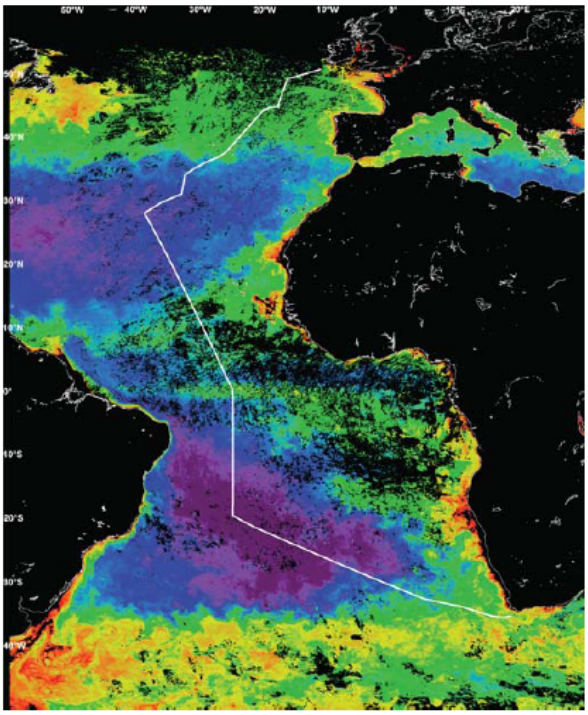
Atlantic Meridional Transect

AMT17 Cruise Report

RRS Discovery

15 October – 28 November 2005



Principal Scientist:

Patrick Holligan (NOC,S)

Plymouth Marine Laboratory

Southampton Oceanography Centre
University of Southampton and Natural Environment Research Council

UEA Norwich

University of Newcastle upon Tyne

The University of Liverpool

University of Southampton

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Preface

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

Detailed information of observational and experimental procedures is given under Scientific Reports only in cases where it has not been provided in earlier Cruise Reports (AMT12-16) which can be accessed via the AMT website (www.amt-uk.org).

Several figures in this report were produced using the Ocean Data View (ODV) Software (Schlitzer, R., Ocean Data View, http://www.awi-bremerhaven.de/GEO/ODV, 2004.

Acknowledgements

We thank the Master, Robin Plumley, and all the officers and crew of RRS Discovery for their constant support and sustenance during cruise D299, and for providing a safe and efficient platform from which to meet the scientific objectives of the AMT programme. We are particularly grateful to the Chief Engineer, George Parkinson, and his colleagues for their hard work in repairing the gantry hydraulics system. Excellent support for (de)mobilisation, CTD work, winch operations, maintenance of equipment and computing was provided by UKORS staff (Jon Short, Terry Edwards, Emma Northrop, Gareth Knight).

Invaluable assistance with cruise logistics was provided by Malcolm Woodward, Dawn Ashby and Carol Robinson at the Plymouth Marine Laboratory, and by Mike Lucas in South Africa with arrangements for the transport of frozen samples. We are also grateful to Rory Hutson (RSDAS) for providing satellite data before and during the cruise.

Special thanks are also due to Tim Adey and Simon Ussher for their good humoured assistance and patience on each station with determining the depths for CTD water bottles, to Ed Mawji for data analysis with ODV, and to Mark Moore for returning to South Africa in January to help with the packing and transport of frozen samples back to the UK. We are also most grateful to the staff of Biocair International for all their help and advice with the shipment of samples from South Africa to the UK.

Scientific Personnel

Prof Patrick Holligan	pmh1@noc.soton.ac.uk	*National Oceanography Centre, Southampton, Empress Dock, European Way, Southampton, SO14 3ZH, UK.*
Dr Eric Achterberg	eric@noc.soton.ac.uk	
Tim Adey	tra1@noc.soton.ac.uk	
Anna Hickman	aeh101@noc.soton.ac.uk	
Dr Mike Lucas	mluc@noc.soton.ac.uk	
Dr Isabelle Mary	imary@noc.soton.ac.uk	
Xi Pan	xp@noc.soton.ac.uk	
Dr Mike Zubkov	mvz@noc.soton.ac.uk	
Katie Chamberlain	kaec@pml.ac.uk	*Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth PL1 3DH, UK.*
Dr Nicola Gist	nigi@pml.ac.uk	
Gerald Moore	gfm@pml.ac.uk	
Nicholas Pope	ndpo@pml.ac.uk	
Karen Weynberg[1]	kwey@pml.ac.uk	
Malcolm Woodward	emsw@pml.ac.uk	
Tim Lesworth	t.lesworth@uea.ac.uk	*School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ, UK..*
Rhiannon Mather	rhiannon.mather@liverpool.ac.uk	*Department of Earth and Ocean Sciences, University of Liverpool, PO Box 147, Liverpool, L69 3BX, UK.*
Ed Mawji[2]	ezm@noc.soton.ac.uk	*School of Earth, Ocean and Environmental Science, University of Plymouth, Drake Circus, Plymouth, PL4 8AA, UK.*
Dr Simon Ussher	simon.ussher@plymouth.ac.uk	
Dr Mark Moore	cmmoore@essex.ac.uk	*John Tabor Laboratory, School of Biological Science, University of Essex, Wivenhoe Park, Colchester, CO4 3SQ, UK.*
Dr David Suggett	dsuggett@essex.ac.uk	
Dr Matthew Mills	mmmills@pangea.Stanford.EDU	*Department of Geophysics, Stanford University, Palo Alto, CA 94305, USA.*
Dr Jan Kaiser[3]	J.Kaiser@uea.ac.uk	*Department of Geosciences, Princeton University, Guyot Hall, Princeton, NJ 08544, USA.*
Bruce Bowler	bbowler@bigelow.org	*Bigelow Laboratory for Ocean Science, PO Box 475, West Boothbay Harbor, Maine 04575-0475, USA.*
Dr Michelle Hale	mhale@mun.ca	*Ocean Sciences Centre, Memorial University of Newfoundland, St John's, Newfoundland, A1C 5S7, Canada.*
Jon Short	jos@noc.soton.ac.uk	*UKORS, National Oceanography Centre, Empress Dock, European Way, Southampton, SO14 3ZH, UK.*
Terrence Edwards	txe@noc.soton.ac.uk	
Gareth Knight	gck@noc.soton.ac.uk	
Emma Northrop	enorth@noc.soton.ac.uk	

[1]Returned to the UK from the Azores
[2]Present address: National Oceanography Centre, Southampton
[3]Present address: University of East Anglia, Norwich

Objectives of Cruise

The biota of the surface ocean has a profound influence on the global budgets of climatically-active trace constituents in the atmosphere (CO_2, DMS, N_2O, CH_4 and aerosols) and hence climate. Our understanding of how biogeochemical cycling in the oceans affects climate, and of how changes in climate influence the structure and activity of oceanic ecosystems is still incomplete, hindering accurate predictions of the future global environment. Realistic model simulations require new observations of both the spatial and temporal variability of planktonic ecosystem structure, multi-element cycling and exchange processes between ocean and atmosphere.

The Atlantic Meridional Transect Programme (AMT) is a UK National Environment Research Council (NERC) funded project which aims to quantify the nature and causes of ecological and biogeochemical variability in the planktonic ecosystems of the Atlantic Ocean, and the effects of this variability on the biological C pump and on air-sea exchange of radiatively active gases and aerosols. The programme continues a series of 12 bi-annual transect cruises between the UK (50^oN) and the Falkland Islands (52^oS) which took place between 1995 and 2000 making measurements of hydrographic and bio-optical properties, plankton community structure and primary production. Six further cruises will take place between 2003 and 2005 to provide a unique decadal time series of spatially extensive observations on the structure and biogeochemical properties of planktonic ecosystems. The project will allow 45 investigators from 6 partner UK institutions to test nine inter-related hypotheses which fall within the following three scientific objectives:

- To determine how the structure, functional properties and trophic status of the major planktonic ecosystems vary in space and time

The first three hypotheses strive to address the question of linking plankton biodiversity with variability in biogeochemical fluxes, in particular the potential for carbon export to the deep sea and ocean / atmosphere exchange of carbon dioxide. A fourth hypothesis will develop and validate models and empirical relationships to enable the use of remote sensing to interpolate in time between the two AMT sampling periods per year and to extrapolate in space from the single track of *in situ* samples to the basin scale.

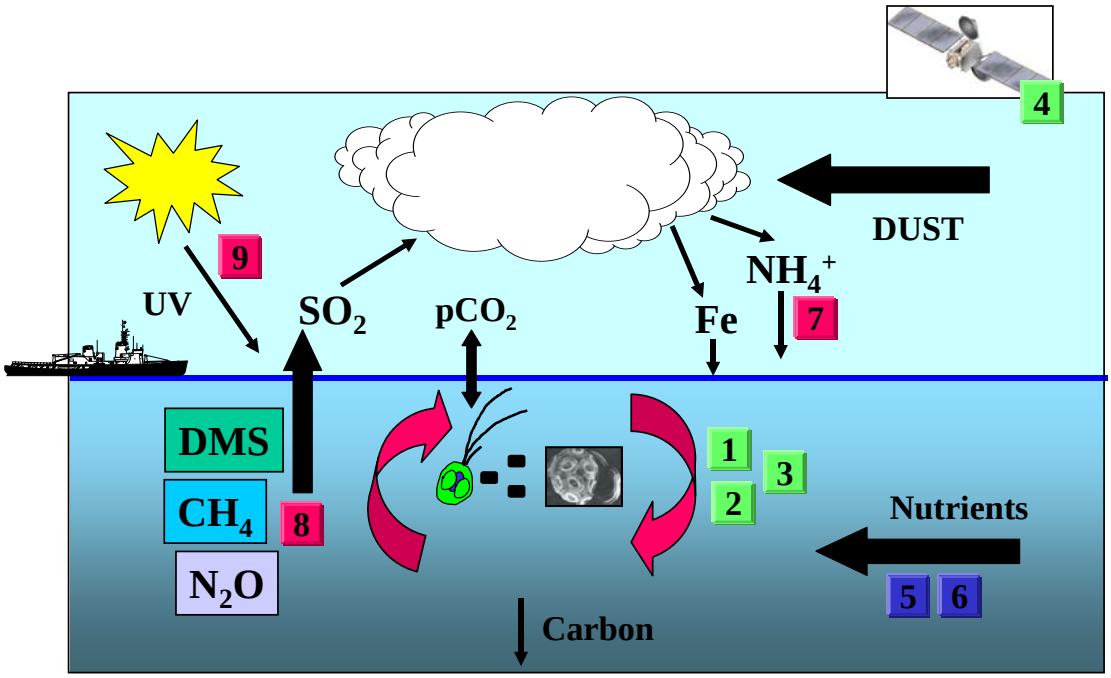
- To determine the role of physical processes in controlling the rates of nutrient supply, including dissolved organic matter, to the planktonic ecosystem

Hypothesis 5 and 6 deal with the physical supply of nutrients on two space and time scales. The programme will derive an indication of lateral transport of nutrients from upwelling regions into the gyres as well as validating models which predict the impact of atmospheric forcing functions on nutrient supply mechanisms.

- To determine the role of atmosphere-ocean exchange and photo-degradation in the formation and fate of organic matter

Hypothesis 7 assesses the impact of atmospheric input of nutrients such as inorganic nitrogen and iron, and hypothesis 8 will further investigate the link between the production of radiatively important gases and plankton community structure with a view to improving basin scale estimates of the fluxes of CO_2, DMS, N_2O and CH_4. Finally hypothesis 9 will determine the magnitude and variability of the photodegradation products of coloured dissolved organic matter.

The schematic shows how the hypotheses follow a climate feedback loop, with plankton community structure and activity impacting gas emissions which influence cloud formation which in turn influence dust solubility and hence deposition of nutrients and so community structure and activity.



AMT17 was the sixth and final cruise of the second phase of the AMT programme, with a focus on the subtropical gyres of both the northern and southern hemispheres. The tracks for AMTs 12 to 14 were between the UK and the Falkland Islands, whereas for AMTs 15 to 17 they were between the UK and South Africa. The legs between the equator and 20°S along the 25°W meridian were the same for all cruises. In the northern hemisphere the track for AMT17 extended south west of the Azores into the subtropical gyre (as did those for AMTs 12, 14 and 16), and was similar to that for AMT14.

The main objectives of AMT17 were to acquire a consistent set of core measurements for comparison with data from earlier cruises, and to carry out new experimental work on planktonic processes relevant both to the AMT objectives and to future work at sea as part of new (e.g. SOLAS) and planned (e.g. as part of OCEANS 2025) marine biogeochemical projects. The latter included oxygen isotope measurements to assess the trophic balance within surface waters, measurements of the turnover rates organic substrates by bacteria, and nutrient addition experiments to identify limiting substrates for phytoplankton growth.

Cruise Narrative

The ship departed from Govan, Scotland on the afternoon of 15 October and arrived in Port Elizabeth, South Africa on the morning of 28 November, a period of just over 41 days at sea. The cruise track is shown on the cover, overlain on a composite MODIS image of surface chlorophyll for the month of November 2005. During the cruise about 6 working days (20-27 October) were lost around the Azores in the North Atlantic; due mainly to a fault with the hydraulics system on the starboard gantry, and a heavy swell prevented any station work for a further day (29 October) soon after leaving the Azores. These delays meant that by the time the equator was reached on 10 November the available stopping time was very low, and some planned stations had to be dropped in the southern gyre. A total of 62 CTD stations were completed (Fig. 1) which included 27 pre-dawn ones and 11 at which Stand Alone Pumps (SAPS) were deployed.

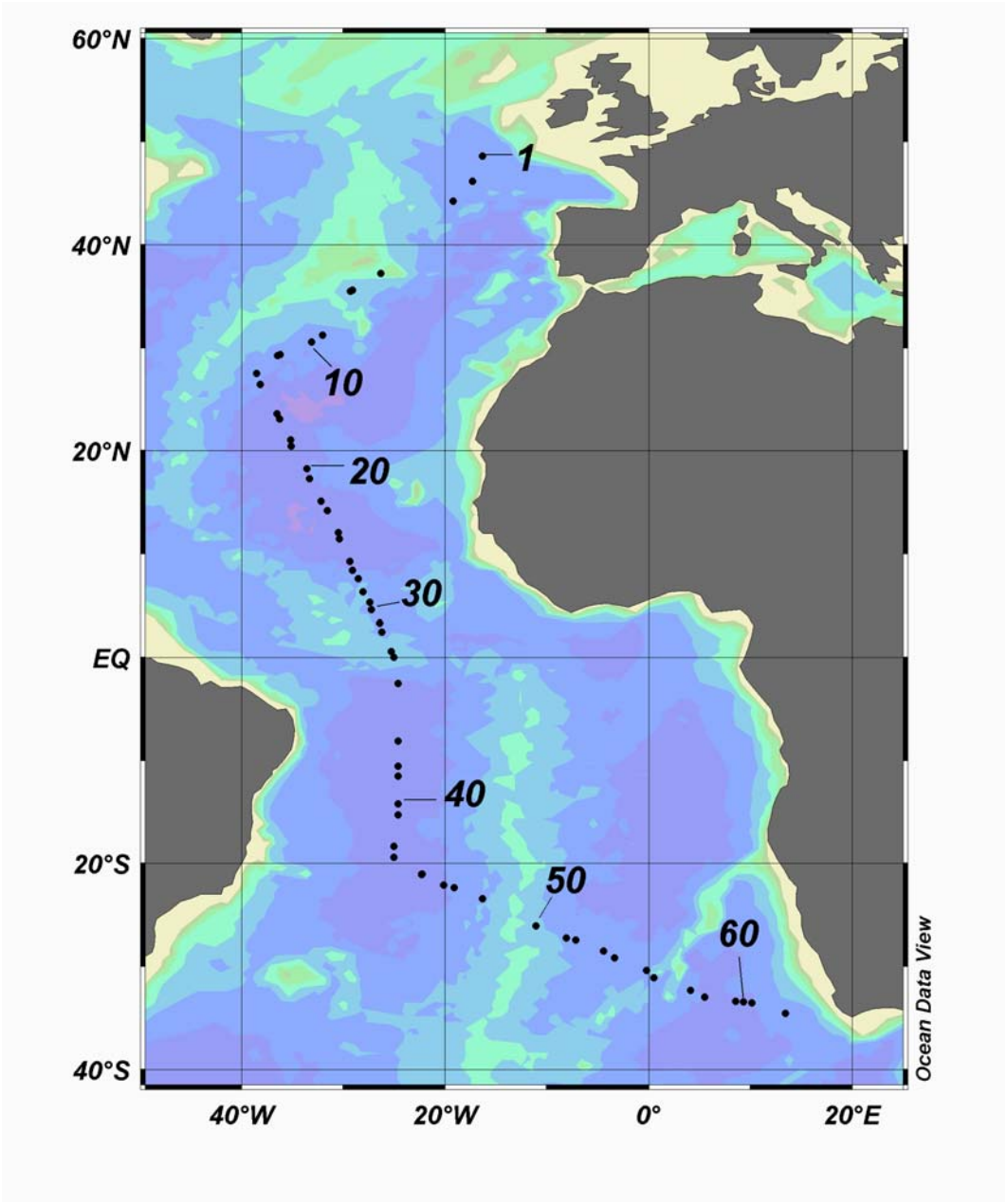


Figure 1. AMT17. CTD station positions and number. See Appendix 1 for further details. Note that CTD stations aborted for technical reasons are not included on this diagram so that fewer than 62 positions are actually marked.

Changes in ship time were made at 0200h as follows:

18 October	Day 291	GMT+1 to GMT
28 October	Day 301	GMT to GMT-1
30 October	Day 303	GMT-1 to GMT-2
6 November	Day 310	GMT-2 to GMT-1
18 November	Day 322	GMT-1 to GMT
21 November	Day 325	GMT to GMT+1
24 November	Day 328	GMT+1 to GMT+2

The dates, positions and times of the CTD stations, together with information on other scientific activities, are listed in Appendix 1. Station 1 was at the PAP long-term observation site after which a slight deviation to the planned track was made in order to recover the following day part a PAP mooring that had broken loose in July. Following the hydraulic system failure port calls into Ponta Delgada (Azores) were made on 22/23 and 26/27 October, with divers also attending the ship on the latter date to remove cable from the free-fall optics sensor that had become entangled around the propeller (see separate accident report and recommendations). On 6-9 November the ship passed through the Inter Tropical Convergence Zone (ITCZ) centred around 8°N. After crossing the equator at midday on 10 November, King Neptune was welcomed aboard on 12 November with the usual celebrations.

Two deep CTD profiles were completed, one in the N gyre at about 23°N (4800 m) and one in the S gyre at about 21°S (5000 m), mainly for measurements of inorganic nutrients including iron. Also two APEX autonomous profiler floats were released in the S gyre on 15 and 17 November at ~20° and 23°S respectively. Towards the end of the transect three stations (CTDs 60–62) on 24 November were occupied in coccolithophore-rich water which were positioned on the basis of satellite reflectance data sent out to the ship (Fig. 2).

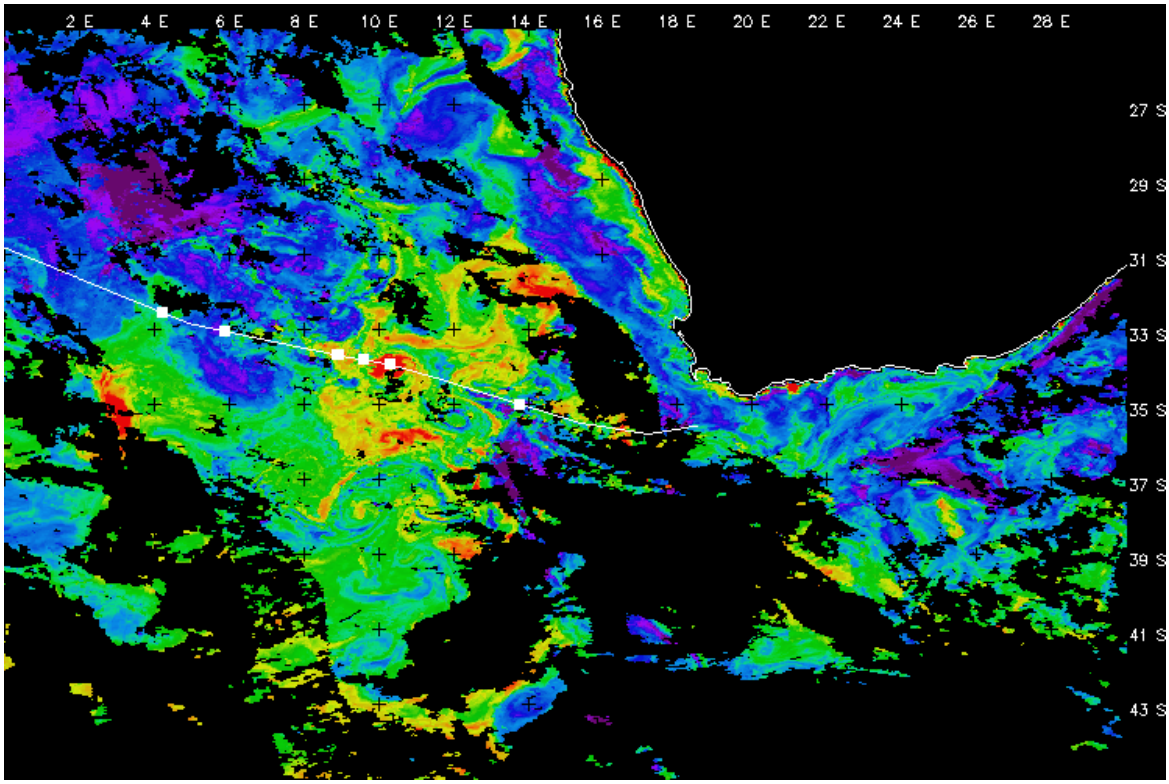


Figure 2. AMT17. Composite (21-27 November, 2005) MODIS image of surface reflectance at 551nm (indicative of coccolithophore abundance) for the southern end of the cruise transect. White squares indicate the positions of CTD stations 57-62. Reflectance values range from high in red to low in purple.

The weather and sea conditions during the cruise were relatively good apart from strong winds and swell around the Azores. Significant rainfall occurred as thunderstorms off the Azores and as showers within the ITCZ.

There were no major equipment failures apart from the entanglement of the free-fall optics cable as mentioned above. Various problems were experienced with the scientific containers which need to be resolved before they are used again at sea, and breakdown of the liquid N_2 generator during the last part of the cruise meant that some experimental work had to be curtailed and that significant problems were encountered in Port Elizabeth with the storage and transport of frozen samples. A large part of the frozen material had to be left on the ship and was returned to the UK from Cape Town in mid-January 2006 at the end of the following cruise (D300).

No serious health and safety issues arose during the cruise. Recommended procedures for the wearing of safety clothing and for the display of risk assessment forms were generally well followed. The site chosen for the scintillation counter in the main deck laboratory proved suitable in terms of access and safety, and is recommended for future cruises.

General Hydrographic and Meteorological Observations

Changes with latitude of sea surface and air temperatures, surface salinity and surface chlorophyll fluorescence during AMT17 are shown in Figure 3. The air temperature was lower than sea surface temperature across almost the whole section, with the largest differences in the northern hemisphere as expected in autumn. Surface salinity was higher in the northern gyre than in the southern one, again reflecting a seasonal difference. Surface water in the ITCZ north of the equator was characterised by high temperature (>27°C) and low salinity (<35) with the low salinity extending across about 8° of latitude. Air temperatures in the ITCZ were also relatively low probably as a result of extensive cloud cover in this region. Surface chlorophyll fluorescence was high and variable at either end of the transect and also in the region of equatorial upwelling region at about 10°N. Note that no corrections have been made to the 'jumps' in the fluorescence record apparent at 27° and 17°N.

Information about daily meteorological conditions are provided in Figure 4. The strongest winds occurred during the first 15 days of the cruise, reaching 40 knots at times, and were generally from a W or NW direction. Relative humidity was variable, especially at higher latitudes, but generally between 60 and 90%. Daily PAR was higher in the southern hemisphere than in the northern one, with two notably cloudy days in the ITCZ (Days 311 and 312) and one in the S gyre (Day 319).

Hydrographic sections based on the CTD sensor and bottle data for temperature, salinity and density and for nitrate, dissolved oxygen and chlorophyll are shown in Figures 5 and 6 respectively. The latitudinal distributions for these parameters conform well with data from previous AMT cruises, allowing for expected differences due to time of year and position of track. The low density surface water around the equator extended well to the north to about 15°N and was associated with a broad region of relatively high chlorophyll. The lowest surface chlorophyll values (<0.04 mg m^{-3}) were found in the S gyre where the depth of the deep chlorophyll maximum (DCM) was >150 m at some stations. In general nitrate was more depleted at the level of the DCM in the N gyre than in the S gyre, probably reflecting the difference between autumn and spring conditions. Diffuse attenuation coefficients ranged from <0.035 m^{-1} in chlorophyll-poor water in the S gyre to maximum values of 0.073 m^{-1} in chlorophyll-rich water north of the equator and 0.124 m^{-1} in coccolithophore-rich water off South Africa (see Fig. 2).

Plots of nitrate and chlorophyll distributions against density are shown in Figure 7. The upward extension of nitrate into relatively low density water around the equator is a measure of the potential for isopycnal transport of nutrients into the oligotrophic gyres to the north and south. Also elevated nitrate levels (> 5 μM l^{-1} at some stations) within the DCM across the equator are a good indicator of conditions favourable for phytoplankton growth in this region.

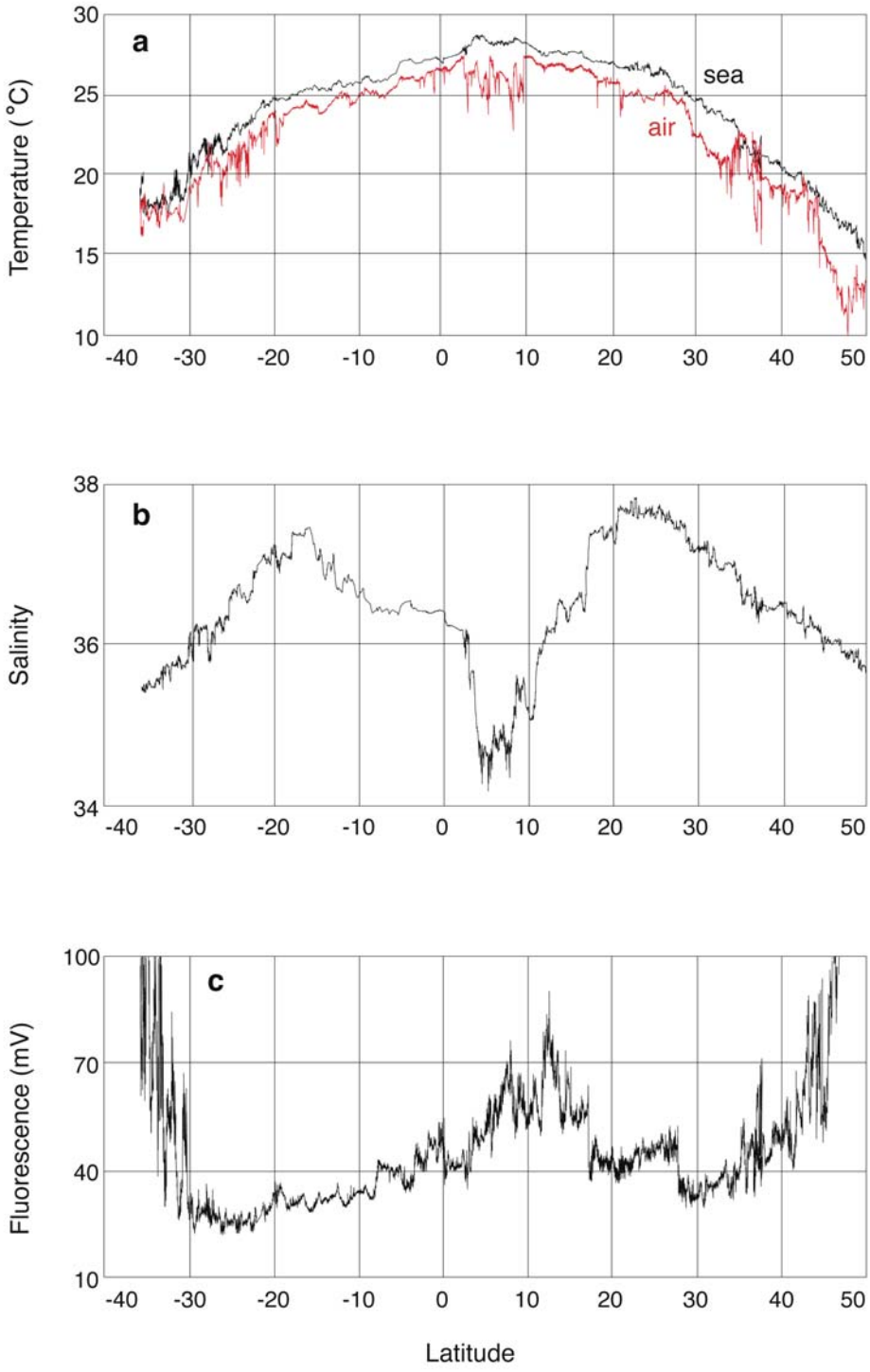


Figure 3. AMT17. Along-track changes with latitude in a) Sea surface and air temperatures (°C), b) Surface salinity, and c) Surface chlorophyll fluorescence (mV, not corrected).

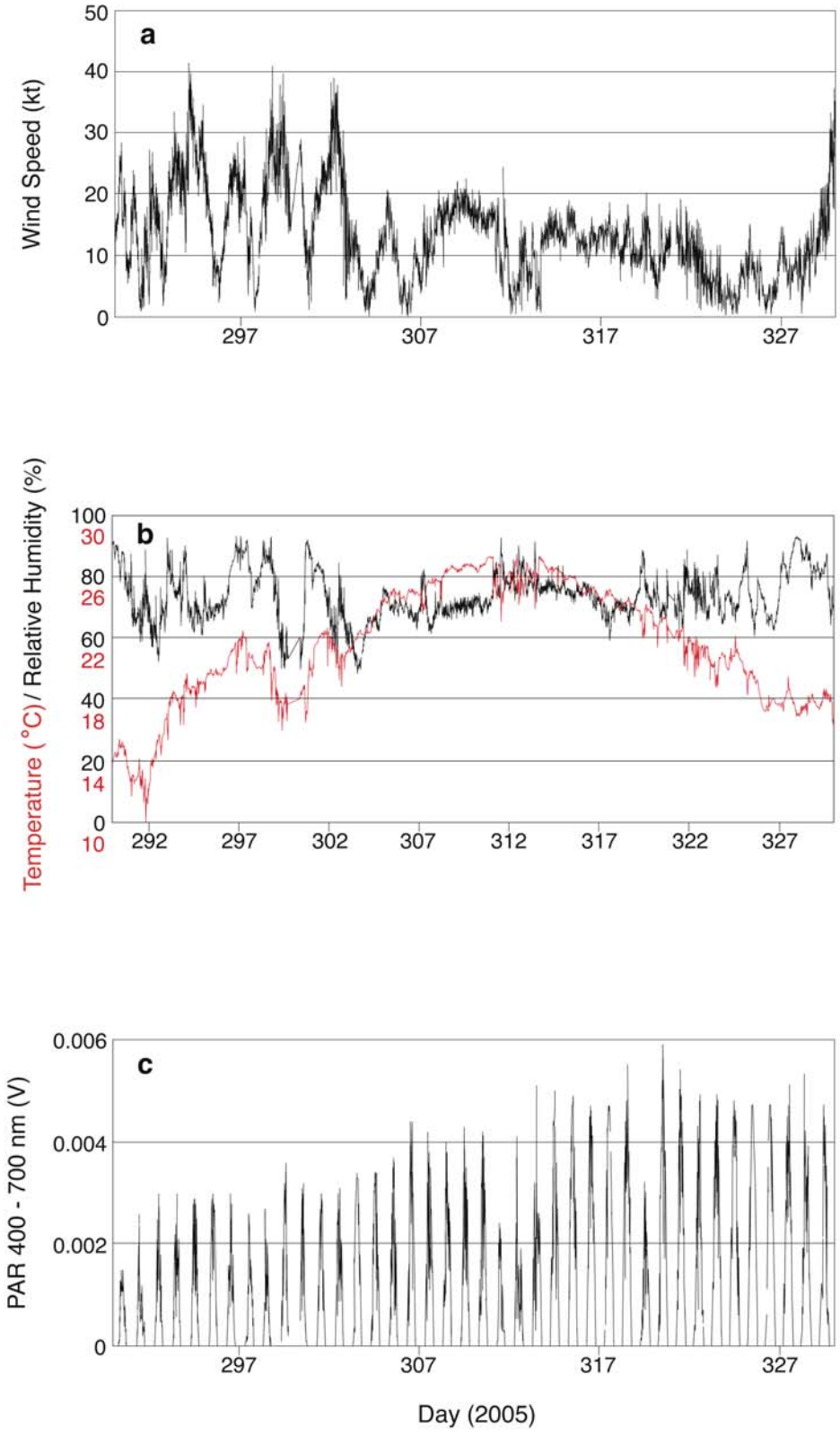


Figure 4. AMT17. Along-track changes with time (Day) in a) Wind speed (knots), b) Air temperature (°C) and relative humidity (%), and c) Photosynthetically Active Radiation (PAR, 400-700nm, V). Note that observations from the N hemisphere are to the left on these diagrams, with the equator being reached on Day 314. The calibration value for the PAR sensor is 1mV per 100W.m^{-2}.

