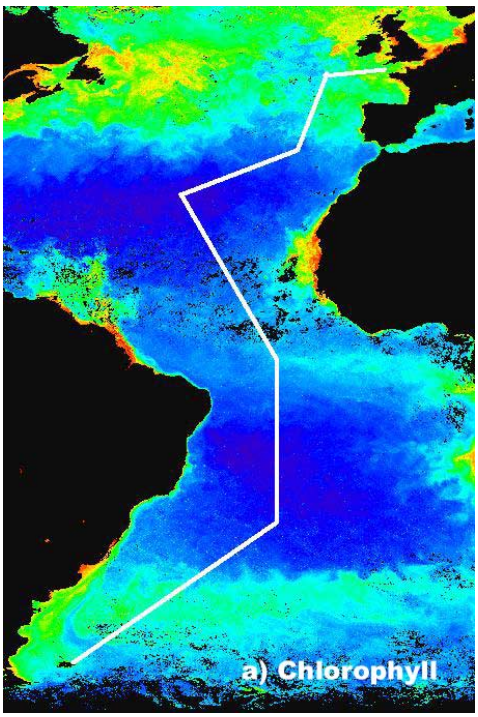
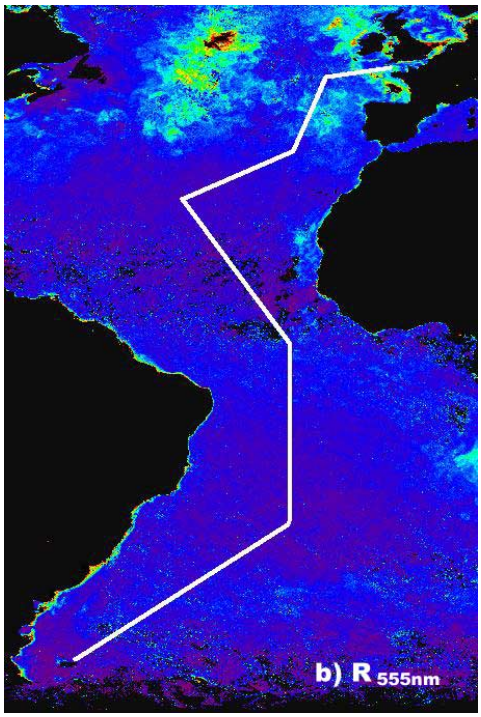
Atlantic Meridional Transect

AMT14 Cruise Report

RRS James Clark Ross
28 April – 1 June 2004

Principal Scientist:
Patrick Holligan (SOC)





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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 and 13) 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 Captain Jerry Burgan and all the officers and crew of RRS James Clark Ross for all their support and sustenance during the cruise, 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 (Duncan Anderson) and to the Deck Engineer (Doug Trevett) for much advice on technical and safety issues relating to incubation systems on the after deck and to atmospheric sampling equipment. Excellent support for CTD work and computing was provided by staff from BAS (Mark Preston, Johnnie Edmonstone) and from UKORS (Jon Short and Dougal Mountifield).

Invaluable assistance with cruise logistics was provided by Malcolm Woodward, Dawn Ashby and Dr Carol Robinson at the Plymouth Marine Laboratory, and by Chris Hindley at BAS, Cambridge. During the cruise Dr Alex Poulton provided vital leadership with the CTD water sampling especially at 0200h each morning.

Special thanks are also due to Andrew Harvey for joining the cruise at such short notice and for putting much effort in learning how to measure ammonium.

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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.

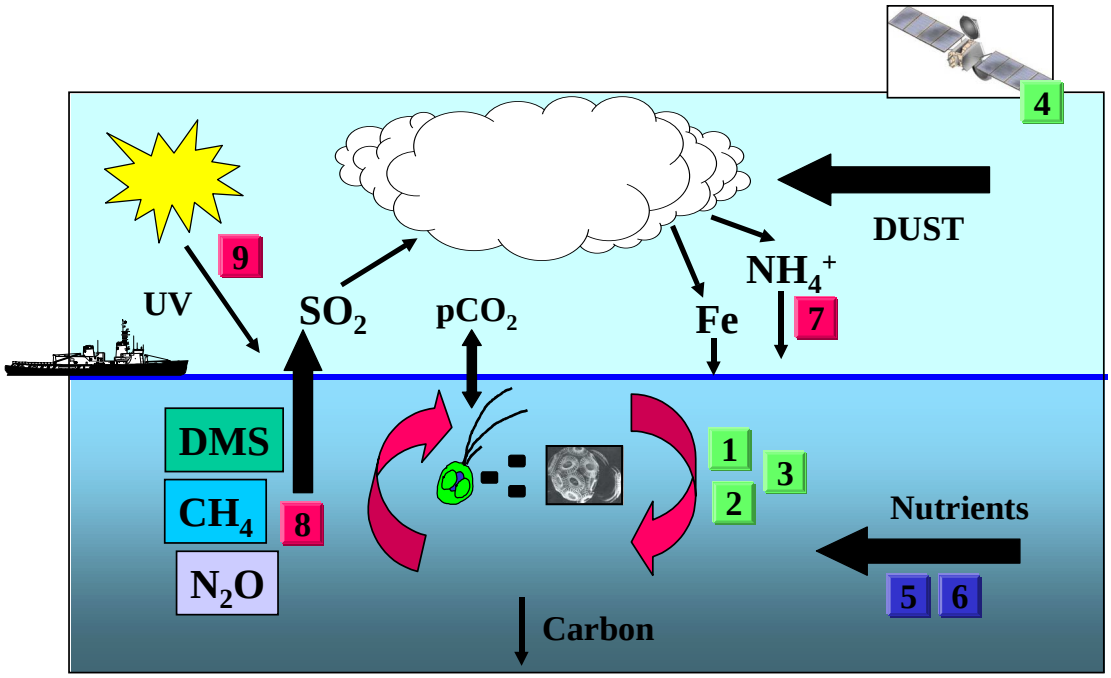
- To determine the role of physical processes in controlling the rates of nutrient supply, including dissolved organic matter, to the planktonic ecosystem

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.



The first two cruises of the second phase of the AMT Programme occurred in May/June (AMT12 northbound) and September/October 2003 (AMT13 southbound), focussing respectively on the northern subtropical gyre of the Atlantic and on the upwelling region off NW Africa. Both cruises included a transect across the southern subtropical gyre. For AMT14 (northbound) a comparable track across the southern gyre and the equator was maintained, and an additional two days of ship-time made it possible to run a line of hydrographic stations on a more westerly route towards the centre of the northern gyre. The main purpose of work in this region was to determine the trophic state of the plankton ecosystem with respect to large scale patterns in the ambient concentrations and supply to the surface waters of inorganic nutrients and of dissolved organic matter. In addition the award of a NERC grant to Dr R. Sanders (AMT PI, SOC) and a NASA grant to Dr W. Balch (AMT Collaborator, Bigelow Laboratory for Ocean Sciences, USA) provided the opportunity to make the first measurements of the standing stocks and rates of formation of biogenic minerals (diatom silica and coccolithophore calcite) on an AMT cruise. Such measurements are likely to provide a better understanding of the control of the biological carbon pump in conjunction with ongoing studies of Th and U isotope disequilibria in surface waters.

Further information about the AMT programme can be found on www.amt-uk.org.

Cruise Narrative

The ship departed from Stanley, Falkland Is on the afternoon of 28 April, following a delay of more than 48 hours while a replacement Electrical Officer travelled out from the UK. Good use was made of the extra time in port for final preparations in the scientific laboratories. The equator was crossed on 14 May, and the port of Grimsby, UK reached on the afternoon tide of 1 June, giving a total of 33 days at sea. The cruise track is shown on the report cover, overlain on a composite SeaWiFS image of surface chlorophyll for May 2004, and the station positions in Figure 1. Changes in ship time were made as follows:

30 April	0100h	GMT-4 to GMT-3
3 May	0100h	GMT-3 to GMT-2
26 May	0100h	GMT-2 to GMT-1
29 May	0100h	GMT-1 to GMT
30 May	0100h	GMT to GMT +1 (BST)

The dates, positions and times of 89 CTD stations completed during the cruise are listed in Appendix 1. Sampling depths for the routine pre-dawn hydrographic and productivity casts and mid-morning optics casts down to 300 or 350m are given in Appendix 2, and times of sunrise and sunset, which determined the length of deck primary production incubations, in Appendix 3.

At 10 pre-dawn stations, approximately every third day, four Stand Alone Pumps (SAPs) were operated at 3 depths for 90 minutes in order to collect particulate material for isotope studies (N, U, Th). On these days the hydrographic CTD profile was extended to 1000m. CTD casts were also carried out at dusk on two sets of three consecutive days, one in the southern gyre and one in the northern one, in order to collect material for studies of cell division by picoplankton. The last pre-dawn station on 28/29 May was at the Porcupine Abyssal Plain (PAP) site at 49^{o}N where a number of long term moorings are maintained. Observational data were subsequently passed on to Dr Richard Lampitt (SOC) who is leading a cruise on RRS Charles Darwin to this site in the latter half of June. The final CTD and optics station of AMT14 was undertaken to the south west of the Scilly Isles on 30 May within a coccolithophore bloom which had been located from SeaWiFS images.

Very little station time was lost during the cruise. No CTD work was possible on 29 April due to winch operating problems, and the pre-dawn station on 1 May was cancelled due to adverse weather conditions (see Fig. 3a). The plankton nets could not be deployed on 7 May, again due to strong winds. At the PAP site on 28/29 May communication with the CTD was lost during the deep (1000m) cast following the SAPS deployment and a connecting cable had to be replaced. No stations were occupied on 24 May, in part to conserve time for the last part of the cruise and in part to provide a rest period. The two stations on the following day, 25 May, were sited within Azores Territorial Waters.

The filters of the non-toxic water supply to the laboratories were cleaned each day. A filter mesh size of 5mm was used for oceanic water (1-31 May), with 1mm filter being used before and after these dates. Routine maintenance of the water intake probe was carried out on 12 May.

Eight APEX-SBE autonomous profiler floats were released for Jon Turton (Met Office) in the S Atlantic following the late morning optics stations on 29 April to 4 May, and 6-7 May (see Scientific Reports for further information).

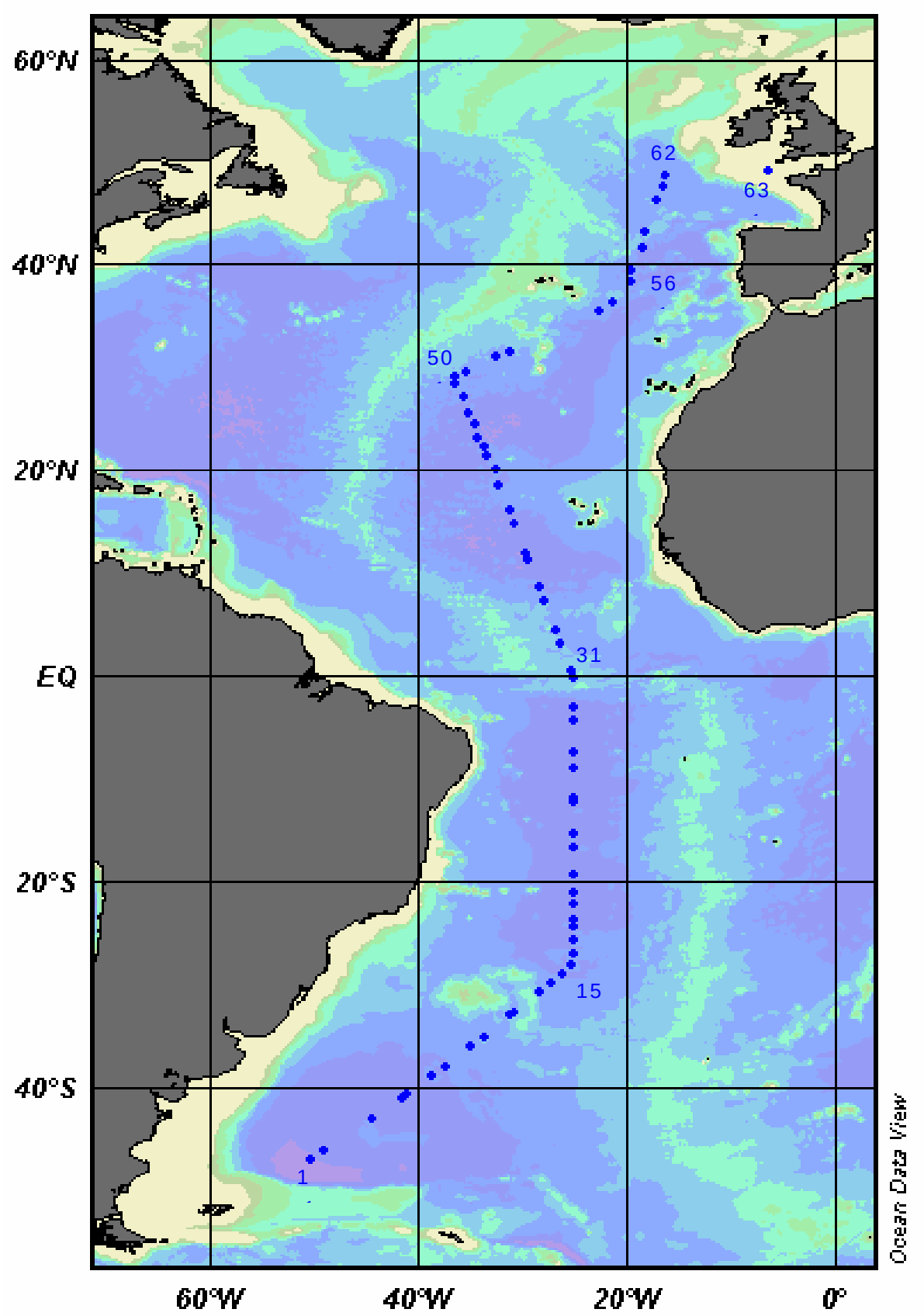
The weather conditions during the cruise were generally good although there were relatively few calm sunny days. Wind and swell during the first 10 days were mainly from astern. Crossing of the Inter Tropical Convergence Zone (ITCZ) on 16/17 May (approximately 10^{o}N) was marked by scattered

showers. A westerly swell during the approach to the PAP site (49^{o}N) caused uncomfortable rolling of the ship.

Equipment failures during the cruise were relatively few, the most serious being damaged fibre optics cables on the spectrometer used for measuring CDOM absorption spectra (Jenna Robinson, Newcastle). Technical knowledge and spares on the ship were insufficient to resolve the problem fully. Use of the on-deck water coolers attached to incubation boxes had to be discontinued to difficulties with electrical supply, and they will need to be replaced by units housed under cover.

No serious health and safety issues arose during the cruise. A number of minor accidents did occur, mainly concerned with breaking glassware and with loss of footholds, but in general these were no more than would be expected during a period of intense practical work. Lapses in concentration by individuals working within normal hours appeared to be the main cause of the accidents. Manipulation of glassware in the clothes locker outside the wet laboratory was stopped during the cruise when it was recognised that tapping of the stoppers of oxygen bottles can release small glass splinters. It is recommended that scientists undertaking sampling on the monkey island adopt better routines when working at night or under rough conditions; they should wear head torches when carrying equipment at night and always be accompanied when there is strong motion of the ship. Recommended procedures for the wearing of safety clothing and for the display of risk assessment forms at places of work were generally well followed.

Figure 1. AMT14 station positions. See Appendix 1 for further details.



General Hydrographic and Meteorological Observations

Changes with latitude of surface sea and air temperatures, surface salinity and surface chlorophyll fluorescence during AMT14 are shown in Figure 2. Note that south of 25^{o}S the air temperature was colder than the sea temperature by up to 5^{o}C or more which, coupled with relatively strong winds, led to vigorous convective mixing of the surface ocean. Sharp changes in both temperature and salinity marked the boundary between subantarctic and subtropical waters at around 45^{o}S. The equatorial minimum in salinity was situated to the north of the equator but somewhat to the south of the ITCZ. The record of chlorophyll fluorescence indicates relatively abundant but patchy phytoplankton at the north and south ends of the transect. However, the effects of equatorial upwelling on phytoplankton abundance are not clearly seen (compare Figs. 2c and 7) probably due to solar inhibition of fluorescence and other related factors.

Information about daily meteorological conditions during the cruise is provided in Figure 3. The strongest winds occurred during the first ten days, and relative humidity was variable but generally in the range 60-90%. The effects of season and latitude on photosynthetically active radiation (PAR) can be clearly seen in terms of day length and maximum daily intensity. 'Cloud free' was approached on only two days.

Hydrographic sections based on bottle data from the pre-dawn, late morning and dusk CTD stations for temperature, salinity and density, and for chlorophyll, oxygen saturation, total nitrate + nitrite and silicate are shown in Figures 4 and 5 respectively. The latitudinal distribution pattern for each of these properties conforms well with observations on previous AMT cruises, allowing for expected seasonal differences between the northbound and southbound transects. The cruise track for AMT14 gave better representation of the northern subtropical than had previously been possible. Notable features are the sub-surface oxygen maximum in the southern gyre, and a broad, hydrographically-complex region across the equator (about 8^{o}S to 15^{o}N) with a relatively shallow (~50m) and steep thermocline. Equatorial waters were characterised by enhanced levels of chlorophyll, zooplankton biomass, and activity of higher predators (night observations on surface fish and squid). Levels of nitrate within the deep chlorophyll maximum (DCM) were generally about 0.2 μM in the southern gyre and up to 1.0μM in the northern gyre, probably reflecting the seasonal difference in environmental factors determining the vertical position of the nitracline. North of 40^{o}N surface levels of chlorophyll were surprisingly low in view of the favourable conditions of ambient light and inorganic nutrients for phytoplankton growth.

Flow cytometer cell counts for water samples from the pre-dawn stations showed well defined patterns in the distributions of autotrophic picoplankton (Fig. 6). Cell counts were lower in the deep chlorophyll maximum (DCM) than in the surface layer, indicating that the DCM represents a pigment maximum rather than a biomass maximum. *Prochlorococcus* was by far the most widely distributed and numerically abundant taxon, with maximum cell densities in equatorial waters. *Synechococcus* and small eukaryotes were the major groups in the northern temperate waters, and a second population of the former was detected just north of the equator. At several stations around 30^{o}N very oligotrophic waters were encountered with chlorophyll levels <0.04 mg m^{-3} (see Fig. 8) and *Prochlorococcus* cell counts <30 x 10^{3} cells ml^{-1}.

A large number of discrete chlorophyll measurements were made during the cruise to ensure proper calibration of fluorometers in use (see example shown in Fig. 7) and to investigate the relationships between the surface (6.5m) distributions of phytoplankton biomass and the biogenic minerals, calcite and opal (silicate). The observed distribution of surface chlorophyll (Fig. 8) is consistent with data from the CTD profiles and gives a good indication of the degree of oligotrophy across the subtropical gyres.

Figure 2. AMT14. Changes (10 minute resolution) in surface water (6.5m) and air properties with latitude: a) Sea and air temperatures (°C), b) Salinity, and c) Chlorophyll fluorescence (V).

