EU-Project

FERRYBOX

From On-line Oceanographic Observations to Environmental Information

2003 - 2005

Summary and Selected Results

Contract number: EVK2-2002-00144
Coordination: GKSS Research Centre

Objectives of the Project

The overall objective of FerryBox has been to show that ship born instrumentation can cost effectively deliver information of immediate scientific value and help to solve environmental problems, and that FerryBox systems provide a reliable instrument for efficient monitoring and management in European waters. The FerryBox systems consist of a fully automated flow-through system with sensors and automatic analysers for the measurement of physical, biological and chemical parameters, which uses ferryboats and other ships of opportunity as the carrier system. The data can be assimilated into prognostic numerical models to improve their accuracy. Finally, it can be concluded that such FerryBox systems offer potentials for a wider European contribution to GOOS, with incorporation of European sensor and information technology.

Benefits of the Project

The benefits of the project are:

- Understanding the seasonal changes in the most important water quality parameters
- Improving our knowledge on the natural ranges in parameters and in ranges impacted by human activities
- Providing baseline data for the assessment of long-term trends in coastal and marine waters
- Providing data sources for operational & ecological models on water transport & environmental parameters
- Delivering a large set of calibrated and quality assured ground truth data for remote sensing applications (e.g. for the ENVISAT).

Conclusions

The project has proven and demonstrated that:

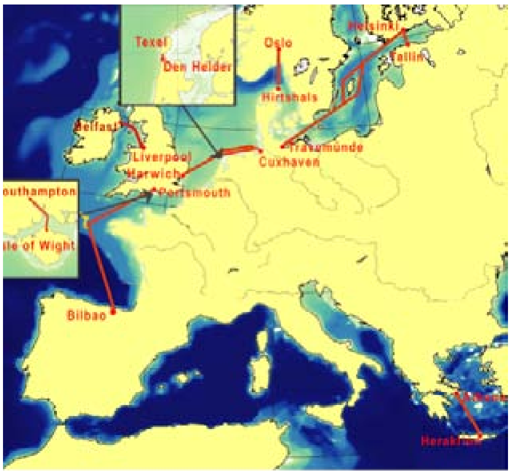
- Ferrybox systems provide a reliable network for efficient monitoring and management
- Ferrybox data are useful and beneficial for a variety of marine research and operational oceanography objectives and can contribute to improve (operational) numerical model and forecasting applications including their accuracy and prediction quality by assimilating field data with higher spatial and temporal observation density.
- Ferrybox systems offer large potentials for a wider European contribution to the GOOS
- European Ferrybox technologies and sensors as well as related scientific, operational, observational and operational methodologies are at the leading edge in this area.

New Developments

During the last GOOS Steering Committee (GSSC) meeting in Paris (6-8. March 2006) the FerryBox concept has been adopted as a Pilot project for the Coastal Implementation of GOOS (Global Ocean Observation System). This will give aditional recognition of the FerryBox concept on a global scale.

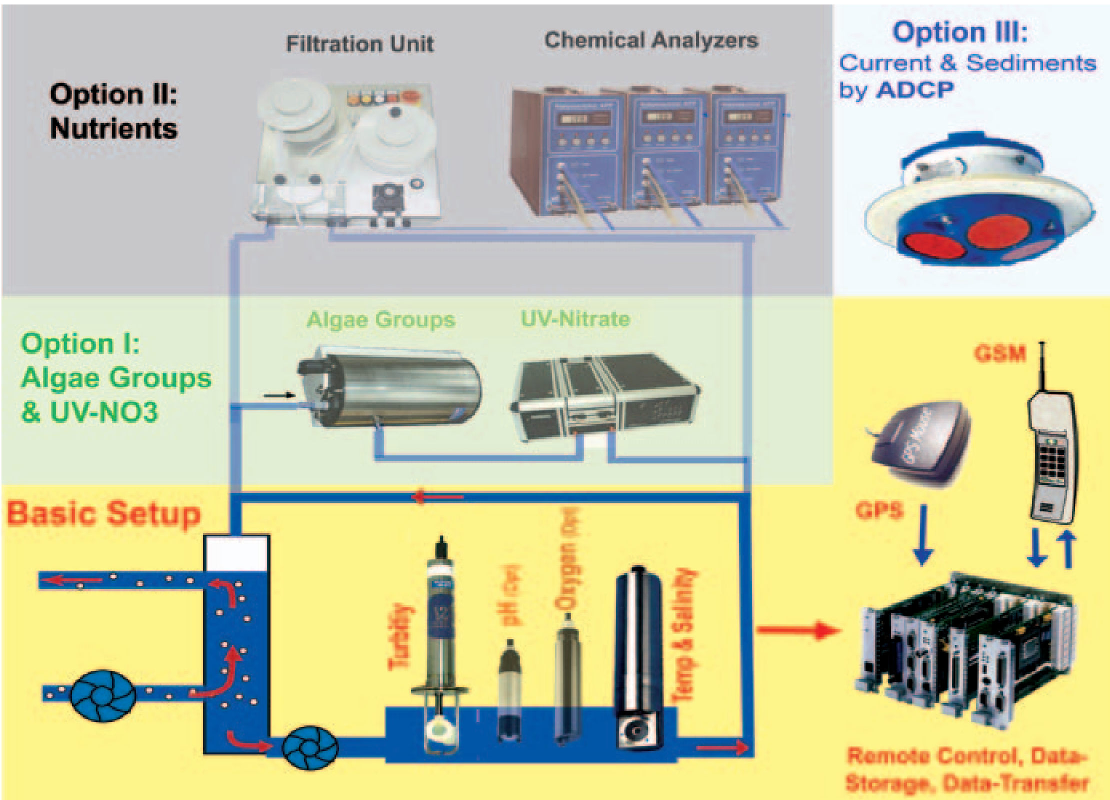
The Ferry Routes within the Project

Baltic Sea:	Helsinki (FI) – Travemünde (D)
	and Helsinki (FI) – Tallinn (EE)
Skagerrak:	Oslo (NO) – Hirtshals (DK)
North Sea:	Cuxhaven (DE) – Harwich (UK)
Wadden Sea:	Den Helder – Texel Island (NL)
Irish Sea:	Liverpool (UK) – Belfast (Ireland)
English Channel	Southampton – Isle of Wight (UK)
Bay of Biscay :	Portsmouth (UK) – Bilbao (ES)
Aegean Sea:	Athens – Heraklion (GR)



Ferries used in the Project

The Principle



The principle of a FerryBox consists of a flow-through system with different sensors for oceanographic, chemical and biological parameters. It is fully automated and some systems provide automated cleaning and antifouling procedures. The data are stored on the ferry and may be transferred to shore by mobile phone or satellite telemetr.

