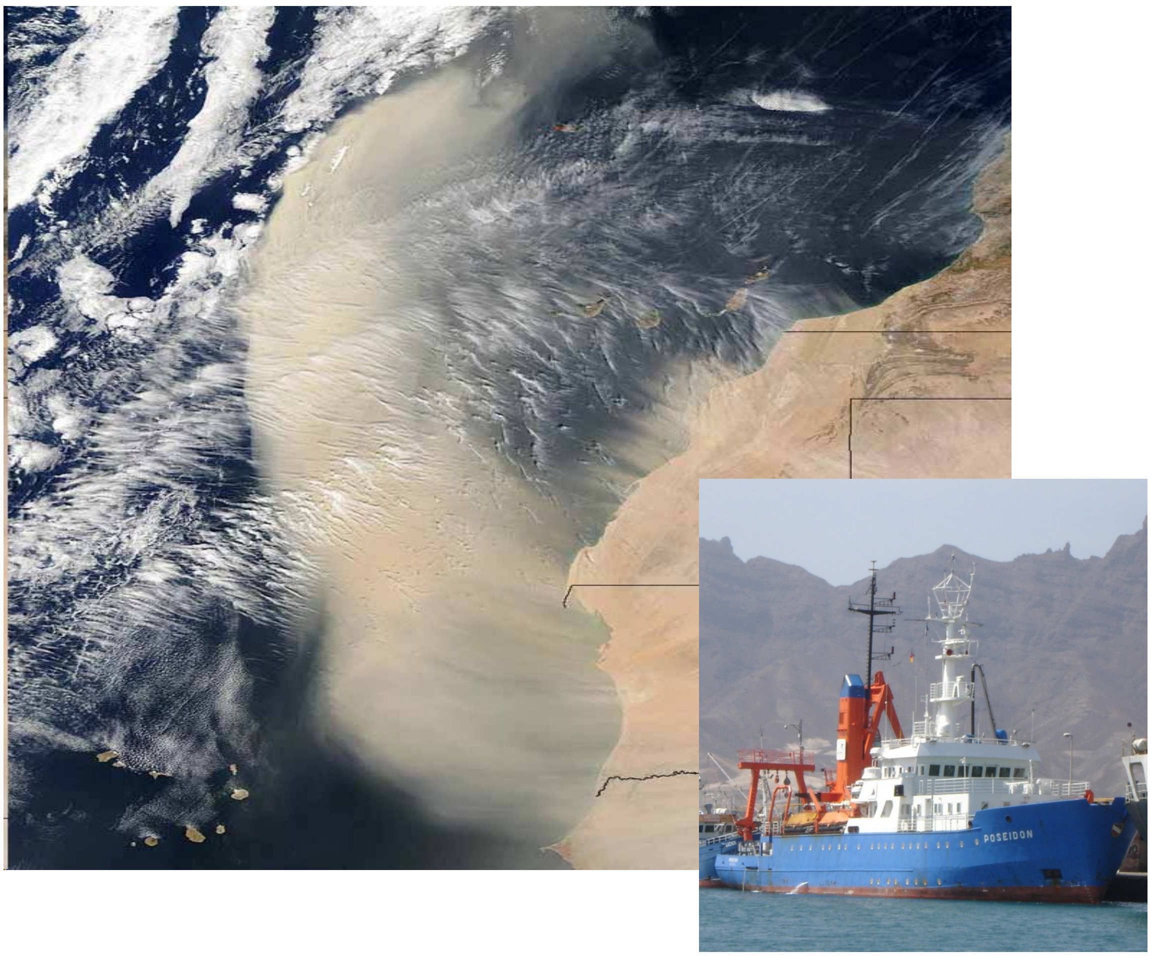
Chasing Saharan Dust Storms

UK-SOLAS Cruise Report

RV "Poseidon" Cruise 332
26 January-26 February 2006



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TITLE

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ABSTRACT

The Poseidon P332 cruise in the Cape Verde Island region was undertaken as part of the UK-SOLAS project (Surface-Ocean / Lower-Atmosphere Study, websites: www.solas-int.org and www.nerc.ac.uk/funding/thematics/solas/) to improve understanding of the atmospheric transport, cycling and deposition of dust and nutrients into the North Atlantic. The cruise was funded by NERC. The objectives of the cruise were:

1) Obtain an improved temporal and spatial estimate of atmospheric dust input to the Tropical N Atlantic.
2) Obtain an improved estimate of the seawater dissolution of N, P and Fe species from aerosol dust.
3) Determine the influence dust exerts on phytoplankton carbon fixation, species diversity and nutrient cycling in surface waters.
4) Determine the impact of atmospheric dust derived micronutrients on microbial community production and species diversity in the surface microlayer and underlying waters.

In particular this cruise aimed to combine in-situ aircraft measurements of the atmosphere (DODO, University of Reading, www.met.rdg.ac.uk/~aer/dodo/dodo.html) with in situ sampling of the lower atmosphere and the water column (University of East Anglia, University of Southampton, National Oceanography Centre Southampton and University of Birmingham) around the Cape Verde islands. However, the Poseidon did not meet up with the aircraft due to a lack of dust in the atmosphere.

The main sampling and data-gathering activities comprised 21 stations for CTD and GoFlo profiles, 175 underway samples from the towed Fish and 6 samples of the surface microlayer. Stand Alone Pumps (SAPS) were deployed 4 times but without success.

One dust event was encountered at 4-8 Feb. The transect sailed at 3-4 Feb. during the dust event was again sampled a week later to investigate changes in nutrients, trace-metals and the microbial community. The Cape Verde Time Series Station was sampled at 9 Feb.

KEYWORDS

CTD OBSERVATIONS, GOFLO CASTS, DISSOLVED IRON, DISSOLVED ALUMINUM, ORGANIC IRON COMPLEXATION, PRIMARY PRODUCTION, NITROGEN FIXATION, HETEROTROPHIC ACTIVITY, SPECIES DIVERSITY, FRRF SYSTEM, AEROSOL TIME-OF-FLIGHT MASS SPECTROMETRY, HIGH VOLUME AEROSOL SAMPLER, NUTRIENTS, NANOMOLAR NUTRIENTS, HEME, AMINO ACIDS, PIGMENTS, PHYTOPLANKTON, BACTERIA, CAPE VERDE ISLANDS, CANARY CURRENT, DUST, AEROSOLS, SAHARA, EQUATORIAL NORTH-ATLANTIC, MARINE PRODUCTIVITY, RV POSEIDON, SALINITY, SEA SURFACE TEMPERATURE, SATELLITE IMAGES, MICROLAYER

ISSUING ORGANISATION

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British Oceanographic Data Centre, website www.bodc.ac.uk (E-mail enquiries@bodc.ac.uk) and from the site of the Natural Environment Research Counsil, website www.nerc.ac.uk/funding/thematics/solas/.
Furthermore, a pdf can be requested from Dr. Eric Achterberg (eric@noc.soton.ac.uk) NOC Southampton, European Way, Southampton SO14 3ZH, United Kingdom, phone: 023 8059 23199.

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Preface

The data presented in this Cruise Report are provisional and should not be used or reproduced without permission. In some cases they are fully calibrated and in other cases not. Further details can be obtained from the originators (see Scientific Reports). In due course the full data set will be lodged with the British Oceanographic Data Centre (BODC).

Acknowledgements

We thank the Master, M. Schneider, and all the officers and crew of the Poseidon for their constant support and sustenance during cruise P332, and for providing a safe and efficient platform from which to meet the scientific objectives of the UK SOLAS program. Excellent support for CTD work, the trace metal clean casts and persistence in trying to run the SAPS was provided by James Cooper (UKORS). James was present every morning (very early) under all weather conditions present to carry the incubation bottles. Furthermore, we want to thank Mark Stinchcombe for handling the logistics of the cruise. Besides the people on board of the Poseidon we also want to thank Duncan Purdie, Peter Statham, Brian Dickie, Paul Gooddy, Matt Mowlem, Richard Sanders and Mike Zubkov who helped us to make it possible to organize the cruise within 3 months after the start of our project. We also thank Julie LaRoche (IFM/GEOMAR at Kiel) and Richard Geider (University of Essex) for loaning us the incubation equipment. We thank Mark Moore, Matt Mills and Simon Ussher for answering all our questions during cruise preparation. NERC-UK-SOLAS is acknowledged for the funding of the cruise.

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Objectives of cruise

Over 70% of the earth's surface is covered by oceans. An estimated 40% of photosynthesis occurs in this marine environment. The turnover time for marine biomass is nearly three orders of magnitude faster than that of terrestrial biomass (Field et al. 1998). This means that the primary production in the oceans plays an important role in the carbon cycle and subsequently in global climate. Furthermore, primary producers form the base of the food chain.

In large parts of the oceans primary production is limited by light and macronutrients as nitrate, phosphate and silicate (Boyd et al. 2001; Graziano et al. 1996; Mills et al. 2004; Nelson et al. 2001; Wu et al. 2000) and/or the trace metal iron (Fe) (Gran 1931; Martin and Gordon 1988). Fe limitation occurs in the so-called "High Nutrient Low Chlorophyll" (HNLC) regions as the Southern Ocean (De Baar et al. 1990; Martin et al. 1990) and the North- and Equatorial Pacific (Chavez et al. 1991; Martin and Gordon 1988) but also in coastal areas (Hutchins and Bruland 1998) and seasonally in the North Atlantic (Moore et al. 2006). Any input of limiting macro nutrients and trace-metals will influence carbon sequestration, species composition and the trophic structure of planktonic communities.

Atmospheric transport of dust and its deposition in the surface ocean is thought to form the most important supply of new nutrients and trace-metals to the euphotic zone of open ocean regions (Baker et al. 2003; Bonnet et al. 2005; Martin and Fitzwater 1988; Sarthou et al. 2003). The North Atlantic Ocean receives about a third of the global oceanic dust inputs, which are estimated to range between 400-1000 x 10^{12} g y^{-1} (Jickells and Spokes 2001). Most dust input in the North Atlantic originates from the Saharan desert and Sahel region (Duce and Tindale 1991). Deposition of dust occurs via dry and via wet deposition and is strongly seasonal and episodic (Gao et al. 2001; Prospero and Carlson 1972). Maximum dust transport from the Saharan region to the North Atlantic moves from around 5N during the northern hemisphere winter, to 20N in summer, being driven by the seasonal migration of the ITCZ. At the Cape Verde islands in the tropical North East Atlantic, the maximum dust deposition takes place in winter with transport of dust mainly occurring in the lower air masses of the trade winds (Chiapello et al. 1995). In summer, the dust is transported higher up within the Saharan Air Layer (1.5-6km) and reaches the America's (Prospero and Carlson 1972; Prospero et al. 1981).

The Poseidon P332 cruise in the Cape Verde Island region was undertaken as part of the UK-SOLAS project (Surface-Ocean / Lower-Atmosphere Study, websites: www.solas-int.org and www.nerc.ac.uk/funding/thematics/solas/) to improve understanding of the atmospheric transport, cycling and deposition of dust and nutrients into the North Atlantic. The objectives of the cruise were:

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This particular cruise aimed to combine in-situ aircraft measurements of the atmosphere (DODO, University of Reading, www.met.rdg.ac.uk/~aer/dodo/dodo.html) with in situ sampling of the lower atmosphere and the water column (University of East Anglia, University of Southampton, National Oceanography Centre Southampton and University of Birmingham) around the Cape Verde islands.

The Poseidon 332 cruise will be followed by a cruise with the Discovery in January/February 2007 in the same region.

Cruise Narrative

After a hectic three months of preparation, the Poseidon departed from Las Palmas, Canaries, on the evening of 26 January 2006. After 31 days at sea the Poseidon arrived back in Las Palmas at 26 February 2006. The cruise track of the Poseidon is shown in Figure 1. During the cruise, the ship time of the Poseidon was according to UTC (i.e. not changed according to time-zones).

A total of 21 CTD stations were completed between 28/01/2006 and 20/02/2006. The dates, positions and times of the CTD stations, together with information on other scientific activities, are listed in Appendix 1, 2. Two stations were lost due to heavy weather conditions (14 and 16 February) and one day was used to re-supply the Poseidon in Mindelo (5 Feb., Cape Verde islands).

Most CTD casts were shallow (~ 230 m). Station 12 (9 Feb.) was a deep cast (3374 m) and located at the designated Cape Verde long term sampling station (17.03.056 N, 24.05.657 W) and station 20 (952 m, 19 Feb.) was completed at 29.59.6 N, 27.36.9 W. Every station consisted of a CTD cast and a trace metal clean GoFlo cast using a plastic coated steel wire and 2 x 3 trace metal clean GoFlo bottles. Stand Alone Pumps (SAPS) were deployed 4 times (01/02, 03/02, 04/04 and 06/02), but without success. The surface microlayer was sampled using an inflatable boat (06/02, 07/02, 08/02, 09/02, 19/02 and 20/02).

The tow Fish (epoxy resin coated steel torpedo) was deployed during the whole cruise starting 29 Jan. until 21 Feb. All underway samples were taken from seawater that was directly pumped up from Fish (through acid cleaned PVC tubing) into the clean container. The dates, positions, times and parameters of the underway samples can be found in Appendix 3. The first 4 days of the cruise were used to recover a surface mooring from the UK NERC RAPID programme which was found at 31 Jan (20.58.60 N, 29.19.08 W). After recovering the mooring we steamed to the Cape Verde islands for a rendezvous with the NERC aircraft. The Rendezvous with the aircraft was scheduled for the period between 7 and 15 Feb. However, a disappointing lack of dust and an abundance of clouds prevented a rendezvous.

At 5 Feb., when the Poseidon was in Mindelo for re-supply, James Randerson a reporter of the Guardian newspaper came on board of the Poseidon. From 5-8 Feb. James stayed on board of the Poseidon to experience the life on board of a research vessel and to write about our research. The article “Floating lab tracks Saharas’ sandstorms effect on ecosystem” was published in the Guardian on Monday 13 Feb., see Appendix 4.

The cruise also drew attention from the Science Museum in London. An exhibition on the cruise as part of their Antenna programme was organized (March-April 2006) and a website developed (http://www.sciencemuseum.org.uk/antenna/saharandust/).

No serious health and safety issues arose during the cruise. Recommended procedures for the wearing of safety clothing and for the display of risk assessment forms were generally well followed.

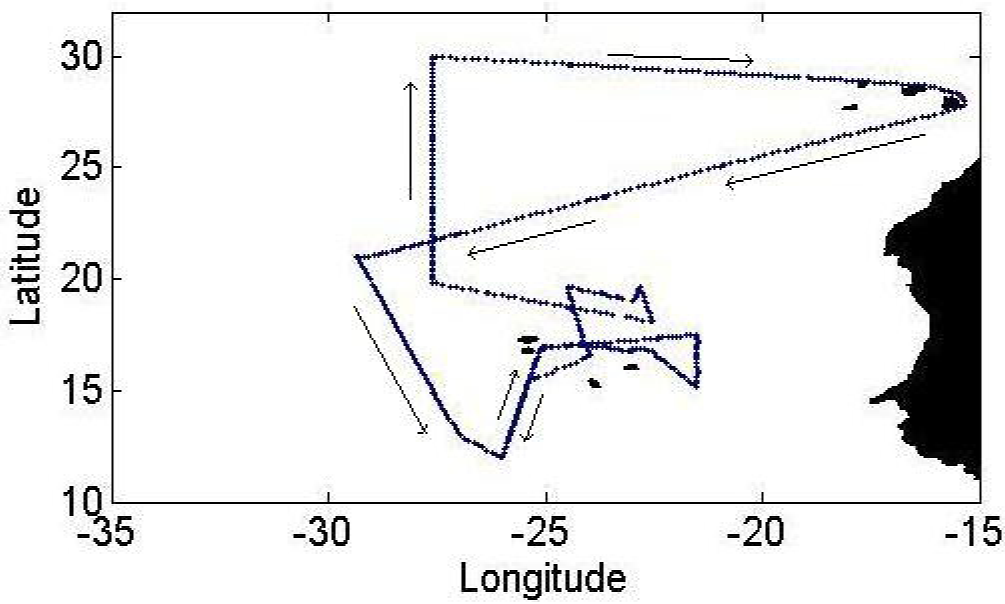


Figure 1. The cruise track of the UKSOLAS Poseidon 332 cruise. The cruise started on 26 January 2006 in Las Palmas (Canary Islands).

General Hydrographic and Meteorological Observations

The sea surface temperature and salinity are show in Figure 2. The temperatures increased from around 20ºC in the northern part of our cruise track to around 24ºC in regions south of the latitude 20ºN. The salinity was lower around the Cape Verde islands as compared to more open oceanic regions. A surface temperature-salinity property-property plot shows that the water mass north of 27ºN was distinctly different from the water mass in the vicinity of the Cape Verde Islands, see Figure 3. Furthermore, temperature-salinity plots show that the minimal depth of the mixed layer varied between 240 and 18 meters from the more open oceanic waters north to the waters in between and south of the Cape Verde Islands respectively, see Figure 4.

The air temperature and absolute wind speed during the cruise are shown in Figure 5. Figure 6 shows the sea surface chlorophyll a concentrations.

Air mass trajectories show that during the cruise period two dust storms occurred in the Cape Verde region (Manuel Dall'osto, personal communication). One dust event was detected during the cruise (4-8 Feb., Figure 7) and another dust event occurred when the Poseidon was further north. Table 1 shows where the air masses that the Poseidon encountered originated from.

Table 1. Calculated back trajectories of the air masses encountered during the Poseidon 332 cruise between 25/01 and 17/02 2006 (Manuel Dall'osto, personal communication).

dates	Originates from
25-27/01	USA
28-31/01	Europe
1-2/02	Canary Islands
3/02	Africa/Europe
4-7/02	Africa
8-11/02	marine
12-13/02	Marine/Africa
14-17/02	Canary Islands

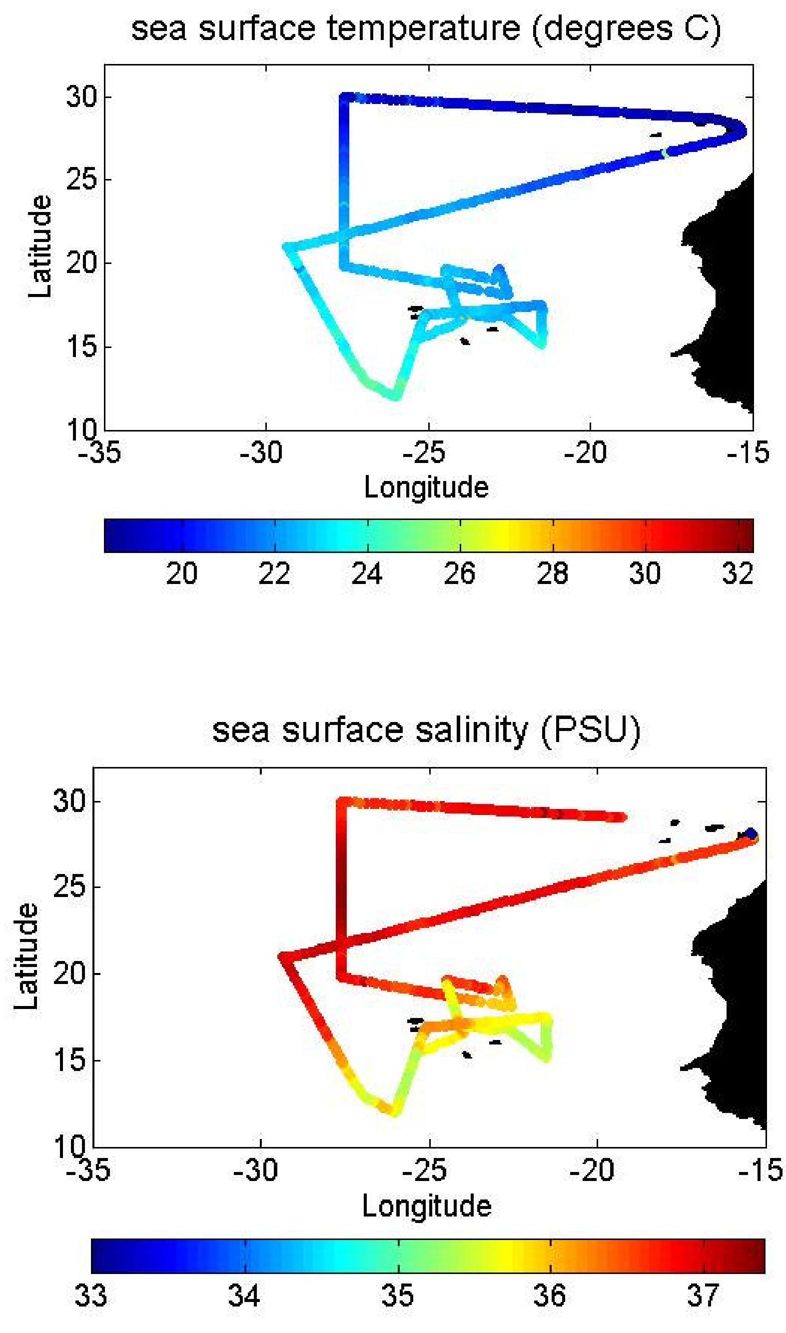
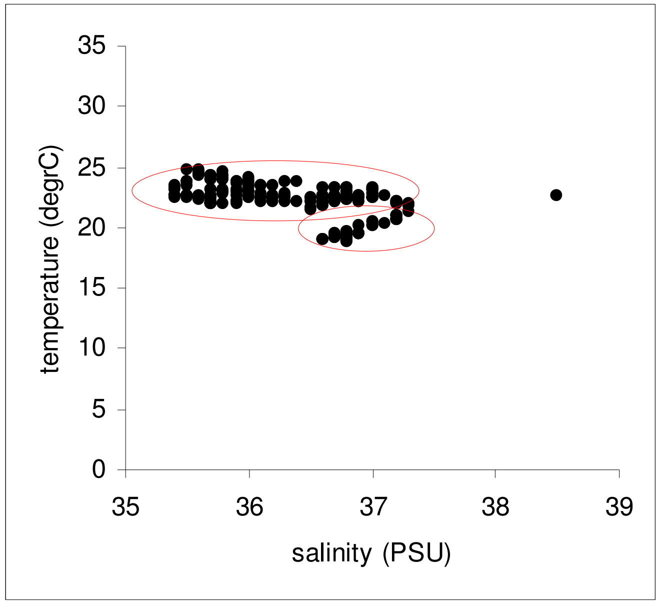


Figure 2. The sea surface temperature (°C) and salinity (PSU) during the UKSOLAS Poseidon 332 cruise in the Cape Verde region.

