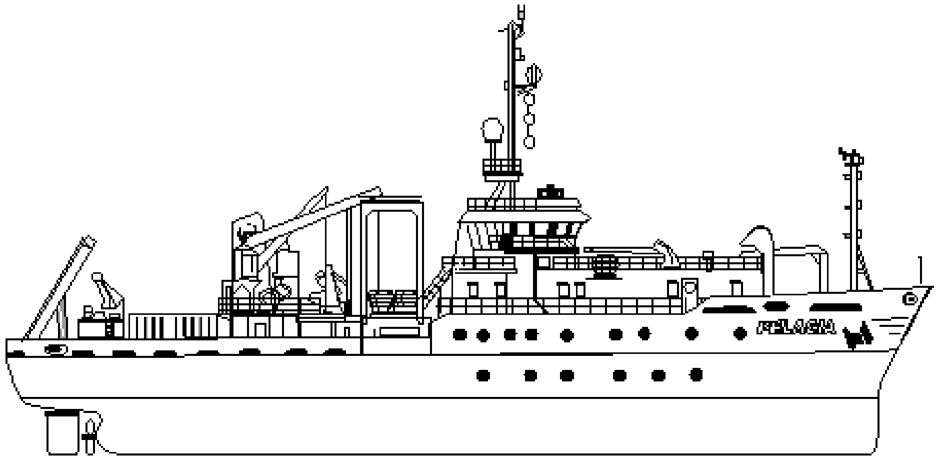

Cruise Report of the cruise 64PE294
Texel, NL – Texel, NL
19.08.2005 – 11.09.2005
Chief Scientist: Henk Zemmelink

CarboOcean (Partner 8)

BSIK (Partner 3)

ALW Vaarprogramma Noordzee: CO2 buffering capacity of the North Sea
Code: ALW1PJ/07015

Contents

1. Introduction

Cruise 64PE294 was a continuation of the project ALW 810.33.004: “The continental shelf pump: a pilot study in the North Sea”. This study and a follow up study in 2005 provided detailed maps of the partial pressure of carbon dioxide (PCO_2) in of the entire North Sea area. A striking increase of 23 ppm of the CO_2 partial pressure (pCO_2) in surface waters was observed over this 4 year time period. This increase is higher than the increase of atmospheric pCO_2, which rose in the same period approximately 10ppm. These results indicate that there might be a decline in the buffering capacity of the inorganic carbonate system of the North Sea (increasing Revelle Factor). In theory this is the predicted feedback loop whereby the invasion of anthropogenic CO_2 reduces the ocean’s ability to uptake additional CO_2. In order to study this fascinating theory we conducted cruise 64PE294, in 2008, which allowed us to organize a follow up of the 2001-2005 CarboOcean/BSIK studies. Cruise 64PE294 provides us with a time series set (from 2001-2008) of the North Sea carbon cycle which will deepen our understanding of the response of the North Sea to rising CO_2 conditions.

1.1. Relation to CARBOOCEAN and BSIK

The cruise 64PE294 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 organizations 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 Canada (Dalhousie University, Halifax), in the Netherlands (Royal Netherlands Institute for Sea Research), and in the United States (Woods Hole Oceanographic Institution).

Relation to BSIK. The cruise 64PE294 contributed to BSIK sub-project: Climate related shifts in the NCP ecosystem, and consequences for future spatial planning. The project aims to provide a detailed spatial overview of the past, present and future ecosystem features of the North Sea (with an emphasis on the Netherlands Continentaal Plat (NCP), i.e. the Dutch part of the North Sea) in relationship to climate change. This aim will be achieved by describing and analyzing relationships between relevant environmental variables (e.g. temperature, nutrient load, turbidity, CO2) and indicators of ecosystem performance (CO2 exchange rates, the seasonal cycle of algal blooms, etc.). Knowing these relationships scenario's of impacts of climate shifts on ecosystem productivity and biodiversity will be verified, using mechanistic ecosystem models, such as The European Regional Seas Ecosystem Model, ERSEM.

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 and in 2005) occupying each time about 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/BSIK 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. Including the 2008 CARBOOCEAN/BSIK cruise and a foreseen 2010 cruise 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 64PE294

The cruise was designed to cover exactly the same period of the year as the summer 2001/2005 cruise. The intention was to sample all (or as many as possible) stations of the 2001/2005 station grid. (Fig. 1).

