vessels allows in observations of the duration, and composition of blooms, to be extended to generate estimates for wider areas. Data extracted along the Ferrybox tracks has been compared to data from the SeaWiFS, MERIS and MODIS satellites. This work has been carried out by NIVA on data from GKSS, FIMR, NIVA, HCMR, NERC.NOC, IEO & EMI.

For example limitations of the currently used algorithms for deriving chlorophyll-a from remote sensing images for coastal and shelf seas (Case-2 water) have been examined, as well as the problem of how representative sampling at a fixed depth or making surface observations are of the whole water column (e.g. Petersen et al., paper 15a, Carlos-Soto, paper 8 and Sorensen et al., paper12).

In the Irish Sea and North Sea work has been carried out by NERC.POL and GKSS comparing Ferrybox data generated by buoys and model observations. In the Irish Sea the ferry measurements are complemented by buoy measurements near the Mersey Bar and in Belfast Lough and by nested 3-D hydrodynamic and ecosystem models run daily, covering the ocean / shelf of northwest Europe (at 12 km resolution), northwest European shelf (at 7 km) and the Irish Sea (at 1.8 km). The ferry measurements have tested the temperature and salinity hindcasts of the Irish Sea model for 2004 and 2005 showing the importance of correct estimation of river discharge for the models. In the North Sea a detailed examination was made (Wehde et al., paper 9) using a hydrodynamic model and an ecosystem model to compare the comparability of the Ferrybox data and an adjacent data buoy (CEFAS Gabbard Buoy – Mills et al., 2003). This work has been valuable in demonstrating that the buoy and Ferrybox data cannot be compared directly. The model demonstrates that the two sites are more distant from one another than might have been expected. However use of the model demonstrates that the two observational data sets are consistent with one another (Wehde, paper 9).

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WP 5 Applications of Ferrybox Data

Task 5.1 Data Analysis and Process Studies

GKSS continued the collaboration with Dr. C. Schrum in order to investigate/explain regional features such as areas where little bloom activity was observed with the Ferrybox system but Remote Sensing data indicates stronger bloom activity. This could be partly explained by aggregation of particles in deeper layers.

In collaboration with the Bundesamt für Wasserbau (BAW), to get deeper insight into the fate of water parcels measured by the Ferrybox system, **GKSS** have applied numerical models to improve the significance of the Ferrybox data for the southern North Sea. Since Ferrybox data sets are limited on the specific tracks of the ferries additional information aside the routes, from e.g. fixed monitoring stations or remote sensing data, are needed to resolve environmental characteristics with a broader spatial extension.

However, the simple comparison between the Ferrybox data and those from fixed stations by using the nearest geographical data points often fails, because of the predominant circulation pattern of the surrounding water masses. The models applied for the present study consists of a general circulation model (GCM), a Lagrangian Tracer model and a primary production module. Water parcels measured with the German Ferrybox were introduced as Lagrangian Tracers into the GCM in order to simulate the geographical displacement.

To simulate the temporal development of non-conservative tracers like the chlorophyll a primary production module (Wehde et al., 2001) is implemented for each of the tracers. The present study is therefore focussing on methodical aspects to resolve and display the fate of water measured with a Ferrybox and compared to data obtained with other methods.

The **HYDROMOD** FerryBox model has been validated with measured data from different tide gauges around the North Sea. The comparison with measurements and model results provided from the German Federal Maritime and Hydrographic Agency (BSH) from Jersey show a good accordance, especially for low water the results from the FerryBox model seem to be better (than BSH). One reason might be that the resolution of the bathymetry in that region, provided by NERC.POL, was more realistic than in the BSH model. The comparison with measured data and BSH model results at Cuxhaven is also satisfying. The model process studies in the North Sea have shown the way of combining Ferrybox information with tracer algorithms to look at phenomena like the movement of coastal fronts and mixing of water masses. In a first step the spring-neap tidal modulation and its effect on water mass transport and mixing have been investigated by releasing an ensemble of tracers and following their pathways. The fate of the water masses represented by the tracers shows that the distribution even after a few days is highly dependent on the hydrographic situation. This fact, however, proves that the area indirectly covered by Ferrybox information may be relatively extensive in periods of spring tides or storm events.