A



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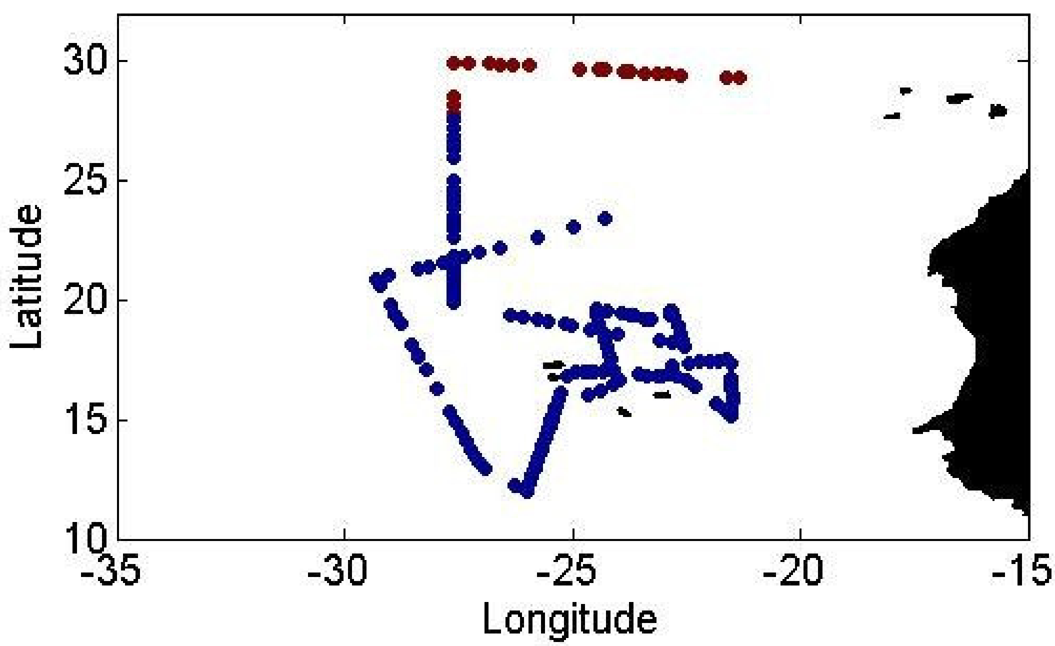

Figure 3. A) A temperature-salinity property-property plot shows the two distinct surface water masses that were sampled during the UKSOLAS Poseidon 332 cruise. B) A geographical representation of the two different surface water masses as distinguished by their different temperature salinity relationships.

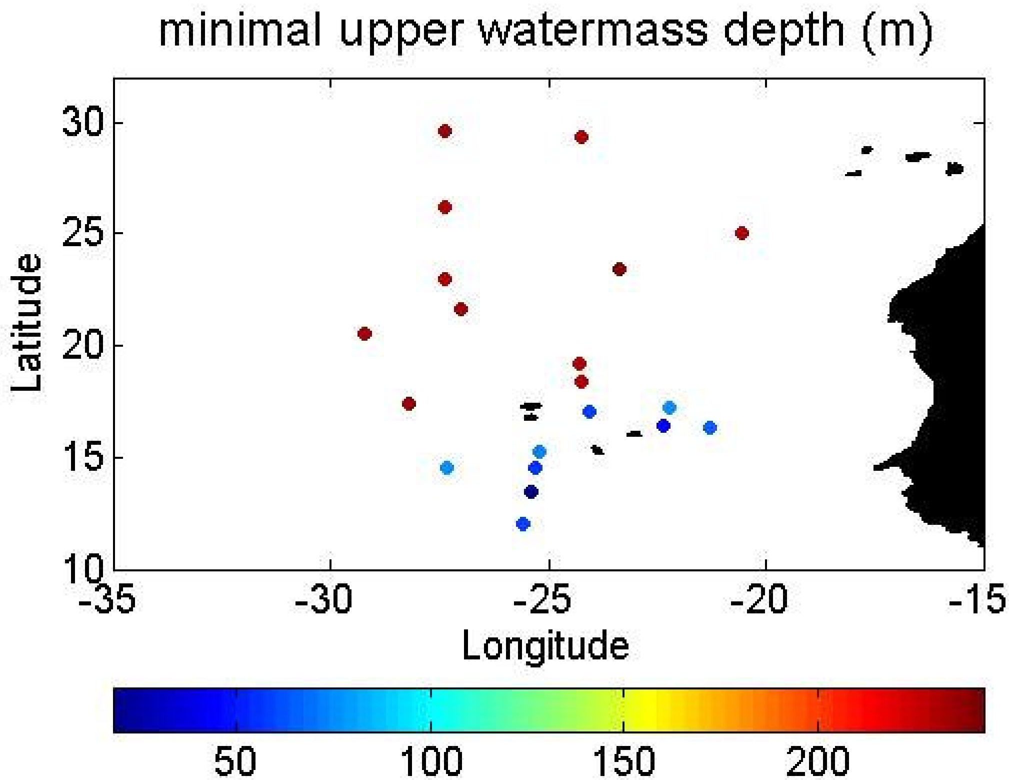

Figure 4. The minimal depth of the mixed layer according to the temperature-salinity property-property plots. The salinity and temperature data of the CTD log sheets were used as the full salinity and temperature data set from the CTD was not yet available.

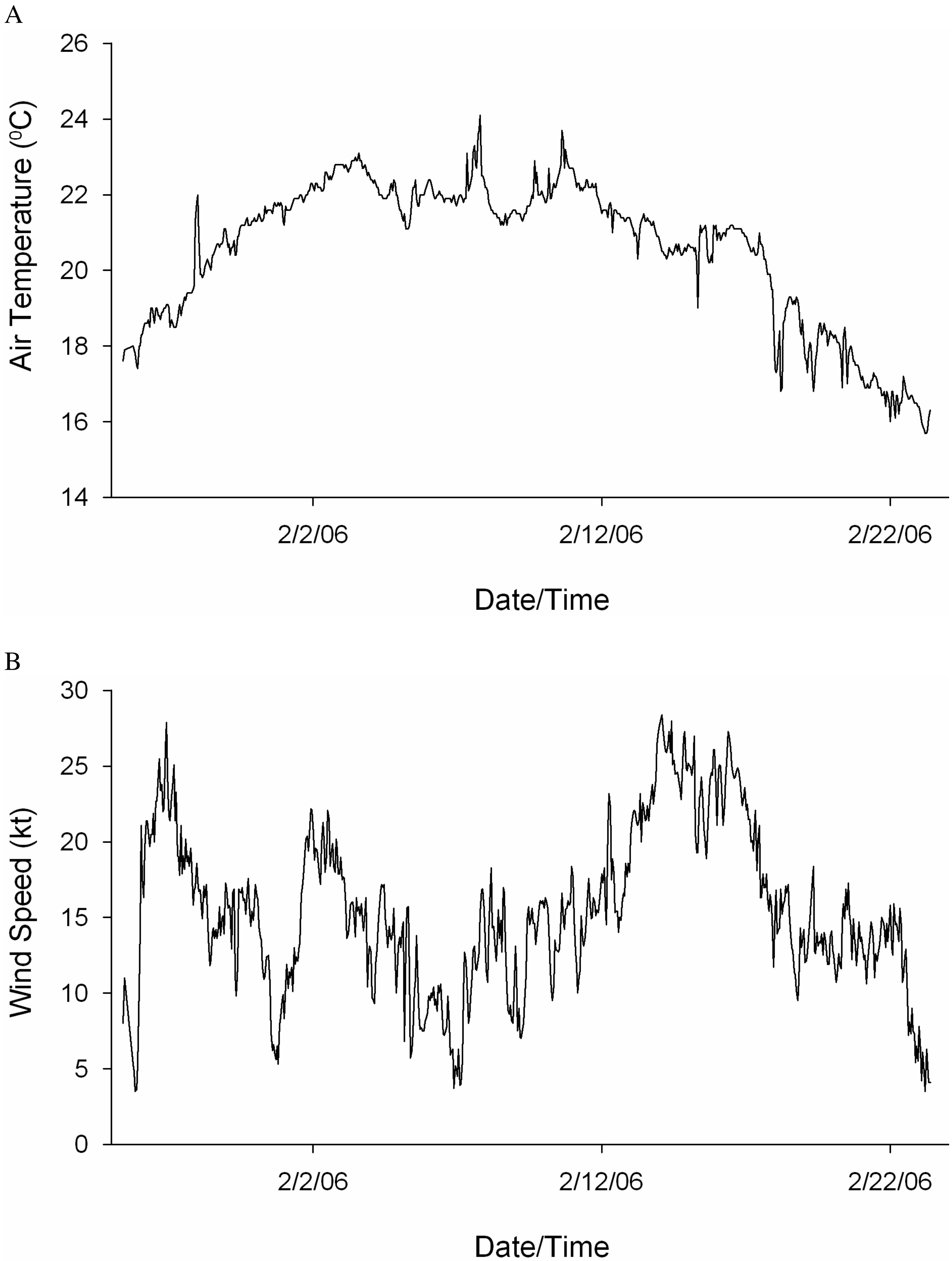

Figure 5. A) The air temperature (°C), and B) the absolute wind speed (knots) during the UKSOLAS Poseidon 332 cruise.

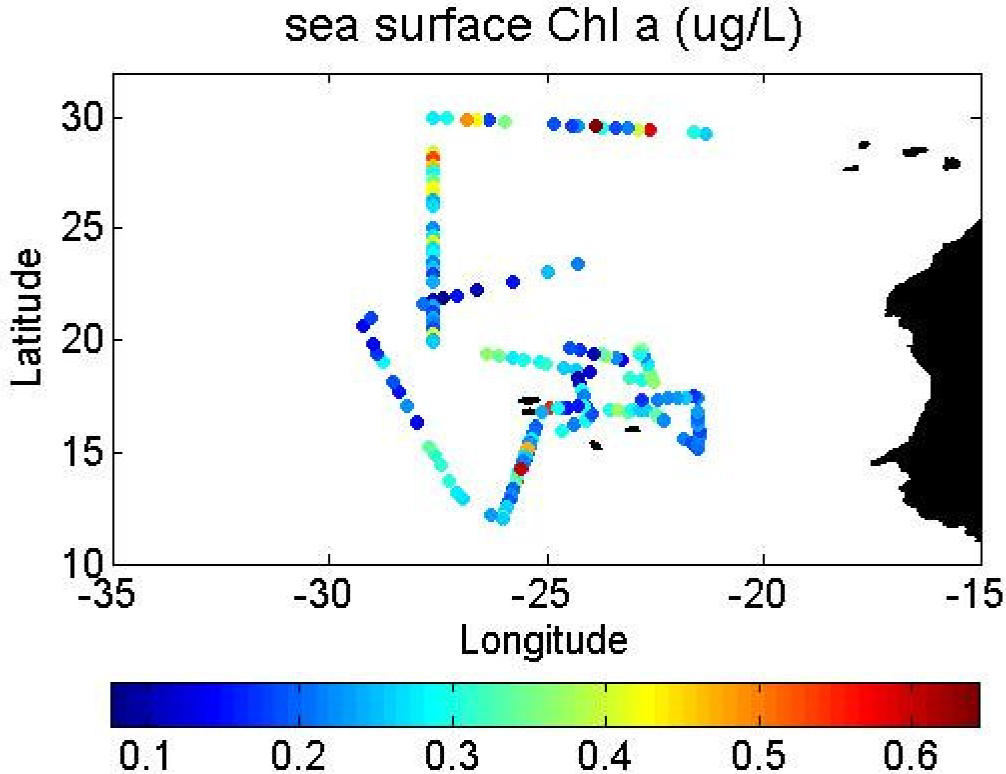

Figure 6. The geographical distribution of the sea surface concentration of chlorophyll a during the UKSOLAS Poseidon 332 cruise.

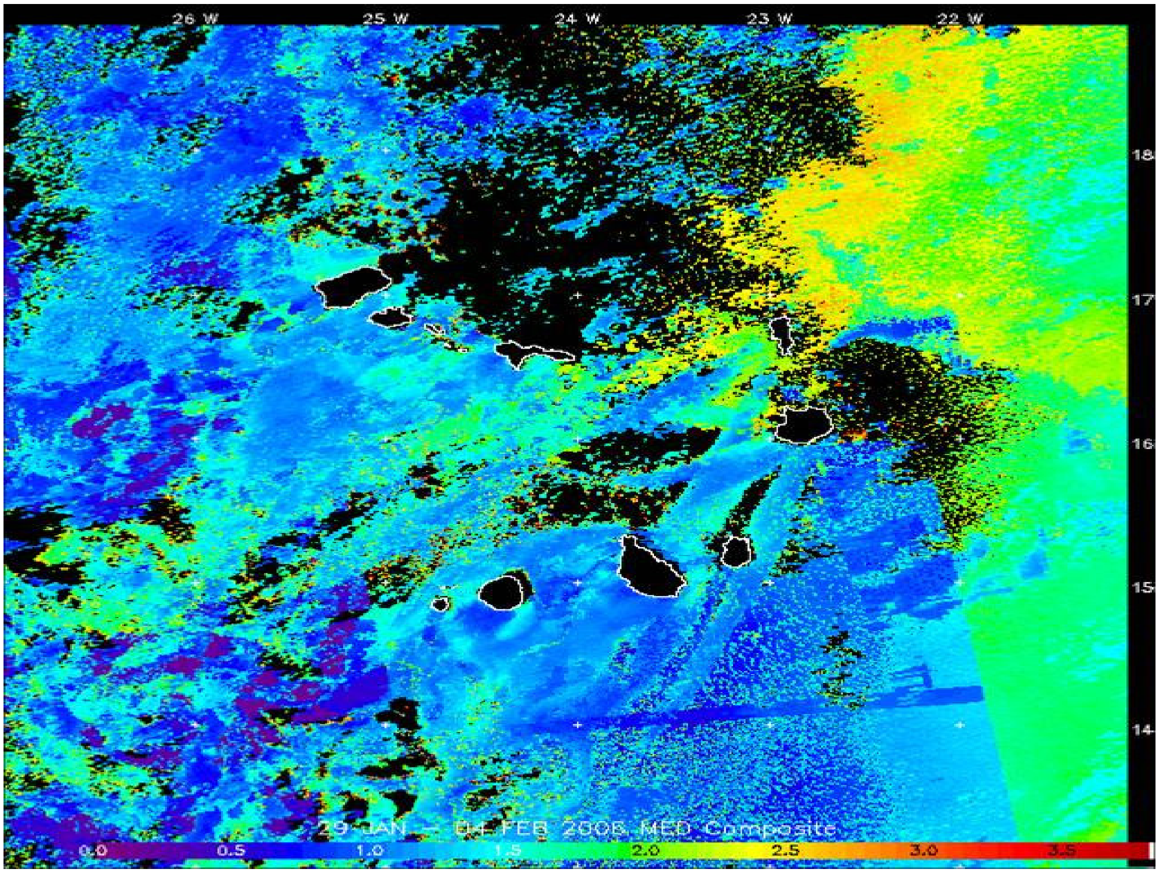

Figure 7. Composite (29 Jan.-4 Feb., 2006) Modis image of the tau865 (aerosol optical thickness at 865 nm).

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Scientific Reports

Atmospheric dust impacts on near surface marine microbial community composition and growth

Polly Hill, National Oceanography Centre, Southampton, UK.

Aim

To investigate the impact of episodic dust inputs on surface planktonic microbial community diversity and production in the eastern north Atlantic.

Objectives

1. Determine the microbial composition in the surface waters in the eastern tropical Atlantic and to link it with competition of dominant groups for available limiting nutrients

2. Quantify the impact of metals and nutrients released from aerosol dust on the marine microbial community composition in the surface water.

3. Evaluate the impact of dust inputs on microbial community dynamics in the eastern tropical Atlantic

Underway sampling

Surface seawater was collected from a fish at 2-hourly intervals between 0600h and 0000h. Two samples of 500ml were filtered on 25mm Fisherbrand MF300 filters for chlorophyll-*a* measurements and 1.6ml samples were fixed with paraformaldehyde (1% final concentration) for analysis of microbial communities by automated flow cytometry. At 6-hourly intervals 3-L samples were also filtered for analysis of phytopigments by high performance liquid chromatography (HPLC). Samples were frozen at -80ºC.

CTD rosette sampling

Daily CTD casts were conducted at 09:00h and samples collected from each depth. Duplicate 500ml samples were filtered for chlorophyll measurement. Subsamples were fixed with paraformaldehyde (1% final concentration) and frozen for flow cytometry analysis of autotrophic and heterotrophic picoplankton abundance post-cruise. Samples were also filtered for analysis by HPLC (3-L) from some depths.

Dust incubation experiments

48-hour incubations were conducted to investigate the impact of dust addition on the picoplankton in terms of both autotrophic and phototrophic production. Samples were filtered for measurement of chlorophyll-*a* and ^{13}C-bicarbonate and ^{15}N-leucine incorporation (3.5L). Samples were fixed with PFA for analysis by automated flow cytometry.

Analysis of samples

Chlorophyll measurements were conducted on-board with a TD-700 Turner Designs fluorometer, calibrated with fresh chl-*a* standard (Sigma, UK) in 90% acetone. Frozen samples were extracted overnight in 90% acetone. HPLC, tracer assimilation and AFC samples will be analyzed at NOC.

Prokaryoplankton community composition and growth
Jane Heywood, National Oceanography Centre, Southampton, UK.

Aims

To compare abundance and growth of prokaryoplankton in surface and deeper waters and to investigate the influence of dust addition on prokaryoplankton communities.

Objectives

4. To assess the growth of different prokaryoplankton groups by detection of DNA synthesising cells.

5. To collect samples for the analyses of prokaryoplankton community composition and abundance.

Methods

Prokaryoplankton growth was determined by incubating seawater samples with the thymidine analogue, 5-Bromo-2'-deoxyuridine (BrdU) that is incorporated into the DNA of dividing cells (Pernthaler et al., 2002). Seawater was collected in HCl washed 1L vacuum flasks from two depths at 12 stations along the cruise track. Samples were also collected from control and dust added bottles from each of the 7 dust addition experiments at time = 0 and 48 h. During 3 of the dust addition experiments, water was also sampled from both the control and dust added bottles at several time points throughout the 48 h incubations to investigate diurnal growth signals and to monitor any changes in cell abundance and community composition. Samples (50 – 60 ml) were incubated in polypropylene bottles with 2 µM BrdU at ambient sea temperature for 0, 3 or 6 hours. Incubations were stopped by the addition of paraformaldehyde (1% final concentration). Cells were subsequently fixed for 24 h at 4 ºC before being collected onto 0.2 µm polycarbonate filters and frozen. The remaining sample processing involves anti-BrdU binding and labeling with fluorescent markers. This technique will be combined with fluorescence *in situ* hybridisation (FISH) to identify various groups of prokaryotes. Both these stages will be completed in Southampton.