Project Achievements

The project successfully operated a standard set of sensors (temperature, salinity, turbidity, chlorophyll-fluorescence) on 9 different routes in the Baltic Sea, the North Sea, the Channel, the Irish Sea, the Bay of Biscay and the Aegean Sea (Mediterranean). The majority of the systems were highly reliable with over 90 % of all possible data being recorded and meeting quality control criteria
The following scientific achievements were reached:

- Impact of frontal systems on the biological activity
- Change of the physiological state of phytoplankton prior, during and after a bloom
- Magnitude and variations in sediment transport in a tidal inlet
- Assessment of inter- and intra-annual variability in concentrations of nutrients and plankton species
- Comparisons of the FerryBox data to satellite based data sets
- Assimilation of FerryBox data into numerical models.

The strategy developed using FerryBoxes successfully demonstrated that a cost effective monitoring system is available for operational services and that an effective linkage with data buoy observations and remote sensing methods with FerryBox systems exists.
The acceptance of the system is well documented before the finalization of the project through installation of further systems on board of other Ferries and vessels of operational services in Norway and the Netherlands.

Recommendations

Authorities, agencies or scientific institutions that consider a potential future implementation of a ferry system in their research/monitoring should consider the following recommendations:

1. In the planning phase a careful assessment should be carried out to judge if the ferry/ship route meets the objectives of the monitoring or research tasks. For example: Will surface measurements from a ship yield enough information to reach the objective or has a combination with buoys to be considered?
2. In order to choose the appropriate FerryBox system for the planned task, helpful hints can be obtained from the Final Report of the project (www.ferrybox.org).
3. The type of instrumentation, i.e., sensors or analysers, their applicability and their limitations for the intended task and the meaningfulness of the scientific results obtained with these instruments should be assessed in advance. More details can be found in the deliverables of the Final Report.
4. The effort/expenditure of the maintenance that depends on the number and type of measured parameters should be carefully observed. More details can be found in deliverable D-6-2 “Cost-Benefit Estimation Report”.
5. Even when a FerryBox system is highly automated, the potential user should keep in mind that regular (1-2 days) data checks and regular maintenance/calibrations (weekly to bimonthly, depending on instrumentation and required accuracy) are needed.

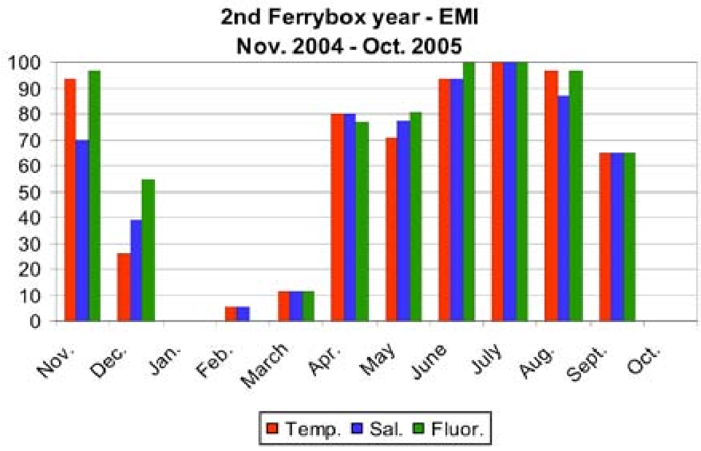
Technical and Operational Benefits

- Compared to offshore deployed devices the operation costs of Ferrybox systems are drastically lower as maintenance works can be conducted in one of the ports the vessel is calling routinely which, however, should be located preferably nearby to the operating institution.
- Ferrybox systems and their sensors and components are much easier and simpler to design, construct and operate than stand-alone marine in-situ devices.
- Ferrybox systems do not need a specially designed platform and can be installed on almost all seagoing vessels providing their owners and operators allow it. Installation costs and efforts are relatively low as available infrastructure on the ship like space, water supplies, cable booms, and communication devices can be used supportively.
- Many technical problems typical for stand-alone marine measuring systems can be entirely omitted. This includes especially constraints in availability of electric energy, installation and consumable storage space as well as protection of several components against harsh marine environments and prevention measures of longer-term fouling with associated maintenance efforts.

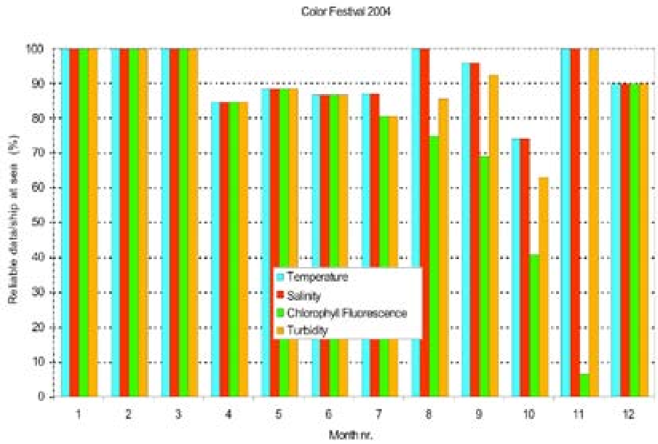
Estimated Costs

FerryBox Basic System (EUR)			
Standard FerryBox	CTG	4H Jena	Includes remote control and data storage computer, GPS system, basic sensor set (temperature, salinity, turbidity, chlorophyll-a fluorescence), Software
	67,000	37,000-43,000	
Shore-based station	n.a.	6,500	Database and presentation system on PC
Installation onboard (pumps, tubes, plumbing etc.)	4,000 – 12,000		depending on ship and configuration of the FB (standard or enhanced)
For the 4H Jena system an automatic antifouling unit is included			
Additional Sensors/Analysers (appr. EUR)			
Oxygen-Optode & pH	4,000		
UV- nitrate Detector	15,000		UV detection (only for nitrate)
Filtration unit	1,500		For wet chemical analysis of nutrients
Nutrients (single channel)	22,000		Wet chemical analysers
Nutrients (double channel)	25,000		
Algal groups	19,000		Excitation at different wavelengths to discriminate between different algal groups (pigments)
ADCP	36,000		
pCO_2 Measuring System	60,000 – 70,000		
Operation Cost (EUR per year)			
Consumables and spare parts	3,000 – 12,000		
Communication fees	600 – 2,400		Depending on data volume
Reference analysis (water samples)	500 – 4,000		Laboratory analysis of salinity, chlorophyll and nutrients
Maintenance of sensors (CTD, fluorescence)	1,000 – 2,000		Yearly check and recalibration by the manufacturer
Operation Cost (person months per year)			
Operation, maintenance and supervision (basic system)	3 - 6		Standard system
Additional sensors (e.g. nutrients)	3 - 10		Depending on system complexity
Data dissemination including Internet services	1 - 6		Depending on the complexity of internet services

