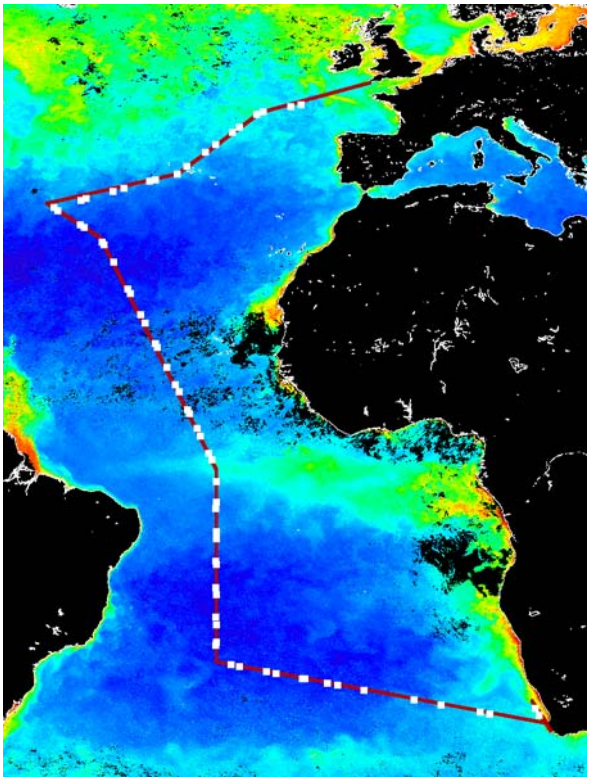
Atlantic Meridional Transect

AMT16 Cruise Report

RRS Discovery
20 May – 29 June 2005



Principal Scientist:
Tony Bale (PML)

Plymouth Marine Laboratory

Southampton Oceanography Centre
UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL

UEA NORWICH

University of Newcastle upon Tyne

THE UNIVERSITY of LIVERPOOL

University of Plymouth

University of Southampton

Contents

Acknowledgements

AMT16 was an extremely successful, if uneventful, passage cruise; we completed 67 stations and the great majority of the objectives were met. Once we were at sea, we experienced very few technical problems.

Much of the success of the AMT 'machine' is built on the experience gleaned from colleagues on previous AMT passages and we acknowledge the value of the organisation that enables this experience to be forwarded to successive holders of the baton. Our thanks therefore go to the AMT Steering Group and the Project Co-ordinator, Carol Robinson, for making this all happen so efficiently.

AMT also benefits from dedicated and enthusiastic teams behind the scenes and we thank Malcolm Woodward and Dawn Ashby at PML and Andy Louch and Colin Day at UKORS.

At sea we were well looked after by Captain Plumley and the company of the RRS Discovery; many of group commented on how welcome we were made to feel whilst on board. The Catering Department kept us fed, watered and comfortable while the Deck and Engineering teams kept everything up and running whilst simultaneously and good-naturedly dealing with the multitude of minor problems, new courses, changes of plan, broken kit and all the other minor hassles that are par for this type of work.

Lastly, though by no means least, our sincere thanks to the UKORS team: Jon Short, Dan Comben, Rob Lloyd, Dougal Mountifield, and Emma Northrop who 'kept the show on the road'.

Scientific Personnel

Dr Tony Bale (PS) Miss Katie Chamberlain Miss Isobel Cook Dr Niki Gist Miss Trish Frickers Dr Glen Tarran	*Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth PL1 3DH, UK*
Dr Alex Poulton Mr Xi Pan	*National Oceanography Centre, European Way, Southampton, SO14 3ZH, UK*
Ms Sarah Reynolds	*Department of Earth and Ocean Sciences, University of Liverpool, PO Box 147, Liverpool, L69 3BX, UK*
Ms Martha Schattenhofer	*Max Planck Institute for Marine Microbiology Molecular Ecology, Flow Cytometry, Celsiusstrasse 1, D-28359 Bremen, Germany*
Dr Simon Ussher Mr Dionysios Raitsos Dr Samantha Lavender Mr Edward Mawji*	*Department of Environmental Science, University of Plymouth, Drake Circus' Plymouth PL4 8AA, UK*
Dr Michal Koblizek	*Institute of Microbiology, Laboratory of Photosynthesis, Opatovicky Mlyn, 379 81 Trebon, Czech Republic*
Dr Jan Kaiser	*Department of Geoscience, Princeton University, Guyot Hall, Princeton NJ 08544, USA*
Dr Michelle Hale	*Ocean Sciences Centre, Memorial University of Newfoundland, St John's Newfoundland A1C 5S7, Canada*
Mr David Drapeau	*Bigelow Laboratory for Ocean Sciences, POB 475, W Boothbay Harbour, ME 04575, USA*
Mr Miguel Frada	*Station Biologique, Place Georges Teissier, BP74 29682 Roscoff Cedex, France*
Mr Jonathan Short Mr Dan Comben Mr Robert Lloyd Mr Dougal Mountifield Miss Emma Northrup	*UKORS, National Oceanography Centre, European Way, Southampton, SO14 3ZH, UK*

* present address: National Oceanography Centre, Southampton

Ships Company

Robin Plumley	**Master**
John Mitchell	Chief officer
Phil Oldfield	2nd Officer
John Holmes	3rd Officer
Euan Doig	Cadet
Stephen (Sam) Moss	Chief engineer
George Parkinson	2nd Engineer
Keith Connor	3rd Engineer
Chris Carey	3rd Engineer
Philip Parker	ETO
Paul Shears	ERPO
Keith Curtis	Senior Catering Manager
Paul Lucas	Chef
Darren Caines	Assistant Chef
Lloyd Sutton	Steward
Kevin Luckhurst	CPO Deck
Simon (Ozzy) Avery	CPO Science
Ian Thomson	PO Deck
Charles Cooney	Seaman
Jonathan Roberts	Seaman
Alan Weatherhead	Seaman
Paul Williams	Seaman

Introduction to AMT – Cruise Objectives

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 carbon 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. The cruises measured 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

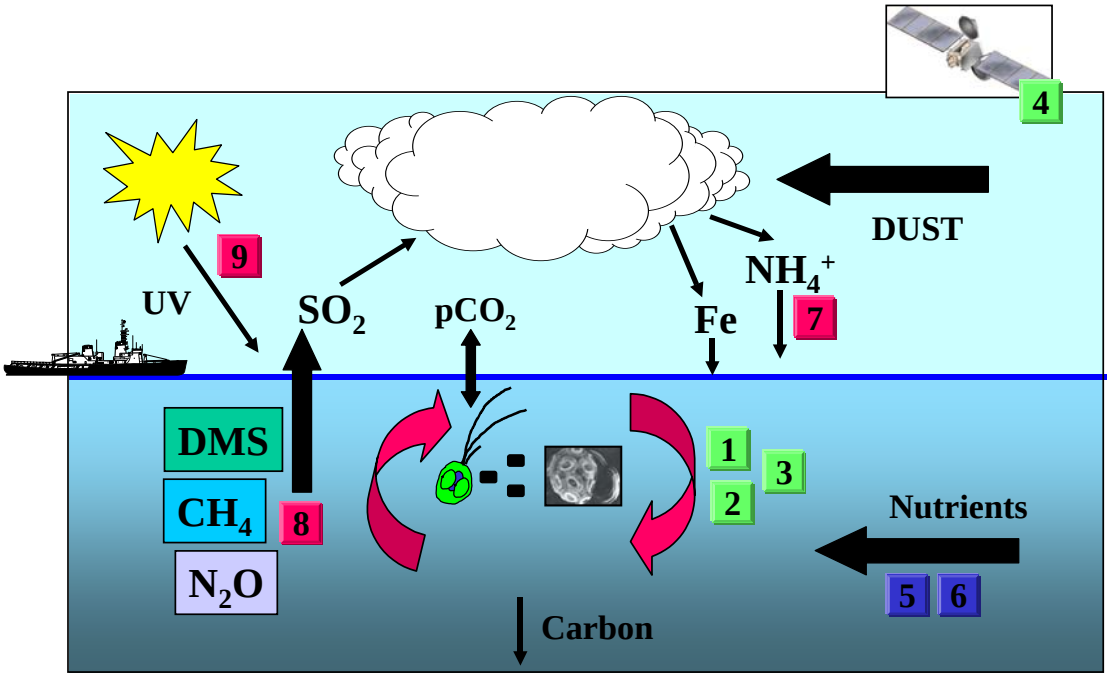
The first three hypotheses strive to address the question of linking plankton biodiversity with variability in biogeochemical fluxes, in particular the potential for carbon export to the deep sea and ocean / atmosphere exchange of carbon dioxide. A fourth hypothesis will develop and validate models and 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 cruise of the programme occurred in May / June 2003 and aimed to compare and contrast the functioning of the plankton in the North and South Atlantic Gyres. The research carried out on the fifth cruise in this series (AMT16) is described in this cruise report.

The website www.amt-uk.org is the main source of cruise updates, contact information and reports

The 'Cruise Directive' set out the following:

> The cruise will commence in Cape Town sailing am Thursday 19th May. This cruise is a continuation of the AMT programme and will aim to compare the northern and southern hemisphere gyres following the 25°W meridian. An opportunity will be taken to investigate the coastal upwelling off SW Africa prior to steaming into the mid-Atlantic to head north. The cruise will terminate in Falmouth no later than Wednesday 29th June.

Cruise Narrative

Tuesday 17th May: Windy (westerly) and grey; scientific party travel to ship via immigration for clearance. Captain advised delay to sailing from Thursday am to Thursday evening to enable welding to deck and then only if 'air con' fixed, plus requirement to test winch at anchor before winch engineer disembarked by boat transfer. Container unpacked and labs mobilised efficiently and smoothly. We were unable to access the chem lab because it was directly underneath welding area; the pCO_2 instrument was installed in Deck lab so that Dorothy Bakker (UEA) could prepare the instrument.

Wednesday 18th May: Continued to set-up labs and lash down equipment. Weather moderated significantly – saw Table Mountain for first time since arriving on board.

Thursday 19th May: Due to sail 1500 for anchorage and winch trials but informed by the Captain that we were unable to sail because of the need to carry out further work on the air-conditioning.

Friday 20th May: Departure delayed further by the availability of a pilot; cleared dock by 1100 in glorious weather. Labs in good order, safety briefing 1400. Decided with scientific party to head up the coast to try to stay in chlorophyll-rich upwelling water indicated by satellite and determined way point (WP) of 30°S 16°E before heading onto the main track. Winch trials for the deep tow system were completed. Departed anchorage 1700 after problems with anchor; making 13.5kts over ground with the Benguela overnight.

Saturday 21st May: First station (#1) in flat-calm conditions at 0430 – stopped for 1 hour for 250 m cast (shallow water here). Seals and porpoises were around the ship during station. Noon cast at 1100 (#2) following muster and boat drill. We were informed by the captain at lunch time that he had to disembark the 3rd Mate. Steaming south east to Soldana Bay for boat transfer tomorrow am. Agent reports forecast NW 40 kts for Cape Town. Cadet, Euan Doig temporarily promoted to 3rd Mate under the supervision of the Captain.

Sunday 22nd May: Boat transfer completed by 0830; underway towards 28°S, 25°W (now 50 hours late). Non-toxic supply found contaminated with small shell fish. Weather deteriorated badly over night with several people 'unhappy', wind 50-60 kts over bridge instruments (which over-read) but met sensors suggest 40 kts. The ship hove-to much of the night - losing more time. No stations Sunday; decided to press on during Monday to head west.

Monday 23rd May: Continuing westwards without stopping today but now to 25°S 25°W (to save a day steaming). The laboratory weathered the storm extremely well. Not such good news on deck as two water bottles had been washed off the clean CTD frame and broken. It was noted that the Bulwark section adjacent to the CTD should have been refitted by the crane in Cape Town - only guard wires in use at present. A small gas bottle escaped from a gas bottle rack on the aft deck but was recovered.

Tuesday 24th May: Pre-dawn and 1100 stations completed, both to 300 m, latter with simultaneous 'optics' from starboard quarter crane. Total stop time about 2 hours for these shallow casts. Wire on trace metal fish (TMF) reported damaged so removed to re-terminate. Proposing to work standard stations on Thursday and Saturday (alternate days) until further west. Making good progress with wind now astern.

Wednesday 25th May: Decided better to do one cast each day rather than two on alternate days so instigated noon cast today, dawn cast Thursday, and noon cast Friday before starting the full routine on Saturday. The MVP is showing problems and was recovered to make a new electrical connection. Distance to WP1 (25°S 25°W) was 1810 miles at 0430 making arrival time midday on 31st May allowing total of 10 hours for stations. Noon cast fine, stopped about 1 hour.

Thursday 26th May: Dawn cast without problems; ships clock back another hour to GMT; only stopped about 1 hour for a standard 300 m cast. 1376 miles to WP1 at 0727 this morning. The TMF was repaired and re-deployed and is pumping well.

Friday 27th May: Midday cast to 300 m with optics today. Sunshine and blue sea, first Deep Chlorophyll Maximum (DCM) at about 100 m. Noted oil leak from gantry contaminating water where CTD bottles emerge. Engineers effect temporary measure to catch oil. MVP has kinked its cable and broken conductors. Presently cutting 5 m lengths to determine where the break is.

Saturday 28th May: 300 m dawn cast went fine but problem with SAP unit slipping on CTD wire but saved by PVC tape for metre above the CTD shackle (and the next SAP). Found the CTD conductor broken which was re-terminated for the midday cast; cast late at 1215 but still OK.

Sunday 29th May: 0330 start for deep (1000 m) CTD and nets followed by SAPS. Raining hard. CTD lost 'comms' at 300 m and aborted. Wire removed for re-termination. Started SAPS while repair underway. Deployed SAP1 to 50 m and winch alarm sounded. Pump 1 started at 50 m (aborted).

Monday 30th May: 380 miles to WP1, estimate 10 hours short of WP at noon tomorrow. First cast to 1000 m at pre-dawn, net deployed also. Cast at 1100 with FRRF, no optics. Clocks retarded 1 hour tonight.

Tuesday 31st May: Standard 300 m station am; completed noon cast and a/c to be on north-going leg by 0430 tomorrow. About 100 miles shy of WP.

Wednesday 1st June: First station on 25°W; normal pre-dawn followed by 3 SAPs, 50 m and 150 m OK, although the 100 m had problems with batteries/motor (4 hours stopped on station). Noon cast to 5300 m (4.5 hours deck to deck). Captain pointed out that the track cuts Irish territorial waters for which we have no clearance therefore we will have to shape the track south if still working.

Thursday 2nd June: 1000 m cast pre-dawn. Safety meeting. Noon station OK but problems with some bottles mis-firing or not sealing (temperatures wrong). Deck test indicates rosette firing sequence OK. Must record temperatures.

Friday 3rd June: Wind now fresher (28 kts) from east; standard pre-dawn station but 40 minutes longer because UKORS unable to prep rig before heaving to. Likewise, vessel unable to move (due to seas coming onboard) until water sampling complete. Several instruments (oxygen titrator and ammonia) seem to be adversely affected by ship motion. Turtle watch briefing meeting planned for 1400. Drill (video) at 1615.

Saturday 4th June: Kept lookout for turtles but sea too rough.

Sunday 5th June: Pre-dawn station to 1000 m OK but wire snarled up for top 30 m on recovery; cropped and re-terminated for the 1100 cast. Vessel stopped at 1030 to enable load test to be carried out on new termination. Noon station aborted when wire jumped traction winch and snarled up. CTD overboard but above water; wire stopped off and CTD package recovered. Again wire will have to stripped off, cropped and re-terminated. Time available per working day is now up to 6 hours; may have to go further west in the northern gyre to use time. Turtles absent

Monday 6th June: No turtles seen.

Tuesday 7th June: SAPS after am cast. Cancelled noon station for equator function; crossed at 1845 a/c to 330^{o} (T) for 30°N 40°W.

Wednesday 8th June: 1000 m cast am, standard cast at noon.

Thursday 9th June: 4300 m cast at noon making sample processing late. We discovered that due to Simon altering the bottle order for deep casts, the 'bottle files' order is not the same as the actual bottle order. Simon has produced keys that are added to the 'CTD' directory as read me files: CTDs 18 and 32 [and 43].

Friday 10th June: Dawn cast - nutrients fridged and run with noon cast.

Saturday 11th June: Real problems with supply of RO water to Milli-Q, some used from clean container. Emma fixed RO system overnight. Scary how much work is dependent on that one small water system.

Saturday 12th June: Decided to drop dawn station tomorrow to give people a mid cruise break. Today's noon cast then aborted itself when wire jumped off sheave – NO CTD, just optics at Station 36. Didn't want to 'undo' the night off so asked ship to slow steam (6 kts) until tomorrow noon to minimise distance between stations. Started 24 hour diel cycle for Fe(II) and peroxide from clean metal fish since no samples available to analyse from the cast.

Monday 14th June: Carried out 0330 standard cast with SAPS.

Tuesday 15th June: 1000 m dawn cast start at 0300.

Wednesday 16th June: Standard CTD, repeated cast to 14 m for extra water because of bottle failure, then SAPS. 5900 m deep cast at noon

Thursday 17th June: Dead Zone? CTD conductor failed on dawn cast- aborted. Sampled some bucket water for productivity. Not ideal.

Thursday 23rd June: Station in Azores today; grey and wet but weather improving quickly all day.

Friday 24th June: Late pm, asked to slow ship so that we reach pilot at required time rather than early.

Saturday 25th June: Last productivity casts; weather now 'fresh' from dead ahead.

Sunday 26th June: Just short of WP4; Stainless CTD refusing to 'listen' but can 'talk'; swapped to the titanium frame and deployed without the five clean bottles. Plenty of water to go around because no productivity work.

Monday 27th June: Last two stations worked at 0400 and 1100. Underway sampling until Tuesday 1700. Trace metal 'fish' reported lost from end of wire.

Tuesday 28th June: 1700 BST; all science work completed. Packing completed and container loaded during Tuesday pm.

Wednesday 29th June: Arrived Falmouth about 08:30 and cleared customs. PML vans already on the quay. Offloaded Jan Kaiser equipment to carrier (Bax Global); offloaded NOC equipment to NOC lorry. Dry ice arrived at 11:15.

Summary of events:

20th May: left Cape Town – 30 hours late.

21st May: worked two stations off the South African coast in upwelling waters.

22nd May: diverted to Soldanna Bay for boat transfer – cost 20 hours. Weather deteriorated during evening, hove-to most of night – cost 12 hours of track.

23rd – 28th May: occupying one station per day instead of two to make up time.

31st May: closest approach to WP1 (25°S, 25°W), a/c to 000^{o} (T)

7th June, late pm: crossed Equator at 25°W, a/c to 335° (T) for WP3 (30°N, 40°W)

17th June: closest approach to WP3, a/c to NW after investigating drifting navigation buoy; added new track (via WPs 3A and 3B) to use time made up since Cape Town.

19th June: a/c for WP3B (38.3°N, 30°W) after noon station

23th June: WP3B, a/c (041°T) for WP4 (46°16.9'N, 19°17.1'W)

26th June: vessel a/c (075°T) at WP4 for Falmouth skirting south of Irish waters

27th June: last Station (#67) at 1100

28th June: underway science completed at 1700 BST

29th June: arrived Falmouth 0830 BST.

Sampling details

Detailed records of cruise sampling events for AMT16 are listed in Appendix 1: A summary of the stations and CTD casts are given in Appendix 2 and a list of CTD bottle failures are given in Appendix 3. The log of sampling events from the underway, pumped water (non toxic) system is given in Appendix 4.

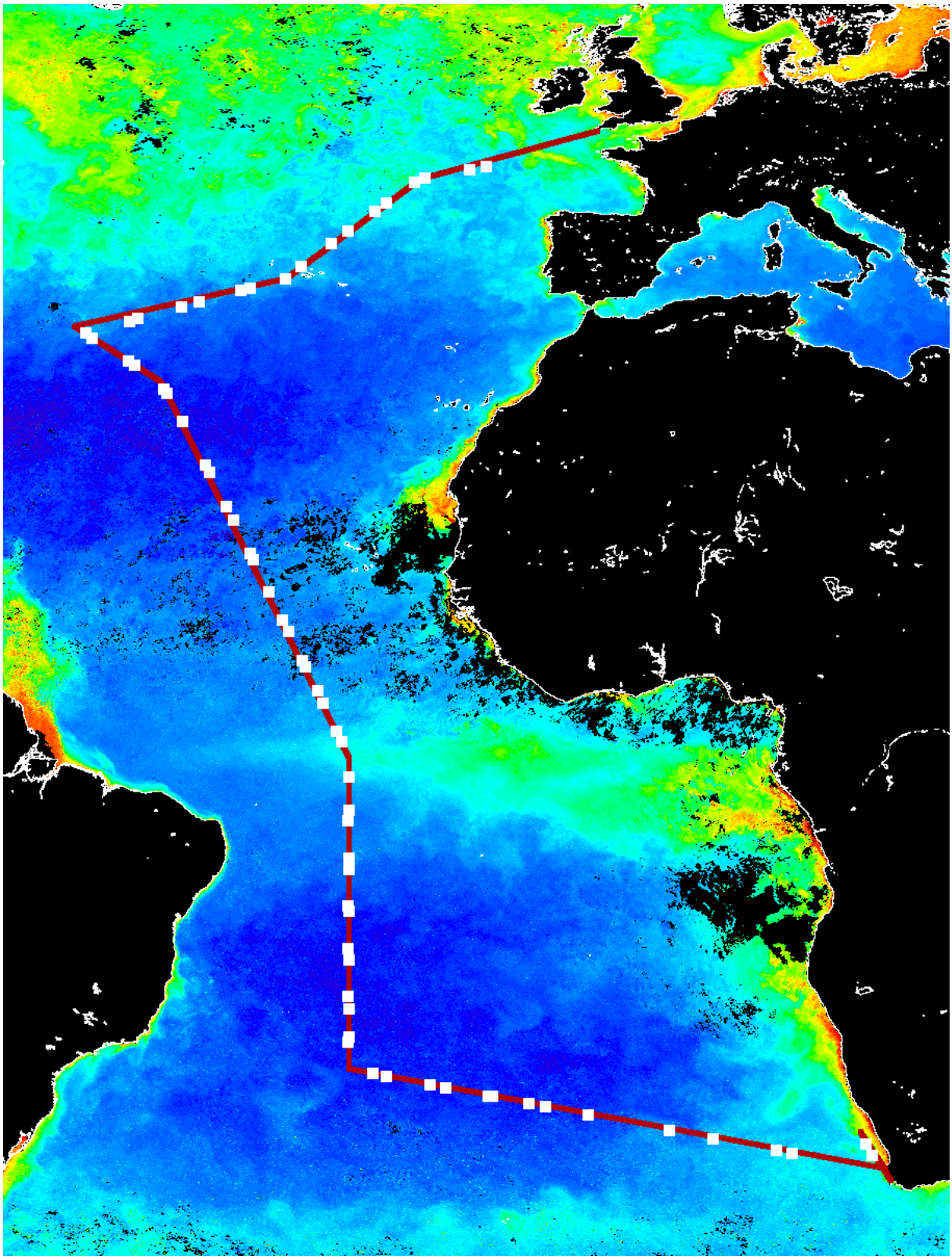


Figure 1. AMT16 stations (white squares) and the cruise track (red line) superimposed on the SeaWiFS composite of the Atlantic for June 2005 (courtesy of Peter Miller and Matthew Oates, RSDAS PML). The station positions are given in Appendix 2.

Carbon fixation (photosynthesis, calcification), chlorophyll, pigments and phytoplankton species

ALEX POULTON (AP)[1] AND ISOBEL COOK (IC)[2]

[1]*National Oceanography Centre, University of Southampton, UK, SO14 3ZH*

[2]*Plymouth Marine Laboratory, Prospect Place, Plymouth*

Cruise Objectives

1. Continued collection of core AMT measurements (chlorophyll *a*, primary production, pigments, phytoplankton identification, particulate organic carbon and nitrogen). [AP, IC]
2. Continued collection of discrete underway samples for analysis of HPLC-derived pigments, particulate organic carbon/nitrogen and chlorophyll *a* as part of a collaborative exercise with the collection of PIC and BSi samples by Dave Drapeau (Bigelow, USA). [AP, IC]
3. Basin-scale measurements of surface calcification rates by coccolithophores [AP]

Sampling

During AMT16 underway samples were collected every 4-5 hours for particulate organic carbon, HPLC pigments, and chlorophyll *a* at the same sampling times as those of Dave Drapeau. Water-column sampling during AMT16 concentrated around collection of the main core measurements from 6 light depths (97, 55, 33, 14, 1 and 0.1% of surface irradiance) from the pre-dawn CTD cast, with a reduced set of measurements (chlorophyll *a*, pigments) and depths (3 for pigments and 6 for chlorophyll) from the late morning 'optics' cast (collected and filtered by Sam Lavender). Light depths were selected assuming that the 1% surface irradiance corresponded to the fluorescence or chlorophyll maximum.

Methods

Chlorophyll, pigments, lugols/formalin and POC/N: From the six main light depths, samples were collected for chlorophyll determination (acetone extraction), pigment composition (High Performance Liquid Chromatography (HPLC) after Barlow *et al.*, 1997), particulate organic carbon and nitrogen concentration and duplicate water samples preserved with 2% acidic Lugol's solution and 4% buffered formalin for phytoplankton 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) [AP, IC].

Photosynthesis (*p*POC): Water samples (3 light, 3 dark) from 4 light depths (97, 55, 14 and 1% surface irradiance) in the water column were collected, spiked with ~20 mCi ^{14}C labelled sodium hydroxide ($NaH^{14}CO_3$) and incubated over a daylight period (dawn to dusk, typically 10 - 15 hours) 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 30-40 minutes over fuming hydrochloric acid in a desiccator. After fuming, samples were placed in 6 ml pony vials with 5 ml of Ultima-Gold liquid scintillation cocktail and activity counted in a TriCarb 2100TR low activity liquid scintillation counter (LSC) onboard. At two depths (55 and 1% of surface irradiance) 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. Stock solutions were prepared daily with fresh filtered seawater and checked by addition of 100 ml of stock solution to 9.9 ml CarboSorb and LS counting of five 100 ml replicates from this mixture in 5 ml PermaFluor E+: coefficient of variance for replicate standards was <2% [AP].

Table 1. Stations (CTD cast number) sampled and measurement(s) made. Abbreviations used are pPOC (photosynthesis), SFChl (size fractionated chlorophyll) and pPIC (calcification). Note: * core measurements are chlorophyll (total), pigments, POC/N, lugol and formalin samples. For further details see methods sections.

CTD No.	Core*	SFChl	*p*POC	*p*PIC	CTD No.	Core*	SFChl	*p*POC	*p*PIC
01	X				**35**	X	X	X	X
02	X				**36**	Cancelled			
03	X	X	X	X	**37**	X			
04	X				**38**	X	X	X	X
05	X				**39**	X			
06	X	X	X	X	**40**	X	X	X	X
07	X				**41**	X			
08	X	X	X	X	**42**	X	X	X	X
09	X				**43**	X			
10	Cancelled				**44****	Cancelled**			
11	X	X			**45**	X			
12	X				**46**	X	X	X	X
13	X	X	X	X	**47**	X			
14	X				**48**	X	X	X	X
15	X	X	X	X	**49**	X			
16	X				**50**	X	X	X	X
17	X	X	X	X	**51**	X			
18	X				**52**	X	X	X	X
19	X	X	X	X	**53**	X			
20	X				**54**	X	X	X	X
21	X	X	X	X	**55**	X			
22	X				**56**	X	X	X	X
23	X	X	X	X	**57**	X			
24	X				**58**	X	X	X	X
25	X	X	X	X	**59**	X			
26	X				**60**	X	X	X	X
27	X	X	X	X	**61**	X			
28	X	X	X	X	**62**	X	X	X	X
29	X	X	X	X	**63**	X			
30	X				**64**	X	X		
31	X	X	X	X	**65**	X			
32	X				**66**	X	X		
33	X	X	X	X	**67**	X			
34	X								
					Total	64	32	30	30

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

Calcification (*p*PIC): Calcification measurements were made following the methodology of Balch *et al*., (2001). Water samples (3 light, 1 formalin killed) from the 55% surface irradiance light depth were collected, spiked with ~80-mCi ^{14}C-labelled sodium hydroxide ($NaH^{14}CO_3$) and incubated parallel to samples for PP (see above). The formalin-killed sample was prepared by addition of 10 ml of filtered (<0.2 mm) neutrally buffered formalin to the sample. At the end of the incubations, samples were filtered onto 0.2 mm 25 mm diameter polycarbonate filters under gentle vacuum (<200 mbar) and placed in 18 ml pony vials. Filter cups, frits and forceps were thoroughly rinsed with fresh filtered (<0.7 mm) seawater after filtration of each sample to remove any contamination from labelled dissolved inorganic carbon ($DI^{14}C$). A gas tight septum and bucket containing a GFA filter with 0.2 ml of 2-polyethylamine (PEA) was attached to each of the 18 ml vials. Using a small gauge syringe, 1 ml of 1% phosphoric acid was injected past the bucket into the bottom of the vial and the samples

were left for 24 hours to equilibrate: acidification of the polycarbonate filter causes the conversion of ^{14}C labelled inorganic carbon ($PI^{14}C$) to be released as $^{14}CO_2$ which is trapped by the PEA onto the GFA filter. After the samples have equilibrated, the septum's were removed, the bucket (with GFA) placed in a fresh pony vial and 5 ml of Ultima-Gold was added to vial containing the bucket and 15 ml of Ultima-Gold was added to the 18 ml vial. Samples were counted in the TriCarb 2100TR low activity liquid scintillation counter (LSC) onboard. Comparison of organic carbon fixation rates from this method and that described in the previous section were in good agreement (model II regression: y = 0.93 - 0.02; r^2=0.96; n =24). The efficiency of capture of $^{14}CO_2$ by the PEA soaked GFA filter was checked by removing 200 ml of the formalin sample before addition of the formalin and treating it identically to a filter sample: addition of septum, bucket with GFA and phosphoric acid. The $^{14}CO_2$ caught on the GFA filter was compared with the estimated spike added to the formalin sample and showed generally 80-110% capture [AP].