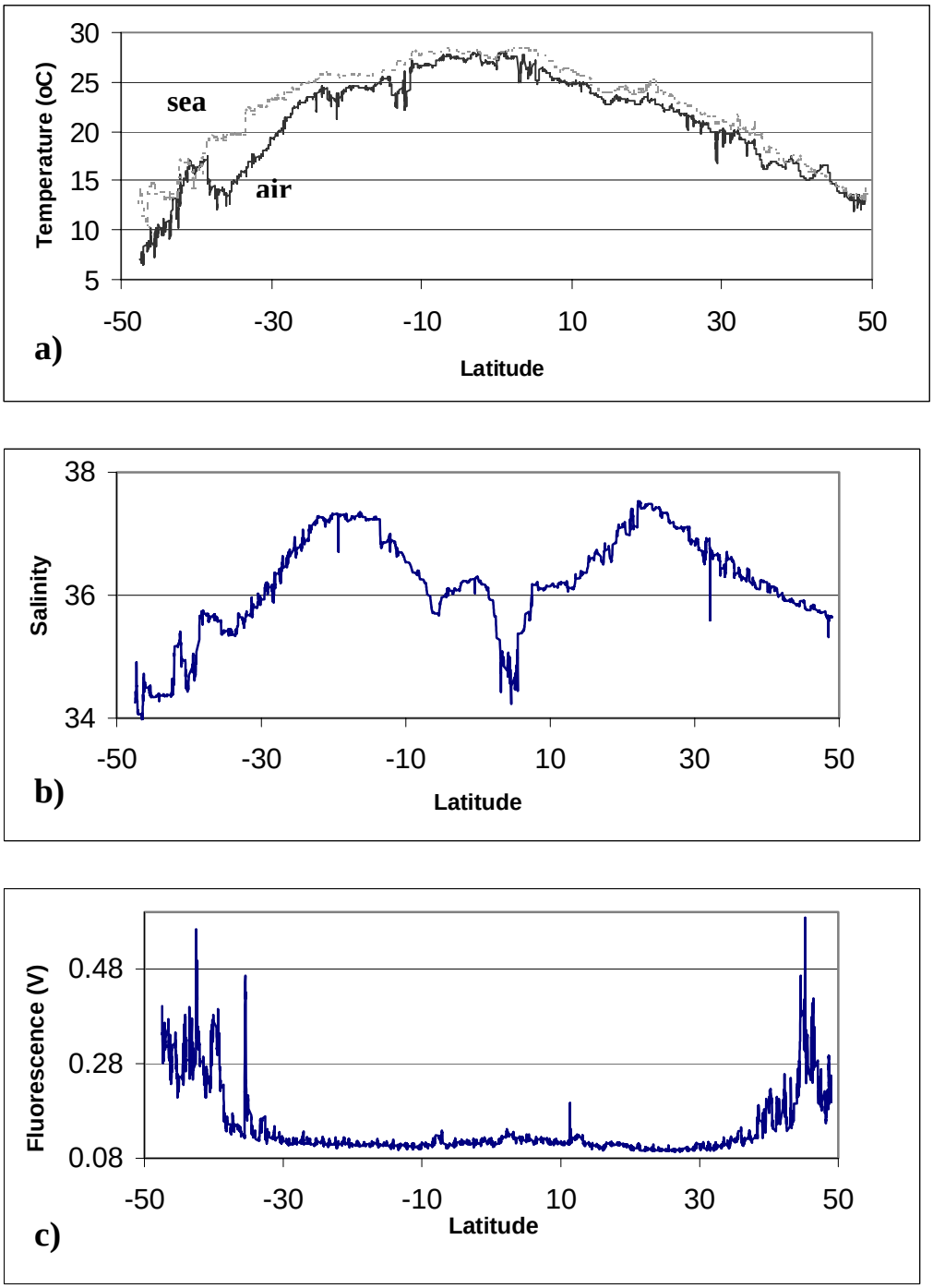
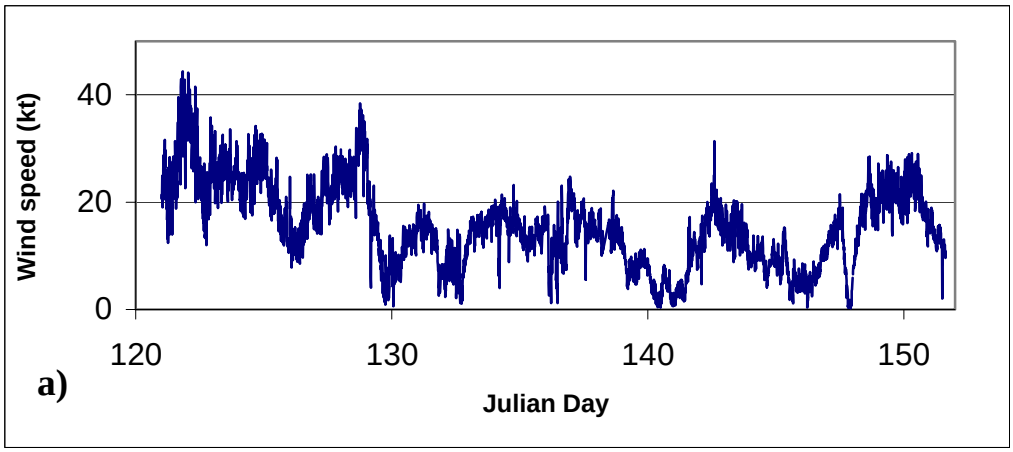
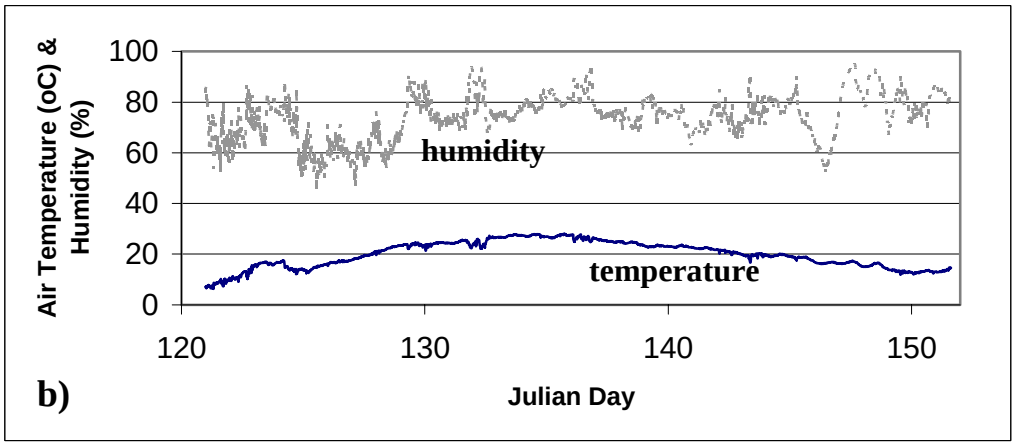


Figure 3. AMT14. Changes (10 minute resolution) in meteorological parameters with time (Julian Day): a) Wind speed (knots), b) Air temperature (°C) and humidity (%), and c) Photosynthetically Active Radiation (PAR, µE m^{-2} s^{-1}). Data spikes in PAR, including all values >2300µE m^{-2} s^{-1}, are probably associated with cloud edges.





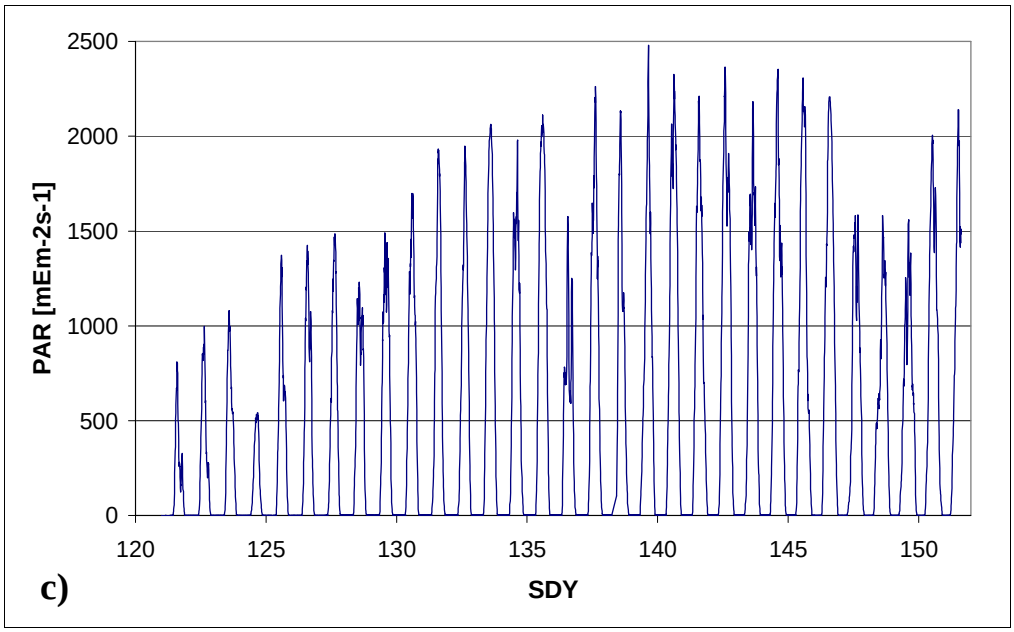


Figure 4. AMT14. Hydrographic sections (0-200m) against latitude for a) Temperature (^{o}C), b) Salinity, and c) Density (kg m^{-3} - 1000).

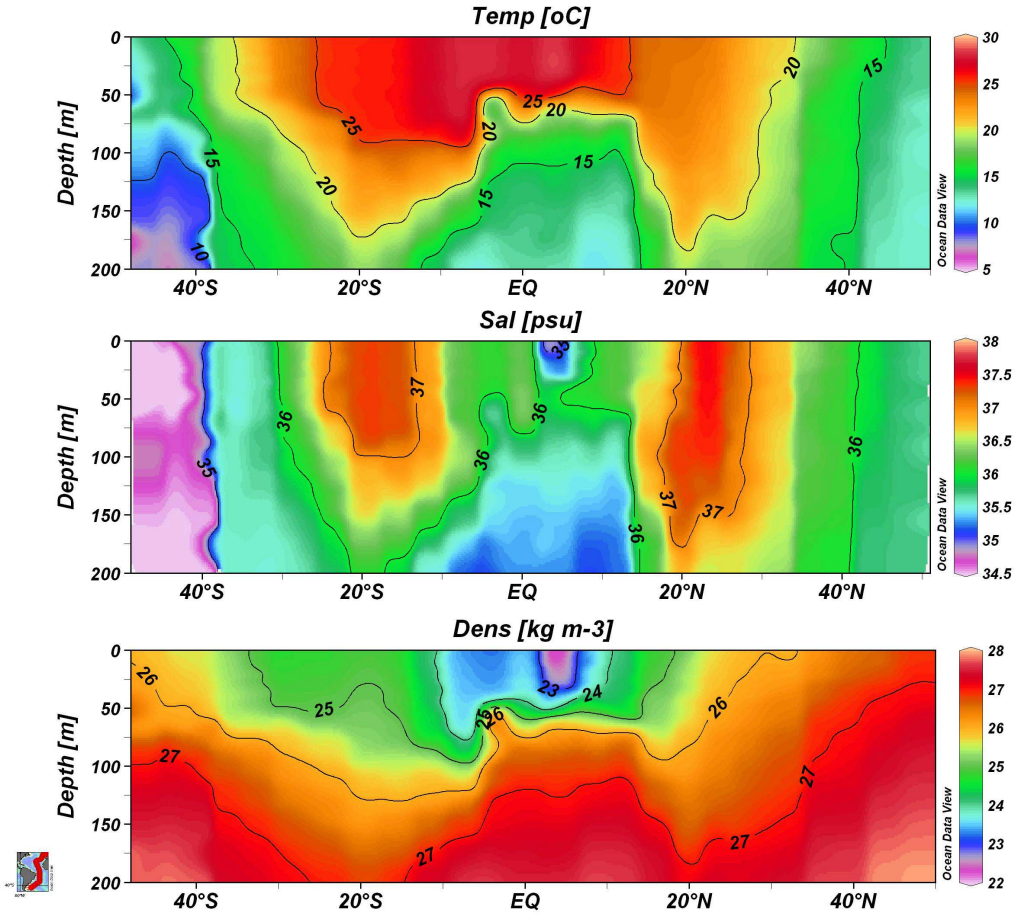


Figure 5. AMT14. Hydrographic sections (0-200m) against latitude for a) Chlorophyll (mg m^{-3}), b) Oxygen saturation (%, uncalibrated), c) Nitrate plus nitrite (μM), and d) Silicate (μM). Silicate was measured through the cruise, but the full data set was not available at the time of writing this report.

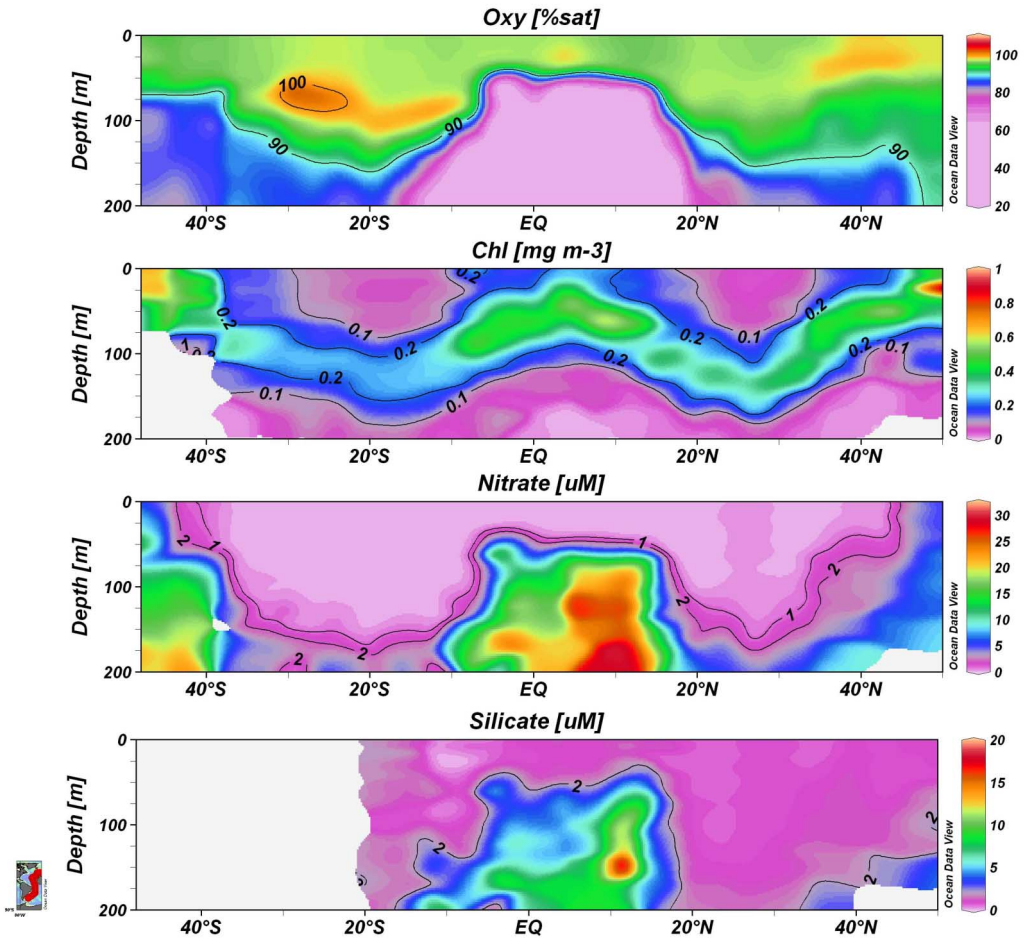


Figure 6. AMT14. Hydrographic sections (0-200m) for a) Chlorophyll (mg m^{-3}), and for cell counts (10^3 cells ml^{-1}) of b) Prochlorococcus (Pro), c) Synechococcus (Syn), and d) Picoeukaryotes (Euk).

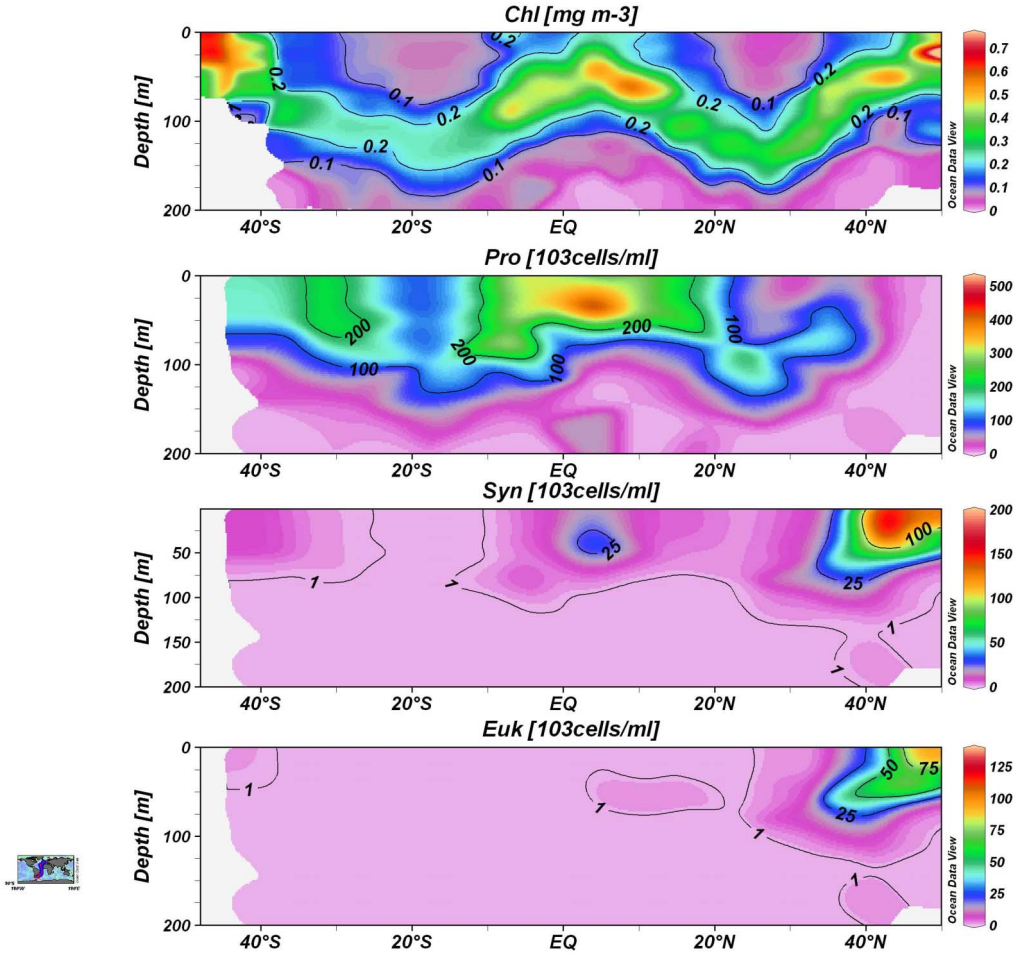


Figure 7. AMT14. Calibration of CTD Fluorometer readings (V) against measured chlorophyll a (mg m^{-3}) for the S and N Subtropical Gyres in the Atlantic Ocean. All samples (day/night, shallow/deep) are shown.

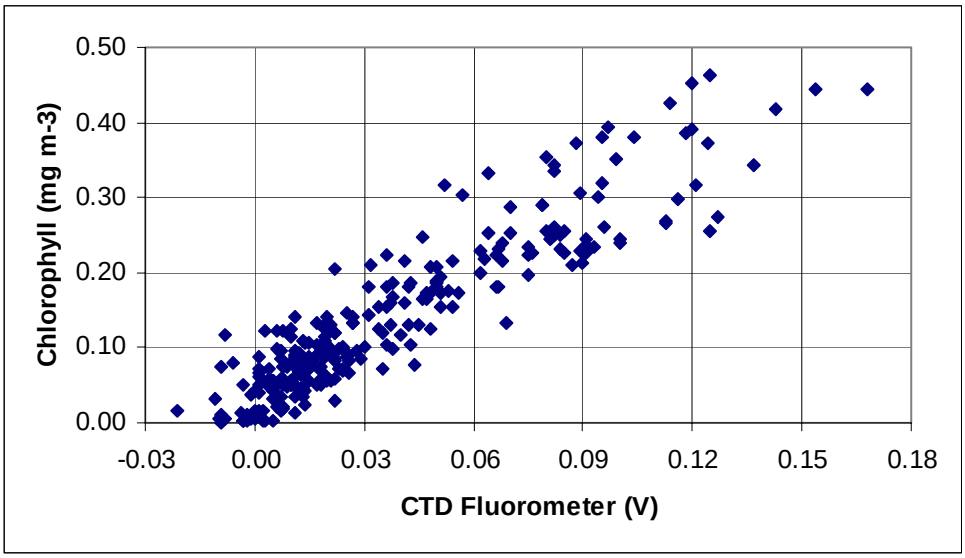
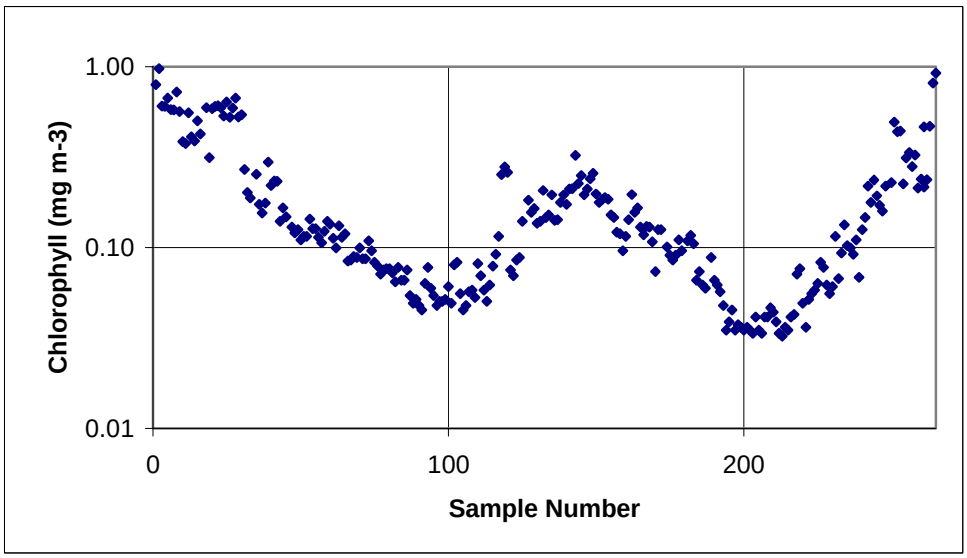


Figure 8. AMT14. Transect of surface (6.5m) chlorophyll a (mg m^{-3}) against latitude. Samples for determinations of particulate inorganic carbon (calcite) and biogenic silica were taken from the same water but have yet to be analysed. Note the logarithmic scale, and the relatively high values around the equator in the middle of the transect.



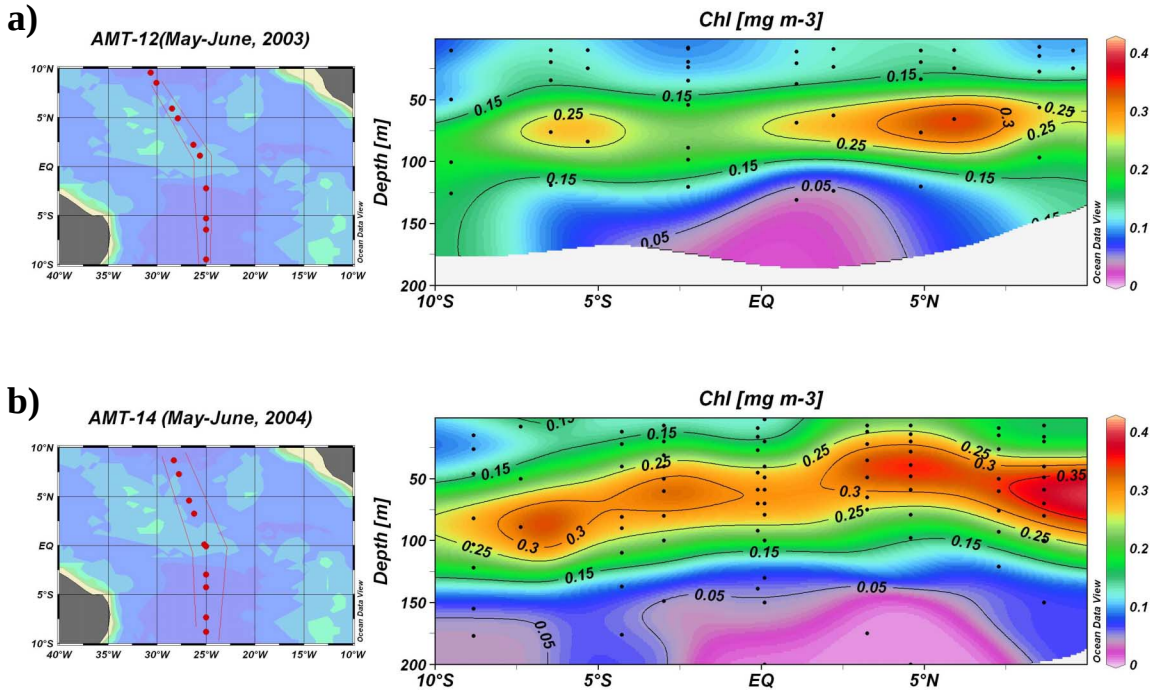
Scientific Highlights of Cruise

The following list of highlights represents selected topics to which particular attention was given on AMT14. It is not intended to be exclusive in any way and cannot, of course, cover any topics for which results are not yet available. Further details about these and other aspects of the scientific work of the cruise can be found in the Scientific Reports which follow.

