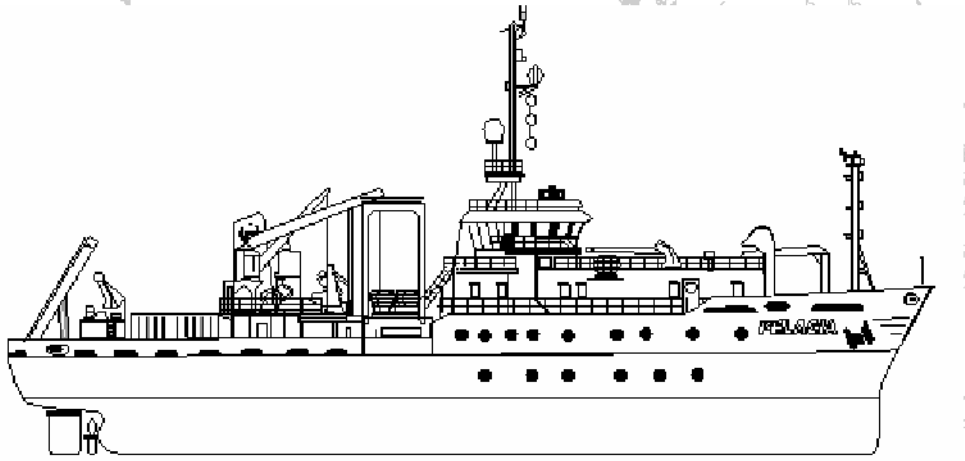


Cruise Report of the cruise 64PE239
Texel, NL – Peterhead, UK
17.08.2005 – 06.09.2005
Chief Scientist: Helmuth Thomas

CARBOOCEAN

Contents

1. Introduction

The combustion of fossil fuels as well as deforestation have led to emission of carbon dioxide (CO_2) into the atmosphere. About half of this CO_2 remains airborne, where it is expected to cause global warming. The other half is partly taken up by the oceans, and partly by the land biosphere. Understanding of the global carbon cycle both in pre-industrial times (before ~1780 A.D.) and with the current perturbation by mankind, is essential for quantifying the fate of fossil fuel CO_2 in the next decades. This in turn is needed to support policy decisions about curtailing emissions (e.g. Kyoto convention).
Thus far global carbon budgets have largely been constructed in terms of oceanic and terrestrial compartments linked by their exchanges with the atmosphere. Coastal seas, here treated as separate compartments, provide a second link between terrestrial and oceanic compartments. The relevance of coastal seas to the global carbon budget is reflected by their high biological activity. Although coastal seas cover less than 10% of the global sea surface, the primary productivity in coastal seas is estimated to be up to 30% of the overall marine productivity. A large part of this primary production is recycled within the euphotic zone by the bacteria and grazers of the planktonic foodweb. Yet some part (10-50%) of the fixed carbon will settle out to the bottom sediments, but then it is mostly (>90%) decomposed at the sediment/water interface, yielding an increase of DIC in bottom waters. The subsequent outflow of such DIC-enriched subsurface waters into the oceans would then provide a net export of DIC from the coastal seas.
The direct impacts of natural terrestrial ecosystems as well as of mankind, of which 37% is living within 100 km of the coast, are buffered or at least smoothed by the coastal seas before they reach the oceanic systems. Largely due to the supply of nutrients (nitrogen (N), phosphorus (P), silicium (Si)) both from river inputs and from shallow marine sediments, there is high primary productivity in coastal surface waters. Additional nutrient input from fertilisers (N, P) used in agriculture, via streams and rivers into the sea, has led to enhancement of this primary productivity (eutrophication) sometimes also leading to severe depletion of oxygen in coastal waters. High loading of rivers with particulate and dissolved organic carbon (POC, DOC) from municipal waste waters may further enhance this oxygen depletion of the coastal zone.

The North Sea is amongst the best-studied coastal areas worldwide with respect to its physical, chemical and biological conditions, since it has been subject to detailed investigations for many decades. After a pioneering carbon cycling study in the late 1980s (Kempe and Pegler, 1991), in 2001/2002 an intense field study led by NIOZ showed that the

North Sea is a sink of CO_2 for the atmosphere and absorbs 1.4 mol C m^{-2} yr^{-1} (Thomas et al., 2004). Bozec et al. (2005) underlined the importance of the late summer season on the annual air-sea fluxes of CO_2 and confirmed the importance of the regional variability in the carbon cycle in the North Sea (Thomas et al. 2005a). A first comprehensive carbon budget has been established and further evaluation of the 2001/2002 data is still in progress. One thesis has recently been finished by Dr. Y. Bozec on the North Sea carbon cycle. It can be found under: http://irs.ub.rug.nl/ppn/286867796.

1.1. Relation to CARBOOCEAN

The cruise 64PE239 contributed to CARBOOCEAN, an Integrated Project of the European Union (www.carboocean.org). The project, which is co-ordinated by the University of Bergen, Norway consists of 5 core themes; core theme 3 focuses on *Carbon uptake and release at European regional scale*. This theme is designed as a novel pilot study towards integration and reconciliation of marine, land and atmospheric assessments of Carbon (read CO_2) sources and sinks in two key West-European regions, the North Sea region and the West Mediterranean region. Both seas bridge the European continent, atmosphere and Atlantic Ocean, hence play a crucial role in the West-European (marine) carbon balance. Theme 3 extends from an ongoing North Sea study, and an ongoing time series in the West Mediterranean Sea. The overarching aim is a closed carbon budget for Western Europe comprising all terrestrial, atmospheric and marine compartments. The joint venture with CarboEurope IP (which covers the partial budgets of the atmosphere and the land) will for the first time ever allow the CARBOOCEAN IP to quantify all relevant fluxes between sea, land and air comprehensively. In this first ever integrated approach, Western Europe is the first case being studied. Policy makers and international organisations will be provided with knowledge on mitigation strategies and estimates on carbon emission scenario and their socio-economic impacts. The institutions participating in the cruise are located in Belgium (University of Liège), in the Netherlands (Royal Netherlands Institute for Sea Research, Netherlands Institute for Ecological Research, NIOO), and in Canada (Dalhousie University, Halifax).

1.3 Details of the research strategy for the North Sea:

The research on the North Sea carbon cycle is in the fortunate situation to rely on a very recent and comprehensive carbon and nutrient data set obtained by the team of Dr. Helmuth Thomas (at that time at NIOZ, NL) The North Sea has been sampled consecutively in 1-month cruises (8/2001, 11/2001, 2/2002, 5/2002) occupying each time 97 stations for sampling the complete water column for the CO2 system and a suite of 20 other parameters. Moreover, cruises have been done by the team of Prof. Michel Frankignoulle (University of Liege) for the CO_2 system in the major rivers and estuaries around the North Sea, of which large parts were found to be strongly supersaturated in CO_2, being a significant source of atmospheric CO_2. These recent activities create a unique foundation for the fundamental CARBOOCEAN research on carbon and nutrient cycle processes. In order to extend this foundation notably towards the investigations of the temporal variability of the North Sea carbon cycle, the field observations will be complemented by multiple cruises and a VOS line between Rotterdam and Bergen. In the later phase of CARBOOCEAN a high quality data set will be available covering a decade. The evaluation will employ field data oriented and sophisticated real-time ecosystem modeling strategies. Mechanistic studies will in turn improve the basin wide models. We will address internal and external carbon fluxes and their controlling processes, but most notably the exchange fluxes between the North Sea and the North Atlantic Ocean, land and atmosphere, with an eye on generating reliable high resolution pCO_2 maps contributing to the below European carbon balance. A special mechanistic focus will be on the CO_2 fluxes related to the Wadden Sea, which can be seen as the intermediate between land and North Sea.

1.4 Location and hydrography of the North Sea: a brief overview

The North Sea is a continental sea with a total surface area of 575000km^2 located on the north-western European continental margin. In the east and south it is bordered by the European continent (Norway in the north to France in the south) while its western boundary is formed by the British Isles. In the south it is connected to the Atlantic Ocean through the English Channel, and in the north it has an open connection to the Norwegian Sea. In the north the shelf break is located at approximately 200m water depth. The maximum water depth in the southern North Sea is 40-50m. Smaller depressions in the central and northern North Sea are in the order of 40-300m deep. In the central North Sea a large shoal with a minimum water depth of less than 20m is present. The Norwegian Channel, a large

depression running in parallel to the Norwegian coast, shows depths of more than 400m and is separated in the south from the Skagerrak by a sill of approximately 280m. The Skagerrak itself is the deepest part of the North Sea (deeper than 780m) and represented the connection to the Baltic Sea.