Using the **NERC.POL** Coastal Ocean Modelling System (POLCOMS) coupled to the European Regional Seas Ecosystem Model (ERSEM), ecosystem variability during a 10 year period (1977-1986) in the Irish Sea has been investigated using a fine resolution (~3.5 km) local area model. The ability of the model to represent observed features of the nutrient cycling and plankton variability has been assessed by comparison with in-situ data and a long time series of measurements from a site to the southwest of the Isle of Man (Cypris station). Data extracted along the Birkenhead to Belfast ferry route indicate the route captures the significant elements of biochemical cycling in the Irish Sea.

Results from the Birkenhead – Belfast ferry in 2004 have been subject to an initial analysis. A temperature time v longitude plot shows mainly the expected seasonal cycle with peak temperatures in August, but with some smaller features such as a heating event around day 160. Summer temperatures are higher in the shallower coastal water and in the stratified surface water at about 5 deg W. The **NERC.POL** Irish Sea model run for this period is in general agreement with this pattern except that model temperatures are approximately 0.5-1 degree C higher. The salinity time v longitude plot is possibly the more interesting as it shows distinct peaks of low salinity at the Liverpool end, corresponding to variations in the freshwater plume. There is no obvious correlation with river outflow data, but a comparison with tidal data strongly suggests that the variations correspond to mixing at spring tides followed by re-stratification at neap tides. The variation in plume extent (several 10s of km) considerably exceeds the tidal excursion (total about 6 km due to M2 and 9 km at springs) which can also produce some variation in the apparent measured position of the plume. This stability cycle in Liverpool Bay has been observed by Sharples and Simpson (1995), but with a much shorter record. The NERC.POL Irish Sea model also shows similar oscillations in the extent of the plume and agrees with its general westward extent. However the model was run with climatological runoff only and this may affect the detailed comparison. A model run forced by the observed river runoff for 2004 (factored to allow for ungauged river discharge) shows modelled salinity in much better agreement. Hence Ferrybox data is potentially able to provide a long record giving information on the stability cycle in Liverpool Bay. Further comparison with models should help improve their ability to represent this important aspect of the dynamics of this region.

A report (deliverable D-5-1, in association with WP4) has been written on the contribution of Ferrybox data to process understanding.

Task 5.2 Data Assimilation Schemes for FerryBox Application

Two partners (HCMR, NERC.POL) have conducted model experiments with the assimilation of Ferrybox data into realistic simulations for 2004; a third (HYDROMOD) has carried out model tracer experiments to explore the potential impact of assimilated data.

HYDROMOD have explored, through tracer techniques in their model of the North Sea, the use of Ferrybox data for assimilation. Ferrybox observations may be used indirectly by tracing certain “conservative” parameters (and their variability) several times along the ferry route. A good prediction of this variability by the model in turn will point to a good approximation of the velocity and turbulence fields in the region concerned. Therefore such tracer methods could be used to “create” a spatial distribution of certain parameters measured by the Ferrybox on its route. This field can then be introduced in the pre-operational model to improve its precision, which otherwise strongly depends on the (relatively coarse) boundary and forcing conditions of the BSH North Sea model. The task of improving meso-scale model predictions in tidal seas by introducing information from Ferry boxes has shown promising results. However, the introduction of such techniques in operational use would necessitate a still prohibitive amount of computing effort.

The **HCMR** research team has continued to develop the SEEK/SFEK assimilation approach, which allows assimilation of multiple data types. In this process several steps have been necessary:

(i) **Implementation of a local gain operator:** The low rank approximation of the background error covariance matrix related to the Aegean Sea model statistics resulted in noisy distant correlations between model variables. The presence of such long range correlations can be harmful to the filter performance especially when the directions of correction (EOF modes) evolve in time.