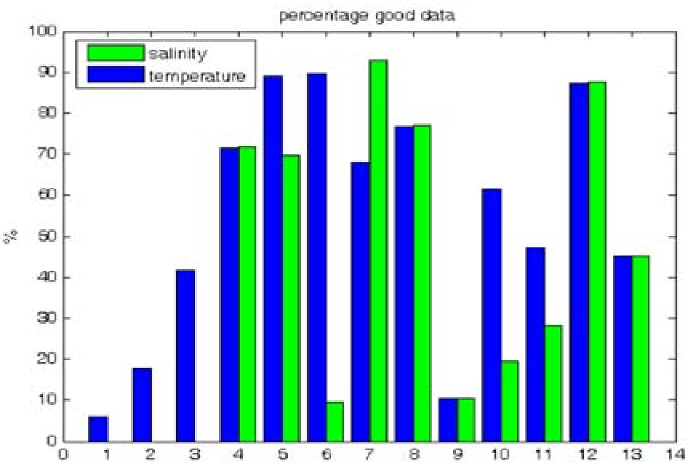
Data Availability for Temperature/Salinity for November 2004 to October 2005



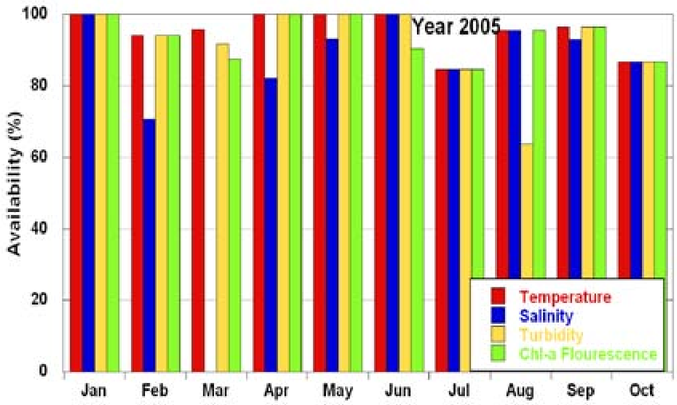
Data Availability on the Route Tallin-Helsinki (EMI&FIMR)



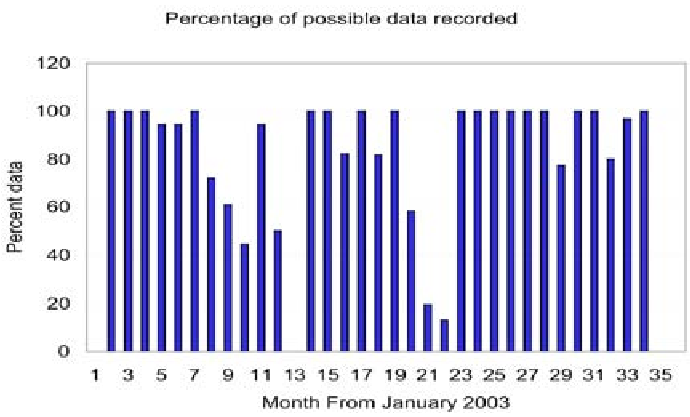
Data Availability on the Route Hirthhals-Oslo (NIVA)



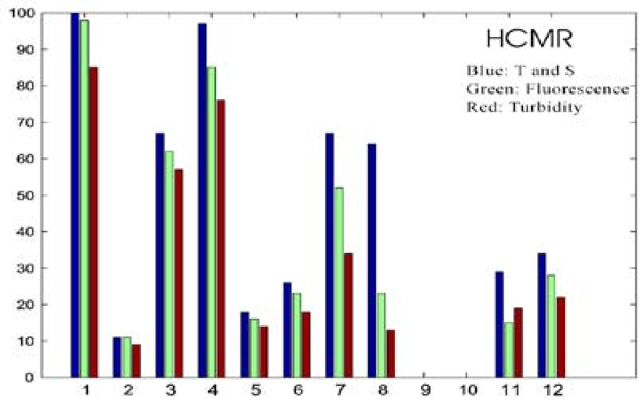
Data Availability on the Route Den Helder-Texel (NIOZ)



Data Availability on the Route Cuxhaven-Harwich (GKSS)



Data Availability on the Route Southampton-Bilbao (NOC)



Data Availability on the Route Athens-Heraklion (HCMR)

Conclusion: The experiences of the consortium after two years of operating the different FerryBoxes show that after solving some start-up problems most of the FerryBox systems were running very well producing high rate of reliable data. The availability of reliable data related on the number of cruises was between 50 and 100%. The data availability depends on the type of sensor or analyser. For example, nutrient analysers are more complex and prone to failure than more simple sensors as temperature, salinity and chlorophyll. Automated cleaning procedures enhance the data availability.