Preliminary Results

Note: All data is considered raw and may be subject to change with post cruise recalibration and further analysis.

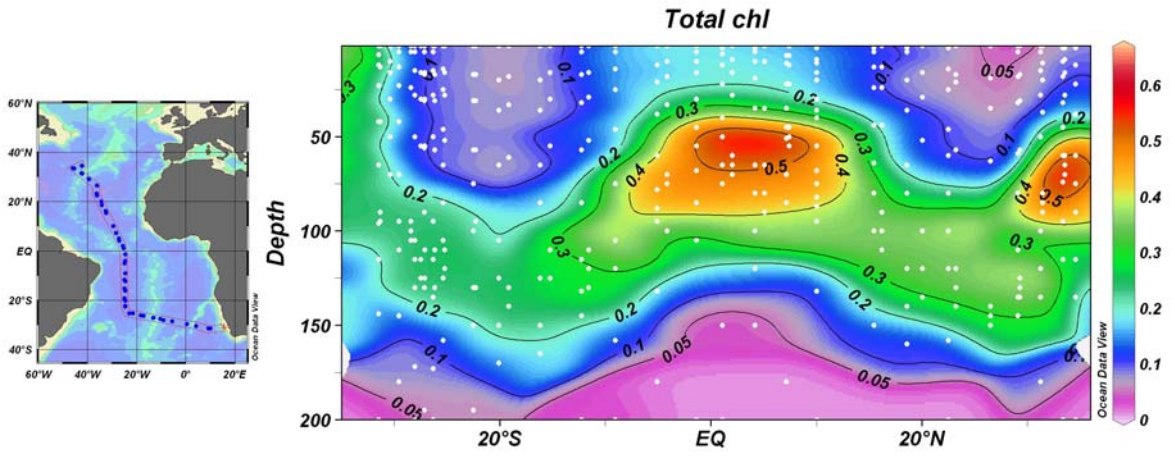


Figure 1. Ocean Data View (ODV) section of total chlorophyll a (mg m^{-3}) distribution.

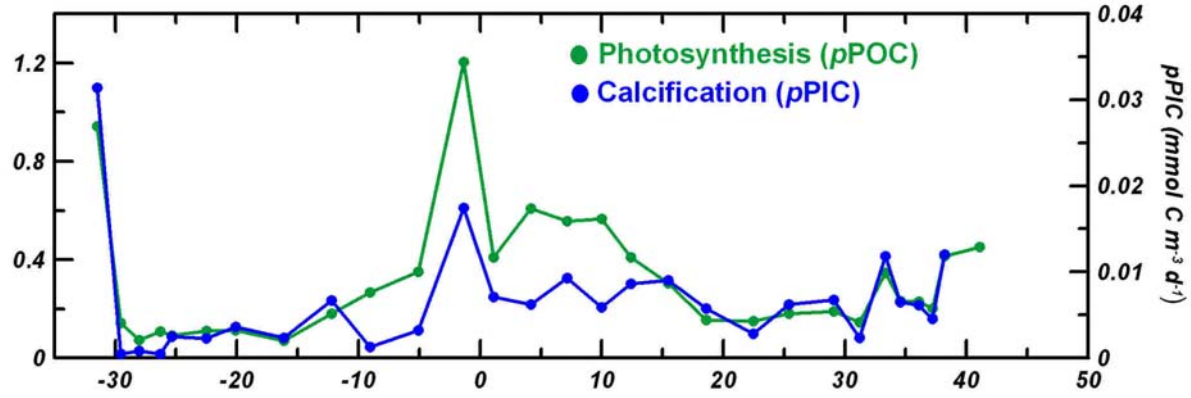


Figure 2. Daily rates of surface photosynthesis (pPOC) and calcification (pPIC). Units are mmol C m^{-3} d^{-1}.

References

Balch, W.M., Drapeau, D.T., Fritz, J.J. 2000. Monsoonal forcing of calcification in the Arabian Sea. Deep Sea Research II 47(7-8), 1301-1337.

Barlow, R.G., Cummings, D.G., Gibb, S.W. 1997. Improved resolution of mono- and divinyl chlorophylls *a* and *b* and zeaxanthin and lutein in phytoplankton extracts using reverse phase C8 HPLC. Marine Ecology Progress Series 161, 303-307.

Welschmeyer, N.A. 1994. Fluorometric analysis of chlorophyll *a* in the presence of chlorophyll b and phaeopigments. Limnology and Oceanography 39(8), 1985-1992.

Gross production, net community production and dark community respiration

NIKI GIST
Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth, PL1 3DH, UK

Objectives:

AMT hypotheses:

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

Other work:

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

Additional work carried out:

- Comparison of net community production depth profiles with oxygen/argon depth profiles.
- Time series to confirm linearity of oxygen consumption during dark incubations.
- Time series and analysis by analytical flow cytometry to examine the effect of bottle incubations on the microbial community.

Samples collected

Depth and latitudinal distribution of P and R: Samples of gross production (GP), dark community respiration (DCP) and net community respiration (NCP) were collected and analysed from up to 5 depths daily (n=26).

***In situ* oxygen for the calibration of the CTD oxygen sensors:** Samples from up to 12 depths were collected from the pre-dawn casts (stainless steel frame CTD, sensor number 0619, 29 stations, 206 calibration samples) and mid-morning casts (titanium frame CTD, sensor number 0612, 24 stations, 159 calibration samples).

Methods

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

Results summary

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

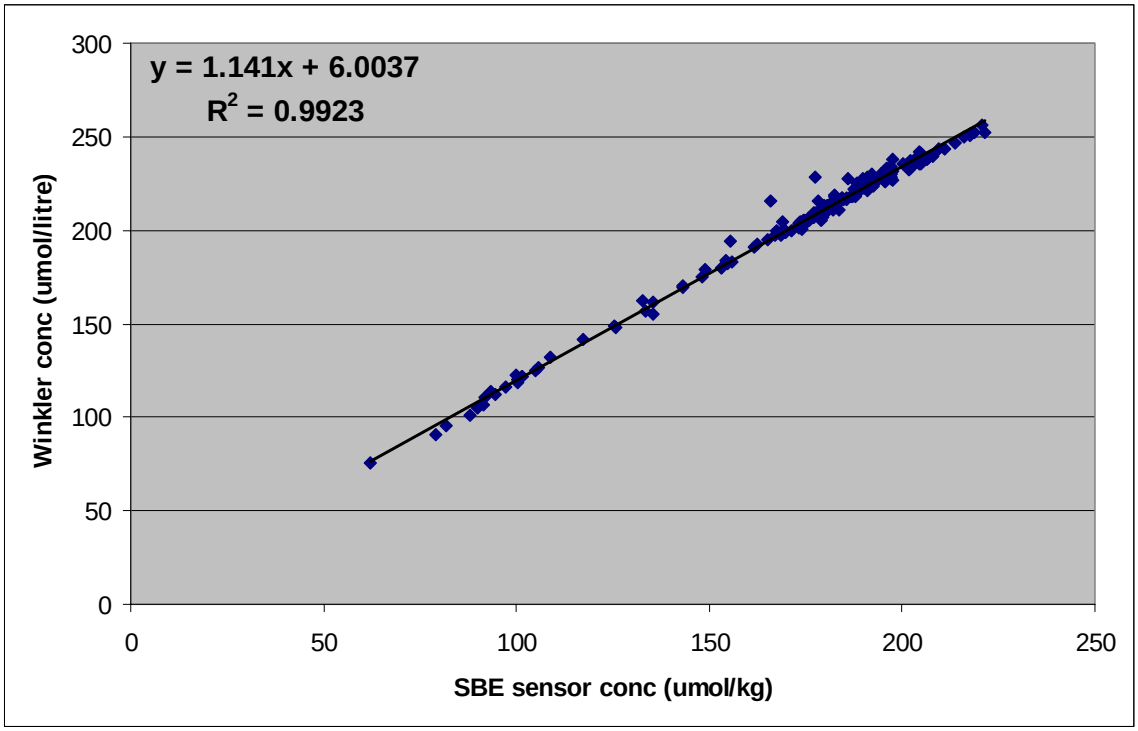


Figure 1. Linear regression of calibration samples taken from the pre-dawn cast (stainless steel frame).

Inter-calibration of the two onboard Winkler systems was carried out via the analysis of simultaneously filled seawater samples on each system, the calibration of thiosulphate using various KIO_3 solutions and simultaneous calibration of a batch of thiosulphate. Productivity data will be processed on our return to the UK, but example depth profiles are shown in Figure 2.

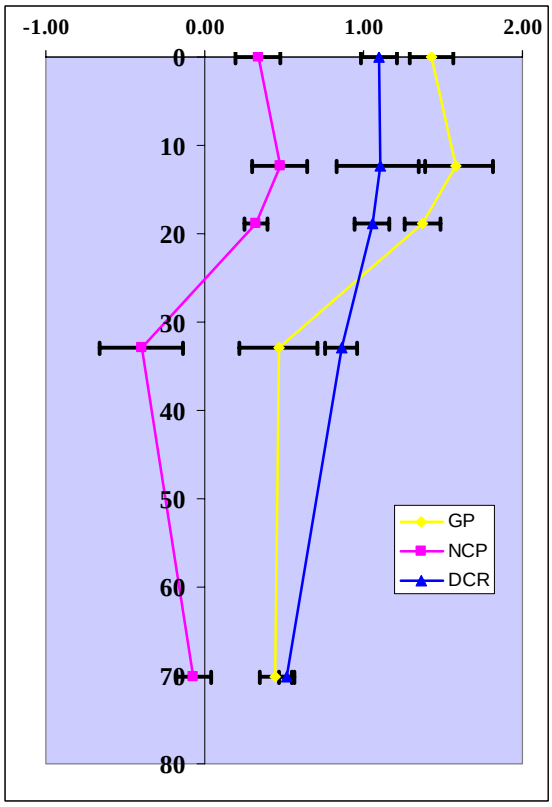


Figure 2a) Depth profile of rates (mmol O_2 m^{-3} day^{-1}) from CTD 31 (4°N, 27°W).

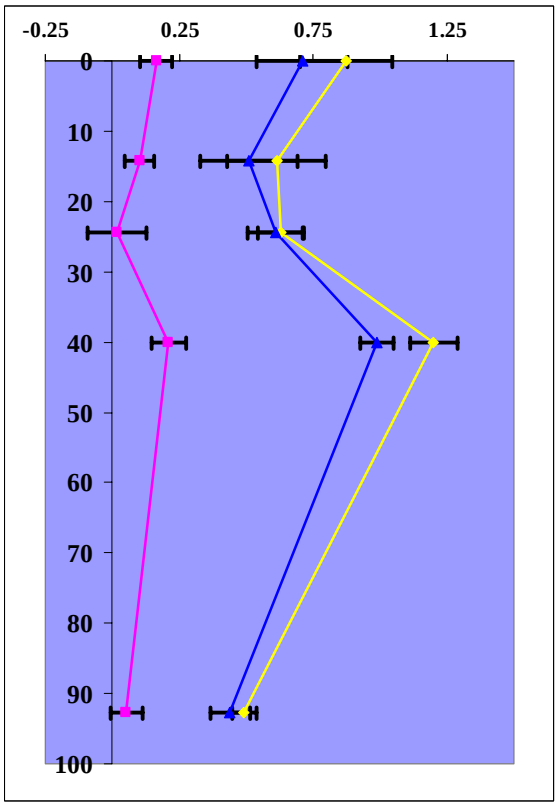


Figure 2b) Depth profile of rates (mmol O_2 m^{-3} day^{-1}) from CTD 52 (35°N, 43°W).

The comparison of oxygen/argon depth profiles with NCP rates is outlined in the report by Jan Kaiser.

It is expected that all O_2, GP, NCP and DCR data will be deposited at BODC by September 2006.

Acknowledgements

I should like to thanks the crew and officers onboard RRS Discovery for all their help and the immense amount of good humour shown at all times. Also thanks to the UKORS team, whose help was invaluable. Many thanks once again to Alex Poulton for all his time and hard work, and for covering the incubators on the occasions when sunset was late and my memory was short! Finally thanks to Tony for his time, patience, charm and humour when helping me out each day with the pre-dawn incubator routine.

AMT16 Bio-optics and remote sensing

DAVID T. DRAPEAU
Bigelow Laboratory for Ocean Sciences, West Boothbay Harbor, ME 04575, USA

Cruise Objectives

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

Methods

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

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

Biogenic Silica (BSi): A 250-1000 ml sub-sample of seawater was taken for the analysis of BSi from 6-8 sampling depths. These depths always included the six light regime depths and for dawn casts two additional sub-euphotic depths were added, particularly if the water column was clear. The sample was vacuum-filtered onto 45 mm 0.4 µm polycarbonate filters. These were then stored in small petri dishes at –20°C for analysis back at Southampton Oceanography Centre (SOC). At the SOC, the BSi will be dissolved with 2.5 ml sodium hydroxide. This solution will be neutralised with 0.1 mol l^{-1} hydrochloric acid, and concentrations will be determined using a flow autoanalyser.

Flow-through bio-optical system: This system operates semi-continuously with water from the ships non-toxic supply. Every 4 minutes it measures temperature, salinity, chlorophyll fluorescence, total backscattering at 532 nm (bb_{tot}), acidified backscattering (bb_{acid}; backscattering of the seawater suspension after the pH has been lowered to dissolve calcium carbonate), acid labile backscattering (bb'; the difference between the bb_{tot} and bb_{acid}), absorption and attenuation at 9 visible wavelengths (made every 2 minutes), absorption and attenuation at 9 visible wavelengths after water was routed through 0.2 µm filters (during intervening 2 minute segments).

Above-Water Radiance Measurements: In order to check the PIC algorithm performance, free of atmospheric error, water-leaving radiance, sky radiance and downwelling irradiance were measured from the bow of the RRS Discovery using a Satlantic SeaWiFS Aircraft Simulator (MicroSAS). The same wavelengths used in the 2-band and 3-band calcite algorithms were measured with the MicroSAS. The system consists of a down-looking radiance sensor and a sky-viewing radiance sensor, both mounted on the bow. A downwelling irradiance sensor was mounted far from any potentially shading structures, on the tallest mast of the RRS Discovery. These data were then used to estimate normalised water-leaving

radiance as a function of wavelength. The radiance detector was set to view the water at 40° from nadir as recommended by Mueller *et al*. (2003b). Sensors were rinsed regularly with Milli-Q water in order to remove salt deposits and any dust. The water radiance sensor was able to view over an azimuth range of ~270° across the ship's heading with no contamination from the ship's wake. The direction of the sensor was adjusted constantly to view the water 120° from the sun's azimuth, to minimize sun glint. This was done using a computer-based system that calculated the sun's azimuth angle relative to the ship's heading and elevation constantly. The system used the ships gyro-compass to determine the heading of the ship. Pitch and roll sensors provided a means to filter out any measurements made from sub-optimal viewing geometries due to the ship's motion. Depending on the ship's course, the computer controlled a stepping motor that turned the sensors to the proper viewing angle. Protocols for operation and calibration were performed according to Mueller (Mueller *et al*. 2003a; Mueller *et al*. 2003b; Mueller *et al*. 2003c). Before 1000h and after 1400h local time, data quality was poorer as the solar elevation decreased. Post-cruise, the 16Hz data will be filtered to remove as much residual white cap and glint as possible (we accept the lowest 5% of the data). When the ship was stopped on station, measurements will also be made. A plaque calibration was performed every several days (using a 10% spectralon plaque) to check for instrument drift.

Description of measurements made

During AMT16 underway samples were collected approximately every 3-6 hours for particulate inorganic carbon and biogenic silica, particulate organic carbon and nitrogen, chlorophyll *a* and (occasionally) pigments. Water-column sampling during AMT16 concentrated around collection of the main core measurements from 6 light depths from the predawn CTD cast (~0300-0430h local time). BSi, PIC and cell count measurements were made on 8 depths from the morning cast, typically to 300 m depth. The same measurements were made from a reduced set of depths from the late morning 'optics' cast (1100h local time).

Details of the sampling undertaken from the CTD profiles and from the underway pumped supply are given in Appendix 5.

References

Haidar A.T., Thierstein H.R., Deuser W.G. 2000. Calcareous phytoplankton standing stocks, fluxes and accumulation in Holocene sediments off Bermuda (North Atlantic). Deep Sea Research 47(9-11), 1907-1938.

Haidar A.T., Thierstein H.R. 2001. Coccolithophore dynamics off Bermuda (North Atlantic). Deep Sea Research 48(8-9), 1925-1956.

Mueller J.L., Austin R.W., Morel A., Fargion G.S., McClain C.R. 2003a. Ocean optics protocols for satellite ocean color sensor validation, Revision 4, Volume I: Introduction, background, and conventions. Greenbelt, MD: Goddard Space Flight Center, 50pp.

Mueller J.L., Morel A., Frouin R., Davis C., Arnone R., Carder K., Lee Z.P., Steward R.G., Hooker S.B., Mobley C.D., McLean S., Holben B., Miller M., Pietras C., Knobelspiesse K.D., Fargion G.S., Porter J., Voss K. 2003b. Ocean optics protocols for satellite ocean color sensor validation, Revision 4, Volume III: Radiometric measurements and data analysis protocols. Greenbelt, MD: Goddard Space Flight Center, 78pp.

Mueller J.L., Pietras C., Hooker S.B., Austin R.W., Miller M., Knobelspiesse K.D., Frouin R., Holben B., Voss K. 2003c. Ocean optics protocols for satellite ocean color sensor validation, Revision 4, Volume II: Instrument specifications, characterisation and calibration. Greenbelt, MD: Goddard Space Flight Center.

Acknowledgements

The participation of DTD in this cruise was made possible through a contract from NASA titled, "The MODIS Ocean Product for Particulate Inorganic Carbon (MOD 25): Refinement of calcium carbonate estimates in the global ocean".

Microbial community structure and abundance analysed by flow cytometry

GLEN TARRAN
Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth, PL1 3DH, UK

Objectives

- To determine the distribution, abundance and community structure of nano and picophytoplankton and heterotrophic bacteria in surface waters from CTD water bottle samples.
- Determine the size structure of nano and picophytoplankton and heterotrophic bacteria within the Southern Gyre, Equatorial Upwelling and Northern Gyre via size fractionation and flow cytometric analysis.
- Collaborate with Martha Schattenhofer, Michal Koblizek and Michelle Hale (see individual cruise reports) at triplicate stations in the Southern Gyre, Equatorial Upwelling and Northern Gyre to study multiple aspects of bacterioplankton community structure, abundance and dynamics.
- Carry out sample collection of seawater samples from predawn CTD casts for post-cruise detection and characterisation of *Prochlorococcus* sp. (cyanobacteria) viruses for Ellie Harrison (Plymouth Marine Laboratory)
- Carry out sample collection of seawater samples from predawn CTD casts for post-cruise characterisation of *Synechococcus* sp. (cyanobacteria) genetic diversity using fluorescence *in situ* hybridisation (FISH) molecular techniques for Katrin Zwirglmaier (University of Warwick).

Methods

Phytoplankton community structure and abundance: Fresh seawater samples were collected in clean 250 ml polycarbonate bottles from a Seabird CTD system containing 24 x 20 l Niskin bottles from predawn and late morning (1100 local time) CTD casts. Samples were stored in a refrigerator and analysed within 1-2 hours of collection. Fresh samples were measured using a Becton Dickinson FACSort flow cytometer which characterised and enumerated *Prochlorococcus* sp. and *Synechococcus* sp. (cyanobacteria), pico-eucaryotes, cryptophytes, coccolithophores and other nanophytoplankton based on their light scattering and autofluorescence properties. The data were immediately stored on disk and will be analysed back in the UK. Table G1 summarises the CTD casts sampled and analysed during the cruise.

Heterotrophic bacteria and autotrophic cyanobacteria distribution and abundance: The most common method for the analysis of heterotrophic bacteria and autotrophic cyanobacteria from scientific cruises is to preserve samples, freeze them and transport them back to the laboratory for post-cruise analysis. During AMT16, studies were carried out to compare the effects of fixation, preservation and time on abundance estimates obtained by flow cytometry. Two comparisons were devised as outlined below.

Analysis of fresh-fixed samples vs. post-cruise analysis of deep-frozen samples: Samples collected for phytoplankton analysis from the predawn cast were also used for the collection of bacteria samples. Duplicate 1.8 ml seawater samples from all depths were preserved with paraformaldehyde (1% final concentration) and left to fix at room temperature for 15-30 minutes. One set of replicates was then flash frozen in liquid nitrogen for approximately 1 minute and then placed in the -60°C freezer for post-cruise analysis by flow cytometry. The other set of replicates was stained with Sybr Green I nucleic acid stain, with the addition of 0.5 µm beads as an internal standard and a potassium citrate buffer and left in the dark at 35°C for at least 1 hour before analysis by flow cytometry onboard ship. The data were immediately stored on disk and will be analysed back in the UK.

Analysis of samples deep frozen for 24 hours versus post-cruise analysis of deep-frozen sample: Samples collected for phytoplankton analysis from the 1100 cast were also used for the collection of bacteria samples. One set of 1.8 ml seawater samples was taken from all depths and a second set taken from the 6 light depths (97, 55, 33, 14, 1 and 0.1% of surface light) and 200 m were preserved with paraformaldehyde (1% final concentration) and left to fix at room temperature for 15-30 minutes. All samples were then flash frozen in liquid nitrogen for approximately 1 minute and then placed in the –60°C freezer. The set taken from all depths remained deep-frozen for post-cruise analysis by flow cytometry. The other set of replicates were thawed after 24 hours, stained with Sybr Green I nucleic acid stain, with the addition of 0.5 µm beads as an internal standard and a potassium citrate buffer and left in the dark at 35°C for at least 1 hour before analysis by flow cytometry onboard ship. The data were immediately stored on disk and will be analysed back in the UK.

It is hoped that these experiments will provide important information for the optimisation of bacterial analysis by flow cytometry (particularly where there is no onboard facility) and should provide suitable error factors associated with long-term storage of samples before analysis. Table G1 summarises the CTD casts sampled and analysed for bacteria during the cruise.

Table 1. CTD casts sampled for phytoplankton and heterotrophic bacteria community structure and abundance

Date	Time (GMT)	CTD	Lat	Long	Depths sampled
21 May	02:43	1	31°58.05'S	16°58.01'E	2 5 10 20 30 40 50 65 85 100 125 175 225 250
21 May	09:16	2	31°00.40'S	16°29.55'E	2 10 20 30 50 100 150 250
24 May	03:40	3	31°49.96'S	10°30.01'E	2 6.5 12 23 42 65 96 115 144 200 250 300
24 May	10:13	4	31°34.74'S	09°19.55'E	2 13 23 42 50 90 95 100 110 125 150 200 225 300
25 May	10:01	5	30°38.07'S	04°13.28'E	2 10 16 30 50 70 80 100 125 150 200 225 300
26 May	03:35	6	29°57.92'S	00°42.01'E	2 5 13 23 42 70 95 110 145 180 240 300
27 May	11:05	7	28°44.60'S	05°45.30'E	2 5 24 44 80 95 100 105 125 150 200 225 300
28 May	04:34	8	28°04.23'S	09°14.97'W	2 5 15 28 50 105 115 130 172 200 250 300
28 May	12:24	9	27°49.76'S	10°30.96'W	2 16 30 55 80 95 115 125 130 135 150 200 225 300
29 May	07:58	11	27°13.81'S	13°26.56'W	2 5 17 31 56 75 90 120 130 140 195 220 250 300
29 May	11:04	12	27°10.03'S	13°49.65'W	2 16 30 55 90 110 125 135 150 170 200 225 300
30 May	04:40	13	26°31.61'S	17°13.74'W	2 5 15 28 50 75 95 115 135 173 200 300 500 1000
30 May	12:03	14	26°17.04'S	18°27.70'W	2 17 31 57 90 110 130 140 150 175 200 225 300
31 May	05:41	15	25°36.29'S	21°55.97'W	2 5 14 25 46 65 85 105 125 158 220 300
31 May	12:07	16	25°23.07'S	23°04.66'W	2 16 29 52 80 95 100 110 120 130 140 160 200 250 300
1 June	05:37	17	22°52.82'S	24°59.98'W	2 5 17 31 57 75 100 130 150 195 245 300
1 June	12:09	18	22°27.28'S	24°59.97'W	2 17 31 57 95 130 150 170 225 300 500 750 1000 2000 3500 4400 5390
2 June	04:37	19	20°11.93'S	24°59.83'W	2 5 20 36 65 105 125 150 225 275 500 1000
2 June	11:59	20	19°14.24'S	25°00.00'W	2 18 33 61 85 110 130 140 150 175 225 300
3 June	05:42	21	16°16.71'S	24°59.92'W	2 5 20 36 65 85 125 150 165 225 275 300
3 June	12:04	22	15°24.55'S	25°00.06'W	2 18 33 61 80 110 130 140 150 175 200 225 300
4 June	05:37	23	12°24.73'S	24°59.71'W	2 5 17 32 57 85 115 132 144 200 250 300
4 June	12:03	24	11°57.03'S	25°00.41'W	2 16 29 52 65 75 90 110 120 130 170 200 225 300
5 June	04:35	25	09°04.76'S	24°59.81'W	2 5 14 25 46 75 95 105 120 158 200 300 500 1000
6 June	05:21	26	05°09.84'S	25°00.11'W	2 5 12 21 38 60 78 88 95 132 180 300
6 June	12:02	27	04°15.07'S	24°59.88'W	2 10 18 33 50 70 75 80 100 110 130 150 200 225 300
7 June	05:03	28	01°37.71'S	24°59.59'W	3 5 10 16 30 45 55 68 85 105 200 300

Date	Time (GMT)	CTD	Lat	Long	Depths sampled
8 June	04:13	29	01°10.38'N	25°34.00'W	3 6.5 12 22 40 48 65 75 150 300 500 1000
8 June	11:58	30	02°03.50'N	25°58.97'W	2 9 16 28 30 45 60 65 70 90 100 120 150 200 225 300
9 June	05:03	31	04°16.33'N	27°01.46'W	3 5 10 19 35 50 65 80 100 120 150 300
9 June	12:11	32	05°09.15'N	27°26.79'W	2 10 20 35 50 65 80 90 120 200 300 500 850 1500 2400 3500 4360
10 June	05:06	33	07°14.99'N	28°27.19'W	2 5 7 11 22 35 45 51 70 85 180 300
10 June	12:07	34	07°41.75'N	28°40.67'W	2 7 12 22 45 50 55 75 100 150 200 225 300
11 June	04:06	35	10°00.42'N	2 9°47.59'W	2 5 9 16 30 40 55 68 95 132 200 350 500
12 June	12:02	37	13°11.71'N	31°20.59'W	2 11 2036 45 75 82 87 100 130 150 200 225 300
13 June	04:43	38	15°45.74'N	32°35.96'W	2 5 13 24 44 64 80 100 115 150 200 300
13 June	12:02	39	16°19.47'N	32°53.18'W	2 13 24 35 44 50 60 90 100 110 120 150 200 225 300
14 June	04:04	40	18°57.91'N	34°12.39'W	2 5 20 36 65 80 120 140 160 225 300 400 600 1000
14 June	12:00	41	20°05.00'N	34°46.34'W	2 16 19 29 52 75 100 120 135 150 175 200 225 300
15 June	04:33	42	22°48.31'N	36°09.82'W	2 5 14 25 46 60 80 105 120 155 200 300
15 June	12:00	43	23°21.58'N	36°27.43'W	2 17 31 57 75 100 120 130 140 180 225 300 500 850 1500 2250 3500 4500 5900
16 June	13:33	45	26°50.46'N	38°17.77'W	2 19 35 63 80 110 140 145 150 160 180 210 225 300
17 June	04:40	46	29°09.43'N	39°32.53'W	2 5 18 32 59 80 110 135 145 202 285 600 1000
17 June	12:18	47	29°27.27'N	39°48.85'W	2 17 31 57 90 125 130 135 150 175 225 300
18 June	05:03	48	31°22.99'N	42°08.65'W	2 5 15 28 50 75 100 120 135 180 225 300
18 June	11:56	49	31°43.41'N	42°38.98'W	2 11 20 37 45 60 80 85 90 100 125 150 175 200 225 300
19 June	05:03	50	33°34.61'N	45°32.31'W	2 5 10 18 32 45 60 74 95 115 200 300
19 June	12:08	51	33°55.55'N	46°04.53'W	2 9 16 28 35 50 60 65 70 100 150 200 225 300
20 June	05:00	52	34°54.18'N	42°33.57'W	2 5 12 22 38 60 75 90 115 135 200 350 500 1000
20 June	12:06	53	35°05.92'N	41°50.69'W	2 12 22 39 45 65 80 90 95 110 135 150 200 225 300
21 June	04:36	54	36°04.11'N	38°20.54'W	2 5 10 17 32 50 65 78 95 120 200 300
21 June	12:01	55	36°27.59'N	36°55.18'W	2 9 16 28 50 60 67 80 100 150 200 225 300
22 June	05:04	56	37°20.94'N	33°39.62'W	2 5 9 13 26 35 52 63 82 100 200 300
22 June	11:59	57	37°34.33'N	32°50.23'W	2 8 15 27 48 55 62 70 100 125 150 200 225 300
23 June	03:02	58	38°18.32'N	30°03.83'W	2 5 7 12 20 28 38 49 65 75 150 300
23 June	12:00	59	39°15.77'N	28°49.34'W	2 9 16 33 60 68 75 100 125 150 200 225 300
24 June	03:10	60	41°08.34'N	26°22.60'W	2 5 10 19 35 50 65 75 95 120 200 400 800 1000
24 June	12:05	61	42°06.65'N	25°04.18'W	2 12 23 30 42 47 52 57 65 100 150 200 225 300
25 June	02:35	62	43°44.12'N	22°52.39'W	2 5 7 12 22 40 50 65 75 180 300
25 June	12:00	63	44°22.10'N	21°59.81'W	2 6 10 18 35 42 47 75 100 150 200 225 300
26 June	05:43	64	46°02.01'N	19°40.21'W	2 5 10 17 22 28 38 50 60 120 300
26 June	11:06	65	46°21.94'N	18°51.22'W	2 5 10 17 30 40 55 75 100 150 200 225 300
27 June	04:03	66	47°02.70'N	15°25.04'W	4 7 13 20 30 35 40 45 50 60 65 70 80 100 150 200 300
27 June	10:59	67	47°16.42'N	13°58.07'W	3 6 11 20 26 30 50 65 80 100 150 200 225 300

Sample depths highlighted in grey were samples for Ellie Harrison's *Prochlorococcus* virus studies. Left hand value on any row is the 55% light level and the right hand value is the 1% light level.