A B

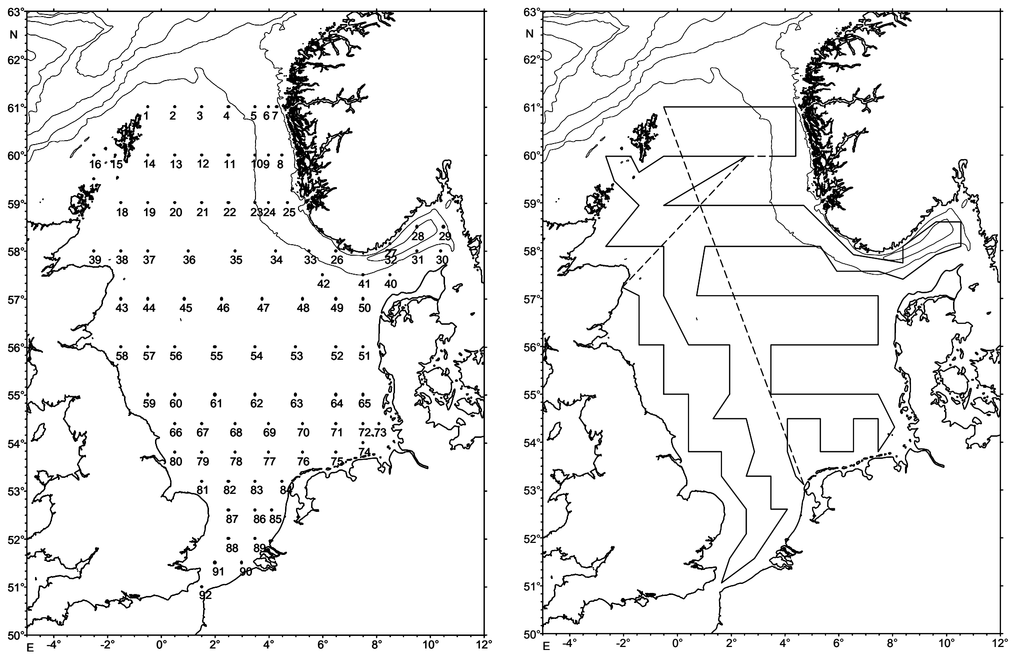

Figure 1: Station grid of the 2008 program to be repeated to the cruise 64PE294. 1A shows the location and labels of the stations, 1B shows the cruise track and the stations sampled during the cruise.

After setting up the equipment on 18 August 2008, we left Texel on 19. August 2008. We started with a test station relatively close to Texel to ensure that all machinery worked well. Our first regular station was station 1, just north of the Shetland Islands. Figure 1B and Appendix I give the cruise track and stations occupied during the cruise. In summary all 92 stations were sampled.

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/BSIK part of the cruise are indicated in Table 1. The methods section is organized first considering the CARBOOCEAN/BSIK work by groups, which carried out the work. Further parameters have been determined, which follow after the description of the CARBOOCEAN/BSIK work.

Table 1: Parameters determined during the CARBOOCEAN/BSIK 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 FE	≈700 ≈700 ≈41	pCO_2, pH, T, S, O_2 pDMS
POC, Chl.a, PON, POP, Bacteria, Phytoplankton,viral particles	≈200	

3.1. Measurements and Sampling carried out by NIOZ / Dalhousie

3.1.1. The partial pressure of CO_2 (pCO_2)

H.J. Zemmelink, L. Salt, F. Prowe, 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.

