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

Report on the Experiences with the Ferrybox Systems during Operational Use

Contract number : EVK2-2002-00144

Deliverable number : D-2-3

Revision : 2.0.

Co-ordinator:

Professor Dr. Franciscus Colijn

GKSS Research Centre
Institute for Coastal Research
Max-Planck-Strasse
D-21502 Geesthacht

http://www.ferrybox.org

Preface

This report is an update of the previously delivered revisions on operation experiences with the Ferry-boxes involved in the European FerryBox Project. Revision 2.0 was finally edited for publication on the FerryBox Report CD and website.

Editor: This report was finally edited and compiled by the leader of work package 2, W. Petersen (GKSS). Final editing for revision 2.0 by FerryBox WP-6 (Klaus D. Pfeiffer).

Contributors: All operators of Ferrybox systems involved in the project respectively contributing to the project's work package 2 provided input and information for this report.

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.:	D-2-3		Revision:	2.0.	
WP number and title:	WP-2	Operation and metrology of the FerryBox Systems			
Work Package Manager:	Wilhelm Petersen, GKSS				
Work Package Team:	FerryBox Work Package 2 Team				
Title of deliverable:	Report on the Experiences with the Ferrybox Systems during Operational Use				
Category of deliverable:	System description				
Classification:	PU – Public				
Contents of deliverable:	Report on the Experiences with the Ferrybox systems during two years of operational use.				
Pages (total):	96	Figures:	77	Tables:	6
Remarks:	This version replaces the previously delivered revision of this report entirely. Revision 2.0 was edited for publication on the FerryBox CD and website.				
Editor:	Wilhelm Petersen	Leader work package 2	GKSS		
Main Author:	Wilhelm Petersen	Leader work package 2	GKSS		
Contributors:	FerryBox Work Package 2 Team				
FerryBox main contact:	FerryBox project co-ordinator:		Alternate contact for this report::		
GKSS Research Centre Institute for Coastal Research Max-Planck-Strasse D-21502 Geesthacht, Germany	Prof. Dr. Franciscus Colijn Tel.: +49 4152 87 – 1533 Fax.: +49 4152 87 – 2020 E-mail: franciscus.colijn@gkss.de		Dr. Wilhelm Petersen Tel.: +49 4152 87 – 2358 Fax: +49 4152 87 – 2366 E-mail: wilhelm.petersen@gkss.de		
Project web site :	http://www.ferrybox.org				

Table of Contents

List of Figures

List of Tables

1 Objectives

The First FerryBox Year (all 9 FerryBox lines should be in operation) started in November 2003. Whilst some of the Ferryboxes were already in operation or came in operation soon after start of the EU project totally new systems had to be installed in the Irish Sea (Birkenhead to Belfast) and in the Mediterranean Sea (Athens to Crete). Other systems had to be completed for the four standard sensors (temperature, salinity, turbidity and chlorophyll fluorescence). All Ferrybox systems reached an operational status until January 2004.

In this report the experiences of the different partners with their specific Ferrybox system are documented after finishing the First FerryBox Year. The partners were asked to describe shortly their route and their system and to show the measured data as coloured dot plots as well as the monthly availability of reliable data on their route. Furthermore the specific requirements and experiences at the different areas should be noted. On the following pages the reports of the partners on the different routes are documented.

For improving the comparability of data between the different ferry lines an inter-comparison test has been carried out in order to validate the turbidity measurements. The Norwegian partner NIVA prepared a stock solution of a Formazine standard which has been used to check the sensors at NIVA, FIMR, EMI and SOC. The long-term stability of the stock solution has been tested on different temperatures.

2 Route 1a – Baltic Sea (FIMR)

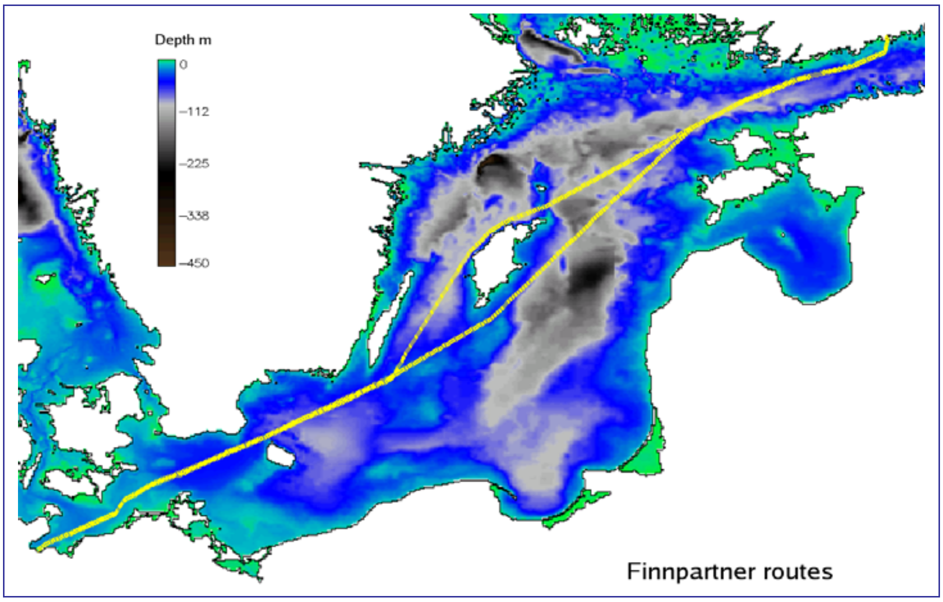


Figure 2-1: Map of the ferry route Helsinki -Travemünde.

2.1 System Description

In the Finnish Institute of Marine Research the field data for the year 2004-2005 was observed on the route Helsinki – Travemünde (Figure 2-1) on-board MS Finnpartner. The system was first installed in the year 1998. Data consists of measurements taken with an automated flow-through system installed on board the ship. The equipment consists computer, GPS navigator, fluorometer Turner Scufa for chlorophyll-a and turbidity fluorescence measurements, thermometer Anderaa T3444 and salinometer Anderaa S/T3210 for flow-through measurements and a refrigerated sequence water sampler ISCO equipped with 24 polyethylene bottles with 1 L volume. Also Turner 10-AU was installed for in vivo fluorescence (600/640 nm ex/emis) measurements to detect filamentous cyanobacteria including phycocyanin. The flow through system records sampling time, position, salinity, temperature and fluorescence at 20 second intervals (equal to 100 to 200 m in space). The sequence water sampler collects water samples for chemical, taxonomic, and chlorophyll-a analysis.

2.2 Ferrybox Operation

The system records the observations on the computer hard disk with GPS georeference control. The operation was checked weekly during the summer and twice a month during winter. Temperature and salinity measurements are stable, but the cuvette for fluorescence records tends to become dirty if not cleaned every week.

2.3 Area Specific Experiences

The required accuracies are for salinity 0.2 units, temperature 0.1 ^{o}C, and chlorophyll-a 0.5 mg/m^3 when chl-a is under 5 mg/m^3, and 1 mg/m^3 when concentration is above 5 mg/m^3.

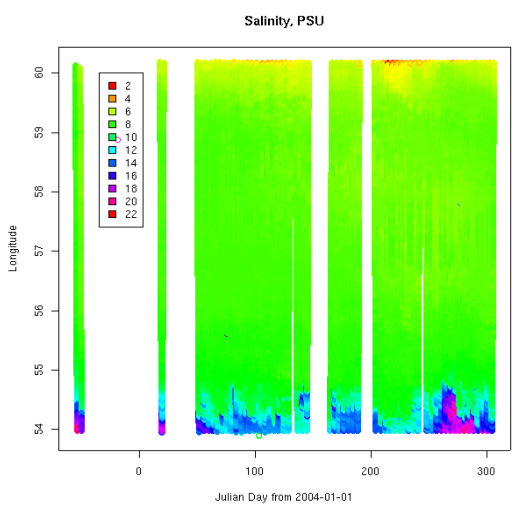
2.4 Maintenance Procedures

The maintenance is carried out weekly by own staff, the crew of the ferry company ·take par only occasionally. About 12 hours of manpower per month are needed for maintenance

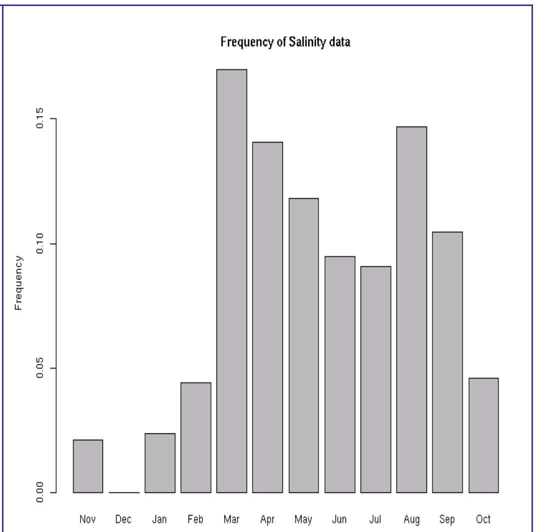
2.5 Data Availability

2.5.1 First FerryBox Year

In the Finnish Institute of Marine Research the field data for the year 2004 was observed on the route Helsinki – Travemünde on-board MS Finnpartner. The data are presented from November 2003 to November 2004 in Figure 2-2 to Figure 2-4.

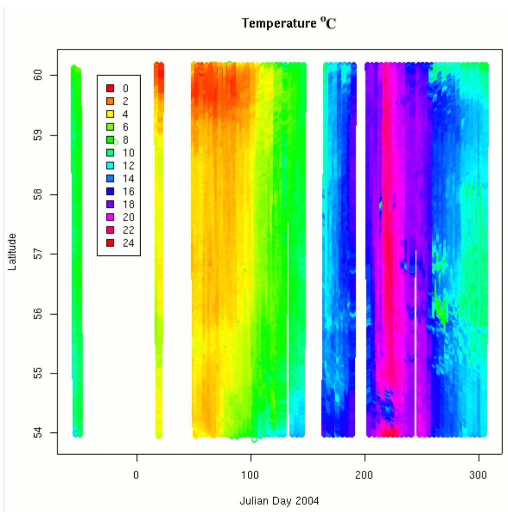


Time/latitude plot of salinity observations (year 2004)

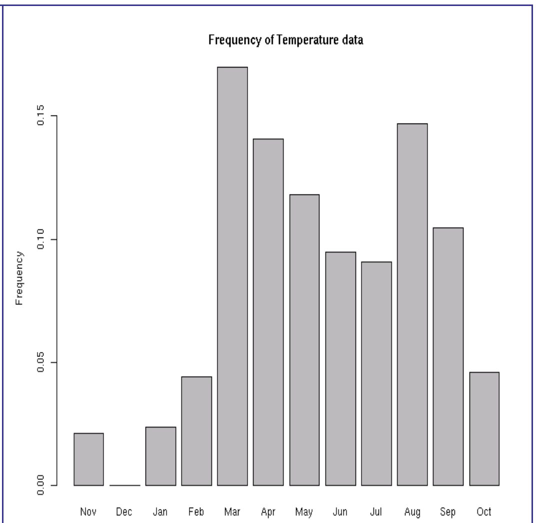


Monthly/annual ratio of salinity observations (year 2004)

Figure 2-2: Salinity measured on the route Helsinki – Travemünde in 2004.

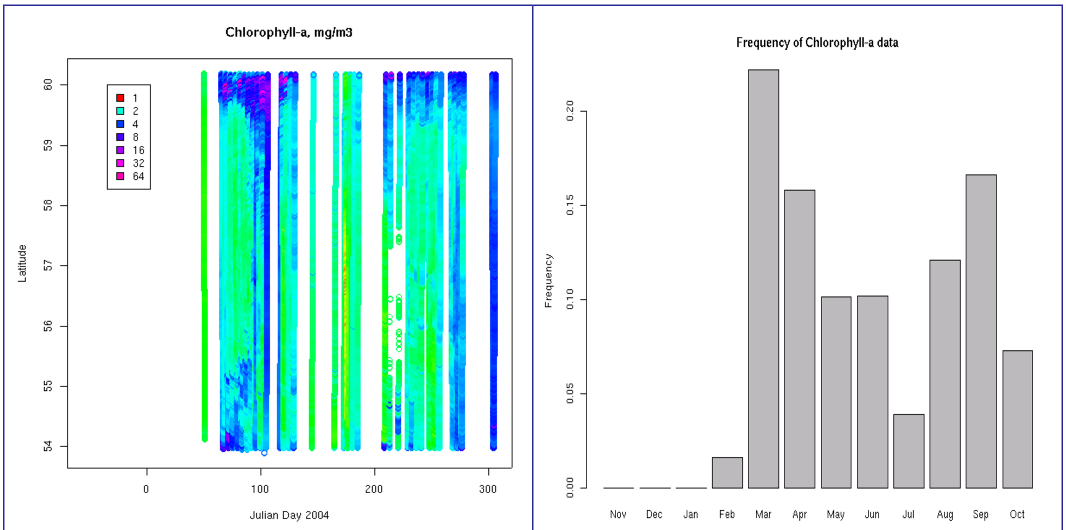


Time/latitude plot of temperature observations (year 2004)



Monthly/annual ratio of temperature observations (year 2004)

Figure 2-3: Temperature measured on the route Helsinki – Travemünde in 2004.



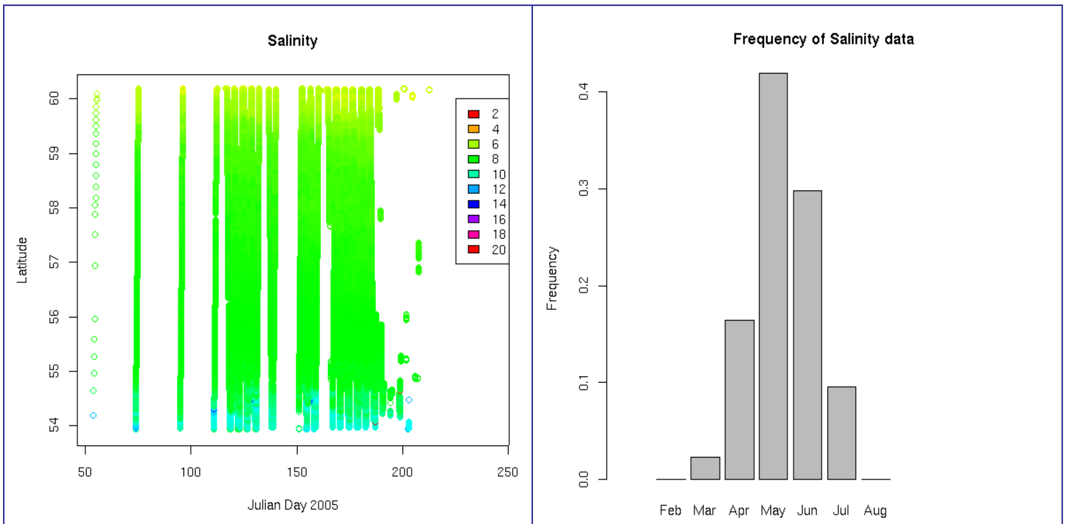
Time/latitude plot of chlorophyll-a observations (year 2004)

Monthly/annual ratio of chlorophyll-a observations (year 2004)

Figure 2-4: Chlorophyll-a measured on the route Helsinki – Travemünde in 2004.

2.5.2 Second FerryBox Year

The data for the Second FerryBox Year are presented in Figure 2-5 to Figure 2-7 from November 2004 to July 2005. Actually the salinometer was broken in mid June and thus the data for the end of June and July are not reliable.

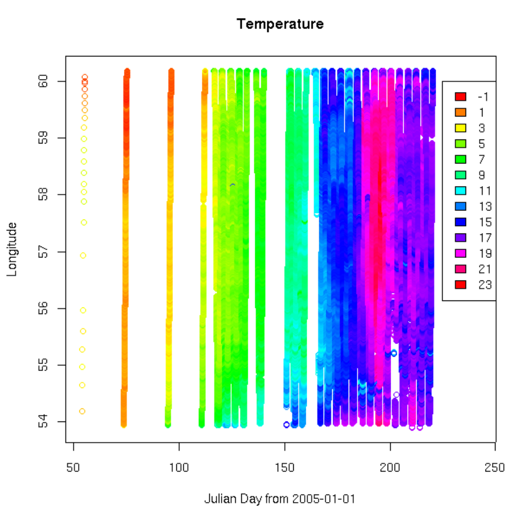


Time/latitude plot of salinity observations (year 2005)

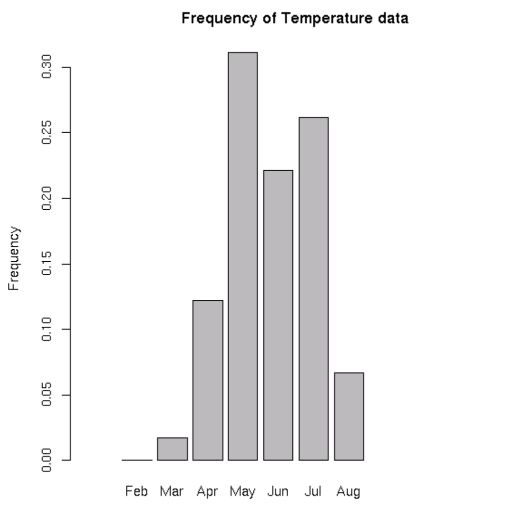
Monthly/annual ratio of salinity observations (year 2005)

Figure 2-5: Salinity measured on the route Helsinki – Travemünde in 2005.

Main reasons for data gaps were that the ship was on the dock in summer and during January and February the system was not in operation due to the ice cover in the northern part of the Baltic Sea.

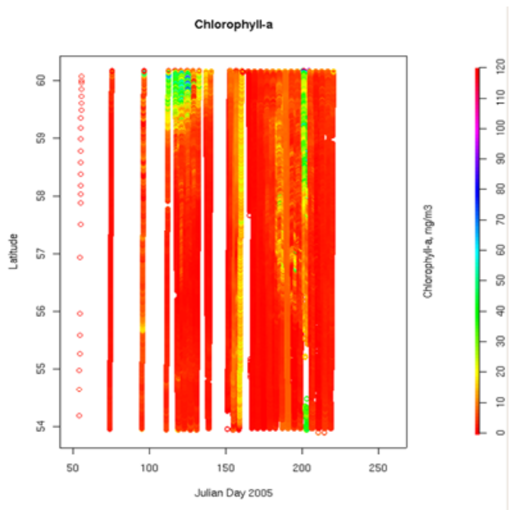


Time/latitude plot of temperature observations (year 2005)

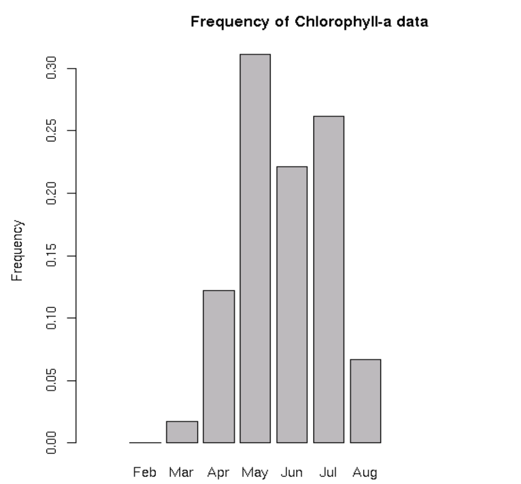


Monthly/annual ratio of temperature observations (year 2005)

Figure 2-6: Temperature measured on the route Helsinki – Travemünde in 2005.



Time/latitude plot of chlorophyll-a observations (year 2005)



Monthly/annual ratio of chlorophyll-a observations (year 2005)

Figure 2-7: Chlorophyll-a measured on the route Helsinki – Travemünde in 2005.

2.6 Quality Assurance of the Data (Metrology)

The first quality check of the data is carried out once a week when the data and water samples are collected from the harbour. The instrument calibration is carried out every 3 months and chlorophyll a validation procedures are implemented every week. About 1.5 weeks of manpower per month is needed for data quality assurance and metrology measures

2.7 Specific Experiences with the Four Basic Parameters

The experiences with the temperature sensor show that records for temperature and salinity are stable without any noticeable drift. Fluorescence records offset tends to grow if special attention is not paid for cuvette cleaning. The lifetime for temperature sensors is 10 years, for salinity sensors 6 years and for the excitation lamp of the fluorometer 2 years.

2.8 Data Storage and Access

The primary records are stored as ASCII files which can be displayed on the in house developed Ferrybox analysis software. The data are stored in the database at the end of the year. The data are published in graphical form immediately on the Baltic Sea Portal website (www.balticseaportal.fi). Numerical data are available for co-operation projects.

3 Route 1b – Baltic Sea (EMI)

3.1 System Description

The Ferrybox system was installed onboard of the passenger ferry "Romantika" in the end of April 2004. The flow-through system contains a thermosalinograph (AANDERAA) and a fluorometer (Turner AU-10). Flow-through measurements are conducted twice a day with the spatial resolution of about 200 m. The system also contains an automatic water sampler (ISCO) which takes water samples at fixed latitudes for chlorophyll-a, nutrient and phyto-plankton analyses. Samples are collected on a weekly base.

Table 3-1: Descriptive data of the ferry route, the ferry and the Ferrybox Tallinn – Helsinki.

Route 1b – EMI & FIMR	
Route	Tallinn – Helsinki (Baltic Sea, Gulf of Finland)
Ship	MS Romantika
Company	Tallink, Estonia
System	Flow through system
Frequency	Flow though data twice per day. Automated sampling for phyto-plankton, chlorophyll-a and nutrients once per week.
Travel time	3.5 hours
Features	Brackish water, salinity about 5
Measured parameters	Salinity, water temperature, chlorophyll *a* fluorescence; automated samples for nutrients, chlorophyll *a* and phytoplankton
Spatial resolution	Flow through system: salinity, temp. and fluorescence 200 m, water sampling for laboratory analysis at fixed latitudes
Remote control	No
Data transfer	Floppy disk
Data storage	Every 20 s outside harbour area
Depth of water intake	4 – 5 m
Website	http://www.fimr.fi

3.2 Ferrybox Operation

- Automatic, position controlled, sampling in predefined positions.
- Check of operation is carried out in a weekly basis (during summer 2005 from June to August every day).
- Identification of high and low reliability of parts of the system: After installation of an UPS no more data losses occurred due to the electrical "black outs".

3.3 Area Specific Experience

Specific problems in the Gulf of Finland area:

- During winter time and early spring there might be an ice cover which makes water sampling and use of fluorometer impossible.
- During summertime the main biomass can be formed by cyanobacteria and in this case the chlorophyll-a measurements are underestimating the biomass of phytoplankton.
- Cyanobacterial specific wavelength measurements have been started/tested in summer 2005 with the Turner Design phycocyanin fluorometer Cyclops 7.

3.4 Maintenance Procedures

The maintenance (cleaning) is carried out manually in harbour on a weekly basis.

The manpower used is about 18 hours per month (6 for standard sensors, 4 for non-standard sensors plus travel time of about 8 h/month)

3.5 Data Availability

Bar diagrams of availability of reliable data for each parameter related to the number of cruises per month for the first and Second FerryBox Year are shown in Figure 3-1.

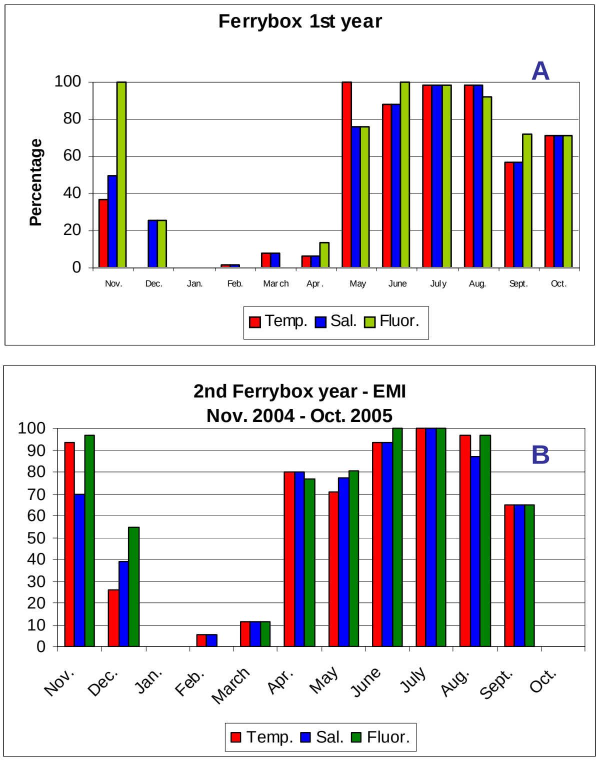


Figure 3-1: The availability of reliable data for three parameters related to number of cruises per month from (A) Nov 2003 – Oct 2004 and (B) Nov 2004 September 2005.

Coloured dot plots are displayed in Figure 3-2 to Figure 3-4 (x-axis: time; y-axis: latitude or longitude) showing the availability of the three standard parameters for the two FerryBox Years.

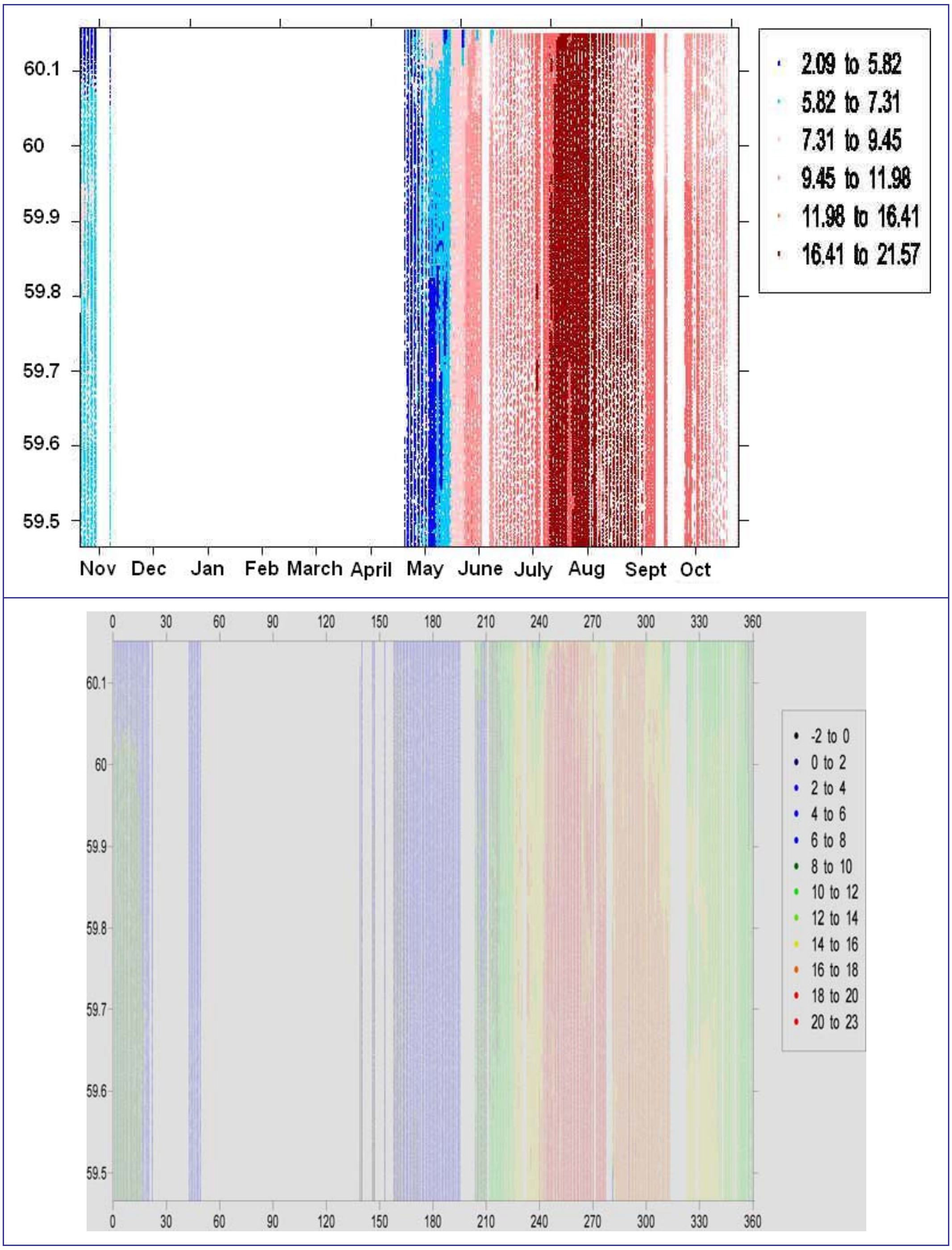


Figure 3-2: Measured temperature along the ferry route Tallinn – Helsinki during (A) the First FerryBox Year (Nov 2003 – Oct 2004 – upper panel) and (B) during the Second FerryBox Year (Julian days from Nov 2004 – Sep 2005 – lower panel).

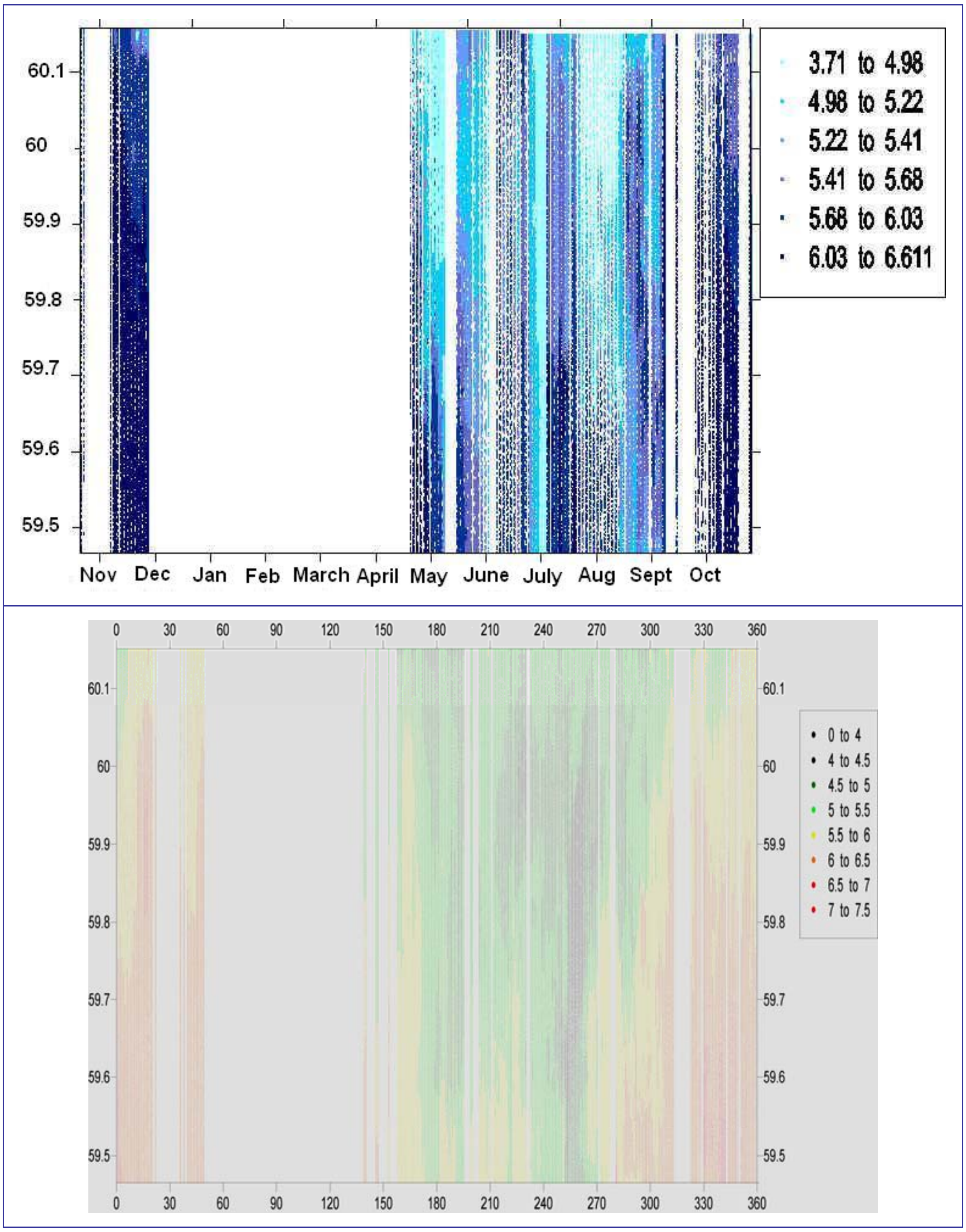


Figure 3-3: Measured salinity along the ferry route Tallinn – Helsinki during the First FerryBox Year (Nov 2003 – Oct 2004 – upper panel) and (B) during the Second FerryBox Year (Julian days from Nov 2004 – Sep 2005 – lower panel).

During the First FerryBox Year in December 2003 the temperature sensor did not work, later the ice conditions did not allow to switch on the system. In April 2004 the change of the ferry, in summer and autumn 2004 and some electricity problems gave reasons for data gaps.

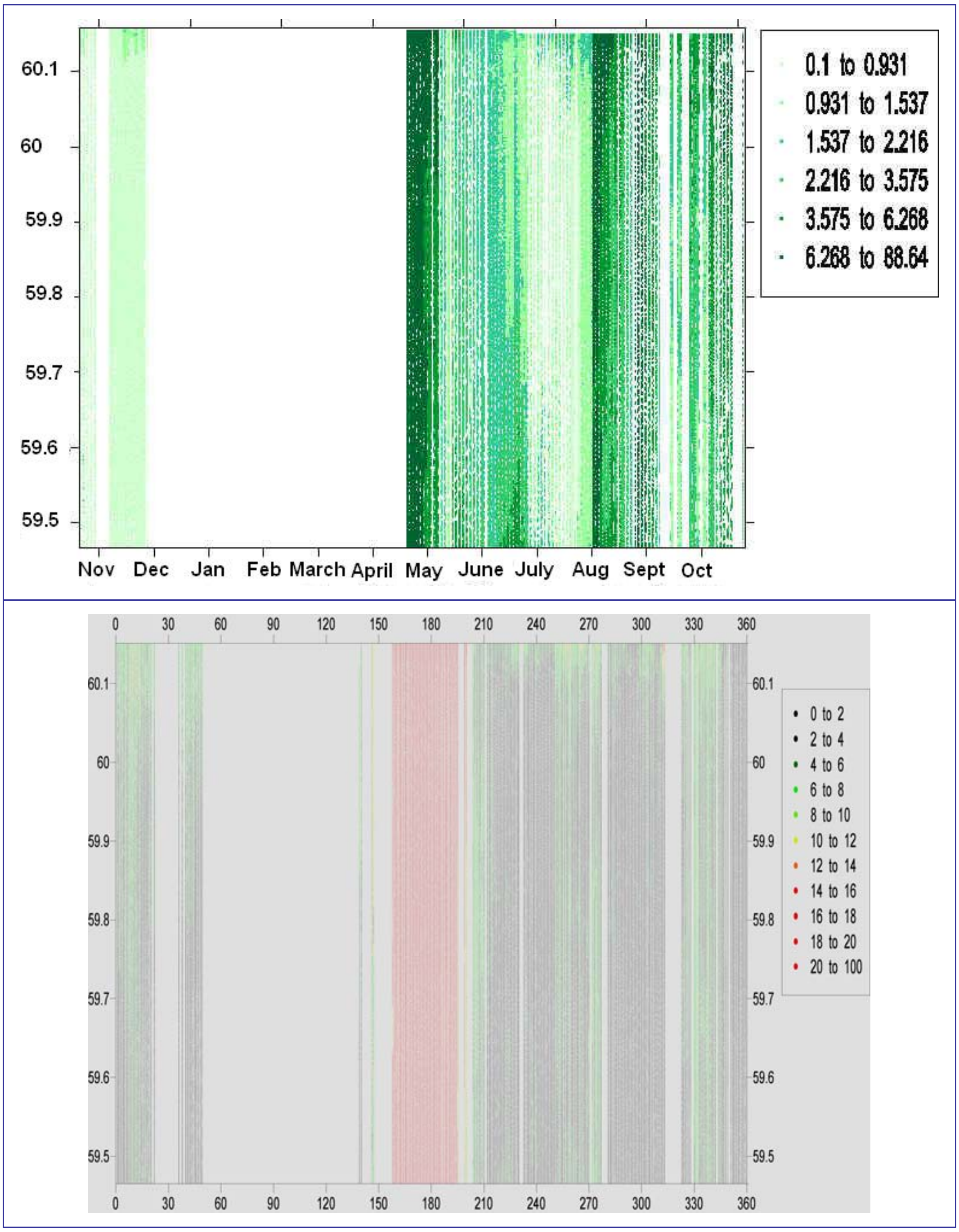


Figure 3-4: Measured fluorescence the ferry route Tallinn – Helsinki during (A) the First FerryBox Year (Nov 2003 – Oct 2004 – upper panel) and (B) the Second FerryBox Year (Julian days from Nov 2004 – Sep 2005 – lower panel).