The dominant hydrographic feature in the North Sea is the tidal motion. It is responsible for the vertical and horizontal mixing of water masses and causes in combination with the long term effect of mainly westerly winds and the baroclinic effect an overall anticlockwise circulation. Atlantic Ocean water enters the North Sea from the south through the English Channel. Baltic Sea water flows through the Kattegatt into the Skagerrak. In the north Norwegian Sea waters enters the North Sea between the Scottish mainland and the Orkney and Shetland Islands and at depths along the western margin of the Norwegian Channel. The main outflow of the North Sea water occurs along the eastern margin of the Norwegian Channel and as the surface current more to the west. During summer only the northern North Sea is stratified allowing the development of several fronts playing an important role in controlling biological processes.

2. The Pelagia Cruise 64PE239

The cruise was designed to cover exactly the same period of the year as the summer 2001 cruise. The intention was to sample all (or as many as possible) stations of the 2001 station grid. (Fig. 1).

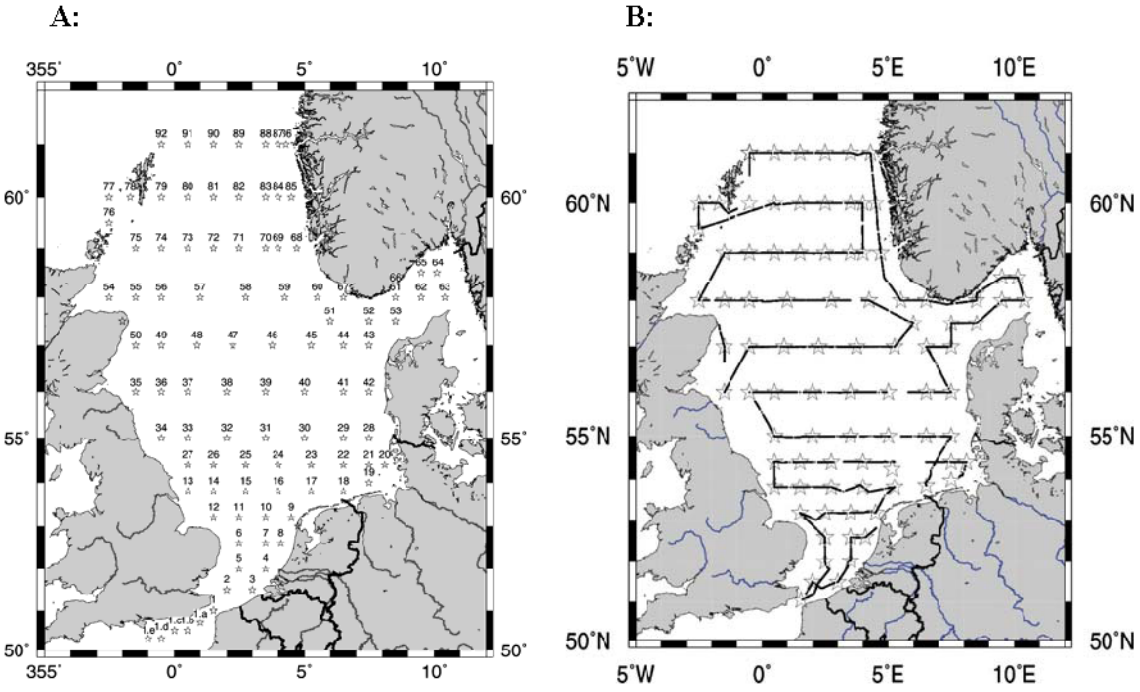


Figure 1: Station grid of the 2001/2002 program to be repeated to the cruise 64PE239. 1a shows the location and labels of the stations, 1b shows the cruise track and the stations sampled during the cruise.

After setting up the equipment on 15. and 16. August 2005, we left Texel on 17. August 2005. We started with a test station relatively close to Texel to ensure that all machinery worked well. In comparison to 2001, in 2005 we had somewhat less time available for the cruise and it was decided to skip the stations 1a-1e on the western side of the English Channel. Our first regular station was station 8, just south of Texel. Figure 2 and Appendix I give the cruise track and stations occupied during the cruise. In summary all but two of the 92 station were sampled. Only stations 87 and 34 could not be sampled because of bad weather conditions. The diary of the cruise on some detailed information on the work can be found at the NIOZ–website under:
http://www.nioz.nl/nioz_nl/fc0a6088226c12c0cf5c325770d75981.php

3. Methods and first results

The methods section briefly describes the methods applied on board for measuring a variety of parameters. The parameters, relevant in the context of the CARBOOCEAN part of the cruise are indicated in Table 1. The methods section is organized first considering the CARBOOCEAN work by groups, which carried out the work. Further parameters have been determined, which follow after the description of the CARBOOCEAN work.

Table 1: Parameters determined during the CARBOOCEAN North Sea program

Discrete vertical samples at the stations	No.	continuous measurements
DIC, A_T, pH, pCO_2, DOC, O_2, $NO_{3/2}$, NH_4, PO_4, SiO_4	≈700	pCO_2, T, S
POC, PIC, Chl.a, DON, DOP, PON, POP	≈200	

3.1. Measurements and Sampling carried out by NIOZ / Dalhousie

3.1.1. The partial pressure of CO_2 (pCO_2)

F. Prowe, S. van Heuven, H. Thomas

The partial pressure of CO_2 (pCO_2) (Fig. 2) in the surface waters was determined using an underway system with continuous flow equilibration. The water flow to the equilibrator was about 60L min^{-1} which was reduced by a bypass just before the equilibrator to 2-3L min^{-1}. The temperature difference between the equilibrator and the surface water was lower than 0.5K, usually 0.1K. The detection of pCO_2 was performed by a non-dispersive infrared spectrometer, which was calibrated against *National Oceanic and Atmospheric Administration* (NOAA) standards every 24 hours. The method is described in detail by Körtzinger et. al. (1996) with an estimated error of approximately 1 µatm. The atmospheric pCO_2 was sampled at the antenna platform of the ship and determined approximately every 1 hour.

3.1.2. Dissolved inorganic carbon (DIC)

F. Prowe, S. van Heuven, H. Thomas

Dissolved inorganic carbon DIC (DIC) was determined the coulometric method by Johnson et al. (1993). The principle of coulometry relies on Faraday's law according to which 96485 Coulombs (C) correspond to 1mol of a chemical substance which electrical charge will be changed by one unit. An automated extraction line takes volumetrically a very accurate subsample which is acidified with 8.5% phosphoric acid (H_3PO_4). Due to this decrease in pH all HCO_3^-- and CO_3^{2-}- ions will be converted to $CO_{2,aqueous}$. The sample is stripped using ultra-pure nitrogen gas and the carrier gas is led into the titration cell. This cell contains a solution of Dimethylsulfoxide (DMSO), ethanolamine and a colourimetric indicator thymolphtalein. The irreversible reaction of the CO_2 gas with the ethanolamine generates the hydroxyethylcarbamic acid (1) which in turn gives a colour change of the (dark blue) indicator. The fading of the colour is detected photometrically. During the electrochemical tritation the hydroxyethylcarbamic acid is neutralised by OH^- ions (2-4). From start to end of the titration the current (*I*) is integrated over the time and the according to Faraday's law the CO_2 molecules titrated, i.e. the concentration of DIC can be computed.

$$CO_2 + HO(CH_2)_2NH_2 \rightarrow HO(CH_2)_2NHCOOH \quad (1)$$

$$2Ag^0 \rightarrow 2Ag^+ + 2e^- \quad (2)$$

$$2H_2O + 2e^- \rightarrow H_2(\uparrow) + 2OH^- \quad (3)$$

$$OH^- + HO(CH_2)_2NHCOOH \rightarrow H_2O + HO(CH_2)_2NHCOO^- \quad (4)$$

At the stations DIC was measured directly after sampling and between the stations approximately every 10 min. using the online-mode of the extraction system.