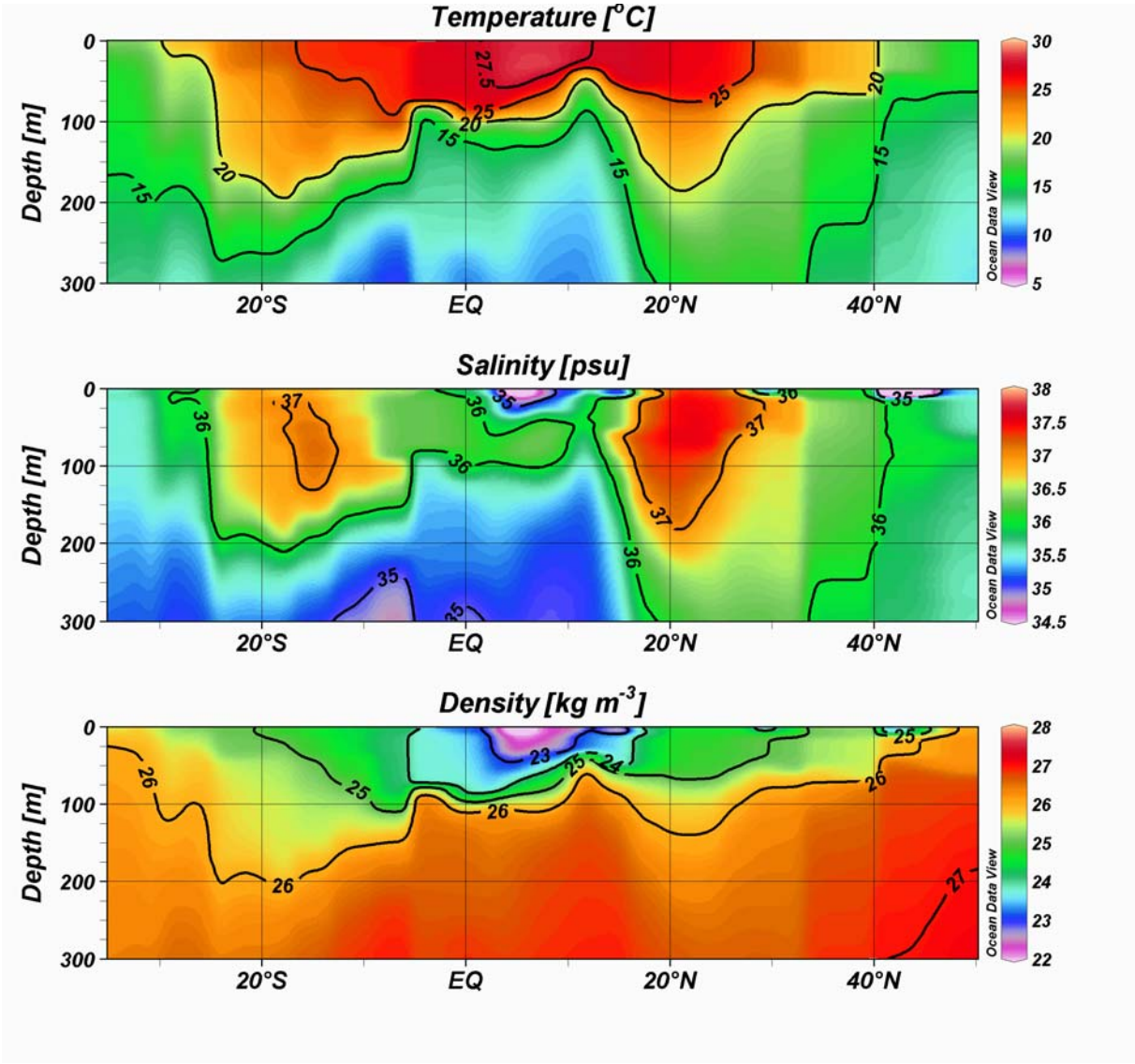


Figure 5. AMT17. CTD hydrographic sections (0-300m) against latitude for a) Temperature (°C), b) Salinity, and c) Density (kg m^{-3} – 1000)

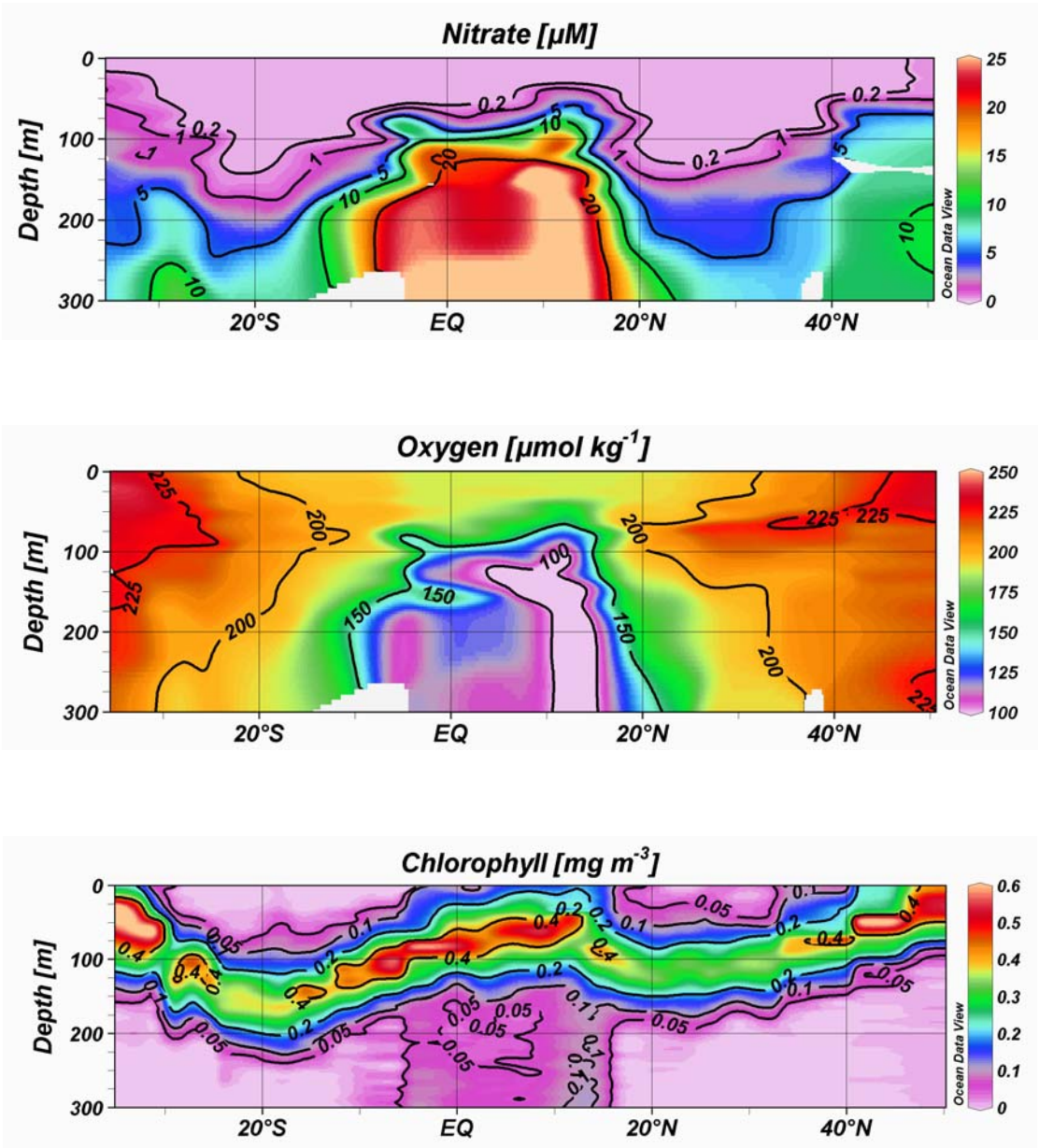


Figure 6. AMT17. Hydrographic sections (0-300m) against latitude for a) Nitrate + nitrite (µM l^{-1}), b) Dissolved oxygen (µM kg^{-1}), and c) Chlorophyll (mg m^{-3}). Nitrate was determined on the ship for water bottle samples (see report by Woodward and Chamberlain), oxygen is given as in situ electrode values for the same bottle depths, and the chlorophyll section is based on 2m-binned values from the CTD fluorometers calibrated against discrete measurements for water bottle samples (see report by Hickman and Holligan). Calibration values for the oxygen electrode indicate that maximum values for the section were ~255µM l^{-1} (see report by Gist).

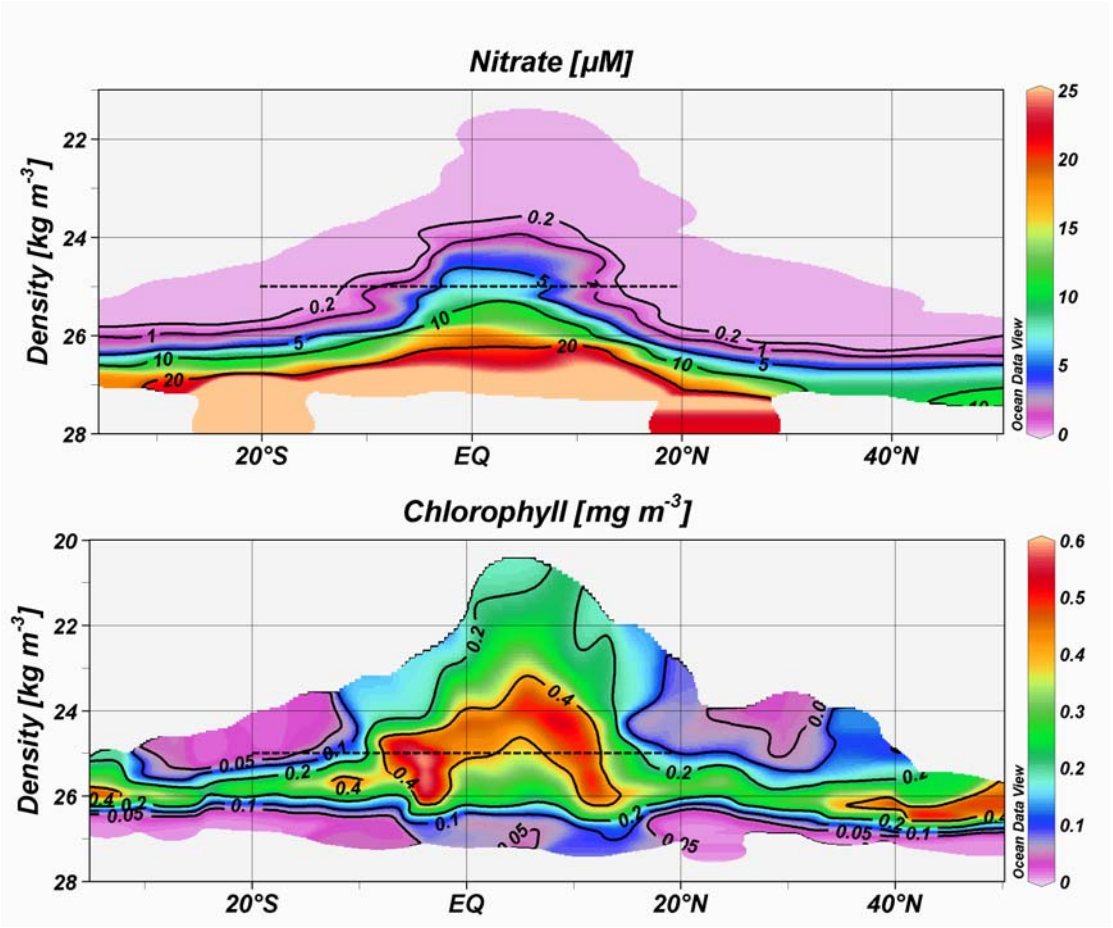


Figure 7. AMT17. Sections against density (kg m^{-3} – 1000) for a) Nitrate + nitrite (µM l^{-1}), and b) Chlorophyll (mg m^{-3}). The dashed line in each diagram indicates nitrate and chlorophyll values across the equatorial region at a density horizon of 25 kg m^{-3} -1000

Scientific Highlights of Cruise

The following list represents selected topics to which particular attention was given on AMT17. It is not intended to be exclusive in any way and cannot, of course, cover areas of work for which results are not yet available. Further details about these topics as well as about other aspects of scientific work on the cruise can be found in the Scientific Reports which follow.

- *Measurements of inorganic nutrients:* The most complete dataset of micro- and nano-molar measurements for the AMT transect was obtained on AMT17. Horizontal surface gradients across the equatorial region are well defined, showing differences between the N and S gyres particularly for phosphate (see Figure in report by Woodward and Chamberlain), and vertical gradients with respect to the DCM indicate strong latitudinal as well as seasonal changes in nutrient supply to phytoplankton (Fig. 7).
- *Coccolithophore optics and calcification:* As part of a global study of particulate inorganic carbon (PIC) distribution in the surface ocean, semi-continuous measurements calcite (coccolithophore) abundance and reflectance in surface water were made on AMTs 15-17 using bio-optical sensors, in conjunction with discrete chemical determinations of PIC and experimental determinations of rates of calcification. The data for AMT17 cover a significantly wider range of PIC concentration than for previous cruises (see Fig. 2 and report by Bowler).
- *Bacterial dynamics*: An extensive set of experiments to determine rates of production and of turnover rates for various growth substrates (organic and inorganic) by heterotrophic bacteria were completed during the cruise (see reports by Mary/Zubkov and Hale). The results should enable the dynamics of the microbial communities in the N and S subtropical gyres to be compared with reference to differences in nutritional state (e.g. available phosphorus) and in bacterial community structure.
- *Oxygen budgets:* Continuous surface measurements of O_2/Ar ratios throughout the transect. This is an in-situ measurement of biologically-induced oxygen supersaturation, which can be used to estimate net community production (NCP) integrated over timescales of gas exchange and physical transport, rather than the "instantaneous" rates yielded by bottle incubations. The O_2/Ar results indicate net autotrophy throughout the transect. This contrasts with in-vitro NCP measurements from the cruise, which give a more mixed picture that includes net heterotrophic patches. A comparison of NCP depth profiles produced from the two methods shows that the relative shape of O_2/Ar ratio and NCP rate profiles agree well in the thermocline, but show differences in the mixed layer, presumably due to more heterogeneous productivity and transport time scales.
- *Nutrient limitation of phytoplankton growth*: Recent work in the subtropical North Atlantic on the responses of the phytoplankton community (including diazotrophs) to additions of nitrogen phosphorus and iron was extended for the first time to Equatorial and S Atlantic waters. Both bioassay and dose response experiments were carried out, and a range of response parameters measured in order to test hypotheses about the nutritional control of primary production and N_2 fixation under contrasting environmental conditions – see reports by Moore, Mills, Suggett and co-authors.
- *Iron speciation and distribution:* The AMT17 cruise benefited from a full suite of iron measurements. These included solid phase extraction of iron binding ligands at various stations (Edward Mawji and Martha Gledhill), dissolved iron measurements for the uptake and nitrogen fixation incubations as well as underway and cast mapping for redox and size fractionated iron species.

Scientific Reports:

Optics

GERALD MOORE
Plymouth Marine Laboratory, UK

Report to be submitted.

Bio-optics and remote sensing

BRUCE BOWLER
Bigelow Laboratory for Ocean Science, USA

Cruise Objectives

1. Collection of Niskin samples from 6-8 depths at pre-dawn and noon stations as well as underway (approximately every 3-6 hours) surface samples for analysis of particulate inorganic carbon (PIC), coccolith enumeration and biogenic silica concentration (BSi). The purpose of these samples was to provide an assessment of the inorganic and organic particles in surface water, along with indices of community composition.
2. Operation of an along-track flow-through system from the ship's non-toxic seawater system to characterise the hydrographic and bio-optical nature of the water.
3. Water-leaving radiance measurements in the visible and near infra red taken from the bow of the ship, for characterizing the particulate content of the seawater, and comparison to NASA's SeaWiFS and MODIS ocean colour satellites.

Methods

Particulate Inorganic Carbon: A 1 litre sample of seawater was taken from between 6-8 depths and was vacuum filtered onto 0.45 μm polycarbonate filters. The filters were rinsed with potassium tetraborate buffer and stored in centrifuge tubes at room temperature. Upon returning to National Oceanography Centre the samples will be analysed using an Inductively-Coupled Plasma Atomic Emission Spectrometer (ICPAES).

Coccolithophore composition (light microscopy): Microscope enumeration of coccolithophores and coccoliths was done by filtering a 100-500 ml water sample through a Millipore HA filter, rinsed with borate buffer, and frozen in a petri dish until counted (Haidar and Thierstein, 2001; Haidar *et al*., 2000). Back in the laboratory, the filter will be placed on a glass microscope slide and 60°C Canada Balsam placed on top of the filter, followed by a cover slip. The clarified filter will be examined with an Olympus BH2 microscope equipped with polarization optics. Birefringent coccoliths and plated coccolithophores will then be counted. For statistical reasons, 200 coccoliths or cells will be counted from each sample, when available.

Biogenic silica (BSi): A 1 litre sub-sample of seawater was taken for the analysis of BSi from 6-8 sampling depths. These depths always included the six light regime depths and for dawn casts one or two additional sub-euphotic depths were added, particularly if the water column was clear. The sample was vacuum-filtered onto 47 mm 0.4 μm polycarbonate filters. These were then stored in small petri dishes at -20°C for analysis back at National Oceanography Centre (NOC). At the NOC, the BSi will be dissolved with 2.5 ml sodium hydroxide. This solution will be neutralised with 0.1 mol l^{-1} hydrochloric acid, and concentrations will be determined using a flow autoanalyser.

Flow-through bio-optical system

This system operates semi-continuously with water from the ships non-toxic supply. Every 6-10 minutes it measures temperature, salinity, chlorophyll fluorescence, total backscattering at 532nm (bb_{tot}), acidified backscattering (bb_{acid}; backscattering of the seawater suspension after the pH has been lowered to dissolve calcium carbonate), acid labile backscattering (bb'; the difference between the bb_{tot} and bb_{acid}), absorption and attenuation at 9 visible wavelengths (made every 2 minutes), absorption and attenuation at 9 visible wavelengths after water was routed through 0.2 μm filters (during intervening 2 minute segments).

Above-Water Radiance Measurements

In order to check the PIC algorithm performance, free of atmospheric error, water-leaving radiance, sky radiance and downwelling irradiance were measured from the bow of the RRS Discovery using a Satlantic SeaWiFS Aircraft Simulator (MicroSAS). The same wavelengths used in the 2-band and 3-band calcite algorithms were measured with the MicroSAS. The system consists of a down-looking radiance sensor and a sky-viewing radiance sensor, both mounted on the bow. A downwelling irradiance sensor was mounted far from any potentially shading structures, on the tallest mast of the RRS Discovery. These data were then used to estimate normalized water-leaving radiance as a function of wavelength. The radiance detector was set to view the water at 40° from nadir as recommended by Mueller et al. (2003b). Sensors were rinsed regularly with Milli-Q water in order to remove salt deposits and any dust. The water radiance sensor was able to view over an azimuth range of ~180° across the ship's heading with no contamination from the ship's wake. The direction of the sensor was adjusted constantly to view the water 120° from the sun's azimuth, to minimize sun glint. This was done using a computer-based system that calculated the sun's azimuth angle relative to the ship's heading and elevation constantly.

The system used the ships gyro-compass to determine the heading of the ship. Pitch and roll sensors provided a means to filter out any measurements made from sub-optimal viewing geometries due to ship's motion. Depending on the ship's course, the computer controlled a stepping motor that turned the sensors to the proper viewing angle. Protocols for operation and calibration were performed according to Mueller (Mueller et al., 2003a; Mueller et al., 2003b; Mueller et al., 2003c). Before 1000h and after 1400h local time, data quality was poorer as the solar elevation decreased. Post-cruise, the 10Hz data will be filtered to remove as much residual white cap and glint as possible (we accept the lowest 5% of the data). When the ship was stopped on station, measurements will also be made. A plaque calibration was performed every several days (using a 2% spectralon plaque) to check for instrument drift.

Description of measurements made

During AMT17 underway samples were collected about every 3-6 hours for particulate inorganic carbon and biogenic silica, particulate organic carbon and nitrogen, chlorophyll a and (occasionally) pigments. Water-column sampling during AMT17 concentrated around collection of the main core measurements from 6 light depths from the predawn CTD cast (~0300 - 0430h local time). BSi, PIC and cell count measurements were made on 8 depths from the morning cast, typically to 300 m depth. The same measurements were made from a reduced set of depths from the late morning 'optics' cast (1100h local time).

Details of the sampling undertaken from the CTD profiles and from the underway pumped supply are given in Appendix 2.

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Micro- and nano-nutrients

MALCOLM WOODWARD AND KATIE CHAMBERLAIN
Plymouth Marine Laboratory

Objectives

To investigate the spatial and temporal variations of the micronutrients nitrate, nitrite, phosphate, silicate and ammonium, through the contrasting oceanic regions along the cruise track between the UK and Southern Africa.

This is the sixth and last cruise as part of the NERC AMT consortium project started in 2003 and the seventeenth AMT cruise since 1995. The track for this cruise was to transect through the north Atlantic gyre, south to the equator and then running south down 25° west which is the remaining fully sampled part of the AMT transect that has survived from AMT1.This brings the track through the south Atlantic Gyre before turning south easterly towards South Africa. The cruise ended in Port Elizabeth.

Methodology

The main micromolar nutrient analyser was a 5 channel Bran and Luebbe AAIII, segmented flow autoanalyser. The analytical chemical methodologies were based on the following:

Nitrate, (Brewer and Riley, 1965); nitrite, (Grasshoff, 1976); phosphate (Kirkwood, 1989); silicate (Kirkwood, 1989), and ammonium (Mantoura and Woodward, 1983) all of which were summarised in Woodward (1994).

For the entire cruise track we also used a nanomolar detection limit ammonium analytical system which is an adaptation from Jones, 1991, and this uses a fluorescent analysis technique following ammonia gas diffusion out of the samples. The ammonia passes across a hydrophobic teflon membrane, due to pH differential chemistry, into the fluorescent reagent.

The analyser worked very well at a detection limit of 3-4 nanomoles/l.

This cruise there was also deployed two three-channel nanomolar analyser for nitrate, nitrite and phosphate, combining the sensitive segmented flow colorimetric analytical techniques with a Liquid Waveguide Capillary Cell (LWCC).

Water samples were taken from the 24 x 20 litre CTD/Rosette system (SeaBird), these were sub sampled into acid clean 60 ml HDPE (nalgene) sample bottles and analysis for the nutrient samples was in most cases complete within 3 hours of sampling. Clean handling techniques were employed to avoid any contamination of the samples, particularly by ammonium. No samples were stored.

As part of the on-board experimentation there was collaborative work carried out with the 'Geider' group consisting of Mark Moore, Dave Suggett and Matt Mills who carried out 10 on-deck experiments for bioassay studies and also similar dose response experiments particularly focussed around the equatorial regions of the transect.

Samples were also analysed for Xi Pan's studies on DOP in the ocean. We analysed the samples again after they had been irradiated which gave the total PO_4 content and compared this with the previous inorganic PO_4 concentration from the time of the CTD sampling.

CTD samples analysed

There were 2 different daily operations for the CTD sampling

There was a pre-dawn productivity CTD cast at approximately 0400 local and then another main cast at 1100. The standard depth for the CTD was 300 m but on occasions sampling was made to 500 m and twice to over 5000 m.

Table 1. CTDs analysed for micromolar nitrate, nitrate, silicate, and phosphate and nanomolar ammonium, nitrate, nitrite and phosphate. CTDs 01, 03 and 04 were additionally analysed for micromolar ammonium.

CTD	Date
01	14/10/05
03	19/10/05
04	20/10/05
07	28/10/05
08	28/10/05
09	30/10/05
10	30/10/05
11	31/10/05
12	31/10/05
13	1/11/05
14	1/11/05
15	2/11/05
17	2/11/05
18	3/11/05
19	3/11/05
20	4/11/05
21	4/11/05
22	5/11/05
23	5/11/05

CTD	Date
24	6/11/05
25	6/11/05
26	7/11/05
27	7/11/05
28	7/11/05
29	8/11/05
30	8/11/05
31	8/11/05
32	9/11/05
33	9/11/05
34	10/11/05
35	10/11/05
36	11/11/05
37	12/11/05
38	13/11/05
39	13/11/05
40	14/11/05
41	14/11/05
42	15/11/05

CTD	Date
43	15/11/05
44	16/11/05
46	16/11/05
47	17/11/05
48	17/11/05
49	18/11/05
50	1911/05
51	20/11/05
52	20/11/05
53	21/11/05
54	21/11/05
55	22/11/05
56	22/11/05
57	23/11/05
58	23/11/05
59	24/11/05
60	24/11/05
61	24/11/05
62	25/11/05

Other analyses

3 sets of analyses were carried out for Xi Pan and the phosphate analysis.

10 bioassay and dose response experiments over 3 day periods were carried out during the cruise.

Preliminary results

Preliminary data work up has been carried out from the autoanalyser micromolar system. This has been plotted using Ocean Data View (thanks to Ed Mawji) and the preliminary results are shown here. These show clearly the two main oceanic gyres with deplete nutrient concentrations down to 150 m in places and it also highlights the increase of nutrients towards the surface in the equatorial region of the transect.

The good operation of the waveguide analyser allowed for the detailed CTD profiles to investigate the nutracline and how sharp it was at the thermocline in its increase from the surface deplete waters above the thermocline.

Post cruise

There are no samples stored or to be analysed. All the data will be worked up back at PML. The intention is to complete the data and submit to BODC before the end of January 2006. Results will be presented at the AMT meeting in February.

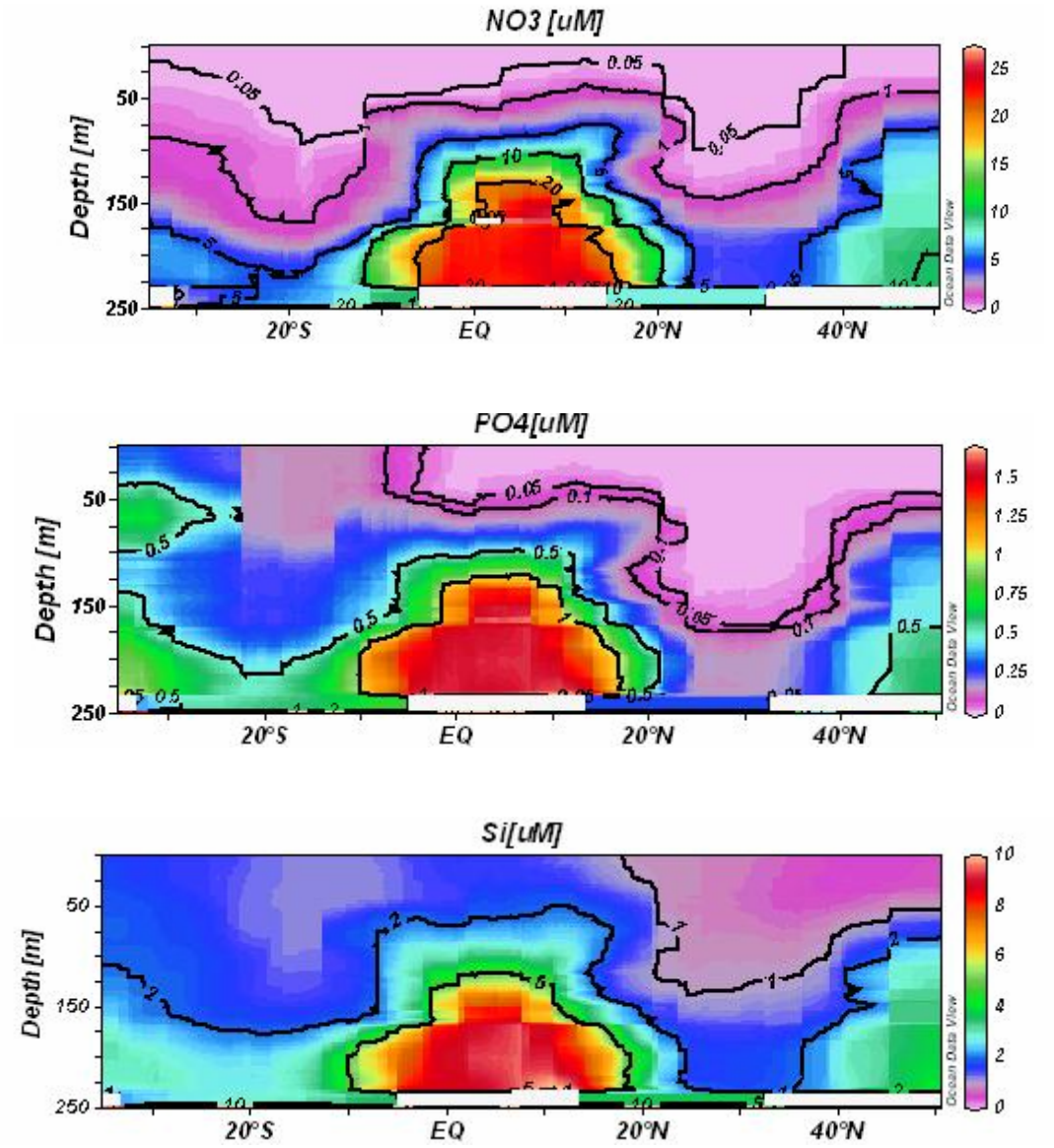

Figure 1. Preliminary Ocean Data View plots of nitrate, phosphate and silicate.

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Biological sampling

ANNA HICKMAN AND PATRICK HOLLIGAN
National Oceanography Centre, Southampton

The types and numbers of biological samples collected during AMT17 are summarised in Table 1. Additional sampling for microzooplankton (Lugols samples) and for autotrophic and heterotrophic picoplankton (flow cytometry samples) are described in other reports.

Total chlorophyll *a*: Water samples (300-500 ml) from CTD bottles and the underway (UW) surface water supply were filtered on 25 mm GFF filters or, for the >2 µm and >0.2 µm size fractions, on 25 mm polycarbonate filters. All filters were extracted in 90% acetone for 24 h, and total chlorophyll *a* measured with a TD-700 Turner Designs fluorometer following the procedure of Welschmeyer (1994) which minimises interference by chlorophyll *b*. The fluorometer was calibrated with dilutions of a solution of pure chlorophyll *a* (Sigma, UK) in 90% acetone, the concentration of which was determined spectrophotometrically after the cruise.

The chlorophyll determinations for the CTD water bottle samples were used to calibrate the two fluorometers used for water column profiles (Fig. 1). The underway chlorophyll measurements are summarised in Figure 2 which shows that the lowest concentrations (~0.035 mg m^{-3}) were in the S gyre.

HPLC pigments: Water samples (2-4 l) from CTD bottles were filtered on 25 mm GFF filters and stored at -80^{o}C for analysis by HPLC, using the methods of Barlow *et al.* (1997a;b) at NOCS.

POC/N and Particle Light Absorption (PABS) samples: Water samples (2-4 l) from CTD bottles were filtered on 25 mm GFF filters (precombusted at 400°C for POC/N samples) and stored at -80°C. The POC/N samples will be analysed at PML. The PABS samples collected from surface water on the morning Optics CTD casts were analysed on the ship by Gerald Moore. The remaining PABS samples will be analysed at the University of Essex by David Suggett following the methods of Tassan and Ferrari (1995).

Scanning Electron Microscope (SEM) samples: Water samples (2 l) from the surface layer and the DCM were filtered through 0.4µm polycarbonate filters supported by a 20 µm backing filter, under low vacuum (<200 bar). The filters were dried and stored at room temperature for coccolithophore species identification and counts by SEM at NOCS.

Phytoplankton and zooplankton samples: Water samples (100-200 ml) from surface water (55% light level) and the DCM (1% light level) were preserved with 4% buffered formalin for light microscope counts of phytoplankton.

Zooplankton samples were collected at 30 stations with a 0.5 m diameter 50 µm-mesh net hauled vertically from a depth of 200 m (or less where the DCM was shallow) to the surface. At 6 stations a second haul was made from a depth of 100 m (or less) in order to obtain some information about the vertical distribution of species/taxa. All samples were preserved with 4% buffered formalin, and will be examined at NOCS with particular attention to the foraminifera.

DNA/RNA samples: Triplicate water samples (2 l) were filtered through 2 mm GFF filters which were stored at -80°C. The samples will be analysed at NOCS by Dr Debora Iglesias-Rodriguez.

Virus samples: Water samples (5 ml) were placed in stoppered tubes and stored at 4°C. The samples will be analysed by Ellie Harrison at PML.

Table 1. Summary of biological samples

Total chlorophyll *a*	**Total: 660**
Predawn CTD	6 light depths + intermediate depths + size fraction for 2 depths
Midday CTD	6 light depths
Underway	3 hour intervals between stations
HPLC	**Total: 270**
Predawn CTD	6 light depths + duplicates for 2 depths
Midday CTD	Surface
POC/N	**Total: 340**
Predawn CTD	6 light depths
Underway	3 hour intervals between stations
PABS	**Total: 75**
Predawn CTD	2 light depths (55% and 1%)
Midday CTD	Surface
SEM	**Total: 75**
Predawn CTD	2 light depths (55% and 1%) + occasional deep samples
Phytoplankton	**Total: 70**
Predawn CTD	2 light depths (55% and 1%)
Zooplankton	**Total: 36**
Nets	36 samples from 30 stations
DNA/RNA	**Total: 60**
Predawn CTD	2 light depths (55% and 1%) in triplicate
Viruses	**Total: 100**
Predawn CTD	6 light depths

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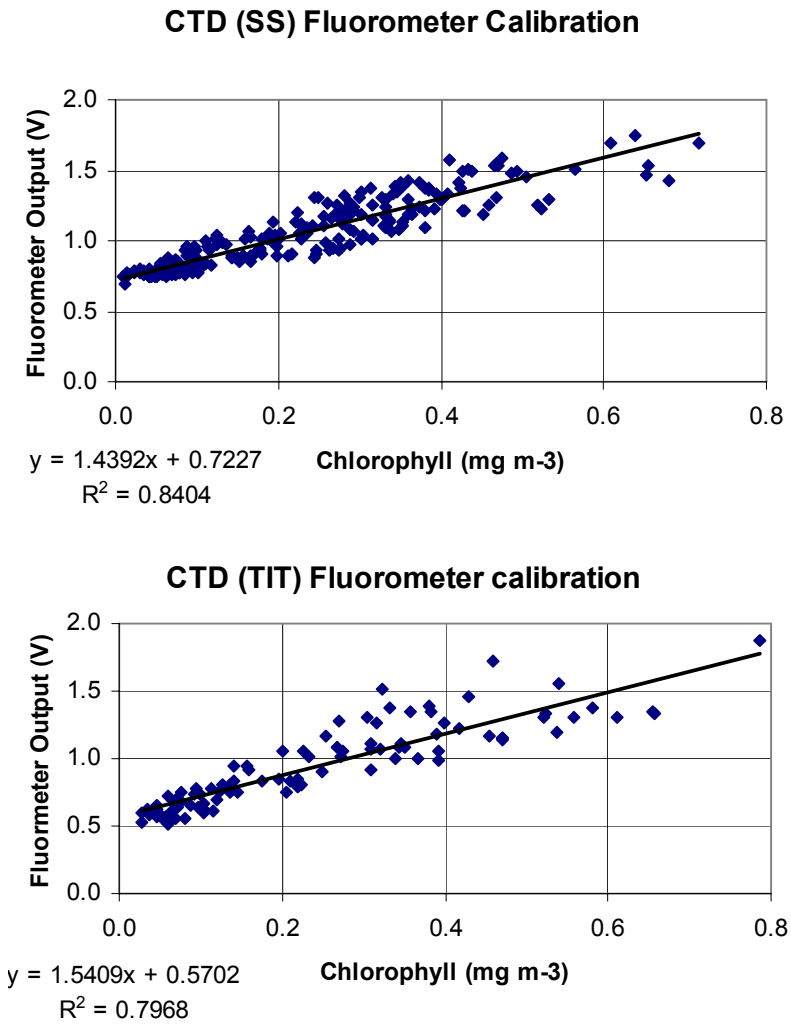

Figure 1. Calibration data for the fluorometers on the stainless steel (SS) and titanium (TIT) CTD frames. The fluorescence values were converted to chlorophyll units, and the data from the two fluorometers combined for constructing the chlorophyll section shown in Figure 6c of the main report. The greater scatter in the TIT fluorometer data can probably be attributed to daylight quenching as this fluorometer was used for the midday optics stations.