During the Second FerryBox Year in December 2004 the temperature and salinity sensors failed. In January 2005 all sensors were taken off from the system for annual calibration. Later in February and March 2005 the ice conditions did not allow to run the system continuously – it was switched on occasionally to follow the situation in the sea. The same applied in the beginning of April 2005. In September 2005 there was a change of air-bubble remover chamber and during this time the system was switched-off.

3.6 Quality Assurance of the Data (Metrology)

Every week the data are copied from the system computer on board of the ferry and the first quality check is carried out using a special program (screening).

No special calibrations have been performed during the FerryBox Years. An overall system calibration is conducted during winter. Fluorometer validation is carried out weekly for which samples are taken with the automatic water sampler and chlorophyll-a is measured spectrophotometrically in the laboratory.

For data quality assurance and metrology measures about 24 hours per month are used (12 for first visual check and further 12 for validation and calibration).

3.7 Specific Experiences with the Four Basic Parameters

Experiences with the sensors:

- As all sensors are quite old already (the line between Tallinn and Helsinki has been running since 1997) there is a need to renew the thermosalinograph. Probably brand new system will be installed in 2006.
- During high phytoplankton seasons there is a constant need to brush the fluorometer cuvette and air bubble separation chamber on a weekly base. Nevertheless the shift in fluorometer reading before and after cleaning is not remarkable.

3.8 Data Storage and Access

All flow-through data are sent to the Alg@line database in FIMR in ASCII format. Water sample analysis data (nutrients and chlorophyll a) are delivered to the Alg@line database in FIMR in Excel format. Phytoplankton data are transferred to the Alg@line database in FIMR as PhytoWin datasheets.

Data access is restricted to the Alg@line consortium partners but if anyone else wants to use the data an agreement can be settled providing data availability to Third Parties for non-commercial purposes.

At the same time, as contributory financing comes also from the Estonian Ministry of Environment, all data are sent to the Estonian Environment Information Centre. The information and data are presented as graphs in several web pages to the public.

4 Route 2 – Skagerrak (NIVA)

4.1 System Description

The Norwegian Ferrybox system has been in operation since August 2001 and the main system consists of sensors measuring the core parameters chlorophyll-a fluorescence, turbidity, temperature and salinity. Optionally a sensor for down-welling irradiance (PAR) is installed on the ferry's top deck. The system has also the possibilities to automatically collect water samples on fixed positions. It runs between Hirtshals in Denmark and Oslo in Norway 6 days a week, normally resting in Oslo on Mondays. During summer (June – August) it runs on some Mondays as well. The ferry departs from Oslo in the evening, arrives in Hirtshals in the morning of the next day and returns on the same day to Oslo during daytime.

4.2 Ferrybox Operation

The system is fully automatic and controlled by the GPS signals (Waypoints). The sensors are controlled with the software LabView and data are collected each minute. The water sampler is controlled by waypoints and can collect 24 one litre samples per cruise or 12 samples of 2 litres.

The system is generally maintained and checked for bio-fouling every week on Monday. It has worked without severe problems. Due to sensor failure or extreme bio-fouling the chlorophyll-a fluorescence or turbidity sensor has been out of order for shorter periods.

4.3 Area Specific Experiences

The area has general low particle concentrations with a yearly mean for the whole area and all seasons of 0.6 FTU. At the Danish coast the turbidity can rise to 15 – 20 FTU for periods during winter or stormy weather. The yearly mean of chlorophyll-a fluorescence concentration for the whole area is 1.2 µg/l (including winter). Values increases to 15 – 20 µg/l during spring blooms and stabilise around 2 µg/l during summer time.

To resolve the “events” the necessary accuracy should be approx. 0.2-0.3 FTU for turbidity and 0.4-0.5 µg/ for Chl-a fluorescence. The sensors should have a resolution of 0.2 -0.3 for salinity and 0.5 °C for temperature.

4.4 Maintenance Procedure

The system is maintained by personnel from NIVA, and once a week the system is cleaned with fresh water. Automatic fresh water cleaning has been tested, but air bubbles caused problems. When the ferry operates also on Mondays only a sensor cleaning is possible due to the short time available during port call. Otherwise the tubing and water intake are cleaned. The water intake is automatically cleaned with air pressure when the ferry is in port.

4.5 Data Availability

For the First FerryBox Year from November 2003 to the end of October 2004 NIVA gained the following periods with reliable data (Figure 4-1). The gaps in data (< 100%) are caused by system stops or periodic problems with sensors or bio-fouling. In the end of the year (Sept.-Nov.) more problems occurred with bio-fouling on the fluorescence sensor.

In average the recovered reliable data are 93% for temperature and salinity, 90% for turbidity and 85% for Chl-a fluorescence.

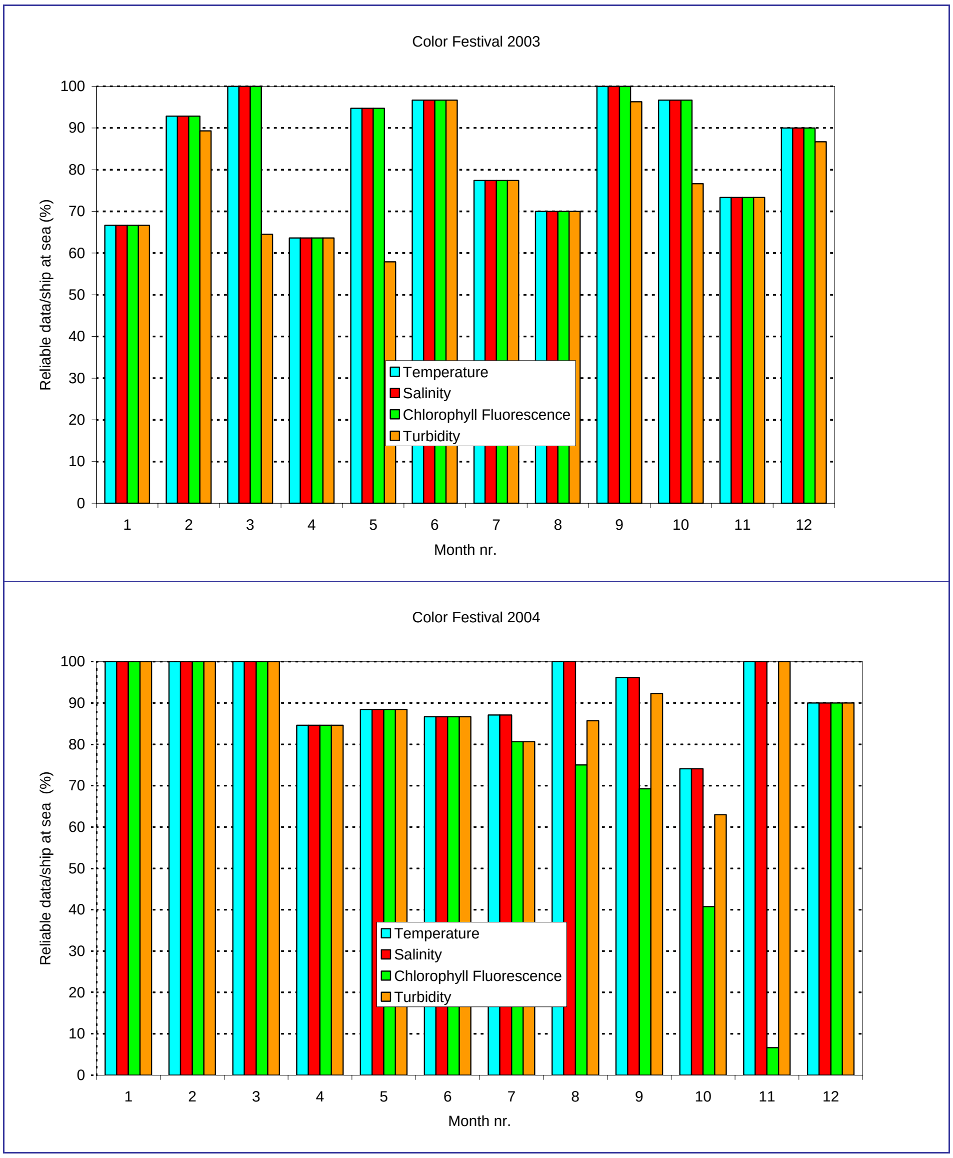


Figure 4-1: Plots of reliable data for the Norwegian ferry route in 2003 (upper) and 2004 (lower panel).

During the period from January to March 2005 the system was reconstructed with a new water inlet located at a new place onboard with extra laboratory space. After finishing the reconstruction the system has run without any remarkable stops from April until December. As the data were not completely checked yet no data plots are presented for 2005.

Figure 4-2 to Figure 4-5 show the dot-plots of the 4 core variables for the FerryBox Year. The data in these plots are quality controlled by removing suspicious data (spikes). Factory or on site calibration of the sensor has been used as well. The turbidity control based on water samples has not been used to correct the data, nor have the chlorophyll-a analyses or irradiance measurements been used to correct for the seasonal or diurnal variations. For the Chl-a fluorescence both night and day fluorescence are used. In the end of the year some problems with the Chl-a fluorescence sensor are seen and the data must be further controlled.

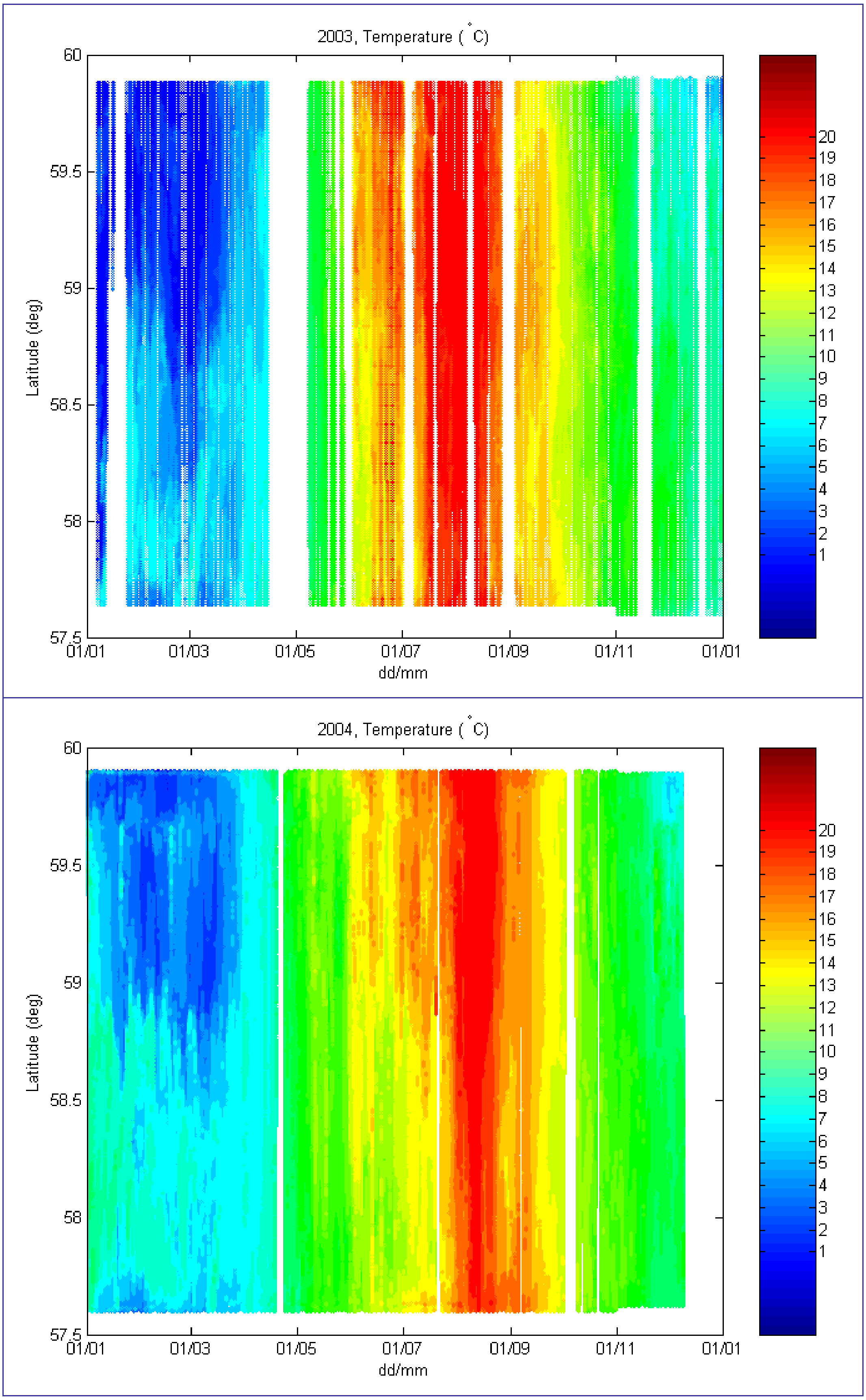


Figure 4-2: Plots of temperature (°C) for the Norwegian ferry route in 2003 (upper) and 2004 (lower panel).

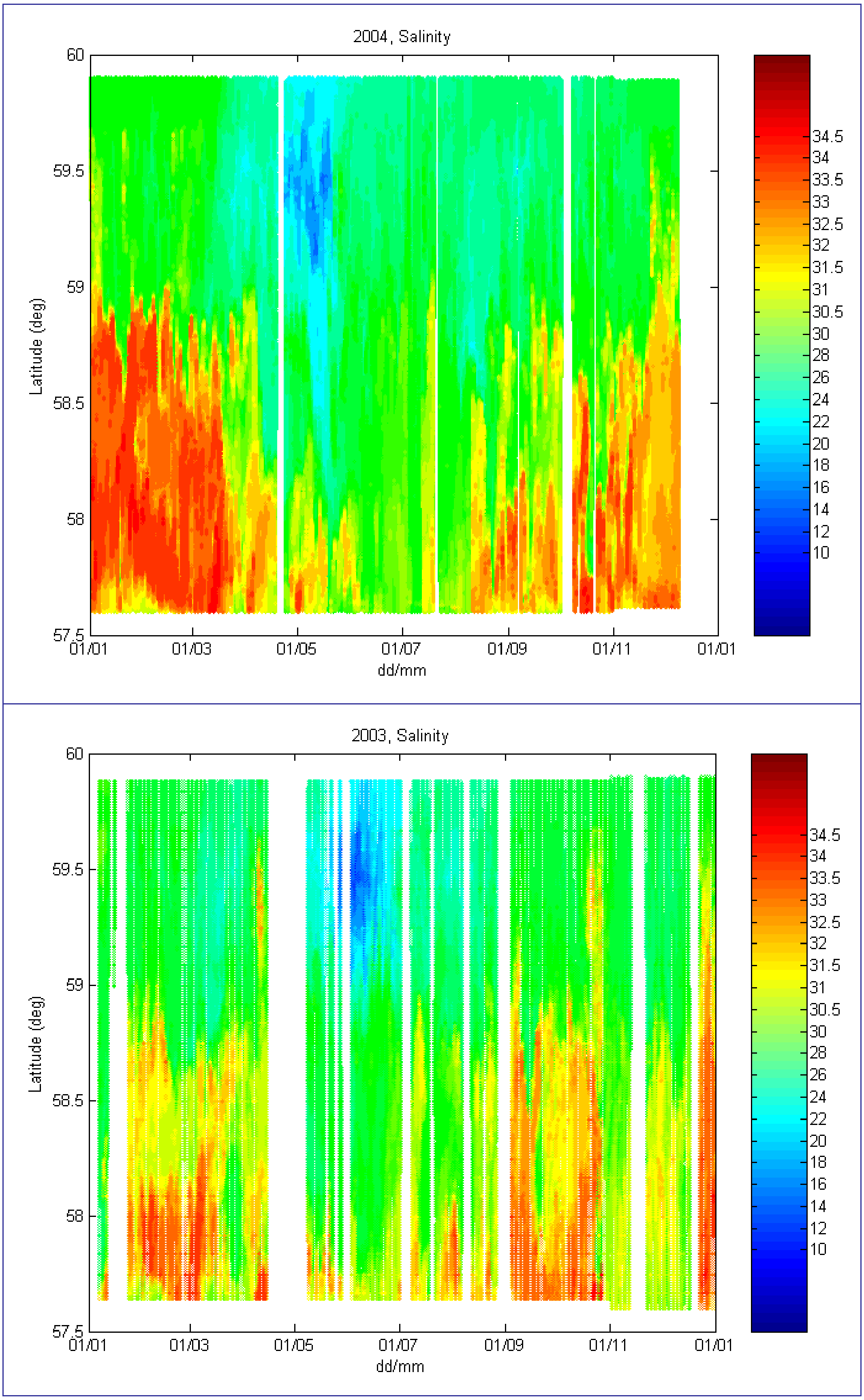


Figure 4-3: Plots of salinity for the Norwegian ferry route in 2003 (upper) and 2004 (lower panel).

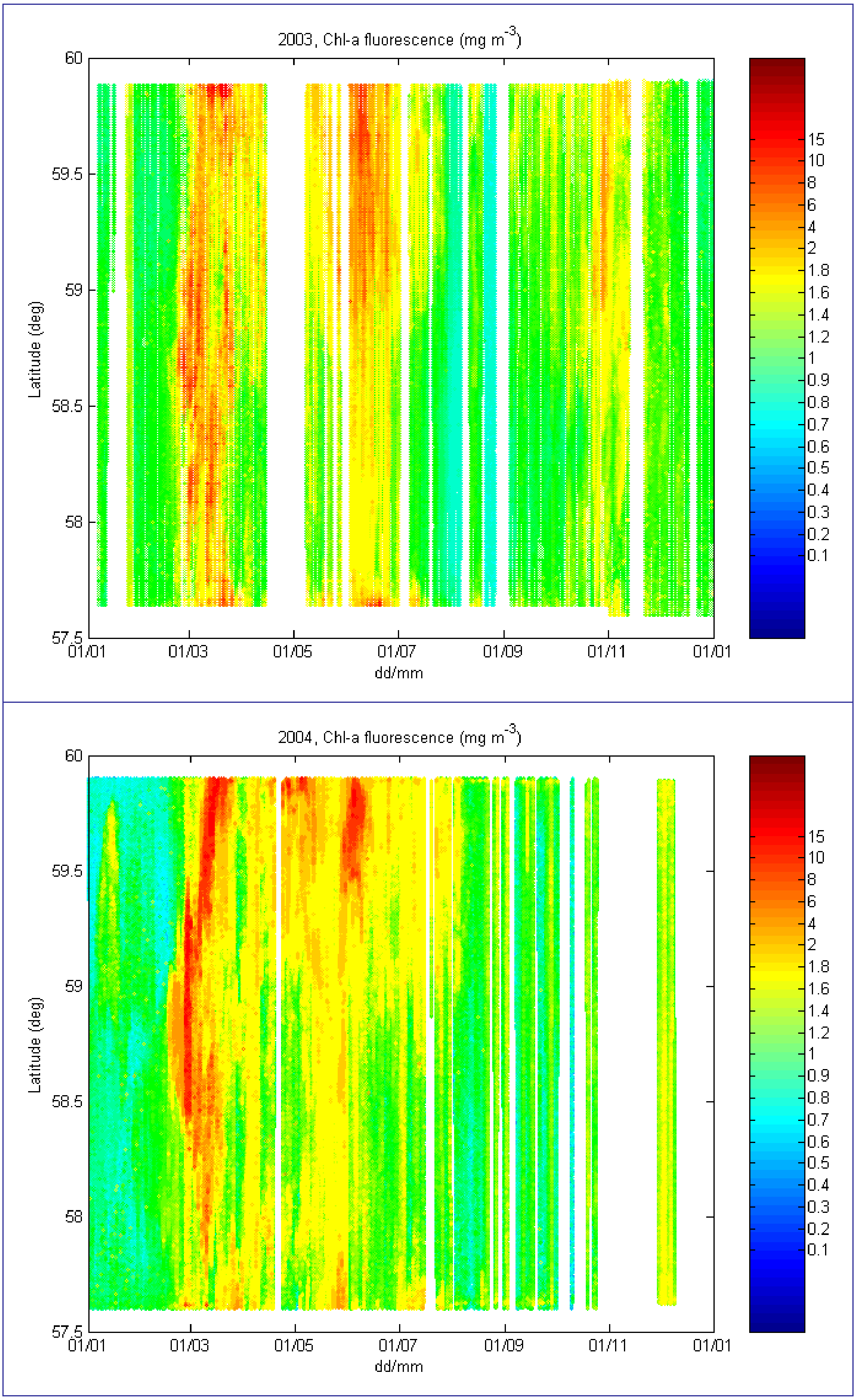


Figure 4-4: Plots of chlorophyll-a fluorescence (µg/l) for the Norwegian ferry route in 2003 (upper) and 2004 (lower panel).

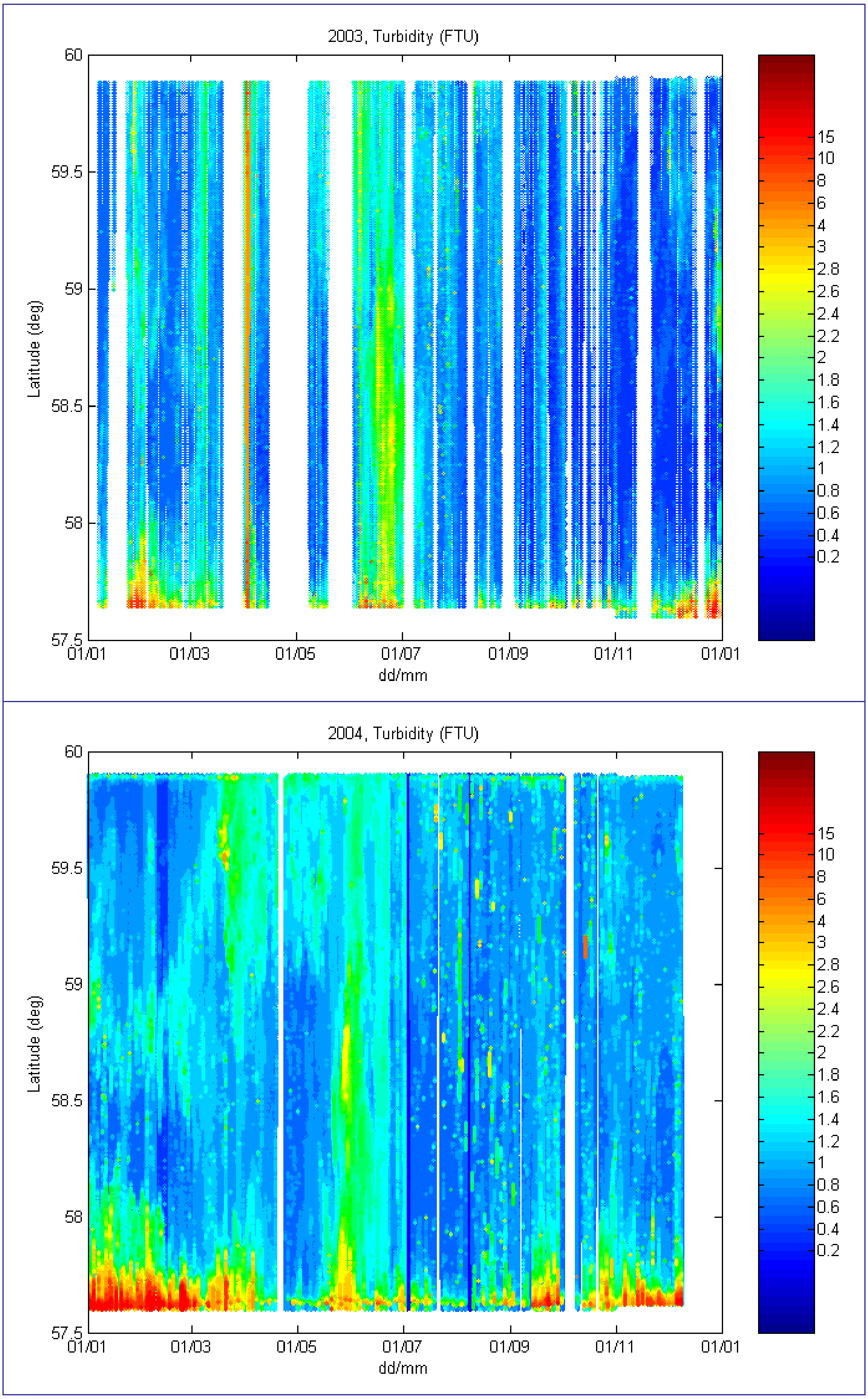


Figure 4-5: Plots of turbidity (FTU) for the Norwegian ferry route in 2003 (upper) and 2004 (lower panel).

4.6 Quality Assurance of the Data (Metrology)

Investigation on the best quality control procedures have been explored for some time. Concerning the core variables the following have been implemented. For the **salinity** water samples have been collected from the water sampler onboard 4 times per year and analysed with a salinometer in the laboratory. The **temperature** control has been done with a calibrated thermometer in the outflow of the thermosalinograph. No comparison with the in-situ conditions (outside ship) was performed.

For Chl-a **fluorescence** and **turbidity** the main control comprised measurements of Chlorophyll-a concentrations and turbidity in the laboratory. The **Chlorophyll-a** analysis has been performed with HPLC and the turbidity analysis follows the ISO 7027 turbidity standard. This has been done frequently during 2004.

4.6.1 Control data Chlorophyll-a Fluorescence:

The Chl-a fluorescence/Chl-a variation has been investigated (Figure 4-6). The chlorophyll-analysis is not a calibration of the sensor since the diurnal variation of this ratio must be considered, which in average varies from 0.6 to 1.5 between January and July 2004.

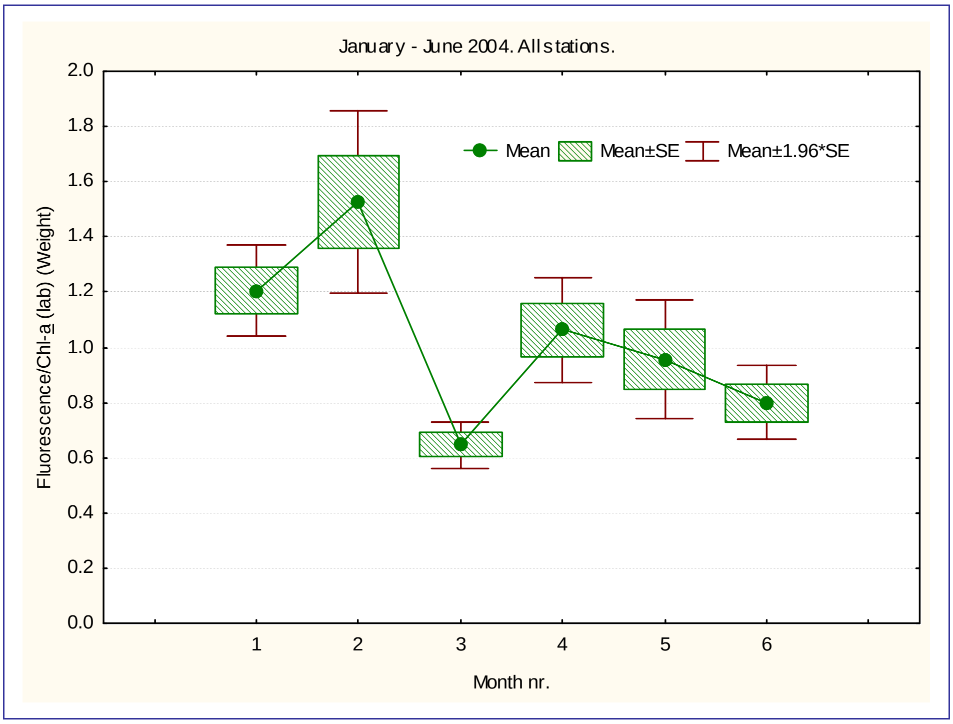


Figure 4-6: Variation in Chl-a fluorescence/Chl-a ratio between January and June 2004.

Approximately 320 chlorophyll-a samples have been analysed at about 24 dates, normally 24 samples per cruise, mainly during day time. Investigation of the night and day variation in Chl-a fluorescence has been preformed (Figure 4-7). After June the number of samples/station per cruise were reduced down to 6 which are the number of tentative "water region"/water types in the area.

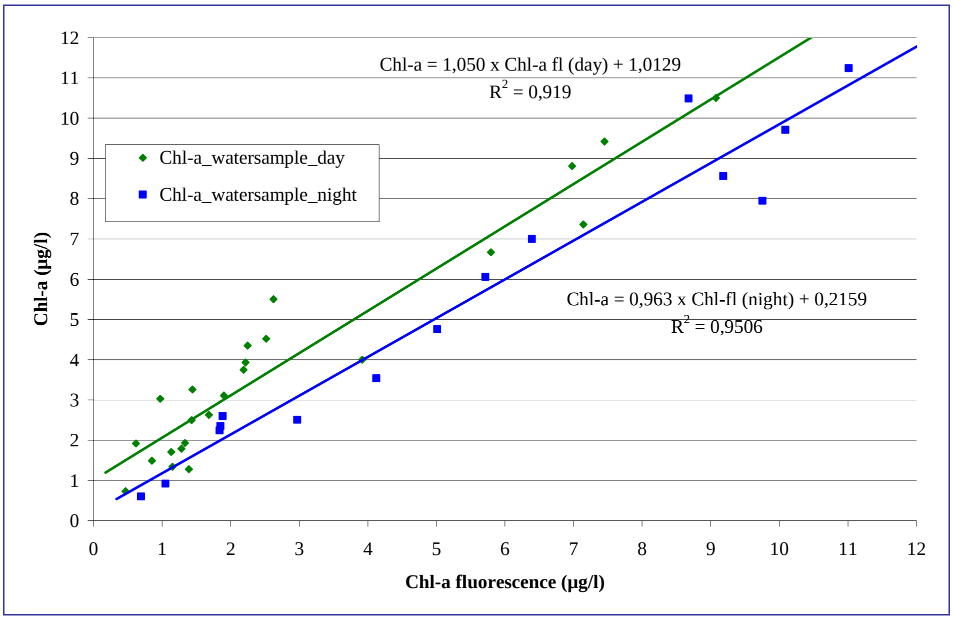


Figure 4-7: Night and day time Chl-a fluorescence relative to Chl-a (µg/l) for approximately the same ferry track on the night and day of 10.-11 of March 2004.

In 2003 and 2004 water samples was collected and analysed for Chl-a with HPLC and Turbidity with the ISO standard 7027 on a HACH turbidimeter. After an individual calibration of the sensor for each year between the sensor data and laboratory the month average deviation from the laboratory data with standard deviation was calculated for chlorophyll data (Figure 4-8 and Figure 4-9).

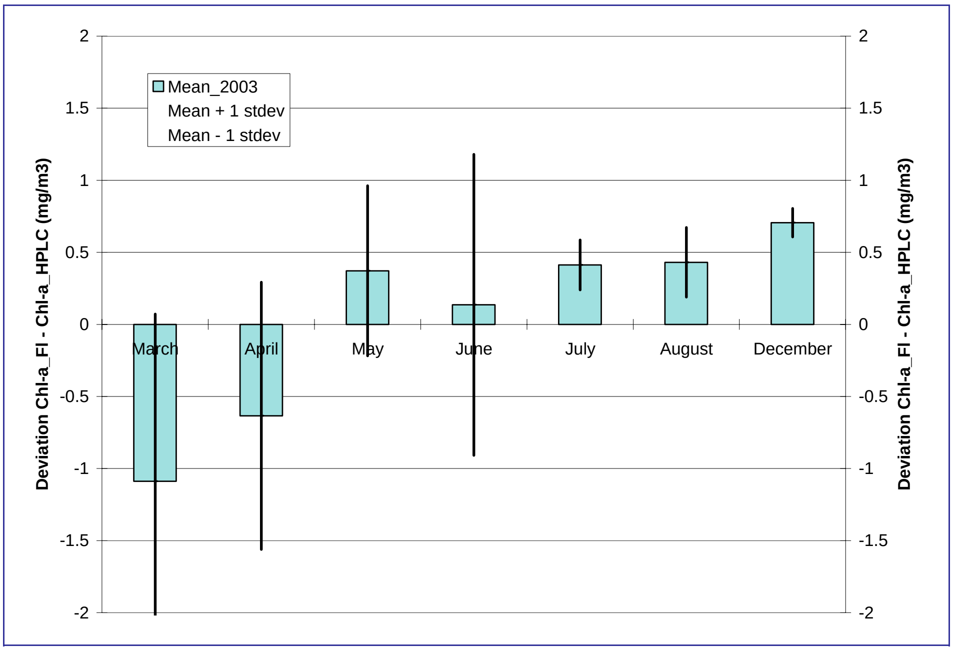


Figure 4-8: Control data Chlorophyll-a fluorescence: Average deviation between calibrated Chl-a-Fl and Chl-a_HPLC in 2003.

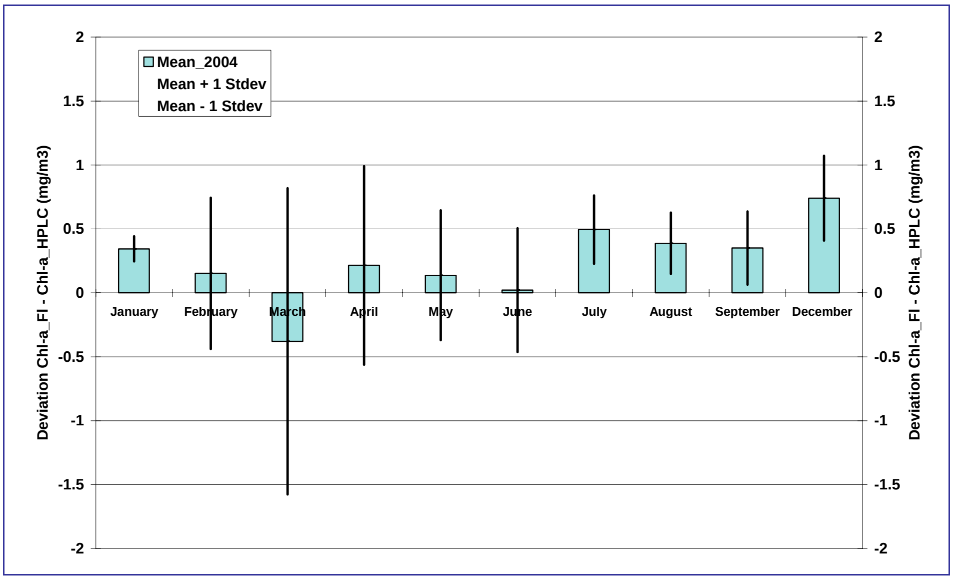


Figure 4-9: Control data Chlorophyll-a fluorescence: Average deviation between calibrated Chl-a_Fl and Chl-a_HPLC in 2004.

4.6.2 Control Data Turbidity

About 620 samples have been analyzed for turbidity in the laboratory (about 28 cruises). An example is given in Figure 4-10. The turbidity sensor has been calibrated on site with Formazine standards 2 times per year or when the sensor was replaced. In September NIVA prepared Formazine standards for all the ferry routes and this system will now be used until eventually “solid state” standards will be available. Example of the calibration on the Polymetron turbidity sensor is presented in Figure 4-11.

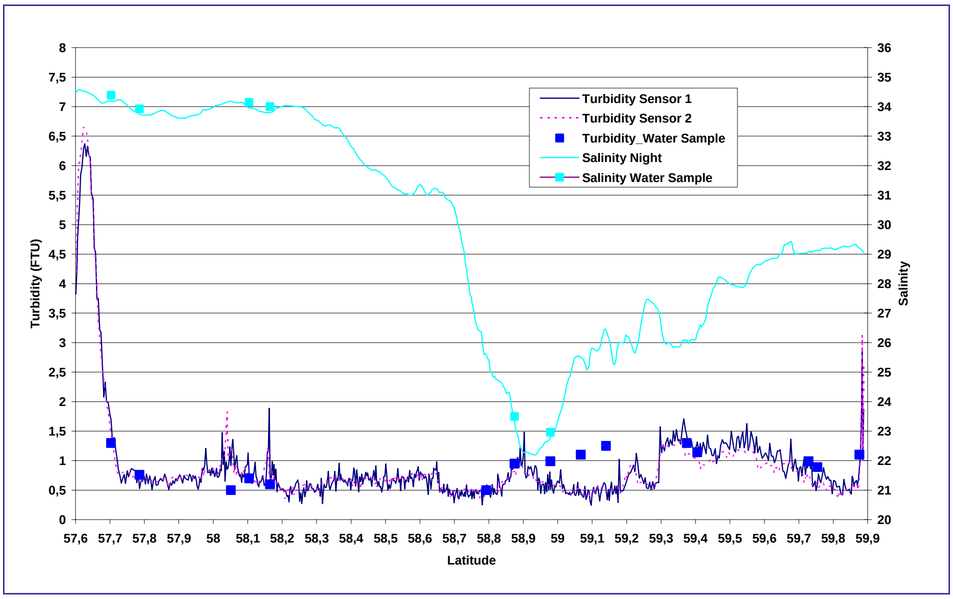


Figure 4-10: Control of the salinity and turbidity sensors with water samples on March 11. 2004.