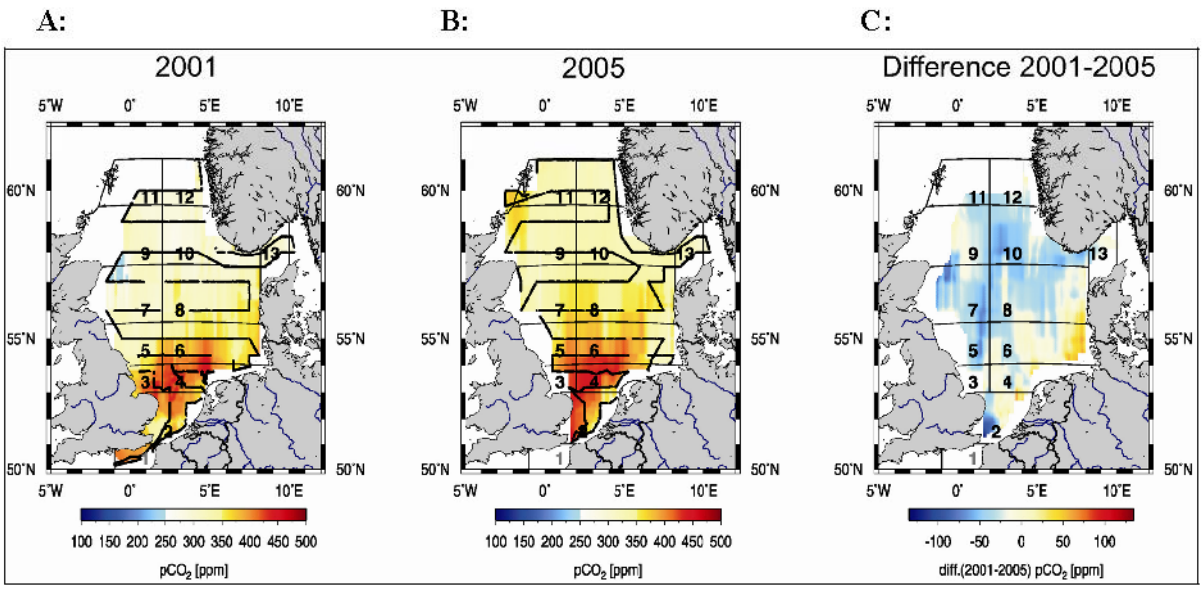


Figure 2: pCO_2 in 2001 (a) and 2005 (b) as well as the pCO_2 difference between both years. Negative numbers in (C) indicate higher values in 2005.

3.1.3. Nutrient measurements

J. van Ooijen

From Noex bottles attached to the CTD-frame samples were drawn for the shipboard determination of the nutrients Ammonium, Nitrate, Nitrite and Phosphate. In the same way samples were taken for the analyses of Silicate. The samples were collected in polypropylene sample bottles after three time rinsing. The samples were filtered on a 0.20 um acrodisc filter, put in a 6ml polyethylene vial and stored dark and cool in a refrigarator at 4 °C. All samples were analysed within 18 hours with a autoanalyser based on colorimetry using a Technicon TRAACS 800 Autoanalyser. A maximum of 50 samples in each run was analyzed and all samples were covered during the run with parafilm to prevent evaporation and contamination of ammonium out of the air. The methods used were described by Grashoff(1983). The samples for the silicate analyses were stored in a different refrigerator and analyzed in our lab at Royal NIOZ.

- Phosphate reacts with ammoniummolybdate at pH=1.0 and potassiumantimonyltartrate was used as an inhibitor. The yellow phosphate-molydenum complex was reduced by ascorbic acid to a blue complex and measured at 880nm.
- Nitrite was diazotated with sulphanilamide and naphtylenediamine to a pink coloured complex and measured at 550nm.

- Nitrate was mixed with a buffer of imidazol at pH=7.5 and reduced to nitrite by a copper-coated cadmium coil (efficiency >98%) and measured as nitrite (see above) to yield the nitrate content after subtraction of the nitrite content. The reduction efficiency of the cadmium coil was measured each run.
- Ammonium reacts with phenol and sodiumhypochlorite at pH=10.5 to a indo-phenol blue complex. Sodiumcitrate is used as a buffer and complexing agent for calcium and magnesium at this pH. The colour is measured at 630nm.
- Silicate reacts with ammoniummolybdate to a yellow complex which, after reduction with ascorbic acid forms a blue silica-molybdenum complex that was measured at 800nm. Oxalic acid was used to prevent the formation of a blue phosphate-molybdenum complex.

Calibration standards were prepared freshly every day by diluting stock solutions of each nutrient in the same nutrient depleted surface ocean water as used for the baseline water. Standards were kept dark and cool in the same refrigerator as the samples. Each run of the system had a correlation coefficient of at least 0.999. The samples were measured from the surface to the bottom to obtain the smallest possible carry-over effects. In each run a mixed control standard containing silicate, phosphate, nitrate and ammonium in a constant and well known concentration was measured. This standard was used to check the performance of the analyses and if necessary used to make corrections.

The statistics of the analyses within 1 run are:

Control Standard	**Phosphate µmol/L**	**Ammonium µmol/L**	**Nitrite µmol/L**	**Nitrate µmol/L**	**Silicate µmol/L**
Average	0.868	0.807	0.035	14.09	13.68
Standard deviation (uM)	0.003	0.025	0.006	0.04	0.01
St.dev. % full scale	0.192	0.550	0.573	0.29	0.07

The statistics of the analyses between the different runs are:

Control Standard	**Phosphate µmol/L**	**Ammonium µmol/L**	**Nitrite µmol/L**	**Nitrate µmol/L**	**Silicate µmol/L**
Average	0.865	0.853	0.032	14.030	13.768
Standard deviation (uM)	0.006	0.026	0.008	0.075	0.050
St.dev. % full scale	0.422	0.238	0.778	0.499	0.296

Samples for dissolved organic nitrogen and phosphorus (DON, DOP) have been taken for later analysis in the home laboratory.

3.1.4. Oxygen measurements

J. van Ooijen and M. Sinke

For the determination of oxygen concentrations, seawater samples were drawn out of the Noex bottles, which were attached to the CTD, into pre-calibrated 120 ml pyrex glass bottles. Each bottle was flushed with at least 3 times its volume. The determination of the dissolved oxygen concentration of water samples was carried out by measuring the formed Iodine colour at 460nm on a Technicon TRAACS 800 continuous flow spectrophotometer, combined with a stand-alone NIOZ-made sampler, based on Winkler technique (See Su-Chen Pai et al., Marine Chemistry 41 (1993), pp 343-351.
Immediately after acidification, all bottles were covered with parafilm against evaporation and shielded with PVC caps to prevent light-induced iodine formation. A stock solution of Potassiumiodate was used in the analyses spiked to seawater blanks (reversed order addition of the Winkler chemicals) to obtain a calibration curve with a correlation coefficient of 1.0000 for 4 calibrants in each run. The stock solution was stored in an airtight water-saturated box (100% humidity) to prevent evaporation through the plastic bottle.
In each run an oxygen saturated seawater sample, which was sampled at the start of the cruise and kept underwater to prevent contamination out of the air, was measured and used for making corrections to the samples in that run. The standard deviation of the oxygen measurement within one run is 0.08%. The standard deviation between the different runs is 0.24 % of the average value of 226 µmol/L.

3.1.5. DOC, POC, PON

J. Snoek, T. Shlomi, K. Elkalay

Samples for dissolved organic carbon (DOC), particulate organic carbon (POC), particulate organic nitrogen (PON) were taken. Water samples were filtered through precombusted GFF filters. From the filtrate acidified samples of 8ml were frozen for later DOC measurements. The residual filters were frozen for the remaining measurements.

3.1.6. CTD

S. Asjes, T. Shlomi, K. Elkalay

The CTD was operated in the standard configuration.