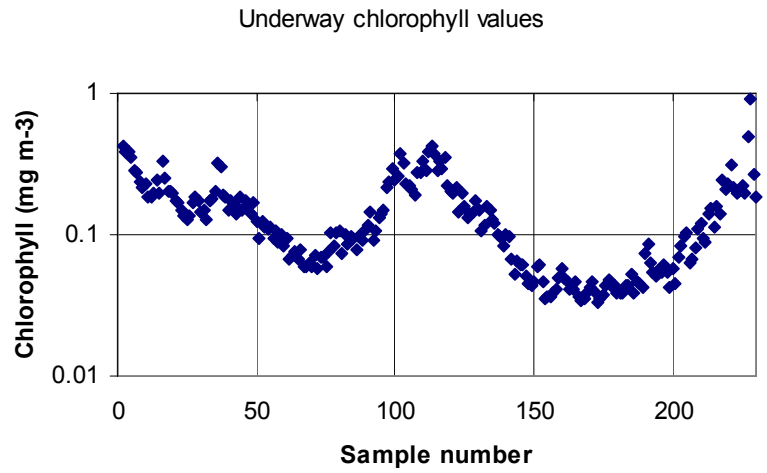

Figure 2. Discrete measurements of surface chlorophyll made from water samples taken from the underway supply. Samples 95-125 are from the equatorial region with earlier ones from the N hemisphere and later ones from the S hemisphere. Note that chlorophyll values are shown on a logarithmic scale.

Microzooplankton sampling

ELAINE FILEMAN AND NICK POPE
Plymouth Marine Laboratory, UK

The aim of this work is to assess the role and diversity of microzooplankton along the AMT and place them in context with other plankton in the oceanic food web. Microzooplankton play an important biogeochemical role within the microbial loop, a subset of the classical food web, that recycles carbon and other elements via excretion, respiration, and the production of submicron faecal particles. Through these processes, carbon and nutrients are retained in surface waters. In contrast, nutrients are lost from surface waters to the deep ocean by mesozooplankton that actively migrate and passively produce large dense faeces. Thus, understanding the relative influence of microzooplankton is essential if we hope to estimate the return of biogenic carbon to the atmosphere and the loss of carbon to the deep ocean. Furthermore, the microzooplankton are a diverse group, occupying several trophic levels, with species-specific behaviours. This AMT study provides an ideal opportunity to investigate latitudinal diversity within the microzooplankton and the factors which may influence this.

Microzooplankton biomass studies

Water samples were collected from 6 depths (representing 97%, 55%, 33%, 14% 1.0% and 0.1% light levels) within the top 300 m of the water column from each of the 27 pre-dawn CTD casts. Samples were treated as follows:

- 500-1000 ml water samples were fixed in 2% acid Lugols solution. These samples will be analysed at PML using inverted microscopy and image analysis for the determination of total microzooplankton abundance, biomass and species composition.
- 100 ml water samples were fixed in 0.5% glutaraldehyde, dual-stained with DAPI and proflavine and filtered onto 0.8 micron black polycarbonate filters. The filters were mounted onto microscope slides and frozen on board *Discovery*. Heterotrophic nanoflagellate abundance and biomass will be determined from these samples by inverted fluorescence microscopy and image analysis at PML.

Dynamics of microbial communities

ISABELLE MARY AND MIKE ZUBKOV
National Oceanography Centre, Southampton, UK

The aim

To compare abundance and metabolic activities of planktonic microorganisms along the trophic gradient in the Atlantic Ocean.

Objectives

1. To determine vertical distribution of picoplankton in the top 300 m.
2. To compare the turnover rates of amino acids and inorganic phosphorus; to assess their diurnal variability in oligotrophic waters.
3. To collect samples for analyses of bacterioplankton community composition using fluorescence *in situ* hybridisation and other molecular methods.

Methods

Water samples were collected and analysed live and preserved for determination of microbial concentration, biomass and composition. Seawater samples were collected in HCl washed 50 ml polypropylene tubes from all 61 stations: predawn, late morning (11:00 local time) and dusk opportunity CTD casts. Thermos flasks were used for collecting large volumes (1 l) of water required for rate measurements and tracer experiments. Live samples were stored in a refrigerator and analysed by flow cytometry (FACSort instrument, Becton Dickinson) within 1-2 hours of collection. *Prochlorococcus* spp., *Synechococcus* spp. cyanobacteria and picoeukaryotic algae were characterised and enumerated based on their light scattering and autofluorescence properties. Microorganisms preserved with paraformaldehyde (1% final) were stained with SYBR Green I nucleic acid dye and enumerated by flow cytometry. In addition to the analysis carried onboard, samples were fixed and frozen for flow cytometry on return to Southampton to determine the effects of freezing and fixation on picoplankton numbers. Samples were also collected for flow sorting as well as molecular identification of microorganisms using fluorescence *in situ* hybridisation (FISH). Microbial production and the compound turnover rates were determined on board by incubating samples with isotopically labelled precursor molecules: ^{35}S-methionine, ^{3}H-leucine, ^{3}H-glucose, ^{3}H-glucosamine and ^{33}P-phosphate.

Detailed analysis of the collected data will be done back in the UK.

Regulation of microbial communities by nutrient availability, temperature and microzooplankton grazing

MICHELLE HALE AND RICHARD RIVKIN
Memorial University of Newfoundland, Canada

Background

The regulation of the growth of marine heterotrophic bacteria is ecologically and biogeochemically important to the cycling of energy and materials in the ocean. The factors that control the growth and loss rates of bacterioplankton can, and do, substantially differ in different marine environments (Ducklow and Carlson, 1992; Ducklow, 2000). Bacterial growth rates may be limited by dissolved organic matter quality or quantity (Carlson and Ducklow, 1996; Carlson *et al.*, 1994; Hutchins *et al.*, 2001; Kirchman, 1990; Pakulski *et al.*, 1996), inorganic nutrients, including iron (Rivkin and Anderson, 1997; Tortell *et al*., 1996; Kirchman, 2000), or temperature (Weibe *et al.*, 1993; Kirchman and Rich, 1997; Rivkin *et al.*, 1996). In contrast, changes in bacterial stocks (i.e. bacterial production) are the balance of concurrent growth and loss processes, where the latter includes grazing (Gasol *et al.,* 2002) and viral lysis (Wilhelm and Suttle, 1999; Suttle, 2005). Each of the above factors may exert an influence over bacterial growth, production and loss over different temporal and spatial scales.

Objectives

The objective of this study was to test the following two hypotheses:

> **Hypothesis 1:** In different biogeochemical provinces of the eastern Atlantic, different combinations of organic and inorganic nutrients will limit bacterial growth rates and control community structure, and that the largest effects will be in the South Atlantic gyre. Moreover, the spatial and seasonal change in the microbial dynamics and nutrient utilization patterns will reflect a succession in bacterial phylotypes.
>
> **Hypothesis 2:** Although grazing mortality will differ with season and among different biogeochemical provinces, the losses will be in close balance with nutrient- (but not temperature-) limited growth rates. Moreover, grazing losses will be a dominant factor in controlling bacterial community structure.

A further objective during AMT17 was to collaborate with Richard Geider's group to measure bacterial production rates during trace metal clean bioassay experiments, to assess the influence of iron on bacterial growth in the presence and absence of phytoplankton and grazers.

Methods

The experiments conducted during AMT17 provide a seasonal comparison to companion experiments conducted during AMT16.

Nutrient Amendment Experiments: To test Hypothesis 1 during AMT17, the effects of temperature and substrate availability on bacterial growth and community structure were assessed and partitioned by conducting nutrient amendment experiments at 13 stations in different biogeochemical provinces in the temperate and tropical eastern Atlantic Ocean. Experiments were conducted using water collected before sunrise at the 55% light depth. Modified seawater (MSW) dilution cultures were made with 1 part 1.0 µm filtered seawater to 4 parts 0.2 µm filtered seawater (Rivkin and Anderson, 1997), and incubated in 500 ml polycarbonate bottles in the dark and at ambient temperature. Triplicate MSW cultures were either unamended (i.e. control) or amended with additions of organic carbon and nitrogen (glucose and glutamic acid), and inorganic nitrogen (NH_4Cl) and phosphorus (Na_2HPO_4), each to a final concentration of 10 µm, in a full factorial matrix. Samples were collected at 24 hours and 48 hours and will be analysed by flow cytometry (FCM), using standard protocols (Marie *et al*., 1999; Li and Dickie, 2001), for heterotrophic bacterial abundance, including quantifying the abundance of cells with high and low DNA content (Zubkov

et al., 2004). Heterotrophic bacterial counts will be confirmed by Acridine Orange Direct Counts (AODC; Hobbie *et al*., 1977). Bacterial cell volume will be determined by image analysis of Acridine Orange (AO) stained cells using an Image-Pro Plus image analysis system (Loferer-Krößbacher *et al*., 1998) and bacterial community composition will be determined by Fluorescence *In Situ* Hybridisation (FISH; Glockner *et al*., 1996; Fuchs *et al*., 2000; Pernthaler *et al*., 2001), using oligonucleotide probes designed to identify Bacteria and Archaea, as well as probes specific for Cytophaga-Flavobacterium, and the α-, β- and γ-subclasses of the Proteobacteria clade. In each replicate bottle, the growth rate (μ) for heterotrophic bacteria and for each phylotype will be determined from the time-dependent change in cell abundance for the linear portion of the growth curve.

Microzooplankton grazing experiments: To test Hypothesis 2, during AMT17 microzooplankton bacterivory and herbivory was determined using a modified dilution assay (Landry and Hassett, 1982; Rivkin *et al*., 1999). Seawater was collected at the same stations/depths as described above for Hypothesis 1, filtered through a 202 μm Nitex mesh to remove larger grazers, and diluted with particle-free filtrate prepared by gravity filtration though a 0.2 μm Gelman cartridge filter to the following target dilutions (< 202 μm: < 0.2 μm filtered water): 1.0, 0.9, 0.75, 0.5, 0.4, 0.3, 0.2 and 0.1. Samples were incubated in 500- ml polycarbonate bottles, in on-deck incubators at ambient temperatures (± 0.5°C) and ~55% of incident irradiance, for 48 hours. Abundances of bacteria as well as pico- and nanophytoplankton, will be determined by flow cytometry as described above. The apparent growth rate of each group at each of the eight dilutions will be computed from the time-dependent changes in abundance or concentration. Rates of grazing mortality will be determined from the linear regression of apparent growth rate against dilution, with the intercept of the line providing an estimate of growth rate and the slope of the line providing an estimate of grazing mortality (Rivkin *et al*., 1999).

Table 1. Study sites for nutrient amendment and microzooplankton grazing experiments.

Target region	Date	Time (GMT)	CTD #	Latitude	Longitude	55% light depth (m)
Temperate North Atlantic	19 Oct	04:50	03	46º23'N	17 º 44'W	16
Temperate North Atlantic	28 Oct	06.59	07	35 º 92'N	29 º 13'W	13
Northern Gyre	31 Oct	06:50	11	29º 53'N	36º 27'W	14
Northern Gyre	2 Nov	06:59	15	23 º 96'N	36º 78'W	16
Northern Gyre	4 Nov	06:54	20	18º 38'N	33º 92'W	17
Equatorial Upwelling	6 Nov	05.47	24	12º 07'N	30º 80'W	4
Equatorial Upwelling	9 Nov	05:44	32	03º 48'N	26º 66'W	10
Equatorial Upwelling	11 Nov	05.39	36	-02º 89'S	25º 00'W	11
Southern Gyre	13 Nov	05:48	38	-11º 00'S	25º 00'W	19
Southern Gyre	16 Nov	06:00	44	-21º 13'S	22º 44'W	19
Southern Gyre	17 Nov	05:43	47	-22º 16'S	20º 16'W	20
Temperate South Atlantic	20 Nov	03:40	53	-28º 85'S	04º 69'W	18
Temperate South Atlantic	22 Nov	03.40	55	-30º 67'S	00º 30'W	9

Bacterial Production during Bioassay Experiments (in collaboration with Richard Geider *et al.*)

Full details of water collection, trace metal clean techniques, nutrient additions and incubation conditions for the 6 bioassay experiments are provided in the AMT17 cruise report prepared by the Geider group (Moore *et al*., this volume). Bacterial production measurements were made on water from 2 sets of experiments: (1) whole water (i.e. phytoplankton and grazers present); and (2) modified seawater (i.e. phytoplankton and grazers removed, see above) bioassays. Water from triplicate bottles were collected from the unamended control at T = 0 hours and from the following treatments at T = 48 hours:

- Control (unamended)
- +DOC (10 μM glucose)
- +N (1 μM ammonium + 1 μM nitrate)
- +P (0.2 μM phosphate)
- +Fe (2 nm Fe in dilute HCl)
- +N+P
- +DOC+N+P+Fe

Bacterial production was estimated from the incorporation rate of [^{14}C]-leucine (final concentration = 10 nm) (Chin-Leo and Kirchman, 1988), during incubation of 10 ml water samples at ambient water temperatures (±1°C), in the dark for 4-6 hours. Particulate matter was collected on 0.2-μm Nucleopore filters and serially rinsed 2 times with filtered sea water (FSW), 3 times with 3 ml of ice-cold 5% trichloroacetic acid (TCA), which stopped the incubations, and 1 time with FSW. This processing typically took < 2 minutes. Filters were immediately placed in vials with and frozen with 1 ml 5% TCA, until extraction in 5 ml of hot (95°C) TCA for 1 hours. The insoluble residue will be collected onto a 0.2-μm membrane filter (Kirchman and Ducklow, 1993; Rivkin and Anderson, 1997), and immediately placed into 7 ml liquid scintillation vials containing scintillation cocktail and counted. Bacterial production will be calculated assuming the standard conversion factor of 3 kg C mol^{-1} [^{14}C]-leucine incorporated (Simon and Azam, 1989).

To assess the response of bacteria to nutrient additions, the specific growth rate (μ) of bacteria in each treatment will be calculated assuming exponential growth of bacteria during the bacterial production incubations:

$$\mu = \log_e[(BP_{\Delta t} + BB)/BB]/\Delta t \qquad (2),$$

where BB is bacterial biomass (μg C l^{-1}), computed from bacterial abundance (determined by flow cytometry) and cell biomass (from image analysis); $BP_{\Delta t}$ is bacterial production obtained during the incubation; and Δt is the incubation time (Peters, 2002).

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Community production

NIKI GIST
Plymouth Marine Laboratory

Objectives

AMT hypotheses:

- To determine the depth and latitudinal distribution of the balance of gross production (P) and respiration (R) and to relate this to community structure and nutrient supply (hypothesis 1).
- To examine the balance of gross production and respiration within the Northern Atlantic gyre, and to relate any changes in the P:R ratio to the transport of organic nutrients into the gyre (hypothesis 5).
- To compare the P:R ratio in the Northern and Southern Atlantic gyres and relate this to atmospheric and hydrographic derived nutrient supply and to community structure (hypothesis 3).

Other work:

- To measure dissolved oxygen concentrations in order to calibrate the oxygen sensors on the CTDs.
- To carry out inter-calibration of the second Winkler system, used to calibrate the underway oxygen optode.

Background

The balance between plankton production and respiration influences the proportion of carbon exported to the deep ocean and the amount returned to the atmosphere as carbon dioxide. Understanding this balance is crucial to our understanding of earth system carbon cycling.

Net heterotrophy (R>P) has been observed in unproductive regions, which has serious implications, since it implies that surface biota could potentially act as a source of CO_2 to the atmosphere. Results from previous AMT cruises (Serrett *et al*., 2002) corroborated other research (Duarte *et al*., 2001) that suggests the North Atlantic Subtropical gyre (NAST) is net heterotrophic. We must establish whether such imbalances are short-term, or whether they are characteristic of large areas of the ocean. However, there is currently a paucity of open ocean P:R measurements and a bias in sampling towards regions and times of high production.

P:R has been measured during all six of the AMT cruises from the current phase (AMT12-17). During this series of 6 transects, we have sampled the South Atlantic Gyre, where P:R measurements are sparse, and have sampled further west into the North Atlantic Gyre than any previously published P:R research (AMT12, 14, 16 and 17). Prior to AMT17, however, these unique P:R measurements from the west of the northern gyre were confined to the boreal spring/summer cruises. The data from this cruise is the therefore the first set of P:R data from the region that was sampled during boreal autumn.

The data collected during AMT 12-17 will help to further our understanding of the factors that affect the spatial and temporal variability of P:R in the ocean.

Samples collected

Depth and latitudinal distribution of plankton production and respiration: Profiles of GP/DCR/NCP samples from up to 5 depths were collected and analysed daily (28 stations).

In situ oxygen for the calibration of the CTD oxygen sensors: Samples from up to 12 depths were collected from the pre-dawn casts (stainless steel frame CTD, sensor number 0621, 28 stations, 213 calibration samples) and mid-morning casts (titanium frame CTD, sensor number 0862, 24 stations, 140 calibration samples).

Methods

Please see methods sections in cruise reports from AMT12 and 13.

Results summary

The complete calibration procedure for the SBE sensor will be undertaken at BODC, but preliminary calibrations carried out onboard show that standardised residuals are well within the limits advised by BODC (Fig. 1).

Productivity data will be processed on our return to the UK, but example depth profiles are shown in Figure 2.

It is expected that all O_2, Gross Production (GP), Net Community Production (NCP) and Dark Community Respiration (DCR) data will be deposited at BODC by March 2006.

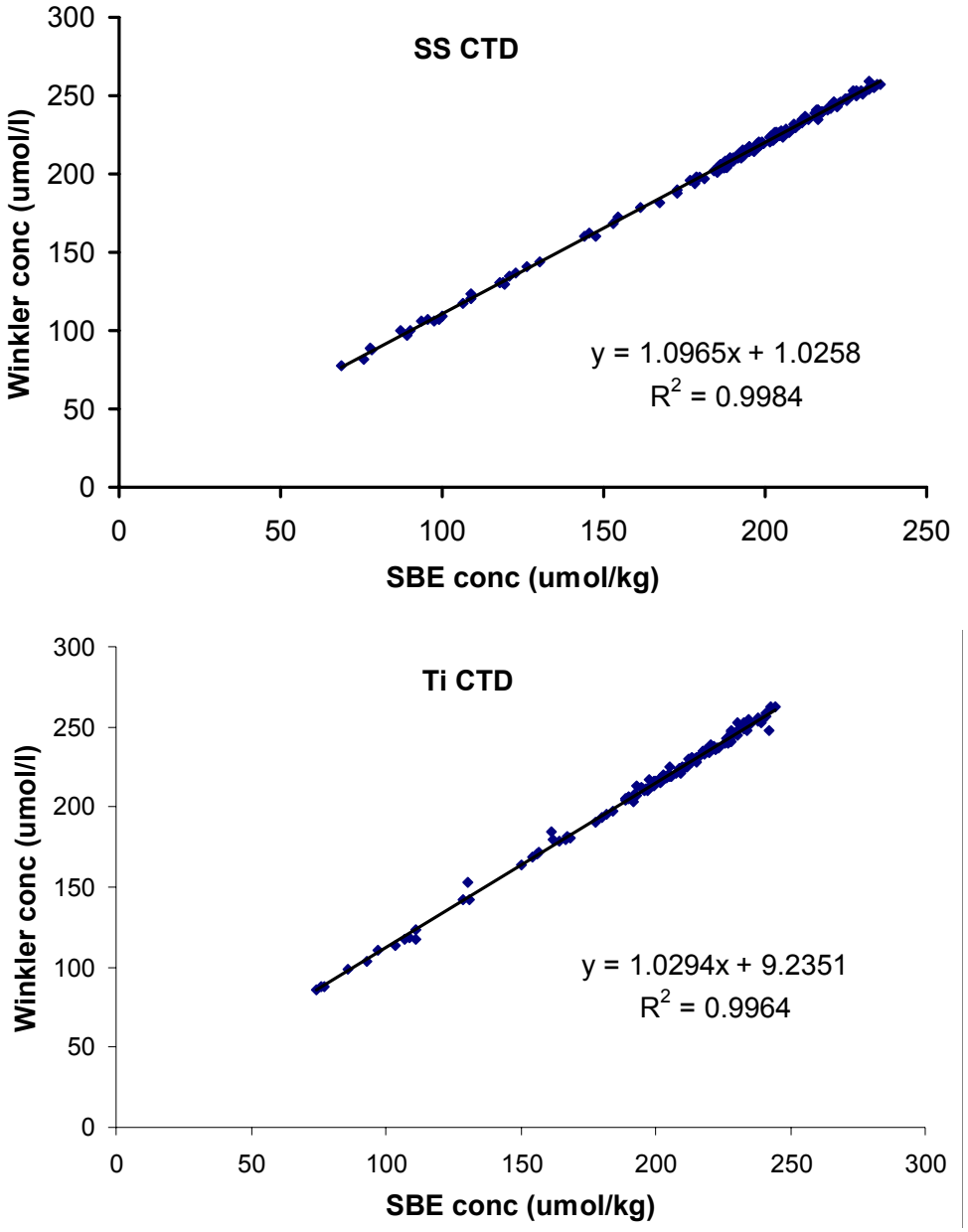
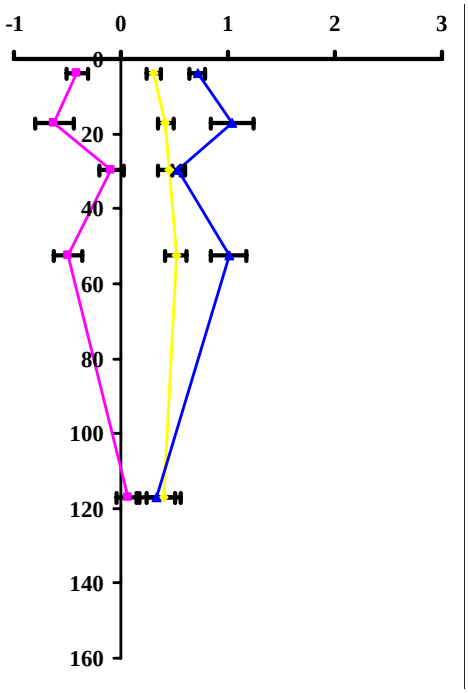
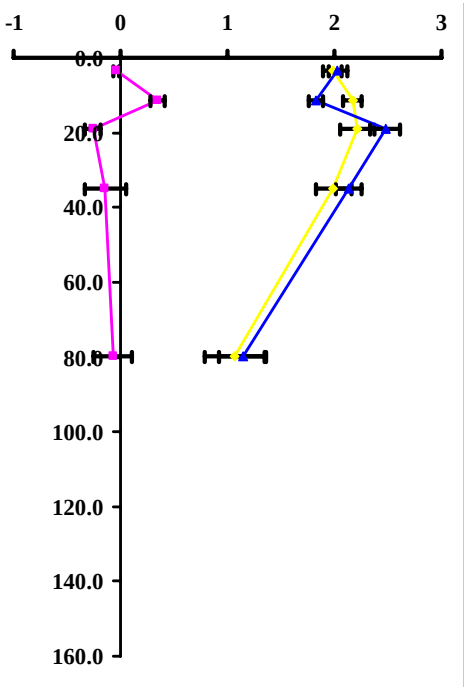


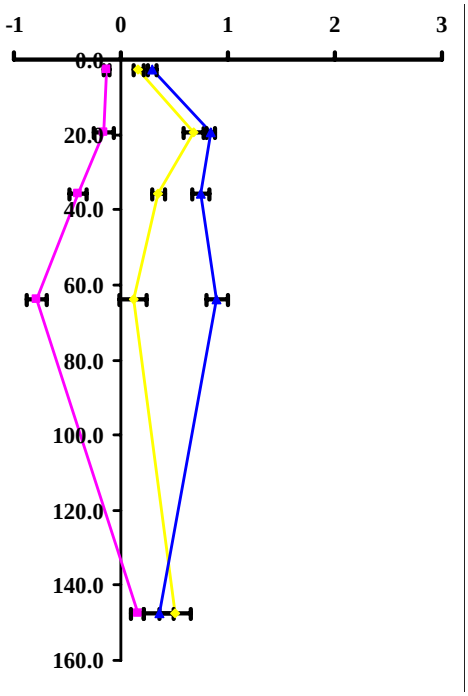
Figure 1. Linear regression of calibration samples taken from the stainless steel frame CTD casts (SS CTD) and titanium frame CTD casts (Ti CTD).



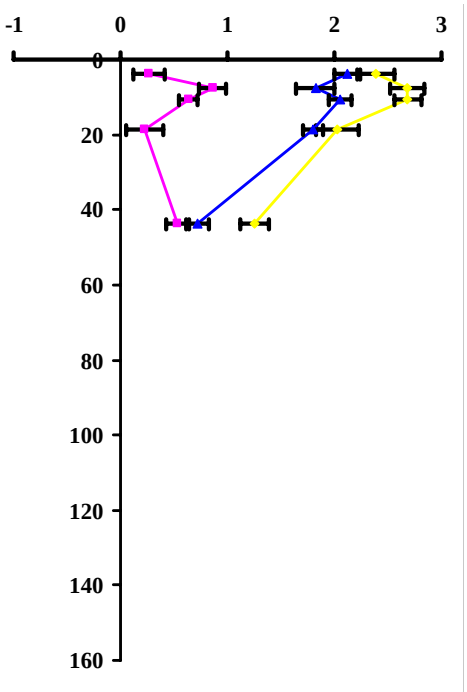
a) CTD 13 (28°N, 39°W), the furthest pre-dawn station west within the northern Atlantic gyre.



b) CTD 36 (3°S, 25°W), within the equatorial region.



c) CTD 40 (14°S, 25°W), from the southern Atlantic gyre. This station was on the cruise track followed during the 6 AMT cruises of the current phase (AMT12-17).



d) CTD 59 (34°S, 9°E), the final pre-dawn station, sampled after leaving the southern gyre on the final leg towards South Africa.

Figure 2. Depth profiles showing rates of gross production (yellow), dark community respiration (blue) and net community production (pink) (in mmol O_2 m^{-3} day^{-1}). Error bars represent standard errors on replicate samples for each rate measurement (n=3-5).

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Net community production estimates from dissolved oxygen/argon ratios measured by membrane inlet mass spectrometry (MIMS) and gross productivity estimates from $^{17}O/^{16}O$ and $^{18}O/^{16}O$ isotope ratios of dissolved oxygen

JAN KAISER

Department of Geosciences, Princeton University, Washington Road, Princeton, NJ 08544-1003, USA

Rationale and objectives

The dissolved oxygen (O_2) concentration of seawater varies because of fundamental physical and biological processes. These include photosynthesis (*P*) and respiration (*R*), diffusive and bubble-mediated gas exchange, temperature and pressure changes, lateral mixing and vertical diffusion. In the absence of physical effects, dissolved O_2 constrains the difference between *P* and *R*, i.e., net community production (*N*). Thus, O_2 can be used as a geochemical tracer that reflects carbon fluxes integrated over characteristic response times. Warming and bubble injection lead to O_2 supersaturation, posing a challenge to this approach.

Craig and Hayward (1987) used oxygen/argon (O_2/Ar) ratios to separate O_2 supersaturations into a biological and a physical component. This method is based on the similar solubility characteristics of O_2 and Ar with respect to temperature and pressure changes as well as bubble injection. One can define an O_2/Ar supersaturation, ΔO_2/Ar, as:

$$\Delta O_2/\mathrm{Ar} = \frac{c(O_2)}{c(\mathrm{Ar})} \Big/ \frac{c_{\mathrm{sat}}(O_2)}{c_{\mathrm{sat}}(\mathrm{Ar})} - 1$$

ΔO_2/Ar essentially records the difference between photosynthetic O_2 production and respiration. c is the dissolved gas concentration (in mol m^{-3}) and c_{sat} is the saturation concentration. c_{sat} is a function of temperature, pressure and salinity. This method, in which discrete samples are collected at sea, stored, and analysed in the lab, has been widely used in subsequent work (Hendricks *et al.*, 2004; Luz and Barkan, 2000; Quay *et al.*, 1993; Spitzer and Jenkins, 1989).

We recently presented an advance of this method for continuous underway measurements of O_2/Ar by membrane-inlet mass spectrometry (MIMS) (Kaiser *et al*., 2005), extending earlier oceanographic MIMS applications (Kana *et al.*, 1994; Tortell, 2005). The measured ΔO_2/Ar values can be used in conjunction with suitable wind-speed gas-exchange parameterizations to calculate biologically induced air-sea O_2 fluxes and, where conditions are appropriate, *N*. The inferred *N* values represent rates integrated over the characteristic mixed layer gas exchange times (ratio of mixed layer thickness and piston velocity), typically between 2 and 4 weeks.

The O_2/Ar method has the advantage not to involve potential biases associated with incubating water samples in a bottle. The *N* estimates derived from the MIMS measurements will be compared with results from currently used bottle incubation techniques (see section on O_2 bottle incubations by Niki Gist and section on ^{14}C productivities by Tim Adey in the present Cruise Report). The data from the AMT17 cruise will be used to quantitatively study the autotrophic or heterotrophic nature of different marine ecosystems along a meridional transect of the Atlantic Ocean.

In addition to the underway measurements, discrete samples were taken for calibration purposes and to measure the $^{17}O/^{16}O$ and $^{18}O/^{16}O$ isotope ratio analysis of dissolved oxygen. Triple oxygen isotope measurements combined with O_2/Ar data can be used to estimate the ratio of net community production (*N*) to gross production (*P*) and the ratio of gas exchange to gross production. Again, in combination with suitable wind-speed gas-exchange parameterizations this can be used to estimate gross production over large regional scales at timescales of weeks to months. Results will be compared with in vitro ^{14}C and O_2 productivity measurements.

Methodology

See appendix 3 for a list of discrete samples taken from Niskin bottles and the underway system.

We used practically the same methodology as during the AMT16 cruise (RRS Discovery cruise D294), with minor improvements. A temperature artefact, which was discovered when using the Faraday cup detector of the quadrupole mass spectrometer, was avoided by using the more sensitive, but negligibly less precise Channeltron detector. A PCMCIA-to-serial adapter was replaced by a USB-to-serial adapter, because the PCMCIA adapter caused data dropouts and communication failures between mass spectrometer and logging computer. Finally, all water-bearing tubing was insulated to avoid condensation on cold surfaces and to further reduce ambient temperature influences. For reference purposes, we repeat the methodology as explained in the AMT16 cruise report in the following, with only slight modifications where appropriate.

Continuous measurements of dissolved N_2, O_2, Ar and CO_2 were made by MIMS on board RRS Discovery. The ship's underway sampling system was used to pump water through an exchange chamber with a tubular Teflon AF membrane (*Random Technologies*) mounted on the inside. The membrane was connected to the vacuum of a quadrupole mass spectrometer (*Pfeiffer Vacuum* Prisma). The intake of the underway sampling system is located at the bow of the ship at a nominal depth of 5 m. The water from the underway sampling system passed through an open bucket at several litres per minute to remove macroscopic bubbles and to avoid pressure bursts. A flow of about 75 ml/min was continuously pumped from the bucket through the membrane chamber, using a gear pump (*Micropump*). In order to reduce O_2/Ar variations due to temperature effects and water vapour pressure variations, the exchange chamber with the membrane was held at a constant temperature of 10 or 15ºC (5 to 14ºC below the sea surface temperature, to avoid temperature-induced supersaturations and subsequent bubble formation). The flight tube was in a thermally insulated box maintained initially at 50ºC, later at 75ºC.

In addition to the continuous underway MIMS measurements, we also analysed eight to twelve CTD samples each from casts #4, 7, 9, 11, 13, 15, 18, 24, 32,34, 38, 44, 49, 51, 55, 59, 60 (see below) in order to characterise the depth profile of the O_2/Ar ratio especially in regions, where the mixed layer depths were too shallow to allow a representative estimate of the trophic status of the euphotic zone from the surface O_2/Ar ratio. The results are compared with depth profiles of O_2-based productivity estimates from bottle incubations.

The O_2/Ar and N_2/Ar ratio measurements will be calibrated with discrete water samples taken from the same seawater outlet as used for the MIMS measurements (see Table 1). 200-300 cm^3 samples were drawn into pre-evacuated glass flasks poisoned with 7 mg $HgCl_2$ (Quay *et al*., 1993). These samples will be later analysed with an isotope ratio mass spectrometer (IRMS, *Thermo Finnigan*) for their dissolved O_2/Ar ratios and the oxygen triple isotope composition relative to air (Hendricks *et al*., 2004). Raw O_2/Ar ion current ratio measurements were made every 10 to 20 s and had a short-term stability of 0.05%.

O_2 concentrations were measured continuously with an optode (*Aanderaa* model 3830, serial no. 241), calibrated by automatic Winkler titration of discrete water samples with potentiometric or photometric endpoint detection. The photometric data were measured on the Winkler titration system of Niki Gist. The analytical precision (1 standard deviation) of the potentiometric analyser was 0.1 µmol kg^{-1}, that of the photometric analyser was 0.05 µmol kg^{-1}. Short-term (60 s) precision of the optode measurements was 0.03%. The accuracy of the Winkler measurements was established by a sample and standard intercomparison with the photometric Winkler system of Plymouth Marine Laboratory (see section by Niki Gist in this report) and Figure 1. Calibration of the optode was achieved by regression of the temperature-corrected optode readings against the Winkler results. Absolute Ar and N_2 supersaturations will be calculated from the absolute O_2 supersaturations measured by Winkler titration and the N_2/Ar and O_2/Ar ratios measured by MIMS.

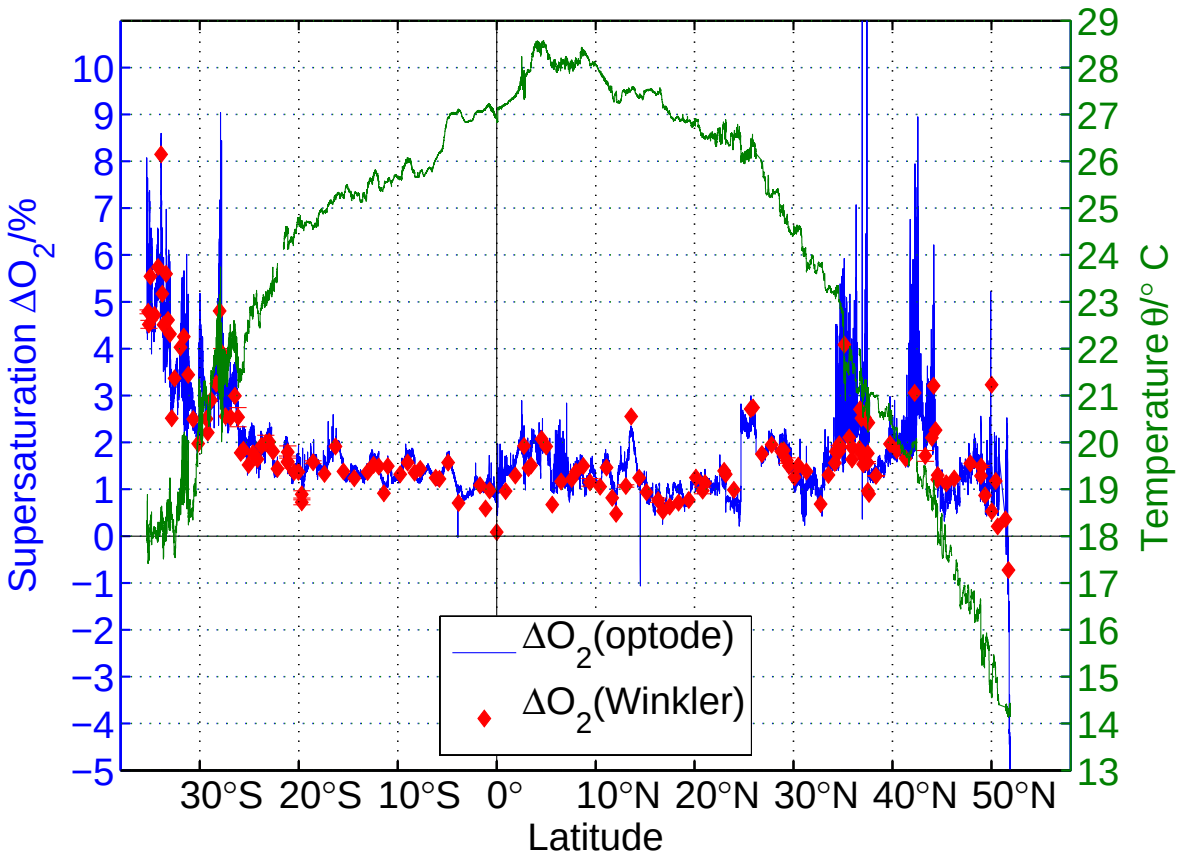

Figure 1. Meridional transect of continuous optode measurements of surface water O_2 supersaturation and sea surface temperatures measured by the "remote" sensor of the ship's thermosalinograph (between 16 October and 25 November 2005). The optode measurements have been calibrated by Winkler titration with potentiometric or photometric endpoint detection.