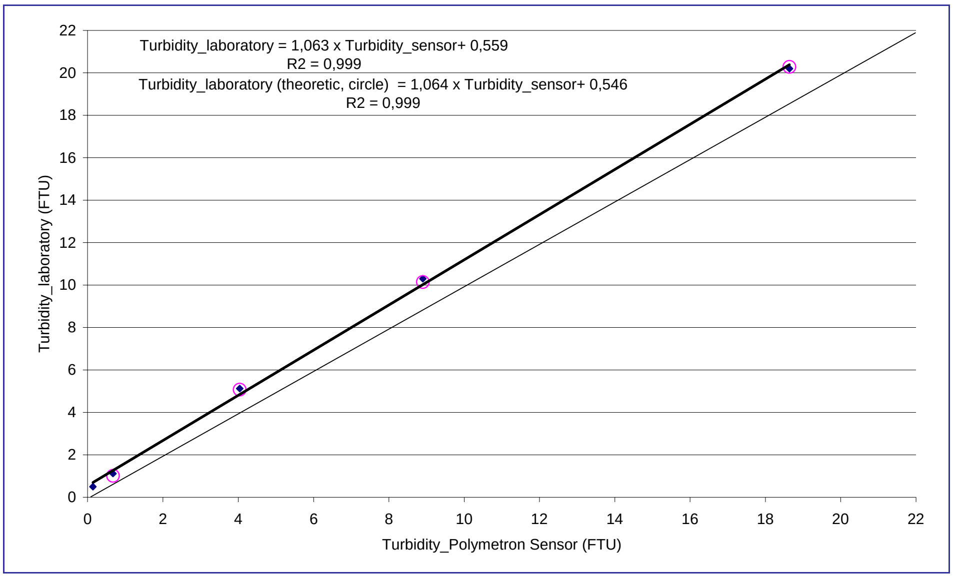


Figure 4-11: Calibration of the turbidity sensor with laboratory measured Formazine standards.

The use of "solid state" standard for the **fluorescence** sensor will be implemented when this will be available. Algal cultures have been tested for calibration, but there is a "problem" with the physiological condition of the alga. Even using the solid state standard will not solve the main calibration of the sensor. The best way to do this is to use a *in vitro* standard which can be related to a HPLC or spectrophotometric determined chlorophyll-a. This can be done since the *in vivo* and *in vitro* Chl-a fluorescence is recorded approximately at the same wavelength (685 nm) by the sensor.

From the experience so far NIVA estimated the manpower for routine maintenance to be about 2 hours per week and an additional 1-2 hour weekly for checking the data. When the new procedures with monthly calibration of the core sensor are implemented, NIVA assumes this to take additionally two days per month, including a minimum of control samples and preparing of standards. In addition one day per month is necessary for maintaining the database.

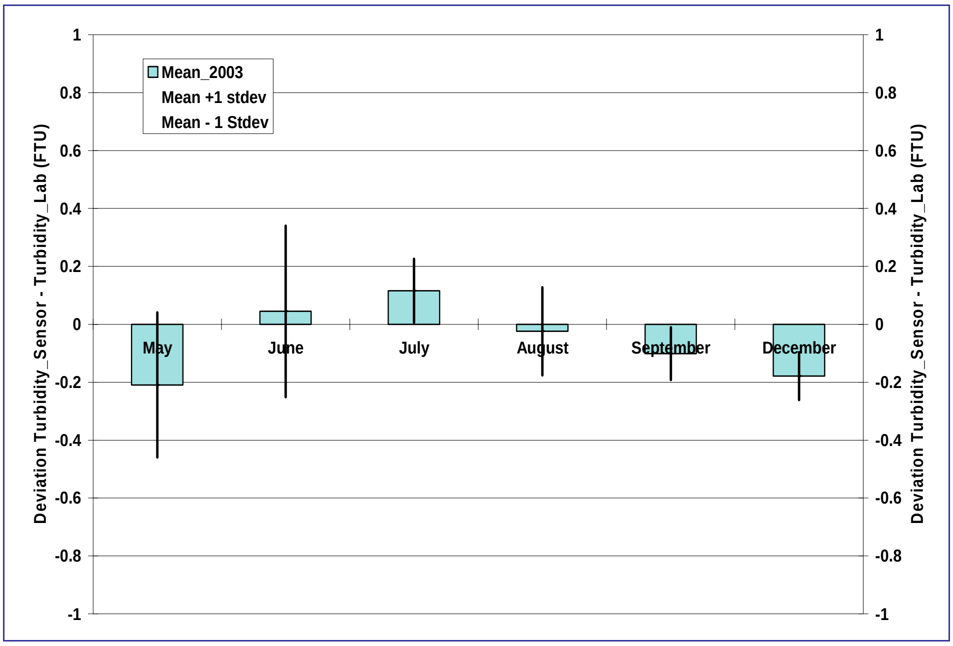


Figure 4-12: Control data turbidity: Average deviation between calibrated Turbidity_Sensor and Turbidity_Lab in 2003.

The monthly average deviation from the laboratory data with standard deviation was calculated for turbidity data in Figure 4-12 and Figure 4-13.

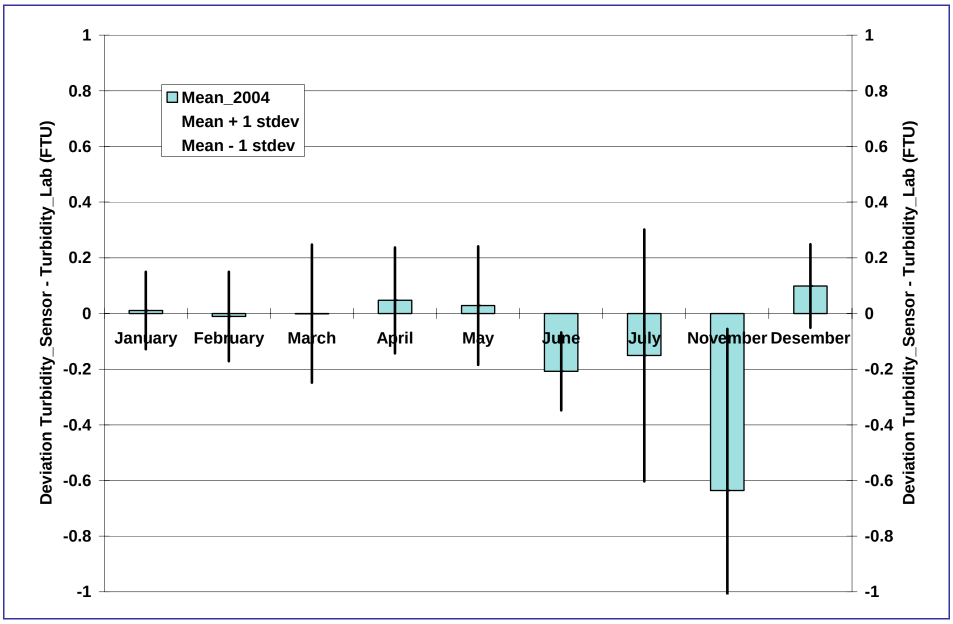


Figure 4-13: Control data turbidity: Average deviation between calibrated Turbidity_Sensor and Turbidity_Lab in 2004.

4.7 Specific Experiences

During the period the turbidity sensor has been exchanged with a self cleaning system to remove some of the bio-fouling problems. Such a sensor also helps on the air bubbles problems that caused refection and high turbidity on the Seapoint sensor in periods. However, a turbidity sensor without self-cleaning equipment is a very good indicator that the system runs well.

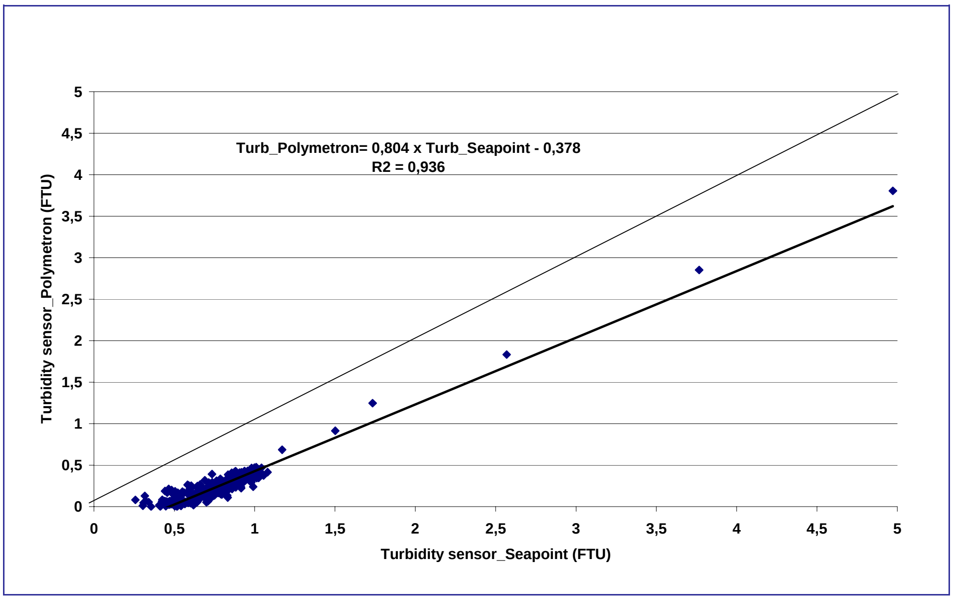


Figure 4-14: Comparison of the Polymetron and Seapoint turbidity sensors on real data and with the factory calibration of the sensor.

Both the chlorophyll-a and the turbidity sensor had to be replaced after 2.5 years of continuous running. NIVA used the same Chl-a fluorescence sensor, but changed to a self cleaning turbidity sensor in 2004. The factory calibration of the two sensors was not correct and new calibration coefficients had to be implemented. Example of the two sensor compared on data from the flow through system is shown in Figure 4-14. The comparison illustrates that each sensors need to be calibrated with standard on site.

4.8 Data Storage and Access

Data are continuously transferred to NIVA and presented on a password protected web page. The data are also stored in a database together with data on all the water samples and analysis. Data are stored on board the ship as well in a log file which is copied into the database on monthly basis. There have been some problems to transfer the data automatically from the log file into the database.

5 Route 3 – North Sea (GKSS)

5.1 System Description

The Ferrybox system in the Southern North Sea was at first installed on the ferry "Princess of Scandinavia" until November 2002. At that time the ferry company stopped the operation of the ferry line and started again in April 2004 with a new ferry boat ("Duchess of Scandinavia"). The system was re-installed on this new ferry at end of August 2003.

The flow-through measurements were conducted every day. Only during the winter months the frequency of ferry crossings was reduced to 6 times per week. The system was mounted in an extra room below the car deck (about 2 m below the waterline). The water inlet was in the machine room on a sea chest (about 5 m below the water line) which was used as water supply for cooling the air-condition system onboard. The water was taken behind a coarse particle filter of the system. To remove smaller particles an additional filter with grid size of about 3 mm was installed in front of the pump of the Ferrybox-system. The length of the pipe between inlet pump and the Ferrybox is about 20 m. The whole line including the filter was flushed back with tap water after each cruise in order to clean the filter and avoid biofouling in the tubes. The Ferrybox is an open system with a debubbling device. Thus the incoming water has to be actively pumped above the water level by a second waste water pump.

The data are recorded with a frequency of 0.1 Hz on the Ferrybox computer and were automatically downloaded to the land station via GSM (GPRS) connection when the ferry was in the harbour.

5.2 FerryBox Operation

The system ran continuously during each cruise. After reaching the harbour which was detected by GPS the system stopped automatically and started a cleaning procedure with acidified (sulphuric acid and later on also oxalic acid) tap water and high pressure rinsing of critical sensors. It remains in a standby status (system is filled with tap water) until the ferry leaves the harbour again. The received data were controlled daily. The Ferrybox can be remotely controlled (GSM connection) to check the system and its sensors. This also gives the possibility to remotely switch of a sensor/device onboard if such fails.

5.3 Area Specific Experiences

The high dynamic range of different variables along the route passing both the strongly limnic influenced Elbe estuary and the English Channel region with nearly open sea conditions requires not only a high accuracy but also a high dynamic range of the operated sensors. This is the case especially for measuring turbidity and nitrate. The range of nitrate which has to be measured is between 0.1 µmol and 20 mmol (more than 5 magnitudes). With the chemical nitrate analyser this range can be covered by performing the photometric measurement at different path lengths simultaneously. In case of the UV-nitrate sensor measurements are carried out by measuring in two cuvettes with a path length of 1 and 2.5 cm.

In addition at open sea conditions a high accuracy (0.01) of the salinity measurements is required in order to discriminate between different water masses. The used salinometer from FSI shows a high stability at one cruise less than 0.01. However, the long-term stability (over several months) seems to be only in the range of 0.1 units. But this has to be proved with more water samples analysed in the laboratory in future.

5.4 Maintenance Procedures

The maintenance is carried out in the harbour (Cuxhaven) on weekly up to fortnightly basis. Due to the self-cleaning feature of the main system it needs not much effort for maintenance. The main work load for maintenance is caused by the chemical analysers. A part of the used chemicals are not longer stable than two weeks and also the calibration has to be regularly checked by standard solutions. Furthermore the analysers often fail due to mechanical problems. A specific problem onboard of this ferry occurred due to formation of iron-oxide coatings which happened irregularly. The origin of the iron which precipitates on the walls and also on the windows of the optical sensors was not quite clear. The high iron concentration is probably not a constituent of the original sea water but comes from the hull of the ship (sea chest) and the pipes and fittings. These coatings first led to serious problems of the UV-nitrate analyser because the optical windows of this device are no longer transparent for the UV radiation. If the coating becomes strong also the Scufa fluorescence detector got problems. By cleaning the whole system with oxalic acid (5-10%) during maintenance the coatings could be completely removed. After tests with adding different concentrations of oxalic acid during the automatic cleaning procedure it turns out that a concentration of about 0.3% oxalic acid in the cleaning water properly removes these precipitations.

Due to the long distance from GKSS to the port of Cuxhaven (2.5 hours travel time) sometimes longer gaps occurred because it was not always possible to intervene immediately after a failure of the system or of sensors was recognized. This is also the reason for a relatively high demand on man power for maintenance (about 60 hours per month).

5.5 Data Availability

A bar diagram of the availability of the Ferrybox system is shown in Figure 5-1.

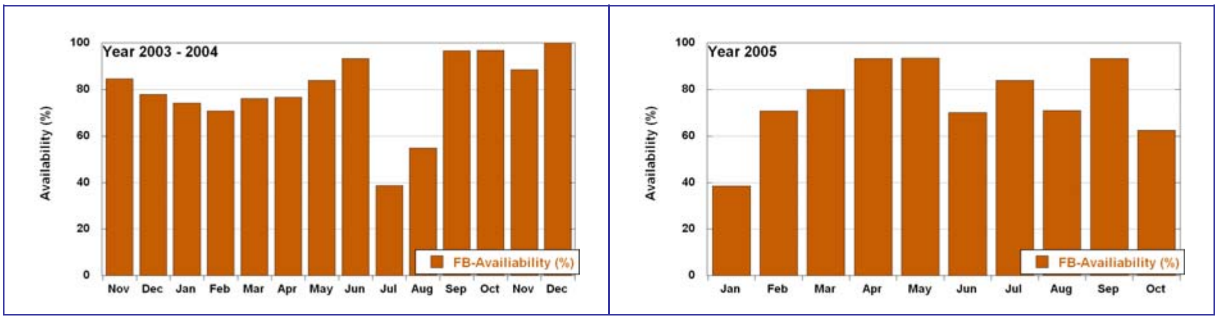


Figure 5-1: FerryBox system availability in the first and Second FerryBox Year.

The availability of the FerryBox system was between 40% and 100%. Main reasons for gaps in the data were mechanical problems with the outlet pump in spring 2004, a broken de-bubbling vessel in July 2004 and electrical problems in August 2004. Another source of data gaps were strong storm events in the winter months (wind force > 10 Beaufort) which caused formation of big air bubbles in the sea chest.

The availability of data of the four standard parameters (water temperature, salinity, turbidity and chlorophyll fluorescence) is shown in Figure 5-2.

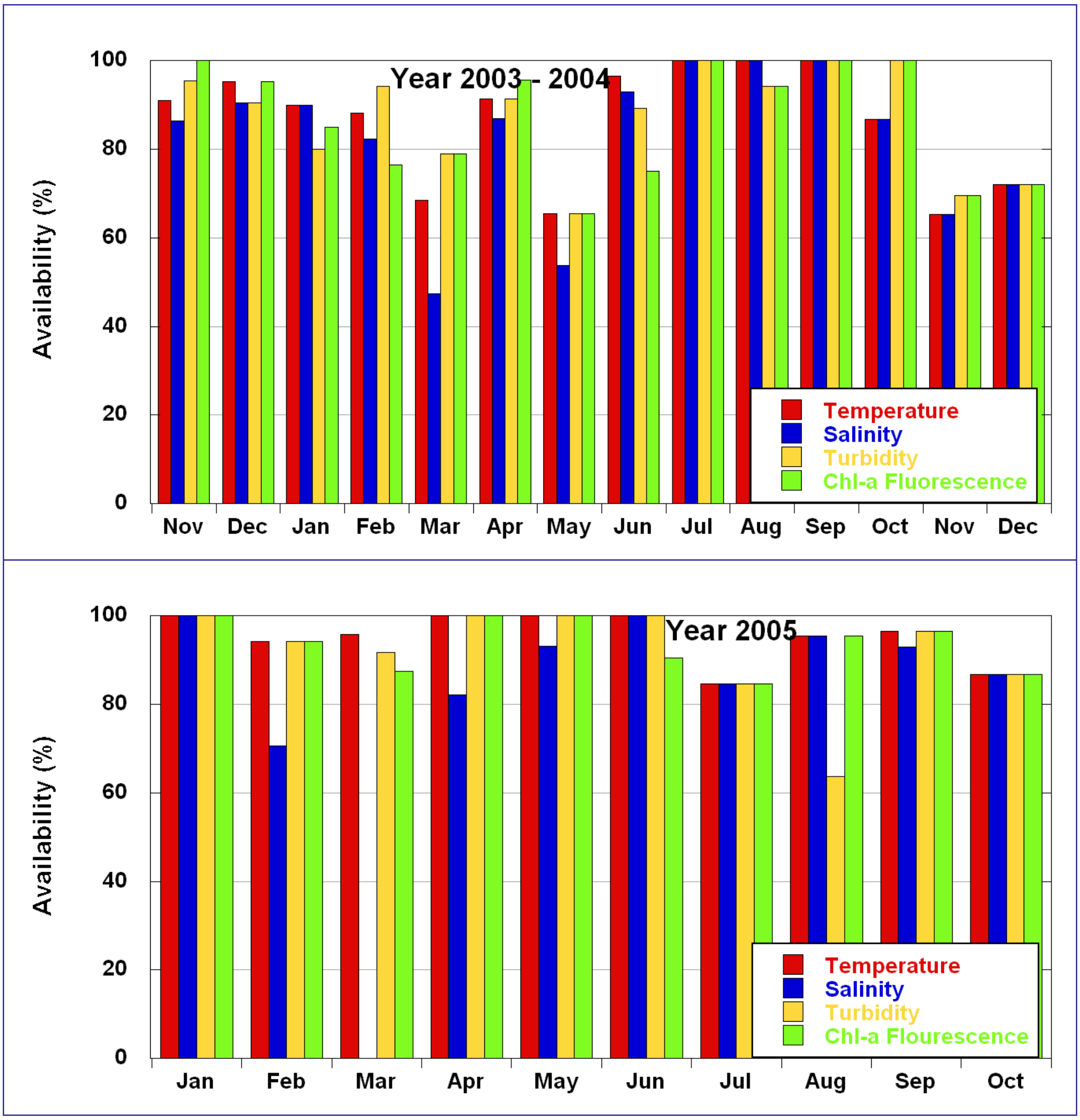


Figure 5-2: Availability of reliable data of the four parameters related to number of cruises per month in 2004 (upper) and 2005 (lower panel).

Coloured dot plots depict the reliable data obtained from the four standard sensors are displayed in Figure 5-3 to Figure 5-6 below.

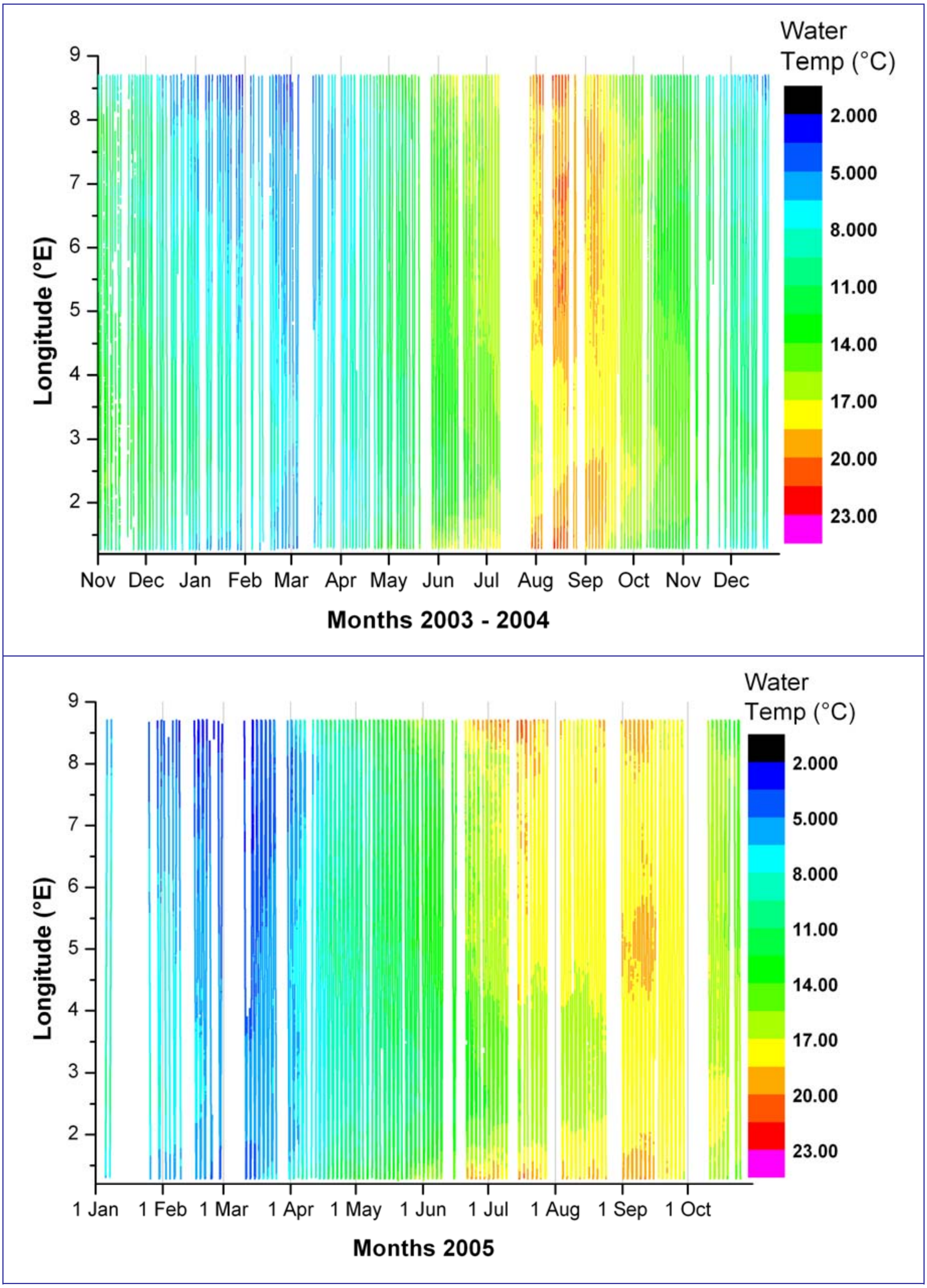


Figure 5-3: Reliable data of water temperature along the transect of the FerryBox between Cuxhaven and Harwich during the First (upper) and Second (lower panel) FerryBox Year.

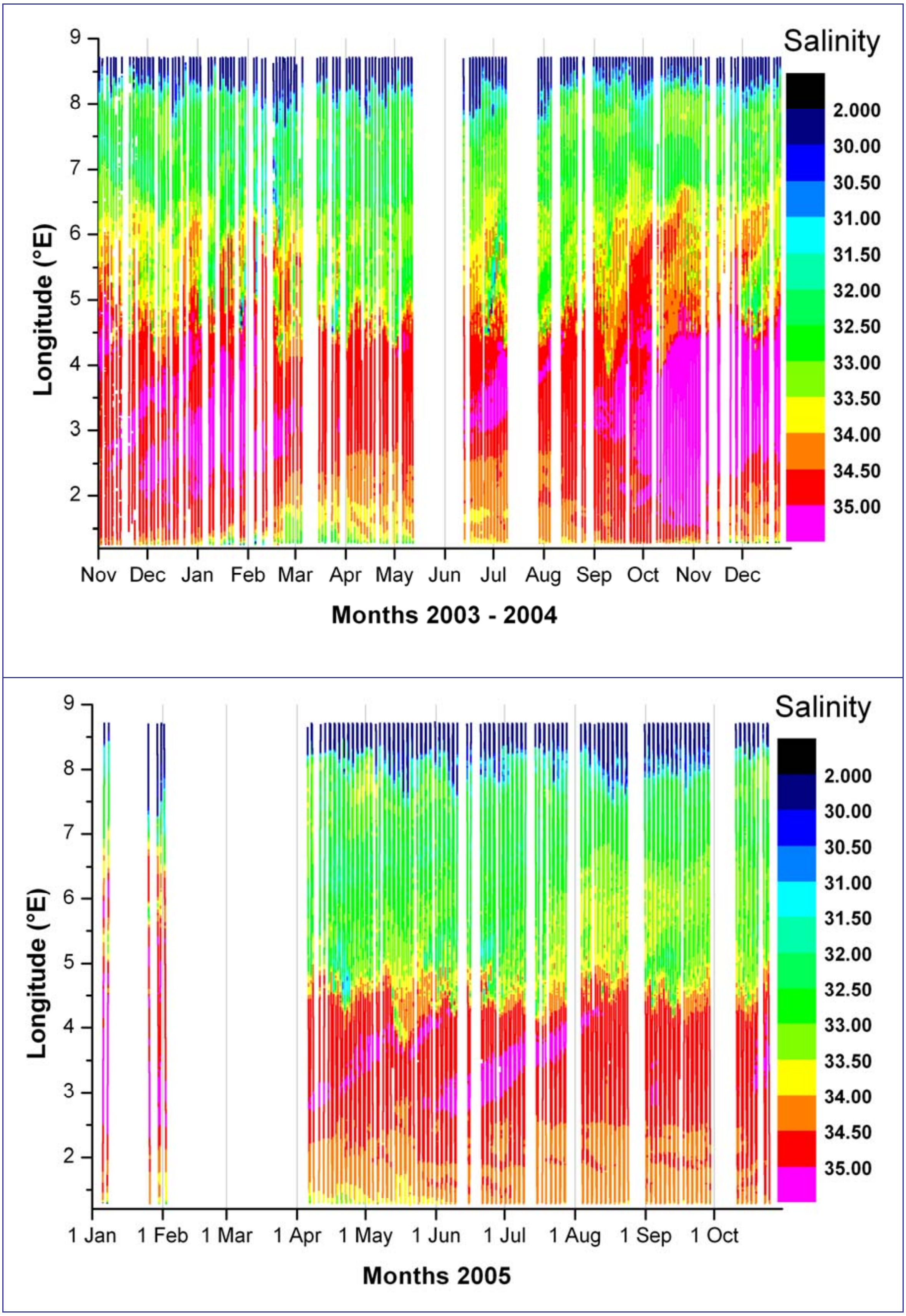
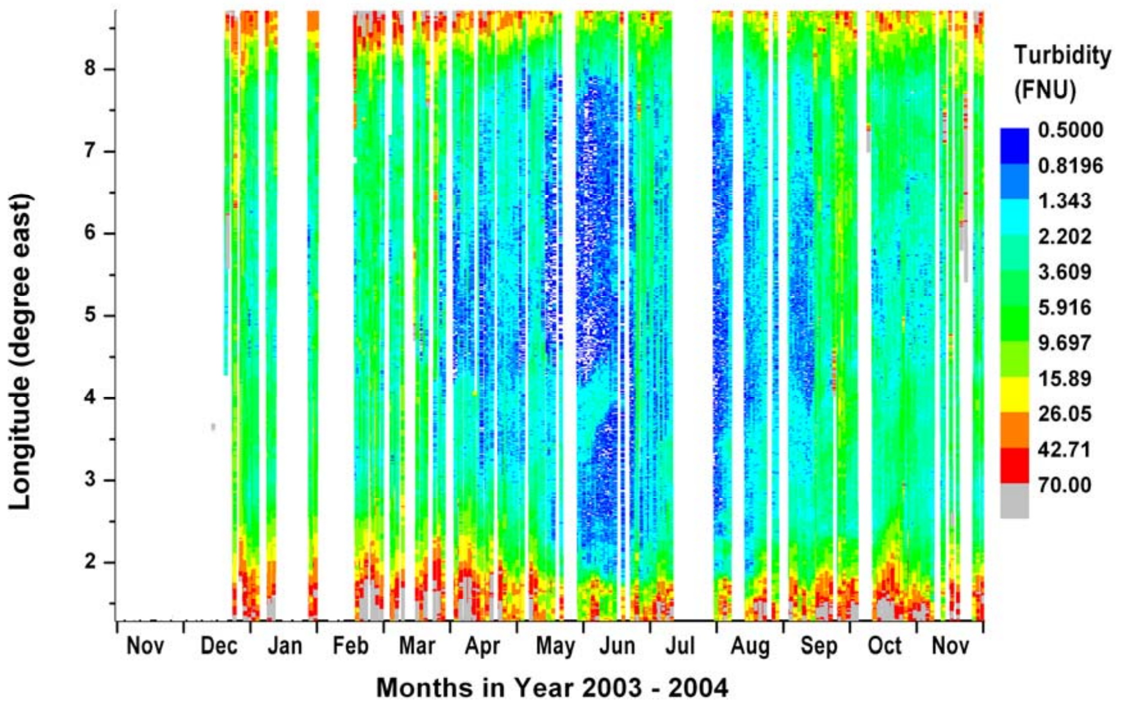


Figure 5-4: Reliable data of salinity along the transect of the FerryBox between Cuxhaven and Harwich during the First (upper) and Second (lower panel) FerryBox Year.



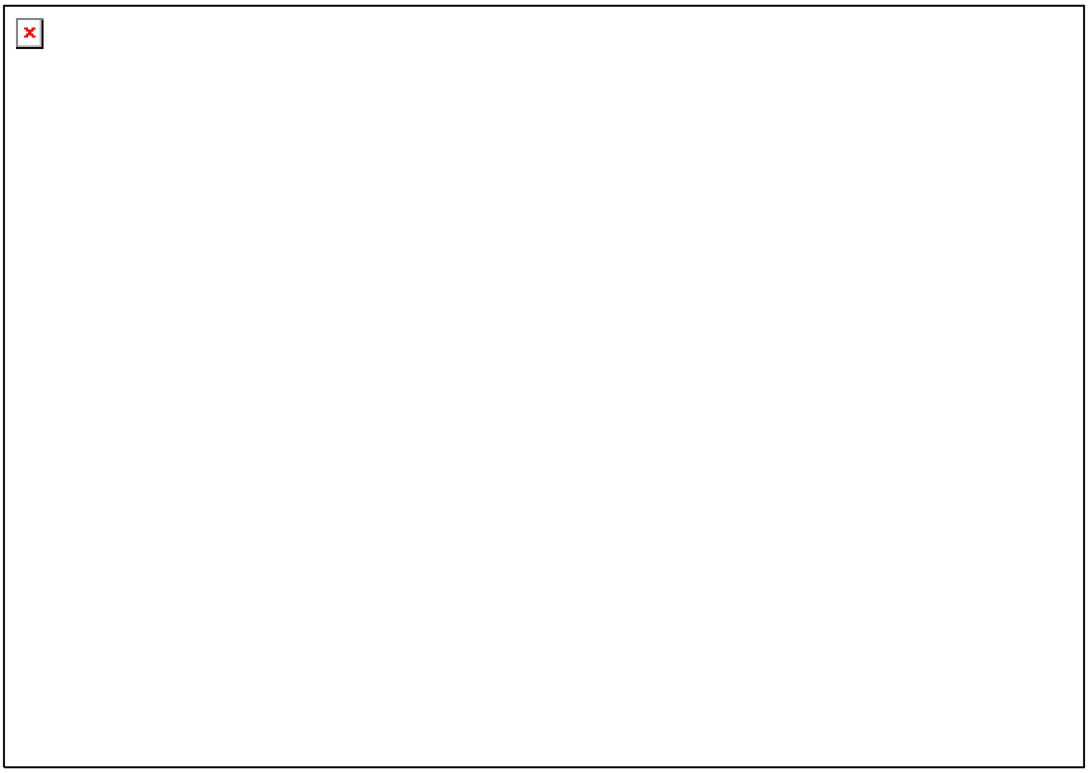


Figure 5-5: Reliable data of turbidity along the transect of the FerryBox between Cuxhaven and Harwich during the First (upper) and Second (lower panel) FerryBox Year.

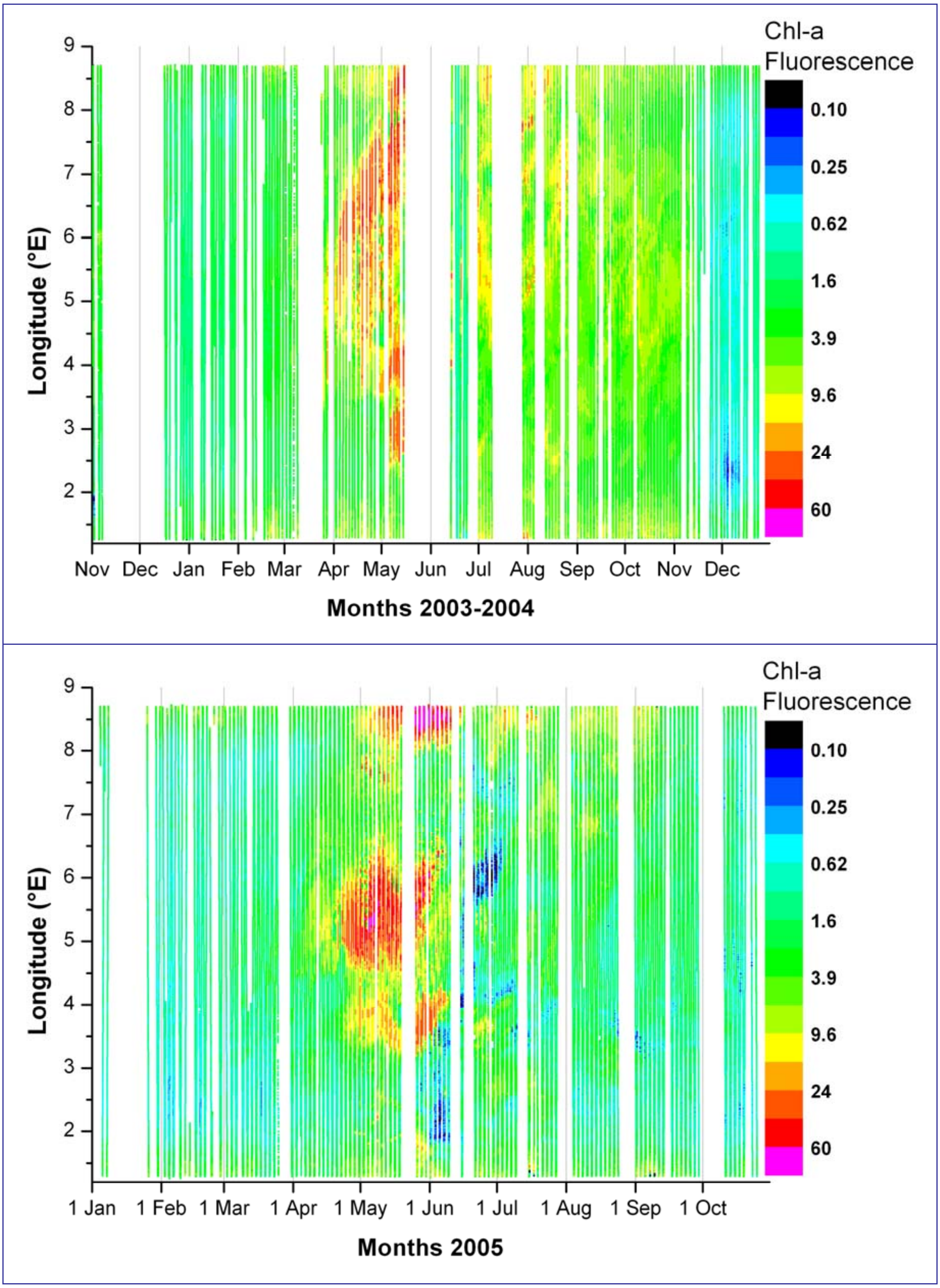


Figure 5-6: Reliable data of chlorophyll fluorescence (µg/l) (Algal-Online-Analyser) along the transect of the FerryBox between Cuxhaven and Harwich during the First (upper) and Second (lower panel) FerryBox Year.