3.2. Measurements and Sampling carried out by the University of Liege

Carbonate system parameters (II): Alkalinity, pH and pCO_2

The tasks of Chemical Oceanography Unit of the University of Liège (http://www.ulg.ac.be/oceanbio/co2/) during the 64PE239 cruise were to measure:

- underway pH and pCO_2 measurements (acquisition every min.)
- discrete pH and total alkalinity (TA) measurements from CTD casts

pH measurements were carried out using a combination electrode calibrated on the Total Hydrogen Ion Scale, using the TRIS and AMP buffers prepared according to DOE (1994). pCO_2 measurements were carried out using a Licor 6262 Infrared Gas Analyser coupled to an equilibrator based on the design described by Frankignoulle et al. (2001). TA measurements were carried out based on classical electro-titration to the second end-point of carbonic acid using HCl as titrant.

Figures 3 and 4 show preliminary results obtained during the 64PE239 cruise by the Chemical Oceanography Unit of the University of Liège.

The distribution of surface water pH mirrors the one of pCO_2 (Fig. 2) and picks up the same structures (Fig. 3). A more detailed analysis in the near future will allow us to determine the overall accuracy of the performed pH measurements by comparing pCO_2 computed from pH and TA with the pCO_2 measured by equilibration.

Figure 4 shows depth integrated values of pH and pCO_2 normalized to a temperature of 11°C and TA normalized to a constant salinity of 35, along the same transect of DIC reported by Bozec et al. (2004) for August 2001 (shown in lower right hand corner of Fig. 4). A distinct decrease of pH and concomitant increase of pCO_2 from West to East is apparent from Fig. 4 in agreement with the increase of DIC reported by Bozec et al. (2005). However, Fig. 4 also shows a distinct increase of TA@35 from West to East suggesting a net export of HCO_3^- and CO_3^{2-} from the North Sea to the adjacent Atlantic Ocean that can be attributed to a combination of river inputs of these quantities and net $CaCO_3$ dissolution. A more detailed analysis in the near future will allow to unravel the relative contribution from these processes and determine if the North Sea is a net sink or source of $CaCO_3$.

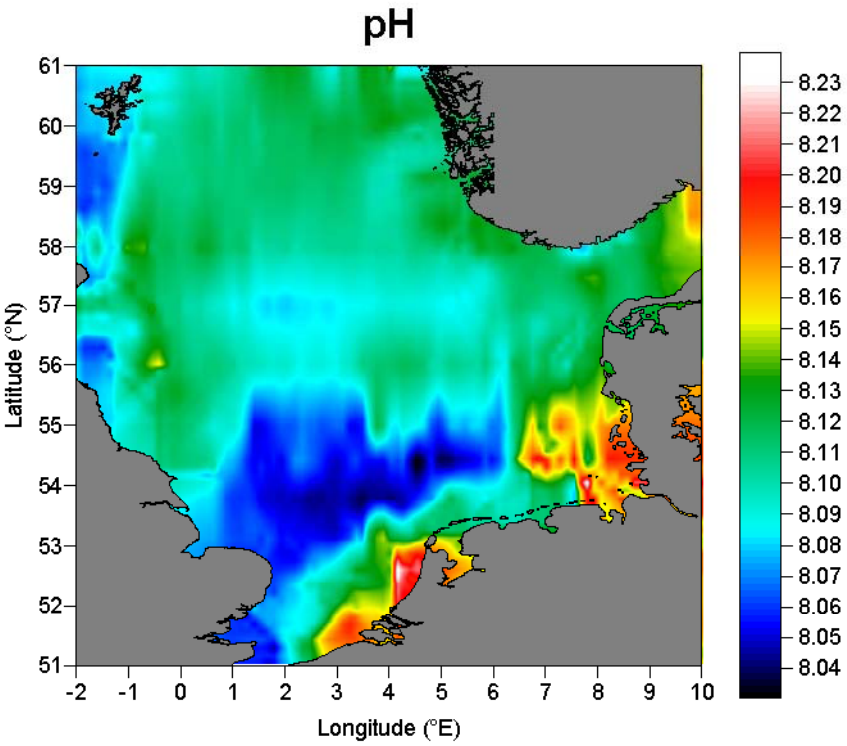
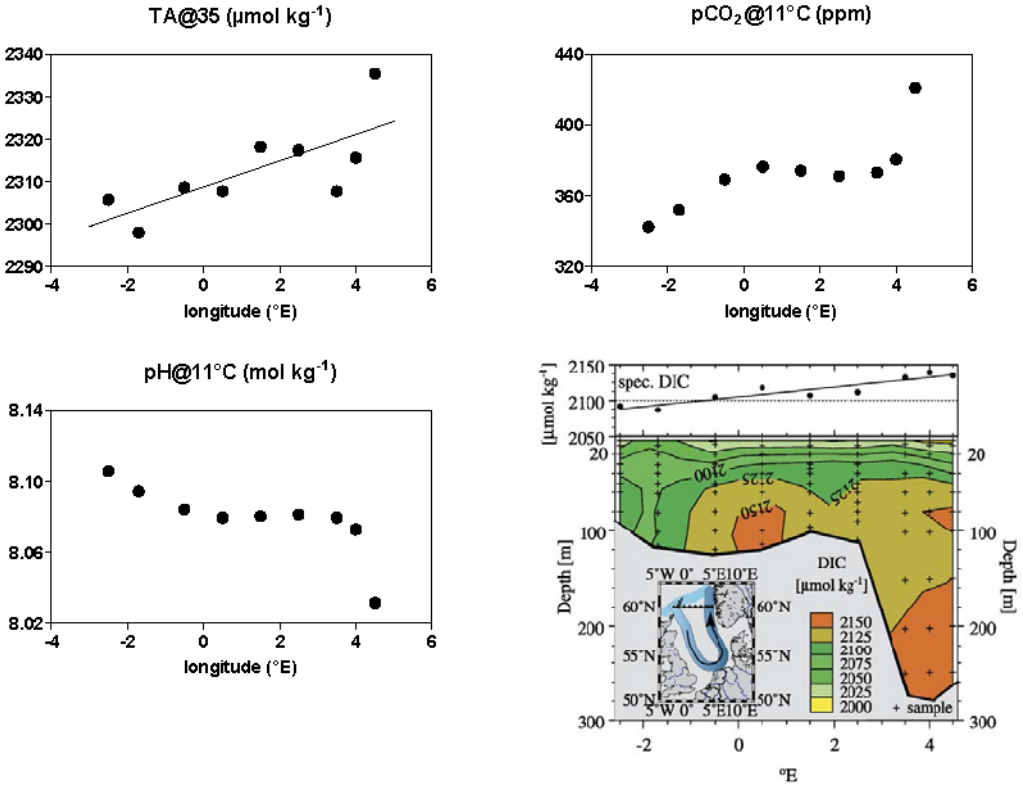


Figure 3: pH in surface waters during the CARBOOCEAN 64PE239 cruise in the North Sea.

Figure 4: Depth integrated total alkalinity normalized to a constant salinity of 35 (TA@35), pH and pCO_2 normalized at a constant temperature of 11°C (pH@11°C, pCO_2@11°C) along a transect following 60°N during the CARBOOCEAN 64PE239 cruise and depth integrated DIC along the same transect in August 2001 (from Bozec et al. 2004).



3.3 The *in situ* copepod production in the North Sea, late summer 2005

(by the natural tracer chitobiase, an enzyme used in the moults of crustaceans)

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Introduction: the usefulness of a wasted enzyme

The measurement of production is a key variable in ecological research, especially if the focus is on the transfer of carbon and energy through the food web. Since the start of the widespread use of the 14C method for estimating primary production and the use of tritium labelled leucine for estimating bacterial production, zooplankton workers have been jealously searching for a similarly easy method to determine secondary production in the field. In animals, however, specific radiolabeled substrates for determining growth are lacking. In practice, marine studies of zooplankton production have concentrated on copepods, the most dominant group in the marine zooplankton, with growth experiments in the laboratory. In the field, populations may be continuously followed and sampled in relatively closed bays and fjords. Secondary production is then deduced from changes in numbers, biomass and size. This type of time series sampling can hardly be done in the open sea where advection, patchiness and vertical migration severely hamper tracking of populations over sufficiently long time spans. Consequently, estimates of secondary production in open marine waters are still almost exclusively based on extrapolations, by combining observed standing stocks with growth rates measured in the laboratory.
So zooplankton ecologists are still in need of an easy field method to estimate copepod growth during cruises, without confinement or extensive manipulation of specimens, and valid for mixed populations that predominate in natural conditions. Biochemical methods to study process rates in plankton have been tested and used in biological oceanography since decades. In zooplankton ecology, biochemical variables like enzymes have been measured in tissue samples or homogenates of animals. These methods, generally, gave little insight and thus have been abandoned in later years. The main reason why this type of study so often failed is because it measures a stock of potential enzyme activity, and not the real activity of the enzyme. In other words, the presence of a certain amount of enzyme in the tissue of the animal does not reflect the actual use or turnover of the enzyme.