- Complementary measurements of primary production and respiration using ^{14}C and oxygen, new and regenerated production using ^{15}N, rates of N fixation, plankton size spectra, the abundance and rates of formation of biominerals using ^{14}C (calcite) and ^{32}Si (opal), and the Th and U isotope disequilibria associated with sinking particles. The results will help unravel the role of mineral phases in determining the downward flux of organic matter from the ocean surface to the ocean interior (the 'ballast hypothesis').
- Ecological, physiological and chemical characterisation of very oligotrophic surface water (chlorophyll concentration <0.04 mg m^{-3}, dissolved inorganic nitrate and phosphate undetectable by standard nanomolar methods) in the northern subtropical gyre which may provide new information about the nature of nutrient limitation of plankton production in the open ocean. Of particular note are observations that large proportions (~50% or more) of phytoplankton biomass and carbon fixation in this water were attributable to eukaryotic cells >2µm in diameter and that levels of DMS were relatively high.
- CTD section for the equatorial region which illustrates the dynamic nature of the upwelling system (see Figs. 4 and 5), and the variable relationships between the distributions of temperature, nutrients, oxygen and chlorophyll in the upper 100m of the water column. Comparison of the equatorial sections for chlorophyll from AMT12`and AMT14 (Fig. 9) shows that the latitudinal extent of a relatively shallow DCM was about the same but that, on the latter cruise, the DCM was shallower by as much as 20m and characterised by considerably higher levels of chlorophyll especially at the surface. At some CTD stations on AMT14 water from the DCM contained >5µM nitrate.
- Acquisition of FRRF P/E curves, using a blue LED light source, for water samples from up to 5 depths at each of the pre-dawn stations. These data will be used to explore the relationship between estimations of primary production by the 14C method (deck SIS and laboratory P/E incubations) and determinations of photosynthetic parameters from in situ FRRF profiles from this cruise as well as earlier AMT cruises.
- Field test of the new Turner 'Cyclops' fluorometer to detect phycoerythrin. The instrument was operated on the CTD rig. Although it lacked the sensitivity required for open ocean observations, coherent signals reflecting the distributions of *Trichodesmium* and *Synechococcus* (see Fig. 6c) were obtained. Furthermore the relatively noisy signal generated by the large colonies and filaments of *Trichodesmium* (similar to that given by colonies of *Phaeocystis* using an ordinary fluorometer) may allow these two types of prokaryotes to be distinguished. The validation exercise will be completed using cell counts from preserved water samples. The ability to determine the abundance of N-fixing *Trichodesmium* in real time represents an important new technique for biogeochemical studies at sea.
- An important development on AMT14 was the effort given to data processing and analysis during the cruise. It enabled errors in sampling techniques (e.g. leaking CTD water bottles) to be detected and corrected, provided the basis for modifying sampling and experimental procedures when unusual hydrographic or ecological conditions were encountered, and led to much better awareness during the cruise of relationships between different types of core measurements. Although individual scientists routinely review their data, it is the bringing together different types of information as far as possible on a daily basis that makes it possible to see the bigger picture

and to recognise and assess by the end of the cruise the main scientific achievements. Procedures for collating and plotting data need to be substantially improved (indeed this task could be a full time one on an AMT cruise for someone with the right computing skills), and it is recommended a small group of people is given specific responsibility and necessary resources for this task on future AMT cruises

Figure 9. Comparison of the distributions (0-200m) of chlorophyll (mg m^{-3}) across the equator on a) AMT12 and b) AMT14.



Scientific Reports:

Optics and Remote Sensing

CHRISTOPHER LOWE
Plymouth Marine Laboratory and University of Plymouth

Equipment

A suite of optical measurements were taken on the cruise:

1. Satlantic free falling optical profiler that measured the optical properties of the upper euphotic zone. The profiler measured the wavelengths corresponding to the MERIS sensor on ENVISAT (412, 443, 490, 510, 560, 620, 665 and 685nm). The sensor had matching surface sensors for normalization to incident light.
2. Wetlabs ac/9 absorption and attenuation meter. This is a multiband spectro-photometer that measures at 9 wavelengths (412, 440, 488, 510, 532, 555, 650, 676 and 715nm). CTD data from the main CTD rosette is used to correct the ac/9 data for the effects in the changes in the optical properties of pure water with temperature and salinity. The system has flow cells to ensure proper operation of the instruments and to correct for any time lags in sampling. It is also capable of measuring chlorophyll absorption at 676 nm as a biomass indicator.
3. Additionally every three days on SAPs stations the ac/9 was used with a 0.2µm SuporCap filter that enabled the determination of CDOM and particulate absorption spectra profiles.
4. Wetlabs VSF. This is a backscatter meter that measures scattering at three discrete angles (100, 125 and 150 degrees). The measurement of the change in angular scattering is key to relating water reflectance at the different sun and view angles that are found in ocean colour observations.
5. Fast repetition rate fluorometer (FRRF) that measures the absorption cross-section of photosystem II, the quantum yield and the rate of photosynthetic electron transport. During the cruise the instrument was calibrated every three days with blanks from 1000m CTD water, deionised clean water from the ships MilliQ system and water filtered through a 0.2µm capsule filter off the ships underway non toxic seawater supply. Daily blanks of the dark chamber were also made using 0.2µm water filtered from various depths in the CTD profile by Y. Kim. The setup options of these instruments can be found at the end of this section.

The optics deployments were through three main methods. A primary optics rig which carried a CI FRRF (SN 182041), a Wetlabs ac/9 (SN AC90277) and a Wetlabs VSF 1 (green, SN0046) was deployed at the 1100h cast and one in three pre dawn casts (on days where SAPs were used). The Southern hemisphere was sampled using a Satlantic Micropro freefall optical profiler. Unfortunately this became flooded at station 48 on the 15th May and was thereafter only usable with half of its sensors working. The main CTD rosette also carried an FRRF (SN 182042) which was deployed on all casts except the first early morning cast on days where SAPs were in operation as these casts went to 1000m, below the depth rating of the FRRF.

Figure 1. The setup options of the two FRRFs, 182041 on the main CTD (left) and 182042 on the optics frame (right).

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   Run Menu
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   1. Discrete Acquire
   2. Programmed Acquire
   3. View/Edit Current Protocol
   4. Save Protocol
   5. Restore Protocol

   0. to Return:

        *** Boot Protocol = 1 ***

   6. 65535     Acquisitions
   7.    16     Flash sequences per acquisition
   8.   100     Saturation flashes per sequence
   9.     4     Saturation flash duration (in instrument units)
   A.     0     Saturation interflash delay (in instrument units)
   B. ENABLED   Relaxation flashes
   C.    20     Relaxation flashes per sequence
   D.     4     Relaxation flash duration (in instrument units)
   E.   120     Relaxation interflash delay (in instrument units)
   F.  1000     ms Sleeptime between acquisition pairs
   G.     4     PMT Gain in Normal Mode
   H. DISABLED  Analog Output
   I. DISABLED  Desktop (verbose) Mode
   J. ACTIVE    Light Chamber (A)
   K. ACTIVE    Dark Chamber (B)
   L. ENABLED   Logging mode to internal flashcard
   M:    90     Upper Limit Autoranging Threshold value
   N:    15     Lower Limit Autoranging Threshold value
```

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   Run Menu
 ====================

   1. Discrete Acquire
   2. Programmed Acquire
   3. View/Edit Current Protocol
   4. Save Protocol
   5. Restore Protocol

   0. to Return:

        *** Boot Protocol = 6 ***

   6. 65535     Acquisitions
   7.    16     Flash sequences per acquisition
   8.   100     Saturation flashes per sequence
   9.     4     Saturation flash duration (in instrument units)
   A.     0     Saturation interflash delay (in instrument units)
   B. ENABLED   Relaxation flashes
   C.    20     Relaxation flashes per sequence
   D.     4     Relaxation flash duration (in instrument units)
   E.   120     Relaxation interflash delay (in instrument units)
   F.  1000     ms Sleeptime between acquisition pairs
   G.    16     PMT Gain in Normal Mode
   H. DISABLED  Analog Output
   I. DISABLED  Desktop (verbose) Mode
   J. ACTIVE    Light Chamber (A)
   K. ACTIVE    Dark Chamber (B)
   L. ENABLED   Logging mode to internal flashcard
   M:    90     Upper Limit Autoranging Threshold value
   N:    15     Lower Limit Autoranging Threshold value
```

Procedures

At every 1100h station the optics frame was deployed along with the main CTD rosette. On most days where SAPs were deployed two casts were made with the ac/9 filtered and not filtered as described below.

The Freefall optical profiler was used in the Southern hemisphere on days when only profile was to be made (due to time constraints) but was flooded near the equator.

On all days where SAPs were deployed two casts were made using the main optics rig, the first with the ac/9 being filtered to measure for CDOM with the FRRF running, the second without the filters and with the FRRF turned off. In the Southern hemisphere the single cast with the FRRF on was used to reduce the risk of battery failure during the profiles. At the equator a new method was tried, connecting the outflow of the filtered ac/9 to the dark chamber of the FRRF thus providing a blank profile similar to the discrete blanks being run in the laboratory (see below). The CDOM cast of the ac/9 run first to reduce contamination by material in the sea water since this would be filtered out on the first cast. Filters for these casts were acid washed in 10% HCL then stored in MilliQ water to avoid accumulation of particulates on the filters which appears to have been a problem on AMT13.

HPLC, Chlorophyll and Particulate Absorption (PAB) samples were taken from three depths from each 1100h cast to correlate with the casts. Depths were dependent on the structure of the data returned by the main CTD but generally covered a surface sample, one at either 20m or in the gyre 50m and one at the fluorescence maximum. For the last 6 1100h stations size fractionated HPLC on 2µm filters were also taken.

A full list of optical deployments can be found at the end of this section.

Blanks and calibration

Blanks were run every day on the optics frame FRRF with water provided by Y. Kim that had been filtered through a 0.2µm filter from 5 points in the 1100h profile. These blanks were only run in the dark chamber as the volume required for a full blank would be prohibitive to sample. In addition both FRRFs had blanks run in a bucket once every three days. These blanks consisted of MilliQ water from the ships system, surface water filtered through a 0.2µm SuporCap capsule filter and as frequently as possible water taken from 1000m on the deep CTD casts.

Air blanks of the ac/9 were run on two occasions to track any variations in the instrument.

In contrast to AMTs 12 and 13 no stabilised light source was available for calibrating the freefall optical profiler and as such calibrations taken at PML before the cruise will be used.

Equipment performance

Everyday operation of the equipment generally ran smoothly. The ac/9 failed to work on a number of occasions. This fault was eventually tracked down to a broken connector in the battery plug which was replaced.

The main equipment failure of the cruise occurred at the equator when one of the optics heads of the freefall optical profiler fell apart on deployment flooding the head with sea water thus rendering the instrument inoperable. The affected electronics were quickly retrieved, washed with MilliQ water and allowed to dry however. On reconnection to the system the unit still gave telemetry but part of the watertight seal was lost and as such redeployment was difficult and only used infrequently.

Results

Data were collated, placed into 1m bins and temperature and salinity corrected with data from the CTD each day. Further iterations of these steps will follow the return to the UK with application of blanks and updated calibrations.

A section plot of the FRRF from the CTD is shown in Figure 2 clearly showing the expected features of an AMT cruise. The two gyres show a less intense, deeper chlorophyll maximum in the Fm with a fairly consistent amplitude of photosynthetic quantum efficiency (Fv/Fm) following the chlorophyll maximum.

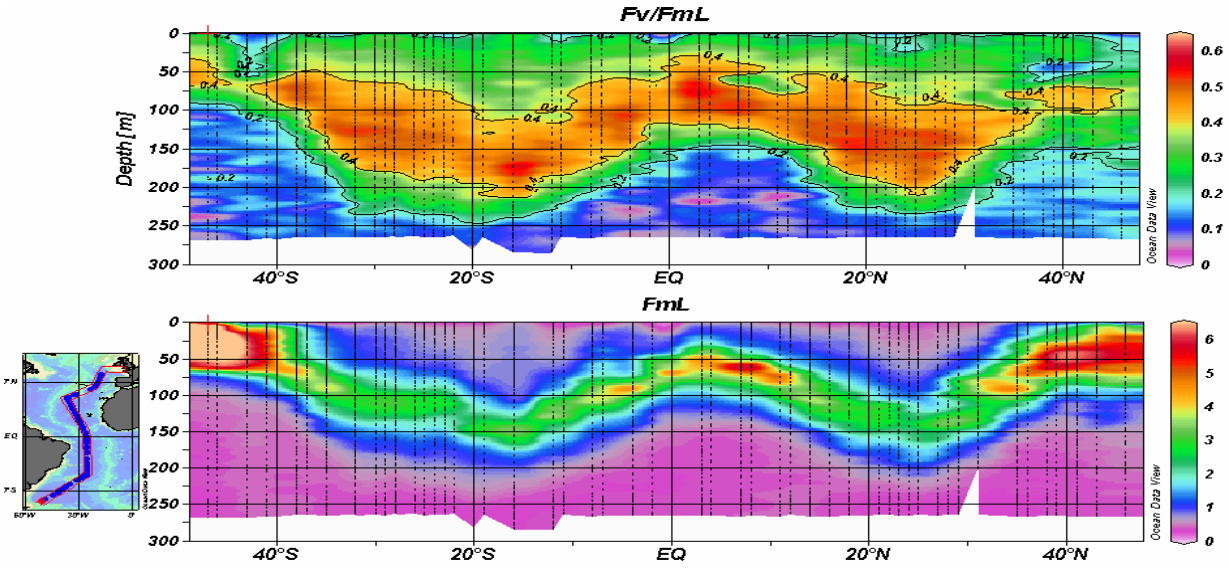

Figure 2. FRRF from the main CTD rosette.

Below are three plots showing the output of a double cast with the ac/9, differentiating the absorption of particulate and dissolved components in the water. The spectrum of the particulates seems to follow the expected absorption spectrum of particulates as would be determined by spectrophotometer but requires further calibration.

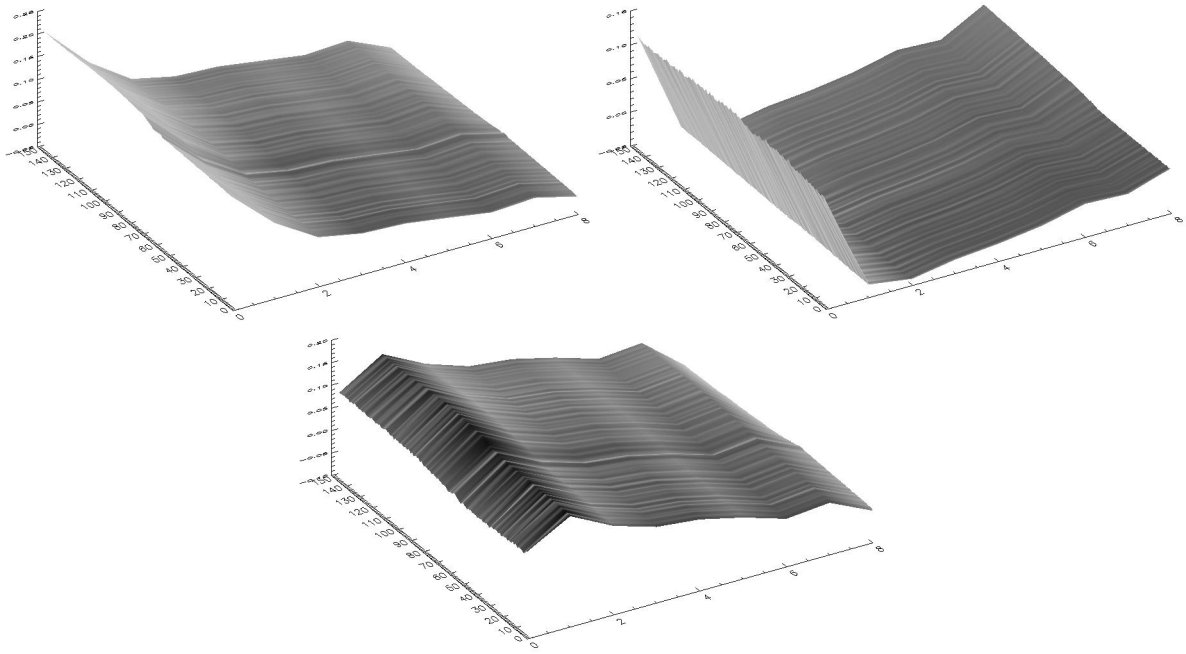

Figure 3. ac/9 absorption spectra as determined by double casts. Top left is an absorption profile from an unfiltered ac/9, top right with 0.2µm filters ('CDOM cast') and bottom is the unfiltered minus the filtered profile ('particulate spectrum'). x = ac/9 channel number (wavelength), y = depth [m] and Z = absorption [m-1]

Data availability

Data from the FRRF are available and will be submitted to BODC on return to the UK as data processed using the standard FRS software. Further calibration and blanking will lead to some changes in these data.

Freefall data will be processed on return to Plymouth. The method of storing this data with BODC has yet to be decided, until this has happened it is available from PML.

Ac/9 data require post cruise calibration after which they will be submitted to BODC.

Remote sensing

Dr Sam Lavender at the University of Plymouth supplied chlorophyll images throughout the cruise as well as composite images of the North Atlantic to pinpoint coccolithophore blooms for sampling at the final station.

Table 1. A list of Optics deployments, numbers in bold designate double casts where CDOM and particulate spectra were measured with the ac/9.

Lat (S/N)	Long (W)	CTD #	CTD FRRF	FRRF	ac/9	Freefall
-47.03	50.25	1	1			
-47.03	50.25	2				
-46.15	48.92	3	1	1	1	
-43.03	44.34	4	1			
-41.03	41.55	5		2	2	
-41.03	41.55	6	1			
-40.68	41.07	7	1	1	1	
-38.87	38.58	8	1			
-38.87	38.58	9	1			
-37.95	37.37	10	1	1		
-35.97	34.80	11	1			
-35.97	34.80	12	1			
-35.00	33.55	13		1		
-32.97	31.01	14		2	2	
-32.97	31.01	15	1			
-32.65	30.60	16	1	2	2	
-30.70	28.22	17	1			
-30.70	28.22	18	1			
-29.77	27.10	19	1	1	1	2
-28.87	26.03	20	1			
-28.08	25.10	21	1			
-28.08	25.10	22	1			
-26.93	25.00	23	1	1		
-25.55	25.00	24	1			
-24.23	25.00	25		2	2	
-24.23	25.00	26	1			
-23.60	25.00	27	1	1	1	
-22.16	25.00	28	1			
-20.93	25.00	29	1			
-20.93	25.00	30	1			
-19.31	25.00	31	1	1	1	2
-16.65	25.00	32	1			
-16.65	25.00	33	1			
-15.20	25.00	34		1	1	1
-12.28	25.00	35		2	2	
-12.28	25.00	36	1			
-11.73	25.00	37	1	2	2	
-8.82	25.00	38	1			
-7.37	25.00	39	1	1	1	3
-4.27	25.00	40	1			
-4.27	25.00	41	1			
-2.98	25.00	42	1	1	2	
-0.10	25.00	43		1	1	
-0.10	25.00	44				
0.52	25.18	45	1	2	2	1
3.25	26.23	46	1			
3.25	26.23	47	1			
4.58	26.73	48	1	1	1	
7.28	27.78	49	1			

Lat (S/N)	Long (W)	CTD #	CTD FRRF	FRRF	ac/9	Freefall
7.28	27.78	50	1			
8.67	28.30	51	1	1	1	
11.40	29.37	52		1	2	
11.40	29.37	53	1			
12.02	29.60	54	1	2	2	
14.75	30.68	55	1			
14.75	30.68	56	1			
16.05	31.12	57	1	1		
18.48	32.17	58	1			
18.48	32.17	59	1			
20.08	32.50	60	1	1		
21.42	33.29	61	1			
22.20	33.44	62		3	3	
22.20	33.44	63	1			
23.26	34.12	64	1	2		
24.58	34.50	65	1			
25.54	35.14	66	1			
25.54	35.14	67	1			
27.27	35.82	68	1	1		1
28.42	36.43	69	1			
29.30	36.70	70				
29.30	36.70	71	1			
29.88	35.52	72	1	1	2	
31.28	32.55	73				
31.28	32.55	74	1			
31.93	31.18	75	1	1	2	
35.75	22.85	76	1			1
35.75	22.85	77	1			
36.48	21.22	78	1	1	2	
38.67	19.97	79				
38.67	19.97	80	1	1	3	
39.25	19.70	81	1	1	3	
41.98	18.60	82	1			
41.98	18.60	83	1			
43.87	18.33	84	1	1	2	
46.26	17.17	85	1			
47.49	16.47	86	1	1	2	
49.00	16.20	87		2	2	
49.00	16.20	88	1			

Acknowledgements

Thanks go to the deck crew and officers of the James Clark Ross for deploying the optics rig at some unsociable hours, also to Dougal Mountifield for processing and providing the main CTD data to allow temperature and salinity correction and to Young Nam Kim for providing blanks for the FRRF.