Sample depths highlighted with a border were samples for Katrin Zwirglmaier's Synechococcus *genetic* diversity studies. Left hand value on any row is the 97% light level and the right hand value is the 1% light level.

Size structure of nano- and picophytoplankton and heterotrophic bacteria: To gain an idea of the size structure of the planktonic communities analysed by flow cytometry, 6 size fractionation experiments were carried out along the transect. For the nano- and picophytoplankton, live 5 ml samples from the 14% light level were gravity filtered through a range of 47 mm polycarbonate filters (0.2, 0.4, 0.6, 0.8, 1, 3, 5, 10 µm) and analysed by flow cytometry to count the numbers of cells passing through the filters. For bacteria, a 6 ml sample of the same seawater was preserved with PFA (1% final concentration) and then stained with a mixture containing Sybr Green I DNA dye, potassium citrate buffer and 0.5 µm beads as an internal standard. By plotting filter pore size against the percentage of cells remaining, compared to an unfiltered sample, it will be possible to draw a line across the plot at the point where 50% of the cells remain until it intersects with the plot line and then draw a line down to the x axis. The point at which the line crosses the x axis will provide an estimate of the median cell size of the plankton group of interest. The data from these experiments have been stored on disk and will be analysed back in the laboratory.

Collaborative studies of bacterial standing stocks, community structure and dynamics: Collaborative bacterial studies were carried out with Martha Schattenhofer, Michelle Hale and Michal Koblizek at 9 stations during the cruise (Table 2). Studies ranged from bacterial standing stocks and community composition to looking at dynamics through short term (hours) substrate uptake experiments to longer (days) nutrient amendment experiments and pigment turnover studies. See individual cruise report contributions for experimental details. The sites chosen provided triplicate studies in the Southern Gyre, Equatorial Upwelling and Northern Gyre. A co-ordinated sampling strategy was followed, with the 55% light level being chosen as a single common depth for a complete comparison of experiments. Results and data will be worked up and interpreted after the cruise.

Table 2. Study sites for collaborative bacterial studies

Region	Date	Time (GMT)	CTD #	Lat	Long	55% light depth (m)
Southern Gyre	30 May	04:40	13	26°31.61'S	17°13.74'W	15
Southern Gyre	1 June	05:37	17	22°52.82'S	24°59.98'W	17
Southern Gyre	3 June	05:42	21	16°16.71'S	24°59.92'W	20
Equatorial Upwelling	6 June	05:21	26	05°09.84'S	25°00.11'W	12
Equatorial Upwelling	8 June	04:13	29	01°10.38'N	25°34.00'W	6.5
Equatorial Upwelling	10 June	05:06	33	07°41.75'N	28°40.67'W	7
Northern Gyre	13 June	04:43	38	15°45.74'N	32°35.96'W	13
Northern Gyre	15 June	04:33	42	22°48.31'N	36°09.82'W	14
Northern Gyre	17 June	04:40	46	29°09.43'N	39°32.53'W	18

Detection and characterisation of *Prochlorococcus* sp. (cyanobacteria) viruses for Ellie Harrison (Plymouth Marine Laboratory): Fresh 5 ml seawater samples from the predawn CTD cast were collected in 5 ml cryovials and stored in the refrigerator. Four depths were sampled every day from the 55, 33, 14 and 1% light depths. There were four exceptions when there was no predawn CTD cast. On these days, samples were collected from the mid-morning cast. Sample depths are highlighted in grey in Table 1, with the left hand value being the 55% light level and the right hand value being the 1% light level. These samples will be returned to the laboratory for analysis.

Analysis of *Synechococcus* sp. genetic diversity using FISH for Katrin Zwirglmaier (University of Warwick): Fresh seawater samples from predawn CTD casts were collected in clean (50% ethanol rinsed) 250 ml polycarbonate bottles. Samples were taken from the 97, 55, 33, 14 and 1% light depths, as well as a sixth sample between the 14 and 1% light depths (See Table G1 for CTDs and depths sampled. Sample depths are highlighted with a border. Left hand value on any row is the 97% light level and the right hand value is the 1% light level.). Samples were stored in a refrigerator for approximately 2 – 2.5 hours until used. 100 ml of sample from each depth was filtered through 0.22 µm 47 mm polycarbonate filters using polycarbonate filter funnels attached to a stainless steel manifold at 5 inches mercury vacuum. The filters were allowed to dry for a few minutes and were then placed upside down in a container of 1% paraformaldehyde (dissolved in PBS) and allowed to fix at room temperature for 1-2 hours. After fixing, the filters were passed sequentially through baths containing 50, 80 and 100% ethanol at 5 minute intervals and were then placed in Petri-slides and allowed to dry. The Petri-slides were then stored in a -60°C freezer. These samples will be returned to the laboratory, where they will be probed with *Synechococcus* sp. specific genetic probes using fluorescence *in situ* hybridisation (FISH) techniques.

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

MICHELLE S. HALE AND RICHARD B. RIVKIN
Memorial University of Newfoundland, St John's, Newfoundland A1C 5S7, Canada

Background

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

Objectives

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

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

A further objective during AMT16 was to collaborate with Glen Tarran, Martha Schattenhofer, and Michal Koblizek (see individual cruise reports) at triplicate stations in the each of the Southern Gyre, Equatorial Upwelling and Northern Gyre, to study multiple aspects of bacterioplankton community structure, abundance and dynamics.

We also aimed to collect samples to determine microzooplankton (including heterotrophic nanoflagellates) abundance and biomass in the upper 300 m of the water column, in collaboration with Elaine Fileman (PML).

Methods

Nutrient Amendment Experiments: To test Hypothesis 1 during AMT16, the effects of temperature and substrate availability on bacterial growth and community structure were assessed and partitioned by conducting nutrient amendment experiments at 13 stations in different biogeochemical provinces in the temperate and tropical eastern Atlantic Ocean. Experiments were conducted using water collected before sunrise at the 55% light depth. Modified seawater (MSW) dilution cultures were made with 1 part 1.0 µm filtered seawater to 4 parts 0.2 µm filtered seawater (Rivkin and Anderson 1997), and incubated in 500 ml polycarbonate bottles in the dark and at ambient temperature. Triplicate MSW cultures were either unlamented (i.e. control) or amended with additions of organic carbon and nitrogen (glucose and glutamic acid), and inorganic nitrogen (NH_4Cl) and phosphorous (Na_2HPO_4), each to a final concentration of 10 µM, in a full factorial matrix. During AMT17, in collaboration with Richard Geider's research team, we will also assess the influence of iron. Samples were collected every 24 hours for 72 hours and will be analysed by flow cytometry (FCM), using standard

protocols (Marie *et al*., 1999; Li and Dickie, 2001), for heterotrophic bacterial abundance, including quantifying the abundance of cells with high and low DNA content (Zubkov *et al*., 2004). Heterotrophic bacterial counts will be confirmed by Acridine Orange Direct Counts (AODC; Hobbie *et al*., 1977). Bacterial cell volume will be determined by image analysis of Acridine Orange (AO) stained cells using an Image-Pro Plus image analysis system (Loferer-Krößbacher *et al*., 1998) and bacterial community composition will be determined by Fluorescence *In situ* Hybridisation (FISH; Glockner *et al*., 1996; Fuchs *et al*., 2000; Pernthaler *et al*., 2001), using oligonucleotide probes designed to identify Bacteria and Archaea, as well as probes specific for Cytophaga-Flavobacterium, and the α-, β- and γ-subclasses of the Proteobacteria clade. In each replication bottle, the growth rate (μ) for heterotrophic bacteria and for each phylotype will be determined from the time-dependent change in cell abundance for the linear portion of the growth curve.

Microzooplankton grazing experiments: To test Hypothesis 2, during AMT16 microzooplankton bacterivory and herbivory was determined using a modified dilution assay (Landry and Hassett, 1982; Rivkin *et al*., 1999). Seawater was collected at the same stations/depths as described above for Hypothesis 1, filtered through a 202 μm Nitex mesh to remove larger grazers, and diluted with particle-free filtrate prepared by gravity filtration though a 0.2 μm Gelman cartridge filter to the following target dilutions (< 202 μm: < 0.2 μm filtered water): 1.0, 0.9, 0.75, 0.5, 0.4, 0.3, 0.2 and 0.1. Samples were incubated in 500 ml polycarbonate bottles, in on-deck incubators at ambient temperatures (± 0.5°C) and ~55% of incident irradiance, for 48 hours. Abundances of bacteria as well as pico- and nanophytoplankton, will be determined by flow cytometry as described above. The apparent growth rate of each group at each of the eight dilutions will be computed from the time-dependent changes in abundance or concentration. Rates of grazing mortality will be determined from the linear regression of apparent growth rate against dilution, with the intercept of the line providing an estimate of growth rate and the slope of the line providing an estimate of grazing mortality (Rivkin *et al*., 1999).

The experiments described above were carried out at 13 stations, including 9 stations where collaborative bacterial studies were carried out with Glen Tarran, Martha Schattenhofer and Michal Koblizek (Table 1). Studies ranged from bacterial standing stocks and community composition to looking at dynamics through short term (hours) substrate uptake experiments to longer (days) nutrient amendment experiments and pigment turnover studies. See individual cruise report contributions for experimental details. The sites chosen provided triplicate studies in the Southern Gyre, Equatorial Upwelling and Northern Gyre. A co-ordinated sampling strategy was followed, with the 55% light level being chosen as a single common depth for a complete comparison of experiments.

Microzooplankton abundance and biomass (in collaboration with Elaine Fileman from PML): To determine the abundance and biomass of microzooplankton, samples were collected from the pre-dawn CTD casts at 6 light depths: 97, 55, 33, 14, 1 and 0.1% surface irradiance (Table 2). Between 500 and 1000 ml of seawater was fixed with Lugols iodine and stored in the dark, in the fridge. Microzooplankton abundance and biomass will be determined from concentrated subsamples, counted on an inverted microscope. For determination of heterotrophic nanoflagellate abundance and biomass, between 100 and 200 ml of water was collected directly from the Niskin bottle and fixed with 0.3% final concentration of glutaraldehyde. Cells were stained with DAPI for 5 min, counterstained with proflavin and concentrated on 0.8 μm black carbonate filter, using a backing filter to enhance even distribution of cells. Filters were mounted on a glass slide with a small drop of immersion oil between the filter and the coverslip. Slides were frozen and will be analysed by Elaine Fileman.

Table 1. Study sites for nutrient amendment and microzooplankton grazing experiments. Stations marked with * indicates where collaborative bacterial studies were conducted.

Region	Date	Time (GMT)	CTD #	Lat	Long	55% light depth (m)
Southeast Atlantic	21 May	02:26	1	31°58.23'S	16°58.42'E	12
South Atlantic	26 May	03.30	6	29°57.97'S	00°2.05'E	15
Southern Gyre*	30 May	04:40	13	26°31.61'S	17°13.74'W	15
Southern Gyre*	1 June	05:37	17	22°52.82'S	24°59.98'W	17
Southern Gyre*	3 June	05:42	21	16°16.71'S	24°59.92'W	20
Equatorial Upwelling*	6 June	05:21	26	05°09.84'S	25°00.11'W	12
Equatorial Upwelling*	8 June	04:13	29	01°10.38'N	25°34.00'W	6.5
Equatorial Upwelling*	10 June	05:06	33	07°41.75'N	28°40.67'W	7
Northern Gyre*	13 June	04:43	38	15°45.74'N	32°35.96'W	13
Northern Gyre*	15 June	04:33	42	22°48.31'N	36°09.82'W	14
Northern Gyre*	17 June	04:40	46	29°09.43'N	39°32.53'W	18
North Atlantic	21 June	04.35	54	36°04.13'N	38°20.54'W	12
North Atlantic	24 June	03.12	60	41°08.32'N	026°22.61'W	11

Table 2. Stations at which samples were collected from 6 light depths (97, 55, 33, 14, 1 and 0.1% surface irradiance) for microzooplankton abundance and biomass.

Date	Time (GMT)	CTD#	Lat	Long
21 May	2:43	1	31°58.05'S	16°58.01'E
24 May	3:40	3	31°49.96'S	10°30.01'E
26 May	3:35	6	29°57.92'S	00°42.01'E
28 May	4:34	8	28°04.23'S	09°14.97'W
30 May	4:40	13	26°31.61'S	17°13.74'W
31 May	5:41	15	25°36.29'S	21°55.97'W
01 Jun	5:37	17	22°52.82'S	24°59.98'W
03 Jun	5:42	21	16°16.71'S	24°59.92'W
04 Jun	5:37	23	12°24.73'S	24°59.71'W
05 Jun	4:35	25	09°04.76'S	24°59.81'W
06 Jun	5:21	26	05°09.84'S	25°00.11'W
07 Jun	5:03	28	01°37.71'S	24°59.59'W
08 Jun	4:13	29	01°10.38'N	25°34.00'W
09 Jun	5:03	31	04°16.33'N	27°01.46'W
10 Jun	5:06	33	07°14.99'N	28°27.19'W
11 Jun	4:06	35	10°00.42'N	29°47.59'W
13 Jun	4:43	38	15°45.74'N	32°35.96'W
14 Jun	4:04	40	18°57.91'N	34°12.39'W
15 Jun	4:33	42	22°48.31'N	36°09.82'W
17 Jun	4:40	46	29°09.43'N	39°32.53'W
18 Jun	5:03	48	31°22.99'N	42°08.65'W
19 Jun	5:03	50	33°34.61'N	45°32.31'W
20 Jun	5:00	52	34°54.18'N	42°33.57'W
21 Jun	4:36	54	36°04.11'N	38°20.54'W
22 Jun	5:04	56	37 20.94'N	33 39.62'W
24 Jun	3:10	60	41 08.34'N	26 22.60'W
25 Jun	2:35	62	43 44.12'N	22 52.39'W
26 Jun	5:43	64	46 02.01'N	19 40.21'W

References

Carlson, C.A., Ducklow, H.W. 1996. Growth of bacterioplankton and consumption of dissolved organic carbon in the Sargasso Sea. Aquatic Microbial Ecology 10(1), 69-85.

Carlson, C.A., Ducklow, H.W., Michaels, A.F. 1994. Annual flux of dissolved organic carbon from the euphotic zone in the northwestern Sargasso Sea. Nature 371(6496), 405-408.

Ducklow, H. 2000. Bacterial production and biomass in the oceans. In: Kirchman, D.L. (Ed). Microbial Ecology of the Ocean. John Wiley, New York. pp.85-119.

Ducklow, H.W., Carlson, C.A. 1992. Oceanic bacterial production. Advances in Microbial Ecology 12: 113-181.

Fuchs, B.M., Zubkov, M.V., Sahm, K., Burkill, P.H., Amann, R. 2000. Changes in community composition during dilution cultures of marine bacterioplankton as assessed by flow cytometric and molecular biological techniques. Environmental Microbiology 2(2), 191-201.

Gasol, J.M., Pedros-Alio, C., Vaque, D. 2002. Regulation of bacterial assemblages in oligotrophic plankton systems: results from experimental and empirical approaches. Antonie van Leeuwenhoek International Journal of General and Molecular Microbiology 81(1-4), 435-452.

Glockner, F.O., Amann, R., Alfreider, A., Pernthaler, J., Psenner, R., Trebesius, K., Schleifer, K.H. 1996. An in situ hybridization protocol for detection and identification of planktonic bacteria. Systematic and Applied Microbiology 19(3), 403-406.

Hobbie, J.E., Daley, R.J., Jasper, S. 1977. Use of nucleopore filters for counting bacteria by fluorescence microscopy. Applied and Environmental Microbiology 33(5), 1225-1228.

Hutchins, D.A., Campbell, B.J., Cottrell, M.T., Takeda, S. 2001. Response of marine bacterial community composition to iron additions in three iron-limited regimes. Limnology and Oceanography 46(6), 1535-1545.

Kirchman, D.L. 1990. Limitation of bacterial-growth by dissolved organic-matter in the Sub-Arctic Pacific. Marine Ecology Progress Series 62(1-2), 47-54.

Kirchman, D.L. (Ed). 2000. Microbial Ecology of the Ocean. John Wiley, New York.

Kirchman, D.L., Rich, J.H. 1997. Regulation of bacterial growth rates by dissolved organic carbon and temperature in the equatorial Pacific Ocean. Microbial Ecology 33(1), 11-20.

Landry, M.R., Hassett, R.P. 1982. **Estimating the grazing impact of marine micro-zooplankton**. Marine Biology 67(3), 283-288.

Li, W.K.W., Dickie, P.M. 2001. Monitoring phytoplankton, bacterioplankton, and virioplankton in a coastal inlet (Bedford Basin) by flow cytometry. Cytometry 44(3), 236-246.

Loferer-Krößbacher, M., Klima, J., Psenner, R. 1998. Determination of bacterial cell dry mass by transmission electron microscopy and densitometric image analysis. Applied and Environmental Microbiology 64(2), 688-694.

Marie, D., Partensky, F., Vaulot, D., Brussaard, C. 1999. Enumeration of phytoplankton, bacteria, and viruses in marine samples. In: Robinson, J.P., Darzynkiewicz, Z., Dean, P.N., Orfao, A., Rabinovitch, P.S., Stewart, C.C., Tanke, H.J., Wheeless, L.L. (Eds.). Current Protocols in Cytometry. Supplement 10, Unit 11.11. John Wiley & Sons, New York, pp.1–15.

Pakulski, J.D., Coffin, R.B., Kelley, C.A., Holder, S.L., Downer, R., Aas, P., Lyons, M.M., Jeffrey, W.H. 1996. Iron stimulation of Antarctic bacteria. Nature 383(6596), 133-134.

Pernthaler *et al.* 2001. In: Paul, J.H. (Ed.) Methods in Microbiology, Vol 30, Academic Press, San Diego. pp: 207-226.

Rivkin, R.B., Anderson, M.R. 1997. Inorganic nutrient limitation of oceanic bacterioplankton. Limnology and Oceanography 42(4), 730-740.

Rivkin, R.B., Anderson, M.R., Lajzerowicz, C. 1996. Microbial processes in cold oceans .1. Relationship between temperature and bacterial growth rate. Aquatic Microbial Ecology 10(3), 243-254.

Rivkin, R.B., Putland, J.N., Anderson, M.R., Deibel, D. 1999. Microzooplankton bacterivory and herbivory in the NE subarctic Pacific. Deep-Sea Research II 46(11-12), 2579-2618.

Suttle, C. 2005. The viriosphere: the greatest biological diversity on Earth and driver of global processes. Environmental Microbiology 7(4), 481-482.

Tortell, P.D., Maldonado, M.T., Price, N.M. 1996. The role of heterotrophic bacteria in iron-limited ocean ecosystems. Nature 383(6598), 330-332.

Wiebe, W.J., Sheldon, W.M., Pomeroy, L.R. 1993. Evidence for an enhanced substrate requirement by marine mesophilic bacterial isolates at minimal growth temperatures. Microbial Ecology 25(2), 151-159.

Wilhelm, S.W., Suttle, C.A. 1999. Viruses and Nutrient Cycles in the Sea - Viruses play critical roles in the structure and function of aquatic food webs. Bioscience 49(10), 781-788.

Zubkov, M.V., Allen, J.I., Fuchs, B.M. 2004. Coexistence of dominant groups in marine bacterioplankton community - a combination of experimental and modelling approaches. Journal of the Marine Biological Association of the United Kingdom 84(3), 519-529.

Triple oxygen isotope measurements of sea water

JAN KAISER[1] FOR BOAZ LUZ[2]

[1]*Department of Geosciences, Princeton University, Washington Road, Princeton, NJ 08544-1003, USA*

[2]*The Institute of Earth Sciences, The Hebrew University of Jerusalem, Jerusalem 91904, Israel*

Rationale

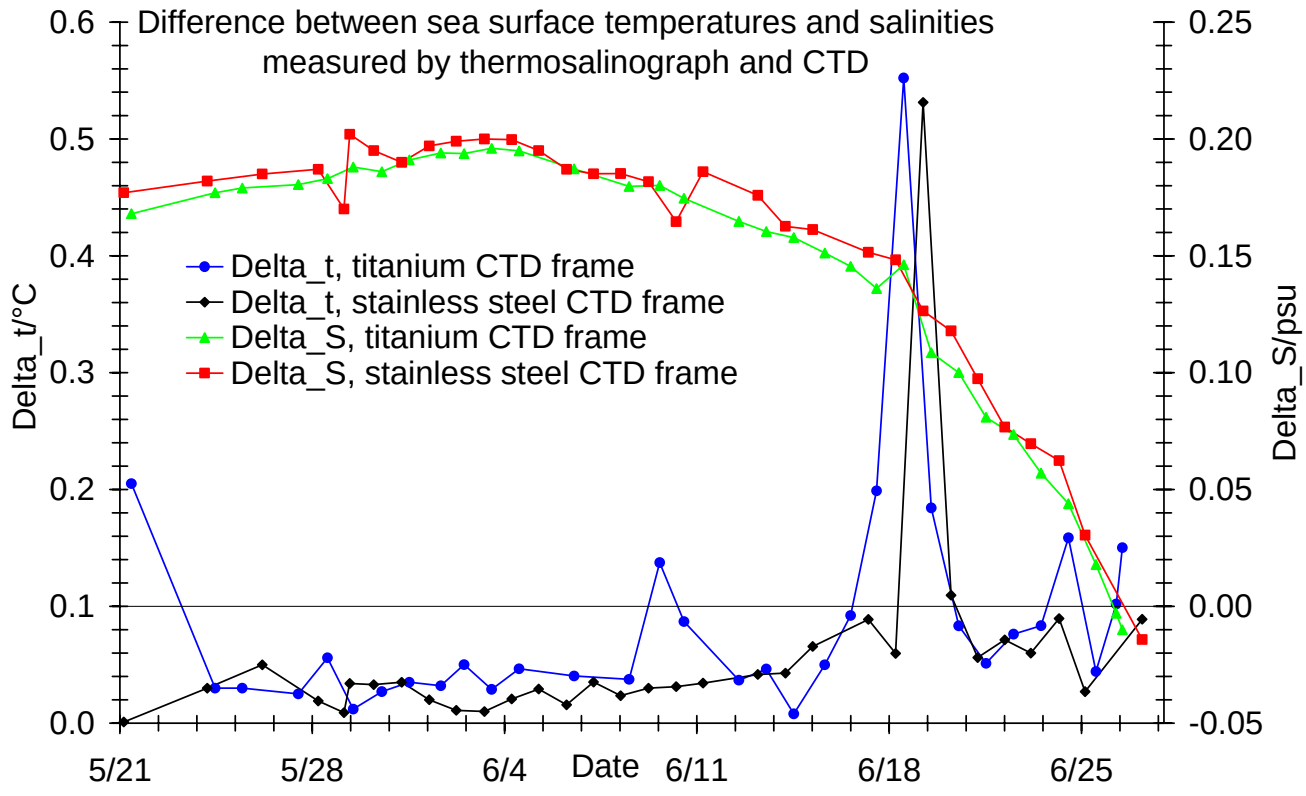
The $^{17}O/^{16}O$ and $^{18}O/^{16}O$ isotope ratios of water are important because water is the substrate for production of photosynthetic O_2. Therefore, the isotopic composition of water strongly affects the composition of dissolved O_2 in the ocean and also of atmospheric O_2. Luz and co-workers have developed a method to estimate photosynthetic production from the triple isotope composition of O_2 gas (Luz *et al.*, 1999; Luz and Barkan, 2000) (note that the same method will be used for analysis of discrete water samples taken during the AMT16 cruise, see section on mass-spectrometric dissolved gas measurements by Kaiser *et al*. in this report). However, proper application of this method requires knowledge of the triple isotope composition of the water substrate. Until very recently, accurate $^{17}O/^{16}O$ isotope ratios were not routinely determined. Instead, $^{17}O/^{16}O$ ratios were estimated indirectly, which results in considerable uncertainty for estimates of photosynthetic rates. In order to decrease the uncertainty, Luz *et al*. have developed a new high-precision method to determine $^{17}O/^{16}O$ in water. The samples collected during the AMT16 cruise will be used to obtain representative figures for oceanic $^{17}O/^{16}O$ ratios.

Methodology

Water samples were drawn from selected CTD Niskin bottles and the non-de-aerated underway seawater supply (see Table 3 for details of the samples taken). Brown borosilicate glass bottles with clear plastic liners and red polypropylene screw caps (*oponorm*) were double-rinsed and filled to the mark with about 50 ml sample each, leaving about 10 ml of headspace to allow for expansion of the water if it freezes during transport in the baggage compartment of an aircraft. The bottles were tightly sealed and shipped to the Institute of Earth Sciences at the Hebrew University of Jerusalem, Israel. Accurate salinity is required for interpretation of the data. Therefore, uncalibrated salinities were recorded from the .BTL files of the Seabird CTD software and the ship's thermosalinograph (TSG). Accurate, calibrated values will be generated using calibration samples analysed on the ship's Autosal salinometer.

Results

A preliminary intercomparison of CTD and TSG salinities shows an initially stable offset of the TSG salinity relative to the CTD salinities by about 0.185 psu. During the second half of the cruise the thermosalinograph entered into a drift and was drifting by about 0.6 psu/month towards the end of the cruise.



References

Luz, B., Barkan, E., Bender, M.L., Thiemens, M.H., Boering, K.A. 1999. Triple-isotope composition of atmospheric oxygen as a tracer of biosphere productivity. Nature 400, 547-550.

Luz, B., Barkan, E. 2000. Assessment of oceanic productivity with the triple-isotope composition of dissolved oxygen. Science 288, 2028-2031.

Water samples for triple oxygen isotope analysis by Boaz Luz, collected by Jan Kaiser

Note: Salinities are uncalibrated values from the underway sampling log and the CTD .BTL files.