Recently, successful tests were done with a new method wherein an enzyme is measured that has been really used once it is found in the water. In the pre-moult phase of crustaceans, the old chitin exoskeleton is degraded by the chitinolytic enzymes chitinase and chitobiase and these enzymes are released into the ambient water when the remnant of the old skin is shed. Chitobiase activity was measured in culture water of the marine copepod *Temora longicornis* and the amount of free chitobiase reflected the increase of body weight, both individually and in the culture population (Oosterhuis et al. 2000, MEPS 196: 195-206). A second study demonstrated that such a relationship might be general among copepod species and that the technique could be made operational for use in temperate marine waters (Baars & Oosterhuis, in prep.).

Material and Methods

Sampling scheme. The CARBOOCEAN cruise did 90 CTD rosette stations in total in the North Sea from 17 August to 6 September 2005. At 63 of these stations, water samples were collected at 3 to 6 discrete depths for chitobiase assays. The usual scheme for chitobiase was 3 or 4 samples at shallow stations, at depths 5, 15, 25 m and near-bottom. At deeper, stratified stations assays were done for up to 6 depths: two samples in the upper layer at 5 and 20 m depth, and up to three samples in the lower layer at 50, 75 and 100 m depth, plus an extra sample at the near-bottom depth.
Zooplankton catches were done with a 200-µm mesh sized WP-2 vertical net. Hauls were from near bottom to surface, or from a depth of 100 m to surface at stations with bottom depth > 100 m. Catches were preserved in formalin, for later analysis at the laboratory. This will include microscopic examination but crustacean (= copepod) biomass will be determined by analysis of the chitin concentration. In tests of this long existing but never widely been used biomass method, the formol preservation did not interfere with the chitin measurement. Subsequently, chitin biomass will be converted to carbon biomass, for a comparison between copepod production and copepod biomass (P/B ratios).

Chitobiase assay. As substrate for the chitobiase assay MUFNAG (methylumbelliferyl *N*-acetyl-ß-D-glucosaminide, Sigma) was used. A substrate stock solution was prepared of MUFNAG dissolved in 2-methoxy-ethanol to a concentration of 7.5 mM (maximum solubility) and stored at -20°C. For the assay of free chitobiase, freshly sampled seawater was filtered under gentle vacuum through 0.2 µm polycarbonate filters (Poretics) to remove the particulate matter. Test tubes were filled with 4.7 ml of the filtrate and 100 µl of MUFNAG

stock after which the mixture was buffered with 200 µl Tris HCl (0.5 M, pH=7.5) which led to a final concentration of 150 µM MUFNAG. At the start and the end of a 120 min incubation period in a water bath at 25°C, the fluorescence of the samples was measured on a Perkin Elmer LS 2B filter fluorometer using an excitation wavelength of 366 nm and an emission wavelength of 450 nm. The increase in fluorescence over the incubation period reflected the free chitobiase activity and was expressed as the quantity of methylumbelliferone (MUF) liberated per hour ($nmol.l^{-1}.h^{-1}$).

Degradation rate. For an estimate of the *in situ* daily release of free chitobiase activity the degradation rate by bacteria was measured. The accuracy of the degradation measurement was increased by spiking the natural water sample with extra free chitobiase, prepared from fresh copepod material. Typically, 15-50 specimens of neritic copepods, or 5-10 of *C. finmarchicus*, were sorted from a net catch, homogenated in a Potter Elvejhem tube and added to 4 ml of diluent. The suspension was filtered through a Whatman GFC filter and subsequently through a 0.2 µm polycarbonate filter. A natural water sample of 0.5 liter, filtered through a 50 µm mesh size screen to remove the zooplankton, was spiked with 0.5 ml of the zooplankton homogenate. The increase of the free chitobiase activity by the spike was aimed for by a factor of 10, approximately. The increased activity level was suitable to run the chitobiase assay within 30 minutes. After the first subsamples to establish the activity level at the start of the degradation experiment, the bottle was kept at ambient seawater temperature in container 11 and final subsamples were taken after 24 hours. The chitobiase activities, measured during the degradation experiments, were log-transformed and regressed versus time. The antilog of the slope then represented the rate of degradation, i.e. the fraction of activity that disappeared each hour (cf. Oosterhuis et al. 2000).

Calculation of copepod production. For each station, it was supposed that there was a shortterm balance between the decay and the release of natural free chitobiase in the water column. The sampling scheme of the cruise provided only one short stop per station without the opportunity to sample free chitobiase during 24 hours in order to track possible changes in the concentrations of free chitobiase. Thus the assumption had to be made that on a daily basis the degradation of free chitobiase by bacteria in natural waters was balanced by the release of fresh chitobiase during new moults in the water column. The total daily release of free chitobiase activity was then calculated by multiplying the natural free chitobiase activity by the measured fraction decayed per hour times 24 hours. Daily total release of free chitobiase was subsequently converted into biomass increase according to the empirical relation found during the experiments on moulted specimens: dry weight increment = 11.6

times daily chitobiase release + 1.1 (Baars & Oosterhuis 2006). Finally, dryweight was converted by a factor 0.4 into carbon.

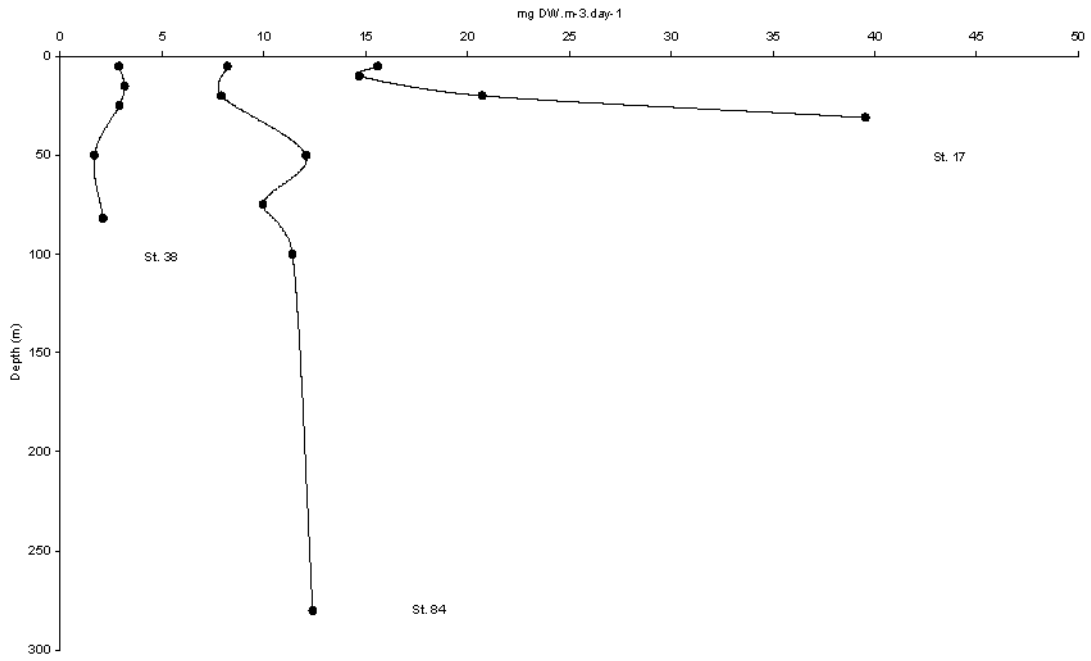
Preliminary results

Examples of the chitobiase measurements and calculations are given in a Table and Figure on the next page. At these, rather randomly chosen stations 17, 38 and 84, the natural free chitobiase activity in the water column was quite uniform, ranging from 1.5 to 2.5 units except for a high near bottom activity of 4.5 at station 17 at the muddy slope of the Oyster Ground, the so called Frisian Front. The rates of decay varied much more. The chitobiase decay in the water column of station 38 in the central North Sea was very low with 0.1 – 0.5 % per hour, whereas at station 17 it was around 3 % per hour. The calculated total decay - or release - of chitobiase per day per depth was low for station 38 and high for station 17 (see Table). The daily released chitobiase was converted to dryweight copepod production (Figure).
The final map-like figure gives a first impression of the carbon copepod production per square metre (till near bottom at shallow stations or till 100 m at deeper stations). Interpretation, and comparison of the copepod production with the hydrographic data, have to await further processing of data. A first comparison between copepod carbon production in the upper 100 m and primary production in the euphotic zone (data by F. Gazeau), gave a mean ratio of 0.23, with a range from 0.09 to 0.59 (n = 12).