Results

Optode calibration and Winkler measurements: Accurate sea surface temperature and salinity measurements are required to calibrate the optode measurements. We therefore compared the data from the underway system (thermosalinograph) with results from near-surface Niskin bottles from the two daily CTD casts. For an initial data evaluation, we have assumed that the CTD measurements are accurate and corrected the underway salinities for their drift relative to the CTD data. Final results will be calculated once the underway data have been calibrated by discrete samples drawn from the underway system and analysed on the ship's Autosal system.

The mean difference between calibrated optode and Winkler measurements of the O_2 supersaturation (ΔO_2) was 0.0±0.2%. Dissolved O_2 was also measured in surface water samples from Niskin bottles in order to assess whether any gas losses occurred from the water pumped from the seawater intake to the laboratory due to warming and potential outgassing or O_2 loss to the pipe walls. The O_2 concentration in the CTD samples was on average 0.6±0.3% higher than for the underway samples at the same point of time. The difference decreased from 0.8% at the beginning of the cruise to 0.3% on day 314 and then stayed approximately constant. A similar decrease was observed for O_2/Ar ratio measurements of Niskin bottle samples (see below) and this is most likely due to biofouling and O_2 consumption in the ship's underway sampling system.

For the entire duration of the AMT17 cruise, O_2 concentrations from the clean seawater supply of the ship were measured by the *Aanderaa* optode, giving a data-set of more than 300,000 individual readings at 10 s resolution. The raw readings from the sensor proved to be stable throughout most of the cruise, however, the internal temperature sensor showed some intermittent behaviour during the middle part of the cruise. They were tentatively identified as being due to humidity problems of the

cable connection to the sensor. Moving the cable slightly higher and regreasing of the o-rings of the connection alleviated this problem. External thermistor measurements were used to correct the faulty temperature data. By calibrating the optode readings with the Winkler results, an accurate, high-resolution surface oxygen record was obtained with an estimated accuracy of 0.4 µmol/kg dissolved O_2 (see Figure 1 for an overview of the data versus latitude).

About 20% of the Winkler calibration data were measured on the potentiometric analyser of Princeton University, the remaining 80% on the photometric system of Plymouth Marine Laboratory (collaboration with Niki Gist), which proved to be a more efficient use of resources than running two Winkler titration systems simultaneously. Thiosulfate solutions were calibrated against three different sets of KIO_3 standards, prepared by Jan Kaiser, Niki Gist and a commercial standard obtained from Wako Chemicals. All three sets of standards agreed to within 0.1%. The use of automatic burette proved to give a far better reproducibility to dispense KIO_3 than pipettes. Some problems were uncovered, however, when the burettes were not flushed sufficiently long (with at least 130 ml of solution). Other problems were due to aged reagents. Figure 2 shows an intercomparison of samples analysed by the potentiometric and the photometric systems. The good agreement proves the success of the intercalibration.

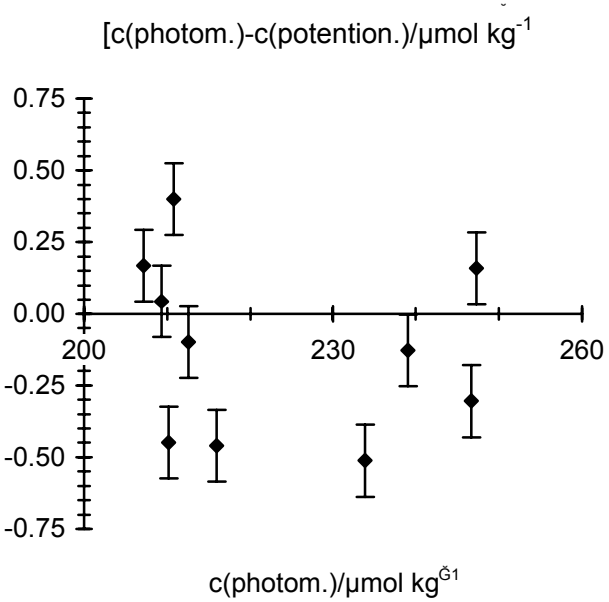

Figure 2. Comparison of Winkler oxygen data obtained by potentiometric (Jan Kaiser, Princeton University) and photometric (Niki Gist, Plymouth Marine Laboratory) end-point detection for a range of CTD and underway samples. The average difference between both methods is(–0.1±0.3) µmol kg^{-1}. The error bars correspond to the expected precision for the difference between both methods, based on their individual precisions of 0.1 µmol kg^{-1} and 0.05 µmol kg^{-1}.

Membrane inlet mass spectrometry

Membrane inlet mass spectrometry (MIMS) was used to analyze dissolved gases continuously, namely O_2, nitrogen (N_2), argon (Ar), and carbon dioxide (CO_2). The still very new instrument worked successfully throughout 95-98% of the cruise. The MIMS measurements are to be calibrated against a total of 146 discrete water samples taken by evacuated flasks. The gas in the headspace of these samples will be analysed for O_2/Ar ratios and the isotopic composition of O_2 on a sector-field isotope ratio mass spectrometer at Princeton University. During the entire of a cruise a direct online-calibration against water samples equilibrated with air was tried out and gave relatively stable results. However, the variability is still too high as to allow a reliable calibration of all the data and we will therefore resort again to the discrete samples as for previous cruises.

Oxygen/argon profiles from discrete CTD samples

Mixed layer depths were very shallow in the North Atlantic Gyre. Therefore, MIMS measurements were undertaken on discrete samples from CTD casts. The left panels of Figure 3 show the results and also a comparison to Winkler- and Winkler-calibrated sensor-based dissolved O_2 measurements. The O_2 supersaturation in the upper thermocline and mixed layer is always larger than the O_2/Ar supersaturation, indicating Ar supersaturations – possibly due to warming by infrared absorption. The right panels show the corresponding results from bottle incubations at the 97%, 55%, 33%, 14%, and 1% light levels (courtesy of Niki Gist).

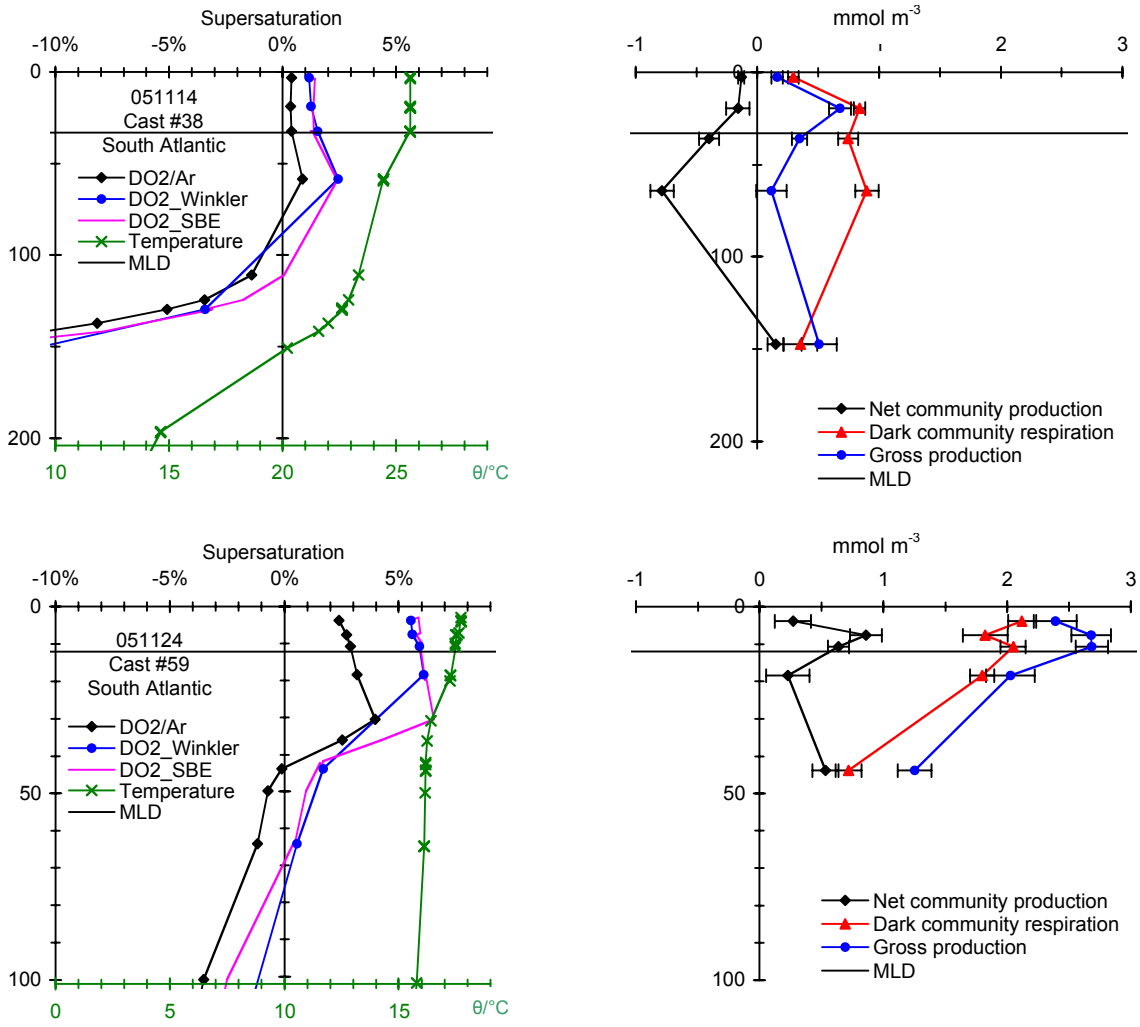

Figure 3. Comparison of biologically-induced oxygen supersaturation ($\Delta O_2/Ar$) and O_2-based productivity measurements from bottle incubations. Relative shape of $\Delta O_2/Ar$ values and NCP rates agree well in the thermocline, but show differences in the mixed layer due to disequilibrium effects. Interestingly, NCP is zero at positive $\Delta O_2/Ar$ values, possibly due to higher past than instantaneous production rates. Since $\Delta O_2/Ar$ integrates over timescales of physical transport, the instantaneous rates do not have to be in agreement with the $\Delta O_2/Ar$-based value.

Acknowledgements

I would like to thank crew, officers and UKORS engineers of RRS Discovery Cruise D299 (AMT17) for their great commitment and straightforward help. Many thanks also to the members of the scientific party, especially to Niki Gist for her spirit and tenacity and a great co-operation.

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Carbon fixation (photosynthesis, calcification)

TIM ADEY
National Oceanography Centre, Southampton, UK

Cruise objectives

1. Continued collection of primary production measurements
2. Basinscale measurements of surface calcification rates by coccolithophores

Sampling

Sampling during AMT17 concentrated around collection of size fractionated productivity (<2 µm and >2 µm) and calcification measurements from surface samples (55% of surface irradiance) at the pre-dawn CTD cast, with the addition of productivity and calcification profiles from 4 light depths (55, 33, 14, and 1% of surface irradiance) from three pre-dawn CTD casts. Light depths were selected assuming that the 1% of surface irradiance corresponded to the fluorescence or chlorophyll maximum.

Table 1. Stations (CTD cast number) sampled and measurement(s) made. Abbreviations used are $pPOC_{sf}$ (size fractionated photosynthesis), pPOC (photosynthesis), and pPIC (calcification). For further details see methods sections.

CTD No.	$pPOC_{sf}$	pPOC	pPIC
04	X	X	X
07	X	X	X
09	X	X	X
11	X	X	X
13	X	X	X
15	X	X	X
18	X	X	X
20	X	X	X
22	X	X	X
24	X	X	X
26	X	X	X
29	X	X	X
32	X	X	X

CTD No.	$pPOC_{sf}$	pPOC	pPIC
34	X	X	X
36	X	X	X
38	X	X	X
40	X	X	X
42	X	X	X
44		X**	X**
47	X	X	X
49	X	X	X
51		X**	X**
53	X	X	X
57	X	X	X
59		X**	X**
Stn X	X	X	X
Total	**32**	**30**	**30**

**Underway samples were collected from cast 44 for production, calcification and core measurements.

Methods

Calcification (*p*PIC), photosynthesis (*p*POC): Calcification and photosynthesis measurements were made following the methodology of Balch *et al*., (2001). Water samples (3 lights, 3 formalin killed) from the 55% surface irradiance light depth (three profiles also run from 55, 33, 14, and 1% surface irradiance light depths) were collected, spiked with ~100 mCi ^{14}C-labelled sodium bicarbonate ($NaH^{14}CO_3$) and incubated over a daylight period (dawn to dusk, typically 10-15 hours) in simulated *in-situ* incubators cooled with sea-surface water (chilled freshwater for the 1% samples) to *in-situ* temperatures +/-3^{o}C. The formalin killed sample was prepared by addition of 3-10 ml of filtered (<0.1 mm) neutrally buffered formalin to the sample. At the end of the incubations, samples were filtered onto 0.2 mm 25 mm diameter polycarbonate filters under gentle vacuum (<200 mbar) and placed in 18- ml pony vials. Filter cups, frits and forceps were thoroughly rinsed with fresh filtered (<0.7 mm)

seawater after filtration of each sample to remove any contamination from labelled dissolved inorganic carbon ($DI^{14}C$). A gas tight septum and bucket containing a GFA filter with 0.2 ml of 2-phenlethylamine (PEA) was attached to each of the 18 ml vials. Using a small gauge syringe, 1 ml of 1% phosphoric acid was injected past the bucket into the bottom of the vial and the samples were left for 24 hours to equilibrate: acidification of the polycarbonate filter causes the conversion of ^{14}C labelled inorganic carbon ($PI^{14}C$) to be released as $^{14}CO_2$ which is trapped by the PEA onto the GFA filter. After the samples have equilibrated, the septum's were removed, the bucket (with GFA) placed in a fresh pony vial and 5 ml of Ultima-Gold was added to vial containing the bucket and 15 ml of Ultima-Gold was added to the 18 ml vial. Samples were counted in the TriCarb 2100TR low activity liquid scintillation counter (LSC) onboard. The polycarbonate filter then gives a measurement of *p*POC, while the GFA filter gives a measure of *p*PIC. A comparison undertaken on the previous AMT cruise of organic carbon fixation rates from this method and the method used to measure only photosynthesis on earlier cruises showed good agreement (model II regression: $y=0.93 - 0.02$; $r^2=0.96$; $n=24$). The efficiency of capture of $^{14}CO_2$ by the PEA soaked GFA filter was checked by removing 200 ml of the formalin sample before addition of the formalin and treating it identically to a filter sample: addition of septum, bucket with GFA and phosphoric acid. The $^{14}CO_2$ caught on the GFA filter was compared with the estimated spike added to the formalin sample and showed generally 90-110% capture].

Size Fractionated Photosynthesis ($pPOC_{sf}$): Water samples (3 light, 3 dark) from the 55% surface irradiance light depth were collected, spiked with ~20 mCi C^{14}-labelled sodium bicarbonate ($NaH^{14}CO_3$) and incubated parallel to samples for calcification (see above). Samples were gravity filtered through 2 mm 25 mm diameter polycarbonate filters before being placed in 18 ml pony vials. 1 ml of 1% phosphoric acid was added to the vials and they were placed in a CO_2 trap inside a fume hood. After 24 hours samples were removed and 15 ml of Ultima-Gold liquid scintillation cocktail was added before activity was counted in a TriCarb 2100TR low activity liquid scintillation counter (LSC) onboard. Stock solutions were prepared daily with fresh filtered seawater and checked by addition of 100 ml of stock solution to 9.9 ml Carbosorb and LS counting of five 100 ml replicates from this mixture in 5 ml PermaFluor E+: coefficient of variance for replicate standards was <2% [AP].

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Distribution of dissolved iron species in the Atlantic Ocean

SIMON USSHER
University of Plymouth, UK.

Rationale

Iron is required by phytoplankton and bacteria for growth but the concentrations in seawater are low (sub nanomolar) due to its solubility. The biogeochemistry of iron is complicated by its low residence times in surface and deep waters and few dissolved iron data have been reported for the Atlantic Ocean. Hence there is paucity in our understanding of its seasonal and spatial distribution and this influences biological cycles.

Specific aims

1. Determine the concentration of labile dissolved Fe(II) and dissolved iron (dFe, <0.2 μm and <0.02 μm fractions) in underway surface water and CTD vertical profiles using Flow Injection Chemiluminescence (FI-CL).
2. Compare the data set to physical properties of different water masses (e.g. temperature, dissolved gases) in the AMT transect to gain insight into the physicochemical control of iron speciation in the Atlantic Ocean.
3. Compare other nutrient (Katie Chamberlain and Malcolm Woodward, PML), chlorophyll and primary production data with iron distributions and assess the significance of iron as a limiting nutrient in different regions covered over the transect.
4. Observe the regional effects of atmospheric flux on dFe concentrations in the surface waters of the transect (collaboration with Alex Baker, UEA) and calculate residence times for dissolved iron in remote surface waters.

Sampling Methodology: Underway Sampling

Protocol: Underway supply seawater was pumped using an all plastic diaphragm pump (Sandpiper II ™) from a trace metal clean towed "fish" (3-6 m depth). This was connected to the clean container by ½" i.d. polyethylene tubing. The tubing and pump system were initially washed with 5% HCl (ARISTAR, BDH) solution. The seawater flow was split via a Y-piece in the clean container allowing unfiltered seawater and filtered water to be collected underway. The samples were collected from an outlet mounted in the clean container under filtered air. The underway filter used was a Sartobran 300 cartridge (Sartorius, 0.2 μm pore size).

Samples: Samples of dissolved iron (<0.02 and <0.2 μm), unfiltered iron and labile iron(II) were collected at ~ 11 am and 11 pm daily from 24th May to 27th June 2005.

Sampling Methodology: CTD sampling

Protocol: Sampled from titanium frame using 10 l trace metal clean, acid washed, Ocean Test™ bottles. Bottles numbered 2, 4, 7, 11 and 16 were stored in clean container between casts and used exclusively for iron work. All handling was conducted under filtered air. Filtration was performed using PTFE membrane (0.2 μm pore size, 25 mm, Whatman syringe filters) and Anotop (0.02 μm pore size syringe, 25 mm). Both filters were connected in-line to an eight channel peristaltic pump (Gilson, Minipuls 3) allowing simultaneous processing of 6 samples.

Table 1. Samples for iron determination and speciation, dissolved iron (<0.2 µm), labile Fe(II) (<0.2 µm), dissolvable iron (unfiltered, weak HCl leach)

Date	Time (GMT)	CTD cast	Latitude	Longitude	Bottle no.	Depth (M)
18/10/05	12:40	2	48°56.574'N	16°28.438'W	2, 4, 7 11, 16, surf	300, 200, 150, 75, 35, surf
28/10/05	14:05	8	35°44.070'N	29°29.000'W	2, 4, 7 11, 16, surf	300, 200, 85, 75, 50, surf
30/10/05	13:06	10	30°50.962'N	33°06.791'W	2, 4, 7 11, 16, surf	300, 200, 120, 105, 55, surf
31/10/05	13:05	12	29°20.003'N	36°43.228'W	2, 4, 7 11, 16, surf	300, 200, 115, 108, 47
01/11/05	13:05	14	26°42.220'N	38°13.855'W	1, 2, 4, 7 11, 16, surf	500, 300, 200, 140, 125, 90, surf
02/11/05	13:26	17	23°08.591'N	36°20.965'W	1, 2, 4, 7 11, 16, surf	4813, 4000, 2750, 1500, 800, 500
0//11/05	13:07	19	20°44.654'N	35°07.142'W	2, 4, 7 11, 16, surf	300, 200, 133, 125, 45, surf
04/11/05	13:04	21	17°28.750'N	33°27.863'W	2, 4, 7 11, 16, surf	300, 200, 103, 95, 55
05/11/05	13:05	23	14°15.488'N	31°52.021'W	2, 4, 7 11, 16, surf	300, 200, 90, 77, 45
06/11/05	12:06	25	11°41.429'N	30°36.724'W	1, 2, 4, 7 11, 16, surf	500, 300, 200, 80, 45, 34, surf
07/11/05	12:01	27	08°36.691'N	29°07.211'W	2, 4, 7 11, 16, surf	300, 200, 62, 56, 24, surf
07/11/05	18:03	28	07°56.590'N	28°47.984'W	2, 4, 7 11, 16, surf	300, 200, 80, 66, 55, surf
08/11/05	13:27	30	05°27.445'N	27°36.359'W	2, 4, 7 11, 16, surf	300, 200, 80, 60, 51, surf
09/11/05	14:01	33	02°45.163'N	26°18.998'W	2, 4, 7 11, 16, surf	300, 200, 105, 90, 75, surf
10/11/05	12:19	35	00°00.048'N	25°00.230'W	2, 4, 7 11, 16, surf	300, 200, 81, 75, 50, surf
12/11/05	12:01	37	08°16.570'S	24°59.745'W	2, 4, 7 11, 16, surf	300, 200, 120, 104, 92, surf
13/11/05	14:05	39	11°55.380'S	24°59.926'W	2, 4, 7 11, 16, surf	300, 200, 125, 113, 49, surf
14/11/05	12:01	41	15°29.205'S	24°59.711'W	2, 4, 7 11, 16, surf	300, 207, 147, 138, 90, surf
15/11/05	12:05	43	19°40.908'S	25°00.210'W	2, 4, 7 11, 16, surf	300, 220, 190, 170, 130, surf
16/11/05	12:08	46	21°06.294'S	22°22.921'W	1, 2, 4, 7 11, 16, surf	5010,4500,3500,2500,1500,600
17/11/05	12:05	48	22°36.683'S	19°07.690'W	2, 4, 7 11, 16, surf	300, 200, 144, 134, 58, surf
19/11/05	11:06	50	26°08.407'S	11°03.119'W	2, 4, 7 11, 16, surf	300, 200, 134, 127, 80, surf
20/11/05	13:02	52	27°47.195'S	07°12.949'W	2, 4, 7 11, 16, surf	300, 200, 115, 97, 82, surf
21/11/05	10:00	54	29°19.181'S	03°34.729'W	2, 4, 7 11, 16, surf	300, 200, 155, 131, 80, surf
22/11/05	10:03	56	31°10.343'S	00°55.532'E	2, 4, 7 11, 16, surf	300, 200, 70, 64, 38, surf
23/11/05	11:31	58	33°01.290'S	05°53.435'E	2, 4, 7 11, 16, surf	300, 200, 62, 58, 38, surf
24/11/05	09:02	60	33°46.836'S	09°35.100'E	2, 4, 7 11, 16, surf	500, 300, 200, 75, 33, 20, surf

Instrumentation and Techniques

Fe determination: The FI-CL method used an automated flow injection analyser for Fe(II) determination, which provided control of 3 peristaltic pumps (Minipuls 3, Gilson), a 3-way, two-position solenoid valve (EW-01367-72, Cole-Parmer Instrument Co., Hanwell, UK) and a six port injection valve (C22, Valco Instruments Co., Houston, USA) whilst simultaneously powering and acquiring measurement data from a photon counting head (H6240-01, Hamamatsu Photonics, Welwyn Garden City, UK). Instrument control and data acquisition were performed using a notebook computer via an RS-232 connection and all software was written in LabVIEW version 7 (National Instruments Corp.). The flow injection manifold was similar to that reported by Bowie *et al*. for the determination of total dissolved iron. It incorporated an 8-HQ preconcentration column and an HCl (0.05 M) carrier was used to elute Fe(II) from the column. An optional buffer line (used only for pH 2 solutions and seawater experiments) mixed ammonium acetate solution with the sample to give a final pH of ~5.5. The 8-HQ column was rinsed before each elution (25 s) to remove any unassociated species using a UHP water wash line controlled via the three-way valve. The flow cell was made from coiled transparent PVC tubing (Altec, Hants, UK) and mounted on the window of the photon counting head. More details can be found in Bowie (1998; 2002).

All measurements reported for both methods are the mean peak heights of 3 or 4 replicates and error bars represent two standard deviations (2s) unless stated otherwise.

Calibration: Experiments conducted with acidified (pH 2) or buffered (pH 5.5) seawater were calibrated by spiking 20 ml aliquots of solution with varying volumes of Fe(II) standard.

Blank measurements: The blank was defined as the signal caused by the elution of the 8-HQ column without sample introduction (i.e. by passing only the buffer solution over the column followed by a UHP water wash and elution). Separate reagent blanks will be made for additions made to sample before analysis (e.g. HCl and sodium sulphite).

Results and data presentation

Labile Fe(II) samples were analysed *in-situ* at each 11:00am station and show increasing concentrations with depth in the concentration range of 5-100 pM. Further data analysis will be carried out to determine whether this was a temperature controlled phenomenon.

Dissolved iron analyses will be made at the shore based lab in Plymouth in April 2006 and data will be available in summer/autumn 2006.

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The detection and quantification of marine siderophores by LC-ESI-MS and LC-ICP-MS

ED MAWJI
National Oceanography Centre, Southampton, UK

Introduction

Marine bacterial growth depends in part upon the availability of iron, which is known to be an essential requirement for most microorganisms. The total amount of iron in surface ocean waters is subnanomolar, potentially making iron the limiting nutrient for primary production in large areas of the oceans. The majority of iron in seawater is through to be complexed by strong organic ligands presumed to be of biological origin. A substantial body of evidence now exists that marine bacteria produce siderophores in order to acquire iron, hence it has been hypothesised that siderophores make up a significant proportion of this organic ligand pool.

Siderophore (from the Greek "iron carriers") are low molecular weight (500-1000), ferric ion specific chelating agents produced by bacteria and fungi growing under low iron stress (Neilands, 1995)

Objectives

- To investigate the distribution and abundance of siderophores in the different biogeochemical provinces along the AMT transect of the Atlantic Ocean.
- To identify and quantify unknown marine siderophores using LC-MS

Method

Incubation method: Incubations were carried out in each distinct regions along the AMT transect to induce bacteria to produce siderophores.

Incubations and solid phase extraction was carried out following the method of Gledhill *et al*., (2004). 1000 ± 20 ml aliquots of sea water were enriched with 2 distinct carbon sources, glucose and chitin, and a combined nitrogen and carbon source, glycin. N and P were also added to the incubations to induce Fe limitation. Samples were incubated for 2-4 days. Bacterial growth was monitored using a spectrophotometer at 600 nm every day. Flow cytometry samples were sub sampled every 24 hours.

Results

No results are available for submission at the moment, incubations and SPE cartridges will be analysed at NOC using LC-ESI-MS and LC-ICP-MS.

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Nutrient limitation and variability of primary productivity, phytoplankton physiology and nitrogen fixation – bioassay experiments

MARK MOORE[1], DAVID SUGGETT[1], MATTHEW MILLS[2], ERIC ACHTERBERG[3], MIKE LUCAS[3], MALCOLM WOODWARD[4] AND KATIE CHAMBERLAIN[4]

[1]*University of Essex, UK*

[2]*University of Stanford, USA*

[3]*National Oceanography Centre, Southampton, UK*

[4]*Plymouth Marine Laboratory, Plymouth, UK*

Introduction

There is long-standing debate as to whether nitrogen or phosphorus is the nutrient that limits phytoplankton productivity in the sea. Nutrient enrichment experiments in oligotrophic waters indicate that nitrogen limits the rate of primary productivity in the modern ocean (Graziano *et al*., 1996; Mills *et al*., 2004; Moore *et al*., in press). However, on geological time scales, nitrogen fixation can increase the nitrate inventory of the ocean, thus increasing primary production. In turn, nitrogen fixation may be limited by either phosphorus (Sanudo-Wilhelmy *et al*., 2001), Fe (Falkowski, 1997) or both (Mills *et al*., 2004). In recent work, bioassay experiments aboard the Meteor 55 and 60 cruises in the sub-tropical and tropical North Atlantic showed that phytoplankton productivity and biomass were nitrogen limited while the active diazotrophic (N_2 fixing) community was phosphorus and iron co-limited and bacterial productivity was nitrogen and phosphorus co-limited (Mills *et al*., 2004; Moore *et al*., in press; Mills *et al*., in prep.). Additionally, Saharan dust can be a source of nitrogen, phosphorus and iron, and thus has the potential to stimulate primary production and nitrogen fixation as well as bacterial production.

Building on work conducted during the Meteor 55 and 60 cruises, we carried out similar bioassay experiments investigating the nutrient limitation of CO_2 fixation, chlorophyll *a* biomass, N_2 fixation, and bacterial productivity during AMT17. Additionally we performed dose response experiments with increasing concentrations of phosphorus and iron in an attempt to define the functional response of diazotrophy to relief from limitation by these elements. Likewise, dose response experiments with increasing gradients of ammonium or nitrate were carried to characterise the inhibitory effects of these compounds on nitrogen fixation. The cruise track, encompassing both the North and South Atlantic sub-tropical gyres, as well as tropical and equatorial regions, provided an excellent opportunity to test hypotheses concerning the factors limiting primary production and nitrogen fixation in the oceans and hence the controls on the biogeochemical cycling of nitrogen and phosphorus.

Involvement in a strong interdisciplinary program such as AMT will provide considerable added value to the work performed. The availability of high quality low level nutrient measurements due to the collaboration with Woodward (PML) will be invaluable, as such data have been lacking from previous work. The work performed within the bioassays will also be complemented by and complementary to much of the other work carried out during AMT17. In particular that carried out by the team from UEA sampling atmospheric dry and wet deposition (Lesworth); from Plymouth University working on iron biogeochemistry (Ussher); from NOC working on phosphorus and nitrogen turnover by the bacterial community (Zubkov and Mary) and from Memorial University working on bacterial limitation (Hale).

Measurements and sampling

Trace metal clean techniques were used throughout the preparation and execution of the experiments. Surface seawater was collected (~5-10 m) after dark using a trace metal clean diaphragm pump.

Seawater was pumped into two 60 l carboys from which it was siphoned into 4.5 l acid-washed polycarbonate bottles. Nutrients were added alone and in combination to nominal final concentrations of 1.0 µm NH_4^+ + 1.0 µm NO_3^-, 0.2 µm NaH_2PO_4, 2.0 nm $FeCl_3$ and, in a separate 10 µm DOC (glucose). An atmospherically processed Saharan dust collected in Turkey and ash from a volcano in Japan were added to an additional set of bottles to concentrations of ~2 mg l^{-1}. For two experiments within the South Atlantic sub-tropical gyre, additions of 7 ml of rainwater collected within the equatorial region was also performed. After filling, bottles were sealed and placed in on-deck incubators with circulating surface seawater. For each treatment, incubations were run in triplicate over 48 hours with nitrogen fixation and primary productivity rate measurements made during the final 24 hours. Chlorophyll *a* concentration and bacterial productivity measurements were determined at 48 hours. Net nitrogen fixation rates were assessed using the $^{15}N_2$ technique while primary productivity was assessed using the ^{13}C technique. Lastly bacterial productivity was measured on sub-samples at 48hr by Michelle Hale using the ^{14}C-luciene method. Simulated *in situ* incubations were conducted in Perspex flow-through incubators cooled by flowing surface seawater. Light was attenuated to 30% of incident surface values by blue filters.

In addition to the rate measurements, other variables monitored or sampled for included nutrient concentrations (NO_3^-, NH_4^+. PO_4^{3-}, DFe), active fluorescence (assessed using fast repetition rate fluorometry, FRRF and a FIRe fluorometer), cell abundance and diversity and DNA/RNA sampling for the presence and activity of nitrogen fixing organisms. Functional photosynthetic responses were also measured using ^{14}C P vs E measurements at 48 hours from a subset of the treatments (see separate section by Suggett and Lucas).

In total ten experiments, six bioassays and 4 dose response experiments, were conducted (Table 1).

Table 1. Locations and start dates for experiments performed during AMT17. For type of experiment, B indicates bioassay and DR indicates Dose Response.

	E01	**E02**	**E03**	**E04**	**E05**	**E06**	**E07**	**E08**	**E09**	**E10**
Lat	44°N	37°N	35°N	28°N	16°N	7°N	6°S	17°S	23°S	29°S
Long	18°W	27°W	31°W	39°W	33°W	28°W	25°W	25°W	17°W	6°W
Date	19/10/05	24/10/05	28/10/05	01/10/05	04/11/05	07/11/05	11/11/05	14/11/05	17/11/05	20/11/05
SST(°C)		22	22.9	25.5	27.7	28.4	26.2	25	23.4	22
Type	B	B	DR	B	DR	DR	DR	B	B	B

Preliminary results

Initial results from bioassay experiments confirmed previous demonstrations (Graziano *et al*., 1996; Mills *et al*., 2004; Moore *et al*., in press) of nitrogen limitation with secondary phosphorus limitation (or nitrogen and phosphorus co-limitation) in the North Atlantic (Fig. 1). Increases in chlorophyll *a* were matched by increases of *in vivo* chlorophyll fluorescence as measured by FRRF. Changes in photosystem II photophysiology in response to relief of nitrogen limitation were, however, generally weak. Bioassays in the South Atlantic indicated nitrogen limitation with no secondary response (or co-limitation) on addition of phosphorus, as might be expected given residual DIP levels of >50nM in the South (Fig. 1). No increases in chlorophyll on addition of iron either as a primary or secondary factor were observed (Fig. 1). As previously observed (Moore *et al*., in press, Mills *et al*., unpublished), the addition of the Saharan dust increased chlorophyll *a* biomass in all experiments. Addition of ash had no detectable influence on any of the parameters measured at sea.

There is considerable work which will be carried out after AMT17. Samples for the nitrogen fixation rates will be analysed by isotope ratio mass spectrometry in the Geophysics department at Stanford University, Palo Alto, CA, USA and the DNA/RNA samples will be analysed in Kiel within the laboratory of Dr J. La Roche (IFM-GEOMAR, Kiel, Germany) during the next 12 months. Additionally the analysis of flow cytometry samples collected for cell abundance and results of bacterial productivity measurements will likely become available during this period.