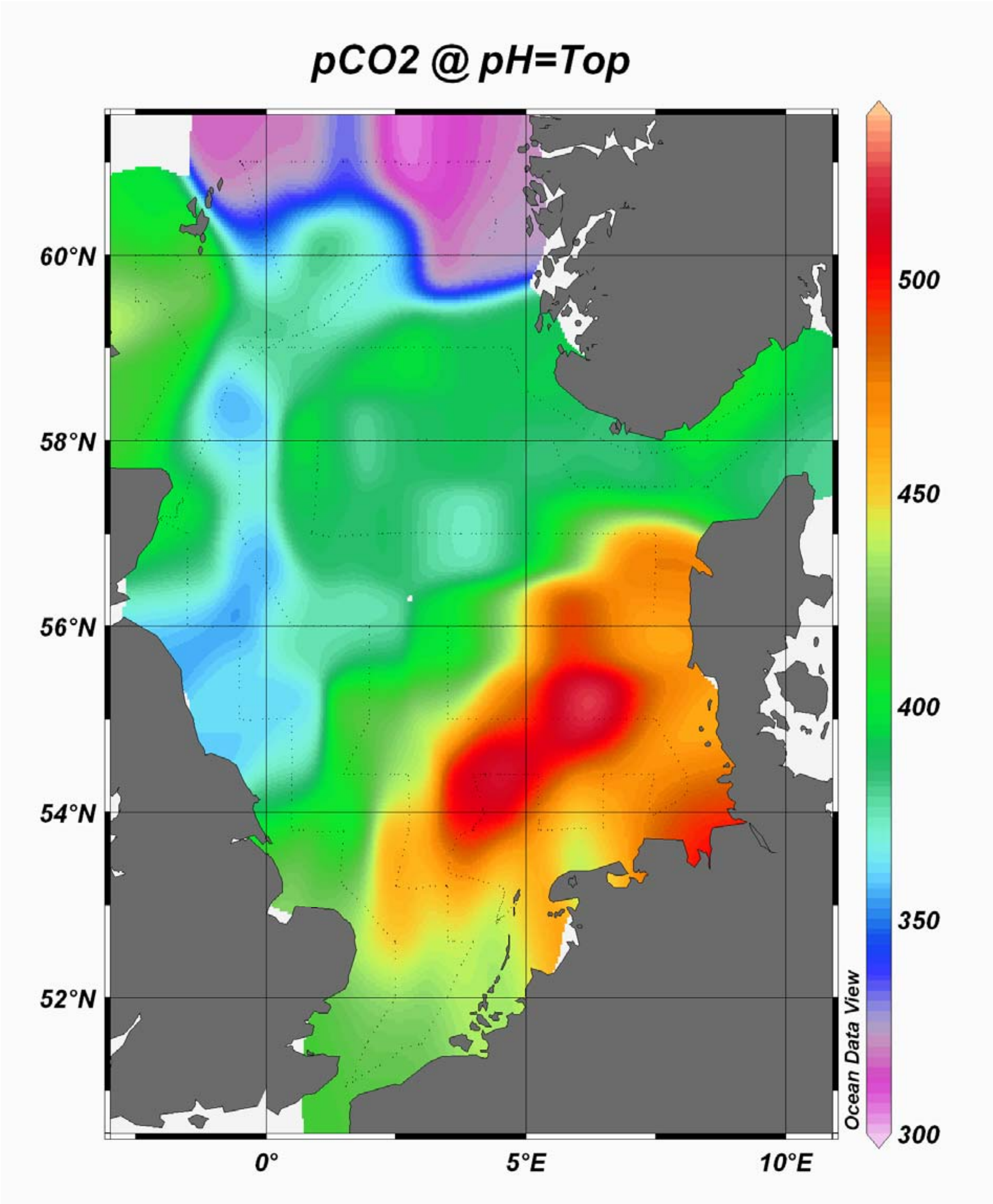

Figure 2: pCO_2 in 2008.

3.1.2. Dissolved inorganic carbon (DIC)

H. Thomas, F. Prowe, L. Salt

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 (H3PO4). 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 CO2 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 CO2 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.

3.1.3. The pH

pH was measured using a SAMI-flow through pH sensor: a photospectrometric based pH measurement that was set up to sample the surface waters every 30 minutes (Fig. 3)

A B C

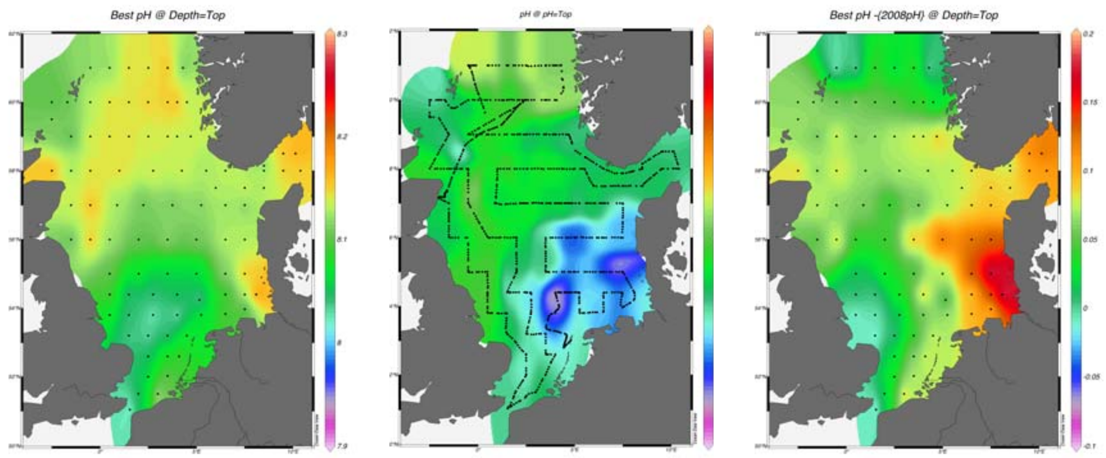

Figure 3. pH in 2005 (A) and (preliminary) 2008 (B) as well as the difference in pH (C) between both years. Negative values indicate a decrease in pH.

3.1.4. Nutrient measurements

E. van Weerlee

795 Samples-from 92 stations have been measured for NH4, PO4 , NOx en Silicate. In addition, an extra 41 samples have been taken and analyzed at Fe stations.

From Noex bottles attached to the CTD-frame samples were drawn for the shipboard determination of the nutrients Ammonium, Nitrate, Silicate and Phosphate. 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 24 hours with an autoanalyser based on colorimetry using a QuAAtro Autoanalyser. 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).

- 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.
- 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 an 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.