Six times during the cruise, neuston samples were colleted from the sea surface microlayer. Seawater was collected in a 1 mm^2 nylon mesh placed on the ocean surface. As a comparison, water was also colleted from approximately 15 cm below the surface. BrdU incubations were performed as stated above and samples were collected for the determination of cell abundance by flow cytometry.

Seawater samples were collected in HCl washed 50ml polypropylene tubes from all depths on the trace metal free casts. Subsamples were fixed with paraformaldehyde (1% final concentration) and frozen for flow cytometry analysis of prokaryoplankton abundance post-cruise. Samples for flow cytometry were also collected and fixed from each sample analysed for DNA synthesis. Flow cytometry analysis will be carried out post cruise in Southampton.

Inorganic nutrients

Mark Stinchcombe, National Oceanography Centre, Southampton, UK.

Preamble

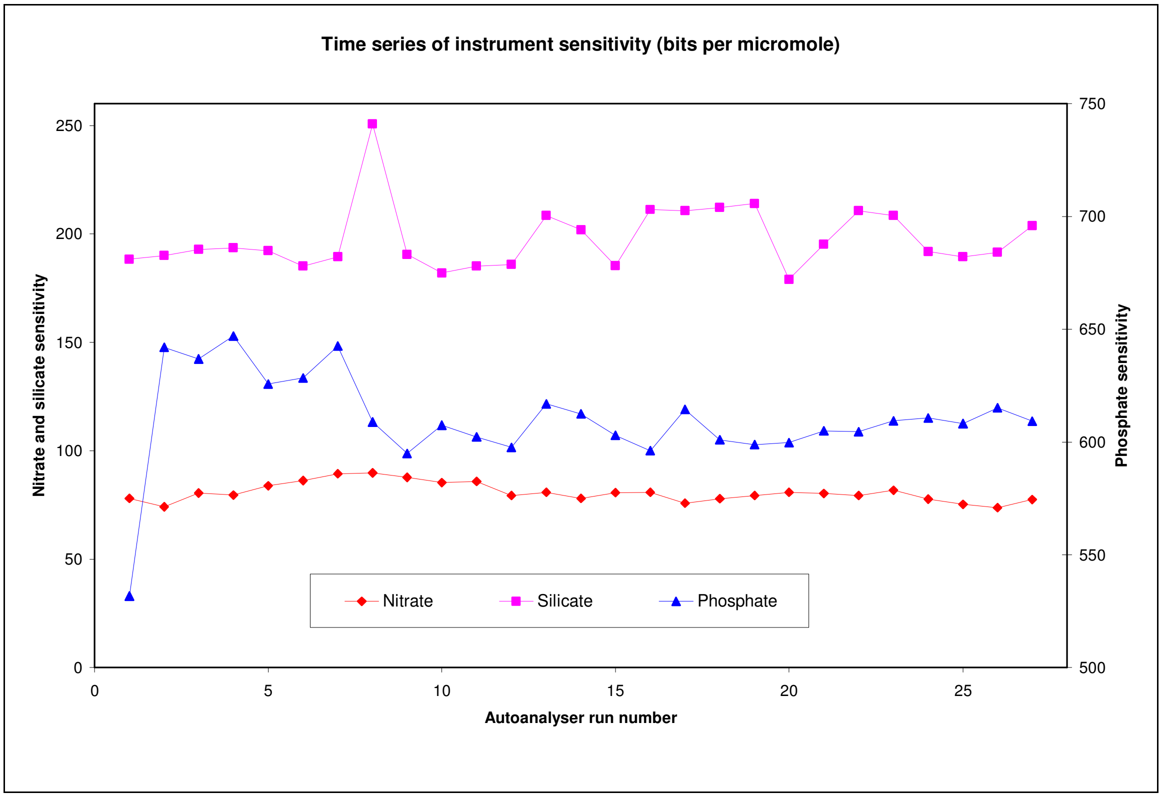
Analysis for nitrate and nitrite (hereinafter nitrate), phosphate and silicate was undertaken on a scalar sanplus autoanalyser following methods described by Kirkwood (1994) with the exception that the pump rates through the phosphate line are increased by a factor of 1.5 which improves reproducibility and peak shape. Samples were drawn from Niskin bottles on the CTD or from the underway non-toxic supply into 25ml sterilin coulter counter vials and kept refrigerated at 4^{o}C until analysis which commenced within 24 hours. Stations were run in batches of 2 to 4 with most runs containing 2 stations. Overall 27 runs were undertaken. An artificial seawater matrix (ASW) of 40g/l sodium chloride was used as the intersample wash and standard matrix. The nutrient free status of this solution was checked by running Ocean Scientific International (OSI) nutrient free seawater on every run. A single set of mixed standards were made up by diluting 5 mM solutions made from weighed dried salts in 1 litre of ASW into plastic 1 litre volumetric. Data was transferred to another computer using an Integral 128MB USB memory stick. This allowed fast data transfer between computers so time between sample analysis and data work up was done within 24 hours. Data processing was undertaken using Skalar proprietary software. The wash time and sample time were 80 seconds; the lines were washed daily with 0.25M sodium hydroxide (P) and 10% Decon (N, Si). Time series of baseline, instrument sensitivity, calibration curve correlation coefficient, nitrate reduction efficiency and duplicate difference were compiled and updated on a daily basis.

Performance of the analyser

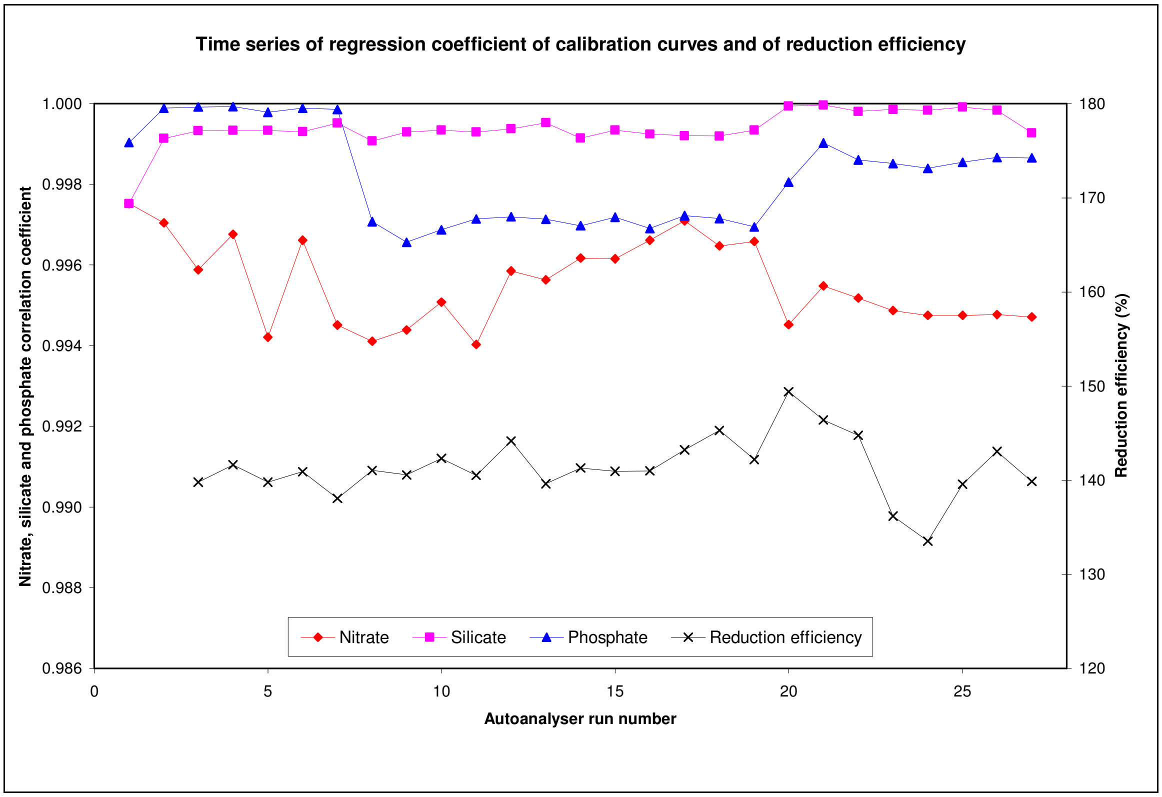
A week into the cruise there was a problem with the Skalar software on the laptop used for the autoanalyser. It wouldn't actually log any data, though it was communicating with the integrator. It seemed to think it was already recording somewhere, though we couldn't find where to and so we couldn't stop it. The problem was eventually solved by uninstalling the software and then reinstalling it. It worked perfectly after that and so no samples were lost during this period. The autoanalyser was only out of action for 12 hours. At times the baselines of the chemistries took quite a while to level off, especially the nitrate baseline. All the reagents were changed regularly and all the standards were changed as well which helped reduce the problem. It didn't affect any of the samples to a great degree as the only samples that might have been affected were the very low ones, which are one the autoanalyser has difficulty picking up anyway and Matt Patey was measuring using a nanomolar technique.

Analyser performance

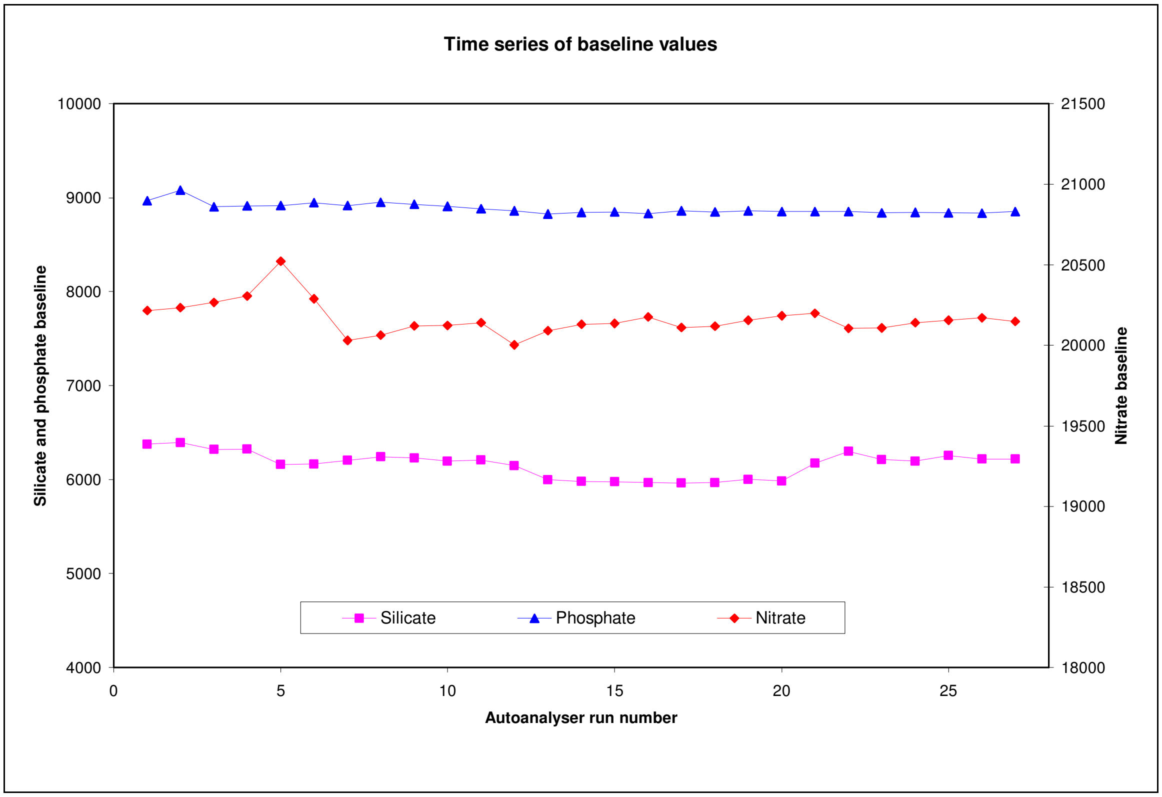
The performance of the analyser is monitored via the following parameters: baseline value, calibration curve slope, regression coefficient of the calibration curve, nitrate reduction efficiency. Time series of these parameters are shown in figures.



The instrument sensitivity for nitrate didn't vary much over the course of the cruise, no more than 5%. The phosphate line was more variable at the start of the cruise, with sensitivity changing by 10 to 15%. The first run can be ignored as I hadn't switched the water bath on and so it was redone. The variation in sensitivity settled out though over the course of the cruise.



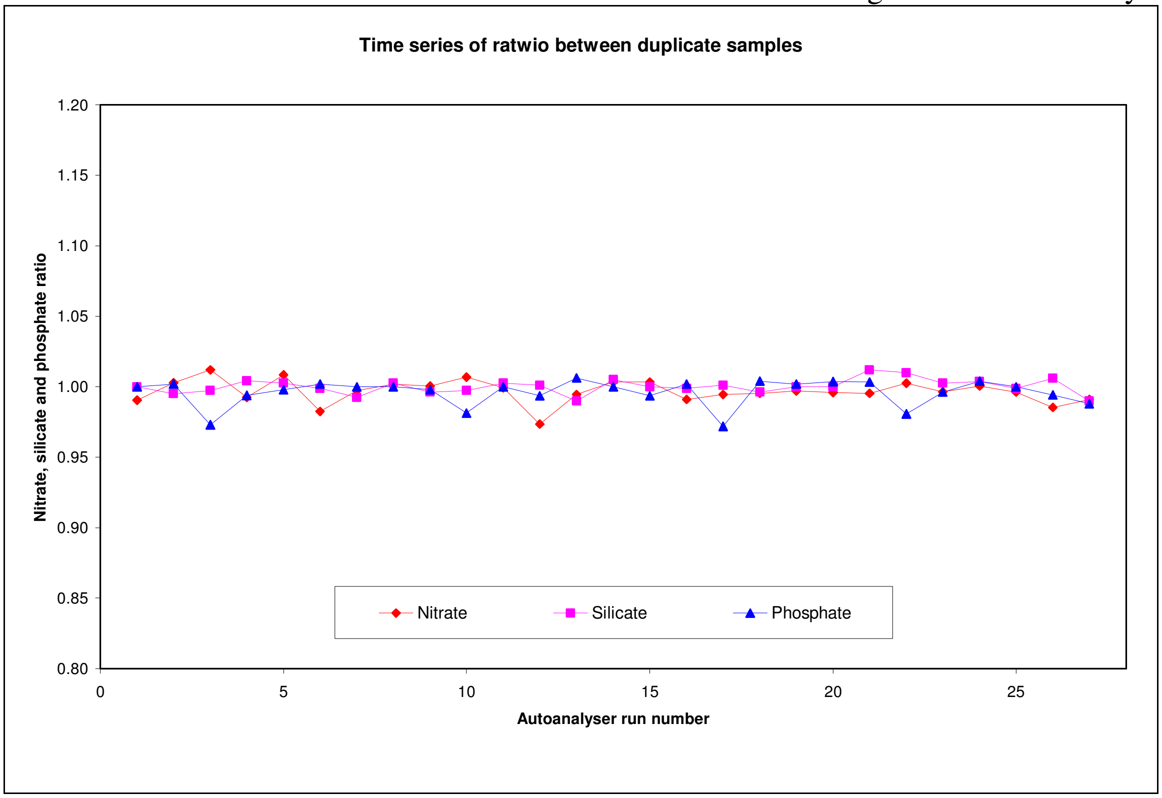
The quality of the calibration curves was generally good with 100% of the silicate and phosphate regression coefficients being greater than 0.998. The nitrate was slightly lower but still all the regression coefficients were higher than 0.994. The reduction efficiency of the cadmium column was greater than 100% for the whole of the cruise, the lowest value being 133% but with the majority of values over 135%.



The baselines of the three inorganic nutrients barely changed throughout the cruise and very little drifting of the baseline was seen in any of the runs for any of the chemistries.

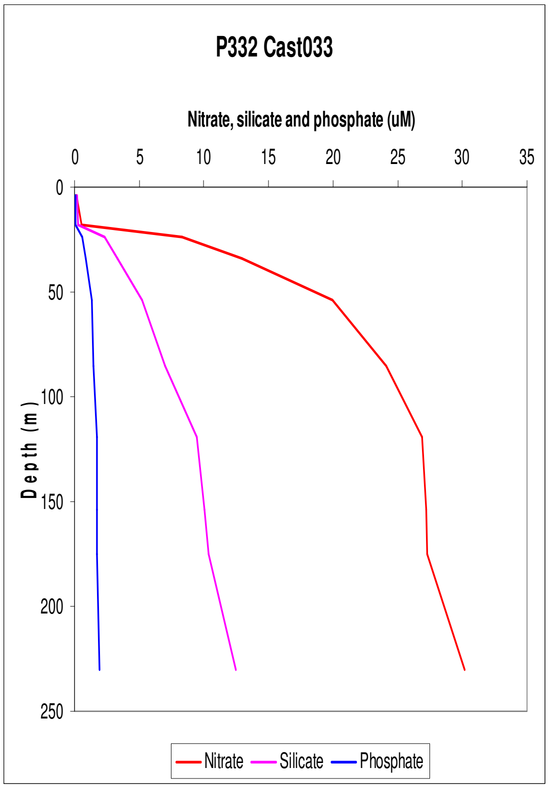
Data quality

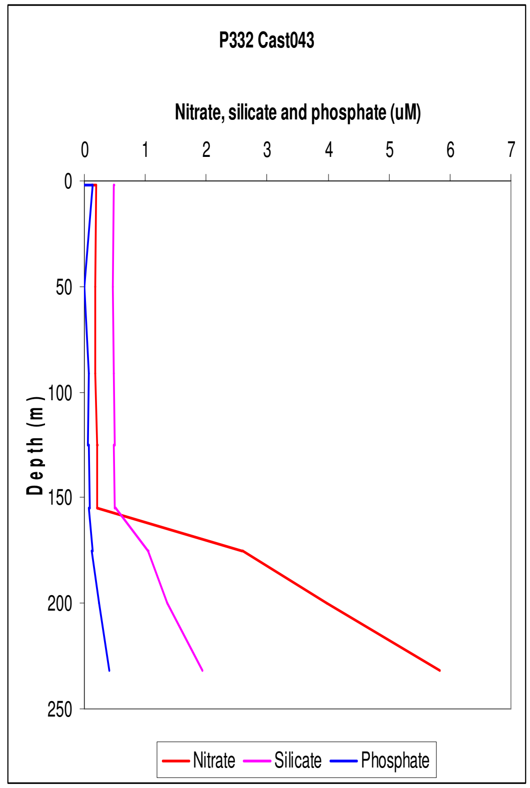
The short term precision of the measurements was evaluated by running duplicate samples each run.. The ratio between the two duplicates was calculated and plotted. The ratios all fell within 0.97 and 1.01 of each other with nitrate showing the most variability.



Examples of Data

The CTD data were plotted up to give a profile of the water column which could then be printed out. All the profiles showed very low values of nutrients above the thermocline with concentrations increasing below the thermocline. The depth of the thermocline varied greatly depending on the influence of upwelling. The two stations with the shallowest and deepest thermoclines are shown below to give an example of the profiles produced and the difference in depth of the thermocline.





Nanomolar Inorganic Nutrients

Matt Patey, National Oceanography Centre, Southampton, UK.

Approach

Analysis for nitrate and nitrite (hereinafter nitrate) and phosphate at nanomolar concentration were undertaken on a purpose-built, segmented-flow autoanalyser following methods similar to those used by Zhang (2000 and 2002). Two liquid waveguide capillary flow cells were used to provide a two metre pathlength, enabling the detection of nanomolar levels. Two Tungsten-halogen light sources were used in conjunction with fibre-optic spectrometers to monitor the absorbance of the solution flowing through the waveguides.

Samples were taken in HCl-washed 60/125 ml HDPE bottles from the CTD and trace-metal clean casts as well as from underway samples drawn from a fish. Samples from the dust incubation experiments were also analysed. In general, samples were only tested if they were thought to contain very low levels of dissolved inorganic nutrients.

A chemical dust dissolution experiment was also carried out. Six different types of dust were added to filtered seawater from the underway supply at four different concentrations. Samples were stored in the dark at approximately 24ºC. Samples were filtered and tested after 48 hours and after 1 week to determine any increase in dissolved nutrients.