Technical Details of the Different FerryBox systems

Route no.:	R-1-A Operator:	FIMR
Description		**Remarks**
Route:	Helsinki (Finland) – Travemünde (Germany)	
Ship:	MS Finnpartner	
Ferry company:	Finnlines, Finland	
System type:	Flow through system	
Frequency:	Flow though data three times per week,, Automated sampling for phytoplankton, clorophyll-a and nutrients once per week from April to September.	
Travel time:	36 hours	
Control:	Once per week	
Features:	Brackish water salinity about 5 – 7 psu	
Measured parameters:	Conductivity, water temperature, fluorescence; automated samples for nutrients, chlorophyll-a, phytoplankton	
Spatial resolution:	Flow through system: salinity, temperature and fluorescence every 200 m Water sampling for laboratory analysis at fixed latitudes	
Remote control:	No	
Data transfer:	Diskette	
Data storage:	Every 20 s outside harbour area	
Depth of water intake:	5 m	
Web site:	http://www2.fimr.fi/en/itamerikanta.html	

Route no.:	R-1-B Operators:	FIMR and EMI
Description		**Remarks**
Route:	Helsinki (Finland) – Tallinn (Estonia)	
Ship:	M/S Romantika	
Ferry company:	Tallinx, Estonia	
System type:	Flow through system	
Frequency:	Flow through data twice per day. Automated sampling for phytoplankton, clorophyll-a and nutrients once per week.	
Travel time:	3.5 hours	
Control:	Once per week	
Features:	Brackish water salinity about 5 psu	
Measured parameters:	Conductivity, water temperature, fluorescence; automated samples for nutrients, chlorophyll-a and phytoplankton	
Spatial resolution:	Flow through system: salinity, temperature and fluorescence approximately every 200 metres Water sampling for subsequent laboratory analysis at fixed latitudes	
Remote control:	No	
Data transfer:	Diskette	
Data storage:	Every 20 s outside harbour area	
Depth of water intake:	4 m	
Web site:	http://www.fimr.fi/en/itamerikanta.html	

Route no.:	R-2 Operators:	NIVA
Description		**Remarks**
Route:	Oslo (Norway) – Hirtshals (Denmark)	Operation from August 2001. New harbour in Denmark in April 2006.
Ship:	Color Festival	
Ferry company:	Color Line	
System type:	Flow through system. Design of NIVA.	
Frequency:	1 round trip per day	
Travel time:	Night time 12 hours, day time 6 hours	
Control:	The system is controlled with a LabView software.	
Features:	Automatic or remotely controlled water sampling and above water radiance measurements for satellite validation.	Water samples triggered during satellite overpass.
Measured parameters:	Conductivity, water temperature, turbidity, Chl-a fluorescence, light sensors. Samples collected for Chl-a with HPLC and TSM measurements	
Spatial resolution:	Every 400 to 800 m depending on night or day measurements 1 observation per minute.	
Remote control:	Via satellite link	
Data transfer:	Continuous over satellite link to NIVA database	
Data storage:	Onboard and database at NIVA	
Depth of water intake:	3-4 meters	
Web site:	http://www.ferrybox.no	Public presentation of the data

Route no.:	R-3 Operator:	GKSS
Description		**Remarks**
Route:	Cuxhaven (Germany) – Harwich (United Kingdom)	Reconstructed system in operation on new ferry boat since September 2003.
Ship:	Duchess of Scandinavia	
Ferry company:	DFDS Seaways	
System type:	Flow through system	
Frequency:	1 round trip every 2 days	
Travel time:		
Control:	Supervised by an industrial programmable logic control	
Features:	Automatic cleaning procedure by acidified tap water after each trip in the harbour	
Measured parameters:	Conductivity, water temperature, turbidity, dissolved oxygen, fluorescence, ammonium, nitrate/nitrite, phosphate, silicate, different algae groups	
Resolution:	Approximately 100 m – every 10 s; nutrients approximately 6 km – every 10 minutes	
Remote control:	System can be remotely controlled by GSM	
Data transfer:	Controlled by an industrial standard PC	
Data storage:	Controlled by an industrial standard PC	
Depth of water intake:	5 m	
Web site:	http://coast.gkss.de/projects/ferrybox	

Route no.:	R-4 Operator:	NIOZ
Description		**Remarks**
Route:	Den Helder – Texel (the Netherlands)	Upgraded system in operation since 2003. Display in passenger lounge.
Ship:	Schulpengat	
Ferry company:	TESO (Texels Eigen Stoomboot Onderneming)	
System type:	Flow through system and hull mounted acoustic current profiling system (ADCP)	
Frequency:	Every 30 minutes, daily between 06.00 and 22.00 local time	
Travel time:		
Control:	External logging and display on ferry	
Features:		
Measured parameters:	Salinity, water temperature, fluorescence, turbidity horizontal current speed and direction	Optical measurements (fluorescence, turbidity) are suspect due to air bubbles in the system
Resolution:	5 – 10 m	
Remote control:	By telemetry	
Data transfer:	Transferred to the nearby research centre by telemetry	
Data storage:	At the nearby research centre	
Depth of water intake:	0.50 m	
Web site:	http://www.nioz.nl/en/deps/fys/niozteso/enhtml	

Route no.:	R-5 Operator:	NERC.POL
Description		**Remarks**
Route:	Liverpool (UK) – Belfast (Northern Ireland)	
Ship:	Liverpool Viking	
Ferry company:	Norse Merchant	
System type:	Flow through system	
Frequency:		
Travel time:		
Control:	External logging	
Features:		
Measured parameters:	Conductivity, water temperature, turbidity, fluorescence	
Resolution:	Approximately 300 m (sampling frequency 30 s)	
Remote control:	None	
Data transfer:	External logging, plus data telemetry of spot values via OrbComm satellite every 15 minutes - started 18 October 2004.	
Data storage:	Files, final data banked at BODC	
Depth of water intake:	3.5 m	
Web site:	http://coastobs.pol.ac.uk	

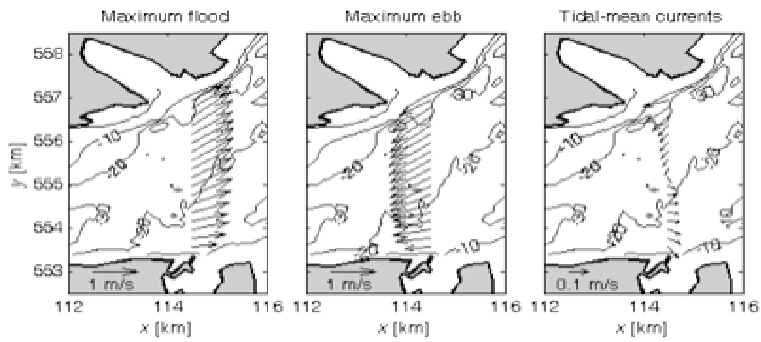
Route no.: R-7	Operator:	NERC.NOC and IEO
Description		**Remarks**
Route:	Portsmouth (UK) – Bilbao (Spain)	FerryBox system fully operational since April 2002. New logger fitted October 2004. System expanded in 2005
Ship:	Pride of Bilbao	
Ferry company:	P & O Ferries Ltd.	
System type:	Flow through system in parallel to ship's refrigerator cooling water. Continuous flow with manual shut off.	
Frequency:	In 2002 - 2004 1 round trip per week – February to mid March, 2 round trips per week – mid March to early January In 2005 shuttle service from late January to new year 2006	
Travel time:	About 33 hours per crossing, 72 hours per round trip	
Control:	Data management: PC with UNIX from 2004 DOS	
Features:	Modular system, extendable for other chemical sensors/analysers; anti-fouling prevention by weekly manual inspection and cleaning.	
Measured parameters:	Conductivity, water temperature, turbidity, fluorescence. From 2005 oxygen, pCO2	
Resolution:	At full speed (20 knots) data rate is 1 Hz giving a spatial resolution of approximately 10 metres. Data are mapped with 5 minute (time) resolution.	Comparison with ISAR hull temperature suggest mixing in the sea chest smooths data.
Remote control:		
Data transfer:	OrbComm satellite link and e-mail. At 5 minute interval data sample sent to web page. Weekly manual collection of 1Hz data	Public access to un-calibrated 5 minute averages via web page.
Data storage:	Combined file of all data channels including GPS collected in engine room and backed up to the ISAR system computer on bridge SQL data base at NERC.SOC for web access. 1 Hz data stored at NOC. 5 minute averaged data sent to BODC as individual parameter files	
Depth of water intake:	5 m	
Web site:	http://www.noc.soton.ac.uk/ops/ferrybox_index.php	