In order to filter out the small background error correlations associated with remote observations, the SEEK/SFEK filters algorithm was modified by implementing a local gain operator (element-wise product of the background error covariance matrix with a correlation function with local support);

(ii) **Validation of SFEK/SEEK filters performance using altimetry data:** Experiments have been conducted with the Aegean Sea model to assess the skill of the localized filters (SFEK/SEEK) in assimilating "real" observational data. The initial error covariance matrix for these experiments has been calculated by considering daily samples of model states during a 2-year integration period (Jan 2002 – Dec 2003). The assimilation experiments extended from January 2004 to June 2004 a period during which altimetry observations (maps of sea level anomalies (SLA) at $1/3^{o}$ resolution from the AVISO project) were assimilated into the model on a weekly basis. The results showed the localized SEEK filter reduced the RMS error in the sea surface height in a manner consistent with the model dynamics. Moreover, the SEEK filter was able to reduce the model RMS error on sea surface salinity (SSS) and temperature (SST) daily Ferrybox data along the ferry route from Athens to Heraklion;

(iii) **Assimilation of Ferrybox data in the Aegean Sea model:** SSS from the Ferrybox system along with SLA satellite data have been assimilated into the Aegean Sea model for the 6-month period Jan 2004 – June 2004 using the localized SEEK filter on a weekly basis. Due to the limited computer resources, only 10 out of 60 correction directions were allowed to evolve according to the model dynamics. Overall, this experiment showed that Ferrybox data can improve the model forecast skill but only on the local scale (Korres et al, 2006).

Results from these activities indicate that the decorrelation length scale along the cruise track is between 90 – 100 km, which is 2 to 3 times larger than the decorrelation length scales estimated directly from the Ferrybox data itself (Kontoyiannis and Ballas, 2005).

At **NERC.POL** an Ensemble Kalman Filter, based on Evensen (1994) and Evensen (2004) has been implemented to assimilate sea surface temperature observations into a 1.8 km resolution setup of POLCOMS in the Irish Sea, model name IRS, (Andreu-Burillo et al., 2006). Experiments assimilating SAF 2 km SST, and examining perturbations in the Mellor-Yamada turbulence closure scheme (Experiment A) and in cloud cover (Experiment B) have been carried out for the summer of 2001. SST standard deviation results for (A) show that uncertainties in the turbulent closure scheme and large scale errors in the wind forcing can account for small scale forecast errors in the positioning of thermal fronts. These errors become negligible near the coasts. Adding noise to the cloud cover (B) spreads the forecast error throughout the whole domain and increases its value. Due to the low number of members in our ensemble a local analysis has been implemented to correct the forecast only in regions where observations are available in the analysis step.

Further IRS assimilation experiments have been carried out for 2004. A series of experiments, designed to maximise the information on assimilation, have been planned. These include a) running the IRS without assimilation but with climatological rivers (as in the operational mode) and with realistic inflows, to understand impact of freshwater on the ferry route; b) in both '(a)' runs, assimilate satellite 2 km resolution SST; c) '(b)' runs with Ferrybox SST and (later) SSS. These runs are in progress, slightly delayed by computer software problems (the CSAR High Performance Computer Centre suffered a major security breach, resulting in several weeks of unavailability).

A report (D-5-3) on the quantification of assimilated Ferrybox data into pre-operational models (based on the work of HCMR and NERC.POL) has been written.

Task 5.3 Pre-operational Modelling

This has continued on a daily basis for the **NERC.POL** models throughout the year.

This has continued on a daily basis for the **HCMR** models throughout the year.

This has been tested by **HYDROMOD** for a few periods with operational transfer of boundary conditions, weather information and model results from BSH.

Task 5.4 Explore the possibility of using Ferrybox Data to Validate Optical and Infra-red (Temperature) Data

NIVA has coordinated the use of Ferrybox data to explore the use for validation of optical satellite data. MERIS level 2 satellite data from the area around the ferry lines have been collected and prepared for such a comparison. The MERIS Level 2 Algal Pigment Index has been used. Both Ferrybox Chl-a fluorescence sensor data as well as water sample Chl-a have collected from FIMR, EMI, IEO, NOC, GKSS, HCMR and NIVA and are by NIVA compared with the MERIS data using the VISAT software and extracting the MERIS Chl-a products along the ferry lines. Both the MERIS standard algorithms as well as new reprocessed MERIS data will evaluated. The ferries lines cover from the high biomass areas in the Baltic with cyanobacteri bloom as well as oligotrophic areas as the Mediterranean area.

