OceanObs'09 Community White Paper

The way forward in developing and integrating FerryBox technologies

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Executive Summary

The state-of-the-art in the use of commercial ships to routinely collect biogeochemical and hydrographic data, known collectively as "Ferryboxes" is briefly outlined. The focus is on biogeochemical and related measurements between ocean margins and estuaries and on surface waters. The EU project FerryBox (2002-2005) amply demonstrated they can provide oceanographic data in a highly cost effective manner over a wide range of time and space scales. In Europe FerryBox output is now an integral part of the vision (EMODNET European Marine Observation and Data Network) for the gathering of data streams together into a pan European system for assimilating data in to the marine management cycle. Practically is this beginning to evolve through systems such as EMECO (European Marine Ecosystem Observatory) which will link national system such as COSYNA (Coastal Observation System for Northern and Arctic Seas). This will enhance the provision of much needed data to reduce the degree of aliasing that can be present in the small data sets that have previously been used in assessments such as the OSPAR Common Procedure looking at for example eutrophication..

The FerryBox concept is already in use globally in Australia, Japan and the USA for example. It has considerable potential for expansion particularly for the study of inputs from the world's major riverine in puts such as the Amazon and those flowing into the China Seas. This aspect of the work should be strongly encouraged. Similarly it has the potential to provide key information on changing levels of productivity helping fisheries science in many areas of the world.

In the next decade the success that is being achieved in the measurement of fluxes of carbon dioxide over the North Atlantic in particular using ships of opportunity should be expanded to include increased study of coastal and shelf regions. The FerryBox concept provides reliable and cheap platforms for making integrated sets of measurements. This particularly important in shelf seas where measurements of the carbonate system must be made along with other chemical, biological and physical measurements that allow changes in CO2 flux and acidification to be related to forcings which are more local in nature than in ocean waters.

To provide FerryBoxes with this needed expansion in capacity, work is needed to improve the reliability and robustness some existing systems that are already being used for example for nutrients, pCO2 and pH and to expand areas which have been

trialed such as the use of ADCPs and automated shipboard plankton zooplankton assessment devices.

1. Background

Until recently a serious hindrance to understanding and forecasting the state of marine systems has been the lack of monitoring systems that provide on-line data, and observations with sufficient spatial coverage and temporal resolution to give a true view state and change. To overcome this hindrance developments have been pursued in measurement technologies, data logging and ship-shore communications. It is now possible for scientists and governmental (environmental) agencies to work with merchant shipping companies to collect this much needed data autonomously in a cost effective manner. In this paper we briefly describe what has been achieved on this matter and possible future contribution to enhancing marine and coastal observatories.

FerryBox (http://www.ferrrybox.org) is about a partnership between scientists and the companies operating the large numbers of ferries around the world - 800 in European seas. The name signifies (1) the use of a **ferry** (or other commercial ship), (2) **box**es of autonomous equipment (3) the ability of data collected on regular route not only to provide much needed time series data but also boundary conditions for numerical models **box**ing in an area of sea or ocean. In Europe some 30 ships are involved in this type of work and systems have also been in operation for sometime in Japan (Harashima & Kunugi, 2000) in the USA (Ensign & Pearl, 2006; Paerl et al., 2005) and elsewhere. A map of the routes currently carrying FerryBoxes is shown in Fig 1. Many of the systems have been developed to support the requirements for both scientific and marine management data. For example, work by the Finnish Marine Institute (now Finnish Environment Institute SYKE) saw the incorporation of the FerryBox in to the AlgaLine system (www.fimr.fi/en/tietoa/algaline_seuranta/en_GB/) aimed at improved surveillance of the harmful and nuisance blooms of algae that plague the Baltic (Backer et al., 2008).

FerryBox systems have considerable potential for increased use as part of marine management systems around the world, particularly making it possible to monitor the world's major estuaries ands coastal waters such as those of eastern Asia. A particular success has been achieved for the monitoring of air-sea fluxes of carbon dioxide through the IOCCP International Ocean Carbon Coordination Project VOS (Voluntary Observing Ship) operations (e.g. Schuster and Watson, 2007). It is important that this work is continued and work particularly in shelf seas is expanded. Coastal carbon issues are important in the international (UN) agenda because it is felt that management and policy decisions are more easily made at the local and regional level. The coastal carbon system needs to be better monitored in respect to the overall carbon cycle issues and natural carbon sequestration processes. The FerryBox approach outlined here is probably the only way that can provide the needed monitoring coverage of carbon import and export in shelf seas and acidification in the coastal zone cost effectively.

