Chasing Saharan Dust Storms II

UK SOLAS Cruise Report

RRS *Discovery* 326
5 January - 5 February 2008

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Chasing Saharan Dust Storms II: RRS *Discovery 326*, 5 January -05 February 2008. UK SOLAS Cruise Report

ABSTRACT

A. The *Discovery* 326 cruise in the subtropical and tropical northeast Atlantic Ocean 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 our understanding of the atmospheric transport, cycling and deposition of dust and nutrients into the North Atlantic, and the consequences of the nutrient inputs on surface water microbial communities. The cruise was funded by the UK Natural Environment Research Council (NERC).
The main testable hypothesis of the cruise was: Atmospheric inputs control rates of primary production and microbial diversity in oceanic waters where nutrients are limiting.
The main objectives of the cruise were:
1) Obtain an improved temporal and spatial estimates of atmospheric dust inputs to the tropical and subtropical N Atlantic Ocean.
2) Obtain an improved estimate of the seawater dissolution of N, P, Al, Mn and Fe species from aerosol dust.
3) Determine the influence that dust exerts on phytoplankton carbon fixation, nitrogen fixation (diazotrophy), diazotroph species diversity and nutrient cycling in surface waters.
4) Determine the impact of atmospheric dust derived micronutrients on microbial community production and species diversity.
The main sampling and data-gathering activities comprised sampling of 54 stations for CTD and trace metal clean profiles, collection of 189 underway samples from the towed trace metal clean Fish and 95 underway samples from the non-toxic seawater supply. Stand Alone Pumps (SAPS) were deployed 9 times.
Dust events were encountered in the periods 17-19/01/08 and 25-26/01/08. The Cape Verde Time Series (also called Tenatso) Station was sampled on 15/01/08.

B. In addition to the objectives relating dust inputs to the functioning and diversity of surface water microbial populations, the cruise also looked at the influence of the dust deposition on iodocarbon production.

C. The cruise also had participants from a UK SOLAS project investigating the roles of DMSP and GBT in protection of microorganisms from photoinhibition/photoxidative stress and consequences for DMS and NH_3 production (Stephen Archer, PML and Richard Geider, University of Essex).
The overall aim of their research was to determine the extent to which the photoprotective roles of DMSP and QAs influence their production rates in marine surface waters and hence, the production of their volatile breakdown products.
On the cruise their objectives were to:
1. relate DMSP and QAC concentrations to plankton community structure, light regime, photoinhibition, xanthophyll cycle and MAA accumulation in varying oceanic provinces and over diel cycles.
2. determine the potential for photoinhibition and DMSP/GBT turnover in natural phytoplankton in contrasting oceanic provinces.

The cruise provided the opportunity to determine particulate DMSP, DMSO and GBT and dissolved DMSP, DMSO, DMS and NH_3/NH_4^+ in oceanic waters experiencing a range of irradiance levels, physical forcing and nutrient availability. This information was combined with in situ determination of photophysiology and photoinhibiton, complemented by on deck measurements and related to water column optical properties. Potential changes in community composition were monitored. A series of incubation studies were conducted.

KEYWORDS

CTD OBSERVATIONS, GOFLO CASTS, DISSOLVED IRON, DISSOLVED ALUMINUM, DISSOLVED

MANGANESE, ORGANIC IRON COMPLEXATION, PRIMARY PRODUCTION, NITROGEN FIXATION, THRICHODESMIUM, HETEROTROPHIC ACTIVITY, SPECIES DIVERSITY, FRRF SYSTEM, 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, RRS Discovery, SALINITY, SEA SURFACE TEMPERATURE, SATELLITE IMAGES, MICROLAYER, DMS, IODOCARBONS, OCEAN OPTICS, IODOCARBON, DMS, DMSP, DMSO, GBT, , PHOTOINHIBITION, PHOTOPHYSIOLOGY

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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 Council, website www.nerc.ac.uk/funding/thematics/solas/.
Furthermore, a pdf can be requested from Prof. Eric Achterberg (eric@noc.soton.ac.uk) NOC Southampton, European Way, Southampton SO14 3ZH, United Kingdom, phone: 023 8059 3199.

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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 (www.bodc.ac.uk/projects/uk/uksolas/cruise_programme).

Acknowledgements

We thank the Master, the officers and the crew of the RRS *Discovery* for their constant support and assistance (and of course sustenance) during cruise D326, and for providing a safe and efficient platform which allowed us to meet the scientific objectives of the UK SOLAS programme. Excellent support for the CTD work, trace metal clean casts and SAPS was provided by Chris Barnard, Allen Davies, John Wynar and John Short of the NMFSS. Furthermore, we want to thank Mark Stinchcombe for handling the logistics of the cruise. Besides the people on board of the *Discovery* we also want to thank Paul Gooddy, Neil Jenkinson and Nigel Eastwood for their help in the preparation for the cruise. We gratefully acknowledge the excellent satellite support during the cruise by the satellite unit (NEODAAS) of Plymouth Marine Laboratory. Without their twice daily dust images, the cruise would not have been possible. NERC UK SOLAS is acknowledged for funding of the cruise.

We thank Ivo Grigorov and Euroceans colleagues for setting-up and maintaining the cruise website, that provided information on our progress and additional background to a very much wider audience (http://www.eur-oceans.info/EN/diary/dust_cruise/). We also thank the BBC, in particular journalist Rebecca Morelle) for setting up an excellent website describing the initial outcomes of our cruise (http://news.bbc.co.uk/1/hi/sci/tech/7228081.stm).

We also acknowledge the support by the UK SOLAS NERC team; Phil Williamson has worked tirelessly to make D326 possible following the disappointing cruise mobilization in January 2007.

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Objectives of cruise

Over 70% of the Earth's surface is covered by the ocean, that provides 97% of the planet's living space (by volume) and around 40% of global photosynthesis.. 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 the oceans primary production is limited by light and nutrients such 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., 1990a; Martin et al., 1990) and the North and Equatorial Pacific Ocean (Chavez et al., 1991; Martin and Gordon, 1988) but also in coastal areas (Hutchins and Bruland, 1998), and on a seasonal basis in the North Atlantic Ocean (Moore et al., 2006). Inputs of limiting nutrients or Fe to low productive ocean regions will enhance productivity, influence species composition and the trophic structure of planktonic communities and thus e.g. carbon sequestration, N_2 fixation and the production of gasses as dimethyl sulphide (DMS) and volatile iodine containing gases (iodocarbons).

Atmospheric transport of dust and its deposition in the surface ocean is considered to form an 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 inputs in the North Atlantic originate 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). The latitude of highest dust transport from the Saharan region to the North Atlantic Ocean changes between winter and summer, and is determined by the seasonal migration of the Inter Tropical Convergence Zone (ITCZ) (Prospero et al., 1981). At the Cape Verde islands in the tropical North East Atlantic Ocean, the maximum dust deposition occurs in winter and is the result of dust transport in the lower air masses of the trade winds (Chiapello et al., 1995). In summer, Saharan dust reaches the American continent (Prospero and Carlson, 1972; Prospero et al., 1981), as it is transported at higher altitude within the Saharan Air Layer (1.5-6 km).

The *Discovery* 326 cruise in tropical and subtropical North Atlantic Ocean 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 our understanding of the atmospheric transport, cycling and deposition of dust and nutrients into the North Atlantic, and the consequences of the dust inputs on the surface microbial community. The objectives of the cruise were:
1) Obtain an improved temporal and spatial estimate of atmospheric dust inputs to the tropical and subtropical North 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, nitrogen fixation (diazotrophy), diazotroph 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 addition to the research relating dust inputs to the functioning and diversity of surface water microbial populations, the cruise also looked at the influence of the dust deposition on iodocarbon production.

The cruise also had participants from a UK SOLAS project investigating the roles of DMSP and GBT in protection of microorganisms from photoinhibition/photoxidative stress and consequences for DMS and NH_3 production (Stephen Archer (PML) and Richard Geider (University of Essex)). The overall aim of their research was to determine the extent to which the photoprotective roles of DMSP and QAs influence their production rates in marine surface waters and hence, the production of their volatile breakdown products. On the cruise their objectives were to:
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The cruise provided the opportunity to determine particulate DMSP, DMSO and GBT and dissolved DMSP, DMSO, DMS and NH_3/NH_4^+ in oceanic waters experiencing a range of irradiance levels, physical forcing and nutrient availability. This information was combined with in situ determination of photophysiology and photoinhibiton, complemented by on deck measurements and related to water column optical properties. Potential changes in community composition were monitored. A series of incubation studies were conducted.

Cruise Narrative

The *Discovery* departed from Santa Cruz, Tenerife - Canaries, on the evening of 05 January 2008. After 30 days at sea the RRS *Discovery* arrived back in Santa Cruz on 04 February 2008. The cruise track of the *Discovery* is shown in Figure 1. During the cruise, the ship's time of the *Discovery* was maintained on UTC (i.e. not changed according during time-zone changes). A total of 54 stations were completed between 05/01/2008 and 04/02/2008. The dates, positions and times of the CTD stations, together with more detailed information on other scientific activities, are listed in a table in Appendix 1 and in the Timetable in Appendix 2.

In essence, during each regular day at sea we have undertaken sampling at two stations. The morning station (commenced at ca. 05:30 h) consisted of two stainless steel CTD casts (1 going to a depth of 300 m and a shallow cast for experimental work), a titanium CTD cast going to a depth of 300 m, a zooplankton net, a net for *Trichodesmium* (sometimes twice) and a particle profiling cast. The afternoon station (commenced at ca. 13:00 h) consisted of a stainless steel and a titanium CTD cast going to 300 m depth and a particle and light profiling cast.

Overall, only a part of one station (stainless steel and titanium CTD) was lost due to problems with the cable (17/01/08) and another station was lost due to bad weather conditions (31/01/08).

The titanium CTD was also used to investigate the trace metal distribution at greater depths, four of the titanium CTD casts were to 1800 m depth to record trace metal biogeochemistry at the oxygen minimum zone (11/01/08, 20/01/08, 22/01/08, 02/02/08) (Stramma et al., 2008), one cast was to 3613 m depth (15/01/08) at the Cape Verde Tenatso time series station and the last cast was to 4560 m depth (03/02/08).

The trace metal clean tow Fish (epoxy resin coated steel torpedo) was continuously deployed during the whole cruise starting 05/01/08 until 03/02/08. All underway samples for trace metals and nanomolar nutrients were taken from seawater that was directly pumped up from a Fish (through acid cleaned PVC tubing) into the trace metal clean container.

Underway macro nutrients, Chl *a*, alkalinity and DIC (dissolved inorganic carbon) were sampled from the non-toxic seawater supply. The dates, positions, times and parameters of the underway samples taken from the fish as well as from the non-toxic seawater supply can be found in Appendix 3. Samples to determine the microbial community were taken every 20 minutes during the whole cruise, furthermore the pH and pCO_2 (PML operated ship-board system) were continuously monitored. Depending on the dust conditions Stand Alone Pumps (SAPS) were deployed to collect particulate material (10/01/08, 15/01/08, 18/01/08, 19/01/08, 23/01/08, 25/01/08 (2x), 26/01/08, 27/01/08).

Following our departure from Santa Cruz, Tenerife – Canaries (07/01/08) the *Discovery* sailed via the more productive waters northwest of the Cape Verde islands to the Cape Verde Tenatso time series station where we arrived on 15/01/08. From the Cape Verde Tenatso time series station we sailed south negotiating the channel between the St Antaõ and St Vincent islands and further along the same transect as sailed during a dust event in 2006 with the *FS Poseidon* (Rijkenberg et al., in press). After following this transect, we headed west on 17/01/08 into the open tropical North Atlantic Ocean. While heading west we encountered a major dust event. The dust event was hidden from the

satellite pictures by cloud cover. The air observed during this event was humid and dusty. The dust event was noticeable between 17/01/08 and 19/01/08 and finished on 20/01/08. To allow us to re-trace the seawater patch fertilized by the dust, a drifter was deployed at 19/01/08. Satellite positions were obtained of the drifter during the days following deployment. However, retrieval of the drifter was very difficult because malfunctioning of the positioning instrumentation for the drifter on the RRS *Discovery*. Therefore, on 23/01/08 it was decided to abandon the lost drifter and head back to the position of station 16418 as a strong dust storm was observed coming to that region.
In order to reach station 16418 prior to the dust event, we only sampled one station on 23/01/08 and one station on 24/01/08. In the morning of 25/01/08 we sampled a station while watching the visual distant signs of an approaching dust storm. Later that day the aerosol filters started to become covered by yellowish red dust and the skies became hazy. The same day a drifter was deployed and during the next three days we would follow the drifter and add an extra station for the titanium CTD and the particle profiler (at 18:00 pm). Also the inflate boat (RIB) was used to take samples at a distance from the *Discovery*. As the dust storm passed over, the atmosphere cleared up and time schedule had to be met, we recovered the drifter on 27/01/08 and headed towards more oligotrophic waters. On the way to these waters we sampled one station in productive waters on 28/01/08. On our way north we revisited station 16397 (now station 16430), 16395 (now station 16431). We were not able to revisit station 16391 due to adverse weather conditions. These conditions also resulted in the cancellation of a planned 24-48 h time-series station at station 16391 on 31/01/08, where Steve Archer (PML) had planned to undertake a diurnal biogas study. We did only one station on 01/02/08 to gain more time for work in the more oligotrophic area's. On 03/02/08 we took our last underway seasurface samples and sampled the last station before heading back to Santa Cruz, where we arrived on 04/02/08.

The cruise progress was very well covered by a dedicated website that was developed and maintained by the European Union programme 'Euroceans' (http://www.eur-oceans.info/diary/dust_cruise/). On a daily basis web blogs and photos were sent to the Euroceans office and the website was then updated. We were in contact with a Hungarian school class, who sent us questions by email, and also sent us film clips of their coverage of our cruise in their class. The cruise was also covered by the BBC. A telephone interview was conducted whilst at sea, and film clips of various research activities were sent to the BBC through NMFSS at NOCS. A website was produced by the BBC which went live on 06/02/08 (http://news.bbc.co.uk/1/hi/sci/tech/7228081.stm). The BBC website resulted in a good exposure of the cruise, and radio interviews were conducted with radio stations in Norway, The Netherlands, the US and a range of science websites covered the story as well. A further newspaper article was produced on 12/05/08 by the Trinidad and Tobago news following an e-mail interview (http://www.trinidadexpress.com/index.pl/article_news?id=161321883).

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 followed throughout the cruise.

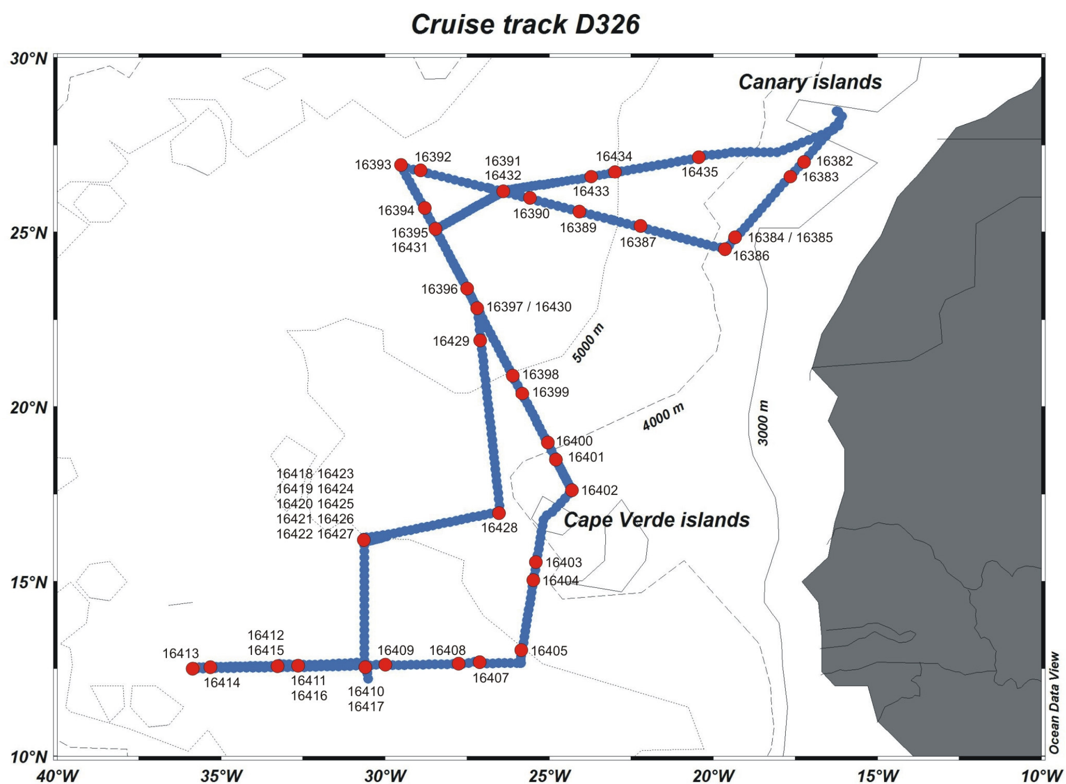

Figure 1. The cruise track of the UK SOLAS *Discovery* 326 cruise. Stations are represented by red circles and station numbers. The cruise started on 05 January and finished on 04 February 2008 in Santa Cruz (Canary Islands).

General Hydrographic and Meteorological Observations

The sea surface temperature in °C is shown in Figure 2. The temperatures increased from around 20ºC in the northern part of our cruise track to around 25ºC in regions south of the latitude 20ºN. The mixed layer depth varied between 183 m north of the Cape Verde islands to 26 m south of the Cape Verde islands, see Figure 3.

The air temperature and absolute wind speed during the cruise are shown in Figure 4. Figure 5 shows the sea surface chlorophyll a concentrations.

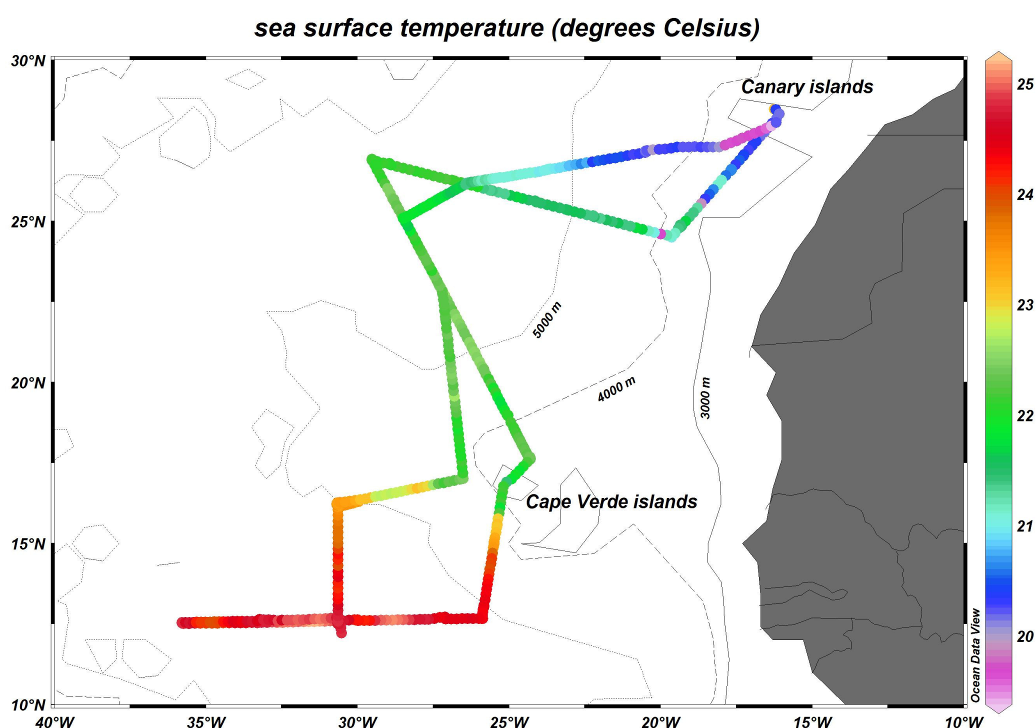

Figure 2. The sea surface temperature (°C) observed during the UK SOLAS D326 in the tropical and subtropical North Atlantic Ocean.

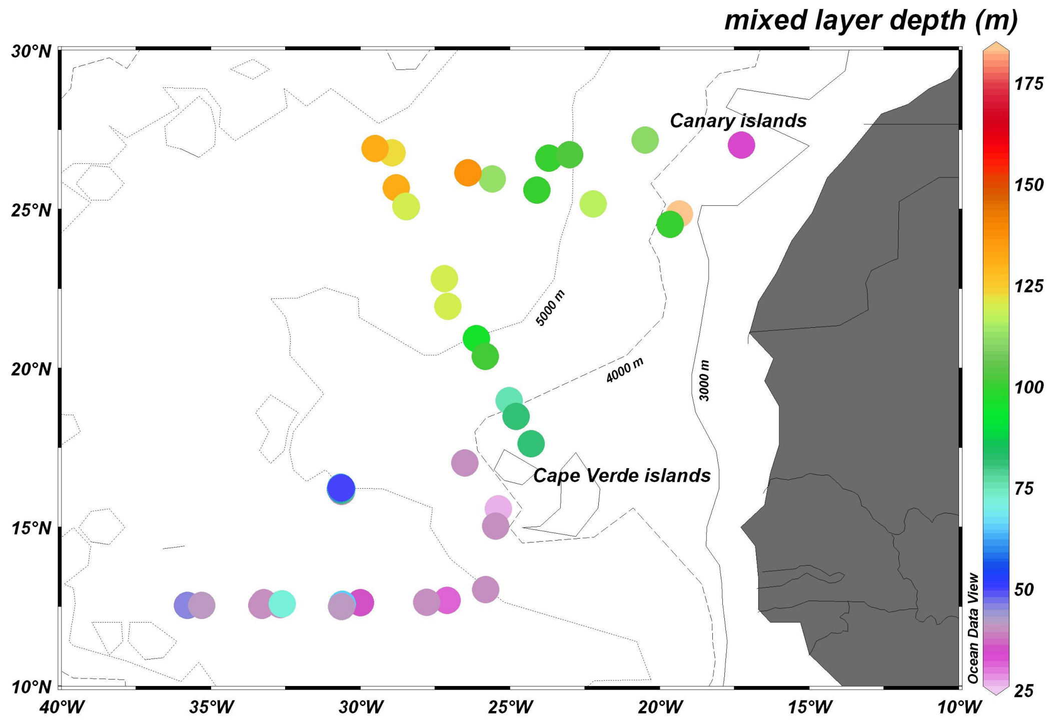

Figure 3. The estimated mixed layer depth during the D326 cruise. Mixed layer depth estimates are based on the bottle temperature and salinity data.

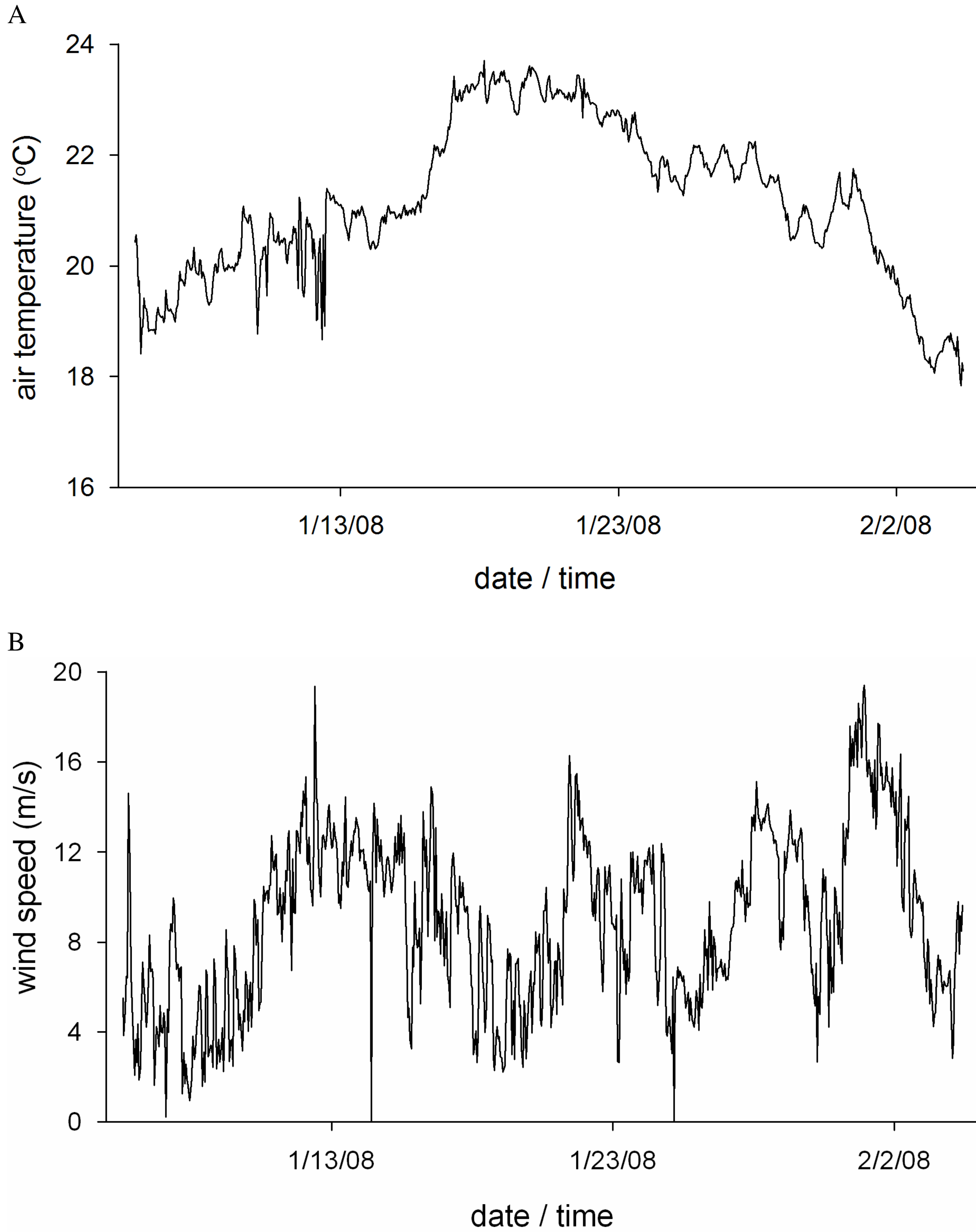

Figure 4. The air temperature (°C) (A), and the absolute wind speed (m/s) (B) during the UK SOLAS *Discovery* 326 cruise.

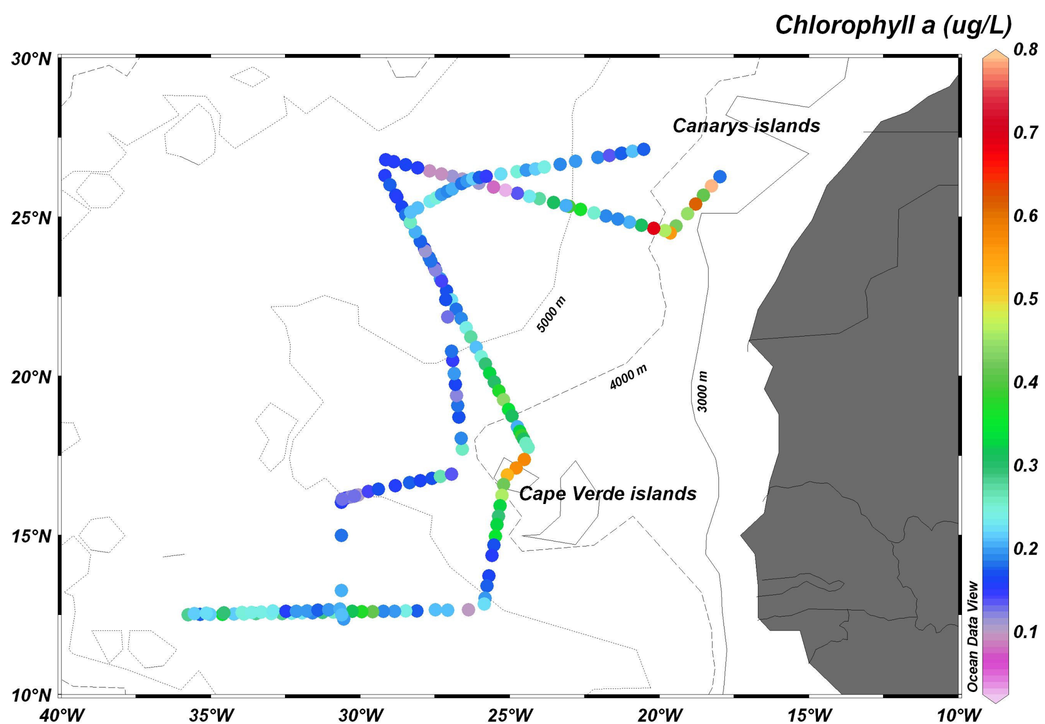

Figure 5. The geographical distribution of the sea surface concentration of chlorophyll a (µg/L) during the UK SOLAS *Discovery* 326 cruise.

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Scientific Reports

Cruise Report D326; Roles of DMSP and GBT

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Introduction

This research forms the field-work component of a UK SOLAS-funded project (Archer & Geider: Roles of DMSP and GBT in protection from photoinhibition/photooxidative stress and consequences for DMS and NH_3 production). In order to understand marine sources of the climate active gas dimethyl sulphide (DMS), we need to understand the physiological constraints on the production of its osmolyte precursor, dimethyl sulphoniopropionate (DMSP) by phytoplankton. DMSP has been attributed a number of roles in phytoplankton, including a grazing deterrent and a compatible solute (Stefels et al., 2000), but to date the proposed roles do not explain the wide variation of DMSP concentration between taxa (Keller et al., 1989), nor why it can contribute as much as 10% of cell carbon in some phytoplankton (Matrai and Keller, 1994). DMSP production and lysis to DMS has been proposed as a mechanism to relieve oxidative stress due to high light, UV exposure or nutrient limitation (Sunda et al., 2002). DMSP, DMS and DMSO are effective scavengers of reactive oxygen species, but direct physiological evidence that DMSP and its breakdown products act to reduce oxidative stress in phytoplankton is still lacking. Oxidative stress can damage photosystem II (PSII) and when damage rates exceed photoprotection and repair of the main photosynthetic proteins (D1 protein) photoinhibition results. Net photoinhibition resulting from the balance between damage and repair can be conveniently monitored as a decrease in the maximum quantum yield of PSII photochemistry, termed *Fv/Fm*. The rate of damage and repair of PSII reaction centers can be determined incubating water samples in the presence and absence of the antibiotic lincomycin which inhibits the replacement of the D1 protein within the PSII (Waring et. al. 2006).
Our experiments during cruise D326 coupled variable fluorescence measurements to determine phytoplankton photoinhibition with measurements of DMS, DMSP, measurement of the recognised xanthophyll cycle photoprotective mechanism and ancillary measurements. The results will provide important evidence for assessing the role of DMSP in protection from photooxidative stress.

Description of Experiments

Incubation experiments were set up in tanks cooled with continuous flow surface seawater. Seawater was collected pre-dawn via a dedicated CTD cast. For the experiment, seawater was gently prefiltered through 100 µm mesh into 2 100 L carboy reservoirs, and then dispensed into 2 L acid-washed Whirlpak bags. The bags were transferred to incubators in the dark and screened with mesh and/or perspex to provide two light treatments (+/- UV; see Table I). Temperature, PAR and UV sensors were placed in the

tanks during the experiments. Samples were taken approximately 1 hour after set up (T0), and every two/three hours until T+12 hours.

Date	Station	Treatment
7th Jan 08	16384C	Surface (5m) & depth (30m) Screen plus mesh
8th Jan 08	16386C	Surface (5m) & depth (30m) Screen plus mesh
9th Jan 08	16388	Surface (5m) & depth (30m) Screen plus mesh
10th Jan 08	16392	*Physiology Experiment*. Open tank +uv; Perspex screen –UV; 1 mesh +uv; screen + mesh –uv; 2 mesh +uv; screen+ 2 mesh –uv
11th Jan 08	16394	Surface (5m) & depth (30m) 1 open and 1 screened. Cloudy day
13th Jan 08	16389	Surface (5m) & depth (30m) 1 open and 1 screened. Cloudy day
14th Jan 08	16400	*Depth profile*. Lincomycin experiments
15th Jan 08	16402	D2O expt. Surface only 1 mesh,
16th Jan 08	16403	D2O expt. Surface only 1 mesh,
17th Jan 08	16405	D2O? Surface only 1 mesh, cloudy.
18th Jan 08	16407	Deep samples and D2O Tested concentrates; Tested MQ with D2O
19th Jan 08	16409	Surface One mesh
20th Jan 08	16411	Surface & concentrates 1 mesh
21st Jan 08	16413	Surface & concentrates 1 tank + uv; 1 screen for –uv
22nd Jan 08	16415	Surface and concentrates 1 tank + uv; 1 screen for –uv
24th Jan	16418	*Depth profile & relaxation expt.*
25th Jan 08	16419	Surface & concentrates No mesh/screen; I screen + mesh+mesh
26th Jan 08	16422	Surface & concentrates/FISH No mesh screen; Screen +mesh+mesh
27th Jan 08	16425	Surface & concentrates/FISH Open tank +uv; I screen +mesh+mesh –uv
28th Jan 08		Lincomycin expt from FISH
29th Jan 08	16428	1 screen_mesh –uv; 1 mesh +uv
30th Jan 08	16429	Surface & concentrates 1 screen +mesh; 1 mesh
1st Feb 08	16432	Surface & concentrates 1 screen +mesh; 1 mesh (cloudy)
2nd Feb 08	16433	Surface & concentrates 1 screen –uv; Open tank

Table I. Station numbers and dates of experiments carried out with treatment details.

Measurements

Photophysiology
Two samples from each replicate bag were collected in dark bottles; one was measured directly and the second was used to concentrate the phytoplankton (and increase the fluorescence signal) using a tangential flow filtration system. Measurements were conducted on both the non-concentrated and the concentrated material. Variable fluorescence was determined using a Fluorescence Induction and Relaxation (FIRe) and a Fast Repetition Rate Fluoremeter (FrrF) system. Measurements were taken after >30 minutes dark adaptation to ensure that modifications in *Fv*/*Fm* were a result of photoinhibition rather than non-photochemical quenching.
To examine the effect of UV on electron transport rates light response curves were conducted using the concentrated material using the FIRe system's automatic light response program.

Lincomycin experiments.
Lincomycin was added to 10 ml of concentrated material from T_0 sampling time point to a final concentration of 0.9mM in quartz tubes. Replicate tubes were placed in the incubations tanks, subjected +/- UV. Controls included concentrated water samples without the addition of lincomycin and tubes darkened with foil. Two replicate tubes from each treatment were removed after 20 min and 60 min and dark adapted for 30 min after which *Fv*/*Fm* was determined using the FIRe.

DMS, DMSP and DMSO measurements
DMS concentrations were routinely monitored in the experiments in 10 ml samples using a purge and cryo-trap system linked to a gas chromatograph with pulsed flame photometric detector. Samples for total and particulate DMSP and dissolved DMSO were preserved for analysis back in Plymouth.

Xanthophyll cycle
4 L samples were filtered immediately after collection onto 25mm GFF filters. The filters were flash frozen in liquid nitrogen and stored at -80°C until analysis. Analysis will be performed post-cruise by HPLC according to Barlow et al. (1997).

DMSP turnover
Stable isotope tracers were added to establish DMSP turnover. 13C sodium bicarbonate (6% TCO2) or deuterium oxide (4-5%) were added to the seawater prior to incubation. At sampling points, the labelled water was gravity filtered onto 47mm GFFs for analysis by GCMS (duplicate 100mL volumes filtered; filters stored in 0.25% sulphuric acid at -20oC) or PTRMS (duplicate 1L volumes filtered, filters stored in sodium hydroxide solution at -20°C). 13C or deuterium incorporation into DMSP will be determined post-cruise by GCMS and PTRMS. Samples for a measure of total uptake of 13C were also collected: Duplicate 1L volumes were vacuum filtered onto 25 mm GFFs, rinsed with unlabelled filtered seawater, flash frozen and stored at -80oC.

Ancillary Measurements

Flow cytometry
Samples were taken for flow cytometry at each sampling point to determine changes in the phytoplankton population during incubation. Flow cytomtery was also performed on samples before and after concentration for variable fluorescence measurements. Analysis was conducted on fresh samples, typically within 1/2 hour of subsampling.

Particulate Organic Carbon (POC)
4L volumes were vacuum filtered onto pre-ashed 25mm GFFs. Filters were flash frozen in liquid nitrogen and stored at -80 degrees prior to analysis post-cruise.

Preliminary Results

Preliminary results indicate that in many of the experiments some degree of photoinhibition occurred during midday and that UV exposure increased the level of photoinhibition (Figure 1 and 2). This was the basis of our experimental approach and now we have to figure out whether the photoinhibition caused any changes in DMSP production and transformation. This will not be apparent until the post-cruise analyses have been done. In general, concentrations of DMS and DMSP were low, < 1 nM and ~ 10 nM, respectively.

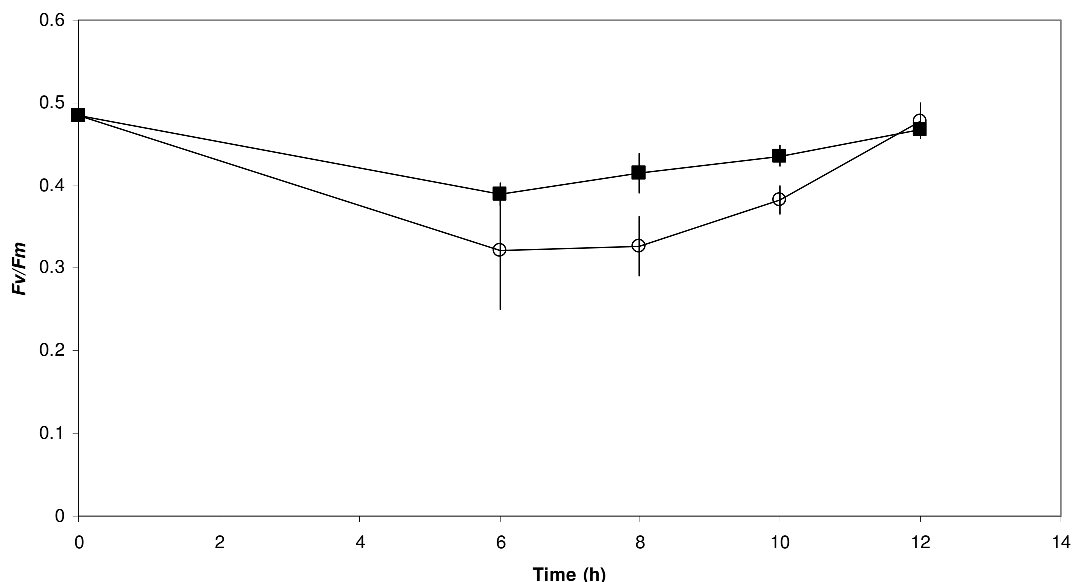

Figure 1. Changes in *Fv*/*Fm* with incubation time and treatment for experiment carried out at station 16402. Open symbols represent exposure to UV, closed symbols represent data from samples screened from UV. Plot shows decrease in *Fv/Fm* caused by photoinhibition in the samples exposed to UV.