In addition **HYDROMOD** have received MERIS satellite data for comparison with models. An extraction of a period with good weather condition was used and a matrix of data was processed

As a part of the D5.4 deliverable **NIVA** also have arranged a Chl-a intercomparison for the partners and some other invited institutions. Total of 13 laboratories including the FerryBox partners, NIVA, FIMR, IEO, EMI, GKSS (2 laboratories), NOC and HCMR participated. Outside the consortium laboratories the following lab was included; SYKE in Finland, TARTU Laboratory in Estonia, PML in UK, EPA in Ireland and MUMM in Belgium.

Details about the methods have been collected and included HPLC, Fluorometric and Spectrophotometric determination and different extraction techniques (Acetone, Methanol and Ethanol). Most of the results were within +/- 1 standard deviation, and most of this variation seems to be the results of the very different methods involved. One laboratory (NIVA) also performed tests on the different methods showing the difference of HPLC and the spectrophotometric techniques. The preliminary result was send to the participant in December and will be included in the final D 5.4.

GKSS have continued the comparison of the Ferrybox data with those from remote sensing and from research vessels to investigate the duration, extent and composition of blooms occurring in the southern German Bight.

NERC.NOC, using the Portsmouth to Bilbao route, have shown the amount of data available to create satellite composite images can used to provide a "clearness index" along a Ferrybox route which gives an indication of changes in the light field from year to year and the variation in cloud cover with latitude. Along track variation in estimations of chlorophyll by satellite and in-situ fluorescence measurements have been compared to data from actual concentrations of chlorophyll in water samples.

These highlight the know problems with the satellite algorithm in Case 2 waters and the variation of the chlorophyll fluorescence ratio in different sea areas.

FIMR participated in chlorophyll-a validation of the MERIS satellite with NIVA. Provided Modis chlorophyll-a maps for comparison to Meris validation for 10 and 15 July, 15 and 31 August 2005 with the appropriate *in situ* data and parallel Modis images.

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WP 6 Exploitation and Dissemination

In this work package the dissemination and exploitation activities of the project were clustered. The main goals comprised distributing information, experiences and results as well as stipulating the use of Ferrybox systems in marine science and operational oceanography. In overall, the project gained a very high outreach both into the marine communities concerned as well as to the general public. Within this work package a comprehensive Technological Implementation Plan ("FerryBox T.I.P.") was compiled and implemented to which one is referred for further details.

All project partners intensively communicated results and experiences on various scientific and technical conferences meetings. These are summarised in a comprehensive list of publication and dissemination activities which is delivered together with other results from this work package (D-6-3). In addition and right after completion of the funded phase, the FerryBox partners will elaborate a publication series with key results which is to be published in a peer-reviewed scientific journal with high outreach into the targeted user communities.

The project has set-up a public FerryBox website and portal (http://www.ferrybox.org) informing on progress and results achieved during the project. This website may also facilitate as a portal to thematically associated websites, web pages and/or information services operated by the project partners. The site will remain operative after the project's funded phase for a period of at least 2 years and will be maintained and updated according to available resources.

Throughout the project all operators of FerryBox systems have established new or upgraded already existing individual websites, web pages, data retrieval and/or public information services for their individual system applications. An inventory of FerryBox websites and web-based data services is provided in Section 6 of this report as well as on the FerryBox website which links directly to these websites and services.

A "FerryBox Cost Benefit Estimate ("FerryBox CBE") was elaborated to inform interested users and institutions intending to apply Ferrybox systems with information on scientific and operational oceanography benefits and also giving reasonable breakdowns of cost and efforts necessary for appropriate implementation and operation. This document has been classified as "Public" for gaining a wider outreach and to support future applications of Ferrybox systems in marine science and monitoring.