Route no.:	R-8 Operator:	HCMR (formerly NCMR)
Description		**Remarks**
Route:	Athens – Heraklion (Greece)	FerryBox system operational with data gaps during November/2003-to-October/2004 FerryBox system not in operation after October/2004 because 1) of technical problems and 2) the ship was moved to another route in the Ionial Sea. Operation is expected to recommence in early 2005 independently of ferry route and after repairmen/improvement by the manufacturer.
Ship:	KRITI II	
Ferry company:	Anek Lines	
System type:	Flow through system	
Frequency:	1 trip every night in alternating directions	
Travel time:	9 hours	
Control:	Supervised by an industrial programmable logic control	
Features:	Automatic cleaning procedure (by acidified water) in the harbour after each trip.	
Measured parameters:	Conductivity, water temperature, turbidity, fluorescence	
Resolution:	Raw measurements every 1 s - approx. every 10 m; stored averages every 60 sec – approx. every 600 m	
Remote control:	Limited remote access on the various settings via GSM when sailing in GSM covered areas.	
Data transfer:	Cell phone data telemetry via industrial standard PC	
Data storage:	On board and on the land station controlled by industrial standard PC	
Depth of water intake:	Approximately 5 m	
Web site:	http://www.poseidon.ncmr.gr/ferrybox	

Example I: Water and Sediment Transport in the Mars Diep (NIOZ)

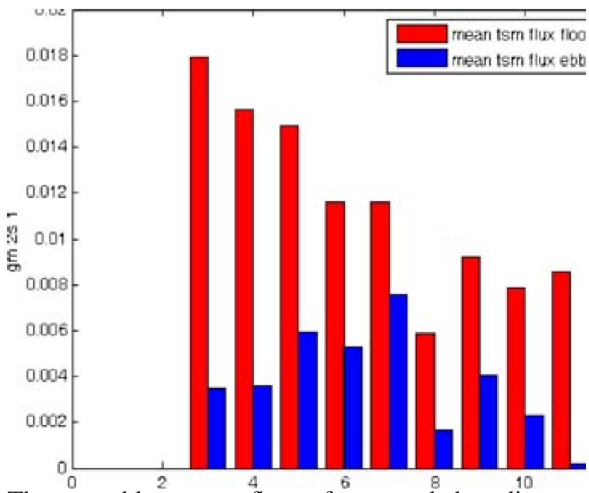
Ferry Route Texel to Den Helder

The ferry from Texel to den Helder across the Marsdiep tidal inlet is equipped with a vessel-mounted acoustic Doppler current profiler (ADCP).



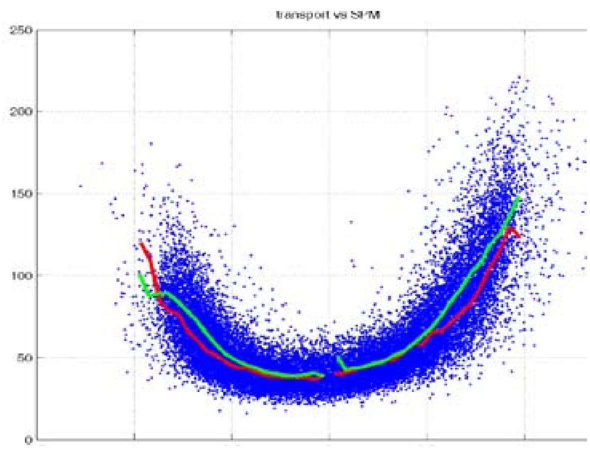
Typical examples of the depth-averaged tidal and mean currents in the Marsdiep inlet

Tidal currents flow east/west through the inlet and reach maximum values of around 1.5 m/s, with strongest currents in the deepest central part of the inlet. The strength of the tidal mean current is about 10% of the time-varying tidal currents and is asymmetric with large spatial variability over the relatively short distance of the inlet (about 4 km). At the northern site of the inlet the mean currents are westward (towards the adjacent North Sea), at the southern site the currents are eastward.
The observations of currents and backscatter from the ADCP are used to obtain insight in the current field and suspended sediment concentration (SSC) 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 very suitable for such studies.
The figure on the right shows the monthly mean absolute value of the flux of suspended sediments through the Marsdiep tidal inlet for 2003, divided between flood and ebb periods. The difference between both indicates the net flux. There appears to be a relatively large net flux of suspended sediments towards the Waddensea. Moreover, this flux is substantially larger during spring and early summer, as compared to the other periods suggesting that biological processes play an important role in influencing the magnitude of this net flux (Ridderinkhof & Merckelbach, 2006).