3.1.5. Oxygen measurements

L.E. Salt

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.

3.1.6. DOC, POC, PON

C. v Slooten, H. Slagter

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.

Similar to POC and PON these samples were only taken closest to the surface level (5m). 40 ml glass vials were used to store the sample. 4 drops of phosphoric acid (H_2PO_4) were added to remove all the inorganic carbon from the sample. The vials were subsequently closed by melting the top of the bottle and stored at 4 ^oC. By measuring TOC and POC, DOC (dissolved organic carbon) can be calculated. DOC is an important parameter in establishing an uptake and sequestration rate of carbon by phytoplankton. During the end of summer when nutrients get depleted, but still plenty of light available, algal cells continue to photosynthesize (Fogg, 1983). Since there are no nutrients left to build new cells from, the algae make polysaccharides containing a high C:N ratio and expel these compounds into their surroundings. These compounds are part of the DOC in seawater. Most of it is broken down again within a few days, but some of the DOC sinks to the bottom and gets transported out of the system, this part plays a role in the global carbon cycle.

3.1.7. algae/bacteria/viral particles/chlorophyll

C. v Slooten, H. Slagter

Algae/bacteria/viruses

Samples were taken at every station up to 100 meters depth. 3,5 ml samples were fixated with formalin/hexamine and frozen in liquid nitrogen and subsequently stored at -80 ^{o}C for algal determination. 1 ml samples were taken for bacteria and viruses, fixated with glutaraldehyde, also frozen in liquid nitrogen and stored at -80 ^{o}C to keep the cells intact.
At the NIOZ, these samples will be processed using a flow-cytometer to get an indication of the relative abundance of the different groups of algae, e.g. diatoms and coccolithophores, by cell count. Virus counts can indicate whether the algae are controlled by viruses. Bacteria are feeding on dying or dead algae, thereby playing a vital role in the nutrient cycling.

Chlorophyll

Samples taken at every station up to 100 m depth. Five litres of seawater was filtered over a 47mm glass fibre GF/F filter. The filter is packed in aluminium foil, frozen in liquid nitrogen and stored at -80 ^{o}C to preserve the chlorophyll proteins. Analysis will be conducted at the NIOZ.

3.1.8. CTD

S. Asjes, J. Grond, H. Zemmelink

The CTD was operated in the standard configuration.

3.1.9 Trace metals

Dissolved iron and manganese measurements.

Dissolved iron is of major importance for the biological activity in the world oceans. The relatively difficult sampling and measurement techniques and sensitivity to contamination made that iron is not widely studied in the world seas and oceans so far. Although in the North Sea there are no reports of growth limitation of primary producers due to lack of iron, it is interesting to determine the amount of iron and manganese; in the international GEOTRACES program, all oceans and seas are studied for their concentrations of trace metals. This enables us to get insight in the system, transport, distribution, sources and sinks in the world seas and oceans.

At 16 stations 79 Go-Flo 12 liter bottles are filled at depths varying from 5 to 350 meter. Stations comprise maximum 8, minimum 3 sample depths. The Go-Flo bottles were mounted on a epoxy coated steel wire. All Go-Flo bottles were filtered (0.2 µm), and sample bottles (60 and 125 µl.) were filled and acidified in the NIOZ clean room container. Samples were taken to measure dissolved iron, dissolved manganese, and silicate. Also a replicate sample was taken from every bottle. Samples were stored in double plastic in the dark.

Shipboard measurements have been performed for three stations. First interpretation of the data seems to indicate high value's at the surface, for stations not too far from the coast. Slightly lower a chlorophyll maximum is present, causing low iron concentrations and then iron concentration increases with depth, either stabilizes or even decrease a little (station1, fig 1) or increase heavily (station 3, fig. 4), most likely due to resuspended material. Error bars were <5% within one sample.

The samples will be analyzed for dissolved iron and manganese concentration in NIOZ clean laboratory facilities and data interpretation, comparison with CTD, nutrients and biological data and presentation is to take place in the coming months.