Problems

Many problems were encountered with air bubbles forming in the waveguide. These problems were due to contamination from a variety of sources. Problems were also encountered with the peristaltic pump wearing out the pump tubing rapidly and causing the instruments' response to vary. Due to these problems, some samples were not analysed, particularly in the first half of the cruise.

Results

Calibration and calculation of results is being carried out using a manual technique that is very time-consuming. Processing of the data will be carried out back at Southampton.

Aluminium measurements in the subtropical and tropical West Atlantic
Maria C. Nielsdóttir, National Oceanography Centre, Southampton, UK.

The overall aim of this study was measure aluminium and to potentially use it as a tracer of dust episodes to the ocean.

Introduction

8.2% of the crust of the Earth is aluminium, which makes it the third must abundant element. However, surface values of oceanic Al are very low and can be used to identify the location and magnitude of atmospheric dust events to the ocean. Due to aluminium's short residence time it can be used as a tracer of oceanic input processes (Resing and Measures 1994).

Method

Dissolved aluminium was measured by complexing aluminium to Lumigallion (Hydes and Liss 1976). An AMENCO fluorescence spectrometer was used with a blue mercury vapour lamp and an excitation wavelength of approximately 485 nm and an emission wavelength of approximately 576 nm was found by using a blue and yellow filter.

Aliquots of 5 mL were decanted from the acidified seawater sample. Ammonium acetate buffer was added to reach pH of around 5. Lumigallion was added to complex the Al and the sample was left for 24 hours. Before measuring Brij 25 was added. All samples were measured in duplicates.

Main objectives of study

1. To map changes in total dissolved (< 0.2 µm) Al taken during the first SOLAS cruise in relation to other key parameters including nano- and macronutrients, chlorophyll, dust particles and iron in order to understand the role of Al in this region.
2. To determine the vertical distribution of Al through the water column.
3.

Sampling Rationale

Underway trace metal Fish

Samples were taken along the cruise from the 26th January to the 23rd February 2006 on cruise P332 onboard RS Poseidon. 170 surface samples were collected along the cruise tract using a trace metal clean fish (Figure 1).

Clean casts

19 clean casts with Go-Flo bottles taken at six different depths and two casts at 12 different depths, were sub-sampled directly into acid washed 250 mL LDPE bottles and subsequently filtered through 25 mm PTFE syringe filters using a peristaltic pump into 125 mL acid washed LDPE bottles in a laminar flow cabinet. Samples were then acidified with ultra-pure HCl (125 µl per 125 mL – 6M).

Samples and Analysis

Dissolved Aluminium

Dissolved Al samples were analysed onboard using the Hydes and Liss method (Hydes and Liss 1976). One standard addition was done for each batch of samples analysed and the concentration calculated relatively from the standard addition. Further interpretation of data will be done back at NOC.

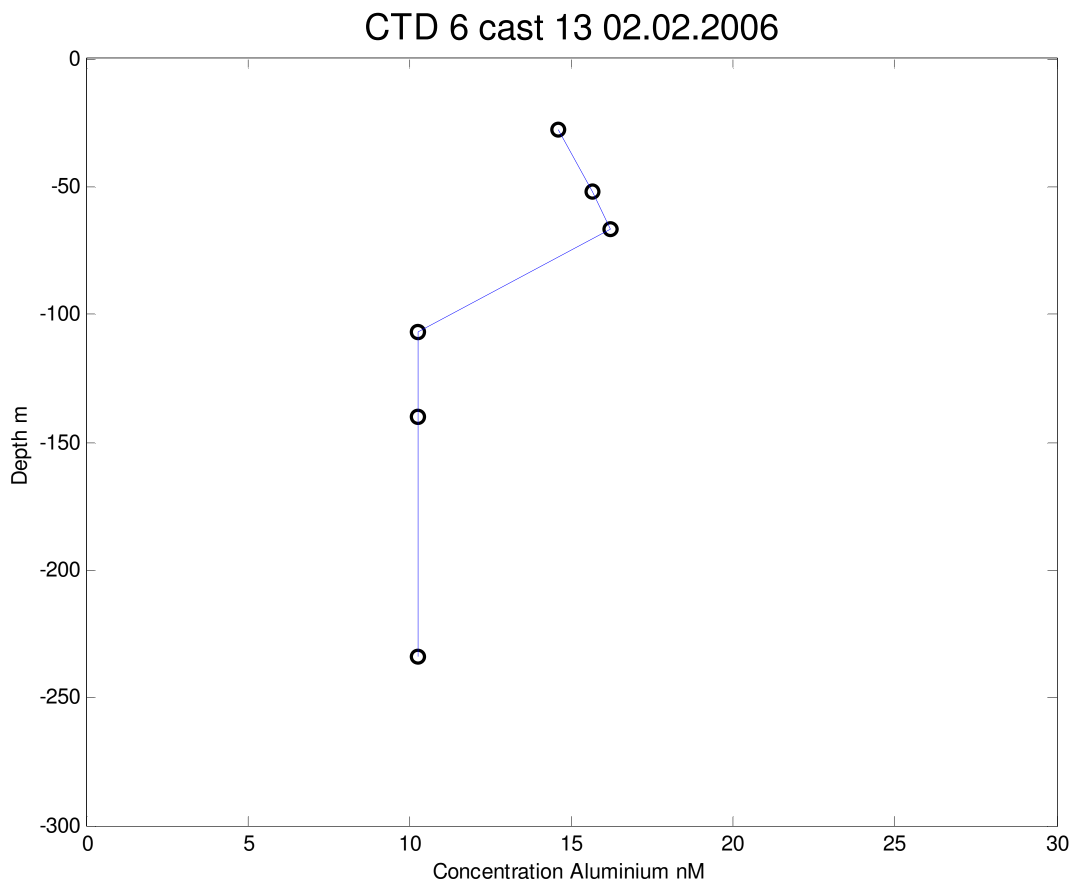


Figure 1. CTD 6 profile

Fast Repetition Rate Fluorometer (FRRF)

Fast Repetition Rate Fluorometer (FRRF) measurements were used to monitor the physiological health of the photosynthetic machinery in the phytoplankton population being studied.

Three different FRRFs were onboard. One for the continuous sampling of the non-tox supply. One was mounted on the CTD for the profiling and one for the discreet samples from the bioassays.

For the bioassays, the samples underwent a 30 minute dark incubation at sea surface temperature to allow relaxation of all photochemical and non-photochemical quenching (Simpson and Hydes, 2003), sub-sampling was generally restricted to periods of darkness or early dawn to limit recovery time.
At NOC the values of dark-adapted maximum photochemical quantum efficiency (Fv/Fm) and the functional absorption cross-section (σPSII) will be calculated by fitting the measured saturation curves to the biophysical model of Kolber et al. (1998) using MATLAB™ code outlined in Laney (2003) that is edited by Dr. Mark Moore.

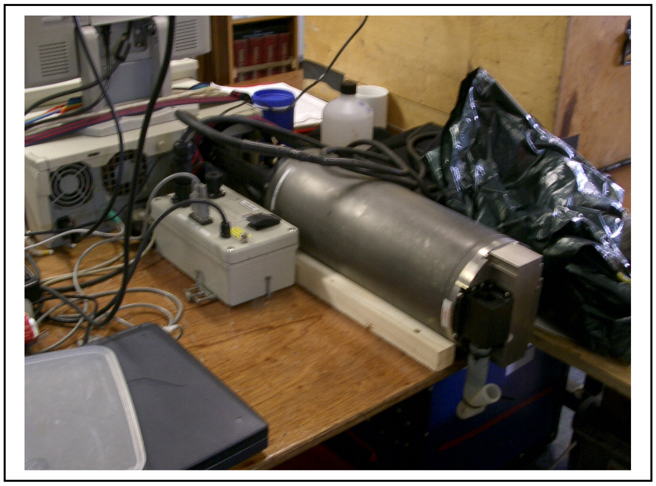


Figure 2. Chelsea Instruments Fast Rate Repetition Fluorometer.

Results and Discussion

The preliminary results show indication of the link between Al and dust episodes. However, the more accurate data will be worked up within a few months of returning to NOC.

Literature

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Measurements of dissolved iron in tropical North Atlantic, Cape Verde Islands
Micha J.A. Rijkenberg, National Oceanography Centre, Southampton, UK.

Introduction

The primary goal of the Poseidon P332 cruise was to combine the investigation of Saharan dust in the atmosphere and in the water column of the tropical North Atlantic. This to elucidate the effect of atmospherically deposited Saharan dust on the concentration (trace-)nutrients (iron, phosphate and nitrate) and on the primary productivity, heterotrophic activity and nitrogen fixation within the natural bacterio- and phytoplankton populations.

Iron is a critical nutrient for the primary productivity in the ocean. Due to its low solubility iron can be a limiting factor for the growth of phytoplankton in the open ocean as well as in coastal seas (Martin and Fitzwater, 1988; de Baar *et al.* 1990; Hutchins and Bruland, 1998). There is an increasing interest in resolving the transport pathways of iron into the oceans.

Over the past few years it became evident that the atmosphere compared to rivers, is a significant transport pathway for iron to the ocean. Duce and Tindale (1991) estimated that atmospheric transport from the continents supplies approximately three times as much dissolved iron to the ocean as is delivered via rivers.

Materials and methods

Samples were taken from trace metal clean bottle casts using a plastic coated steel wire. Underway samples were taken using a epoxy resin coated steel torpedo and in-line transport into a clean container. All Fe analyses were performed in the clean container. Dissolved Fe (<0.2 µm) was measured by flow injection analysis and chemiluminescence detection. The dissolved Fe(II+III) was determined after reduction of all Fe(III) to Fe(II) by sulfite and subsequent matrix elimination and pre-concentration on a 8-hydroxyquinoline chelating resign column (Bowie *et al.* 1998).

Results

The dissolved iron was measured in special trace-metal clean bottle casts, in underway samples and in the incubation experiments. The field measurements of dissolved Fe will tell us how Saharan dust input effects the concentration Fe in the water column. The measurements of dissolved Fe in the incubations (Polly Hill, Eric Achterberg) give us an indication of Fe dissolution from the atmospherically processed dust collected at Barbados and used during the incubations. Samples taken from an additional dust dissolution experiment (Matt Patey), where six different kinds of dust were in varying concentrations added to filtered seawater, will be measured at the home institute (NOCS).

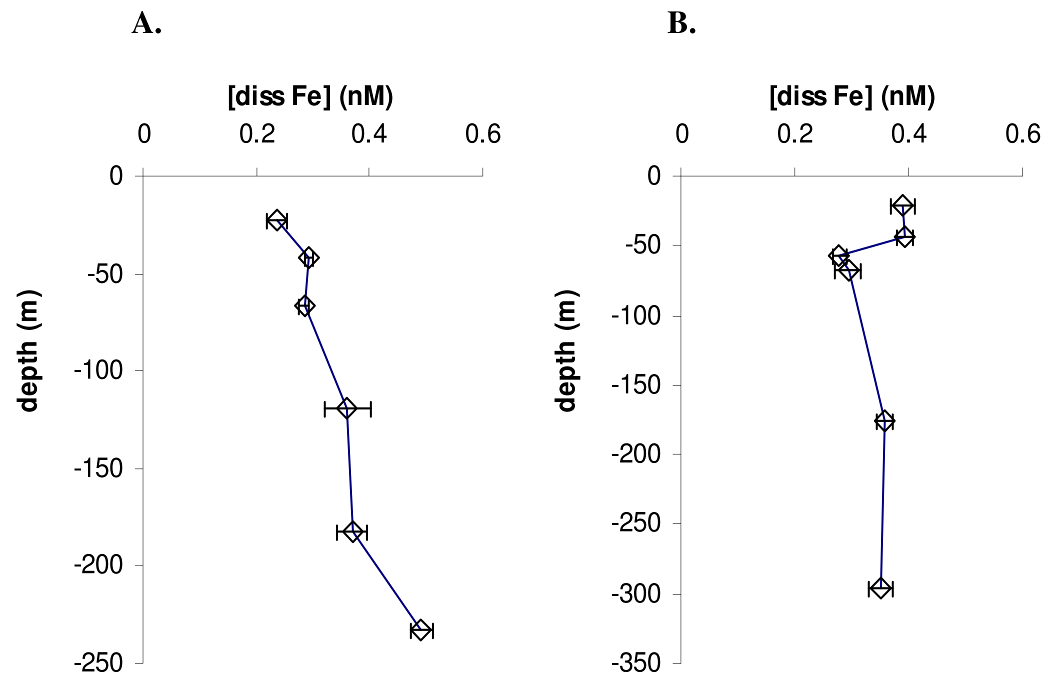

Figure 1) The dissolved Fe concentration in a trace metal clean bottle cast at A.) Station 4, cast 8 31/01/2006, and B.) Station 5, cast 10 01/02/2006.

Acknowledgements

We want to thank the captain Schneider and crew of the Poseidon for support during the cruise, and to Eric Achterberg, the chief scientist.

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Bowie, A. R., Achterberg, E. P., Mantoura, R. F. C., and Worsfold, P. J. (1998) Determination of sub-nanomolar levels of iron in seawater using flow injection with chemiluminescence detection. *Analytica Chimica Acta* 361: 189-200

Duce, R.A. and Tindale, N.W. (1991) The atmospheric transport of iron and its deposition in the ocean. *Limnology and Oceanography* 36: 1715-1726

Hutchins, D. A. and Brulkand, K. W. (1998) Iron-limited diatom growth and Si:N uptake ratios in a coastal upwelling regime. *Nature* 393(6685): 561-564

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Aerosol time-of-flight mass spectrometry of atmospheric dust
Manuel Dall'Osto, University of Birmingham, UK

The overarching aims of DODO are to:

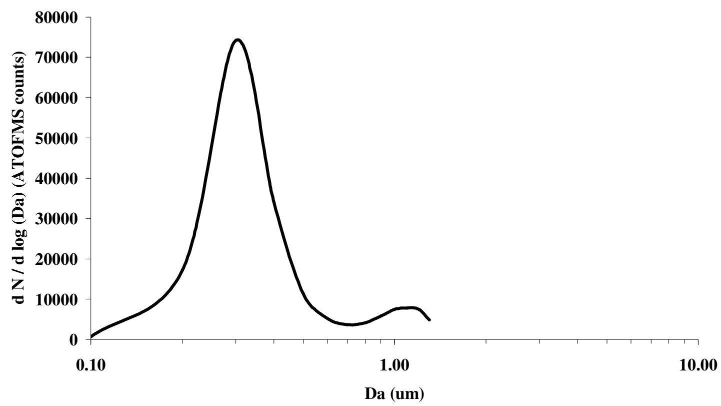
1) Deliver case study based predictions of dust deposition to the northern hemisphere Atlantic Ocean constrained by in situ aircraft measurements.
2) Describe how chemical and physical changes in the dust affect its transport over the ocean, and are themselves affected by the transport
3) Assess the size distributed iron loading in the dust, and characterise the chemical form of the iron
4) Fingerprint dust sources using single particle characterisation and assess their main composition, including iron content
5) Assess the climatological representativity of the case studies and therefore predict the seasonal footprint of dust deposition and its associated iron to the north Atlantic Ocean.

The University of Birmingham operates the first of only two TSI Model 3800 Aerosol Time-of-Flight Mass Spectrometers in the UK. The aerosol time-of-flight mass spectrometer (ATOFMS; TSI-Model 3800) provides information on a polydisperse aerosol, acquiring precise aerodynamic diameter (±1%) within the range 0.1 to 1.4 micrometers and individual particle positive and negative mass spectral data in real time. Point 3 and 4 of the aim of DODO were achieved with the ATOFMS during the cruise P332 (RV Poseidon).

Additional high time resolution size distributions were provided with two additional instruments (SMPS and APS). Aerodynamic Particle Sizer (APS, Model 3321, TSI Inc. St. Paul, MN) measures the particle size distributions from 0.5 µm to 20 µm (52 channels) by determining the time-of-flight of individual particles in an accelerating flow field. Scanning Mobility Particle Sizer (SMPS) provides aerosol size-resolved number concentrations within the range 10÷550 nm.

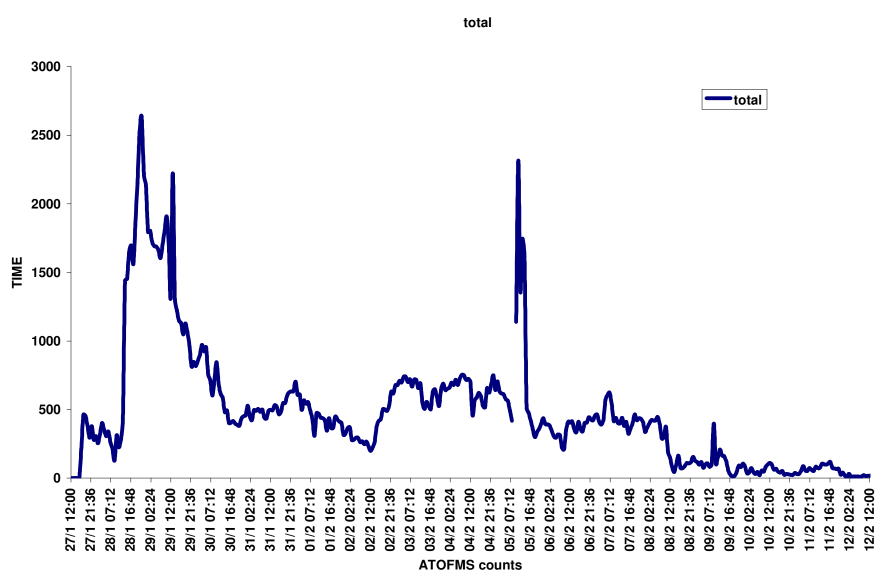
APS and SMPS were operating in real time during the whole cruise between 17:00 27/01/2006 and 10:00 22/02/2006. Data are going to be analysed at the University of Birmingham during the month of May 2006.

During the cruise, on 13/02/2006ATOFMS stopped working. The reason is thought to be due to laser alignment due to extreme movement of the ship and to the malfunction of one of the two sizing lasers. However, nearly 200.000 mass spectra were recorded in real time between 17:00 27/01/2006 and 10:00 13/02/2006. . The size distribution of the particles detected is given below.



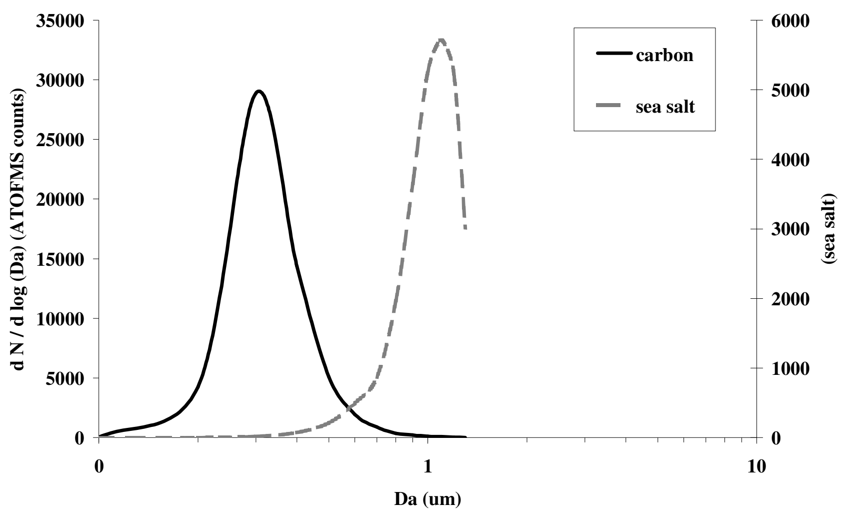
YAADA (Yet another ATOFMS Data Analyzer) is a software toolkit to analyze single particle mass spectral data including data collected with ATOFMS. During the cruise 187.205 particles were imported into YAADA and the ATOFMS dataset was analysed with the powerful artificial intelligence algorithm ART-2a with a computer on board of the ship. Learning rate 0.05, vigilant factor 0.85 and a total number of 20 iterations were chosen as ART-2a parameters for these studies.