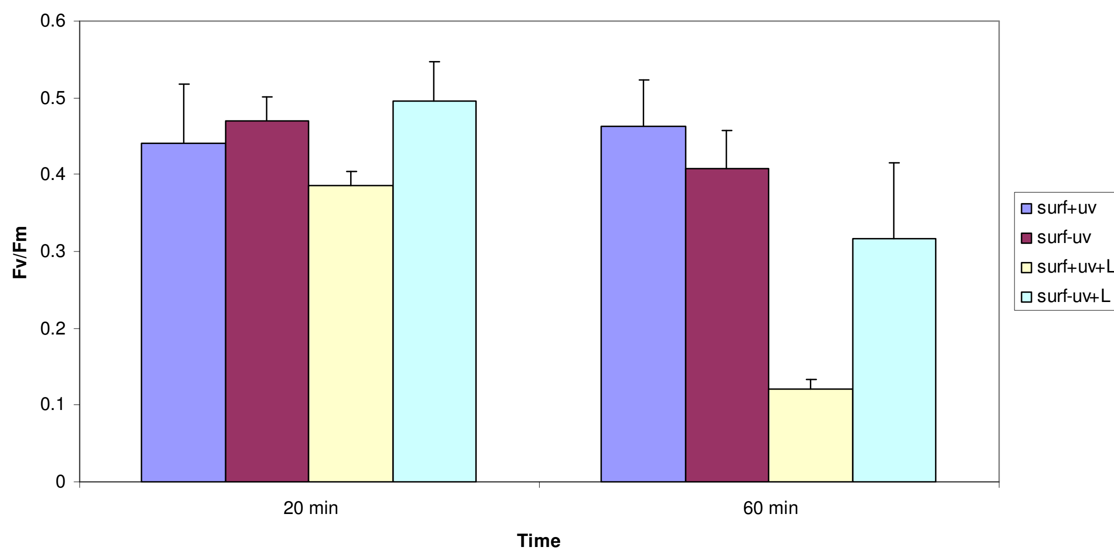

Figure 2. Changes in *Fv/Fm* with and without addition of Lincomycin at two time points. Plot shows decreased *Fv/Fm* when D1 protein repair inhibited in samples exposed to UV

Thiol distribution measurements in phytoplankton cells and seawater

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Introduction

Phytoplankton species deal with metal deficiency and toxicity using a variety of strategies. Some specific responses involve the production of intracellular metal-binding thiol peptides and/or the exudation of thiol or sulfydryl compounds. During this cruise my work was mainly focused on the determination of particulate and dissolved thiols present in seawater and phytoplankton cells. Glutathione (GSH), Cysteine (Cys) and phytochelatins (PCs) are the major metal-binding thiol peptides produced by marine phytoplankton to regulate their metal contents. These polypeptides are involved in metal ion homeostasis and cellular metal detoxification mechanisms.
Among the enzymes involved in the biosynthesis of thiols, I will focus my work on the phytochelatin synthase (PCS) which allows the post-translational synthesis of phytochelatins.
PCS catalyzes the transpeptidation of a part of GSH (the γ-Glu-Cys moiety) either onto a second GSH molecule to form a dimer PC_2 or onto a previous synthesized PC molecule to produce a $PC_{(n+1)}$ oligomer.
In natural waters, the low concentrations of both PCs and GSH in phytoplankton cells (picoM level) and the nanoM concentration of dissolved GSH, associated with a rapid oxidation of thiols in seawater, require sensitive analytical methods. Cathodic Stripping Voltammetry (CSV) is usually used for the dissolved thiol determination because of this technique has very low detection limits. Reversed Phase Liquid Chromatography (RPLC) combined by fluorescence detection is one of the most common techniques to achieve PC speciation and determination in seawater.

Determination of thiols (Glutathione and Cysteine) in seawater

Highly sensitive voltammetric detection (CSV) on a mercury drop electrode (Le Gall and Van den Berg, 1993, 1998; Al-Farawati and Van den Berg, 2001) was used on board to measure glutathione (GSH) and cysteine (Cys) present in seawater without sample pre-treatment.

Sampling
Samples were collected directly on the Stainless steel CTD in a 50ml sterilised and single-used TPP tube (see Table 1 for details).

Equipment and reagents
The Autolab electrochemical analyser (*Ecochemie*, Netherlands) was connected to a hanging mercury electrode (HMDE), a reference electrode Ag/AgCl/3 mol/l KCl and a platinum wire counter electrode (*Metrohm*, Switzerland)

A stock standard solution of borate buffer (1 mol/L, pH=8.3) was prepared weekly. Working standard glutathione and cysteine solutions were prepared daily in MilliQ water from a 0.1/L stock solutions prepared weekly and stored under refrigeration.

Procedure

The voltammetric cell and the electrodes were rinsed with 20-30ml of sample before starting the analysis. A 10 ml aliquot of unfiltered seawater collected from the surface was pipetted into the polarographic cell and the pH was adjusted 8.5 by addition of 100 µl of borate buffer, giving a final concentration of 0.01 mol/L borate. The magnetic stirrer was switched on and the solution was purged with oxygen-free nitrogen for 5 min to remove oxygen. The potentiostat was set to a deposition potential of -0.05 V. Four mercury drops were discarded before a new mercury drop was extruded and the adsorption time, usually 240 s, was measured from this point; then the stirrer was switched off and, after a quiescent period of 8 s, a negative potential scan (from -0.15 to -0.9 V) was made using the square-wave modulation (frequency 50 Hz, step potential 0.002 V, modulation amplitude 0.1 V). 3-5 scans were averaged to eliminate noise due to ship's engine vibrations. The procedure was repeated after standard addition of glutathione and cysteine.

The peak height was used as a measure of the thiol concentration; the reference baseline was interpolated with the computer software (GPES3) as a straight line between the minima in the current preceding and following peak. The sensitivity was calibrated by standard additions o each sample to correct for variations as a result of interference by surface-active material.

These analyses were initiated as soon as possible after sampling because of the instability of the thiol peptides in aqueous solutions and their rapid oxidation.

During my experiment, the reduction peak appeared at -0.3 V and – 0.5V respectively for cysteine and glutathione. Voltammetry of seawater collected during this cruise revealed the presence of a thiol-type peak at -0.4V. Unfortunately, the identity of this thiol-type peak was difficult to define and to distinguish because of this very low concentration close to the detection limit (0.05nM) and this behaviour after standard addition.

Determination of intracellular metal-binding thiols (Glutathione and Phytochelatins) and Study of the expression of the enzyme – phytochelatin synthase, in phytoplankton cells

Sampling

Samples were taken on the Stainless steel CTD once a day, at several depths from the mixed layer to the surface (see table 1 for details).

A silicone tube was used for the sampling. Samples were stored in a 10L or 2*5L trace metal clean plastic container, rinsed once with the sample in order to remove trace of the previous sample Followed by filtrations under gentle vacuum pressure to avoid cells break, as soon as possible after collecting.

Procedure
For each depth, duplicate 2L seawater were filtered through nitrate cellulose membrane filters (*Whatman* 0.2 and 0.45µm) for future intracellular thiol determination and in parallel duplicate 2L seawater were filtered through membrane filters (*Supor450 Pall Life Science Corporation* same size and same conditions) for future molecular work (RNA extraction experiments to study phytochelatin synthase (PCS) expression).

Filters are placed in amber vials (eppendorfs) (thiol analysis) and cryotubes (RNA extraction - after addition of the storage reagent RNA later, *Ambion*) and will be stored in the -80°C freezer until analysis and extraction.

Dissolved thiol analysis will be done back to the National Oceanography Centre (Southampton). Dissolved thiols including glutathione and phytochelatins (PCs) potentially present in phytoplankton cells will be determined by Reverse Phase Liquid Chromatography coupled with fluorescence detection (method adapted from Kawakami et al., 2005). The identification of phytochelatins and glutathione was based on the comparison of their retention times, respectively, with pure standard PC2 and GSH used for calibration purposes and prepared in an acidic medium 0.12 M HCl/ 5mM DTPA in order to minimise oxidation. The concentrations of thiols will be normalised to chlorophyll *a.*

In Plymouth (Marine Biological Association), the PCS gene expression will be evaluated with the reverse-transcriptase polymerase chain reaction (Rt-PCR) after RNA extraction, using universal and specific primers from alignments of PCS genes, specifically focusing on the *Pfam domain 05023*. I will also integrate the screening and identification of other gene expression induced by metal stress utilizing a PCR-based subtractive cDNA approach. Multiple alignments will be performed using ClustalW.

Additional sampling

At the sampling stations, samples (250 mL) were also taken from the titanium CTD, filtered and acidified by Dr. Micha Rijkenberg in trace metal clean conditions. They will be kept in the fridge for future trace metals determination (back in NOCS).

In addition I sampled and filtered seawater for another scientist not present on board (Dr. Martha Gledhill – see table 1). All the filters will be kept in the -80°C freezer until heme determination can be undertaken at NOCS (Gledhill, 2007).

Table 1: List of sampling stations

Cast	Time	Depth - PCs/PCS	Depth - Trace metals	Dissolved GSH	Hemes	Day
16383A	15.00	50 & 65m	-	-	3L – 8 depths	06/01/2008
16386A	14.00	130, 75 & 50m	130, 65 & 50m	-	3L – 8 depths	07/01/2008
16387A	07.00	-	-	115, 75 & 50m	-	08/01/2008
16389A	20.20	100 & 50m	100 & 50m	-	3L – 8 depths	08/01/2008
16390A	07.00	-	-	110, 50 & 10m	-	09/01/2008
16391A	15.30	110, 81, 50 & 30m	110, 81, 50 & 20m	-	3.5L – 8 depths	09/01/2008
16392A	07.15	-	-	160, 50 & 10m	-	10/01/2008
16393A	17.00	120, 100, 75 & 50m	130, 80, 50 & 30m	-	4L – 8 depths	10/01/2008
16394A	06.45	-	-	100, 50 & 30m	-	11/01/2008
16395A	17.00	120, 100, 75, 50 & 30m	110, 80 & 60m	-	4L – 8 depths	11/01/2008
16396A	06.30	-	-	100, 50 & 10m	-	12/01/2008
16397A	15.00	120, 100, 78, 50 & 30m	115, 75, 50 & 30m	-	4L – 8 depths	12/01/2008
16398A	06.50	-	-	110, 50 & 5m	-	13/01/2008
16399A	15.30	95, 50, 30, 10 & 5m	100, 50 & 30m	-	4L – 8 depths	13/01/2008
16400A	07.15	-	-	50 & 5m	-	14/01/2008
16401A	15.00	80, 60, 40, 20 & 5m	80 & 50m	-	4L – 8 depths	14/01/2008
16402A	06.45	-	-	2*5m	-	15/01/2008
16402AA	13.45	100, 90, 70, 50 & 20m	100, 50 & 30m	-	4L – 8 depths	15/01/2008
16403A	07.00	-	-	5m	-	16/01/2008
16404A	15.00	57, 40, 20, 10 & 5m	100, 50 & 20m	-	4L – 8 depths	16/01/2008
16405A	07.00	-	-	5m	-	17/01/2008
16407A	06.30	75, 55, 30, 20, 10 & 5m	55 & 20m	-	-	18/01/2008
16408A	14.45	75, 61, 40, 20 & 10m	50, 40 & 20m	-	4L – 8 depths	18/01/2008
16409A	07.00	-	-	5m	-	19/01/2008
16410A	16.00	63, 50, 20, 10 & 5m	65, 50 & 20m	-	4L – 8 depths	19/01/2008
16412A	15.45	70, 60, 40, 20 & 10m	70, 40 & 20m	-	4L – 8 depths	20/01/2008
16414A	15.30	100, 80, 60 & 10m	60, 40 & 20m	-	4L – 8 depths	21/01/2008
16416A	15.30	75, 50, 30, 20 & 10m	70, 50 & 20m	-	4L – 8 depths	22/01/2008
16417A	13.40	150, 100, 64, 40, 30, 20, 10 & 5m	70, 40 & 20m	-	-	23/01/2008
16418A	16.00	100, 87, 40, 30, 20, 10 & 5m	100, 77 & 40m	-	-	24/01/2008
16419A	06.46	-	-	2*5m	-	25/01/2008
16420A	15.45	100, 87, 40, 30, 20, 10 & 5m	80, 45 & 20m	-	4L – 8 depths	25/01/2008
16423AA	16.30	85, 70, 40, 20, 10 & 4m	92, 40 & 20m	-	4L – 8 depths	26/01/2008
16425A	06.45	-	-	5m	-	27/01/2008
16426A	15.00	85, 60, 40, 20, 10 & 4m	83, 60 & 40m	-	4L – 8 depths	27/01/2008
16428A	22.10	100, 81, 68, 40, 10 & 5m	100, 60 & 40m	-	-	28/01/2008
16430A	15.30	100, 80, 50, 20, 10 & 5m	100, 80 & 50m	-	4L – 8 depths	30/01/2008
16431A	07.30	140, 120, 80, 60, 20 & 5m	140, 80 & 60m	-	4L – 8 depths	31/01/2008
16432A	08.45	138, 100, 60, 40, 20, 10 & 5m	120 m	-	4L – 8 depths	01/02/2008
16433A	06.10	-	-	5m	-	02/02/2008
16434A	15.15	147, 100, 80, 60, 20 & 5m	100, 60 & 20m	-	4L – 8 depths	02/02/2008
16435A	05.45	125, 100, 80, 60, 40, 20 & 5m	110, 60 & 20m	-	4L – 8 depths	03/02/2008

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Dissolved Inorganic Carbon (DIC), Total Alkalinity (TA) and pH determination

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Sampling

The sampling procedure used for the determination of Dissolved Inorganic Carbon and Total Alkalinity was according to DOE (1994). Samples were taken as soon as possible after the Niskin bottle was opened (following trace gases samples) to prevent any gas exchange of the sample with the head space of the Niskin bottle. A piece of silicone tubing was used for the sampling and care was taken to prevent any air bubbles being trapped in the sample. The sample was stored in a borosilicate glass bottle (250 mL), which was rinsed once with the sample in order to remove traces of a previous sample. The tubing was inserted at the bottom of the bottle which was then filled and water was let to overflow by at least half a bottle volume. The glass stopper was inserted in the bottle in order to remove the stopper volume and a head space of 1% (2.5mL) was allowed for water expansion. The sample was then poisoned with a saturated solution of mercuric chloride (7g/100mL) in a 0.02% volume ratio (50µL) in order to prevent any biological activity in the stored sample. The bottle was air-tight sealed with a glass stopper and shaken to mix the mercuric chloride homogeneously. Samples were stored in a cool and dark place until analysis. DIC samples were generally analysed within less than 2 days after sampling and water for alkalinity measurements was stored for analysis back at NOC.

During the cruise, underway DIC/alkalinity samples were taken from the non-toxic seawater supply (intake at ~5m depth) along with nutrients, and chlorophyll samples in order to obtain a good surface coverage of the cruise track (Table 1). A potentiometric pH system was installed on the non-toxic sea water supply and was run continuously during the cruise. The measurements were set to a rate of 1 minute intervals.

Profiles of DIC and TA were sampled from the Stainless steel CTD (see Table 2 for list of the stations and depths sampled). Three deep casts (16395B, 16402B, and 16435) were sampled from the Titanium CTD.

DIC measurements

All the DIC samples were analysed using a coulometric titration. The instrument used for this purpose was the VINDTA 3C from Marianda (Kiel, Germany) connected with a coulometer (UIC). Repeated measurements on the same batch of seawater ($n \geq 3$) were run every day of analysis, prior to the samples analysis, in order to assess the precision of the method. The standard deviation of the subsamples analysed ranged between 0.01% and 0.10%, with a mean value of 0.04% for the whole cruise (less than 2 µmol/kg), which is well within the expected value of less than 0.1% (Bates et al., 1996 ; Johnson et al. 1998). Certified Reference Materials (CRMs) from A.G. Dickson (Scripps Institution of

Oceanography) were used as standards to calibrate the system at the beginning of each day of analysis. A correction factor was applied to all measured values according to Millero et al. (1998) in order to normalize the measured values:

DIC (corr.) = DIC (meas.) x (CRM_{cert}/CRM_{meas});

where CRM_{cert} is the certified value for the specific batch of CRMs used.

The sample is acidified with phosphoric acid 10% which results in the conversion of total dissolved inorganic carbon ($[CO_2^*] + [HCO_3^-] + [CO_3^{2-}]$; where $[CO_2^*] = [CO_2] + [H_2CO_3]$) to CO_2 gas. The CO_2 generated is carried into the coulometric cell using an inert gas (N_2) and titrated coulometrically.

The coulometric cell is composed of two half cells : anode and cathode. The cathode cell contains mono-ethanolamine, a colorimetric pH indicator (Thymol blue) and a platinum electrode, whereas the anode cell is composed of a silver electrode and contains an anode solution saturated with potassium iodide crystals. The purged CO_2 causes the indicator to fade and the percentage of transmission (%T) to increase, and the titration current is automatically activated. The final titration point is determined spectrophotometrically when the final transmittance of the solution is kept at a constant value (29%T).

Total Alkalinity determination
The TA measurements at sea failed because of software and communication problem between the computer and the titration unit. After determination of DIC concentration, samples were well sealed and kept for TA analysis back to NOCS.

For the determination of TA, the sample of seawater is titrated with hydrochloric acid 0.1M. The acid solution is added in small increments until the carbonic acid equivalence point is reached (protonation of carbonate and bicarbonate ions). The total volume added allows the calculation of total alkalinity to be undertaken. A glass electrode/reference electrode system monitors the titration (measurement of the electromotive force).

pH measurement
The potentiometric method for the determination of pH in seawater consists of the measurement of the electromotive force (EMF) of a cell composed of a silver/silver chloride electrode and a glass pH electrode. The instrument used for the determination of pH was the portable pH monitor from Ruthern Instrument. This system consists in a highly reproducible free-diffusion liquid junction which has been shown to reduce the usual liquid junction potential error encountered with the electrode systems (Whitfield et al. 1985; Covington et al. 1988). A capillary liquid junction is formed between the reference reservoir (containing the silver/silver chloride electrode) and the pH cell (containing the pH electrode and the sample to be analysed). The bridge solution (2.5 M KCl in deionised water) allows the ionic contact between the hydrogen and reference electrode and is introduced below the sample via a solenoid pump.

To avoid errors with electrode drift, calibration of the system was undertaken every 8 to 12 hours with Tris buffer made up in artificial sea water according to Millero (1986). Tris buffer was run as sample after each batch of new buffer was made in order to check the accuracy of the measurements. Difference observed between theoretical pH and measured pH was 0.01 to 0.03 pH units. The buffer was brought approximately to the sea water temperature (within 5°C) in order to maximize the accuracy. The temperature of the pH cell was recorded using a Platinum Resistance Thermometer (0.1°C precision). The overall precision of the method is of 0.01 pH unit. The pH scale used in the pH calculation of the system is the free hydrogen ion concentration scale: pH_F, which uses the concentration of free proton to define the hydrogen ion activity (Bates 1975).

Event	Day	Time	Latitude	Longitude	Event	Day	Time	Latitude	Longitude
UW1	06/01/2008	21:00	25,973	-18,256	UW49	19/01/2008	19:00	12,585	-30,892
UW2	07/01/2008	01:00	25,4	-18,789	UW50	19/01/2008	23:00	12,565	-31,599
UW3	07/01/2008	05:00	24,853	-19,299	UW51	20/01/2008	03:00	12,548	-32,293
UW4	07/01/2008	11:00	24,766	-19,413	UW52	20/01/2008	11:00	12,539	-32,976
UW5	07/01/2008	15:00	24,519	-19,646	UW53	20/01/2008	17:00	12,531	-33,488
UW6	07/01/2008	19:00	24,646	-20,194	UW54	20/01/2008	21:00	12,521	-34,231
UW7	08/01/2008	01:00	24,936	-21,391	UW55	21/01/2008	01:00	12,511	-34,988
UW8	08/01/2008	11:00	25,236	-22,632	UW56	21/01/2008	07:00	12,520	-35,779
UW9	08/01/2008	15:00	25,354	-23,122	UW57	21/01/2008	11:00	12,537	-35,546
UW10	08/01/2008	19:30	25,577	-24,05	UW58	21/01/2008	17:00	12,545	-35,155
UW11	08/01/2008	23:00	25,648	-24,346	UW59	21/01/2008	21:00	12,557	-34,565
UW12	09/01/2008	03:00	25,84	-25,142	UW60	22/01/2008	01:00	12,569	-33,955
UW13	09/01/2008	11:00	26,055	-26,035	UW61	22/01/2008	11:00	12,616	-32,931
UW14	09/01/2008	17:00	26,187	-26,589	UW62	22/01/2008	17:00	12,614	-32,489
UW15	09/01/2008	21:00	26,353	-27,284	UW63	22/01/2008	21:00	12,626	-31,778
UW16	10/01/2008	01:00	26,543	-28,082	UW64	23/01/2008	01:00	12,658	-31,052
UW17	10/01/2008	11:00	26,797	-29,147	UW65	23/01/2008	10:00	12,505	-30,610
UW18	10/01/2008	17:40	26,91	-29,512	UW66	23/01/2008	19:00	13,257	-30,634
UW19	11/01/2008	01:00	26,305	-29,178	UW67	23/01/2008	23:00	13,950	-30,633
UW20	11/01/2008	09:00	25,628	-28,779	UW68	24/01/2008	11:00	16,036	-30,634
UW21	11/01/2008	19:00	24,821	-28,326	UW69	24/01/2008	17:00	16,166	-30,478
UW22	12/01/2008	01:00	23,998	-27,858	UW70	24/01/2008	21:00	16,260	-30,067
UW23	12/01/2008	11:00	23,062	-27,329	UW71	25/01/2008	01:00	16,204	-30,322
UW24	12/01/2008	17:00	22,68	-27,113	UW72	25/01/2008	06:40	16,143	-30,633
UW25	12/01/2008	21:00	22,103	-26,79	UW73	27/01/2008	23:00	16,281	-30,410
UW26	13/01/2008	01:00	21,516	-26,464	UW74	28/01/2008	03:00	16,377	-29,734
UW27	13/01/2008	11:00	20,627	-25,97	UW75	28/01/2008	08:20	16,550	-28,832
UW28	13/01/2008	23:00	19,811	-25,519	UW76	28/01/2008	11:00	16,642	-28,374
UW29	14/01/2008	03:00	19,26	-25,217	UW77	28/01/2008	17:00	16,841	-27,324
UW30	14/01/2008	11:00	18,741	-24,933	UW78	29/01/2008	07:00	18,043	-26,623
UW31	14/01/2008	17:00	18,402	-24,751	UW79	29/01/2008	11:00	18,709	-26,702
UW32	14/01/2008	21:00	18,133	-24,604	UW80	29/01/2008	15:00	19,390	-26,782

UW33	15/01/2008	01:00	17,888	-24,469	UW81	29/01/2008	19:00	20,082	-26,865
UW34	15/01/2008	17:00	17,378	-24,52	UW82	29/01/2008	23:00	20,776	-26,948
UW35	15/01/2008	21:00	16,895	-25,081	UW83	30/01/2008	11:00	22,383	-27,142
UW36	16/01/2008	01:00	16,256	-25,27	UW84	30/01/2008	17:00	22,979	-27,286
UW37	16/01/2008	11:00	15,327	-25,43	UW85	30/01/2008	21:00	23,613	-27,643
UW38	16/01/2008	17:00	14,97	-25,485	UW86	31/01/2008	11:00	25,155	-28,321
UW39	16/01/2008	21:00	14,36	-25,597	UW87	31/01/2008	17:00	25,495	-27,669
UW40	17/01/2008	01:00	13,726	-25,705	UW88	31/01/2008	21:00	25,705	-27,280
UW41	17/01/2008	11:00	12,848	-25,858	UW89	01/02/2008	11:00	26,200	-26,249
UW42	18/01/2008	01:00	12,657	-26,364	UW90	01/02/2008	15:00	26,276	-25,788
UW43	18/01/2008	11:00	12,662	-27,464	UW91	01/02/2008	19:00	26,346	-25,298
UW44	18/01/2008	19:00	12,626	-28,114	UW92	01/02/2008	23:00	26,420	-24,755
UW45	18/01/2008	23:00	12,613	-28,854	UW93	02/02/2008	11:00	26,658	-23,321
UW46	19/01/2008	03:00	12,598	-29,594	UW94	02/02/2008	17:00	26,745	-22,801
UW47	19/01/2008	07:00	12,608	-29,997	UW95	02/02/2008	21:00	26,873	-22,056
UW48	19/01/2008	11:00	12,609	-30,278	UW96	03/02/2008	01:00	26,997	-21,290

Table 1. List and position of the underway samples

Cast	Depths sampled	Cast	Depths sampled
16384A	5,10,30,70,110,180,300 m	16407A	5,10,30,55,75,100,150,300 m
16387A	5,10,30,50,75,100,150,300 m	16411A	5,20,40,65,80,100,150,300 m
16390A	2,10,30,50,80,110,150,300 m	16415A	5,20,40,65,80,100,150,300 m
16392A	5,10,30,50,160 m	16418A	5,20,40,66,77,100,150,300 m
16392AA	80,120,140,300 m	16420A	5,20,60,77,87,100,150,300 m
16394A	5,10,30,50,75,130,160,300 m	16423A	2,20,40,70,83,120,150,300 m
16395B	5,60,110,150,300,500,1000, 1500(x2),1800(x2) m	16425A	2,20,40,60,85,100,150,300 m
16396A	2,10,30,50,100,120,150,300 m	16428A	5,20,40,65,80,100,150,300 m
16398A	5,10,30,70,95,110,150,300 m	16429A	2,20,40,60,90,120,150,300 m
16400A	5,20,35,55,75,100,150,300 m	16431A	5,20,40,80,120,140,200,300 m
16402A	5,10,30,45,60,80,150,300 m	16432A	5,30,50,75,100,135,200 300 m
16402B	600,989,1483,1986,2484,3596 m	16433A	5,10,20,60,100,155,200,300 m
16403A	5,25,40,57,80,100,200,300 m	16435BB	20,150,308,507,995,1485,1979, 2475,3475,4223,4532 m

Table 2. List of the stations and depths sampled for DIC and TA measurements

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Surface water concentrations of iodocarbons in the Tropical Atlantic

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Introduction

'Over the side' measurements
The sea to air transfer of volatile iodine containing gases (iodocarbons) is the primary route of iodine into the atmosphere. Once in the atmosphere iodocarbons are photolysed to form iodine radicals which react with ozone to form iodine oxides. The iodine oxides have been shown to produce particles which can potentially cause cloud formation. During high dust events atmospheric mixing ratios of methyl iodide (CH_3I) were found to be elevated relative to those in low dust conditions (Williams et al., 2007). Despite the rapid CH_3I production observed in a series of dust addition experiments using filtered, uv-irradiated seawater, the concentrations required to produce the increase in atmospheric mixing ratios were more than double those found at 5 m water depth. Here, iodocarbon analysis was carried out on surface water samples (<1-5 m) before, during and after 2 major dust events in the Tropical Atlantic. In addition to methyl iodide, chloroiodomethane (CH_2ClI), iodoethane (C_2H_5I), diiodomethane (CH_2I_2) and bromoiodomethane (CH2BrI) were also measured quantitatively. To examine potential factors which may also impact iodocarbons, surface water concentrations were measured in a range of water masses during non-dust events.

Incubation studies
As well as the potential increase in iodocarbon concentrations due to atmospheric dust inputs, these compounds are known to have other multiple oceanic sources and sinks. Photochemical and biological iodocarbon production and removal have been observed with an additional chemical loss occurring through nucleophilic substitution with the chloride ion (Moore and Zafirou, 1994; Tokarczyk and Moore, 1994; Elliot and Rowland, 1993). While the level of understanding of these production/destruction pathways is improving, there is a need for quantification of the rates at which these processes occur in order to predict the impact of these climatically active gases. Here, stable isotope addition experiments were used to determine iodocarbon loss and production rates in Tropical Atlantic surface waters. This work was started on the previous cruise D325 (13/11/07 – 18/12/07) and continued on D326. During D326, the focus of this work was to quantify the rates of photochemical and biological losses of CH_2I_2 in light and dark incubations of filtered and unfiltered surface seawater, respectively, both with $^{13}CH_2I_2$ enrichment.

Methods

Over the side measurements
Seawater was sub-sampled into 300 ml ground glass stoppered amber bottles from 20 litre steel sprung Niskin bottles on the CTD sampling rosette. Forty ml aliquots of the seawater were filtered through a GF/F filter (0.7 µm pore size, Fisher) into a 100 ml glass stripper. Seawater was purged for 20 minutes with high purity nitrogen (Built in purifier (BIP™). Water vapour was removed with a Nafion™ counter-flow (Perma-Pure, USA) drier and iodocarbons were cryogenically trapped in an unpacked steel loop at -150°C. Samples were desorbed at 100°C prior to injection onto a ZB-624 megabore capillary column (75 m x 0.53 mm x 3 µm film thickness) and analysed on a Hewlett-Packard 5890 gas chromatograph with electron capture detection (GC-ECD). For calibration of the individual iodocarbons liquid standards of known concentrations were injected into pre-purged filtered seawater and analysed using the same method as the sample analysis. The samples analysed for the over the side iodocarbon concentrations are listed in Table 1.

Table 1: CTD stations sampled for iodocarbon analysis.

Date	Station	Niskin	Depth (m)	Sample bottle
07/01/08	CTD16385A	14	5	B7
	CTD16385A	14	5	B8
	CTD16385A	15	3	B4
	CTD16385A	15	3	B5
	CTD16385A	24	3	B8
	CTD16385A	24	3	B9
08/01/08	CTD16387A	13	5	B7
	CTD16387A	13	5	B8
	CTD16387A	13	5	B9
09/01/08	CTD16390C	13	5	B4
	CTD16390C	13	5	B5
	CTD16390C	13	5	B6
10/01/08	CTD16392C	13	5	B4
	CTD16392C	13	5	B5
	CTD16392C	13	5	B6
11/01/08	CTD16394C	13	5	B4
	CTD16394C	13	5	B5
	CTD16394C	13	5	B6
12/01/08	CTD16396A	21	2	B4
	CTD16396A	21	2	B5
	CTD16396A	21	2	B6
13/01/08	CTD16398C	13	5	B4
	CTD16398C	13	5	B5
	CTD16398C	13	5	B6
14/01/08	CTD16400C	11	5	B4
	CTD16400C	11	5	B5

	CTD16400C	11	5	B6
15/01/08	CTD16402C	13	5	B4
	CTD16402C	13	5	B5
	CTD16402C	13	5	B6
16/01/08	CTD16403C	13	5	B4
	CTD16403C	13	5	B5
	CTD16403C	13	5	B6
17/01/08	CTD16405C	13	5	B4
	CTD16405C	13	5	B5
	CTD16405C	13	5	B6
18/01/08	CTD16407C	24	5	B4
	CTD16407C	24	5	B5
	CTD16407C	24	5	B6
19/01/08	CTD16409C	14	5	B4
	CTD16409C	14	5	B5
	CTD16409C	14	5	B6
20/01/08	CTD16411C	16	5	B4
	CTD16411C	16	5	B5
	CTD16411C	16	5	B6
21/01/08	CTD16413C	14	5	B4
	CTD16413C	14	5	B5
	CTD16413C	14	5	B6
22/01/08	CTD16415C	14	5	B4
	CTD16415C	14	5	B5
	CTD16415C	14	5	B6
23/01/08	CTD16417A	19	5	B4
	CTD16417A	19	5	B5
	CTD16417A	19	5	B6
24/01/08	CTD16419C	16	5	B4
	CTD16419C	16	5	B5
	CTD16419C	16	5	B6
25/01/08	CTD16420A	21	2	B4
	CTD16420A	21	2	B5
	CTD16420A	19	10	B9
	CTD16420A	19	10	B6
26/01/08	CTD16422A	21	2	B4
	CTD16422A	19	10	B6
	CTD16423A	21	2	B4
	CTD16423A	19	10	B6
27/01/08	CTD16425A	21	2	B4
	CTD16425A	21	2	B5
	CTD16425A	19	10	B6
	CTD16426A	21	4	B4
	CTD16426A	21	4	B5

	CTD16426A	19	10	B6
	CTD16428A	21	5	B4
	CTD16428A	21	5	B5
30/01/08	CTD16429A	24	2	B4
	CTD16429A	24	2	B5
	CTD16429A	19	10	B6
	CTD16429A	19	10	B9
	CTD16430A	21	2	B4
	CTD16430A	21	2	B5
	CTD16430A	19	10	B6
	CTD16430A	19	10	B9
31/01/08	CTD16431A	21	5	B4
	CTD16431A	21	5	B5
	CTD16431A	19	10	B6
	CTD16431A	19	10	B9

In addition, 58 underway samples were collected from the trace metal fish (FSH) and bucket samples from the near-surface and analysed for iodocarbons.

Incubation studies
Seawater was sub-sampled into 2 L ground glass stoppered bottles from 10 or 20 litre steel sprung Niskin bottles on the CTD sampling rosette. The water was then transferred to a 1 L glass stoppered bottle (no headspace) and $^{13}CH_2I_2$ was added with a gas tight syringe (Hamilton) at approximately 3-50 times the surface concentration. The process was repeated with 300 kDa filtered water. Following a 30 minute mixing period the labelled water was transferred into 100 ml glass stoppered bottles and foil wrapped for dark incubations or 100 ml quartz tubes for light incubations. Prior to addition, serial dilutions (primary and secondary) of the primary compounds were carried out in 60 ml of in methanol with a tertiary dilution into de-ionised water (MQ water). All incubations were carried out in on-deck incubators with flow through seawater. Forty ml aliquots of the incubated seawater were filtered through a GF/F filter (0.7 µm pore size, Fisher) into a 100 ml glass stripper. Seawater was purged for 20 minutes with high purity helium (Built in purifier (BIP™). Water vapour was removed with a Nafion™ counter-flow (Perma-Pure, USA) drier and iodocarbons were cryogenically trapped in an unpacked steel loop at -150°C. Samples were desorbed at 100°C prior to injection onto a DB-VRX capillary column (60 m x 0.32 mm x 1.8 µm film thickness) and analysed on an Agilent 6890/5973 Network GC-MS with mass selective detector operating in selective ion monitoring mode (SIM). During stripping, 40 pmol of CD_3I (99% CK Gas, UK) was injected from a 100 ul gas loop (10 ppb) into the helium flow upstream of the seawater sample to use as an internal standard). For calibration of the individual iodocarbons liquid standards of known concentrations were injected into pre-purged filtered seawater and analysed using the same method as the sample analysis.

Preliminary Results

Over the side measurements

CH_3I and CH_2ClI were found to have the highest overall concentrations of the measured iodocarbons with mean concentrations of 4.2±1.6 (1.5-10.5) pmol dm^{-3} and 4.7±1.3 (2.5-9.4) pmol dm^{-3}, respectively (Figure 1). C_2H_5I, CH_2I_2 and CH_2BrI were detected at much lower concentrations in all samples but their precise concentrations have yet to be calculated. There was an apparent rise in the surface water concentration of CH_3I while in 'dusty' waters but these results need to be checked against the ancillary data to check for potential differences in water masses, communities and biomass that could also cause the observed increase.

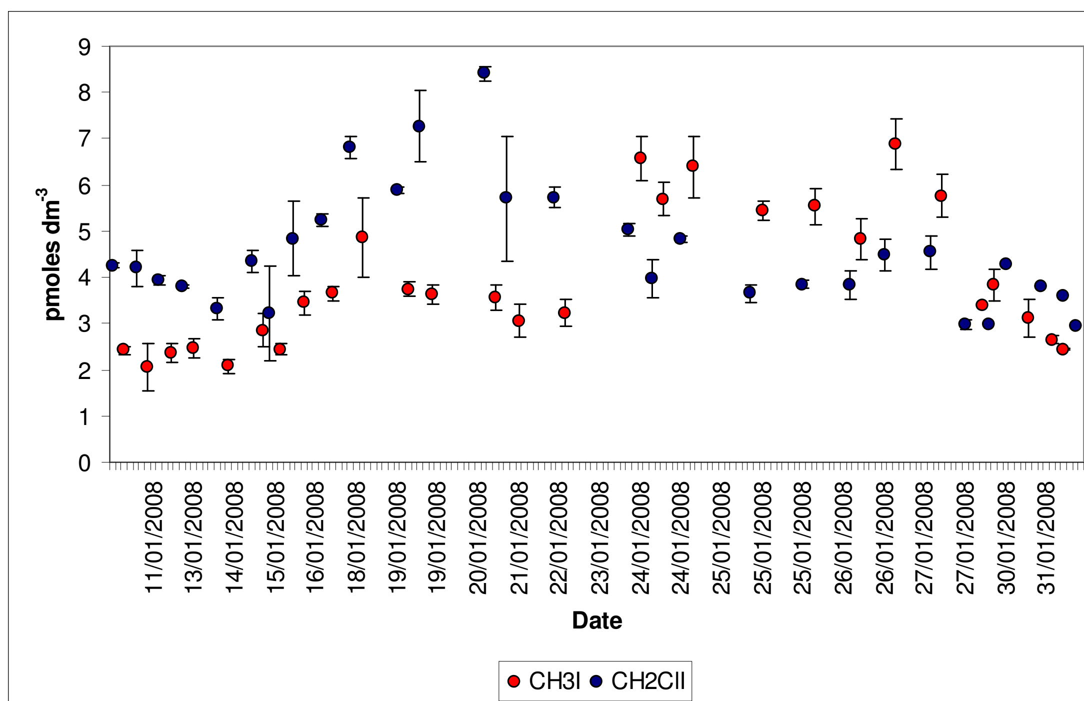

Figure 1: Surface (2-5 m) water concentrations of methyl iodide (CH_3I) and chloroiodomethane (CH_2ClI) in pmol dm^{-3} measured during D326.