Dynamics of Microbial Communities

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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 and microbial production rates in the top 300 m.
2. To compare the turnover rates of different organic nutrients, i.e. amino acids, sugars, aminosugars, organic and inorganic phosphorus; to assess diurnal variability of amino acid uptake in oligotrophic waters.
3. To compare the rates of top down control on bacterioplankton in oligotrophic and mesotrophic waters.
4. To assess microbial spatial variability at ten km scale, and to estimate growth rates of cyanobacterial populations using automated sampling from the underway seawater supply.
5. 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 predawn, late morning (1100h local time) and dusk opportunity CTD casts. Thermos flasks were used for collecting large volumes (1L) 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. and *Synechococcus* spp. (cyanobacteria), picoeukaryotes, cryptophytes, coccolithophores and other nanophytoplankton were characterised and enumerated based on their light scattering and autofluorescence properties. Micro-organisms 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 later flow sorting as well as molecular identification of micro-organisms using fluorescence *in situ* hybridisation. 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-tyrosine, ^{3}H-glucose, ^{3}H-glucosamine, ^{33}P-ATP and ^{33}P-phosphate. Bacterivory was estimated using indigenous microorganisms pulse-chased labelled with ^{35}S-methionine and size fractionation (1 μm and 0.2 μm pore size filters). Detailed analysis of the collected data will be done back in the UK.

Autotrophic Community Structure and Dynamics

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Cruise Objectives

1. Continued collection of core AMT measurements (chlorophyll *a*, primary production, pigments, phytoplankton identification, particulate organic carbon and dissolved organic carbon, nitrogen and phosphorus) [AD, PH, YNK, AP, MS, ST].
2. An integrated basin scale investigation of mineralisation (silicate, inorganic carbon) rates in relation to community structure, standing stocks and estimates of export production (from ^{234}Th measurements) [MS, AP, AD, ST].
3. Comparison of photosynthetic parameters derived from traditional carbon-14 photosynthesis v irradiance incubations and fast-repetition-rate-fluorometer (FRRF) electron transport rates (ETR) [YNK, AP].
4. Deployment of a new phycoerythrin fluorometer (Cyclops-7) provided by Turner Designs to detect cyanobacteria.
5. Collection of underway (every 2 hrs) samples for analysis of particulate inorganic carbon (PIC) and biogenic silica (BSi) as part of a collaborative exercise with Dr Barney Balch (Bigelow, USA). (Additional samples for analysis of chlorophyll *a* and pigment composition were collected to allow PIC and BSi concentrations to be related to community composition).

Sampling

During AMT14 underway samples were collected every 2 hrs for particulate inorganic carbon and biogenic silica, chlorophyll *a* and (occasionally) pigments. Water-column sampling during AMT14 concentrated around collection of the main core measurements from 5 or 6 light depths from the pre-dawn CTD cast (~0200 – 0400h local time), with a reduced set of measurements and depths (chlorophyll *a*, HPLC, ETR) from the late morning 'optics' cast (1100h local time).

(a) Underway

Table 1. Ships time, measurement(s) collected and personnel responsible each day of the cruise.

Time (local)	Measurement(s)	Person(s) responsible
0200	PIC, BSi, Chl (HPLC)	AP
0600	PIC, BSi, Chl	TA, MS
0800	PIC, BSi, Chl	TA, MS
1000	PIC, BSi, Chl	TA, MS
1200	PIC, BSi, Chl (HPLC)	PH
1400/1500	PIC, BSi, Chl (HPLC)	PH
1600	PIC, BSi, Chl (HPLC)	PH
1800	PIC, BSi, Chl	TA, MS, AP, PH
2000	PIC, BSi, Chl (HPLC)	TA, MS, AP
2200	PIC, BSi, Chl	TA, MS, AP, SP
0000	PIC, BSi, Chl	SP

(b) CTD stations

Table 2. Stations (CTD cast number) sampled and measurement(s) made. Abbreviations used are PP (primary production or carbon-fixation), $Ca^{14}CO_3$ (calcification or inorganic carbon fixation), ^{32}Si (silicification), BSi (particulate biogenic silica), PIC (particulate inorganic carbon), SEM (samples for scanning electron microscopy) and ETR (electron transport rates derived from the FRRF). Note: * core measurements are chlorophyll (total), pigments, POC/N, DOC/N/P, lugol's and formalin samples.

CTD No.	Core*	PP	$Ca^{14}CO_3$	^{32}Si	BSi, PIC	SEM	ETR
02 (3 am)	X	X			X	X	X
03 (11 am)	X						
04 (11 am)	X						X
05/06 (SAPs-1)	X	X	X	X	X	X	X
07 (11 am)	X						X
09 (3 am)	X	X			X	X	X
10 (11 am)	X						X
11 / 12 (3 am)	X	X			X	X	X
13 (11 am)	X						X
14/15 (SAPs-2)	X	X	X	X	X	X	X
16 (11 am)	X						X
18 (3 am)	X				X	X	X
19 (11 am)	X						X
20 (7 pm)	X					X	X
22 (3 am)	X	X			X	X	X
23 (11 am)	X						X
24 (7 pm)	X						X
25/26 (SAPs-3)	X	X	X	X	X	X	X
27 (11 am)	X						X
28 (7 pm)	X					X	X
30 (3 am)	X	X			X	X	X
31 (11 am)	X						X
33 (3 am)	X	X			X	X	X
34 (11 am)	X						X
35 / 36 (SAPs-4)	X	X	X	X	X	X	X
37 (11am)	X						X
38 (3 am)	X	X			X	X	X
39 (11 am)	X						X
41 (3 am)	X	X			X	X	X
42 (11 am)	X						X
43/44 (SAPs-5)	X		X	X	X	X	X
45 (11 am)	X						
47 (3 am)	X	X			X	X	X
48 (11 am)	X						X
50 (3 am)	X	X	X	X	X	X	X
51 (11 am)	X						X
52/53 (SAPs-6)	X	X	X	X	X	X	X
54 (11 am)	X						X
56 (3 am)	X	X			X	X	X
57 (11 am)	X						X
59 (3 am)	X	X		X	X	X	X
60 (11 am)	X						X
62/63 (SAPs-7)	X	X	X	X	X	X	X
64 (11 am)	X						X
65 (8 pm)	X						X

CTD No.	Core*	PP	$Ca^{14}CO_3$	^{32}Si	BSi, PIC	SEM	ETR
67 (3 am)	X	X		X	X	X	X
68 (11 am)	X						X
69 (8 pm)	X					X	X
70/71 (SAPs-8)	X	X	X	X	X	X	X
72 (11 am)	X						X
74 (3 am)	X	X			X	X	X
75 (11 am)	X						X
77 (3 am)	X	X	X	X	X	X	X
78 (11 am)	X						X
79/80 (SAPs-9)	X	X	X	X	X	X	X
81 (11 am)	X						X
83 (3 am)	X	X		X	X	X	X
84 (11 am)	X						X
85 (3 am)	X	X	X	X	X	X	X
86 (11 am)	X						X
88 (SAPs-10)	X	X	X	X	X	X	X
Total CTDs sampled		**26**	**13**	**16**	**28**	**31**	**60**
Total measurements (estimate)		**1400**	**260**	**250**	**310**	**200**	**200**

Methods

Chlorophyll, pigments, Lugols / Formalin and POC/N: From the five main light depths, samples were collected for chlorophyll determination (acetone extraction), pigment composition (High-Perfomance-Liquid-Chromotography after Barlow *et al*., 1997a, b), particulate organic carbon and nitrogen concentration and duplicate water samples preserved with 2% acidic Lugol's solution and 4% buffered formalin for species identification. Chlorophyll measurements were made onboard with a TD-700 Turner Designs fluorometer, calibrated with fresh chlorophyll *a* standard (Sigma, UK) in 90% acetone and set up to measure chlorophyll *a* in the presence of chlorophyll b following Welschmeyer (1994) [AD, PH, MS, YNK, ST].

Dissolved Organic Carbon, Nitrogen and Phosphorus: Water samples were collected from the five main light depths during the pre-dawn CTD cast. Duplicate samples for DOC were collected in glass ampoules, preserved with 5 µl 2M hydrochloric acid and flame-sealed using a handheld butane-gas torch. Samples for DON and DOP were collected in 50-ml plastic screw-top containers and frozen at -20^{o}C. Analysis will follow the methodology of Knap *et al*., (1996) [MS].

Particle Absorbance (PABS): Water samples (1 - 3 l) were collected from the five main light depths during the pre-dawn CTD cast and filtered through 25 mm dia. Whatman GF/F filters, placed in small petri-dishes and stored at -80^{o}C. Analysis will follow the methodology of Tarran *et al*., (1995) in association with Dave Suggett (University of Essex) [AP].

Carbon fixation (PP): Water samples (3 light, 3 dark) from 5/6 light depths in the water column were collected, spiked with 20 µCi ^{14}C-labelled sodium hydroxide ($NaH^{14}CO_3$) and incubated over a daylight period (dawn to dusk, typically 10 - 12 hrs) in simulated in-situ incubators cooled with either sea-surface water or chilled freshwater to in-situ temperatures +/-3^{o}C. Samples were filtered onto 0.2 mm 47-mm diameter polycarbonate filters under gentle vacuum (<200 mbar) and fumed for 30 minutes over concentrated hydrochloric acid in a desiccator. After fuming samples were placed in 6-ml pony vials with 5-ml of Optiphase HiSafe 3 and activity counted in a TriCarb 2100TR low activity liquid scintillation counter (LSC) onboard. At two depths (55% and 1% of E_0) samples were first gravity filtered through 2 mm 47-mm diameter polycarbonate filters and then sequentially filtered through 0.2 mm filters with both filters fumed and counted separately. At a small number of stations, 12 samples from either the surface (55% E_0) or fluorescence maximum (typically 1% E_0) were collected, spiked with

20 - 60 µCi ^{14}C labelled sodium hydroxide (NaH^{14}CO3) and incubated along a light gradient to produce photosynthesis v irradiance (PvE) curves for analysis of photosynthetic parameters. After 2 - 3 hrs samples were removed, filtered, fumed and counted in the TriCarb LSC onboard. Stock solutions were prepared daily with fresh filtered seawater and checked by addition of 100 µl of stock solution to 9.9 ml Carbosorb and LS counting of five 100 µl replicates from this mixture in 5 ml PermaFluor E+: coefficient of variance for replicate standards was <2% [AP, MS, TA].

Calcification ($Ca^{14}CO_3$) (after Balch *et al*., 2001): Water samples (3 light, 1 dark) from 3/5 light depths were collected, spiked with 80 µCi ^{14}C-labelled sodium hydroxide ($NaH^{14}CO_3$) and incubated identically to samples for PP (see above). Samples were filtered onto 0.2 mm (later 0.4 mm) 47 mm diameter polycarbonate filters under gentle vacuum and placed in 6 ml pony vials. Filter cups, frits and forceps were thoroughly rinsed with fresh filtered seawater after filtration of a sample and between samples with 10% hydrochloric acid and copious amounts of filtered seawater to remove any contamination from labelled dissolved inorganic carbon (DI^{14}C) and remaining acid. Filters were dried for 1 - 2 hrs at 30 - 40^{o}C in an oven and then allowed to cool before a septum and bucket was attached to each vial. Inside the bucket, a polyethylamine (PEA) soaked GFA filter was folded and electrical tape was used to secure the septum to the vial. Using a small gauge syringe, 1 ml of a 1% phosphoric acid was injected past the bucket into the bottom of the vial and the samples were left for 20-24 hrs: 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 septums were removed, the bucket (with GFA) placed in a fresh pony vial and 4 ml of Optiphase Hisafe was added to both the polycarbonate containing vial and the GFA containing vial. Samples were counted in the TriCarb 2100TR low activity liquid scintillation counter (LSC) onboard. Comparison of organic carbon fixation rates from this method and that described previously generated good agreement (model II regression: y = 1.28; r^2=0.90; n =27) and although there were problems (contamination and sensitivity issues) with some measurements, preliminary estimates of rates of inorganic carbon fixation (i.e. calcification) were typically 3% or less of total carbon fixation [AP, AD, MS].

Particulate Inorganic Carbon: A 1 litre sample of seawater was taken from between nine and ten depths and was vacuum filtered onto 0.45µm cellulose nitrate filters. The filters were rinsed with potassium tetraborate buffer and stored in cryo vials at room temperature. Upon returning to Southampton Oceanography Centre the samples will be analysed using ICPAES. [TA]

Coccolithophore composition (SEM): Between 250ml and 2 litres of seawater was filtered onto 0.4µm polycarbonate filters for each of the five light depths. These filters will be analysed upon return to SOC using a LEO scanning electron microscope. [TA]

Silicate uptake using the ^{32}Si radiotracer method (after Brown *et al*., 2003): Water samples were collected from 4, 5 or 6 depths corresponding to different light intensities as a percentage of surface irradiance. Three 250 ml samples were taken from each depth. At one or two stations, blank samples (filtered seawater poisoned with mercuric chloride) were also spiked to assess abiotic ^{32}Si uptake. 100µl of 0.5 µCi ml^{-1} ^{32}Si stock solution, in a sodium hydroxide solution was added to each bottle with a pipette. The bottles were capped and incubated for 24 hours in deck incubators simulating the *in situ* light intensities. These incubations were terminated by filtering samples through 47mm diameter 0.22 µm (and later 0.4 µm) polycarbonate filters. Each filter was placed in a 20ml vial and covered with 2.5ml of 0.2M sodium hydroxide and digested at 100^{o}C for an hour to dissolve the silica. When cooled, 10ml of Hi-Safe3 scintillation cocktail is added to the vial. These vials will then be taken back to Southampton Oceanography Centre for counting [MS, AP].

Biogenic Silica (BSi): A one litre sub-sample of seawater was taken from nine sampling depths, including the six light regime depths, for the analysis of BSi. The litre sample was vacuum filtered onto 0.4µm polycarbonate filters. These were then stored in scintillation vials at –20^{o}C for analysis back at Southampton Oceanography Centre (SOC). At the SOC, the BSi will be dissolved with 2.5ml

sodium hydroxide. This solution will be neutralised with 0.1mol L^{-1} hydrochloric acid, and concentrations will be determined using a flow autoanalyser [MS].

Photosynthesis v Electron Transport Rates (ETR): Discrete samples were collected for laboratory Fast Repetition Rate Fluorometer (FRRF) measurements of light responses. Such complementary measurements were likely to be very important given the ambiguity in interpretation inherent with *in situ* FRR data, where a vertical gradient in phytoplankton physiology may directly relate to the vertical gradient in light, particularly in stratified waters. Samples were collected in every pre-dawn and mid morning cast from the CTD rosette and quickly transferred to a controlled temperature laboratory on the ship. Size-fractionated samples were made by gravity filtering 200 ml water samples through 2µm polycarbonate (Poretics UK) filters. Some of surface samples were concentrated for overcome weak photosynthetic signals. Samples were allowed to dark acclimate for >30 minutes before being placed in a clear glass chamber attached to the optical head of an FRRF in the U.I.C room. Temperature within the chamber was controlled within 2°C of the *in situ* temperature using a cooler (US-T/S; Walz). The micro-processor controlled LED system was used to provide actinic light at a range of irradiances from 5-650 µmol photons m^{-2} s^{-1}. Relative changes in light levels were monitored using a CI 2π PAR sensor placed beside the sample chamber. Absolute light levels were measured within the sample chamber using a Biospherical Instruments QSL-2000 4π PAR sensor. Blanks for these experiments were generated by filtering the sample through a GF/F, a 0.2µm polycarbonate filter and then one more GF/F filter. The filtrate was then analysed using the FRRF set at the same gain as the sample run. A total of 200 light response curves were collected spanning the environmental gradients sampled during the cruise. These included 80 non filtered samples, 60 of larger than 2 µm and 60 of less 2 µm [YNK].

Preliminary Results

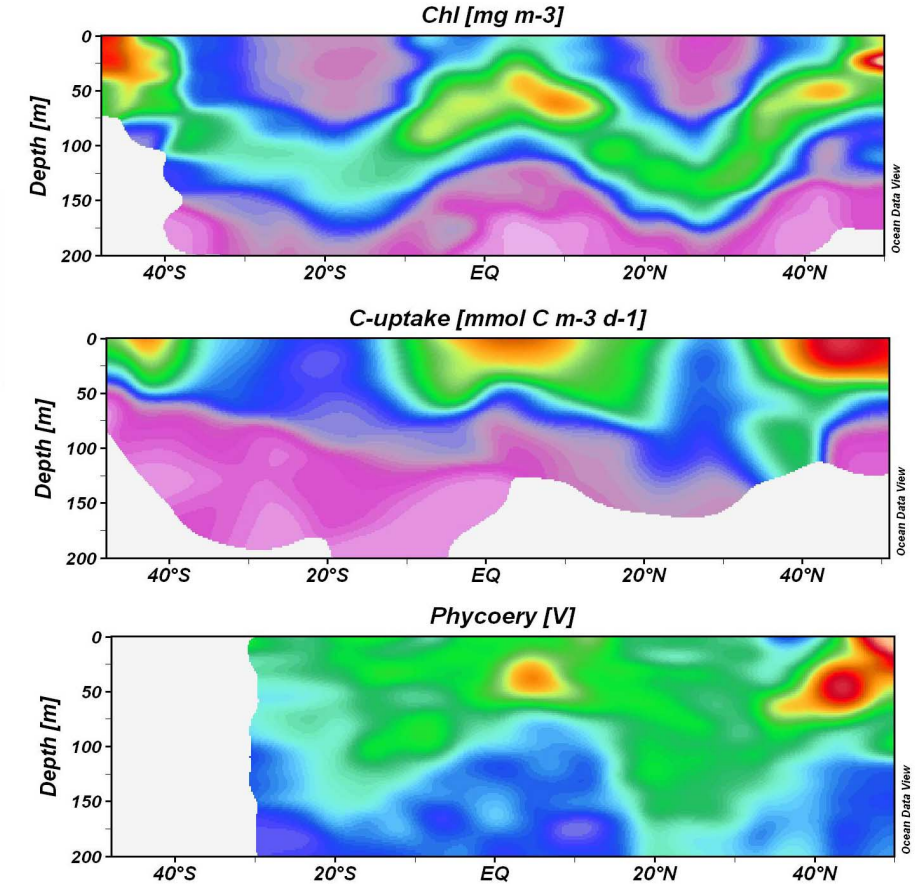

Figure 1. Preliminary results from AMT14; chlorophyll concentration (top panel, mg chl m^{-3}), rates of carbon fixation (middle panel, mmol C m^{-3} d^{-1}), and phycoerythrin concentration (bottom panel, raw volts). Plots constructed using Ocean Data View (ODV).

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^{15}N and ^{13}C Dual Labelled Isotopic Studies of New and Regenerated Production

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Rationale

The relative importance of different forms of nitrogen (N) within the oligotrophic sub-tropical gyres to the daily planktonic N budget is still a debated issue. The technical limitations involved in producing accurate nutrient concentrations at nanomolar levels and of difficulties with the mass spectrometric analysis of ^{15}N labelled filters with low sample sizes (<5µg N) have in recent years become surmountable. This has led to the potential of performing trace level (<10% ambient) uptake experiments in extremely oligotrophic waters, whereas previous work may actually have been attempted with spike concentrations in excess of 100% ambient, and could instead be considered to be nutrient addition experiments.

The work carried out during this cruise examined the uptake of nitrate (NO_3), ammonium (NH_4) and urea facilitated by using highly enriched (>98.5%) forms of each of these three nutrients labelled with ^{15}N – a stable isotope of nitrogen. Often a dual labelling approach was used when ^{13}C was added to the incubation bottles as this will allow for the determination of carbon (C) uptake during the incubation period which recent literature indicates may not be in accordance with the Redfield ratio. In addition the ^{13}C data will provide a means of identifying spike response uptake (where spikes are added at sufficiently high concentrations to perturb the natural uptake rates) through the comparison of ^{13}C to ^{14}C data. Following the conventions of Dugdale and Goering (1967) the uptake of NO_3 is considered to be new production, whereas the uptake of NH_4 and urea is defined as regenerated production.

Method

The water required for the experiments was collected from a pre-dawn CTD cast (0200-0300h local time) using a Seabird CTD with bottles being fired at depths corresponding to surface irradiance levels of 97, 55, 33, 14, 1 and 0.1% surface PAR. The water from each depth was then split into 2 litre bottles which were then inoculated with the $^{15}N/^{13}C$ spike and placed in the incubators. For the ^{15}N spikes inoculations were assumed to be at 10% or less of the ambient nutrient concentration, whereas ^{13}C was added at a baseline level of approximately 5% ambient. Bottles incubated under the 1 and 0.1% light levels were cooled with the use of onboard chillers whilst the other samples (97-14% PAR) were incubated with water from the underway supply (collected from approximately 7m depth).

Samples from the 55% level and below were incubated everyday with an additional series of samples at the 97% level being included intermittently. At each depth and on each day one 2 litre bottle for NO_3, NH_4 and urea was incubated. In addition, dark bottles were also used for the purpose of producing a dark uptake profile through the water column which had either NO_3, NH_4 or urea in it. Constraints on equipment and water precluded the inclusion of simultaneous dark profiles for the 3 nutrients and subsequently the dark incubations were cycled on a daily basis, meaning that a 3 day rotation period for each nutrient exists.

In addition to these standard incubations, the necessary work required for the correction of NH_4 remineralization occurring throughout the duration of the incubation was carried out. This involved pre- and post-incubation determinations of NH_4 concentrations and the collection and preservation of sample water for isotopic measurement in accordance with the method of Glibert *et al*., (1984). Seawater samples for the determination of urea were also collected and frozen and will be analysed back in the lab.