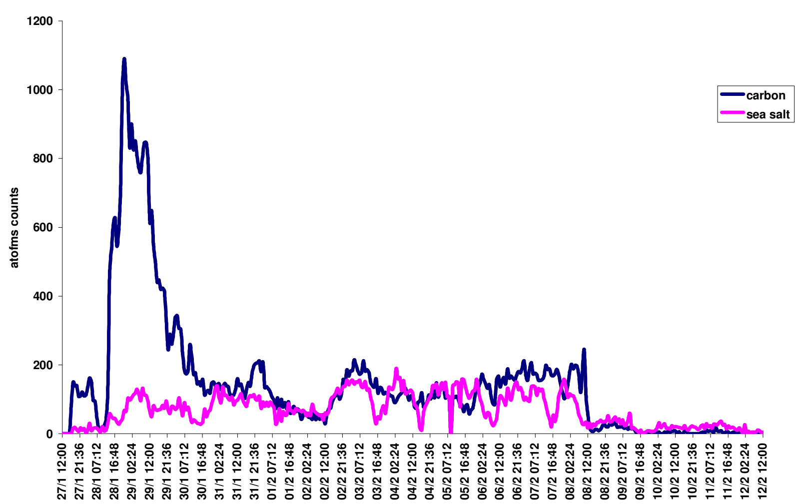
The temporal trends of all the particles detected with ATOFMS are shown below.



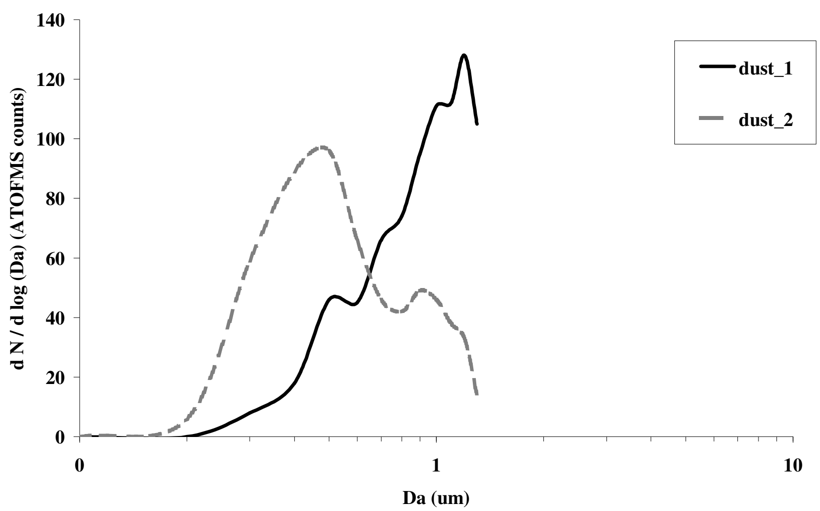
20 main types of particles were found. Some particles were due to anthropogenic sources (i.e. carbon rich particles) and some to natural sources (sea salt and dust).

The temporal trends and the size distributions of selected classes are shown as an example below. Whilst dust and sea salt present a coarse size distribution (>1 μm), carbon containing particles present a finer mode (<1 μm).





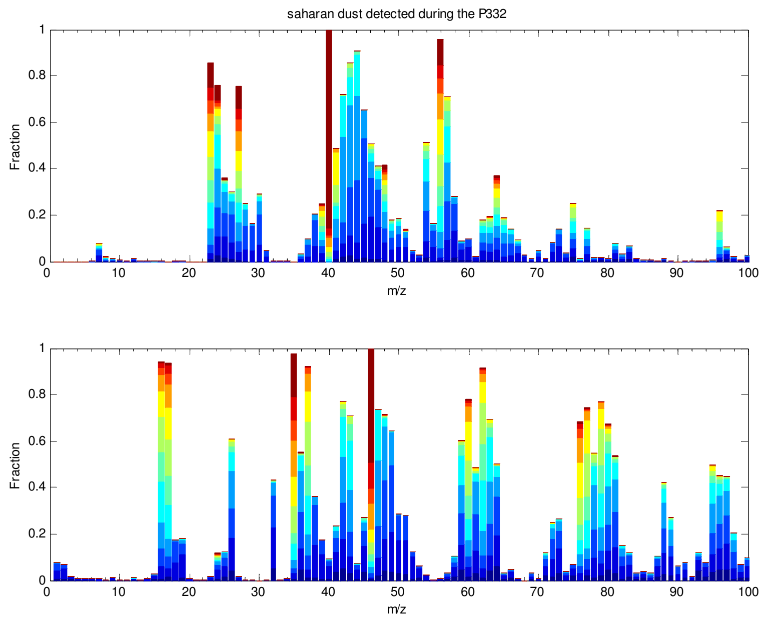
It is important to note that two types of dust particles were detected during the cruise P332.



Dust_1 was detected during a likely dust storm that occurred on the 4th of February. APS and SMPS showed dramatically different size distributions of airborne particles.
It is likely the ATOFMS saw only the end of the dust size distribution and these type of particles present size distribution peaking at a coarser mode (>3 µm).

Peaks due to sodium, aluminium, calcium and iron can be found in the positive spectra. In the negative spectra, strong peaks due to nitrate, phosphate and silicate can be seen.

Much more phosphate and silicate are found in this type of Saharan dust in comparison to the one detected at mace head (dall'osto 2004)



The second type of dust particles (dust_2) present a finer size distribution (see figure above) and it was detected during the stop in Mindelo (Cape Verde) on the 5th of February. The origin of this particle type is still unclear cause a full analysis have not been conducted yet. Wind speed and wind direction, along with 5-day air masses back trajectories need to be compared with the ATOFMS dataset in order to fully characterise the airborne particle sources.

Atmospheric Sampling on P332
Claire Powell, UEA

Introduction
In addition to the real time measurements of airborne particles carried out by Manuel Dall'Osto (see section ???) atmospheric sampling on P332 was carried out for aerosols and gases along the length of the cruise track. Aerosols, particulates suspended in the atmosphere ranging in size from 0.1 – 100 µm diameter, were sampled a high volume (1 m^3min^{-1}) sampler and a compact cascade impactor. Gas phase samples were taken using a vacuum pump with gas bottles. Rainwater was also collected at every opportunity to assess wet deposition.

Method

High Volume Sampler

In preparation for the cruise paper filters were washed in hydrochloric acid (HCl). For each sample two slotted filters were loaded into stages three and four of a six stage cascade impactor, along with a backup filter for fine mode aerosol (less than 1µm).

Filters were handled, loaded in to and removed from the cascade impactor whilst wearing gloves in a laminar flow hood situated in the ship's wet lab, which was dedicated to aerosol and gas sampling for the duration of the cruise, to prevent dust contamination. They were sealed in zip-loc bags for transportation to the sampler (located on the wheelhouse roof). After sampling the paper aerosol filters were folded in two and sealed in zip-loc bags. All filters were stored frozen in a -20ºC chest freezer for later analysis at UEA.

The samplers were fitted with a chart recorder for recording flow rate and duration and also have an analogue count which counts as long as the motor is running. A new chart was fitted at the beginning of each sampling period and the count recorded, time, date and position were also noted. Recording the number on the analogue count was done so that if a motor failed, there was a record of how long the sampler was active for (this is also replicated on the chart recorder).

On the 8th February the chart recording showed the flow rate varying by as much as 20%, indicating a problem with the motor of the sampler. Apparently the foam between the sampler opening and the motor had come loose, causing the flow rate to become erratic. The foam was adjusted and the motor worked fine, with small adjustments necessary for the rest of the cruise to ensure it was in place.

The sampler was calibrated to give a flow rate of 1 m^3min^{-1}. This was performed four times during the cruise, once at the start (26th Jan 2006, day 26) and once half way through (5th Feb, day 36) once at the end (22nd Feb, day 53) and once after the problems with the motor outlined above (9th Feb, day 40).

Rainwater

Rainwater was collected using two funnels, an acid washed funnel for trace metal analysis and a Decon-90 washed funnel for major ion analysis. Rain water bottles were also washed accordingly with trace metal bottles washed in a nitric acid solution and major ion bottles washed in Decon-90 and thoroughly rinsed with ultra-pure water. Trace metal bottles contained a weak (0.01M) nitric acid solution for storage and major ion bottles contained ultra-pure water for storage. Rain samples were frozen to be returned to UEA for analysis for major ions and trace metals.

Gas Samples

A total of 44 gas sampling bottles were provided by Jim McQuaid at Leeds University to sample gases via the sampling line that was set up in the wet lab. Gas was drawn into the bottles via a vacuum pump until the pressure leveled out (generally at about 3 bar). The frequency of the sampling was occasional due to the availability of the sampling line and the fact that most of the samples were saved for when the airplane flights were overhead. As a result only 22 bottles were sampled.

Compact Cascade Impactor

The compact cascade impactor (CCI) was originally to be deployed on the NERC aircraft. However, due to restrictions on the number of holes in the fuselage initial experiments were carried out on board.

Two experiments were carried out with the CCI: mass loading experiments and optical experiments. In both cases Poly Urethane Foam (PUF) substrates were loaded into the four stages of the impactor and connected to a vacuum pump with a flow rate of 30 lpm. Initially the system was also loaded with a backup filter, but it was found that this restricted the flow rate through the CCI too much so these were abandoned. In the case of mass loading experiments the CCI was left to run for 12-24 hours. For optical experiments times varied from 10 minutes to an hour, in addition PUF substrates were fitted with a smooth slide designed to catch a monolayer of dust.

The whole assembly was located on the wheelhouse roof, so samples should be comparable to the high volume samples. CCI samples were sent back to Gerard Capes at Manchester University for analysis.

Ammonium, dissolved organic carbon and nitrogen (DOC-DON), amino acids, heme, *nifh* genes and nitrogen fixation in the tropical and subtropical North Atlantic Ocean, Cape Verde Islands
Biological dust addition experiments
Chemical dust dissolution experiments
Eric P. Achterberg, National Oceanography Centre, Southampton, UK.

Introduction

My contribution towards the research activities on the cruise consisted of my role as Principal Scientist, assisting the researchers with their work, and undertaking ship-board measurements of ammonium. Furthermore, samples were collected and preserved for DOC-DON, amino acids, heme analyses in the laboratory at NOCS. Heme and amino acid analyses are to be undertaken by Dr Martha Gledhill. The measurements of nitrogen fixation were undertaken in the dust incubations and in water samples collected using the towed fish. Samples were collected for *nifh* genes (expression of ability to undertake nitrogen fixation) for subsequent analyses by Prof. Julie La Roche (IFM-GEOMAR, Kiel).

The suite of samples collected and subsequent analysed will provide detailed information on the various microbial processes occurring in the study region.

Materials and methods

Samples for ammonium, DOC-DON, heme and amino acids were taken from the Niskin bottles deployed on the stainless steel CTD rosette frame. Samples were taken on a nearly daily basis, and most of the CTD stations were covered. Samples for ammonium were collected and reagent added, with subsequent fluorimetric analysis 24 h later. The method by Kerouel, Aminot (1997) was followed, allowing nanomolar ammonium concentrations to be determined. Typically 6-8 depths were covered for a CTD cast.

Samples for DOC-DON analyses were filtered using pre-ashed GFF filters and a pre-ashed glass filtration apparatus. The filtrate was acidified to pH2 and sealed in glass ampoules for subsequent analysis using high temperature catalytic combustion (Shimadzu TOC5000-Antek) at NOCS (Badr et al., 2003). Typically 6-8 depths were covered for a CTD cast.

Samples for dissolved amino acids were filtered using 0.2 µm pore sized syringe filters. The filtrate was frozen in eppendorf vials (2.5 ml) for subsequent OPA HPLC analysis at NOCS. Typically 6-8 depths were covered for a CTD cast.

Samples for heme (Fe containing compounds) were filtered onto GFF filters (4 litres of water filtered) and the filters stored at -80ºC for subsequent HPLC analyses at NOCS. Typically 6 depths were covered for a CTD cast.

Samples for *nifh* genes were filtered using 0.2 µm filters on a stainless steel glass filtration apparatus. The filters were stored frozen at -80ºC in Eppendorf vials. Samples were processed from the dust incubation experiments. Also samples were filtered from underway station for nitrogen fixation. Analyses will be conducted at Kiel.

Nitrogen fixation measurements were undertaken in dust incubation experiments (see below) and in underway samples of ambient seawater. For the nitrogen fixation measurement, 4 ml of labeled 15-nitrogen gas was injected by syringe to 4 liter poly carbonate incubation bottles. In addition, 1 ml of a 13-carbonate solution was added (for production measurement). The bottles were incubated for 24 h in the incubators (at 20% of ambient light levels, and cooled with surface ocean water). Following the incubations, the samples were filtered on ashed GFF filters (Whatman). The filters were subsequently dried and stored in Eppendorf vials. The protocol was according to Mills et al. (2004). Analysis for 15N and 13C is to be undertaken at Stanford University by Dr Matt Mills.

Biological Incubation experiments

A series of 7 incubation experiments were conducted along the cruise transects. Table 1 provides dates and station positions for the experiments.

The incubation experiment consisted of additions of 2 mg/l of atmospheric dust (collected at Barbados, atmospherically processed) to incubation bottles filled with ambient surface seawater (collected using tow fish). In addition, controls were incubated, without the addition of dust. All treatments were undertaken in triplicate. Labeled N ($15N_2$) and C (13 carbonate) was added to bottles for nitrogen fixation and productivity measurements (at t=0 for ambient seawater samples followed by 24 incubation for productivity and nitrogen fixation, and t=24 for controls and dust added bottles for 24 hour incubation for productivity and nitrogen fixation). Bottles were incubated for a period of 48 h in incubators at 20% ambient light level and cooled with surface ocean sea water.

From the ambient seawater at t=0, and controls and dust added bottles, samples were collected for analyses of photophysiology, chlorophyll a, Fe, nutrients, flow cytometry, *nifh* genes.

The outcome of the experiments will become clear following laboratory analysis of the various variables, in particular nitrogen fixation.

Table 1.) The dates and positions of the seawater samples used in the biological incubation experiments.

Experiment	Date	Latitude	Longitude
I	29/01/06	22.8744	-25.3192
II	01/02/06	16.4827	-28.021
III	05/02/06	17.0954	-23.952
IV	10/02/06	15.3777	-25.3908
V	13/02/06	18.9878	-24.3961
VI	16/02/06	19.6998	-27.2261
VII	19/02/06	29.4613	-27.6069

Chemical Incubation experiment

On February 13 a chemical dust dissolution experiment was conducted using a 6 different dust types at different concentrations (0.01. 0.1, 2 and 5 mg/l).

Incubation periods used were 2 days and 7 days.

Samples were incubated separately for nutrients in 30 ml sterilins and metals in 125 ml LDPE bottles. Nutrient analyses were conducted at sea, whereas Fe analyses is to be conducted in the laboratory at NOCS.

Results

The results for the majority of the analyses will become available upon return to the UK. Ammonium measurements at sea were successful. The concentrations were typically low (<20 nM) with enhanced concentrations (ca. 60-80 nM) in the chlorophyll maximum as a result of bacterial breakdown of phytoplankton.

Acknowledgements

We want to thank the captain Schneider and crew of the Poseidon for support during the cruise. The researchers all did a great job and made this cruise a great success.

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Mills, M.; Ridame, C.; Davey, M.; La Roche, J.; Geider, R.J. *Nature* 2004, *429*, 292-294.

UKORS instrumentation

James Cooper, UKORS

CRUISE DETAILS

CRUISE ID	:	P332
SHIP	:	RV POSEIDON
CRUISE DATES	:	27TH JAN 2006 TO 23RD FEB 2006
SAILING FROM	:	LAS PALMAS
DEBARKATION	:	LAS PALMAS
PORT CALLS	:	CAPE VERDE (5TH FEB 2006)

SCIENTIFIC EQUIPMENT

Seabird CTD system

Seabird main tube	:	9Plus system rated to 6885m, Serial# 09P10108-410
Pressure sensor	:	Serial# 61184
Temperature sensor	:	Serial# 03P2120
Conductivity sensor	:	Serial# 041494 (Part# 90008.2)
Oxygen sensor	:	Serial# 0130398 (Part# 90142)
Pump	:	Serial# 051308 (Part#90160)

Chelsea Tech group Fast Repetition rate flourometer system (attached to CTD frame)

FRF	:	'Fast Tracka' Serial# 182041
Battery pack	:	Serial# 182042
Depth sensor	:	Serial# 1265903
PAR	:	Serial# 004673097

General Oceanics Metal free sampling system

Bottles x 3	:	10 litre 'Go-Flo' messenger triggered bottles

Challenger Oceanic systems Stand Alone Pumps

SAPs x 3	:	Magnetically coupled battery powered impeller pump system Serial# 02-004(Mk1), 002-02(Mk1) and 3-04(Mk2)

STATION LOG

28th JAN 2006 STATION #1
CAST #1 CTD TO APPROX 240M
CAST #2 TRACE METAL 'GO-FLO'

29TH JAN 2006 STATION #2
CAST #3 CTD TO APPROX 240M
CAST #4 TRACE METAL 'GO-FLO'
245M, 163M, 92M, 72M, 33M, 10M

30TH JAN 2006 STATION #3
CAST #5 CTD TO APPROX 240M
CAST #6 TRACE METAL 'GO-FLO'
233M, 150M*, 116M, 103M, 70M, 41M
*initial 150m sample bottle failed to close, repeat sample taken

31ST JAN 2006 STATION #4
CAST #7 CTD TO APPROX 240M
CAST #8 TRACE METAL 'GO-FLO'
233M, 182M, 119M, 67M, 42M, 23M
*Recovery of UKORS instrumentation buoy

1ST FEB 2006 STATION #5
CAST #9 CTD TO APPROX 240M
CAST #10 TRACE METAL 'GO-FLO'
296M, 176M, 68M, 57M, 44M, 21M
CAST #11 SAP
68M(27LITRES PUMPED), 44M(33LITRES PUMPED),
21M(1352LITRES PUMPED)*
* SAP filter later found to be fitted without o ring.

2ND FEB 2006 STATION #6
CAST #12 CTD TO APPROX 240M
CAST #13 TRACE METAL 'GO-FLO'
234M, 140M, 107M, 67M, 52M, 28M

3RD FEB 2006 STATION #7
CAST #14 CTD TO APPROX 240M
CAST #15 TRACE METAL 'GO-FLO'
239M, 113M, 57M, 48M, 32M, 22M
CAST #16 SAP
57M(17LITRES PUMPED), 32M(21LITRES PUMPED),
22M(3170LITRES PUMPED)*
* SAP filter later found to be fitted without o ring

4TH FEB 2006 STATION #8
CAST #17 CTD TO APPROX 240M
CAST #18 TRACE METAL 'GO-FLO'
239M, 193M, 133M, 72M, 53M, 37M
CAST #19 SAP
72M(NO FILTER FITTED AS TEST, SEVERAL THOUSAND LITRES PUMPED), 37M(12LITRES PUMPED), 20M(3LITRES PUMPED)

5TH FEB 2006 NO STATION
PORT CALL AT MINDELO, CAPE VERDE.

6TH FEB 2006 STATION #9
CAST #20 CTD TO APPROX 240M
CAST #21 TRACE METAL 'GO-FLO'
230M, 147M, 79M, 75M, 62M, 32M
CAST #22 SAP
62M(2424 LITRES PUMPED)* , 32M(17LITRES PUMPED),
20M(24LITRES PUMPED)
* SAP filter housing clamp not secured

7TH FEB 2006 STATION #10
CAST #23 CTD TO APPROX 240M
CAST #24 TRACE METAL 'GO-FLO'
233M, 159M, 131M, 102M, 50M, 31M

8TH FEB 2006 STATION #11
CAST #25 CTD TO APPROX 240M
CAST #26 TRACE METAL 'GO-FLO'
233M, 180M, 120M, 51M, 45M, 25M

9TH FEB 2006 STATION #12
CAST #27 CTD TO APPROX 240M
CAST #28 TRACE METAL 'GO-FLO'
220M, 172M, 115M, 94M, 69M, 38M
CAST #29 CTD TO APPROX 4000M
CAST #30 TRACE METAL 'GO-FLO'
900M, 800M, 600M, 400M, 300M, 250M

10TH FEB 2006 STATION #12
CAST #31 CTD TO APPROX 240M
CAST #32 TRACE METAL 'GO-FLO'
230M, 179M, 135M, 74M, 55M, 28M

Remote Stand Alone pump system tested in clean container with sea water fed from fish. Start time 1435, end time 1945, total pump time 5hours 10minutes. With a 1micron polycarbonate filter fitted the total water volume pumped during the test was 36litres.