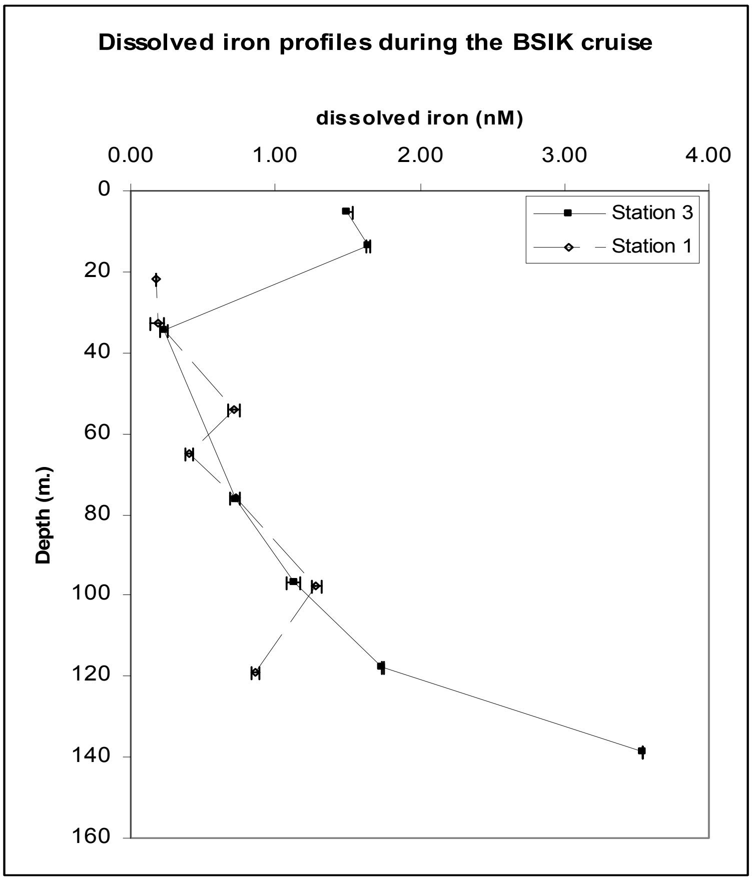

Fig. 4 Two iron profiles. (error bars reflect standard deviation)

3.2. the Woods Hole Oceanographic Institution

J. Dacey

Waterside DMS

The variability of waterside DMS was studied by continuous underway sampling. These measurements will be made using an automated aqueous DMS analyzer which measures DMS in 1 ml subsamples taken from the ships seawater system, seawater from the ships sampling system will likely be representative of surface DMS concentrations. DMS is removed from the water by vigorous bubbling with nitrogen after which the DMS is concentrated onto an Carboxen absorbent at room temperature and analyzed by desorption at 180ºc into a gas chromatograph equipped with a pulsed flame photometric detector. This system allows analysing 1 sample per 5 minutes which will allow to study the small scale variability of this compound in the surface sea water.

4. Acknowledgements

The success of the cruise 64PE294 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 was also supported by the BSIK ('Besluit subsidies investeringen in de kennisinfrastructuur') and by the ALW Vaarprogramma Noordzee: CO2 buffering capacity of the North Sea, ALW1PJ/07015.

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Appendix 1:

Stations occupied during the cruise 64PE294.
For activity and parameters codes see Appendix 2.