Samples were normally incubated from dawn till dusk before being filtered onto pre-ashed (450^{o}C for 4-6 hrs) 25mm GFF filters. These filters were then frozen for return to the lab where they will be dried, prepared and analysed on a GV Isoprime mass spec coupled to a Europa elemental analyser.

Stations sampled

The following is a list of the stations sampled and a brief description of the work carried out.

Nominal Station	CTD No.	Date	Description
1	1	30/04/04	Standard
2	6	02/05/04	Standard
3	8 & 9	03/05/04	Standard + SF
4	11 & 12	04/05/04	Standard + SF
5	15	05/05/04	Standard
6	17 & 18	06/05/04	Standard + SF
7	21 & 22	07/05/04	Standard + SF
8	26	08/05/04	Standard
9	29 & 30	09/05/04	Standard
10	32 & 33	10/05/04	Standard
11	36	11/05/04	Standard
12	40 & 41	13/05/04	Standard + SF
13	44	14/05/04	Standard + Additional
14	46	15/05/04	Additional
15	49 & 50	16/05/04	Standard
16	52 & 53	17/05/04	Standard
17	55 & 56	18/05/04	Standard + Additional
18	58 & 59	19/05/04	Standard
19	63	20/05/04	Standard + Additional
20	71	22/05/04	Standard
21	73 & 74	23/05/04	Standard + Additional
22	77	25/05/04	Standard
23	80	26/05/04	Standard
24	82 & 83	27/05/04	Standard
25	85	28/05/04	Standard
26	88	29/05/04	Standard

A “standard” station denotes NO_3, NH_4 and urea uptake at 5/6 light depths, plus 1 dark uptake profile, all usually with dual labelling ($^{15}N/^{13}C$). A size fractionated (SF) station considers the uptake of NO_3, NH_4 and urea over 3 size fractions (total, <10μm, <2μm) at one light depth. “Additional” refers to some form of experiment examining relevant features of incubation techniques (e.g. NH_4 uptake time series, 24hr incubations, spike additions in conjunction with ^{14}C data).

Results

All results from this work are to be obtained post-cruise following the mass spec analysis of the frozen filters. It is expected that the final results (^{15}N and ^{13}C uptake) will be available 6-12 months after the end of the cruise, and will be submitted to BODC shortly thereafter.

Dinitrogen Fixation in the Atlantic Ocean

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Objectives

- Develop an acetylene reduction gas chromatographic method for use with marine oligotrophic water samples as an indirect measure of dinitrogen fixation
- Further develop the ^{15}N stable isotope method for atmospheric dinitrogen fixation.
- To make measurements of dinitrogen fixation by means of the acetylene reduction technique.
- To make measurements of dinitrogen fixation by means of the ^{15}N stable isotope incorporation technique.
- Further develop protocols for both the ^{15}N and acetylene reduction techniques in a research vessel environment.
- Test and establish the validity of the large volume direct acetylene reduction technique as a direct measure of oceanic dinitrogen fixation

Methods

Acetylene reduction: Dinitrogen fixation is based upon the biodegradation of acetylene to ethylene, by means of the triple bond in the acetylene being broken by the nitrogenase enzyme. This enzyme is only present in organisms that possess the ability to fix atmospheric dinitrogen, and it therefore a reliable measure of the dinitrogen fixation by the natural biota.

Water was collected each morning from the "monster" (0200h) CTD from 4 depths equivalent to (97%, 55%, 33% and 14%) of surface irradiance. The samples were spiked with saturated sample water and incubated in 250 ml gas tight bottles for 12hrs, in on-deck incubators, with the appropriate light filters.

The required light depths were calculated from PAR data from the previous day's data. The samples were removed after incubation and stored in a dark box. A 20ml headspace (OFN) was added to the bottles, which were then equilibrated and analysed by gas chromatography (flame ionisation detection).

^{15}N stable isotope technique: This technique is a direct measure of the uptake of ^{15}N by the dinitrogen fixing organisms. ^{15}N was introduced as a gas into the cubitainers and any uptake of ^{15}N labelled nitrogen, therefore must be as a result of atmospheric dinitrogen fixation. Water was collected each morning from the monster CTD from 2 light depths equivalent to 97% and 33% of surface irradiance. This was then transferred into 8 gas tight cubitainers, 4 for each depth.

To each set of cubitainers the following additions were carried out:

Cubitainer number	Light level	Incubation time
1,2	97% and 33%	^{15}N 0 hr
3,4	97% and 33%	^{14}N 0 hr
5.6	97% and 33%	^{15}N 24hr
7,8	97% and 33%	^{14}N 24hr

These were incubated for the appropriate time in on deck incubators with the appropriate light filters, removed and filtered on to glass fibre filters (GFFs), placed in small Petri dishes, dried and sealed.

CTD samples analysed

Date	CTD number	Acetylene reduction rate	^{15}N filter
04/05/04	8	✓	
05/05/04	15	✓	✓
06/05/04	17		✓
06/05/04	18	✓	
06/05/04	21		✓
07/05/04	22	✓	
07/05/04	25		✓
08/05/04	26	✓	
08/05/04	29		✓
09/05/04	30	✓	
09/05/04	32		✓
10/05/04	33	✓	
10/05/04	35		✓
11/05/04	36	✓	
13/05/04	40	✓	✓
14/05/04	43-44	Method test	Method test
15/05/04	46	✓	✓
16/05/04	49	*Trichodesmium* tests	*Trichodesmium* tests
17/05/04	52	✓	✓
1805/04	55	✓	✓
19/05/04	58	✓	✓
20/05/04	62	✓	✓
21/05/04	66 + 67	✓ + *Trichodesmium* tests	✓ + *Trichodesmium* tests
22/05/04	70	✓	✓
25/05/04	76	✓	✓
26/05/04	79	✓	✓
27/05/04	82	✓	✓

Preliminary Results

^{15}N gaseous uptake: ^{15}N results will not be available until mass spectrometry analysis can be done later in the year.

Acetylene reduction: The acetylene reduction technique has shown a relatively low back ground level of dinitrogen fixation, within the Northern gyre (extending in to some mesotrophic areas). Slightly higher rates were observed with in the Southern gyre, and the highest dinitrogen fixation levels were found around the equator.

***Trichodesmium* sub-experiments:** During AMT14 it became apparent that a positive control was needed to test the validity of the acetylene reduction technique. This was done fairly early in to the cruise, and gave clear evidence that the acetylene reduction techniques was working and had a good sensitivity range. Further experiments using natural population of *Trichodesmium* sort to gain a colonial fixation rate, to this end we were successful, showing that different populations of *Trichodesmium* do in fact show different colonial fixation rates. This seems to be dependent on colony density, nutrient levels and where the populations were collected.

CTD 67 proved to be a very interesting station. Within the samples collected and analysed, there seemed to be no natural levels of ethylene or dinitrogen fixation present. However on the addition of *Trichodesmium* the fixation rate increased significantly, showing that that station in terms of nitrogen fixation was relatively dead, whereas the stations previously and directly after showed natural level of nitrogen fixation.

Conclusion

During the first week of the cruise there was a series of technique problems, appearing as zero fixation levels. This was identified as toxin build up due to supersaturation of the large volume of water needed for sample incubation. It was decided to saturate smaller volumes, thereby reducing the level of contaminants. This change in method proved successful.

The acetylene reduction technique after great deal of development has proven be a useful and relatively accurate tool for measuring diazotrophic-nitrogen fixation in situ. This technique provides real time, relatively rapid data collection and can be effectively operated by a single person. It provides an indirect rate measurement which, if combined with ^{15}N isotopic gaseous uptake, will provide a very powerful tool for the assessment of diazotrophic-nitrogen fixation within oceanic environment.

Acknowledgements

I would like thank Dr Alex Poulton, for all his advice and help with the *Trichodesmium* experiments.

Atlantic Microzooplankton: community composition and the role of UV in carbon flux

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Aims and Objectives

- Profile surface solar UVR (ultra-violet radiation) along the AMT.
- Quantify the effects of UVR on microzooplankton community composition and cell size and on taxon-specific growth rates in relation to latitude and to water temperature.
- Quantify the effects of UVR on the growth of a 'representative species' of microzooplankton in culture.
- Quantify the effects of UVR on chlorophyll-containing organisms in the same size range as microzooplankton and on potential microzooplankton prey (pico- and nano-plankton).
- Identify the species composition in relation to latitude by vertical profiling.

This study has four interrelated parts: i. To assess the vertical distribution of microzooplankton in the water column, ii. To assess the latitudinal distribution of microzooplankton and how environmental parameters may influence community composition, iii. To investigate experimentally the effects of UVR surface microzooplankton growth rates in surface waters, and iv. To assess the effects of latitude-related temperature on the microzooplankton size.

Experimental Design and Setup

1. The effect of UVR on microzooplankton community, specific taxa and cultured sample growth rates, and on species diversity

Water samples were collected from 14 stations along the AMT tract, chosen to represent a general gradient of varying UV exposures. These samples were incubated as described in the AMT13 report under 3 different UV filtered conditions: i. PAR+UVA+UVB (280-700 nm) treatment with no filters i.e., exposed to ambient sunlight; ii. PAR+UVA (320-700 nm); iii. PAR only (400-700 nm).

At 6 different stations, at regular intervals along the transect, 150 ml cultures of the heterotrophic dinoflagellate, *Oxyrrhis marina*, were also incubated in the incubators but for a period of 72 hours.

To account for the low ciliate numbers experienced in natural samples from AMT13, larger samples were taken and 2 l Whirlpak® polyethylene bags (Nasco, Fort Atkinson, USA) were used. The volume fixed in the triplicates (at T_0, T_{24} and T_{48}) was increased from 250 ml to 1 l. The increased volume will allow a greater prevalence of ciliates in these samples. The fixed samples will be analysed as AMT13.

1.8 ml was also taken from each triplicate sample at T_0, T_{24} and T_{48} and fixed in paraformaldehyde (final concentration 1%) and frozen. These samples will be returned to the laboratory for flow cytometery analysis to assess the effects of UVR on pico- and nano-plankton numbers. This will tie in with the investigation of UVR on the microbial food web. 150 ml volumes were also taken from these triplicates to filter and dye for epifluorescent slides. These were frozen for later analysis to identify effects of UVR on autotrophic and heterotrophic flagellates ratios which is not only important to the microbial food webs but also the chemistry of the oceans.

Oxyrrhis marina was cultured and incubated by previous protocols and 1.8 ml samples collected, fixed in paraformaldehyde (final concentration 1%) and frozen at T_0, T_{24}, T_{48} and T_{72} for later flow cytometry analysis.

On three occasions duplicate experiments were run using the standard collected sample alongside a standard sample that had been spiked with a volume of *Nanochloropsis*, a phytoplankton within the size range of microzooplankton prey. This was to assess if an increased source of prey may reflect UVR effects better by reducing pressure caused by potential prey loss.

UVR was recorded as on AMT13 (*N.B.* See 'Problems' section at the end of this report).

2. Effect of UVR on a culture of microzooplankton potential prey, chlorophyll containing organisms (<200 µm), pico- and nano-plankton and on heterotrophic and autotrophic flagellates.

Nanochloropsis was cultured on-board using filtered sea-water. On four different occasions 150 ml samples were incubated in acid washed 150 ml Whirlpak® bags in the UV filtered incubators. 1.8 ml samples were fixed at T_0, T_{24}, T_{48} and T_{72} in paraformaldehyde (final concentration 1%) and then frozen for later flow cytometry analysis. Any adverse effects on cell numbers by UVR will be indicative of potential microzooplankton prey loss and will tie in with the 'spiking' experiment (described in section 1).

At 6 different sites along the transect, 2 l of 200 µm screened water, collected from either the surface or chlorophyll maximum, was incubated in acid washed 2 l Whirlpak® bags and incubated in the UV filtered incubators. An initial T_0 reading of chlorophyll content was taken by filtering 250 ml (500 ml in the gyres) through a GFF filter. The filter was chilled in 10 ml of 90% acetone for 24 h and then analysed using a Turner fluorometer. Further readings were taken at T_{24} and T_{48}. Results, that will be analysed and corrected at the laboratory, will again indicate any UVR effects on potential microzooplankton prey and possible UVR effects on food webs.

3. Vertical Profiling

The same sampling technique was used as on AMT13 except that a larger volume was gathered for profiling. 1 l water samples were fixed in 2% Lugol's solution in gyre areas and 500 ml samples were fixed in areas of high production.

Assessment of the presence of heterotrophic and autotrophic flagellates using epifluorescent staining also utilized a larger volume of water with 250 ml being filtered in the gyres and 75 ml in temperate waters.

Effect of temperature on cell size

Using the sample protocol described in the AMT13 report.

Data

Data generated for the microzooplankton UVR experiments was 9 samples from each incubator at T_{24} and T_{48} (with a T_0 of 3 samples). A similar number of epifluorescence slides and flow cytometry samples were taken from each experiment.

Nine daily samples were collected from each of the *Oxyrrhis marina* and *Nanochloropsis* cultured experiments at T_{24}, T_{48} and T_{72} including 9 T_0 readings.

Three T_0 filters were analysed for the chlorophyll extraction experiment. Nine samples were then filtered at both T_{24} and T_{48} for analysis in the Turner fluorometer. A similar number of flow cytometry samples were also taken from these experiments.

7 daily samples were collected for vertical profiling with corresponding epifluorescent slides created for each profile.

Additional Experimentation

When possible (on 8 occasions) 10 l samples were taken from 97%, 55%, 33% and 1% light irradiance levels. These samples were reverse filtered from their carboys, leaving a concentrate of between 250ml and 750ml. This was fixed in 2% Lugol's solution for analysis by Elaine Fileman at the Plymouth Marine Laboratory, investigating tintinnid prevalence.

Problems

The UV sensor was a replacement item. This replacement item was not well manufactured and despite a continued effort from myself, Mark Preston (on-ship BAS Electronics Engineer) and the duty electrician, the sensor never functioned properly. As a result UV irradiance data has not been recorded.

Analysis

The completion of data and deposition at BODC will be dependent on analysis of collected samples at the Plymouth Marine Laboratory. Analysis will start at the beginning of June and will continue until AMT15, at which point the flow cytometry and epifluorescent slide analysis and a majority of the UVR effect analysis will be completed. Profile analysis will be completed after AMT15.

Sample Collection for UVR experiments and profiles

Date	CTD	Test	Latitude	Longitude	GMT
30/04/2004	1	UV			05:50:58
	3	profile			15:01:41
02/05/2004	5	UV	41 02.44 S	041 33.57 W	06:12:16
	6	profile	41 02.09 S	041 33.52 W	07:40:12
03/05/2004	8	UV	38 51.57 S	038 35.42 W	04:39:45
	9	profile	38 52.88 S	038 35.12 W	06:04:53
04/05/2004	11	UV	35 58.01 S	034 47.39 W	04:40:31
	12	profile	35 57.99 S	034 47.39 W	05:58:00
05/05/2004	15	profile	32 58.42 S	031 00.47 W	06:53:22
06/05/2004	17	UV	30 41.61 S	028 12.49 W	04:36:22
	18	profile	30 41.61 S	028 12.48 W	06:01:19
	19	chloro	29 46.13 S	027 05.65 W	14:03:10
07/04/2004	22	profile	28 05.29 S	025 06.12 W	05:48:48
08/05/2004	25	UV	24 13.87 S	024 59.70 W	04:59:13
	26	profile	24 13.87 S	024 59.70 W	06:24:16
09/05/2004	29	UV	20 55.84 S	024 59.95 W	04:34:20
	30	profile	20 55.77 S	025 00.22 W	05:54:37
10/05/2004	32	chloro	16 38.71 S	024 59.70 W	04:32:08
	33	profile	16 38.67 S	024 59.77 W	05:43:15
11/05/2004	35	UV	12 16.51 S	024 59.71 W	04:59:53
	36	profile	12 16.55 S	024 59.66 W	06:39:07
12/05/2004	38	profile	08 49.05 S	025 00.12 W	05:44:34
14/05/2004	43	UV	00 05.60 S	024 59.87 W	04:56:07
	44	profile	00 06.08 S	024 59.79 W	06:20:13
15/05/2004	47	profile	03 14.68 N	026 14.60 W	05:49:43
16/05/2004	49	UV	07 17.45 N	027 46.78 W	04:31:54
	50	profile	07 17.33 N	027 46.90 W	05:39:45
17/05/2004	53	profile	11 24.03 N	029 22.07 W	06:13:04
18/05/2004	56	profile	14 45.32 N	030 40.99 W	05:52:59
19/05/2004	58	UV	18 47.79 N	032 17.29 W	04:34:18
	59	profile	18 47.79 N	032 17.31 W	05:47:18
20/05/2004	63	profile	22 20.07 N	033 44.00 W	07:03:37
21/05/2004	66	UV	25 55.40 N	035 14.22 W	04:35:54
	67	profile	25 55.31 N	035 14.17 W	05:47:13
22/05/2004	71	profile	29 18.03 N	036 41.96 W	06:59:13
23/05/2004	73	tin	31 16.96 N	032 33.52 W	04:52:05
	74	profile	31 16.68 N	032 33.35 W	06:13:38
25/05/2004	76	UV	35 45.17 N	022 51.18 W	04:35:03
	77	profile	35 44.82 N	022 51.10 W	05:43:08
26/05/2004	80	profile	38 39.98 N	019 57.63 W	05:20:58
27/05/2004	82	UV	41 59.09 N	018 47.56 W	03:36:46
	83	profile	41 59.17 N	018 47.55 W	04:42:10
28/05/2004	85	profile	46 26.08 N	017 16.67 W	04:48:07

Plankton Size Spectra

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Can the size spectrum of planktonic organisms be used as a descriptor of energy or organic matter transfer between trophic levels of the planktonic food web? The extent to which plankton size spectra can be used as a measure of a community's capacity to export organic carbon to larger pelagic organisms or deep water, in the form of POC or DOC, via the biological carbon sink will be assessed. Thus, the challenge is to ascertain the mechanisms governing the trophic structure and status of the major planktonic ecosystems.

The latitudinal distribution of plankton will be characterised along this 50˚N to 52˚S Atlantic Meridional Transect (AMT14) cruise by applying a range of image analysis techniques. Size fractionated zooplankton feeding experiments were also conducted to determine the extent of different carbon pathways in the pelagic food web and therefore improve our understanding of factors shaping the spectral slope. Comparisons of plankton size spectra to other biogeochemical measurements will also help understand the causative mechanisms that affect the structure and energy transfer efficiency of the planktonic community with a view to using size spectra as a descriptor of carbon export. Ultimately, planktonic size spectra may have the potential to help understand the impact that climate change and over-exploitation of fish stocks have on the marine pelagic ecosystem. Hence, if validated, the importance of plankton size spectra as a tool in evaluating the oceanic system is evident.

Hypothesis: The size spectrum of plankton can be used as a descriptor of the transfer of energy to compare different pelagic ecosystems.

Objective: Can the slope of a size spectrum be used as a measure of a pelagic community's capacity to export organic carbon?

Samples Collected

Plankton Size Spectra

CTD	Date	CTD Depths	Bongo nets – 200 & 50 µm (200 & 50 m)	Size fractionated Zooplankton Biomass
2	30.04.04	11	Y	Y
6	2.05.04	11	Y	Y
9	3.05.04	11	Y	Y
12	4.05.04	11	Y	Y
15	5.05.04	11	Y	Y
18	6.05.04	11	Y	
22	7.05.04	11	Y	
26	8.05.04	11	Y	Y
28	8.05.04	11	Y	
30	9.05.04	11	Y	Y
33	10.05.04	11	Y	
36	11.05.04	11	Y	Y
38	12.05.04	11	Y	Y
41	13.05.04	11	Y	
44	14.05.04	11	Y	Y
47	15.05.04	11	Y	
50	16.05.04	11	Y	Y
53	17.05.04	11	Y	Y
56	18.05.04	11	Y	Y

CTD	Date	CTD Depths	Bongo nets – 200 & 50 µm (200 & 50 m)	Size fractionated Zooplankton Biomass
59	19.05.04	11	Y	
63	20.05.04	11	Y	Y
67	21.05.04	11	Y	
71	22.05.04	11	Y	Y
74	23.05.04	11	Y	Y
77	25.05.04	11	Y	
80	26.05.04	11	Y	
83	27.05.04	11	Y	
85	28.05.04	11	Y	
88	29.05.04	5	Y	

Mesozooplankton Feeding Experiments

Feeding Experiment	CTD	Date
1	17	6.05.04
2	32	10.05.04
3	46	15.05.04
4	55	18.05.04
5	66	21.05.04
6	76	25.05.04

Preliminary results and scientific highlights

There are no results to discuss at present as all analysis is performed back in the laboratory. The sampling, however, was carried out without any problems or inconveniences. The only qualitative observation that can be made was that there was an apparent difference in the amount of plankton found in the nets in the different oceanic regions. There were generally fewer and smaller animals in the oligotrophic regions compared to a more abundant and apparent diverse sample in mesotrophic and eutrophic waters. It has also been noted that the majority of the mesozooplankton sampled from CTD 67 were moribund, which ties in with some of the interesting production results and DMS concentrations found at that station.

Future analysis

The microplankton samples will be sized and counted using FlowCAM, an instrument that instantaneously counts and sizes particles in the 10 – 500 µm range at AZTI (Spain). Spectral analysis will be performed on the mesozooplankton net samples using another auto-imaging programme at Plymouth Marine Laboratory (PML). The size fractionated zooplankton biomass and HPLC samples will be analysed at PML. The size fractionated zooplankton used in the grazing experiments will be counted and analysed under the microscope at PML. The 50 µm net samples will be investigated for the presence of large phytoplankton at Southampton Oceanography Centre as part of an undergraduate third year project.

Gross Production, Net Community Production and Dark Community Respiration

NICOLA GIST
Plymouth Marine Laboratory

Objectives

- 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).
- To measure dissolved oxygen concentration in order to calibrate the oxygen sensors on the CTDs.