Incubation studies

A total of 13 isotope addition experiments were carried out during different periods of the sunlit day (early morning/midday/late afternoon) to determine the light dependent variability in the rate of CH_2I_2 photolysis. The results show that $^{13}CH_2I_2$ was rapidly photolysed with conversion of $^{13}CH_2I_2$ into $^{13}CH_2ClI$ with an approximately 25%, mole to mole, yield. Differences in the rate of $^{13}CH_2I_2$ were observed with the fastest rate generally occurring in the midday period. There was a high degree of variability in the extent of cloud cover on a day to day basis and the UV and irradiance data will be examined in an attempt to relate any differences in photolysis rates directly to variability in UV and solar irradiance. In addition, while $^{13}CH_2I_2$ generally reached non-detectable

concentrations rapidly, very low concentrations of $^{12}CH_2I_2$ remained. It is therefore hoped that a rate of CH_2I_2 production can also be derived from these experiments.

Acknowledgements

Many thanks to the captain and crew of the RRS *Discovery*. Special thanks to Ian Slater (Chief engineer) and Dennis Jakobaufderstroht (ETO) for fixing the GCMS oven when much required. Also thanks to the NMFers for CTD operations and technical support. In addition, thanks to Gareth Lee and Claire Hughes (UEA) for providing the liquid iodocarbon standards.

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Collection of samples for protein and DNA/RNA analysis

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Introduction

Samples were collected for protein and DNA/RNA analysis to investigate the effect of iron (Fe) availability on phytoplankton physiology. Iron (Fe) is a fundamental requirement for photosynthetic cells due to the absolute iron requirement of key metabolic proteins in their photosynthetic apparatus and additionally for diazotrophs within their nitrogen fixation apparatus (Shi et al. 2007). Thus Fe availability has the potential to limit the abundance of these proteins and set a limit on metabolic activity and hence primary production and/or nitrogen fixation. Quantification of key metabolic proteins in samples taken from regions of high and low Fe will provide an insight into the effect of Fe availability on the synthesis of these proteins.

Methods

Water samples were collected from the stainless steel CTD for both protein and DNA/RNA samples. For protein samples 20L of water was taken from both the surface (2m or 5m) and the deep chlorophyll maximum (DCM). In the absence of a DCM, water samples were taken from the bottom of the mixed layer depth (See Table 1 for station numbers and water collection depth). For DNA/RNA samples 3L of water was taken from the same depths as above. Water samples were collected in either polyethylene carboys (protein samples) or polycarbonate bottles (DNA/RNA samples). All carboys and bottles were darkened using black refuse sacks. Pluronic acid solution was added to a final concentration of 0.02% to all water samples before filtering. All samples were collected using a peristaltic pump set at 100 rpm. Samples for protein analysis were collected using a 0.2µm CellTrap. Estimates of cell recovery from the CellTraps were made using Fast Repetition Rate Fluorometry (FRRF) and the Fluorescence Induction and Relaxation (FIRe) technique. 2ml of concentrate were eluted from the CellTraps and flash-frozen using liquid nitrogen. Initially concentrates were eluted at the end of filtering (~3.5 hour for 20L), however this gave low cell recovery (see below). To improve cell recovery concentrates were eluted at 1 hour and 0.5 hour intervals (see below for results). Sub samples of the concentrate were taken and diluted with 0.2µm filtered seawater to run on the FRRF and FIRe and for flow cytometry analysis. Flow cytometry samples were fixed with paraformaldehyde and frozen at -80°C for analysis at the NOCS. DNA/RNA samples were filtered using 0.2µm Supor membrane filters. Filters were placed in RNA*later* solution and flash-frozen in liquid nitrogen. *Trichodesmium* samples were collected for protein and DNA/RNA analysis using a plankton net with a 60µm mesh (See Mark Moore's report for details on station numbers and samples taken). Picked colonies were flash-frozen in liquid nitrogen. All protein and DNA/RNA samples were stored at -80°C.

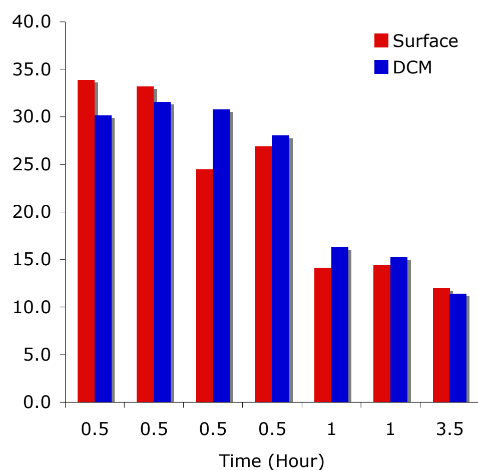

Figure 1. *Comparison of cell recoveries from both surface and DCM samples. Time indicates different time intervals of sample elution.*

Cell Recovery from the CellTrap

Protein samples were eluted at 0.5 hour intervals as this time period was found to give the highest cell recovery. Cell recovery was between 25 and 30% for 0.5 hour intervals, 15 – 20% for 1 hour intervals and ~10% when the sample was eluted at the end of filtering (~3.5 hours) (Fig. 1).

Table 1. *Station numbers, dates, depths of water collection and samples collected for protein and DNA/RNA analysis.*

Station Number	Date	Depth	Samples collected	
16384A	7/01/08	5m	Protein	
		110m	Protein	
16386A	7/01/08	5m	Protein	
		130m	Protein	
16387A	8/01/08	5m	Protein	DNA/RNA
		115m	Protein	DNA/RNA
16390A	9/01/08	5m	Protein	DNA/RNA
		130m	Protein	DNA/RNA
16392A	10/01/08	5m	Protein	DNA/RNA
		140m	Protein	DNA/RNA
16394A	11/01/08	5m	Protein	DNA/RNA
		130m	Protein	DNA/RNA
16396A	12/01/08	2m	Protein	DNA/RNA
		120m	Protein	DNA/RNA
16398A	13/01/08	5m	Protein	DNA/RNA
		95m	Protein	DNA/RNA
16400A	14/01/08	2m	Protein	
		55m	Protein	
16402A	15/01/08	5m	Protein	DNA/RNA
		60m	Protein	DNA/RNA
16403A	16/01/08	5m	Protein	DNA/RNA
		57m	Protein	DNA/RNA
16407A	18/01/08	5m	Protein	DNA/RNA
		55m	Protein	DNA/RNA
16409A	19/01/08	5m	Protein	DNA/RNA
		56m	Protein	DNA/RNA
16411A	20/01/08	5m	Protein	DNA/RNA
		65m	Protein	DNA/RNA
16413A	21/01/08	5m	Protein	DNA/RNA
		65m	Protein	DNA/RNA
16415A	22/01/08	5m	Protein	DNA/RNA
		65m	Protein	DNA/RNA
16517A	23/01/08	5m	Protein	
		80m	Protein	
16419A	25/01/08	5m	Protein	DNA/RNA
		80m	Protein	DNA/RNA
16422A	26/01/08	2m	Protein	DNA/RNA
		90m	Protein	DNA/RNA
16423A	26/01/08	4m	Protein	
		85m	Protein	
16425A	27/01/08	2m	Protein	DNA/RNA
		85m	Protein	DNA/RNA
16428A	28/01/08	5m	Protein	
		68m	Protein	
16429A	30/01/08	2m	Protein	DNA/RNA
		120m	Protein	DNA/RNA
16431A	31/01/08	5m	Protein	DNA/RNA
		140m	Protein	DNA/RNA

16432A	1/02/08	5m	Protein	DNA/RNA
		135m	Protein	DNA/RNA
16433A	2/02/08	5m	Protein	DNA/RNA
		155m	Protein	DNA/RNA
16435A	3/02/08	5m	Protein	
		125m	Protein	

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Determination of alkaline phosphatase activity in surface seawater and isolated *Trichodesmium* colonies

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Introduction

The eastern North Atlantic (sub) tropical gyre is characterized by extremely low concentrations of nitrate and phosphate (< 10nM) in the upper water column supporting low phytoplankton biomass and rates of primary production. However, this oceanic region receives large aeolian inputs from the Sahara desert, naturally fertilizing the upper water column with iron. It is hypothesized that episodic inputs of iron-rich dust supports and periodically enhances extensive communities of iron-demanding nitrogen fixers that have the ability to fix dinitrogen gas (N_2). However, N_2 fixers are phosphate-demanding and to date, there is no evidence for an equivocal input of phosphorus from aeolian dust inputs. Thus, the source of phosphorus to the N_2 fixing community remains a conundrum in these subtropical regions of the ocean.

Despite inorganic phosphate concentrations being depleted in the subtropical ocean, there is a large complex pool of dissolved organic-bound phosphorus (DOP) that can be up to two orders of magnitude more abundant than phosphate. Little is known about the composition of DOP, but both autotrophic and heterotrophic organisms have the ability to access DOP via extracellular hydrolytic enzymes, such as alkaline phosphatase and nucleotidase that cleave phosphate esters from organic molecules.

The ubiquitous marine nitrogen fixer, *Trichodesmium* spp., and potentially other members of the N_2 fixing community, are known to produce alkaline phosphatase in response to phosphorus stress, the activity of the enzyme being indicative of relative phosphorus limitation. Some organisms (including *Trichodesmium*) may also use enzymes to access the phosphorus contained in phosphonate bonds (Dyhrman et al., 2006).

The objective of this study was to take advantage of the natural-iron fertilization event being investigated by UK SOLAS cruise in January 2008 (*Discovery* 326) and to assess the ability of the phytoplankton community, and *Trichodesmium* specifically, to relieve phosphorus stress through production of alkaline phosphatase and assimilation of some part of the DOP pool. Alkaline phosphatase activity (APA) was determined using methods described by Ammerman (1993). The principle of the technique involves incubating seawater or species-specific concentrates with an organic phosphate analog which has little fluorescence when derivatized with phosphate (4-methylumbelliferyl phosphate, MUFP) but is highly fluorescent when not derivatized (4-methylumbelliferone, MUF). Thus, the activity of alkaline phosphatase is determined simply by the increase in fluorescence over time as more phosphate is hydrolyzed by the enzyme, alkaline phosphatase. In addition, surface seawater samples were collected for laboratory assessment of the chemical lability/stability of the DOP pools in different

regions sampled (dust-rich versus dust poor). Samples were also collected for determination of particulate phosphorus concentrations.

Methods

Alkaline phosphatase activity was determined at morning stations only (except on one occasion, see Table 1), either using seawater collected from titanium-framed CTD (20m or profile) or using *Trichodesmium* collected using a plankton net.

Whole community alkaline phosphatase activity

Seawater was collected from the non-toxic seawater system (~7m) or from Niskin bottles attached to the titanium CTD frame (either 20m water or 5 light depths, 97%, 55%, 33%, 14% and 1% surface irradiance). 250ml of seawater was placed in an acid-cleaned 250ml polycarbonate bottle. If activity was to be determined at one depth only (20m), a kinetics study was performed, involving the addition of MUF-P at concentrations ranging from 100nM to 1000nM in 250ml. If activity was to be determined throughout the water column, MUF-P was added to yield a final concentration of 200nM. Bottles were placed in an on-deck, surface seawater-cooled incubator for a period of at least 12-hours.

Trichodesmium-specific alkaline phosphatase activity

Colonies of *Trichodesmium* were collected using a 50 cm (3:1 ratio), 100µm mesh or a 50 cm (4:1 ratio), 60 µm mesh plankton net with a solid cod end deployed to a depth of 10-15 m. Both "tuff" and "puff" colonial forms were picked using plastic inoculating loops and placed in unfiltered surface seawater. 20 to 22 colonies were placed into 125ml acid-cleaned polycarbonate containing 125ml unfiltered seawater. MUF-P was added to each polycarbonate bottle to yield a final concentration of 200nM. The alkaline phosphatase activity of the unfiltered seawater containing no *Trichodesmium* colonies was also determined. The bottles were placed in an on-deck, surface seawater-cooled incubator for a period of at least 12-hours. Upon termination of the experiment, the contents of each polycarbonate bottle were filtered onto a glass fiber filter and stored at -80°C for analysis of chlorophyll *a* at the University of Liverpool.

Alkaline phosphatase activity

Fluorescence was determined using a Turner 10Au field fluorometer fitted with optical filters with excitation near 365nm and emission near 455nm (Optical kit #10-302R). Upon addition of the MUF-P to either seawater or *Trichodesmium* incubations, 2ml of sample was removed immediately from each bottle to represent the initial fluorescence of the sample (T_{zero}) and added to 2ml of borate buffer (pH > 10.5). Fluorescence measurements were made every 1-2 hours for at least 12 hours.

MUF standards (50, 100, 200nM), blanks and killed controls (boiled seawater plus 200nM or 400nM MUFP) were incubated each day with seawater or *Trichodesmium* incubations. Fluoresence of MUF standards was determined at T_{zero} only, but fluorescence of the seawater blank and killed control was monitored throughout the day.

Rates of phosphorus hydrolysis by alkaline phosphatase were determined by calculating the change in fluorescence observed during the incubation time and dividing

by the fluorescence of the appropriate MUF standard. Rates were normalized to biomass, either chlorophyll or number of *Trichodesmium* colonies.

Bioassay experiments

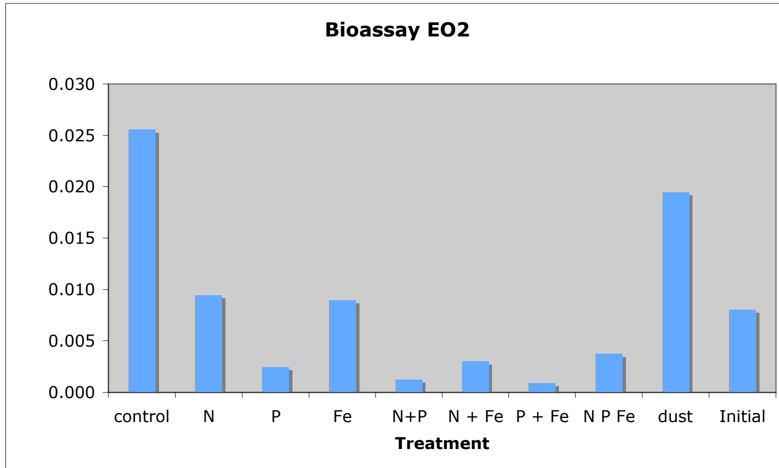
Alkaline phosphatase activity was determined on Bioassay experiments led by NOC. Activity was determined during the initial setup of the experiment (T_{zero}) using water collected from the tow-fish. Seawater was amended with up to 10 combinations of nitrate, phosphate, iron and dust. After 72 hours, 125ml of amended seawater was decanted into acid-cleaned 125ml polycarbonate bottles and MUF-P added to a final concentration of 200nM. Fluoresence was determined every hour for 12 hours. Biomass normalized alkaline phosphatase activity are shown in the preliminary results section below.

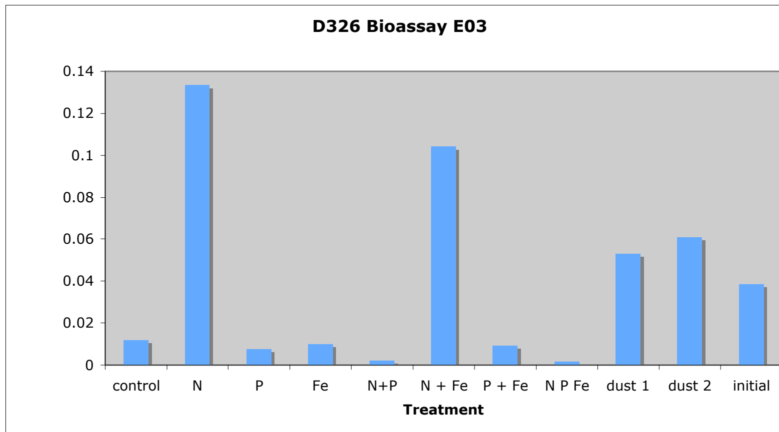
DOP lability studies and particulate phosphorus determinations

Seawater was collected from a niskin bottle fired at 20m on the titanium framed CTD in an acid-cleaned HDPE 250ml screw-top bottle and stored immediately at -20°C. One liter of seawater from 20m was filtered onto a pre-combusted/acid washed 25mm GFF, wrapped in foil and stored immediately at -20°C. Analysis will be performed at the University of Liverpool by high temperature combustion/acid hydrolysis.

Preliminary results

Rates of alkaline phosphatase activity from three bioassay experiments are shown in figure 1. Relative to EO3 and EO4, bioassay EO2 supported relatively low rates of alkaline phosphatase activity, with the control (no nutrient amendment) have the highest enzymatic activity. EO3 and EO4 yielded similar results, with the highest alkaline phosphatase activity being observed in the treatments were nitrogen was added as ammonium nitrate, leaving the microbial community phosphorus-starved. Interestingly, there was a considerable increase in alkaline phosphatase activity with the addition of natural dust relative to the control in EO3 and EO4.





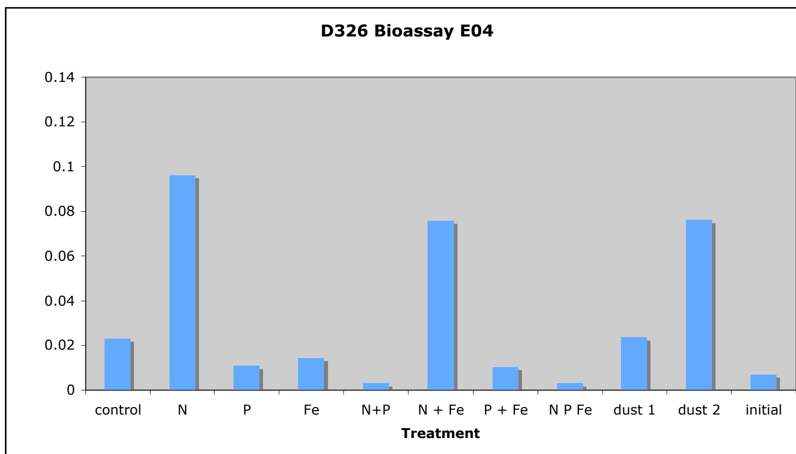


Figure 1. Rates of biomass normalized alkaline phosphatase activity (nmols P per hour per µg chlorophyll) for bioassay EO2 (top) bioassay EO3 (middle) and bioassay E04. Note the change in scale.

Supplementary sample collection

Supplementary samples were collected for *nifH*-gene analysis (La Roche, IFM-GEOMAR, Kiel) and determination of the genetic make-up of the *Prochlorococcus* community (Mine Berg, University of Stanford). Briefly, 2-3L and 5-10L were filtered for *nifH*-gene and *Prochlorococcus* community assessment, respectively. *nifH*-gene samples were stored at -80°C. *Prochlorococcus* community samples were flash-frozen in liquid nitrogen and stored at -80°C.

References

Ammerman, J. W., 1993. Microbial cycling of inorganic and organic phosphorus in the water column, p. 621-631 *In* P. F. Kemp, B. F. Sherr, E. B. Sherr and J. J. Cole [eds.], Handbook of methods in aquatic microbial ecology. Lewis Press.

Summary tables

Table 1. Summary of stations sampled and source of water for determination of whole community and *Trichodesmium* specific alkaline phosphatase activity, DOP lability studies and collection of sample for particulate phosphorus determinations.

Station number	Date	Sample source for APA	DOP lability studies	Particulate phosphate
16387	8/1/08	Non-toxic supply	250ml at 20m	
16390	9/1/08	Non-toxic supply and *Trichodesmium*	250ml at 20m	
16392	10/1/08	Non-toxic supply	250ml at 20m	
16394	11/1/08	Non-toxic supply	250ml at 20m	
16396	12/1/08	Tow-Fish	250ml at 20m	
16398	13/1/08	Non-toxic supply	250ml at 20m	
16400	14/1/08	Ti CTD profile	250ml at 20m	
16402	15/1/08	Ti CTD profile	250ml at 20m	
16403	16/1/08	Ti CTD profile and *Trichodesmium*	250ml at 20m	
16405	17/1/08	Ti CTD profile	250ml at 20m	
16407	18/1/08	Ti CTD profile	250ml at 20m	
16409	19/1/08	Ti CTD profile and *Trichodesmium*	250ml at 20m	
16411	20/1/08	Ti CTD 20m only and *Trichodesmium*	250ml at 20m	
16413	21/1/08	Ti CTD 20m only and *Trichodesmium*	250ml at 20m	1L onto GFF
16415	22/1/08	Ti CTD profile and *Trichodesmium*	250ml at 20m	1L onto GFF
16417	23/1/08	Ti CTD 20ml only and *Trichodesmium*	250ml at 20m	1L onto GFF
16418	24/1/08	Ti CTD 20ml only and *Trichodesmium*	250ml at 20m	1L onto GFF
16419	25/1/08	Ti CTD 20ml only and *Trichodesmium*	250ml at 20m	1L onto GFF
16422	26/1/08	Ti CTD 20ml only and *Trichodesmium*	250ml at 20m	1L onto GFF
16425	27/1/08	Ti CTD 20ml only, *Trichodesmium* and Bioassay EO4	250ml at 20m	1L onto GFF
16428	28/1/08	Ti CTD profile	250ml at 20m	1L onto GFF
16429	30/1/08	Ti CTD 20m only and *Trichodesmium*	250ml at 20m	1L onto GFF
16431	31/1/08	Ti CTD 20m only	250ml at 20m	1L onto GFF
16432	1/2/08	Ti CTD 20m only	250ml at 20m	1L onto GFF
16433	2/2/08	Ti CTD, 20m only	250ml at 20m	1L onto GFF

Table 2.

Station number	Date	nifH-gene: depth/light level collected and volume filtered	Prochlorococcus community: vol. filtered (ml)
16384	7/1/08	55%: 2740	No sample
16387	8/1/08	55%: 2650	No sample
16390	9/1/08	55%: 3250	No sample
		1%: 3100	
16392	10/1/08	55%: 2350	55%: 6390
		1%: 2500	1%: 6640
16394	11/1/08	55%: 3190	55%: 5940
		1%: 3050	1%: 6440
16396	12/1/08	Tow-fish: 3000	No sample
16398	13/1/08	55%: 3000	55%: 5860
		1%: 2700	1%: 6500
16400	14/1/08	55%: 2000	55%: 5000
		1%: 2000	1%: 5000
16402	15/1/08	55%: 4000	No sample
		1%: 4000	
16403	16/1/08	55%: 2500	55%: 7000
16405	17/1/08	55%: 3100	55%: 6540
16407	18/1/08	55%: 2700	No sample
16409	19/1/08	55%: 2200	55%: 6550
16411	20/1/08	55%: 2650	55%: 5300
16413	21/1/08	55%: 2000	20m: 6700
16415	22/1/08	20m: 2600	20m: 6600
16417	23/1/08	20m: 2750	20m: 5200
16418	24/1/08	20m: 2650	20m: 6400
16419	25/1/08	20m: 2720	20m: 6750
16422	26/1/08	20m: 2600	20m: 6400
16425	27/1/08	20m: 2450	20m: 7650
16428	28/1/08	20m: 2100	20m: 5700
16429	30/1/08	20m: 2650	20m: 6300
16431	31/1/08	20m: 2800	20m: 6900
16432	1/2/08	20m: 3100	20m: 6400
16433	2/2/08	20m: 2100	20m: 7100

Optics, D326 Cruise Report

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Aims

The main reason for participating on D326 was to generate a set of in situ optical measurements recorded before, during and immediately after a major Saharan dust deposition event in the eastern North Atlantic Ocean. This data set would be used to determine the impact of Saharan dust on water leaving radiance signals and the performance of satellite ocean colour retrieval algorithms. A second major objective would be determination of the impact of Saharan dust deposition on the underwater light climate and associated light availability for photosynthesis.

Work Completed

The optics work package consisted of three elements: Inherent Optical Property measurements (referred to as *particle profiling* during the cruise), Radiometry (referred to as *light profiling* during the cruise), and associated sample analyses.

The IOP package consisted of:
1x AC9+ ……absorption and attenuation at 9 wavelengths in visible and NIR
1x BB9………backscattering at 9 wavelength in visible and NIR
1x BB3………backscattering at 3 wavelength in visible and deeper NIR
1x CTD……...T and S for AC9+ correction, depth for BB3/BB9 and pump control
1x Chl F……..Chlorophyll fluorescence
1x CDOM F…Coloured Dissolved Organic Material fluorescence
1x H2………...backscattering at 2 wavelengths in visible

The radiometry package was based on Trios hyperspectral radiometers operating between ~350nm and 900nm, and included:
1x Ed………..downwards planar irradiance
1x Eod………downwards scalar irradiance
1x Eou………upwards scalar irradiance
1x Lu………..upwards radiance
1x Es………...above surface downwards planar irradiance

Associated analyses were carried out on filtered samples including:
FPA……….absorption by total particulate material retained on GF/F filter pads
BPA……….absorption by bleached particulate material (algal pigments extracted)
CDOM……absorption by dissolved material passed through 0.2mm membrane filters
SPM………mass concentration of particulate material retained on 90mm GF/F filters

The IOP package is based on sensors with active light sources that can be used during day and night conditions. This package was deployed 52 times with a single failure when

the AC9 suffered a memory corruption problem. Each cast of the IOP package was supported by sets of filter pad absorption measurements, usually at three depths. 148 total and bleached particulate absorption measurements were analysed using a benchtop spectrophotometer during the cruise. Initial difficulties with the experimental method meant that fewer CDOM measurements were taken, with a total of 83 samples being analysed with the benchtop spectrophotometer from station 21 onwards. SPM measurements did not commence until the latter half of the cruise once other core measurements were being made routinely. The large volume of water needed for these measurements (~50 L) necessitated bucket samples from the sea surface and considerable additional filtration time. As a result only 15 SPM samples were taken. Given the speculative nature of this measurement in these waters, this represents a cautious commitment of time and effort.

Work to be Completed

All in situ optical data has still to be processed including application of calibrations and corrections (scattering, temperature, salinity). IOP data will be stored in raw format and as 1m bin-averaged, fully corrected profiles. Other formats can be delivered upon request, subject to time constraints. Radiometric data will be processed to provide reflectances, diffuse attenuation coefficients and other derived products.

Filter pad and CDOM absorption measurements will be processed for baseline corrections and conversion to absorption coefficient units (m^{-1}). Filter pad absorption data will be presented as 1nm resolution spectra between 350 and 800nm, including total particulate, algal and detrital absorption spectra. SPM filters have been dried on board the vessel and will be re-weighed before and after ashing in a furnace at 500ºC to give total particulate, inorganic and organic mass concentrations.

Successes

During the course of the cruise we had the good fortune to be in position as a major dust deposition episode took place. We were able to observe baselines before the event took place and then monitor the impact of the dust deposition with an extensive set of in situ optical data with corresponding sample analyses. This is a unique data set that should be of considerable benefit for assisting in the interpretation of remote sensing data from this type of event.

From a personal perspective his cruise was extremely beneficial as I was able to improve my technical proficiency working with material concentrations at least an order of magnitude lower than I generally work with in coastal waters. The multidisciplinary nature of the research undertaken during the cruise was very interesting and I found discussing work with colleagues from such varied backgrounds highly stimulating. I am sure that participation in this cruise will bring long term career benefits and will assist in integrating my work into that of the broader UK oceanography community (a key goal of my current NERC Advanced Fellowship).

Areas for Future Development

The optically clear nature of the oligotrophic stations encountered during this cruise provided a distinct challenge in terms of measurement accuracy for optical data. This is particularly true for AC9+ and CDOM measurements where there is no scope for concentrating samples. The AC9+ performed well throughout the cruise, close to the theoretical tolerances provided by the manufacturer. Calibrations with ultra-pure water were performed on 4 occasions and in each case offsets were within reasonable tolerances. However, given the low signal to noise generated in these waters, it would be beneficial in future if calibrations could be performed before each cast. This is labour intensive, but would be justified in terms of guaranteed data quality. Measuring CDOM with a 10 cm cuvette in a benchtop spectrophotmeter was extremely challenging, with the signal to noise being generally rather poor. Other options that might be explored in future would include increasing the path length e.g. using a light guide system, or using a second AC9 with 0.2 µm filters on the intakes (25 cm pathlength).

A significant amount of time and effort was spent filtering samples for subsequent optical analyses. This was partly due to the optical clarity of these waters requiring filtration of approximately an order of magnitude more water in order to achieve the same optical density as previously found in coastal waters. For example, where in coastal waters 0.5L is sufficient for filter pad absorption and 5L is adequate for SPM, in these clear waters the required volumes were ~3 or 4L and ~50L respectively. My current filtration equipment was inadequate for efficiently handling these volumes and should be replaced with a system that permits handling of these volumes without continuous manual intervention. This would reduce the amount of time spent per sample, enabling the handling of a greater number of samples per cast and giving improved coverage of interesting structures within the water column. Of course, the availability of manpower remains a limiting consideration in these matters.

Conclusions

The value of the optical measurements taken during D326 will become apparent upon completion of processing and subsequent data analysis. Initial examination of raw data suggests that we have been successful in our attempts to observe the impact of dust on optical properties of the water column. For example, there is clear evidence of increased absorption in the blue and UV on bleached filter pad absorption measurements. Further analysis will undoubtedly lead to new insights into the optical effects of Saharan dust deposition.

Acknowledgements

I would like to record my gratitude to the PSO, Eric Achterberg, for providing me with the opportunity to participate on D326. It has been a pleasure to work with both the rest of the scientific party and the NMF personnel on board. All involved in the planning of this cruise deserve congratulations on the organisation which has been exemplary.

Measurement of D- and L-amino acids, Dissolved Organic Carbon, Dissolved Organic Nitrogen and Dissolved Organic Phosphorus

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Bacteria play an important role in degradation of organic compounds in the marine environment. Most amino acids in the seawater are L-amino acids. Peptidoglycan, the main component of bacteria cell walls, is the biochemical source of D-amino acids. In order to understand an effect of atmospheric inputs (dust and biomass burning aerosol) on bacterial activities in an open sea environment, seawater samples were collected from a stainless steel CTD for the measurement of D- and L-amino acids, Dissolved Organic Carbon (DOC), Dissolved Organic Nitrogen (DON) and Dissolved Organic Phosphorus (DOP) as shown in table 1.

Table 1. List of sampling stations

Cast	Time	Julian Day	Day
16382A	07.30	06	06/01/2008
16383A	15.00	06	06/01/2008
16384A	06.00	07	07/01/2008
16386A	14.00	07	07/01/2008
16387A	07.00	08	08/01/2008
16389A	20.20	08	08/01/2008
16390A	07.00	09	09/01/2008
16391A	15.30	09	09/01/2008
16392A,AA	07.15,09.20	10	10/01/2008
16393A	17.30	10	10/01/2008
16394A	06.45	11	11/01/2008
16395A	17.00	11	11/01/2008
16396A	06.30	12	12/01/2008
16397A	15.00	12	12/01/2008
16398A	06.50	13	13/01/2008
16399A	15.30	13	13/01/2008
16400A	07.15	14	14/01/2008
16401A	15.00	14	14/01/2008
16402A	06.45	15	15/01/2008
16402AA	13.45	15	15/01/2008
16403A	07.00	16	16/01/2008
16404A	15.00	16	16/01/2008
16405A	07.00	17	17/01/2008
16407A	06.30	18	18/01/2008
16408A	14.45	18	18/01/2008
16409A	07.00	19	19/01/2008
16410A	16.00	19	19/01/2008
16411A	07.00	20	20/01/2008
16412A	15.45	20	20/01/2008
16413A	06.30	21	21/01/2008
16414A	15.30	21	21/01/2008
16415A	07.00	22	22/01/2008
16416A	15.30	22	22/01/2008
16417A	09.40	23	23/01/2008
16418A	12.00	24	24/01/2008
16419A	06.46	25	25/01/2008
16420A	15.45	25	25/01/2008
16422A	06.30	26	26/01/2008
16423A	15.30	26	26/01/2008
16425A	06.45	27	27/01/2008
16426A	15.00	27	27/01/2008

16428A	22.10	28	28/01/2008
16429A	06.30	30	30/01/2008
16430A	15.30	30	30/01/2008
16431A	07.30	31	31/01/2008
16432A	08.45	32	01/01/2008
16433A	06.10	33	02/01/2008
16434A	15.15	33	02/01/2008
16435A	05.45	34	03/01/2008

Seawater samples for measurement of D- and L-amino acid concentrations were gently filtered through 0.2 µM Syringe Filter (33 mm, Cellulose Acetate) immediately after collection to remove phytoplankton and protests and stored frozen (-80 °C) until analysis. The samples will be analyzed at National Oceanography Centre, Southampton, by HPLC following the method reported by Lindroth and Mopper (1979).

Seawater samples for measurement of DOC and DON concentrations were filtered through combusted (450 °C, 4-6 h) glass-fibre filters (Whatman, GF/F). The filtrate was transferred to a combusted (450 °C, 4-6 h) glass ampoule and stabilised by acidification to pH 2 using 100 µL of 50 % v/v hydrochloric acid per 100 mL sample. After acidification, the ampoule was flame-sealed using butane burner. The ampoules have been stored in the refrigerator (4 °C) until analysis. The samples will be analyzed at National Oceanography Centre, Southampton, by HTCO (high-temperature catalytic oxidation) following Badr et.al. (2003).

Seawater samples for measurement of DOP concentration were filtered through glass-fibre filters (Fisherband) to remove particle materials. Total dissolved phosphorus (TDP) was measured by irradiating the filtrate under a UV lamp to oxidise organic phosphorus into phosphate, which was measured by colorimetry. DOP was calculated by measuring TDP and subtracting DIP. Figure 1 shows the profile of DOP concentration at station 16405 A.

Due to an inefficiency of the UV lamp, the measurement of DOP for station 16383-16404 will be repeated by using seawater from Titanium CTD at National Oceanography Centre, Southampton.

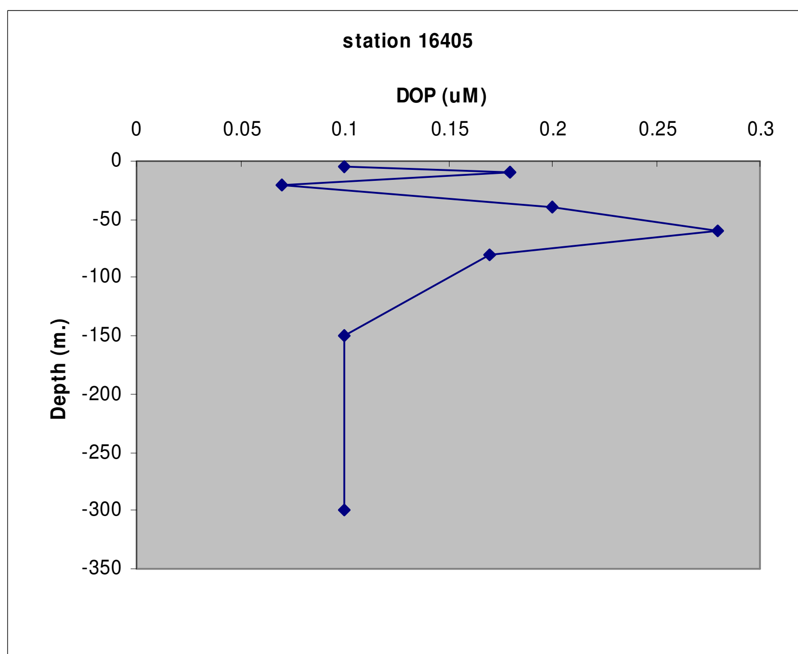

Figure 1 Profile of DOP concentration in seawater collected at station 16405 A (depths : 5,10,20,40,60,80,150 and 300 metres)

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Nitrogen fixation measurements and sampling for *Trichodesmium* abundance and activity

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Introduction

The importance of marine nitrogen fixation in fuelling new production in open ocean environments has likely been underestimated until recently. Additionally, the relative importance of various abiotic and biotic factors in controlling the distribution and activity of nitrogen fixers in the ocean remain unclear (Mahaffey et al. 2005). The bulk of marine nitrogen fixation was previously attributed to the filamentous cyanobacteria *Trichodesmium* sp., however new evidence suggests that the diversity of marine diazotrophs is greater than previously believed, and that the activity of these newly recognized diazotrophs may be equal to, or greater than, that of *Trichodesmium* sp. The D326 cruise presented an ideal opportunity to quantify the abundance and activity of different diazotroph groups in a region of high atmospheric dust inputs. Enhanced nitrogen fixation has been hypothesized to occur in this region as a result of the relief of the iron limitation suggested to prevail elsewhere in the ocean (Falkowski, 1997; Mahaffey et al. 2005).

N_2 fixation rate measurements

Water column measurements of nitrogen fixation by the whole community and the <10 µm fraction allowed for the determination of the contribution of *Trichodesmium* sp. (and potentially diatoms with endosymbiontic diazotrophs) and free living non-filamentous diazotrophs respectively, to total community nitrogen fixation (Table 1). Depending on the station (Table 1), samples were either collected from 5 depths nominally chosen to approximate 97, 55, 33, 14 and 1 % of surface irradiance or in duplicate from a single depth in the mixed layer (20 m) and incubated at the 55% light level. Samples for the <10 µm fraction were prefiltered through Nitex mesh. Nitrogen fixation measurements were made by incubating 4.5 litres of seawater with the stable isotope $^{15}N_2$. Incubations were terminated after 24 h by filtration onto precombusted GF/F filters and the samples dried and stored for isotope ratio mass spectrometry analysis. In the majority of stations the stable isotope ^{13}C was also added, allowing additional assessment of CO_2 fixation. At 2 stations (16417 and 16420) *Trichodesmium* colonies were also collected from net hauls and resuspended in filtered seawater for assessment of nitrogen fixation (and hence diazotrophic growth rates) specific to this organism (Table 1).

Assessment of *Trichodesmium* abundance and biomass

Samples for assessment of *Trichodesmium* spp. abundance were obtained from a single depth within the mixed layer (5 or 20 m) at all dawn stations and a limited number of afternoon stations (Table 1). The entire contents of a 10 L Niskin bottle were filtered through a 10 µm Nitex mesh. Particulate material including *Trichodesmium* colonies and filaments as well as any other large plankton was then gently resuspended off the mesh using filtered seawater and preserved in acidic lugols iodine for return to the laboratory and later enumeration by microscopy. In order to asses the relative contribution *Trichodesmium* to total autotrophic community biomass, chlorophyll content per colony was also assessed on 5-20 individual colonies picked from net hauls (see below) at a number of stations (Table 1). Additionally, a further whole 10 L Niskin bottle was gravity filtered onto a 10 µm polycarbonate filter at a limited number of stations in order to asses the chlorophyll concentration in the >10 µm (likely *Trichodesmium* dominated) size fraction (Table 1).