Sample	Station	Cast	Niskin	Date	GMT	Lat.	Long.	z_{approx} m	*S*(TSG) psu	*S*(CTD) psu	T(TSG) ºC	T(CTD) **35**ºC	Water mass
1	1	1	23	5/21/05	3:18	31°58'S	16°58'E	2	35.592	35.415	18.934	18.933	
2	underway			5/23/05	7:28	32°51'S	14°36'E	5	35.675		19.471		
3	underway			5/25/05	7:47	30°43'S	04°41'E	5	35.875		19.638		
4	7	7	23	5/27/05	11:48	28°45'S	05°45'W	2	36.129	35.949	.	20.118	
5	10	11	23	5/29/05	8:47	27°14'S	13°27'W	2	36.739	36.537	22.486	22.452	
6	underway			5/31/05	11:21	25°24'S	22°59'W	5	37.068		24.115		
7	17	18	1	6/01/05	13:53	22°28'S	25°00'W	5390		34.701		0.682	Antarctic Bottom Water
8	17	18	1	6/01/05	13:53	22°28'S	25°00'W	5390		34.701		0.682	Antarctic Bottom Water
9	17	18	4	6/01/05	15:05	22°28'S	25°00'W	2000		34.950		3.298	North Atlantic Deep Water
10	17	18	4	6/01/05	15:05	22°28'S	25°00'W	2000		34.950		3.298	North Atlantic Deep Water
11	17	18	6	6/01/05	15:32	22°28'S	25°00'W	750		34.384		4.840	Antarctic Intermediate Water
12	17	18	6	6/01/05	15:32	22°28'S	25°00'W	750		34.384		4.840	Antarctic Intermediate Water
13	18	19	21	6/02/05	5:46	20°12'S	25°00'W	5	37.478	37.279	25.493	25.482	
14	underway			6/04/05	11:18	12°31'S	25°00'W	5	37.181		26.853		
15	underway			6/06/05	10:53	04°26'S	25°00'W	5	35.906		27.855		
16	29	29	20	6/08/05	5:20	01°11'N	25°34'W	6	35.095	35.095	28.396	28.372	
17	underway			6/10/05	10:00	07°23'N	28°31'W	5	35.518		28.378		
18	underway			6/12/05	7:44	12°49'N	31°10'W	5	35.483		26.441		
19	underway			6/14/05	6:12	19°04'N	34°16'W	5	37.013		25.362		
20	underway			6/16/05	9:55	26°20'N	38°01'W	5	37.104		24.014		
21	48	48	23	6/18/05	5:38	31°23'N	42°08'W	2	36.947	36.801	24.018	24.035	
22	51	51	23	6/19/05	12:48	33°55'N	46°05'W	2	36.579	36.471	20.635	20.451	westernmost point of cruise
23	52	52	23	6/20/05	6:05	34°55'N	42°53'W	4	36.731	36.613	22.144	7.298	
24	52	52	1	6/20/05	5:24	34°55'N	42°53'W	1000		35.172		22.055	Mediterranean Water (???)
25	underway			6/22/05	20:04	37°55'N	31°34'W	5	36.248		19.929		
26	60	60	23	6/24/05	4:29	41°09'N	26°23'W	2	36.105	36.046	18.959	18.866	
27	60	60	1[a]	6/24/05	3:37	41°09'N	26°23'W	1000		35.495		8.189	Mediterranean Water (???)
28	63	63	23	6/26/05	12:37	46°22'N	18°52'W	2	35.904	35.892	17.340	17.286	

[a]Niskin not sealed properly (nitrate concentration lower than expected)

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

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

Rationale and objectives

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

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

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

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

We recently presented an advance of this method for continuous underway measurements of O_2/Ar by membrane-inlet mass spectrometry (MIMS) (Kaiser *et al.*, 2005), extending earlier oceanographic MIMS applications (Kana *et al*, 1994; Tortell, 2005). The measured ΔO_2/Ar values can be used in conjunction with suitable wind-speed gas-exchange parameterizations to calculate biologically induced air-sea O_2 fluxes and, where conditions are appropriate, *N*. The inferred *N* values represent rates integrated over the characteristic mixed layer gas exchange times (ratio of mixed layer thickness and piston velocity), typically between 10 and 30 days.

The O_2/Ar method has the advantage not to involve potential biases associated with incubating water samples in a bottle. The *N* estimates derived from the MIMS measurements will be compared with results from currently used bottle incubation techniques (see section on O_2 bottle incubations by Niki Gist and section on ^{14}C productivities by Alex Poulton). The data from the AMT16 cruise will be used to quantitatively study the autotrophic or heterotrophic nature of different marine ecosystems along a meridional transect of the Atlantic Ocean.

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

Methodology

Continuous measurements of dissolved N_2, O_2, Ar and CO_2 were made by MIMS on board the RRS Discovery. The ship's underway sampling system was used to pump water through an exchange chamber with a tubular Teflon AF membrane (Random Technologies) mounted on the inside. The membrane was connected to the vacuum of a quadrupole mass spectrometer (Pfeiffer Vacuum Prisma). The intake of the underway sampling system is located at the bow at a nominal depth of 5 m. The water from the underway sampling system passed through an open bucket at several litres per minute to remove macroscopic bubbles and to avoid pressure bursts. A flow of about 80 ml/min was continuously pumped from the bucket through the membrane chamber, using a gear pump (Micropump). In order to reduce O_2/Ar variations due to temperature effects and water vapour pressure variations, the exchange chamber with the membrane was held at a constant temperature of 7–15ºC (5 to 10ºC below the sea surface temperature, to avoid temperature-induced supersaturations and subsequent bubble formation). The flight tube was in a thermally insulated box maintained at 50ºC.

In addition to the continuous underway MIMS measurements, we also analysed eight to nine CTD samples each from casts #46, 48, 50, 52, 54, 56, 59, 60, 62, and 62 (see below) in order to characterize the depth profile of the O_2/Ar ratio in regions of the North Atlantic gyre where the mixed layer depths were too shallow to allow a representative estimate of the trophic status of the euphotic zone from the surface O_2/Ar ratio. The results are compared with depth profiles of O_2-based productivity estimates from bottle incubations.

The O_2/Ar and N_2/Ar ratio measurements will be calibrated with discrete water samples taken from the same seawater outlet as used for the MIMS measurements (Appendix 6). 200 cm^3 samples were drawn into pre-evacuated glass flasks poisoned with 7 mg $HgCl_2$ (Quay *et al.*, 1993). These samples will be later analyzed with an isotope ratio mass spectrometer (IRMS, Thermo Finnigan) for their dissolved O_2/Ar ratios and the oxygen triple isotope composition relative to air (Hendricks *et al.*, 2004). Raw O_2/Ar ion current ratio measurements were made every 10 to 20 s and had a short-term stability of 0.05%.

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

Results

Optode calibration and Winkler measurements: Accurate sea surface temperature and salinity measurements are required to calibrate the optode measurements. We therefore compared the data from the underway system (thermosalinograph) with results from near-surface Niskin bottles from the two daily CTD casts (see section on triple oxygen isotope measurements of H_2O by Kaiser and Luz in this report). For an initial data evaluation, we have assumed that the CTD measurements are accurate and corrected the underway salinities for their drift relative to the CTD data. Final results will be calculated once the underway data have been calibrated by discrete samples drawn from the underway system and analysed on the ship's Autosal system.

The mean difference between calibrated optode and Winkler measurements of the O_2 supersaturation (ΔO_2) was (0.0±0.3)%. Dissolved O_2 was also measured in surface water samples from Niskin bottles in order to assess whether any gas losses occurred from the water pumped from the seawater intake to the laboratory due to warming and potential outgassing or O_2 loss to the pipe walls. A mean ΔO_2

decrease of (0.7±0.3)% was recorded and corrected for in the results presented here. A similar decrease was observed for O_2/Ar ratio measurements of Niskin bottle samples (see below) and this is most likely due to biofouling and O_2 consumptions in the ship's underway water supply.

For the entire duration of the AMT16 cruise, O_2 concentrations from the clean seawater supply of the ship were measured by the *Aanderaa* optode, giving a data-set of more than 300000 individual readings at 10 s resolution. The raw readings from the sensor proved to be stable throughout most of the cruise, however, the internal temperature sensor showed some intermittent behaviour during the middle part of the cruise. This was tentatively identified as being due to humidity problems of the cable connection to the sensor. Moving the cable slightly higher and regreasing the o-rings of the connection alleviated this problem. External thermistor measurements were used to correct the faulty temperature data. By calibrating the optode readings with the Winkler results, an accurate, high-resolution surface oxygen record was obtained estimated accuracy of 0.5 µmol/kg dissolved O_2 (see Figure 1 for an overview of the data versus latitude).

Membrane inlet mass spectrometry: Membrane inlet mass spectrometry (MIMS) was used to analyse dissolved gases continuously, namely O_2, nitrogen (N_2), argon (Ar), and carbon dioxide (CO_2). The still very new instrument worked successfully throughout 95–98% of the cruise. The MIMS measurements are to be calibrated against a total of 143 discrete water samples taken by evacuated flasks. The gas in the headspace of these samples will be analyzed for O_2/Ar ratios and the isotopic composition of O_2 on a sector-field mass spectrometer at Princeton University. During the entire cruise a direct online-calibration against water samples equilibrated with air was tested and gave relatively stable results. However, despite this the variability is still too high as to allow a reliable calibration of all the data and we will therefore resort again to the discrete samples as for previous cruises.

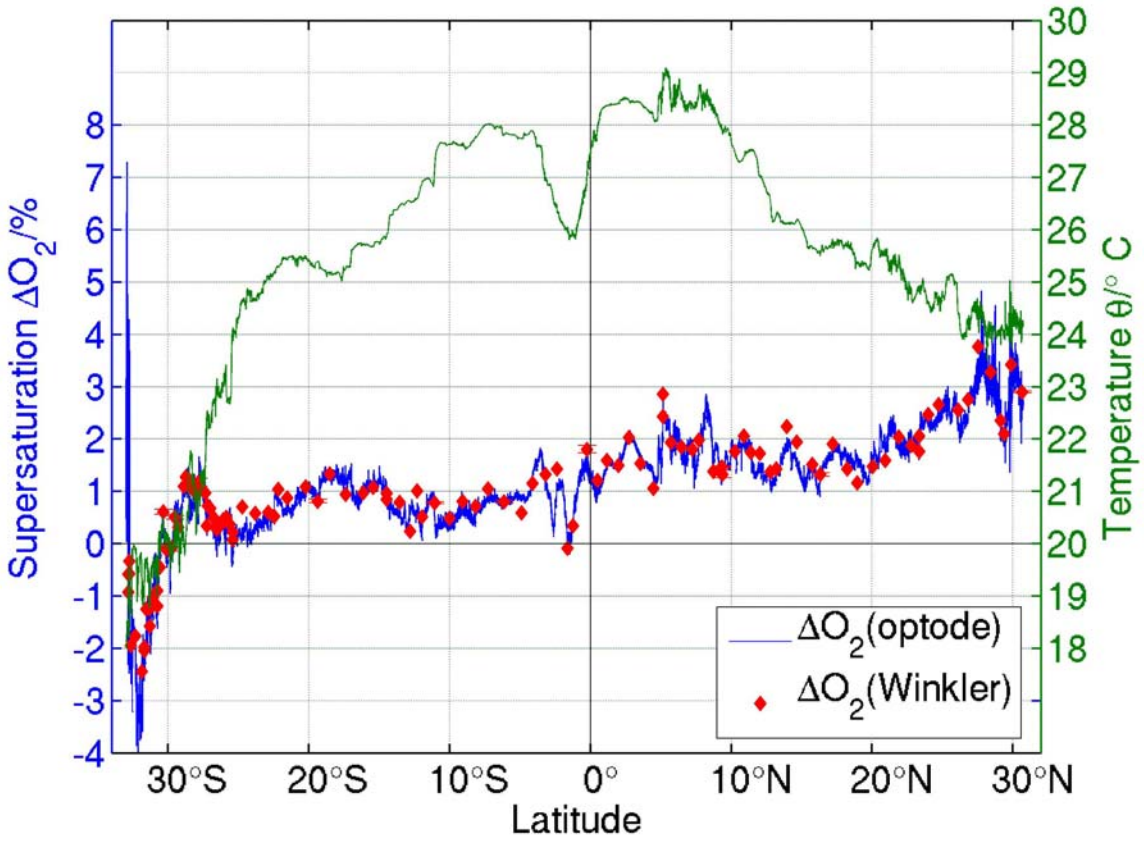


Figure 1. Meridional transect of continuous optode measurements of surface water O_2 supersaturation and sea surface temperatures measured by the "remote" sensor of the ship's thermosalinograph (between 22 May and 17 June 2005).

Oxygen/argon profiles from discrete CTD samples: Mixed layer depths were very shallow in the North Atlantic Gyre. Therefore, MIMS measurements were undertaken on discrete samples from CTD casts. The left panels of Figure 2 show the results and also a comparison to Winkler- and Winkler-calibrated sensor-based dissolved O_2 measurements. The O_2 supersaturation in the upper thermocline and mixed layer is always larger than the O_2/Ar supersaturation, indicating Ar supersaturations – possibly due to warming. In the lower thermocline, both O_2 and O_2/Ar supersaturations agree, indicating saturated Ar concentrations.

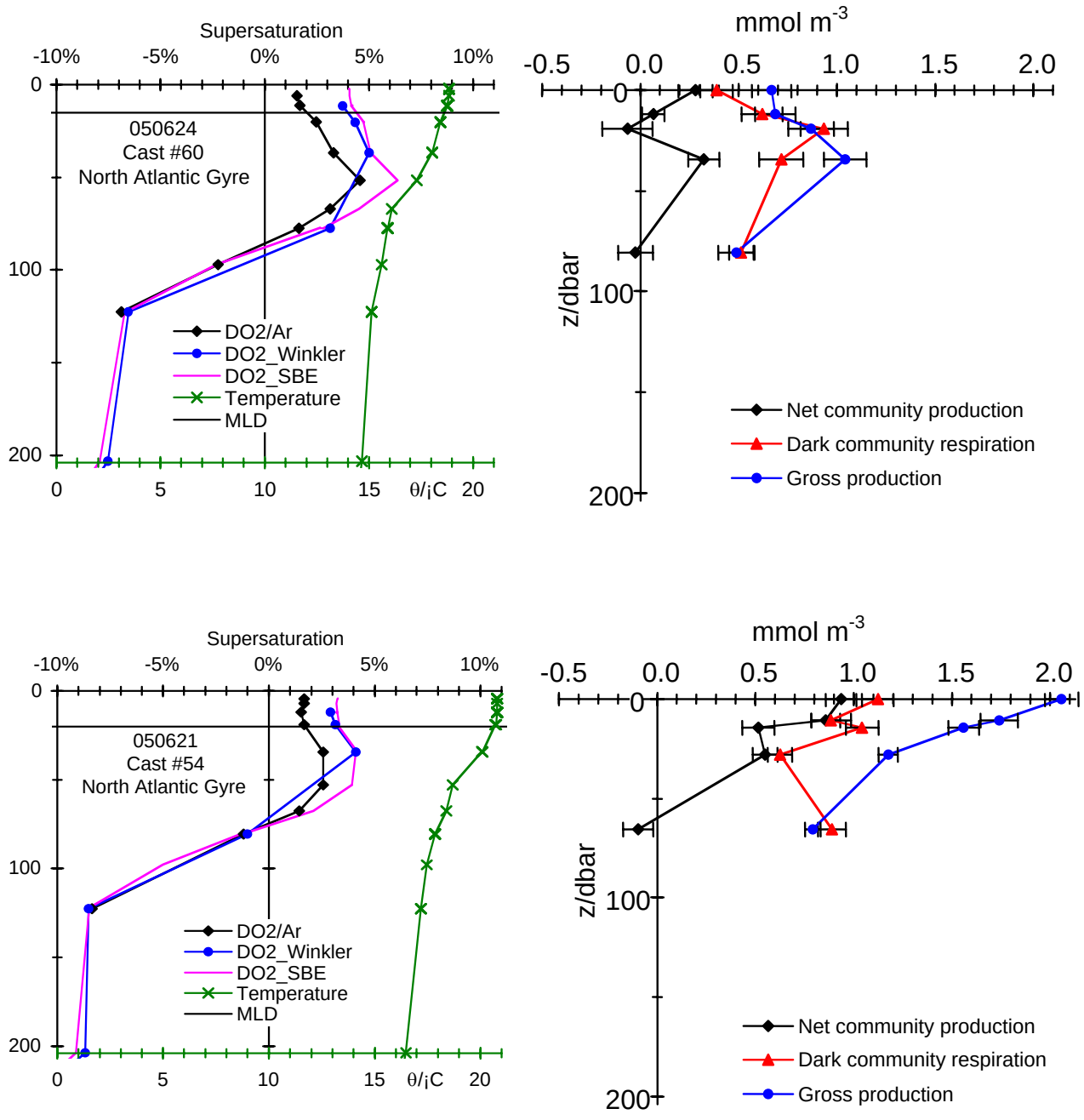


Figure 2. Comparison of biologically-induced oxygen supersaturation (ΔO_2/Ar) and O_2 based productivity measurements from bottle incubations. Relative shape of ΔO_2/Ar values and net community production rates agree well in the thermocline, but show differences in the mixed layer due to disequilibrium effects. Interestingly, NCP is zero at positive ΔO_2/Ar value, possibly due to higher past than the instantaneous production rates. Since ΔO_2/Ar integrates over timescale of physical transport, the instantaneous rates do not have to be in agreement with the ΔO_2/Ar-based value.

References

Craig, H., Hayward, T. 1987. Oxygen supersaturation in the ocean: Biological versus physical contributions. Science, 235, 199-202.

Hendricks, M.B., Bender, M.L. Barnett, B.A. 2004. Net and gross O_2 production in the Southern Ocean from measurements of biological O_2 saturation and its triple isotope composition. Deep Sea Research I 51, 1541-1561.

Kaiser, J., Reuer, M.K., Barnett, B., Bender, M.L. submitted. Marine productivity estimates from continuous oxygen/argon ratio measurements by shipboard membrane inlet mass spectrometry, Geophysical Research Letters.

Kana, T.M., Darkangelo, C., Hunt, M.D., Oldham, J.B., Bennett, G.E., Cornwell, J.C. 1994. Membrane inlet mass spectrometer for rapid high-precision determination of N_2, O_2, and Ar in environmental water samples. Analytical Chemistry 66, 4166-4170.

Luz, B., Barkan, E. 2000. Assessment of oceanic productivity with the triple-isotope composition of dissolved oxygen. Science 288, 2028-2031.

Quay, P.D., Emerson, S., Wilbur, D.O., Stump, C. 1993. The $\delta^{18}O$ of dissolved oxygen in the surface waters of the subarctic Pacific: A tracer of biological productivity. Journal of Geophysical Research 98C, 8447-8458.

Spitzer, W.S., Jenkins, W.J. 1989. Rates of vertical mixing, gas exchange and new production: Estimates from seasonal gas cycles in the upper ocean near Bermuda. Journal of Marine Research 47, 169-196.

Tortell, P.D. 2005. Dissolved gas measurements in oceanic waters made by membrane inlet mass spectrometry. Limnology and Oceanography: Methods, 3, 24-37.

Details of the discrete samples taken from underway system for calibration of O_2/Ar and N_2/Ar ratios as well as $^{17}O/^{16}O$ and $^{18}O/^{16}O$ isotope ratio measurements of dissolved O_2 are given in Appendix 6.

Nitrogen isotope measurements of nitrate and dissolved organic nitrogen (DON)

JAN KAISER[1], DANIEL SIGMAN[1] AND KAREN CASCIOTTI[2]

1Department of Geosciences, Princeton University, Washington Road, Princeton, NJ 08544-1003, USA

[2]Department of Marine Chemistry and Geochemistry, Woods Hole Oceanographic Institution, 360 Woods Hole Rd, Mail Stop 8, Woods Hole, MA 02543, Massachusetts, USA

Rationale

Nitrate (NO_3^-) is the dominant form of bioavailable nitrogen in the ocean. Its nitrogen isotopic composition provides important insights into the relative rates of biological processes (assimilation, remineralisation, dinitrogen fixation, nitrification, denitrification) and transport (Sigman and Casciotti, 2002). The combination with oxygen isotope ratio measurements enhances the versatility of this tool by providing complementary information on the nature of the uptake process (denitrification, assimilation) or its mechanism.

An important pool of the nitrogen isotope budget especially in the oligotrophic gyres is dissolved organic nitrogen (DON). A major part of the newly fixed nitrogen can go into the DON pool, thereby enhancing ambient DON concentrations. Since atmospheric N_2 is isotopically light relative to deep-water nitrate, the isotopic composition of DON provides insights into the relevance of nitrogen fixation for marine productivity.

Methodology

Water samples were taken from selected bottle depths and selected CTD casts (see Appendix 8 for details). About 60 ml of sample each were drawn into clear acid-cleaned Nalgene flasks, tightly capped and frozen at –20ºC. A small headspace was left to allow for expansion of the water upon freezing.

We strove to obtain a comprehensive meridional cross section from the Northern Gyre through the equatorial upwelling to the Northern Gyre and further focused on deeper samples with sufficiently high nitrate concentrations to facilitate $^{15}N/^{14}N$ and $^{18}O/^{16}O$ isotope ratio analysis. However, we also strove to obtain a comprehensive set of samples from the euphotic zone for $^{15}N/^{14}N$ isotope ratio analysis of dissolved organic nitrogen (DON).

Within the next two years, the samples will be analysed for their nitrate $^{15}N/^{14}N$ and $^{18}O/^{16}O$ isotope ratios using the denitrifier method (Casciotti *et al*., 2002; Sigman *et al*., 2001) and possibly their DON $^{15}N/^{14}N$ isotope ratios after oxidation of the total dissolved nitrogen pool (nitrate, nitrite, ammonium and DON) to nitrate using a wet-chemical oxidation method (Knapp *et al*., 2005).

References

Casciotti, K.L., Sigman, D.M., Hastings, M.G., Böhlke, J.K., Hilkert, A. 2002. Measurement of the oxygen isotopic composition of nitrate in seawater and freshwater using the denitrifier method. Analytical Chemistry 74, 4905-4912, doi:10.1021/ac020113w.

Knapp, A.N., Sigman, D.M., Lipschultz, F. 2005. N isotopic composition of dissolved organic nitrogen and nitrate at the Bermuda Atlantic Time-series Study site. Global Biogeochemical Cycles 19, GB1018, doi:10.1029/2004GB002320.

Sigman, D.M., Casciotti, K.L., Andreani, M., Barford, C., Galanter, M., Böhlke, J.K. 2001. A bacterial method for the nitrogen isotopic analysis of nitrate in seawater and freshwater. Analytical Chemistry 73, 4145-4153.

Sigman, D.M., Casciotti, K. 2002. Nitrogen isotopes in the ocean. In: Steele, J.H., Turekian, K.K., Thorpe, S.A. (Ed.). Encyclopedia of Ocean Sciences, Academic Press, London. pp.1884-1894.

Distribution and turnover of Aerobic Anoxygenic Phototrophs along a south-north transect of the Atlantic Ocean

MICHAL KOBLIZEK[1,2]

[1]*Institute of Microbiology, Dept of Autotrophic Microorganisms, Opatovicky Mlyn, 379 81 Trebon, Czech Republic*

[2]*Institute of Physical Biology, University of South Bohemia, Zamek 136, 373 33 Nove Hrady Czech Republic*

Objectives

Recently bacteriochlorophyll *a*-containing bacteria were found to account for a significant fraction of the microbial community in the upper ocean (Kolber *et al.*, 2000; Kolber *et al*., 2001). Since then, the presence of those bacteria in various marine environments was confirmed by many independent studies using genetic analyses (Beja *et al.*, 2002; Oz *et al.*, 2005), HPLC (Goericke, 2002), epifluorescence microscopy (Schwalbach and Fuhrman, 2005) as well as IR fluorometry (Koblizek *et al.*, 2005). These organisms, Aerobic Anoxygenic Phototrophs (AAPs) perform a photoheterotrophic form of metabolism requiring a supply of organic substrates for growth, but being able to derive a significant portion of their energy requirements from light (Koblizek *et al.*, 2003). The ability to utilize light energy appears to offer an ecological advantage serving as an auxiliary source of ATP.

Recently we developed an ultra-sensitive kinetic infra-red fluorometer which makes it possible to record a BChl *a* signal in oceanic water samples without the need of pre-concentration. The instrument was successfully tested during several research cruises in the Baltic Sea, Sargasso Sea and South Pacific Ocean.

The presence of AAPs was reported in several isolated studies from various locations in the Pacific Ocean and from the Baltic Sea. So far, there is no information from the Atlantic. The survey undertaken during the AMT16 cruise should fill this gap and provide much broader information about AAP distribution and dynamics in the marine environment.

Methods

Samples were collected from Niskin bottles and occasionally from the underway system.

The ultra sensitive infra red kinetic fluorometer was assembled using the standard PSI fluorometer control unit (FL200/PS, Photon Systems Instruments Ltd., Brno, Czechia) and custom made optics as described earlier (Koblizek *et al.*, 2005) with the following modifications: 1) The sample chamber was made of white Teflon containing a spherical compartment (60 ml), with an inlet and an outlet for sample injection and removal. 2) The chamber had four ports: two ports were used to introduce excitation light, the other two ports were used to interface with Chl *a* and BChl *a* detectors made of two cooled large area avalanche photodiodes (Advance Photonix, USA). 3) The 10 µs excitation pulses we generated by two flashing units, each populated with four blue Luxeon diodes (LXHL PB09, 470 nm).

To separate the chlorophyll and bacteriochlorophyll signal we used the herbicide DCMU as described earlier (Koblizek *et al.*, 2005). In short: phytoplankton was selectively inhibited, whereas the bacterial reaction centers were unaffected. In the presence of 10^{-5} M DCMU, the part of the signal originating from the phytoplankton rapidly rose, reaching the maximum within about 2 ms. The signal originating from the bacterial reaction centers was not affected, rising slowly and reaching a maximum at about 100 ms, allowing separation of both signals. The instrument was calibrated using the diluted culture of *Roseobacter* strain COL2P where the BChl *a* content was determined spectroscopically in the acetone:methanol 7:2 (vol:vol) pigment extracts. The instrument sensitivity was sufficient to allow processing water samples with an absolute detection limit of 0.1 ng BChl *a* l^{-1} and 1 ng Chl *a* l^{-1} and relative detection limit of about 10^{-3} bacteriochlorophyll to chlorophyll ratio (mol:mol).

The decay of BChl *a* signal during the day-light period was followed during on deck incubations. The experiments were performed with 55% light depth samples collected during the pre-dawn casts. The sample was placed in the 55% light incubator. The samples were regularly taken (every 1-2 hours) and the decay of the BChl *a* signal was followed until dusk. The decay was analysed by curve fitting assuming simple exponential kinetics.

The 77K spectra were measured using a custom built spectrofluorometer based on an Ocean Optics CCD fiber optics spectrophotometer. The phytoplankton sample was collected on Macherey Nagel fibre glass filter GF-5 (5 µm pore size) and frozen in liquid nitrogen. The emission spectrum was collected between 550 and 800 nm. The blank reading was subtracted from each signal.

Samples measured

The BChl *a* content was determined in almost all euphotic zone samples from all the casts performed during the AMT16 cruise.

The BChl *a* turnover was determined during on deck incubations for 55% light depth samples taken from the pre dawn casts #6,13,17,19,21,23,25,28,29,31,33,35,38,40,42,46,48,50,52,58, 60, 62, 64.

77K spectra were recorded for following samples: cast #3 - 6 m, cast #4 - 13 m and 125 m, cast #5, cast #6 -13 m, cast #19 - 20 m, cast #27 - 75 m, cast #30 - 65 m, cast 31 - *Trichodesmium* sample collected on 63 µm mesh, cast #34 - 7 m. A software problem occurred on June 15th which meant that measurements had to be stopped.

Results

BChl *a* content was surveyed by means of kinetic fluorometry. The highest BChl *a* concentration was observed in Benguela current (Station 1) about 20 ng BChl *a* l^{-1} (such high values were previously never observed in the Ocean, the higher values were only registered in the Baltic Sea). In the South Atlantic gyre the content of BChl *a* dropped down to approx 2.5 ng l^{-1} in the mixed layer, with a deep subsurface maximum of about 4 ngl^{-1} frequently associated with oxygen maximum and placed above the Chl *a* maximum. In the equatorial upwelling region the concentration of BChl *a* rose to 5ng l^{-1} in the mixed layer with a distinct deep maximum of 15 ng l^{-1}. The BChl *a* content was gradually declining as we headed north reaching its minimum of about 0.5 ng l^{-1} in the North Atlantic gyre. The distribution of BChl *a* was affected by strong stratification, similarly to the South Atlantic gyre a distinct deep BChl *a* maxima (about 3 pM) were observed at 70-100 m depth. Unlike in the southern gyre the BChl *a* maxima in the northern gyre was typically found between the Chl *a* and oxygen maxima. In the North Atlantic BChl *a* content was rather patchy, ranging in the mixed layer from 0.5 to 6 ng l^{-1}. The BChl *a*/Chl *a* ratio was around 1%. No BChl *a* was registered within the instrument sensitivity below 180 m.

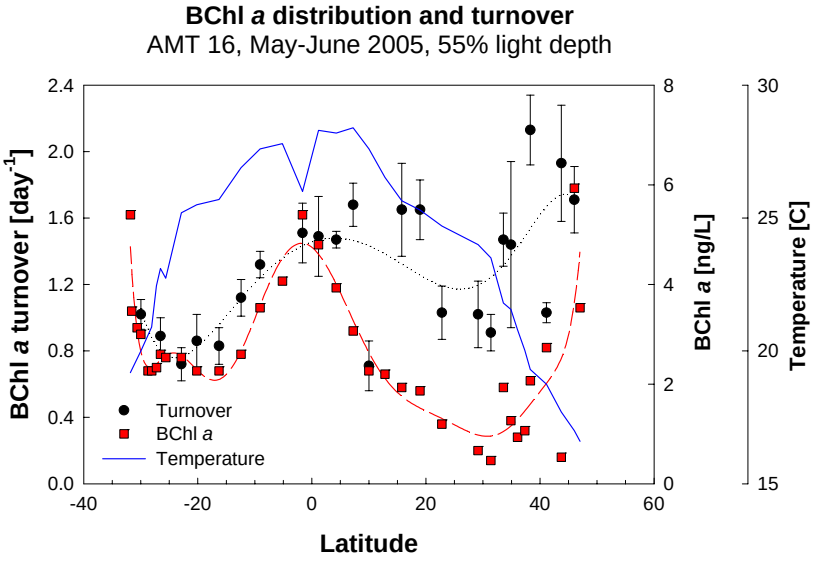


Figure 1. BChl a distribution and turnover determined along at 55% light depth during the AMT16 cruise in May-June 2005.