Samples collected

Depth profiles of GP/DCR samples were collected daily (n=27).

In situ oxygen for the calibration of the CTD oxygen sensor: Samples from up to 8 depths collected from deep monster, pre-dawn and mid-morning casts on 43 occasions.

Methods

Please see methods sections in cruise reports from AMT 12 and 13.

Results summary

O_2 samples for the calibration of the CTD SBE sensor have been collected. The complete calibration procedure will be undertaken at BODC, but preliminary calibrations carried out onboard suggest that the "drift" of the SBE sensor experienced on AMT13 did not occur on this cruise. The calibration is well constrained with standard residuals well within the limits advised by BODC (Fig. 1).

Productivity data will be processed on our return to the UK, but it is expected that all O_2, GP, NCP and DCR data will be deposited at BODC by September 2004. Contour plots of GP and DCR (Figs. 2 and 3) are attached for interest only since the data is provisional at this stage. For this reason, no key or scale is included.

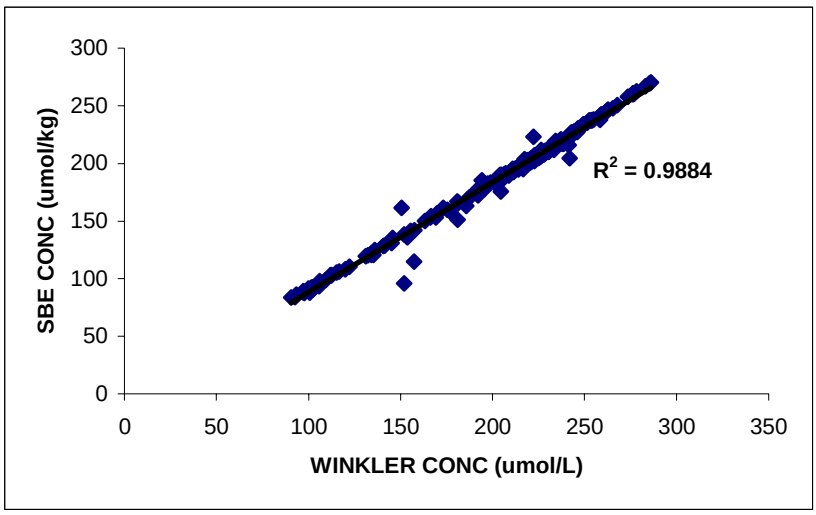


Figure 1. Calibration line at the latest point at which calibration was carried out onboard.

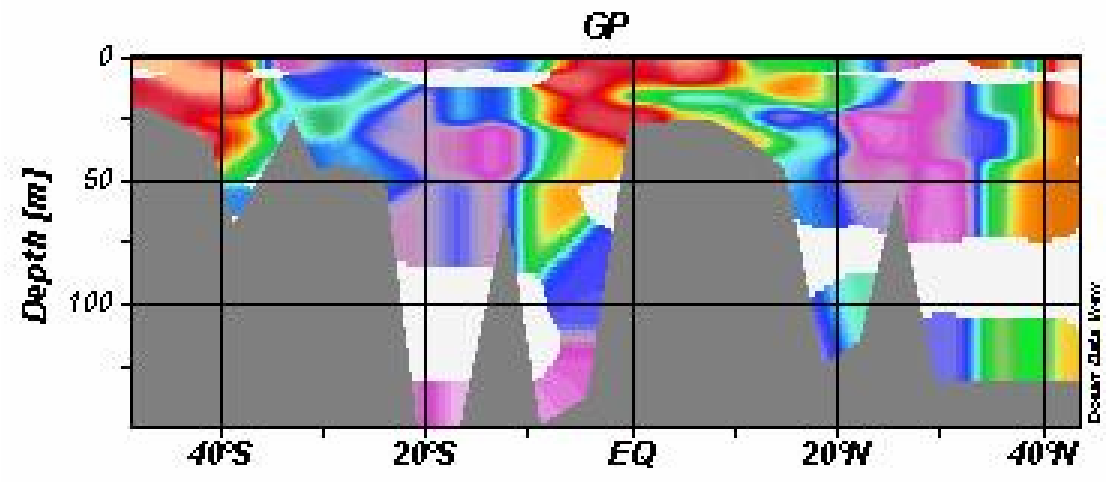


Figure 2. Variation in gross production over the transect.

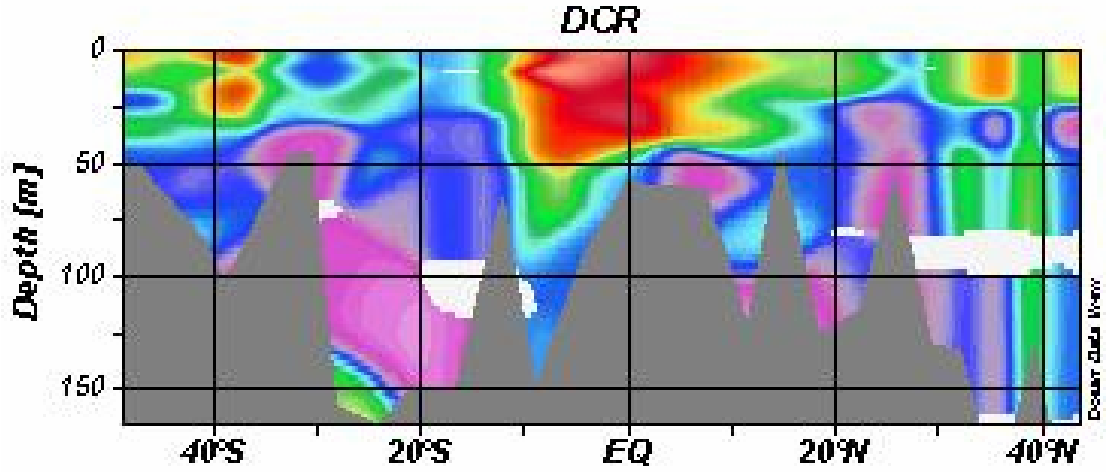


Figure 3. Variation in dark community respiration over the transect

Acknowledgments

I must thank Alex Poulton and Emma Wilson whose help was invaluable throughout the cruise and to Sarah, Sandy and Jenna who helped out with in-situ samples when time till dawn was tight.

Micro- and Nano-molar Nutrients

KATIE CHAMBERLAIN
Plymouth Marine Laboratory

Objectives

To study spatial and temporal variations in levels of inorganic nutrients (nitrate, nitrite, phosphate, silicate and ammonium as part of AMT Objective 2 (hypotheses 5 and 6).

Two analytical systems were used: the Bran+Luebbe Autoanalyser, which is a classic colorimetric nutrient autoanalyser that measures micromolar nutrient concentrations; and Waveguide Capillary Cells for measuring nanomolar concentrations of nitrate, nitrite and phosphate.

Generally, PML provides measurements nanomolar ammonium. However, due to unforeseen circumstances before the cruise, this task was taken on by the SOC using a manual method (see following report).

It was discovered during the first part of the cruise that CTD bottles 9 and 16 occasionally failed to close properly. This problem was resolved on 19th May.

Methodology

The Bran+Luebbe AAIII consists of five channels that measure micromolar nitrite, nitrate, ammonium, silicate and phosphate. This machine is now into the third consecutive AMT cruise. Software problems encountered during AMT12 have been resolved which has permitted provisional data processing at sea.

Nanomolar nitrate, nitrite and phosphate were determined using Waveguides made by World Precision Instruments which are based on a 2m capillary small diameter cell and fibre optics. Chart outputs have been provisionally processed at sea to provide real time nutrient data.

CTD water samples were taken from the 24 x 20 litre CTD/Rosette system and sub sampled into MilliQ clean 100ml and 60ml HDPE (nalgene) bottles. Gloves were used when collecting the water from the CTD. The nutrient samples were analyzed within two hours on the Bran+Luebbe AAIII and three to four hours on the Waveguide. No samples were stored.

Underway sampling

Daily sampling was carried out from the surface (7m) non – toxic sea water supply and the majority of these samples were analysed for nutrients, DMS, chlorophyll and pCO_2. Nutrients were analyzed only from the 1500h GMT underway sampling.

Other Analyses

DON and DOP samples were analyzed for nitrate and phosphate after UV irradiation. This work was carried out in collaboration with Sarah Reynolds from Liverpool University.

Samples for micromolar ammonium were analyzed during the course of zooplankton feeding experiments conducted by Elena San Martin.

Nanomolar nitrate and nitrite values were determined for Nick Millwards' dinitrogen fixation work.

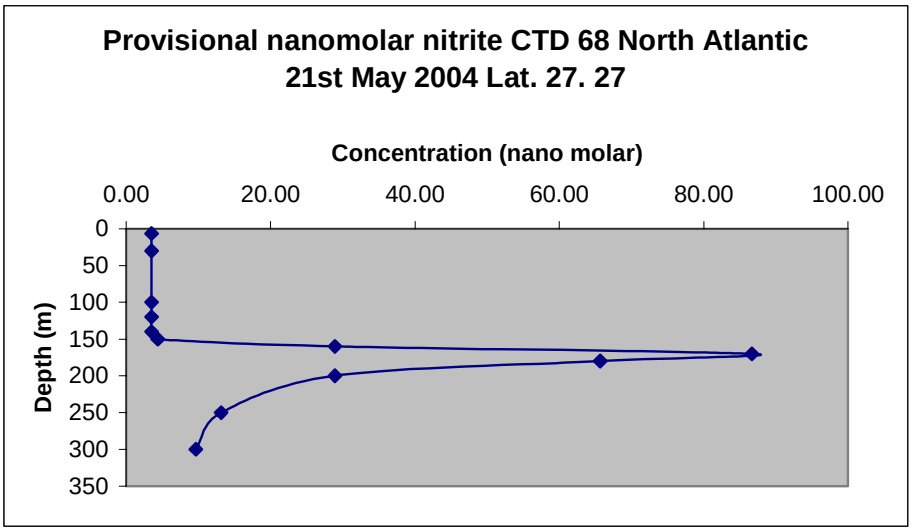
Results

The Falklands' Shelf is a region of frontal zones that exhibit high nutrient concentrations in the surface waters. Notably this was the only region of the cruise where micromolar ammonium was detected. As we progressed into the Southern Atlantic Gyre, the waters became more stratified and this is reflected in a reduction of nutrient concentrations. There is a significant change from micromolar surface

nitrate, nitrite and phosphate to nanomolar. The chlorophyll maxima became deeper the further into the oligotrophic gyre and a nanomolar nitrite maximum was detected at depths of about 120m. Across the Equatorial Upwelling region the thermocline and chlorophyll maximum were as shallow as 50m. The upwelled waters had typical nitrate and silicate nutrient concentrations of >10micro moles at depths of 300m. Levels in surface waters remained in the nanomolar range.

This is the first AMT cruise that has sampled so far west into the Northern Gyre. CTD 68 (21st May Latitude 27.27N) showed a deep chlorophyll maximum with nanomolar levels of nitrate down to 150m and a well defined nitrite maximum at the base of the euphotic zone (see figure below).

On return to Plymouth Marine Laboratory Katie Chamberlain and Malcolm Woodward will complete the calibration and validation procedures jointly before submitting all the nutrient data to BODC.



CTD Samples analysed

There were two different daily operations for the CTD sampling. Each day pre-dawn sampling (11 nutrient depths) was carried out as a biogeochemistry cast as well as providing the water for the primary production and nitrogen uptake in-situ determination. Prior the pre-dawn there was a monster cast to 300m (no nutrient samples required) and every third day this cast went to a 1000m due to SAPs deployed at that station. 500m and 1000m depth samples were collected. The mid-morning cast went to 300m, bottles were fired every ten meters to permit a high resolution study of the nutricline. On average, nutrients were sampled from 13 depths.

Table 1. CTD samples analysed

Date	CTD number	CTD Bottle number sampled
29/04/2004	01-14	Cancelled
30/04/2004	02-14	24, 20, 17, 14, 12, 9, 7, 4, 3, 2, 1
	03-14	24, 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1
01/05/2004	04-14	24, 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12 ,11, 9, 8, 7, 6, 5, 4, 3, 2, 1
02/05/2004	05-14	3, 2
	06-14	24, 20, 17, 14, 12, 9, 7, 4, 3, 2, 1
	07-14	24, 23, 22, 21, 20, 19, 16, 15, 14, 13, 2, 1
03/05/2004	09-14	24, 20, 17, 14, 12, 9, 7, 4, 3, 2, 1
	10-14	23, 22, 21, 20, 19, 17, 16, 15, 14, 2, 1
04/05/2004	12-14	24, 20, 17, 14, 12, 9, 7, 4, 3, 2, 1
	13-14	24, 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 4, 3, 2, 1
05/05/2004	14-14	3, 1
	15-14	24, 20, 17, 14, 12, 9, 7, 4, 3, 2, 1
	16-14	24, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10

Date	CTD number	CTD Bottle number sampled
06/05/2004	19-14	24, 20, 17, 14, 12, 9, 7, 4, 3, 2, 1
07/05/2004	22-14	24, 20, 17, 14, 12, 7, 4, 2, 1
	23-14	24, 22, 21, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 3, 2, 1
08/05/04	25-14	3, 1
	26-14	24, 20, 17, 14, 12, 7, 4, 3, 2, 1
	27-14	24, 16, 15, 14, 13, 12, 11, 10, 4, 3, 2, 1
09/05/2004	30-14	24, 20, 17, 14, 12, 9, 7, 4, 3, 2, 1
	31-14	25, 17, 16, 15, 14, 13, 11, 15, 14, 13, 1
10/05/2004	33-14	24, 16, 15, 14, 13, 12, 11, 10, 4, 3, 2, 1
	34-14	24, 20, 17, 15, 13, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1
11/05/2004	35-14	3, 1
	36-14	24, 20, 17, 15, 13, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1
	37-14	21, 18, 15, 13, 11, 10, 9, 8, 7, 5, 3, 2, 1
12/05/2004	39-14	24, 20, 17, 15, 13, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1
	40-14	23, 18, 15, 14, 13, 9, 7
13/05/2004	41-14	24, 20, 17, 15, 13, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1
	42-14	23, 21, 19, 17, 16, 14, 12, 10, 8, 6, 3, 2, 1
14/05/2004	43-14	3, 1
	44-14	24, 20, 17, 15, 13, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1
	45-14	23, 21, 18, 17, 16, 15, 14, 12, 11, 8, 3, 2, 1
15/05/2004	47-14	24, 20, 17, 15, 13, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1
16/05/2004	50-14	24, 20, 17, 15, 13, 10, 9, 8, 7, 6, 5, 3, 2, 1
	51-14	23, 21, 19, 18, 17, 16, 15, 14, 13, 15, 8, 3, 1
17/05/2004	52-14	3, 1
	53-14	24, 20, 17, 15, 13, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1
	54-14	23, 20, 18, 17, 16, 15, 14, 13, 11, 8, 3, 2, 1
18/05/2004	56-14	24, 20, 17, 15, 13, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1
	57-14	23, 18, 15, 13, 12, 11, 10, 9, 8, 6, 3, 2, 1
19/05/2004	59 – 14	24, 20, 17, 15, 13, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1
	60 – 14	23, 18, 15, 13, 11, 10, 9, 8, 7, 5, 3, 2, 1
20/05/2004	62 – 14	3, 1
	63 - 14	24, 20, 17, 15, 13, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1
	64 – 14	23, 21, 18, 13, 11, 10, 9, 8, 7, 5, 3, 2, 1
21/05/2004	67 - 14	24, 20, 17, 15, 13, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1
	68 – 14	23, 20, 13, 11, 9, 8, 7, 6, 5, 3, 2, 1
22/05/2004	70 -14	3, 1
	71 - 14	24, 20, 17, 15, 13, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1
	72 – 14	23, 18, 13, 11, 10, 9, 8, 7, 6, 5, 3, 2, 1
23/05/2004	73 – 14	3, 1
	74 – 14	24, 20, 17, 15, 13, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1
	75 – 14	23, 18, 15, 13, 11, 10, 9, 7, 5, 3, 2, 1
25/05/2004	77 - 14	24, 20, 17, 15, 13, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1
	78 – 14	23, 22, 20, 18, 17, 16, 15, 14, 13, 11, 7, 3, 2
26/05/2004	79 – 14	1
	80 – 14	24, 20, 17, 15, 13, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1
	81 – 14	23, 21, 20, 19, 18, 17, 16, 15, 13, 8, 3, 2, 1
27/05/2004	83 - 14	24, 20, 15, 13, 10, 9, 8, 7, 6, 5, 4, 3, 2,
	84 – 14	23, 20, 19, 18, 17, 16, 15, 13, 8, 3, 2, 1
28/05/2004	85 - 14	24, 20, 17, 15, 13, 10, 9, 8, 7, 6, 5, 4, 3, 1
	86 – 14	23, 21, 20, 19, 18, 15, 13, 11, 8, 3, 2, 1
29/05/2004	87 – 14	24, 21, 18, 15, 12, 9, 6, 4, 2

Acknowledgements

I would just like to say a big thanks to Andy Harvey for stepping in one week before the cruise and for all his help. His dedication to collecting the CTD water and general lab work is much appreciated. Without his help, it would not be possible to have sampled so many CTDs.

Ammonium Measurements

ANDREW HARVEY
Southampton Oceanography Centre

Objectives

1. To investigate temporal and spatial variations in the concentration of ammonium at the nano-molar level through contrasting oceanic regions along the cruise track between the Falkland Islands and the UK. This is a continuation of work carried out by Malcolm Woodward on AMT12 and AMT13, albeit utilising a different analytical technique.
2. To make routine measurements of the changes in ammonium concentrations during 12 and 24 h incubations to support Stuart Painter's work investigating oceanic nitrogen budgets and new and regenerated phytoplankton production.

Methodology

Ammonium concentration in seawater samples was measured using an adaptation of the method described by Holmes *et al.* (1999) (Johnson, *pers. comm.*). The method involves i) the addition of a working reagent to seawater samples; ii) incubation of samples for 3-8h in the dark; iii) measurement of sample fluorescence using, in this case, a Turner Designs TD-700 Fluorometer.

Sample collection

Following difficulties at the outset of the cruise with contamination of samples initially collected into carboys and later sub-sampled, cleaner sampling techniques were developed. Seawater was collected from the Niskin bottle tap using a silicon rubber tube directly into 50ml centrifuge tubes prior to water collection for any other analyses except gas concentrations. Tubes were first rinsed three times with the sample water and then sealed with polypropylene caps to minimise air contact. In the laboratory 10ml analytical samples were prepared from these sample stocks in triplicate by the addition of 800µl of the OPA working reagent. In addition a 5ml analytical sample was prepared by the addition of 400µl of disodium tetraborate buffer solution and used to assess the background auto-fluorescence of the samples.

Calibration

The fluorometer was calibrated prior to sample analysis on a daily basis. Eight point calibration curves were prepared using the following concentrations of NH_4Cl diluted in MilliQ:

0, 5, 10, 50, 100, 200, 500, 1000 nM	CTD's 1-8
0, 5, 10, 50, 100, 150, 200, 250 nM	CTD's 8-77
0, 5, 10, 50, 100, 150, 200, 250, 500 nM	CTD's 78-87

Periodically during the cruise assessments of the matrix effects on sample fluorescence were made by comparing calibration standards to standards made up in either surface or deep (1000m) seawater.

CTD Samples Analysed

Initially only samples taken from the pre-dawn CDT cast were analysed for ammonium concentrations. As issues with the method were overcome sampling was increased to include the mid-morning CDT cast during the latter stages of the cruise.

Table 1: Summary of CTD bottles sampled.

CTD	Date	AMT Bottle No.
AMT14-001	30/4/04	5,7,9,15,16,19
AMT14-006	2/5/04	5,8,11,16,20
AMT14-008	3.5.04	5
AMT14-009	3/5/04	5,8,11,16,20
AMT14-011	4/5/04	5
AMT14-012	4/5/04	5,8,11,16,20
AMT14-015	5/5/04	1,5,8,11,19
AMT14-018	6/5/04	1,5,7,8,11,16,21
AMT14-022	7/5/04	1,5,7,8,11,21
AMT14-026	8/5/04	1,5,7,8,11,16,21
AMT14-030	9/5/04	1,5,8,11,16,21
AMT14-033	10/5/04	1,5,8,11,16,21
AMT14-036	11/5/04	1,5,8,11,16,21
AMT14-038	12/5/04	1,5,8,11,16,21
AMT14-041	13/5/04	1,5,8,11,16,21
AMT14-044	14/5/04	1,5,8,11,16,21
AMT14-047	15/5/04	5,8,11,16,21
AMT14-050	16/5/04	1,5,8,11,16,21
AMT14-053	17/5/04	1,5,8,11,16,21
AMT14-056	18/5/04	1,5,8,11,16,21
AMT14-059	19/5/04	1,5,8,11,16,21
AMT14-060	19/5/04	2,3,5,7,14,21
AMT14-063	20/5/04	1,5,8,11,16,21
AMT14-064	20/5/04	1,5,7,14,21
AMT14-067	21/5/04	1,5,8,11,16,21
AMT14-068	21/5/04	1,4,5,8,17,22
AMT14-071	22/5/04	1,5,8,11,16,21
AMT14-072	22/5/04	2,7,12,13,14,15,16,17,20,22,24
AMT14-073	23/5/04	15,16,17
AMT14-074	23/5/04	1,5,8,11,16,21,22,23,24
AMT14-075	23/5/04	2,7,10,12,13,14,15,16,18,20,22,24
AMT14-077	25/5/04	1,5,8,11,13,16,18,21,22,23,24
AMT14-078	25/5/04	2,3,5,7,8,9,10,11,14,17,22,23
AMT14-079	26/5/04	24
AMT14-080	26/5/04	1,5,8,11,13,16,18,21,22,23,24
AMT14-081	26/5/04	2,4,5,6,7,8,9,10,12,17,22,24
AMT14-083	27/5/04	1,5,11,13,16,18,21,22,23,24
AMT14-084	27/5/04	2,5,6,7,8,9,10,12,17,22,24
AMT14-085	28/5/04	1,5,11,13,16,18,21,22,24
AMT14-086	28/5/04	2,4,5,6,7,10,12,14,17,22,24
AMT14-087	29/5/04	1,4,7,10,13,16,19,21,23

Underway Analyses

Samples were collected from the surface (7m) non-toxic seawater supply at 1500h on a daily basis and analysed for ammonium concentrations.