Collection of *Trichodesmium* using drift nets

Plankton nets of 60 and 100 µm mesh sizes were deployed in order to collect intact *Trichodesmium* colonies for assessment of a number of variables/rates including alkaline phosphatase activity (see separate section by Mahaffey), colony chlorophyll content (see above), colony protein abundance (see separate section by Macey) and P700 abundance/activity (see below). Nets were deployed off the CTD gantry using the small capston winch. Nets were held at a depth of 10 meters to allow gentle concentration of *Trichodesmium* to occur via the drift of water past the ship. Unfortunately the 100 µm net was lost on cast 16396, likely as a result of a carabineer rather than a locking shackle being used to attach the net to the weighted wire. Hence from station 16398 onwards only the 60 µm net was used.

Preliminary results

Colony sizes and *Trichodesmium* abundance varied greatly, with highest densities observed towards the south of the study region. Preliminary data analysis indicated a range of around 5- 60 ng chlorophyll per colony and concentrations of up to 0.035 mg *Trichodesmium* chlorophyll m^{-3}, equivalent to 10-20% of total community chlorophyll. These preliminary data are in good agreement with previous results from this region, albeit during a different season (Carpenter et al. 2004).

Station	**N_2 fixation, Whole water and < 10 µm (light depths)**	**Tricho' lugols sample (name)**	**Tricho' specific N_2 fixation**	**Tricho' colony chlorophyll**	**>10 um chlorophyll**	**Tricho' DNA sample**	**Tricho' colonies collected for protein (# samples)**	**Tricho' concentrate collected for protein (# samples)**	**P700**
16382	97,55,33,14,1								
16384	97,55,33,14,1	Tricho 1							
16387	97,55,33,14,1	Tricho 2				✓			
16390	97,55,33,14,1	Tricho 3							
16392	97,55,33,14,1	Tricho 4							
16394	97,55,33,14,1	Tricho 5				✓			
16396	55	Tricho 6		✓		✓			
16398	97,55,33,14,1	Tricho 7							
16400	55	Tricho 8							
16402	97,55,33,14,1	Tricho 9							
16403	55	Tricho 10		✓		✓	**1**	**2**	✓
16405	55	Tricho 11							
16407	55	Tricho 12		✓			**1**		
16409	97,55,33,14,1	Tricho 13		✓		✓	**6**	**1**	✓
16410	97,55,33,14,1	Tricho 14					**4**		✓
16411	97,55,33,14,1	Tricho 15		✓			**5**	**1**	✓
16413	97,55,33,14,1	Tricho 16		✓					
16414		Tricho 17							
16415	55	Tricho 18		✓			**3**		
16416	55	Tricho 19			✓				
16417	55	Tricho 20	✓	✓	✓		**4**	**3**	✓
16418	55	Tricho 21			✓		**3**	**3**	✓
16419	97,55,33,14,1	Tricho 22		✓	✓		**4**	**1**	✓
16420			✓				**6**	**3**	✓
16422	97,55,33,14,1	Tricho 23			✓		**3**	**3**	✓
16423							**4**	**3**	✓
16425	97,55,33,14,1	Tricho 24			✓		**4**	**2**	✓
16426							**5**	**2**	✓
16427							**4**	**3**	
16428	97,55,33,14,1	Tricho 25							
UW 1		Tricho 26							
UW 2		Tricho 27							
16429	97,55,33,14,1	Tricho 28			✓				
16430		Tricho 29			✓		**1**		
16431	97,55,33,14,1	Tricho 30			✓		**1**		
16432	97,55,33,14,1	Tricho 31			✓				
16433	97,55,33,14,1	Tricho 32			✓				

Table 1. List of stations sampled for N_2 fixation and/or *Trichodesmium* along with measurements or samples taken. For water column rate measurements the number and value of nominal light depths are indicated. For protein samples the number of replicates is indicated. Sample names for lugols bottles also provided.

Active chlorophyll fluorescence and P700 measurements (FRR and FIRe fluorometry and Dual-PAM fluorometery/spectroscopy)

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Introduction

Active chlorophyll *a* fluorescence is a non-invasive method of probing phytoplankton photophysiology by providing information on the functioning of photosystem II within the photosynthetic apparatus (Kolber et al. 1998; Suggett et al. 2005). Changes in biophysical parameters measured by active fluorescence techniques can then be used to infer the factors influencing phytoplankton growth in situ, including nutrient and light availability/stress. During D326 a number of active chlorophyll fluorometers were employed in a variety of modes including; continuous underway measurements, *in situ* measurements on the stainless steel CTD rosette, analysis of discrete samples of *Trichodesmium* from net hauls (see above), analysis of discrete samples from CTDs, incubation experiments and algal concentrates (see also separate sections by Lawson and Macey). Instruments used for active fluorescence measurements were the FAST*tracka*™ I Fast Repetition Rate (FRR) Fluorometer, manufactured by Chelsea Technologies Group (CTG) (UK), the Fluorescence Induction and Relaxation (FIRe) fluorometer, manufactured by SATLANTIC (Canada) and the Dual-PAM-100 manufactured by Walz (Germany).

Assessment of the abundance and activity of the reaction centre of photosystem I (P700) via the absorption change at 820nm was also attempted on concentrates of *Trichodesmium* collected from net hauls. Photosystem I is the major iron (Fe) containing complex within the photosynthetic electron transport chain and, moreover, is thought to be present at very high concentrations within *Trichodesmium* (potentially >20 times the PSII content) likely as a result of a high ATP requirement for nitrogen fixation in this organism driven by cyclic electron transport around PSI (Subramaniam et al. 1999).

Underway measurements on ships non-toxic supply

A CTG FAST*tracka*™ I FRRf was connected to the ships non-toxic supply within the bottle annex in order to monitor the physiological state of photosystem II (PSII) within the surface phytoplankton population throughout the study area. The instrument was run in auto-ranging mode. Saturation of variable chlorophyll fluorescence was performed using 100 flashlets of 1.1µs duration with a 2.3µs repetition rate. Subsequent relaxation of fluorescence was monitored using flashlets provided at 98.8µs spacing, giving a total relaxation protocol length of around 2ms. The data were stored internally on the instrument and downloaded daily throughout D326 (Table 2). Instrument optics were cleaned whilst the download operation was being carried out. A total of 26 files were collected. Data were then analysed using custom software in a Matlab™ environment. A mistake was made when setting the time stamp on the instrument as the

year was incorrectly entered as 2007. Thus time stamps in raw data should be offset by one year. Days of month are correct but days of the week will also be offset due to the look up table on the instruments calendar referencing 2007. The mistake was corrected in post processing.

	Start date	Start time	End date	End time	Gain
UW1	06/01	0858	07/01	2000	Auto
UW2	07/01	2054	08/01	1954	Auto
UW3	08/01	2007	09/01	2050	Auto
UW4	09/01	2100	10/01	1038	Auto
UW5	10/01	2042	11/01	1932	Auto
UW6	11/01	1942	12/01	1937	Auto
UW7	12/01	1950	13/01	2015	Auto
UW8	13/01	2025	14/01	2020	Auto
UW9	14/01	1940	15/01	1955	Auto
UW10	15/01	2001	16/01	1956	Auto
UW11	16/01	2007	17/01	2006	Auto
UW12	17/01	2022	18/01	1958	Auto
UW13	18/01	2009	19/01	2005	Auto
UW14	19/01	2016	20/01	2004	Auto
UW15	20/01	2014	21/01	2025	Auto
UW16	21/01	2042	22/01	1938	Auto
UW17	22/01	1945	23/01	1922	Auto
UW18	23/01	1930	24/01	1931	Auto
UW19	24/01	1944	25/01	1919	Auto
UW20	25/01	1932	26/01	1950	Auto
UW21	26/01	2002	28/01	1112	Auto
UW22	28/01	1131	29/01	1201	Auto
UW23	29/01	1212	30/01	1850	Auto
UW24	30/01	1903	31/01	1910	Auto
UW25	31/01	1933	01/01	1903	Auto
UW26	01/02	1928	02/01	1928	Auto
UW27	02/02	1948	04/01	0757	Auto

Table 2 Underway FRRf sampling files, dates and times.

In situ measurements on stainless steel CTD

A CTG FAST*tracka*™ I FRRf was deployed *in situ* on the stainless steel CTD frame. The instrument was turned on before each cast. Saturation of variable chlorophyll fluorescence was again achieved using 100 flashlets of 1.1µs duration with a 2.3µs repetition rate. No relaxation protocol was employed. The data were stored internally on the instrument and downloaded by NMF technicians periodically. A total of 73 files were collected. Data were then analysed using custom software in a Matlab™ environment.

Measurement of ΔA820 using Dual-PAM-100

Measurements of absorption differences at 820 nm (hereafter ΔA820) caused by changes in the redox state of P700 within photosystem I require high concentrations of material (>~1 µg chl ml^{-1}). In order to make measurements on natural *Trichodesmium*

communities, samples collected using net hauls were further concentrated by gentle filtration onto 10 µm polycarbonate filters then resuspended in filtered seawater. Despite this large concentration step, adequate biomass was only found at a limited number of stations (Table 1). Photochemical activity in the concentrates was assessed by measuring F_v/F_m using the saturation pulse method on the PAM and comparing with values measured on isolated colonies from net hauls using the FIRe (Figure 1b & c). In general the values of F_v/F_m were comparable to isolated (i.e. pre-concentrated) colonies, suggesting that the production of concentrates did not in itself impare photochemical activity over short timescales (Figure 1c). Concentrates were then diluted by factors ranging from 3:1 to 1:2 and analysed on the Dual-PAM following addition of 3-(3,4-Dichlorophenyl)-1,1-dimethylurea (DCMU) in 1% ethanol to a final concentration of 25 µM. Absolute changes in ΔA820, were calibrated as $\Delta I/I \times 10^{-3}$. Expected linear responses of magnitudes of absorption change with chlorophyll concentration (Figure 1d) provided confidence in the ability to derive the ratio of P700:chlorophyll from the data.

Preliminary results

Surface patterns of variable fluorescence parameters measured by the inline underway instrument were dominated diel signals (Figure 2). Some spatial variability in night-time (dawn) maxima in F_v/F_m was apparent and may be related to spatial gradients in either nutrient stress or taxonomy (Figure 2). Similarly spatial variability in σ_{PSII} was also evident, in particular higher values were found in the more productive waters near the Cape Verde islands. Near surface patterns of physiological parameters derived from data collected by the *in situ* instrument on the CTD were comparable with data collected using the underway instrument (Figure 2). Diel variability was also apparent in F_v/F_m measured on isolated colonies of *Trichodesmium* and on concentrates (Figure 1a & b). In this case, such depressions in F_v/F_m in the middle of the photoperiod may represent downregulation of PSII activity during the period of active nitrogen fixation (Berman-Frank et al. 2001).

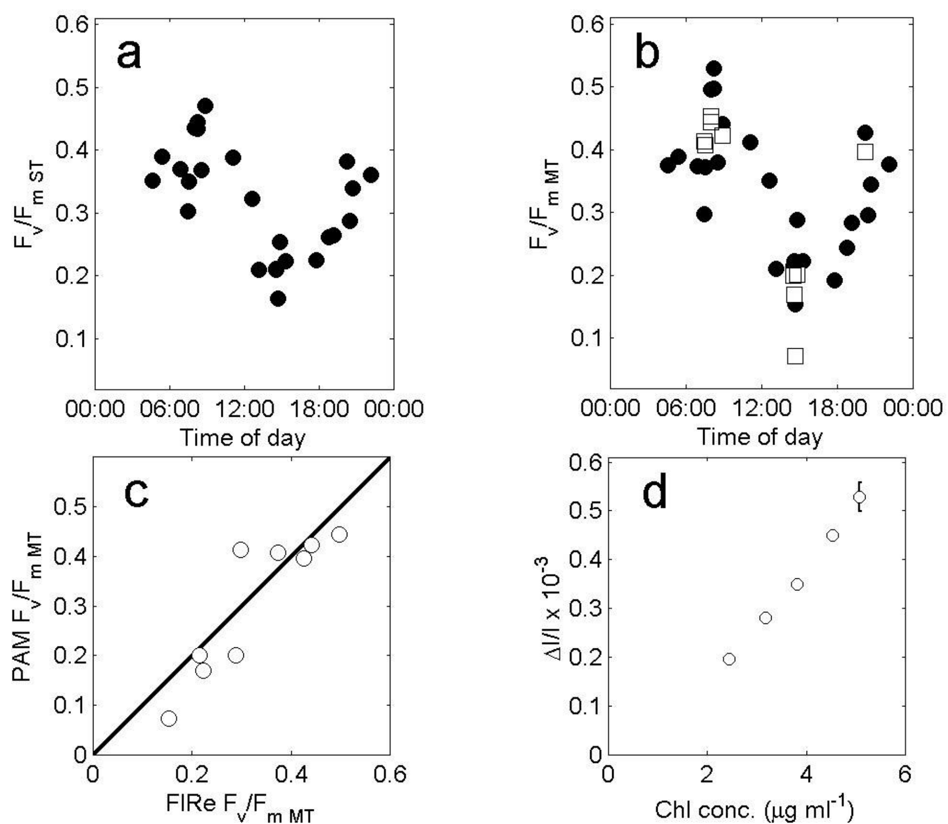

Figure 1 Biophysical measurements on natural *Trichodesmium* colonies. (a, b) Diel variability of F_v/F_m measured using either a single turnover (FIRe Fluorometer, a) or multiple turnover (FIRe Fluorometer closed symbols, PAM, open symbols, b) fluorescence technique. (c) comparison of F_v/F_m measured using FIRe Fluorometer on isoloated colonies with concentrates of same samples measured on PAM, solid line indicates 1:1 line. (d) absolute absorption change at 820 nm measured on various dilutions of concentrates from the same station.

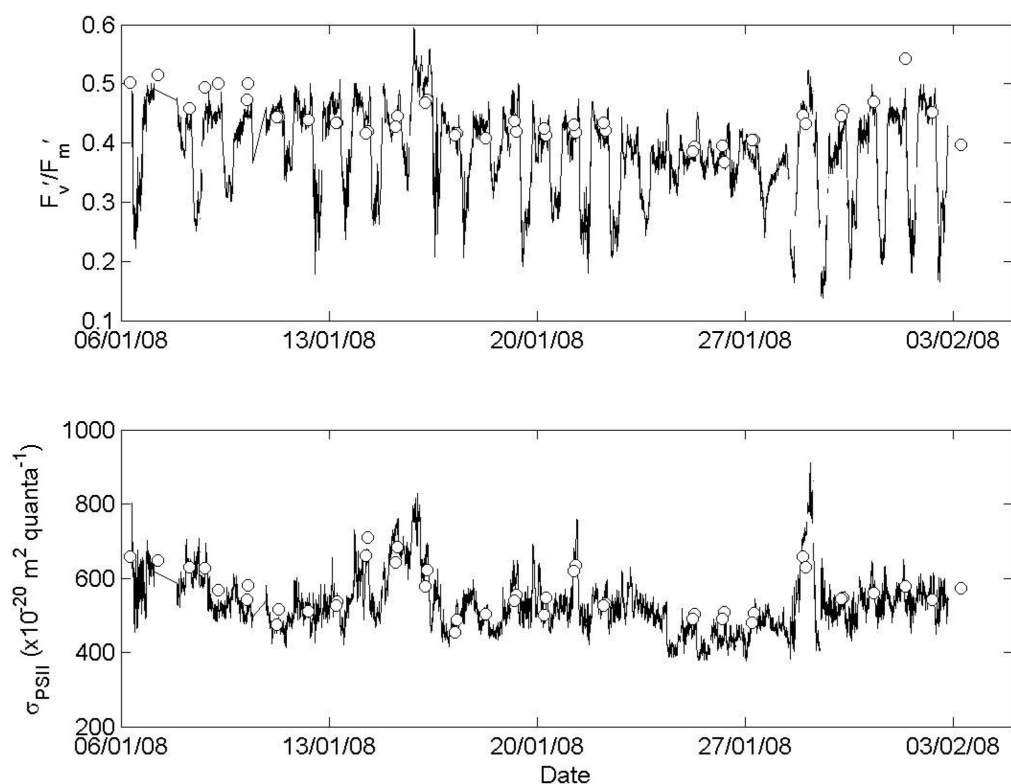

Figure 2 Time series of FRRf data collected during D326. Solid lines indicate continuous record from underway instrument, symbols indicate corresponding pre dawn value of F_v/F_m (top) and σPSII from instrument on stainless steel CTD frame.

References

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Nanomolar Inorganic Nutrients

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Approach

Analysis for nitrate and nitrite (hereinafter nitrate) and phosphate at nanomolar concentration were undertaken on a purpose-built, segmented-flow autoanalyser following a method described in Patey et al. (2008). Two liquid waveguide capillary flow cells were used to provide a two-metre path-length, 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 ml LDPE bottles from the CTD as well as from underway samples drawn from a fish. Samples from various 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.

Samples analysed

CTD Profiles – measured surface concentrations in the steel CTD at every station between 16386A (7/1/08) and 16435A (3/2/08). A few samples were taken from the Ti CTD when requested (16421B, 16424B, 16425B, 16427B). Samples were measured unfiltered.
Underway samples – started measuring from UT66 and continued till end of cruise (UT189). Samples were taken directly from the (0.2 µm) filtered supply from the fish.
Samples from on-board experiments – a number of samples from my own and other's experiments were measured.
Interference studies
Some simple tests were carried out to investigate the effect of three potential interferences on the nutrient measurements:

Arsenate – a known interference with the Molybdenum Blue method for phosphate analysis. The interference of concentrations of up to 100 nM arsenate was investigated. The interference was measured in the presence of several background phosphate concentrations (from 0 to 50 nM).

Silicate – another interference with phosphate measurements – the effect of up to 100 µM silicate on measured phosphate concentrations was determined

Filtration – since some researchers filter nutrient samples, while others do not, and since on this cruise underway samples were filtered, while CTD samples were not, the effect of filtration on observed nitrate and phosphate concentrations was investigated. On several

occasions, four sample bottles were filled from the fish instead of the usual single one; two were filtered and two unfiltered.

Example Results

Surface nutrient concentrations are given in figure 1.

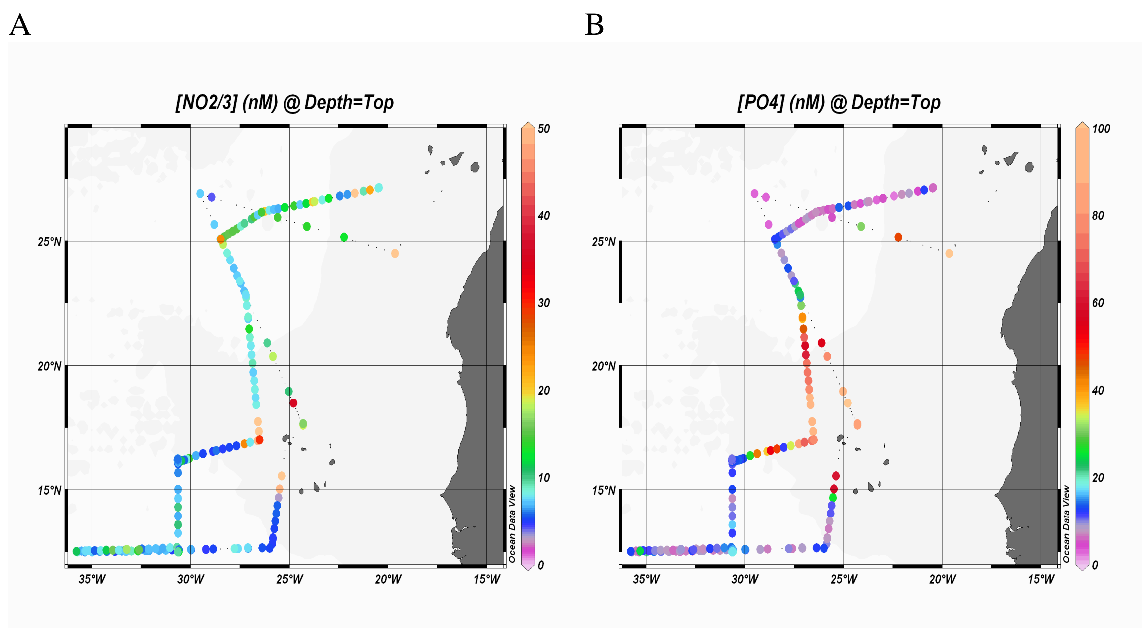

Figure 1. Underway sea surface concentrations of nitrate/nitrite (A) and phosphate (B).

Aerosol collection

Using a low-volume aerosol sampler, during the cruise, aerosol dust was collected on four replicate 47 mm filters for sampling periods of between 12 and 24 hours (Figure 2.). Leaching experiments were carried out by passing 100 ml of filtered seawater through the filters. This approach follows the one used by Bill Landing on several cruises (Buck et al., 2006). Samples of the leach solution were used for bioassay experiments by Polly Hill and Duncan Purdie. At the same time, a sample was taken for nutrient measurement. Any remaining leach solution was acidified and will be analysed at a later date for dissolved metal concentrations using matrix extraction followed by ICP-MS analysis. The majority of the filters have been frozen for later analysis, where further leaching experiments will be conducted with the other replicate filters will be carried out. HF / HNO_3 digestion followed by ICP-MS analysis will be used to determine the total composition of the dust. De-ionised water leaches will be used to investigate the soluble fraction of the dust and will be followed by ICP-MS, ion chromatography and standard nutrient analysis (for nitrate, phosphate and silicate). A total of 29 sets of filters were collected.

Figure 2. The aerosol sampler on the monkey island

Dust dissolution experiments

Using seawater sampled using the trace metal clean fish, a sieved Saharan soil (< 20 µm fraction) was added to 0.2 µm filtered seawater at a fixed concentration. The bottles were stored in the dark on a rotating bottle stirrer at a constant a temperature of 20°C (Figure 3.). After 2 days and 3 days, bottles were removed and filtered (<0.2 µm) to remove any undissolved dust. Samples were taken for nutrients (measured using the nanomolar nutrient analyser) dissolved organic ligands (to be measured in Southampton by cathodic stripping voltammetry) and trace metals (Fe measured onboard by Micha Rijkenberg, using a luminol-based chemiluminescence FIA system; Al to be measured later using a lumogallion fluorometric FIA system; Mn to be measured later using a catalytic spectrophotometric FIA system). A total of six dust dissolution experiments were conducted during the cruise.

Figure 3. The dust dissolution experiments. Agitation of dust containing seawater samples.

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Atmospheric Sampling on D236

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Introduction

Atmospheric sampling on D236 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 using two high volume (1 m^3 min^{-1}) samplers and fitted with cascade impactors. Gas phase samples were taken using a vacuum pump with gas bottles. Rainwater was also collected at every opportunity to assess wet deposition. In addition measurements of atmospheric optical thickness were made using a sun photometer.

Method

High Volume Samplers
Two samplers were used in order to sample for trace metals and major ions separately. For the trace metal samples the filters were washed in hydrochloric acid (HCl) and nitric acid (HNO3) prior to the cruise. For each trace metal sample and most of the major ion samples 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 1 µm). In a minority of major ion samples only a single filter was used, so only a bulk sample taken.

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 main lab. 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).

The samplers were calibrated to give a flow rate of 1 m^3 min^{-1}. This was performed twice during the cruise, once at the start (6th Jan 2008) and once at the end (3rd Feb).

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 (0.01 M) nitric acid solution for storage and major ion bottles contained ultra-pure water for storage. Only one rain sample was taken, along with one blank for each of the funnels. These 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 a sampling line situated on the wheelhouse roof. 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 variable due to the sporadic nature of dust deposition, but samples were taken at least once a day when the ship was on station with head to wind. There was one period during a dust storm when the ship was on station for a prolonged amount of time and samples were taken at 4 hour intervals. All bottles were sampled.

Atmospheric Optical Depth
Measurements of AOD were taken using a sun photometer provided by Alexander Smirnov at NASA. Ideally measurements were to be taken at hourly intervals. However measurements require there to be no cloud, and the weather was often surprisingly cloudy.

Discovery 326 Cruise Report on biological measurements

Dr Duncan A. Purdie

National Oceanography Centre, Southampton

Chlorophyll Measurements

Water samples were taken from all stainless CTD casts and chlorophyll measured at up to 10 depths from 300 m to 5 m. Water samples were collected from the CTD Niskin bottles at the same time for fixation of microbial samples for possible later flow cytometer analysis. Duplicate 250 mL volumes (measured out using a cut off plastic measuring flask) were filtered through MF 300 glass fibre filters and chlorophyll extracted in 6 mL of 90% acetone for about 24 hours at -5°C. Chlorophyll was then measured using a TD70 fluorometer. The fluorometer was left on for the whole month period of the cruise but was calibrated daily using a stock standard chlorophyll solution. At the beginning of the cruise a 1 mg pellet of chlorophyll (Sigma spinach standard) was dissolved in 500 mL of 90% acetone. The standard was divided up into four 150 mL aliquots stored at -5ºC in brown screw capped glass bottles. The standard was calibrated using absorption measurements made daily on a Cecil spectrophotometer. Absorption of the standard solution was measured in 1 cm path length cuvettes at the following wavelengths, 750, 664, 647, 630 nm. Chlorophyll concentration was determined from:

chl a mg/L = $11.85 * E_{664} - 1.54 * E_{647} - 0.08 * E_{630}$

where

E664 is = to absorption at 664nm – absorption at 750nm
E647 is = to absorption at 647nm – absorption at 750nm
E630 is = to absorption at 630nm – absorption at 750nm

The standard solution was diluted 0.1ml to 10 mL in a measuring flask and the Turner fluorometer calibrated using a single point calibration. On some days three dilutions were made as follows;
0.2 mL to 10 mL
0.1 mL to 10mL
0.05 mL to 10mL

The calibration routine was run daily and standards checked at the end of an analysis run. Samples were analysed each day after the fluorometer had been calibrated.

In addition to samples collected from CTD Niskin bottles water samples were routinely collected from the non- toxic sea water supply to the wet lab at 2 hourly intervals when the ship was underway between CTD stations. These samples were filtered in duplicate

and analysed for chlorophyll as described above. Position and time of collection were noted and nutrient samples collected at the same time.

A total of 49 CTD profiles were sampled for chlorophyll analysis. Throughout the cruise over 1500 individual chlorophyll measurements were made.

Pigment samples for later HPLC analysis

From most morning CTD profiles water samples were collected from 6 or 7 depths (see Table 1) and filtered onto MF 300 glass fibre filters for later pigment analysis by HPLC. 2.5 litres were filtered in duplicate and filters stored either in Petri slides or Eppendorfs in the -70°C freezer.

Samples for phytoplankton counting

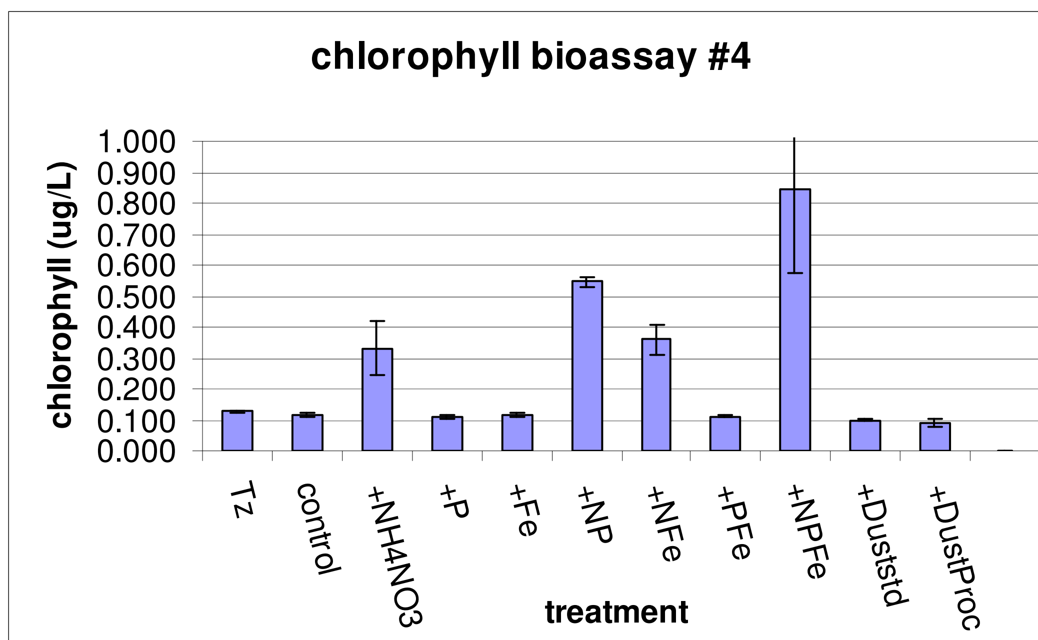
From some profiles, 100 mL volumes of water from 6 or 7 depths were preserved with either 1 mL of Lugols iodine or 1mL of Buffered Formalin solution. These may be used to enumerate phytoplankton at a later date.

Bioassay Experiments

Chlorophyll measurements were made as part of the four bioassay experiments conducted during the cruise.

Bioassay Experiments	Date initiated	Date completed
Bioassay #1	09-Jan	11-Jan
Bioassay #2	15-Jan	17-Jan
Bioassay #3	21-Jan	23-Jan
Bioassay #4	25-Jan	27-Jan

Initial chlorophyll concentration was measured in triplicate (25 mL volumes) on the source water collected using the pumped fish supply. Chlorophyll was then measured in triplicate from each treatment after 48 hours incubation. Provisional results from bioassay #4 are shown below.



Results show an increase in chlorophyll concentration in + N treatment and +N+Fe treatment with further increased growth in +NP and +N+P+Fe treatment. The +P, +Fe, +P+Fe and added dust had no affect on chlorophyll concentration in comparison to the control.

Zooplankton Nets

A 200 µm mesh zooplankton net was deployed at most morning stations (see Table 2). It was lowered to 50 m then drawn up through the water column slowly. The contents of the net were decanted into one or two plastic bottles and about 20mL of buffered formalin added to preserve the zooplankton sample prior to later counting and identification. A total of 26 zooplankton trawls were completed.

Experiments with dust leachates

A number of experiments were conducted to investigate the possible effect of adding milliQ water leachate from dust samples collected while at sea.

Dust Leachate Experiments

date	CTD#
10-Jan	16392B
14-Jan	16400B
31-Jan	16431B
01-Feb	16432B
02-Feb	16433B
03-Feb	16435B

These leachates plus a blank sample were produced by Matt Patey. Water samples from 20 m were collected from the titanium CTD system and added to 6 clean 4.4 L polycarbonate bottles. To all bottles 13C bicarbonate and 15N nitrate solutions were added in the clean container. To three of the bottles between 10 and 20 mL of leachate was added to the other three bottles an equivalent volume of blank filter leach was added. All six bottles were incubated on deck in blue screened incubator supplied with flowing sea water. After dusk each bottle was taken into the clean container and 2L filtered through either a combusted MF 300 filter or GK75 filter. A small volume of filtered seawater was poured through the filters to remove excess tracer. These filters were frozen at -70^{0}C and will be analysed on a mass spectrometer in due course.
Chlorophyll and flow cytometry samples plus low nutrient samples were also taken from each experiment.
Similar incubation experiments were undertaken with 15N- nitrate and 13-C bicarbonate without added leachate during the drogue station while in dust deposition area on following dates 25, 26 and 27 Jan .

Table 1. Chlorophyll, HPLC pigments and Lugols/Formalin samples

Date	Time	CTD #	Position		Depths	HPLC samples	Lugol/Formalin
			deg N	deg W	10 depths down to 300 m	6 or 7 depths	6 or 7 depths
6-Jan	7:30	16382A	27:00.7	17:16.2			
	14:35	16383A	26:35.6	17:39.6			
7-Jan	6:00	16384A	24:48.8	19:20.2			
	13:02	16386A	24:29.9	19:37.8			
8-Jan	6:47	16387A	25:09.2	22:13.6		√	
	20:02	16389A	25:35.4	24:06.6			
9-Jan	6:47	16390A	25:57.1	25:35.6		√	
	15:21	16391A	26:09.4	26:24.3			
10-Jan	6:45	16392A	26:45.8	28:56.3		√	
	17:00	16393A	26:54.4	29:30.9			
11-Jan	6:30	16394A	25:39.9	28:47.9		√	
	16:14	16395A	25:04.9	28:29.1			
12-Jan	6:45	16396A	23:23.9	27:30.6		√	√
	15:00	16397A	22:49.8	27:11.8			
13-Jan	6:42	16398A	20:54.7	26:07.2		√	
	15:18	16399A	20:22.4	25:49.6			
14-Jan	7:06	16400A	18:57.7	25:01.9		√	
	15:06	16401A	18:29.0	24:47.8			
15-Jan	6:40	16402A	17:36.0	24:18.0		√	√
	13:30	16402AA	17:39.9	24:18.2			
16-Jan	6:45	16403A	15:33.4	25:23.2		√	
	15:00	16404A	15:02.3	25:29.2			
17-Jan	6:40	16405A	13:01.6	25:49.3		√	√
18-Jan	6:20	16407A	12:39.8	27:06.5		√	
	15:00	16408A	12:37.8	27:46.6			
19-Jan	6:55	16409A	12:36.4	29:59.8		√	√

	15:10	16410A	12:35.2	30:36.2		
20-Jan	6:50	16411A	12:33.0	32:40.7	√	
	15:30	16412A	12:32.5	33:17.8		
21-Jan	7:00	16413A	12:31.1	35:46.8	√	
	15:00	16414A	12:32.6	35:18.6		
22-Jan	6:30	16415A	12:36.2	33:14.5	√	
	15:30	16416A	12:35.2	32:36.4		
23-Jan	9:30	16417A	12:30.1	30:36.5	√	
24-Jan	12:00	16418A	16:07.3	30:37.9	√	
25-Jan	6:46	16419A	16:08.5	30:38.0	√	√
	15:45	16420A	16:11.3	30:39.2		
26-Jan	6:45	16422A	16:12.6	30:39.2	√	
	14:59	16423A	16:12.3	30:37.5		
27-Jan	7:00	16425A	16:13.8	30:39.0	√	√
	15:15	16426A	16:13.2	30:38.7		
28-Jan	22:15	16428A	17:00.0	26:30.2	√	
29-Jan						
30-Jan	6:45	16429A	21:56.2	27:05.0	√	
	15:20	16430A	22:49.1	27:11.8		
31-Jan	7:09	16431A	25:04.4	28:28.4	√	
1-Feb	8:52	16432A	26:09.6	26:25.0	√	√
2-Feb	6:30	16433A	26:35.5	23:43.4	√	
	15:15	16434A	26:42.8	23:00.5		
3-Feb	5:30	16435A	27:08.5	20:26.7	√	

Table 2. Zooplankton Net

Date	Time	CTD #	Position		Zooplankton Bottle#
			deg N	deg W	
6-Jan	7:30	16382A	27:00.7	17:16.2	Z1
7-Jan	6:00	16384A	24:48.8	19:20.2	Z2
8-Jan	6:47	16387A	25:09.2	22:13.6	Z3
9-Jan	6:47	16390A	25:57.1	25:35.6	Z4
10-Jan	6:45	16392A	26:45.8	28:56.3	Z5
11-Jan	6:30	16394A	25:39.9	28:47.9	Z6
12-Jan	6:45	16396A	23:23.9	27:30.6	Z7
13-Jan	6:42	16398A	20:54.7	26:07.2	Z8
14-Jan	7:06	16400A	18:57.7	25:01.9	Z9
15-Jan	6:40	16402A	17:36.0	24:18.0	Z10
16-Jan	6:45	16403A	15:33.4	25:23.2	Z11
17-Jan	6:40	16405A	13:01.6	25:49.3	Z12
18-Jan	6:20	16407A	12:39.8	27:06.5	Z13
19-Jan	6:55	16409A	12:36.4	29:59.8	Z14
20-Jan	6:50	16411A	12:33.0	32:40.7	Z15
21-Jan	7:00	16413A	12:31.1	35:46.8	Z16
22-Jan	6:30	16415A	12:36.2	33:14.5	Z17
23-Jan	9:30	16417A	12:30.1	30:36.5	Z18
24-Jan	12:00	16418A	16:07.3	30:37.9	Z19
25-Jan	6:46	16419A	16:08.5	30:38.0	Z20
26-Jan	6:45	16422A	16:12.6	30:39.2	Z21
27-Jan	7:00	16425A	16:13.8	30:39.0	Z22
28-Jan	22:15	16428A	17:00.0	26:30.2	Z23
31-Jan	7:09	16431A	25:04.4	28:28.4	Z24
1-Feb	8:52	16432A	26:09.6	26:25.0	
2-Feb	6:30	16433A	26:35.5	23:43.4	Z25
	15:15	16434A	26:42.8	23:00.5	
3-Feb	5:30	16435A	27:08.5	20:26.7	Z26

Chasing Saharan dust storms: dissolved iron in the equatorial North Atlantic

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Introduction

The primary goal of the *Discovery* D326 cruise was to elucidate the effects of atmospherically deposited Saharan dust on the concentration of oceanic (trace-)nutrients (iron, phosphate and nitrate) and on the primary productivity, heterotrophic activity and nitrogen fixation within the natural bacterio- and phytoplankton populations of the tropical and subtropical North-Atlantic.

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 (de Baar et al., 1990b; Hutchins and Bruland, 1998; Martin and Fitzwater, 1988). Furthermore, it has been suggested that iron may limit nitrogen fixation in the North Atlantic Ocean (Mills et al., 2004). 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 titanium frame. Underway surface seawater was sampled by pumping it into a trace metal clean laboratory container using a Teflon diaphragm pump (Almatec A-15, Germany) connected by an acid-washed braided PVC tubing to a towed fish positioned at approximately 3 m depth alongside the ship. The seawater was filtered in-line using a Sartobran 300 filter capsule (Sartorius) with a 0.2 µm cut-off. All low density polyethylene bottles (Nalgene) were cleaned according to a standard protocol (Achterberg et al., 2001). Samples for DFe were acidified to pH 2 (a final concentration of 0.011 M) using ultra clean HCl (Romil UHP grade). Samples for Fe-binding ligand analysis were immediately frozen at −20°C for subsequent land-based analysis.

Dissolved Fe (<0.2 µm) was measured by flow injection analysis and chemiluminescence detection according to (Obata et al., 1993) and (de Jong et al., 1998) following pre-concentration on a column of 8-hydroxyquinoline (8-HQ) immobilized on Toyopearl gel (Landing et al., 1986).