Acknowledgement. This is the first time that the chitobiase method was routinely applied for estimating the secondary production on the scale of the entire North Sea. We are very grateful to chief scientist Dr Helmuth Thomas for his enthusiast response to our request to accommodate this topic on the cruise CARBOOCEAN. Helmuth generously provided ample deck time for the net hauls. We feel fortunate that we were part of his cruise. We thank crew and scientific crew for all their help and cooperative efforts.

Some measurements of natural free chitobiase activity and decay rate at different depths

	Depth (m)	Chitobiase activity V (nmol.l-1.h-1)	Chitobiase rate of decay (% h-1)	Daily released chitobiase activity (nmol.l-1.h-1)	Copepod production (mg DW.m-3.day-1)
Station 17	5	1.8	2.9	1.25	15.6
Frisian Front	10	1.8	2.7	1.17	14.7
	20	2.2	3.3	1.69	20.7
	31	4.5	3.0	3.31	39.5
Station 38	5	2.0	0.3	0.15	2.9
central North Sea	15	1.6	0.5	0.18	3.2
	25	1.5	0.4	0.16	2.9
	50	1.8	0.1	0.05	1.7
	82	1.4	0.3	0.09	2.1
Station 84	5	2.3	1.1	0.61	8.2
Norwegian Channel	20	1.7	1.4	0.59	7.9
	50	2.6	1.5	0.95	12.1
	75	2.4	1.3	0.76	10.0
	100	2.5	1.5	0.89	11.4
	280	2.5	1.7	0.97	12.4



Copepod production, mg carbon per m^2 per day.

Southern stations: surface to bottom; other stations surface till 100 m.

61°			326	582		834		485						
60°		388	149		354	314		402						
	229													
59°			223		259		215	454						
														368
58°	583	288	386	585				326	528	572			90	292
											377			
57°				356	284				253	102	164			
56°			74	105	77		79			133	119			
				207	134		108		208	316	500			
55°				292	341	144			190	317	393	213		
				121		272	116		265	415				
					77	140	147							
								61						
52°						130		338						
								446						
							384							
51°						355								

3.4. Community metabolism measurements

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A system is autotrophic when production of organic matter by primary producers exceeds the consumption of this matter by the overall community. Such systems are potentially net sinks for atmospheric CO_2 although air-sea CO_2 flux is also controlled by external inputs of dissolved inorganic carbon, calcium carbonate (CaCO3) precipitation and dissolution and thermodynamic effects. In contrast, an ecosystem is heterotrophic when organic matter consumption exceeds primary production, leading generally to high CO_2 partial pressures (pCO_2) and low oxygen (O_2) concentrations in the water column. During this cruise, we estimated the metabolism of the mixed-layer using the oxygen light-dark method in a 5-compartment on-deck incubator. Samples (in triplicate) were kept at *in situ* temperature by flowing water and irradiance was controlled in each compartment with filters of shading capacity of 0, 81, 87, 92 and 100%. In order to avoid sedimentation of particulate material in the samples, the incubated bottles were fixed on a rotating device (1 rpm). Incubations took place from sunrise to sunset.

Concentrations of dissolved O_2 were measured before and after incubation using an automated Winkler titration technique with a potentiometric end-point detection. Analyses were performed with an Orion redox electrode (9778-SC). Hourly planktonic community respiration (CR; expressed as a negative value) and hourly net community production during the day (NCP_d) were estimated as the difference between the O_2 concentration at the end and the beginning of the incubations divided by the time of incubation, in the dark and transparent bottles, respectively. Hourly planktonic GPP was calculated as the difference between NCP_d and CR. Daily planktonic CR were calculated by multiplying the hourly rates by 24, assuming a constant rate over this period. Hourly GPP were multiplied by the daylight duration to estimate daily planktonic GPP. Using information on light penetration depth, planktonic volumetric rates (GPP and CR) were depth-integrated using a simple trapezoidal procedure.

4. Acknowledgements

The success of the cruise 64PE239 heavily relied upon the excellent and supportive co-operation of the captain and the crew of RV PELAGIA. In a very pleasant atmosphere the crew allowed us to achieve our goal of resampling the 92 stations grid of the North Sea and to generate a great data set to be evaluated in the near future. We are also deeply indebted to the administrative, technical and leading "ground staff" of NIOZ, taking care of the enormous background organization of this cruise. The cruise contributed to and was supported by CARBOOCEAN, an integrated project of the European Union's 6th framework program. The cruise also contributed to the IGBP core project LOICZ, which considers the core theme 3 of CARBOOCEAN as regional project.

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Appendix 1:

Stations occupied during the cruise 64PE239.
For activity and parameters codes see Appendix 2.

Date, Time	°N	°E	Station Label	Station-order	Cast	Activity	Max. Depth	Comments and Parameters
Aug 17 2005 17:37:36	52.77	4.43	test	1	1	ros	22	Test
Aug 17 2005 17:56:25	52.77	4.43	test	1	2	vn200	22	Test
Aug 17 2005 18:00:20	52.77	4.43	test	1	3	vn200	22	Test
Aug 17 2005 19:41:15	52.60	4.10	8	2	1	ros	25	1-7, 20-27
Aug 17 2005 22:15:34	52.60	3.50	7	3	1	ros	31	1-7, 20-27
Aug 18 2005 02:12:06	52.03	3.50	4	4	1	ros	31	1-7, 20-27
Aug 18 2005 02:26:08	52.03	3.50	4	4	2	vn200	31	
Aug 18 2005 06:19:12	51.50	3.00	3	5	1	ros	26	1-7, 20-27
Aug 18 2005 06:33:03	51.50	3.00	3	6	1	vn200	25	
Aug 18 2005 10:42:09	51.51	1.99	2	7	1	ros	47	failed
Aug 18 2005 11:00:33	51.51	1.99	2	8	1	vn200	47	
Aug 18 2005 11:08:19	51.51	1.99	2	9	1	ros	47	failed
Aug 18 2005 11:39:08	51.51	1.99	2	10	1	ros	47	1-7, 20-27
Aug 18 2005 16:33:54	51.04	1.54	1	11	1	ros	42	1-7, 20-27
Aug 18 2005 16:51:27	51.04	1.54	1	11	2	vn200	42	failed
Aug 18 2005 16:55:55	51.04	1.54	1	11	3	vn200	42	
Aug 19 2005 01:22:41	52.00	2.50	5	12	1	ros	47	1-7, 20-27
Aug 19 2005 05:06:33	52.60	2.50	6	13	1	ros	48	1-7, 20-27
Aug 19 2005 05:20:55	52.60	2.50	6	13	2	vn200	48	
Aug 19 2005 11:18:57	53.20	1.50	12	14	1	ros	24	1-7, 20-27
Aug 19 2005 11:35:27	53.20	1.50	12	15	1	vn200	24	
Aug 19 2005 16:34:47	53.20	2.50	11	16	1	ros	31	1-7, 20-27
Aug 19 2005 16:46:35	53.20	2.50	11	16	2	vn200	31	
Aug 19 2005 20:26:23	53.20	3.50	10	17	1	ros	26	1-7, 20-27
Aug 19 2005 20:38:01	53.20	3.50	10	18	1	vn200	26	
Aug 20 2005 00:33:19	53.20	4.50	9	19	1	ros	29	1-7, 20-27
Aug 20 2005 05:14:46	53.80	5.25	17	20	1	ros	33	1-7, 20-27
Aug 20 2005 05:32:16	53.80	5.25	17	20	2	vn200	34	
Aug 20 2005 11:08:30	53.80	4.00	16	21	1	ros	41	1-7, 20-27
Aug 20 2005 11:29:39	53.80	4.00	16	22	1	vn200	40	
Aug 20 2005 11:30:05	53.80	4.00	16	23	1	vn200	41	
Aug 20 2005 16:34:32	53.80	2.75	15	24	1	ros	13	1-7, 20-27
Aug 20 2005 16:47:52	53.80	2.75	15	24	2	vn200	46	
Aug 20 2005 22:34:17	53.80	1.50	14	25	1	ros	30	1-7, 20-27
Aug 21 2005 02:20:07	53.80	0.50	13	26	1	ros	37	1-7, 20-27
Aug 21 2005 08:03:18	54.40	0.50	13	27	1	vn200	69	
Aug 21 2005 08:10:38	54.40	0.50	13	28	1	vn200	69	
Aug 21 2005 12:44:03	54.40	0.50	27	29	1	ros	66	1-7, 20-27
Aug 21 2005 16:42:39	54.40	1.50	26	30	1	ros	59	1-7, 20-27
Aug 21 2005 16:58:33	54.40	1.50	26	30	2	vn200	58	