station order	station label	Cast / Action	Datum/ Tijd	Lat. (decimal!)	Lon (decimal!)	CAST Type	MAX. PRESS.	NO OF BOTTLES	parameters
	test	1	8/20/03 13:15	54 46.48 N	003 11.51 E	CTD	17.5	6	1,2,3-7,9, 10,11,12,21
			8/20/03 13:15						
1	001	001	22/08/08 :08:05	60 59.99 N	000 29.76 W	CTD	125	24	1,2,3-7,9, 10,11,12,21
2	001	002	22/08/08 :09:05			NIS	125	8	20
3	002	001	22/08/08 13:54	60 59.97 N	000 30.02 E	CTD	143	22	1,2,3-7,9, 10,11,12,21
4	003	001	22/08/08 18:02	61 00.09 N	001 30.10 E	NIS	146	8	20
5	003	002	22/08/08 18:45			CTD	146	24	1,2,3-7,9, 10,11,12,21
6	004	001	22/08/08 21:55	61 00.00 N	002 30.12 E	CTD	129.9	24	1,2,3-7,9, 10,11,12,21
7	005	001	23/08/08 00:25	61 00.00 N	003 29.97 E	CTD	348.5	24	1,2,3-7,9, 10,11,12,21
8	006	001	23/08/08 04:10	60 59.99 N	004 00.00 E	CTD	343	24	1,2,3-7,9, 10,11,12,21
9	007	001	23/08/08 06:18	61 00.49 N	004 18.66 E	NIS	396	7	20
10	007	002	23/08/08 07:18			CTD	396	24	1,2,3-7,9, 10,11,12,21
11	008	001	23/08/08 14:18	60 00.00 N	004 29.99 E	CTD	256	24	1,2,3-7,9, 10,11,12,21
12	009	001	23/08/08 16:24	60 00.00 N	003 59.97 E	CTD	278	24	1,2,3-7,9, 10,11,12,21
13	010	001	23/08/08 18:30	59 59.98 N	003 30.03 E	CTD	269	24	1,2,3-7,9, 10,11,12,21
14	043	001	25/08/08 11:08	57 00.09 N	001 30.00 W	CTD	60	14	1,2,3-7,9, 10,11,12,21
15	058	001	25/08/08 18:48	56 00.03 N	001 29.96 W	CTD	74	14	1,2,3-7,9, 10,11,12,21
16	057	001	25/08/08 22:19	55 59.99 N	000 30.06 W	CTD	73	15	1,2,3-7,9, 10,11,12,21
17	059	001	26/08/08 04:43	55 00.02 N	000 29.96 W	CTD	67	15	1,2,3-7,9, 10,11,12,21
18	060	001	26/08/08 08:08	54 59.99 N	000 29.97 E	CTD	67	14	1,2,3-7,9, 10,11,12,21
19	066	001	26/08/08 11:45	54 24.01 N	000 30.02 E	CTD	61	18	1,2,3-7,9, 10,11,12,21
20	080	001	26/08/08 15:27	53 48.97 N	000 29.98 E	CTD	36	17	1,2,3-7,9, 10,11,12,21
21	079	001	26/08/08 19:02	53 48.04 N	001 29.97 E	CTD	36	13	1,2,3-7,9, 10,11,12,21
22	081	001	26/08/08 23:05	53 12.01 N	00130.03 E	CTD	48	9	1,2,3-7,9, 10,11,12,21
23	087	001	27/08/08 04:00	52 36.00 N	002 29.99 E	NIS	43	4	20
24	087	002	27/08/08 04:46			CTD	43	13	1,2,3-7,9, 10,11,12,21
25	088	001	27/08/08 08:20	52 00.02 N	002 30.12 E	CTD	43	16	1,2,3-7,9, 10,11,12,21
26	091	001	27/08/08 12:54	51 31.52 N	001 57.98 E	NIS	45	4	20
27	091	002	27/08/08 12:54			CTD	45	17	1,2,3-7,9, 10,11,12,21
28	092	001	27/08/08 16:55	51 02.56 N	001 32.63 E	NIS	40	4	20
29	092	002	27/08/08 16:55			CTD	40	14	1,2,3-7,9, 10,11,12,21
30	090	001	27/08/08 23:02	51 30.03 N	003 00.04 E	CTD	24	12	1,2,3-7,9, 10,11,12,21
31	089	001	28/08/08 02:23	52 00.01 N	003 29.96 E	CTD	24	12	1,2,3-7,9, 10,11,12,21
32	085	001	28/08/08 06:40	52 35.99 N	003 59.95 E	CTD	23	10	1,2,3-7,9, 10,11,12,21
33	086	001	28/08/08 08:39	52 36.00 N	003 30.07 E	CTD	32	12	1,2,3-7,9, 10,11,12,21
34	083	001	28/08/08 12:10	53 12.01 N	003 30.04 E	CTD	25	12	1,2,3-7,9, 10,11,12,21