Results

The dissolved iron was measured in samples obtained during the special trace-metal clean bottle casts (for an example, see Figure 1), in all underway samples collected

using the trace metal clean fish (see Figure 2.) and in a sub-set of the incubation experiments. The field measurements of dissolved Fe will tell us how Saharan dust input affects the concentration Fe in the water column (Rijkenberg et al. 2008). The measurements of dissolved Fe in the incubations were performed to check for possible contamination of Fe. Furthermore, samples taken from an additional dust dissolution experiment by Matt Patey as well as Alex Xylouri were measured on board ship.

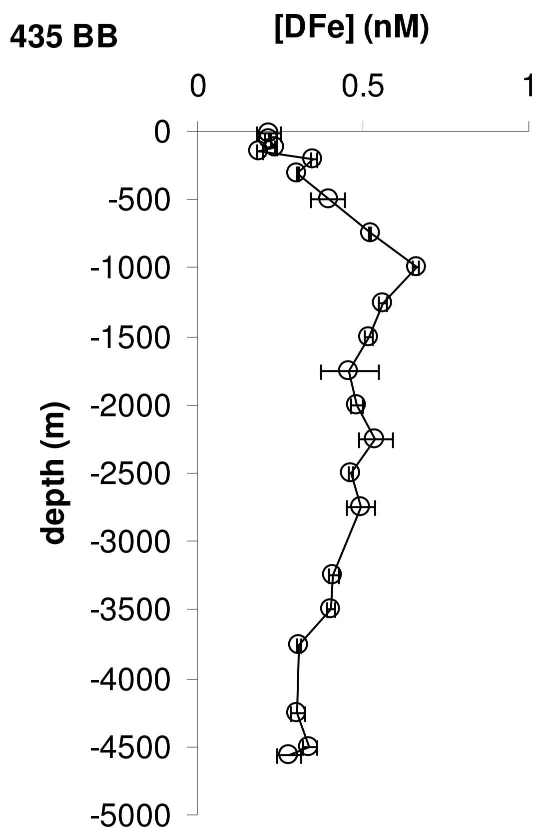

Figure 1) The dissolved Fe concentration in a trace metal clean bottle cast at station 16435BB (date: 03/02/08, latitude: 27.1682, longitude: -20.4825).

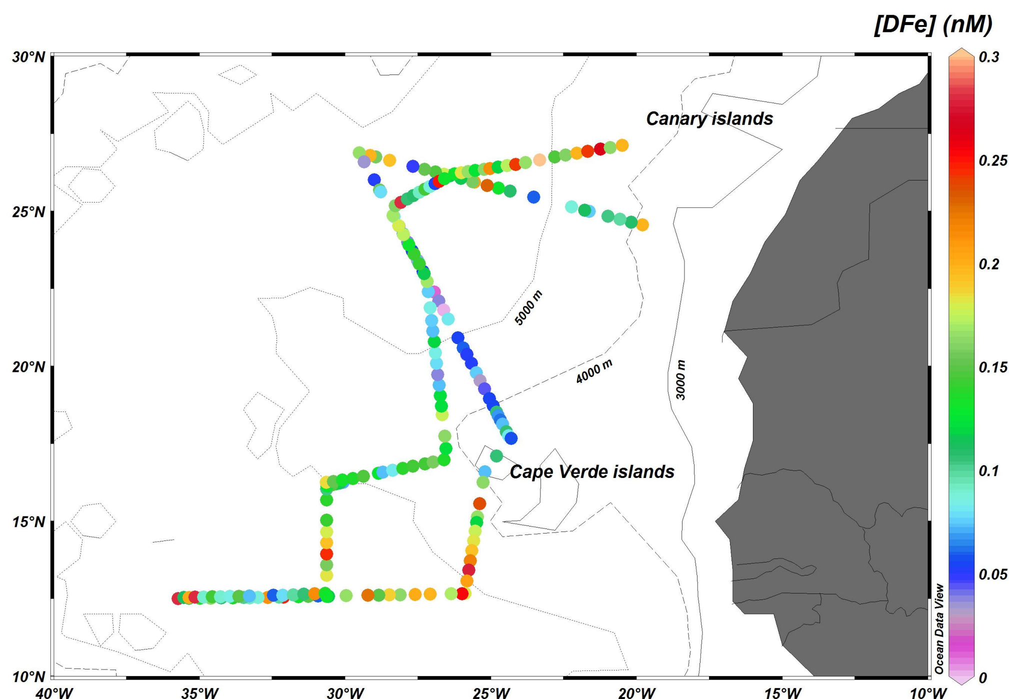

Figure 2) The underways seasurface concentrations of dissolved Fe during D326.

Acknowledgements
We want to thank the captain and crew of the *Discovery* for support during the cruise, and to Eric Achterberg, the chief scientist.

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Dissolved manganese analyses

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Manganese can be dissolved from Saharan dust and thus may be a useful indicator of dust inputs to the surface ocean. Samples from underway and vertical profiles have been or are to be analysed using a flow injection system, that was set up on the ship. The method is based on a flow injection analysis (FIA) technique (Mallini, L. J. and A. M. Shiller, 1993) where Mn catalyses the peroxide oxidation of Tiron in the presence of 2-2 bipyridyl, to give a yellow coloured semi-quinone that is detected at a wavelength of 440nm. However, the method as used here has some important modifications, including using a commercially available complexing resin, and dual wavelength absorbance measurements to compensate for refractive index issues with the detector. During the first part of the cruise optimisation of the system was done, in which 2 detectors were set up in series. All samples were measured in duplicate and each takes 10 minutes to pass through the analyser.

Over the course of the cruise circa 31 underway samples and 6 profiles were measured, together with a large number of samples from dissolution experiments that were carried out on the ship using artificially aged atmospheric dust samples. An example profile showing the characteristic surface increase in concentration of Mn is given in Fig. 1.

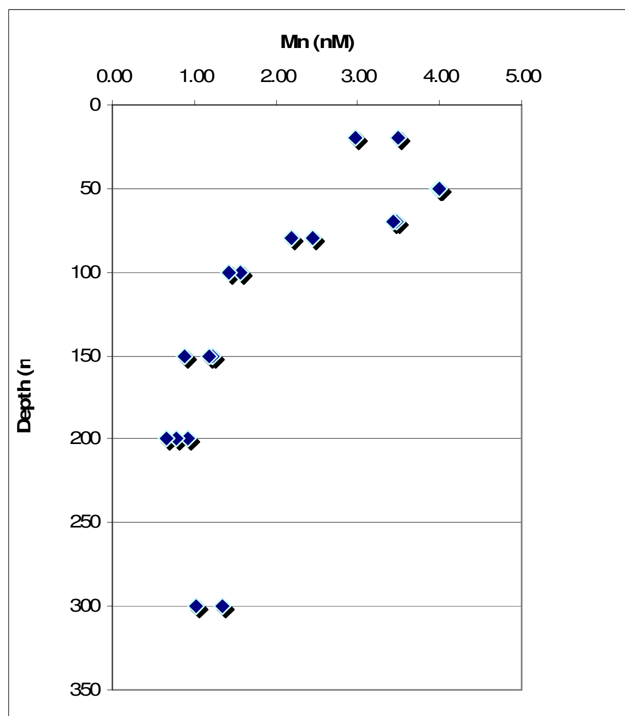

Figure 1. Vertical distribution of dissolved (<0.2 micron) Mn at Station 16401 (preliminary data).

References

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In Situ collection of water column particles

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The objective was to collect significant amounts of particulate material from the water column for subsequent geochemical and mineralogical analyses. Evidence of dust particles in the water column will especially be sought.

Samples were collected using Challenger Oceanic stand alone *in situ* pump systems (SAPS); sampling stations are shown in Table 1. Initially some difficulties were encountered with mounting the fragile 1 micron polycarbonate filters in the filter heads, but this process was found to be much easier when they were supported on a 53 micron Nitex mesh. One or two samples were also taken with just 53 micron Nitex meshes, as this size is meant to be representative of the size fraction exiting the upper water column and falling into the deeper water column. The residual water in the SAPS head was removed by a gentle vacuum prior to the head being disassembled. As the filters were fairly dry, no attempt to rinse with MQ water was made because of concerns over cell lysis and resulting loss of cell contents. A small area was removed from some filters, rinsed with deionised water (to remove sea salt) for subsequent scanning electron microscope examination. Filters from each batch of filters were stored to act as blanks for the samples. In total 33 samples were collected plus blank filters. All collected samples were frozen for storage and transport.

Deployments 16419 to 16427 were made whilst on one station observing the impact of dust fall at this location. Numerous *Trichodesmium* colonies were evident on these filters, and the later samples were collected at a depth of 15m as there was some evidence from light measurements that there were non biogenic particles in the uppermost water column.

At the NOCS laboratory the intention is to carry out a chemical leach to removes more environmentally available metals, followed by a total digestion. Elements in dissolution solutions will be analysed by ICP-MS.

These SAPS deployments also allowed the testing of a new development version of the SAPS by UKORS personnel, where a computer interface allowed setting of the pumped delay and active times, rather than the conventional magnet initialisation process. The new system had a ~ 50% success rate.

Station number	**Deployment depths (m)**	**Comments**
16393E	150	53 micron Nitex mesh
16399E	50,50,100	All SAPS pumped large volumes of water (>1000L); used only 53 micron
16402E	30, 60, 100	Mix of 1 micron PC, and 53 micron Nitex
16408E	20, 40, 60	As used subsequently all 1 micron PC membranes backed by 53 micron Nitex
16410E	20, 50, 65, 85	Test only of UKORS modified system at 85m
16419E	20, 60, 100, 100	The second 100m sample was UKORS test system with a 53 micron mesh
16421E	20, 60, 85, 85	The second 85m sample was UKORS test system with a 53 micron mesh
16423E	15, 50, 90	
16425E	15, 40, 85	
16427E	15, 40, 85, 85	The second 85m sample was UKORS test system with a 53 micron mesh
16435E	40, 809, 110,110	All filters were 1 micron Nitex meshes, except for one mesh of 53 micron at 110 m

Table 1. Details of SAPS deployments. Unless otherwise specified, samples were collected on 1 micron polycarbonate filters, backed by a 53 micron Nitex mesh.

Dissolved Oxygen Analysis

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Cruise objectives

The objectives of the dissolved oxygen analysis were to provide a calibration for the oxygen sensor mounted on the frame of the CTD for cruise D326 to the tropical North Atlantic. For this, a Winkler titration was done from a number of water samples from the Niskin bottles mounted on the CTD frame.

Methods

Dissolved oxygen samples were only taken from the stainless steel CTD casts and they were the second or third samples to be drawn from the Niskin bottles. Approximately six oxygen samples were taken from the Niskin bottles that had fired during a cast. The depths sampled were decided by the trace from the oxygen sensor on the CTD, which provided near to real time results. Samples for calibration of the sensor are best taken where there are no gradients in the concentration of oxygen, so where the trace appears flat. The samples were drawn through short pieces of silicon tubing into clear, pre-calibrated, wide necked glass bottles. The temperature of the sample water at the time of sampling was measured using an electronic thermometer probe. The temperature would be used to calculate any temperature dependant changes in the sample bottle volumes. Each of these samples was fixed immediately using 1 ml of manganese chloride and alkaline iodide. The samples were shaken thoroughly and then left to settle before being shaken again. The samples were then left for a few hours before analysis.

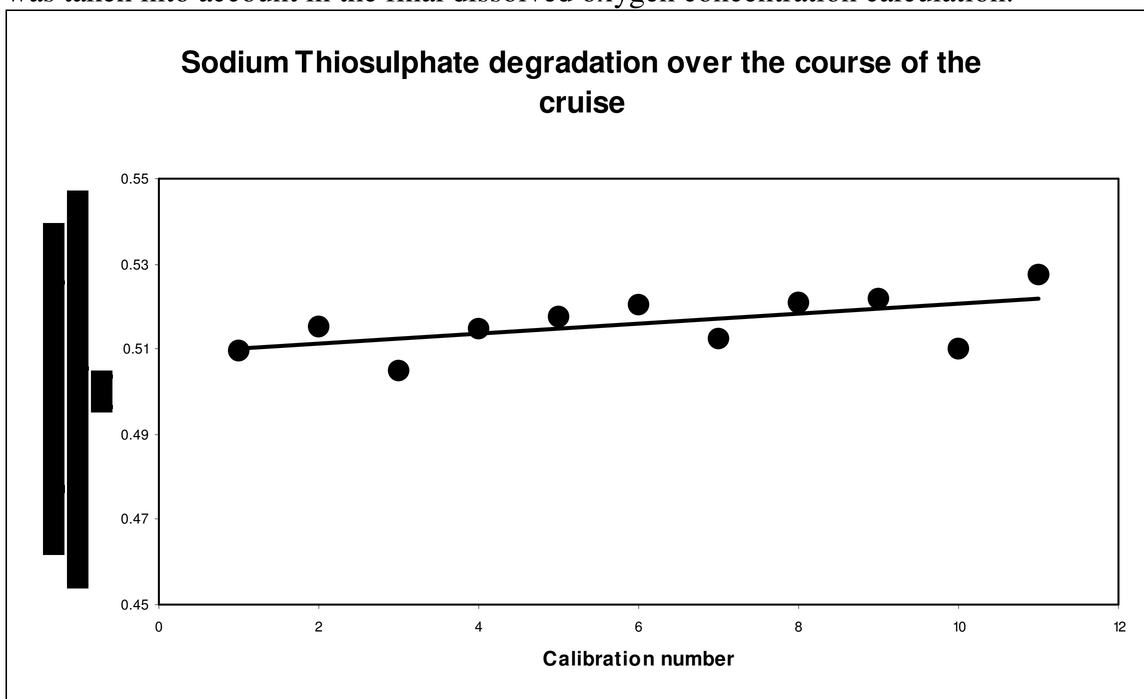
The samples were analysed following the procedure outlined in Holley and Hydes (1995). The samples were acidified using 1ml of sulphuric acid immediately before titration and stirred using a magnetic stirrer. The Winkler whole bottle titration method with amperometric endpoint detection (Culberson and Huang, 1987), with equipment supplied by Metrohm, was used to determine the oxygen concentration.

The normality of the sodium thiosulphate titrant was checked using a potassium iodate standard. This was done four times throughout the cruise. Thiosulphate standardisation was carried out by adding the 5 ml of 5 N iodate solution after the other reagents had been added to a water sample in reverse order. This standardisation was then used in the calculation of the final dissolved oxygen spreadsheet. The required volume of sodium thiosulphate needed to titrate the 5ml potassium iodate standard can be seen in figure 1.

The amount of dissolved oxygen in the reagents was also checked by performing a blank correction. This was also done using potassium iodate. The reagents were added to a water sample in reverse, as with the thiosulphate standardisation method, and then 1 ml

of 5 N iodate was added. This was titrated to completion. Then another 1ml of iodate was added to the same bottle and was titrated again. This was repeated once more. The whole process was then repeated twice. The blank was found by subtracting the average of the second and third titration values from the first and then the average of all three blanks was taken. This value was the used in the calculation of the final dissolved oxygen spreadsheet.

Figure 1: The volume of sodium thiosulphate required to titrate 5ml of 5N potassium iodate. The thiosulphate did degrade over the course of the cruise but this degradation was taken into account in the final dissolved oxygen concentration calculation.



Station numbers and sampling regime

All the stations occupied during the cruise were sampled, although only approximately six samples from each cast were taken. These didn't correspond to any depth, but instead corresponded to regimes of low oxygen gradients as described above. The number of samples taken from each cast can be seen in table 1.

Table 1. The number of dissolved oxygen samples taken for each of the stations.

CTD station	**Number of depths sampled for dissolved oxygen**
16382A	**6**
16383A	**7**
16384A	**5**
16386A	**6**
16387A	**6**
16389A	**6**
16290A	**6**
16291A	**6**
16292A	**4**
16293A	**7**
16294A	**6**
16295A	**7**
16296A	**5**
16297A	**6**
16298A	**6**
16299A	**5**
16400A	**6**
16401A	**6**
16402A	**5**
16402AA	**5**
16403A	**6**
16404A	**5**
16405A	**5**
16407A	**5**
16408A	**6**
16409A	**6**
16410A	**5**
16411A	**5**
16412A	**6**
16413A	**5**
16414A	**5**
16415A	**5**
16416A	**6**
16417A	**2**
16417AA	**6**
16418A	**3**
16418AA	**5**
16419A	**5**
16420A	**5**
16422A	**5**
16423A	**5**
16425A	**5**
16426A	**5**
16428A	**3**
16429A	**5**
16430A	**4**
16431A	**6**

16432A	**5**
16433A	**4**
16434A	**5**
16435A	**5**

Inorganic nutrient analysis

Mark Stinchcombe

National Oceanography Centre, Southampton

Cruise Objectives

My objectives of cruise D326 to the (sub-)tropical North Atlantic were to measure micromolar levels of the inorganic nutrients nitrate; silicate and phosphate using segmented flow analysers.

Methods

Analysis for micro-molar concentrations of nitrate and nitrite (hereinafter nitrate), phosphate and silicate was undertaken on a Skalar Sanplus autoanalyser, following methods described by Kirkwood (1996) with the exception that the pump rates through the phosphate line were increased by a factor of 1.5, which improved reproducibility and peak shape. All samples were into 25 ml coulter counter vials (Sterilin) and kept refrigerated at 4°C until analysis, which commenced within 24 hours. Samples were collected from the stainless steel CTD, the titanium CTD, the non-toxic water supply for underway samples, from the towed trace-metal fish and also from experiments run by other people on board.

Overall 40 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 flasks that had been cleaned thoroughly.

Data processing was undertaken using Skalar proprietary software and was done within a few days hours of the run being finished. The wash time and sample time were 90 seconds; the lines were washed daily with 0.5 M sodium hydroxide and 10% Decon. Time series of baseline, instrument sensitivity, calibration curve correlation coefficient, nitrate reduction efficiency and duplicate difference were compiled to check the performance of the autoanalyser over the course of the cruise.

Station numbers and sampling regime

All the CTD stations were sampled for nutrients. All depths were sampled for micro-molar concentrations of nitrate, silicate and phosphate. Table 1 represents the number of depth sampled for micromolar nutrients.

Table 1. The number of depths sampled for inorganic nutrients for each of the CTD stations on cruise D326 using a micro-molar segmented flow autoanalyser.

CTD station	***Number of depths*** **sampled for µM nutrients**
16382A	**10**
16383A	**10**
16384A	**9**
16384B	**8**
16386A	**10**
16386B	**10**
16387A	**11**
16387B	**9**
16389A	**10**
16289B	**9**
16290A	**10**
16290B	**9**
16291A	**10**
16291B	**9**
16292A	**5**
16292AA	**5**
16292B	**9**
16293A	**10**
16293B	**9**
16294A	**10**
16294B	**9**
16295A	**10**
16295B	**10**
16296A	**12**
16297A	**10**
16297B	**9**
16298A	**10**
16298B	**9**
16299A	**10**
16299B	**9**
16400A	**10**
16400B	**8**
16401A	**10**
16401B	**8**
16402A	**10**
16402AA	**10**
16402B	**12**
16403A	**10**

16403B	**8**
16404A	**10**
16404B	**8**
16405A	**10**
16405B	**8**
16407A	**10**
16407B	**8**
16408A	**9**
16408B	**8**
16409A	**10**
16409B	**8**
16410A	**11**
16410B	**8**
16411A	**10**
16411B	**8**
16412A	**10**
16412B	**12**
16413A	**10**
16413B	**8**
16414A	**10**
16414B	**8**
16415A	**8**
16415B	**8**
16416A	**10**
16416B	**12**
16417A	**10**
16417AA	**9**
16417B	**10**
16418A	**11**
16418AA	**8**
16418B	**8**
16420A	**11**
16420B	**8**
16421B	**8**
16422A	**10**
16422B	**8**
16423A	**10**
16423B	**9**
16425A	**10**
16425B	**10**
16426A	**10**
16426B	**9**
16427B	**8**
16428A	**10**

16428B	**8**
16429A	**10**
16429B	**8**
16430A	**10**
16430B	**8**
16431A	**10**
16431B	**8**
16432A	**8**
16432B	**8**
16433A	**8**
16433B	**8**
16434A	**10**
16434B	**12**
16435A	**10**
16435BB	**24**

Performance of the analyser

During the year 2007, the analyser has been on numerous cruises. It has been apparent that if the analyser isn't cleaned properly in between runs and also in between cruises, there can be problems. These problems have arisen on previous cruises with the phosphate baseline failing and jumping suddenly. This has resulted in the loss of some samples or the need to rerun them if there is enough sample left. During this cruise I have been keen to ensure this didn't happen. I have pumped a lot of 0.2 M sodium hydroxide and 10% Decon before and after each run. In transit, the analyser was left with Decon in its tubes to ensure the coils were as clean as possible before the start and a lot of Decon and sodium hydroxide were pumped through it before I started plumbing in the reagents for the first time. This has meant that I had no failures of any of the baselines during the cruise and only once was there a problem with a dirty line, which was the silicate line. The jumpy baseline was cleared though by tapping and cleaning the coils before a run was put on and nothing affected the actual analyses themselves.

Four problems occurred during cruise D326, one of them I could not do anything about, three of them were fixable. The first was that the Skalar software kept crashing. Although seemingly fine when watching the traces of the baselines through the real-time window, when I tried to start the analysis it would not record the data. This has also happened on previous cruises and no easy solution has been found. This has meant I have had to reinstall the software. On this cruise I reinstalled it three times, much more than on previous cruises and this problem will be followed up when I am back at NOCS. Once reinstalled the software would work fine again and so no samples were lost because of it, just time.

The second fixable problem was the waste line coming from the autoampler. For some reason there the pressure would gradually increase in this line and the connection would then come undone behind the sampler. This would leak waste solution all over the back

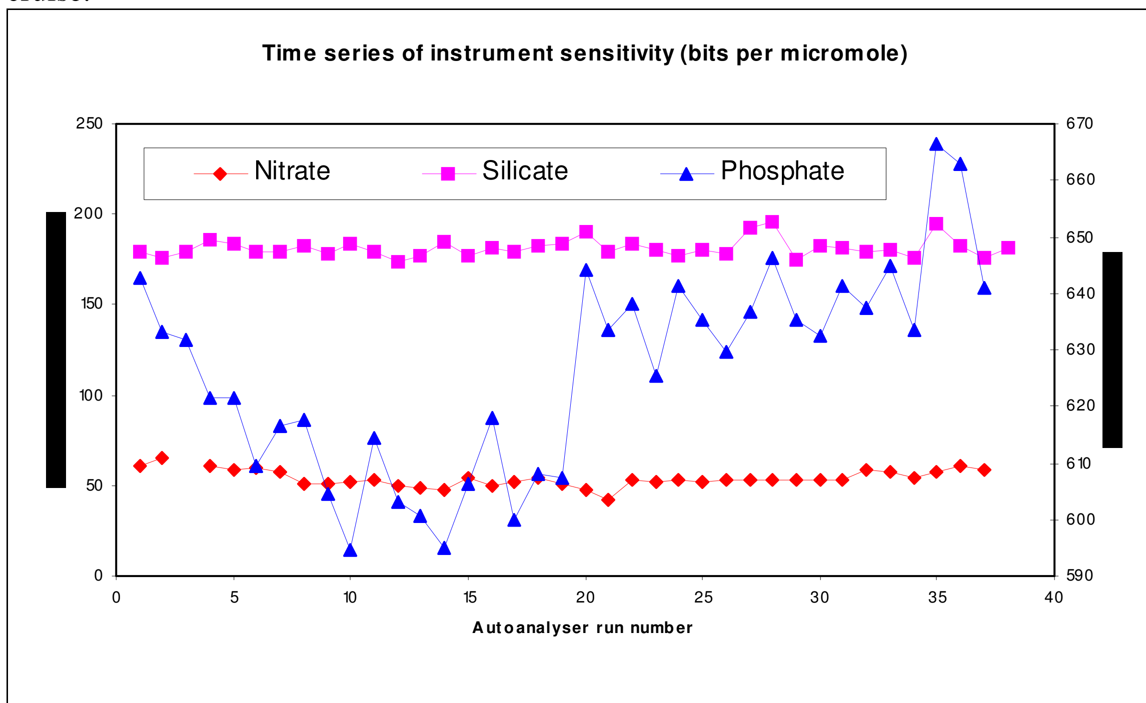
of the sampler and the desk. Unfortunately on one occasion this wasn't noticed until liquid had got into the sampler. This resulted in the sampler having a slight malfunction. It skipped four samples, drawing in air, and at the end of the run it failed to stop and so also drew in air. This resulted in the loss of four total dissolved phosphorous (TDP) samples. Once I had realised the seriousness of the problem I re-plumbed the waste line and the problem was solved.

The third and unfixable problem was the noise levels on the three lines. This was higher than has been seen in the past, but the noise problem has been noticed on recent cruises. I believe this noise is electrical interference as the noise patterns are identical in all three lines at exactly the same time. If it were as a result of the chemistry there would be a time delay between the three lines. It may also because of the movement of the ship. This is something we are going to investigate further back at NOCS.

The fourth problem was a drifting nitrate baseline. The baseline appeared to drift throughout the day. It was only when I had a long day trying to get the analyser up and running that I noticed the baseline eventually became stable. It seemed to be taking 6-8 hours for the lamps and spectrophotometers to warm up properly. I solved this problem by just leaving the lamps on all the time and just disconnecting the pump tubing at the end of a run.

All in all though the analyser worked well. Time series of instrument sensitivity, calibration curve correlation coefficient, nitrate reduction efficiency and duplicate difference were compiled to check the performance of the autoanalyser over the course of the cruise and these can be seen in figures 1-3.

Figure 1: Instrument sensitivity or nitrate, silicate and phosphate for the duration of the cruise.



The instrument sensitivity can be seen in Figure 1. The sensitivity for silicate and nitrate remained relatively constant throughout the cruise at approximately 60 bits per micromole for nitrate and 180 for silicate. Phosphate sensitivity was much more variable, ranging from 590 to 670 bits per micromole. The sensitivity des seem to have increased as well after run 20 as the average bits per micromole rise from approximately 610 to 640.

The regression coefficient of the calibration curves and the reduction efficiency of the cadmium column are shown in Figure 2. The regression coefficient for the silicate and phosphate lines is very high throughout the cruise, being above 0.999 for the majority of runs. For nitrate it is generally much lower, but it is still above 0.965 for all runs with the majority falling above 0.975. It does appear that during the second half of the cruise the regression coefficient is lower for nitrate. This could be because of a change in the batch of sodium chloride used for the artificial seawater or because of a standard which was not quite the concentration it should have been. Either way, due to the high values obtained anyway, I don't think this will affect the adversely data. The cadmium column shows that its efficiency was always above 80% with the majority of runs having an efficiency of over 96% indicating that it was working well for the whole cruise.

Figure 2: Regression coefficients for nitrate, silicate and phosphate as well as the cadmium column reduction efficiency.

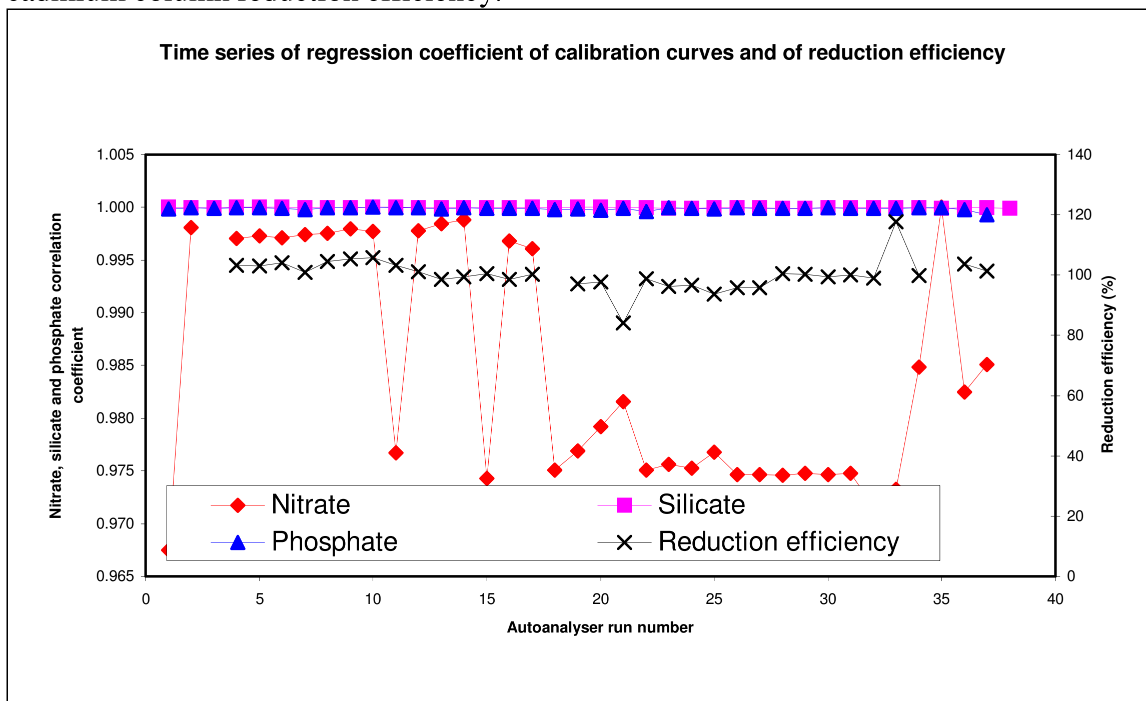


Figure 3: The percentage error in the duplicate samples.

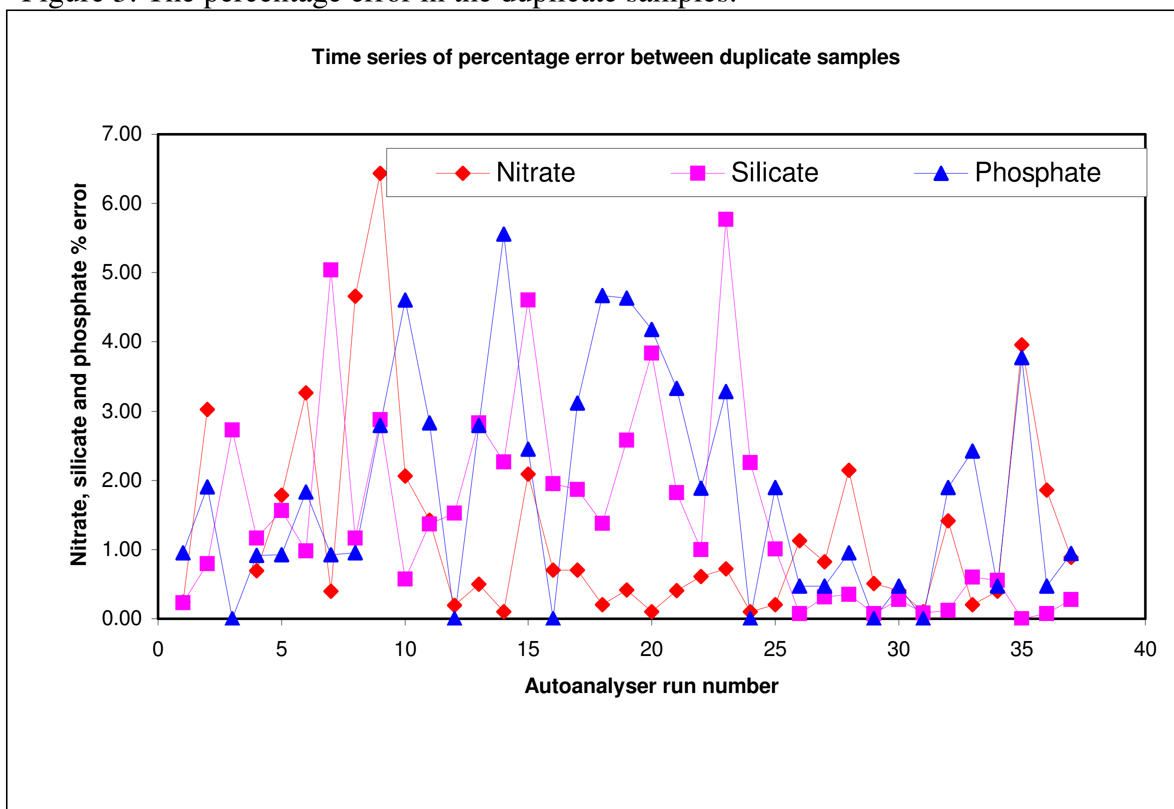


Figure 3 shows the percentage error between individual samples for nitrate, silicate and phosphate. The error was higher on this cruise than previous cruises. This could be because of the high noise level in the baseline as described earlier. The highest error was approximately 6.5% for nitrate, 6% for silicate and 5.5% for phosphate. Though these may seem quite hih, it should be noted that the majority of all the percentage errors were below 3%, with nitrate regularly being below 1%. The average error for nitrate was 1.2%, for silicate it was 1.48% and for phosphate it was 1.79%.

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Dissolution of dust

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The atmosphere is recognized to be an important pathway for the transport of trace elements of continental origin to oceanic areas. The inputs of iron (Fe), nitrogen (N) and phosphorus (P), which are essential nutrients for the biological growth of oceanic biota, are of particular interest, especially for oligotrophic oceanic areas and semi-enclosed seas. Atmospheric inputs may therefore stimulate the development of marine ecosystems, with implications for biological uptake of atmospheric carbon. Fitzwater (1998) and Martin et al. (1994) have shown that biological productivity in some oceans regions is limited by iron and there are suggestions that other metals including manganese, copper and zinc may also be limiting, perhaps synergistically (De Baar 1990; Bruland, Donat et al. 1991; Morel 1994).

The aim of my work on cruise D326 was to determine whether solubility of iron and manganese has been altered by cloud processing and whether this solubility is real (truely dissolved) or due to colloid formation. It is hypothesized that the solubility of both iron and manganese increases if the dust particles have been subjected to atmospheric cycling through the clouds. We will examine this hypothesis by simulating the cloud processing of particles and then using these particles for dissolution experiments in order to measure the release of iron and manganese from the particles into the seawater.

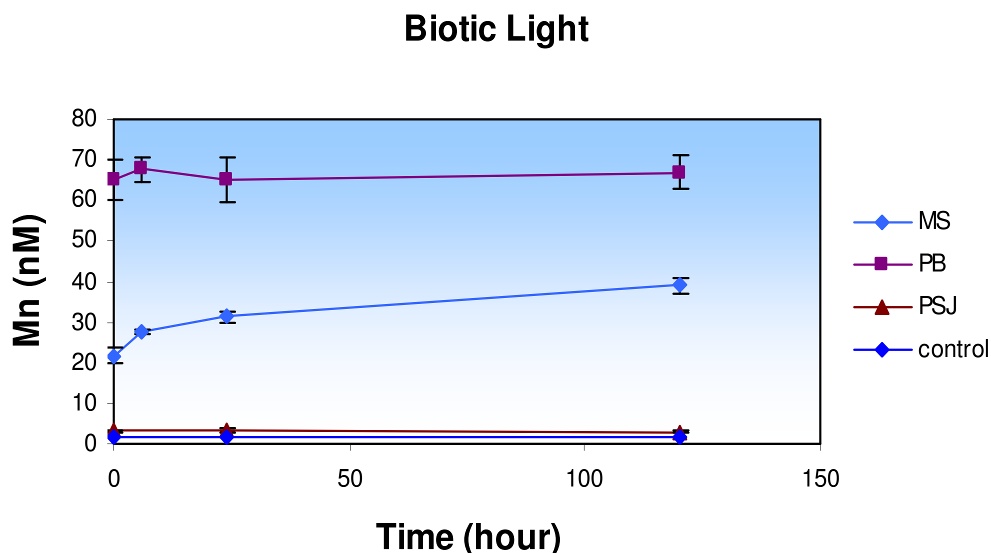
1. Dissolution experiments

The seawater dissolution experiments were conducted during the D326 UK SOLAS Cruise on board of the RRS *Discovery* during the period 5 January 2008- 5 February 2008. Twelve polycarbonate bottles were used for the incubation of treated and not treated Saharan soil carrying the same principle of Teflon tubing through the cap of the bottles used for the sub sampling during the course of the experiment which was performed inside a clean lab and under a laminar flow hood Class 100.

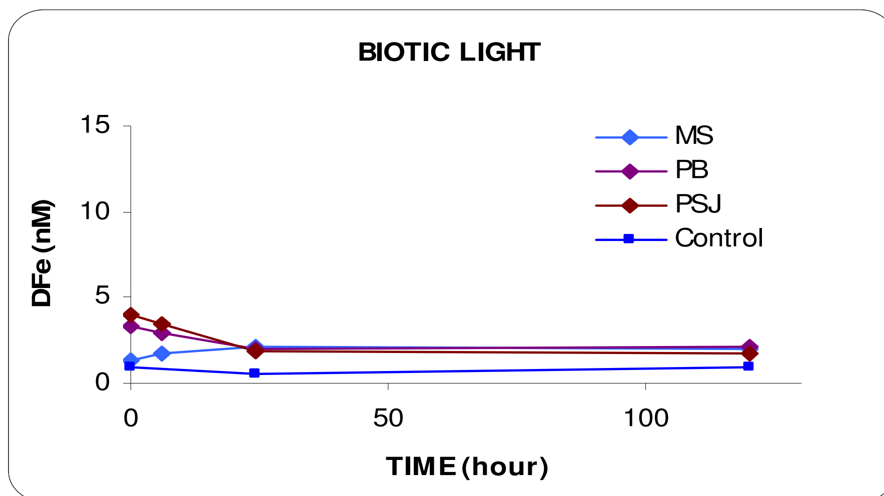
The seawater for the first experiment was collected on the 11/01/08 from the Titanium CTD cast at station 16394B with coordinates 25 40.2*ºN* 28 48.3º*W*. The depth of the sampling was 30m and it was used without being filtered on the same day. For the other two experiments the seawater was collected during the station 16419B with coordinates 16 09.6ºN 30 38.1ºW on the 25/01/08 and it was filtered through a 0.2 μm filter directly into the polycarbonate bottles for the Light experiment and in a carboy for the Dark experiment. The carboy was double bagged using black bags to prevent the sunlight and the water remained in there for another two days before being used for the experiment. The addition of dust and the sub sampling took place in a clean lab under a laminar flow hood. After each sampling the polycarbonate bottles were sealed with parafilm, double bagged and placed in incubators on the deck of the ship under direct sunlight and constant temperature as seawater was constantly flowing through the incubators. The bottles from the dark experiment were treated similarly with the only difference before put in the incubator they were firstly put in double black rubbish bags. The sub samples were acidified on the same day with 1μL/mL of solution HCl Romil SpA.

The sub samples were analysed for Fe and Mn during the cruise, using the flow injection analysers with preconcentration step.

Some results are given at the following graphs.