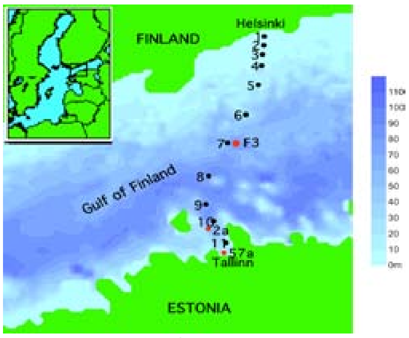
The monthly mean flux of suspended sediments through the Marsdiep tidal inlet

From many velocity measurements the averaged volume flow through the Marsdiep channel can be calculated. In combination with measured suspended sediment concentrations the dependency of suspended matter from the volume flow can be derived. Fig. 46 shows the transect-averaged suspended sediment concentration (SSC) (vertical axis) as a function of the water volume transport for measurements during a period of one year. Red lines show the mean SSC during the accelerating phase of the tide, green lines during the decelerating phase. A characteristic phase lag in the response SSC to an increase in the current speed can be recognized. Moreover it is clear that the SSC is larger during flood tide (positive volume transport) than during ebb tide. This causes a net flux of suspended sediments into the Wadden Sea.

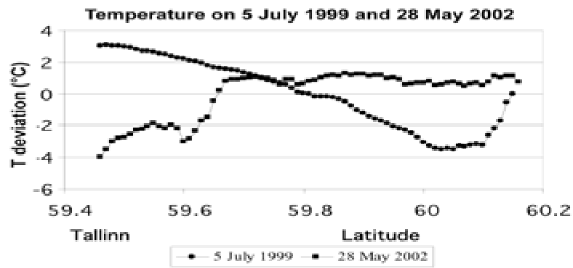


Transect-averaged suspended sediment concentrations as function of the water volume transport.
Red: Accelerating tidal phase,
Green: Decelerating tidal phase

Example II: Upwelling in the Gulf of Finland (EMI)



The ferry route

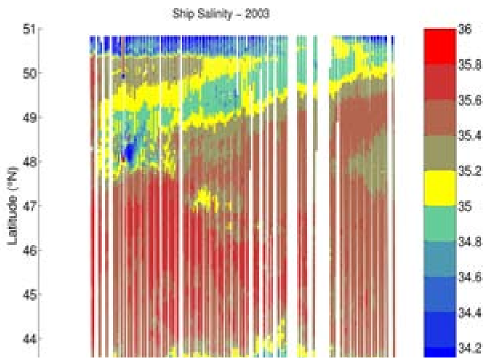


Temperature deviations along the ferry line Tallinn-Helsinki showing upwelling events near the southern (28 May 2002) and northern (5 July 1999) coasts of the Gulf of Finland developing after 5 days of easterly or westerly winds, respectively.

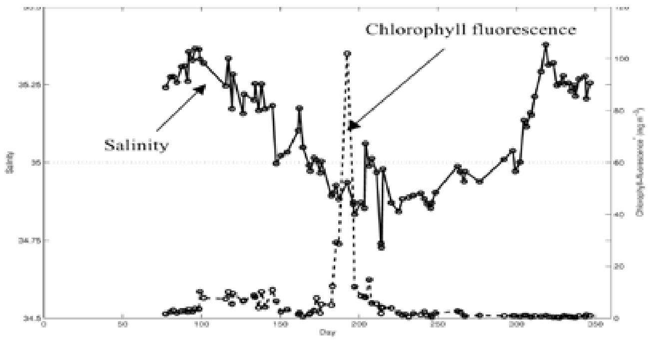
In the Gulf of Finland the seasonal thermocline is usually situated at the depth of 10-20 m. The phosphacline is located in the upper part of the thermocline and the nitracline is about 5 m deeper (Laanemets et al., 2004). Thus, the upwelling events and wind induced mixing favour enrichment of the near-surface layer mainly with phosphate. Cold upwelled water appears very close to the shoreline near the southern (Estonian) coast where the slope is steeper while it stays offshore from the Finnish coast.
Since nutrient concentrations are not measured in a routine basis on the ferry route the nutrient input into the near-surface layer caused by the upwelling events could be estimated on the basis of unattended temperature measurements. One can make a rough assumption that the phosphate input from below the thermocline is proportional to the temperature difference between upwelled water and the surrounding water. An upwelling index is introduced and calculated as a mean temperature deviation in a 20-km wide coastal zone from the cross-gulf average temperature for every day. Operational estimates of intensities of pre-bloom upwelling events are used to forecast the late summer cyanobacterial blooms in the Gulf of Finland (Laanemets et al., 2006). Analysis of Ferrybox data from 1997-2004 revealed a good correlation between the seasonally integrated intensities of upwelling events (from 1 May until 30 June) and the integrated cyanobacterial bloom biomasses (Lips, 2005).

Example III: The origin of Low salinity intrusions in the western English Channel and its Consequences for a Plankton Bloom(NOC)

The ferry route



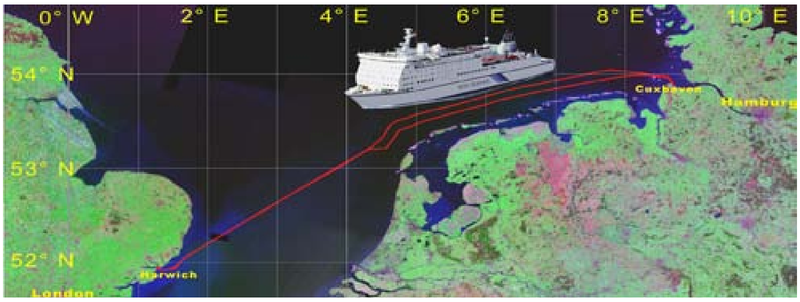
Sea surface salinity between Portsmouth and Bilbao in 2003 showing low salinity waters entering the western English Channel (~48°N)