The widely spread and intensive exploitation and dissemination activities in the FerryBox project already led to sound recognition and considerations in the user communities. Direct proves for this are e.g. the installation and operation of a Ferrybox system by the Dutch North Sea Directorate/Rijkswaterstaat on one of their research, monitoring and work vessels in spring 2005, the order of a Ferrybox system of the Swedish Meteorological and Hydrological Institute, the decision to successively install Ferrybox systems on German research vessels, or the installation of Ferrybox systems on two ferry lines between Tallinn and St. Petersburg and between Poland and Sweden which are both planned for becoming operative in 2006. The German Maritime and Hydrographic Agency (BSH) will conduct a pilot-project starting in 2006 in the German Bight.

Three additional Ferrybox systems were set up by organisations in Norway which has already implemented Ferrybox systems as a key-component in the countries' monitoring approach. The first one is installed on a route (operated by Fjord Line) between Hanstholm (DK), Bergen (NO) and Newcastle (UK), the second one on a ferry running between Bergen and Kirkenes (operated by Troms Fylkes Dampskibsselskap). The third Ferry (operated by Ofoten and Vesterålen Dampskipsselskap) is also running between Bergen and Kirkenes and here the thermosalinograph that Institute for Marine Research (IMR) has used for many decades will be replaced by the more modern system based on the experience from the NIVA Ferrybox system. NIVA will build this system together with IMR. These activities clearly show the great interest in these systems.

The FerryBox project partners will continue to keep their network and collaboration together and alive. It may also be enlarged with other interested parties. Some networking activities like occasional meetings and keeping the FerryBox website and Internet services alive are considered to be coverable by own funds of the partners for a limited period of time. However, a series of reasonable activities cannot be conducted without contributory funding and consequently the project partners will seek for complementary opportunities, for instance under the European Operational Oceanography Cluster in the Sixth and Seventh RTD Framework Programmes of the European Commission.

Already from the very beginning of the project presentations on the FerryBox project were given. Early presentations were specifically within the framework of operational services, environmental agencies, ICES, and (Euro)-GOOS. A series of presentations and posters were presented at the 2002 Third International EuroGOOS conference in Athens: Building the European Capacity for Operational Oceanography. Again at the 4th EUROGOOS conference in 2005 in Brest a series of presentations by partners of the FerryBox project were given in a specifically dedicated session. Apart from these, conferences on operational services, contributions were given to major scientific conferences such as on the 2005 ASLO Summer Meeting in Santiago de Compostela, Spain where a special session with 15 contributions was presented on the use of Ferrybox systems. Several partners gave also presentations in North and South America and across Asia (for a complete list of presentations and exploitation activities see Section 6.6 and deliverable D-6-3).

Public Awareness

A specific activity at first developed and implemented on the Dutch ferry between Den Helder and the island of Texel is an on-line display presenting Ferrybox data on board to the passenger areas embedded in other interesting information during the trip. Thereby a large public community gets insight in currents, current directions, water temperature, salinity and phytoplankton density. The whole is combined with several explanations. This contributes to the understanding of the sea in a general sense. Plans exist on Norwegian ferries to offer similar displays comparable to those presented on long intercontinental flights in aircrafts. Meanwhile passenger display units are also available as add-ons to commercially available Ferrybox systems.

Transfer to the Marine Industry

Europe has two major instrumentation and system manufacturers which have Ferrybox systems and components in their portfolio of products. One (CTG – Chelsea Technology Group in UK) was a partner in the project and the other one (-4H- Jena Engineering GmbH in Germany) closely cooperated with GKSS in further developing a marketable Ferrybox product and system line. Along with the project Ferrybox systems and sensor packs as well as periphery like onboard displays became more advanced and market ready. Also service providers using Ferrybox data (like the project partner HYDROMOD) had considerable benefits from their engagement in the project. Besides direct and indirect transfer of know-how and technology, the FerryBox project together with the outreach of its consortium contributed significantly in improving market positions and competitiveness of these European companies.