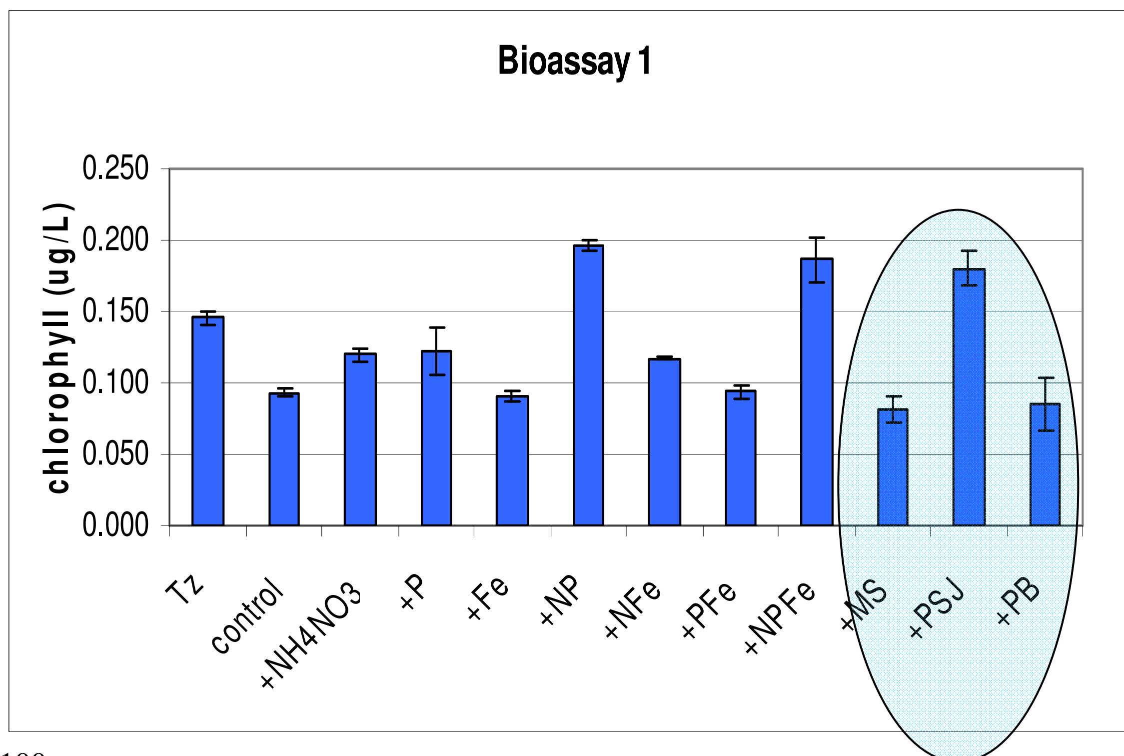
Graph 1. Concentration of Mn released during the biotic seawater dissolution experiment under direct sunlight.



Graph 2. Concentration of Fe released during the biotic seawater dissolution experiment under direct sunlight.(PB- processed acid treated Saharan soil, PSJ – processed low pH cycled S.soil and MS- non treated S.soil)

2. Bioassays

Moreover I took part in the Bioassays Experiments carried out on board by using the soil that had been treated in low pH cycling (in order to simulate the atmospheric processing) previously.



Dissolved Aluminium, Ammonium, and particulate Hemes

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During RRS *Discovery* cruise 326 shipboard water column ammonium and dissolved aluminium measurements were made, and samples were collected for particulate hemes for subsequent analyses in the laboratory at NOC.

Samples for dissolved aluminium were taken from 10 L trace metal clean OTE bottle casts using a titanium frame. Underway surface seawater was sampled by pumping it into a trace metal clean laboratory container using a Teflon diaphragm pump (Almatec A-15, Germany) connected by an acid-washed braided PVC tubing to a towed fish positioned at approximately 3 m depth alongside the ship. The seawater was filtered in-line using a Sartobran 300 filter capsule (Sartorius) with a 0.2 µm cut-off. All low density polyethylene bottles (Nalgene) were cleaned according to a standard protocol (Achterberg et al., 2001). Samples for DFe were acidified to pH 2 (a final concentration of 0.011 M) using ultra clean HCl (Romil UHP grade).
Samples for ammonium and particulate hemes were collected from the 20 litre OTE bottles mounted on the CTD rosette. The analyses were conducted using a flow-injection system, with fluorescence detection of the lumigallion-aluminium complex (part of the samples will require analyses at NOCS as there was insufficient time to complete this at sea). The analyses were successful, and 53 profiles were analysed (> 400 samples), with another 189 underway samples (collected from the towed fish). The aluminium concentrations ranged from 8-50 nmol L^{-1} in the surface waters to 10-20 nmol L^{-1} at depth (up to 1000 m).

A total of 53 water column profiles (productivity casts) were analysed for ammonium on the cruise with typically 6 samples for each profile (total >300 samples). The ammonium measurements were conducted using the OPA fluorescence method. A volume of 2 mL mixed OPA-borate reagent was added to 25 mL of sample, and this was allowed to react for 24 h.
Samples were subsequently analysed on a Turner Design fluorimeter (TD700) equipped with filters for ammonium measurements. The ammonium measurements have been successful, with <10-100 nmol L^{-1} concentrations throughout the water column. Distinct maxima were observed at the chlorophyll maximum in a number of casts.

For hemes (to be analysed by Dr Martha Gledhill at NOC), samples have been collected from 30 water column profiles (typically 6 samples for each profile; generally productivity casts). Sample analyses will be conducted over the coming months in Southampton.

Microbial community abundance, structure and dynamics

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The aim

To study abundance, community composition and metabolic activities of dominant microbial groups within planktonic communities and to assess the effect of dust on the rates of their carbon fixation and nutrient acquisition in the subtropical North East Atlantic Ocean. In providing a significant source of new nutrients to surface waters of the open ocean, atmospheric dust is hypothesised to play a key role in enhancing oceanic primary productivity. The amount of nutrients that are delivered to the ocean from arid land, and how much of these are available to the microbial community, remains uncertain.

Objectives

1) To determine the spatial distribution, abundance and community structure of nano- and picoplankton in the euphotic zone by flow cytometry, using underway sampling from the ship's uncontaminated seawater supply.
2) To collect concentrated seawater samples for analysis of plankton community composition in the euphotic zone using molecular approaches, including fluorescence *in situ* hybridisation (FISH).
3) To estimate rates of carbon fixation by dominant phototrophic microbes.
4) To estimate the turnover of dissolved organic nutrients and phosphorus using methionine, leucine, ATP and phosphate tracers; to assess the effect of dust on the microbial uptake of these compounds.

Plankton community structure and abundance by flow cytometry
Seawater samples for flow cytometric analysis were drawn from the ship's non-toxic seawater supply and fixed in paraformaldehyde (PFA, final concentration 1%) using a Miniprep 60 automated liquid handling robot (Tecan, Reading, UK) at a sampling frequency of once every 30 minutes for the duration of the cruise. Underway sampling began at 1230 GMT on 06/01/08 and was discontinued after 1500 GMT on 03/02/08. Samples were analysed on a Becton Dickinson FACSort (BD Biosciences, Oxford, UK) Analytical Flow Cytometer. Samples were stained with SYBR Green I DNA stain. Two analysis protocols were used to resolve and enumerate populations of heterotrophic bacterioplankton, *Prochlorococcus* and *Synechococcus* cyanobacteria, picoplanktonic and nanoplanktonic algae and heterotrophic protists on bivariate dotplots of 90° light scatter and green (DNA stain) fluorescence, orange fluorescence and red fluorescence.

CTD samples were collected (With thanks to Duncan Purdie and Anna Macey) from each station and 1.5ml from each bottle fixed in PFA and stored at -80°C for later shoreside AFC analysis.

Microbial cell collection for molecular analyses of phylogenetic composition of planktonic eukaryotic and prokaryotic communities.
Photosynthetic picoeukaryotes (PPEs), comprising cells smaller than 3 µm in diameter, are widespread in marine environments and may be responsible for the majority of C fixation in the world's oceans. It is of obvious importance to quantify the dominating phylogenetic groups of PPEs in the natural environment in order to begin to understand their contribution both to the microbial food web and to global C cycling. To assess PPE diversity, a clone library will be constructed using both 18S rDNA eukaryote primers and 16S rDNA primers targeting specifically photosynthetic eukaryotes. To determine the distribution, the abundance and the contribution of specific PPE classes to total phytoplankton biomass TSA-FISH technique will be used. To determine the vertical variation of the PPE diversity and the abundance of PPE classes, surface samples were collected at 48 stations and from 3 different depths at 6 stations. Finally, PPE community composition will be determined for the samples used for tracer experiments. Samples taken to construct clone libraries and for FISH consisted of the filtration of 5 L of seawater after prefiltration through 10µm to screen out larger organisms. The samples were then frozen and stored at -80°C.

Estimation of rates of carbon fixation by dominant microbial groups.
A series of experiments using radioactive tracer techniques were conducted during the cruise. Sodium ^{14}C-bicarbonate was used to trace photosynthetic fixation by microbes to determine relative contributions by dominant groups of microorganisms using flow cytometric sorting. Microbial cells were fixed with PFA (1 %) and filtered on 0.2 µm polycarbonate filters. The filters were treated with hydrochloric acid to remove traces of unfixed $^{14}CO_2$. Filters were placed in scintillation vials filled with scintillation cocktail and radio-assayed using an on-board liquid scintillation counter (Packard 3100).
Sampling details:

date	Station	depth (m)	bottle
7/01/08	16386 A	5	23, 24
8/01/08	16387 A	5	23, 24
9/01/08	16390 A*	2	23, 24
	16391 A	110	12, 13
10/01/08	16392A*	5	23, 24
	16393 A	120	11
11/01/08	16391 A*	5	23, 24
	16395 A	5, 120	23, 9
12/01/08	16396 A*	5	23, 24
	16357 A	5, 100, 120	24, 12, 10
13/01/08	16398 A	5	23, 24
	16399 B	5	23, 24
14/01/08	16400 A*	5	23, 24
	16401 A	5	23, 24
15/01/08	16402 A	5	23, 24
	16402 AA	5, 90, 100	24, 13, 10
16/01/08	16403 A*	5	23, 24
	16404 A	5	23, 24
17/01/08	16405 B*	5	22, 23, 24
18/01/08	16407 A*	5, 300	20, 23, 1
	16408 A	5	23, 24
19/01/08	16409 A*	5, 300	20, 23, 1
	16410 A	5, 59, 63	24, 14, 12
20/01/08	16411 B*	20	22, 23, 24
	16412 A	5	23, 24
21/01/08	16413 B*	20	23, 24
	16414 A	5	23, 24
22/01/08	16415 B*	20	22, 23, 24
	16416 A	5	23, 24
23/01/08	16417 A*	5	23, 24
24/01/08	16418 A*	5	22, 23
25/01/08	16419 B*	20	22, 23, 24
	16420 B	5, 77, 87	23, 12, 9
26/01/08	16422 B*	20	22, 23
	16423 A	4	23, 24
27/01/08	16425 B*	20	22, 23, 24
	16426 A	4	23, 24
28-29/01/08	16428 B*	20	22, 23, 24
30/01/08	16429 B*	20	22, 23, 24
	16430 A	5	23, 24
31/01/08	16431 B*	20	22, 23, 24
1/02/08	16432 B*	20	22, 23, 24
2/02/08	16433 B*	20	22, 23, 24
	16434 B	20	
	16434 A	5, 60, 147	24, 14, 7
3/02/08	16435 B	20	

Stations marked with a star have been sampled for carbon uptake activity of the PPEs. All stations and depths have been sampled to analyse PPE diversity and for FISH analysis. No definitive results are available at the moment. Samples will be analysed within the next 2 months at Warwick University.

Examining the effect of nutrients, released from aerosol dust, on the metabolic activities of dominant planktonic microbes in surface waters studied.
Ambient concentrations and turnover rates of two amino acids, leucine and methionine, by total bacterioplankton were measured using isotopic dilution time-series incubations. Using the same seawater sample, additions of dust leachate prepared from aerosol collected during the cruise were made and the response of the bacterioplankton community measured in terms of the change in rate of amino acid uptake. Response to dust leachate additions were measured during short term (30 min – 1 h) and long term (17 – 24 h) incubations.

Radiolabelled phosphate and ATP were used at some stations to estimate ambient concentration and turnover of the bioavailable fraction of these nutrients, with the overall aim being to use the method to test whether dust deposition would lead to an increase in bioavailability of these nutrients. However, the ambient concentrations were generally too high for the method to work effectively.

Replicate aerosol samples were collected over 48 h periods throughout the cruise. Seawater samples were incubated in the presence of clean control, and dust loaded filters with ^{3}H-leucine uptake used as an indicator of community response.

Seawater samples used for experimentation were collected from 5 or 20 m, mostly using the titanium CTD frame (Table 2). This water was used for amino acid bioassay incubations within an hour of collection.

Table 2. List of seawater samples taken.

Date	Station	Depth, m
07/01/08	16386B	5
09/01/08	16390B	5
09/01/08	16391B	5
10/01/08	16392B	5
10/01/08	16393BB	5
11/01/08	16394B	5
12/01/08	16397B	5
13/01/08	16398B	5
14/01/08	16400B	5
15/01/08	16402A	5
16/01/08	16403A	5
17/01/08	16405B	5
18/01/08	16407B	5
19/01/08	16409B	5
20/01/08	16411B	20
21/01/08	16423B	20
22/01/08	16415B	20

23/01/08	16417B	20
24/01/08	16418B	20
25/01/08	16419B	20
25/01/08	16420B	20
25/01/08	16421B	20
26/01/08	16422B	20
26/01/08	16423	Neuston (zodiac)
26/01/08	16424B	20
27/01/08	16427B	20
28/01/08	16428B	20
30/01/08	16429B	20
30/01/08	16430B	20
31/01/08	16431B	20
01/02/08	16432B	20
02/02/08	16433B	20
02/02/08	16434B	20
03/02/08	16435B	20

Preliminary observations

The heterotrophic bacteria community in the survey area was reasonably constant in terms of the flow cytograms of light scatter vs green fluorescence from stained DNA. Abundance in the surface waters varied from 0.5 to 1.6 million cells mL^{-1}. *Prochlorococcus* and *Synechococcus* sp. cyanobacteria were more variable, abundance ranging from 50 to 250 thousand cells mL^{-1} and 2,000 to 50,000 cells mL^{-1}, respectively. Ultraphytoplankton ($<5 \mu m$) were the most abundant eukaryotic organisms, with concentrations varying by an order of magnitude from 800 to 14,000 cells mL^{-1}.

Scintillation counts were done on board the ship and a five fold range of rates of microbial activity was observed. Bioassayed concentrations of methionine in surface waters ranged between 0.1-0.8 nM. Estimated turnover of methionine molecules by bacterioplankton ranged between 20-140 hours. Detailed analysis of the collected tracer samples will be carried out after the cruise on low background scintillation counters back at the NOCS, because of the sensitivity limitations of the scintillation counter on board the ship. When completed, the data set will allow estimation of the rates of

bacterioplankton metabolic activity, production and mortality due to grazing, as well as linking between bacterial function, composition, hydrological structure of the water column and dust deposition.

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Computing and Instrumentation Report
Cruise: *Discovery* 326

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RVS LEVEL ABC System

The LEVEL ABC system is a system comprised of multiple components that can be adjusted and altered to suit the needs of the cruise in progress. The system is due to be retired due to its age and the difficulty in acquiring spares. The ABC system is created of 3 tiers:

- Level A - The Level A's role in the system is to acquire the data from an instrument, parse the data stream into the necessary format to be recorded by the level B and also place a timestamp on each piece of data. The instruments are connected to the Level A's via RS-232 and are also connected to the level B in the same way. This allows simple interrogation of messages when attempting to track a problem with the system.

- Level B - The level B is sent all data from the Level A's and allows you to view all the data as it is coming in. The Level B allows the backup of the data to magnetic disks which are backed up on the Level C in compressed Zip format. The Level B transmits the data to the Level C and the data is parsed directly into the RVS data files that we use now. All data, errors, comments can be viewed for each individual instrument.

- Level C - The level C system is a Sun Solaris 10 UNIX Workstation discovery1 also known as ABCGATE. The RVS software suite is available on this machine. This suite of software allows the processing, editing and viewing of all data within the RVS data files. This system also has monitors that allow us to ensure that the level C is receiving data from the level B.

The Level A's acquire their timestamp from a Radio code GPS Clock that is distributed via the RVS Master / Slave Clock System.

The ABC system still remains the main data logging format for the ship, this is being run in parallel with the new Ifremer Techsas Sensor Acquisition System. This system is currently being proven and a database of drivers being built to enable us to interface with the instruments on board.

This system will then become the primary system for data logging.

For this cruise the Level A system were used to log:

1) Ashtech ADU-2 multi antenna GPS with attitude (gps_ash)
2) Ashtech GPS G12 integral to the FUGRO Seastar DGPS receiver (gps_g12)
3) NMFD Surface-water and Meteorology instrument suite (surfmet)
4) NMFD Winch Cable Logging And Monitoring CLAM (winch)

The RVS level ABC system suffered no major issues during the cruise with the exception of the full loss of power to all ships systems, total loss of data was around 2 hours for most instruments, mainly due to the need to reset almost all devices that are used in the data logging process. During the power outage the computer room clean supply was turned off incase of spiking in order to protect equipment. This was successful and no further damage occurred to the ABC system or the Ifremer Techsas system.

Ifremer Techsas System

The Ifremer data logging system is the system that will inevitably replace the existing Level A + B system while for the most part the Level C will remain as the main system for outputting, viewing and editing the acquired data.

The Techsas software is installed on an industrial based system with a high level of redundancy. The operating system is Red Hat Enterprise Linux Edition Release 3. The system itself logs data on to a RAID 0 disk mirror and is also backed up from the Level C using a 200GB / 400GB LTO 2 Tape Drive. The Techsas interface displays the status of all incoming data streams and provides alerts if the incoming data is lost. The ability exists to broadcast live data across the network via NMEA.

The storage method used for data storage is NetCDF (binary) and also pseudo-NMEA (ASCII). At present there are some issues on some data streams with file consistency between the local and network data sets for the ASCII files. NetCDF is used as the preferred data type as it does not suffer from this issue.

The Techsas data logging system was used to log the following instruments:

1) Trimble GPS 4000 DS Surveyor (converted to RVS format as gps_4000)
2) Chernikeef EM speed log (converted to RVS format as log_chf)
3) Ships Gyrocompass (converted to RVS format as gyronmea)
4) Simrad EA500 Precision Echo Sounder (ea500d1)
5) NMFD Surface-water and Meteorology (SURFMET) instrument suite
6) NMFD Winch Cable Logging And Monitoring CLAM (winch2)
7) Ashtech GPS G12 integral to the FUGRO Seastar DGPS receiver (gps_g12T)

This system is still being trial run by the platform systems as the replacement to the aging RVS system, no major issues occurred during this cruise and no substantial data losses occurred. The recent upgrade of the software on both TECHSAS systems allows the software to continue logging without the memory leak issue which was causing crashes in the system every few days.

Techsas NetCDF to RVS Data Conversion

During this cruise there is no reliance upon the data provided by Techsas, however it has been included on the data archive in the standard rvs form using a piece of software used to make it compatible with the RVS ASCII data structure. The University of Rhode

Island instruments were logged using the Techsas system and had to be converted to the RVS format in order to be able to create data logs that included multiple variables from other RVS streams.

An in house application was used to handle the conversion of NetCDF files to the RVS format. This was then parsed back to the data file and was processed as normal. These 2 new applications being ncvars and nclistit.

These new binaries require to environment variables in order to function:

$NCBASE – the base for the NetCDF binaries system, set to /rvs/def9

$NCRAWBASE – the base for the raw data files, set to /rvs/pro_data/TECHSAS/T1backup/D325/NetCDF

The existing $PATH variable must also include the path to the nc binaries, the path /rvs/def9/bin was appended to the $PATH variable.

All Techsas data file names are in the format of YYYYMMDD-HHMMSS-name-type.category with the data/timestamp being the time the file was created by Techsas.

The files were each processed in the following way for this cruise:

nclistit 20060813-000001-gyro-GYRO.gyr - | sed s/head/heading > $DARAWBASE/gyro.225

At this stage the data is converted to the correct format and its header replaced by the header required by the RVS software suite.
Another issue with the conversion of the files to the RVS format is that the top timestamp is always outputted as 00 00/ 00:00:00. The file outputted with nclistit is then edited in VI in order to alter that timestamp to the correct time and day. This is done as it would not be imported into the RVS data format with this timestamp error.

The file is then passed to the titsil application which simply reads the data from the text file that was created and enters it as records in the RVS data file.

cat $DARAWBASE/gyro.225 | titsil gyronmea –

This command reads the gyro.225 file in the /rvs/raw_data directory and passes it to titsil for input in the gyronmea file. The – dictates that all variables will be included.

The TECHSAS system was set to create a new file for each day, however on days when errors occurred multiple files were created as that is normal practice for Techsas when it is restarted.

Fugro Seastar DGPS Receiver

The Fugro Seastar is the source of custom differential corrections based on its position fixed by its internal Ashtec G12 GPS module. It outputs corrections via RS-232 using the standards RTCM message. The message is distributed among all GPS receivers where they are used to compute their own DGPS positions.

The Fugro Seastar functioned correctly throughout the cruise. There have been issues with this system previously not detecting the correct satellites due to location. However in this instance it performed correctly and differential positions were calculated throughout the cruise.

The module for logging this instrument was written prior to the cruise sailing and was run during the cruise. The system reported no errors however it failed to log the 'sec' field that holds the utc time of the data sent from the gps. This field appears blank in the NetCDF files for this system PASHRPOS-G12.PASHR.

The Level A B system has correctly logged this data for the entirety of the cruise and was used in bestnav calculations.
The issue was resolved during the cruise however due to problem with the way techsas work you cannot change the code and compile a binary without shutting down logging to ensure it creates a new file. As this means that logging ceases I was not willing to make the change during science.

Trimble 4000 DS Surveyor

The Trimble 4000DS is a single antenna survey-quality advanced GPS receiver with a main-masthead antenna. It uses differential corrections from the Fugro Seastar unit to produce high quality differential GPS (DGPS) fixes. It is the prime source of scientific navigation data aboard RRS *Discovery* and is used as the data source for Navigation on the ships display system (SSDS). This system worked reliably during the cruise following its replacement during the port call prior to sailing. This antenna is directly on top of the mast and suffers from negligible interference from other items on the mast. It is also almost directly at the centre point of the ship making it an ideal navigation system.

Ashtec ADU-2

This is a four antenna GPS system that can produce attitude data from the relative positions of each antenna and is used to correct the VMADCP for ship motion. Two antennae are on the Bridge Top and two on the boat deck.
The Ashtec system worked reliably throughout the cruise with some gaps that are quite usual with this system due to the amount of calculations necessary. No Large data gaps are present. The ADU-2 forms part of the bestnav system which is an assembly of multiple GPS signals including the gyronmea and emlog stream in order to calculate the best possible position, speed heading pitch and roll of the ship. The Ashtech is not as reliable as the G12 and the 4000DS mainly due to its low position on the ship it is hard

for this system to maintain locks on satellites when the ship is maneuvering and the bridge and main mast come into its direct line of sight with the satellites.

The ADU-2 module on the TECHSAS system was upgraded to log more of the messages that the ADU-2 produces. This was successful but only when the ADU-2 was able to transmit good data. When the satellites were not synced well no data.

Gyronmea

The Gyronmea is a file that receives its data from the Ships gyro compass located on the bridge. There are two such Gyros on the bridge and we are able to use either one of them as a source of heading. The selected Gyro is logged by the TECHSAS system and is used as part of the bestnav calculation.

RDI Ocean Surveyor 75KHz Vessel Mounted ADCP (VMADCP)

Data from the RDI Ocean Surveyor was logged throughout the cruise and backed up to the /data32 shared data area. The ADCP 75 was setup to follow the settings as agreed with Ricardo Torres. The system was reconfigured to 4 meter bins in order to achieve a better resolution through the mixed layer.
50 Bins
4 m
8 m Blanking Distance
This can also be viewed in the command files that were used for both legs of the cruise that are included in the ADCP area of the data archive.

RDI 150KHz Vessel Mounted ADCP (VMADCP)

Following several difficulties in the previous cruises with this system the transducer head was replaced prior to sailing D317. The ship was attended by a Teledyne RDI consultant who assisted in checking over the setup of the ADCP 150Khz and ADCP 75Khz systems. The transducer had been giving several errors during the cruise which would indicate that the transducer head was damaged. Problems also existed with the PC that was in use. No navigation signals were being received by the unit and the ensemble out would not function. This ensemble out allows the RVS system to grab data on a 2 minute interval from the ADCP 150Khz system. Following the visit by the RDI Consultant the system was able to handle both navigation input and ensemble output. However that seems to have now changed once more. The ADCP 150 is still receiving the GPS messages and still has the setup within its file to handle the data however it does not seem to function correctly. This appears to be a fault in the way that the VMDAS software is handling the navigation or possibly the comm ports. The system was logged without navigation to the local hard disk and also to the RVS Level C where it can be concatenated with the navigation data. This system is due for upgrade next year during the 2008 dry dock.

50 Bins
4 m

8 m Blanking Distance

Chernikeef EM log

The Chernikeef EM log is a 2-axis electromagnetic water speed log. It measures both longitudinal (forward-aft) and transverse (port – starboard) ships water sped.

The EM log was not calibrated prior to the cruise and was reading at -0.8 knots astern when alongside (-0.8 knots)

The system was logged by the TECHSAS logging system.

Simrad EA500 Precision Echo Sounder (PES)

The PES system was used throughout the cruise, with a variation between use of the Fish and use of the hull transducer.

The PES outputs its data to a stream called ea500d1 on the TECHSAS System.

The PES was enabled on departure and the fish was deployed at 0946 on Jday 006. The PES was switched to Hull transducer at 0900 and the fish recovered post switchover.

Surfmet System

This is the NMFD surface water and meteorology instrument suite. The surface water component consists of a flow through system with a pumped pickup at approx 5m depth. TSG flow is approx 25 litres per minute whilst fluorometer and transmissometer flow is approx 3 l/min. Flow to instruments is degassed using a debubbler with 40 l/min inflow and 10/l min waste flow.

The meteorology component consists of a suite of sensors mounted on the foremast at a height of approx 10m above the waterline. Parameters measured are wind speed and direction, air temperature, humidity and atmospheric pressure. There is also a pair of optical sensors mounted on gimbals on each side of the ship. These measure total irradiance (TIR) and photo-synthetically active radiation (PAR).

The Non Toxic system was enabled as soon as we were far enough away from land.
Non Toxic On : 080051800
Non Toxic Off : 080350900

Salinity samples were taken on a daily basis while the Non toxic supply was taken, 1 sample a day was taken for calibration of the TSG. For Times and Salinity Values. Please see the Excel Sheet in the tsg_salin folder

The data here shows a good standard trend for all data points used. Some data points were removed due to them affecting the regression. This amounted to a small number of points

and indicates a bad sample. The TSG shows that it is reading quite a bit higher salinity value than the autosal samples done.

There are several files in the system for Surfmet due to the Level B having a time error.
Surfmet is the Level B logged file
Surfmet2 is the TECHSAS Logged file
Surftmp is the cleaned level B file
Protsg is the protsg version of the level B data set

Meteorological Instrumentation

Measurement	Wind Speed	Spec : Range 0.4-75m/s, output: 0-75m/s = 0-750Hz, Accuracy: +/-0.17m/s^2
Manufacturer	Vaisala	
Model N^o	WAA151	

Measurement	Wind Direction	Spec : Range: 0-360°, output: 6bit parallel grey code
Manufacturer	Vaisala	
Model N^o	WAV151	

Measurement	PAR	Spec : Range 350-700nm output depends on sensor, (see cal sheet), Accuracy: +/-5%
Manufacturer	ELE	
Model N^o	DRP-5	

Measurement	TIR	Spec : spectral Range 335-2200nm (95%) irradiance 0-1440W/m^2, Sensitivity 9-15uv/W/m^2
Manufacturer	Kipp & Zonen	
Model N^o	CM 6B	

Measurement	Temp & Humidity	Spec : Temp, -20 - +60°C, accuracy at 20^{0}C, +/-0.4^{0}C Humidity, 0-100% RH Accuracy, +/-4%
Manufacturer	Vaisala	
Model N^o	HMP45	

Measurement	Barometric Pressure	Spec : Range 800-1060mbar, Accuracy at 20°C : +/-0.3mbar
Manufacturer	Vaisala	
Model N^o	PTB100A	

Surface Sampling

Measurement	Housing Temperature	Spec Range:-2 - +32°C, accuracy: +/-0.003^{o}C, res:0.0001^{o}C Stability: +/-0.0005 ^{o}C
Manufacturer	FSI	
Model N^o	OTM	

Measurement	Remote Temperature	Spec Range:-2 - +32°C, accuracy: +/-

Manufacturer	FSI	0.003°C, res:0.0001°C
Model N°	OTM	Stability: +/-0.0005 °C

Measurement	Conductivity	Spec : Range 0.4-75m/s, output: 0-75m/s = 0-750Hz, Accuracy: +/-0.17m/s^2
Manufacturer	FSI	
Model N°	OCM	

Measurement	Turbidity	Spec : Range 0-100% or 90-100%, Output: 0-5vdc Or -5 - +5vdc Accuracy: 0.1%
Manufacturer	Wetlabs	
Model N°	20cm	

Measurement	Fluorescence	Spec : Output ∞ emitted light at 685nm Output: 0-+5vdc
Manufacturer	Wetlabs	
Model N°	WETStar	

Plots

Plots were made using the standard bestnav system on DVD1.
Plots were made for each station using Matlab 2006b. These can be found on the DVD along with the RVS Cruise Data.

CASIX PCO2 System

This system is an autonomous pCO2 system developed by PML and Dartcom. I am not entirely sure of the full details of this and so I am not going to pretend like I do for fear of being incorrect. I advise that you contact Nick Hardman-Muntford at PML for information. The system was run at the same time as the Surfmet system and cleaned periodically. The PCO2 ProForma can be found on the data archive.

The PCO2 was switched on immediately as the water was available. The systems PRT was changed and the data was segmented into D326 and D326A to show the change. The data is available from BODC post cruise.
The PCO2 water supply ended at 08 035 0900 which was earlier than expected due to a leak in the Constant Temperature lab.

Network Services

The networking system was used continually throughout the cruise with connections on the monkey island being used for computers logging GPS and Drifter buoy positions. The system in general performed well, however some comments on the speed were submitted. The ships old 10base2 network that is available in cabins is currently being replaced in order to help improve services and speed.

Wireless network

Previous known network issues had been addressed prior to the cruise allowing the existing system to continue to work uninterrupted. Wireless worked throughout the cruise where available.

E-mail system

The email system worked fairly well for the entire length of the cruise. There were several issues due to the heading of the vessel which were unavoidable at certain stations due to the head to wind requirement. Email's were done at opportunistic times whenever the samplers where turned off or we were required to re maneuver back to station.

Data Storage

Two USB external hard drives are being use as a RAID 0 mirror hosted by Discovery3 at the /data32 export. The mirror uses the modern meta device commands available in Solaris 10. This increases storage robustness by providing another layer of redundancy at the online storage level. The maintenance and administration of the disk set is minimal and the performance more than adequate.

All cruise data except for the /rvs path were stored on this storage area. Access was given to scientists to some of the folders via Samba shares.

All CTD, FRRF and Minilog data was backed up to these drives on acquisition.

Level C data was logged to the discovery1 internal disk, Techsas backs its data to here under /rvs/pro_data/TECHSAS and also stores it on its own internal raided drive array.

Data Backups

Backups of the Level C data were done twice daily as a tar file to DLT tape and LTO tape. Alternating between the standard backup below and a full /rvs backup. The following paths were included in the tar file:

/rvs/raw_data
/rvs/pro_data
/rvs/def7/control
/rvs/users

In addition to the redundancy provided by the RAID 0 pair, daily backups of the /data32 directory were done by a level tar of the file system to the LTO 2 tape. The whole disk was backed up not just current cruise data.

The LTO2 system was backed up on a daily basis in a rolling 2 tape system.

Data Archiving

The proposed data archive will consist of the following components.

1) All CTD data
2) All FRRF data
3) All TECHSAS NMEA and NetCDF data files
4) All RVS Data Streams including Listit Text file outputs
5) All Minilog Data from Saps and Incubators.

All data was written to DVD with 10 copies made.
1 copy for BODC (LTO)
1 copy for PSO
1 copy for RRS DISCOVERY
1 copy for return to NOC

CTD CRUISE REPORT D326

Two CTD systems were used during the cruise. A 'standard' stainless steel unit for general sampling plus a titanium unit for trace metal sampling. Both units were fitted with Seabird 9+ CTD and associated equipment.

CTD configurations

The stainless CTD package comprised of the following instruments:
SBE 911+ CTD with dual pumped temperature and conductivity sensors. The primary sensor pair was vane mounted to reduce salinity spiking and entrainment effects. A Seabird SBE 43 oxygen sensor was fitted in the secondary duct.
Seabird carousel type SBE 32.
Chelsea instruments Alphatracka (transmissometer) and Aquatracka (fluorometer).
PML 2 pie PAR light sensors for up-welling and down-welling light.
Chelsea Instruments Fast Repetition Rate Fluorimeter with its own PAR sensor.
Benthos altimeter type 915T.
Wet-Labs light back scatter sensor.
Twenty four, 20 litre OTE Water bottles.

The titanium CTD was configured as follows:
Seabird 911+ CTD with dual pumped temperature and conductivity sensors, both pairs were mounted on the CTD.
A Seabird SBE 43 oxygen sensor in line with the secondary sensor duct.
SBE 32 carousel.
Chelsea Instruments Alphatracka and Aquatracka.
PML 2 pie PAR light sensors, one for down-welling and one for up-welling light.
WetLabs back scatter sensor.
Tritech P200 altimeter.
Twenty four, 10 litre OTE trace metal water bottles.

Equipment performance.

There were very few problems with the stainless frame CTD. Most of the problems experienced were with the titanium CTD. Various communication faults and noisy data problems (particularly on casts 16386B, 16388B, 16393B, 16395B and 16396B) were eventually traced to a corroded connector JB2 on the 9+. The unit was removed from the frame, the connector and conductivity sensor cable replaced, and the 9+ re-fitted. This resulted in the elimination of associated comms. problems. Fluorimeter s/n: 088163 exhibited signs of failure and was finally replaced after cast 16412B with s/n: 088195. During the down-cast of 16435BB some temperature spiking occurred between approximately 2000 and 4000m on the secondary sensor pair. The spiking ceased on the up-cast after 4000m depth.

The 20 litre water bottles had a 'sealing failure' rate of approximately one to two bottles per cast. This is quite normal with these bottles, the bottom end cap being the source of failure. There was also the problem of the lanyards breaking when the bottles were cocked. This was mitigated by leaving the bottle cocking (and hence reducing the time the lanyards were under maximum tension on deck) until immediately before the cast. However, bottle lanyards still had to be repaired at an average of one every four or five casts.

The CTD termination was renewed at the beginning of D326 in an attempt to forestall any failures at that point. However the termination had to be re-made 3 times during the cruise because of failure of the CTD cable, not of the termination, eventually a total of over 200m of cable was cut off. The cause was probably fatigue in the first 200m or so of CTD cable due to repeated use of this section of wire during previous cruises.

Appendices

Appendix 1.

Station times, positions and casts. Casts: Stainless steel CTD (A), Titanium CTD (B), Stainless Steel CTD experimental (C), SAPS (E), zooplankton net (F), Trichodesmium net (G), particle profiler (H), optical profiler (I), RIB (J) (letter designation according to cast coding except for the stainless steel CTD experimental and the RIB). For more detailed information see the Timetable, Appendix 2.