11TH FEB 2006 STATION #14
CAST #33 CTD TO APPROX 240M
CAST #34 TRACE METAL 'GO-FLO'
230M, 175M, 119M, 53M, 24M, 18M

12TH FEB 2006 STATION #15
CAST #35 CTD TO APPROX 240M
CAST #35 TRACE METAL 'GO-FLO'
233M, 184M, 142M, 98M, 57M, 33M
98M 'Go-Flo' bottle damaged on recovery

13TH FEB 2006 STATION #16
CAST #37 CTD TO APPROX 240M
CAST #38 TRACE METAL 'GO-FLO'
232M, 180M, 110M, 71M,, 47M, 28M

14TH FEB 2006 NO STATION
ADVERSE WEATHER

15TH FEB 2006 STATION #17
CAST # 39 CTD TO APPROX 240M
CAST #40 TRACE METAL 'GO-FLO'
230M, 183M, 151M, 62M, 31M, 12M

16TH FEB 2006 NO STATION
ADVERSE WEATHER

17TH FEB 2006 STATION #18
CAST #41 CTD TO APPROX 240M
CAST #42 TRACE METAL 'GO-FLO'
231M, 184M, 138M, 117M, 82M, 50M

18TH FEB 2006 STATION #19
CAST #43 CTD TO APPROX 240M
CAST #44 TRACE METAL 'GO-FLO'
232M, 200M, 155M, 125M, 91M, 50M

19TH FEB 2006 STATION #20
CAST #45 CTD TO APPROX 240M*
CAST #46 TRACE METAL 'GO-FLO'
234M, 194M, 144M, 110M, 73M, 40M
CAST #47 CTD TO APPROX 1000M
CAST #48 TRACE METAL 'GO-FLO'
950M, 810M, 665M, 543M, 407M, 285M
*CTD deck computer failure midway though cast. Two files named CAST0045 and CAST0045A for this deployment.

20TH FEB 2006 STATION #21
CAST #49 CTD TO APPROX 240M
CAST #50 TRACE METAL 'GO-FLO'
233M, 169M, 145M, 115M, 81M, 36M

Appendices

Appendix 1. CTD stations, positions and times

date	station	cast	latitude	longitude	Time (UTC)	activities	notes
28/01	1	1	25.05 ºN	20.56 ºW	13:04	CTD	
28/01	1	2	25.05 ºN	20.56 ºW	14:03	GoFlo	
29/01	2	3	23.43 ºN	23.36 ºW	09:12	CTD	
29/01	2	4	23.43 ºN	23.36 ºW	10:03	GoFlo	
30/01	3	5	21.59 ºN	27.02 ºW	09:02	CTD	
30/01	3	6	21.59 ºN	27.02 ºW	10:00	GoFlo	
31/01			20.58 ºN	29.21 ºW	09:28		Recovery mooring buoy
31/01	4	7	20.58 ºN	29.22 ºW	10:09	CTD	
31/01	4	8	20.58 ºN	29.22 ºW	10:50	GoFlo	
01/02	5	9	17.39 ºN	28.21 ºW	09:00	CTD	
01/02	5	10	17.39 ºN	28.21 ºW	09:38	GoFlo	
01/02	5	11	17.40 ºN	28.22 ºW	11:31	SAPS	
02/02	6	12	14.51 ºN	27.33 ºW	09:00	CTD	
02/02	6	13	14.51 ºN	27.34 ºW	09:40	GoFlo	
03/02	7	14	11.59 ºN	25.59 ºW	09:00	CTD	
03/02	7	15	11.59 ºN	25.59 ºW	09:30	GoFlo	
03/02	7	16	12.00 ºN	26.00 ºW	10:56	SAPS	
04/02	8	17	15.24 ºN	25.22 ºW	14:02	CTD	
04/02	8	18	15.24 ºN	25.23 ºW	14:38	GoFlo	
04/02	8	19	15.24 ºN	25.23 ºW	15:37	SAPS	
05/02							Mindelo/reporter Guardian on board
06/02	9	20	17.21 ºN	22.22 ºW	09:01	CTD	
06/02	9	21	17.21 ºN	22.23 ºW	09:25	GoFlo	
06/02	9	22	17.22 ºN	22.23 ºW	11:11	SAPS	
06/02			17.21 ºN	22.23 ºW	~09:25	Rubber dingy	Microlayer samples
07/02	10	23	16.28 ºN	21.30 ºW	09:04	CTD	
07/02	10	24	16.28 ºN	21.30 ºW	09:33	GoFlo	
07/02	10		16.28 ºN	21.30 ºW	~09:33	Rubber dingy	Microlayer samples
08/02	11	25	16.44 ºN	22.32 ºW	09:00	CTD	
08/02	11	26	16.44 ºN	22.32 ºW	09:45	GoFlo	
08/02	11		16.44 ºN	22.32 ºW	~09:45	Rubber dingy	Microlayer samples
08/02	11						Sal/reporter Guardian of board
09/02	12	27	17.03 ºN	24.06 ºW	09:03	CTD	Shallow part
09/02	12	28	17.03 ºN	24.06 ºW	09:40	GoFlo	Shallow part
09/02	12	29	17.03 ºN	24.06 ºW	11:16	CTD	Deep part
09/02	12	30	17.03 ºN	24.06 ºW	14:31	GoFlo	Deep part
09/02	12		17.03 ºN	24.06 ºW	~11:16	Rubber dingy	Microlayer samples
10/02	13	31	14.49 ºN	25.29 ºW	09:01	CTD	
10/02	13	32	14.49 ºN	25.29 ºW	09:32	GoFlo	

Continued Appendix 1. CTD stations, positions and times.

date	station	cast	latitude	longitude	Time (UTC)	activities	notes
11/02	14	33	13.50 ºN	25.40 ºW	09:01	CTD	
11/02	14	34	13.50 ºN	25.40 ºW	09:40	GoFlo	
12/02	15	35	17.02 ºN	24.06 ºW	13:37	CTD	
12/02	15	36	17.02 ºN	24.05 ºW	14:12	GoFlo	
13/02	16	37	19.24 ºN	14.27 ºW	08:58	CTD	
13/02	16	38	19.23 ºN	14.27 ºW	09:47	GoFlo	
14/02							Rough weather
15/02	17	39	18.42 ºN	23.23 ºW	09:11	CTD	
15/02	17	40	18.41 ºN	23.23 ºW	09:53	GoFlo	
16/02							Rough weather
17/02	18	41	23.00 ºN	27.35 ºW	09:09	CTD	
17/02	18	42	23.00 ºN	27.35 ºW	09:36	GoFlo	
18/02	19	43	26.20 ºN	27.35 ºW	09:00	CTD	
18/02	19	44	26.20 ºN	27.35 ºW	09:40	GoFlo	
19/02	20	45	29.58 ºN	27.36 ºW	09:03	CTD	Shallow cast
19/02	20	46	29.58 ºN	27.36 ºW	09:49	GoFlo	Shallow cast
19/02	20	47	29.59 ºN	27.36 ºW	11:29	CTD	Deep cast
19/02	20	48	29.59 ºN	27.36 ºW	12:25	GoFlo	Deep cast
19/02					~12:25	Rubber dingy	Microlayer samples
20/02	21	49	29.38 ºN	24.23 ºW	09:01	CTD	
20/02	21	50	29.38 ºN	24.24 ºW	09:42	GoFlo	

Appendix 2. CTD and GoFlo samples

Samples were taken for a) Chlorophyll a, b) microbial community, c) nutrients, d) TDN, TDP and DOC, e) photosynthetic parameters, f) amino acids, g) hemes, h) pigments, i) dissolved Fe, j) dissolved Al

Date	Time (UTC)	CTD/ GoFlo	station	Cast	Decimal latitude	Decimal longitude	Depth (m)	Samples taken
28/01	13:14	CTD	1	1	25.0889	-20.9410	230	a,b,c,d,e,f,g
28/01	13:14	CTD	1	1	25.0889	-20.9410	153	a,b,c,d,e,f,g
28/01	13:14	CTD	1	1	25.0889	-20.9410	122	a,b,c,d,e,f,g
28/01	13:14	CTD	1	1	25.0889	-20.9410	113	a,b,c,d,e,f,g
28/01	13:14	CTD	1	1	25.0889	-20.9410	104	a,b,c,d,e,f,g
28/01	13:14	CTD	1	1	25.0889	-20.9410	84	a,b,c,d,e,f,g
28/01	13:14	CTD	1	1	25.0889	-20.9410	64	a,b,c,d,e,f,g
28/01	13:14	CTD	1	1	25.0889	-20.9410	43	a,b,c,d,e,f,g
28/01	13:14	CTD	1	1	25.0889	-20.9410	23	a,b,c,d,e,f,g
28/01	13:14	CTD	1	1	25.0889	-20.9410	13	a,b,c,d,e,f,g
28/01	14:03	GoFlo	1	2	25.0879	-20.9394	230	c,i,j
28/01	14:03	GoFlo	1	2	25.0879	-20.9394	122	c,i,j
28/01	14:03	GoFlo	1	2	25.0879	-20.9394	113	c,i,j
28/01	14:03	GoFlo	1	2	25.0879	-20.9394	64	c,i,j
28/01	14:03	GoFlo	1	2	25.0879	-20.9394	23	c,i,j
28/01	14:03	GoFlo	1	2	25.0879	-20.9394	13	c,i,j
29/01	09:12	CTD	2	3	23.7231	-23.6068	243	a,b,c,d,e,f,g
29/01	09:12	CTD	2	3	23.7231	-23.6068	205	a,b,c,d,e,f,g
29/01	09:12	CTD	2	3	23.7231	-23.6068	163	a,b,c,d,e,f,g
29/01	09:12	CTD	2	3	23.7231	-23.6068	111	a,b,c,d,e,f,g
29/01	09:12	CTD	2	3	23.7231	-23.6068	92	a,b,c,d,e,f,g
29/01	09:12	CTD	2	3	23.7231	-23.6068	72	a,b,c,d,e,f,g
29/01	09:12	CTD	2	3	23.7231	-23.6068	53	a,b,c,d,e,f,g
29/01	09:12	CTD	2	3	23.7231	-23.6068	33	a,b,c,d,e,f,g
29/01	10:03	GoFlo	2	4	23.7201	-23.6148	245	c,i,j
29/01	10:03	GoFlo	2	4	23.7201	-23.6148	163	c,i,j
29/01	10:03	GoFlo	2	4	23.7201	-23.6148	92	c,i,j
29/01	10:03	GoFlo	2	4	23.7201	-23.6148	72	c,i,j
29/01	10:03	GoFlo	2	4	23.7201	-23.6148	33	c,i,j
29/01	10:03	GoFlo	2	4	23.7201	-23.6148	10	c,i,j
30/01	09:02	CTD	3	5	21.9985	-27.0333	233	a,b,c,d,e,f,g
30/01	09:02	CTD	3	5	21.9985	-27.0333	184	a,b,c,d,e,f,g
30/01	09:02	CTD	3	5	21.9985	-27.0333	150	a,b,c,d,e,f,g
30/01	09:02	CTD	3	5	21.9985	-27.0333	116	a,b,c,d,e,f,g
30/01	09:02	CTD	3	5	21.9985	-27.0333	103	a,b,c,d,e,f,g
30/01	09:02	CTD	3	5	21.9985	-27.0333	70	a,b,c,d,e,f,g
30/01	09:02	CTD	3	5	21.9985	-27.0333	41	a,b,c,d,e,f,g
30/01	09:02	CTD	3	5	21.9985	-27.0333	3	a,b,c,d,e,f,g
30/01	10:00	GoFlo	3	6	22.0006	-27.0468	233	c,i,j

Continued Appendix 2. CTD and GoFlo samples

Date	Time (UTC)	CTD/ GoFlo	station	Cast	Decimal latitude	Decimal longitude	Depth (m)	Samples taken
30/01	10:00	GoFlo	3	6	22.0006	-27.0468	150	c,i,j
30/01	10:00	GoFlo	3	6	22.0006	-27.0468	116	c,i,j
30/01	10:00	GoFlo	3	6	22.0006	-27.0468	103	c,i,j
30/01	10:00	GoFlo	3	6	22.0006	-27.0468	70	c,i,j
30/01	10:00	GoFlo	3	6	22.0006	-27.0468	41	c,i,j
31/01	10:09	CTD	4	7	20.9779	-29.3661	233	a,b,c,d,e,f,g
31/01	10:09	CTD	4	7	20.9779	-29.3661	182	a,b,c,d,e,f,g
31/01	10:09	CTD	4	7	20.9779	-29.3661	119	a,b,c,d,e,f,g
31/01	10:09	CTD	4	7	20.9779	-29.3661	66.9	a,b,c,d,e,f,g
31/01	10:09	CTD	4	7	20.9779	-29.3661	67	a,b,c,d,e,f,g
31/01	10:09	CTD	4	7	20.9779	-29.3661	42	a,b,c,d,e,f,g
31/01	10:09	CTD	4	7	20.9779	-29.3661	23.9	a,b,c,d,e,f,g
31/01	10:09	CTD	4	7	20.9779	-29.3661	23.3	a,b,c,d,e,f,g
31/01	10:09	CTD	4	7	20.9779	-29.3661	2.7	a,b,c,d,e,f,g
31/01	10:50	GoFlo	4	8	20.9743	-29.3706	233	c,i,j
31/01	10:50	GoFlo	4	8	20.9743	-29.3706	182	c,i,j
31/01	10:50	GoFlo	4	8	20.9743	-29.3706	119	c,i,j
31/01	10:50	GoFlo	4	8	20.9743	-29.3706	67	c,i,j
31/01	10:50	GoFlo	4	8	20.9743	-29.3706	42	c,i,j
31/01	10:50	GoFlo	4	8	20.9743	-29.3706	23	c,i,j
01/02	09:00	CTD	5	9	17.6616	-28.3651	236	a,b,c,d,e,f,g
01/02	09:00	CTD	5	9	17.6616	-28.3651	176	a,b,c,d,e,f,g
01/02	09:00	CTD	5	9	17.6616	-28.3651	132	a,b,c,d,e,f,g
01/02	09:00	CTD	5	9	17.6616	-28.3651	68	a,b,c,d,e,f,g
01/02	09:00	CTD	5	9	17.6616	-28.3651	57	a,b,c,d,e,f,g
01/02	09:00	CTD	5	9	17.6616	-28.3651	44	a,b,c,d,e,f,g
01/02	09:00	CTD	5	9	17.6616	-28.3651	33	a,b,c,d,e,f,g
01/02	09:00	CTD	5	9	17.6616	-28.3651	21	a,b,c,d,e,f,g
01/02	09:00	CTD	5	9	17.6616	-28.3651	3	a,b,c,d,e,f,g
01/02	09:38	GoFlo	5	10	17.6603	-28.3632	296	c,i,j
01/02	09:38	GoFlo	5	10	17.6603	-28.3632	176	c,i,j
01/02	09:38	GoFlo	5	10	17.6603	-28.3632	68	c,i,j
01/02	09:38	GoFlo	5	10	17.6603	-28.3632	57	c,i,j
01/02	09:38	GoFlo	5	10	17.6603	-28.3632	44	c,i,j
01/02	09:38	GoFlo	5	10	17.6603	-28.3632	21	c,i,j
02/02	09:00	CTD	6	12	14.8565	-27.5630	234	a,b,c,d,e,f,g
02/02	09:00	CTD	6	12	14.8565	-27.5630	140	a,b,c,d,e,f,g
02/02	09:00	CTD	6	12	14.8565	-27.5630	107	a,b,c,d,e,f,g
02/02	09:00	CTD	6	12	14.8565	-27.5630	76	a,b,c,d,e,f,g
02/02	09:00	CTD	6	12	14.8565	-27.5630	67	a,b,c,d,e,f,g
02/02	09:00	CTD	6	12	14.8565	-27.5630	68	a,b,c,d,e,f,g
02/02	09:00	CTD	6	12	14.8565	-27.5630	52	a,b,c,d,e,f,g
02/02	09:00	CTD	6	12	14.8565	-27.5630	28	a,b,c,d,e,f,g
02/02	09:00	CTD	6	12	14.8565	-27.5630	4	a,b,c,d,e,f,g

Continued Appendix 2. CTD and GoFlo samples

Date	Time (UTC)	CTD/ GoFlo	station	Cast	Decimal latitude	Decimal longitude	Depth (m)	Samples taken
02/02	09:40	GoFlo	6	13	14.8608	-27.5698	234	c,i,j
02/02	09:40	GoFlo	6	13	14.8608	-27.5698	140	c,i,j
02/02	09:40	GoFlo	6	13	14.8608	-27.5698	107	c,i,j
02/02	09:40	GoFlo	6	13	14.8608	-27.5698	67	c,i,j
02/02	09:40	GoFlo	6	13	14.8608	-27.5698	52	c,i,j
02/02	09:40	GoFlo	6	13	14.8608	-27.5698	28	c,i,j
03/02	09:00	CTD	7	14	12.0000	-25.9985	239	a,b,c,d,e,f,g
03/02	09:00	CTD	7	14	12.0000	-25.9985	113	a,b,c,d,e,f,g
03/02	09:00	CTD	7	14	12.0000	-25.9985	57	a,b,c,d,e,f,g
03/02	09:00	CTD	7	14	12.0000	-25.9985	48	a,b,c,d,e,f,g
03/02	09:00	CTD	7	14	12.0000	-25.9985	33	a,b,c,d,e,f,g
03/02	09:00	CTD	7	14	12.0000	-25.9985	22	a,b,c,d,e,f,g
03/02	09:00	CTD	7	14	12.0000	-25.9985	3	a,b,c,d,e,f,g
03/02	09:30	GoFlo	7	15	11.9982	-25.9978	230	c,i,j
03/02	09:30	GoFlo	7	15	11.9982	-25.9978	113	c,i,j
03/02	09:30	GoFlo	7	15	11.9982	-25.9978	57	c,i,j
03/02	09:30	GoFlo	7	15	11.9982	-25.9978	48	c,i,j
03/02	09:30	GoFlo	7	15	11.9982	-25.9978	32	c,i,j
03/02	09:30	GoFlo	7	15	11.9982	-25.9978	22	c,i,j
03/02	09:30	GoFlo	7	15	11.9982	-25.9978	2	c,i,j
04/02	14:02	CTD	8	17	15.4042	-25.3823	239	a,b,c,d,e,f,g
04/02	14:02	CTD	8	17	15.4042	-25.3823	193	a,b,c,d,e,f,g
04/02	14:02	CTD	8	17	15.4042	-25.3823	133	a,b,c,d,e,f,g
04/02	14:02	CTD	8	17	15.4042	-25.3823	72	a,b,c,d,e,f,g
04/02	14:02	CTD	8	17	15.4042	-25.3823	52	a,b,c,d,e,f,g
04/02	14:02	CTD	8	17	15.4042	-25.3823	37	a,b,c,d,e,f,g
04/02	14:02	CTD	8	17	15.4042	-25.3823	12	a,b,c,d,e,f,g
04/02	14:38	GoFlo	8	18	15.4006	-25.3838	239	c,i,j
04/02	14:38	GoFlo	8	18	15.4006	-25.3838	193	c,i,j
04/02	14:38	GoFlo	8	18	15.4006	-25.3838	133	c,i,j
04/02	14:38	GoFlo	8	18	15.4006	-25.3838	72	c,i,j
04/02	14:38	GoFlo	8	18	15.4006	-25.3838	53	c,i,j
04/02	14:38	GoFlo	8	18	15.4006	-25.3838	33	c,i,j
06/02	09:01	CTD	9	20	17.3583	-22.3797	230	a,b,c,d,e,f,g
06/02	09:01	CTD	9	20	17.3583	-22.3797	147	a,b,c,d,e,f,g
06/02	09:01	CTD	9	20	17.3583	-22.3797	79	a,b,c,d,e,f,g
06/02	09:01	CTD	9	20	17.3583	-22.3797	75	a,b,c,d,e,f,g
06/02	09:01	CTD	9	20	17.3583	-22.3797	62	a,b,c,d,e,f,g
06/02	09:01	CTD	9	20	17.3583	-22.3797	32	a,b,c,d,e,f,g
06/02	09:01	CTD	9	20	17.3583	-22.3797	4	a,b,c,d,e,f,g
06/02	09:25	GoFlo	9	21	17.3575	-22.3854	230	c,i,j
06/02	09:25	GoFlo	9	21	17.3575	-22.3854	147	c,i,j
06/02	09:25	GoFlo	9	21	17.3575	-22.3854	79	c,i,j
06/02	09:25	GoFlo	9	21	17.3575	-22.3854	75	c,i,j