The EU FP5 project "FerryBox" (2002-2005) proved particularly successful in demonstrating the utility of the approach (Petersen et al., 2006). The core work of the FerryBox project focused on the use by all the participants of four "core" sensors for-temperature, salinity, chlorophyll-fluorescence and turbidity along with testing of a wider range of sensors by individual groups (Petersen et al., 2007). Even basic sensors such as salinity proved to provide scientifically interesting data for example on water transport when collected as part of a consistent time series (Kelly Gerreyn et al.,

2006) and it is an important variable for any coastal monitoring programme.. Even if most VOS systems only sample surface waters, the repetitively, the frequency of measurement in time and space and in many instances their real time capability makes it a unique observation facility, highly complementary to other observations from fixed buoys and research vessels. Besides profiling instruments such as ADCPs (Acoustic Doppler Current Profiler) can enable VOS ships to successfully see below the surface (Flagg et al., 2006; Buijsman & Ridderinkhof, 2007) and biological information can be gained from the use of scientific echo sounders (Griffiths & Diaz, 1996). In the Mediterranean Sea VOS are widely used as launcher for XBT (expendable bathy thermographs) profiling the water column for temperature (e.g. Fuda et al., 2000).Also a combination with towed instruments would be possible such as with the CPR (Continuous Plankton Recorder; see below).

The FerryBox community is evolving from single institute-driven VOS (voluntary observing ship) lines to strategic multi-partner and trans-boundary work. In Europe such coordination is sought as a pillar for the future deployment of pan-European coastal observing systems and will facilitate the implementation of the EU's Marine Strategy Framework and the Water Framework Directives.

The use of FerryBoxes in integrated monitoring schemes being developed in Europe is described below. On longer time scale a SCOR working group 'OceanScope' will start work in 2009 to look at the long term future and enhancing the partnership between the ocean observing community and merchant marine shipping industry. The targets of OceanScope are 1) an enhanced ability to identify routes and operators in all oceans, 2) new instruments and technologies to be developed and optimized for automated operation on commercial vessels, and 3) real time data streams, automated data processing and distribution to the user community. One option for implementation of this concept would be through the establishment of an international agency, something like space agencies, which are designed to operate on decadal time lines appropriate to the challenges faced.

2 Integration of FerryBoxes into observing systems networks and the Marine Monitoring Cycle

2.1 Marine monitoring cycle exemplified for eutrophication problems

Eutrophication remains an important environmental issue globally and within Europe. Schemes for monitoring and assessment of eutrophication have been put in place so that individual countries can comply with international conventions (OSPAR and HELCOM) and a range of European Directives (e.g. Nitrates Directive, Water Framework Directive). The first and second application of the OSPAR Comprehensive Procedure, which is a formal assessment methodology, has led to the diagnosis of eutrophication in a range of European coastal and estuarine water bodies OSPAR, 2003). These include much of the offshore and coastal water bodies of continental Europe (e.g. Netherlands, Belgium and Germany) as well as selected estuaries. OSPAR defines eutrophication as the enrichment of waters by nutrients causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned. To meet OSPAR needs for detection and diagnosis of eutrophication monitoring is carried out for a range of assessment parameters. These include the level of over-winter nutrients, N:P ratios, growing season chlorophyll concentration, abundance of phytoplankton indicator species, shifts in phytoplankton species composition and levels of dissolved oxygen concentration. Multi-year trends in ambient nutrient concentration and riverine nutrient inputs are also taken into account in determining the outcome to an assessment.

Traditional monitoring of coastal and offshore waters has relied upon intermittent sampling using survey vessels. Such an approach is costly and given the significant temporal and spatial variability of the eutrophication assessment parameters (e.g. phytoplankton blooms, storm induced increased freshwater input) these can lead to large uncertainties in the accuracy of data used for assessments. In Europe this uncertainty in the evidence base for environmental assessments is a serious concern when the outcome to an assessment may be subject to legal scrutiny with the threat of punitive fines and costly remediation. More recently novel monitoring methods based on the use of FerryBoxes using ships of opportunity or fixed point monitoring from buoys have begun to be used. As a result there has been, for some countries, a step-wise increase in the size of the data base used to assess eutrophication leading to greater accuracy and robustness in assessments, thus improving reliability. After data processing, analysis, the information is returned to the managing environmental agencies for assessment and thence to policy makers.