Station	date	time	lat	long	casts
16382	06/01/08	06:00	27 00.9	017 16.5	A, B, H
16383	06/01/08	13:00	26 36.2	017 39.7	A, F, G, H, I
16384	07/01/08	05:30	24 51.1	019 18.0	A, B, C, F, G, H
16386	07/01/08	12:58	24 29.8	019 37.8	A, B, H, I
16387	08/01/08	05:20	25 08.7	022 13.8	A, B, C, F, G, H
16388	08/01/08	13:00	25 19.9	023 01.5	A, B, H, I
16390	09/01/08	05:20	25 57.0	025 35.6	A, B, C, F, G, H
16391	09/01/08	12:58	26 08.8	026 24.9	A, B, H, I
16392	10/01/08	05:25	26 45.2	028 56.6	2xA, B, C, F, G, H
16393	10/01/08	12:58	26 53.2	029 31.2	A, 2xB, E, H, I
16394	11/01/08	05:20	25 39.8	028 48.2	A, B, C, F, G, H
16395	11/01/08	12:58	25 04.6	028 28.4	A, B, H, I
16396	12/01/08	05:20	23 24.2	027 31.0	A, B, H, F, G
16397	12/01/08	12:58	22 49.1	027 11.7	A, B, H, I
16398	13/01/08	05:22	20 54.1	026 07.2	A, B, C, F, G, H
16399	13/01/08	12:56	20 21.8	025 49.7	A, B, E, H, I
16400	14/01/08	05:25	18 57.2	025 02.4	A, B, C, F, 2xG, H
16401	14/01/08	12:56	18 29.1	024 47.7	A, B, H, I
16402	15/01/08	05:25	17 35.3	024 18.3	2xA, B, C, E, F, G, 2xH, I
16403	16/01/08	05:25	15 32.6	025 23.4	A, B, C, F, 2xG, H
16404	16/01/08	12:55	15 02.0	025 29.1	A, B, H, I
16405	17/01/08	05:25	13 01.1	025 49.4	A, B, C, F, 2xG, H
16406	17/01/08	13:00	12 39.3	025 53.3	G, H, I
16407	18/01/08	05:20	12 38.8	027 06.6	A, B, F, 2xG, H
16408	18/01/08	12:52	12 37.7	027 47.1	A, B, E, H, I
16409	19/01/08	05:20	12 35.4	030 00.0	A, B, C, F, 2xG, H
16410	19/01/08	12:54	12 34.4	030 36.2	A, B, E, G, H, I
16411	20/01/08	05:27	12 32.3	032 41.2	A, B, C, F, 2xG, H
16412	20/01/08	12:54	12 31.6	033 17.8	A, B, H, I
16413	21/01/08	05:27	12 30.3	035 46.7	A, B, C, F, 2xG, H
16414	21/01/08	12:54	12 32.4	035 18.3	A, B, H, I
16415	22/01/08	05:27	12 35.4	033 15.2	A, B, C, F, 2xG, H
16416	22/01/08	12:54	12 35.2	032 36.9	A, B, H, I
16417	23/01/08	09:23	12 30.1	030 36.6	2xA, B, E, F, 2xG, H, I

16418	24/01/08	11:40	16 07.3	030 37.9	2xA, B, F, 2xG, H, I
16419	25/01/08	05:20	16 07.8	030 38.1	A, B, C, E, F, 2xG, H
16420	25/01/08	12:00	16 11.0	030 38.5	A, B, 2xG, H, I
16421	25/01/08	18:00	16 11.4	030 40.2	B, E, H
16422	26/01/08	05:20	16 12.2	030 39.0	A, B, C, F, 2xG, H
16423	26/01/08	12:50	16 12.4	030 37.5	A, B, C, E, 2xG, H, I, J
16424	26/01/08	18:02	16 12.2	030 38.1	B, H
16425	27/01/08	05:20	16 13.1	030 38.8	A, B, C, E, F, 2xG, H
16426	27/01/08	12:50	16 13.8	030 38.7	A, B, 2xG, H, I
16427	27/01/08	17:55	16 13.9	030 38.9	B, E, G
16428	28/01/08	21:58	16 59.9	026 30.1	A, B, C, F, G, H
16429	30/01/08	05:26	21 55.6	027 05.0	A, B, C, G, H
16430	30/01/08	13:36	22 49.0	027 11.8	A, B, G, H, I
16431	31/01/08	06:54	25 04.4	028 28.5	A, B, F, G, H
16432	01/02/08	07:18	26 08.8	026 24.9	A, B
16433	02/02/08	05:55	26 35.5	023 43.4	A, B, F, G, H
16434	02/02/08	12:54	26 42.5	023 00.7	A, B, I
16435	03/02/08	05:28	27 08.5	020 26.6	A, 2xB, E, F, H

Appendix 2. Cruise Timetable of Events D326

Date	Time (UT)	Event
02/01/08		
	2100	Mobilisation of vessel in Santa Cruz De Tenerife commences
		Majority of cruise participants have arrived in Tenerife and go in hotel for 2 nights.
03/01/08		
	1700	Mobilisation Cruises 326 completed – awaiting airfreighed chemicals and computer
04/01/08		
	1400	Scientists and technicians join vessel and sign on.
	1500-1600	All new joining personnel familiarised.
		Still awaiting chemicals and computer. Consignment of Chemicals still at Gatwick airport, but now shipped by Thomsonfly. Mobilisation has progressed fine, but without acids and other reagent it was not possible to clean equipment and get instruments operational. Anna Macey arrived with new codends for nets.
05/01/08		
	1030-1115	Emergency and Lifeboat Musters and lectures.
	1100	Airfreighted chemicals arrive.
	1300-1400	Cruise Planning Meeting underway
	1600-30	Final Pre sailing checks to all critical equipment and propulsion
	1710	Computer arrives on board, delivered by Richard Marsh.
	1822	All gone and clear of berth
	1854	FULL AWAY on passage South end of breakwater bore 265˚ T x 2.22M Course 130˚ T
	2010	a/c to 220˚ T 28 17.7N 016 04.0 W
06/01/08		
	0000	Position Latitude 27 45.0 N Longitude 016 34.8 W
	0525	Hove to on **STATION 16382** 27 00.9N 017 16.5 W
	0600-05	**Tricho NET cast outboard - aborted (16382 G)**
	0615-45	**Particulate Sampler cast outboard 27 00.8N 017 16.3W (16382H)**
	0707-43	**SS CTD cast to 300 m 27 00.7N 017 16.2W (16382 A)**
	0909-37	**TIT CTD cast to 100 m 27 01.2N 017 15.8W (16382 B)**
	0946	PES Fish (10 kHz) deployed
	1000	Set Course 220˚ T 27 01.0N 017 16.1 W
	1300	Hove to on **STATION 16383** 26 36.2N 017 39.7 W
	1310-40	**Light Profiler cast outboard 26 36.1N 017 39.6W (16383 I)**
	1354-1412	**Particulate Sampler cast outboard 26 35.9N 017 39.5W (16383 H)**
	1434-1532	**SS CTD cast to 300 m 26 35.5N 017 39.6W (16383 A)**
	1612-15	**Zooplankton NET cast outboard 26 35.4N 017 39.3W (16383 F)**
	1630-35	**Tricho NET cast outboard 26 35.3N 017 39.3W (16383 G)**
	1636	Set Course 220˚ T 26 35.3N 017 39.3 W
	1800	Position Latitude 26 24.6 N Longitude 017 50.8 W
07/01/08		
	0000	Position Latitude 25 32.4 N Longitude 018 39.4 W
	0530	Hove to on **STATION 16384** 24 51.1N 019 18.0 W
	0540-0622	**SS CTD cast to 300 m 24 48.9N 019 20.2W (16384 A)**
	0635-45	**Tricho NET cast outboard 24 49.5N 019 20.5W (16384 G)**

0650-0700	**Zooplankton NET cast outboard 24 49.6N 019 20.5W (16384 F)**
0710-30	**Particulate Sampler cast outboard 24 50.0N 019 20.6W (16384 H)**
0759-0850	**TIT CTD cast to 300 m 24 50.6N 019 20.6W (16384 B)**
0932-50	**SS CTD cast to 30 m 24 51.9N 019 20.7W (16385 A), for Steve Archer**
	1004 TMS Fish deployed
1014	Set Course 220˚ T 24 52.3N 019 20.5 W
1258	Hove to on **STATION 16386** 24 29.8N 019 37.8 W
1302-52	**SS CTD cast to 300 m 24 30.1N 019 38.0W (16386 A)**
1404-34	**Light Profiler cast outboard 24 30.6N 019 38.4W (16386 I)**
1440-58	**Particulate Sampler cast outboard 24 30.9N 019 38.8W (16386 H)**
1522-1610	**TIT CTD cast to 300 m 24 31.7N 019 38.9W (16386 B)**
1610	Set Course 285˚ T 24 32.0N 019 39.0 W to more productive waters.
1800	Position Latitude 24 35.8 N Longitude 019 59.4 W

08/01/08

0000	Position Latitude 24 53.3 N Longitude 021 11.4 W
0520	Hove to on **STATION 16387** 25 08.7N 022 13.8 W
0534-45	**SS CTD cast to 30 m 25 08.9N 022 13.5W (16387 A # 1)**
0555-0615	**Particulate Sampler cast outboard 25 09.1N 022 13.5W (16387 H)**
0633-0711	**SS CTD cast to 300 m 25 09.2N 022 13.6W (16387 A # 2). Ammonia and nanomolar nutrients still not working very well. Challenges with alkalinity measurements.**
0723-36	**Tricho NET cast outboard 25 09.5N 022 13.5W (16387 G)**
0742-50	**Zooplankton NET cast outboard 25 09.6N 022 13.5W (16387 F)**
0803-47	**TIT CTD cast to 300 m 25 09.8N 022 13.6W (16387 B)**
0856	Set Course 285˚ T 25 10.0N 022 13.7 W
1300	Hove to on **STATION 16388** 25 19.9N 023 01.5 W
1302-24	**TIT CTD cast outboard 25 19.9N 023 01.5W (16388 B)** ABANDONED – cable problems
1330-56	**Light Profiler cast outboard 25 20.2N 023 01.6W (16388 I)**
1402-22	**Particulate Sampler cast outboard 25 20.2N 023 01.6W (16388 H)**
1428	Set Course 285˚ T 25 20.2N 023 01.6 W
1950	Hove to on **STATION 16389** 25 35.4N 024 06.0 W
1955-2028	**SS CTD cast to 300 m 25 35.5N 024 06.1W (16389 A)**
2051-2132	**TIT CTD cast to 300 m 25 36.5N 024 06.4W (16389 B)**
2140	Set Course 285˚ T 25 36.7N 024 06.6 W

Today, peristaltic pump replaced by Teflon bellows pump for trace metal, iodocarbon and DMS work. This now works very well. Experiments by Steve Archer are working well now. Some dust has been observed in the Cape Verde region and further south.
Supply of satellite images from Plymouth Marine Laboratory works very well. The Met Office (Mark Harrison is supplying backward and forward airmass trajectories. The supplied materials are key to our ship track decisions.
The Euroceans web site with our web blogs seems to work very well, with very positive comments on the quality of the website.
We are heading for more oligotrophjc waters to allow us to contrast these with other waters.

09/01/08

0000	Position Latitude 25 41.8 N Longitude 024 32.5 W

0500	First bioassay set up (bioassay experiment 1). We set up a nutrient addition experiment using 1 L bottles, and a dust addition experiment for nitrogen fixation. The set-up of the experiments worked well.
0520	Hove to on **STATION 16390** 25 57.0N 025 35.6 W
0535-45	**SS CTD cast to 30 m 25 57.1N 025 35.5W (16390 A # 1)**
0555-0625	**Particulate Sampler cast outboard 25 57.1N 025 35.6W (16390 H)**
0638-0710	**SS CTD cast to 300 m 25 57.0N 025 35.7W (16390 A # 2)**
0723-36	**Tricho NET cast outboard 25 56.9N 025 36.0W (16390 G)**
0740-45	**Zooplankton NET cast outboard 25 56.9N 025 36.0W (16390 F)**
0803-41	**TIT CTD cast to 300 m 25 56.8N 025 36.2W (16390 B)**
0848	Set Course 285˚ T 25 56.7N 025 36.5 W
1258	Hove to on **STATION 16391** 26 08.8N 026 24.9 W
1306-52	**TIT CTD cast to 300 m 26 08.8N 026 24.9W (16391 B)**
1356-1424	**Light Profiler cast outboard 26 09.2N 026 24.3W (16391 I)**
1430-1500	**Particulate Sampler cast outboard 26 09.3N 026 24.3W (16391 H)**
1508-54	**SS CTD cast to 300 m 26 09.4N 026 24.2W (16391 A)**
1558	Set Course 285˚ T 26 09.4N 026 24.2 W
1830-1900	Hove to to straighten out TMS Fish hoses and cables 26 15.5N 026 52.6 W

10/01/08

0000	Position Latitude 26 29.7 N Longitude 027 52.8 W
0530	Initial for nitrogen fixation experiment was filtered.
0525	Hove to on **STATION 16392** 26 45.2N 028 56.6 W
0532-45	**SS CTD cast to 50 m 26 45.3N 028 56.5W (16392 A # 1)**
0552-0622	**Particulate Sampler cast outboard 26 45.6N 028 56.3W (16392 H)**
0635-0706	**SS CTD cast to 300 m 26 45.8N 028 56.3W (16392 A # 2)**
0718-30	**Tricho NET cast outboard 26 46.1N 028 56.4W (16392 G)**
0740-45	**Zooplankton NET cast outboard 26 46.2N 028 56.4W (16392 F)**
0800-40	**TIT CTD cast to 300 m 26 46.5N 028 56.4W (16392 B)**
0908-42	**SS CTD cast to 300 m 26 47.0N 028 56.6W (16392 AA)**
0951	Set Course 285˚ T 26 47.3N 028 56.6 W
1258	Hove to on **STATION 16393** 26 53.2N 029 31.2 W
1300-1430	**TIT CTD cast to 1800 m 26 53.4N 029 31.1W (16393 B # 1)**
1436-1502	**Light Profiler cast outboard 26 53.7N 029 31.0W (16393 I)**
1510-32	**Particulate Sampler cast outboard 26 53.9N 029 31.1W (16393 H)**
1546-1622	**TIT CTD cast to 300 m 26 54.2N 029 31.0W (16393 B # 2)**
1645-1722	**SS CTD cast to 300 m 26 54.4N 029 30.9W (16393 A)**
1830-2037	**SAPS cast outboard 26 54.8N 029 30.7W (16393 E)**
2047	Set Course 153˚ T 26 55.4N 029 30.7 W for the Cape Verde region

11/01/08

0000	Position Latitude 26 27.1 N Longitude 029 15.7 W
0520	Hove to on **STATION 16394** 25 39.8N 028 48.2 W
0532-44	**SS CTD cast to 50 m 25 39.9N 028 48.0W (16394 A # 1)**
0552-0620	**Particulate Sampler cast outboard 25 39.9N 028 47.9W (16394 H)**
0632-0707	**SS CTD cast to 300 m 25 40.0N 028 48.0W (16394 A # 2)**
0715-30	**Tricho NET cast outboard 25 40.1N 028 48.1W (16394 G)**
0735-40	**Zooplankton NET cast outboard 25 40.1N 028 48.1W (16394 F)**
0750-0830	**TIT CTD cast to 300 m 25 40.2N 028 48.3W (16394 B)**

0837	Set Course 153˚ T 25 40.6N 028 48.1 W
1258	Hove to on **STATION 16395** 25 04.6N 028 28.4 W
1306-1456	**TIT CTD cast to 1800 m 25 04.6N 028 28.5W (16395 B)**
1500-24	**Light Profiler cast outboard 25 04.8N 028 28.7W (16395 I)**
1532-56	**Particulate Sampler cast outboard 25 04.9N 028 28.9W (16395 H)**
1602-40	**SS CTD cast to 300 m 25 04.9N 028 29.2W (16395 A)**
1650	Set Course 153˚ T 25 05.2N 028 29.4 W

12/01/08

0000	Position Latitude 24 07.8 N Longitude 027 55.9 W
0520	Hove to on **STATION 16396** 23 24.2N 027 31.0 W
0530-0612	**Particulate Sampler cast outboard 23 24.0N 027 30.7W (16396 H)**
0635-0712	**SS CTD cast to 300 m 23 23.8N 027 30.6W (16396 A)**
0722-33	**Tricho NET cast outboard 23 23.8N 027 30.5W (16396 G)**
0738-42	**Zooplankton NET cast outboard 23 23.8N 027 30.5W (16396 F)**
0752-0824	**TIT CTD cast to 300 m 23 23.8N 027 30.5W (16396 B)**
0832	Set Course 153˚ T 23 24.0N 027 30.5 W
1258	Hove to on **STATION 16397** 22 49.1N 027 11.7 W
1302-42	**TIT CTD cast to 300 m 22 49.2N 027 11.6W (16397 B)**
1350-1415	**Light Profiler cast outboard 22 49.4N 027 11.6W (16397 I)**
1422-44	**Particulate Sampler cast outboard 22 49.6N 027 11.6W (16397 H)**
1454-1536	**SS CTD cast to 300 m 22 49.8N 027 11.8W (16397 A)**
1548	Set Course 153˚ T 22 49.9N 027 11.9 W

13/01/08

0000	Position Latitude 21 40.0 N Longitude 026 32.8 W
0522	Hove to on **STATION 16398** 20 54.1N 026 07.2 W
0530-40	**SS CTD cast to 50 m 20 54.2N 026 07.1W (16398 A # 1)**
0550-0620	**Particulate Sampler cast outboard 20 54.6N 026 07.2W (16398 H)**
0630-0707	**SS CTD cast to 300 m 20 55.2N 026 07.1W (16398 A # 2)**
0720-30	**Tricho NET cast outboard 20 55.4N 026 07.0W (16398 G #1) TRICHO NET LOST**
0735-43	**Zooplankton NET cast outboard 20 55.6N 026 07.1W (16398 F)**
0746-53	**Tricho NET cast outboard 20 55.7N 026 07.2W (16398 G #2)**
0809-47	**TIT CTD cast to 300 m 20 55.9N 026 07.3W (16398 B)**
0851	Set Course 153˚ T 20 56.3N 026 07.3 W
1256	Hove to on **STATION 16399** 20 21.8N 025 49.7 W
1302-42	**TIT CTD cast to 300 m 20 21.8N 025 49.7W (16399 B)**
1352-1418	**Light Profiler cast outboard 20 22.0N 025 49.6W (16399 I)**
1424-46	**Particulate Sampler cast outboard 20 22.2N 025 49.6W (16399 H)**
1506-46	**SS CTD cast to 300 m 20 22.4N 025 49.6W (16399 A)**
1620-1840	**SAPS cast outboard 20 23.3N 025 49.8W (16399 E)**
1840	Set Course 153˚ T 20 23.9N 025 49.9 W

14/01/08

0000	Position Latitude 19 40.6 N Longitude 025 26.6 W
0525	Hove to on **STATION 16400** 18 57.2N 025 02.4 W
0530-50	**SS CTD cast to 150 m 18 57.3N 025 02.3W (16400 A # 1)**
0555-0625	**Particulate Sampler cast outboard 18 57.5N 025 02.0W (16400 H)**

0637-55	Bottle problem on SS CTD
0655-0730	**SS CTD cast to 300 m 18 57.8N 025 01.8W (16400 A # 2)**
0740-47	**Tricho NET cast outboard 18 58.1N 025 01.8W (16400 G #1)**
0750-0803	**Tricho NET cast outboard 18 58.1N 025 01.9W (16400 G #2)**
0806-17	**Zooplankton NET cast outboard 18 58.3N 025 02.0W (16400 F)**
0835-0912	**TIT CTD cast to 300 m 18 58.4N 025 02.3W (16400 B)**
0918	Set Course 153˚ T 18 58.6N 025 02.4 W
1256	Hove to on **STATION 16401** 18 29.1N 024 47.7 W
1302-46	**TIT CTD cast to 300 m 18 29.0N 024 47.7W (16401 B)**
1352-1412	**Light Profiler cast outboard 18 28.9N 024 47.7W (16401 I)**
1416-38	**Particulate Sampler cast outboard 18 28.9N 024 47.7W (16401 H)**
1452-1538	**SS CTD cast to 300 m 18 29.0N 024 47.8W (16401 A)**
1540	Set Course 153˚ T 18 29.0N 024 47.8 W

15/01/08

0000	Position Latitude 17 57.0 N Longitude 024 30.2 W
0400	Bioassay experiment 2 set up at Tenatso station.
0525	Hove to on **STATION 16402** 17 35.3N 024 18.3 W. This is the Cape Verde Tenatso time series station
0530-39	**SS CTD cast to 50 m 17 35.4N 024 18.2W (16402 A # 1)**
0550-0617	**Particulate Sampler cast outboard 17 35.6N 024 18.1W (16402 H # 1)**
0628-0705	**SS CTD cast to 300 m 17 36.0N 024 17.9W (16402 A # 2)**
0715-25	**Tricho NET cast outboard 17 36.3N 024 17.8W (16402 G)**
0735-40	**Zooplankton NET cast outboard 17 36.4N 024 17.7W (16402 F)**
0750-1055	**TIT CTD cast to 3613 m 17 37.1N 024 17.7W (16402 B)**
1143-1350	**SAPS cast outboard 17 39.2N 024 18.0W (16402 E)**
1320-58	**SS CTD cast to 300 m 17 40.0N 024 18.2W (16402 A # 3)**
1356-1420	**Light Profiler cast outboard 17 40.3N 024 18.2W (16402 I)**
1426-48	**Particulate Sampler cast outboard 17 40.6N 024 18.2W (16402 H # 2)**
1448	Set Course 224˚ T 17 40.7N 024 18.2 W
2000	a/c to 241˚ T 16 59.5N 024 54.6 W
	Negotiating Channel between St Antaõ and St Vincent islands
2129	a/c to 189˚ T 16 51.0N 025 10.0 W

16/01/08

0000	Position Latitude 16 25.8 N Longitude 025 14.3 W
0525	Hove to on **STATION 16403** 15 32.6N 025 23.4 W
0530-44	**SS CTD cast to 100 m 15 32.7N 025 23.4W (16403 A # 1)**
0550-0625	**Particulate Sampler cast outboard 15 32.9N 025 23.4W (16403 H)**
0640-0720	**SS CTD cast to 300 m 15 33.5N 025 23.2W (16403 A # 2)**
0727-40	**Tricho NET cast outboard 15 33.9N 025 23.2W (16403 G # 1)**
0740-55	**Tricho NET cast outboard 15 34.1N 025 23.2W (16403 G # 2)**
0757-0808	**Zooplankton NET cast outboard 15 34.3N 025 23.2W (16403 F)**
0825-0908	**TIT CTD cast to 300 m 15 34.7N 025 23.2W (16403 B)**
0924	Set Course 189˚ T 15 34.9N 025 23.4 W
1255	Hove to on **STATION 16404** 15 02.0N 025 29.1 W
1256-1338	**TIT CTD cast to 300 m 15 02.0N 025 29.1W (16404 B)**
1342-1408	**Light Profiler cast outboard 15 02.1N 025 29.2W (16404 I)**
1410-32	**Particulate Sampler cast outboard 15 02.2N 025 29.2W (16404 H)**
1438-1514	**SS CTD cast to 300 m 15 02.4N 025 29.1W (16404 A)**
1522	Set Course 189˚ T 15 02.6N 025 29.2 W

1615-1715 Hove to – untangle TMS Fish 14 58.2N 025 29.1 W
1715 Set Course 189˚ T

17/01/08

0000 Position Latitude 13 53.1 N Longitude 025 40.6 W
0525 Hove to on **STATION 16405** 13 01.1N 025 49.4 W
0530-42 **SS CTD cast to 100 m 13 01.2N 025 49.4W (16405 A # 1)**
0550-0620 **Particulate Sampler cast outboard 13 01.5N 025 49.4W (16405H)**
0632-0705 **SS CTD cast to 300 m 13 01.6N 025 49.3W (16405 A # 2)**
0715-25 **Tricho NET cast outboard 13 01.7N 025 49.2W (16405 G # 1)**
0725-35 **Tricho NET cast outboard 13 01.8N 025 49.1W (16405 G # 2)**
0740-47 **Zooplankton NET cast outboard 13 01.8N 025 49.1W (16405 F)**
0759-0835 **TIT CTD cast to 300 m 13 02.0N 025 49.1W (16405 B)**

0900 Set Course 189˚ T 13 02.3N 025 49.1 W
1300 Hove to on **STATION 16406** 12 39.3N 025 53.3 W
1302-41 **TIT CTD cast outboard 12 39.4N 025 53.4W (16406 B)**
1322 ABANDONED – cable problems **– Heaving on board from 711 m**
1341 TIT CTD back on deck and being investigated**.**
1307-34 **Light Profiler cast outboard 12 39.4N 025 53.3W (16406 I)**
1346-1415 **Particulate Sampler cast outboard 12 39.5N 025 53.5W (16406 H)**
1446-58 **Tricho NET cast outboard 12 39.7N 025 53.7W (16406 G)**
1458 TMS Fish inboard
1458-2212 Hove to air sampling whilst awaiting CTD cable.
1910 Load test on newly terminated CTD cable
2200 TMS Fish outboard again
2212 Set Course 269˚ T 12 39.0N 025 52.0 W

We are in a major dust event now. The dust cloud is hidden in clouds on the satellite pictures. The air is humid and dusty.

18/01/08

0000 Position Latitude 12 39.6 N Longitude 026 10.8 W
0520 Hove to on **STATION 16407** 12 38.8N 027 06.6 W
0530-0600 **Particulate Sampler cast outboard 12 38.9N 027 06.6W (16407H)**
0612-54 **SS CTD cast to 300 m 12 40.2N 027 06.5W (16407 A)**
0703-15 **Tricho NET cast outboard 12 40.8N 027 06.5W (16407 G # 1)**
0715-30 **Tricho NET cast outboard 12 40.9N 027 06.4W (16407 G # 2)**
0730-40 **Zooplankton NET cast outboard 12 41.1N 027 06.3W (16407 F)**
0804-45 **TIT CTD cast to 300 m 12 41.6N 027 06.0W (16407 B)**
0900 Set Course 269˚ T 12 42.1N 027 06.3 W
1252 Hove to on **STATION 16408** 12 37.7N 027 47.1 W
1300-40 **TIT CTD cast to 300 m 12 37.7N 027 47.0W (16408 B)**
1344-08 **Light Profiler cast outboard 12 37.7N 027 46.7W (16408 I)**
1412-38 **Particulate Sampler cast outboard 12 37.8N 027 46.7W (16408 H)**
1432-1512 **SS CTD cast to 300 m 12 37.9N 027 46.5W (16408 A)**
1502-1700 **SAPS cast outboard 12 38.1N 027 46.3W (16408 E)**
1700 Set Course 269˚ T 12 38.3N 027 46.1 W

We are in a major dust event now. The dust cloud is hidden in clouds on the satellite pictures. The air is humid and dusty.

19/01/08 0000 Position Latitude 12 36.5 N Longitude 029 02.7 W

0520	Hove to on **STATION 16409** 12 35.4N 030 00.0 W
0530-43	**SS CTD cast to 100 m 12 35.6N 030 00.0W (16409 A # 1)**
0553-0622	**Particulate Sampler cast outboard 12 35.9N 029 59.9W (16409H)**
0643-0720	**SS CTD cast to 300 m 12 36.4N 029 59.9W (16409 A # 2)**
0730-40	**Tricho NET cast outboard 12 36.8N 029 59.8W (16409 G # 1)**
0740-50	**Tricho NET cast outboard 12 36.9N 029 59.8W (16409 G # 2)**
0752-0800	**Zooplankton NET cast outboard 12 37.0N 029 59.8W (16409 F)**
0816-0904	**TIT CTD cast to 300 m 12 37.3N 029 59.9W (16409 B)**
0918	Set Course 269˚ T 12 37.7N 029 59.9 W
1254	Hove to on **STATION 16410** 12 34.4N 030 36.2 W
1300-44	**TIT CTD cast to 300 m 12 34.6N 030 36.2W (16410 B)**
1348-1414	**Light Profiler cast outboard 12 34.9N 030 36.2W (16410 I)**
1352-1404	**Tricho NET cast outboard 12 34.9N 030 36.2W (16410 G)**
1422-44	**Particulate Sampler cast outboard 12 35.0N 030 36.3W (16410 H)**
1458-1546	**SS CTD cast to 300 m 12 35.4N 030 36.2W (16410 A)**
1504-1705	**SAPS cast outboard 12 35.8N 030 36.1W (16410 E)**
1710-12	**Drifter Deployed 12 36.5N 030 35.8W (16410 J)**
1712	Set Course 269˚ T 12 36.5N 030 35.8 W

We are in a major dust event now. The dust cloud is hidden in clouds on the satellite pictures. The air is humid and dusty.

20/01/08

0000	Position Latitude 12 33.5 N Longitude 031 46.4 W
0527	Hove to on **STATION 16411** 12 32.3N 032 41.2 W
0530-47	**SS CTD cast to 100 m 12 32.4N 032 41.0W (16411 A # 1)**
0555-0625	**Particulate Sampler cast outboard 12 32.7N 032 40.8W (16411H)**
0640-0715	**SS CTD cast to 300 m 12 33.1N 032 40.7W (16411 A # 2)**
0722-37	**Tricho NET cast outboard 12 33.4N 032 40.6W (16411 G # 1)**
0737-45	**Tricho NET cast outboard 12 33.5N 032 40.6W (16411 G # 2)**
0750-58	**Zooplankton NET cast outboard 12 33.6N 032 40.6W (16411 F)**
0812-55	**TIT CTD cast to 300 m 12 34.0N 032 40.6W (16411 B)**
0900	Set Course 269˚ T 12 34.2N 032 40.5 W
1254	Hove to on **STATION 16412** 12 31.6N 033 17.8 W
1258-1446	**TIT CTD cast to 1800 m 12 31.9N 033 17.8W (16412 B)**
1310-38	**Light Profiler cast outboard 12 31.9N 033 17.8W (16412 I)**
1344-1406	**Particulate Sampler cast outboard 12 32.1N 033 17.9W (16412 H)**
1510-50	**SS CTD cast to 300 m 12 32.6N 033 17.8W (16412 A)**
1550	Set Course 269˚ T 12 32.7N 033 17.8 W

We are out of the dust event.

21/01/08

0000	Position Latitude 12 30.9 N Longitude 034 48.2 W
0400	Bioassay experiment 3 is set up. Two types of dust added (standard and sulphuric acid treated).
0527	Hove to on **STATION 16413** 12 30.3N 035 46.7 W
0530-43	**SS CTD cast to 100 m 12 30.3N 035 46.7W (16413 A # 1)**

0550-0620	**Particulate Sampler cast outboard 12 30.7N 035 46.7W (16413H)**
0640-0725	**SS CTD cast to 300 m 12 31.2N 035 46.7W (16413 A # 2)**
0730-44	**Tricho NET cast outboard 12 31.4N 035 46.7W (16413 G # 1)**
0744-52	**Tricho NET cast outboard 12 31.5N 035 46.8W (16413 G # 2)**
0800-05	**Zooplankton NET cast outboard 12 31.6N 035 46.8W (16413 F)**
0818-55	**TIT CTD cast to 300 m 12 31.9N 035 47.0W (16413 B)**
0906	Set Course 089˚ T 12 32.2N 035 47.1 W
1254	Hove to on **STATION 16414** 12 32.4N 035 18.3 W
1304-46	**TIT CTD cast to 300 m 12 32.4N 035 18.3W (16414 B)**
1354-1420	**Light Profiler cast outboard 12 32.5N 035 18.4W (16414 I)**
1426-48	**Particulate Sampler cast outboard 12 32.5N 035 18.4W (16414 H)**
1456-1546	**SS CTD cast to 300 m 12 32.6N 035 18.6W (16414 A)**
1546	Set Course 089˚ T 12 32.8N 035 18.8 W

22/01/08

0000	Position Latitude 12 34.0 N Longitude 034 07.0 W
0527	Hove to on **STATION 16415** 12 35.4N 033 15.2 W
0530-45	**SS CTD cast to 100 m 12 35.5N 033 15.1W (16415 A # 1)**
0551-0620	**Particulate Sampler cast outboard 12 35.9N 033 14.8W (16415H)**
0635-0712	**SS CTD cast to 300 m 12 36.4N 033 14.5W (16415 A # 2)**
0722-30	**Tricho NET cast outboard 12 36.7N 033 14.4W (16415 G # 1)**
0730-43	**Tricho NET cast outboard 12 36.8N 033 14.3W (16415 G # 2)**
0748-55	**Zooplankton NET cast outboard 12 39.6N 033 14.2W (16415 F)**
0810-52	**TIT CTD cast to 300 m 12 37.4N 033 14.0W (16415 B)**
0900	Set Course 089˚ T 12 37.7N 033 13.9 W
1254	Hove to on **STATION 16416** 12 35.2N 032 36.9 W
1310-1454	**TIT CTD cast to 1800 m 12 35.3N 032 36.7W (16416 B)**
1318-46	**Light Profiler cast outboard 12 35.3N 032 36.7W (16416 I)**
1356-1418	**Particulate Sampler cast outboard 12 35.2N 032 36.4W (16416 H)**
1510-50	**SS CTD cast to 300 m 12 35.2N 032 36.3W (16416 A)**
1543	PES Fish hauled inboard for maintenance
1600	Set Course 087˚ T 12 35.1N 032 36.2 W
1615-1700	Emergency and Lifeboat drills

23/01/08

0000	Position Latitude 12 39.0 N Longitude 031 14.0 W
0400	Begin to search for DRIFTER 12 41.1N 030 26.7 W
0400-0900	SEARCHING FOR DRIFTER using different methods – no luck at all
0923	Hove to on **STATION 16417** 12 30.1N 030 36.6 W
0925-1012	**SS CTD cast to 300 m 12 30.2N 030 36.4W (16417 A # 1)**
1005-1212	**SAPS cast outboard 12 30.3N 030 36.6W (16417 E)**
1018-31	**Tricho NET cast outboard 12 30.3N 030 37.0W (16417 G # 1)**
1032-45	**Tricho NET cast outboard 12 30.3N 030 37.1W (16417 G # 2)**
1049-1106	**Zooplankton NET cast outboard 12 30.3N 030 27.4W (16417 F)**
1120-1200	**TIT CTD cast to 300 m 12 30.2N 030 37.8W (16417 B)**
1250-1334	**SS CTD cast to 300 m 12 30.2N 030 38.8W (16417 A # 2)**
1256-1322	**Light Profiler cast outboard 12 30.2N 030 38.5W (16417 I)**
1300	PES Fish re-deployed
1328-48	**Particulate Sampler cast outboard 12 30.2N 030 38.9W (16417 H)**

1350-1430	Deliberations on whether to keep searching for drifter or to proceed to image proven dust event to the North
1430	Set Course 360˚ T 12 30.0N 030 38.0 W
1900	Position Latitude 13 15.5 N Longitude 030 38.0 W

24/01/08

0000	Position Latitude 14 07.4 N Longitude 030 38.0 W
0600	Position Latitude 15 11.4 N Longitude 030 38.0 W
1140	Hove to on **STATION 16418** 16 07.3N 030 37.9 W
1143-1230	**SS CTD cast to 300 m 16 07.4N 030 37.9W (16418 A # 1)**
1236-1310	**Light Profiler cast outboard 16 07.5N 030 38.3W (16418 I)**
1318-40	**Particulate Sampler cast outboard 16 07.5N 030 38.1W (16418 H)**
1332-1412	**TIT CTD cast to 300 m 16 07.7N 030 38.1W (16418 B)**
1422-32	**Tricho NET cast outboard 16 07.7N 030 38.1W (16418 G # 1)**
1434-46	**Tricho NET cast outboard 16 07.7N 030 38.1W (16418 G # 2)**
1450-1506	**Zooplankton NET cast outboard 16 07.8N 030 38.2W (16418 F)**
1516-56	**SS CTD cast to 300 m 16 07.8N 030 38.2W (16418 A # 2)**
1630	Set Course 076˚ T 16 07.8N 030 38.2 W
2000	Head back to position of station 16418 as strong dust storm is observed coming towards that region, and we will have sampled that station prior to the dust storm. We are sailing back slowly (4 knots) to arrive there for 0530 h 25/01/08.

25/01/08

0000	Position Latitude 16 13.2 N Longitude 030 15.4 W
0400	Bioassay experiment 4 set in. Nutrient addition experiment in 1 litre bottles, and nitrogen fixation experiment (4.5 L bottles). The bioassay is done here to assess the limiting nutrient(s) prior to arrival of dust storm
0520	Hove to on **STATION 16419** 16 07.8N 030 38.1 W
0530-44	**SS CTD cast to 100 m 16 07.9N 030 38.1W (16419 A # 1)**
0555-0622	**Particulate Sampler cast outboard 16 08.2N 030 38.0W (16419H)**
0635-0714	**SS CTD cast to 300 m 16 08.7N 030 38.0W (16419 A # 2)**
0725-45	**2 x Tricho NETS cast outboard 16 09.2N 030 38.0W (16419 G # 1 & 2)**
0746-0800	**Zooplankton NET cast outboard 16 09.3N 030 38.0W (16419 F)**
0810-54	**TIT CTD cast to 300 m 16 09.6N 030 38.1W (16419 B)**
0915-1120	**SAPS cast outboard 16 10.4N 030 38.4W (16419 E)**

Signs of dust storm in distance. Aerosol filters are becoming dusty.

1200	Hove to on **STATION 16420** 16 11.0N 030 38.5 W
1302-48	**TIT CTD cast to 300 m 16 11.3N 030 38.6W (16420 B)**
1310-38	**Light Profiler cast outboard 16 11.4N 030 38.7W (16420 I)**
1344-1406	**Particulate Sampler cast outboard 16 11.5N 030 38.8W (16420 H)**
1406-10	**Drifter Deployed 16 11.7N 030 38.8W (16420 J)**
1430-58	**2 x Tricho NETS cast outboard 16 12.2N 030 38.5W (16420 G # 1 & 2)**
1458-1528	Vessel re-locating downwind of drifter
1528-1615	**SS CTD cast to 300 m 16 11.2N 030 39.2W (16420 A)**
1800	Hove to on **STATION 16421** 16 11.4N 030 40.2 W
1800-40	**TIT CTD cast to 300 m 16 11.5N 030 40.2W (16421 B)**
1810-35	**Particulate Sampler cast outboard 16 11.5N 030 40.2W (16421 H)**
1850-2103	**SAPS cast outboard 16 12.7N 030 39.9W (16421 E)**

We are now in dust storm. Skies are hazy, and filters very yellow red (changed twice per day).

26/12/08

0000	Position Latitude 16 13.4 N Longitude 030 40.2 W
0520	Hove to on **STATION 16422** 16 12.2N 030 39.0 W
0526-42	**SS CTD cast to 100 m 16 12.2N 030 39.0W (16422 A # 1)**
0550-0617	**Particulate Sampler cast outboard 16 12.3N 030 39.1W (16422H)**
0630-0712	**SS CTD cast to 300 m 16 12.7N 030 39.2W (16422 A # 2)**
0722-45	**2 x Tricho NETS cast outboard 16 13.0N 030 39.3W (16422 G # 1 & 2)**
0752-0800	**Zooplankton NET cast outboard 16 13.1N 030 39.3W (16422 F)**
0814-0900	**TIT CTD cast to 300 m 16 13.4N 030 39.4W (16422 B)**
0915-44	Re-locating to get visual contact with drifter.
1250	Hove to on **STATION 16423** 16 12.4N 030 37.5 W
1300-50	**TIT CTD cast to 300 m 16 12.5N 030 37.5W (16423 B)**
1312-50	**Light Profiler cast outboard 16 12.4N 030 37.5W (16423 I)**
1356-1420	**Particulate Sampler cast outboard 16 12.4N 030 37.5W (16423 H)**
1404-32	**2 x Tricho NETS cast outboard 16 12.4N 030 37.5W (16423 G # 1 & 2)**
1440-1650	**SAPS cast outboard 16 12.2N 030 37.5W (16423 E)**
1446-1540	**SS CTD cast to 300 m 16 12.2N 030 37.5W (16423 A #1)**
1552	RIB being Prepared for launch **16 12.2N 030 37.5W (16423 K)**
1600	RIB launched – Crew: P. Allison (cox) A. Oakham, C.Carey
1626	RIB Takes 10 Samples **16 12.0N 030 37.8W (16423 K)**
1636	RIB recovered and stowed.
1700-22	**SS CTD cast to 40 m 16 12.0N 030 38.0W (16423 A #2)**
1802	Hove to on **STATION 16424** 16 12.2N 030 38.1 W
1802-42	**TIT CTD cast to 300 m 16 12.3N 030 38.2W (16424 B)**
1807-30	**Particulate Sampler cast outboard 16 12.4N 030 38.2W (16424 H)**

We are now in dust storm. Skies are hazy, and filters very yellow red (changed twice per day).