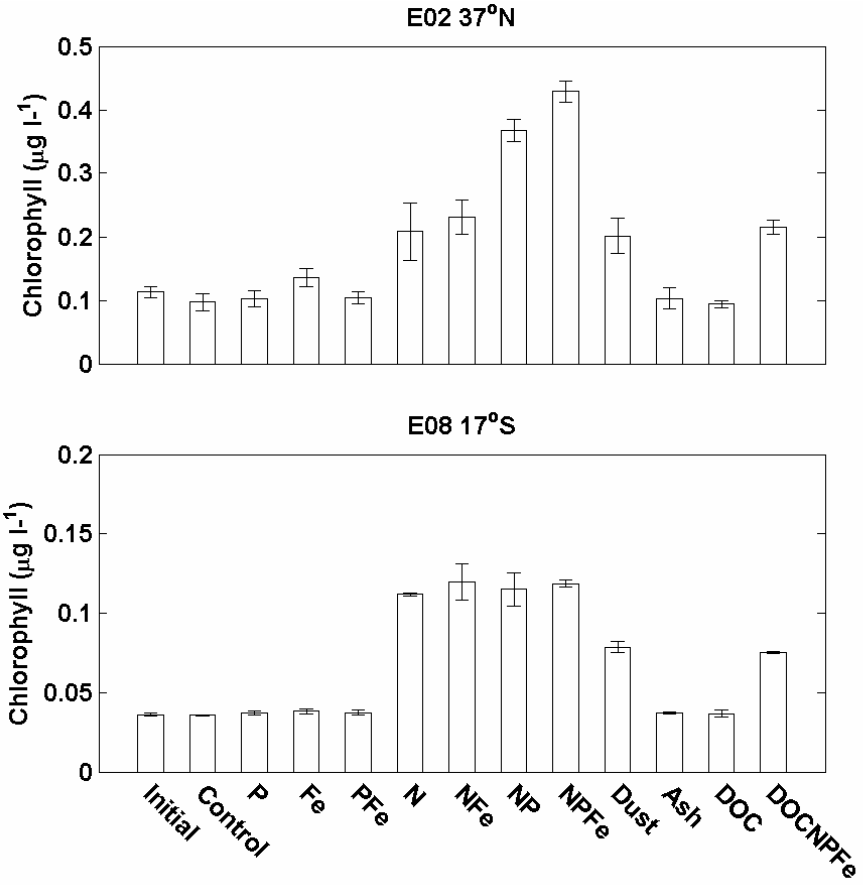

Figure 1. Preliminary results from two nutrient addition bioassay experiments performed during AMT17. Upper panel demonstrates a weak +N response with a stronger +NP response in the North Atlantic. Lower panel indicates a strong +N response with no secondary response to either P or Fe in the South Atlantic.

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Water column N_2 - fixation and diazotroph diversity

MATTHEW MILLS[1], MIKE LUCAS[2], MARK MOORE[3] AND DAVID SUGGETT[3]
[1]*University of Stanford, USA*
[2]*National Oceanography Centre, Southampton, UK*
[3]*University of Essex, UK*

The importance of marine nitrogen fixation in fuelling new production in open ocean environments has been underestimated until recently. The bulk of marine nitrogen fixation has been attributed to the filamentous cyanobacteria *Trichodesmium* sp., though new evidence suggests the diversity of marine diazotrophs is greater than previously believed, and that the activity of these newly recognised diazotrophs may be equal to, or greater than, that of *Trichodesmium* sp. Building on two previous cruises that transected the North Atlantic from west to east (Meteor 55 and Meteor 60), we have used the Atlantic Meridional Transect (AMT17) to obtain samples that will increase our understanding of diazotroph diversity in the North Atlantic and extend this database to the yet unstudied (with respect to diazotroph diversity) South Atlantic (Table 2).

Briefly, 2 litre samples were collected along the cruise track, filtered onto 0.2 µm durapore filters, and stored frozen (-80°C) for DNA/RNA for the presence and expression of the nitrogen fixing gene *nifH* analysis in the laboratory of Dr J. La Roche (IFM-GEOMAR, Kiel, Germany).

Additionally, these samples were coupled with water column measurements of nitrogen fixation by the whole community and the < 20 µm fraction allowing for the determination of the contribution of *Trichodesmium* sp. and the "non-Tricho" diazotrophs respectively, to total community nitrogen fixation (Table 2). Nitrogen fixation measurements were made by incubating 4.5 litres of seawater from several depths with the stable isotope $^{15}N_2$ for 24 hours. All seawater was collected using trace metal clean techniques. Incubations were terminated after 24 hours by filtration onto precombusted GF/F filters, and the samples dried and stored for isotope ratio mass spectrometry analysis in the Geophysics department at Stanford University, Palo Alto, CA, USA. In all incubations CO_2 fixation was also assessed using the stable isotope ^{13}C.

Table 2. List of casts that diazotrophic diversity samples were collected and $^{15}N_2$ fixation and $^{13}CO_2$ fixation rate measurements were made.

Cast	Latitude	Longitude	DNA/RNA	N_2 Fix.	$^{13}CO_2$ Fixation	Size Fractionated
8	35.7°N	29.5°W	✓	✓	✓	
12	29.3°N	36.7°W	✓	✓	✓	
14	26.7°N	38.2°W	✓			
17	23.1°N	36.4°W	✓	✓	✓	✓
21	17.5°N	33.5°W	✓	✓	✓	✓
23	14.3°N	31.9°W	✓			
27	8.6°N	29.1°W	✓	✓	✓	✓
30	5.5°N	27.6°W	✓			
32	3.5°N	26.7°W	✓			
34	0.9°N	25.4°W	✓	✓	✓	✓
37	8.3°S	25°W	✓			
39	11.9°S	25°W	✓	✓	✓	✓
43	19.7°S	25°W	✓			
46	21.1°S	22.4°W	✓			
48	22.6°S	19.1°W	✓	✓	✓	✓
50	26.1°S	11.1°W	✓	✓	✓	✓
56	31.8°S	0.9°W	✓			
58	33.0°S	5.9°W	✓	✓	✓	✓
60	33.8°S	9.6°W	✓			
61	33.9°S	10.3°W	✓			

Coupling of electron turnover by photosystem II (PSII) with carbon fixation in subtropical and tropical phytoplankton communities

DAVID SUGGETT[1], MARK MOORE[1] AND MIKE LUCAS[2]
[1]*University of Essex, UK*
[2]*National Oceanography Centre, Southampton, UK*

Background

Bio-optical and biophysical measurements are increasingly used to conveniently follow the productivity of phytoplankton communities throughout the vast open ocean provinces. Energetic potential for carbon (C-) fixation is directly determined by the rate of ATP and NADPH formation that, in turn, is governed by the rate of photosynthetic electron turnover by photosystem II (PSII). During eukaryotic-dominated phytoplankton blooms in coastal waters both PSII electron turnover and C-fixation are very tightly coupled. However, evidence suggests that this tight coupling may not exist during other stages of microalgal growth (Suggett, unpublished) or throughout the subtropical and tropical open ocean (Suggett *et al*., 2001). Most likely, this loss of coupling represents both taxonomic and physiological alterations to photosynthetic pathways that modify the amount of PSII turnover-derived energy that is available for C-fixation. Quantifying the extent of coupling between PSII photochemistry and C-fixation can begin to unravel (1) how well we can predict C-fixation and community metabolism from bio-optical and biophysical techniques, (2) which components of photosynthetic machinery are preferentially altered to established and maintain the required coupling and (3) the importance of energy demanding photosynthetic pathways other than C-fixation for these phytoplankton communities.

Balance between PSII photochemistry and the maximum rate of C-fixation is reflected in the stoichiometry of electron turnover at several intermediary steps throughout the whole chain of electron transport: τ_{QA} and τ_{PQ}, the turnover time of electrons form the light harvesting antennae to the primary electron acceptor and plastoquinone pool, respectively; τ_{PSII}, the turnover time of electrons from the antennae to the Calvin cycle. τ_{QA} and τ_{PQ} can be measured directly by active fluorescence techniques (Kolber *et al*., 1998) whilst τ_{PSII} must be calculated indirectly using additional knowledge of the light response of carbon fixation (Moore *et al*., in press). Here we employed both active fluorescence and ^{14}C uptake measurements for routine CTD profiles and bioassay experiments to explore our previous suggestion that PSII photochemistry and C-fixation are not tightly coupled in subtropical and tropical phytoplankton communities.

Methodology

Fast Repetition Rate (FRR, *Chelsea Technologies Group*) and Induction-Relaxation (FIRe, *Satlantic Inc.*) fluorescence and ^{14}C uptake was measured (1) upon discrete water samples drawn from the pre-dawn CTD and (2) for the initial and 48 hour time points of the bioassay nutrient enrichment experiments.

An FRR fluorometer was programmed to deliver single turnover (ST) sequences of 100 1.1 μs saturation flashes at 2.8 μs intervals followed by 20 1.1 μs relaxation flashes at 98.8 μs intervals as reported previously (Moore *et al*., in press). Samples were maintained in the dark chamber of the fluorometer and exposed to 500 (32 · 16 acquisitions) individual sequences. These sequences were then averaged into a single induction curve to minimise error (Suggett *et al*., 2004). Blanks were run on filtrates from each sample. Non-linearity in instrument response was characterised using extracts of chlorophyll *a* at both the beginning and end of the cruise. Each induction curve was fit with the biophysical model of Kolber *et al*., (1998) using modified v4 software (c/o Sam Laney) to yield photophysiological parameters specific to photosystem II of the photosynthetic light reaction:

maximum fluorescence yield (F_m, instrument units), photochemical efficiency (F_v/F_m, dimensionless), effective absorption cross section (σ_{PSII}, $Å^2$ $quanta^{-1}$) and the turnover time of the primary electron acceptor QA (τ_{QA}, ms).

A FIRe fluorometer was programmed at gain 2400 to deliver both single (ST, 100µs; Nopd1 = 60) multiple (MT, Nopp2 = 600; Nopd2 = 60) turnover sequences upon the same samples as for the FRR fluorometer. Samples were placed within a cuvette and exposed to 50 ST-MT sequences each separated by 60 ms. The fluorescence transient from each sequence is recorded cumulatively. Therefore, as with the FRR data, the final transient represents a highly averaged sequence. Instrument non-linearities and blanks were run as for the FRR. Induction curves were fit with a model that retrieved the maximum MT fluorescence yield (F_m^{MT}, instrument units) and the turnover time of the plastoquinone pool (τ_{PQ}, ms), in addition to F_m, F_v/F_m, σ_{PSII}, and τ_{QA}. These data will be re-analysed upon return to the UK and are not presented here.

Photosynthesis-light response measurements of ^{14}C-uptake were determined using a method modified from that previously reported by Suggett *et al*. (2001). 30 ml samples were inoculated with 250 µCi and subsequently separated into 29 1 ml aliquots each within a 7 ml scintillation vial. Twenty-four of these scintillation vials were housed within a photosynthetron designed to deliver a gradient of PPFDs between *ca*. 0 and 1500 µmol photons m^{-2} s^{-1}. Each experiment was run for 4 hours. The remaining five aliquots were used for replicate time zeros, immediately treated with 250 µl 37% HCL and placed within a fume hood. Total counts (5 replicates) were determined at the beginning of each P-E curve by adding 4.5 ml Ultima Gold scintillation cocktail (UG) and 200µl phenylethylamine to 20 µl of the inoculated sample within additional scintillation vials. Upon termination of the experiment the 1 ml aliquots were acidified with 250µl 37% HCL and placed within the fume hood along side the time zeros for 12 hours. Each sample and time zero was subsequently treated with 6 ml (UG) and counted on board for 2 minutes. All counts will be repeated for 15 minutes upon return of the samples to Cape Town.

Preliminary results and future work

FRR-derived photophysiological variables of F_m, F_v/F_m and σ_{PSII} were consistent with those observed from previous AMTs (Suggett *et al*. in press) and largely reflect changes in taxonomy between both surface and DCM waters through the tropical and subtropical Atlantic. Generally, both F_v/F_m and σ_{PSII} were lower in surface waters than at the DCM in the Equatorial. In contrast, both F_v/F_m and σ_{PSII} were higher in surface waters than at the DCM in the subtropical gyres. In both cases, values of σ_{PSII} varied by a factor of *ca*. 1.5-2 between the surface and DCM. FRR-derived values of τ_{QA} and EK (ETR) have not been previously reported for these waters. Ek (ETR) is equal to $1/(\tau_{QA} \cdot \sigma_{PSII})$. τ_{QA} was higher by a factor of *ca*. 4-5, whilst EK (ETR) was lower by a factor of *ca*. 3-4, at the surface than at the DCM throughout equatorial and subtropical gyre waters. Therefore, our results indicate that variability of EK (ETR) is largely determined by the changes in the turnover of QA and not σ_{PSII} throughout these tropical and subtropical environments. Similar observations have been reported for shelf sea communities (Moore *et al.*, in press).

Our preliminary ^{14}C uptake experiments indicate that the light saturation parameter for whole chain electron transfer (ie. ETR→^{14}C), Ek determined as P^{max}/α, was always 2-4 times higher at the surface than at the DCM (not shown). Whilst this trend is consistent with that of Ek (ETR), we cannot determine absolute difference and hence the extent with which electron turnover and C-fixation are truly coupled from these data alone. Both estimations of the light saturation parameter must be corrected for spectral differences in the FRR- and photosynthetron-sources of excitation (Suggett *et al*. 2004). We will perform this correction using spectophotometric analyses of filter samples collected by Anna Hickman upon return to the UK. Finally the relationship between ETR and C-fixation will be explored using the turnover times measured at intermediate sites within the whole chain electron transfer series, PSII reaction centre concentration calculated indirectly from pigment and spectrophotometric absorption measurements (Suggett *et al*., 2004) and quantitative knowledge of alternative energetic sinks for electrons, such as N_2 fixation.

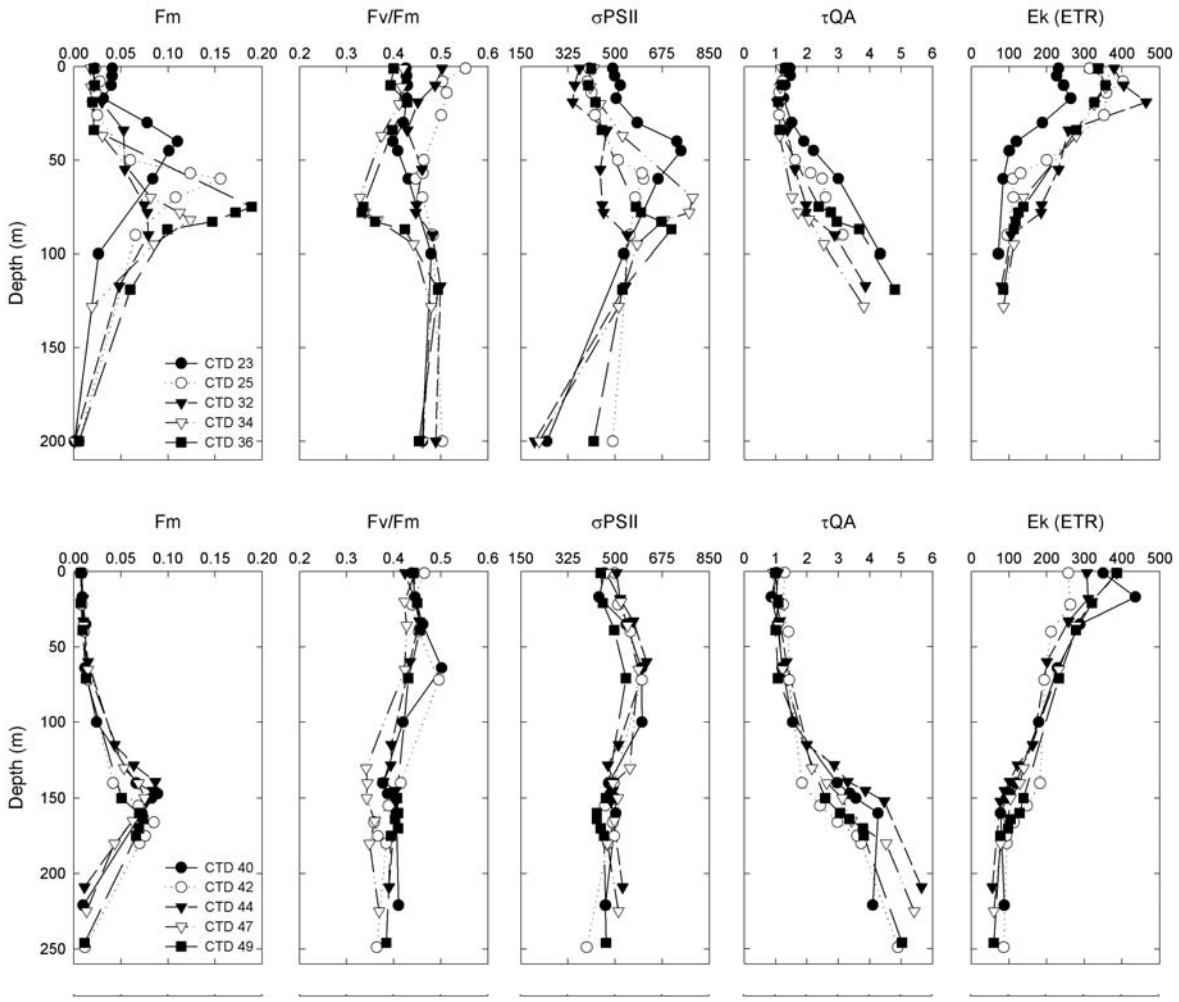

Figure 1. Example water column profiles of FRR-derived photophysiological variables within the Atlantic equatorial (upper 5 panels) and southern subtropical gyre (lower 5 panels). See main text for definition of variables.

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Reactivity, nature and supply of organic nutrients

RHIANNON MATHER
University of Liverpool

Objectives

In order to investigate the reactivity of the organic nutrient pool alkaline phosphatase activity (APA) and leucine aminopeptidase activity will be investigated by employing the fluorogenic substrates 4-methulumbelliferyl phosphate (4-MUP) and L-leucine-7-amido-4-methylcoumarin hydrochloride (Leu-AMC) respectively. A fraction of the DON pool is to be characterised with samples being analysed for amino acids, and the ratio of the D and L enantiomers examined. The sources of the organic nutrients shall be investigated through stable nitrogen isotopes, samples for which will be collected through the deploying of Stand Alone Pumps (SAPs).

Sampling

Samples were collected daily from the pre-dawn cast for investigation of amino acids and enzyme activities. SAPs were deployed approximately every 3 days to obtain stable nitrogen isotope samples.

Methods

Amino Acid Collection and Storage: Samples were collected directly from the CTD niskin bottles into prepared 500 ml wide mouthed Nalgene bottles, after rinsing 3 times with the sample water. Samples were filtered using an all glass syringe and 25 mm 0.7 μm GF/F filters and transferred to 28 ml muffled glass vials. Six amino acid samples were collected daily from the surface, 55% light, upslope chlorophyll maximum, the chlorophyll maximum, downslope of the chlorophyll maximum, and 300 m (the deepest sub-euphotic) depths. Once filtered samples were transferred to a -20°C freezer. These will be transported to the University of Liverpool for analysis by High Performance Liquid Chromatography (HPLC) to investigate the ratio of the D and L enantiomers of the amino acids.

Alkaline Phosphatase and Leucine Aminopeptidase Activities: APA and leucine aminopeptidase activities were investigated following a method described by Hoppe (1993). 500 ml to 1000 ml of sample was collected daily from the 55% light depth, directly from the CTD niskin bottles into prepared wide mouthed Nalgene bottles, after rinsing 3 times with the sample water. Sample water was made up to 10 ml with 4-MUP and Leu-AMC to produce concentrations from 10 to 1000μM. Initial fluorescence readings (T_0) were taken on sub-samples at a pH of 10 using a Turner Designs TD-700 fluorometer, after addition of 0.2 M glycine/ammonium hydroxide solution to terminate any activity. The excitation wavelength was set at 340nm and the emission wavelength was set to 465nm. Duplicate samples were placed in a dark on deck incubator and a further duplicate set in a 55% light depth on deck incubator for a 24-hour period. After incubation the final fluorescence (T_1) was measured in the same manner as before. Michaelis-Menten kinetics (Stryer, 1995) was applied to the fluorescence data in order to determine the turnover rate of the 4-MUP and Leu-AMC (equation 1).

$$\frac{[S]}{[S] + K_M}$$ **Equation 1**

Fluorescence readings were converted to the concentration of substrate hydrolysed by constructing a calibration curve with the fluorophores of the fluorogenic substrates; 4-Methylumbelliferone (MUF) and 7-amino-4-Methylcoumarin (AMC). Calibrations were run daily from 1 mM stock solutions of the respective fluorophores to account for any possible temperature effects and instrument drift.

Autoclaved controls were run to determine non-enzyme related hydrolysis of the model substrates.

Bioassay*:* Alkaline Phosphatase activities were determined for a single bioassay experiment in the South Atlantic (28°30.08°S, 5°31.3°W) to investigate the effect of 9 different nutrient additions on APA. After the 48 hour bioassay incubation samples were inoculated with 250μM 4-MUP and incubated in a dark on-deck incubator for a 24 hour period after which the increase in fluorescence was measured. Fluorescence was converted to concentration using a calibration curve as for normal APA samples. Samples were run in triplicate.

Stand Alone Pumps (SAPs): SAPs were deployed at a frequency of approximately every third day throughout the cruise (Table 1). Three SAPs were pumped for between 1.5 and 2 hours at depths of 50 m, 100 m, and 150 m with the intention of being able to capture the chlorophyll maximum. Filter beds were loaded with muffled 293 mm 0.7 μm GF/F filters. Once recovered the filters were placed in muffled foil, and transferred to a -20°C freezer. Filters will be transferred to the University of Liverpool to investigate nitrogen isotopes and for C and N analysis. A total of 11 stations were sampled along the cruise tract. A further fourth SAP was deployed for each SAP station at a depth of 100 m to obtain trial silica samples to be analysed at the University of East Anglia. 1.0 μm nucleopore filters were used and treated in the same manner as the GF/F filters.

Results

Alkaline Phosphatase and Leucine Aminopeptidase Activities: Preliminary data for V_{max} according to Michaelis-Menten kinetics at each station is shown (Table 2). Data will later be corrected for biomass at the University of Liverpool and investigated in greater detail. Full Leu-AMC experiments were unsuccessful prior to station 036 due to problems with the methodology that were later resolved. Light APA experiments were not carried out everyday due to limited chemicals.

Bioassay: Bioassay treatments yielded APA activities from 0.0012 to 0.0194 $\mu mol^{-1}l^{-1}hr^{-1}$. Data is shown in Figure 1.

Amino Acids and Stand Alone Pumps: Analyses of SAP filters collected and amino acid water samples will take place at the University of Liverpool. Data analysis will hopefully be completed within a year.

References

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Acknowledgements:

Special thanks go to Dr Michelle Hale and Dr Matt Mills.

Table 1. SAP station positions

Station Number	Date	Latitude (ºN)	Longitude (ºW)
X	23/10/2005	37.29833	26.03612
X2	24/10/2005	36.40313	27.14766
007	28/10/2005	35.55213	29.07524
011	31/10/2005	29.31558	36.16381
017	03/11/2005	21.03195	35.16.362
024	06/11/2005	12.04161	30.48257

Station Number	Date	Latitude (ºN)	Longitude (ºW)
031	09/11/2005	3.28751	26.39559
038	13/11/2005	-10.59805	24.5977
044	16/11/2005	-21.0741	22.26077
051	20/11/2005	-27.23481	8.06555
059	24/11/2005	-33.38738	–8.58072

Table 2. V_{max} values for Leucine aminopeptidase and Alkaline Phosphatase activities at each station

Station	Latitude	Longitude	Leu-AMC		APA	
			55% Light	Dark	55% Light	Dark
003	46.13699°N	17.26573°W			0.0021	0.0027
004	44.21107°N	19.19465°W			0.0077	0.0041
007	35.55230°N	29.07557°W			0.0128	0.0125
009	31.18044°N	32.02516°W			-1.2228	0.0105
011	29.31558°N	36.16381°W			0.0129	0.0170
013	27.46839°N	38.48518°W			0.0133	0.0196
015	28.57702°N	36.46745°W			0.0243	0.0239
020	18.22954°N	33.54865°W			0.0097	0.0124
022	15.07549°N	32.17777°W				0.0211
024	12.04161°N	30.48257°W			0.0381	0.0193
026	9.26356°N	29.30828°W				0.0150
029	6.30605°N	28.06468°W			0.0778	0.0218
031	3.28751°N	26.39559°W				0.0120
034	0.53328°N	25.26191°W			0.0361	0.0221
036	2.53183°S	24.59557°W	0.0240	0.0084		0.1184
038	10.59805°S	24.59777°W	0.0056	0.0060	0.0056	0.0078
040	14.22814°S	24.59814°W	0.0284	0.0062		0.0075
042	18.33323°S	24.59571°W	0.0175	0.0256	0.0145	0.0076
044	21.07410°S	22.26077°W	0.0274	0.0300		
047	22.09298°S	20.09298°W	0.0014	0.0003		0.0047
049	23.45372°S	16.31447°W	0.0016	0.0024		0.0048
051	27.23481°S	8.06555°W	0.0005	0.0035		0.0042
053	28.51141°S	4.40583°W	0.0027	0.0015		0.0038
055	30.40154°S	0.18044°W	-0.0008	0.0006		0.0062
057	32.31529°S	4.14304°E	0.0065	0.0053		0.0035
059	33.38738°S	8.55072°E	0.0098	0.0103		0.0059

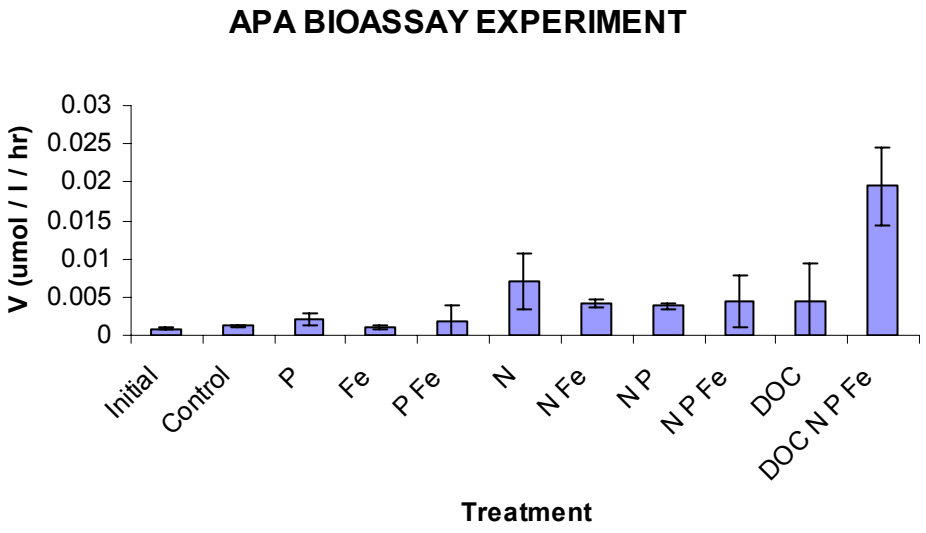

Figure 1. Bioassay APA results

Dissolved inorganic carbon[13] (and total alkalinity) samples

PAUL QUAY[1] AND NICK POPE[2]
[1]*University of Washington, USA*
[2]*Plymouth Marine Laboratory, UK*

Samples were collected while underway from the ships non-toxic seawater supply. A total of 74, 250 ml samples were taken at 1 degree latitude intervals between 45°N and 31°S with additional samples every half degree of latitude between 2°N and 2°S (Table 1).

All samples were immediately fixed with 250 µl of saturated mercuric chloride, sealed with airtight stoppers and packed in crates ready for shipping to USA. The analysis for $^{13}C/^{12}C$ ratio of the dissolved inorganic carbon will be done by Paul Quay in the Stable Isotope Laboratory at the University of Washington. The analysis typically takes about 6 months to finish, at which point the data will be provided to the AMT data office. The purpose of these measurements is two fold:

- First, the $^{13}C/^{12}C$ measurements are used to determine the rate of anthropogenic CO_2 uptake in the Atlantic Ocean, since fossil fuel produced CO_2 has a much lower $^{13}C/^{12}C$ ratio than CO_2 in the ocean.
- Second, the $^{13}C/^{12}C$ ratio is used to estimate net community production, since photosynthesis yields organic matter with a much lower $^{13}C/^{12}C$ than that for dissolved inorganic carbon.

The $^{13}C/^{12}C$ samples collected on the AMT cruises will be compared with similar measurements from other cruises in the Atlantic (e.g. Polarstern, Hesperides) to determine the spatial and temporal variability in the $^{13}C/^{12}C$ of the dissolved inorganic carbon in the surface ocean.

Paul Quay is currently completing a paper which uses all our surface $^{13}C/^{12}C$ measurements in the Atlantic, including the AMT results, to estimate the rate of anthropogenic CO_2 uptake.

Total alkalinity samples

ANDREW DICKSON[1] AND NICK POPE[2]
[1]*SIO/Marine Physical Laboratory, La Jolla, CA 92037, USA*
[2]*Plymouth Marine Laboratory, UK*

Samples for total alkalinity were collected in parallel with samples for DI^{13}C, since sampling strategy and processing were identical. Sixty, 250 ml samples were collected between 45°N and 21°S at every degree of latitude, fixed with 250 µl of saturated mercuric chloride, sealed with air tight septa and packed in crates ready for shipping to La Jolla for analysis. We will be analysing these samples for total alkalinity, as we are putting together information about the distribution of alkalinity in the surface waters. High quality surface alkalinity data is an integral part of current oceanic carbon cycle science. In particular, it is an essential part of the current method used for the estimation of anthropogenic CO_2 in the ocean. The transects on AMT will allow us to ascertain how variable such a parameter is, and hence allow us to better constrain the uncertainties in assessing CO_2 uptake.

Partial pressure of CO_2 in surface water and marine air

DOROTHEE BAKKER[1] AND NICK POPE[2]
[1]*University of East Anglia, UK*
[2]*Plymouth Marine Laboratory, UK*

Continuous measurements of pCO_2 in surface water and marine air were made throughout the cruise with the underway pCO_2 system designed by Ute Schuster (UEA). Marine air was collected through tubing from the monkey island (above the ship's bridge) while seawater from the ship's non-toxic surface water supply was introduced at a rate of 3 l min^{-1} into a slow response equilibrator. Samples from the equilibrator headspace and marine air were partly dried to 10°C below ambient temperature in an electric cool box. Two Pt100 probes accurately determined the water temperature in the equilibrator and a vent kept the headspace of the equilibrator at atmospheric pressure. At one minute intervals, the CO_2 and moisture content of the headspace gas was determined by an infrared LI-COR 6262 analyser. Analysis of the CO_2 content in the headspace was interrupted for analysis of the CO_2 content in marine air (20 minutes per 6 hours) and in two CO_2 standards (30 minutes per six hours each. The standards of 267.84 (later 267.58) and 479.72 µmol CO_2 mol^{-1} (s of 0.5 µmol mol^{-1}) had been calibrated against certified NOAA standards. The correction by Takahashi *et al*. (1993) was used to correct for warming of the seawater between the ship's water intake and the equilibrator. The pCO_2 measurements were time stamped and located using a GPS receiver positioned on the monkey island. The precision and accuracy of the pCO_2 data was approximately 1.0 µatm, as determined in previous cruises.

Overall the pCO_2 system performed admirably, with no major breakdowns or component failures. The absence of a vent hole in the outer wall of the new equilibrator (a production error) led to some spikes in the surface water pCO_2 data in the early part of AMT17, but once a hole was added, few spikes were seen.

Figure 1 shows preliminary results from the latter part of AMT17 between 10°N and 20°S, although final corrections for temperature and salinity will need to be applied.

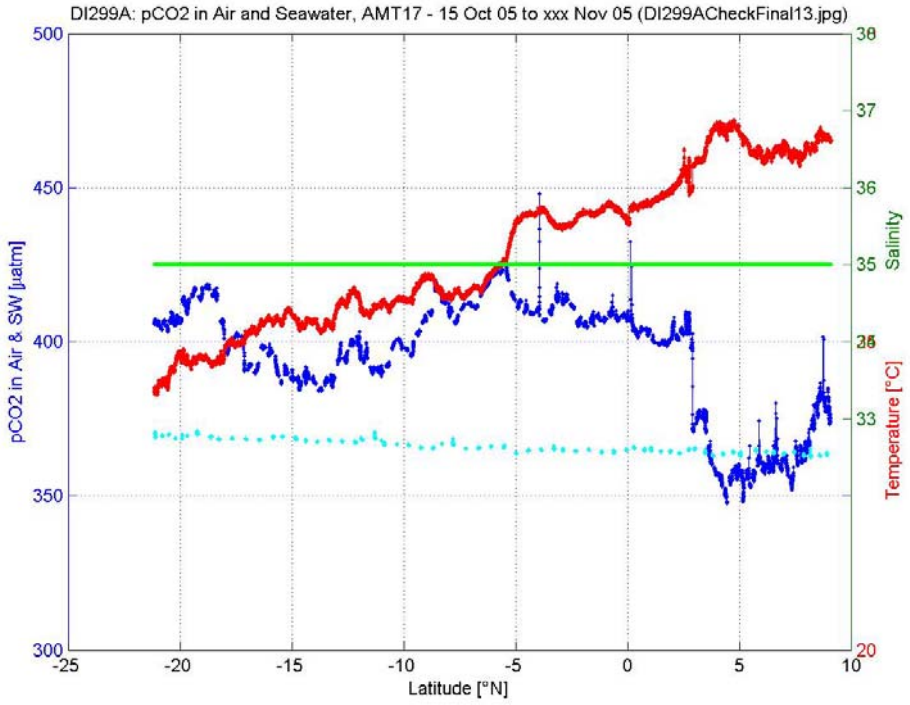

Figure 1. pCO_2 in air and seawater.

Oxygen concentration of surface water

The oxygen (O_2) concentration was measured with an optode, model 3930 from Aanderaa. The oxygen measurement is based on dynamic luminescence quenching of luminophore molecules (platinum porphyrine) embedded in a sensing foil, which is exposed to the surrounding water. The instrument is in a cylindrical titanium housing with a length of 160 mm and a diameter of 40 mm. The housing positioned the optode in the seawater flow with the optical window of the optode in the centre of the flow. The external housing was positioned vertically. The data from the optode were saved every minute to the laptop of the online pCO_2 system. The optode has a measuring range of 0-500 mm for oxygen, with a resolution better than 1 mm and accuracy better than 8 mm or 5%, whichever is greater. The oxygen data will be checked against oxygen concentrations determined by the Winkler method.

The final pCO_2 and O_2 data will be stored with other cruise data at the British Oceanographic Data Centre (http://www.bodc.ac.uk/) following AMT data policy. Surface water pCO_2 data will also be submitted to the international, publicly accessible surface water pCO_2 database at the US Carbon Dioxide Information Analysis Center (http://cdiac.esd.ornl.gov/oceans/).

The CASIX-PML-Dartcom pCO_2 system.

GERALD MOORE, NICK POPE, NICK HARDMAN-MOUNTFORD
Plymouth Marine Laboratory, UK

The CASIX-PML-Dartcom pre-production pCO_2 system was installed on the RRS Discovery in the standard configuration: marine air collected on the Monkey Island and seawater from the non-toxic supply. As a new system, some time was needed for installation, mobilisation and fixing initial teething problems (leaks in the equilibrator and cooling system and modifications of the equilibrator set-up). Data were successfully collected soon after the departure of the vessel from the Azores (after repair) and stored in the integral computer system. Software for the satellite communications links was incomplete on departure, so development continued during the cruise and was completed by the time the vessel was in the southern hemisphere. From this point the system provided the transmission of data ~6 times per day, direct to the home-base, internet addresses at Dartcom and PML.