5.6 Quality Assurance of the Data (Metrology)

Automated water sampling to check the calibration of the salinometer and the nutrient analysers on a regular basis was implemented after installing a cooled water sampler in September 2004. The water samples were taken automatically at fixed positions. The samples for nutrients are filtrated and store at –18°C after the ferry reached the port. The salinity samples remained untreated. Before the sampler was installed samples for comparison have only been taken by manual sampling during three cruises in November 2003, April 2004 and July 2004. Until now no check of the absolute temperature measurements have been carried out. An example of a comparison of water samples with salinity measurements in the lab is shown in Figure 5-7.

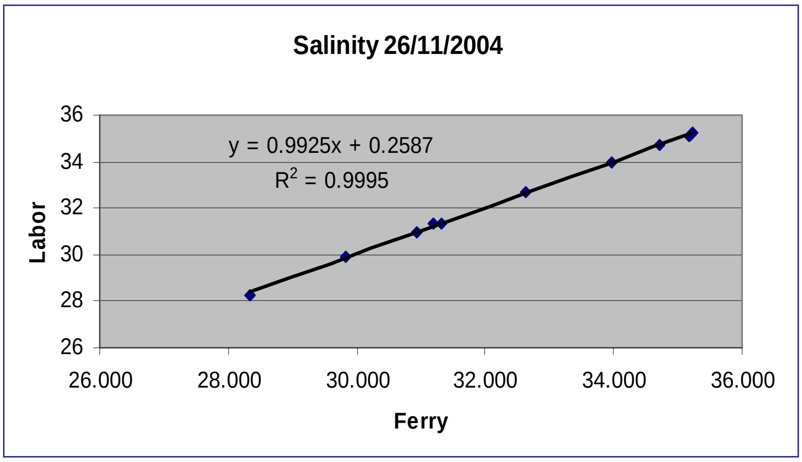
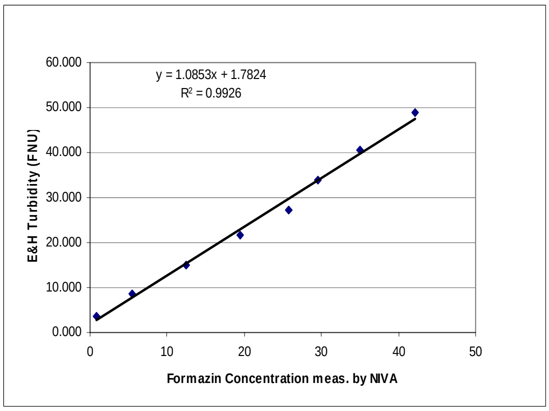


Figure 5-7: Validation of salinity measurements by measuring water samples in the laboratory.

The turbidity sensor has been tested inside the system with certified Formazine solutions from NIVA. Figure 5-8 shows the calibration curve and the comparison with sub samples checked by NIVA after calibration.



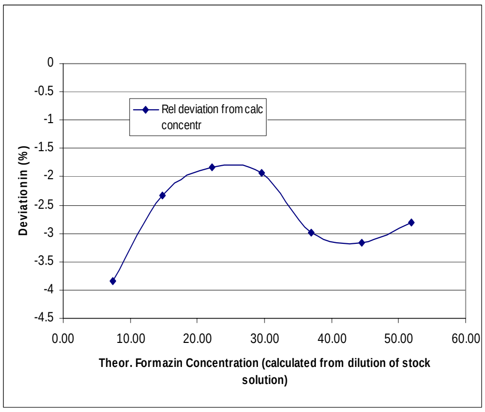


Figure 5-8: Intercomparison of the turbidity sensor by using certified stock solutions delivered by NIVA (left panel: Correlation between certified Formazine concentration and measured values, right panel percentage of deviation of the measured concentration).

The sensor shows a very good linearity and the data are well comparable. However, there is an offset (about 2 FTU) due to the formation of very small air bubbles which cannot be removed by the debubbling device.

The stability of the fluorescence sensor has been checked during maintenance by using a solid standard (secondary standard) from Turner Design.

5.7 Specific Experiences with the Four Basic Parameters

The data of temperature were obtained from the salinity sensor which works very well. Until now the offset of temperature signal due to warming up of the water between inlet and FerryBox has not been proved but seems to be in the range of 0.5 °C. A second certified temperature sensor was mounted near the water inlet.

The salinity sensor (FSI, USA) ran very stable over a long period of time. However, in Mai 2004 the sensor had to be returned to the manufacturer for recalibration due to a sudden shift of about 1 unit.

The turbidity sensor (Endress & Hauser, Germany) worked also properly throughout the whole period. Due to the internal wiper no disturbances by coatings of iron were detected.

The used chlorophyll fluorescence sensors (Turner Design & bbe moldaenke) worked well. However, it turned out that the SCUFA-II (Turner Design) showed shifts in the sensitivity due to iron coatings. These effects did not appear for the AOA sensor (bbe moldaenke). The reason may be that this sensor incorporates a cleaning brush which cleans the optical windows automatically.

5.8 Data Storage and Access

The data are automatically transferred to a database system (Oracle) when the ferry reaches the harbour. All data from the database can be graphical presented on the internet (http://ferrydata.gkss.de) in different ways.

1.) Plot of one or more variables from one selected transect against the distance (from Harwich harbour)

2.) Plot of one selected variable from one or more transects against the distance. This shows the development of the selected variable along the transect during time

3.) Plot of a time series at a certain position (interactive selection from a map) from one or more variables.

4.) Coloured dot plot from one selected variable in a position/time diagram in order to show the temporal behaviour of one variable along the transect

For un-registered users only the graphical presentation is possible. Registered users can download selected data from the database.

6 Route 4 – Wadden Sea (NIOZ)

6.1 System Description

Royal NIOZ operates a continuous through-flow system and a continuously recording Acoustic Doppler Current Profiler (ADCP) on the ferry Schulpengat that crosses the southernmost tidal inlet of the Wadden Sea between the island Texel and den Helder (mainland) every 30 minutes, daily between 06.00 am and 22.00 pm. The distance between both harbours is approximately 4 km. Each crossing takes about 15 minutes. The system was first installed in 1998. Since early 2004 the flow-through system has been extended with optical sensors for fluorescence and optical backscatter, in addition to the temperature and salinity sensor.

6.2 FerryBox Operation

The system runs automatically and is controlled by the ferry position. When the ferry leaves the harbour the ADCP and flow-through system starts running. The sensors are manually cleaned weekly. Some parts of the system (ADCP, temperature sensor) are checked daily by a check on the display in the passenger lounge of the ferry. Other sensors are checked weekly. Data is stored on the ferry on a workstation. Every time the ferry is on the island Texel, the data are transferred to the nearby (few 100 m) research institute by telemetry.

Results from the optical sensors (fluorescence, backscatter) appear to be not reliable. Most probably air bubbles in the system cause these problems. Installing a de-bubbling device is not an option since this would cause unwanted high residence times of the water in the flow-through system (several minutes). Given that the journey time of the each crossing is only 12 to 15 minutes this is not a feasible option. Therefore it was concluded that optical observations are not possible on this short route.

6.3 Area Specific Experiences

Variations in salinity can be high both on tidal and seasonal time scales, ranging from 15 to 35. Even within one transect the spatial variability can exceed a few pot. A similar large variability is present in the temperature signal. From other observations it is known that also the variations in fluorescence and optical back scatter can be large. This variability is especially large during ebb tide when water originating from the Wadden Sea flows through the inlet.

6.4 Maintenance Procedures

The maintenance needed varies enormously. Under normal (good) circumstances the sensors are manually checked weekly, taking roughly 1 hour per week. However, failures of the software and/or sensors and/or problems caused by biofouling can increase the time needed substantially. The total time needed for maintenance of the flow-through system is estimated to be some 2 man months per year.

The ADCP only requires maintenance during installation. During six years of operations there was only a marginal problem with the power supply (broken cable) during the first year. In 2004 the ferry hit the ground causing serious damage to the hardware. For maintenance, divers are needed to recover and reinstall the ADCP. However, no maintenance is needed once the system runs again.

6.5 Data Availability

In 2004 new hardware (sensors, pump, pipes) was installed together with a revised software system. This gave all kind of problems during the beginning of the year resulting in a bad data return till roughly April 2004. During the summer period the data return was reasonable although especially the salinity sensor had some problems (possibly due to biofouling) in summer.

The main reason for failures during the fall appeared to be a very low flow rate through the system during a large number of periods that was discovered only later when the data were checked. Apparently biofouling within the pipes (possibly due to growth of mussels etc.) caused these problems. In December 2004 and January 2005 the data return was good (Figure 5-1). In January the ferry went out of service. Then temperature and salinity sensors were sent back to the factory for calibration.

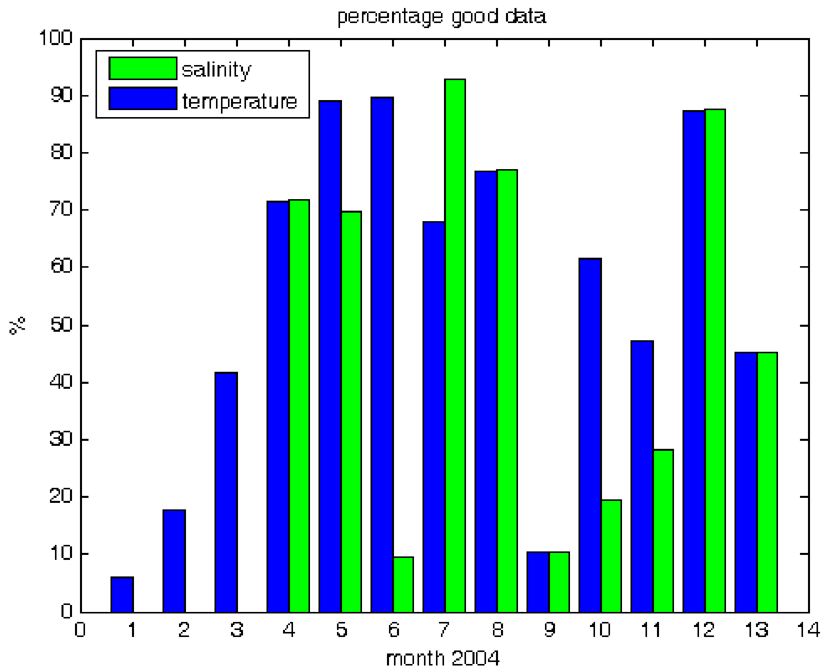


Figure 6-1: Percentage of good data from the salinity and temperature sensors of the flow-through-system (1 = January 2004, 13 = January 2005) on the Texel – Den Helder ferry.

Given the large problems with biofouling combined with the planned new ferry coming into service in June, it was decided not to reinstall the sensors on this system. Moreover, on the new ferry NIOZ's wishes for doing continuous observations were taking into account already during the design of the ferry. This results in a moonpool through which a platform can be lowered with the sensors attached. Then, these sensors measure directly underneath the ferry and no flow-through system is needed. Doing so, NIOZ hopes to get rid of the biofouling problems in these eutrophic and turbid waters. However, there was a long delay in the delivery of this new ferry and no further observations are available after mid January 2005.

Temperature and salinity data for the year 2004 are displayed in Figure 6-2 and Figure 6-3. For the optical sensors no data are shown since the quality of the data is not good, most probably due to air bubbles in the flow-through system.

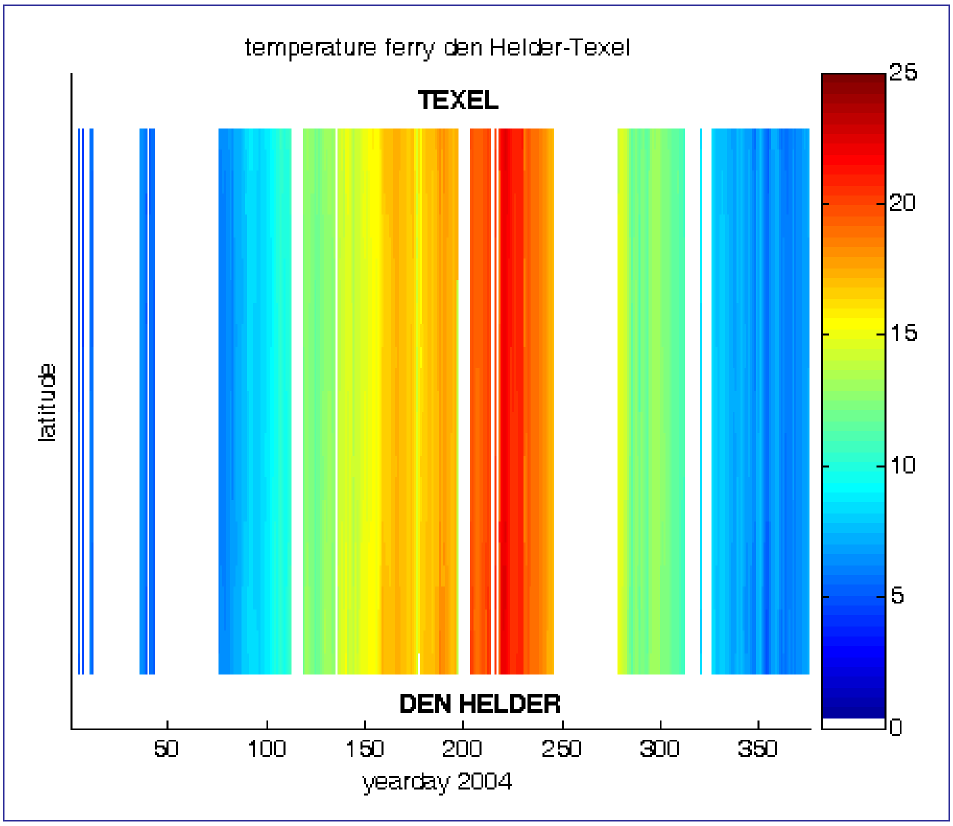


Figure 6-2: Observed temperature from the flow-through system on the Texel – Den Helder ferry.

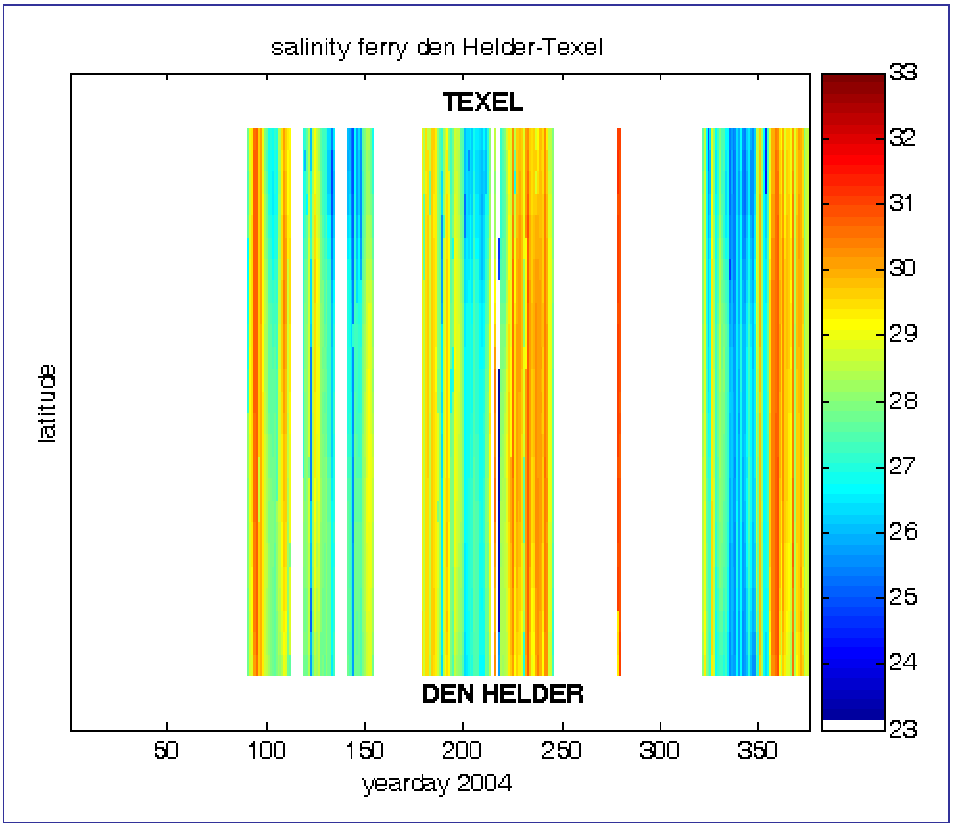


Figure 6-3: Observed salinity from the flow-through system on the Texel – Den Helder ferry.

6.6 Quality Assurance of the Data (Metrology)

First visual check of the data is done weekly. Calibration and validation of the temperature and salinity sensor is done by yearly calibration of the sensor by the manufacturer and by comparing the observations on the Texel side of the inlet with the continuous observations on temperature and salinity that are done from the nearby (100 m) NIOZ jetty.

Calibration of the optical backscatter is done by comparing with observations (water samples and CTD) that are regularly (2 – 4 times per year) done during 13 hours calibration cruises with the NIOZ research vessel RV “Navicula” which was anchored in the middle of the inlet, nearby the transect of the ferry.

Calibration of the fluorescence data was be done by comparing to the fluorescence and chlorophyll observations that are done regularly (once per week in spring) by taking water samples from the nearby NIOZ jetty.

6.7 Specific Experiences with the Four Basic Parameters

During 2004 a new flow-through system, both with new hardware (sensors, pump, pipes) and software was installed. This gave many start-up problems, in hindsight mainly due to failure of the software. Once these problems were solved the temperature and salinity sensors functioned well. The optical sensors seem to function well, but the data output is such that there is serious doubt on their quality. Most probably this is caused by air bubbles floating in the system. Due to the very short track of the Texel – Den Helder route, a de-bubbling device cannot be installed.

In the end of 2005 / beginning of 2006 the sensors were directly deployable into the water, below the vessel, via a platform that can move through a moonpool. This was made possible by taking into account the specific wishes of NIOZ already during the design phase of the new ferry.

6.8 Data Storage and Access

Files are stored internally on a database at the NIOZ. At the moment these data are accessible only internally, within the institute. Part of the data can be inspected visually from graphs that are shown on a public website.

7 Route 5 – Irish Sea (NERC.POL)

7.1 Introduction

NERC.POL has instrumented the Liverpool Viking, which crosses the Irish Sea from the Mersey. Measurements started in December 2003 and continue to the present. The results contribute both to the Liverpool Bay Coastal Observatory and to the European FerryBox Project, which brings together users of instrumented ferries on a variety of European routes from the Baltic Sea to the Mediterranean and the Bay of Biscay.

7.2 Ferry Routes

The ferry is the "Lagan Viking" operated by Norse Merchant. The ferry's name changed to "Liverpool Viking" on 10 January 2005 so that a new ferry brought into service in the Irish Sea from 20 July 2005 could be called "Lagan Viking". On 9 November 2005 the ferry company, Norse Merchant, was acquired by the company Norfolkline.

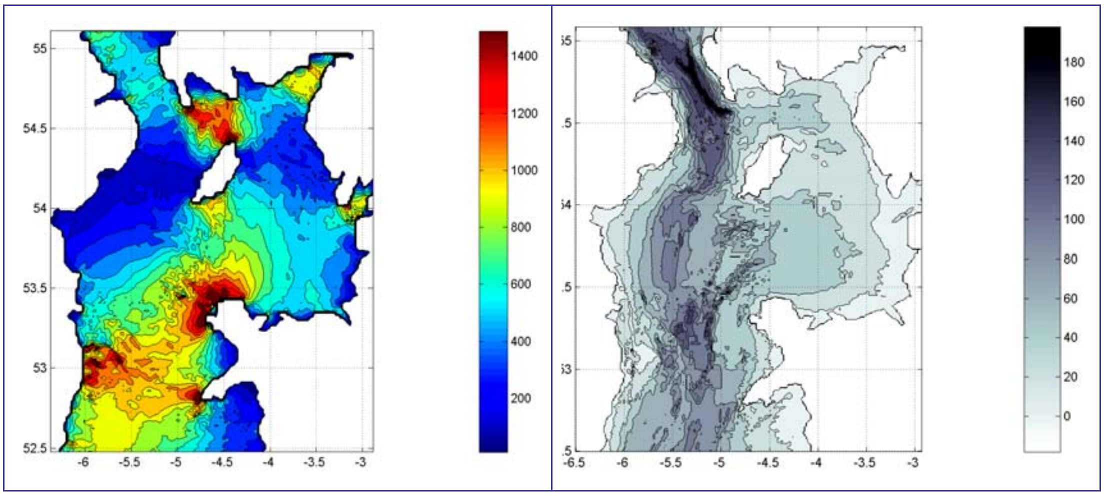


Figure 7-1: Irish Sea water depths (m); contours every 20 m (left panel) and maximum amplitude (right panel) of the M_2 tidal current in mm s^{-1} (contours ever 0.1 m s^{-1}).

The ferry has been operated on two routes across the Irish Sea (Figure 7-1 and Figure 7-2) since instruments were installed in December 2003 – Birkenhead to Belfast and Birkenhead to Dublin. The Birkenhead to Belfast crossing is 135 miles (250 km) long and takes about 7 hours each way, with an average speed of just less than 20 knots. On this route the ferry operates 6 days a week, completing 13 one way crossings, with Mondays off. Mondays alternate between Birkenhead and Belfast, imposing at best a fortnightly servicing pattern for the equipment.

The ferry nominally departs at 10:30 and 22:30 each day but in fact the sailing times are quite variable (between 11:00 and 15:00 and between 21:00 and 04:00 – Figure 7-3). Initially the ferry almost always passed to the south and west of the Isle of Man (Figure 7-2), but more recently it has also frequently gone to the east and north (104 times out of a total of 1000 crossings, up to 5 December 2005). The distances and passage times are almost identical.

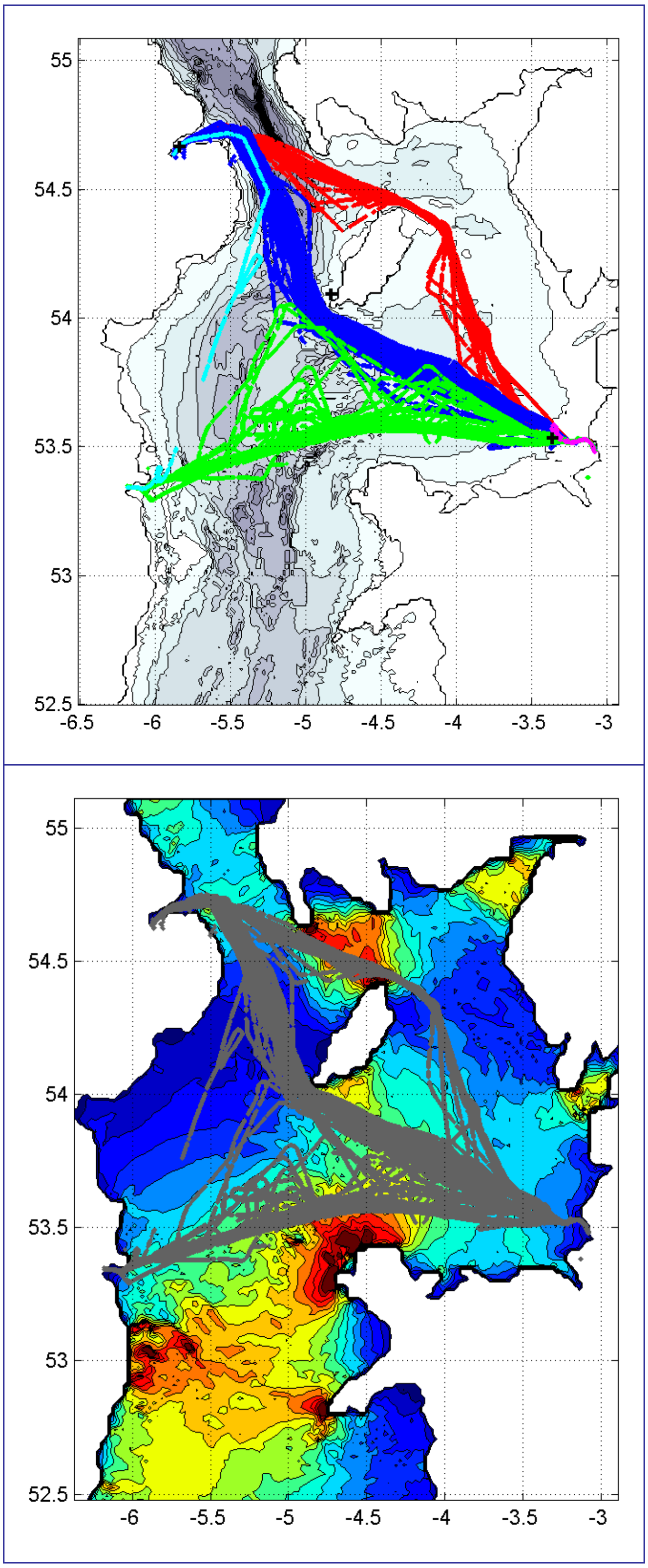


Figure 7-2: Upper panel: Ferry routes 18 October 2004 – 5 December 2005. Blue Birkenhead – Belfast south of Isle of Man; red Birkenhead – Belfast north of Isle of Man; green Birkenhead – Dublin. There has been one ´cruise from Belfast – Dublin (cyan) and another short one out of the Mersey as far as the Mersey Bar (magenta). The sites of buoy measurements and the Cypris station are denoted by a cross (superimposed on water depths). Lower panel: Ferry routes 18 October 2004 – 7 November 2005 (superimposed on tidal currents).

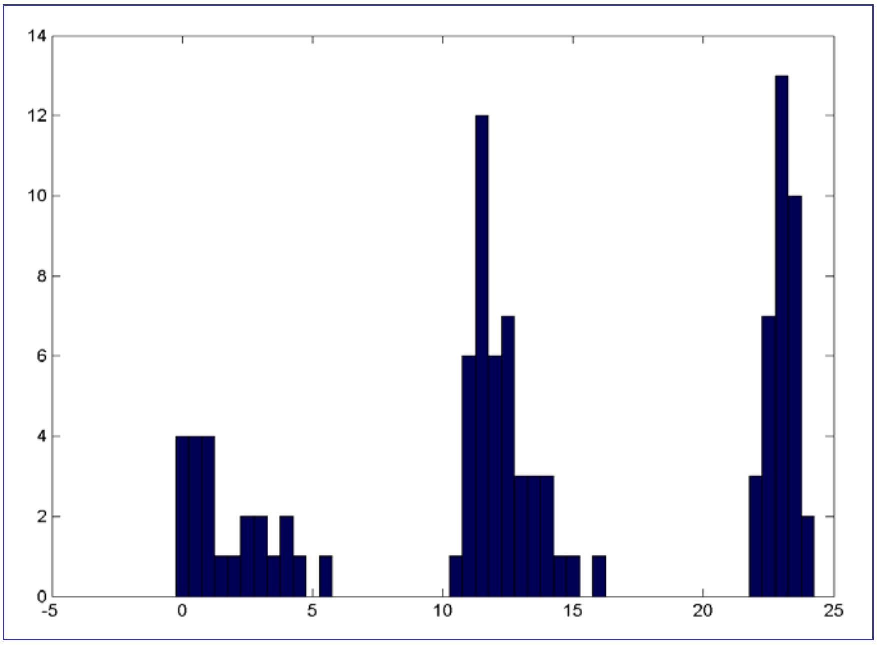


Figure 7-3: Histogram showing time in hours of sailing, for period 26 April to 24 May 2004.

When the new ferry came into operation on 20 July 2005 the "Liverpool Viking" transferred to the Birkenhead to Dublin route, a distance of 115 miles, which took on average 6.25 hours. The pattern of sailings changed slightly – there were 12 crossings in a week, with each Sunday spent in Dublin and each Monday in Birkenhead. Sailing times were nominally 10:00 and 22:00. On 12 September 2005 the ferry reverted to the Birkenhead to Belfast route, having completed 93 crossings to Dublin (there had been a further 6 in the previous year, in November 2004). Particularly on the Birkenhead to Dublin route the track shows considerable day to day variations and deviations from the shortest route.

The Birkenhead – Belfast route south of the Isle of Man is scientifically varied passing through six different hydrodynamic regions (see for instance, Simpson, 1998), which also significantly impacts their ecological function.

a) The Mersey estuary which is tidally energetic and is strongly influenced by freshwater river discharge (annual mean about 70 m^3 s^{-1}), has high nutrient concentrations and is very turbid.

b) Liverpool Bay which is tidally energetic (M_2 max amplitude in the range 0.4 to 0.6 m s^{-1}) with depths less than 40 m and can stratify through temperature and / or salinity at any time of the year. There are also significant horizontal salinity gradients resulting from the combined discharge from the rivers Dee, Mersey and Clwyd (annual mean about 200 m^3s^{-1}). The area has elevated winter nutrient levels.

c) The eastern Irish Sea, between about 4º and 5º W and between Anglesey and the Isle of Man, where the water column is well-mixed throughout the year because of the fast tidal currents (M_2 max amplitude greater than 0.8 m s^{-1}) although water depths are in the region of 50 m.

d) The western Irish Sea, to the west of the Isle of Man, where the water column stratifies thermally in summer, with surface to bed temperature differences of up to 6ºC, because of the weak tidal currents (M_2 max amplitude less than 0.2 m s^{-1}) and significant water depths 80 – 100 m.

e) The western Irish Sea / North Channel which remains well mixed throughout the year because of the fast tidal currents. The highest salinity water on the route, up to 34.3, occurs here and in region d).

f) Belfast Lough which has a small freshwater input from the river Lagan (mean 30 $m^3\ s^{-1}$) and weak tidal currents; the salinity is about 33.

There are fronts between the well-mixed and stratified regions, especially c) and d), accompanied by an anti-clock wise gyre with average currents up to 0.2 ms^{-1}, but also between d) and e) and between b) and e) – the so-called 4º W front. During winter months the water is warmest in the middle of the crossing, region d), whereas in summer the warmest water is at the ends, closest to the coasts. Hence the temperature seasonal cycle is largest close to the coast, particularly in Liverpool Bay (amplitude ~15 ºC) and smallest (about half this amplitude) in region d).

The route to Belfast north of the Isle of Man passes through regions a), b), e) and f) and regions with some similarity to c) and d) but in reverse order.

g) To the east of the Isle of Man tidal currents are weak, but not as weak as to the west in d); the M_2 max amplitude is approximately 0.3 m s^{-1}.

However, water depths are shallow so that thermal stratification occurs sometimes but does not become well established and hence is broken down by storms or spring tides. There are shallow sandbanks to the north-east of the Isle of Man, for instance Bahamas and King William Banks. The salinity is less than d).

h) Between the Isle of Man and the Mull of Galloway / Burrow head the water depth is less than 50 m but the tidal current are very strong, The M_2 maximum amplitude is greater than 1.2 ms^{-1}, so that mixing is intense.

The Birkenhead to Dublin route crosses regions a), b) and c) and a vertically well mixed region of high salinity water similar to region e), between Anglesey and Dublin The end of the crossing, Dublin Bay is similar to f), but this time influenced by the discharge from the river Liffey, with a mean annual discharge of 26 $m^3\ s^{-1}$. Apart from region (b) the water column is well-mixed throughout the year on this route. Because of the shipping separation zone off the north-west coast of Anglesey the route avoids the strongest tidal currents there.

The different regions encountered by the ferry are illustrated by two schematic diagrams showing the different types of water column structure in the Irish Sea and their ecological consequences. Figure 7-4 and the accompanying Table 7-1 on undesirable disturbances (Tett, 2004) and Figure 7-5 from the JNCC report on the Irish Sea Pilot Project (JNCC, 2004).

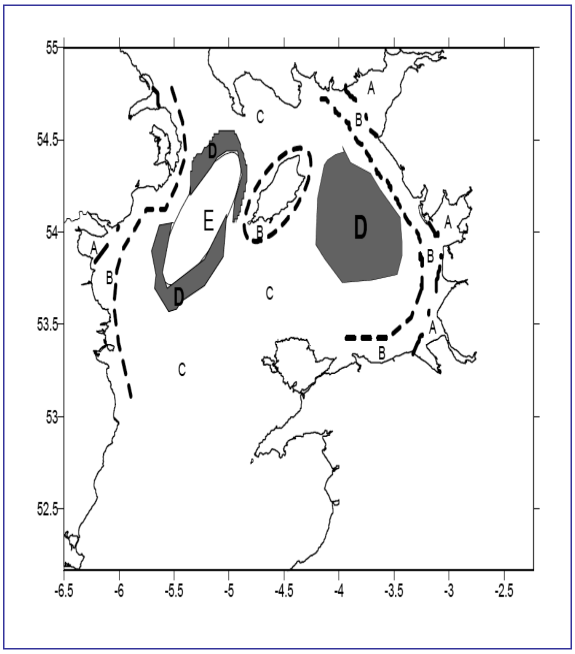


Figure 7-4: A view of the ecohydrodynamic regions of the Irish Sea (Tett, 2004). The letters denoting the different regions are explained in Table 7-1.

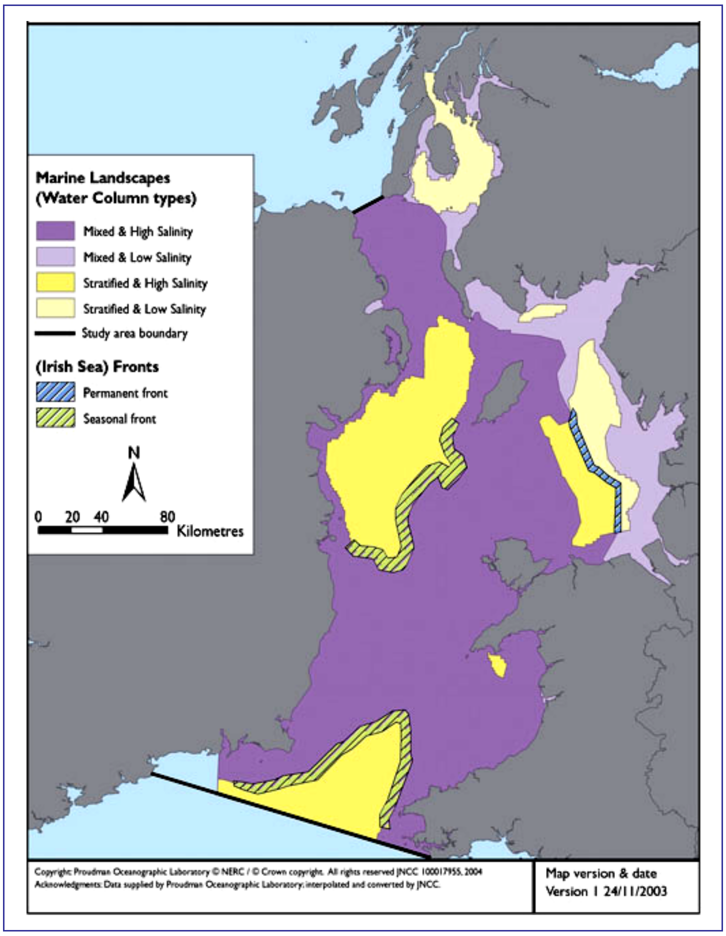


Figure 7-5: Different water column structure in the Irish Sea (JNCC, 2004).