The distinct difference between the situation in the southern gyre was also observed in BChl *a* to Chl *a* relationship. In the south the BChl *a* linearly risen with the Chl *a* content (Fig. 2) however the linear relationship did not pass through the origin as it intercepts the BChl *a* axes at about 1.8 ng l^{-1}. This fact was reflected also in the BChl *a*/Chl *a* ratio which ranged from about 1% to almost 5% in the center of the gyre. This is in good agreement with original estimation made by Kolber *et al* (2000). In the equatorial upwelling and northern gyre there is a fairly linear relationship between BChl *a* and Chl *a* content as the BChl *a*/Chl *a* ratio display and almost constant value of about 2%. This difference might be due to the different limitation of bacterioplankton growth in the south and in the north. In the north the linear relationship passing through the origin might signal that the both phytoplankton and bacterioplankton are limited by the same nutrient most likely phosphorus. In the south the phytoplankton and bacterioplankton might be limited by different nutrients most likely phosphorus for phytoplankton and carbon for bacterioplankton. The carbon limitation of bacterioplankton in the southern gyre hypothesis is also supported by relatively much higher BChl *a* content that was observed in the north. AAPs have an advantage of more economical carbon metabolism over heterotrophic bacteria (Koblizek, unpublished) whereas in metabolism of phosphorus they have no advantage.

The BChl *a* decay measurements were performed almost along the whole track of AMT16 (Fig. 4) except for a few stations of Leg 1. Decay rates of between 0.7 to 1.0 day^{-1} were obtained in the southern gyre. In the equatorial upwelling region the rates rose to 1.3-1.6 day^{-1}. Later the rates dropped in the northern gyre back to about 0.9-1.0 day^{-1}. Finally the rates rose again in the more productive north Atlantic region to about 1.4-2.1 day^{-1}. The observed pattern did not show any correlation either with total irradiance input or temperature, however it showed a common trend with the primary production data which indicates that the numbers obtained reflect the turnover times of the AAPs community as suggested earlier (Koblizek *et al.*, 2005).

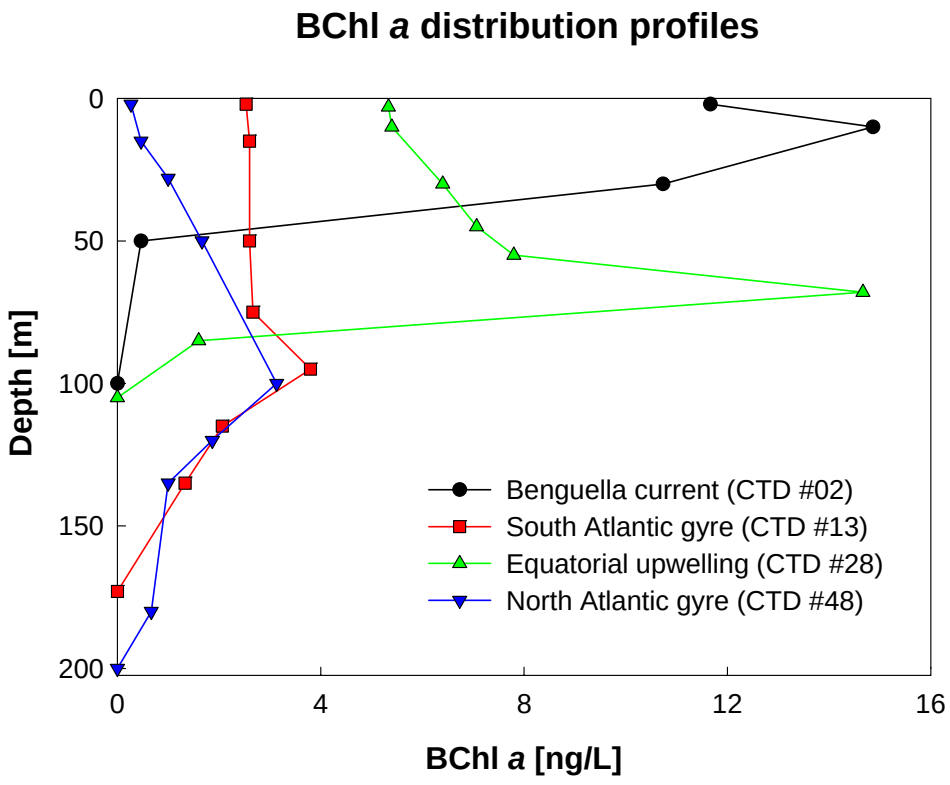


Figure 2. Depth profiles of BChl a distribution. In the gyres the Chl a maxima were placed about 20 m bellow the BChl a maxima, in upwelling regions both maxima collided.

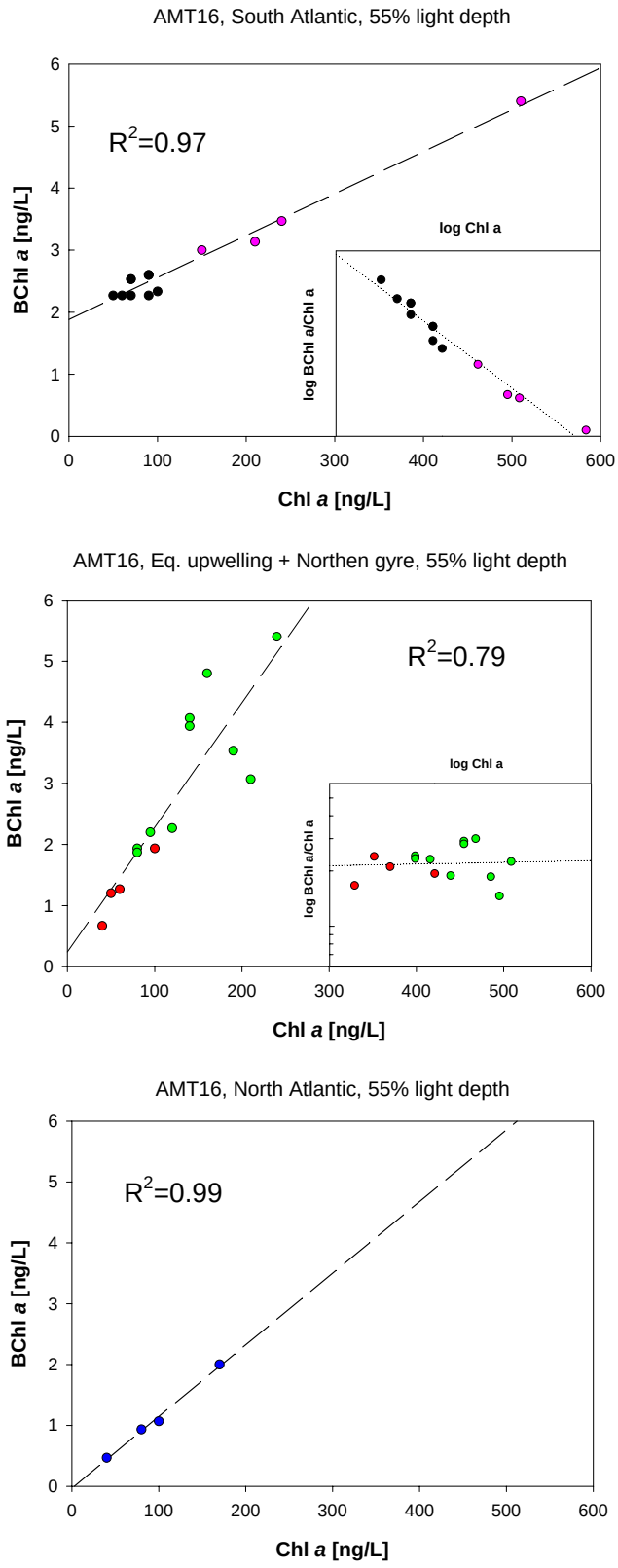


Figure 3. Relationship between Chl a and BChl a content in 55% optical depth (which is equal to the mixed layer values) distribution in the South Atlantic (excluding upwelling regions), equatorial + northern gyre and the North Atlantic. The colour of the symbols code for the marine provinces: Black - southern gyre, pink - transition region between South Africa and the southern gyre, green - equatorial region, red - northern gyre, blue - North Atlantic.

.

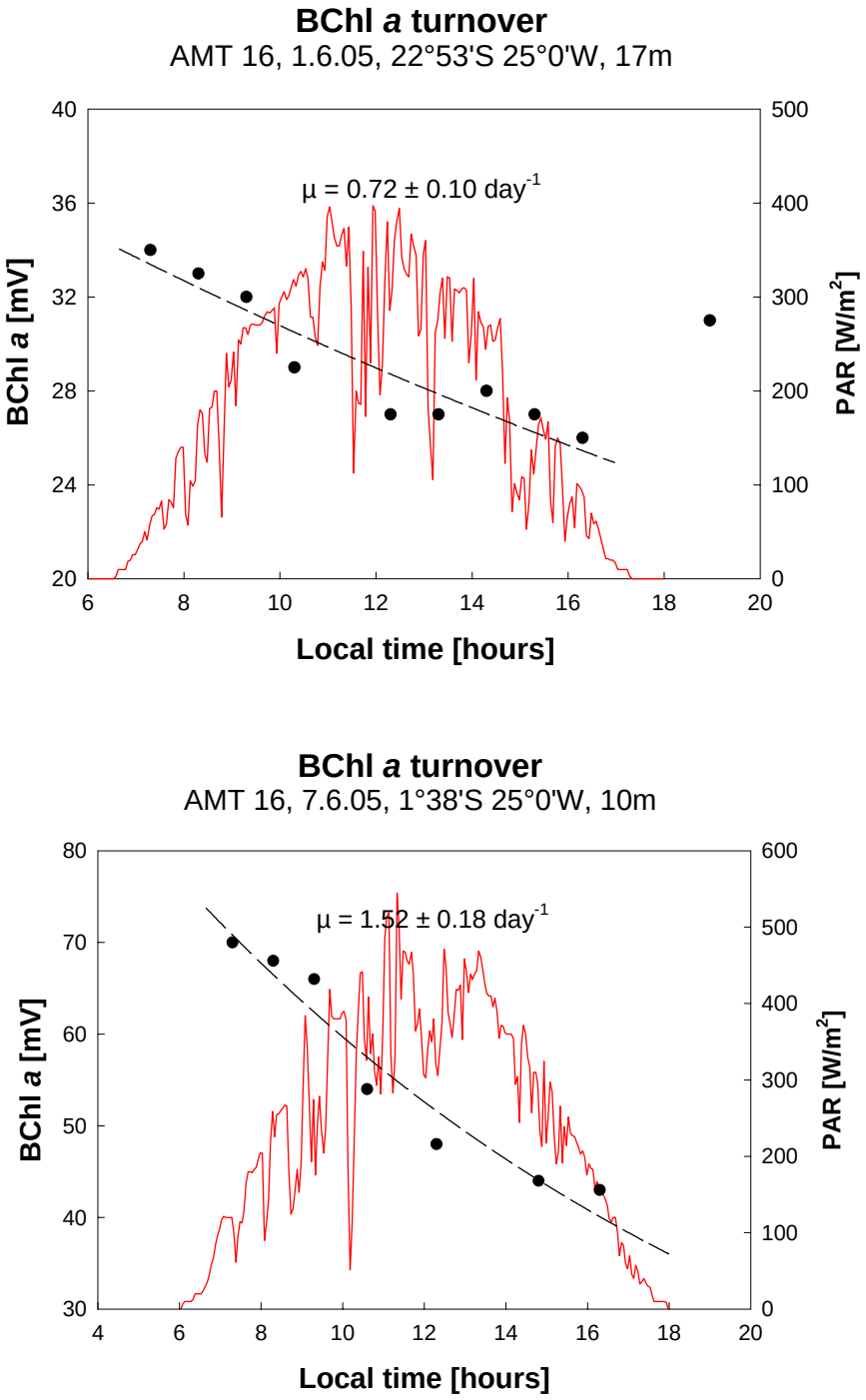


Figure 4. An example of two BChl a decay measurements performed in the south Atlantic gyre (top) and the Equatorial upwelling region (bottom).

References

Béjà, O., Suzuki, M.T., Heidelberg, J.F., Nelson, W.C., Preston, C.M., Hamada, T., Eisen, J.A., Fraser, C.M., DeLong, E.F. 2002. Unsuspected diversity among marine aerobic anoxygenic phototrophs. Nature 415, 630-633

Goericke, R. 2002. Bacteriochlorophyll *a* in the ocean: Is anoxygenic bacterial photosynthesis important? Limnology and Oceanography 47, 290-295.

Koblížek, M., Béjà, O., Bidigare, R.R., Christensen, S., Benetiz-Nelson, B., Vetriani, C., Kolber, M.K., Falkowski, P.G., Kolber, Z.S. 2003. Isolation and characterization of *Erythrobacter* sp. strains from the upper ocean. Archiv fur Mikrobiologie 180, 327-338.

Koblížek, M., Stoń-Egiert, J., Sagan, S., Z. Kolber. 2005. Diel changes in bacteriochlorophyll *a* concentration suggest rapid bacterioplankton cycling in the Baltic Sea. FEMS Microbiology Ecology 51, 353-361

Oz, A., Sabehi, G., Koblížek, M., Massana, R., O. Béjà. 2005. Roseobacter-like bacteria in Red and Mediterranean Sea aerobic anoxygenic photosynthetic populations. Applied and Environmental Microbiology 71, 344-353

Kolber, Z.S., Van Dover, C.L., Niederman, R.A., Falkowski, P.G. 2000. Bacterial photosynthesis in surface waters of the open ocean. Nature 407, 177-179.

Kolber, Z.S., Plumley, F.G., Lang, A.S., Beatty, J.T., Blankenship, R.E., VanDover, C.L., Vetriani, C., Koblizek, M., Rathgeber, C., Falkowski, P.G. 2001. Contribution of aerobic photoheterotrophic bacteria to the carbon cycle in the ocean. Science 292, 2492-2495.

Schwalbach, M.S., Fuhrman, J.A. 2005. Wide-ranging abundances of aerobic anoxygenic phototrophic bacteria in the world ocean revealed by epifluorescence microscopy and quantitative PCR. Limnology and Oceanography 50(2), 620-628.

Microbial community composition and dynamics in different planktonic communities of the Atlantic Ocean

MARTHA SCHATTENHOFER
Max Planck Institute for Marine Microbiology Molecular Ecology, Flow Cytometry, Celsiusstrasse 1, D-28359 Bremen, Germany

Objectives

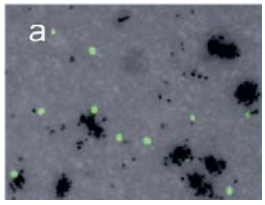
- Determine the vertical distribution, abundance and community structure of picoplankton in the top 300 m by flow cytometry using several vital and fixed cell staining techniques.
- Collect samples for analyses of bacterioplankton community composition using molecular approaches including fluorescence *in situ* hybridization (FISH).
- Measure bacterial production at selected stations along the track.
- Measure group-specific uptake of amino acids.
- Measure bacterial growth using a BrdU-Incorporation technique.

Methods

Fluorescence *in situ* hybridization (FISH): Fresh seawater samples were collected from a Seabird CTD system containing 24 x 20 l Niskin bottles from predawn and late morning (11:00 local time) CTD casts for post-cruise molecular identification of microorganisms using fluorescence *in situ* hybridization (FISH). After fixation with particle-free formaldehyde solution (final concentration, 1% v/v) for 2 hours at room temperature the samples were filtered onto polycarbonate filters (type GTTP; pore size, 0.2 µm; diameter, 47 mm; Millipore, Eschborn, Germany).

Further analysis by fluorescence *in situ* hybridization with horseradish peroxidase-labelled oligonucleotide probes and catalysed reporter deposition (CARD-FISH) to determine the percentages of different microbial taxa will be carried out at the MPI in Bremen, Germany.

Microautoradiography fluorescence *in situ* hybridization (MARFISH): At six stations along the cruise track (see Table 1) samples (30 ml) were taken from depths 55% and 1% and incubated with cold substrates (leucine, methionine, valine, glucose and ammonium) at a concentration of 10 nM for 2 hours in the dark at *in situ* temperature. Radiolabelled substrates (L-[4,5-^{3}H]leucine and L-[^{3}H]methionine) were added (final concentration of 2 nM) and samples again incubated in the dark at *in situ* temperature for 4 hours. After fixation with formaldehyde solution (final concentration, 1% v/v) samples were filtered through polycarbonate filters (type GTTP; pore size, 0.2 µm; diameter, 25 mm; Millipore, Eschborn, Germany).



Photomicrographs of hybridized bacteria after MAR and CARDFISH Probe ALT1413 (*Alteromonas* spp.)

Microautoradiography (MAR) is an approach to track the uptake of radiolabelled tracers in single microbial cells. In order to assign physiological functions to particular bacterioplankton groups, MAR can be combined with single-cell identification by fluorescence *in situ* hybridization (FISH) with rRNA-targeted oligonucleotide probes to measure activity in open-ocean microbes. The sample preparation for CARD-FISH and MAR will be carried out at the MPI in Bremen.

In order to detect group-specific responses, parallel short (0.5 hours) and long-term (4 hours) incorporation experiments with L-[4,5-^{3}H]leucine were carried out without preincubations. Samples (30 ml) were fixed with formaldehyde solution (final concentration, 1% v/v) and filtered onto polycarbonate filters (see above).

Bromodeoxyuridine (BrdU)-Incorporation: Pulse-labelling with bromodeoxyuridine in combination with FISH was applied to quantify the percentage of proliferating cells along the AMT16 transect.

At every predawn cast samples were taken from 55% and 1% depth and supplemented with 5-bromo-2`-deoxy-uridine (BrdU) [20 µM] and thymidine [33 nM] and incubated for 2 hours in the dark at *in situ* temperature. After the incubations samples were fixed with particle-free formaldehyde solution (final concentration, 1% v/v) for 19 hours at 4°C. Fixed samples were filtered onto white polycarbonate membrane filters (type GTTP; pore size, 0.2 µm; diameter, 47 mm; Millipore, Eschborn, Germany), washed with Milli-Q and stored at -20°C until further processing in Bremen.

Additional to the experiments described above, experiments were carried out in collaboration with Dr. Mike Zubkov and Jane Heywood from the NOC and Glen Tarran (see individual cruise report).

Bacterial production: At nine stations along the cruise track (see Table 1) water samples used for bulk rate measurements were collected from two different depths (55% and 1%). Two differently labelled amino acids, L-[4,5-^{3}H]leucine and [^{35}S]methionine were used as precursors and added at 5 nM and ~ 1 nM respectively to determine the approximate *in situ* rates of amino acid turnover. The samples (1.6 ml) were inoculated with L-[4,5-^{3}H]leucine and [^{35}S]methionine and incubated in the dark at *in situ* temperatures. Samples were fixed with 1% paraformaldehyde (PFA) at 0.5, 1, 1.5 hours. The sample particulate materials were harvested onto 0.2 µm pore-size nylon filters and the radioactivity retained on the filters was measured as disintegrations per minute with a liquid scintillation counter. Data will be interpreted back in the laboratory.

Group-specific amino acid uptake experiments: Four replicated samples (1.6 ml) from two depths (55%, 1%) were incubated with L-[4,5-^{3}H]leucine and [^{35}S]methionine or no precursor at *in situ* temperatures in the dark, fixed with PFA after 2 hours, flash frozen with liquid nitrogen and stored at -60°C. These samples will be thawed in Plymouth and individual bacterial groups sorted by flow cytometry, cells harvested onto filters and their radioactivity measured with a liquid scintillation counter. This will provide information on cellular methionine and leucine uptake rates of the dominant bacterial groups as defined by flow cytometry.

Table 1. CTD casts sampled for bacteria community structure and abundance

Date	Time (GMT)	CTD #	Lat	Long	Depths sampled
21 May	02:43	1	31°58.05'S	16°58.01'E	2 30 50 85 175 250
21 May	09:16	2	31°00.40'S	16°29.55'E	2 30 50 100 150 250
24 May	03:40	3	31°49.96'S	10°30.01'E	2 65 96 144 200 300
24 May	10:13	4	31°34.74'S	09°19.55'E	2 42 100 150 225 300
25 May	10:01	5	30°38.07'S	04°13.28'E	2 50 80 125 225 300
26 May	03:35	6	29°57.92'S	00°42.01'E	2 70 95 110 240 300
27 May	11:05	7	28°44.60'S	05°45.30'W	2 80 100 125 225 300
28 May	04:34	8	28°04.23'S	09°14.97'W	2 105 115 130 200 300
28 May	12:24	9	27°49.76'S	10°30.96'W	2 95 125 150 225 300
29 May	07:58	11	27°13.81'S	13°26.56'W	2 120 130 140 220
29 May	11:04	12	27°10.03'S	13°49.65'W	2 110 125 150 225 300
30 May	04:40	13	26°31.61'S	17°13.74'W	15 95 115 135 200 300 600 1000
30 May	12:03	14	26°17.04'S	18°27.70'W	17 110 130 150 225 300
31 May	05:41	15	25°06.29'S	21°55.97'W	14 85 105 125 220 300
31 May	12:07	16	25°23.07'S	23°04.66'W	16 100 120 140 200 300
1 June	05:37	17	22°52.82'S	24°59.98'W	17 100 130 150 245 300
1 June	12:09	18	22°27.28'S	24°59.97'W	17 57 130 150 225 300 500 1000
2 June	04:37	19	20°11.93'S	24°59.83'W	20 125 150 225 275 500 1000
2 June	11:59	20	19°14.24'S	25°00.00'W	18 130 140 150 225 300
3 June	05:42	21	16°16.71'S	24°59.92'W	20 125 150 165 225 300

Date	Time (GMT)	CTD #	Lat	Long	Depths sampled
3 June	12:04	22	15°24.55'S	25°00.06'W	18 130 140 150 225 300
4 June	05:37	23	12°24.73'S	24°59.71'W	17 115 132 145 200 300
4 June	12:03	24	11°57.03'S	25°00.41'W	16 110 120 130 225 300
5 June	04:35	25	09°04.76'S	24°59.81'W	14 95 105 120 200 300 500 1000
6 June	05:21	26	05°09.84'S	25°00.11'W	12 78 88 95 180 300
6 June	12:02	27	04°15.07'S	24°59.88'W	10 50 75 80 225 300
7 June	05:03	28	01°37.71'S	24°59.59'W	10 55 68 85 200 300
8 June	04:13	29	01°10.38'N	25°34.00'W	6 40 48 65 150 300 500 1000
8 June	11:58	30	02°03.50'N	25°58.97'W	9 45 65 90 225 300
9 June	05:03	31	04°16.33'N	27°01.46'W	10 65 80 100 150 300
9 June	12:11	32	05°09.15'N	27°26.79'W	10 65 80 120 200 300 500 850
10 June	05:06	33	07°14.99'N	28°27.19'W	7 45 51 70 180 300
10 June	12:07	34	07°41.75'N	28°40.67'W	7 45 50 55 225 300
11 June	04:06	35	10°00.42'N	29°47.59'W	9 55 68 95 200 350 500
12 June	12:02	37	13°11.71'N	31°20.59'W	11 75 82 87 225 300
13 June	04:43	38	15°45.74'N	32°35.96'W	13 80 100 115 200 300
13 June	12:02	39	16°19.47'N	32°53.18'W	13 90 100 110 225 300
14 June	04:04	40	18°57.91'N	34°12.39'W	20 120 140 160 225 300 600 1000
14 June	12:00	41	20°05.00'N	34°46.34'W	16 100 120 135 225 300
15 June	04:33	42	22°48.31'N	36°09.82'W	14 80 100 120 200 300
15 June	12:00	43	23°21.58'N	36°27.43'W	17 120 130 140 225 300 500 850 1500 2250 3500 4500 5900
16 June	13:33	45	26°50.46'N	38°17.77'W	19 140 145 150 225 300
17 June	04:40	46	29°09.43'N	39°32.53'W	18 110 135 145 202 285 600 1000
17 June	12:18	47	29°27.27'N	39°48.85'W	17 125 130 150 225 300
18 June	05:03	48	31°22.99'N	42°08.65'W	15 100 120 135 225 300
18 June	11:56	49	31°43.41'N	42°38.98'W	11 80 85 100 225 300
19 June	05:03	50	33°34.61'N	45°32.31'W	10 60 74 95 200 300
19 June	12:08	51	33°55.55'N	46°04.53'W	9 50 65 70 225 300
20 June	05:00	52	34°54.18'N	42°33.57'W	12 75 90 115 200 350 500 1000
20 June	12:06	53	35°05.92'N	41°50.69'W	12 80 90 110 225 300
21 June	04:36	54	36°04.11'N	38°20.54'W	10 65 78 95 200 300
21 June	12:01	55	36°27.59'N	36°55.18'W	9 60 67 80 225 300
22 June	05:04	56	37°20.94'N	33°39.62'W	9 52 63 82 200 300
22 June	11:59	57	37°34.33'N	32°50.23'W	8 55 62 70 225 300
23 June	03:02	58	38°18.32'N	30°03.83'W	7 36 49 65 150 300
23 June	12:00	59	39°15.77'N	28°49.34'W	9 60 68 75 225 300
24 June	03:10	60	41°08.34'N	26°22.60'W	10 65 80 95 200 400 800 1000
24 June	12:05	61	42°06.65'N	25°04.18'W	7 47 52 57 225 300
25 June	02:35	62	43°44.12'N	22°52.39'W	7 40 50 65 180 300
25 June	12:00	63	44°22.10'N	21°59.81'W	6 35 42 47 225 300
26 June	5:50	64	46°02.05'N	19°40.22'W	5 28 38 50 120 300
26 June	11:05	65	46°21.95'N	18°51.38'W	5 30 40 55 225 300

Sample depths highlighted in grey were samples for BrdU-incorporation.
Left hand value on any row is the 55% light level and the right hand value is the 1% light level.

Sample depths highlighted with a border were samples for MARFISH, bacterial production and group-specific amino acid uptake experiments.
Left hand value on any row is the 55% light level and the right hand value is the 1% light level.

Sample depths highlighted with a border were samples for additional group-specific amino acid uptake experiments.
Left hand value on any row is the 55% light level and the right hand value is the 1% light level.

Analysis of hydrogen peroxide

TONY BALE[1], ANGELA MILNE[2], SIMON USSHER[2] AND PAUL WORSFOLD[2]
[1]*Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth, PL1 3DH, UK*
[2]*University of Plymouth, Drakes Circus, Plymouth, PL4 8AA, UK*

Introduction

Hydrogen peroxide (H_2O_2) is thought to play a key role in redox processes in surface marine waters and is likely to influence the speciation of dissolved metals and participate in oxidation reactions involving labile and residual organic compounds. Hydrogen peroxide is predominantly formed by photochemical action via free radical intermediates on organic chromophores (coloured dissolved organic material, CDOM). Wet and dry deposition can be a significant transient source to the ocean surface (Cooper *et al*., 1987; Weller *et al*., 1993). However, biotic (enzymatic) breakdown of hydrogen peroxide is known to occur (Cooper *et al*., 1990) so that hydrogen peroxide concentrations can vary rapidly with solar irradiance and, possibly, with the species 'composition' and abundance of the phytoplankton population.

During AMT16 we have analysed H_2O_2 in the range 0-180 nM using a flow injection analytical system (Price *et al*., 1998) which allows rapid (minutes between collection and analysis) and sensitive (5 +/-1 nM) detection.

Methodology

Analytical system: The flow-injection analytical (FIA) system used a peristaltic pump (Gilson Minipulse 2) to transport a Luminol reagent to a Thorn EMI photomultiplier tube (PMT) operating at a potential of 1.2 kV. A second pump channel transferred cobalt nitrate (catalyst) to blend with the Luminol stream at a 'T' junction immediately prior to the coiled glass flow cell situated in front of the PMT tube. A third pump channel transported sample which was introduced to the Luminol stream using a six-port injection valve with a 100 µL sample loop. Tubing runs between the valve and flow cell were minimised. The chemiluminescent (CL) emission (L_{max} = 440 nm) resulting from the oxidation of Luminol was directly proportional to the concentration of H_2O_2 and signals from the PMT were recorded on a chart recorder at 0.2 or 0.5 V Full Scale Deflection (FSD).