Figure 1 shows the data of marine air pCO_2 (corrected with real time SST and salinity) Equilibrator pCO_2, SST and salinity (calculated from surface C & T, but not validated or corrected) received in 'real time' and archived at PML from 20 S (15/11/05) to just before the end of the cruise (26/11/05) in Port Elizabeth. The data compare closely (qualitative assessment) with the data acquired by the UEA system and simple quality assurance checks; e.g. the marine air measurements (ca 375 ppm) were close to S Atlantic reference station observation.

Figure 2 shows ancillary data on O_2 (Aanderaa Optrode 3830, part of system) and Chlorophyll-fluorescence (ship's sea-chest) in the 'real time' data stream received at PML. The data combination allows on-line salinity and temperature correction and knowledge-based data quality assurance by comparison with geographical climatologies, mean, range and standard deviations. System errors can be identified and ship-board operators alerted to implement service procedures.

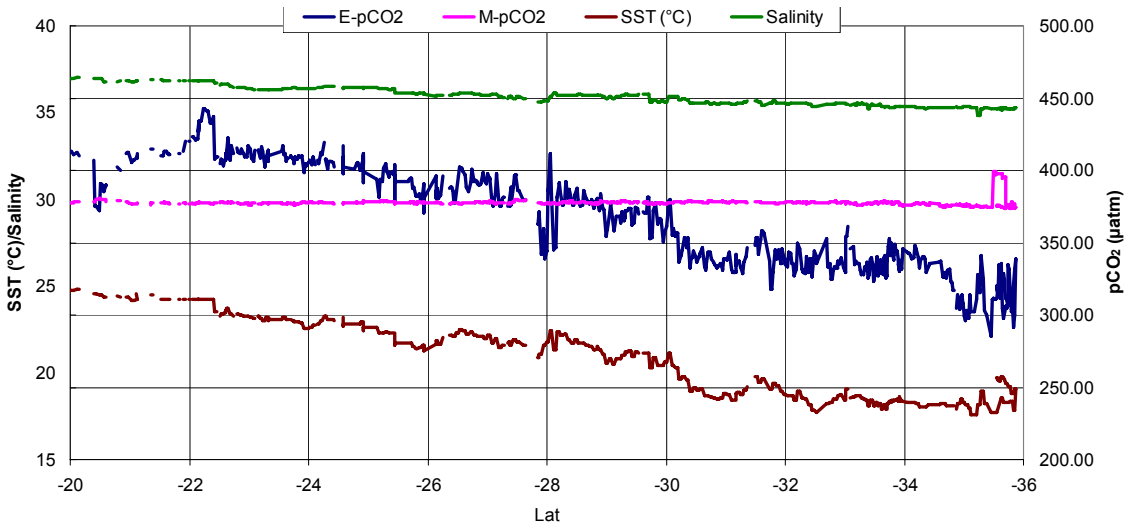

Figure 1. CASIX-PML-Dartcom pCO_2 system data of marine air pCO_2 (corrected with real time SST and salinity), equilibrator pCO_2, SST and salinity, from 20°S to the end of the cruise, received and processed in 'real time' at PML

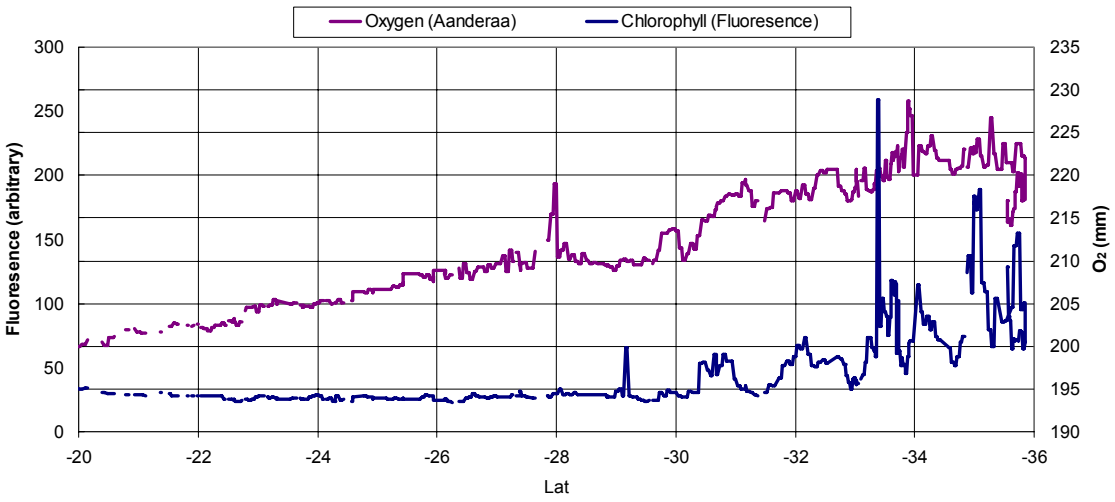

Figure 2. Ancillary data of O_2 (Aanderaa Optrode 3830, part of system) and chlorophyll-fluorescence (ship's sea-chest), from 20°S to the end of the cruise, received in the 'real time' data stream at PML

Dissolved organic carbon, nitrogen and phosphorus

XI PAN
National Oceanography Centre, Southampton, UK

Aims

To investigate the vertical distributions and long-range transport of dissolved organic carbon (DOC), dissolved organic nitrogen (DON) and dissolved organic phosphorus (DOP) in the southern and northern oligotrophic gyres and the equatorial upwelling regions in the Atlantic Ocean along the AMT17 transect.

Methods

Sample collection: Seawater samples were collected from 12 depths, including 6 main light depths at top 300 m, during the pre-dawn CTD cast using previously acid-cleaned (10% HCl, v/v) HDPE bottles.

Sample filtration: The sub-samples were subsequentially filtered through ashed (450°C, 6 hours) GF/F filters (0.7 μm). The glass filtration unit was previously acid-cleaned (10% HCl, v/v) and combusted (450°C, 6 hours), and acid-washed between CTD stations.

Sample preservation: The filtrates were transferred to clean glass ampoules (450°C, 6 hours) and stabilised by acidification (pH 2, 50% (v/v) HCl) for DOC and DON analyses. The ampoules were sealed using a butane propane mixture gas torch and stored in a fridge (4°C).

DON and DOC analyses: DON concentrations are defined as the differences between total dissolved nitrogen (TDN) and dissolved inorganic nitrogen (DIN) concentrations. DIN (NO_3^-, NO_2^- and NH_4^+) analyses were undertaken immediately upon sample collection using standard colorimetric technique. TDN and DOC analyses will be performed using a coupled high temperature catalytic (HTC) combustion system consisting of a Shimadzu 5000A total organic carbon (TOC) analyser and an Antek 705E nitrogen chemiluminescence detector.

A full analytical cycle of the coupled HTC system consists of two steps: (1) The acidified samples are decarbonated by sparging pure oxygen gas (99.995%, 8 min) and injected into the TOC combustion column, which was filled with a catalyst (Al_2O_3 coated with 0.5% Pt) at 680^{o}C, producing CO_2, NO and H_2O. After purification the resulting CO_2 is detected using an infrared detector. (2) The gas stream is routed into the reaction chamber of the Antek instrument in which the NO reacts with O_3 to form NO_2* radicals, which in turn chemiluminescence upon decay to the ground state. The emitted light is detected and recorded.

DOP analyses: DOP fraction is the difference between total dissolved phosphorus (TDP) and dissolved inorganic phosphorus (DIP). DIP (PO_4^{3-}) analyses were carried out on-board using colorimetric technique. UV photooxidation technique was used to liberate organically bond P using a 705 UV digester (2 hours, 84±6^{o}C), followed by standard colorimetric technique.

Acknowledgements

I would like to thank Malcolm Woodward and Katie Chamberlain for TDP analyses.

Table 1. Sample details

CTD No.	Date	Bottle No.	Notes
3	19/10/05	24, 19, 17, 14, 11, 8, 7, 3, 2, 1	
4	20/10/05	24, 21, 18, 15, 12, 11, 9, 6, 5, 3, 2, 1	
7	28/10/05	24, 20, 17, 14, 11, 10, 8, 5, 4, 2, 1	
9	30/10/05	24, 21, 18, 15, 12, 11,10, 8, 5, 4, 2, 1	10 may be contaminated
11	31/10/05	24, 20, 17, 14, 11, 10, 8, 5, 4, 2, 1	
13	01/11/05	24, 21, 18, 15, 12, 11, 8, 5, 4, 2, 1	
15	02/11/05	24, 18, 17, 14, 11, 10, 9, 8, 5, 4, 2, 1	11 may be contaminated
17	02/11/05	24, 22, 20, 19, 18, 17, 16, 15, 14, 11, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1	
18	03/11/05	22, 19, 16, 13, 10, 9, 8, 7, 4, 3, 1	
20	04/11/05	24, 20, 17, 14, 11, 10, 9, 7, 4, 3, 1	
22	05/11/05	24, 21, 18, 15, 12, 11, 8, 5, 4, 2, 1	21 and 11 may be contaminated
24	06/11/05	24, 20, 17, 14, 11, 10, 9, 6, 5, 3, 2, 1	11 may be contaminated
26	07/11/05	22, 19, 16, 13, 10, 9, 8, 5, 4, 2, 1	
29	08/11/05	24, 18, 17, 14, 14, 11, 10, 8, 5, 4, 2, 1	24 taken from the fish; 4 may be contaminated
32	09/11/05	24, 18, 17, 14, 11, 10, 9, 6, 5, 4, 2, 1	
34	10/11/05	24, 21, 18, 15, 12, 11, 8, 5, 4, 2, 1	
36	11/11/05	24, 20, 17, 14, 11, 9, 6, 5, 4, 2, 1	
37	12/11/05	24, 22, 21, 20, 19, 18, 17, 16, 14, 12, 9, 7, 6, 5, 3, 1	
38	13/11/05	24, 20, 15, 14, 11, 10, 9, 6, 5, 4, 3, 1	
40	14/11/05	24, 21, 18, 15, 12, 11, 8, 5, 4, 3, 1	
42	15/13/05	24, 21, 18, 15, 12, 11, 8, 5, 4, 3, 1	
44	16/11/05	24, 20, 17, 14, 11, 10, 8, 5, 4, 3, 1	
46	16/11/05	24, 23, 21, 20, 19, 18, 17, 16, 15, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1	23 and 21 from surface as well
47	17/11/05	24, 20, 17, 14, 11, 10, 8, 6, 5, 4, 3, 1	6 may be contaminated
49	18/11/05	24, 21, 18, 15, 13, 12, 10, 6, 5, 4, 2	21 may be contaminated
50	19/11/05	24, 22, 20, 18, 16, 15, 14, 10, 7, 5, 4, 3, 2, 1	
51	20/11/05	24, 20, 17, 14, 11, 10, 9, 6, 5, 4, 2, 1	
53	21/11/05	24, 21, 18, 15, 13, 12, 11, 6, 5, 4, 1	
55	22/11/05	24, 20, 17, 15, 13, 12, 10, 7, 6, 5, 3, 1	
57	23/11/05	24, 21, 18, 15, 12, 11, 9, 7, 6, 56, 4, 1	
59	24/11/05	24, 21, 18, 15, 12, 11, 9, 6, 5, 3, 2, 1	
61	24/11/05	21, 17, 15, 13, 11, 9, 7, 6, 5, 4, 3, 2, 1	
62	25/11/05	23, 22, 20, 18, 16, 15, 14, 13, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1	13 may be contaminated; 10 leaky

Atmospheric sampling

TIM LESWORTH
University of East Anglia

Introduction

Atmospheric sampling on D299 was carried out for aerosols and gas phase ammonia along the AMT17 cruise track (Govan - Port Elizabeth) between 15th October and 28th November 2005. Aerosols, particulates suspended in the atmosphere ranging in size from 0.1 – 100 μm diameter, were sampled using three high volume (1 m^3 min^{-1}) samplers. Gas phase ammonia was sampled using a low volume vacuum pump with filter packs. Rainwater was also collected at every opportunity to assess wet deposition.

Sampling procedure

Three separate high volume samplers were used to sample aerosols: one sampler was loaded with paper substrates for major ion analysis of aerosols, one loaded with quartz fibre substrates for analysis of organic carbon and nitrogen and the third was loaded with acid washed paper substrates for trace metal analysis. In preparation for the cruise the quartz fibre filters were ashed in a muffler oven at 400°C for four hours to remove any organic substances that may have initially been on the filters, they were then packed in aluminium foil for transport and storage. The acid washed filters for trace metal analysis were washed in hydrochloric and nitric acid solutions and rinsed in ultra-pure water. Paper filters were taken straight form the manufacturers packaging.

Sampling of aerosols was done using slotted filers and backup filters with a six stage cascade impactor. For normal sampling on D299, only plates three and four of the cascade impactor were used. This was in order to split the size range of aerosol particles collected, with the > 1 μm fraction being collected on the slotted filters between the impactor plates and the < 1 μm fraction being collected on the backup filter. Filters were handled, loaded in to and removed from the cascade impactors whilst wearing gloves in a laminar flow hood situated in the ship's main laboratory to prevent dust contamination. They were sealed in zip-loc bags for transportation to the samplers (located on the wheelhouse roof).

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 20-48 hour 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}, calibration was performed twice during the cruise, once at the start (15th October, day 288) and once half way through (7th November, day 311).

Ammonia sampling was performed using a low volume vacuum pump with filter packs (Fig. 1). Each filter pack holds three filters and is fitted with a cyclone separator for separating out large particles. The filters used with the filter packs are 4.7 cm diameter, the first of the three filters is a 1 μm PTFE filter for the removal of large particles, the second an third filters are paper filters soaked in a 0.1 M oxalic acid solution. The filters are soaked in the acid, loaded in to and unloaded from the filter packs in a glove box, which is supplied with air filtered through an additional acid soaked filter in an attempt to eliminate contamination from background ammonia in the lab. The glove box was set up in the main laboratory and the filters were transported between the main lab and low volume system in sealed zip-loc bags.

After sampling the paper aerosol filters were folded in two and sealed in zip-loc bags and the same procedure was applied to the quartz samples, which were re-wrapped in aluminium foil to prevent contamination from the organics in the bags. All the filters from the ammonia system were placed individually in 15 ml centrifuge tubes a sealed in two zip-loc bags. All filters were stored frozen in a -20ºC chest freezer for later analysis at UEA.

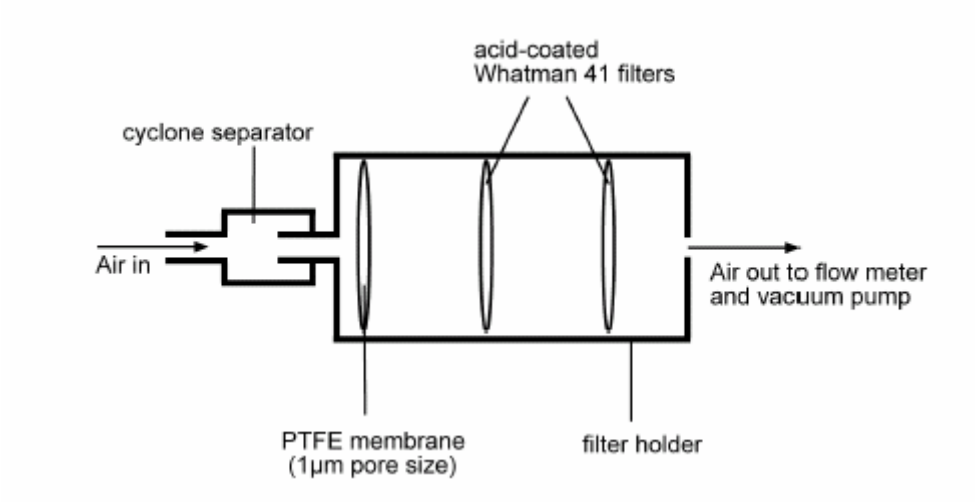

Figure 1. Filter-pack used for ammonia sampling

An electrical flow meter was used with the ammonia system, this is a new piece of equipment and had not been calibrated at the time of sampling, this will be done after the cruise at UEA.

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. Rain samples were frozen to be returned to UEA for analysis for major ions and trace metals.

Equipment set up and progress

Main Lab/Chem Lab: Equipment used in the main lab was a glove box (supplied by UEA), a laminar flow cabinet (supplied by UEA) and a fume cupboard (supplied by UKORS). The glove box and flow cabined were used as described above. The fume cupboard was used for making the oxalic acid solution from oxalic acid, methanol and glycerol. The fume cupboard was used once a week to make a new batch of acid solution. Also in the main lab there was a repeater monitor for the ship's surfmet system, which was useful for monitoring wind direction.

Monkey Island (Wheelhouse roof): The samplers are situated on the monkey island because this is the highest point of the ship and receives the cleanest air. If there was a relative following wind, the samplers were switched off to avoid contamination from the ship's funnel.

All the samplers were set up on the monkey island. They run of a 240V power supply and to be used were insulated to IP65 standard. They were plugged in inside the access stairwell and extension leads were lead through a duct in the housing. For this kind of work onboard *RRS Discovery* it is necessary to bring sufficient extension lead to be able to plug in up to five electrical components up to 30 m away from their power supply. This is the first time that there have been five components to plug in for atmospheric sampling and there was considerable pressure on the power outlets. Initially this problem was overcome by using multiple sockets plugged in to one of the ship's two power outlets. This drew too much power from the one socket and caused fuses to blow and the samplers to function unreliably. The problem was overcome with the help of the chief engineer and the ETO by installing an additional socket in the access stairwell. It should be noted that although there were originally two outlets in the access stairwell, there was other scientific equipment plugged in on the monkey island, meaning that not all the ships power outlets on the monkey island were available for atmospheric sampling. The addition of a third outlet provided sufficient power.

Rainwater Sampling: Rainwater sampling was performed by lashing lengths of drainpipe to the ship and securing funnels and sample bottles in them whenever it rained. The sample bottles and funnels

were stored at the back of the bridge so as to be close at hand. It is necessary to keep rain sampling equipment on non-slip material on the bridge.

Progress on D299: Progress on D299 was very satisfactory. Although there were problems with the CTD gantry on this cruise, this did not affect the atmospheric sampling which was able to continue mostly unhindered during the resulting port calls to the Azores.

In order to ensure clean air enters the samplers, sampling can only be carried out when the wind approaches the ship forward of the beam. On this cruise relative following winds were very rare and less than one day's sampling was lost as a result of following winds. On leaving Govan strong westerly winds were experienced for the first two weeks of the cruise, bringing clean air. As a result of this the samplers were left to run for 48 hours over days 293, 294 and 295 to ensure sufficient aerosols are collected for analysis. It was during this period that the CTD gantry failed and the ship headed for the Azores.

Throughout the steam to the Azores and the work done around the Azores, normal sampling was maintained as much as possible. We remained close to the Azores for approximately three days awaiting parts for the gantry, and this provided the opportunity to carry on sampling and build up a three day time series. Whilst every effort was made to sample as normal during the diversion to the Azores, two days sampling were lost whilst alongside in Ponta Delgada and waiting to enter the port.

On leaving the Azores and heading south through the tropics towards the equator the wind direction change to easterly and dust was picked up between days 308 and 312. Between days 312 and 320 evidence of biomass burning was seen on the filters which faded as the ship headed south along 25°W between the equator and 20°S. After turning east at 20°S the filters became clean and sapling was carried out for 48 hours so as to collect a sufficient quantity of aerosol for analysis.

At the time of writing, 28 periods of aerosol and gas phase ammonia sampling had been completed of between 20 and 48 hours duration. It is anticipated that there will be another two sampling periods before the end of the cruise. Figure 1 summarises the aerosol and rain sampling on D299, showing the mid-point latitude and longitude of each period of sampling.

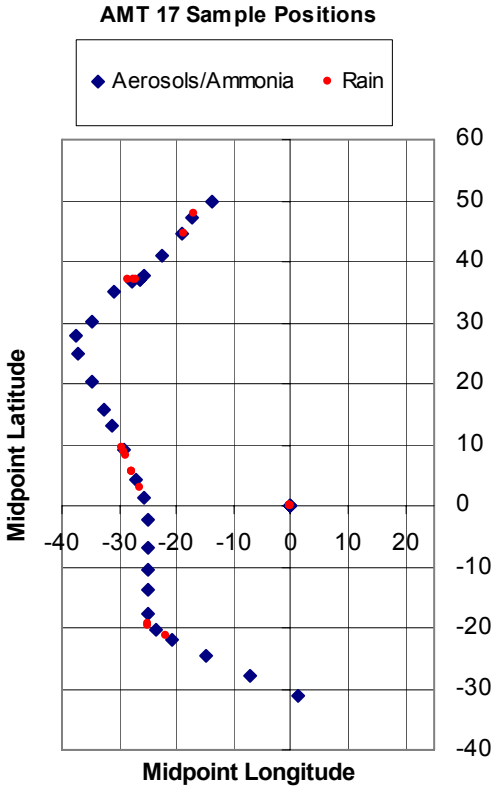

Figure 1. Aerosol/ammonia midpoint and rain sampler locations on D299.

UKORS instrumentation

JON SHORT AND TERRY EDWARDS
UKORS Sensors and Moorings Group, National Oceanography Centre, Southampton, UK

1. CTD Operations

A total of 68 CTD casts were undertaken on the cruise, 34 of which used the stainless steel frame and 34 used the titanium frame.

1.1. Stainless Steel CTD Frame

The stainless steel frame configuration was as follows:

- Sea-Bird 9/11 *plus* CTD System
- 24 by 20 l Ocean Test Equipment External Spring Water Samplers
- Sea-Bird 43 Oxygen Sensor
- Chelsea MKIII Aquatracka Fluorometer
- Chelsea MKII Alphatracka 25cm path Transmissometer
- OED LADCP Pressure Case Battery Pack
- RD Instruments Workhorse 300 KHz Lowered ADCP (downward-looking master configuration)
- RD Instruments Workhorse 300 KHz Lowered ADCP (upward-looking slave configuration)
- Chelsea FRRF/Battery Pack/PAR/Pressure Sensor (removed for 1000 m casts)

The pressure sensor is located 15cm from the bottom of the water samplers, and 132 cm from the top of the water samplers. This frame was used for the pre-dawn casts and was either deployed to 300 m or 1000 m.

1.1.1 Stainless Steel CTD Frame Instrument Configuration

The Sea-Bird CTD configuration can be found in the relevant con files on the D299 SeaBird data disk.

1.1.2. Stainless Steel CTD Frame Deployment Notes

There were the usual occasions of the 20 l water bottles not sealing properly. There were never more than a couple per cast and the scientists sampling from these casts were informed and so did not take water from these bottles. This is an unfortunate design flaw of these particular bottles and there is no method of getting 100% closures.

The usual warm-water hysteresis problems with the Chelsea transmissometers were encountered. Past cruise reports refer to a 25°C maximum operating temperature for this instrument, however there is no such temperature specification present in the manufacturer's manual for the instrument. It should be noted that considerable hysteresis was observed below this temperature.

1.2. Titanium CTD Frame

The titanium frame configuration was as follows:

- Sea-Bird 9/11 *plus* CTD system
- 24 by 10 l Ocean Test Equipment External Spring Trace-metal Water Samplers
- Sea-Bird 43 Oxygen Sensor
- Chelsea MKIII Aquatracka Fluorometer
- Wetlabs BBRTD Back Scatter Sensor
- Chelsea MKII Alphatracka 10cm path Transmissometer (Faulty as supplied, removed Jday 145)
- RVS 2 Second Interval Pinger – Fitted for full-depth, near bottom casts

The pressure sensor is located 30 cm from the bottom of the water samplers, and 119 cm from the top of the water samplers. This frame was used for the midday casts and was either deployed to 300 m or full ocean depth up to 6000 m. A Wetlabs sea star transmissometer was trialled on 7th November, and was later moved to the st frame on 9 November (cast 36). The results from this instrument were positive, but it should be noted that trials with the sea star to deep casts continually have resulted in distortion. This unit is only rated to 1000 m, so it is not a permanent solution.

1.2.1. Titanium CTD Frame Instrument Configuration

The Titanium Sea-Bird CTD configuration can be found in the relevant con files on the D299 SeaBird data disk.

2. Stand Alone Pumps (SAPs)

Four Challenger Oceanic Stand Alone Pumps were deployed simultaneously at 50, 100, and 150 m, on the core wire. The timer delay was set to 0.3 hours and the pumping time to 1.5 hours. SAP 03-01 suffered from slight water ingress, after drying and cleaning it functioned well for the remainder of the cruise.

3. Surface Sampling and Meteorology (SurfMet) System

SurfMet, the UKORS surface water and meteorological suite of instrumentation was run for the duration of the cruise. See separate notes on trials of the new logging system.

3.1. Surfmet System Instrument Configuration

Table 1. Composition of the SurfMet system

Manufacturer	Sensor	Serial no	Comments
FSI	OTM temperature	1370	HOUSING, calibration held internally in sensor
FSI	OTM temperature	1360	REMOTE, calibration held internally in sensor
Wetlabs	fluorometer	246	
Seatech	transmissometer	114R	
Vaisala	Barometer PTB100A	Z4740021	
Vaisala	Temp/humidity HMP44L	U1420016	
SKYE	PAR	28558	port
SKYE	PAR	28557	stb
Kipp and Zonen	TIR CMB6	07462	port
Kipp and Zonen	TIR CMB6	07463	stb
Sensors without cal			
FSI	OCM conductivity	1376	Original manufactures calibration. Surface salinity is produced from computed PRO_TSG then corrected with wet samples if taken.
Vaisala	Sensor collector QLI		
Vaisala	Anemometer WAA		
Vaisala	Wind vane WAV		
Rhopoint	+/- 5v		
Rhopoint	+/- 5v		

4. Salinometry

An Autosal 8400B salinometer (s/n 65764) was used on this cruise to all samples collected either from the CTD casts or the underway non-toxic supply. The salinometer was located in the Stable Laboratory and operated at 27°C bath temperature and 25.2°C to 27°C ambient lab temperature. The samples were run using the Softsal software running on a desktop PC. All samples were processed according to WOCE standards and protocols.

Discrete samples for calibrating the SurfMet TSG were taken from the outflow from the TSG.

All samples were collated from sample logsheets in digital format as an Excel Spreadsheet and graphs for regression to Autosal data, and drift over the cruise were created for each of the four CTD sensors and the Surfmet TSG sensor.

The constant offset noted on both pairs of the titanium sensors is at the time of writing being looked into by T. Edwards and seabird.

5. Miscellaneous

Both the 75kHz and 150 kHz UKORS vessel mounted ADCPs were run for the duration of the cruise and their data included by the UKORS Computing Engineer in the main cruise archive.

Appendices

Appendix 1. CTD station positions and times

All CTD's to 300 m or 350 m unless otherwise stated.

JD	Date	Station	Latitude	Longitude	Time (ship)	Activities	Notes
288	15/10/05				1500		Depart Govan (GMT+1)
290	17/10/05		50.49°N	11.28°W	1300-1430	CTD tests	
291	18/10/05				0200		Clocks back 1h (GMT)
		1	48.97°N	16.50°W	1040-1119	CTD 1 (SS)	PAP Site
		2	48.93°N	16.48°W	1238-1346	CTD 2 (TIT) to 500 m	Freefall optics
292	19/10/05	3	46.23°N	17.44°W	0404-0447	CTD 3 (SS)	
			44.85°N	17.89°W	1301-1320		Freefall optics
			44.56°N	17.78°W	1500-1545		Recover PAP mooring
					1655-0054		Deploying deep tow cable overnight
293	20/10/05		44.54°N 44.55°N	18.54°W 18.74°W	2310 to 0056		Water collection for Expt 1 (Bioassay)
		4	44.45°N	19.32°W	435-515	CTD 4 (SS)	Plankton net
		5	44.06°N	20.15°W	1100	CTD 5 aborted	Gantry hydraulics failure
			44.06°N	20.21°W	1538-1600	Optics rig profile	
294	21/10/05						Steaming to Ponta Delgada (Azores)
295	22/10/05				~1830		Alongside Ponta Delgada
296	23/10/05				0800		Departed Ponta Delgada
			37.50°N	26.05°W	1118-1221	Optics rig profile	Freefall optics and water bottles
			37.48°N	26.01°W	1455-1748	SAPS 1 deployment	
297	24/10/05		36.66°N	27.25°W	0522-0600	Optics rig profile	Water bottles
			36.67°N	27.26°W	0745-1020	SAPS 2 deployment	
			36.66°N	27.27°W	1110-1146	Optics rig profile	Freefall wire fouled around prop
298	25/10/05		37.07°N 37.18°N	26.64°W 26.47°W	2308 to 0100		Water collection for Expt 2 (Bioassay)
					1030		Hove to off Ponta Delgada
							Evening gale and thunderstorms
299	26/10/05				1500		Alongside Ponta Delgada. Hydraulics engineer and divers to ship
300	27/10/05				0800		Departed Ponta Delgada
		6	37.34°N	26.50°W	1428-1500	CTD 6 (TIT) to 200 m	
301	28/10/05				0200		Clocks back 1h (GMT-1)
		7	35.92°N	29.13°W	0505-0555	CTD 7 (SS)	Plankton net
			35.93°N	29.12°W	0715-0950	SAPS 3 deployment	
		8	35.73°N	29.38°W	1305-1405	CTD 8 (TIT)	Optics rig
302	29/10/05		35.06°N 34.90°N	30.76°W 31.06°W	2315 to 0050		Water collection for Expt 3 (Dose response)
							No stations due to poor weather
303	30/10/05				0200		Clocks back 1h (GMT-2)
		9	31.30°N	32.05°W	0400-0455	CTD 9 (SS)	Plankton net. Course 244°
		10	30.85°N	33.11°W	1100-1150	CTD 10 (TIT)	Optics rig

JD	Date	Station	Latitude	Longitude	Time (ship)	Activities	Notes
304	31/10/05	11	29.53°N	36.27N	0400-0448	CTD 11 (SS)	Plankton net
			29.51°N	36.27°W	0537-0828	SAPS 4 deployment	
		12	29.34°N	36.72°W	1104-1155	CTD 12 (TIT)	Optics rig
305	01/11/05		28.46°N 28.38°N	38.79°W 39.07°W	2306 to 0030		Water collection for Expt 4 (Bioassay)
			28.34°N	39.09°W	0038		A/C to 155°
		13	27.78°N	38.81°W	0400-0446	CTD 13 (SS)	Plankton net. Some *Trichodesmium*
		14	26.70°N	38.23°W	1100-1205	CTD 14 (TIT) to 500 m	Optics rig
306	02/11/05	15	23.96°N	36.78°W	0407-0459	CTD 15 (SS)	Plankton net. *Trichodesmium*
		16				CTD 16 (TIT) - aborted at 786 m	
		17	23.14°N	36.35°W	1126-1516	CTD 17 (TIT) to 4813m	Optics rig
307	03/11/05	18	21.05°N	35.28°W	0408-0522	CTD 18 (SS) - winch problem	Plankton net (x2). *Trichodesmium*
			21.06°N	35.29°W	0600-0845	SAPS 5 deployment	
		19	20.74°N	35.12°W	1107-1155	CTD 19 (TIT)	Optics rig
308	04/11/05	20	18.38°N	33.92°W	0404-0454	CTD 20 (SS)	Plankton net.
		21	17.48°N	33.47°W	1104-1148	CTD 21 (TIT)	Optics rig
309	05/11/05		15.84°N 15.55°N	32.67°W 32.51°W	2300 to 0100		Water collection for Expt 5 (Dose response)
		22	15.13°N	32.30°W	0405-0449	CTD 22 (SS)	Plankton net
		23	14.26°N	31.87°W	1105-1150	CTD 23 (TIT)	Optics rig
310	06/11/05				0200		Clocks forward 1h (GMT-1)
		24	12.07°N	30.80°W	0402-0447	CTD 24 (SS)	Plankton net (x2)
			12.07°N	30.82°W	0525-0807	SAPS 6 deployment	
		25	11.69°N	30.61°W	1106-1212	CTD 25 (TIT) to 500 m	Optics rig
311	07/11/05	26	09.43°N	29.52°W	0402-0440	CTD 26 (SS)	Plankton sample lost
		27	08.61°N	29.12°W	1101-1144	CTD 27 (TIT) + Wetlabs T/M	Optics rig
		28	07.95°N	28.80°W	1703-1739	CTD 28 (TIT)	Plankton net
312	08/11/05		07.22°N 07.00°N	28.46°W 28.35°W	2300 to 0030		Water collection for Expt 6 (Dose response)
		29	06.51°N	28.11°W	0401-0441	CTD 29 (SS) bottle firing problem	Plankton net cancelled
		30	05.46°N	27.61°W	1227-1405	CTD 30 (TIT)	Optics rig. Heavy rain
		31	04.95°N	27.36°W	1502-1542	CTD 31 (TIT)	Plankton net
313	09/11/05	32	03.48°N	26.66°W	0402-0444	CTD 32 (SS)	Plankton net (x2)
			03.50°N	26.65°W	0522-0730	SAPS 7 deployment	Optics rig at surface
		33	02.75°N	28.32°W	1301-1350	CTD 33 (TIT)	Optics rig
314	10/11/05	34	00.89°N	25.44°W	0403-0445	CTD 34 (SS)	Plankton net
		35	00.00°N	25.00°W	1119-1156	CTD 35 (TIT) on Equator	Optics rig. A/C to 180°
315	11/11/05	36	02.89°S	25.00°W	0400-0439	CTD 36 (SS) + Wetlabs T/M	Plankton net. T/M transferred to SS CTD
							3 Birthday parties
316	12/11/05		06.16°S 06.39°S	25.00°W 25.00°W	2300 to 0030		Water collection for Expt 7 (Dose response)