2.2 Examples of integrated monitoring EMODNET, EMECO and COSYNA

The value of this integrated approach required by OSPAR and other authorities is beginning to be recognised. Concerted efforts are underway to expand the approach to ensure that the benefits that can be achieved are fully realised. An objective of the EU's new maritime policy is to integrate existing, but fragmented initiatives in order to facilitate access to primary data for public authorities, maritime services, related industries and researchers. Marine related data are available from many sources but assembling them for particular applications takes considerable effort and there is no overall policy for keeping them for posterity. The EU Commission therefore set up EMODNET (European Marine Observation and Data Network) to open up opportunities for high technology commercial companies in the maritime sector to improve the efficiency of activities such as marine observation, management of marine resources and marine research in European laboratories. The EMODNET vision is for an end-to-end, integrated and inter-operable network of European marine observations, data communications, management and delivery systems, supported by comprehensive user-oriented toolkits.

In practice these ideas are being realised by practical and more local initiatives such as the EMECO (European Marine Ecosystem Observatory) which are actually (rather than talking about it) setting about providing a framework and the tools to integrate data sources from different agencies, using different platforms (ships, buoys, satellites) from different countries. The building blocks of EMECO include national marine monitoring programmes, regional marine and coastal observatories (e.g. COSYNA Coastal Observation System for Northern and Arctic Seas), FerryBox routes, buoy networks and satellite remote sensing. This will provide integrated information products via web interfaces that will form part of the evidence base to underpin regional scale assessments of eutrophication and in the future of ecosystem health. EMECO and COSYNA will also help to meet the new challenges posed by the new European Marine Strategy Framework Directive (MSFD) and the implicit need to deliver an ecosystem approach. The MSFD requires a wide range of marine scientific evidence to support the ecosystem approach. The evidence required will be cross-boundary and be based on observations from physics to fish over wide time and space scales. Delivery of an ecosystem approach at basin scale can only be done through collaboration and coordination of effort between agencies and countries.

The delivery the data for assessments will be on a broader scale than that prescribed in the OSPAR Common Procedure. This will be achieved by providing information on other parameters such as the ambient oxygen concentrations, changes in the phytoplankton composition, availability of food for higher trophic levels. The processes being observed do not recognise national boundaries so that a major improvement in knowledge will be achieved when initiatives from different countries are linked allowing a basin wide approach to be undertaken.

2.3 An example: role of FerryBoxes in COSYNA

Marine observation systems need to cover a wide range of time and spatial scales. Ferry Box (in situ) observations are being linked with other observational mechanisms and models to obtain a wide spatial and temporal coverage. One example of integrated monitoring in which FerryBoxes play a prominent role is the COSYNA system in the German Bight of the North Sea (http://www.cosyna.de). The system that is under construction consists of the following observational components (see Figure 2): Three FerryBoxes routes are included along with two measuring poles in the Wadden Sea, two coastal X-band radar stations, a HF Radar network that covers the German Bight, wave-rider buoys for calibration of the radar measurements and two stationary FerryBox type instrument modules on shore. These modules operated by the GKSS research centre and are complemented by several stations operated by other institutions (BSH, AWI, University of Oldenburg). In the near future additional sensors will be installed on existing research platforms and wind energy platforms.

These automated and remote-controlled measurements are complemented by regular ship cruises (four times per year), which include continuous surface measurements (using FerryBox type systems on the research ships) and continuous measurements with an undulating tow-fish in the depth. Under suitable weather conditions data from satellites (e.g., ENVISAT) are used to get a better spatial coverage of SST, chlorophyll, suspended sediments and yellow substance. Data from all these systems are quality-controlled by the project partners and stored in a data base with web access (http://www.coastlab.org). Quality-assured, near-real time COSYNA data from observations are assimilated into models in order to provide reliable now-casts and short-term forecasts. The systematic coupling of observations and forecasts will be the basis for scientific applications that support different end users from science and political bodies to make environmental management decisions.