Reagents: Luminol, cobalt nitrate hexahydrate and hydrogen peroxide (30%) were analytical grade. Stock solutions of luminol ($1x10^{-3}$ M) and cobalt nitrate ($1x10^{-2}$ M) were prepared in 0.1 m sodium carbonate buffer. Working reagents (luminol: 3×10^{-5} M; cobalt: $5x\ 10^{-4}$ M) were prepared daily or every two days, by serial dilution in 1 litre volumes. 10.61g of sodium carbonate was added to both reagents to buffer the pH to >10. The luminol was prepared 24 hours in advance to ensure maximum CL reactivity.

Standards: calibration standards were made by serial dilution of analytical grade, 30%, H_2O_2. A 10 mM stock standard was made up weekly by diluting 111 µl of 30% H_2O_2 in 100 ml of Milli-Q, UHP water. A 50 µM 'daily stock' was made by diluting 500 µl of the working standard in 100 ml of UHP water. Working standards were made by diluting the 'daily stock' in sea water from below 300 m (DSW) to give concentrations in the range: 20-100 nM H_2O_2. Deep sea water (DSW) collected from the previous (dawn) cast and kept in the dark and at 4°C for the production of standards. The DSW was taken to have a negligible peroxide concentration; this assumption was tested by the addition of 500 units ml^{-1} of catalase enzyme (Sigma-Aldrich Co) which did not reduce the apparent concentration of peroxide in DSW (though it did reduce the sensitivity of the analyser for the next couple hours). Because the response of the analytical system varied over a period of time (1-2 hours), samples were run in pairs with a standard interspersed between them. Standards always gave a linear response in the range 0-120 nM so, typically, only two standards were employed with a series of samples. Cross-checking each new batch of stock standard showed no evidence of deterioration over 7-8 days.

Sampling: Water samples were collected from the noon (trace metal clean) CTD cast in 250 ml, dark glass, medicine bottles and analysed within 1 hour, though the surface samples were generally analysed within 10 minutes of collection. The cast and bottle details are given in the Table 1. In addition, over two, 24 hour periods, water samples were collected from the trace metal-clean (underway) pumped supply to the clean container to examine diel changes in surface peroxide concentrations in conjunction with analyses of Fe(II) (Simon Ussher). All H_2O_2 measurements were made on unfiltered samples.

31 profiles were measured from the noon cast in parallel with the dissolved Fe(II) measurements by Simon Ussher. Samples were always taken from the five iron-sampling Go-Flow bottles. A further four samples were taken from the remaining Go-Flow bottles to increase resolution near the surface. In addition, a bucket sample was taken at about the same time as the CTD was coming on board.

Results

All the profiles measured show high values of H_2O_2 near surface and levels which reduced to below detection at depths greater than 200 m; examples of profiles are given in Figure 1. The level of peroxide in the surface bucket sample was sometimes higher than the 2 m Go-Flow bottle concentration and sometimes lower. There is no apparent reason for this but it may be speculated that variation in the degree of aeration associated with bucket sampling, or extreme patchiness, may account for this anomaly. It was also observed that the first few replicate analyses of surface samples with high peroxide concentrations showed a rapid, almost first-order, loss of peroxide. Quoted values are for the concentrations reached at quasi-stable levels. Back-calculation, based on time between sampling and analyses might enable a projected ‘upper’ value to be calculated. Standards made up in water from 300 m or below were usually stable over the period of the analyses (typically one hour) and replicate standards were always consistent. Where different Go-Flow bottles from the same depth were sampled, the analyses were generally in good agreement. The sample from the ‘iron’ Go-Flow often had marginally higher (4-5%) peroxide than the concentration sampled from the same depth from the rosette into dark glass bottles.

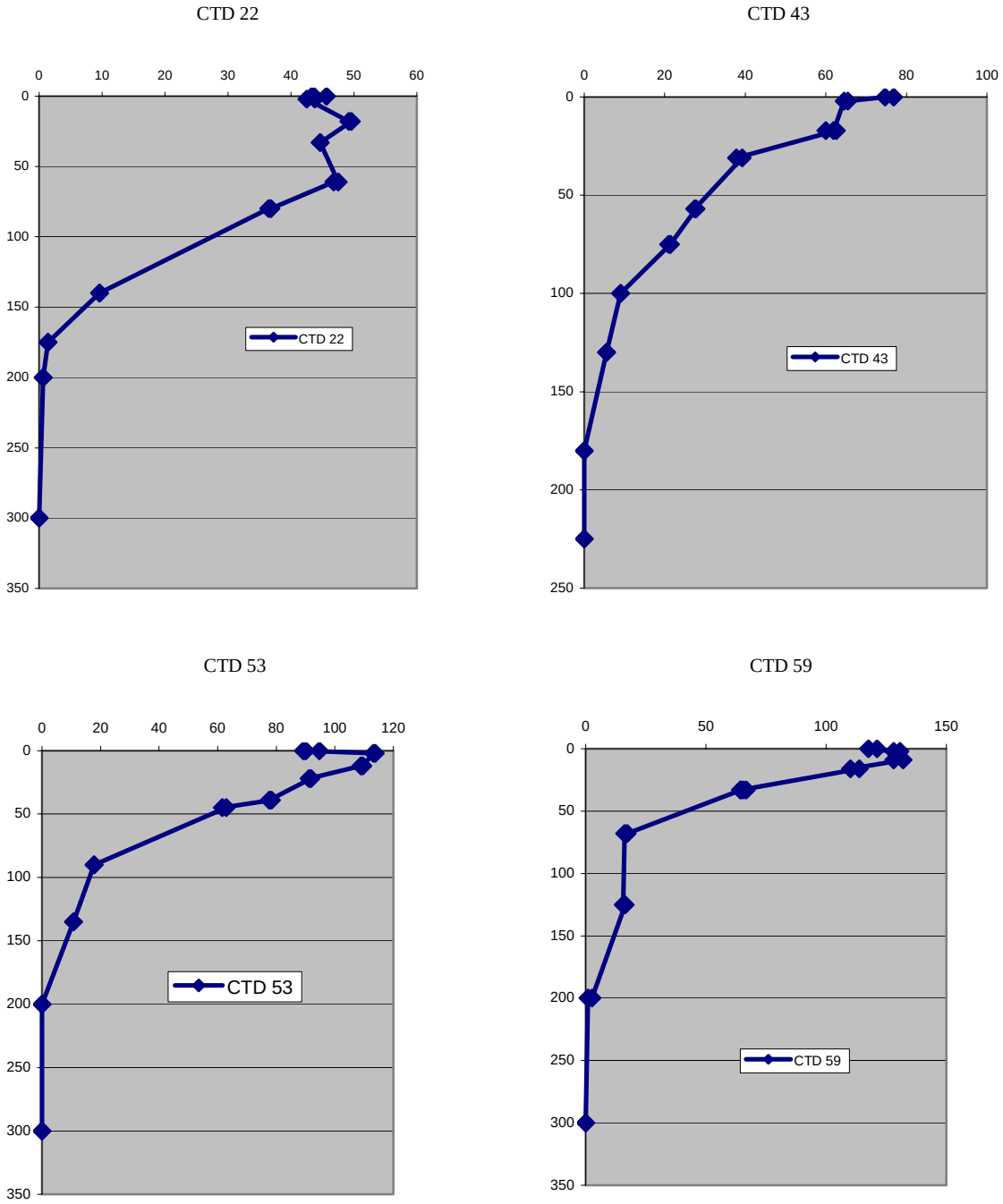


Figure 1. A selection of depth profiles for hydrogen peroxide (concentrations in nM) showing examples where surface peroxide concentrations are uniform through the upper 60 m (CTD 22), where the surface (bucket) sample is significantly higher than the 2 and 12 m rosette samples (CTD 43), and where the surface (bucket) sample is lower than the depths immediately below. Each sample was generally analysed in at least duplicate and all replicates are shown on the plots above.

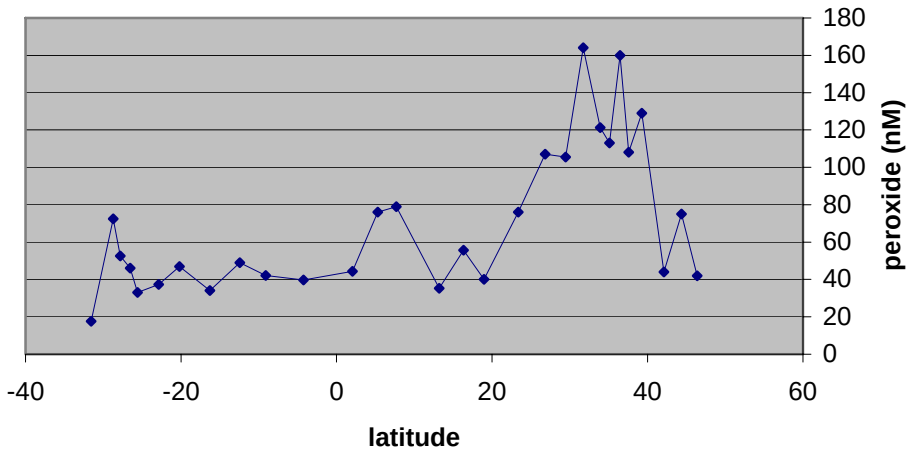


Figure 2. Latitudinal distribution of hydrogen peroxide in the surface waters.

The latitudinal distribution of peroxide in the surface waters (Fig. 2) shows a peak around the northern tropic where solar energy would be at a maximum. However, the 'picture' is complicated by variable cloud cover and sea state which both appeared to reduce the surface concentration, presumably through reduction of solar energy and increased mixing of surface water, respectively. These factors have not been examined quantitatively as yet but with PAR, wind direction/strength and wave height data available, this can be addressed in due course.

There is no obvious indication of a biological factor influencing the distribution of peroxide at first glance; for example, there was no increase (or decrease) in peroxide concentration coincident with the deep chlorophyll maximum. However, it could be that biological (peroxidase) activity may be most 'active' in the very surface water (where phytoplankton are subject to the most extreme solar radiation) and this might account for the apparent rapid reduction in peroxide concentrations in the surface samples during analysis.

Experiments need to be designed to examine the relative contribution of photochemical production versus chemical loss through oxidation of reduced species; and the effect of biological input and removal. Filtration of samples to remove phytoplankton combined with incubation experiments may help to elucidate this. However, preliminary experiments need to be undertaken to assess the impact of filtration on the stability of peroxide.

References

Cooper, W.J., Zepp, R.G. 1990. Hydrogen peroxide decay in waters with suspended soils – evidence for biologically mediated processes. Canadian Journal of Fisheries and Aquatic Sciences 47(5), 888-893.

Cooper, W.J., Saltzman, E.S., Zik, A.R.G. 1987. The contribution of rainwater to variability in surface hydrogen peroxide. Journal of Geophysical Research 92(C3), 2970-2980.

Price, D., Mantoura, R.F.C., Worsfold, P.J. 1998. Shipboard determination of hydrogen peroxide in the western Mediterranean sea using flow injection with chemiluminescence detection. Analytica Chimica Acta 377(2-3), 145-155.

Weller, R., Schrems, O. 1993. H_2O_2 in the marine troposphere and seawater of the Atlantic Ocean (48°N-63°S). Geophysical Research Letters 20(2), 125-128.

Sample collection for dissolved inorganic carbon analysis

TRISH FRICKERS
Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth, PL1 3DH

Procedure

Discrete surface seawater samples were collected at both the pre-dawn and 11:00 CTD stations as listed below. Non-toxic seawater samples were collected in clean borosilicate glass containers via a flexible silicon tube from the supply in the deck laboratory. The samples were poisoned with saturated mercuric chloride and sealed with a ground glass stopper held firmly in place by rubber bands and tie grips. The samples were stored in cool, dark conditions.

The date, time, station number, latitude and longitude, bottle numbers were logged.

Date	Time GMT	Latitude	Longitude	Station	Bottle a	Bottle b
24.05.05	03:34	31°49.98'S	010°30.01'E	3	1	429
25.05.05	10:47	30°38.07'S	004°13.28'E	5	2	508
26.05.05	03:49	29°57.92'S	000°42.01'E	6	3	430
27.05.05	10:48	28°44.60'S	005°45.30'W	7	4	504
28.05.05	04:42	28°04.23'S	009°15.06'W	8	5	505
28.05.05	13:09	27°49.7'S	010°31.43'W	9	6	506
29.05.05	08:30	27°13.81'S	013°26.56'W	10	7	435
29.05.05	11:17	27°10.03'S	013°49.65'W	11	8	502
30.05.05	05:31	26°31.72'S	017°13.65'W	12	9	436
30.05.05	12:06	26°17.04'S	018°27.70'W	13	10	437
31.05.05	05:30	25°36.29'S	021°55.97'W	14	11	438
31.05.05	12:20	25°23.05'S	023°04.76'W	15	12	439
01.06.05	05:30	22°52.82'S	024°59.98'W	16	13	440
01.06.05	14:14	22°27.41'S	024°59.29'W	17	14	441
02.06.05	05:47	20°11.06'S	024°59.75'W	18	15	442
02.06.05	12:13	19°14.31'S	024°59.97'W	19	16	516
03.06.05	05:33	16°16.71'S	024°59.92'W	20	17	517
03.06.05	12:14	15°24.59'S	025°00.59'W	21	18	510
04.06.05	05:47	12°24.64'S	024°59.76'W	22	19	519
04.06.05	12:22	11°57.10'S	025°00.45'W	23	20	520
05.06.05	04:39	09°04.76'S	024°59.82'W	24	21	512
06.06.05	05:15	05°09.84'S	025°00.11'W	26	22	521
06.06.05	11:54	04°15.07'S	024°59.88'W	27	23	522
07.06.05	05:12	01°37.86'S	024°59.60'W	28	24	523
08.06.05	04:30	01°10.40'N	025°34.10'W	29	25	514
08.06.06	12:21	02°03.45'N	025°59.20'W	30	26	926
09.06.05	05:00	04°16.33'N	027°01.58'W	31	27	940
09.06.05	12:10	05°09.15'N	027°26.79'W	32	28	936
10.06.05	05:00	07°14.99'N	028°27.19'W	33	29	941
10.06.05	12:00	07°41.75'N	028°40.67'W	34	30	929
11.06.05	04:00	10°00.42'N	029°47.59'W	35	31	927
12.06.05	12:02	13°11.71'N	031°20.59'W	37	32	932
13.06.05	04:42	15°45.74'N	032°35.96'W	38	33	8
13.06.05	12:00	16°19.47'N	032°53.18'W	39	34	947
14.06.05	04:12	18°51.91'N	034°12.89'W	40	35	927
14.06.05	12:00	20°05.00'N	034°46.34'W	41	36	933

Date	Time GMT	Latitude	Longitude	Station	Bottle a	Bottle b
15.06.05	05:10	22°48.12’N	036°09.58’W	42	37	934
15.06.06	12:00	23°21.58’N	036°27.43’W	43	38	930
16.06.05	04:59	25°40.52’N	037°40.09’W	44	39	935
16.06.06	13:30	26°50.46’N	038°17.77’W	45	40	943
17.06.05	04:40	29°09.43’N	039°32.53’W	46	41	948
18.06.05	05:05	31°22.99’N	042°08.65’W	48	42	939
19.06.05	05:10	33°34.52’N	045°32.31’W	50	43	931
19.06.05	12:10	33°55.55’N	046°04.53’W	51	44	942
20.06.05	05:00	34°54.17’N	042°33.57’W	52	45	944
21.06.05	04:40	36°04.11’N	038°20.54’W	54	46	945
22.06.05	04:10	37°20.94’N	033°39.62’W	56	47	946
22.06.05	04:10	37°20.94’N	033°39.62’W	56	48	949
22.06.05	04:10	37°20.94’N	033°39.62’W	56	49	950
24.06.05	03:12	41°08.34’N	026°22.61’W	60	50	298
24.06.05	12:10	42°06.65’N	025°04.18’W	61	51	3509
25.06.05	02:40	43°44.11’N	022°52.40’W	62	52	3504
26.06.05	04:43	46°01.89’N	019°40.28’W	64	53	3503
26.06.05	11:22	46°22.05’N	018°51.48’W	65	54	3502
27.06.05	04:10	47°02.03’N	015°15.30’W	66	55	3501
27.06.05	11:10	47°16.57’N	013°58.09’W	67	56	3510

pCO_2 determinations

TRISH FRICKERS
Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth, PL1 3DH

Objective

To quantify the flux of CO_2 between the atmosphere and the Atlantic Ocean in order to predict future oceanic uptake of CO_2. Oceanic CO_2 uptake varies with biological processes, ocean circulation, mixing, seawater temperature and wind speed

Measurement principles

- The CO_2 detector, a LICOR 6262, measures the absorption of infrared radiation by CO_2 content in a gas, e.g. within air. The higher the absorption, the more CO_2 is in the air.
- To measure CO_2 in seawater, the CO_2 in water is brought into equilibrium or 'equilibrated' with the CO_2 content of a headspace. This is done in a gas-exchanger, the "equilibrator". The LICOR also determines the CO_2 content of marine air.
- Two standard gases, compressed air containing a certified amount of CO_2 at 250 and 450 ppm ($\mu mol\ mol^{-1}$) CO_2, are analysed regularly throughout the measurement to compensate for detector drift.
- Additional parameters are recorded with each CO_2 measurement, i.e. equilibrator temperature and equilibrator pressure. Data are recorded continuously during this time. The LICOR also determines measurements automatically with the results being continuously saved on the computer

After a clean, shellfish free non-toxic supply was on stream, the system ran continuously between 23.05.05 and 28.06.05. Minor breaks in data collection occurred when some minor maintenance or data backup was performed. From the 28.05.05 the equilibrator was supplied with an independent supply of non toxic.

Acknowledgments

I would particularly like to thank Dorothee Bakker for setting up the instrument in Cape Town and for all the help she gave via email throughout the cruise. Also Gareth Lee and Ute Schuster, the officers and crew of the RRS Discovery and Tony Bale as our Principal Scientist.

Dissolved organic carbon, nitrogen and phosphorus

XI PAN
National Oceanography Centre, European Way, Southampton, SO14 3ZH, UK

Aims

To investigate the distributions of dissolved organic carbon (DOC), dissolved organic nitrogen (DON) and dissolved organic phosphorous (DOP) in the southern and northern oligotrophic gyres and the equatorial upwelling regions in the Atlantic Ocean along the AMT16 transect.

Methods

Sample collection: Seawater samples were collected from 11 depths, including 6 main light depths, during the pre-dawn CTD cast. 250 ml Nalgene bottles previously soaked in 10% (v/v) HCl for 12 hours were used for temporary storage of the samples.

Sample filtration: The samples were subsequentially filtered through GF/F filters with 0.7 μm pore size using a clean glass filtration unit. The GF/F filters were previously combusted at 450^{o}C for 5 hours. The glass filtration unit was previously soaked in 10% (v/v) HCl for 12 hours, followed by thorough Milli-Q water rinsing.

Sample preservation: The filtrates were transferred to 20 ml clean glass ampoules (previously combusted at 450^{o}C for 5 hours) and stabilised by acidification to pH 2.2 using 20 μl of 50% (v/v) HCl for DOC and DON analyses. The ampoules were sealed using a butane-propane mixture gas torch and stored in a fridge (4^{o}C) until analysis. The sample collection, filtration, acidification and flame-sealing were completed within 2 hours in order to minimise sample changes.

DON and DOC analyses

DON analyses rely on independent dissolved inorganic nitrogen (DIN) and total dissolved nitrogen (TDN) measurements. DON concentrations are calculated as the differences between TDN and DIN concentrations. DIN (NO_3^- + NO_2^- and NH_4^+) analyses were undertaken immediately after sample collection using a standard colorimetric technique. TDN and DOC analyses will be undertaken using a coupled high temperature catalytic oxidation (HTCO) system. This combined system consists of a Shimadzu 5000A total organic carbon (TOC) analyser and an Antek 705E nitrogen chemiluminescence detector.

A full analytical cycle of the coupled HTCO TOC-Antek system includes two steps: (1) The acidified samples are sparged by ultra-pure oxygen gas (99.995%) at 100 ml/min (8 minutes) to drive off inorganic carbon (CO_3^{2-} and HCO_3^-). Then the decarbonised samples are injected into the Shimadzu combustion column filled with a catalyst (Al_2O_3) at 680^{o}C. The samples injected are pushed through the catalysts by the carrier gas (ultra-pure O_2 gas), producing CO_2, NO and H_2O. The gas stream is purified via a dehumidifier, halogen scrubber and particle filter and then routed to a non-dispersive infrared detector (NDIR), where CO_2 is detected. The signals from the NDIR are recorded using a data acquisition/integration system. The TOC software generates peaks and calculates peak area, which is proportional to the C concentration in the samples. (2) The gas stream is drawn out of the NDIR by a vacuum pump and routed into the reaction chamber of the Antek 705E nitrogen analyser. As a gas chromatographic detector, the Antek 705E is capable of determining N compounds in simple or complex matrices. NO in the gas stream reacts with O_3, produced by an on-board O_3 generator, to form NO_2. species, which chemiluminescences upon decay to its ground state:

$$NO + O_3 \rightarrow NO_2^{\cdot} + O_2$$
$$NO_2^{\cdot} \rightarrow NO_2 + h\nu$$

A quanta of emitted light is detected by a photomultiplier tube and converted to voltage signals. The produced signals are stoichiometrically proportional to the amount of total chemically bound N in the samples. Class-VP software is used to generate peaks and quantify peak area.

DOP analyses

DOP fraction is the difference between total dissolved phosphorous (TDP) and dissolved inorganic phosphorous (DIP). DIP (PO_4^{3-}) analyses were carried out immediately after sample collection using standard colorimetric technique. TDP (DOP+DIP) analyses comprise two steps: (1) a preliminary oxidation of the sample filtrates to break down all the organic phosphorous and (2) subsequent measurements of the oxidised filtrates. A 705 UV digester was used for the oxidation. It is a digestion apparatus for the UV photolysis of liquid samples with a moderate organic load. The oxidation is based upon the photolytic generation of OH radicals. Then, the radicals react with the organic compounds and decompose them.

$$H_2O + h\nu \rightarrow H^{\cdot} + OH^{\cdot}$$

Approximately 12 ml of seawater sample filtrates were transferred to the clean 705 UV digester sample vessels (previously soaked in 10% (v/v) HCl for 12 hours, followed by thorough Milli-Q water rinsing). The whole UV oxidation process lasted for 2 hours. After the oxidation, all of the DOP in the original filtrates was oxidised into DIP, together with the DIP derived directly from the original filtrates, which was quantified collectively using standard colorimetric technique.

Acknowledgements

Big thanks to Katie Chamberlain for TDP analyses and Sarah Reynolds for her help.

Table 1. Sample details

Date	CTD	CTD bottles
21/05/2005	1	23,19, 13, 12, 11, 6, 5, 4, 3, 2, 1
24/05/2005	3	23, 19, 13, 11, 10, 9, 4, 3, 2, 1
26/05/2005	6	23, 19, 13, 11, 10, 9, 4, 2, 1
28/05/2005	8	23, 19, 13, 11, 10, 9, 6, 4, 3, 2, 1
29/05/2005	11	23, 19, 15, 13, 11, 10, 9, 6, 4, 3, 2
30/05/2005	13	23, 19, 15, 13, 11, 10, 7, 5, 3, 2, 1
31/05/2005	15	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1
01/06/2005	17	23, 19, 15, 13, 12, 11, 8, 5, 3, 2, 1
01/06/2005	18	23, 21, 20, 18, 16, 15, 12, 11, 10, 9, 8, 7, 6, 4, 3, 2, 1
03/06/2005	21	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1
04/06/2005	23	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1
05/06/2005	25	23, 19, 16, 13, 12, 11, 10, 7, 5, 4, 3, 2, 1
06/06/2005	26	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1
07/06/2005	28	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1
08/06/2005	29	23, 19, 15, 13, 11, 10, 7, 5, 4, 3, 2, 1
09/06/2005	31	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1
09/06/2005	32	23, 21, 19, 18, 16, 15, 14, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1
11/06/2005	35	23, 19, 15, 13, 12, 11, 10, 7, 5, 4, 3, 2
13/06/2005	38	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1
14/06/2005	40	23, 19, 15, 13, 12, 11, 10, 7, 6, 4, 3, 2, 1
15/06/2005	42	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1
15/06/2005	43	23, 21, 20, 18, 16, 15, 14, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1
17/06/2005	46	23, 20, 16, 14, 13, 12, 11, 8, 6, 5, 4, 3, 2
18/06/2005	48	23, 19, 13, 11, 9, 8, 5, 3, 2
19/06/2005	50	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1
20/06/2005	52	23, 19, 15, 13, 12, 11, 9, 7, 5, 4, 3, 2, 1
21/06/2005	54	23, 19, 13, 11, 10, 9, 8, 5, 4, 2, 1
22/06/2005	56	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1
23/06/2005	58	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1
24/06/2005	60	23, 19, 15, 13, 12, 11, 10, 7, 5, 4, 3, 2, 1
25/06/2005	62	23, 19, 13, 11, 9, 8, 5, 3, 2, 1
26/06/2005	64	24, 22, 20, 18, 15, 14, 13, 10, 9, 6, 3
27/06/2005	66	23, 21, 19, 18, 17, 16, 14, 13, 10, 7, 5, 4, 3, 2, 1

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

EDWARD MAWJI
School of Earth, Ocean and Environmental Science, University of Plymouth
(present address, National Oceanography Centre, European Way, Southampton, SO14 3ZH, UK)

Introduction

Marine bacterial growth depends in part upon the availability of iron, which is known to be an essential requirement for most microorganisms. The total amount of iron in surface ocean waters is subnanomolar, potentially making iron the limiting nutrient for primary production in large areas of the oceans.

The majority of iron in seawater is thought to be complexed by strong organic ligands (Gledhill *et al*., 1998) presumed to be of biological origin. A substantial body of evidence now exists that marine bacteria produce siderophores in order to acquire iron, hence it has been hypothesised that siderophores make up a significant proportion of the organic ligand pool.

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

Objectives

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

Method

Water samples were collected from the dawn cast at 55% light depth using 20 litre carboys (Table 1). Seawater was then filtered and siderophore type chelates where extracted using polystyrene divinyl benzene SPE cartridges (Isolute ENV+, 100 mg x 3 ml, Esslab) (McCormack *et al*., 2003). Cartridges were conditioned with 15 ml methanol and 1 ml 11.2 mM ammonium carbonate (Gledhill *et al*., 2004). Samples were pumped through the cartridges using a peristaltic pump. 1 ml of 11.2 mM ammonium carbonate was used to wash the cartridges prior to elution with 5 ml of 1:20:80 (v/v/v) formic acid: water: methanol. Samples were then frozen for latter analysis.

Incubation method

Incubations were carried out in each distinct region along the transect to induce bacteria to produce siderophores in large enough quantities so that selected masses can undergo fragmentation using ESI-MS which will help identify different functional groups and eventually their structure. Incubations and solid phase extraction was carried out following the method of Gledhill *et al*., (2004). 600 ± 20 ml aliquots of sea water were enriched with 5 ml of 20% glucose solution, 0.5 ml of 2 x 10^{-4} M ammonium chloride and 0.5 ml 2 x 10^{-5} M potassium dihydrogen phosphate. Samples were then incubated for 2-4 days in deck incubators in the dark, cooled with surface seawater. Sea water samples which had not been enriched with nutrients were also incubated to act as a procedural blank. Bacterial growth was monitored using spectrophotometry at 600bnm every day. Once maximum growth had been reached sub samples were taken for flow cytometry analysis and the main sample was frozen to be processed back at Plymouth University.

Table 1. Sample Details

Date	Time (GMT)	CTD #	Lat	Long	Depth and light intensity	Bottle number
24 May	03:40	3	31°49.96'S	10°30.01'E	55 %, 12M	15,16
26 May	03:35	6	29°57.92'S	00°42.01'E	55%, 13M	15,16
28 May	04:34	8	28°04.23'S	09°14.97'W	55%, 15M	15,16
29 May	11:04	12	27°10.03'S	13°49.65'W	1%,125M	11 (Incubation)
31 May	05:41	15	25°36.29'S	21°55.97'W	55%,	15,16
1 June	05:37	17	22°52.82'S	24°59.98'W	1%,130M	15,16
3 June	05:42	21	16°16.71'S	24°59.92'W	55%, 20M	15,16 (Incubation)
4 June	05:37	23	12°24.73'S	24°59.71'W	55%, 17M	15,16
6 June	05:21	26	05°09.84'S	25°00.11'W	55%, 12M	15,16
7 June	05:03	28	01°37.71'S	24°59.59'W	55%	15,16 (incubation)
9 June	05:03	31	04°16.33'N	27°01.46'W	55%, 10M	15,16
10 June	05:06	33	07°14.99'N	28°27.19'W	55%, 7M	15,16
13 June	04:43	38	15°45.74'N	32°35.96'W	55%, 13M	15,16
14 June	12:00	41	20°05.00'N	34°46.34'W	14%,52M	16 (incubation)
15 June	04:33	42	22°48.31'N	36°09.82'W	55%, 14M	15,16
18 June	05:03	48	31°22.99'N	42°08.65'W	55%, 15M	15,16
19 June	05:03	50	33°34.61'N	45°32.31'W	55%, 10M	15,16 (Incubation)
21 June	04:36	54	36°04.11'N	38°20.54'W	55%, 10M	15,16
22 June	05:04	56	37°20.94'N	33°39.62'W	55%, 9M	15,16
23 June	03:02	58	38°18.32'N	30°03.83'W	55%, 7M	15,16(Incubation)
25 June	02:35	62	43°44.12'N	22°52.39'W	55%, 7M	15,16

Results

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

References

Gledhill, M., McCormack, P., Ussher, S., Achterberg, E.P., Mantoura, R.F.C., Worsfold, P.J. 2004. Production of siderophore type chelates by mixed bacterioplankton populations in nutrient enriched seawater incubations. Marine Chemistry 88(1-2), 75-83.