27/01/08

0520	Hove to on **STATION 16425** 16 13.1N 030 38.8 W
0528-42	**SS CTD cast to 100 m 16 13.1N 030 38.9W (16425 A # 1)**
0550-0620	**Particulate Sampler cast outboard 16 13.4N 030 38.9W (16425H)**
0635-0710	**SS CTD cast to 300 m 16 13.9N 030 39.1W (16425 A # 2)**
0720-42	**2 x Tricho NETS cast outboard 16 14.4N 030 39.1W (16425 G # 1 & 2)**
0745-55	**Zooplankton NET cast outboard 16 14.6N 030 39.2W (16425 F)**
0807-56	**TIT CTD cast to 300 m 16 14.9N 030 39.3W (16425 B)**
0915-44	Re-locating to get visual contact with drifter.
1015-1216	**SAPS cast outboard 16 13.6N 030 38.6W (16425 E)**
1250	Hove to on **STATION 16426** 16 13.8N 030 38.7 W
1302-46	**TIT CTD cast to 300 m 16 13.1N 030 38.8W (16426 B)**
1314-36	**Light Profiler cast outboard 16 13.0N 030 38.8W (16426 I)**
1344-1408	**Particulate Sampler cast outboard 16 13.1N 030 38.8W (16426H)**
1402-30	**2 x Tricho NETS cast outboard 16 13.2N 030 38.7W (16426 G # 1 & 2)**
1444-1528	**SS CTD cast to 300 m 16 13.2N 030 38.7W (16426 A #1)**
1534	Commence recovery of the drifter
1550	Drifter Inboard and secured 16 13.4N 030 38.6 W
1755	Hove to on **STATION 16427** 16 13.9N 030 38.9 W

1800-40	**TIT CTD cast to 300 m 16 13.9N 030 39.0W (16427 B)**
1855-2113	**SAPS cast outboard 16 14.5N 030 39.4W (16427 E)**
1955-2014	**Tricho NET cast outboard 16 14.7N 030 39.3W (16427 G)**
2124	Set Course 079˚ T 16 14.9N 030 39.9 W

We have been at the southern boundary of a major dust storm, which reached all the way to Plymouth. The low volume aerosol filters are now less loaded.

28/01/08

0000	Position Latitude 16 18.1 N Longitude 030 14.7 W
1200	Position Latitude 16 40.4 N Longitude 028 12.1 W
1800	Position Latitude 16 52.5 N Longitude 027 09.0 W
2158	Hove to on **STATION 16428** 16 59.9N 026 30.1 W
2208-50	**SS CTD cast to 300 m 17 00.2N 026 30.3W (16428 A # 1)**
2212-37	**Particulate Sampler cast outboard 17 00.2N 026 30.4W (16428H)**
2257-2309	**Tricho NET cast outboard 17 00.5N 026 30.6W (16428 G)**
2313-24	**Zooplankton NET cast outboard 17 00.6N 026 30.7W (16428 F)**
2335-0020	**TIT CTD cast to 300 m 17 00.9N 026 30.8W (16428 B)**

29/01/08

0042-0102	**SS CTD cast to 300 m 17 01.5N 026 31.0W (16428 A # 2)** **This is the 'productive' station for Steve Archer's experiment, in the Cape Verde Region. Following this station we are moving north to the oligotrophic waters. We are re-visiting stations on the way north (16397, 16395, 16391).**
0106	Set Course 354˚ T 17 01.6N 026 31.0 W
0600	Position Latitude 17 53.0 N Longitude 026 36.3 W
1200	Position Latitude 18 52.7 N Longitude 026 43.3 W
1800	Position Latitude 19 54.4 N Longitude 026 50.7 W

30/01/08

0000	Position Latitude 20 57.0 N Longitude 026 58.5 W
0526	Hove to on **STATION 16429** 21 55.6N 027 05.0 W
0531-43	**SS CTD cast to 100 m 21 55.6N 027 05.0W (16429 A # 1)**
0550-0620	**Particulate Sampler cast outboard 21 55.9N 027 05.0W (16429H)**
0630-0700	**SS CTD cast to 300 m 21 56.3N 027 05.0W (16429 A # 2)**
0716-30	**Tricho NET cast outboard 21 56.6N 027 04.9W (16429 G)**
0740-0825	**TIT CTD cast to 300 m 21 56.9N 027 04.8W (16429 B)**
0830	Set Course 354˚ T 21 57.2N 027 04.7 W
1336	Hove to on **STATION 16430** 22 49.0N 027 11.8 W (repeat of 16397)
1338-1424	**TIT CTD cast to 300 m 22 49.0N 027 11.8W (16430 B)**
1340-1408	**Light Profiler cast outboard 22 49.0N 027 11.8W (16430 I)**
1416-38	**Particulate Sampler cast outboard 22 49.1N 027 11.8W (16430H)**
1444-58	**Tricho NET cast outboard 22 49.1N 027 11.8W (16430 G)**
1508-52	**SS CTD cast to 300 m 22 49.1N 027 11.8W (16430 A)**
1556	Set Course 333˚ T 22 49.1N 027 11.8 W

31/01/08

0000	Position Latitude 24 04.5 N Longitude 027 54.2 W
0654	Hove to on **STATION 16431** 25 04.4N 028 28.5 W (repeat of 16395)

0658-0736	**SS CTD cast to 300 m 25 04.5N 028 28.4W (16431 A)**
0730-0804	**Particulate Sampler cast outboard 25 04.8N 028 28.4W (16431H)**
0746-0804	**Tricho NET cast outboard 25 04.8N 028 28.4W (16431 G)**
0805-13	**Zooplankton NET cast outboard 25 04.9N 028 28.5W (16431 F)**
0825-0908	**TIT CTD cast to 300 m 25 05.2N 028 28.8W (16431 B)**
0918	Set Course 070˚ T – then 060 T 25 05.5N 028 29.0 W
0918-2400	Labouring in rough weather
1200	Position Latitude 25 13.0 N Longitude 028 12.5 W
1800	Position Latitude 25 33.2 N Longitude 027 33.4 W

We were not able to repeat station 16391 because of adverse weather conditions. Station 16432is quite nearby and has very low nutrient conditions required for Mike Zubkov's experiments.
Adverse weather condition led to cancellation of planned 24-48 h station at 16391, where Steve Archer would do diurnal biogas study.

01/02/08

0000	Position Latitude 25 50.2 N Longitude 027 01.2 W
0000-0700	Labouring in rough weather
0718	Hove to on **STATION 16432** 26 08.8N 026 24.9 W
0732-0822	**TIT CTD cast to 300 m 26 09.0N 026 24.8W (16432 B)**
0843-0921	**SS CTD cast to 300 m 26 09.8N 026 25.0W (16432 A)**
0930	Set Course 080˚ T 26 10.0N 026 25.0 W
1200	Position Latitude 26 13.2 N Longitude 026 08.1 W
1800	Position Latitude 26 19.7 N Longitude 025 25.5 W

02/02/08

0000	Position Latitude 26 26.6 N Longitude 024 36.0 W
0555	Hove to on **STATION 16433** 26 35.5N 023 43.4 W
0600-35	**SS CTD cast to 300 m 26 35.6N 023 43.3W (16433 A)**
0642-0715	**Particulate Sampler cast outboard 26 35.9N 023 42.9W (16433H)**
0700-12	**Tricho NET cast outboard 26 36.0N 023 42.9W (16433 G)**
0720-30	**Zooplankton NET cast outboard 26 36.2N 023 42.6W (16433 F)**
0740-0826	**TIT CTD cast to 300 m 26 36.4N 023 42.5W (16433 B)**
0830	Set Course 080˚ T 26 36.8N 023 42.4 W
1200	Position Latitude 26 41.1 N Longitude 023 09.1 W
1254	Hove to on **STATION 16434** 26 42.5N 023 00.7 W
1256-1444	**TIT CTD cast to 1800 m 26 42.6N 023 00.6W (16434 B)**
1310-46	**Light Profiler cast outboard 26 42.6N 023 00.6W (16434 I)**
1456-1546	**SS CTD cast to 300 m 26 42.8N 023 00.5W (16434 A)**
1546	Set Course 080˚ T 26 43.0N 023 00.4 W
1800	Position Latitude 26 46.6 N Longitude 022 36.6 W

Weather has improved and we have made more distance now, allowing additional station time at 16435.

03/02/08

0000	Position Latitude 26 57.6 N Longitude 021 29.2 W
0500	Last discrete underway samples collected. Underway continuous analyses of pH will continue until midday.
0528	Hove to on **STATION 16435** 27 08.5N 020 26.6 W
0540-0605	**SS CTD cast to 300 m 27 08.6N 020 26.8W (16435 A)**
0615-47	**Particulate Sampler cast outboard 27 08.9N 020 27.4W**

		(16435H)
	0620-35	**Zooplankton NET cast outboard 27 08.9N 020 27.3W (16435 F)**
	0703-12	**TIT CTD cast to 20 m 27 09.2N 020 27.9W (16435 B # 1)**
	0748-1136	**TIT CTD cast to 4560 m 27 10.1N 020 28.9W (16435 B # 2)**
	0834-1043	**SAPS cast outboard 27 10.2N 020 29.7W (16435 E)**
	1140	Set Course 080˚ T 27 10.8N 020 30.4 W
		SCIENCE (STATION WORK) ENDS – Heading for Tenerife
	1200	Position Latitude 27 11.2 N Longitude 020 26.8 W
04/02/08		
05/02/08		
	0800	Arrival tenerife (Provisional)

Appendix 3.

Underway samples, date, time and position and the parameters sampled for. The samples taken from the fish were used for the measurement of trace metals (Mn, Al, Fe) (A), nanomolar nutrients (phosphate and nitrate) (B), organic complexation of Fe (C). The samples taken from the non-toxic seawater supply were used for the measurement of Chl a (D), micromolar nutrients (phosphate, nitrate and silicate) (E), and DIC (F). The first table contains the underway samples from the trace metal clean seawater supply in the clean container and the second table contains the underway samples sampled from the non-toxic seawater supply.

Table with the underway samples from the trace metal clean surface seawater supply (UT).

Code	date	time	lat	long	measurements
UT1	7/01/2008	17:05	24.563700	-19.799683	A
UT2	7/01/2008	18:56	24.643303	-20.180385	A
UT3	7/01/2008	20:52	24.737475	-20.571194	A
UT4	7/01/2008	22:57	24.836895	-20.987431	A
UT5	8/01/2008	2:10	24.992807	-21.623199	A
UT6	8/01/2008	2:58	25.030124	-21.778027	A
UT7	8/01/2008	5:20	25.144325	-22.229917	A
UT8	8/01/2008	17:00	25.453709	-23.533762	A
UT9	8/01/2008	19:00	25.648074	-24.345555	A
UT10	9/01/2008	1:00	25.744512	-24.745379	A
UT11	9/01/2008	2:55	25.835238	-25.125500	A
UT12	9/01/2008	5:08	25.941864	-25.568930	A
UT13	9/01/2008	9:00	25.951371	-25.633399	A
UT14	9/01/2008	11:00	26.054589	-26.034725	A
UT15	9/01/2008	12:50	26.142135	-26.407397	A
UT16	9/01/2008	17:07	26.192145	-26.612044	A
UT17	9/01/2008	19:08	26.265549	-26.903654	A
UT18	9/01/2008	21:00	26.352576	-27.283830	A
UT19	9/01/2008	23:00	26.447462	-27.682052	A

UT20	10/01/2008	2:55	26.635558	-28.468695	A
UT21	10/01/2008	5:20	26.752564	-28.946656	A
UT22	10/01/2008	11:00	26.797058	-29.146696	A
UT23	10/01/2008	12:50	26.881166	-29.512321	A
UT24	10/01/2008	23:00	26.595595	-29.346440	A
UT25	11/01/2008	1:00	26.305293	-29.178163	A
UT26	11/01/2008	2:58	26.010704	-29.007606	A
UT27	11/01/2008	5:05	25.689181	-28.822838	A
UT28	11/01/2008	9:00	25.628258	-28.779220	A
UT29	11/01/2008	12:45	24.820543	-28.326346	A
UT29	11/01/2008	19:00	24.820543	-28.326346	A
UT30	11/01/2008	21:00	24.527605	-28.158725	A
UT31	11/01/2008	23:00	24.269012	-28.010197	A
UT32	12/01/2008	1:00	23.998046	-27.857828	A
UT33	12/01/2008	2:58	23.727545	-27.704134	A
UT34	12/01/2008	5:05	23.414942	-27.526871	A
UT35	12/01/2008	9:00	23.342874	-27.483507	A, C
UT36	12/01/2008	11:00	23.062094	-27.328886	A
UT37	12/01/2008	19:04	22.386934	-26.948887	A
UT38	12/01/2008	21:00	22.102520	-26.790287	A
UT39	12/01/2008	23:00	21.807877	-26.625753	A
UT40	13/01/2008	1:00	21.516393	-26.463645	A, C
UT41	13/01/2008	5:00	20.919245	-26.132185	A
UT42	13/01/2008	11:15	20.591697	-25.949623	A
UT43	13/01/2008	12:45	20.375221	-25.833564	A, C
UT44	13/01/2008	19:00	20.377063	-25.822366	A
UT45	13/01/2008	21:00	20.091895	-25.674235	A, C
UT46	13/01/2008	23:10	19.787781	-25.506624	A
UT47	14/01/2008	1:00	19.536270	-25.368414	A
UT48	14/01/2008	2:56	19.269462	-25.221572	A
UT49	14/01/2008	5:11	18.958068	-25.050701	A
UT50	14/01/2008	11:05	18.728627	-24.926582	A, C
UT51	14/01/2008	12:35	18.512737	-24.808826	A, C
UT52	14/01/2008	17:00	18.402441	-24.750813	A
UT53	14/01/2008	19:04	18.262252	-24.674658	A
UT54	14/01/2008	21:00	18.132900	-24.604018	A
UT55	14/01/2008	22:59	18.011644	-24.537564	A
UT56	15/01/2008	1:00	17.888141	-24.469419	A
UT57	15/01/2008	2:56	17.754281	-24.395103	A
UT58	15/01/2008	15:00	17.671441	-24.307435	A, C
UT59	15/01/2008	19:10	17.097688	-24.800884	A
UT60	15/01/2008	20:56	16.901543	-25.068638	A
UT61	15/01/2008	23:00	16.593798	-25.211631	A
UT62	16/01/2008	1:00	16.256159	-25.269736	A, C
UT63	16/01/2008	5:10	15.562385	-25.389829	A
UT64	16/01/2008	12:10	15.139213	-25.462981	A
UT65	16/01/2008	17:25	14.956945	-25.483977	A, C
UT66	16/01/2008	19:04	14.679763	-25.541159	A, B
UT67	16/01/2008	21:00	14.360459	-25.596997	A, B
UT68	16/01/2008	22:55	14.045295	-25.650168	A, B

UT69	17/01/2008	1:00	13.725755	-25.704951	A, B
UT70	17/01/2008	2:55	13.421750	-25.758321	A, B
UT71	17/01/2008	5:00	13.063379	-25.818632	A, B, C
UT72	17/01/2008	11:12	12.830010	-25.859324	A, B
UT73A	17/01/2008	12:45	12.675410	-25.885570	A
UT73	17/01/2008	23:00	12.654009	-25.995724	A, B, C
UT74	18/01/2008	1:00	12.657430	-26.364170	A, B, C
UT75	18/01/2008	5:00	12.644932	-27.083604	A, B
UT76	18/01/2008	11:43	12.637488	-27.594672	A, B
UT77	18/01/2008	19:00	12.626044	-28.114126	A, C
UT78	18/01/2008	21:10	12.618641	-28.481645	A
UT79	18/01/2008	23:00	12.613138	-28.853629	A, B
UT80	19/01/2008	1:00	12.605169	-29.227272	A, B, C
UT81	19/01/2008	2:56	12.573478	-30.603096	A, B
UT82	19/01/2008	5:05	12.591889	-29.971186	A, B
UT83	19/01/2008	11:00	12.581166	-30.939142	A, B, C
UT83B	19/01/2008	12:42	12.575540	-30.578850	A, B
UT83A	19/01/2008	19:16	12.581170	-30.939140	A, B
UT84	19/01/2008	21:05	12.567725	-31.262547	A, B
UT84A	19/01/2008	23:00	12.564859	-31.599177	A, B
UT85	20/01/2008	0:58	12.552602	-32.112643	A, B, C
UT86	20/01/2008	2:55	12.548587	-32.277699	A, B
UT87	20/01/2008	5:05	12.537590	-32.657503	A, B
UT88	20/01/2008	11:07	12.537817	-32.997031	A, B
UT89	20/01/2008	12:43	12.526560	-33.280850	A, B, C
UT89A	20/01/2008	17:00	12.530720	-33.486020	A, B
UT90	20/01/2008	19:00	12.526370	-33.853410	A, B
UT91	20/01/2008	21:06	12.521020	-34.248870	A, B
UT92	20/01/2008	23:00	12.516960	-34.609440	A, B
UT93	21/01/2008	1:00	12.511310	-34.986200	A, B, C
UT94	21/01/2008	2:58	12.508220	-35.356910	A, B
UT95	21/01/2008	5:00	12.503770	-35.737390	A, B
UT96	21/01/2008	11:06	12.537470	-35.534200	A, B
UT97	21/01/2008	12:27	12.540030	-35.356350	A, B, C
UT98	21/01/2008	17:00	12.545047	-35.154710	A, B
UT99	21/01/2008	19:00	12.551220	-34.860910	A, B
UT100	21/01/2008	21:02	12.556730	-34.560410	A, B
UT101	21/01/2008	22:57	12.563880	-34.276130	A, B
UT102	22/01/2008	1:00	12.569260	-33.955450	A, B, C
UT103	22/01/2008	2:57	12.575850	-33.643940	A, B
UT104	22/01/2008	5:05	12.580720	-33.289670	A, B
UT105	22/01/2008	17:07	12.613560	-32.468980	A, B, C
UT106	22/01/2008	19:00	12.612880	-32.140070	A, B
UT107	22/01/2008	21:00	12.625850	-31.778350	A, B
UT108	22/01/2008	22:58	12.642200	-31.420000	A, B
UT109	23/01/2008	1:00	12.658250	-31.051530	A, B, C
UT110	23/01/2008	2:57	12.675400	-30.693390	A, B
UT111	23/01/2008	15:00	12.567740	-30.634180	A, B, C
UT112	23/01/2008	18:57	13.248430	-30.633750	A, B
UT113	23/01/2008	20:57	13.589780	-30.634100	A, B

UT114	23/01/2008	22:55	13.934980	-30.633140	A, B
UT115	24/01/2008	1:00	14.304420	-30.633290	A, B, C
UT116	24/01/2008	3:00	14.653520	-30.633290	A, B
UT117	24/01/2008	5:10	15.027090	-30.633320	A, B
UT118	24/01/2008	9:00	15.683520	-30.633810	A, B
UT119	24/01/2008	11:00	16.035950	-30.634450	A, B
UT120	24/01/2008	17:15	16.176960	-30.435790	A, B
UT121	24/01/2008	19:00	16.249640	-30.132950	A, B
UT122	24/01/2008	21:07	16.258020	-30.075640	A, B
UT123	24/01/2008	22:55	16.234670	-30.188520	A, B
UT124	25/01/2008	0:57	16.204800	-30.318660	A, B
UT125	25/01/2008	3:00	16.169250	-30.459570	A, B, C
UT126	25/01/2008	5:10	16.131210	-30.628410	A, B
UT127	27/01/2008	21:30	16.249410	-30.650950	A, C
UT128	27/01/2008	23:00	16.280750	-30.410320	A
UT129	28/01/2008	0:55	16.320980	-30.091270	A
UT130	28/01/2008	3:00	16.377370	-29.733770	A, B
UT131	28/01/2008	5:06	16.445120	-29.381550	A, B
UT132	28/01/2008	8:07	16.542880	-28.867350	A, B
UT133	28/01/2008	9:05	16.574490	-28.704220	A, B
UT134	28/01/2008	11:00	16.641930	-28.373670	A, B
UT135	28/01/2008	13:00	16.706650	-28.027350	A, B
UT136	28/01/2008	15:00	16.773940	-27.671530	A, B
UT137	28/01/2008	17:18	16.851110	-27.271520	A, B
UT138	28/01/2008	19:00	16.907760	-26.977800	A, B
UT139	28/01/2008	21:07	16.980230	-26.604610	A, B
UT140	29/01/2008	2:56	17.341090	-26.539670	A, B
UT141	29/01/2008	5:10	17.740220	-26.587200	A, B
UT142	29/01/2008	9:18	18.428710	-26.668040	A, B
UT143	29/01/2008	11:00	18.709400	-26.701810	A, B
UT144	29/01/2008	13:00	19.048410	-26.741470	A, B
UT145	29/01/2008	15:00	19.389610	-26.782060	A, B
UT146	29/01/2008	17:00	19.733530	-26.823420	A, B
UT147	29/01/2008	19:05	20.096150	-26.866080	A, B
UT148	29/01/2008	21:00	20.428470	-26.905640	A, B
UT149	29/01/2008	23:05	20.790490	-26.949490	A, B
UT150	30/01/2008	1:00	21.129740	-26.991450	A, B, C
UT151	30/01/2008	2:54	21.470430	-27.031760	A, B
UT152	30/01/2008	5:10	21.884570	-27.081860	A, B
UT153	30/01/2008	11:07	22.403370	-27.144350	A, B
UT154	30/01/2008	13:00	22.728650	-27.186350	A, B, C
UT155	30/01/2008	17:00	22.979070	-27.285610	A, B
UT156	30/01/2008	19:00	23.297650	-27.464230	A, B
UT157	30/01/2008	21:00	23.613070	-27.642850	A, B
UT158	30/01/2008	23:00	23.921330	-27.816570	A, B
UT159	31/01/2008	1:05	24.244150	-27.999880	A, B, C
UT160	31/01/2008	2:55	24.528090	-28.160700	A, B
UT161	31/01/2008	5:15	24.866610	-28.355130	A, B
UT162	31/01/2008	11:20	25.175130	-28.284250	A, B
UT163	31/01/2008	13:03	25.278680	-28.085890	A, B

UT164	31/01/2008	15:00	25.391560	-27.869680	A, B
UT165	31/01/2008	17:02	25.496790	-27.665870	A, B
UT166	31/01/2008	19:10	25.605760	-27.455930	A, B
UT167	31/01/2008	21:07	25.711210	-27.269510	A, B
UT168	31/01/2008	23:00	25.796840	-27.102280	A, B
UT169	1/02/2008	1:12	25.888040	-26.916730	A, B, C
UT170	1/02/2008	2:58	25.964710	-26.773460	A, B
UT171	1/02/2008	5:05	26.051280	-26.599330	A, B
UT172	1/02/2008	11:01	26.200950	-26.246640	A, B
UT173	1/02/2008	13:04	26.238620	-26.011140	A, B
UT174	1/02/2008	15:00	26.276260	-25.787900	A, B
UT175	1/02/2008	17:00	26.309400	-25.546970	A, B
UT176	1/02/2008	19:30	26.349520	-25.234000	A, B
UT177	1/02/2008	21:00	26.376750	-25.032390	A
UT178	1/02/2008	23:00	26.420260	-24.755360	A, B
UT179	2/02/2008	1:05	26.471530	-24.441970	A, B
UT180	2/02/2008	2:58	26.504110	-24.148800	A, B
UT181	2/02/2008	5:10	26.573020	-23.820420	A, B
UT182	2/02/2008	11:00	26.657740	-23.320560	A, B
UT183	2/02/2008	16:58	26.743940	-22.807300	A
UT184	2/02/2008	19:00	26.806190	-22.435420	A, B
UT185	2/02/2008	21:00	26.873290	-22.056440	A, B
UT186	2/02/2008	23:00	26.925640	-21.675980	A, B
UT187	3/02/2008	1:15	27.004710	-21.240870	A, B
UT188	3/02/2008	2:56	27.057960	-20.909350	A, B
UT189	3/02/2008	5:05	27.125740	-20.494950	A, B

Table with the underway samples from the non-toxic surface seawater supply (NT).

Code	date	time	lat	long	measurements
NT1	6/01/2008	3:00	27.338360	-16.971540	D
NT2	6/01/2008	11:20	26.841840	-17.441270	D
NT3	6/01/2008	13:00	26.604890	-17.662490	D
NT4	6/01/2008	17:09	26.535010	-17.714830	D
NT5	6/01/2008	19:00	26.265730	-17.980290	D, E
NT5	6/01/2008	19:00	26.265730	-17.980290	D
NT6	6/01/2008	21:00	25.972540	-18.255690	D, E, F
NT7	6/01/2008	23:00	25.681460	-18.526720	D, E
NT8	7/01/2008	1:00	25.399740	-18.788930	D, E, F
NT9	7/01/2008	3:09	25.106410	-19.061340	E
NT10	7/01/2008	5:00	24.8534	-19.298500	F
NT11	7/01/2008	11:20	24.715240	-19.444760	E, F
NT12	7/01/2008	12:55	24.496290	-19.631050	E
NT13	7/01/2008	15:00	24.51882	-19.646410	F
NT14	7/01/2008	17:09	24.566080	-19.813820	E
NT15	7/01/2008	19:00	24.64635	-20.194050	E, F

NT16	7/01/2008	21:00	24.743970	-20.597960	D, E
NT17	7/01/2008	23:00	24.839420	-20.997080	D, E
NT18	8/01/2008	1:00	24.936410	-21.391130	D, E, F
NT19	8/01/2008	3:00	25.031410	-21.784430	D, E
NT20	8/01/2008	5:00	25.128220	-22.183290	D, E
NT21	8/01/2008	11:00	25.236170	-22.631680	D, E, F
NT22	8/01/2008	13:00	25.330800	-23.024640	D, E
NT23	8/01/2008	15:00	25.353740	-23.121630	D, E, F
NT24	8/01/2008	17:00	25.453710	-23.533760	D, E
NT25	8/01/2008	19:20	25.569150	-24.015460	D, E, F
NT26	8/01/2008	23:00	25.648070	-24.345560	D, E, F
NT27	9/01/2008	1:00	25.744510	-24.745380	D, E
NT28	9/01/2008	3:00	25.839560	-25.142180	D, E, F
NT29	9/01/2008	5:00	25.935220	-25.542610	D, E
NT30	9/01/2008	11:01	26.055420	-26.038080	D, E, F
NT31	9/01/2008	12:55	26.145760	-26.416990	D, E
NT32	9/01/2008	17:02	26.188350	-26.595320	D, E, F
NT33	9/01/2008	19:15	26.271600	-26.929990	D, E
NT34	9/01/2008	21:00	26.352580	-27.283830	D, E, F
NT35	9/01/2008	23:00	26.447460	-27.682050	D, E
NT36	10/01/2008	1:00	26.543160	-28.081620	D, E, F
NT37	10/01/2008	3:00	26.639380	-28.485680	D, E
NT38	10/01/2008	5:00	26.735160	-28.887300	D, E
NT39	10/01/2008	11:00	26.797060	-29.146700	D, E, F
NT40	10/01/2008	17:40	26.90988	-29.511860	F
NT41	11/01/2008	1:00	26.305290	-29.178160	D, E, F
NT42	11/01/2008	3:00	26.005840	-29.004770	D, E
NT43	11/01/2008	5:08	25.681710	-28.818570	D, E
NT44	11/01/2008	9:03	25.620640	-28.775810	D, E, F
NT45	11/01/2008	11:08	25.326790	-28.614130	D, E
NT46	11/01/2008	17:06	25.071060	-28.485340	D, E
NT47	11/01/2008	19:00	24.820540	-28.326350	D, E, F
NT48	11/01/2008	21:10	24.520620	-28.154860	D, E
NT49	11/01/2008	23:02	24.264450	-28.007630	D, E
NT50	12/01/2008	1:00	23.998050	-27.857830	D, E, F
NT51	12/01/2008	3:00	23.722750	-27.701370	D, E
NT52	12/01/2008	5:15	23.404510	-27.517510	D, E
NT53	12/01/2008	9:06	23.328100	-27.476020	D, E
NT54	12/01/2008	11:02	23.057650	-27.326400	D, E, F
NT55	12/01/2008	17:00	22.680080	-27.113340	D, E, F
NT56	12/01/2008	19:02	22.391900	-26.951550	D, E
NT57	12/01/2008	21:00	22.102520	-26.790290	D, E, F
NT58	12/01/2008	23:00	21.807880	-26.625750	D, E
NT59	13/01/2008	1:00	21.516390	-26.463650	D, E, F
NT60	13/01/2008	3:00	21.223400	-26.300560	D, E
NT61	13/01/2008	5:20	20.901400	-26.120240	D, E
NT62	13/01/2008	11:05	20.615430	-25.963100	D, E, F
NT63	13/01/2008	19:00	20.377060	-25.822370	D, E
NT64	13/01/2008	21:00	20.091890	-25.674230	D, E
NT65	13/01/2008	23:00	19.811000	-25.519420	D, E, F

NT66	14/01/2008	1:00	19.536270	-25.368410	D, E
NT67	14/01/2008	3:00	19.260360	-25.216740	D, E, F
NT67	14/01/2008	3:00	19.260360	-25.216740	D
NT68	14/01/2008	5:20	18.951920	-25.041690	D, E
NT69	14/01/2008	11:00	18.741140	-24.933400	D, E, F
NT70	14/01/2008	17:00	18.402440	-24.750810	D, E, F
NT71	14/01/2008	19:00	18.266870	-24.677250	D, E
NT72	14/01/2008	21:00	18.132900	-24.604020	D, E, F
NT73	14/01/2008	22:52	18.018810	-24.541570	D, E
NT74	15/01/2008	1:00	17.888140	-24.469420	D, E, F
NT75	15/01/2008	3:00	17.749430	-24.392470	E
NT76	15/01/2008	17:00	17.378420	-24.519580	D, E, F
NT77	15/01/2008	19:02	17.115180	-24.783450	D, E
NT78	15/01/2008	21:00	16.895130	-25.080730	D, E, F
NT79	15/01/2008	23:00	16.593800	-25.211630	D, E
NT80	16/01/2008	1:00	16.256160	-25.269740	D, E, F
NT81	16/01/2008	3:00	15.925500	-25.326770	D, E
NT82	16/01/2008	4:58	15.595670	-25.384510	D, E
NT83	16/01/2008	11:00	15.327460	-25.430200	D, E, F
NT84	16/01/2008	17:10	14.973370	-25.482440	D, E, F
NT85	16/01/2008	19:00	14.691190	-25.539180	D, E
NT86	16/01/2008	21:00	14.360460	-25.597000	D, E, F
NT87	17/01/2008	1:00	13.725750	-25.704950	D, E, F
NT88	17/01/2008	3:00	13.407880	-25.760910	D, E
NT89	17/01/2008	5:16	13.016690	-25.825530	D, E
NT90	17/01/2008	11:05	12.840820	-25.858620	D, E, F
NT91	18/01/2008	1:05	12.657340	-26.379650	D, E, F
NT92	18/01/2008	5:00	12.644930	-27.083600	D, E
NT93	18/01/2008	11:10	12.656520	-27.495000	D, E, F
NT94	18/01/2008	19:00	12.626040	-28.114130	D, E, F
NT95	18/01/2008	21:02	12.618470	-28.487770	D, E
NT96	18/01/2008	23:02	12.613070	-28.859810	D, E, F
NT97	19/01/2008	1:00	12.605170	-29.227270	D, E
NT98	19/01/2008	3:00	12.598030	-29.593870	D, E, F
NT99	19/01/2008	5:00	12.592120	-29.955980	D, E
NT100	19/01/2008	7:00	12.607980	-29.997420	F
NT101	19/01/2008	11:00	12.608570	-30.277570	D, E, F
NT102	19/01/2008	19:05	12.584070	-30.906750	D, E, F
NT103	19/01/2008	21:06	12.567730	-31.265470	D, E
NT104	19/01/2008	23:00	12.564860	-31.599180	D, E, F
NT105	20/01/2008	1:00	12.554990	-31.943620	D, E
NT106	20/01/2008	3:00	12.547700	-32.292650	D, E, F
NT107	20/01/2008	4:53	12.536980	-32.622230	D, E
NT108	20/01/2008	11:00	12.538950	-32.976410	D, E, F
NT109	20/01/2008	17:00	12.530720	-33.486020	D, E, F
NT110	20/01/2008	19:13	12.525850	-33.893550	D, E
NT111	20/01/2008	21:00	12.521310	-34.229820	D, E, F
NT112	20/01/2008	23:00	12.516960	-34.609440	D, E
NT113	21/01/2008	1:10	12.511120	-35.017680	D, E, F
NT114	21/01/2008	3:00	12.507930	-35.363110	D, E

NT115	21/01/2008	5:09	12.503690	-35.763930	D, E
NT116	21/01/2008	7:00	12.52024	-35.778790	F
NT117	21/01/2008	11:00	12.537070	-35.546290	D, E, F
NT118	21/01/2008	17:00	12.545050	-35.154710	D, E, F
NT119	21/01/2008	21:00	12.556760	-34.565280	D, E, F
NT120	22/01/2008	1:00	12.569260	-33.955450	D, E, F
NT121	22/01/2008	3:00	12.576240	-33.635540	D, E
NT122	22/01/2008	4:55	12.579950	-33.317440	D, E
NT123	22/01/2008	11:00	12.615500	-32.930720	D, E, F
NT124	22/01/2008	17:05	12.614030	-32.489000	D, E, F
NT125	22/01/2008	19:00	12.612880	-32.140070	D, E
NT126	22/01/2008	21:00	12.625850	-31.778350	D, E, F
NT127	22/01/2008	23:00	12.642440	-31.413880	D, E
NT128	23/01/2008	1:00	12.658250	-31.051530	D, E, F
NT129	23/01/2008	3:00	12.676620	-30.684410	D, E
NT130	23/01/2008	5:05	12.372840	-30.549860	D, E
NT131	23/01/2008	10:00	12.50527	-30.610320	F
NT132	23/01/2008	11:00	12.504890	-30.622230	E
NT133	23/01/2008	19:00	13.256810	-30.633740	D, E, F
NT134	23/01/2008	19:07	13.276490	-30.633560	D
NT135	23/01/2008	21:00	13.598530	-30.634090	D
NT136	23/01/2008	23:00	13.949750	-30.633020	D, F
NT136	23/01/2008	23:00	13.949750	-30.633020	D
NT137	24/01/2008	1:00	14.304420	-30.633290	D
NT138	24/01/2008	4:59	14.996320	-30.633210	D, E
NT139	24/01/2008	5:06	15.015980	-30.633290	D
NT140	24/01/2008	11:00	16.035950	-30.634450	D, E, F
NT140	24/01/2008	11:00	16.035950	-30.634450	D
NT141	24/01/2008	17:00	16.166390	-30.477990	D, E, F
NT142	24/01/2008	19:00	16.249640	-30.132950	E
NT143	24/01/2008	21:00	16.26025	-30.066590	E, F
NT144	24/01/2008	23:00	16.233830	-30.193860	E
NT145	25/01/2008	1:00	16.20396	-30.321960	E, F
NT146	25/01/2008	5:00	16.134850	-30.613550	E
NT147	25/01/2008	6:40	16.1434	-30.633340	F
NT148	27/01/2008	23:00	16.233830	-30.193860	D, E
NT149	28/01/2008	3:00	16.377370	-29.733770	D, E, F
NT150	28/01/2008	5:00	16.442060	-29.398250	D, E
NT151	28/01/2008	8:22	16.550660	-28.826190	D, E, F
NT152	28/01/2008	11:08	16.647050	-28.350590	D, E, F
NT153	28/01/2008	13:10	16.711800	-27.998410	D, E
NT154	28/01/2008	15:20	16.785850	-27.613360	D, E
NT155	28/01/2008	17:00	16.841460	-27.323520	D, E, F
NT156	28/01/2008	19:10	16.913450	-26.948440	D, E
NT157	29/01/2008	5:00	17.711730	-26.583730	D, E
NT158	29/01/2008	7:00	18.043130	-26.623240	D, E, F
NT159	29/01/2008	9:21	18.436990	-26.668800	D
NT160	29/01/2008	11:00	18.709400	-26.701810	D, E, F
NT161	29/01/2008	13:10	19.077270	-26.745230	D, E
NT162	29/01/2008	15:00	19.389610	-26.782060	D, E, F

NT163	29/01/2008	17:01	19.736390	-26.823790	D, E
NT164	29/01/2008	19:00	20.081660	-26.864540	D, E, F
NT165	29/01/2008	21:20	20.486150	-26.912570	E
NT166	29/01/2008	23:00	20.776140	-26.947750	D, E, F
NT167	30/01/2008	5:03	21.863440	-27.079280	D, E
NT168	30/01/2008	5:03	21.863440	-27.079280	D
NT169	30/01/2008	11:06	22.400560	-27.144020	D, E, F
NT170	30/01/2008	17:00	22.979070	-27.285610	D, E, F
NT171	30/01/2008	19:15	23.337240	-27.486290	D, E
NT172	30/01/2008	21:00	23.613070	-27.642850	D, E, F
NT173	30/01/2008	23:03	23.928970	-27.821010	D, E
NT174	31/01/2008	0:59	24.229150	-27.990960	D, E
NT175	31/01/2008	2:59	24.538340	-28.166410	E
NT176	31/01/2008	5:00	24.832140	-28.334190	E
NT177	31/01/2008	11:00	25.154620	-28.320590	D, E, F
NT178	31/01/2008	13:06	25.281530	-28.080150	D, E
NT179	31/01/2008	17:00	25.495000	-27.669380	D, E, F
NT180	31/01/2008	19:00	25.596890	-27.471310	D, E
NT181	31/01/2008	21:00	25.705280	-27.280070	D, E, F
NT182	31/01/2008	23:11	25.803960	-27.087590	D, E
NT183	1/02/2008	1:02	25.879890	-26.931110	D, E
NT184	1/02/2008	4:57	26.046040	-26.610250	D, E
NT185	1/02/2008	7:00	26.136170	-26.434840	D, E
NT186	1/02/2008	11:00	26.200450	-26.248540	D, E, F
NT187	1/02/2008	13:00	26.237240	-26.018560	D, E
NT188	1/02/2008	15:00	26.276260	-25.787900	D, E, F
NT189	1/02/2008	19:00	26.345750	-25.298400	D, E, F
NT190	1/02/2008	23:00	26.420260	-24.755360	D, E, F
NT191	2/02/2008	1:00	26.468560	-24.454770	D, E
NT192	2/02/2008	3:02	26.505120	-24.138120	E
NT193	2/02/2008	5:00	26.567190	-23.845550	D, E
NT194	2/02/2008	11:00	26.657740	-23.320560	D, E, F
NT195	2/02/2008	17:00	26.744810	-22.801290	D, E, F
NT196	2/02/2008	21:00	26.873290	-22.056440	D, E, F
NT197	2/02/2008	23:00	26.925640	-21.675980	D, E
NT198	3/02/2008	1:00	26.996780	-21.289560	D, E, F
NT199	3/02/2008	1:10	27.002090	-21.257180	D, E
NT200	3/02/2008	2:59	27.059540	-20.899590	E
NT201	3/02/2008	4:57	27.121280	-20.521240	D, E