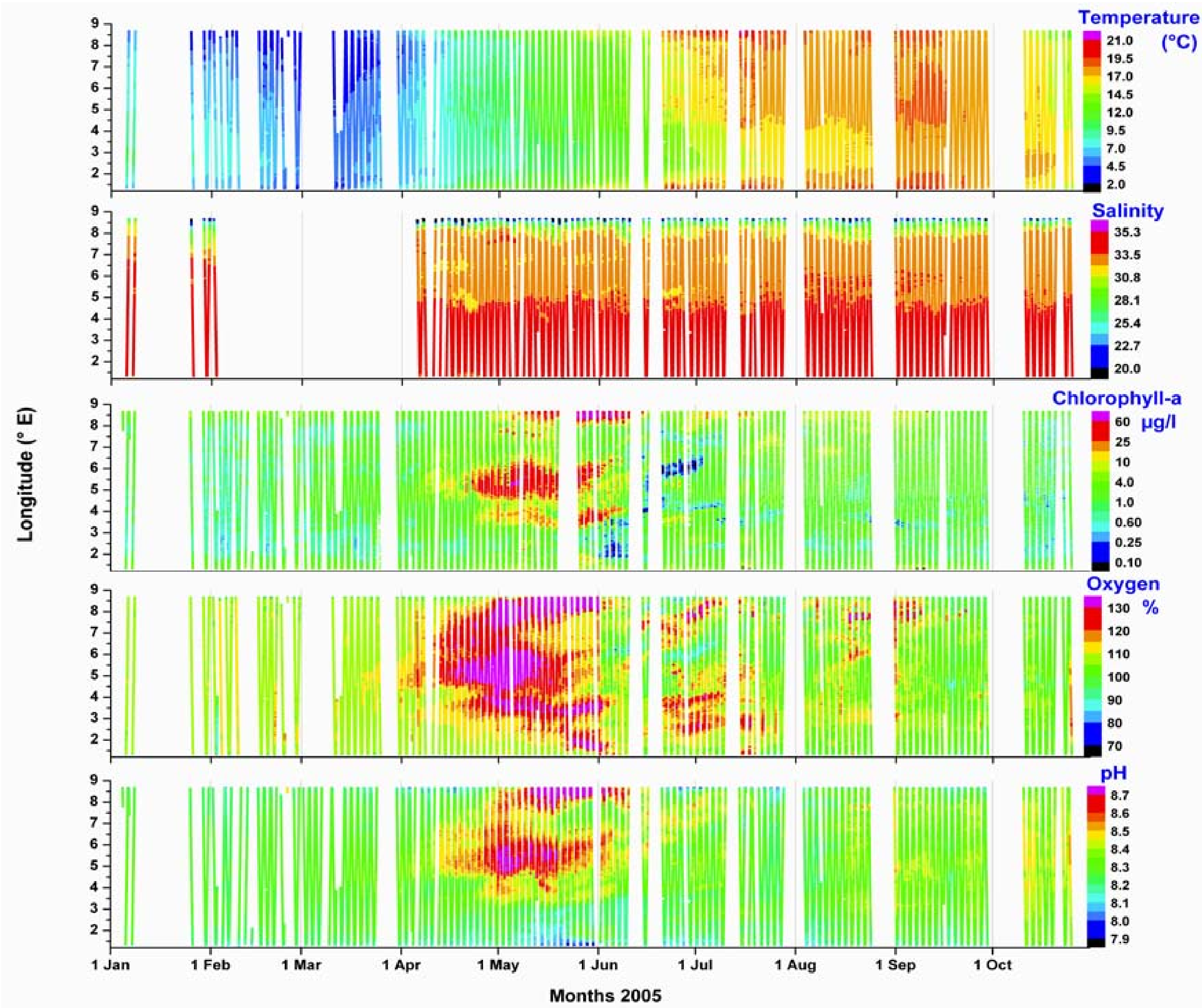


Timeseries data of chlorophyll-fluorescence and salinity showing the coincidence in the timing of the bloom in Karenia mikimotoi and the arrival of low salinity water in the western English Channel (49.1°N, 4.1°W)

During FerryBox measurements low salinity (<35) surface waters (LSSW) at the southern entrance to the western English Channel (48.5°N, 5.1°W, near Ushant) were observed in late winter (March-April) in three successive years (2002 - 2004). The LSSW intruded into the western English Channel in each year, suggesting a common phenomenon. The source of the LSSW is the northward spreading plumes from the Loire and Gironde along the French Atlantic coast (Kelly-Gerreyn et al. 2006).
Within 2 days of the arrival of the LSSW an intense monospecific bloom (~100 mg Chl a m-3) of the dinoflagellate Karenia mikimotoi was observed. It is proposed that changes in surface density due to these low salinity intrusions influences the summer bloom intensity of K. mikimotoi. The hypothesis is that the low salinity intrusions enhance blooms of K. mikimotoi through increased buoyancy of the upper water column and thereby influence the observed interannual variability in the abundance of this phytoplankter in the western English Channel.

Example IV: Algae Bloom in the Southern North Sea (GKSS)



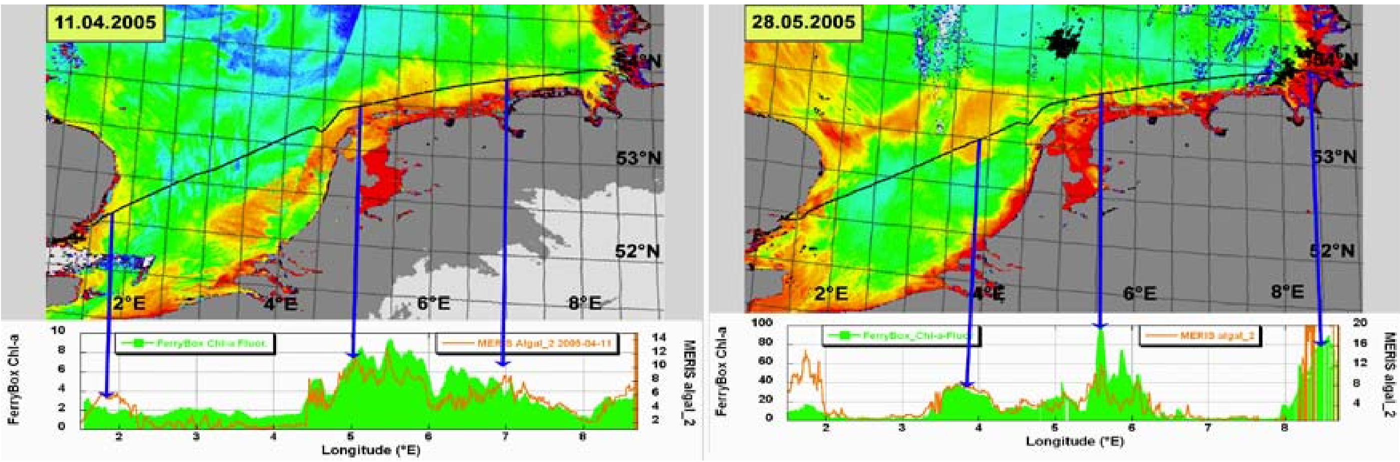


Temporal development of temperature, salinity, chlorophyll, oxygen and pH along the ferry transect in 2005 (GKSS)

The plankton blooms in the Southern North Sea always start in spring near the Belgium coast. With regular FerryBox measurements this phenomena can be more closely resolved in time and space and the extent of the primary production can be estimated.
From the diagrams above the typical spring bloom in April-May can be seen not only from the chlorophyll but as well from oxygen and pH. The high productivity is evident from oxygen oversaturation of more than 130% and high pH values of >8.6. Only with such (temporal) high resolution measurements by means of a FerryBox this information about algal processes can be obtained.