Table 7-1: Ecohydrodynamic typology for the Irish Sea (Tett, 2000).

Type	Physical conditions (inc. practical salinities)	Nutrient (DAIN, DIP and Dsi) concentrations	N:Si (atoms) ratio	Oxygen	Diatom: dino-flagellate ratio	Phytoplankton, general
A	Low salinity (generally <30); no thermal , some haline, stratification	High: Winter: DAIN > 20 μM; DIP > 3 μM; DSi > 10 μM	Spring peak ~ 5, Winter <2	Little difference between surface and bottom water concentrations at any time of year	Early spring peak: ~20-25	Prolonged growth season (~ 6-7 months). Diatoms abundant throughout. Dinoflagellates peak initially in early Summer with highest abundances in late Summer. Nanoflagellates peak after silicate depleted
B	Salinity ~ 30-33; no thermal , some haline ,stratification	High: Winter: DAIN ~ 16 μM; DIP ~ 1 μM; DSi ~ 10 μM	Spring peak ~4, Winter <2	Generally well mixed throughout year. Bottom waters 10-25% lower than surface.	Highest during early spring: ~12-18	Diatom abundances show a clear spring peak. Dinoflagellates similar to type A. Nanoflagellates abundant throughout Spring and Summer coinciding with period of low silicate concentrations
C	Offshore mixed; salinity > 34	Moderate: Winter: DAIN < 10 μM; DIP < 0.6 μM; Dsi < 6 μM	Peak in early Summer: ~2-3; Winter < 1.5.	*no data*	Early (winter) peak >20 declining thereafter	Distinctive Summer peak in abundances of all major algal classes. Abundances generally low throughout the remainder of the year.
D	Offshore intermediate. Summer stratific-ation in some years; salinity >33	Moderate: Winter: DAIN < 10 μM; DIP < 0.6 μM; Dsi < 6 μM	Peak (time between B & C): ~2.5; Winter < 1.5	Some evidence for decreased bottom water O_2 % saturation during some years	Early (winter) peak > 6 declining thereafter.	Similar to type C although abundances of all classes are higher.
E	Offshore stratified. Salinity >34; thermocline present in Summer.	Moderate-low: Winter: as D (DAIN 8-10 μM). Depleted in upper water column during Summer	Winter > 1.5	Bottom O_2 saturation 15-25% less than surface during Summer		Spring bloom of variable timing and magnitude, dominated in most but not all years by diatoms.

7.3 Instrumentation, Maintenance and Quality Assurance (Metrology)

The ferry was instrumented with a Sea-Bird SBE 16plus CTD fitted with a Seapoint turbidity sensor (range maximum 25 FTU) and a CTG MINI^{tracka} II fluorimeter. The instruments were immersed in 900 mm high by 290 mm diameter cylindrical tank situated in the ship's engine room which was fed with water from the engine's cooling system, intake at 3.5 m below the surface, at a rate to flush the tank every 30 s. Data were recorded every 30 s (because of the fluorimeter set up), equivalent to a 300 m horizontal resolution. As well as being recorded internally data were sent via a cable to the bridge where a combined ORBCOMM GPS unit was located, recording position every 10s.

The ship's position and a spot reading were e-mailed every 15 minutes, starting on 18 October 2004, and plots displayed on the web site of the Coastal Observatory (http://coastobs.pol.ac.uk). Two sets of instrumentation have been used with the intention, if both are working, of swapping them on each visit to allow cleaning and testing at leisure back at the laboratory. The sets are Sea-Bird 4490, turbidity sensor 10216 (10223 from 29 November 2004; 1836 from 18 April 2005), fluorimeter 175199 and Sea-Bird 4741, turbidity sensor 10223, fluorimeter 4745, first deployed on 7 February 2005.

All the instruments were purchased new for the project. Their calibration history by the manufacturer is

Sea-Bird

4741	Prior to first deployment
6 July 2005	After failure of the conductivity cell
4490	Prior to first deployment
16 February 2005	Routine, at NERC.NOC, Southampton

Seapoint Turbidity

10216	Prior to first deployment
10223	Prior to first deployment (14 January 2002)
1836	Prior to first deployment (20 December 2001)

CTG MINI^{tracka}

4745	Prior to first deployment (23 November 2004)
175199	Prior to first deployment (14 January 2002)

7.3.1 Temperature and Salinity Sensor Checks

The ferry Sea-Bird CTD was configured to measure the temperature, conductivity and salinity of a specimen of water of a known and accurately measured salinity. The water was acquired on Coastal Observatory cruises and its salinity determined at the School of Ocean Sciences at Menai Bridge using a Portasal precision salinometer. A reference temperature was obtained using a Tinsley-ASL precision thermometer with a pt100 platinum resistance "smart" probe with its tip immersed in the same specimen of water. Measurements were taken before and after an acid clean of the Sea-Bird conductivity cell (see Table 7-2).

The procedure is as follows:

- Fill a bucket with water of a known salinity.
- Place the Seabird CTD in the bucket so that the conductivity cell is fully immersed.
- Use a 60 ml syringe to force the specimen water through the conductivity cell several times to ensure the cell is fully 'wet' and reduce the possibility of trapped air bubbles within the cell.
- Place a pt100 Platinum resistance (PRT) 'smart' temperature probe tip in the bucket of water of known salinity.
- After several minutes, take a series of readings of temperature, conductivity and salinity from the Seabird CTD to confirm that the measurement has stabilized.

- Then take three consecutive temperature, conductivity and salinity readings from the CTD and use the mean of these values.
- Record the reading generated by the PRT probe using a Tinsley-ASL F200 precision digital thermometer.
- Perform an acid clean of the Seabird CTD conductivity cell, place the CTD back in the specimen water and repeat the measurement procedure.

Table 7-2: Results of the checks of the Sea-Bird temperature and salinity sensors.

Temperature (ºC)

Date	Sensor number	Pre-acid clean			Post acid clean		
		Instrument	Reference	Difference	Instrument	Reference	Difference
22/08/05	4490	20.286	20.308	-0.022	20.326	20.291	0.035
05/09/05	4741	20.700	20.694	0.006	20.801	20.804	-0.003
26/09/05	4490	18.835	18.806	0.029	18.674	18.703	-0.029
10/10/05	4741	17.860	17.840	0.020	17.757	17.783	-0.026
24/10/05	4490	17.684	17.675	0.009	17.643	17.650	-0.007

Salinity

Date	Sensor number	Pre-acid clean			Post acid clean		
		Instrument	Salinometer	Difference	Instrument	Salinometer	Difference
13/10/04	4490				31.15	31.43	-0.28
22/08/05	4490	33.200	33.297	-0.097	33.177	33.297	-0.120
05/09/05	4741	32.072	32.231	-0.159	32.153	32.231	-0.078
26/09/05	4490	33.062			33.180		
10/10/05	4741	31.990			32.576		
24/10/05	4490	31.969			33.050		

7.3.2 Turbidity Sensor Checks

The procedure was designed to verify that the sensor maintains the manufacturer’s tolerance of ± 2% for the 0 to 25, 0 to 125 and 0 to 500 FTU ranges. Readings for air, filtered water and with the sensor face covered with opaque tape were recorded to test for any offsets. The Seapoint OBS turbidity sensor was then configured to make measurements of carefully diluted samples of a stock Formazine solution of a known and accurately measured turbidity. The dilutions were selected to form a representative range of values likely to be encountered in practice. Results of the turbidity sensor checks are presented in Table 7-3.

The measurement procedure was as follows:

- Cover the turbidity sensor face with opaque tape and record the turbidity reading.
- Record the sensor turbidity reading in air.
- Record the sensor turbidity reading for a bucket of 10 litres of filtered water with sensor measurement face at least 10 cm away from the bucket walls and the water / air interface.
- Fill a bucket with 10 litres of filtered water.
- Shake the bottle of stock solution of 3980 FTU so as to evenly distribute the suspension.
- Measure 15 ml of the stock suspension and add it to the 10 litre bucket of water. Stir the solution in the bucket so as to evenly dilute the stock solution. This should produce bucket of water with a solution that has a turbidity of 5.97 FTU.
- Suspend the turbidity sensor in the bucket of solution so that the sensor measurement face is at least 10 cm away from the bucket walls and the water / air interface.
- Record the turbidity reading from the Seapoint sensor.
- Repeat the above procedure for dilutions of 30 ml and 50 ml of the stock solution to test turbidity values of 11.94 FTU and 19.9 FTU respectively.
- Take a small sample of the stock 3980 FTU solution, the filtered water that has been used for testing purposes and samples of each of the dilutions used. These specimens are then to be sent to The Norwegian Institute for Water Research (NIVA) for accurate measurements for cross referencing and validation of the experimental results obtained during the Ferrybox sensor calibration testing procedure.

Table 7-3: Results of the checks of the turbidity sensors (all values in FTU).

Date	Sensor number	Instrument			Filtered water, measured at NIVA
		Covered	Air	Filtered water	
05/09/05	10223	0.00	0.02	0.64	0.15
26/09/05	1836	0.01	0.07	0.17	0.1
10/10/05	10223	0.00	0.50	0.29	0.13
24/10/05	1836	0.00	0.03	0.25	0.11

15 October 2004: Sensor 10216				
Ferry	8.0	35.0	63.7	120.0
Theoretical	8.0	39.8	62.7	119.4
Measured at NIVA	6.4	34.8	62.4	102.0

Table 7-3 continued.

5 September 2005: Sensor 10223			
Instrument	6.8	14.2	22.2
Theoretical	6.0	11.9	19.9
Measured at NIVA	5.5	12.6	20.8
26 September 2005: Sensor 1836			
Instrument	6.8	13.0	23.4
Theoretical	6.0	11.9	19.9
Measured at NIVA	5.8	11.6	20.8
10 October 2005: Sensor 10223			
Instrument	6.8	13.2	20.2
Theoretical	6.0	11.9	19.9
Measured at NIVA	6.4	12.8	19.6
24 October 2005: Sensor 1836			
Instrument	7.0	12.6	20.3
Theoretical	6.0	11.9	19.9
Measured at NIVA	6.5	11.4	18.0

Stability of stock Formazine solution; initial value 3980 FTU	
Date	Sample measured at NIVA
Date	Sample measured at NIVA
05 September 2005	4030
26 September 2005	4088
10 October 2005	4111
24 October 2005	4038

7.3.3 Chlorophyll-a Fluorescence Sensor Checks

The Chelsea Technologies Group MINI^{tracka} II fluorometer measures Chlorophyll-a concentrations from 0 to 100 µg l^{-1}. Readings were taken with the sensor in air, immersed in filtered water and using a $4x10^{-10}$ Molar Rhodamine reference block to test for any measurement offsets indicating significant changes since calibration (Table 7-4).

Table 7-4: Results of the fluorescence sensors checks (Chlorophyll-a concentrations in µg l-1).

Date	Sensor number	Air	Filtered water	Reference block
05/09/05	4745	0.04	0.17	
26/09/05	175199	0.21	0.19	
10/10/05	4745	0.12	0.12	
24/10/05	175199	0.15	0.08	1.16

7.4 Deployment History

15 December 2003	CTD suite only installed.
24 December 2003	Data download.
5 January 2004	Data download.
26 January 2004	Data download; tank cleaned.
16 February 2004	Data download.
1 March 2004	Data download.
15 March 2004	Data download. CTD data sparse because of interference from trial of ORBCOMM telemetry system.
26 April 2004	Data download; tank cleaned. GPS logger installed, sampling every minute, ORBCOMM system failed to work.
17 May 2004	Data download.
24 May 2004	Logging of GPS data stopped.
13 September 2004	Service visit. CTD and sensors removed for cleaning; 140 days since previous cleaning because of staff shortages.
4 October 2004	GPS and ORBCOMM system re-installed with aerial re-positioned to the rail above the bridge; the system now works.
	The conductivity sensor was rinsed with Triton X-100.
	Salinity and turbidity calibration tests.
18 October 2004	CTD and sensors re-installed; start of data telemetry via ORBCOMM every 15 minutes.
27 October 2004	The Belfast to Birkenhead crossing passes to the north of the Isle of Man.
30 October 2004	Ferry docked in Birkenhead for 2 days.
1 November 2004	Data download.
	First 3 crossings to Dublin as a replacement ferry.
	All salinities too low; data wrong.
15 November 2004	Data download. Conductivity sensor cleaned with hydrochloric acid resulting in an increase in salinity by 4.3.

The Sea-Bird power supply was accidentally switched during this period resulting in only 2 days data as the internal batteries drained. No turbidity data.

29 November 2004	Data download; conductivity cell acid cleaned. Turbidity sensor replaced by serial number 10223, the instrument had leaked with one pin completely corroded away.
13 December 2004	Data download; conductivity cell acid cleaned. Fluorimeter replaced by serial number 04-4745-001 for thorough cleaning. A broken ship's separator valve meant no water would now flow though the system - it took a month to replace. Therefore no subsequent data. Temperature data wrong for period 29 November -13 December – valve not working properly for these crossings?
January 2005	Lagan Viking docked in Liverpool.
13 January	Sailings restarted; first strip triangular Birkenhead – Dublin – Belfast, then back to normal route.

7 February 2005	First Monday in Birkenhead since New Year. CTD replaced with 4741 to check clock and give good clean and for sensor calibration at SOC. Turbidity sensor and fluorimeter not changed. New CTD fitted with pressure sensor (strain gauge) therefore e-mail message length different. Management problems with Vascotrack and ORBCOMM; e-mails restart on 16 February. 4490 sent to SOC for re-calibration. Deployment lasts 70 days; no salinities since anti-fouling plugs not removed.
18 April 2005	Data download, tank clean, instrument swapped to 4490. Deployment lasts 56 days, 10.5 days in Liverpool dock (19 -30 May).
13 June 2005	Data download, tank cleaned, instrument cleaned and re-installed. Conductivity cell on 4471 faulty; instrument returned to Sea-Bird for repair.
5 crossings north of Isle of Man	
27 June 2005	Data download, tank cleaned, instrument cleaned and re-installed. 9 crossings north of Isle of Man
11 July 2005	Data download, tank cleaned, instrument cleaned and re-installed. 2 crossings north of Isle of Man; swapped to Dublin route on 20 July.
25 July 2005	Data download, tank clean, instrument swapped to 4471. Dublin route.
8 August 2005	Data download, tank clean, instrument swapped to 4490. Dublin route.
22 August 2005	Data download, tank clean, instrument swapped to 4741. Dublin route.
5 September 2005	Data download, tank clean, instrument swapped to 4490. First week Dublin route; last two weeks Belfast routes; 12 crossings north of Isle of Man. First crossing on Belfast route data wrong – pump not switched on?
26 September 2005	Data download, tank clean, instrument swapped to 4741. 13 crossings north of Isle of Man.
10 October 2005	Data download, tank clean, instrument swapped to 4490. 11 crossings north of Isle of Man.
24 October 2005	Data download, tank clean, instrument swapped to 4741. 4490 returned to manufacturer for testing of conductivity cell. 19 crossings north of Isle of Man.
7 November 2005	Data download, tank clean, instrument cleaned and re-installed. 15 crossings north of Isle of Man.
21 November 2005	Data download, tank clean, instrument cleaned and re-installed. 10 crossings north of Isle of Man.
5 December 2005	Data download, tank clean, instrument cleaned and re-installed.

7.5 Data Return and Quality

7.5.1 Position

26 April to 24 May	2004 data every minute.
4 October 2004 to present	Every 10 seconds. There are significant gaps in the logged position data since the GPS aerial is sited inside the bridge – there were no spare channels to take a lead outside for an external mounting of the aerial. This system is completely separate from the telemetry system.

CTD sensor data taken from between Longitudes 3.08º W (Liverpool) to 5.875º W (Belfast) or 6.185º W (Dublin).

7.5.2 All CTD Sensors

15 December 2003 – 15 September 2004.	Data. Between 1 and 15 March 2004 the data were sparse (average 45 samples per crossing compared with normal 802) because of interference between CTD and prototype telemetry system.
15 September – 18 October 2004.	No data; system removed for a thorough clean.
18 October - 17 November 2004.	Data.
17 November – 29 November 2004.	No data; the power supply to the battery charger was switched off by someone on the ship.
29 November – 13 December 2004.	Data doubtful; separator valve already misbehaving?
13 December 2004 – 7 February.	No data; broken ship's separator valve, and then waiting to visit ferry and re-install instrumentation.
7 February – 18 May 2005.	Data.
19 – 30 May 2005.	Ferry in dry dock.
1 June – 5 December 2005.	Data except for one crossing on 12/13 September when valve not opened?

7.5.3 Temperature

The data quality was good throughout, relying on manufacturer's calibration Figure 7-6. Figure 7-7 shows the temperature and salinity data returns for the two years of operation.

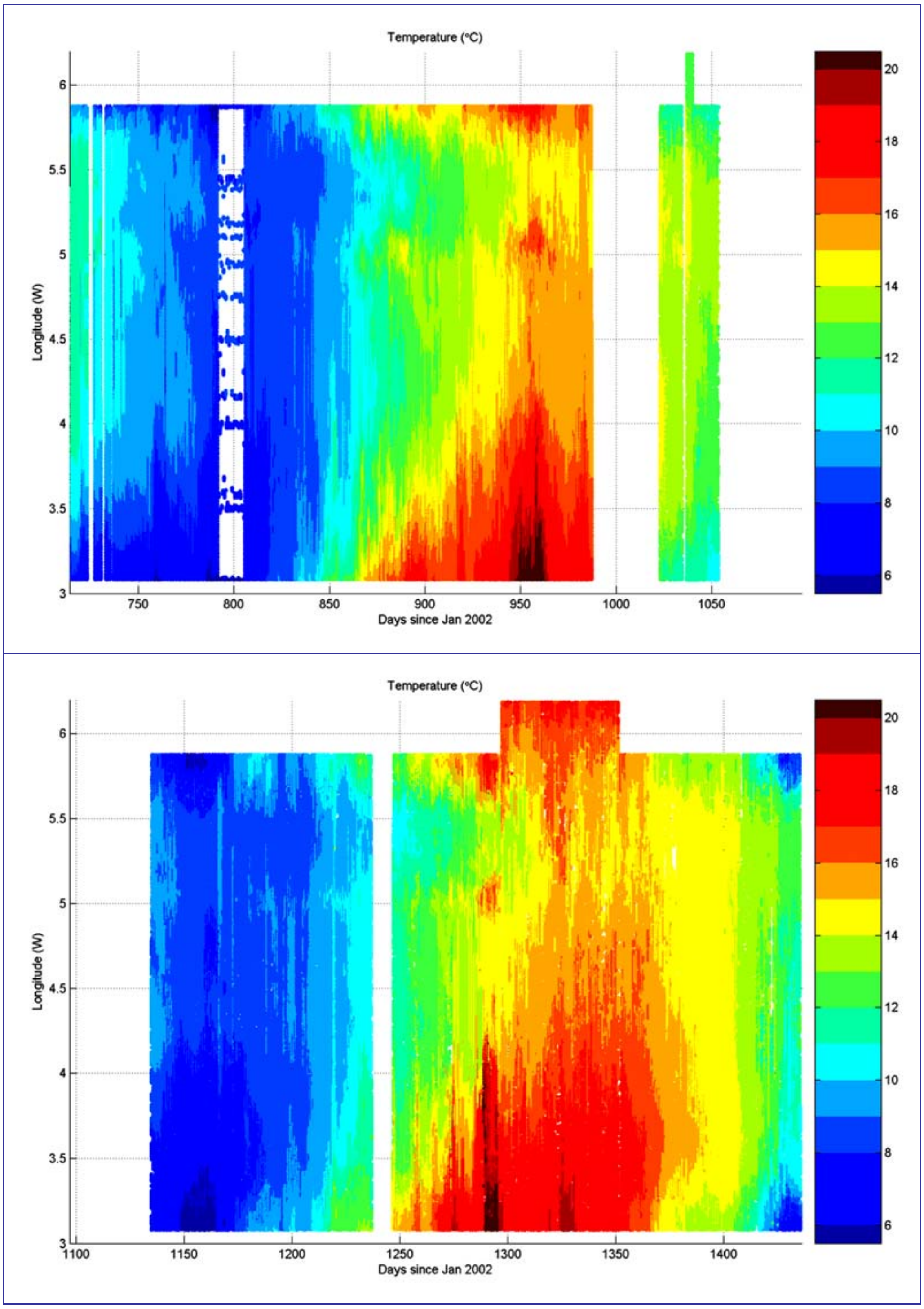


Figure 7-6: Upper panel: Temperature from 15 December 2003 (day 714) to 31 December 2004 (day 1096), Lowe panel: Temperature from 1 January (day 1097) to 5 December 2005 (day 1435). Birkenhead is at the bottom of the plot and Belfast / Dublin (west of 6º W) at the top.

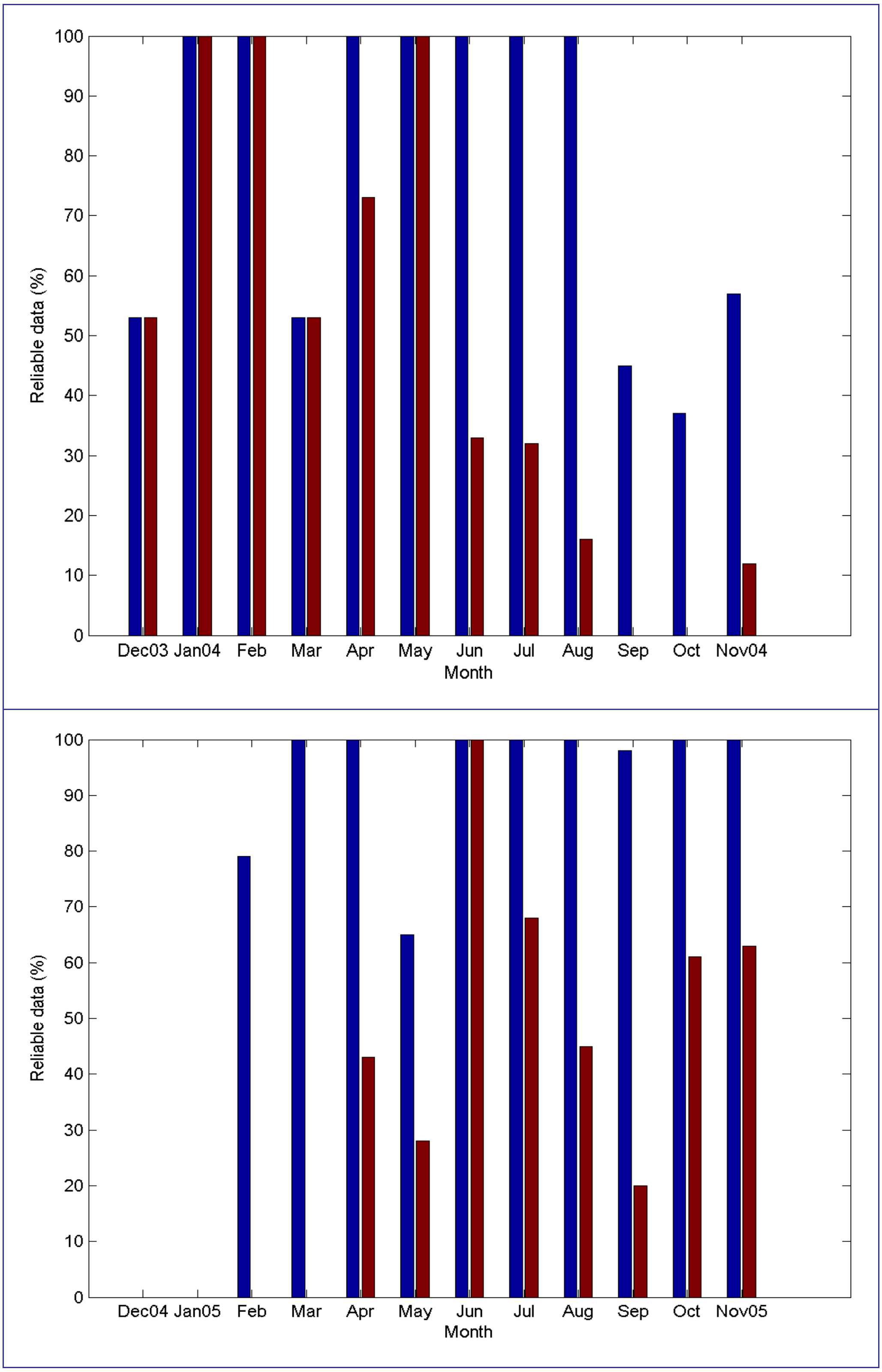


Figure 7-7: Plot of reliable data from December 2003 – November 2004 (upper) and December 2004 – November 2005 (lower panel). Temperature is in blue and salinity in red.

7.5.4 Conductivity / Salinity

The data (Figure 7-8) quality was patchy throughout; sensor subject to fouling. Manufacturer's calibration applied.

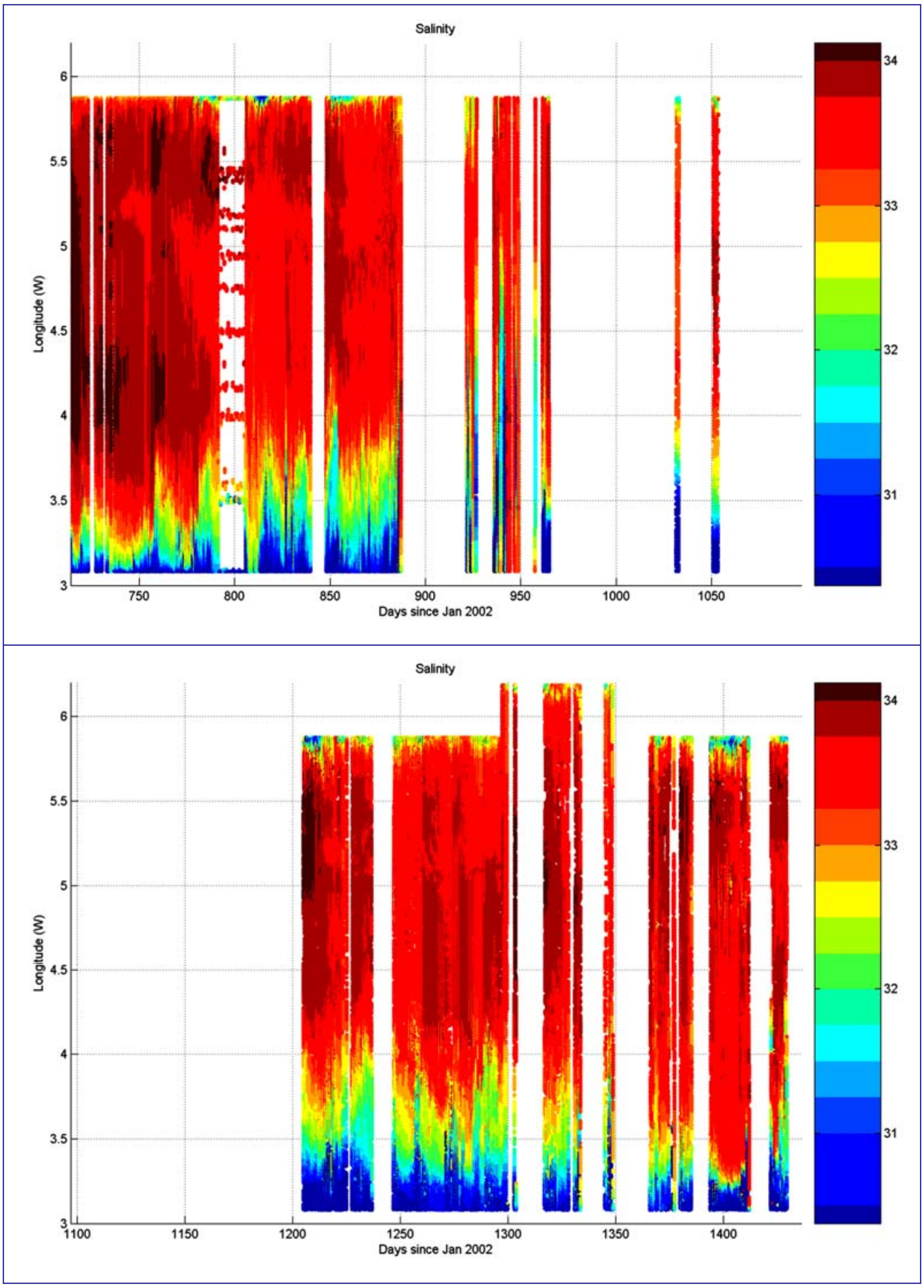


Figure 7-8: Upper panel: Salinity from 15 December 2003 (day 714) to 31 December 2004 (day 1096). Lowe panel: Salinity from 1 January (day 1097) to 5 December 2005 (day 1435). Birkenhead is at the bottom of the plot and Belfast / Dublin (west of 6º W) at the top.

Good salinity data was achieved from

- 15 December 2003 - 18 April 2004
- 26 April 2004 - 6 June 2004
- Patchy data in July, August 2004
- 15 – 17 November 2004
- 18 April – 20 July 2005
- 8 - 19, 22 – 25 August 2005
- 5 - 8 September 2005
- 26 September – 15 October 2005 patchy
- 24 October – 11 November 2005
- 21 – 28 November 2005

The quality of the salinity data was patchy – data were rejected for any crossing if the average value between 5º and 5.5º W, taken as a region of stable salinity, was less than 33.4. Out of 1073 crossings with a good temperature record there were 589 crossings with a good salinity record.

Even with regular servicing since June 2005 it was disappointing that the data return has only been 60%. One reason maybe that the Mersey is very turbid and particles lodging in the Sea-Bird conductivity sensor affect its operation. NERC.POL is developing a system which isolates the instrumentation as the ferry approaches the Mersey.

7.5.5 Turbidity

Data quality was unknown throughout; manufacturer's calibration applied.

The sensor was faulty and changed on 29 November 2004.

7.5.6 Chlorophyll Fluorescence

Data quality was unknown throughout; no calibration tests. Manufacturer's conversion from fluorescence to chlorophyll applied.

The sensor was changed on 13 December 2004 for cleaning.

7.5.7 Telemetry

The ORBCOMM telemetry system failed to work on installation. A lack of effort meant it took several months to sort out the problem, which was due to the positioning of the aerial. Initially this was placed on the roof of the bridge in a fairly central location with what seemed to be reasonable visibility for satellite communication. This appears not to have been the case as the system only worked satisfactorily when the aerial was moved to the rail on the edge of the bridge roof and raised by 1 m.

It took considerable data processing effort to sort out the crossings when there was no GPS data.

7.5.8 In-situ Checks

All ferry routes pass close by a buoy at the Mersey Bar Light, at 53º 32´ N, 3º 21.8´ W deployed as part of the POL Coastal Observatory. There is a second buoy in inner Belfast Lough at 54º 39.9´ N, 5º 50.3´ W operated in a collaborative project by the Environment and Heritage Service and the Department of Agriculture and Rural Development, Northern Ireland (http://www.afsni.ac.uk/services/coastalmonitoring). The temperature data are in good agreement (Figure 7-9 – upper panel).

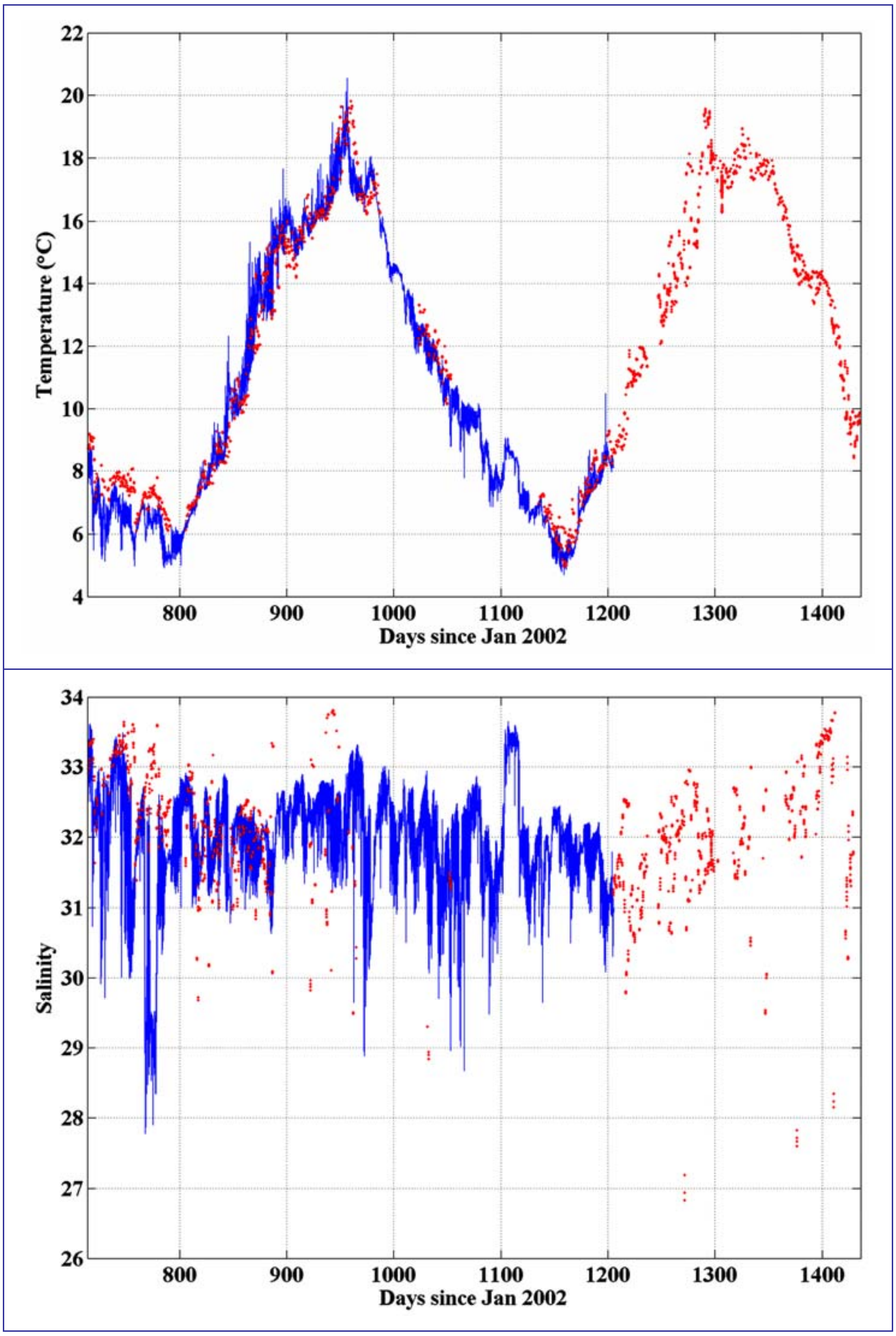


Figure 7-9: Upper panel: Comparison of buoy temperatures (blue) measured near the Mersey Bar Light and ferry temperatures (red). Lower panel: As above for salinity.

Both buoys measure temperature, conductivity, turbidity and chlorophyll fluorescence. When travelling to the south and west of the Isle of Man the route also passes close to the Port Erin Marine Laboratory's Cypris station, at 54º 05.5´ N 4º 50´ W, where measurements including temperature, salinity, chlorophyll and phytoplankton are made twice monthly. Comparisons of the temperature and salinity data against measurements at 1 m below the surface at the Mersey Bar buoy are shown in Figure 7-9 above.

The salinity comparison (Figure 7-10) was disappointing, showing little correlation between the ferry and the buoy for 1107 values for crossings which had passed the quality control. More work has to be done to establish which are good quality salinity measurements, but it also shows how difficult it is to obtain good quality salinity measurements.