For example, FerryBoxes will a measure a wide range of parameters (S, T, O2, CO2, pH, turbidity, chlorophyll (fluorescence), nutrients, species composition (based on discrete water samples), algal groups (fluorescence spectra). This suite of data together with remote sensing, and other observational data and model outputs, will form the basis for a synoptic description of the system (www.cosyna.de). Data collected by FerryBoxes are being used directly as continuous ground truth data for remote sensing: Using appropriate transport models the data of the FerryBox and the satellite over flight are matched temporally and spatially (e.g. Petersen et al., 2008).

3. What we need to improve the capacity of FerryBoxes

The EU FerryBox project focused on the use by all the participants of sensors for temperature, salinity, chlorophyll-fluorescence and turbidity along with testing of a wider range of sensor by individual groups (Petersen et al., 2007). The findings of the project showed that generally good data could be collected with these sensors with a high percentage of possible data being collected. However even with these sensors care needs to be taken to achieve good data. Systems need to be set up appropriately for the waters being sampled, as some systems tend to suffer from biological fouling more than others and accumulation of sediment in the measurements chambers can cause problems. It should be emphasized that there now exists a considerable amount of experience in operating systems and that new groups wanting set up systems should consult among the experienced operators before specifying their new system. As this work progresses the design of systems will evolve. One key requirement in systems is that maintenance should be kept to a minimum A target for the next 10 years will be finding the best combination of robust sensors that can be cleaned by the ships staff and automated cleaning systems that do not themselves need frequent skilled maintenance. A particular success in the last 4 years has been the oxygen optode sensor, which offers simplicity, reliability and good precision and durability (Hydes et al., In Press). It exemplifies the kind of development that is needed and as such the oxygen optodes has rapidly becomes a standard part of many FerryBox and Ship of Opportunity systems.

A constant dialogue with equipment manufacturers is essential to ensure they keep in mind the practical use of the equipment they are building and the circumstances in which it is going to be used. Working in 40 ^{o}C temperatures in ships engine room or on the heaving deck of ship is not the same as in an air conditioned laboratory on shore. Reliability needs to be built into equipment. Often this can easily be enhanced by good design – on say chemical analyser this can be as simple as unambiguously labelling tube connections and making them easy to reach and change. Nutrient analysers have for example been commercially available for 10 years but there is still the potential for making instruments that could provide improved reliability by introducing simple design changes.

Concerns over the relationship between anthropogenic CO2 release and ocean uptake and consequent ocean acidification mean that increasingly instruments that can measure components of the carbonate system are needed as part of ship of opportunity systems (Borges et al.; Feeley et al and Schuster et al., this volume). Instruments to determine pCO2 are available. Equilibrator based systems have been commonly used in ship of opportunity systems however they have high maintenance overheads and considerable effort is needed in the measurement and calculation of pCO2 values (Pierrot et al., 2009). Simpler systems based on gas transfers across an in-situ membrane are being developed and offer the potential to provide high quality data at a lower over head and be more easily set up on wider range of vessels (see de Grandpre et al., this volume). Particularly when used in conjunction with measurements of total dissolved gas pressure (McNeil et al., 1995) they offer the potential for improved and more robust measurement systems in the near future. Work is under way to manufacture reliable high precision (± 0.001) instruments for the determination of pH following on earlier work which proved the concept of using colorimetry (Friis et al., 2004). Equipment for pH should be being manufactured in the near future. It would be highly desirable to able to measure total alkalinity and total dissolved inorganic carbon autonomously.

There is a need for further improvements and extension of the sensors into the direction of more biological relevant measurements. One of the first systems used regularly on ships of opportunity was the Continuous Plankton Recorder CPR (see Reid et al., this volume). Using a machine in use since the 1930s, zooplankton are collected on silk screens and are sent ashore for taxonomy analysis some months later. More rapid assessment of zooplankton abundance is needed in systems like EMECO to be able to say why plankton blooms are behaving in the way they are. Often it will only be necessary to know if zooplankton are abundant or not, and accurate taxonomic data can be provided later. Rapid data assessment can be provided in “flow cams” as part of an inboard FerryBox system- in this field promising systems that use video cameras with sophisticated pattern recognition software are on the horizon (Blaschko et., 2005; Tang et al., 1998). Or using acoustic sensors (such as the ASL Multiple – Frequency Acoustic Water Column Profiler) attached to the hull or on towed body. Such measurements would also serve to reduce the aliasing inherent in the CPR measurements which are traditionally only made monthly.