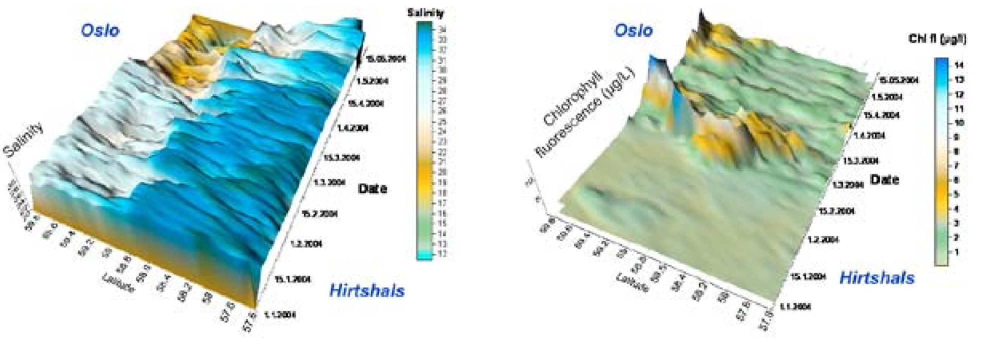
Example V: Comparison of FerryBox data with data from remote sensing (GKSS)

Another application of a FerryBox is the comparison with satellite data: 1) FerryBox measurements can be used for validation/calibration of satellite data for suspended matter and chlorophyll. 2) Satellite data expand the view of the FerryBox (which is limited to the transect) to the area. Whereas the algorithms for class-1 water (open ocean with only little turbidity and yellow substance) are well accepted, improvements are needed for turbid class-2 waters near the coast. For this FerryBox measurments are an excellent tool.



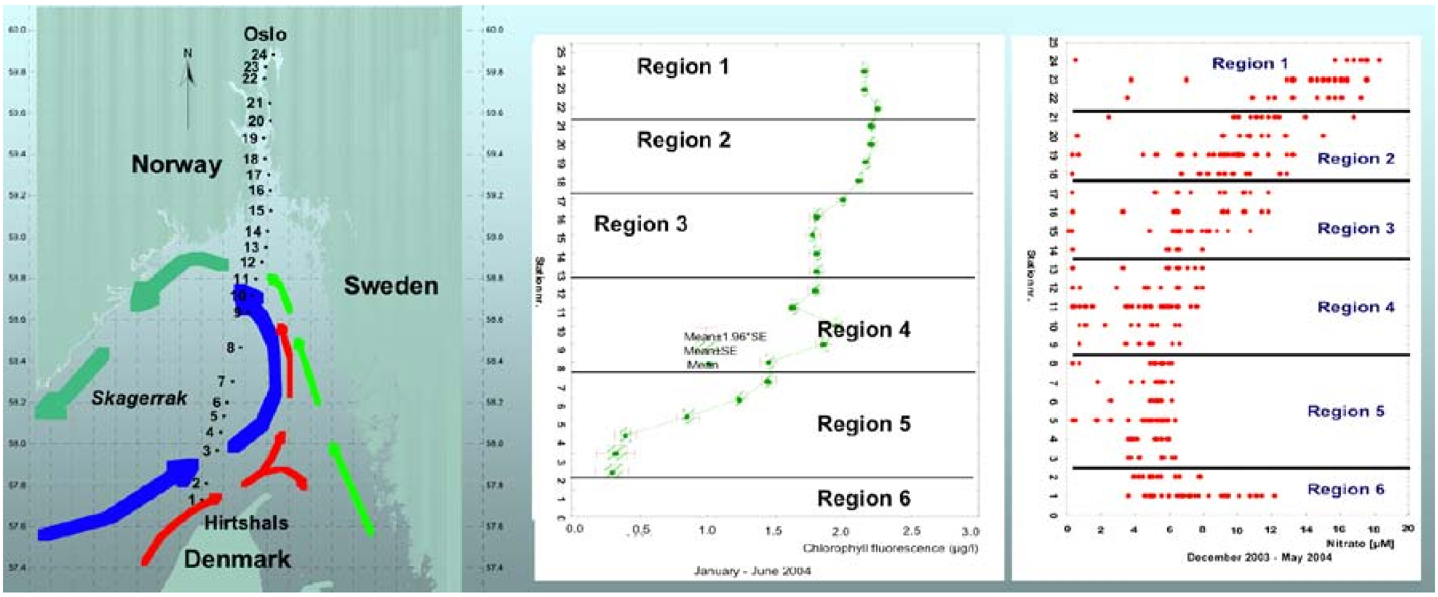
Chlorophyll concentration map of May 11th and June 28th from ENVISAT/MERIS (top). The diagrams below show a comparison of pixels extracted along the FerryBox transect and data measured by the FerryBox. Due to the time shift between the ferry cruise and the satellite pass a correction of the water movement by a numerical model has been applied (model calculation by the BSH).

Example VI: Classification of Water Masses (NIVA)



Development of salinity and Chlorophyll between Oslo and Hirtshals in spring 2004 (left).
The development of the spring bloom in the Oslo Fjord can clearly be seen.

Classification of water bodies into 6 regions according to the chlorophyll- and nitrate concentrations (below). For a more detailed classification other winter nutrients are included in the classification scheme.



FerryBox measurements are a useful tool for routine water quality monitoring. The frequent data can be utilised to define regions which meet specific water quality criteria.

The project achieved its objectives very effectively with operating and comparing different European FerryBox systems. The generated data are available from the website and from the British Oceanographic Data Centre (BODC). The series of scientific studies, numerical model experiments, data assimilation and validation exercises of satellite-borne remote sensing data have all achieved results which have or are being written up in peer reviewed scientific papers. Its success is shown in the large number of follow-on and associated activities that are happening or planned, as well as by increasing utilisation of FerryBox systems by other groups.
Overall the project has demonstrated that the FerryBox concept is one which both provides data of scientific value and that can be expected to make a cost effective contribution to future European (and global) operational marine monitoring and management systems.

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Further Information

Download of the Final Report and Deliverables at:
http://www.ferrybox.org

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