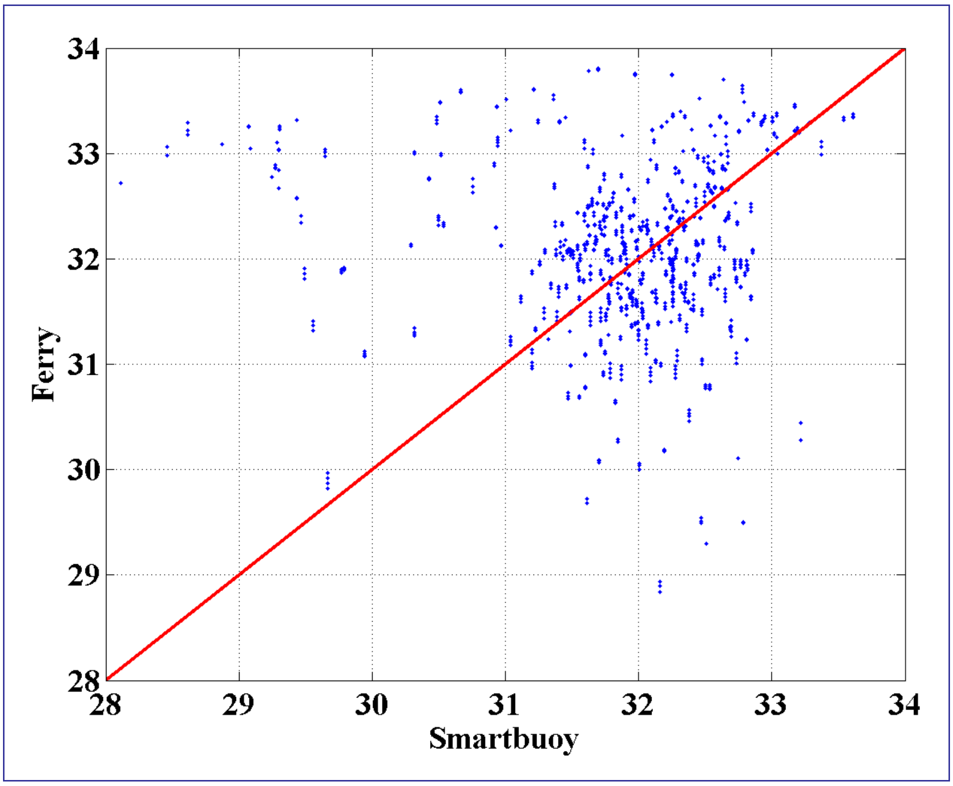


Figure 7-10: Comparison of ferry and buoy salinities. The solid line is the 1:1 line.

The comparison between the ferry and buoy temperatures near the Mersey Bar Light is shown as a scatter plot in Figure 7-10. 2586 values were obtained within 1 km east-west and 20 minutes in time. The agreement is excellent – the correlation coefficient is 0.98 and the mean difference of 0.05ºC suggests that there is very little warming of the water within the ferry. The standard deviation of the difference is 0.83ºC.

There are some suggestions of systematic differences – that the ferry temperatures are too high at both ends of the seasonal cycle, this is also apparent for the winter of 2003/4 at the beginning of Figure 7-11. Also Figure 7-12 of the time series of the differences, suggests that when the water column is stratified (in early summer, days 880 and 1280) the ferry temperatures are less than the buoy temperatures. Comparisons like these are one of the few ways of checking the operation of the ferry temperature sensor.

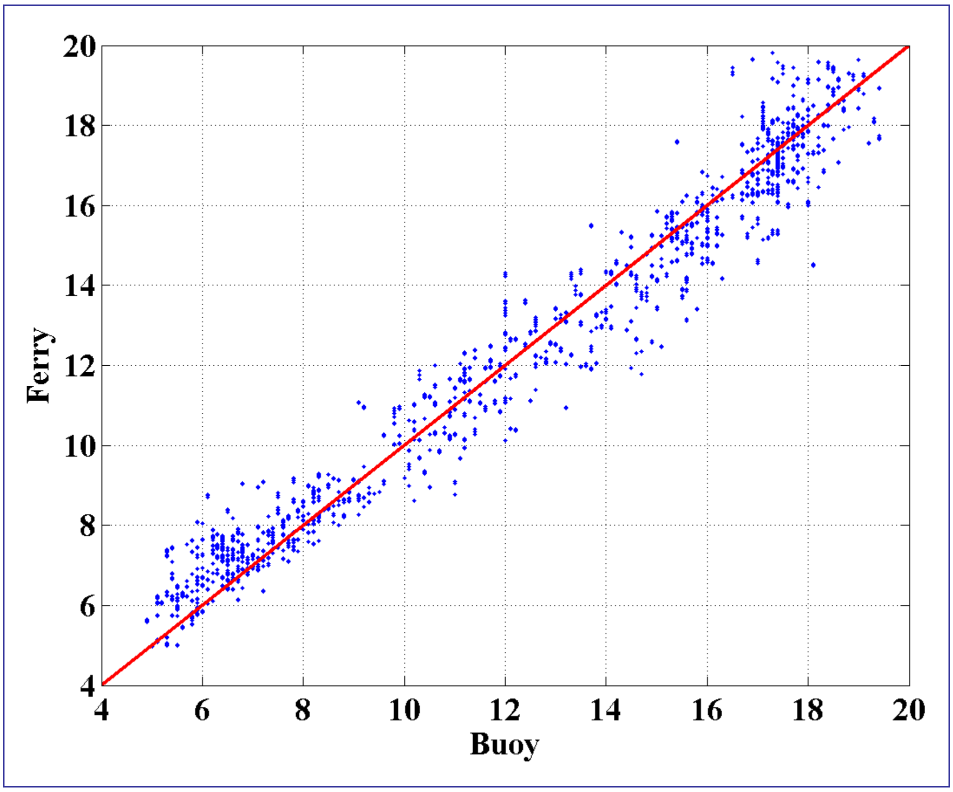


Figure 7-11: Comparison of ferry and buoy temperatures. The solid line is the 1:1 line.

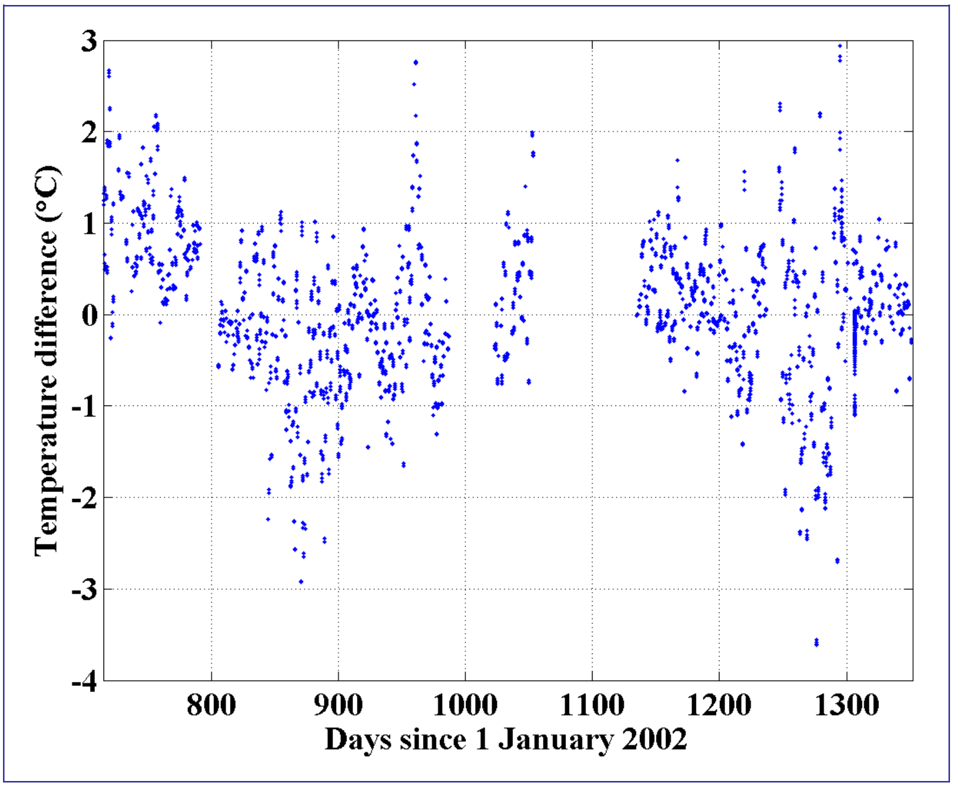


Figure 7-12: Time series of temperature differences (ferry minus buoy).

7.6 Problems

7.6.1 Fortnightly Servicing

Access to the ferry for an appreciable length of time, and hence for a service / cleaning visit, is only possible once a fortnight. If, for operational reasons at NERC.POL, a visit is not possible then it becomes a month or longer between visits.

A second set of instrumentation has been purchased to speed up service visits. A regular pattern of fortnightly visits may be adequate for cleaning and checking the instrumentation. It is unlikely that any problem within a fortnightly period will be able to be rectified but at least it can be identified from the data telemetry. Examples were disruption of the power supply in late November 2004 and at the same time the failure of the turbidity sensor.

7.6.2 Lack of Effort (Technician and Data Processing / Analysis)

Up until September 2004 (after a technician had been appointed) there was a serious lack of effort for maintaining the system. The technician left in February 2005, so that servicing visits were irregular until a second technician was appointed in May 2005. Regular (fortnightly) visits have now been established and the situation improved much. There is still a lack of effort to process the data on a routine basis to ensure its quality.

7.6.3 Calibration Checks / Cleaning

The system needs regular cleaning. The only calibration checks of the sensors so far have been a very limited testing in port; it is hoped to set up a system for obtaining in situ validation samples on an occasional basis.

7.6.4 Operation of the Ferry

As with all instrumented ferries NERC.POL is at the dictates of the ferry company. In this case different tracks, not always a problem, but more significantly a valve failure meant no measurements from 15 December 2004 until the instrument was re-installed on 7 February 2005. Apart from the valve problem the ferry seems to have been very reliable and had little downtime for servicing.

7.7 References

Joint Nature Conservation Committee, (2004), The Irish Sea Pilot Final Report (see http://www.jncc.gov.uk)

Proctor, R., Howarth, M.J., Knight, P.J., Mills, D.K. (2004) The POL Coastal Observatory – Methodology and some first results. Proc. Estuarine & Coastal Modelling Conf., 3-5 November 2003, ASCE, pp. 273 – 287.

Simpson, J.H. (1998). The Celtic Seas. In 'The Sea', 11, ed. A.R. Robinson & K.H. Brink, John Wiley & Sons, pp. 659 - 698.

Tett, P.B. 2004. Understanding of undesirable disturbance in the context of eutrophication, and development of UK assessment methodology for coastal and marine waters: Stage 2 Report: measuring undesirable disturbance. Prepared for Department for Environment, Food and Rural Affairs. Published by Napier University, Edinburgh. July 2004.
Available at http://www.lifesciences.napier.ac.uk/research/Envbiofiles/EUD.htm.

8 Route 6 and 7 – Solent and Atlantic (NERC.NOC)

8.1 System Description

During the period of the FerryBox Project NERC.NOC operated two systems. The principal route operated by NERC.NOC is with the P&O ferry “Pride of Bilbao” operating between Portsmouth (UK) and Bilbao (Spain) (Figure 8-1). This system is operated year round. The system was installed in April 2002. The initial set up was a continuous through-flow system with a thermosalinograph and two fluorimeters (CTG MINI^{pack} CTD-F and CTG MINI^{tracka}). The sensors are mounted in the engine room 5 m below the water line (Figure 8-2 shows a picture of the installation). They are feed by water taken off the cooling water supply to the ship refrigeration system. They are connected to a data logging computer in the engine room which is connected to a GPS and satellite communication units mounted in the radio room at level of the ship's bridge deck.

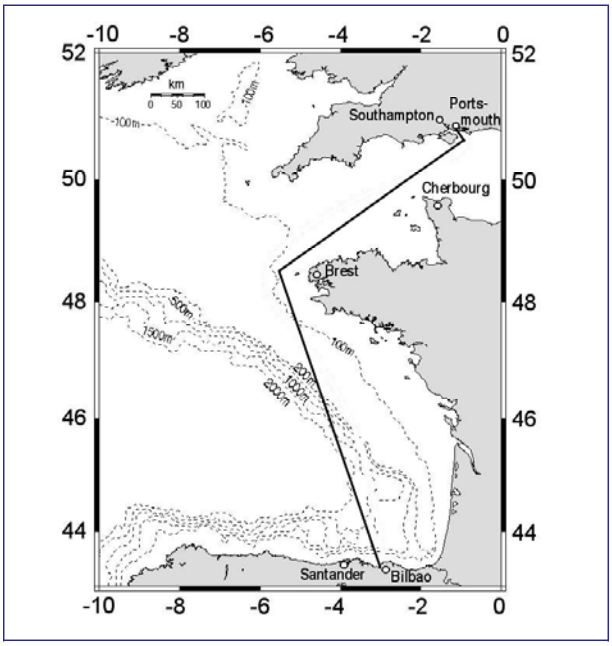


Figure 8-1: Route Map of NERC.NOC Ferrybox on the P&O ferry “Pride of Bilbao”.

Data from the sensors and GPS are recorded on board at 1 Hz and downloaded once a week on board the ship. The data stream is sub-sampled at 10 minute interval and this data is transmitted to shore by a satellite based communications system (ORBCOMM). In October 2004 the data logging system was replaced and the message ate to shore was increased to 5 minute intervals. In December 2004 the CTG MINI^{tracka} fluorimeter was replaced by a turbidity sensor and an Anderaa Oxygen Optode was added to the standard set of sensors. In June a system for measuring the partial pressure of carbon dioxide in seawater was added. This system has now been described in a number of papers (e.g. Hydes et al 2003, Kelly-Gerreyn et al., submitted).

NERC.NOC’s first system was operated in the Southampton Water and Solent estuary from April 1999 until November 2004 (Holley et al., 2004). This system was only operated in spring to autumn to follow the progress of plankton blooms in Southampton Water and the Solent (which is a so called OSPAR “Potential Problem Area with respect to eutrophication”). Operations started in 1999 and the same equipment was used up until 2003 when severe technical difficulties were encountered with the equipment when the Ferrybox was re-installed on the Red Funnel ferry in April 2003.

A new system had to be built and installed, this delayed work on this route during the Ferry-Box Project until April 2004. An intensive calibration regime was undertaken with weekly calibration crossing in 2004 during which 2 scientists travelled on the round trip between Southampton and Cowes. All this date was entered into the FerryBox Project Calibration Forms developed by John Elliott of CTG with the help of Mark Hartman from NERC.NOC. A detailed report on these operations and the data processing has been written (Hartman et al., 2005). Work on this ferry line stopped in November 2004 due to lack of manpower.

8.2 Ferrybox Operation

Water flow through the systems and sampling of data is continuous. The systems do not include any functions which are controlled by the position of the ship. The operation of the system is monitored using a webpage (http://www.soc.soton.ac.uk/ops/ferrybox_index.php) which is immediately updated when the satellite data arrives at NERC.NOC. The ships are and were visited once a week for checking and cleaning. The sensor heads were removed from their housings, cleaned and replaced. Calibration samples are collected once a month on the Pride of Bilbao and approximately weekly on the Red Falcon in 2004.

The sensors on the Pride of Bilbao have been serviced by the manufacturer once a year and the only failure was a new CTG MINI^{pack} CTD-F fitted on the Pride of Bilbao in September 2005, which failed after 6 hours of service. The CTG MINI^{pack} on the Red Falcon failed in operation after about one month in 2004, however, this unit was approximately 5 years old.

The data logging computer on the Pride of Bilbao gave problems in late summer in 2002 and 2003 when the temperature in the engine room approached 40 °C with a humidity of 100%. This resulted in problems logging into the computer to down load data and the failure of the system to log data for about 2 weeks in 2003.

In 2004 the system failed completely and had to be rebuilt. Data was lost for 45 days while it was being replaced (12 Sept – 27 October). A supply water pipe failed in 2004 and took data was lost for 17 days (18 Aug – 4 Sept). The GPS and satellite transmission system have worked without problems except due to cables being damaged when other equipment was being installed in 2002 and when the ground station in Italy was on strike in early 2004. This did not affect logging of the 1 Hz data. The use of the satellite data transmission system has improved with experience and the rate transfer and its reliability were improved. The only losses of data in 2005 have been due to loss of power in the engine room and the failure of the CTG MINI^{pack} giving a total data loss of 10 days.

8.3 Area Specific Experiences

8.3.1 Salinity

The Portsmouth – Bilbao route crosses ocean waters were changes in salinity can be expected to be small so detecting change in these waters requires an accuracy for salinity measurements to be 0.01 or better.

8.3.2 Temperature

Relative to the satellite AVHRR data the Ferrybox readings are about 1 °C higher (Hydes et al 2003) and about 0.1 °C higher than the hull mounted probe. Comparison of the hull mounted temperature probe and the CTG MINI^{pack} probe records also show the hull mounted probe is responding more quickly. It is assumed that this is due mixing of water in the sea chest from which the sampled water is pumped. The hull temperatures are close to temperatures measured by the ISAR sea surface radiometer mounted on the bridge.

The question of the relative off-sets is being investigated by a PhD student (W. Wimmer) working on the ISAR project.

8.3.3 Fluorimeter

Calibration of the fluorescence measurements against measurements of extracted chlorophyll show that the ratio fluorescence to chlorophyll ratio varies between over 10 to 0.5 depending on location and time of year. The change in ratio can be mapped in space and time suggesting it variation are real and are caused by changes in both plankton species and photo-physiology. (Qurban et al., 2004) Difference between day and night measurements are small this may be due to the depth of sampling and substantial mixing the sea chest reducing the degree of photo-quenching due to the delay induced in the system by these effects. In 2005 worse problem were experienced with fouling than in previous years and all data collected in July to September were flagged as unreliable.

8.3.4 Turbidity

Turbidity was measured on the Red Falcon in 2004. The data tends to be noisy due to the presence of large aggregated particles passing through the system. These are clearly visible on filters after samples have been filtered to for gravimetric calibration of the turbidity sensor

On the “Pride of Bilbao” turbidity was measured in 2005. Values were low but consistent signal were seen. The turbidity sensor suffered from a high background reading in the design of flow housing used. As with fluorescence measurements fouling was a major problem between June and September in 2005.

8.4 Maintenance Procedures

All maintenance procedures are carried out by trained personnel. The ferries have been visited approximately weekly to down load data and to clean the sensors. The removal cleaning and replacement of the sensor heads takes about 30 minutes. The only problems have been with the data logger (see above). Water samples have been collected to calibrate the sensors once a month on the “Pride of Bilbao” and once a week when possible on the “Red Falcon”.

Weekly servicing on the “Pride of Bilbao” requires 1 person and 3 hours time – 1.5 travel time and 1.5 hours to access the ship and carry out the work. This is done when the ship is in dock, where to stays for approximately 4 hours.

The monthly calibration crossings require 3 people on board so sampling can be done round the clock. The amounts to 12 man days – 1 day preparation time and 3 days on the ship. In addition 1 man day is required for helping load and unload the ship and transport to and from the ship. Processing the nutrient, salinity and chlorophyll samples on return requires 3 man days. Total is 16 man days per month.

The weekly calibration crossings on the Red Falcon require 2 people working for 4 hours (one man day) and another man day for processing the samples on return. The procedures used are described in detail in the report by Hartman et al (2005).

In 2003 and 2004 this cleaning regime seemed to be sufficient to reduce fouling of the optical windows of the fluorimeter to a level where it was difficult to detect in the data. However in 2005 from early July until late September each time the units were cleaned they were found to be coated with a brown slime (Figure 8-2).

Use of the flourimeter check blocks (Hartman et al., in press) indicated that the windows are highly obscured by this slime. Examination of the material under an electron microscope showed that it contains both plankton and fine sediment debris (Figure 8-3). Fouling of this type may be due the presence of mucous forming organisms in the water such as *Phaeocystis*.

Figure 8-2: Photograph of the CTG MINI^{pack} head immediately after removal from the flow chamber in August 2005 prior the cleaning.

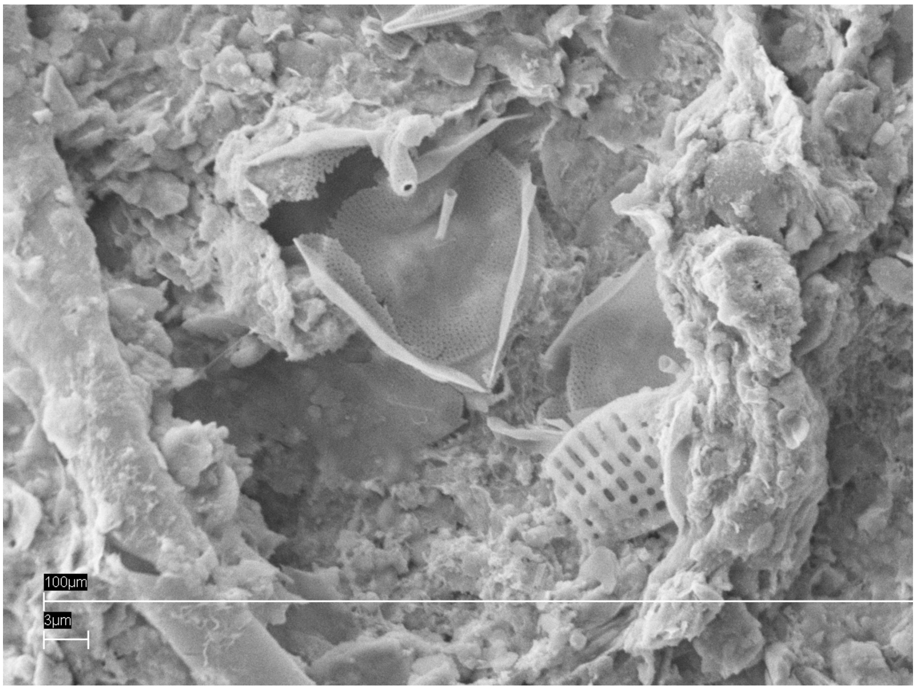


Figure 8-3: Scanning electron microscope image of brown material shown in Figure 8-2 after washing off into a collecting bottle and filtering on a Whatman GF/F filter.

8.5 Data Availability

Figure 8-4 shows the relative return of data from the Pride of Bilbao Ferrybox through the three of the FerryBox Project. The graph displays the percentage of time the system was successfully able to record data while it was installed on the ship.

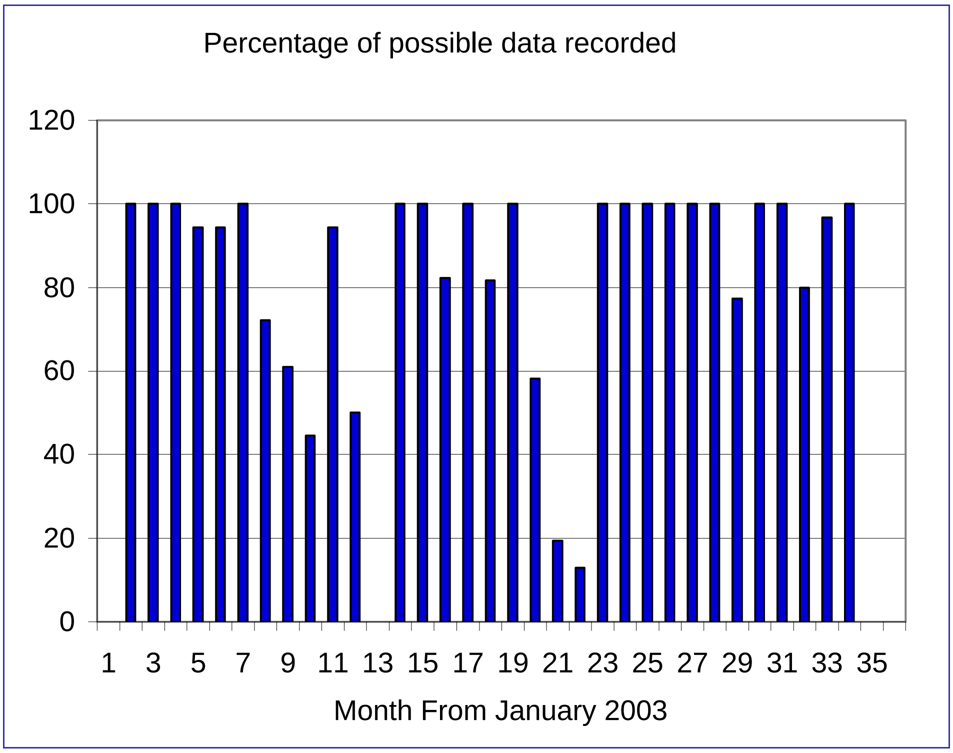


Figure 8-4: Plot of the percentage of all possible data that was recorded by the NERC.NOC Ferrybox system. Values are zero in January 2003 and 2004 because the ship was not operating.

Figure 8-5 to Figure 8-13 present the available data for salinity temperature and fluorescence from each of the FerryBox Years 2003-2005 as “posted dot plots” mapped against latitude and time in each year.

Figure 8-14 shows a similar plot for the oxygen anomaly (observed concentration of oxygen minus the saturation concentration) for the data collected in 2005.

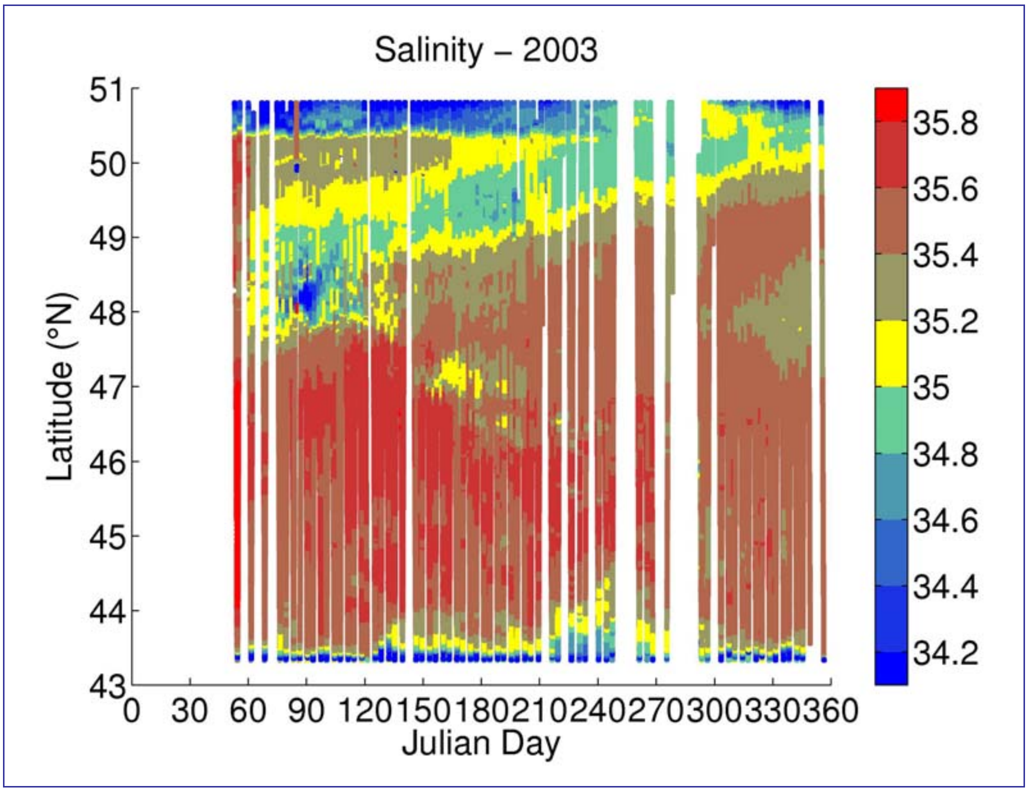


Figure 8-5: All available salinity data mapped against latitude and time for the Portsmouth – Bilbao Ferrybox in 2003 after correction of the salinity against data from water samples.

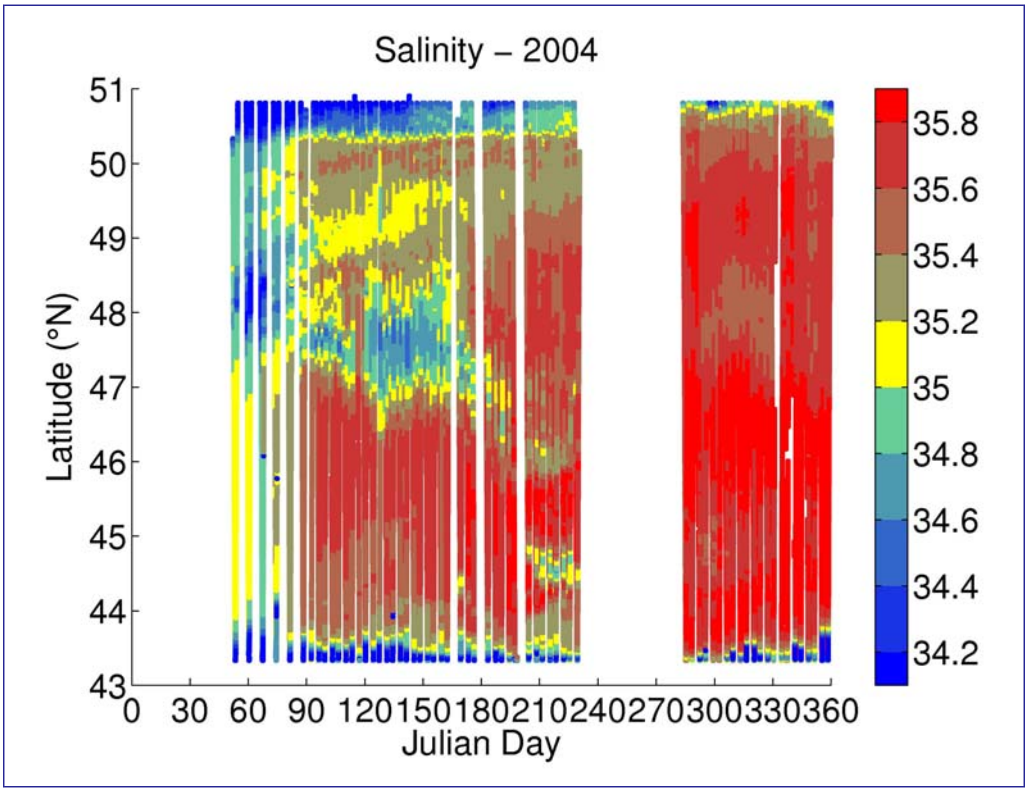


Figure 8-6: All available salinity data mapped against latitude and time for the Portsmouth – Bilbao Ferrybox in 2004 after correction of the salinity against data from water samples.

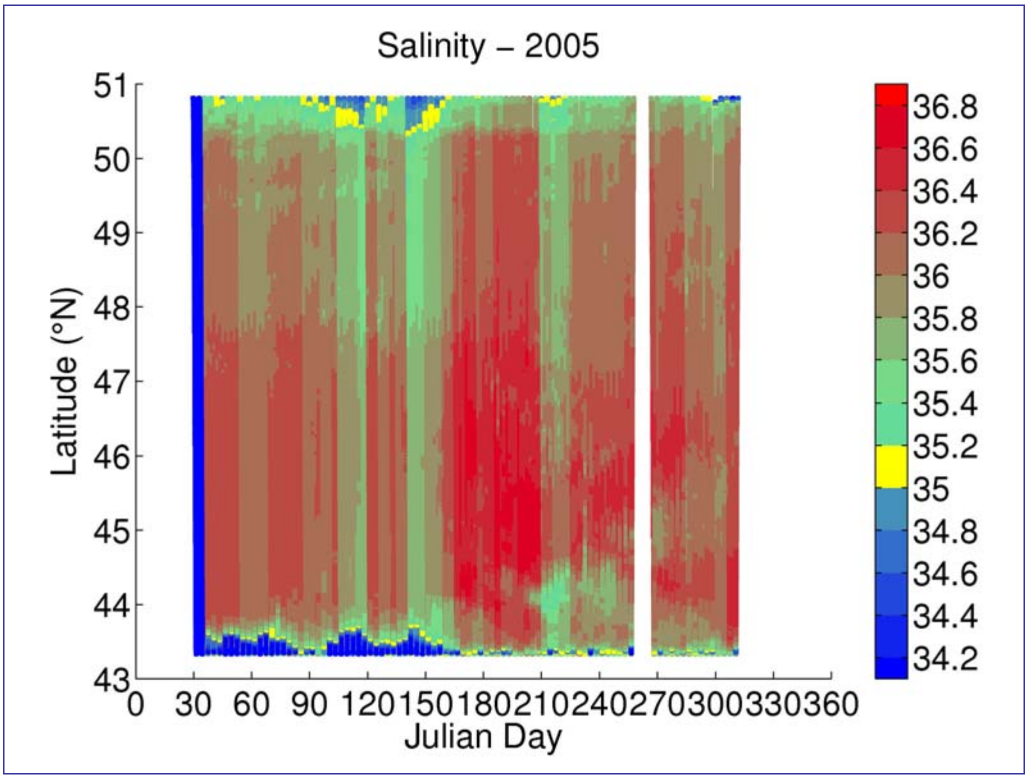


Figure 8-7: All available salinity data mapped against latitude and time for the Portsmouth – Bilbao Ferrybox in 2005 after correction of the salinity against data from water samples.

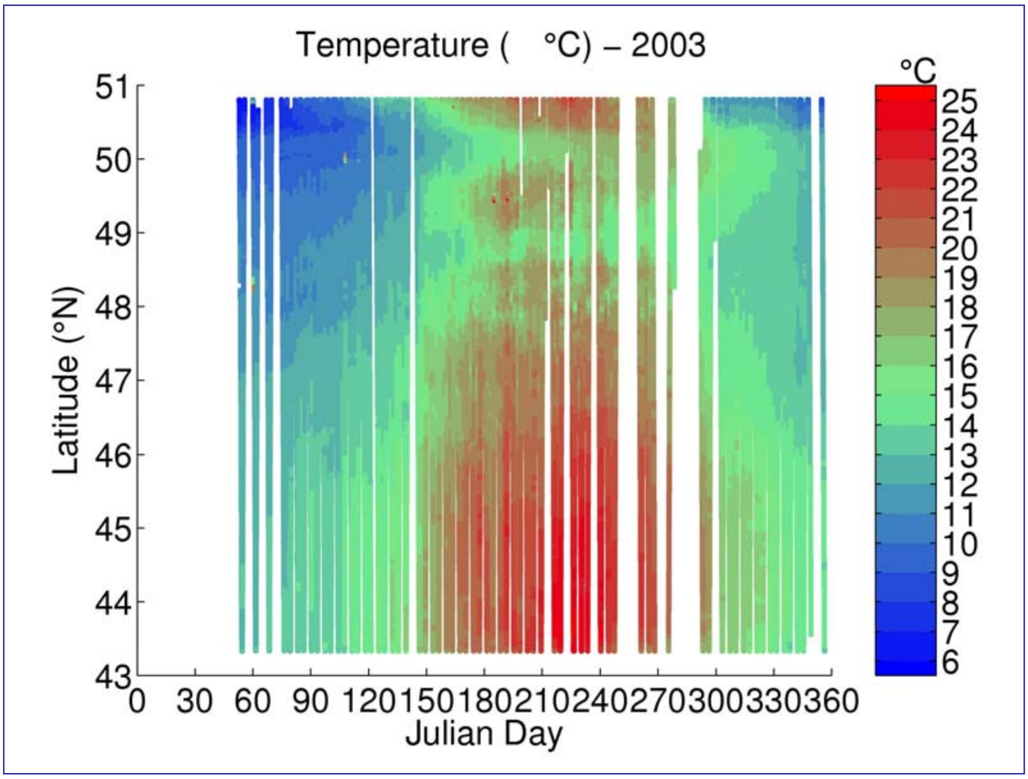


Figure 8-8: All available temperature data mapped against latitude and time for the Portsmouth – Bilbao FerryBox in 2003.

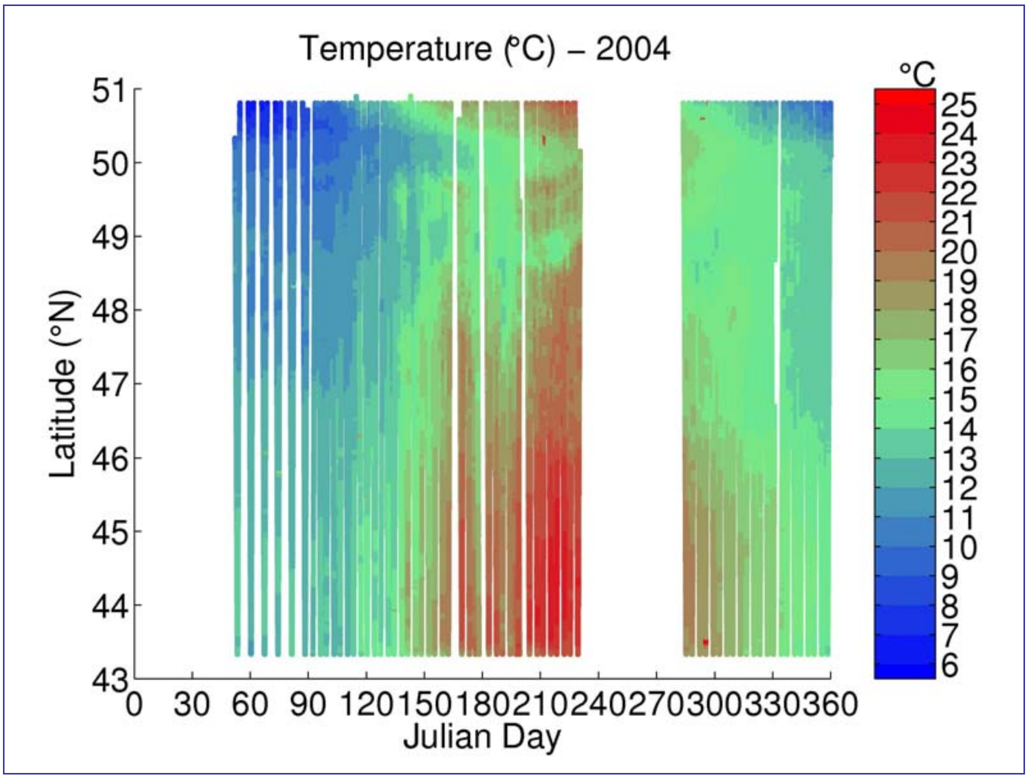


Figure 8-9: All available temperature data mapped against latitude and time for the Portsmouth – Bilbao FerryBox in 2004.