Other sensor systems that are now in the experimental stage use modern bioengineering/genetic processes to automatically identify single phytoplankton species or – groups (“Geneprobe”). This may be especially useful for the specific detection of harmful algae (Metfies et al., 2006; Scholin et al 2008; Scolin, 2009; Scholin et al., this volume). Such systems have already been packaged for use on moored systems making them robust enough for autonomous use on ships. Simple measurements of chlorophyll-fluorescence provide a crude indication of phytoplankton abundance and these can be extended using multiple wavelength techniques to provide some indication of the presence of different algal groups an dissolved organic matter (Blue Green Algae Phycocyanin/Phycoerythrin and CDOM). Other systems such as flow cytometers have been trialled and offer the potential for providing extra key biological information at a species level (www.cytobuoy.com).

Some chemical and biological determinations will continue to require the collection of water samples. Some FerryBox systems have done this using relatively crude water samplers such as the Teledyne-ISCO ones (www.isco.com). It is recommended that some effort be put into the development of water samplers capable of collecting and preserving 10s of samples. A second requirement is for automated filtering with preservation of the filtrate. Some work is underway to produce robotic sampling devices capable of operating autonomously filtering samples and placing the filtered material into a low temperature freezer.

4. Context of Ocean Obs’09

The FerryBox concept is already in use globally in Australia, Japan and the USA for example. It has considerable potential for expansion particularly for the study of inputs from the world’s major riverine in puts such as the Amazon and those following into the China Seas. This aspect of the work should be strongly encouraged. Similarly it has the potential to provide key information on changing levels of productivity helping fisheries science in many areas of the world. As such FerryBoxes can make an important contribution to the development of a global system for observing the coastal ocean: For work in developing countries the FerryBox approach is particularly important because it is highly cost effective. It can enable the Coastal Module of GOOS to happen in the third world. Key to the success of GOOS is its practical wing JCOMMOPS (Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) Observing Platform Support Centre). The OceanObs’09 Conference, will provides the opportunity to discuss how local FerryBox operations might be coordinated globally through JCOMM to provide input to a Coastal GOOS system (this volume).

With all the observations being collected, and all the new technology being used – it is key that the data be properly quality controlled, maintained, disseminated and archived in standard way around the globe. The EU FerryBox project made some progress by defining meta-data protocols. One important piece of work developing out of Ocean Obs'09 will how data managers can prepare and manage the potential increase in data that will hit them the next few years.

In the next decade the success that is being achieved in the measurement of fluxes of carbon dioxide over the North Atlantic in particular using ships of opportunity can be expanded to include increased study of coastal and shelf regions. The FerryBox concept is to provide reliable and cheap platforms for making integrated sets of measurements. This is particularly important in shelf seas where measurements of the carbonate system must be made along with other chemical, biological and physical measurements that allow changes in CO2 flux and acidification to be related to forcings which are more local in nature than in ocean waters. Ocean Obs'09 is already providing a forum for exploring how these developments can take place. A future network must have the capability to measure $CaCO_3$ saturation states and $CaCO_3$ production- and dissolutions rates. Measurements of net primary production, either directly or from nutrient or oxygen inventories along with hydrodynamic considerations in coastal zones, are essential to allow physical and biological modifications to ocean acidification to be identified. These additional measurements are needed to predict ecosystem responses to ocean acidification.

References

Backer, H.; Leppänen, J-M., (2008) The HELCOM system of a vision, strategic goals and ecological objectives : implementing an ecosystem approach to the management of human activities in the Baltic Sea – Aquatic conservation: marine and freshwater ecosystems 18:321-334.

Blaschko, M.B., Holness, G., Mattar, M.A., Lisin, D., Utgoff, P.E., Hanson, A.R. Schultz, H., Riseman, E.M. (2005) Automatic In Situ Identification of Plankton Seventh (In IEEE Workshops on) Application of Computer Vision, Volume 1. 79-86 ISBN: 0-7695-2271-8

Belbeoch, M. et al., (This Volume) The JCOMM in situ Observing Platform Support Centre: A decade of progress and remaining challenges

Borges, A.V. (This Volume) A global sea surface carbon observing system: Dissolved inorganic carbon dynamics in coastal environments.