Continued Appendix 2. CTD and GoFlo samples

Date	Time (UTC)	CTD/ GoFlo	station	Cast	Decimal latitude	Decimal longitude	Depth (m)	Samples taken
06/02	09:25	GoFlo	9	21	17.3575	-22.3854	62	c,i,j
06/02	09:25	GoFlo	9	21	17.3575	-22.3854	32	c,i,j
07/02	09:04	CTD	10	23	16.4799	-21.5067	233	a,b,c,d,e,f,g
07/02	09:04	CTD	10	23	16.4799	-21.5067	158	a,b,c,d,e,f,g
07/02	09:04	CTD	10	23	16.4799	-21.5067	131	a,b,c,d,e,f,g
07/02	09:04	CTD	10	23	16.4799	-21.5067	102	a,b,c,d,e,f,g
07/02	09:04	CTD	10	23	16.4799	-21.5067	67	a,b,c,d,e,f,g
07/02	09:04	CTD	10	23	16.4799	-21.5067	57	a,b,c,d,e,f,g
07/02	09:04	CTD	10	23	16.4799	-21.5067	32	a,b,c,d,e,f,g
07/02	09:04	CTD	10	23	16.4799	-21.5067	4	a,b,c,d,e,f,g
07/02	09:33	GoFlo	10	24	16.4815	-21.5071	233	c,i,j
07/02	09:33	GoFlo	10	24	16.4815	-21.5071	159	c,i,j
07/02	09:33	GoFlo	10	24	16.4815	-21.5071	131	c,i,j
07/02	09:33	GoFlo	10	24	16.4815	-21.5071	102	c,i,j
07/02	09:33	GoFlo	10	24	16.4815	-21.5071	50	c,i,j
07/02	09:33	GoFlo	10	24	16.4815	-21.5071	31	c,i,j
08/02	09:00	CTD	11	25	16.7446	-22.5455	230	a,b,c,d,e,f,g
08/02	09:00	CTD	11	25	16.7446	-22.5455	181	a,b,c,d,e,f,g
08/02	09:00	CTD	11	25	16.7446	-22.5455	120	a,b,c,d,e,f,g
08/02	09:00	CTD	11	25	16.7446	-22.5455	81	a,b,c,d,e,f,g
08/02	09:00	CTD	11	25	16.7446	-22.5455	45	a,b,c,d,e,f,g
08/02	09:00	CTD	11	25	16.7446	-22.5455	25	a,b,c,d,e,f,g
08/02	09:00	CTD	11	25	16.7446	-22.5455	2	a,b,c,d,e,f,g
08/02	09:45	GoFlo	11	26	16.7445	-22.5482	233	c,i,j
08/02	09:45	GoFlo	11	26	16.7445	-22.5482	180	c,i,j
08/02	09:45	GoFlo	11	26	16.7445	-22.5482	120	c,i,j
08/02	09:45	GoFlo	11	26	16.7445	-22.5482	51	c,i,j
08/02	09:45	GoFlo	11	26	16.7445	-22.5482	45	c,i,j
08/02	09:45	GoFlo	11	26	16.7445	-22.5482	25	c,i,j
09/02	09:03	CTD	12	27	17.0499	-24.0994	230	a,b,c,d,e,f,g
09/02	09:03	CTD	12	27	17.0499	-24.0994	173	a,b,c,d,e,f,g
09/02	09:03	CTD	12	27	17.0499	-24.0994	114	a,b,c,d,e,f,g
09/02	09:03	CTD	12	27	17.0499	-24.0994	94	a,b,c,d,e,f,g
09/02	09:03	CTD	12	27	17.0499	-24.0994	69	a,b,c,d,e,f,g
09/02	09:03	CTD	12	27	17.0499	-24.0994	39	a,b,c,d,e,f,g
09/02	09:03	CTD	12	27	17.0499	-24.0994	2	a,b,c,d,e,f,g
09/02	09:40	GoFlo	12	28	17.0521	-24.0952	220	c,i,j
09/02	09:40	GoFlo	12	28	17.0521	-24.0952	172	c,i,j
09/02	09:40	GoFlo	12	28	17.0521	-24.0952	115	c,i,j
09/02	09:40	GoFlo	12	28	17.0521	-24.0952	94	c,i,j
09/02	09:40	GoFlo	12	28	17.0521	-24.0952	69	c,i,j
09/02	09:40	GoFlo	12	28	17.0521	-24.0952	38	c,i,j
09/02	11:16	CTD	12	29	17.0509	-24.0942	3374	a,b,c,d,g,h
09/02	11:16	CTD	12	29	17.0509	-24.0942	2951	a,b,c,d,g,h

Continued Appendix 2. CTD and GoFlo samples

Date	Time (UTC)	CTD/ GoFlo	station	Cast	Decimal latitude	Decimal longitude	Depth (m)	Samples taken
09/02	11:16	CTD	12	29	17.0509	-24.0942	2554	a,b,c,d,g,h
09/02	11:16	CTD	12	29	17.0509	-24.0942	2158	a,b,c,d,g,h
09/02	11:16	CTD	12	29	17.0509	-24.0942	1768	a,b,c,d,g,h
09/02	11:16	CTD	12	29	17.0509	-24.0942	1365	a,b,c,d,g,h
09/02	11:16	CTD	12	29	17.0509	-24.0942	976	a,b,c,d,g,h
09/02	11:16	CTD	12	29	17.0509	-24.0942	783	a,b,c,d,g,h
09/02	11:16	CTD	12	29	17.0509	-24.0942	589	a,b,c,d,g,h
09/02	11:16	CTD	12	29	17.0509	-24.0942	392	a,b,c,d,g,h
09/02	11:16	CTD	12	29	17.0509	-24.0942	230	a,b,c,d,g,h
09/02	14:31	GoFlo	12	30	17.0503	-24.1007	900	c,i,j
09/02	14:31	GoFlo	12	30	17.0503	-24.1007	800	c,i,j
09/02	14:31	GoFlo	12	30	17.0503	-24.1007	600	c,i,j
09/02	14:31	GoFlo	12	30	17.0503	-24.1007	400	c,i,j
09/02	14:31	GoFlo	12	30	17.0503	-24.1007	300	c,i,j
09/02	14:31	GoFlo	12	30	17.0503	-24.1007	250	c,i,j
10/02	09:01	CTD	13	31	14.8250	-25.4875	230	a,b,c,d,e,f,g
10/02	09:01	CTD	13	31	14.8250	-25.4875	179	a,b,c,d,e,f,g
10/02	09:01	CTD	13	31	14.8250	-25.4875	135	a,b,c,d,e,f,g
10/02	09:01	CTD	13	31	14.8250	-25.4875	99	a,b,c,d,e,f,g
10/02	09:01	CTD	13	31	14.8250	-25.4875	74	a,b,c,d,e,f,g
10/02	09:01	CTD	13	31	14.8250	-25.4875	55	a,b,c,d,e,f,g
10/02	09:01	CTD	13	31	14.8250	-25.4875	28	a,b,c,d,e,f,g
10/02	09:01	CTD	13	31	14.8250	-25.4875	3	a,b,c,d,e,f,g
10/02	09:32	GoFlo	13	32	14.8273	-25.4898	230	c,i,j
10/02	09:32	GoFlo	13	32	14.8273	-25.4898	179	c,i,j
10/02	09:32	GoFlo	13	32	14.8273	-25.4898	135	c,i,j
10/02	09:32	GoFlo	13	32	14.8273	-25.4898	74	c,i,j
10/02	09:32	GoFlo	13	32	14.8273	-25.4898	55	c,i,j
10/02	09:32	GoFlo	13	32	14.8273	-25.4898	28	c,i,j
11/02	09:01	CTD	14	33	13.8355	-25.6740	230	a,b,c,d,e,f,g
11/02	09:01	CTD	14	33	13.8355	-25.6740	175	a,b,c,d,e,f,g
11/02	09:01	CTD	14	33	13.8355	-25.6740	154	a,b,c,d,e,f,g
11/02	09:01	CTD	14	33	13.8355	-25.6740	119	a,b,c,d,e,f,g
11/02	09:01	CTD	14	33	13.8355	-25.6740	85	a,b,c,d,e,f,g
11/02	09:01	CTD	14	33	13.8355	-25.6740	54	a,b,c,d,e,f,g
11/02	09:01	CTD	14	33	13.8355	-25.6740	34	a,b,c,d,e,f,g
11/02	09:01	CTD	14	33	13.8355	-25.6740	24	a,b,c,d,e,f,g
11/02	09:01	CTD	14	33	13.8355	-25.6740	18	a,b,c,d,e,f,g
11/02	09:01	CTD	14	33	13.8355	-25.6740	4	a,b,c,d,e,f,g
11/02	09:40	GoFlo	14	34	13.8346	-25.6746	230	c,i,j
11/02	09:40	GoFlo	14	34	13.8346	-25.6746	175	c,i,j
11/02	09:40	GoFlo	14	34	13.8346	-25.6746	119	c,i,j
11/02	09:40	GoFlo	14	34	13.8346	-25.6746	53	c,i,j
11/02	09:40	GoFlo	14	34	13.8346	-25.6746	24	c,i,j

Continued Appendix 2. CTD and GoFlo samples

Date	Time (UTC)	CTD/ GoFlo	station	Cast	Decimal latitude	Decimal longitude	Depth (m)	Samples taken
11/02	09:40	GoFlo	14	34	13.8346	-25.6746	18	c,i,j
12/02	13:37	CTD	15	35	17.0500	-24.1012	231	a,b,c,d,e,f,g
12/02	13:37	CTD	15	35	17.0500	-24.1012	183	a,b,c,d,e,f,g
12/02	13:37	CTD	15	35	17.0500	-24.1012	172	a,b,c,d,e,f,g
12/02	13:37	CTD	15	35	17.0500	-24.1012	142	a,b,c,d,e,f,g
12/02	13:37	CTD	15	35	17.0500	-24.1012	112	a,b,c,d,e,f,g
12/02	13:37	CTD	15	35	17.0500	-24.1012	77	a,b,c,d,e,f,g
12/02	13:37	CTD	15	35	17.0500	-24.1012	58	a,b,c,d,e,f,g
12/02	13:37	CTD	15	35	17.0500	-24.1012	33	a,b,c,d,e,f,g
12/02	13:37	CTD	15	35	17.0500	-24.1012	3	a,b,c,d,e,f,g
12/02	14:12	GoFlo	15	36	17.0492	-24.0982	233	c,i,j
12/02	14:12	GoFlo	15	36	17.0492	-24.0982	184	c,i,j
12/02	14:12	GoFlo	15	36	17.0492	-24.0982	142	c,i,j
12/02	14:12	GoFlo	15	36	17.0492	-24.0982	78	c,i,j
12/02	14:12	GoFlo	15	36	17.0492	-24.0982	57	c,i,j
12/02	14:12	GoFlo	15	36	17.0492	-24.0982	33	c,i,j
13/02	08:58	CTD	16	37	19.4055	-24.4656	232	a,b,c,d,e,f,g
13/02	08:58	CTD	16	37	19.4055	-24.4656	179	a,b,c,d,e,f,g
13/02	08:58	CTD	16	37	19.4055	-24.4656	142	a,b,c,d,e,f,g
13/02	08:58	CTD	16	37	19.4055	-24.4656	110	a,b,c,d,e,f,g
13/02	08:58	CTD	16	37	19.4055	-24.4656	71	a,b,c,d,e,f,g
13/02	08:58	CTD	16	37	19.4055	-24.4656	46	a,b,c,d,e,f,g
13/02	08:58	CTD	16	37	19.4055	-24.4656	28	a,b,c,d,e,f,g
13/02	08:58	CTD	16	37	19.4055	-24.4656	7	a,b,c,d,e,f,g
13/02	09:37	GoFlo	16	38	19.3995	-24.4659	232	c,i,j
13/02	09:37	GoFlo	16	38	19.3995	-24.4659	180	c,i,j
13/02	09:37	GoFlo	16	38	19.3995	-24.4659	110	c,i,j
13/02	09:37	GoFlo	16	38	19.3995	-24.4659	71	c,i,j
13/02	09:37	GoFlo	16	38	19.3995	-24.4659	47	c,i,j
13/02	09:37	GoFlo	16	38	19.3995	-24.4659	28	c,i,j
15/02	09:11	CTD	17	39	18.7054	-24.3886	230	a,b,c,d,e,f,g
15/02	09:11	CTD	17	39	18.7054	-24.3886	183	a,b,c,d,e,f,g
15/02	09:11	CTD	17	39	18.7054	-24.3886	151	a,b,c,d,e,f,g
15/02	09:11	CTD	17	39	18.7054	-24.3886	129	a,b,c,d,e,f,g
15/02	09:11	CTD	17	39	18.7054	-24.3886	103	a,b,c,d,e,f,g
15/02	09:11	CTD	17	39	18.7054	-24.3886	63	a,b,c,d,e,f,g
15/02	09:11	CTD	17	39	18.7054	-24.3886	31	a,b,c,d,e,f,g
15/02	09:11	CTD	17	39	18.7054	-24.3886	12	a,b,c,d,e,f,g
15/02	09:53	GoFlo	17	40	18.6905	-24.3889	230	c,i,j
15/02	09:53	GoFlo	17	40	18.6905	-24.3889	183	c,i,j
15/02	09:53	GoFlo	17	40	18.6905	-24.3889	151	c,i,j
15/02	09:53	GoFlo	17	40	18.6905	-24.3889	62	c,i,j
15/02	09:53	GoFlo	17	40	18.6905	-24.3889	31	c,i,j
15/02	09:53	GoFlo	17	40	18.6905	-24.3889	12	c,i,j

Continued Appendix 2. CTD and GoFlo samples

Date	Time (UTC)	CTD/GoFlo	station	Cast	Decimal latitude	Decimal longitude	Depth (m)	Samples taken
17/02	09:09	CTD	18	41	23.0087	-27.5874	232	a,b,c,d,e,f,g
17/02	09:09	CTD	18	41	23.0087	-27.5874	182	a,b,c,d,e,f,g
17/02	09:09	CTD	18	41	23.0087	-27.5874	136	a,b,c,d,e,f,g
17/02	09:09	CTD	18	41	23.0087	-27.5874	117	a,b,c,d,e,f,g
17/02	09:09	CTD	18	41	23.0087	-27.5874	82	a,b,c,d,e,f,g
17/02	09:09	CTD	18	41	23.0087	-27.5874	51	a,b,c,d,e,f,g
17/02	09:09	CTD	18	41	23.0087	-27.5874	12	a,b,c,d,e,f,g
17/02	09:36	GoFlo	18	42	23.0086	-27.5864	231	c,i,j
17/02	09:36	GoFlo	18	42	23.0086	-27.5864	184	c,i,j
17/02	09:36	GoFlo	18	42	23.0086	-27.5864	138	c,i,j
17/02	09:36	GoFlo	18	42	23.0086	-27.5864	117	c,i,j
17/02	09:36	GoFlo	18	42	23.0086	-27.5864	81	c,i,j
17/02	09:36	GoFlo	18	42	23.0086	-27.5864	50	c,i,j
18/02	09:00	CTD	19	43	26.3426	-27.5951	232	a,b,c,d,e,f,g
18/02	09:00	CTD	19	43	26.3426	-27.5951	200	a,b,c,d,e,f,g
18/02	09:00	CTD	19	43	26.3426	-27.5951	175	a,b,c,d,e,f,g
18/02	09:00	CTD	19	43	26.3426	-27.5951	155	a,b,c,d,e,f,g
18/02	09:00	CTD	19	43	26.3426	-27.5951	125	a,b,c,d,e,f,g
18/02	09:00	CTD	19	43	26.3426	-27.5951	91	a,b,c,d,e,f,g
18/02	09:00	CTD	19	43	26.3426	-27.5951	50	a,b,c,d,e,f,g
18/02	09:00	CTD	19	43	26.3426	-27.5951	2	a,b,c,d,e,f,g
18/02	09:44	GoFlo	19	44	26.3463	-27.5975	232	c,i,j
18/02	09:44	GoFlo	19	44	26.3463	-27.5975	200	c,i,j
18/02	09:44	GoFlo	19	44	26.3463	-27.5975	155	c,i,j
18/02	09:44	GoFlo	19	44	26.3463	-27.5975	125	c,i,j
18/02	09:44	GoFlo	19	44	26.3463	-27.5975	91	c,i,j
18/02	09:44	GoFlo	19	44	26.3463	-27.5975	50	c,i,j
19/02	09:03	CTD	20	45	29.9700	-27.6039	144	a,b,c,d,e,f,g
19/02	09:03	CTD	20	45	29.9700	-27.6039	110	a,b,c,d,e,f,g
19/02	09:03	CTD	20	45	29.9700	-27.6039	73	a,b,c,d,e,f,g
19/02	09:03	CTD	20	45	29.9700	-27.6039	40	a,b,c,d,e,f,g
19/02	09:03	CTD	20	45	29.9700	-27.6039	10	a,b,c,d,e,f,g
19/02	09:03	CTD	20	45	29.9700	-27.6039	3	a,b,c,d,e,f,g
19/02	09:49	GoFlo	20	46	29.9705	-27.6066	234	c,i,j
19/02	09:49	GoFlo	20	46	29.9705	-27.6066	194	c,i,j
19/02	09:49	GoFlo	20	46	29.9705	-27.6066	144	c,i,j
19/02	09:49	GoFlo	20	46	29.9705	-27.6066	110	c,i,j
19/02	09:49	GoFlo	20	46	29.9705	-27.6066	73	c,i,j
19/02	09:49	GoFlo	20	46	29.9705	-27.6066	40	c,i,j
19/02	11:29	CTD	20	47	29.9937	-27.6158	952	a,b,c,d,g,h
19/02	11:29	CTD	20	47	29.9937	-27.6158	875	a,b,c,d,g,h
19/02	11:29	CTD	20	47	29.9937	-27.6158	802	a,b,c,d,g,h
19/02	11:29	CTD	20	47	29.9937	-27.6158	726	a,b,c,d,g,h
19/02	11:29	CTD	20	47	29.9937	-27.6158	660	a,b,c,d,g,h

Continued Appendix 2. CTD and GoFlo samples

Date	Time (UTC)	CTD/GoFlo	station	Cast	Decimal latitude	Decimal longitude	Depth (m)	Samples taken
19/02	11:29	CTD	20	47	29.9937	-27.6158	600	a,b,c,d,g,h
19/02	11:29	CTD	20	47	29.9937	-27.6158	538	a,b,c,d,g,h
19/02	11:29	CTD	20	47	29.9937	-27.6158	470	a,b,c,d,g,h
19/02	11:29	CTD	20	47	29.9937	-27.6158	403	a,b,c,d,g,h
19/02	11:29	CTD	20	47	29.9937	-27.6158	342	a,b,c,d,g,h
19/02	11:29	CTD	20	47	29.9937	-27.6158	283	a,b,c,d,g,h
19/02	11:29	CTD	20	47	29.9937	-27.6158	233	a,b,c,d,g,h
19/02	12:25	GoFlo	20	48	29.9937	-27.6157	950	c,i,j
19/02	12:25	GoFlo	20	48	29.9937	-27.6157	810	c,i,j
19/02	12:25	GoFlo	20	48	29.9937	-27.6157	665	c,i,j
19/02	12:25	GoFlo	20	48	29.9937	-27.6157	543	c,i,j
19/02	12:25	GoFlo	20	48	29.9937	-27.6157	407	c,i,j
19/02	12:25	GoFlo	20	48	29.9937	-27.6157	285	c,i,j
20/02	09:01	CTD	21	49	29.6442	-24.3935	231	a,b,c,d,e,f,g
20/02	09:01	CTD	21	49	29.6442	-24.3935	196	a,b,c,d,e,f,g
20/02	09:01	CTD	21	49	29.6442	-24.3935	158	a,b,c,d,e,f,g
20/02	09:01	CTD	21	49	29.6442	-24.3935	144	a,b,c,d,e,f,g
20/02	09:01	CTD	21	49	29.6442	-24.3935	115	a,b,c,d,e,f,g
20/02	09:01	CTD	21	49	29.6442	-24.3935	81	a,b,c,d,e,f,g
20/02	09:01	CTD	21	49	29.6442	-24.3935	36	a,b,c,d,e,f,g
20/02	09:01	CTD	21	49	29.6442	-24.3935	5	a,b,c,d,e,f,g
20/02	09:42	GoFlo	21	50	29.6427	-24.4020	233	c,i,j
20/02	09:42	GoFlo	21	50	29.6427	-24.4020	169	c,i,j
20/02	09:42	GoFlo	21	50	29.6427	-24.4020	145	c,i,j
20/02	09:42	GoFlo	21	50	29.6427	-24.4020	115	c,i,j
20/02	09:42	GoFlo	21	50	29.6427	-24.4020	81	c,i,j
20/02	09:42	GoFlo	21	50	29.6427	-24.4020	36	c,i,j