Date, Time	°N	°E	Station Label	Station-order	Cast	Activity	Max. Depth	Comments and Parameters
Aug 21 2005 21:04:27	54.40	2.75	25	31	1	ros	28	1-7, 20-27
Aug 21 2005 21:16:13	54.40	2.75	25	32	1	vn200	28	
Aug 22 2005 01:40:49	54.40	4.00	24	33	1	ros	44	1-7, 20-27
Aug 22 2005 06:30:47	54.40	5.25	23	34	1	ros	42	1-7, 20-27
Aug 22 2005 06:51:34	54.40	5.25	23	35	1	vn200	42	
Aug 22 2005 11:14:33	54.40	6.50	22	36	1	ros	39	1-7, 20-27
Aug 22 2005 11:28:41	54.40	6.50	22	37	1	vn200	39	
Aug 22 2005 11:43:23	54.40	6.50	22	38	1	ros	39	1-7, 20-27
Aug 22 2005 15:17:19	54.40	7.50	21	39	1	ros	27	1-7, 20-27
Aug 22 2005 15:29:22	54.40	7.50	21	39	2	vn200	27	
Aug 22 2005 17:59:53	54.40	8.10	20	40	1	ros	18	1-7, 20-27
Aug 22 2005 18:11:30	54.40	8.10	19	40	2	vn200	18	
Aug 22 2005 23:24:01	53.97	7.50	19	41	1	ros	30	1-7, 20-27
Aug 23 2005 03:17:09	53.83	6.50	18	42	1	ros	22	1-7, 20-27
Aug 23 2005 03:27:16	53.83	6.50	18	42	2	vn200	22	
Aug 23 2005 11:27:09	55.00	7.50	28	43	1	ros	27	1-7, 20-27
Aug 23 2005 11:38:48	55.00	7.50	28	44	1	vn200	46	
Aug 23 2005 15:26:45	55.00	6.50	29	45	1	ros	41	1-7, 20-27
Aug 23 2005 15:41:29	55.00	6.50	29	45	2	vn200	38	
Aug 23 2005 21:03:36	55.00	5.00	30	46	1	ros	27	1-7, 20-27
Aug 23 2005 21:20:19	55.00	5.00	30	47	1	vn200	45	
Aug 24 2005 03:05:10	55.00	3.50	31	48	1	ros	40	1-7, 20-27
Aug 24 2005 03:22:12	55.00	3.50	31	48	2	vn200	38	
Aug 24 2005 10:07:35	55.00	2.00	32	49	1	ros	27	1-7, 20-27
Aug 24 2005 10:17:31	55.00	2.00	32	50	1	vn200	27	
Aug 24 2005 19:21:41	55.00	0.50	33	51	1	ros	68	1-7, 20-27
Aug 24 2005 19:38:22	55.00	0.50	33	52	1	vn200	74	
Aug 25 2005 02:53:56	56.00	-0.50	36	53	1	ros	76	1-7, 20-27
Aug 25 2005 03:13:57	56.00	-0.50	36	53	2	vn200	76	
Aug 25 2005 06:47:03	56.00	0.50	37	54	1	ros	84	1-7, 20-27
Aug 25 2005 07:10:35	56.00	0.50	37	55	1	vn200	84	
Aug 25 2005 12:17:28	56.00	2.00	38	56	1	ros	85	1-7, 20-27
Aug 25 2005 12:34:24	56.00	2.00	38	57	1	vn200	85	
Aug 25 2005 17:33:49	56.00	3.50	39	58	1	ros	69	1-7, 20-27
Aug 25 2005 17:49:35	56.00	3.50	40	58	2	vn200	70	
Aug 25 2005 22:44:56	56.00	5.00	40	59	1	ros	43	1-7, 20-27
Aug 26 2005 03:45:49	56.00	6.50	41	60	1	ros	42	1-7, 20-27
Aug 26 2005 04:03:28	56.00	6.50	41	60	2	vn200	42	
Aug 26 2005 07:32:29	56.00	7.50	42	61	1	ros	23	1-7, 20-27
Aug 26 2005 07:42:25	56.00	7.50	42	62	1	vn200	24	
Aug 26 2005 14:42:58	57.00	6.50	44	63	1	ros	59	1-7, 20-27
Aug 26 2005 15:00:08	57.00	6.50	44	63	2	vn200	59	
Aug 26 2005 18:11:49	57.00	7.50	43	64	1	ros	31	1-7, 20-27
Aug 26 2005 18:24:14	57.00	7.50	43	64	2	vn200	31	
Aug 26 2005 21:39:32	57.50	7.50	52	65	1	ros	27	1-7, 20-27
Aug 26 2005 22:09:32	57.50	7.50	52	66	1	vn200	27	

Date, Time	°N	°E	Station Label	Station-order	Cast	Activity	Max. Depth	Comments and Parameters
Aug 27 2005 01:24:02	57.50	8.50	53	67	1	ros	73	1-7, 20-27
Aug 27 2005 05:45:13	58.00	9.50	62	68	1	ros	279	1-7, 20-27
Aug 27 2005 06:24:20	58.00	9.50	62	68	2	vn200	279	
Aug 27 2005 09:16:29	58.00	10.40	63	69	1	ros	105	1-7, 20-27
Aug 27 2005 09:35:55	58.00	10.40	63	70	1	vn200	105	
Aug 27 2005 12:54:20	58.50	10.13	64	71	1	ros	279	1-7, 20-27
Aug 27 2005 13:34:06	58.50	10.13	64	72	1	vn200	514	
Aug 27 2005 17:04:21	58.50	9.50	65	73	1	ros	568	1-7, 20-27
Aug 27 2005 17:45:12	58.50	9.50	65	73	2	vn200	568	
Aug 27 2005 21:54:44	58.15	8.50	66	74	1	ros	205	1-7, 20-27
Aug 28 2005 00:30:24	58.00	8.50	61	75	1	ros	544	1-7, 20-27
Aug 28 2005 07:38:17	58.00	6.50	67	76	1	ros	362	1-7, 20-27
Aug 28 2005 08:15:39	58.00	6.50	67	77	1	vn200	361	
Aug 28 2005 12:03:47	58.00	5.50	60	78	1	ros	234	1-7, 20-27
Aug 28 2005 12:29:01	58.00	5.50	60	79	1	vn200	233	
Aug 28 2005 19:11:09	59.00	4.70	68	80	1	ros	276	1-7, 20-27
Aug 28 2005 19:38:46	59.00	4.70	68	80	2	vn200	276	
Aug 29 2005 01:26:50	60.00	4.50	85	81	1	ros	261	1-7, 20-27
Aug 29 2005 07:54:18	61.00	4.30	86	82	1	ros	426	1-7, 20-27
Aug 29 2005 08:32:49	61.00	4.30	86	83	1	vn200	429	
Aug 30 2005 01:12:19	61.00	3.50	88	84	1	ros	373	1-7, 20-27
Aug 30 2005 08:05:10	61.00	2.50	89	85	1	ros	215	1-7, 20-27
Aug 30 2005 08:29:39	61.00	2.50	89	86	1	vn200	133	
Aug 30 2005 12:11:40	61.00	1.50	90	87	1	ros	146	1-7, 20-27
Aug 30 2005 12:35:59	61.00	1.50	90	88	1	vn200	147	
Aug 30 2005 16:32:43	61.00	0.50	91	89	1	ros	143	1-7, 20-27
Aug 30 2005 16:52:53	61.00	0.50	91	89	2	vn200	143	
Aug 30 2005 20:46:17	61.00	-0.50	92	90	1	ros	129	1-7, 20-27
Aug 30 2005 21:06:21	61.00	-0.50	92	91	1	vn200	128	
Aug 31 2005 03:47:40	60.00	-0.50	79	92	1	ros	123	1-7, 20-27
Aug 31 2005 04:10:44	60.00	-0.50	79	92	2	vn200	124	
Aug 31 2005 09:11:29	60.00	-1.70	78	93	1	ros	117	1-7, 20-27
Aug 31 2005 09:35:50	60.00	-1.70	78	94	1	vn200	118	
Aug 31 2005 12:18:42	60.00	-2.50	77	95	1	ros	102	1-7, 20-27
Aug 31 2005 16:33:16	59.50	-2.50	76	96	1	ros	81	1-7, 20-27
Aug 31 2005 16:47:08	59.50	-2.50	76	96	2	vn200	81	
Sep 01 2005 02:17:29	60.00	0.50	80	97	1	ros	119	1-7, 20-27
Sep 01 2005 07:02:41	60.00	1.50	81	98	1	ros	138	1-7, 20-27
Sep 01 2005 07:22:32	60.00	1.50	81	99	1	vn200	101	
Sep 01 2005 11:27:20	60.00	2.50	82	100	1	ros	138	1-7, 20-27
Sep 01 2005 11:50:31	60.00	2.50	82	101	1	vn200	138	
Sep 01 2005 15:35:34	60.00	3.50	83	102	1	ros	273	1-7, 20-27
Sep 01 2005 17:37:28	60.00	4.00	84	103	1	ros	287	1-7, 20-27
Sep 01 2005 18:03:19	60.00	4.00	84	103	2	vn200	288	
Sep 02 2005 01:12:53	59.00	4.00	69	104	1	ros	320	1-7, 20-27
Sep 02 2005 03:19:50	59.00	3.50	70	105	1	ros	206	1-7, 20-27