Other Analyses

Measurements were made of the change in ammonium concentrations during incubation experiments run by Stuart Painter to investigate new and regenerated phytoplankton production.

Difficulties encountered

Depth profile samples were initially collected by Stuart Painter into large capacity carboys that were later sub-sampled for determination of ammonium concentrations. There was some indication that this method was leading to contamination of samples so a different sampling method was employed after CDT cast 12. This involved the collection of samples directly into 50mL centrifuge tubes as described in the methodology.

At the start of the cruise a consistent problem which diminished over time was a high blank fluorescence compared to sample fluorescence, resulting in large negative concentrations in some cases. Possible causes for this phenomenon include contaminated MilliQ water used in standard preparation, contaminated reagents, matrix effects caused by substances in the sample that alter the intensity of the fluorescence caused by the OPA- ammonium reaction compared to MilliQ, and working at the limits of detection of the technique. Various tests were conducted to overcome this problem but so far remain inconclusive as to the cause and further work upon return to Southampton is required to verify the measurements obtained during the early stages of the cruise.

Preliminary results

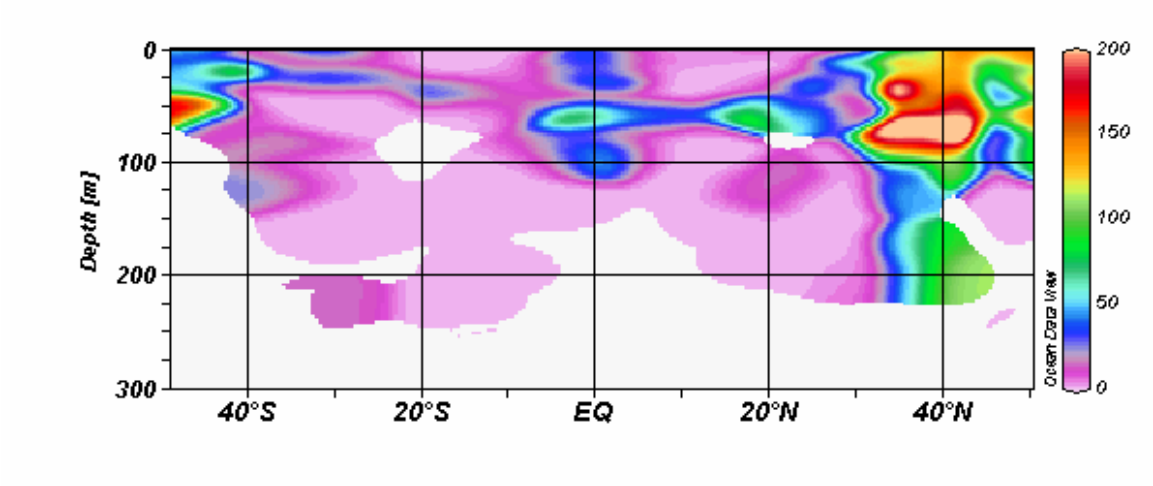


Figure 1. Predawn NH_4 concentrations (nM).

Conclusions

The outset of this cruise represented a steep learning curve due to adjusting to working onboard ship as well as trouble-shooting an unfamiliar analytical technique. Consequently the volume and accuracy of absolute data in the early stages of this cruise may not be as good as subsequent stages. That being said a high degree of confidence can be assigned to the qualitative data generated throughout this cruise, and the accuracy of quantitative data will improve during post-processing.

Acknowledgements

The advice and support of Stuart Painter was indispensable, as was the assistance of Mark Stinchcombe and Alex Poulton during pre-cruise preparations.

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Supply of Nitrogen and Phosphorus to the Surface Atlantic Ocean

SARAH REYNOLDS
University of Liverpool

Introduction

The Atlantic Ocean circulation is dominated by two large anticyclonic gyres, which give rise to differences in the primary production within the surface waters of each region.

The downwelling regions within the Atlantic Ocean are oligotrophic and have traditionally been thought of as ocean deserts. However, measurement of export production in the gyres suggests that they may be responsible for 50% of the global ocean biological carbon pump. The maintenance of this productivity is a key question in the assessment of carbon and nutrient budgets. A number of driving forces for export production have been proposed, including Ekman advection, mesoscale eddies, fronts and DOP/DON as a source of nutrients (Williams & Follows 2003 and references therein), dinitrogen fixation (Karl *et al*., 1997, Montoya *et al*., 2002, Mahaffey *et al*., 2003) and atmospheric deposition of nitrogen and phosphorus (Owens *et al*., 1992; Herut *et al*., 2002). It is clear that the sources of nitrogen and phosphorus to the oligotrophic regions of the Atlantic Ocean are critical and assessing the extent that each process contributes is influenced by temporal and spatial variability.

Objectives

Focus is on the use of biogeochemical signatures in an attempt to identify the source of organic nutrients to the oligotrophic regions of the Atlantic Ocean. These include the analyses of phospholipids, DON and DOP concentrations and the use of stable nitrogen isotopes in an attempt to determine the sources of the organic nutrients.

Methods

Particulate and dissolved fractions of organic nitrogen and phosphorous have been collected from the CTD casts, underway supply and SAPs (stand alone pumping systems). See Table 1.

Cast	Number sampled	Depths	Volume (l)	Method
Deep Monster	10	4 light depths, 200m, 300m, 400m, 500m, 1000m	2	Filtered through 47mm precombusted GF/F filter
Pre – Dawn	26	4 light depths, F_{max}, Downslope Chl. Max., 300m	2	Filtered through 47mm precombusted GF/F filter
Mid Morning	22	4 – 5 depths (max. 300m)	2	Filtered through 47mm and 25mm* precombusted GF/F filter
SAPs	10	50m, 100m, 150m	Avg 300l	Filtered through 293 mm precombusted GF/F filter
Underway	31	N/A	40	Filtered through 142 mm precombusted GF/F filter

Table 1: Stations sampled and methods.

All filters were placed in pre-combusted aluminium foil and stored at - 20°C until further analysis.

* 2 x 40 ml aliquots of filtered seawater were retained from near surface waters and 200m, then UV oxidised for 2 hours. These samples were then analysed for DON and DOP onboard with an autoanalyser by Katie Chamberlain. ~ 20 ml of the filtered seawater was also retained prior to UV oxidation, acidified and stored at - 20°C. These back-ups will be analysed for DON and DOP using HTCO in an attempt to compare methods.

* ~ 20 ml of filtered seawater was retained from the chlorophyll max. in precombusted glass vials and stored at - 20°C. These will later be analysed for DHAA.

Results

No results are available for submission at present as the analyses of the filters collected will take place at The University of Liverpool. Data will hopefully be submitted to BODC within a year.

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Carbon and Nitrogen Export Estimated from ^{234}Th and ^{238}U Disequilibria

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Biological activity in surface waters drives the oceanic particle cycle, which in turn controls the scavenging of trace metals and sedimentation to the sea floor. Carbon fixation and carbon export is central to understanding oceanic productivity, and its long term effect on atmospheric CO_2 concentration. The particle- reactive radioisotope ^{234}Th (half life 24.1 days) is often in disequilibrium with its parent nuclide ^{238}U in surface ocean waters. This occurs because ^{234}Th but not ^{238}U partitions strongly onto particle surfaces and its removal on the sinking flux of material leads to radioactive disequilibrium. Consequently ^{234}Th/^{238}U disequilibrium is potentially a powerful tool to study the downward flux of carbon in the ocean via sinking particles.

Knowledge of the integrated disequilibrium in the water column combined with a steady-state assumption and with the decay constant of ^{234}Th yields an estimate for the flux of ^{234}Th from the surface ocean caused by settling particles. To calculate the POC flux from the surface ocean, the ratio of POC to ^{234}Th on sinking particles is multiplied by the estimated ^{234}Th flux.

Methods

Samples for thorium analysis were collected from a designated CTD cast every 3 days (see Table1 for station positions). Twenty litre water samples were collected from nine depths. The sampling distribution is concentrated in the surface 300m where a significant export of thorium on settling particles is expected to result in radioactive disequilibrium between thorium and uranium. The samples collected at 1000m represent radioactive equilibrium between ^{234}Th and ^{238}U.

Total uranium is calculated from salinity and does not have to be measured separately.

Total ^{234}Th is measured by adding potassium permanganate ($KMnO_6$), manganese dichloride ($MnCl_2$), and concentrated ammonia (NH_3) to the 20 litre water sample. Dissolved and particulate ^{234}Th is precipitated from the water as MnO_2 precipitate within 8 hours. This precipitate is filtered onto 142mm 0.8µm polycarbonate filters which are then folded in a reproducible way, wrapped in mylar foil and counted directly in a beta counter. Appropriate corrections are made for self-absorption of radiation due to the filter and for detector efficiencies <100%, and corrections for ^{234}Th decay and ^{234}Th in growth from ^{238}U decay since sampling. The extraction efficiency of the precipitate was tested by collecting the filtered sea water after the MnO_2 precipitate had been filtered out and adding the chemicals again. After letting the water stand for 8 hours the precipitate was once again filtered out and processed and the filters counted to see if any thorium was still present in the water.

^{234}Th decays via beta decay to ^{234}Pa. ^{234}Pa has higher energy betas than ^{234}Th. It has a short half life of 1.2 minutes and therefore always in radioactive equilibrium with ^{234}Th. Hence, what actually is measured by the beta counter is ^{234}Pa decaying via beta decay to ^{234}U.

On two CTD's replicate samples (9 from CTD 65 and 6 from CTD73) were taken at 1000m to assess the precision of the sampling process. These samples are all processed in the same way to test the reproducibility of the sampling methods. Accuracy may be assessed by comparing the determined activity of total ^{234}Th with the ^{238}U activity at depth 1000m.

At each of the thorium depths, a 4.2 litre sample was filtered onto GFF filters for particulate organic carbon (POC) and particulate organic nitrogen (PON). Filters are stored frozen at -20^{o}C in a dark room for future analysis at the Southampton Oceanography Centre.

The large particulate thorium fraction >60µm was sampled by deploying an in-situ Stand Alone Pump (SAP) at the bottom of the export layer (100m or 160m depending on the depth of the chlorophyll maximum). A 293mm 60µm nylon mesh was inserted into the filter holder of the SAP which was set to pump for 90 minutes. Once the SAPs pumps are back on board the 60µm mesh is removed and rinsed with 1 litre of filtered thorium free sea water. The SAP sample is then split using a Fulsam sample splitter. 6/8^{ths} of the sample is filtered onto 142mm 0.8µm polycarbonate filters which are then processed and counted in the beta counter. 1/8th of the sample is filtered onto GFF filters for POC and PON analysis and stored in the -20 degree freezer. The remaining 1/8th of the sample is analysed for particulate inorganic carbon (PIC) and biogenic silicate.

Table1. Thorium station positions

CTD	Latitude	Longitude
5	41 02.44’S	4133.57’W
14	32 58.42’S	31 00.85’W
25	24 13.87’S	24 59.70’W
35	12 16.51’S	24 59.71’W
43	00 05.60’S	24 59 87W
52	11 24.26’N	29 22.04’W
62	22 19.91’N	33 44.10’W
70	29 18.27’N	36 41.84’W
79	38 39.99’N	19 57.62’W
88	48 59.99’N	16 23.68’W

Basin Scale Variability of CDOM and Photoreactivity

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Objectives

- To measure the absorbance and concentration of Chromophoric Dissolved Organic Matter (CDOM) throughout Atlantic Ocean provinces.
- To measure the photoreactivity of Chromophoric Dissolved Organic Matter through on deck incubations.
- To measure the consumption of oxygen during Photo degradation of CDOM, and to compare this to the consumption of oxygen during respiration.

Results

The Samples collected were as in the following table:

CTD no.	Photoreactivity of CDOM Consumption of Oxygen	CDOM Absorbance
6		Light Depths
13		Light Depths
14		Light Depths
15		Light Depths
22		Light Depths
23		Light Depths
53		Light Depths
56		Light Depths
57		Light Depths
59		Light Depths
63		Light Depths
67		Light Depths
71		Light Depths
73		Light Depths
74		Light Depths
77		Light Depths
81		Light Depths

The analysis of the results from the photo reactivity experiments and the measurement of CDOM absorbance will be carried out at Newcastle University.

pCO_2

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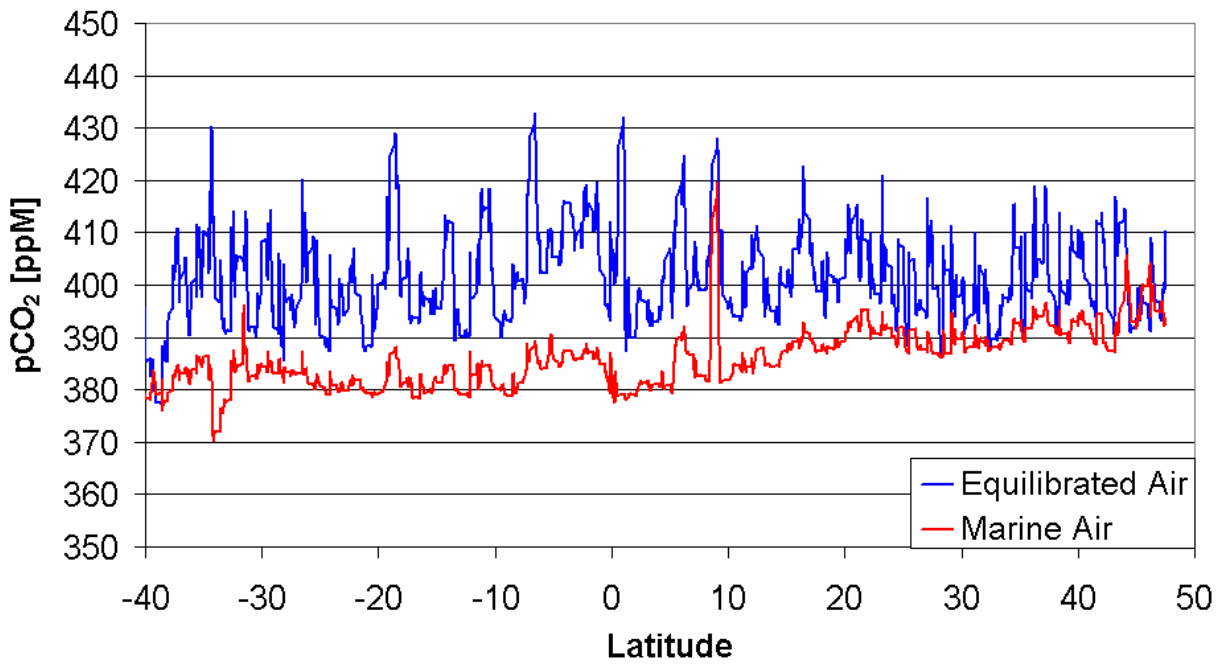
The pCO_2 system was run throughout the cruise until the 28th September when the instrument was turned off. The data remain in their raw state to be analysed by Andy Hind on return to the UK. The system ran for the entire trip on standards of 250ppm and 450ppm, these will be returned to UEA after the cruise for final calibration prior to analysis.

Some data prior to 40 degrees South were impacted due to a leak in the high air standard leaking into the system but this was rectified and the problem data will be obvious in post processing due to anomalies in the reported standard pCO_2.

Full data (marine and equilibrated air and standards pCO_2, GPS position, equilibrator temperature and barometric pressure) are included in the data file.

A plot of the raw data is shown below and seems to show unusually that the equilibrated air is consistently higher in pCO_2 than the marine air.



Alkalinity and TCO_2 Measurements

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Approximately 65 CTDs were sampled at depths between the ocean surface and 1000 metres. In addition, a daily underway sample was taken from the ship's non-toxic supply between stations. The water samples were stored by the method of Dickson *et al*. (1994). The samples, of volume either 250 or 500 ml, were collected in ground glass stoppered Schott ® bottles. 0.02% by volume saturated mercuric chloride ($MgCl_2$) solution was added to fix the samples. Apiezon ® high vacuum grease and Keck ® clamps were used to create an air-tight seal.

The samples will be analysed for the total carbon dioxide (TCO_2) and total alkalinity (TA). TCO_2 will be determined by coulometric titration and TA will be determined by potentiometric titration as detailed in the AMT12 and AMT13 cruise reports. Data is expected to be at BODC by late 2004.

A further 90 250ml samples were taken form the underway non-toxic supply for parallel determination of alkalinity by Professor Andrew Dickson at Scripps, USA.

Reference

Dickson, A.G., Goyet, C. (Eds). 1994. Handbook of methods for the analysis of the various parameters in the carbon dioxide system in sea water. United States, Department of Energy, 202pp.

DMS and DMSP Measurements

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Introduction

During AMT14 I have been analysing seawater samples for dimethylsulphide (DMS) and its precursor, dimethylsulphoniopropionate (DMSP) in both the particulate and dissolved form. DMS is volatile and considered climatically significant as it impacts cloud formation and hence the climate, at least on a local scale. DMSP is produced by phytoplankton and its conversion to DMS is both intra and extra cellular. These processes are complicated, involving a myriad of factors. My work on AMT14 comes under hypothesis 8 (see below) but can be linked with every other hypothesis in some way or another.

Hypothesis 8: pCO_2 and trace gas exchange are a function of phytoplankton community structure and biomass and significantly influence aerosol formation over the remote oceans

In addition to this routine sampling, I also filtered water for an indication of the enzyme activity of the DMSP lyase enzyme (DLA) which is known to cleave DMSP to DMS and acrylic acid.

Sampling Methodology and Times

I analysed both DMS and DMSP using a system termed 'Purge and Trap'. For more details of this method, please see the cruise reports from AMT12 and AMT13. Along the AMT14 cruise track, I sampled every pre-dawn CTD cast (approx. 0300hrs local time) at 8 depths - the light depths plus three depths in and around the chlorophyll max), the mid-morning CTD cast (approx. 1100hrs local time) for the surface bottle, and took an underway sample from the underway supply at 1500hrs (local time).

DLA samples were collected by filtering a known volume of water and then frozen at -80^0C for analysis back at UEA. Samples were generally collected from the surface and the chlorophyll maximum at both the pre-dawn and mid-morning CTDs, although 2 pre-dawn profiles (8 depths) were also collected in the Northern gyre.

Data

I have worked up the DMS and dissolved DMSP data whilst on the ship. Problems with the sensitivity of my gas chromatograph have meant that particulate DMSP samples have had to be stored and I shall be analysing these upon arrival back at UEA. This is in addition to the planned analysis of the DLA samples.

Trends in DMS and dissolved DMSP concentrations (Fig. 1, data not finalised) are reasonably similar to AMT12, with lower concentrations in the Southern gyre, increasing in the equatorial upwelling and as we moved North through the Northern gyre. The most interesting data from AMT14 is the very high DMS concentrations observed around stations 67 and 70 (approx. 28 degrees North), which is in contrast to the pattern observed during AMT12. At these stations, other data indicate very little biological activity in the upper water column (above the chlorophyll maximum). Further analysis of this data is required, but it is hoped that the increased DMS concentrations can be explained through the other parameters that were measured.

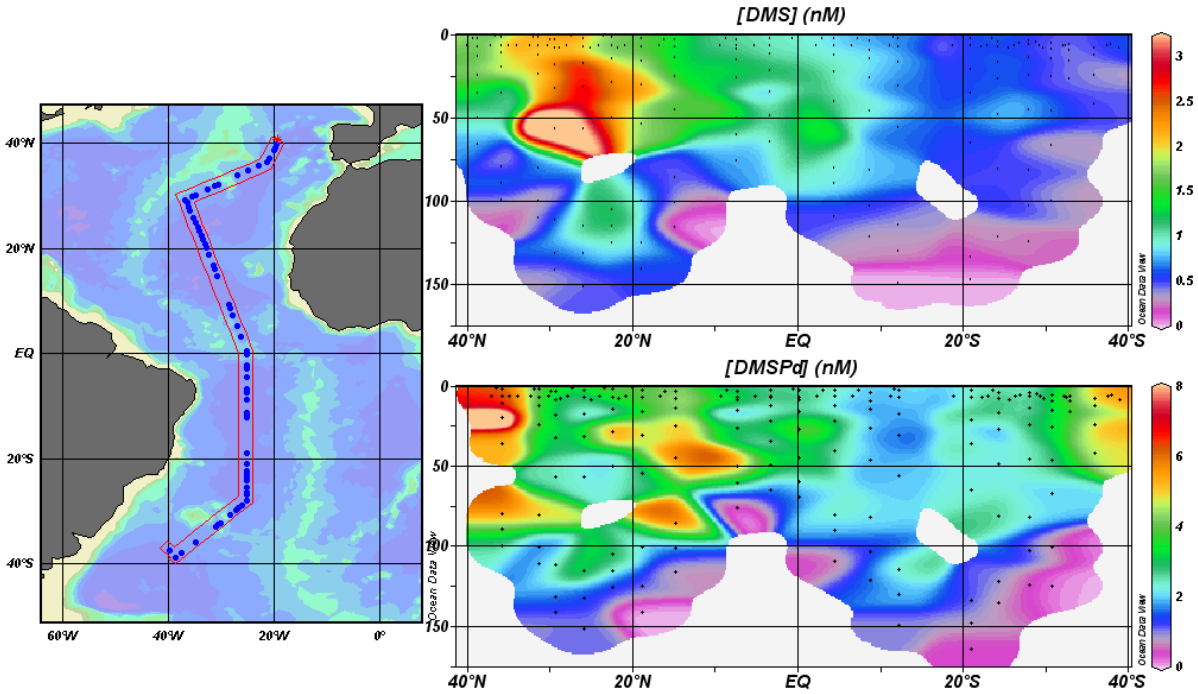

Figure 1. Trends in DMS and dissolved DMSP concentrations (nM) during AMT14. Data interpolated using Ocean Data View.