Buijsman, M.C. and H. Ridderinkhof, 2007. Long-term ferry-ADCP observations of tidal currents in the Marsdiep inlet. J. Sea Res. 57, 237-256

Davis, C. S., S. M. Gallager, M. S. Berman, L. R. Haury, and J. R. Strickler. 1992a. The Video Plankton Recorder (VPR): Design and initial results. Arch. Hydrobiol. Beih. 36: 67-81

Ensign, S.H. and HW. Paerl. 2006. Developing an unattended estuarine nutrient monitoring program using ferries as data-collecting platforms. Limnology and Oceanography Methods 4:70-76

Feeley R. et al., (This Volume) Ocean Acidification Observational Network

Flagg, C. N., M. Dunn, D.-P. Wang, H. T. Rossby, and R. L. Benway (2006), A study of the currents of the outer shelf and upper slope from a decade of shipboard

ADCP observations in the Middle Atlantic Bight, *J. Geophys. Res.*, 111, C06003, doi:10.1029/2005JC003116.

Friis, K. , K., Körtzinger, A., Wallace, D. W.R. (2004). Spectrophotometric pH measurement in the ocean: Requirements, design, and testing of an autonomous charge-coupled device detector system.Limnology and Oceanography Methods 2, 126-136.

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

Griffiths G.1; Diaz J.I. (1996) Comparison of acoustic backscatter measurements from a ship-mounted Acoustic Doppler Current Profiler and an EK500 scientific echo-sounder. ICES Journal of Marine Science, 53, 487-491

Harashima, A. and M. Kunugi, (2000). Comprehensive Report on Marine Environmental Monitoring and Related Studies Using Ferry Boats. CGER-Report, National institute for Environmental Studies, Environmental Agency of Japan, CGER-M007-2000, ISSN 1341-4356

Hydes, D.J. Hartman, M. C., Kaiser, J., Campbell, J.M. (In Press) Measurement of dissolved oxygen using optodes in a FerryBox system Estuarine and Coastal Shelf Research

Kelly-Gerreyn, B.A., Hydes, D.J., Jegou, A.M., Lazure, P., Fernand, L.J., Puillat, I.. Garcia-Soto, C., 2006. Low salinity intrusions in the western English Channel. Continental Shelf Research, 26, 1241-1257

McNeil, C. L., B. D. Johnson, and D. M. Farmer, (1995): In situ measurement of dissolved nitrogen and oxygen in the ocean. Deep-Sea Res., 42A, 819–826

Metfies, K., Tobe, K., Scholin, C., and Medlin, L. K.: 2006 Laboratory and field applications of ribosomal RNA probes to aid the detection and monitoring of harmful algae, in Ecology of Harmful Algae, edited by: Graneli, E., and Turner, J. T., Springer Verlag, Berlin, 311–325, 2006.

OSPAR Commission, 2003. The OSPAR Integrated Report 2003 on the Eutrophication Status of the OSPAR Maritime Area based upon the first application of the Comprehensive Procedure. Includes "baseline/assessment levels used by Contracting Parties and monitoring data (MMC 2003/2/4; OSPAR Publication 2003: ISBN: 1-904426-25-5).

Paerl, H.W., L.M. Valdes, J.E, Adolf, B.M. Peierls and L.W. Harding Jr. 2005. Anthropogenic and climatic influences on the eutrophication of large estuarine ecosystems. Limnology and Oceanography.51: 448-462

Petersen, W., Colijn, F., Hydes, D., Schroeder, F., 2007. FerryBox: From On-line Oceanographic Observations to Environmental Information.EuroGOOS Publication No. 25. EuroGOOS Office, SHMI, 601 76 Norkoepping, Sweden ISBN 978-91097828-4-4

Petersen, W., F. Colijn, J. Elliot, M.J. Howarth, D.J. Hydes, S. Kaitala, H. Kontoyiannis, A. Lavín, I. Lips, K.D. Pfeiffer, R. Proctor, H. Ridderinkhof and K. Sørensen, (2006). European FerryBox Project: From Online Oceanographic Measurements to Environmental Information. In: Dahlin, H. et al. (eds) European Operational Oceanography: Present and Future.