Date, Time	°N	°E	Station Label	Station-order	Cast	Activity	Max. Depth	Comments and Parameters
Sep 02 2005 03:49:35	59.00	3.50	70	105	2	vn200	206	
Sep 02 2005 07:23:20	59.00	2.50	71	106	1	ros	120	1-7, 20-27
Sep 02 2005 11:15:06	59.00	1.50	72	107	1	ros	123	1-7, 20-27
Sep 02 2005 11:33:36	59.00	1.50	72	108	1	vn200	123	
Sep 02 2005 14:39:28	59.00	0.50	73	109	1	ros	146	1-7, 20-27
Sep 02 2005 15:00:57	59.00	0.50	73	109	2	vn200	146	
Sep 02 2005 18:09:17	59.00	-0.50	74	110	1	ros	132	1-7, 20-27
Sep 02 2005 18:28:55	59.00	-0.50	74	110	2	vn200	133	
Sep 02 2005 21:41:02	59.00	-1.50	75	111	1	ros	106	1-7, 20-27
Sep 03 2005 04:09:24	58.00	-2.50	54	112	1	ros	77	1-7, 20-27
Sep 03 2005 04:25:01	58.00	-2.50	54	112	2	vn200	77	
Sep 03 2005 07:58:18	58.00	-1.50	55	113	1	ros	71	1-7, 20-27
Sep 03 2005 08:10:18	58.00	-1.50	55	114	1	vn200	71	
Sep 03 2005 11:24:56	58.00	-0.50	56	115	1	ros	107	1-7, 20-27
Sep 03 2005 11:40:36	58.00	-0.50	56	116	1	vn200	107	Failed
Sep 03 2005 11:51:57	58.00	-0.50	56	117	1	vn200	107	
Sep 03 2005 19:11:57	58.00	1.00	57	118	1	ros	138	1-7, 20-27
Sep 03 2005 19:28:52	58.00	1.00	57	119	1	vn200	138	
Sep 04 2005 01:24:25	58.00	2.75	58	120	1	ros	63	1-7, 20-27
Sep 04 2005 06:27:19	58.00	4.25	59	121	1	ros	98	1-7, 20-27
Sep 04 2005 06:51:28	58.00	4.25	59	122	1	vn200	98	
Sep 04 2005 13:04:13	57.50	6.00	51	123	1	ros	79	1-7, 20-27
Sep 04 2005 17:37:49	57.00	5.25	45	124	1	ros	57	1-7, 20-27
Sep 04 2005 17:48:44	57.00	5.25	45	124	2	vn200	57	
Sep 04 2005 23:46:29	57.00	3.75	46	125	1	ros	67	1-7, 20-27
Sep 05 2005 05:41:20	57.00	2.25	47	126	1	ros	80	1-7, 20-27
Sep 05 2005 06:02:34	57.00	2.25	47	126	2	vn200	79	
Sep 05 2005 11:18:41	57.00	0.88	48	127	1	ros	97	1-7, 20-27
Sep 05 2005 11:49:13	57.00	0.88	48	128	1	vn200	93	
Sep 05 2005 16:32:55	57.00	-0.50	49	129	1	ros	78	1-7, 20-27
Sep 05 2005 23:23:32	56.00	-1.50	35	130	1	ros	78	1-7, 20-27
Sep 06 2005 05:32:32	57.00	-1.50	50	131	1	ros	67	1-7, 20-27

Appendix 2:

Activity and Parameter codes

Code	Parameter	Code	Parameter	Code	Activity
1	Salinity	20	Dissolved inorganic carbon	Ros	CTD rosette sampler
2	Oxygen	21	pH	vn200	Vertical net, 200µm
3	Si	22	Total Alkalinity		mesh size
4	PO4	23	DOC		
5	NH4	24	DON		
6	NO3	25	DOP		
7	NO2	26	POC		
		27	PON		

Appendix 3:

Participants lists:

A: Ship's crew:

Name	Given Name	Responsibility
Joor	Peter	Captain
Puyman	Engbert A.	1st mate
De Louwere	Eric	2nd mate
Seepma	Jaap	Chief engineer
Kleine	Marcel	2nd engineer
Mik	Garl	cook
Betsema	John	sailor
Stevens	Cor	Ship's technician
Van der Slikke	Ron	sailor
Vitoria	Jose Israel	sailor

B: Scientific crew:

Name	Given Name	Responsibility	Affiliation	City	Country
Asjes	Alexander	CTD	NIOZ	Den Burg	The Netherlands
Baars, Dr.	Martien	Enzyme activity	NIOZ	Den Burg	The Netherlands
Borges, Dr.	Alberto	CO_2 system	Univ. Liège	Liège	Belgium
Bothun	Bjorn	Film team	Univ. Bergen	Bergen	Norway
Elkalay, Dr.	Khalid	CTD, Filtration	NIOZ	Den Burg	The Netherlands
Gazeau	Frederic	Community metabolism	NIOO-CEME	Yerseke	The Netherlands
Kone	Mathieu	CO_2 system	Univ. Liège	Liège	Belgium
Oosterhuis	Swier	Enzyme activity	NIOZ	Den Burg	The Netherlands
Prowe	Friederike	CO_2 system	Univ. Oldenburg	Oldenburg	Germany
Shlomi	Tuvit	CTD, Filtration	NIOZ	Den Burg	The Netherlands
Sinke	Michel	Oxygen	NIOZ	Den Burg	The Netherlands
Snoek	Johanna	Filtration	NIOZ	Den Burg	The Netherlands
Suykens	Kim	CO_2 system	Univ. Liège	Liège	Belgium
Thomas, Prof. Dr.	Helmuth	CO_2 system	Dalhousie/NIOZ	Halifax	Canada
van Heuven	Steven	CO_2 system	NIOZ/RUG	Den Burg	The Netherlands
van Ooijen	Jan	Nutrients	NIOZ	Den Burg	The Netherlands

Appendix 4:

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