Gledhill, M., van den Berg, C.M.G., Nolting, R.F., Timmermans, K.R. 1998. Variability in the speciation of iron in the northern North Se. Marine Chemistry 59(3-4), 283-300.

McCormack, P., Worsfold, P.J., Gledhill, M. 2003. Separation and detection of siderophores produced by marine bacterioplankton using high-performance liquid chromatography with electrospray ionization mass spectrometry. Analytical Chemistry 75(11), 2647-2652.

Neilands, J.B. 1995. Siderophores - structure and function of microbial iron transport compounds. Journal of Biological Chemistry 270(45), 26723-26726.

Distribution of dissolved iron species in the Atlantic Ocean

SIMON USSHER
School of Earth, Ocean and Environmental Sciences, University of Plymouth, Drakes Circus, Plymouth, PL4 8AA, UK

Rationale

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

Specific aims

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

Sampling methodology: underway sampling

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

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

Sampling methodology: CTD sampling

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

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

Date	Time (GMT)	CTD cast	Latitude	Longitude	Bottle no.	Depth (m)
24/05/05	10:13	3	31°34.74'S	09°19.55'E	2, 4, 7, 11, 16, surf	300, 200, 125, 95, 50, 5
2505//05	10:00	5	30°38.08'S	04°13.28'E	2, 4, 7, 11, 16, surf	300, 200, 125, 70, 30, 5
27/05/05	10:00	7	28°44.61'S	05°45.27'W	2, 4, 7, 11, 16, surf	300, 200, 125, 100, 60, 5
28/05/05	12:24	9	27°49.76'S	10°30.96'W	2, 4, 7, 11, 16, surf	300, 200, 135, 125, 80, 5
29/05/05	11:04	12	27°10.03'S	13°49.65'W	2, 4, 7, 11, 16, surf	300, 200, 150, 125, 90, 5
30/05/05	12:03	14	26°17.04'S	18°27.70'W	2, 4, 7, 11, 16, surf	300, 200, 150, 130, 90, 5
31/05/05	12:02	16	25°23.07'S	23°04.66'W	2, 4, 7, 11, 16, surf	300, 200, 140, 120, 80, 5
01/06/05	12:09	18	22°27.28'S	24°59.97'W	2, 4, 1, 7, 3, 11, 16, surf	5390, 4400, 3500, 2000, 1000, 750, 500, 5
02/06/05	11:59	20	19°14.24'S	25°00.00'W	2, 4, 7, 11, 16, surf	300, 225, 175, 140, 85, 5
0306//05	12:04	22	15°24.55'S	25°00.07'W	2, 4, 7, 11, 16, surf	300, 200, 175, 140, 80, 5
04/06/05	12:03	24	11°57.03'S	25°00.41'W	2, 4, 7, 11, 16, surf	300, 200, 170, 120, 65, 5
0506//05	cancelled				2, 4, 7, 11, 16, surf	300, 200
06/06/05	12:02	27	04°15.07'S	24°59.88'W	2, 4, 7, 11, 16, surf	300, 200, 110, 75, 50, 5
08/06/05	11:58	30	02°03.50'N	25°58.97'W	2, 4, 7, 11, 16, surf	300, 200, 100, 65, 30, 5
09/06/05	12:11	32	05°09.15'N	27°26.79'W	1, 2, 4, 7, 11, 16, surf	4310, 3500, 2400, 1500, 850, 500, 5
10/06/05	12:07	34	07°41.75'N	28°40.67'W	2, 4, 7, 11, 16, surf	300, 200, 100, 50, 45, 5
11/06/05	36 failed				2, 4, 7, 11, 16, surf	300, 200
12/06/05	12:02	37	13°61.71'N	31°20.59'W	2, 4, 7, 11, 16, surf	300, 200, 100, 82, 36, 5
1306//05	12:00	39	16°19.47'N	32°53.18'W	2, 4, 7, 11, 16, surf	300, 200, 120, 100, 35, 5
14/06/05	12:00	41	20°05.00'N	34°46.34'W	2, 4, 7, 11, 16, surf	300, 200, 150, 120, 52, 5
15/06/05	12:00	43	23°21.58'N	36°27.43'W	1, 2, 4, 7, 11, 16, 3, surf	5900, 4500, 3500, 2250, 1500, 850, 500
1606//05	13:33	45	26°50.46'N	33°17.77'W	2, 4, 7, 11, 16, surf	300, 210, 160, 145, 63, 5
17/06/05	12:18	47	29°27.27'N	39°48.85'W	2, 4, 7, 11, 16, surf	300, 200, 150, 130, 57, 5
18/06/05	13:26	49	31°43.41'N	42°38.98'W	2, 4, 7, 11, 16, surf	300, 200, 125, 85, 45, 5
1906//05	12:08	51	33°55.55'N	46°04.53'W	2, 4, 7, 11, 16, surf	300, 200, 100, 65, 35, 5
20/06/05	12:06	53	35°5.92'N	41°50.60'W	2, 4, 7, 11, 16, surf	300, 200,135, 90, 45, 5
2106//05	12:01	55	36°27.59'N	36°55.18'W	2, 4, 7, 11, 16, surf	300, 200, 100, 67, 28, 5
22/06/05	11:59	57	37°34.33'N	32°50.23'W	2, 4, 7, 11, 16, surf	300, 200, 100, 62, 27, 5
2306//05	12:00	59	39°15.77'N	28°49.54'W	2, 4, 7, 11, 16, surf	300, 200, 125, 68, 33, 5
24/06/05	1:12	61	42°06.65'N	25°04.18'W	2, 4, 7, 11, 16, surf	300, 200, 100, 52, 47, 5
2506//05	12:00	63	44°22.10'N	29°59.81'W	2, 4, 7, 11, 16, surf	300, 200, 100, 75, 42, 5
26/06/05	11:06	65	46°21.94'N	18°51.22'W	2, 4, 7, 11, 16, surf	300, 200, 100, 55, 40, 5

Instrumentation and Techniques

Fe determination: The FI-CL method used an automated flow injection analyser for Fe(II) determination, which provided control of 3 peristaltic pumps (Minipuls 3, Gilson), a 3 way, two position solenoid valve (EW-01367-72, Cole-Parmer Instrument Co., Hanwell, UK) and a six port injection valve (C22, Valco Instruments Co., Houston, USA) whilst simultaneously powering and acquiring measurement data from a photon counting head (H6240-01, Hamamatsu Photonics, Welwyn Garden City, UK). Instrument control and data acquisition were performed using a notebook computer via an RS-232 connection and all software was written in LabVIEW version 7 (National Instruments Corp.). The flow injection manifold was similar to that reported by Bowie *et al*. for the determination of total dissolved iron. It incorporated an 8-HQ preconcentration column and an HCl (0.05 M) carrier was used to elute Fe(II) from the column. An optional buffer line (used only for pH 2 solutions and seawater experiments) mixed ammonium acetate solution with the sample to give a final

pH of ~5.5. The 8-HQ column was rinsed before each elution (25 s) to remove any unassociated species using a UHP water wash line controlled via the three-way valve. The flow cell was made from coiled transparent PVC tubing (Altec, Hants, UK) and mounted on the window of the photon counting head. More details can be found in Bowie (1998; 2002).

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

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

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

Results and data presentation

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

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

References

Bowie, A.R., Achterberg, E.P., Mantoura, R.F.C., Worsfold, P.J. 1998. Determination of sub-nanomolar levels of iron in seawater using flow injection with chemiluminescence detection. Analytica Chimica Acta 361(3), 189-200.

Bowie, A.R., Achterberg, E.P., Sedwick, P.N., Ussher, S., Worsfold, P.J. 2002. Real-time monitoring of picomolar concentrations of iron(II) in marine waters using automated flow injection-chemiluminescence instrumentation. Environmental Science and Technology 36(21), 4600-4607.

Micro and nano molar nutrients

KATIE CHAMBERLAIN AND TRISH FRICKERS
Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth, PL1 3DH, UK

Objectives

To study the spatial and temporal variations of the dissolved nutrients; nitrate, nitrite, phosphate, silicate and ammonium. The results will be used to help answer hypothesis 5 and 6 from objective 2 of the AMT program. In addition to the CTD samples and collaboration with National Oceanography Centre, samples treated by UV digestion for total phosphate by Xi Pan were analysed on the Bran+Luebbe Autoanalyser.

The AMT16 cruise track has allowed sampling of contrasting oceanic regions; Benguela Current, Southern Gyre oligotrophic waters, Equatorial Upwelling, Northern Gyre, Azores water and the Bay of Biscay. Each area is unique and has a specific nutrient depth profile signature.

AMT16 is the fifth in the current series of Atlantic Meridional Transect cruises funded as a NERC consortium project. AMT16 cruise track has repeated part of the AMT 12-15 cruise tracks, to permit inter-annual and seasonal comparisons.

Three analytical systems were used to measure nutrient concentrations. (1)Bran+Luebbe Autoanalyser III, this is a classic colorimetric nutrient autoanalyser which measures micro molar nutrient concentrations (here after Bran+Luebbe AAIII). (2) Three World Guide Precision Waveguides to measure nano-molar concentrations of nitrate, nitrite and phosphate (here after Waveguide) and (3) an ammonium diffusion technique across a Teflon membrane with fluorescence detection.

Through provisional bacteria and nutrient data it was discovered that CTD bottles occasionally failed to close properly, please see table for further details.

Methodology

Stock solutions were made at the beginning of the cruise, preserved with 500 µl of chloroform, and kept refrigerated. Fresh sub stocks and working stocks were made prior each CTD station, and each machine calibrated. The sub stocks and working stocks varied in accordance for each oceanic region for micromolar analysis. The sub stocks and working stocks for nanomolar analysis remained the same throughout the cruise due to the saturation limit of the waveguides and ammonia system. Two copper – cadmium columns were made at the beginning of the cruise (for determination of nano and micromolar nitrate+nitrite) and these satisfied the cruise duration.

Pump tubing was replaced every 5 – 7 days on the Bran+Luebbe AAIII and Waveguide and every 3 days for the ammonia system. Reagents were made every three days for the Bran+Luebbe and Waveguide. Optical matrix effects were observed in the Bran+Luebbe AAIII and Waveguides when changing from Milli-Q to saline water. Salinity corrections were measured prior to pump retubing for the Bran+Luebbe AAIII and daily on the Waveguides.

The Bran+Luebbe AAIII consists of five channels which measures micro molar nitrite, nitrate, ammonium, silicate and phosphate. This machine is now into the fifth consecutive AMT cruise and, daily problems were encountered with the XYZ sampler, which were resolved by switching the machine on and off. Provisional data processing was done through out the cruise to provide an idea of the nitrate+nitrite and silicate contour depth profile (Fig. 1).

Nano molar nitrate, nitrite and phosphate were determined using Waveguides made by World Precision Instruments. Waveguides can successfully monitor nano molar concentrations due to the uniqueness of the design; 2 m capillary small diameter cell and fibre optics.

The ammonia analysis was carried out on a method using the principles of converting NH_4 to NH_3 by diffusion across a micro-porous hydrophobic Teflon membrane in a stream of *o*-phthaldialdehyde reagent (Jones, 1991). The concentration of ammonia being directly proportional to the fluorescence measured.

CTD samples were collected into Milli Q clean and three rinses of CTD water into 60 ml Nalgenes for the analysis of micromolar nutrients and nanomolar analysis of ammonia. CTD samples were collected in 120 ml Nalgenes for the nanomolar analysis of nitrite, nitrate+nitrite, and phosphate. All volumetric and Nalgenes were rinsed three times with Milli Q water after analysis and two times prior to each CTD station. Sample analysis time was four minutes on the Bran+Luebbe and eight to ten minutes for Waveguide analysis.

Results

The AMT16 track can loosely be divided into six nutrient provinces;

1. Benguela region: CTD1 - CTD3
2. South Atlantic Gyre: CTD4 - CTD21
3. Equatorial Upwelling: CTD22 - CTD39
4. North Atlantic Gyre: CTD40 - CTD60
5. Azores Waters: CTD61 - CTD63
6. Bay of Biscay: CTD64 - CTD67

It was noted that surface nano molar phosphate concentrations were higher throughout the South Atlantic Gyre than the North Atlantic Gyre. All data will be processed on return to PML and micromolar data submitted to BODC within three months and nanomolar data six months.

The ammonia analyser had several days of down time. The recorder trace was intermittently too noisy to accurately determine nanomolar ammonia, the cause of which will be determined on return to the laboratory. See tables below for successful analyses.

Table 1. All CTDs sampled for micromolar nitrate + nitrite, nitrite, silicate and phosphate, and nanomolar nitrate + nitrite, nitrite, phosphate, and ammonia unless otherwise stated

Date	CTD	Bottles	Comments
21/05/05	1	23, 19, 15, 13, 12, 11, 6, 5, 4, 3, 2, 1	
21/05/05	2	24, 22, 17, 15, 14, 8, 5, 3	
24/05/05	3	23, 19, 13, 11, 10, 9, 4, 3, 2, 1	
24/05/05	4	23, 21, 19, 17, 15, 14, 10, 9, 6, 5, 3, 1	
25/05/05	5	23, 21, 19, 17, 15, 14, 10, 9, 8, 5, 3, 1	
26/09/05	6	23, 19, 13, 11, 10, 9, 4, 3, 2, 1	
27/05/05	7	23, 21, 19, 17, 15, 14, 10, 9, 8, 5, 3, 1	
28/05/05	8	23, 19, 13, 11, 10, 9, 6, 4, 3, 2, 1	
28/05/05	9	23, 21, 20, 18, 15, 14, 10, 9, 8, 5, 3, 1	
29/05/05	10		Cancelled
29/05/05	11	23, 19, 15, 13, 10, 9, 6, 4, 3, 2, 1	
29/05/05	12	23, 21, 20, 18, 15, 14, 10, 9, 8, 5, 3, 1	No ammonia data
30/05/05	13	23, 19, 15, 13, 11, 10, 7, 5, 4, 3, 2, 1	No ammonia data
30/05/05	14	23, 22, 20, 18, 15, 14, 10, 9, 8, 5, 3, 1	No ammonia data
31/05/05	15	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	No ammonia data
31/05/05	16	23, 21, 20, 18, 17, 15, 14, 13, 10, 9, 8, 6, 5, 3, 1	No ammonia data
01/06/05	17	23, 19, 15, 13, 12, 11, 8, 5, 3, 2, 1	No ammonia data
01/06/05	18	23, 21, 20, 18, 6, 15, 12, 10, 9, 8, 16, 11, 3, 7, 1, 4, 2	No ammonia data
02/06/05	19	23, 21, 19, 15, 13, 12, 11, 10, 7, 6, 4, 3, 2, 1	No ammonia data

Date	CTD	Bottles	Comments
02/06/05	20	23, 21, 20, 18, 15, 14, 13, 9, 8, 5, 3, 1	No ammonia data
03/06/05	21	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	No ammonia data
03/06/05	22	23, 21, 20, 18, 15, 14, 13, 9, 8, 6, 3, 1	No ammonia data
04/06/05	23	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	No ammonia data
04/06/05	24	23, 21, 20, 18, 15, 14, 13, 9, 8, 6, 3, 1	No ammonia data
05/06/05	25	23, 19, 16, 13, 12, 11, 10, 7, 5, 4, 3, 2, 1	No ammonia data
06/06/05	26	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	No ammonia data
06/06/05	27	23, 21, 20, 18, 15, 14, 10, 9, 8, 5, 3, 1	
07/06/05	28	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	
08/06/05	29	23, 19, 15, 13, 11, 10, 7, 5, 4, 3, 2, 1	
08/06/05	30	23, 21, 20, 18, 15, 14, 10, 9, 8, 5, 3, 1	
09/06/05	31	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	
09/06/05	32	23, 21, 19, 18, 6, 14, 10, 9, 8, 3, 16, 11, 7, 4, 2, 1	
10/06/05	33	23, 21, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	Samples analysed 5 hours later No ammonia data
10/06/05	34	23, 21, 20, 18, 15, 14, 10, 9, 8, 5, 1	No ammonia data
11/06/05	35	23, 19, 15, 13, 12, 11, 10, 7, 5, 4, 3, 2, 1	
11/06/05	36		Cancelled
12/06/05	37	23, 21, 20, 18, 15, 14, 10, 9, 8, 5, 3, 1	No ammonia data
13/06/05	38	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	No ammonia data
13/06/05	39	23, 21, 20, 18, 15, 14, 13, 12, 8, 5, 3, 1	No ammonia data
14/06/05	40	23, 19, 15, 13, 12, 11, 10, 7, 6, 4, 3, 2, 1	No ammonia data
14/06/05	41	23, 21, 20, 18, 15, 14, 10, 9, 8, 6, 3, 1	No ammonia data
15/06/05	42	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	
15/06/05	43	23, 21, 20, 18, 16, 6, 15, 14, 12, 5, 10, 9, 8, 3, 16, 11, 7, 4, 2, 1	
16/06/05	44		Cancelled
16/06/05	45	23, 21, 20, 18, 15, 14, 13, 12, 8, 6, 3, 1	
17/06/05	46	23, 20, 16, 14, 13, 12, 11, 8, 6, 5, 4, 3, 2	
17/06/05	47	23, 21, 20, 18, 15, 14, 10, 9, 8, 6, 3, 1	
18/06/05	48	23, 21, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	
18/06/05	49	23, 21, 20, 18, 17, 15, 14, 12, 10, 9, 8, 6, 5, 3, 1	
19/06/05	50	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	
19/06/05	51	23, 21, 20, 18, 15, 14, 10, 9, 8, 5, 3, 1	No ammonia data
20/06/05	52	23, 19, 15, 13, 12, 11, 9, 7, 5, 4, 3, 2, 1	No ammonia data
20/06/05	53	23, 21, 20, 18, 15, 14, 10, 9, 8, 5, 3, 1	No ammonia data
21/06/05	54	23, 19, 13, 11, 10, 9, 8, 5, 4, 2, 1	No ammonia data
21/06/05	55	23, 21, 20, 18, 15, 14, 10, 9, 8, 5, 3, 1	No ammonia data
22/06/05	56	23,19, 13, 11, 10, 9, 8, 5, 3, 2, 1	No ammonia data
22/06/05	57	23, 21, 20, 18, 15, 14, 10, 9, 8, 5, 3, 1	No ammonia data
23/06/05	58	23, 20, 13, 11, 10, 9, 6, 5, 3, 2, 1	No ammonia data
23/06/05	59	23, 21, 20, 18, 15, 14, 10, 9, 8, 5, 3, 1	No ammonia data
24/06/05	60	23, 19, 15, 13, 12, 11, 10, 7, 5, 4, 3, 2, 1	No ammonia data
24/06/05	61	23, 21, 20, 18, 15, 14, 10, 9, 8, 5, 3, 1	No ammonia data
25/06/05	62	23, 19, 13, 11, 10, 9, 8, 5, 3, 1	No ammonia data
25/06/05	63	23, 21, 20, 17, 15, 14, 10, 9, 8, 5, 3, 1	No ammonia data
26/06/05	64	24, 22, 20, 17, 15, 14, 13, 10, 9, 5, 3	No ammonia data
26/06/05	65	23, 21, 20, 17, 15, 14, 10, 9, 8, 5, 3, 1	Micromolar only
27/06/05	66	23, 21, 19, 18, 17, 15, 14, 13, 11, 9, 3, 1	Micromolar only
27/06/05	67	23, 19, 18, 14, 13, 12, 10, 9, 8, 5, 3, 1	Micromolar only

Table 2. All CTDs total phosphate samples measured on the Bran+Luebbe AAIII by Katie Chamberlain post UV digestion treatment by Xi Pan

Date	CTD	Bottles	Comments
26/09/05	6	23, 19, 13, 11, 10, 9, 4, 2, 1	
28/05/05	8	23, 19, 13, 11, 10, 9, 6, 4, 3, 2, 1	
29/05/05	11	23, 19, 15, 13, 10, 9, 6, 4, 3, 2,	
30/05/05	13	23, 19, 15, 13, 11, 10, 7, 5, 3, 2, 1	
30/05/05	13	23, 19, 15, 13, 11, 10, 7, 5, 3, 2, 1	0.2 µm filtered
01/06/05	17	23, 19, 15, 13, 12, 11, 8, 5, 3, 2, 1	
01/06/05	18	23, 21, 20, 18, 6, 15, 12, 10, 9, 8, 16, 11, 3, 7, 1, 4, 2	duplicated
03/06/05	21	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	
04/06/05	23	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	
08/06/05	25	23, 19, 13, 12, 11, 10, 7, 4, 3, 2, 1	
07/06/05	28	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	
08/06/05	29	23, 19, 15, 13, 12, 11, 10, 7, 5, 4, 3, 2, 1	
09/06/05	31	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	
09/06/05	32	23, 21, 19, 18, 6, 14, 10, 9, 8, 3, 16, 11, 7, 4, 2, 1	duplicated
11/06/05	35	23, 19, 15, 13, 12, 11, 10, 7, 5, 4, 3, 2	
11/06/05	36		Cancelled
12/06/05	37	23, 21, 20, 18, 15, 14, 10, 9, 8, 5, 3, 1	
13/06/05	38	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	
14/06/05	40	23, 19, 15, 13, 11, 10, 7, 6, 4, 3, 2	
15/06/05	42	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	
17/06/05	43	23, 21, 20, 18, 15, 14, 12, 10, 9, 8, 6, 5, 16, 11, 7, 4, 3, 2, 1	
18/06/05	48	23, 19, 13, 11, 9, 8, 5, 3, 2	
19/06/05	50	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	
20/06/05	46	23, 20, 16, 14, 13, 12, 11, 8, 6, 5, 4, 3, 2	
21/06/05	52	23, 18, 15, 13, 12, 11, 9, 7, 5, 4, 3, 2, 1	
21/06/05	54	23, 19, 13, 11, 10, 9, 8, 5 4, 2, 1	
22/06/05	56	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	
23/06/05	58	23, 19, 13, 11, 10, 9, 8, 5, 3, 2, 1	
24/06/05	60	23, 21, 20, 18, 15, 14, 10, 9, 8, 5, 3, 1	
25/06/05	62	23, 19, 13, 11, 9, 8, 5, 3, 2, 1	
26/06/05	64	24, 22, 20, 18, 15, 14, 13, 10, 9, 6, 3	

NB. Provisional results for nanomolar ammonia.

Reference

Jones, R.D. 1991. An improved fluorescence method for the determination of nanomolar concentrations of ammonium in natural waters. Limnology and Oceanography 36(4) 814-819.

Acknowledgments

We would like to thank the crew and officers of the RRS Discovery, the UKORS technicians and the other participating scientists for making the cruise so enjoyable and successful. Special thanks to Dionysios Raitsos – Exarchopoulos for his bottle washing and for keeping us entertained washing the Greek way!!

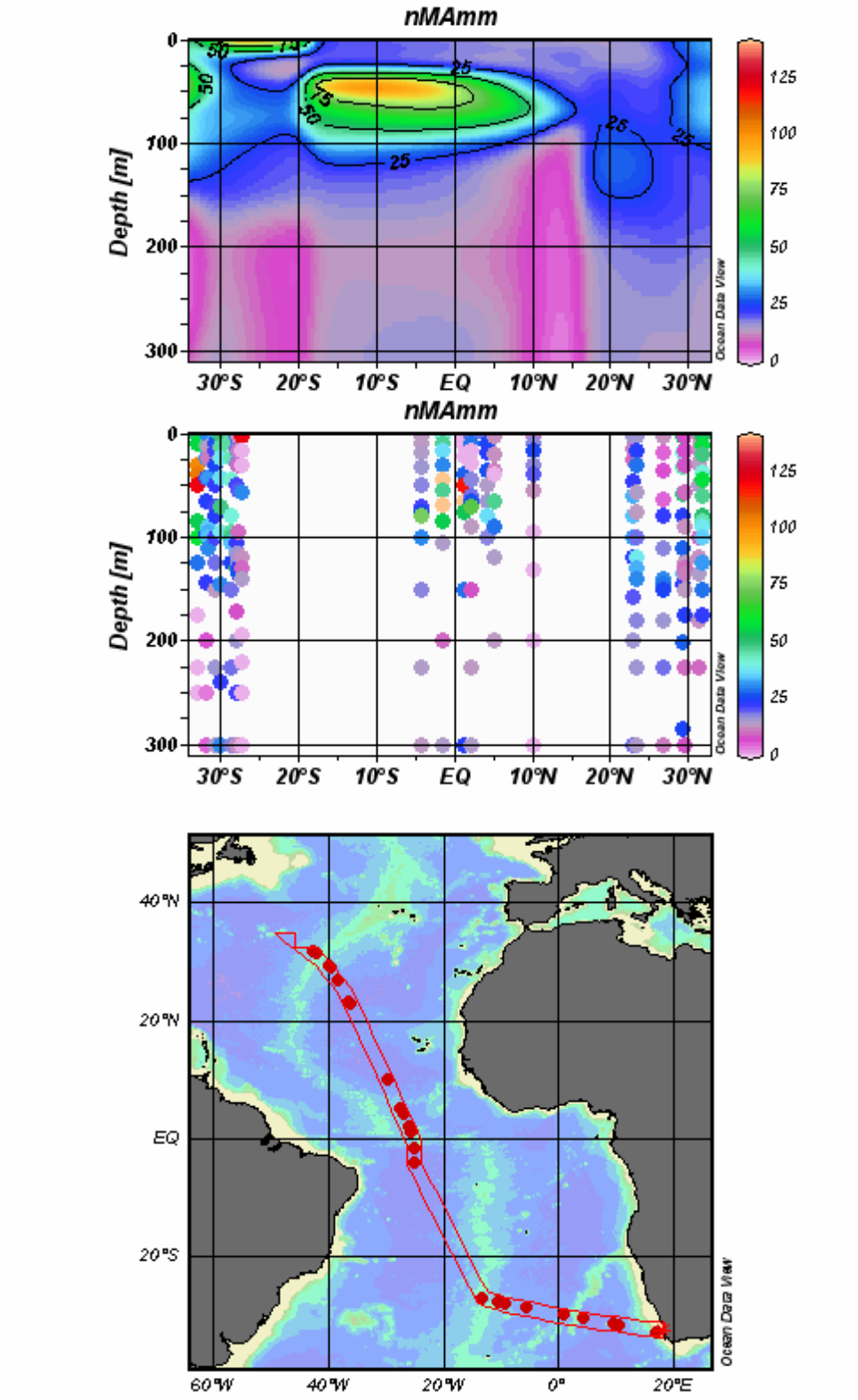


Figure 1. Contour plot (upper) and depth profiles (middle) of the ammonia data collected at the stations shown on the cruise track (lower panel) between 30°S and 30°N.

Optics and satellite imagery

SAMANTHA LAVENDER AND DIONYSIOS E. RAITSOS
University of Plymouth, Drakes Circus, Plymouth, PL4 8AA

Objectives

1. Measurement of Coloured Dissolved Organic Matter (CDOM) absorption profiles at both the pre-dawn and midday CTDs to a depth below the chlorophyll maximum.
2. Profiling with a Fast Repetition Rate Fluorometer (FRRF) and Profiling Reflectance Radiometer (PRR) at the midday CTD.
3. Satellite imagery.

Methods and preliminary results

CDOM: The Ultrapath UV-Visible Spectrometer with a waveguide measurement system (kept at the 200 cm pathlength) was used as on previous AMTs. Samples were regularly collected from the 97%, 55%, 33%, 14% and 01% light depth plus depths above and below the chlorophyll maximum on both the pre-dawn and midday casts. In addition, extra depths where measured when deeper CTDs were undertook (1000 and 5000 m). The samples were kept in the dark (glass amber containers) and allowed to reach room temperature.

Initially the reference and samples were carefully syringed into the waveguide (as had been undertaken on previous AMTs), but this did allow contamination by microbubbles. This was removed by normalising the spectra to zero at 700 nm, but overall it was felt to be unsatisfactory as this was a large proportion of the signal. Therefore, as suggested by Miller *et al.* (2002), from CTD16 onwards the sample was drawn into the waveguide using vacuum pressure by having the peristaltic pump attached to the outlet of the waveguide.

Three measurements were taken for each sample: unfiltered sample with Milli-Q reference, 0.2 μm filtered sample with Milli-Q reference and 0.2 μm filtered sample with saline Milli-Q reference (prepared using NaCl with any organic components burnt off by heating it to greater than 500°C).

The performance of the deuterium lamp deteriorated (loss of signal) until it was providing very little output at the end of the cruise. This was not due to the lamp overheating as the LEDs did not become red and there was plenty of space for ventilation (it may be that the lamp had reached the end of its normal lifetime). Measurements were still possible using the Tungsten lamp, but there was a loss of UV sensitivity and change of calibration. As saline Milli-Q was used daily, it is hoped that this can provide a means of calculating the changing calibration for the combined lamps.