Proceedings of the 4th EuroGOOS Conference, Brest (France); ISBN 92-894-9722-2.

Petersen, W., Wehde, H., Krasemann, H., Colijn, F., Schroeder, F., 2008. FerryBox and MERIS Assessment of coastal and shelf sea ecosystems by combining in situ and remotely sensed data. Estuarine, Coastal and Shelf Science 77, 296-307

Pierrot, D., C. Neill, K. Sullivan, R. Castle, R. Wanninkhof, H. Lüger, T. Johannessen, A. Olsen, R. A. Feely, C. E. Cosca (2009) Deep Sea Research Part II: Topical Studies in Oceanography, Available online 13 December 2008

Reid, P.C. et al., (This Volume) A global Continuous Plankton Recorder programme

Scholin, A., 2009 What are "ecogenomic sensors?" –a review and thoughts for the futureC. Ocean Sci. Discuss., 6, 191–213, 2009 www.ocean-sci-discuss.net/6/191/2009/

Scholin, C. A., Doucette, G. J. and Cembella, A. D.: 2008. Prospects for developing automated systems for in situ detection of harmful algae and their toxins, in Real-Time Coastal Observing Systems for Ecosystem Dynamics and Harmful Algal Blooms, edite by: Babin, M., Roesler, C. S., and Cullen, J. J., UNESCO Publishing, Paris, France.

Scholin, C.A. et al (This Volume) Ecogenomic sensors (Theme 4A)

Schuster, U. et al., (This Volume) A global sea surface carbon observing system: assessment of sea surface CO_2 and air-sea CO_2 fluxes.

Schuster, U., A. J. Watson. A.J., (2007). A variable and decreasing sink for atmospheric CO2 in the North Atlantic, J. Geophys. Res., 112, C11006, doi:10.1029/2006JC003941

Tang, X. Stewart W. K, Vincent, L Huang, H., Marra, M.,. Gallager S M., Davis, C S. 1998 Automatic Plankton Image Recognition, Artificial Intelligence Review 12: 177–199.

Figures

Figure 1. Map of the North West Europeans Shelf showing the routes of FerryBox systems in operation in March 2009.

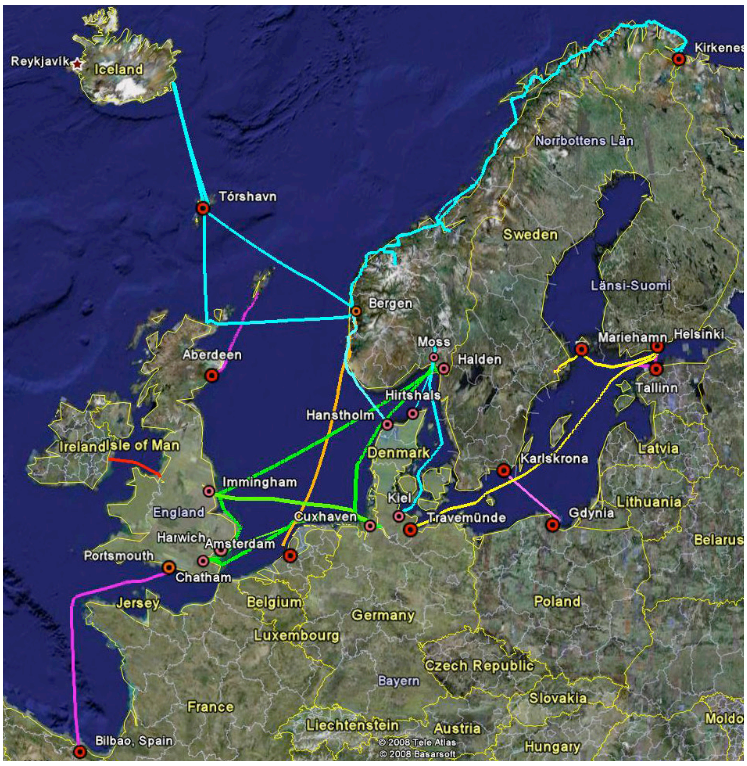

Figure 2. Map of the southern bight of the North Sea indicating the disposition of the range of data collection platforms used by the COSYNA project