35	082	001	28/08/08 16:29	53 11.99 N	002 30.05 E	CTD	30	15	1,2,3-7,9, 10,11,12,21
36	078	001	28/08/08 20:54	53 48.00N	002 45.03 E	CTD	46	14	1,2,3-7,9, 10,11,12,21
37	068	001	28/08/08 00:42	54 23.98 N	002 44.98 E	CTD	28	11	1,2,3-7,9, 10,11,12,21
38	067	001	28/08/08 05:24	54 23.99 N	001 30.02 E	CTD	57	16	1,2,3-7,9, 10,11,12,21
39	061	001	28/08/08 09:00	55 00.00 N	001 59.99 E	NIS	26	3	20
40	061	001	28/08/08 09:40			CTD	26	12	1,2,3-7,9, 10,11,12,21
41	055	001	29/08/08 15:40	56 00.01 N	001 59.99 E	NIS	85	6	20
42	055	002	29/08/08 16:12			CTD	85	20	1,2,3-7,9, 10,11,12,21
43	056	001	29/08/08 21:35	56 00.00 N	003 30.04 E	CTD	85	18	1,2,3-7,9, 10,11,12,21
44	044	001	30/08/08 04:32	56 59.99 N	000 29.98 W	CTD	78	19	1,2,3-7,9, 10,11,12,21
45	037	001	30/08/08 10:29	58 00.00 N	000 29.96 W	CTD	107	20	1,2,3-7,9, 10,11,12,21
46	038	001	30/08/08 14:03	57 59.99 N	001 29.98 W	CTD	71	21	1,2,3-7,9, 10,11,12,21
47	039	001	30/08/08 17:22	58 00.01 N	002 30.01 W	CTD	76	24	1,2,3-7,9, 10,11,12,21
48	018	001	31/08/08 00:07	59 00.00 N	001 29.93 W	CTD	104	20	1,2,3-7,9, 10,11,12,21
49	017	001	31/08/08 05:03	59 30.05 N	002 30.14 W	CTD	76	17	1,2,3-7,9, 10,11,12,21
50	016	001	31/08/08 08:00	60 00.01 N	002 30.01 W	NIS	101	6	20
51	016	002	31/08/08 08:45			CTD	101	24	1,2,3-7,9, 10,11,12,21
52	015	001	31/08/08 11:12	60 00.00 N	001 41.98 W	CTD	116	24	1,2,3-7,9, 10,11,12,21
53	014	001	31/08/08 16:43	60 00.05 N	000 30.03 W	CTD	124	21	1,2,3-7,9, 10,11,12,21
54	013	001	31/08/08 20:05	60 00.01 N	000 30.00 E	CTD	116	22	1,2,3-7,9, 10,11,12,21
55	012	001	31/08/08 23:53	60 00.01 N	001 29.96 E	NIS	98	6	20
56	012	002	31/08/08 23:00			CTD	98	21	1,2,3-7,9, 10,11,12,21
57	011	001	1/9/08 4:03	60 00.03 N	002 29.94 E	CTD	110	24	1,2,3-7,9, 10,11,12,21
58	019	001	1/9/08 15:25	59 00.01 N	000 29.94 W	CTD	133	24	1,2,3-7,9, 10,11,12,21
59	020	001	1/9/08 19:01	59 00.03 N	000 29.98 E	CTD	147	24	1,2,3-7,9, 10,11,12,21
60	021	001	1/9/08 22:15	59 00.01 N	001 30.01 E	NIS	116	6	20
61	021	002	1/9/08 23:07			CTD	116	24	1,2,3-7,9, 10,11,12,21
62	022	001	2/9/08 2:40	59 00.02 N	002 30.00 E	CTD	116	21	1,2,3-7,9, 10,11,12,21
63	023	001	2/9/08 6:06	59 00.02 N	003 29.94 E	CTD	210	24	1,2,3-7,9, 10,11,12,21
64	024	001	2/9/08 8:04	59 00.01 N	004 00.00 E	CTD	293	24	1,2,3-7,9, 10,11,12,21
65	025	001	2/9/08 10:35	59 00.02 N	004 41.99 E	CTD	281	24	1,2,3-7,9, 10,11,12,21
66	026	001	2/9/08 21:00	58 00.06 N	006 29.90 E	CTD	350	24	1,2,3-7,9, 10,11,12,21
67	032	001	3/9/08 4:19	57 59.98 N	008 29.98 E	CTD	530	24	1,2,3-7,9, 10,11,12,21
68	027	001	3/9/08 6:35	58 09.00 N	008 29.98 E	CTD	195	24	1,2,3-7,9, 10,11,12,21
69	028	001	3/9/08 10:48	58 29.99 N	009 29.99 E	CTD	532	24	1,2,3-7,9, 10,11,12,21
70	029	001	3/9/08 13:28	58 30.00 N	010 07.90 E	CTD	508	24	1,2,3-7,9, 10,11,12,21
71	030	001	3/9/08 17:24	58 00.01 N	010 24.19 E	CTD	104	24	1,2,3-7,9, 10,11,12,21
72	031	001	3/9/08 21:15	58 00.00 N	009 30.05 E	NIS	302	8	20
73	031	001	3/9/08 22:15			CTD	302	24	1,2,3-7,9, 10,11,12,21
74	040	001	4/9/08 4:12	57 53.03 N	008 30.65 E	CTD	73	17	1,2,3-7,9, 10,11,12,21
75	041	001	4/9/08 8:36	57 30.03 N	007 30.09 E	CTD	214	24	1,2,3-7,9, 10,11,12,21
76	042	001	4/9/08 15:03	57 30.00 N	006 00.03 E	CTD	79	24	1,2,3-7,9, 10,11,12,21
77	033	001	4/9/08 18:54	57 59.96 N	005 30.10 E	CTD	238	22	1,2,3-7,9, 10,11,12,21
78	034	001	4/9/08 23:15	58 00.03 N	004 15.06 E	CTD	98	23	1,2,3-7,9, 10,11,12,21
79	035	001	5/9/08 4:13	57 59.99 N	002 44.99 E	CTD	63	15	1,2,3-7,9, 10,11,12,21
80	036	001	5/9/08 9:30	57 59.99 N	001 00.00 E	CTD	139	6	1,2,3-7,9, 10,11,12,21
81	036	001	5/9/08 10:08			CTD	139	24	1,2,3-7,9, 10,11,12,21
82	045	001	5/9/08 16:30	56 59.97 N	000 52.67 E	CTD	98	24	1,2,3-7,9, 10,11,12,21