Appendix 3. Underway samples

Samples were taken for a) Chlorophyll a, b) microbial community, c) dissolved Al, d) nutrients (uM), e) nutrients (nM), f) dissolved Fe, g) organic Fe-binding ligands, h) pigments

Date	Time (UTC)	Decimal latitude (ºN)	Decimal longitude (ºW)	Sample ID	Samples taken
29/01	15:45	23.4091	-24.2682	1	a,b,c,d,e,f
29/01	20:05	23.0515	-24.9779	2	a,b,c,d,e,f,h
30/01	01:00	22.6441	-25.7667	3	a,b,c,d,e,f
30/01	06:10	22.2180	-26.6049	4	a,b,c,d,e,f
30/01	09:00	21.9991	-27.0327	5	a,b,c,d,e,f
30/01	14:00	21.8589	-27.3556	6	a,b,c,d,e,f
30/01	18:35	21.6145	-27.8281	7	a,b,c,d,e,f
30/01	22:00	21.4362	-18.1744	8	a,b,c,d,e,f,h
31/01	00:00	21.3342	-28.3856	8A	a,b,c,d,e,f,h
31/01	06:00	21.0295	-29.0107	9	a,b,c,d,e,f
31/01	12:30	20.8984	-29.2870	10	a,b,c,d,e,f
31/01	14:10	20.6475	-29.2158	11	a,b,c,d,e,f
31/01	19:15	19.8358	-28.9997	12	a,b,c,d,e,f
31/01	22:00	19.4042	-28.8730	13	a,b,c,d,e,f,h
01/02	00:12	19.0509	-28.7759	14	a,b,c,d,e,f
01/02	06:00	18.1167	-28.5050	15	a,b,c,d,e,f
01/02	08:50	17.6632	-28.3694	16	a,b,c,d,e,f
01/02	14:50	17.6516	-28.3781	17	a,b,c,d,e,f
01/02	18:30	17.0734	-28.1965	18	a,b,c,d,e,f
01/02	23:15	16.3221	-27.9738	18A	a,b,c,d,e,f,h
02/02	06:00	15.2881	-27.6747	19	a,b,c,d,e,f
02/02	08:40	14.8776	-27.5731	20	a,b,c,d,e,f
02/02	14:10	14.4068	-27.4374	21	a,b,c,d,e,f
02/02	16:15	14.0870	-27.3299	22	a,b,c,d,e,f
02/02	18:30	13.7378	-27.2132	23	a,b,c,d,e,f
02/02	20:05	13.4883	-27.1278	24	a,b,c,d,e,f
02/02	22:00	13.1835	-27.0365	25	a,b,c,d,e,f
03/02	00:00	12.9094	-26.9093	25A	a,b,c,d,e,f
03/02	06:20	12.2398	-26.2497	26	a,b,c,d,e,f
03/02	08:15	12.0552	-26.0455	27	a,b,c,d,e,f
03/02	08:55	12.0003	-25.9987	28	a,b,c,d,e,f,g
03/02	14:30	12.0949	-25.9840	29	a,b,c,d,e,f
03/02	16:20	12.3459	-25.9352	30	a,b,c,d,e,f,h
03/02	18:05	12.5846	-25.8906	31	a,b,c,d,e,f
03/02	20:00	12.8481	-25.8434	32	a,b,c,d,e,f
03/02	22:05	13.1426	-25.7948	33	a,b,c,d,e,f,g,h
03/02	23:50	13.3885	-25.7483	34	a,b,c,d,e,f
04/02	06:00	14.2410	-25.5987	35	a,b,c,d,e,f
04/02	08:30	14.6117	-25.5410	36	a,b,c,d,e,f
04/02	10:00	14.8269	-25.4867	37	a,b,c,d,e,f,g,h
04/02	12:00	15.1232	-25.4327	38	a,b,c,d,e,f
04/02	13:40	15.3680	-25.3902	39	a,b,c,d,e,f
04/02	19:00	15.4678	-25.3729	40	a,b,c,d,e,f,h
04/02	20:00	15.6125	-25.3423	41	a,b,c,d,e,f

Continued Appendix 3. Underway samples

Date	Time (UTC)	Decimal latitude (ºN)	Decimal longitude (ºW)	Sample ID	Samples taken
04/02	22:00	15.8829	-25.2932	42	a,b,c,d,e,f,g
04/02	23:55	16.1167	-25.2507	43	a,b,c,d,e,f,h
05/02	17:00	16.9692	-24.7501	44	a,b,c,d,e,f,h
05/02	18:30	16.9977	-25.5301	45	a,b,c,d,e,f
05/02	20:00	17.0404	-24.3084	46	a,b,c,d,e,f,g
06/02	06:00	17.2851	-22.8075	47	a,b,c,d,e,f,h
06/02	08:30	17.3472	-22.4371	48	a,b,c,d,e,f,g
06/02	16:00	17.3988	-22.2303	49	a,b,c,d,e,f,h
06/02	18:20	17.4251	-21.9866	50	a,b,c,d,e,f
06/02	20:05	17.4519	-21.8003	51	a,b,c,d,e,f
06/02	22:00	17.4861	-21.5900	52	a,b,c,d,e,f,g,h
07/02	00:00	17.3882	-21.5003	53	a,b,c,d,e,f
07/02	06:05	16.7715	-21.5017	54	a,b,c,d,e,f,h
07/02	08:20	16.5359	-21.5078	55	a,b,c,d,e,f,g
07/02	12:15	16.2666	-21.5038	56	a,b,c,d,e,f
07/02	14:00	15.9771	-21.4950	57	a,b,c,d,e,f
07/02	15:45	15.7286	-21.4962	58	a,b,c,d,e,f,h
07/02	18:10	15.3759	-21.5082	59	a,b,c,d,e,f
07/02	20:00	15.1681	-21.5169	60	a,b,c,d,e,f
07/02	22:00	15.4113	-21.6756	61	a,b,c,d,e,f,g
08/02	00:00	15.6546	-21.8339	62	a,b,c,d,e,f
08/02	06:05	16.3963	-22.3154	63	a,b,c,d,e,f,h
08/02	08:30	16.6753	-22.4997	64	a,b,c,d,e,f,g
08/02	12:20	16.8402	-22.6993	65	a,b,c,d,e,f
08/02	14:00	16.9063	-22.8642	66	a,b,c,d,e,f
08/02	15:50	16.8599	-23.0451	67	a,b,c,d,e,f,h
08/02	20:00	16.7926	-23.1526	68	a,b,c,d,e,f
08/02	21:55	16.8458	-23.3465	69	a,b,c,d,e,f,g,h
09/02	00:00	16.9042	-23.5639	70	a,b,c,d,e,f
09/02	06:00	17.0542	-24.1569	71	a,b,c,d,e,f,h
09/02	08:30	17.0376	-24.0863	72	a,b,c,d,e,f,g
09/02	18:15	16.6743	-23.9832	73	a,b,c,d,e,f
09/02	20:00	16.4436	-24.1010	74	a,b,c,d,e,f
09/02	22:00	16.2220	-24.3736	75	a,b,c,d,e,f,g,h
10/02	00:00	15.9971	-24.6506	76	a,b,c,d,e,f
10/02	08:00	14.9596	-25.4654	77	a,b,c,d,e,f,g
10/02	12:15	14.5617	-25.5389	78	a,b,c,d,e,f
10/02	13:50	14.3117	-25.5797	79	a,b,c,d,e,f
10/02	16:10	13.9338	-25.6504	80	a,b,c,d,e,f
10/02	18:20	13.5832	-25.7083	81	a,b,c,d,e,f
10/02	20:15	13.2663	-25.7761	82	a,b,c,d,e,f
10/02	22:05	12.9546	-25.8271	83	a,b,c,d,e,f,h
10/02	23:45	12.6578	-25.8821	84	a,b,c,d,e,f,g
11/02	06:00	13.4024	-25.7420	85	a,b,c,d,e,f,h
11/02	08:15	13.7500	-25.6825	86	a,b,c,d,e,f
11/02	08:45	13.8273	-25.6711	87	a,b,c,d,e,f,g
11/02	12:20	14.1332	-25.6143	88	a,b,c,d,e,f
11/02	14:00	14.2754	-25.5703	89	a,b,c,d,e,f
11/02	16:35	14.7496	-25.4989	90	a,b,c,d,e,f,h

Continued Appendix 3. Underway samples

Date	Time (UTC)	Decimal latitude (ºN)	Decimal longitude (ºW)	Sample ID	Samples taken
11/02	18:00	14.9630	-25.4581	91	a,b,c,d,e,f
11/02	20:10	15.2930	-25.4062	92	a,b,c,d,e,f
11/02	22:00	15.5691	-25.3546	93	a,b,c,d,e,f,g,h
12/02	00:00	15.8712	-25.2986	94	a,b,c,d,e,f
12/02	06:10	16.7950	-25.1300	95	a,b,c,d,e,f,h
12/02	08:10	16.9768	-24.9194	96	a,b,c,d,e,f
12/02	10:00	17.0006	-24.6454	97	a,b,c,d,e,f,g
12/02	12:00	17.0282	-24.3381	98	a,b,c,d,e,f
12/02	13:20	17.0469	-24.1331	99	a,b,c,d,e,f
12/02	14:00	17.0495	-24.0991	100	a,b,c,d,e,f,h
12/02	18:25	17.5094	-24.1668	101	a,b,c,d,e,f
12/02	19:55	17.7266	-24.2029	102	a,b,c,d,e,f
12/02	22:00	18.0229	-24.2472	103	a,b,c,d,e,f,h
12/02	23:55	18.2831	-24.2870	104	a,b,c,d,e,f,g
13/02	06:00	19.0565	-24.4057	105	a,b,c,d,e,f
13/02	08:50	19.4124	-24.2658	106	a,b,c,d,e,f,g
13/02	12:10	19.6249	-24.4854	107	a,b,c,d,e,f
13/02	14:35	19.5744	-24.2512	108	a,b,c,d,e,f
13/02	17:00	19.4202	-23.9305	109	a,b,c,d,e,f,h
13/02	18:50	19.3794	-23.7401	110	a,b,c,d,e,f
13/02	20:00	19.3293	-23.6339	111	a,b,c,d,e,f
13/02	22:00	19.2152	-23.4305	112	a,b,c,d,e,f,g,h
13/02	23:45	19.1551	-23.2697	113	a,b,c,d,e,f
14/02	06:35	19.3817	-22.8780	114	a,b,c,d,e,f,h
14/02	08:10	19.5292	-22.8454	115	a,b,c,d,e,f,g
14/02	10:00	19.5654	-22.8058	116	a,b,c,d,e,f
14/02	12:00	19.2644	-22.7468	117	a,b,c,d,e,f
14/02	14:05	18.9555	-22.6934	118	a,b,c,d,e,f
14/02	16:35	18.5860	-22.6238	119	a,b,c,d,e,f,h
14/02	18:10	18.3465	-22.5854	120	a,b,c,d,e,f
14/02	19:55	18.0888	-22.5365	121	a,b,c,d,e,f
14/02	22:00	18.1853	-22.8157	122	a,b,c,d,e,f,g,h
15/02	00:00	18.2875	-23.1069	123	a,b,c,d,e,f
15/02	06:15	18.5997	-24.0020	123A	a,b,c,d,e,f,h
15/02	08:30	18.7083	-24.3349	124	a,b,c,d,e,f,g
15/02	12:10	18.7917	-24.6117	125	a,b,c,d,e,f
15/02	15:00	18.9410	-25.0317	126	a,b,c,d,e,f
15/02	15:45	18.9829	-25.1437	127	a,b,c,d,e,f,h
15/02	18:25	19.1110	-255370	128	a,b,c,d,e,f
15/02	20:00	19.1981	-25.7786	129	a,b,c,d,e,f
15/02	22:00	19.3091	-26.0782	130	a,b,c,d,e,f,g,h
15/02	23:50	19.4016	-26.3536	131	a,b,c,d,e,f
16/02	08:45	19.8935	-27.5986	132	a,b,c,d,e,f,g
16/02	10:00	20.0397	-27.5984	133	a,b,c,d,e,f
16/02	12:15	20.3167	-27.5985	134	a,b,c,d,e,f
16/02	14:15	20.5685	-27.6010	135	a,b,c,d,e,f
16/02	16:10	20.8084	-27.5996	136	a,b,c,d,e,f,h
16/02	18:00	21.0366	-27.5925	137	a,b,c,d,e,f
16/02	20:00	21.2957	-27.6000	138	a,b,c,d,e,f

Continued Appendix 3. Underway samples

Date	Time (UTC)	Decimal latitude (ºN)	Decimal longitude (ºW)	Sample ID	Samples taken
16/02	22:00	21.5532	-27.5988	139	a,b,c,d,e,f,g,h
16/02	23:50	21.7951	-27.5983	140	a,b,c,d,e,f
17/02	06:15	22.6571	-27.5969	141	a,b,c,d,e,f,h
17/02	08:30	22.9586	-27.5969	142	a,b,c,d,e,f,g
17/02	12:15	23.2526	-27.5952	143	a,b,c,d,e,f
17/02	14:00	23.5125	-27.6022	144	a,b,c,d,e,f
17/02	16:15	23.8427	-27.5965	145	a,b,c,d,e,f,h
17/02	18:10	24.1292	-27.5925	146	a,b,c,d,e,f
17/02	20:10	24.4312	-27.5865	147	a,b,c,d,e,f
17/02	21:45	24.6744	-27.5926	148	a,b,c,d,e,f,h
17/02	23:50	24.9973	-27.5987	149	a,b,c,d,e,f
18/02	06:15	25.9959	-27.6003	150	a,b,c,d,e,f,h
18/02	08:50	26.3341	-27.5989	151	a,b,c,d,e,f,g
18/02	12:10	26.5886	-27.5981	152	a,b,c,d,e,f
18/02	13:50	26.8473	-27.5863	153	a,b,c,d,e,f
18/02	15:50	27.1654	-27.5971	154	a,b,c,d,e,f,h
18/02	18:30	27.5978	-27.5909	155	a,b,c,d,e,f
18/02	20:00	27.8474	-27.5877	156	a,b,c,d,e,f
18/02	21:50	28.1643	-27.5885	157	a,b,c,d,e,f,g,h
18/02	23:50	28.4802	-27.5993	158	a,b,c,d,e,f
19/02	08:40	29.9361	-27.6130	159	a,b,c,d,e,f,g
19/02	16:00	29.9503	-27.2862	160	a,b,c,d,e,f,h
19/02	18:40	29.9056	-26.8388	161	a,b,c,d,e,f
19/02	20:10	29.8764	-26.5783	162	a,b,c,d,e,f
19/02	21:40	29.8509	-26.3231	163	a,b,c,d,e,f,g,h
20/02	00:00	29.8095	-25.9218	164	a,b,c,d,e,f
20/02	06:10	29.6946	-24.8413	165	a,b,c,d,e,f,h
20/02	08:40	29.6473	-24.4205	166	a,b,c,d,e,f,g
20/02	12:10	29.6484	-24.2840	167	a,b,c,d,e,f
20/02	15:10	29.5828	-23.8712	168	a,b,c,d,e,f
20/02	16:10	29.5667	-23.7332	169	a,b,c,d,e,f,h
20/02	18:30	29.5315	-23.4042	170	a,b,c,d,e,f
20/02	20:10	29.5034	-23.2559	171	a,b,c,d,e,f
20/02	22:00	29.4753	-22.8869	172	a,b,c,d,e,f,h
20/02	23:50	29.4432	-22.6183	173	a,b,c,d,e,f
21/02	06:20	29.3309	-21.6240	174	a,b,c,d,e,f,h
21/02	08:15	29.3008	-21.3348	175	a,b,c,d,e,f

Appendix 4. The article as published by James Randerson in the Guardian

Floating lab tracks Sahara sandstorms' effect on ecosystem

UK oceanographers are trying to find out how dust and oceans interact

James Randerson in Cape Verde Islands
Monday February 13, 2006
The Guardian

Eric Achterberg calmly retrieves the two large plastic bottles that have just fallen off the table and careered towards him across the lab. He staggers back to his seat, avoiding a chair that is now sliding in the other direction.

"Where were we?" he says. The risk of injury from objects flung around by the ocean swell makes it difficult to concentrate on his answers.

Dr Achterberg and his team from the National Oceanography Centre (NOC) in Southampton have given the Guardian exclusive access to a leading research project. They are trying to plug a hole in the understanding of climate change - how dust in the atmosphere affects the climate and oceans.

"There's a complete lack of data," says Dr Achterberg. What they find out will help scientists predict global warming patterns more accurately. The research vessel Poseidon, which is on loan from Kiel University in Germany, and the nine scientists on board, are dust-hunting in the eastern Atlantic Ocean between the coast of Senegal and the Cape Verde Islands. This is where gigantic dust clouds from the Sahara embark on a 5,000-mile journey across the Atlantic to South America. On the way they act as atmospheric sunscreen and fertilise the ocean.

Both effects should mitigate climate change, by bouncing heat back into space and by stimulating the growth of algae which, when they die, carry carbon to the sea floor. Charles Darwin commented on the quantities of dust he encountered. "The falling of impalpably fine dust," he wrote in The Voyage of the Beagle, "was found to have slightly injured the astronomical instruments".

The dust is also responsible for the spectacular Cape Verde sunsets. What is special about the British expedition is that it will look at the sunscreen and fertiliser effects simultaneously, something that has never been done before. The £600,000 project, which is funded by the Natural Environment Research Council, a government research body, involves coordinating samples taken at sea with measurements done from a plane.

Science at sea is notoriously difficult. Dr Achterberg admits that little work was done in the first two days of the cruise. "I was only out of bed for two hours on the first day," said Polly Hill, a research student at NOC. The German captain uses oompah music to keep him awake on his late shift on the bridge and the chef serves sausage at breakfast, lunch and dinner.

Problems

There are many practical problems. To work out the effect of the dust on the plankton, the scientists need precise measurements of elements such as iron and aluminium in the air and water. A change of wind that brings the smoke from the ship's funnel into the air filter can wipe out an afternoon's results.

Water samples, too, must be timed to avoid the daily discharge of the ship's sewerage system. The dust clouds we are following are essential to the food chain in oceans. Even at the surface, where light is plentiful, around a third of the ocean is a virtual desert. Plankton cannot operate because they lack essential nutrients. The rust-coloured Saharan dust provides these and so kick-starts the ecosystem. "For many parts of the ocean, dust is the main nutrient source," said Dr Achterberg.

So will global warming increase or decrease the quantity of dust in the atmosphere? At the moment the Sahara desert is growing, and so more of the ochre red fertiliser is being pumped into the African sky, but this may not continue.

"The world heating up means more moisture in the atmosphere, so it doesn't necessarily mean the Sahara getting bigger and drier," says Phil Williamson, a biological oceanographer at the University of East Anglia who is also involved in the project.

Which way it will go is still being argued over by climate modellers, but the science of what dust does to the ocean is still in its infancy. "The big question is to try to quantify the effects of dust on the whole system," says Micha Rijkenberg, who studies ocean chemistry at NOC and is also on the cruise.

Hurricane researchers will also eye the data from Poseidon with interest. It is this region where hurricanes like the one that hit New Orleans form. By affecting the sea surface temperature, dust may have a hand in this too.

Dust storms are common over the driest regions of the Earth. The bigger particles of soil or sand whipped up into the atmosphere by wind eventually return to Earth but the tiniest particles stay airborne for much longer, and can be swept thousands of kilometres downwind. Dust storms in the Sahara desert regularly end up on the other side of the Atlantic Ocean.

These clouds of dust have all sorts of influences on weather and climate. They block sunlight, thereby cooling the Earth's surface, but they also absorb the sun's heat, causing the atmosphere to warm up. According to researchers at Nasa, temperatures under a dust cloud are typically 1C cooler than normal, similar to the effect of a rain cloud.

In summer, the deserts surrounding the Arabian Sea are the main source of dust clouds in the northern hemisphere. The Indian monsoon winds carry these clouds towards Asia and North Africa. The clouds heading west are augmented by dust from the Sahara. In the southern hemisphere, most of the dust starts from the Australian outback. Scientists estimate that half of the dust in today's atmosphere might be the result of human activity.

Modelling the movement of these dust storms can help to predict extreme weather. Hurricanes from the Atlantic slam into Florida every year. These storms form off the west coast of Africa but scientists have found in recent years that the hurricane risk is reduced if nascent storms run into dusty air from the Sahara. If meteorologists could predict better how and when a storm will hit a dust cloud, it would give more warning of potential disasters.