JD	Date	Station	Latitude	Longitude	Time (ship)	Activities	Notes
		37	08.28°S	25.00°W	1101-1141	CTD 37 (TIT)	Plankton net and Optics rig
							King Neptune aboard
317	13/11/05	38	11.00°S	25.00°W	0409-0448	CTD 38 (SS)	Plankton net (x2)
			10.99°S	24.99°W	0530-0735	SAPS 8 deployment	Optics rig at surface
		39	11.92°S	25.00°W	1305-1415	CTD 39 (TIT)	Optics rig
318	14/11/05	40	14.38°S	25.00°W	0404-0450	CTD 40 (SS)	Plankton net
		41	15.49°S	25.00°W	1101-1149	CTD 41 (TIT)	Optics rig
319	15/11/05		17.63°S 17.93°S	25.00°W 25.00°W	2300 to 0030		Water collection for Expt 8 (Bioassay)
		42	18.56°S	25.00°W	0400-0444	CTD 42 (SS)	Plankton net
		43	19.68°S	25.00°W	1105-1205	CTD 43 (TIT)	Optics rig. Kd 0.0325 m^{-1}.
					1214		A/C to 121° 1st APEX float released
320	16/11/05	44	21.13°S	22.44°W	0421-0500	CTD 44 (SS)	Plankton net (x2)
			21.12°S	22.43°W	0538-0747	SAPS 9 deployment	
		45				CTD 45 (TIT) aborted	Wire readout fault
		46	21.10°S	22.38°W	1108-1458	CTD 46 (TIT) to 5010 m	Optics rig (x2)
321	17/11/05	47	22.16°S	20.16°W	0407-0443	CTD 47 (SS)	Plankton net
		48	22.61°S	19.13°W	1105-1147	CTD 48 (TIT)	Optics rig. 2nd APEX float released
322	18/11/05		23.46°S 23.63°S	17.23°W 16.85°W	2345 to 0100		Water collection for Expt 9 (Bioassay). Clocks forward 1h (GMT).
		49	23.76°S	16.53°W	0401-0438	CTD 49 (SS)	Plankton net
323	19/11/05	50	26.14°S	11.05°W	1106-1147	CTD 50 (TIT)	Optics rig and Plankton net.
324	20/11/05	51	27.40°S	08.12°W	0400-0440	CTD 51 (SS)	Plankton net (x2)
			27.39°S	08.12°W	0517-0800	SAPS 10 deployment	
		52	27.79°S	07.22°W	1302-1402	CTD 52 (TIT)	Optics rig. Whale sighted. Calm
325	21/11/05		28.58°S 28.71°S	05.33°W 05.02°W	2345 to 0115		Water collection for Expt 10. (Bioassay). Clocks forward 1h (GMT+1).
		53	28.85°S	04.69°W	0404-0440	CTD 53 (SS)	Plankton net
		54	29.32°S	03.58°W	1100-1142	CTD 54 (TIT)	Optics rig. Albatrosses.
326	22/11/05	55	30.67°S	00.30°W	0400-0440	CTD 55 (SS)	Plankton net
		56	31.75°S	00.93°E	1103-1145	CTD 56 (TIT)	Optics rig. Whales and seal. Very calm
327	23/11/05	57	32.53°S	04.24°E	0402-0440	CTD 57 (SS)	Plankton net
		58	33.02°S	05.89°E	1231-1319	CTD 58 (TIT)	Optics rig.
					2400		A/C to 103°
328	24/11/05				0200		Clocks forward 1h (GMT+2)
		59	33.65°S	08.92°E	0404-0442	CTD 59 (SS)	Plankton net
			33.66°S	08.91°E	0520-0740	SAPS 11 deployment	
		60	33.78°S	09.59°E	1102-1153	CTD 60 (TIT)	Optics rig
		61	33.91°S	10.30°E	1527-1611	CTD 61 (SS)	Plankton net. Optics rig. Coccolithophores
							A/C to 111°
329	25/11/05	62	34.98°S	13.78°E	0900-0945	CTD 62 (SS)	Plankton net. Optics rig
332	28/11/05				0800		A/C to Arrive Port Elizabeth

Appendix 2. Underway sampling log and CTD stations

(a) Underway

Date	Time (GMT)	Cal. Day	CTD#/ UW id.	Decimal Latitude	Decimal Longitude	Sample #	PIC?	CC?	BSi?
11/14/2005	17:05	318	AA	48.3900°N	16.7014°W	7	Y	Y	Y
11/14/2005	19:58	318	AB	47.8193°N	16.8990°W	8	Y	Y	Y
11/15/2005	08:30	319	AC	45.6470°N	17.6288°W	17	Y	Y	Y
11/15/2005	12:00	319	AD	45.0112°N	17.8377°W	18	Y	Y	Y
11/15/2005	15:13	319	AE	44.5579°N	17.7834°W	19	Y	Y	Y
11/15/2005	19:03	319	AF	44.5534°N	18.1626°W	20	Y	Y	Y
11/15/2005	22:07	319	AG	44.5351°N	18.4365°W	21	Y	Y	Y
11/16/2005	01:14	320	AH	44.5335°N	18.7947°W	22	Y	Y	Y
11/16/2005	09:41	320	AI	44.1519°N	19.8843°W	31	Y	Y	Y
11/16/2005	13:46	320	AJ	44.0452°N	20.1724°W	32	Y	Y	Y
11/16/2005	20:40	320	AK	43.5483°N	20.6172°W	33	Y	Y	Y
11/17/2005	03:42	321	AL	42.5414°N	21.4067°W	34	Y	Y	Y
11/17/2005	07:45	321	AM	41.9658°N	21.8527°W	35	Y	Y	Y
11/17/2005	10:45	321	AN	41.5281°N	22.1882°W	36	Y	Y	Y
11/17/2005	13:46	321	AO	41.0277°N	22.5702°W	37	Y	Y	Y
11/17/2005	16:33	321	AP	40.5755°N	22.9124°W	38	Y	Y	Y
11/17/2005	20:04	321	AQ	40.0056°N	23.3414°W	39	Y	Y	Y
11/18/2005	04:16	322	AR	38.6638°N	24.2072°W	40	Y	Y	Y
11/18/2005	07:04	322	AS	38.1673°N	24.4829°W	41	Y	Y	Y
11/18/2005	10:10	322	AT	37.6124°N	24.7879°W	42	Y	Y	Y
11/18/2005	13:10	322	AU	37.4991°N	25.3516°W	43	Y	Y	Y
11/19/2005	10:51	323	AV	37.5082°N	26.0256°W	44	Y	Y	Y
11/19/2005	20:00	323	AW	37.3425°N	26.2605°W	46	Y	Y	Y
11/20/2005	13:10	324	AX	36.6477°N	27.2788°W	49	Y	Y	Y
11/20/2005	16:17	324	AY	36.7312°N	27.1537°W	50	Y	Y	Y
11/20/2005	19:54	324	AZ	36.9071°N	26.8842°W	51	Y	Y	Y
11/21/2005	03:14	325	BA	37.3138°N	26.2755°W	52	Y	Y	Y
11/21/2005	06:10	325	BB	37.4905°N	26.0105°W	53	Y	Y	Y
11/21/2005	09:00	325	BC	37.6375°N	25.7638°W	54	Y	Y	Y
10/27/2005	11:47	300	BD	37.5519°N	26.1674°W	55	Y	Y	Y
10/27/2005	19:00	300	BE	36.9706°N	27.1250°W	61	Y	Y	Y
10/27/2005	21:00	300	BF	36.7660°N	27.5147°W	62	Y	Y	Y
10/27/2005	23:38	300	BG	36.4967°N	28.0331°W	63	Y	Y	Y
10/28/2005	19:14	301	BH	35.4057°N	30.1067°W	78	Y	Y	Y
10/28/2005	22:06	301	BI	35.1527°N	30.5847°W	79	Y	Y	Y
10/29/2005	01:25	302	BJ	34.8687°N	31.1180°W	80	Y	Y	Y
10/29/2005	05:10	302	BK	34.6224°N	31.5935°W	81	Y	Y	Y
10/29/2005	09:14	302	BL	34.3866°N	32.0186°W	82	Y	Y	Y
10/29/2005	12:11	302	BM	34.2573°N	32.4117°W	83	Y	Y	Y
10/29/2005	15:10	302	BN	34.0121°N	32.5385°W	84	Y	Y	Y
10/29/2005	18:06	302	BO	33.4606°N	32.4461°W	85	Y	Y	Y
10/29/2005	21:13	302	BP	32.8793°N	32.3623°W	86			
10/30/2005	02:32	303	BQ	31.9034°N	32.1503°W	87			
10/30/2005	10:30	303	BR	31.0473°N	32.6227°W	95	Y	Y	Y
10/30/2005	17:14	303	BS	30.5711°N	33.7726°W	102	Y	Y	Y

Date	Time (GMT)	Cal. Day	CTD#/ UW id.	Decimal Latitude	Decimal Longitude	Sample #	PIC?	CC?	BSi?
10/30/2005	20:00	303	BT	30.3424°N	34.3224°W	103	Y	Y	Y
10/30/2005	22:50	303	BU	30.1124°N	34.8734°W	104	Y	Y	Y
10/31/2005	01:34	304	BV	29.8865°N	35.4169°W	105	Y	Y	Y
10/31/2005	17:06	304	BW	29.1020°N	37.2833°W	120	Y	Y	Y
10/31/2005	20:07	304	BX	28.8587°N	37.8595°W	121	Y	Y	Y
10/31/2005	23:19	304	BY	28.5998°N	38.4724°W	122	Y	Y	Y
11/1/2005	01:48	305	BZ	28.4042°N	38.7843°W	123	Y	Y	Y
11/1/2005	10:07	305	CA	27.2200°N	38.4991°W	132	Y	Y	Y
11/1/2005	17:14	305	CB	26.1534°N	37.9301°W	139	Y	Y	Y
11/1/2005	20:01	305	CC	25.6558°N	37.6619°W	140	Y	Y	Y
11/1/2005	22:41	305	CD	25.1858°N	37.4174°W	141	Y	Y	Y
11/2/2005	00:39	306	CE	24.8441°N	37.2377°W	142	Y	Y	Y
11/2/2005	10:27	306	CF	23.4245°N	36.4962°W	151	Y	Y	Y
11/2/2005	20:25	306	CG	22.6371°N	36.0882°W	158	Y	Y	Y
11/2/2005	22:51	306	CH	22.2194°N	35.8721°W	159	Y	Y	Y
11/3/2005	02:26	307	CI	21.6156°N	35.5618°W	160	Y	Y	Y
11/3/2005	17:04	307	CJ	20.2634°N	34.8719°W	174	Y	Y	Y
11/3/2005	20:14	307	CK	19.8134°N	34.6375°W	175	Y	Y	Y
11/3/2005	23:01	307	CL	19.3757°N	34.4219°W	176	Y	Y	Y
11/4/2005	10:04	308	CM	17.9223°N	33.6904°W	184	Y	Y	Y
11/4/2005	16:48	308	CN	17.0146°N	33.2369°W	191	Y	Y	Y
11/4/2005	19:54	308	CO	16.5869°N	33.0240°W	192	Y	Y	Y
11/4/2005	23:05	308	CP	16.1167°N	32.7906°W	193	Y	Y	Y
11/5/2005	02:04	309	CQ	15.6842°N	32.5762°W	194	Y	Y	Y
11/5/2005	10:57	309	CR	14.5473°N	32.0149°W	203	Y	Y	Y
11/5/2005	17:13	309	CS	13.7664°N	31.6306°W	210	Y	Y	Y
11/5/2005	19:56	309	CT	13.3708°N	31.4372°W	211	Y	Y	Y
11/5/2005	23:00	309	CU	12.9253°N	31.2190°W	212	Y	Y	Y
11/6/2005	16:20	310	CV	11.2560°N	30.4053°W	227	Y	Y	Y
11/6/2005	19:01	310	CW	10.8577°N	30.2120°W	228	Y	Y	Y
11/6/2005	22:40	310	CX	10.3243°N	29.9534°W	229	Y	Y	Y
11/7/2005	09:43	311	CY	8.9176°N	29.2735°W	238	Y	Y	Y
11/7/2005	15:54	311	CZ	8.2105°N	28.9333°W	245	Y	Y	Y
11/7/2005	22:23	311	DA	7.4470°N	28.5657°W	247	Y	Y	Y
11/8/2005	00:08	312	DB	7.2004°N	28.4473°W	248	Y	Y	Y
11/8/2005	08:48	312	DC	6.0602°N	27.9005°W	257	Y	Y	Y
11/8/2005	12:05	312	DD	5.6119°N	27.6766°W	258	Y	Y	Y
11/8/2005	22:15	312	DE	4.4376°N	27.1238°W	266	Y	Y	Y
11/8/2005	23:39	312	DF	4.3000°N	27.0390°W	267	Y	Y	Y
11/9/2005	11:36	313	DG	3.0922°N	26.4691°W	276	Y	Y	Y
11/9/2005	19:05	313	DH	2.2398°N	26.0751°W	283	Y	Y	Y
11/9/2005	22:03	313	DI	1.8332°N	25.8822°W	284	Y	Y	Y
11/9/2005	23:11	313	DJ	1.6813°N	25.8087°W	285	Y	Y	Y
11/10/2005	08:37	314	DK	0.5033°N	25.2475°W	294	Y	Y	Y
11/10/2005	15:58	314	DL	0.5316°S	25.0002°W	301	Y	Y	Y
11/10/2005	19:01	314	DM	1.0754°S	25.0000°W	302	Y	Y	Y
11/10/2005	23:07	314	DN	1.8213°S	24.9999°W	303	Y	Y	Y
11/11/2005	08:53	315	DO	3.4311°S	25.0007°W	312	Y	Y	Y
11/11/2005	11:55	315	DP	3.9841°S	25.0010°W	313	Y	Y	Y
11/11/2005	15:17	315	DQ	4.5865°S	25.0009°W	314	Y	Y	Y

Date	Time (GMT)	Cal. Day	CTD#/ UW id.	Decimal Latitude	Decimal Longitude	Sample #	PIC?	CC?	BSi?
11/11/2005	18:03	315	DR	5.0771°S	24.9999°W	315	Y	Y	Y
11/11/2005	22:25	315	DS	5.8458°S	25.0000°W	316	Y	Y	Y
11/12/2005	05:02	316	DT	7.0261°S	24.9998°W	317	Y	Y	Y
11/12/2005	08:04	316	DU	7.5842°S	24.9999°W	318	Y	Y	Y
11/12/2005	16:29	316	DV	8.8485°S	25.0000°W	325	Y	Y	Y
11/12/2005	19:14	316	DW	9.3095°S	25.0001°W	326	Y	Y	Y
11/13/2005	12:05	317	DX	11.5882°S	25.0001°W	334	Y	Y	Y
11/13/2005	17:58	317	DY	12.4053°S	25.0001°W	341	Y	Y	Y
11/13/2005	20:59	317	DZ	12.9663°S	24.9999°W	342	Y	Y	Y
11/13/2005	22:36	317	EA	13.2615°S	25.0000°W	343	Y	Y	Y
11/14/2005	01:42	318	EB	13.8095°S	25.0002°W	344	Y	Y	Y
11/14/2005	08:58	318	EC	14.9061°S	25.0002°W	352	Y	Y	Y
11/14/2005	15:37	318	ED	16.0121°S	24.9999°W	359	Y	Y	Y
11/14/2005	19:03	318	EE	16.6744°S	25.0001°W	360	Y	Y	Y
11/14/2005	23:16	318	EF	17.4913°S	25.0001°W	361	Y	Y	Y
11/15/2005	00:49	319	EG	17.7937°S	25.0000°W	362	Y	Y	Y
11/15/2005	08:52	319	EH	19.0997°S	24.9999°W	370	Y	Y	Y
11/15/2005	16:22	319	EI	19.9519°S	24.5257°W	377	Y	Y	Y
11/15/2005	19:02	319	EJ	20.2052°S	24.0793°W	378	Y	Y	Y
11/15/2005	22:51	319	EK	20.5666°S	23.4403°W	379	Y	Y	Y
11/16/2005	00:10	320	EL	20.6895°S	23.2231°W	380	Y	Y	Y
11/16/2005	19:28	320	EM	21.4122°S	21.8414°W	398	Y	Y	Y
11/16/2005	22:36	320	EN	21.6600°S	21.2865°W	399	Y	Y	Y
11/17/2005	01:40	321	EO	21.9040°S	20.7383°W	400	Y	Y	Y
11/17/2005	08:30	321	EP	22.3809°S	19.6637°W	408	Y	Y	Y
11/17/2005	16:11	321	EQ	22.8696°S	18.5573°W	415	Y	Y	Y
11/17/2005	19:03	321	ER	23.0892°S	18.0642°W	416	Y	Y	Y
11/17/2005	22:18	321	ES	23.3438°S	17.4863°W	417	Y	Y	Y
11/18/2005	07:44	322	ET	23.9737°S	16.0530°W	425	Y	Y	Y
11/18/2005	11:04	322	EU	24.2403°S	15.4446°W	426	Y	Y	Y
11/18/2005	14:06	322	EV	24.4902°S	14.8743°W	427	Y	Y	Y
11/18/2005	16:53	322	EW	24.7095°S	14.3700°W	428	Y	Y	Y
11/18/2005	19:42	322	EX	24.9328°S	13.8563°W	429	Y	Y	Y
11/18/2005	21:55	322	EY	25.1125°S	13.4434°W	430	Y	Y	Y
11/19/2005	04:00	323	EZ	25.5945°S	12.3312°W	431	Y	Y	Y
11/19/2005	07:00	323	FA	25.8967°S	11.6312°W	432	Y	Y	Y
11/19/2005	15:04	323	FB	26.3515°S	10.5749°W	439	Y	Y	Y
11/19/2005	18:18	323	FC	26.6130°S	9.9653°W	440	Y	Y	Y
11/19/2005	22:19	323	FD	26.9539°S	9.0032°W	441	Y	Y	Y
11/20/2005	00:56	324	FE	27.1617°S	8.6885°W	442	Y	Y	Y
11/20/2005	10:30	324	FF	27.5932°S	7.6692°W	451	Y	Y	Y
11/20/2005	17:14	324	FG	28.0366°S	6.6246°W	458	Y	Y	Y
11/20/2005	21:16	324	FH	28.3705°S	5.8343°W	459	Y	Y	Y
11/21/2005	01:00	325	FI	28.6930°S	5.0677°W	460	Y	Y	Y
11/21/2005	06:54	325	FJ	29.0912°S	4.1200°W	468	Y	Y	Y
11/21/2005	14:13	325	FK	29.6063°S	2.8826°W	475	Y	Y	Y
11/21/2005	17:04	325	FL	29.8528°S	2.2869°W	476	Y	Y	Y
11/21/2005	20:56	325	FM	30.1804°S	1.4953°W	477	Y	Y	Y
11/22/2005	01:00	326	FN	30.5230°S	0.6663°W	478	Y	Y	Y
11/22/2005	06:44	326	FO	30.9146°S	0.2844°E	487	Y	Y	Y

Date	Time (GMT)	Cal. Day	CTD#/ UW id.	Decimal Latitude	Decimal Longitude	Sample #	PIC?	CC?	BSi?
11/22/2005	14:43	326	FP	31.5115°S	1.7162°E	494	Y	Y	Y
11/22/2005	17:19	326	FQ	31.7213°S	2.2543°E	495	Y	Y	Y
11/22/2005	21:20	326	FR	32.0581°S	3.0828°E	496	Y	Y	Y
11/23/2005	00:50	327	FS	32.3527°S	3.8043°E	497	Y	Y	Y
11/23/2005	06:51	327	FT	32.7889°S	4.8896°E	506	Y	Y	Y
11/23/2005	09:15	327	FU	32.9227°S	5.4212°E	507	Y	Y	Y
11/23/2005	15:25	327	FV	33.1640°S	6.5619°E	515	Y	Y	Y
11/23/2005	18:18	327	FW	33.3013°S	7.2126°E	516	Y	Y	Y
11/23/2005	20:53	327	FX	33.4278°S	7.8113°E	517	Y	Y	Y
11/23/2005	23:46	327	FY	33.5590°S	8.4537°E	518	Y	Y	Y
11/24/2005	08:39	328	FZ	33.7270°S	9.5400°E	527	Y	Y	Y
11/24/2005	16:56	328	GA	34.0623°S	10.8779°E	544	Y	Y	Y
11/24/2005	20:24	328	GB	34.3065°S	11.6544°E	545	Y	Y	Y
11/24/2005	22:46	328	GC	34.4557°S	12.1300°E	546	Y	Y	Y
11/25/2005	01:36	329	GD	34.6345°S	12.7010°E	547	Y	Y	Y
11/25/2005	03:45	329	GE	34.7716°S	13.1366°E	548	Y	Y	Y
11/25/2005	12:52	329	GF	35.3529°S	15.0056°E	557	Y	Y	Y
11/25/2005	16:03	329	GG	35.5897°S	15.7701°E	558	Y	Y	Y
11/25/2005	20:51	329	GH	35.8248°S	16.9125°E	559	Y	Y	Y
11/26/2005	03:48	330	GI	35.5601°S	18.4554°E	560	Y	Y	Y

(b) CTD stations

Table 2. Stations (CTD cast number) sampled and measurement(s) made. Abbreviations used are BSi (particulate biogenic silica), PIC (particulate inorganic carbon), and CC (cell counts, coccolithophores and coccoliths). A blank indicates no sample taken.

Date	Time (GMT)	Cal. Day	CTD#/ UW id.	Decimal Latitude	Decimal Longitude	Sample #	Depth (m)	PIC?	CC?	BSi?
10/18/2005	10:52	291	1	48.9652°N	16.5042°W	1	1	Y	Y	Y
10/18/2005	10:52	291	1	48.9652°N	16.5042°W	2	10	Y		Y
10/18/2005	10:52	291	1	48.9652°N	16.5042°W	3	18	Y		Y
10/18/2005	10:52	291	1	48.9652°N	16.5042°W	4	33	Y		Y
10/18/2005	10:52	291	1	48.9652°N	16.5042°W	5	75	Y		Y
10/18/2005	10:52	291	1	48.9652°N	16.5042°W	6	113	Y		Y
10/19/2005	04:03	292	3	46.2329°N	17.4412°W	9	1	Y	Y	Y
10/19/2005	04:03	292	3	46.2329°N	17.4412°W	10	14	Y	Y	Y
10/19/2005	04:03	292	3	46.2329°N	17.4412°W	11	26	Y	Y	Y
10/19/2005	04:03	292	3	46.2329°N	17.4412°W	12	48	Y	Y	Y
10/19/2005	04:03	292	3	46.2329°N	17.4412°W	13	110	Y	Y	Y
10/19/2005	04:03	292	3	46.2329°N	17.4412°W	14	165	Y	Y	Y
10/19/2005	04:03	292	3	46.2329°N	17.4412°W	15	200	Y	Y	Y
10/19/2005	04:03	292	3	46.2329°N	17.4412°W	16	300	Y	Y	Y
10/19/2005	04:35	292	4	44.3485°N	19.3326°W	23	1	Y	Y	Y
10/19/2005	04:35	292	4	44.3485°N	19.3326°W	24	6	Y	Y	Y
10/19/2005	04:35	292	4	44.3485°N	19.3326°W	25	12	Y	Y	Y
10/19/2005	04:35	292	4	44.3485°N	19.3326°W	26	21	Y	Y	Y
10/19/2005	04:35	292	4	44.3485°N	19.3326°W	27	48	Y	Y	Y
10/19/2005	04:35	292	4	44.3485°N	19.3326°W	28	72	Y	Y	Y

Date	Time (GMT)	Cal. Day	CTD#/ UW id.	Decimal Latitude	Decimal Longitude	Sample #	Depth (m)	PIC?	CC?	BSi?
10/19/2005	04:35	292	4	44.3485°N	19.3326°W	29	200	Y	Y	Y
10/19/2005	04:35	292	4	44.3485°N	19.3326°W	30	300	Y	Y	Y
10/19/2005	14:30	292	6	37.3361°N	26.5032°W	56	S ML	Y	Y	Y
10/19/2005	14:30	292	6	37.3361°N	26.5032°W	57	D ML	Y		Y
10/19/2005	14:30	292	6	37.3361°N	26.5032°W	58	74	Y		Y
10/19/2005	14:30	292	6	37.3361°N	26.5032°W	59	150	Y		Y
10/19/2005	14:30	292	6	37.3361°N	26.5032°W	60	NT	Y	Y	Y
10/20/2005	06:00	293	7	35.9227°N	29.1311°W	64	1	Y	Y	Y
10/20/2005	06:00	293	7	35.9227°N	29.1311°W	65	12	Y	Y	Y
10/20/2005	06:00	293	7	35.9227°N	29.1311°W	66	23	Y	Y	Y
10/20/2005	06:00	293	7	35.9227°N	29.1311°W	67	41	Y	Y	Y
10/20/2005	06:00	293	7	35.9227°N	29.1311°W	68	86	Y	Y	Y
10/20/2005	06:00	293	7	35.9227°N	29.1311°W	69	141	Y	Y	Y
10/20/2005	06:00	293	7	35.9227°N	29.1311°W	70	200	Y	Y	Y
10/20/2005	06:00	293	7	35.9227°N	29.1311°W	71	300	Y	Y	Y
10/20/2005	14:05	293	8	35.7346°N	29.4834°W	72	1	Y	Y	Y
10/20/2005	14:05	293	8	35.7346°N	29.4834°W	73	10	Y		Y
10/20/2005	14:05	293	8	35.7346°N	29.4834°W	74	18	Y		Y
10/20/2005	14:05	293	8	35.7346°N	29.4834°W	75	33	Y		Y
10/20/2005	14:05	293	8	35.7346°N	29.4834°W	76	75	Y		Y
10/20/2005	14:05	293	8	35.7346°N	29.4834°W	77	150	Y		Y
10/21/2005	06:08	294	9	31.2980°N	32.0484°W	88	1	Y	Y	Y
10/21/2005	06:08	294	9	31.2980°N	32.0484°W	89	13	Y	Y	Y
10/21/2005	06:08	294	9	31.2980°N	32.0484°W	90	24	Y	Y	Y
10/21/2005	06:08	294	9	31.2980°N	32.0484°W	91	44	Y	Y	Y
10/21/2005	06:08	294	9	31.2980°N	32.0484°W	92	100	Y	Y	Y
10/21/2005	06:08	294	9	31.2980°N	32.0484°W	93	150	Y	Y	Y
10/21/2005	06:08	294	9	31.2980°N	32.0484°W	94	300	Y	Y	Y
10/21/2005	06:08	294	9	31.2980°N	32.0484°W	93A	200	Y	Y	Y
10/21/2005	14:06	294	10	30.8481°N	33.1127°W	96	2	Y	Y	Y
10/21/2005	14:06	294	10	30.8481°N	33.1127°W	97	14	Y		Y
10/21/2005	14:06	294	10	30.8481°N	33.1127°W	98	25	Y		Y
10/21/2005	14:06	294	10	30.8481°N	33.1127°W	99	46	Y		Y
10/21/2005	14:06	294	10	30.8481°N	33.1127°W	100	105	Y		Y
10/21/2005	14:06	294	10	30.8481°N	33.1127°W	101	160	Y		Y
10/22/2005	06:05	295	11	29.5262°N	36.2731°W	106	1	Y	Y	Y
10/22/2005	06:05	295	11	29.5262°N	36.2731°W	107	13	Y	Y	Y
10/22/2005	06:05	295	11	29.5262°N	36.2731°W	108	24	Y	Y	Y
10/22/2005	06:05	295	11	29.5262°N	36.2731°W	109	44	Y	Y	Y
10/22/2005	06:05	295	11	29.5262°N	36.2731°W	110	100	Y	Y	Y
10/22/2005	06:05	295	11	29.5262°N	36.2731°W	111	150	Y	Y	Y
10/22/2005	06:05	295	11	29.5262°N	36.2731°W	112	200	Y	Y	Y
10/22/2005	06:05	295	11	29.5262°N	36.2731°W	113	300	Y	Y	Y
10/22/2005	13:05	295	12	29.3334°N	36.7205°W	114	2	Y	Y	Y
10/22/2005	13:05	295	12	29.3334°N	36.7205°W	115	14	Y		Y
10/22/2005	13:05	295	12	29.3334°N	36.7205°W	116	26	Y		Y
10/22/2005	13:05	295	12	29.3334°N	36.7205°W	117	47	Y		Y
10/22/2005	13:05	295	12	29.3334°N	36.7205°W	118	108	Y		Y
10/22/2005	13:05	295	12	29.3334°N	36.7205°W	119	162	Y		Y

Date	Time (GMT)	Cal. Day	CTD#/ UW id.	Decimal Latitude	Decimal Longitude	Sample #	Depth (m)	PIC?	CC?	BSi?
10/23/2005	06:02	296	13	27.7661°N	38.8077°W	124	2	Y	Y	Y
10/23/2005	06:02	296	13	27.7661°N	38.8077°W	125	15	Y	Y	Y
10/23/2005	06:02	296	13	27.7661°N	38.8077°W	126	28	Y	Y	Y
10/23/2005	06:02	296	13	27.7661°N	38.8077°W	127	50	Y	Y	Y
10/23/2005	06:02	296	13	27.7661°N	38.8077°W	128	115	Y	Y	Y
10/23/2005	06:02	296	13	27.7661°N	38.8077°W	129	173	Y	Y	Y
10/23/2005	06:02	296	13	27.7661°N	38.8077°W	130	200	Y	Y	Y
10/23/2005	06:02	296	13	27.7661°N	38.8077°W	131	300	Y	Y	Y
10/23/2005	13:05	296	14	26.7037°N	38.2309°W	133	2	Y	Y	Y
10/23/2005	13:05	296	14	26.7037°N	38.2309°W	134	16	Y		Y
10/23/2005	13:05	296	14	26.7037°N	38.2309°W	135	30	Y		Y
10/23/2005	13:05	296	14	26.7037°N	38.2309°W	136	54	Y		Y
10/23/2005	13:05	296	14	26.7037°N	38.2309°W	137	125	Y		Y
10/23/2005	13:05	296	14	26.7037°N	38.2309°W	138	188	Y		Y
10/24/2005	06:07	297	15	23.9624°N	36.7778°W	143	2	Y	Y	Y
10/24/2005	06:07	297	15	23.9624°N	36.7778°W	144	14	Y	Y	Y
10/24/2005	06:07	297	15	23.9624°N	36.7778°W	145	26	Y	Y	Y
10/24/2005	06:07	297	15	23.9624°N	36.7778°W	146	47	Y	Y	Y
10/24/2005	06:07	297	15	23.9624°N	36.7778°W	147	105	Y	Y	Y
10/24/2005	06:07	297	15	23.9624°N	36.7778°W	148	161	Y	Y	Y
10/24/2005	06:07	297	15	23.9624°N	36.7778°W	149	200	Y	Y	Y
10/24/2005	06:07	297	15	23.9624°N	36.7778°W	150	300	Y	Y	Y
10/24/2005	13:26	297	17	23.1432°N	36.3494°W	152	2	Y	Y	Y
10/24/2005	13:26	297	17	23.1432°N	36.3494°W	153	14	Y		Y
10/24/2005	13:26	297	17	23.1432°N	36.3494°W	154	25	Y		Y
10/24/2005	13:26	297	17	23.1432°N	36.3494°W	155	46	Y		Y
10/24/2005	13:26	297	17	23.1432°N	36.3494°W	156	105	Y		Y
10/24/2005	13:26	297	17	23.1432°N	36.3494°W	157	160	Y		Y
10/25/2005	06:07	298	18	21.0541°N	35.2720°W	161	2	Y	Y	Y
10/25/2005	06:07	298	18	21.0541°N	35.2720°W	162	17	Y	Y	Y
10/25/2005	06:07	298	18	21.0541°N	35.2720°W	163	31	Y	Y	Y
10/25/2005	06:07	298	18	21.0541°N	35.2720°W	164	57	Y	Y	Y
10/25/2005	06:07	298	18	21.0541°N	35.2720°W	165	127	Y	Y	Y
10/25/2005	06:07	298	18	21.0541°N	35.2720°W	166	195	Y	Y	Y
10/25/2005	06:07	298	18	21.0541°N	35.2720°W	167	300	Y	Y	Y
10/25/2005	13:07	298	19	20.7441°N	35.1191°W	168	2	Y		Y
10/25/2005	13:07	298	19	20.7441°N	35.1191°W	169	16	Y	Y	Y
10/25/2005	13:07	298	19	20.7441°N	35.1191°W	170	30	Y		Y
10/25/2005	13:07	298	19	20.7441°N	35.1191°W	171	54	Y		Y
10/25/2005	13:07	298	19	20.7441°N	35.1191°W	172	125	Y		Y
10/25/2005	13:07	298	19	20.7441°N	35.1191°W	173	200	Y		Y
10/26/2005	06:04	299	20	18.3772°N	33.9145°W	177	2	Y	Y	Y
10/26/2005	06:04	299	20	18.3772°N	33.9145°W	178	16	Y	Y	Y
10/26/2005	06:04	299	20	18.3772°N	33.9145°W	179	30	Y	Y	Y
10/26/2005	06:04	299	20	18.3772°N	33.9145°W	180	54	Y	Y	Y
10/26/2005	06:04	299	20	18.3772°N	33.9145°W	181	114	Y	Y	Y
10/26/2005	06:04	299	20	18.3772°N	33.9145°W	182	186	Y	Y	Y
10/26/2005	06:04	299	20	18.3772°N	33.9145°W	183	300	Y	Y	Y
10/26/2005	13:06	299	21	17.4792°N	33.4644°W	185		Y	Y	Y

Date	Time (GMT)	Cal. Day	CTD#/ UW id.	Decimal Latitude	Decimal Longitude	Sample #	Depth (m)	PIC?	CC?	BSi?
10/26/2005	13:06	299	21	17.4792°N	33.4644°W	186		Y		Y
10/26/2005	13:06	299	21	17.4792°N	33.4644°W	187		Y		Y
10/26/2005	13:06	299	21	17.4792°N	33.4644°W	188		Y		Y
10/26/2005	13:06	299	21	17.4792°N	33.4644°W	189		Y		Y
10/26/2005	13:06	299	21	17.4792°N	33.4644°W	190		Y		Y
10/27/2005	06:05	300	22	15.1234°N	32.2957°W	195	2	Y	Y	Y
10/27/2005	06:05	300	22	15.1234°N	32.2957°W	196	11	Y	Y	Y
10/27/2005	06:05	300	22	15.1234°N	32.2957°W	197	20	Y	Y	Y
10/27/2005	06:05	300	22	15.1234°N	32.2957°W	198	37	Y	Y	Y
10/27/2005	06:05	300	22	15.1234°N	32.2957°W	199	84	Y	Y	Y
10/27/2005	06:05	300	22	15.1234°N	32.2957°W	200	126	Y	Y	Y
10/27/2005	06:05	300	22	15.1234°N	32.2957°W	201	200	Y	Y	Y
10/27/2005	06:05	300	22	15.1234°N	32.2957°W	202	300	Y	Y	Y
10/27/2005	13:05	300	23	14.2581°N	31.8670°W	204		Y	Y	Y
10/27/2005	13:05	300	23	14.2581°N	31.8670°W	205		Y		Y
10/27/2005	13:05	300	23	14.2581°N	31.8670°W	206		Y		Y
10/27/2005	13:05	300	23	14.2581°N	31.8670°W	207		Y		Y
10/27/2005	13:05	300	23	14.2581°N	31.8670°W	208		Y		Y
10/27/2005	13:05	300	23	14.2581°N	31.8670°W	209		Y		Y
10/28/2005	05:02	301	24	12.0705°N	30.8017°W	213	2	Y	Y	Y
10/28/2005	05:02	301	24	12.0705°N	30.8017°W	214	5	Y	Y	Y
10/28/2005	05:02	301	24	12.0705°N	30.8017°W	215	10	Y	Y	Y
10/28/2005	05:02	301	24	12.0705°N	30.8017°W	216	17	Y	Y	Y
10/28/2005	05:02	301	24	12.0705°N	30.8017°W	217	40	Y	Y	Y
10/28/2005	05:02	301	24	12.0705°N	30.8017°W	218	60	Y	Y	Y
10/28/2005	05:02	301	24	12.0705°N	30.8017°W	219	200	Y	Y	Y
10/28/2005	05:02	301	24	12.0705°N	30.8017°W	220	300	Y	Y	Y
10/28/2005	12:06	301	25	11.6905°N	30.6121°W	221	2	Y	Y	Y
10/28/2005	12:06	301	25	11.6905°N	30.6121°W	222	6	Y		Y
10/28/2005	12:06	301	25	11.6905°N	30.6121°W	223	11	Y		Y
10/28/2005	12:06	301	25	11.6905°N	30.6121°W	224	20	Y		Y
10/28/2005	12:06	301	25	11.6905°N	30.6121°W	225	45	Y		Y
10/28/2005	12:06	301	25	11.6905°N	30.6121°W	226	68	Y		Y
10/29/2005	05:02	302	26	9.4345°N	29.5181°W	230	2	Y	Y	Y
10/29/2005	05:02	302	26	9.4345°N	29.5181°W	231	6	Y	Y	Y
10/29/2005	05:02	302	26	9.4345°N	29.5181°W	232	14	Y	Y	Y
10/29/2005	05:02	302	26	9.4345°N	29.5181°W	233	26	Y	Y	Y
10/29/2005	05:02	302	26	9.4345°N	29.5181°W	234	60	Y	Y	Y
10/29/2005	05:02	302	26	9.4345°N	29.5181°W	235	90	Y	Y	Y
10/29/2005	05:02	302	26	9.4345°N	29.5181°W	236	200	Y	Y	Y
10/29/2005	05:02	302	26	9.4345°N	29.5181°W	237	300	Y	Y	Y
10/29/2005	12:02	302	27	8.6116°N	29.1212°W	239	2	Y	Y	Y
10/29/2005	12:02	302	27	8.6116°N	29.1212°W	240	7	Y		Y
10/29/2005	12:02	302	27	8.6116°N	29.1212°W	241	13	Y		Y
10/29/2005	12:02	302	27	8.6116°N	29.1212°W	242	24	Y		Y
10/29/2005	12:02	302	27	8.6116°N	29.1212°W	243	56	Y		Y
10/29/2005	12:02	302	27	8.6116°N	29.1212°W	244	84	Y		Y
10/29/2005	18:14	302	28	7.9454°N	28.7980°W	246	2	Y	Y	Y
10/30/2005	05:01	303	29	6.5066°N	28.1100°W	249		Y	Y	Y