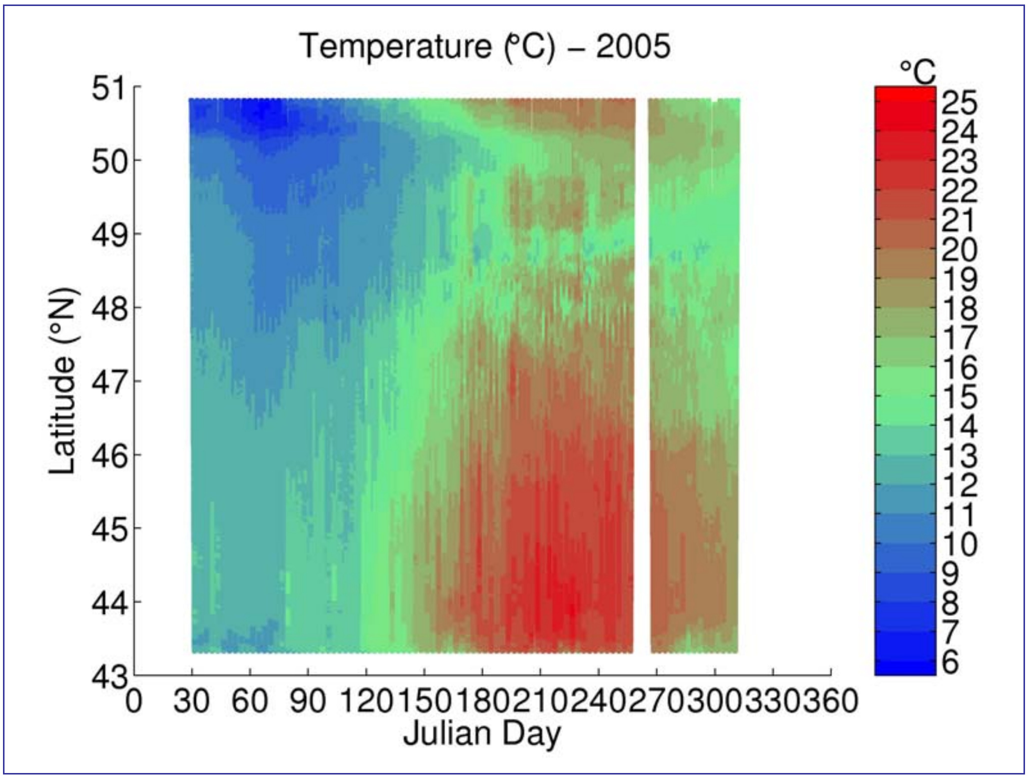


Figure 8-10: All available temperature data mapped against latitude and time for the Portsmouth – Bilbao FerryBox in 2005.

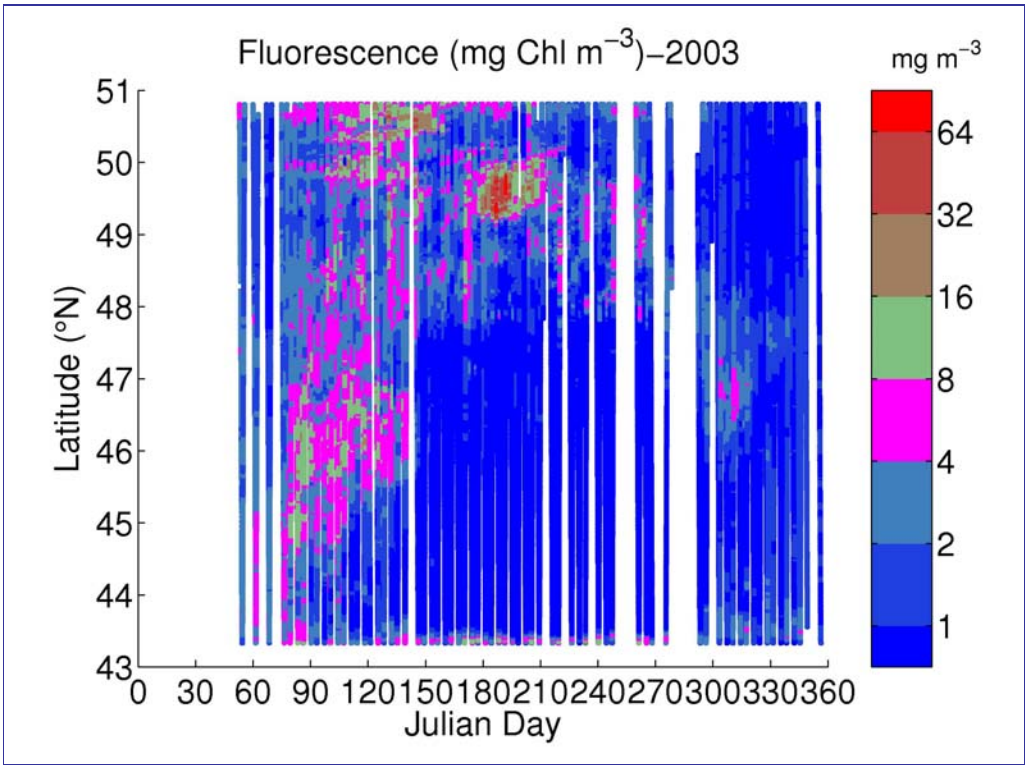


Figure 8-11: All available chlorophyll-fluorescence data mapped against latitude and time for the Portsmouth – Bilbao FerryBox in 2003. Single laboratory calibration applied to all data.

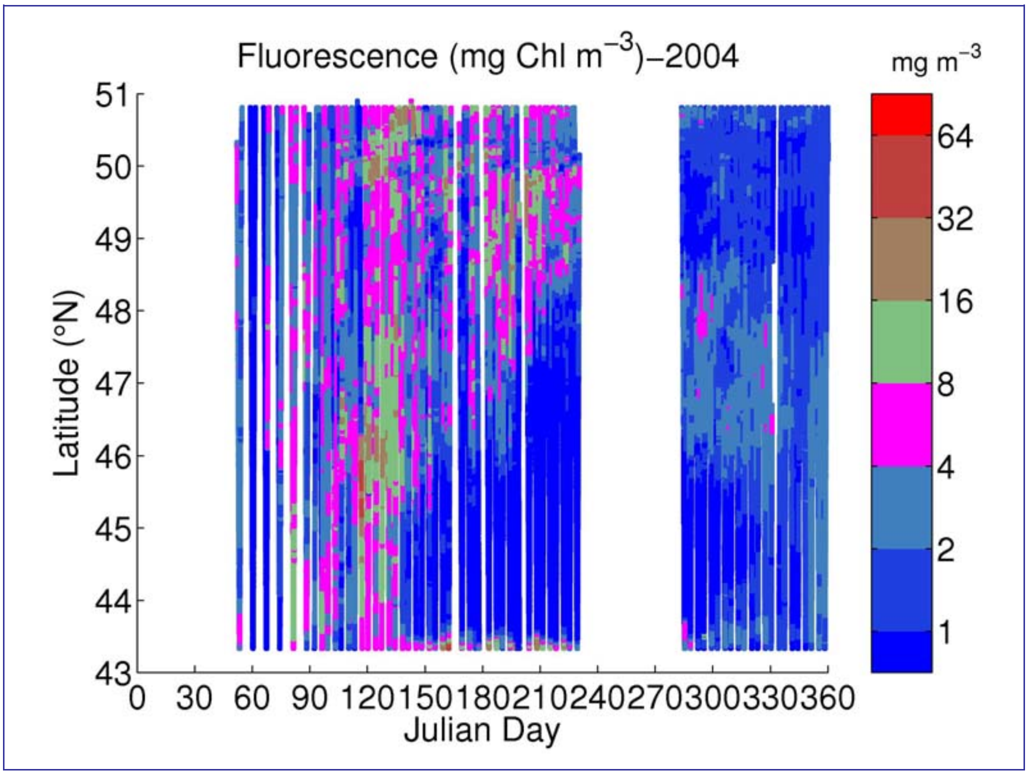


Figure 8-12: All available chlorophyll-fluorescence data mapped against latitude and time for the Portsmouth – Bilbao Ferrybox in 2004. Single laboratory calibration applied to all data.

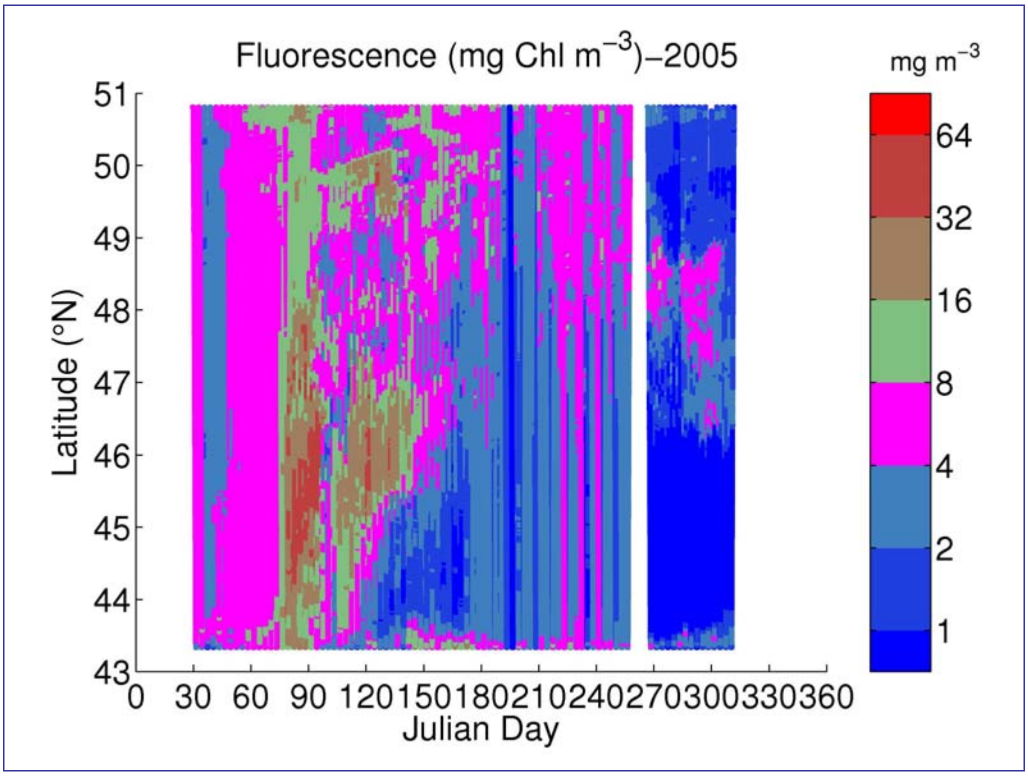


Figure 8-13: All available chlorophyll-fluorescence data mapped against latitude and time for the Portsmouth – Bilbao Ferrybox in 2005. Single laboratory calibration applied to all data.

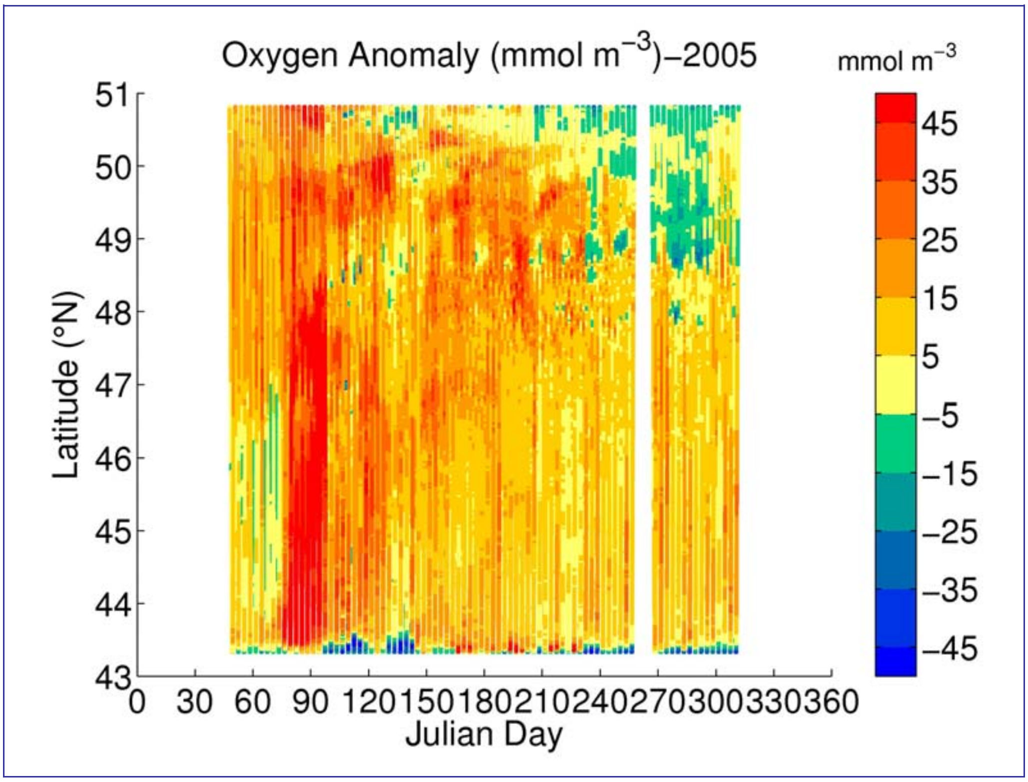


Figure 8-14: All available oxygen anomaly data mapped against latitude and time for the Portsmouth – Bilbao Ferrybox in 2004. Single laboratory calibration applied to all data.

In 2003 87% of the all possible was collected between the start of sampling in February and removing the equipment before the refit at the end of December. Data losses in 2003 were due to problems with the logging computer in high temperature conditions and in December due to system failing to reboot after power to the system was switched off briefly during ships operations.

In 2004 5.5 days of data were lost due to the power supply in engine room being accidentally switched off. Between 18 August and 4 September 17.2 days of data were due to break in the water pipe supplying the system. On the 12 September the logging system failed and had to be rebuilt to restore the supply. That took until 27 October. This resulted 45 days of data being lost. The improved system then ran without data loss until it was shut down on 3 January 2005 prior to the refit. The system was reinstalled on 29 January 2005. The data return has been much improved so far in 2005. Data was lost for 3 days in May due to loss of electrical power caused by a loose cable and for 16 hours in October due to a blown fuse in the power supply. The largest loss of six days of data in 2005 was caused by failure of a new CTG MINI^{pack} six hours after it was fitted on 14 September.

8.6 Quality Assurance of the Data (Metrology)

The weekly down loaded data are separated into individual crossing files and each data set is plotted against latitude. These plots are than visually checked for anomalous data points.

The temperature data are calibrated once a year when the CTD is calibrated by the manufacturer. The salinity data are currently calibrated using an average calibration coefficient derived from all the salinity calibration data for the year. NERC.NOC also compares their Ferrybox data to that from another ship of opportunity line which crosses the ferry track in the Bay of Biscay. By this one can see if fitting the data for individual months reduces the discrepancies between the two data sets.

The fluorescence data are calibrated using the manufacturer's laboratory calibration only. Data are displayed along side the information from the monthly data on the ratio of fluorescence to chlorophyll.

The manpower for calibration and metrology is a given above.

Data processing requires two trained man days per month.

Developing the required data processing skills and a data processing system requires about 2 man months for a numerate and computer literate technician.

However in 2005 more than 2 man months of time to identify inconsistencies in the output from the CTG MINI^{pack} system and to find acceptable way of adjusting the data. This is still an on going problem and it may require that all the 2005 salinity data is flagged as unreliable because an accuracy of the salinity data to better than 0.2 cannot be guaranteed.

8.7 Specific Experiences with the Four Basic Parameters

The same CTD unit was used since in 2002 and 2003, a new unit was fitted in 2004 and used in 2005. These have been returned to the manufacturer for checks and calibrations each year during the refit of the ship.

8.7.1 Temperature

The temperature sensor shows offsets relative to the hull mounted sensor and satellite derived values. This off set appears constant with time.

8.7.2 Salinity

Salinity is calculated from measurements of conductivity and temperature made using a Chelsea Technologies Group (CTG) MINI^{pack} CTD-F. The manufacture claims accuracies and precisions of 0.005 ±0.001 mS/cm for conductivity and 0.003 ±0.0005°C for temperature measurements. However in-situ calibration of the salinity measurements has to be carried out because the mounting of the instrument in the flow cell on the Pride of Bilbao distorts the field round the conductivity head of the CTG MINI^{pack}. Calibration is done by collecting water samples for the determination of salinity during manned "calibration crossing" – round trips between Portsmouth and Bilbao.

The salinity of these samples was then determined using a Guildline Salinometer in a temperature controlled laboratory on shore. Approximately 36 samples are collected per trip, 26 trips in total in 2003 – 2005. The precision of calibration expressed as the standard error varied between 0.034 and 0.010. This data was then used to adjust the CTG MINI^{pack} output for changes through time. In 2003 the calibration factor varied between 1.063 and 1.067. In 2004 it drifted from 1.074 in March to 1.065 in December.

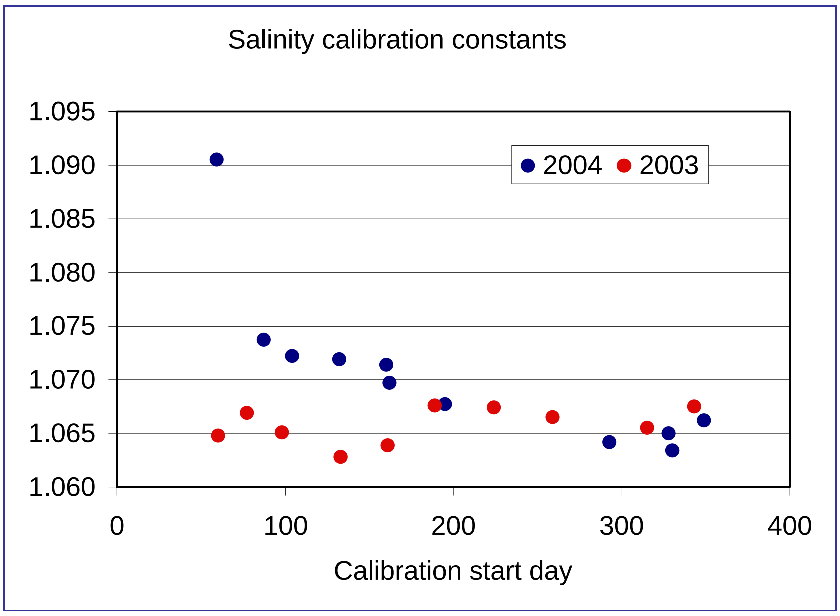


Figure 8-15: Plot of variation of salinity calibration factors with time in 2003 and 2004.

Figure 8-15 shows that there was more variation in the slope of these plots in 2004 than in 2003. The big difference between the slope on the first crossing in 2004 and all the others was that the CTG MINI^{pack} was rotated by 180° for the first month of operation in 2004 before it was realised that it was not in the same position as 2003. Why the variation was greater over the rest of the year was unknown as the it contrast to the fact that the R^2 values for 2004 were generally better for 2004 than 2003 suggesting the extra variation was not noise related (Figure 8-16). Generally better fits in 2004 may be due to better bottle salinity data as all 2004 samples were measured by trained technician working in dedicated laboratory whereas samples in 2003 were measured by four different people on two different salinometers.

Applying the 2004 calibration factors to estimate a "true" salinity value from a CTG MINI^{pack} result of salinity 33, gives values with a range of over 0.3 salinity units compared to a target precision of 0.01 salinity units. The range was smaller but still 0.2 salinity units in 2003. A better impression of the precision of the data can be obtained when the data from 2003 and 2004 were compared over the periods when data as returned in both years.

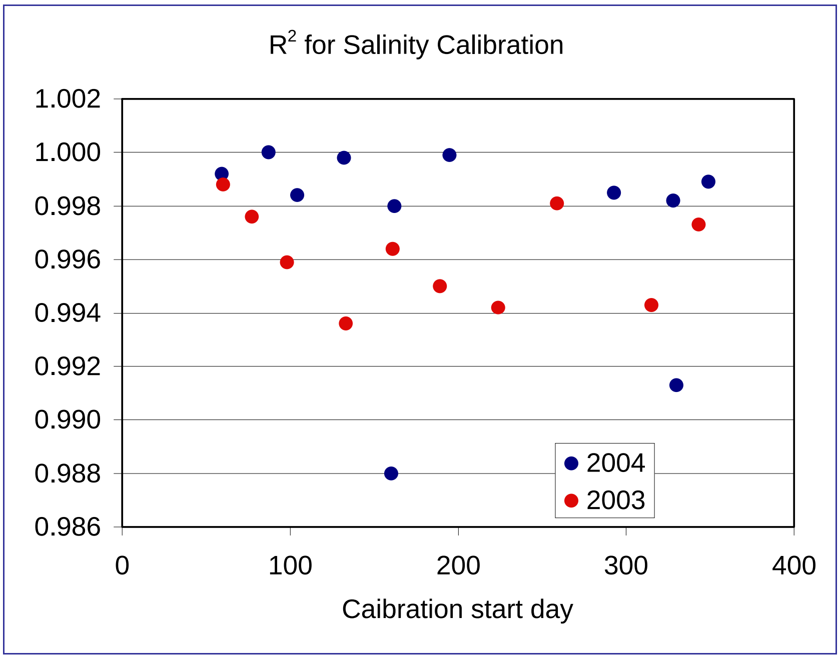


Figure 8-16: Plot of variation in R squared regression coefficients for the 2003 and 2004 salinity calibrations.

This comparison shows that in the region of most stable salinity between 45.0° and 45.5° N the mean salinity in both years was 35.6 with a standard deviation of 0.05. However for 2003 the data from the "Pride of Bilbao" can be compared to that collected by CSIC Vigo who was operating a Sea-Bird SBE 45 MicroTSG Thermosalinograph on a route between Vigo and St Nazaire. The range of variations CSIC find in their calibration slopes is small suggesting their precision of the order of 0.01. (CSIC were able to clean their system regularly twice per week as the ship docked for 24 hours in Vigo within ten minutes walk of the CSIC laboratory. The data have been compared at the crossover point at 46.2 N (Figure 8-17).

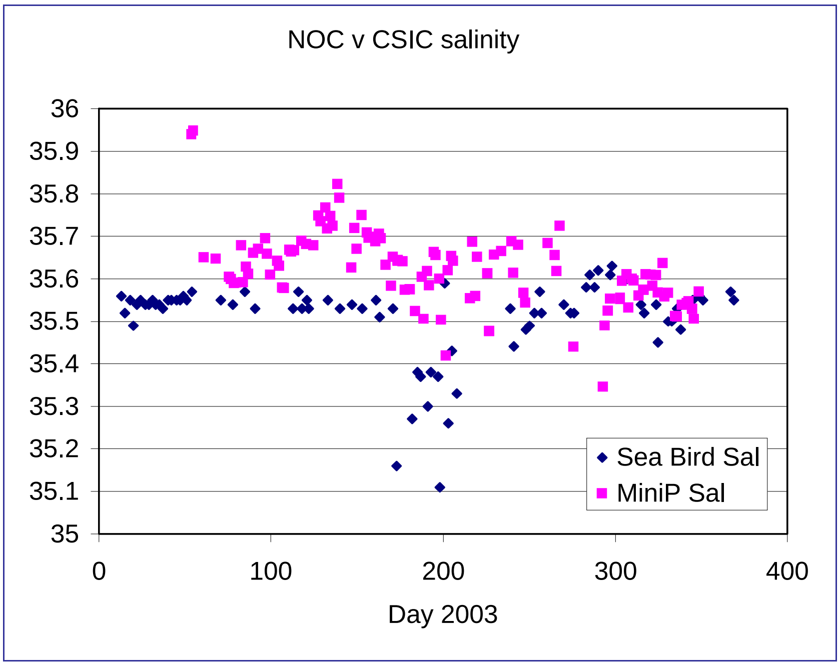


Figure 8-17: Plot comparing data collected by the NERC.NOC and CSIC systems at the crossing point of the two tracks across the Bay of Biscay in 2003.

There are differences in the salinities recorded by the two systems through much of the year. In the early part of the year before June the data might be expected to relatively stable as the water will be well mixed before summer stratification occurs. This is true for the CSIC data but not the NERC.NOC data. The range in variation in the data is comparable to that due to the variations in the calibration coefficients of the CTG MINI^{pack}. The CSIC data also does contain some values which look doubtful, around day 200.

Before refitting the CTG MINI^{pack} at the start of 2005 CTG recalibrated the instrument in its flow housing. This reduced the offset between the output from the sensor and the true conductivity. However the error was still 3%. Figure 8-18 compares the calibration factors for the three years.

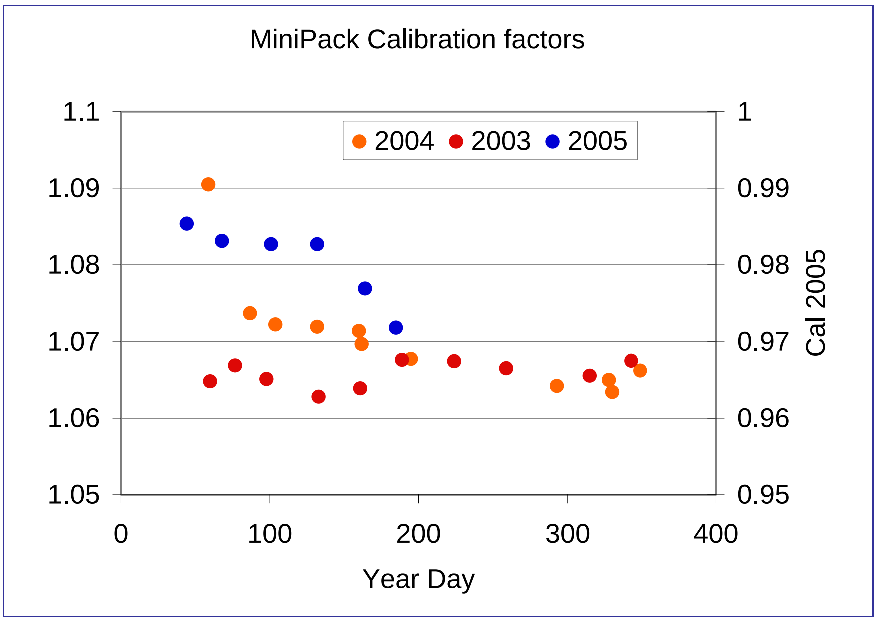


Figure 8-18: Plot of variation of salinity calibration factors with time in 2003 and 2004.

Calibrating the CTG MINI^{pack} in its housing and improving the reproducibility of the relocation back into the housing after cleaning does not appear to have improved the performance. At the time of writing NERC.NOC thinks that the problem lies in the spacer put into the system to give positive relocation actually has the CTG MINI^{pack} deeper in the housing than was the case in previous years actually making it more sensitive to slight shifts in position and changing the field round the inductive head of the conductivity sensor. A number of approaches to reduce the error in the data have been tried.

Figure 8-19 shows the data adjusted salinity of minimum change at 45° to 45.5° N. This produces a more consistent data set than that shown in Figure 8-7, but is at the expense of masking true variation in the region of 45° to 45.5° N.

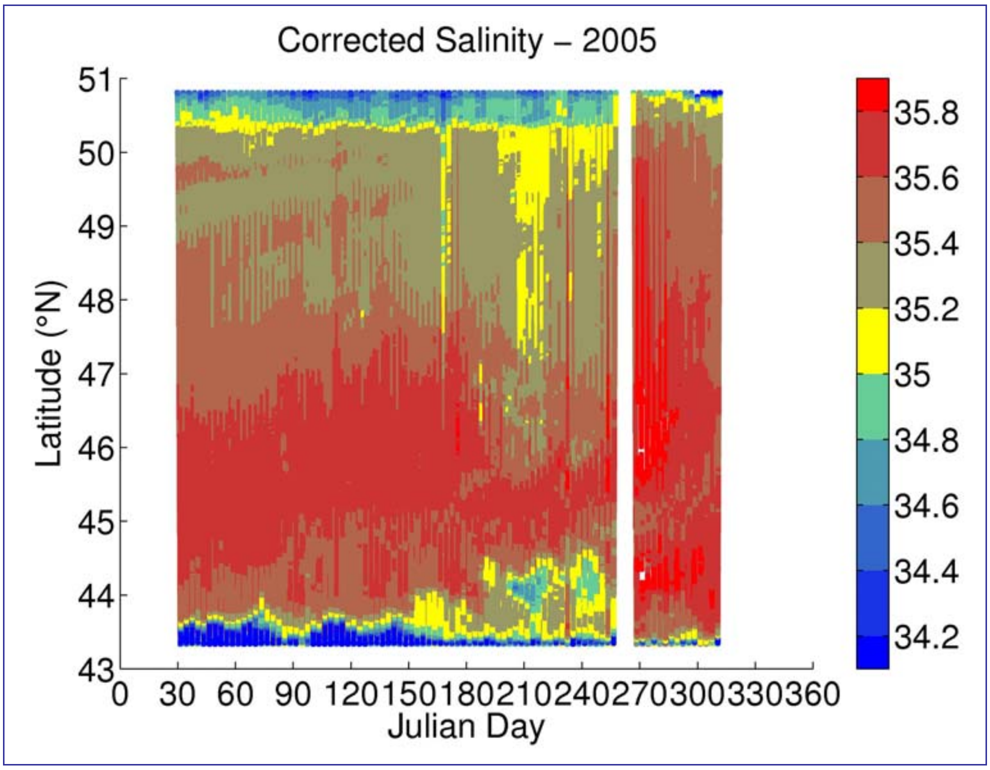


Figure 8-19: All available salinity data mapped against latitude and time for the Portsmouth – Bilbao Ferrybox in 2005. Adjusted to give a salinity of 35.6 between 45° and 45.5° N. Compare to the unadjusted data shown in Figure 8-7.

8.7.3 Fluorescence

The fluorimeter calibration varies in time and space but as said above this due to biological changes rather than drift in the instrument.

Tests using solid state fluorescence standards on the Red Falcon system suggest that the basic physical stability of the fluorimeter is better than 5%. In the Red Falcon system fouling of the system was severe with growth on the sensor windows producing an apparent chlorophyll signal in excess of 10 µg/l after about four to five days during the productive summer months and a reduction in the transmission of the lens of over 50%. In the “Pride of Bilbao” system although material was removed from the lens on cleaning associated shifts in the signal response were not generally detectable in 2003 and 2004. However, the system was seriously affected by fouling in 2005.

8.8 Data storage data access:

We accumulated four data sets in 2004 and 2005.

1. The data sent back by satellite. The satellite data is un-calibrated this displayed on the webpage and is stored in a publicly accessible data base that allows the data to be plotted for checking he operation of the system.
2. The 1 Hz data that is collected from the ship. This raw data set is divided into individual crossings and than archived
3. The archived 1 Hz data is then used to generate a data set consisting of data binned in 5 minute averages. This data is checked and calibrated and stored as the raw data file and the calibrated data file
4. These files are converted to the agreed FerryBox Data Format for transfer to HYDROMOD and BODC from where they are made publicly accessible.

8.9 References

Hartman, M.C., Hartman, S.E. and D.J. Hydes (2005). Improvements in continuous, systematic monitoring of phytoplankton growth using a ‘FerryBox’. In "European Operational Oceanography: Present and Future". In: Dahlin, H., Flemming, N., Marchand P. and S. Petersson (eds.) EuroGOOS Conference 2005 Proceedings, in press.

Hartman, M.C., Hartman, S.E., Hydes, D.J. and J. Campbell (2005). A report on the Red Funnel FerryBox 2004 – An overview of the data obtained, improvements and calibration procedures. Southampton Oceanography Centre, Southampton Research and Consultancy Report 102, 220 pp.

Holley, S.E., Purdie, D.A, Hydes D.J. and M.C Hartman (2004). 5 years of plankton monitoring in Southampton Water and the Solent including FerryBox, Dock Monitor and discrete sample data Southampton Oceanography Centre Research & Consultancy Report No. 82, 72 pp.

Hydes, D.J. Hartman, S.E. Kelly-Gerreyn, B.A. Dodgson, J. Campbell, J.M. Crisp, N.A. Edwards, M., Dupee, B., Lavin, A.M. and C.M. Gonzalez-Pola (2003). Use of a Ferrybox system to look at shelf sea and ocean margin process pp 297-303 In Building the European Capacity in Operational Oceanography , (H. Dahlin, N.C. Flemming, K. Nittis & S.E. Petersson, eds.) EuroGOOS Publication 19. Elsevier Oceanography Series, 69. Elsevier Amsterdam.

Kelly-Gerreyn, B.A., Hydes, D.J., Fernand, L.J., Jégou, A.M., Lazure, P., and I. Puillat (2005). Low salinity intrusions in the western English Channel and possible consequences for biological production. Cont. Shelf Res. 43 pp., submitted.

Qurban, M. A., D.J. Hydes, A. M. Lavin, C. M. González-Pola, B. A. Kelly-Gerreyn, P. Miller (2004) Sustained "Ferry-Box" Ship of Opportunity observations of physical and biogeochemical conditions across the Bay of Biscay ICES Annual Science Conference Vigo Spain 2004, paper no. CM 2004/N:09 19 pp, CD ROM publication.

9 Route 8 – Mediterranean Sea (HCMR)

9.1 System Description

A commercially available flow-through system manufactured by 4-H JENA provides measurements of temperature, salinity, chlorophyll-a fluorescence and turbidity. The system was installed in November 2003 on the line Athens-to-Crete providing daily coverage of the route with the same departure and arrival ports every other day. The data are sent to the land station via GSM telemetry and additionally saved on the system's database on board of the ferry. In November 2004 the ship shifted operation on another line from Patras to Venice. Originally HCMR was informed by the ferry company that this shift was temporary for only 40 days. However, it practically lasted until mid of June 2005 with a short return to the Piraeus. . Iraklion line for sometime in between.

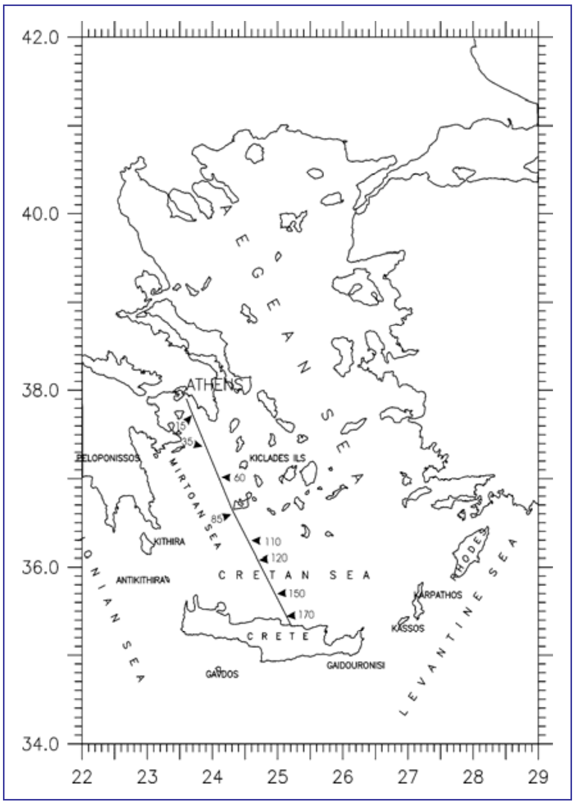


Figure 9-1: Route (R8) from Athens to Heraklion (Crete) of HCMR Ferrybox.

9.2 Ferrybox Operation

The Ferrybox system was operated fully automatically. Positions were controlled daily (if not absent from the office) and check of operation was done through online automatic error-reports. Electro-mechanical components and physical-parameter measuring sensors were of high quality but operation/control algorithms and overall integration and functioning were highly problematic.

In February 2005, almost 1.5 years after the installation of the system in November 2003, the operation manual for the software that controls the functions on board of the ship became available to HCMR.