Atmospheric Sampling

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The atmospheric sampling campaign aims to determine deposition fluxes of key nutrients (N, P and Fe) along the AMT track and to use this information to assess the importance of atmospheric nutrient supply and its contribution to the nutrient limitation of primary productivity. In addition to determining fluxes, our work aims to identify the sources of these nutrients using air-parcel back trajectories and inter-element and isotopic relationships. In addition sampling aims to help determine the role of marine emissions in regulating atmospheric chemistry, particularly in terms of the formation of aerosol S and N compounds. This objective is shared with groups measuring trace gases.

Atmospheric sampling was conducted on the JCR's monkey island when wind conditions permitted, i.e. apparent wind direction was forward of the monkey island ensuring no contamination from ship's stacks.

Aerosol sampling

Three high volume samplers (flow rate approx 1 m^3/min) were deployed. One was for size resolved aerosol major ions and used conventional and slotted Whatman 41 filter substrates. One for size segregated aerosol trace metals and used conventional and slotted Whatman 41 filters after rigorous acid pre-cleaning. A third system provided by University of Liverpool (M Preston) was for aerosol amino acid sampling and used pre-ashed glass fibre filters. All three collectors operated continuously throughout the entire cruise and average sampling period was 22 hours. Filters were changed in a laminar flow cabinet and subsequently frozen at -20^{o}C. Cascade impactors were used for aerosol major ion and trace metal sampling, to separate aerosol particles at a diameter of 1µm. Aerosol samples of amino acid were not size segregated.

Gas-phase ammonia sampling

One low volume air sampling system (approx 0.05m^3/min) was also operational connected to a filter pack system for the analysis of ammonia gas concentrations. Filters were changed in a glove box under positive pressure of ammonia-free air and frozen at -20^{o}C.

Atmospheric precipitation sampling

Two rain samplers (for major ions and trace metals sampling) were deployed when the opportunity presented itself. The funnels were deployed at the end of a boom extended ~1.5m forward of the monkey island screen in order to minimise contamination of the samples by bounce-off from the ship's superstructure. The samples were processed where practical in laminar flow cabinet and subsequently frozen.

Analysis

All subsequent analysis will take place at home laboratories. In the case of high volume systems, it was clear that samples collected close to the equator were influenced by desert dust, though the quantification of this dust source awaits subsequent analysis.

A log of atmospheric samples collected is in the appendix. The JCR standard meteorological system was operational throughout the cruise.

Acknowledgements

Sincere thanks to Douglas, JCR's deck engineer, for constructing the rain sampling gear and the mates (Andy, Dave and Joe) for their 'wake-up' and 'alert' calls whenever rain appeared during the cruise. Also thanks to the colleagues and JCR crews and officer for their enthusiasm towards my rain sampling!

Atmospheric samples collected

Date 2004	Start latitude	Aerosol Major ion	Aerosol Metal	Aerosol Amino acid	Gaseous Ammonia	No. of Rain samples	Comment
29-30/4	-49.17	Blank	Blank	Blank		1	Aerosol collectors deployed for blanks
30/4-01/5	-46.09	Blank	Blank	Blank		2	
01-02/5	-42.25	x	x	x	Blank		Continuous aerosol sampling starts; NH_3 sampling interrupted
02-04/5	-40.18	x	x	x	x	1	
04-06/5	-34.25	x	x	x			
06-07/5	-29.45	x	x	x			
07-08/5	-26.00	x	x	x	x		
08-09/5	-22.42	x	x	x			
09-10/5	-18.47	x	x	x	x		Continuous NH_3 sampling starts
10-11/5	-14.13	x		x	x	1	
11-12/5	-10.55	x	x	x	x		
12-13/5	-6.28	x	x	x	x		
13-14/5	-2.11	x	x	x	x		
14-15/5	0.38	x	x	x	x	2	
15-16/5	4.52	x	x	x	x	1	
16-17/5	8.46	x	x	x	x		
17-18/5	12.04	x	x	x	x		
18-19/5	16.05	x	x	x	x		
19-20/5	20.11	x	x	x	x		
20-21/5	23.26	x	x	x	x		
21-22/5	29.55	x	x	x	x	2	
23-24/5	31.59	x	x	x	x		
24-25/5	34.23	x	x	x	x		
25-26/5	36.29	x	x		x		
26-27/5	39.16	x	x		x	1	Aerosol collection paused due to wind condition
28/5	47.49	x	x		x	1	
29-30/5	49.06	x	x		x		
30-31/5	49.18	x	x		x		

UKORS Scientific Support

JON SHORT & DOUGAL MOUNTIFIELD
UKORS, Southampton Oceanography Centre

CTD Operations

1. A total of 89 CTD casts were undertaken on the cruise. The stainless steel frame configuration was as follows:

Sea-Bird 9/11 plus CTD system
24 by 20L 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
Chelsea PAR Sensor (upwelling)
Chelsea PAR Sensor (downwelling)
Turner Designs Cyclops-7 Fluorometer (added in place of PAR upwelling sensor on 8 May - see App. 1)
RD Instruments Workhorse 300 KHz Lowered ADCP (downward-looking configuration) RD Instruments Workhorse 300 KHz Lowered ADCP (upward-looking configuration)
Chelsea FRRF/battery pack/pressure sensor

The pressure sensor is located 15cm from the bottom of the water samplers, and 132 cm from the top of the water samplers. Deep cast configuration was the same with the exception of the removal of the Chelsea PAR sensors and the FRRF pressure sensor for the 1000m casts

2. The Sea-Bird CTD configuration was as follows:

SBE 9 plus Underwater unit s/n 09P-19817-0528
Frequency 0 - SBE 3P Temperature sensor s/n 03P-4301 (primary)
Frequency 1 - SBE 4C Conductivity sensor s/n 04C-2580 (primary)
Frequency 2 - Digiquartz temperature compensated pressure sensor s/n 73299
Frequency 3 - SBE 3P Temperature sensor s/n 03P-4151 (secondary)
Frequency 4 - SBE 4C Conductivity sensor s/n 04C-2841 (secondary)
SBE 5T submersible pump s/n 05T-3002
SBE 5T submersible pump s/n 05T-2279
SBE 32 Carousel 24 position pylon s/n 0344
SBE 11 *plus* deck unit

3. The auxiliary A/D output channels were configured as below:

V2 - SBE 43 Oxygen s/n 43B-0363
V3 - Chelsea MKIII Aquatracka Fluorometer s/n 88/2050/95
V4 - Chelsea PAR Sensor (UWIRR) s/n 10 (removed on 8 May)
V5 - Chelsea PAR Sensor (DWIRR) s/n 11 (transferred to V4 on 8 May, with V5 channel then used for Cyclops fluorometer - see above)
V6 - WetLabs Light Scatter Sensor
V7 - Chelsea MKII Alphatracka 25cm path Transmissometer s/n 161045

4. The additional self-logging instruments were configured as follows:

Chelsea FRRF s/n 182042
RDI Workhorse 300 KHz Lowered ADCP (downward-looking configuration) s/n 1855
RDI Workhorse 300 KHz Lowered ADCP (upward-looking configuration) s/n 4275

4 * Challenger Oceanic In-situ Particle Measurment Systems (Stand Alone Pumps (SAPs). S/n's: 03-1, 03-2, 03-03, 03-04.

Miscellaneous

1. Salinometer - An Autosal 8400B (BAS) salinometer was used on this cruise to process 92 samples either from the CTD casts or the underway water. The salinometer was located in the Prep Laboratory and operated at 24C bath temperature and 21C to 24C ambient lab temperature. All samples were processed according to WOCE standards and protocols.
2. SAPs – Three of the SAPs performed well for the duration of the cruise. S/n 03-03 suffered from water ingress during the first deployment and, although the unit was cleaned and dried and all o-rings replaced, it would only pump for between 30 minutes and one hour of the 1.5 hours pump time. S/n 03-02 suffered with a pumping tube becoming detatched on the first two deployments, this was repaired with silicone sealant and resealable cable ties.

Argo float deployments

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Southampton Oceanography Centre

JON TURTON
Meteorological Office

A batch of eight APEX floats manufactured by Webb Research Corp and fitted with SeaBird CTDs was deployed for the UK Argo program. Times and position of deployments are given in an Appendix. Float data are usually tracked by WMO platform ID, but are sometimes accessed by ARGOS platform number. In order of deployment, the following triplets identify the Webb Research instrument number, the ARGOS PTT number and the assigned WMO platform ID respectively: (856, 09953, 3900112), (857, 09962, 3900247), (858, 10033, 3900248), (859, 10034, 3900249), (888, 08763, 3900250), (889, 08765, 3900251), (892, 08769, 3900253), (891, 08766, 3900252). At the time of writing (late June 2004) all eight floats are performing normally.

Argo is an international program, made up of national contributions from about 20 countries. The fundamental basis of the program is free access to all data in real time. To this end, data are transmitted on the GTS within 24 hours of receipt ashore, and also posted at one of two global data assembly centres (GDACs). The GDAC holdings are synchronised daily. All Argo data are fully public and can be downloaded by browser and FTP access. Data will be issued on CD from time to time for the benefit of users with limited internet access. The GDACs provide browser tools for identifying and selecting data from particular floats.

Floats deployed in the Argo program are set to drift at depths between 1000 and 2000 metres. On a preset cycle, usually of ten days duration, the floats rise to the surface collecting a CTD profile as they go. Upon arrival at the surface they transmit the data by satellite, requiring a surface duration of 6 to 12 hours. At present, most floats use the ARGOS positioning and data relay system flying on NOAA Polar Orbiter satellites. Data are collected by national data centres and submitted to the GDACs. The UK Argo program is managed at the UK Met Office. Data from UK floats is managed at BODC, and the status of the UK floats can be monitored there (http://www.bodc.ac.uk/ projects/ argo.html). Further details about the international program can be found at the project web site (http:// www.argo.ucsd.edu), which also provides links to the GDAC sites for data access.

Argo was conceived to serve two purposes. First, to provide global subsurface measurements to feed data assimilation exercises, especially within GODAE. GODAE applications of ocean forecasting range from timescales of days to seasons. Second, to initiate systematic global subsurface measurements of temperature and salinity, so that changes in global and regional inventories of heat and freshwater can be detected with confidence. The subsurface trajectories of Argo floats also reveal ocean circulation patterns.

Appendices

1. CTD Station Positions and Times

All CTDs to 300 or 350m unless stated otherwise

JD	Date	Day	Station	Lat (S/N)	Long (W)	Time (ship)	Activities	Notes
119	28-Apr	Wednesday				1700		Depart Falklands
120	29-Apr	Thursday		-48.25	52.11	1630		CTD winch not working all day APEX float 1 released. Good weather
121	30-Apr	Friday	1	-47.03	50.25	0200	CTD 1 + Nets	
						0345	CTD 2	
			2	-46.15	48.92	1400	CTD 3 + Optics	APEX float 2 released
122	01-May	Saturday				200		No early station due to poor weather
			3	-43.03	44.34	1100	CTD 4	APEX float 3 released
123	02-May	Sunday	4	-41.03	41.55	0200	CTD 5 to 1000m + Nets	
						0400	CTD 6 + Optics	
						0600	SAPs 1	3 out of 4 pumps worked
			5	-40.68	41.07	1115	CTD 7 + Optics	APEX float 4 released
124	03-May	Monday	6	-38.87	38.58	200	CTD 8 + Nets	
						330	CTD 9	
			7	-37.95	37.37	1100	CTD 10 + Optics	APEX float 5 released
125	04-May	Tuesday	8	-35.97	34.80	200	CTD 11 + Nets	CTD fluorometer not working all day
						330	CTD 12	
			9	-35.00	33.55	1100	CTD 13 + Optics	APEX float 6 released
126	05-May	Wednesday	10	-32.97	31.01	200	CTD 14 to 1000m + Nets	
						415	CTD 15 + Optics	
						600	SAPs 2	Hose on one pump disconnected
			11	-32.65	30.60	1100	CTD 16 + Optics	
127	06-May	Thursday	12	-30.70	28.22	200	CTD 17 + Nets	
						330	CTD 18	
			13	-29.77	27.10	1100	CTD 19 + FOP + Optics	APEX float 7 released
			14	-28.87	26.03	1900	CTD 20	MZ dusk station
128	07-May	Friday	15	-28.08	25.10	200	CTD 21	Nets cancelled due to weather
						330	CTD 22	
			16	-26.93	25.00	1100	CTD 23 + FOP + Optics	APEX float 8 released
			17	-25.55	25.00	1900	CTD 24	MZ dusk station
129	08-May	Saturday	18	-24.23	25.00	200	CTD 25 to 1000m + Nets	
						345	CTD 26 + Optics	Cyclops-7 fluorometer placed on CTD
						530	SAPs 3	and d/w PAR sensor to u/w position
			19	-23.60	25.00	1100	CTD 27 + Optics	
			20	-22.27	25.00	1900	CTD 28	MZ dusk station

JD	Date	Day	Station	Lat (S/N)	Long (W)	Time (ship)	Activities	Notes
130	09-May	Sunday	21	-20.93	25.00	200	CTD 29 + Nets	
						330	CTD 30	
			22	-19.52	25.00	1100	CTD 31 + FOP + Optics	
131	10-May	Monday	23	-16.65	25.00	200	CTD 32 + Nets	
						310	CTD 33	Coccolithophore profile
			24	-15.20	25.00	1100	CTD 34 + FOP + Optics	
132	11-May	Tuesday	25	-12.28	25.00	200	CTD 35 to 1000m + Nets	
						410	CTD 36 + Optics	
						600	SAPs 4	
			26	-11.73	25.00	1100	CTD 37 + FOP + Optics	
133	12-May	Wednesday	27	-8.82	25.00	300	CTD 38 + Nets	
			28	-7.37	25.00	1100	CTD 39 + FOP + Optics	Clear day
134	13-May	Thursday	29	-4.27	25.00	200	CTD 40 + Nets	
					25.00	300	CTD 41	
			30	-2.98	25.00	1100	CTD 42 + Optics	Shallow chl max, *Trichodesmium*
135	14-May	Friday	31	-0.10	25.00	200	CTD 43 to 1000m + Nets	
						345	CTD 44 + Optics	
						530	SAPs 5	
			32	0.52	25.18	1100	CTD 45 + FOP + Optics	Coccolithophore profile
136	15-May	Saturday	33	3.25	26.23	200	CTD 46 + Nets	
						320	CTD 47	
			34	4.58	26.73	1100	CTD 48 + Optics	*Trichodesmium* profile
137	16-May	Sunday	35	7.28	27.78	200	CTD 49 + Nets	
						315	CTD 50	
			36	8.67	28.30	1100	CTD 51 + Optics	Crossing ITCZ
138	17-May	Monday	37	11.40	29.37	200	CTD 52 to 1000 m + Nets	
						345	CTD 53 + Optics	
						530	SAPs 6	
			38	12.02	29.60	1100	CTD 54 + Optics	
139	18-May	Tuesday	39	14.75	30.68	200	CTD 55 + Nets	
						315	CTD 56	
			40	16.08	31.25	1100	CTD 57 + Optics	
140	19-May	Wednesday	41	18.60	32.28	200	CTD 58 + Nets	
						315	CTD 59	
			42	20.13	32.83	1100	CTD 60 + Optics	Large *Trichodesmium* at surface
			43	21.70	33.48	2000	CTD 61	MZ dusk samples + centrifugation

JD	Date	Day	Station	Lat (S/N)	Long (W)	Time (ship)	Activities	Notes
141	20-May	Thursday	44	22.33	33.73	0	SAPs 7	
						230	CTD 62 to 1000m + Nets	
						430	CTD 63 + Optics	
			45	23.38	34.20	1100	CTD 64 + Optics	?Fl peak at 30m
			46	24.97	34.85	2000	CTD 65 to 1000m	MZ dusk samples + deep water for Sandy
142	21-May	Friday	47	25.92	35.23	200	CTD 66 + Nets	
						310	CTD 67	
			48	27.27	35.82	1100	CTD 68 + FOP + Optics	Very low chlorophyll water
			49	28.42	36.43	2000	CTD 69	MZ dusk samples + coccolithophore profile
143	22-May	Saturday	50	29.30	36.70	0	SAPs 8	
						230	CTD 70 to 1000m + Nets	
						430	CTD 71 + Optics	
			51	29.88	35.52	1100	CTD 72 + Optics	
144	23-May	Sunday	52	31.28	32.55	200	CTD 73 to 1000m + Nets	Deep water for Sandy and Jenna
						345	CTD 74	
			53	31.93	31.18	1100	CTD 75 + Optics	
146	25-May	Tuesday	54	35.75	22.85	200	CTD 76 + Nets	
						310	CTD 77	Strong PE signal from chl max &
			55	36.48	21.22	1100	CTD 78 + Optics	difficult filtering. Many *Velella*.
147	26-May	Wednesday	56	38.67	19.97	200	CTD 79 to 1000m + Nets	
						300	CTD 80 + Optics	
						530	SAPs 9	
			57	39.25	19.70	1100	CTD 81 + Optics	Broad and strong chl max at 50m
148	27-May	Thursday	58	41.98	18.60	200	CTD 82 + Nets	
						310	CTD 83	
			59	43.87	18.33	1100	CTD 84 + Optics	Abundant *Velella* all day
149	28-May	Friday	60	46.43	17.28	300	CTD 85 + Nets	Swell
			61	47.82	16.78	1100	CTD 86 + Optics	
			62	49.00	16.40	2200	SAPs 10 + Optics	PAP site
150	29-May	Saturday				30	CTD 87 to 1000m	Lost communication with CTD at 800m
						240	CTD 88 + Nets	CTD cable repaired
151	30-May	Sunday	63	49.25	6.43	1240	CTD 89 + Optics	*E. huxleyi* station
153	01-Jun	Tuesday				1600		Arrive Grimsby

2. Standard CTD Sampling Depths

(DCM = Deep Chlorophyll Maximum)

a) Pre-dawn Hydrographic Deep (Monster) Casts (SAPs stations) to 1000m

Bottle No.		Bottle Depth (m)/ Light Depth (%)
CTD No	AMT No	
1, 2	24, 23	1000m
3, 4	22, 21	500m
5, 6	20, 19	400m
7, 8	18, 17	300m
9, 10	16, 15	200m
11, 12	14, 13	1%
13, 14	12, 11	14%
15, 16	10, 9	33%
17, 18	8, 7	55%
19, 24	6-1	97%

b) Pre-dawn Hydrographic Shallow Cast (non-SAPs stations) to 300m

Bottle No.		Bottle Depth (m)/ Light Depth (%)
CTD No	AMT No	
7, 8	18, 17	300m
9, 10	16, 15	200m
11, 12	14, 13	1%
13, 14	12, 11	14%
15, 16	10, 9	33%
17, 18	8, 7	55%
19, 24	6-1	97%

c) Pre-dawn Productivity Cast to 300m

Bottle No.		Bottle Depth (m)/ Light Depth (%)
CTD No	AMT No	
1	24	300m
2	23	200m
3	22	175m
4-6	21-19	0.1%
7	18	Below DCM
8-11	17-14	DCM (~1%)
12	13	Above DCM
13-15	12-10	14%
16-18	9-7	33%
19-22	6-3	55%
23	2	6.5m
24	1	97%

d) Mid-morning Optics Cast to 300m

Bottle No.		Bottle Depth (m)/ Light Depth (%)
CTD No	**AMT No**	
1	24	300m
2	23	250m
3	22	200m
4	21	190m
5	20	180m
6	19	170m
7	18	160m
8	17	150m
9	16	140m
10	15	130m
11	14	120m
12	13	110m
13	12	100m
14	11	90m
15	10	80m
16	9	70m
17	8	60m
18	7	50m
19	6	40m
20	5	30m
21	4	20m
22	3	15m
23	2	6.5m
24	1	Surface (0-5m)

3. Times of Sunrise and Sunset

1. All times are local ship time
2. Sunset takes into account estimated movement of the ship during the day

Date	Position		Sunrise (h)	Sunset (h)
	Latitude	Longitude		
30 April	47°11’S	50°28’W	0711	1714
1 May	44°10’S	45°57’W	0649	1701
2 May	41°01’S	41°31’W	0628	1649
3 May	38°01’S	37°42’W	0707	1737
4 May	35°10’S	33°46’W	0647	1726
5 May	32°59’S	31°00’W	0636	1719
6 May	30°22’S	27°50’W	0617	1709
7 May	27°03’S	25°00’W	0606	1707
8 May	24°14’S	25°00’W	0603	1709
9 May	21°06’S	25°00’W	0558	1715
10 May	15°55’S	25°00’W	0553	1720
11 May	12°44’S	25°00’W	0548	1724
12 May	08°49’S	25°00’W	0542	1731
13 May	04°30’S	25°00’W	0536	0515
14 May	00°15’S	25°00’W	0532	1741
15 May	03°03’N	26°09’W	0533	1753
16 May	07°07’N	27°43’W	0533	1805
17 May	11°08’N	29°16’W	0533	1815
18 May	14°25’N	30°33’W	0533	1828
19 May	18°29’N	32°10’W	0533	1842
20 May	22°32’N	33°49’W	0532	1853
21 May	25°49’N	35°12’W	0531	1908
22 May	29°50’N	36°55’W	0524	1915
23 May	31°11’N	32°24’W	0505	1902
24 May	32°12’N	28°28’W	0443	1846
25 May	33°26’N	23°32’W	0520	1930
26 May	36°17’N	20°34’W	0505	1932
27 May	39°41’N	19°32’W	0448	1940
28 May	43°54’N	18°07’W	0428	1949
29 May	48°06’N	16°39’W	0408	1958