Date	Time (GMT)	Cal. Day	CTD#/ UW id.	Decimal Latitude	Decimal Longitude	Sample #	Depth (m)	PIC?	CC?	BSi?
10/30/2005	05:01	303	29	6.5066°N	28.1100°W	250	6	Y	Y	Y
10/30/2005	05:01	303	29	6.5066°N	28.1100°W	251	12	Y	Y	Y
10/30/2005	05:01	303	29	6.5066°N	28.1100°W	252	21	Y	Y	Y
10/30/2005	05:01	303	29	6.5066°N	28.1100°W	253	48	Y	Y	Y
10/30/2005	05:01	303	29	6.5066°N	28.1100°W	254	72	Y	Y	Y
10/30/2005	05:01	303	29	6.5066°N	28.1100°W	255	200	Y	Y	Y
10/30/2005	05:01	303	29	6.5066°N	28.1100°W	256	300	Y	Y	Y
10/30/2005	13:27	303	30	5.4577°N	27.6060°W	259	2	Y	Y	Y
10/30/2005	13:27	303	30	5.4577°N	27.6060°W	260	8	Y		Y
10/30/2005	13:27	303	30	5.4577°N	27.6060°W	261	14	Y		Y
10/30/2005	13:27	303	30	5.4577°N	27.6060°W	262	26	Y		Y
10/30/2005	13:27	303	30	5.4577°N	27.6060°W	263	60	Y		Y
10/30/2005	13:27	303	30	5.4577°N	27.6060°W	264	90	Y		Y
10/30/2005	18:02	303	31	4.9489°N	27.3643°W	265	2	Y	Y	Y
10/31/2005	05:02	304	32	3.4757°N	26.6600°W	268	2	Y	Y	Y
10/31/2005	05:02	304	32	3.4757°N	26.6600°W	269	10	Y	Y	Y
10/31/2005	05:02	304	32	3.4757°N	26.6600°W	270	19	Y	Y	Y
10/31/2005	05:02	304	32	3.4757°N	26.6600°W	271	34	Y	Y	Y
10/31/2005	05:02	304	32	3.4757°N	26.6600°W	272	78	Y	Y	Y
10/31/2005	05:02	304	32	3.4757°N	26.6600°W	273	117	Y	Y	Y
10/31/2005	05:02	304	32	3.4757°N	26.6600°W	274	200	Y	Y	Y
10/31/2005	05:02	304	32	3.4757°N	26.6600°W	275	300	Y	Y	Y
10/31/2005	14:01	304	33	2.7527°N	26.3166°W	277	2	Y	Y	Y
10/31/2005	14:01	304	33	2.7527°N	26.3166°W	278	12	Y		Y
10/31/2005	14:01	304	33	2.7527°N	26.3166°W	279	22	Y		Y
10/31/2005	14:01	304	33	2.7527°N	26.3166°W	280	39	Y		Y
10/31/2005	14:01	304	33	2.7527°N	26.3166°W	281	90	Y		Y
10/31/2005	14:01	304	33	2.7527°N	26.3166°W	282	135	Y		Y
11/1/2005	05:03	305	34	0.8922°N	25.4353°W	286	2	Y	Y	Y
11/1/2005	05:03	305	34	0.8922°N	25.4353°W	287	11	Y	Y	Y
11/1/2005	05:03	305	34	0.8922°N	25.4353°W	288	20	Y	Y	Y
11/1/2005	05:03	305	34	0.8922°N	25.4353°W	289	37	Y	Y	Y
11/1/2005	05:03	305	34	0.8922°N	25.4353°W	290	85	Y	Y	Y
11/1/2005	05:03	305	34	0.8922°N	25.4353°W	291	128	Y	Y	Y
11/1/2005	05:03	305	34	0.8922°N	25.4353°W	292	200	Y	Y	Y
11/1/2005	05:03	305	34	0.8922°N	25.4353°W	293	300	Y	Y	Y
11/1/2005	12:19	305	35	0.0008°S	25.0038°W	295	2	Y	Y	Y
11/1/2005	12:19	305	35	0.0008°S	25.0038°W	296	10	Y		Y
11/1/2005	12:19	305	35	0.0008°S	25.0038°W	297	18	Y		Y
11/1/2005	12:19	305	35	0.0008°S	25.0038°W	298	23	Y		Y
11/1/2005	12:19	305	35	0.0008°S	25.0038°W	299	75	Y		Y
11/1/2005	12:19	305	35	0.0008°S	25.0038°W	300	113	Y		Y
11/2/2005	05:00	306	36	2.8874°S	24.9990°W	304	2	Y	Y	Y
11/2/2005	05:00	306	36	2.8874°S	24.9990°W	305	10	Y	Y	Y
11/2/2005	05:00	306	36	2.8874°S	24.9990°W	306	19	Y	Y	Y
11/2/2005	05:00	306	36	2.8874°S	24.9990°W	307	34	Y	Y	Y
11/2/2005	05:00	306	36	2.8874°S	24.9990°W	308	79	Y	Y	Y
11/2/2005	05:00	306	36	2.8874°S	24.9990°W	309	119	Y	Y	Y
11/2/2005	05:00	306	36	2.8874°S	24.9990°W	310	200	Y	Y	Y

Date	Time (GMT)	Cal. Day	CTD#/ UW id.	Decimal Latitude	Decimal Longitude	Sample #	Depth (m)	PIC?	CC?	BSi?
11/2/2005	05:00	306	36	2.8874°S	24.9990°W	311	300	Y	Y	Y
11/2/2005	12:01	306	37	8.2762°S	24.9958°W	319	2	Y	Y	Y
11/2/2005	12:01	306	37	8.2762°S	24.9958°W	320	14	Y		Y
11/2/2005	12:01	306	37	8.2762°S	24.9958°W	321	25	Y		Y
11/2/2005	12:01	306	37	8.2762°S	24.9958°W	322	45	Y		Y
11/2/2005	12:01	306	37	8.2762°S	24.9958°W	323	104	Y		Y
11/2/2005	12:01	306	37	8.2762°S	24.9958°W	324	156	Y		Y
11/3/2005	05:09	307	38	11.0008°S	24.9971°W	327	2	Y	Y	Y
11/3/2005	05:09	307	38	11.0008°S	24.9971°W	328	17	Y	Y	Y
11/3/2005	05:09	307	38	11.0008°S	24.9971°W	329	31	Y	Y	Y
11/3/2005	05:09	307	38	11.0008°S	24.9971°W	330		Y	Y	Y
11/3/2005	05:09	307	38	11.0008°S	24.9971°W	331		Y	Y	Y
11/3/2005	05:09	307	38	11.0008°S	24.9971°W	332	195	Y	Y	Y
11/3/2005	05:09	307	38	11.0008°S	24.9971°W	333	300	Y	Y	Y
11/3/2005	14:05	307	39	11.9230°S	24.9989°W	335	2	Y	Y	Y
11/3/2005	14:05	307	39	11.9230°S	24.9989°W	336	15	Y		Y
11/3/2005	14:05	307	39	11.9230°S	24.9989°W	337	27	Y		Y
11/3/2005	14:05	307	39	11.9230°S	24.9989°W	338	49	Y		Y
11/3/2005	14:05	307	39	11.9230°S	24.9989°W	339	113	Y		Y
11/3/2005	14:05	307	39	11.9230°S	24.9989°W	340	170	Y		Y
11/4/2005	05:04	308	40	14.3806°S	24.9963°W	345	2	Y	Y	Y
11/4/2005	05:04	308	40	14.3806°S	24.9963°W	346	19	Y	Y	Y
11/4/2005	05:04	308	40	14.3806°S	24.9963°W	347	35	Y	Y	Y
11/4/2005	05:04	308	40	14.3806°S	24.9963°W	348	64	Y	Y	Y
11/4/2005	05:04	308	40	14.3806°S	24.9963°W	349	147	Y	Y	Y
11/4/2005	05:04	308	40	14.3806°S	24.9963°W	350	221	Y	Y	Y
11/4/2005	05:04	308	40	14.3806°S	24.9963°W	351	300	Y	Y	Y
11/4/2005	12:03	308	41	15.4870°S	24.9953°W	353	2	Y	Y	Y
11/4/2005	12:03	308	41	15.4870°S	24.9953°W	354	18	Y		Y
11/4/2005	12:03	308	41	15.4870°S	24.9953°W	355	33	Y		Y
11/4/2005	12:03	308	41	15.4870°S	24.9953°W	356	60	Y		Y
11/4/2005	12:03	308	41	15.4870°S	24.9953°W	357	138	Y		Y
11/4/2005	12:03	308	41	15.4870°S	24.9953°W	358	207	Y		Y
11/5/2005	05:00	309	42	18.5597°S	24.9989°W	363	2	Y	Y	Y
11/5/2005	05:00	309	42	18.5597°S	24.9989°W	364	22	Y	Y	Y
11/5/2005	05:00	309	42	18.5597°S	24.9989°W	365	40	Y	Y	Y
11/5/2005	05:00	309	42	18.5597°S	24.9989°W	366	72	Y	Y	Y
11/5/2005	05:00	309	42	18.5597°S	24.9989°W	367	166	Y	Y	Y
11/5/2005	05:00	309	42	18.5597°S	24.9989°W	368	249	Y	Y	Y
11/5/2005	05:00	309	42	18.5597°S	24.9989°W	369	300	Y	Y	Y
11/5/2005	12:05	309	43	19.6820°S	25.0036°W	371	2	Y	Y	Y
11/5/2005	12:05	309	43	19.6820°S	25.0036°W	372	22	Y		Y
11/5/2005	12:05	309	43	19.6820°S	25.0036°W	373	41	Y		Y
11/5/2005	12:05	309	43	19.6820°S	25.0036°W	374	74	Y		Y
11/5/2005	12:05	309	43	19.6820°S	25.0036°W	375	170	Y		Y
11/5/2005	12:05	309	43	19.6820°S	25.0036°W	376	255	Y		Y
11/6/2005	05:21	310	44	21.1286°S	22.4368°W	381	2	Y	Y	Y
11/6/2005	05:21	310	44	21.1286°S	22.4368°W	382	18	Y	Y	Y
11/6/2005	05:21	310	44	21.1286°S	22.4368°W	383	33	Y	Y	Y

Date	Time (GMT)	Cal. Day	CTD#/ UW id.	Decimal Latitude	Decimal Longitude	Sample #	Depth (m)	PIC?	CC?	BSi?
11/6/2005	05:21	310	44	21.1286°S	22.4368°W	384	60	Y	Y	Y
11/6/2005	05:21	310	44	21.1286°S	22.4368°W	385	139	Y	Y	Y
11/6/2005	05:21	310	44	21.1286°S	22.4368°W	386	209	Y	Y	Y
11/6/2005	05:21	310	44	21.1286°S	22.4368°W	387	300	Y	Y	Y
11/6/2005	12:08	310	46	21.1049°S	22.3820°W	388	2	Y	Y	Y
11/6/2005	12:08	310	46	21.1049°S	22.3820°W	389	23			
11/6/2005	12:08	310	46	21.1049°S	22.3820°W	390	42	Y		Y
11/6/2005	12:08	310	46	21.1049°S	22.3820°W	391	76	Y		Y
11/6/2005	12:08	310	46	21.1049°S	22.3820°W	392	174	Y		Y
11/6/2005	12:08	310	46	21.1049°S	22.3820°W	393	261	Y		Y
11/6/2005	12:08	310	46	21.1049°S	22.3820°W	394	500	Y		Y
11/6/2005	12:08	310	46	21.1049°S	22.3820°W	395	1000	Y		Y
11/6/2005	12:08	310	46	21.1049°S	22.3820°W	396	3500	Y		Y
11/6/2005	12:08	310	46	21.1049°S	22.3820°W	397	5010	Y		Y
11/7/2005	05:05	311	47	22.1589°S	20.1593°W	401	2	Y	Y	Y
11/7/2005	05:05	311	47	22.1589°S	20.1593°W	402	20	Y	Y	Y
11/7/2005	05:05	311	47	22.1589°S	20.1593°W	403	36	Y	Y	Y
11/7/2005	05:05	311	47	22.1589°S	20.1593°W	404	65	Y	Y	Y
11/7/2005	05:05	311	47	22.1589°S	20.1593°W	405	150	Y	Y	Y
11/7/2005	05:05	311	47	22.1589°S	20.1593°W	406	225	Y	Y	Y
11/7/2005	05:05	311	47	22.1589°S	20.1593°W	407	300	Y	Y	Y
11/7/2005	12:05	311	48	22.6115°S	19.1282°W	409	2	Y	Y	Y
11/7/2005	12:05	311	48	22.6115°S	19.1282°W	410	18	Y		Y
11/7/2005	12:05	311	48	22.6115°S	19.1282°W	411	32	Y		Y
11/7/2005	12:05	311	48	22.6115°S	19.1282°W	412	58	Y		Y
11/7/2005	12:05	311	48	22.6115°S	19.1282°W	413	134	Y		Y
11/7/2005	12:05	311	48	22.6115°S	19.1282°W	414	200	Y		Y
11/8/2005	04:02	312	49	23.7627°S	16.5270°W	418	2	Y	Y	Y
11/8/2005	04:02	312	49	23.7627°S	16.5270°W	419	21	Y	Y	Y
11/8/2005	04:02	312	49	23.7627°S	16.5270°W	420	39	Y	Y	Y
11/8/2005	04:02	312	49	23.7627°S	16.5270°W	421	71	Y	Y	Y
11/8/2005	04:02	312	49	23.7627°S	16.5270°W	422	164	Y	Y	Y
11/8/2005	04:02	312	49	23.7627°S	16.5270°W	423	246	Y	Y	Y
11/8/2005	04:02	312	49	23.7627°S	16.5270°W	424	300	Y	Y	Y
11/8/2005	11:00	312	50	26.1401°S	11.0520°W	433	2	Y	Y	Y
11/8/2005	11:00	312	50	26.1401°S	11.0520°W	434	17	Y		Y
11/8/2005	11:00	312	50	26.1401°S	11.0520°W	435	30	Y		Y
11/8/2005	11:00	312	50	26.1401°S	11.0520°W	436	55	Y		Y
11/8/2005	11:00	312	50	26.1401°S	11.0520°W	437	127	Y		Y
11/8/2005	11:00	312	50	26.1401°S	11.0520°W	438	190	Y		Y
11/9/2005	04:02	313	51	27.3974°S	8.1175°W	443	2	Y	Y	Y
11/9/2005	04:02	313	51	27.3974°S	8.1175°W	444	13	Y	Y	Y
11/9/2005	04:02	313	51	27.3974°S	8.1175°W	445	23	Y	Y	Y
11/9/2005	04:02	313	51	27.3974°S	8.1175°W	446	43	Y	Y	Y
11/9/2005	04:02	313	51	27.3974°S	8.1175°W	447	98	Y	Y	Y
11/9/2005	04:02	313	51	27.3974°S	8.1175°W	448	147	Y	Y	Y
11/9/2005	04:02	313	51	27.3974°S	8.1175°W	449	200	Y	Y	Y
11/9/2005	04:02	313	51	27.3974°S	8.1175°W	450	300	Y	Y	Y
11/9/2005	13:00	313	52	27.7866°S	7.2158°W	452	2	Y	Y	Y

Date	Time (GMT)	Cal. Day	CTD#/ UW id.	Decimal Latitude	Decimal Longitude	Sample #	Depth (m)	PIC?	CC?	BSi?
11/9/2005	13:00	313	52	27.7866°S	7.2158°W	453	13	Y		Y
11/9/2005	13:00	313	52	27.7866°S	7.2158°W	454	23	Y		Y
11/9/2005	13:00	313	52	27.7866°S	7.2158°W	455	42	Y		Y
11/9/2005	13:00	313	52	27.7866°S	7.2158°W	456	97	Y		Y
11/9/2005	13:00	313	52	27.7866°S	7.2158°W	457	150	Y		Y
11/10/2005	03:04	314	53	28.8553°S	4.6872°W	461	2	Y	Y	Y
11/10/2005	03:04	314	53	28.8553°S	4.6872°W	462	17	Y	Y	Y
11/10/2005	03:04	314	53	28.8553°S	4.6872°W	463	31	Y	Y	Y
11/10/2005	03:04	314	53	28.8553°S	4.6872°W	464	56	Y	Y	Y
11/10/2005	03:04	314	53	28.8553°S	4.6872°W	465	128	Y	Y	Y
11/10/2005	03:04	314	53	28.8553°S	4.6872°W	466	192	Y	Y	Y
11/10/2005	03:04	314	53	28.8553°S	4.6872°W	467	300	Y	Y	Y
11/10/2005	10:00	314	54	29.3198°S	3.5788°W	469	2	Y	Y	Y
11/10/2005	10:00	314	54	29.3198°S	3.5788°W	470	17	Y		Y
11/10/2005	10:00	314	54	29.3198°S	3.5788°W	471	31	Y		Y
11/10/2005	10:00	314	54	29.3198°S	3.5788°W	472	56	Y		Y
11/10/2005	10:00	314	54	29.3198°S	3.5788°W	473	128	Y		Y
11/10/2005	10:00	314	54	29.3198°S	3.5788°W	474	192	Y		Y
11/11/2005	03:00	315	55	30.6727°S	0.2990°W	479	2	Y	Y	Y
11/11/2005	03:00	315	55	30.6727°S	0.2990°W	480	8	Y	Y	Y
11/11/2005	03:00	315	55	30.6727°S	0.2990°W	481	15	Y	Y	Y
11/11/2005	03:00	315	55	30.6727°S	0.2990°W	482	28	Y	Y	Y
11/11/2005	03:00	315	55	30.6727°S	0.2990°W	483	64	Y	Y	Y
11/11/2005	03:00	315	55	30.6727°S	0.2990°W	484	96	Y	Y	Y
11/11/2005	03:00	315	55	30.6727°S	0.2990°W	485	200	Y	Y	Y
11/11/2005	03:00	315	55	30.6727°S	0.2990°W	486	300	Y	Y	Y
11/11/2005	10:04	315	56	31.1726°S	0.9256°E	488	2	Y	Y	Y
11/11/2005	10:04	315	56	31.1726°S	0.9256°E	489	8	Y	Y	Y
11/11/2005	10:04	315	56	31.1726°S	0.9256°E	490	15	Y	Y	Y
11/11/2005	10:04	315	56	31.1726°S	0.9256°E	491	28	Y	Y	Y
11/11/2005	10:04	315	56	31.1726°S	0.9256°E	492	64	Y	Y	Y
11/11/2005	10:04	315	56	31.1726°S	0.9256°E	493	96	Y	Y	Y
11/12/2005	03:02	316	57	32.5300°S	4.2374°E	498	2	Y	Y	Y
11/12/2005	03:02	316	57	32.5300°S	4.2374°E	499	8	Y	Y	Y
11/12/2005	03:02	316	57	32.5300°S	4.2374°E	500	15	Y	Y	Y
11/12/2005	03:02	316	57	32.5300°S	4.2374°E	501	28	Y	Y	Y
11/12/2005	03:02	316	57	32.5300°S	4.2374°E	502	64	Y	Y	Y
11/12/2005	03:02	316	57	32.5300°S	4.2374°E	503	96	Y	Y	Y
11/12/2005	03:02	316	57	32.5300°S	4.2374°E	504	200			
11/12/2005	03:02	316	57	32.5300°S	4.2374°E	505	300	Y	Y	Y
11/12/2005	11:31	316	58	33.0215°S	5.8906°E	508	2	Y	Y	Y
11/12/2005	11:31	316	58	33.0215°S	5.8906°E	509	8	Y		Y
11/12/2005	11:31	316	58	33.0215°S	5.8906°E	510	14	Y		Y
11/12/2005	11:31	316	58	33.0215°S	5.8906°E	511	25	Y		Y
11/12/2005	11:31	316	58	33.0215°S	5.8906°E	512	50	Y	Y	Y
11/12/2005	11:31	316	58	33.0215°S	5.8906°E	513	58	Y		Y
11/12/2005	11:31	316	58	33.0215°S	5.8906°E	514	100	Y		Y
11/13/2005	02:03	317	59	33.6467°S	8.9187°E	519				
11/13/2005	02:03	317	59	33.6467°S	8.9187°E	520		Y	Y	Y

Date	Time (GMT)	Cal. Day	CTD#/ UW id.	Decimal Latitude	Decimal Longitude	Sample #	Depth (m)	PIC?	CC?	BSi?
11/13/2005	02:03	317	59	33.6467°S	8.9187°E	521		Y	Y	Y
11/13/2005	02:03	317	59	33.6467°S	8.9187°E	522		Y	Y	Y
11/13/2005	02:03	317	59	33.6467°S	8.9187°E	523		Y	Y	Y
11/13/2005	02:03	317	59	33.6467°S	8.9187°E	524		Y	Y	Y
11/13/2005	02:03	317	59	33.6467°S	8.9187°E	525		Y	Y	Y
11/13/2005	02:03	317	59	33.6467°S	8.9187°E	526		Y	Y	Y
11/13/2005	09:02	317	60	33.7806°S	9.5850°E	528	2	Y	Y	Y
11/13/2005	09:02	317	60	33.7806°S	9.5850°E	529	4	Y		Y
11/13/2005	09:02	317	60	33.7806°S	9.5850°E	530	8	Y		Y
11/13/2005	09:02	317	60	33.7806°S	9.5850°E	531	14	Y		Y
11/13/2005	09:02	317	60	33.7806°S	9.5850°E	532	33	Y		Y
11/13/2005	09:02	317	60	33.7806°S	9.5850°E	533	50	Y		Y
11/13/2005	13:28	317	61	33.9065°S	10.3032°E	534	2	Y	Y	Y
11/13/2005	13:28	317	61	33.9065°S	10.3032°E	535	5	Y	Y	Y
11/13/2005	13:28	317	61	33.9065°S	10.3032°E	536	10	Y	Y	Y
11/13/2005	13:28	317	61	33.9065°S	10.3032°E	537	15	Y	Y	Y
11/13/2005	13:28	317	61	33.9065°S	10.3032°E	538	20	Y	Y	Y
11/13/2005	13:28	317	61	33.9065°S	10.3032°E	539	25	Y	Y	Y
11/13/2005	13:28	317	61	33.9065°S	10.3032°E	540	27	Y	Y	Y
11/13/2005	13:28	317	61	33.9065°S	10.3032°E	541	100	Y	Y	Y
11/13/2005	13:28	317	61	33.9065°S	10.3032°E	542	200	Y	Y	Y
11/13/2005	13:28	317	61	33.9065°S	10.3032°E	543	300	Y	Y	Y
11/14/2005	07:00	318	62	34.9845°S	13.7784°E	549	2	Y	Y	Y
11/14/2005	07:00	318	62	34.9845°S	13.7784°E	550	5	Y	Y	Y
11/14/2005	07:00	318	62	34.9845°S	13.7784°E	551	9	Y	Y	Y
11/14/2005	07:00	318	62	34.9845°S	13.7784°E	552	18	Y	Y	Y
11/14/2005	07:00	318	62	34.9845°S	13.7784°E	553	38	Y	Y	Y
11/14/2005	07:00	318	62	34.9845°S	13.7784°E	554	57	Y	Y	Y
11/14/2005	07:00	318	62	34.9845°S	13.7784°E	555	200	Y	Y	Y
11/14/2005	07:00	318	62	34.9845°S	13.7784°E	556	300	Y	Y	Y

Appendix 3. Discrete samples taken from Niskin bottles and underway system for calibration of O_2/Ar and N_2/Ar ratios as well as $^{17}O/^{16}O$ and $^{18}O/^{16}O$ isotope ratio measurements of dissolved O_2

Flask	Cast	Niskin	Date	Time	Latitude	Longitude
9	3	23	19/10/05	04:47:22	46°14'N	17°27'W
15	4	23	20/10/05	05:14:30	44°22'N	19°19'W
66	7	23	28/10/05	06:49:16	35°55'N	29°08'W
85	9	23	30/10/05	06:46:41	31°18'N	32°20'W
91	11	23	31/10/05	06:48:50	29°31'N	36°16'W
106	13	23	01/11/05	06:47:06	27°47'N	38°49'W
116	15	23	02/11/05	06:53:58	23°58'N	36°47'W
806	18	21	03/11/05	07:16:09	21°03'N	35°17'W
814	20	23	04/11/05	06:50:06	18°23'N	33°55'W
828	22	23	05/11/05	06:46:08	15°08'N	32°18'W
838	24	23	06/11/05	05:47:30	12°04'N	30°48'W
880	32	23	09/11/05	05:36:40	03°29'N	26°40'W
891	34	23	10/11/05	05:37:43	00°54'N	25°26'W
919	38	23	13/11/05	05:41:56	11°00'S	25°00'W
953	44	23	16/11/05	05:54:37	21°08'S	22°26'W
980	49	23	18/11/05	04:33:25	23°46'S	16°32'W
1004	51	23	20/11/05	04:34:35	27°24'S	08°07'W
1030	55	23	22/11/05	03:35:55	30°40'S	00°18'W
1031	55	13	22/11/05	03:24:29	30°40'S	00°18'W
1033	55	1	22/11/05	03:09:38	30°40'S	00°18'W
1061	59	23	24/11/05	02:35:32	33°39'S	08°55'E
1	underway		18/10/05	06:46:00	49°17'N	15°31'W
2	underway		18/10/05	13:47:00	48°56'N	16°29'W
7	underway		18/10/05	19:47:30	47°51'N	16°53'W
8	underway		19/10/05	04:40:00	46°14'N	17°27'W
11	underway		19/10/05	13:09:30	44°51'N	17°54'W
12	underway		19/10/05	21:42:00	44°32'N	18°23'W
13	underway		20/10/05	05:02:00	44°21'N	19°19'W
17	underway		20/10/05	13:29:30	44°03'N	20°10'W
18	underway		20/10/05	22:20:30	43°18'N	20°49'W
22	underway		21/10/05	06:04:30	42°13'N	21°40'W
27	underway		21/10/05	12:02:30	41°19'N	22°21'W
28	underway		21/10/05	17:26:30	40°26'N	23°01'W
29	underway		21/10/05	21:46:00	39°45'N	23°32'W
33	underway		22/10/05	06:14:30	38°19'N	24°24'W
34	underway		22/10/05	13:30:00	37°30'N	25°22'W
40	underway		23/10/05	12:44:00	37°30'N	26°04'W
41	underway		23/10/05	12:58:00	37°30'N	26°04'W
42	underway		23/10/05	17:28:30	37°29'N	26°00'W
45	underway		23/10/05	21:38:00	37°12'N	26°29'W
46	underway		24/10/05	06:16:00	36°40'N	27°15'W
47	underway		24/10/05	06:50:00	36°40'N	27°15'W
49	underway		24/10/05	11:25:00	36°40'N	27°16'W
52	underway		24/10/05	17:41:30	36°48'N	27°03'W
54	underway		24/10/05	22:16:00	37°02'N	26°42'W

Flask	Cast	Niskin	Date	Time	Latitude	Longitude
57	underway		25/10/05	07:21:30	37°33'N	25°54'W
63	underway		27/10/05	21:56:00	36°40'N	26°42'W
65	underway		28/10/05	06:35:00	35°55'N	29°08'W
67	underway		28/10/05	22:21:00	35°08'N	30°38'W
68	underway		29/10/05	05:12:30	34°37'N	31°36'W
71	underway		29/10/05	13:44:30	34°15'N	32°34'W
73	underway		29/10/05	18:06:30	33°28'N	32°27'W
74	underway		29/10/05	22:09:30	32°43'N	32°20'W
84	underway		30/10/05	06:38:00	31°18'N	32°03'W
86	underway		30/10/05	19:19:00	30°24'N	34°11'W
88	underway		30/10/05	23:12:00	30°05'N	34°57'W
89	underway		31/10/05	06:14:30	29°32'N	36°16'W
94	underway		31/10/05	13:23:00	29°20'N	36°43'W
98	underway		31/10/05	21:31:30	28°45'N	38°08'W
103	underway		01/11/05	06:34:00	27°47'N	38°49'W
108	underway		01/11/05	12:36:53	26°46'N	38°15'W
110	underway		01/11/05	21:44:00	25°21'N	37°30'W
113	underway		02/11/05	06:19:30	23°58'N	36°47'W
117	underway		02/11/05	12:18:30	23°09'N	36°21'W
119	underway		02/11/05	23:51:50	22°03'N	35°47'W
805	underway		03/11/05	06:28:10	21°03'N	35°16'W
808	underway		03/11/05	18:53:10	19°59'N	34°44'W
811	underway		03/11/05	22:40:30	19°26'N	34°27'W
813	underway		04/11/05	06:25:30	18°23'N	33°55'W
815	underway		04/11/05	13:37:40	17°29'N	33°28'W
822	underway		04/11/05	18:10:30	16°48'N	33°08'W
825	underway		04/11/05	21:41:40	16°19'N	32°53'W
827	underway		05/11/05	06:14:40	15°08'N	32°18'W
830	underway		05/11/05	17:04:30	13°47'N	31°39'W
831	underway		05/11/05	22:18:10	13°02'N	31°16'W
834	underway		06/11/05	05:17:30	12°04'N	30°48'W
842	underway		06/11/05	13:22:00	11°41'N	30°37'W
843	underway		06/11/05	21:49:10	10°27'N	30°01'W
848	underway		07/11/05	05:19:00	09°26'N	29°31'W
849	underway		07/11/05	10:55:30	08°45'N	29°11'W
854	underway		07/11/05	17:21:40	08°11'N	28°50'W
856	underway		07/11/05	21:41:10	07°33'N	28°37'W
863	underway		08/11/05	05:19:50	06°31'N	28°07'W
872	underway		08/11/05	12:09:00	05°36'N	27°40'W
876	underway		08/11/05	17:35:00	04°59'N	27°23'W
878	underway		08/11/05	21:37:30	04°32'N	27°10'W
879	underway		09/11/05	05:24:00	03°29'N	26°40'W
883	underway		09/11/05	10:41:20	03°13'N	26°31'W
886	underway		09/11/05	14:40:30	02°46'N	26°19'W
889	underway		09/11/05	21:43:00	01°53'N	25°54'W
890	underway		10/11/05	05:20:00	00°54'N	25°26'W
893	underway		10/11/05	12:23:40	00°00'N	25°00'W
894	underway		10/11/05	17:03:30	00°43'S	25°00'W
896	underway		10/11/05	22:24:50	01°41'S	25°00'W
897	underway		11/11/05	05:19:50	02°53'S	25°00'W
899	underway		11/11/05	11:16:30	03°52'S	25°00'W

Flask	Cast	Niskin	Date	Time	Latitude	Longitude
900B	underway		11/11/05	17:05:00	04°54'S	25°00'W
902	underway		11/11/05	22:02:20	05°47'S	25°00'W
904	underway		12/11/05	04:59:00	07°01'S	25°00'W
907	underway		12/11/05	12:16:00	08°16'S	25°00'W
909	underway		12/11/05	17:15:00	08°59'S	25°00'W
910	underway		12/11/05	21:40:30	09°45'S	25°00'W
912	underway		13/11/05	05:15:50	11°00'S	25°00'W
920	underway		13/11/05	11:08:20	11°25'S	25°00'W
921	underway		13/11/05	18:07:30	12°26'S	25°00'W
924	underway		13/11/05	21:16:20	13°01'S	25°00'W
926	underway		14/11/05	05:16:30	14°23'S	25°00'W
928	underway		14/11/05	12:03:00	15°29'S	25°00'W
929	underway		14/11/05	17:05:00	16°18'S	25°00'W
930	underway		14/11/05	22:48:10	17°24'S	25°00'W
933	underway		15/11/05	05:16:30	18°33'S	25°00'W
934	underway		15/11/05	12:27:30	19°41'S	25°00'W
936	underway		15/11/05	17:14:00	20°21'S	24°23'W
937	underway		15/11/05	21:43:30	20°28'S	23°38'W
943	underway		16/11/05	05:18:40	21°08'S	22°26'W
954	underway		16/11/05	12:03:00	21°06'S	22°23'W
959	underway		16/11/05	21:55:00	21°36'S	22°25'W
962	underway		17/11/05	05:23:00	22°09'S	20°09'W
970	underway		17/11/05	12:33:10	22°36'S	19°08'W
972	underway		17/11/05	17:39:30	22°59'S	18°18'W
974	underway		17/11/05	21:53:40	23°19'S	17°34'W
977	underway		18/11/05	04:19:00	23°46'S	16°32'W
981	underway		18/11/05	10:08:20	24°10'S	15°37'W
992	underway		18/11/05	15:38:00	24°37'S	14°36'W
993	underway		18/11/05	21:19:20	25°04'S	13°33'W
995	underway		19/11/05	03:56:30	25°35'S	12°20'W
997	underway		19/11/05	11:35:00	26°08'S	11°03'W
999	underway		19/11/05	21:30:30	26°53'S	09°21'W
1003	underway		20/11/05	04:22:00	27°24'S	08°07'W
1008	underway		20/11/05	14:02:20	27°47'S	07°14'W
1012	underway		20/11/05	20:50:20	28°20'S	05°55'W
1013	underway		21/11/05	03:14:20	28°51'S	04°41'W
1016	underway		21/11/05	10:34:40	29°19'S	03°35'W
1019	underway		21/11/05	20:43:00	30°10'S	01°32'W
1024	underway		22/11/05	03:16:30	30°40'S	00°18'W
1036	underway		22/11/05	10:17:00	31°10'S	00°55'E
1041	underway		22/11/05	20:03:30	31°57'S	02°49'E
1043	underway		23/11/05	03:15:10	32°32'S	04°14'E
1046	underway		23/11/05	11:42:30	33°01'S	05°53'E
1057	underway		23/11/05	20:08:30	33°23'S	07°38'E
1060	underway		24/11/05	02:10:40	33°39'S	08°55'E
1069	underway		24/11/05	09:03:40	33°47'S	09°35'E
1073	underway		24/11/05	13:58:00	33°54'S	10°18'E
1076	underway		25/11/05	00:31:10	34°34'S	12°29'E
1080	underway		25/11/05	07:36:00	34°59'S	13°46'E
1086	underway		25/11/05	13:13:30	35°23'S	15°06'E