The second year (November 2004 to October 2005) of Ferrybox operation for HCMR was characterised by the complete absence of data.

The repair of the FSI salinity sensor, which was drifting during the first year of operation and was sent back to the Ferrybox manufacturer in November 2004, lasted 4.5 months. During this period (November 2004 to mid-March 2005) the ferry was servicing another line in the Ionian Sea sailing between Patras and Venice and the Ferrybox was turned off since there was no extra salinity/temperature sensor to replace the drifting one.

After the installation of the repaired FSI sensor in April 2005 the Ferrybox system featured a series of problems until November 2005 that do not allow the recording and storage of reliable en-route data. The procedures of calibrating the sensors were continued despite that there were no data.

In brief, the Ferrybox problems in the second year are related to the position control (control of the various functions as the ship moves in and out of the various ports), the storage of data in the database during cruising, uncontrolled telemetry of messages in case of system problems and leakage of freshwater into the system that contaminates the measurements. These problems occurred in parallel due to the fact that the ferry has not been sailing on a given line constantly but was shifting its operation between Piraeus – Iraklion and Patras – Venice on a non-anticipated pattern.

The actions taken in the second year in detail were as follows:

- On 7 November 2004 HCMR removed the T-S FSI sensor and sent it back to the Ferrybox manufacturer to investigate the problem with the salinity drift. Operation of the Ferrybox had to be terminated because HCMR had no other sensor and mostly because the Ferry was sailing on another line (Greece to Italy). The ship stopped service on the Athens to Crete line on 9 November 2004.
- The FSI sensor was returned to HCMR by the Ferrybox manufacturer after ~4 months around mid March 2005. By then, the ferry was still on the Greece to Italy line. She was scheduled back to the Piraeus – Iraklion route in mid June 2005. During the ship's operation on the Greece to Italy line, the ship was spending more than 2 or 3 hours in a Greek port only on Fridays which were the only days for having direct access to the system.
- HCMR installed the FSI back on 1 April 2005 and tried to put the Ferrybox in operation on the Greece – Italy line. There was a problem with the position control of the Ferrybox because it was confusing the positions for Patras and Venice. HCMR went to Patras three times for troubleshooting and sensor calibration despite that no data were retrieved. By mid June the ferry returned on the Piraeus – Iraklion line and after HCMR removed the position of Venice from the position list, the Ferrybox could run normally but was not saving the data into the database. On the 24 June 2005 HCMR staff went on a cruise to Iraklion to watch the system and try to troubleshoot it. The Ferrybox manuals had no relevant information and the Ferrybox manufacturer could not provide any valuable help. In the same time it a leakage of a freshwater valve was detected which rinsed fresh water into the system all the time. From mid June until end of July 2005 HCMR staff went to Piraeus 8 times (14/6, 16/6, 20/6, 24/6, 28/6, 30/6, 13/7, 18/7, 20/7), while the ship was in the harbour. HCMR tried each time a different combination of settings in the menu of the program that controls it and to get it to save the data into the database. From end July until end of August 2005, the ship was actually spending very minimal time in the harbour, trying to accommodate the many vacationers/tourists travelling to Crete.
- HCMR also checked the Ferrybox status by visiting the ship on 8 and 18 September. On 23 September 23 the ship returned to the Greece – Italy line.

- The repair to the Ferrybox by the manufacturer was originally scheduled for November 2005 but was postponed until the beginning of 2006 when, as the manufacturer stated that a new option for GPRS data transmission is expected to be available for installation after extensive tests.

9.3 Area Specific Experiences

The monitoring area is characterised by very low fluorescence and turbidity signals which implies challenging measurements. For most of the ferry route, the actual chlorophyll-a concentrations are on the order of 0.02 – to 0.06 µg/l. and the chlorophyll-a to chlorophyll–fluorescence ratio is on the order to 0.1. On the route chlorophyll water samples are necessary (at least seasonally) and further investigation of fluorescence sensors on the market which better perform on low signal levels is needed.

9.4 Maintenance Procedures

The basic maintenance procedure (washing with fresh-water) is automatic. However, it has not worked properly for all the time after the installation. After automatic washing with fresh water in the harbour and before filling the de-bubbling container with fresh water, as, is typically done, some quantity of sea water was entering into the system flowing through the lower part where the salinity and temperature sensors are located. So, the fresh water washing had no effect for these sensors since a lot of rust was found in their compartment one year after the installation, whereas the de-bubbler appeared to be clean and free of rust or fouling.

The washing cycle was repaired by the Ferrybox manufacturer in September 2004 and the rust was responsible for the salinity drift of the inductive FSI salinity sensor. Currently the washing cycle performs satisfactorily since no fouling or rust was found again while HCMR's nominal procedure is to visit the ship every 2-3 weeks and force the Ferrybox system to go into a wash cycle that lasts 10 minutes. In this oxalic acid is added manually to prevent the accumulation of rust on the sensors.

Every other visit, the fluorescence and turbidity sensors are cleaned manually but the temperature and salinity sensors are not opened for physical/manual cleaning, since the original factory calibration coefficients are changed if this happens.

The typical procedure to be followed – once all technical problems are solved and the operational situation is settled – will be to send all sensors to their manufacturers every 12 to 18 months for factory maintenance and calibration.

9.5 Data Availability

150 days of cleaned (de-drifted and de-spiked) data have been collected in the first year (November 2003 to October 2004). Actually this should have been 340 days of daily trips (considering a 20 days dry-docking period in March). Additionally, during the period from 21 June 2003 to 14 September 2004 the Ferrybox was not functioning due to a problem in the fresh-water valves while HCMR was waiting for the Ferrybox manufacturer to do the necessary repairs.

Main reasons for data gaps were caused by having to deal with an unknown non-documented device (large delays in fixing even small problems). Small problems were mostly caused by human errors (e.g., after maintenance and leaving the ferry in December 2003 it was forgotten to turn on the sea-water supply on). It took more than a month to fix the problem(s) and bring the system back into its normal operation. The operation manual for HCMR's Ferrybox system was delivered in February 2005.

In the bar graph (Figure 9-2) data availability is displayed throughout the year 2004. The smaller percentages for the fluorescence and turbidity data represent flagged/noisy data due to bubble noise.

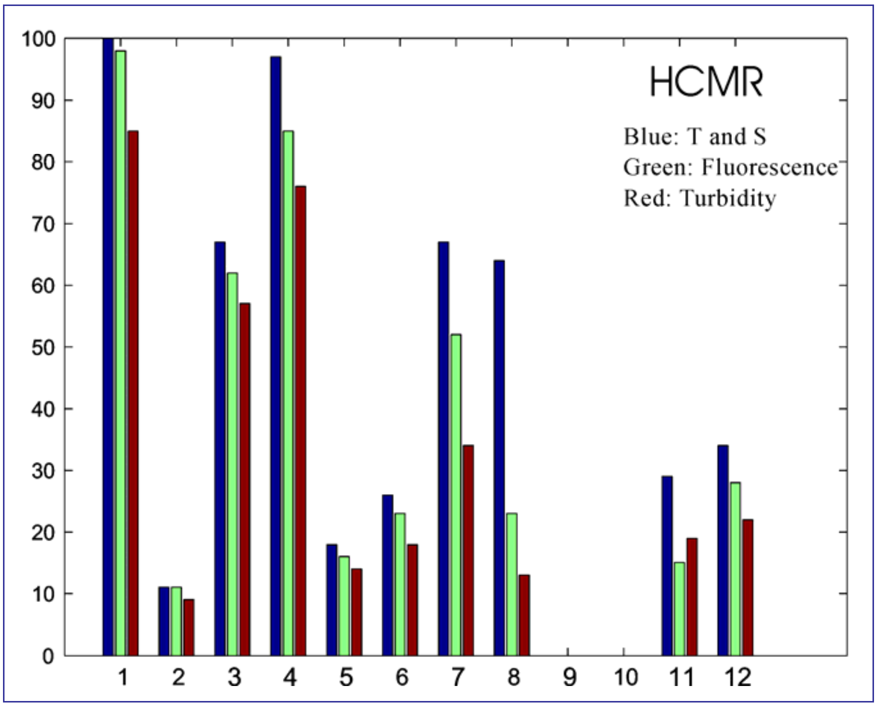


Figure 9-2: Percentage of data availability for HCMR during the first Ferrybox operational year (November/2003 (month 1) to October 2004 (month 12). 100% availability implies that all scheduled ferry crossings are made, all voyages return full lengths of data records and no data point is deleted or flagged due to noisy measurement.

No data were available throughout the Second FerryBox Year as pointed out above.

9.6 Quality Assurance of the Data (Metrology)

In the First FerryBox Year monthly checks of

a) Salinity through bottle-samples

b) Chlorophyll-a validation through comparison with chlorophyll-a estimates based on lab analyses of water samples and

c) Turbidity through comparison with standards provided by NIVA

have been carried out.

Items (a) and (b) started in May 2003, only to reveal that the salinity sensor had a very big drift (which was traced back by comparison with data from other coastal projects) and the actual chlorophyll-a surface concentrations were 10 times lower than those recorded by the SCUFA sensor of the Ferrybox.

In June the system failed (due to the problem with the fresh water valves) and at the end of October 2004 the salinity sensor was returned to 4H-JENA while the ferry was temporarily (for 1-2 months) servicing another line (Italy – Greece). The turbidity standards provided by NIVA were received in October 2004.

Half a month of manpower was needed per month for the above quality assurance procedure(s) including the time for two persons for joining a ferry cruise for water sample collection.

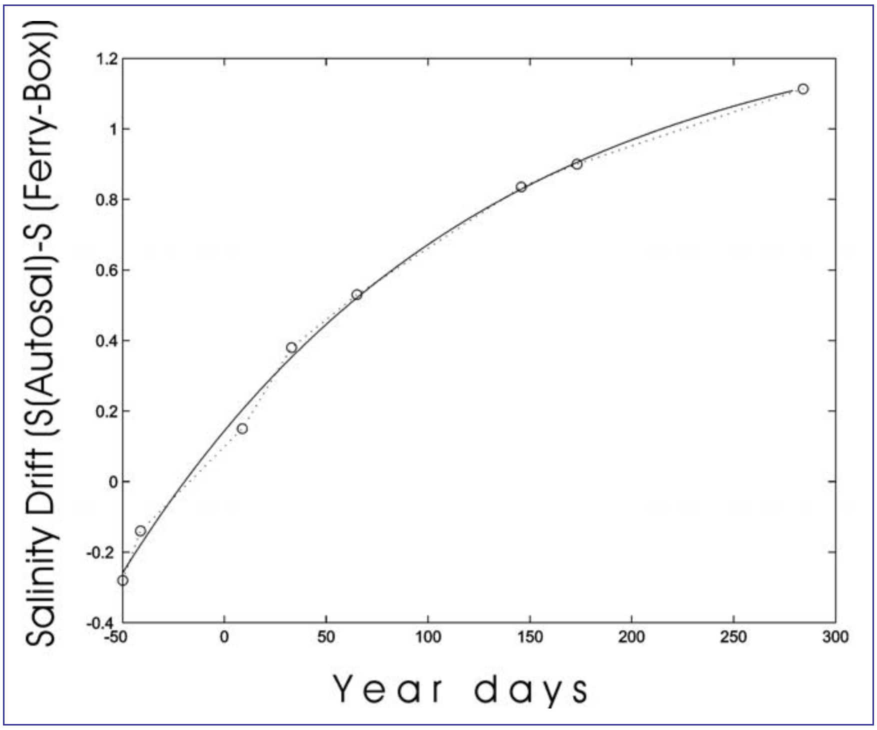


Figure 9-3: Salinity drift error as a function of time. Year day 50 is the installation day in November 2003, year day 300 is near the end of October 2005. Circles represent measured salinity offsets between the Ferry-box and 1) Autosal measured en-route samples or 2) CTD measurements from monthly hydrographic cruises near Athens intersecting the ferry route.

Note that on installation at day 50 the drift is non-zero. One year after the installation, it was revealed to HCMR that the Ferrybox manufacturer had changed the original factory specifications and thus the factory calibration of the FSI sensor. No documentation was ever delivered that the sensor upon installation had a set of valid calibration coefficient and that it was performing according to advertised specifications

During the period from April 2005 to September 2005 (Second FerryBox Year), three quality assurance tests (sensor calibrations) were done for salinity, fluorescence and turbidity measurements. The overall experience with the salinity drift of the first year was that a quality assurance test on salinity every other month based on en-route sampling is adequate to track any drift and to provide enough drift data for modelling and, finally, for correcting a possible drift of the salinity sensor from the data.

The relation of fluorescence versus actual chlorophyll-a concentration of on-route samples varied very much in the area from season to season. HCMR believes that a more appropriate test would be more convincing with respect to the quality assurance of chlorophyll fluorescence which should be use of known concentrations of chlorophyll obtained from laboratory cultures and compare them with fluorescence readings.

The quality assurance test for turbidity was performed with given Formazine concentrations. After confirmation that all sensors performed satisfactorily, i.e., the salinity agrees with the Autosal laboratory values obtained from collected water samples and that for the optic measurements (chlorophyll-fluorescence and turbidity) the relations between the instrument readings and the corresponding chlorophyll-a and Formazine concentrations are constant in time, HCMR visually checked all space series of downloaded data and removed spikes with standard de-spiking routines.

9.7 Specific Experiences with the Four Basic Parameters

The temperature offset compared to outside temperature during late spring 2003 was around 0.5 - 0.6 °C. This based on en-route temperature measurements outside the ship.

The salinity performance is already documented in Section 9.4 and 9.6 above.

9.8 Data Storage and Access

Data are stored a) on board the ferry, b) on a PC (the land station) in the laboratory, and c) as ASCII files on a UNIX computer in the laboratory.

Currently there are no possibilities for public data access. Soon there will be possibilities for visualisation of gross results through a website.

Data handling, particularly in cases of problematic data, can demand up to 2/3 of a man month per month.

10 Bay of Biscay (IEO)

10.1 System Description

The IEO operated a continuous through-flow system with a termosalinograph with external thermometer (SBE-21 – since October 2003) and a fluorescence and algal classes detector (Bbe-FluoroProbe – since January 2003) on the small research vessel "Jose Rioja" on the Southern Bay of Biscay (Cantabrian Sea). The ship collects data on monthly schedules on three Spanish standard sections (Figure 10-1). The system works along these sections once per month and on the tracks between the standard sections twice per month. There was no turbidity sensor installed.

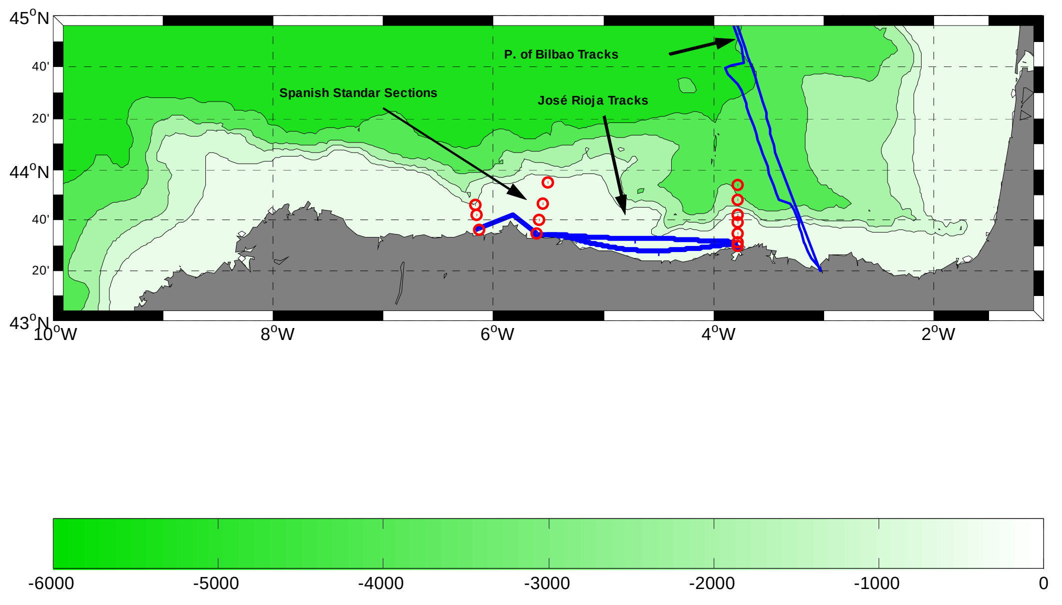


Figure 10-1: Spanish standard sections and track lines surveyed with IEO's Ferrybox installed on RV "Jose Rioja".

10.2 Ferrybox Operation

The system was operated by the crew of the research vessel so the level of automatism required is much lower than in cases where Ferrybox systems are installed on commercial ships.

Data are stored on PCs and recovered once per month. Fluorescence data were not automatically integrated but geo-referenced later by clock-crossing. Water samples are taken on each track from April 2004 manually by the crew.

10.3 Area Specific Experiences

The southern Bay of Biscay presents relative low salinity seasonal and interannual variance (about one unit) except in areas and/or seasons with river outflows. The chlorophyll content is low compared to other areas.

10.4 Maintenance Procedures

The maintenance was made on each cruise by the crew of the vessel (cleaning, water samples and first quality check of the measurements). It was not easy to establish the manpower needed because the crew operates the system besides the routine sampling work. IEO has not accounted work time on board dedicated directly to the Ferrybox system. Under good operation circumstances about 15 minutes before each track are needed (7 tracks per month) plus the time used for water sampling.

10.5 Data Availability

The data availability in the years 2003 to 2005 is graphically displayed in Figure 10-2.

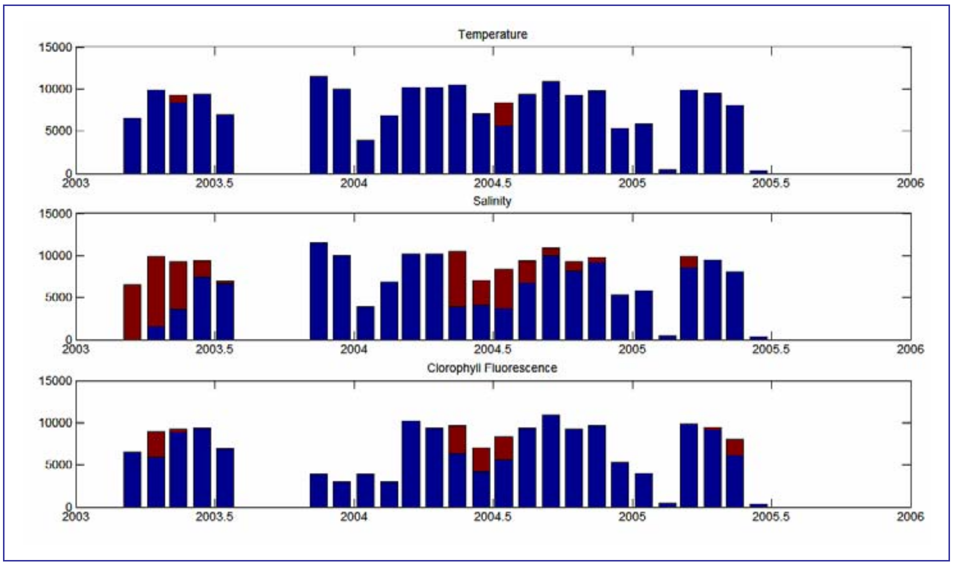


Figure 10-2: Data availability for salinity, temperature and chlorophyll fluorescence for the Ferrybox installed on RV Jose Rioja in the years 2003 – 2005.

There are about $2*10^6$ scans of data at intervals of 10 seconds available (about 550 hours until May 2005). The rejected Data ("L") was about 2% for temperature, 28% for salinity and 9% for chlorophyll fluorescence.

Some data gaps were caused due to removal of the system to check for the salinity drifting problem and an interruption of navigation in winter 2005.

Figure 10-3 to Figure 10-5 present time versus latitude plots of salinity, temperature and chlorophyll fluorescence data from 2003 to 2005.

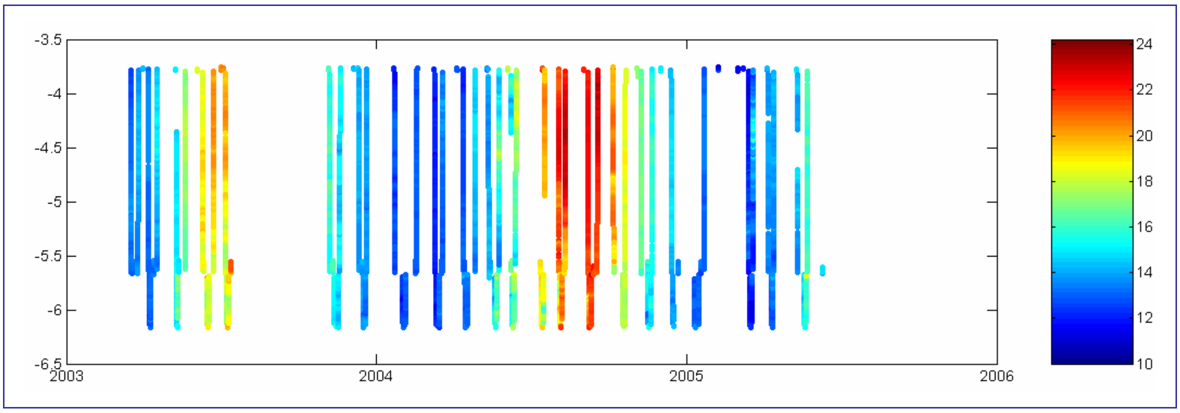


Figure 10-3: Temperature data obtained from 2003 to 2005 with the Ferrybox system installed on RV “Jose Rioja” (time versus latitude plot of all available data).

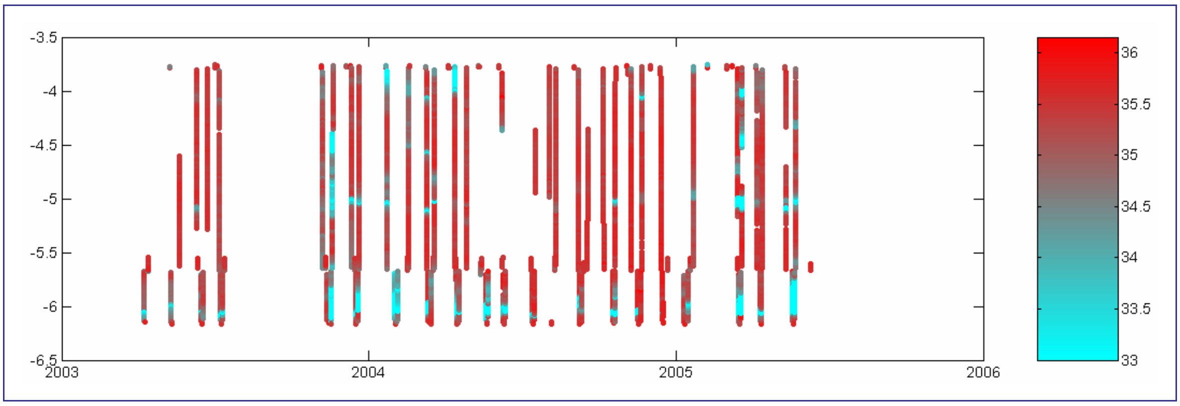


Figure 10-4: Salinity data obtained from 2003 to 2005 with the Ferrybox system installed on RV “Jose Rioja” (time versus latitude plot of all available data).

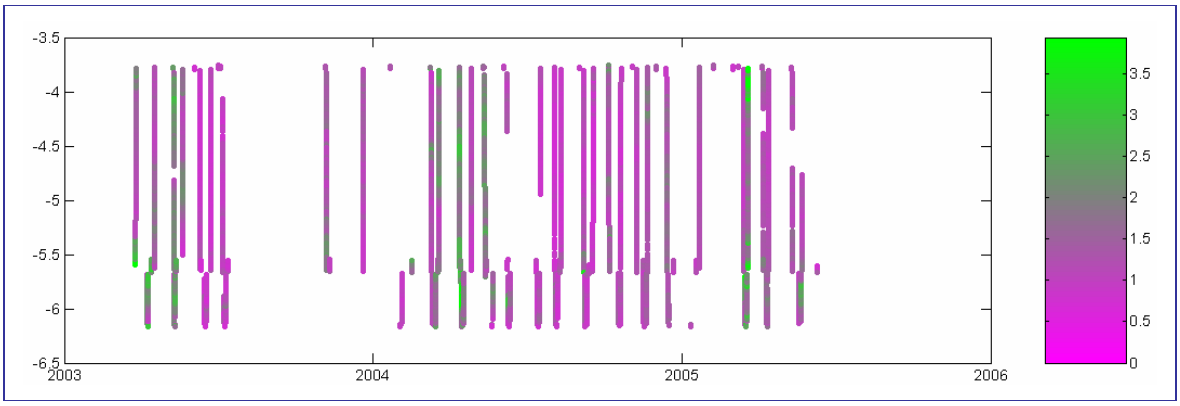


Figure 10-5: Chlorophyll fluorescence data obtained from 2003 to 2005 with the Ferrybox system installed on RV “Jose Rioja” (time versus latitude plot of all available data).

10.6 Quality Assurance of the Data (Metrology)

Data ranges are visually checked after each track by the crew of the vessel and noise and functional form are checked each month at the lab. IEO has developed software for systematic treatment of their Ferrybox data, which includes calibration of all sensors and piecewise interpolation if desired for salinity as well as also geo-referencing for fluorometry.

One to two days per month are needed to manage the data.

10.6.1 Temperature

Both thermometers, the internal Sea-Bird SBE-3 and the external SBE-38, are supposed to present very low drifts in comparison with the natural noise signal in surface waters (about 0.002 ºC per year). Therefore IEO does not calibrate the thermometer despite the manufacturer's routine checks. Further IEO checks that temperature values agree with the CTD cast to discard cases of clear malfunction. However, under normal circumstances IEO expects more confidence on the stability of the sensor than on these checks. IEO has not experienced problems with the external thermometer and with drops of the internal provided for the detection of some problems with the flow through circuit.

10.6.2 Salinity

Salinity behaviour in the IEO system was in general quite poor and drifting problems occurred. A clear diagnostic was not achieved during the FerryBox Project but probably the coastal navigation of the small research vessel and the shallow intake causes premature dirtying of the conductivity cell. From March 2004 salinity samples were taken regularly on each cruise to correct the salinity data independently for each track and CTD SSS were available for the standard sections as illustrated in Figure 10-6.

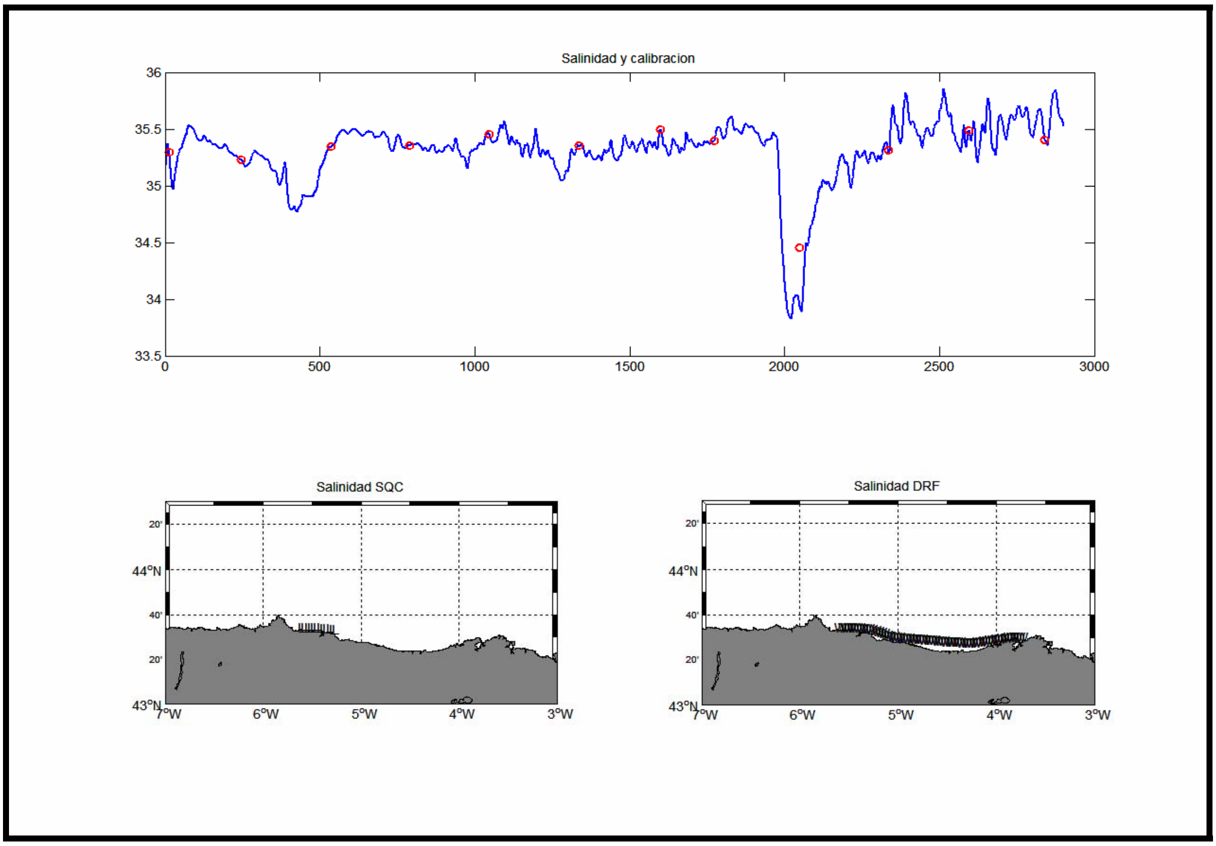


Figure 10-6: Illustrations of salinity quality checks and results with the IEO Ferrybox data.

In cases of identified clear continuous drifts, the correction was made by piecewise interpolation functions whereas in cases of constant differences a constant offset was calculated. In June 2005 the salinometer in IEO's laboratory was damaged and the bottle calibrations were discontinued.

10.6.3 Chlorophyll-Fluorescence

Chlorophyll samples are only taken during specific tracks intended for calibration of the fluorometer. As there is no room on the small research vessel to conduct filtration onboard specific cruises are conducted in 12 month intervals. The first one was in May 2004 and the second one in June 2005. Both calibrations gave similar values for the slope and good correlation. The total time of operation between calibrations is, however, much less than a Ferrybox normal month of operation (less than 40 hours per month). The results for the algal group discrimination were good for most groups but some specific tracks gave unreliable results. Hence the validity of these data is under question.

10.7 Specific Experiences with the Four Basic Parameters

The IEO Ferrybox system on the research vessel “Jose Rioja” suffered serious problems with the salinity measurements as reported above.

The vessel continues to measure both internal and external temperatures. A comparison of the differences between both thermometers from some research cruises was prepared and presented on a FerryBox meeting in Texel in February 2004.

10.8 Data Storage and Access

The diagram (Figure 10-7) below illustrates the work flow and processing steps as described above which have been applied to quality control the IEO’s Ferrybox data up to the stage for inclusion into the Final FerryBox Dataset. After all data have been calibrated, data files have been migrated to the agreed ASCII format and were sent to HYDROMOD on 15 November 2005.

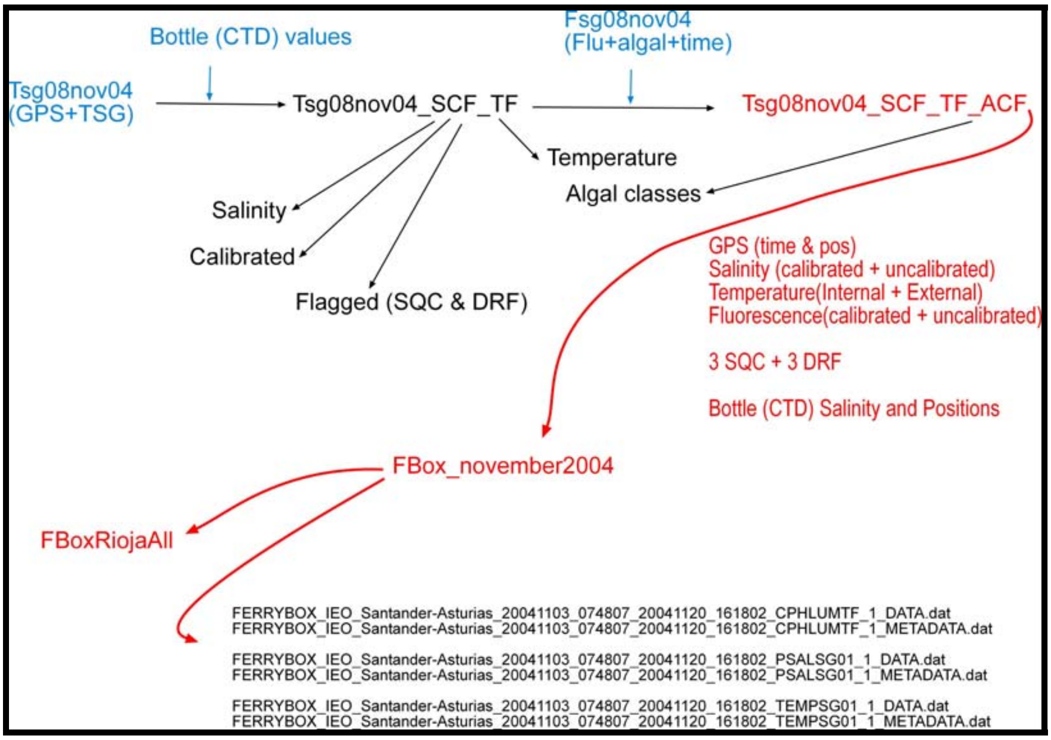


Figure 10-7: Flow diagram of the data quality check and calibration procedure applied for the IEO Ferrybox data.

11 Conclusions

The experiences of the FerryBox Consortium after two years of operating the Ferrybox systems show that after solving some start-up problems most of the Ferrybox systems were running very well producing high rates of reliable data. The availability of reliable data related to the number of cruises was between 50 and 100% year.

The serious problems with somewhere low data retrieval rates and/or lack of reliable data occurring on both newly installed Ferryboxes in the Irish Sea and the Mediterranean Sea in the First FerryBox Year could not completely overcome in the second year. Whereas on the Irish ferry the situation improved after establishing regular visits the operation of the Greek ferry still suffered under the lack of regular maintenance partly caused by numerous changes of the route of the ferryboat by the ferry company but also due to lack of effort. In the second year also the operation of the ferry between Southampton and Cowes (Isle of Wight) had to be stopped due to lack of manpower. All other Ferryboxes were running well.

Another problem which turned out in higher gear in the Second FerryBox Year was addressed to biofouling. The experiences showed that biofouling occurs occasionally and was not predictable. For instance on the Atlantic route the Ferrybox was running for two years with a regular manual cleaning without any biofouling problems. However, in 2005 serious problems with biofouling in the summer months were encountered suddenly. Biofouling problems were also reported in the Irish Sea and on the Dutch route to Texel.

Although the used Ferrybox systems are very different ranging from very simple to highly automatic flow-through systems the partners were also asked to indicate the frequency of maintenance and data quality assurance measures and to estimate their workload for these activities. In Table 11-1 these estimated data after the first year of operating Ferryboxes are shown:

Table 11-1: Frequency and estimated workload for maintenance and data quality assurance at the different ferry lines.

	frequency of maintenance	time of maintenance (hours/month)		travel time (hours/month)	frequency of first data quality check (e.g. visual inspection)	time of first quality check (hours/month)	time of validation/ calibration (hours/month)
		standard sensors	non standard				
FIMR	weekly	8	4	8	weekly	10	45
EMI	weekly	6	4	8	weekly	12	12
NIVA	weekly	8	2	4	daily	12	30
GKSS	fortnightly (chem. analyser weekly)	10	20	25	daily	20	60
NIOZ	weekly	12	0	-	weekly	?	?
SOC	weekly	14	-	8	weekly	12	130 *
NERC.POL	fortnightly	14	-	-	fortnightly	14	7
HCMR	fortnightly	5	-	8	fortnightly	4	100 *

* including sailing time on board of the ferry

As can be seen from the table above most of the lines are maintained on a weekly basis. On the ferries with automatic cleaning systems (GKSS and HCMR) a fortnightly maintenance was considered sufficient. The workload for maintenance was between 5 and 14 hours/month for the four standard sensors. The time to maintain additional sensors/analysers depends strongly on the type of instrument. For instance, when using chemical analysers for nutrients (GKSS Ferrybox) the workload for maintenance and metrology increases dramatically. The workload for metrology measures also depends strongly on the kind of sensor. The time spent for data validation and calibration of the sensors varies between several hours and hundred of hours per month.