83	046	001	5/9/08 21:30	57 00.00 N	001 14.98 E	CTD	80	6	1,2,3-7,9, 10,11,12,21
84	046	001	5/9/08 21:55			CTD	80	17	1,2,3-7,9, 10,11,12,21
85	047	001	6/9/08 4:05	56 59.95 N	003 44.92 E	CTD	66	15	1,2,3-7,9, 10,11,12,21
86	048	001	6/9/08 12:13	56 59.98 N	005 14.97 E	CTD	57	17	1,2,3-7,9, 10,11,12,21
87	049	001	6/9/08 17:34	57 00.00 N	006 29.92 E	CTD	58	20	1,2,3-7,9, 10,11,12,21
88	050	001	6/9/08 21:05	57 00.20 N	007 00.20 E	CTD	30	12	1,2,3-7,9, 10,11,12,21
89	051	001	7/9/08 3:33	56 00.01 N	007 30.02 E	CTD	23	9	1,2,3-7,9, 10,11,12,21
90	052	001	7/9/08 7:00	55 59.99 N	006 30.23 E	CTD	42	13	1,2,3-7,9, 10,11,12,21
91	053	001	7/9/08 12:15	56 00.00 N	005 00.04 E	CTD	43	14	1,2,3-7,9, 10,11,12,21
92	054	001	7/9/08 17:23	56 00.02 N	003 30.02 E	CTD	70	18	1,2,3-7,9, 10,11,12,21
93	062	001	8/9/08 2:06	55 00.00 N	003 30.00 E	CTD	38	13	1,2,3-7,9, 10,11,12,21
94	063	001	8/9/08 5:18	55 00.00 N	004 59.97 E	CTD	42	13	1,2,3-7,9, 10,11,12,21
95	064	001	8/9/08 10:24	55 00.03 N	006 30.05 E	CTD	45	14	1,2,3-7,9, 10,11,12,21
96	065	001	8/9/08 13:49	55 00.03 N	007 30.03 E	CTD	26	12	1,2,3-7,9, 10,11,12,21
97	073	001	8/9/08 18:18	54 24.02 N	008 06.03 E	CTD	20	10	1,2,3-7,9, 10,11,12,21
98	074	001	8/9/08 22:34	53 58.38 N	007 30.06 E	CTD	28	11	1,2,3-7,9, 10,11,12,21
99	072	001	9/9/08 1:55	54 23.99 N	007 30.03 E	CTD	28	9	1,2,3-7,9, 10,11,12,21
100	071	001	9/9/08 5:46	54 23.99 N	006 29.94 E	CTD	38	13	1,2,3-7,9, 10,11,12,21
101	075	001	9/9/08 9:24	53 49.99 N	006 29.98 E	CTD	22	14	1,2,3-7,9, 10,11,12,21
102	076	001	9/9/08 14:22	53 47.99 N	005 15.04 E	CTD	33	15	1,2,3-7,9, 10,11,12,21
103	070	001	9/9/08 18:58	54 24.02 N	005 14.90 E	CTD	41	15	1,2,3-7,9, 10,11,12,21
104	069	001	10/9/08 3:09	54 23.98 N	004 00.08 E	CTD	44	13	1,2,3-7,9, 10,11,12,21
105	077	001	10/9/08 10:04	53 48.02 N	004 00.03 E	CTD	40	15	1,2,3-7,9, 10,11,12,21
106	084	001	10/9/08 19:36	53 12.00 N	004 29.95 E	CTD	28	13	1,2,3-7,9, 10,11,12,21

Appendix 2:

Parameter and Cast Type codes

Code	Parameter	Code	Parameter	Code	Cast type
1	Salinity	11	phytoplankton	CTD	CTD rosette sampler
2	Oxygen	12	bacteria	NIS0	NISkin, Fe sampling
3	Si	20	Trace metals		
4	PO4	21	DIC, Alkalinity		
5	NH4				
6	NO3				
7	NO2				
9	Chla, DOC, POC, PON				

Appendix 3:

Participants lists:

A: Ship's crew:

Name	
Adriaanse, D.	Ch_Off
Graaff, C.G. de	Master
Heide, R. van der	St
Hermans, L.F.	Ch_Eng
Israel Vitoria, J.A.	Ab
Lindenbergh, M.H.	2_Off
Mik, G.	Ck
Maas, J.J.M.	St
Vermeulen, G.P.	Ab
Vesseur, E.	

B: Scientific crew:

Name	Responsibility	Affiliation	City	Country
Asjes, A.J.	CTD	NIOZ	Den Burg	Netherlands
Dacey, J.W.H.	Underway DMS	WHOI	Woods Hole	United States
Grond, J.	Trace Metals	RUG	Groningen	Netherlands
Klunder, M.B.	Trace Metals	NIOZ	Den Burg	Netherlands
Prowe, F.	CO2 system	Univ. Oldenburg	Oldenburg	Germany
Salt, L.A.	CO2 system	NIOZ	Den Burg	Netherlands
Slagter, H.	Biology	NIOZ	Den Burg	Netherlands
Slooten, C. v	Biology	NIOZ	Den Burg	Netherlands
Thomas, H.	CO2 system	Dalhousie	Halifax	Canada
Weerlee, E.M. v	Nutrients	NIOZ	Den Burg	Netherlands
Zemmelink, H.J.	CO2 system	NIOZ	Den Burg	Netherlands

Appendix 4:

Addresses:

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