Figure 1 shows some example profiles normalised to their maximum value. Work on calibration will continue after the cruise.

2) FRRF and PRR: The PRR and FRRF were lowered at the same time as the CTD frame during the midday cast.

The PRR was normally lowered first, to the side or aft depending on the location of the sun relative to the orientation of the ship, and would descend to a depth of between 50 and 70 m. The data have been used to calculated PAR attenuation coefficients.

The FRRF was lowered over the side as slowly as possible and then brought up fast, which gave 400-500 sampling points to a depth of around 150 m. It was set to acquire both dark and light chamber data using a fixed gain of 16. Figure 2 shows some preliminary data from the FRRF midday casts. A second FRRF was mounted on the pre-dawn CTD frame, which was set to the same parameters as the midday system. Both FRRFs were calibrated with 1000 m water when casts occurred and at least once with Milli-Q.

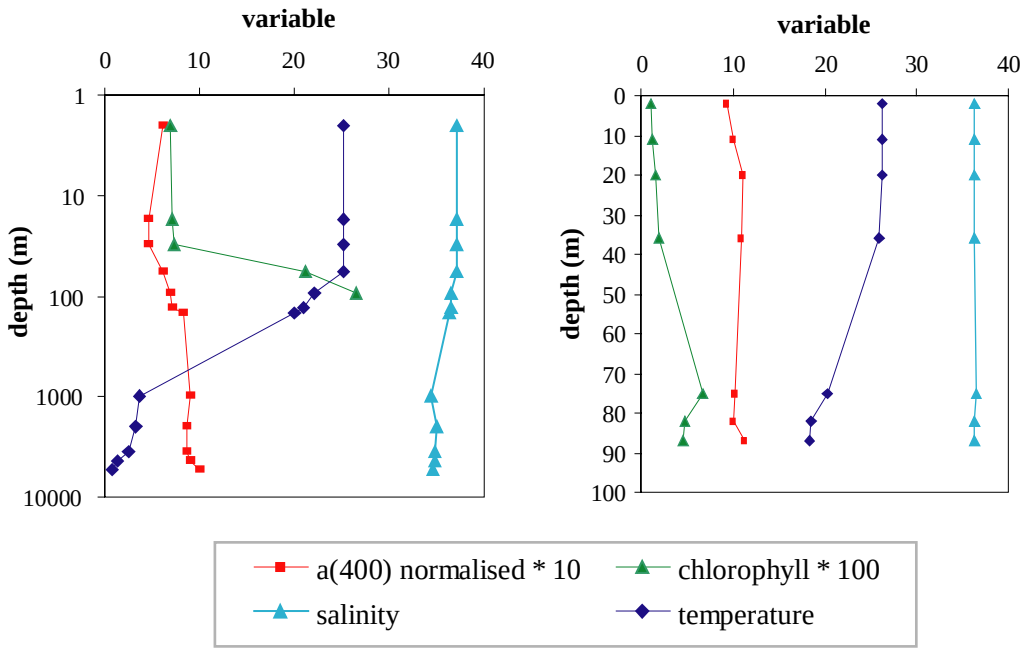


Figure 1. Example profiles normalised to their maximum value: a) CTD018 (southern gyre) and b) CTD037.

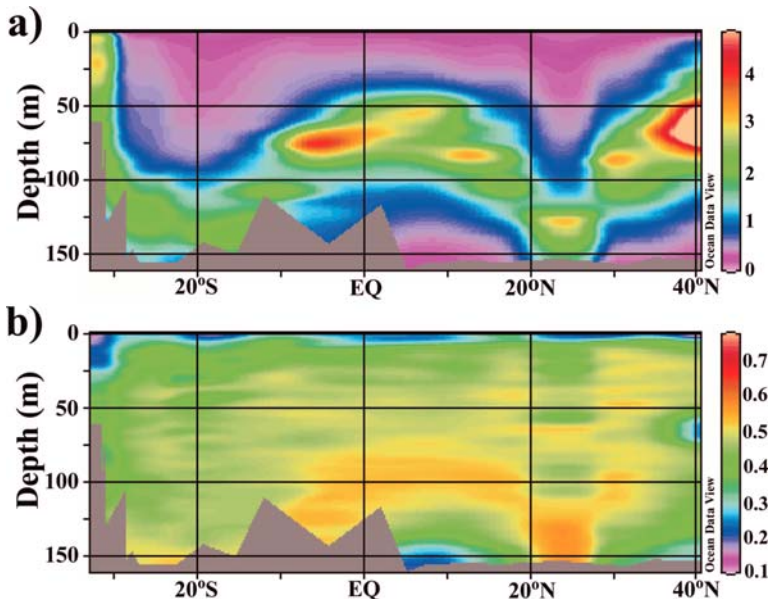


Figure 2. FRRF data from the midday cast showing the a) maximum fluorescence (related to biomass) and b) Photosynthetic Quantum Efficiency (related to productivity).

3) Satellite imagery: MODIS Aqua ocean colour imagery was provided directly from NASA using their automated system. Figure 3 shows the three regions with all available chlorophyll imagery composited (the compositing process replaces zero values with successive images rather than averaging as the data arrived as colour mapped pictures rather than values).

Imagery was also provided by the Remote Sensing and Data Analysis Service (RSDAS):

- 3 day Aqua true colour composites for the Dundee receiving station range: highlighted the presence of coccolithophore blooms on the edge of the continental shelf.
- Microwave sea surface temperature (SST) imagery for locating the Azores front.

a)

b)

c)

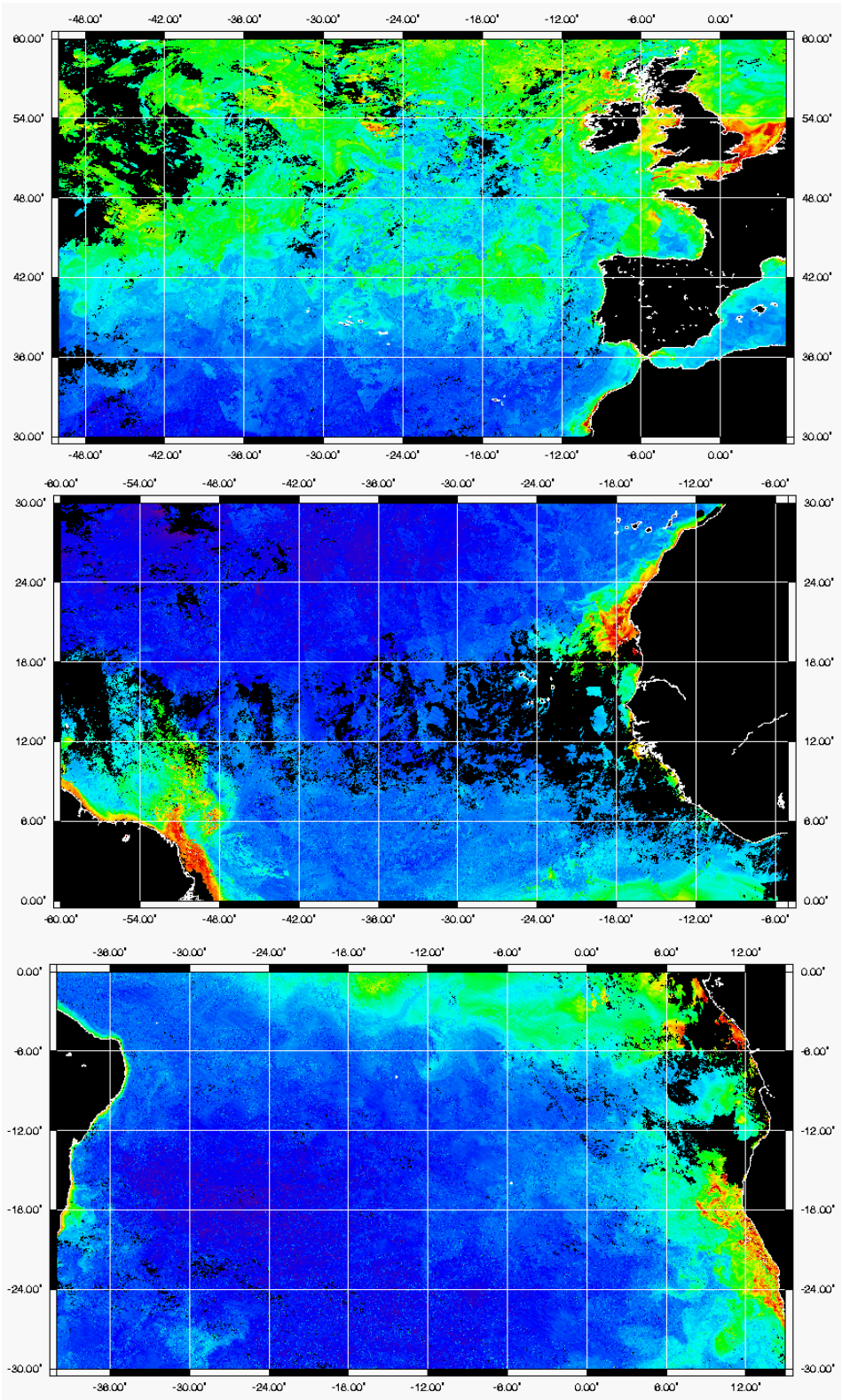


Figure 3. MODIS Aqua composites for the a) Northern b) Central and c) Southern regions.

Reference

Miller, R.L., Belz, M., Castillo, C.D., Trzaska, R. 2002. Determining CDOM absorption spectra in diverse coastal environments using a multiple pathlength, liquid core waveguide system. Continental Shelf Research, 22, 1301-1310.

Acknowledgements

Thanks to the crew and UKHORS technicians for help in deploying the FRRF and PRR.

Table 1. Instrument deployments

CTD[1] (day/month)	FRRF	PRR	CDOM[2]	PABS	Comment
01D (21/05)	CTD	N	Ys	N	
02O (21/05)	Y	Y	Ys	Y	
03D (24/05)	CTD	N	Ys	N	
04O (24/05)	Y	Y	Ys	Y	Sunny + swell (PRR on shadow side)
05O (25/05)	Y	Y	Ys	Y	Cloudy with swell
06D (26/05)	CTD	N	Ys	N	
07O (27/05)	Y	Y	Ys	Y	Cloudy during PRR cast
08D (28/05)	CTD	N	Ys	N	
09O (28/05)	Y	Y	Ys	Y	Late, around 12:15. Small amount of cirrus, calm seas
11D (29/05)	CTD	N	N	N	Late, around 08:00, so didn't do CDOM
12O (29/05)	Y	Y	Ys	Y	Overcast sky
13D (30/05)	N	N	Ys	N	1000 m CTD
14O (30/05)	Y	N	Ys	Y	
15D (31/05)	CTD	N	Ys	N	
16O (31/05)	Y	N	Y	Y	
17D (01/06)	CTD	N	Y	N	
18O (01/06)	Y	N	Y (extra depths)	Only surface	5000 m CTD
19D (02/06)	N	N	Y	N	1000 m CTD
20O (02/06)	Y	N	Y	Y	
21D (03/06)	CTD	N	Y	N	
22O (03/06)	Y	N	Y	Y	
23D (04/06)	CTD	N	Y	N	
24O (04/06)	Y	Y	Y	Y	Overcast sky
25D (05/06)	N	N	Y	N	1000 m CTD
25bO (05/06)	Y	Y	Only surface	Only surface	No CTD so sampled from underway
26D (06/06)	CTD	N	Y	N	
27O (06/06)	Y	Y	Y	Y	
28D (07/06)	CTD	N	Y	N	CDOM time series, 07:00 to 12:00 GMT. Tricho.
29D (08/06)	N	N	Y	N	1000 m CTD. Tricho.
30O (08/06)	Y	Y	Y	Y	Clear sky. Tricho.
31D (09/06)	CTD	N	Y	N	Tricho.
32O (09/06)	Y	Y	Y (extra depths)	Y	Some cirrus. Tricho. 5000 m CTD.
33D (10/06)		N	Y	N	Tricho.
CTD [1] (day/month)	FRRF	PRR	CDOM [2]	PABS	Comment
34O (10/06)	Y	Y	Y	Y	Tricho.
35D (11/06)		N	Y	N	
35bO (11/06)	Y	Y	N	Only Surface	No CTD so sampled from underway.
37O (12/06)	Y	Y	Y	Y	
38D (13/06)	Y	N	N	N	
39O (13/06)	Y	Y	Y	Y	
40D (14/06)	N	N	N	N	1000 m CTD.
41O (14/06)	Y	Y	Y	Y	Sargasso seaweed and small amounts of Tricho.

CTD[1] (day/month)	FRRF	PRR	CDOM[2]	PABS	Comment
42D (15/06)	Y	Y	Y	N	
43O (15/06)	Y	N	Y	Y	
44D (16/06)	N	N	N	Only Surface	No CTD so sampled from underway.
45O (16/06)	Y	Y	Y	Y	
46D (17/06)	N	N	Y	N	1000 m CTD.
47O (17/06)	Y	Y	Y	Y	Sargasso seaweed
48D (18/06)	Y	N	Y	N	
49O (18/06)	Y	Y	Y	Y	
50D (19/06)	Y	N	Y	N	
51O (19/06)	N	Y	Y	Y	
52D (20/06)	N	N	Y	N	1000 m CTD.
53O (20/06)	Y	Y	Y	Y	
54D (21/06)	Y	N	N	N	
55O (21/06)	Y	Y	N	Y	
56D (22/06)	Y	N	N	N	
57O (22/06)	Y	Y	Y	Y	
58D (23/06)	Y	N	Y	N	
59O (23/06)	Y	Y	Y	Y	
60D (24/06)	N	N	Y	N	1000 m CTD.
61O (24/06)	Y	Y	Y	Y	
62D (25/06)	Y	N	Y	N	Phaeocyctis?
63O (25/06)	Y	Y	Y	Y	Phaeocyctis?
64D (26/06)	N	Y	Y	N	Went in late with midday frame.
65O (27/06)	Y	Y	Y	Y	
66D (28/06)	N	N	Y	N	
67O (28/06)	Y	Y	Y	Y	

[1]D for dawn and O for optics cast
[2]Initially used a syringe for sample injection (afterwards moved to peristaltic pump, see Section xx)

Underway data processing and visualisation

DIONYSIOS E. RAITSOS
University of Plymouth, Drakes Circus, Plymouth, PL4 8AA

The aim of managing the real-time CTD dataset was a) to identify any significant errors in the CTD data and correct them during the cruise and b) to plot continuously the vertical profiles and produce contour plots of CTD data in order to observe the spatial distribution of parameters along the cruise track.

Methodology

The first lines of data from every "raw-data CTD file" were extracted using Access. Then the "cleaned" raw CTD dataset was binned at 1 m intervals using an IDL programme written by Samantha Lavender. The data were processed and the final CTD files were added together in an Excel file format to enable them to be 'read' by GIS or geostatistical software (i.e. Arc View GIS, ODV, Surfer).

Examples of vertical profiles, and contour plots are given below:

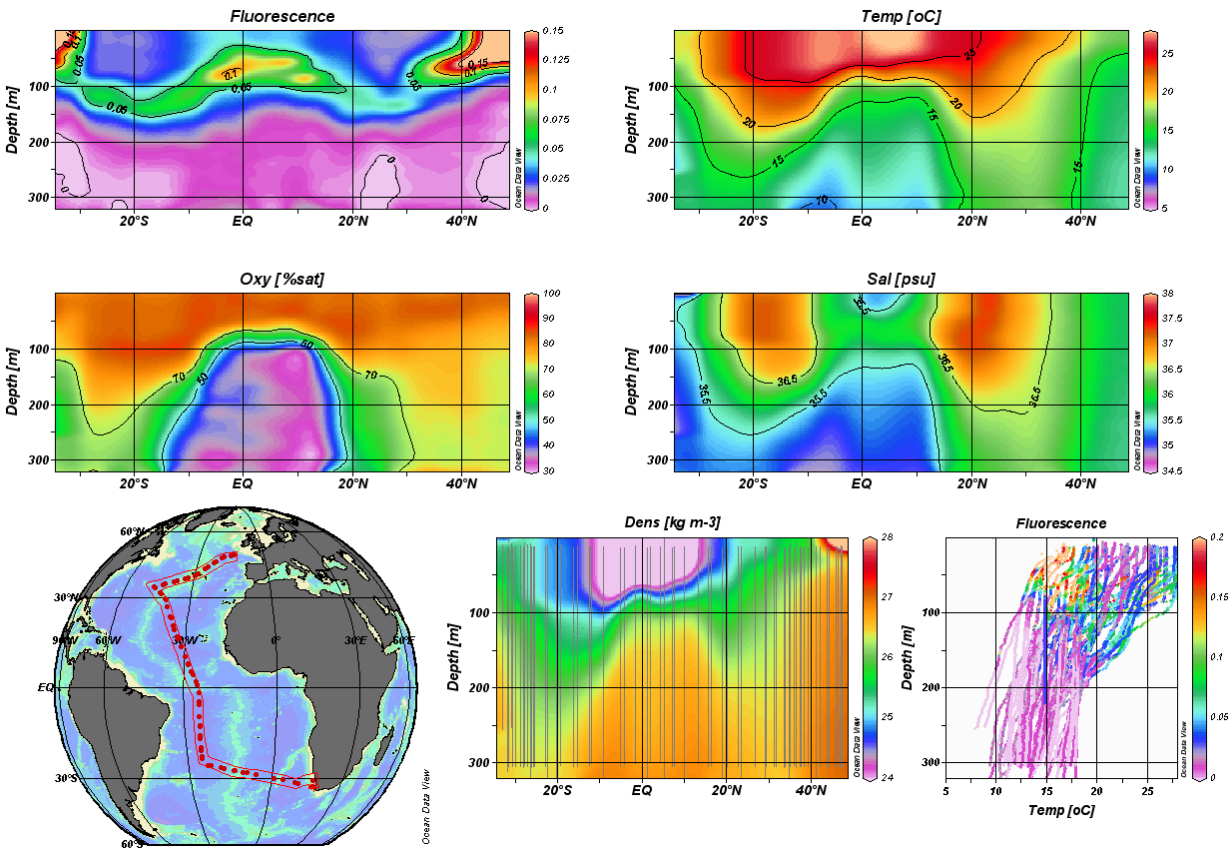


Figure 1. Examples of parameter-depth-latitude plots of data acquired on AMT16: upper panels and lower central panel are fluorescence, temperature, oxygen, salinity and density. The lower left graphic shows the track plot on a global representation and the lower right plot is a composite of temperature profiles on which the fluorescence values have been visualised in colour.

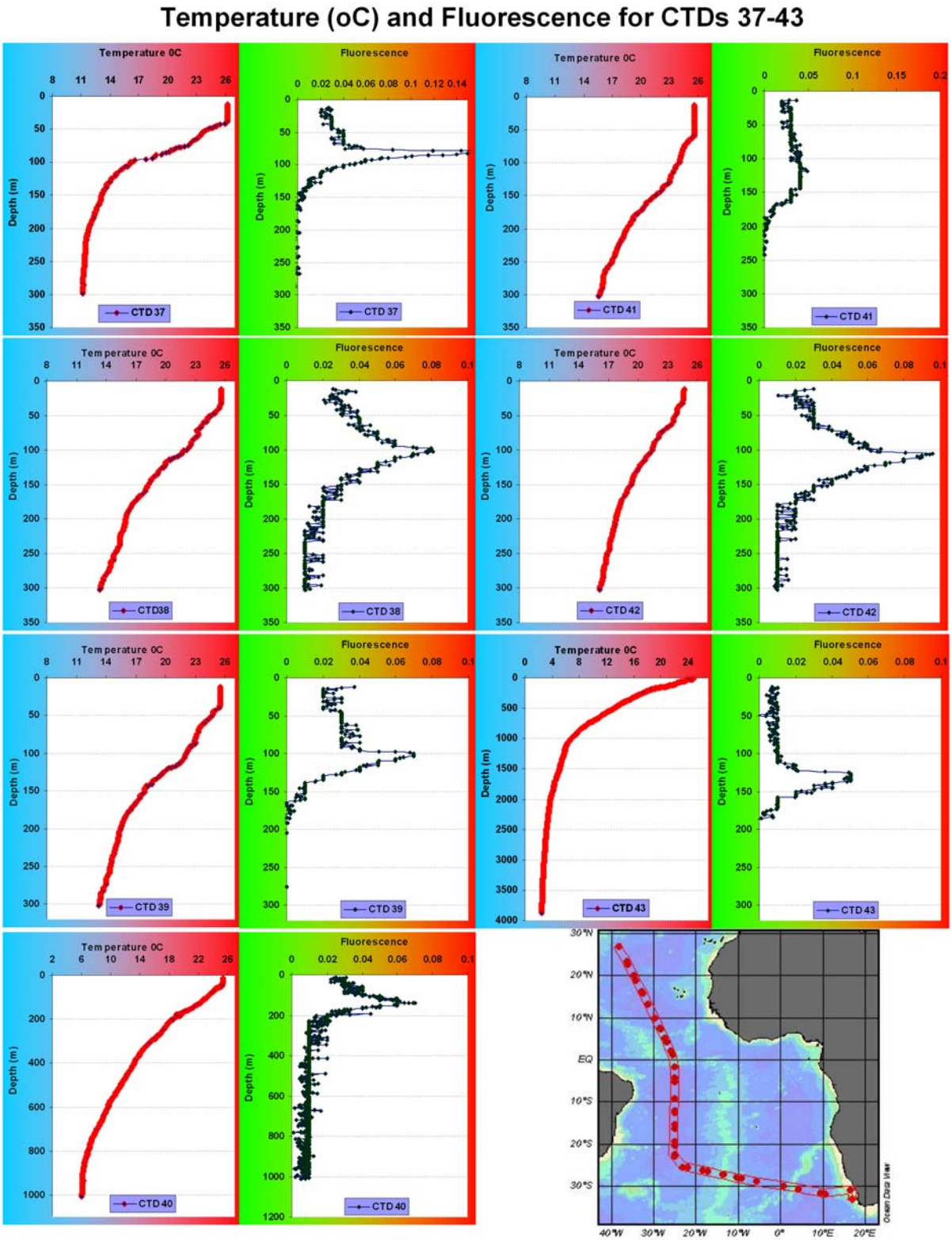


Figure 2. Profiles of temperature and fluorescence obtained from CTD casts 37 - 43 showing the presence of a deep chlorophyll maximum at each of these stations.

Coccolithophores: diversity, biogeography and life cycles strategies

MIGUEL FRADA[1,2]
[1]*Institute of Marine and Coastal Sciences, Rutgers University, USA*
[2]*Department of Geology,* [2]*Faculty of Sciences, University of Lisbon, Portugal*

Introduction

The coccolithophores (Haptophyta) are unicellular phytoplanktonic organisms distributed worldwide and known to have calcified scales, coccoliths, at some stage of their life cycle. They are extremely important in the marine ecosystem, both as primary producers and blooming organisms, where the processes of photosynthesis, respiration and calcification occurring in such large bloom, have important implications in the global C and S cycle. Moreover, after death, the coccoliths are transported to the sea floor constituting one of the most commonly used microfossil in stratigraphy and palaeoceanography. Unveiling their real diversity, biogeography and life cycle strategies are the fundamental questions to establish their importance and implications in the modern oceans and their accuracy as markers for the past.

Objectives

- To collect sea water samples for DNA, Scanning Electronic Microscopy (SEM) and optical microscopy for morphological and genetic analysis of coccolithophore diversity and community composition along the Atlantic Ocean.
- To collect samples for Calcareous Optical Detection Fluorescent *In Situ* Hybridisation (COD-FISH) to study coccolithophores life cycles diversity and strategies along the transect and their importance in carbon cycle dynamics.

Methods

1. A range between 4 and 7 litres, depending whether we were in a low or high productivity region, of sea water was taken from the dawn CTD from four depths: surface- collected with a regular bucket, 14%, 1% and 0.1% light depth (Table 1). These were filtered through 0.45 µm polyethersulphone filters and 0.4 µm polycarbonate filters for DNA and SEM respectively. Once the sample had been processed the filters were stored in the -80°C freezer.
2. 1 litre of each light depth (dawn CTD) has also been processed for COD-FISH analysis. For that the samples were fixed with paraformaldehyde for 1 hour at 4°C. Subsequently, the fixed samples have been filtered through 0.2 µm anodisc filters (Whatman) and finally dehydrated by a series of ethanol baths (50%, 80% and 100%) of 3 minutes each. After this procedure the filters were dried at room temperature and then stored at –20°C.
3. During the pre-down period a 5 m length net with a porosity of 5µm was deployed to collect concentrated samples from the surface water (Table 2). The period of netting was usually 20 minutes. The concentrated sample (around 1.5 litres) collected from the cod-end of the net was processed in the same way as described above, but with volumes between 600-500 ml for DNA, 500-400 for SEM and 200-100 ml for COD-FISH.

Sample processing and future analysis

The samples collected during this AMT16 cruise will be processed and studied by Hui Liu, Rutgers University (liu@imcs.rutgers.edu) and Miguel Frada as part of their PhD theses.

Table 1. Sampling plan for DNA, SEM and COD-FISH analysis

Date	Sample #	Station	CTD	Niskin	Depth (m)
21 May 05	1	001	001	bucket	0
				19	10
				11	50
				6	85
	2	002	002	bucket	0
				19	10
				11	50
				6	100
24 May 05	3	003	003	bucket	0
				19	12
				9	96
				4	144
	4	004	004	bucket	0
				20	bottle leaking
				13	95
				8	125
25 May 05	5	005	005	bucket	0
				20	16
				13	70
				6	150
26 May 05	6	006	006	bucket	0
				23	13
				9	95
				4	145
27 May 06	7	007	007	bucket	0
				20	5
				13	100
				6	150
28 May 05	8	009	009	bucket	0
				17	55
				13	125
				6	150
29 May 05	9	011	011	bucket	0
				19	17
				9	130
				4	195
30 May 05	10	013	014	bucket	0
				17	57
				13	130
				6	175
31 May 05	11	014	015	bucket	0
				19	14
				8	105
				No	bottle leaking
1 June 05	12	017	018	bucket	0
				17	57
				13	130
				5	170

Date	Sample #	Station	CTD	Niskin	Depth (m)
2 June 05	13	019	020	bucket	0
				17	61
				13	140
				6	175
3 June 05	14	021	022	bucket	0
				17	61
				12	140
				5	200
4 June 05	15	023	024	bucket	0
				17	52
				12	120
				5	200
6 June 05	16	026	026	bucket	0
				19	12
				8	88
				No	bottle leaking
	17	027	027	bucket	0
				17	33
				12	75
				5	130
8 June 05	18	030	030	bucket	0
				17	28
				12	65
				6	120
10 June 05	19	034	034	bucket	0
				17	22
				12	50
				6	150
12 June 05	20	037	037	bucket	0
				17	36
				12	82
				6	130
13 June 05	21	039	039	bucket	0
				11	44
				8	100
				3	150
14 June 05	22	041	041	bucket	0
				17	52
				12	120
				5	200
16 June 05	23	045	045	bucket	0
				17	63
				10	145
				5	210
17 June 05	24	047	047	bucket	0
				17	57
				12	130
				5	225

Date	Sample #	Station	CTD	Niskin	Depth (m)
19 June 05	25	050	050	bucket	0
				17	57
				13	130
				6	225
	26	051	051	bucket	0
				17	28
				13	65
				6	150
20 June 05	27	052	052	bucket	0
				19	12
				9	90
				5	135
	28	053	053	bucket	0
				17	39
				13	90
				6	150
21 June 05	29	054	054	bucket	0
				19	10
				8	73
				4	120
	30	055	055	bucket	0
				18	28
				10	67
				5	150
22 June 05	31	056	056	bucket	0
				19	9
				8	63
				3	100
	32	057	057	bucket	0
				17	27
				13	62
				6	125
23 Jun 05	33	059	059	bucket	0
				18	33
				14	68
				8	125
24 Jun 05	34	061	061	bucket	0
				18	33
				14	52
				8	100
25 Jun 05	35	063	063	bucket	0
				17	18
				14	42
				8	100
26 Jun 05	36	065	065	bucket	0
				17	18
				14	40
				8	100
27 Jun 05	37	067	067	bucket	0
				17	11
				14	26
				8	100

Table II. Phytoplankton Net (5µm mesh size) sampling plan.

Date	Net sample#	Station	Depth
28 May 05	1	008	surface
30 May 05	2	012	surface
1 Jun 05	3	016	surface
2 Jun 05	4	018	surface
7 Jun 05	5	028	surface
9 Jun 05	6	031	surface
10 Jun 05	7	033	surface
11 Jun 05	8	035	surface
13 Jun 05	9	038	surface
14 Jun 05	10	040	surface
16 Jun 05	11	044	surface
17 Jun 05	12	046	surface
18 Jun 05	13	048	surface
23 Jun 05	14	058	surface
24 Jun 05	15	060	surface
25 Jun 05	16	062	surface
26 Jun 05	17	064	surface
27 Jun 05	18	066	surface

UKORS Instrumentation

J. SHORT AND D. MOUNTIFIELD
UKORS Sensors and Moorings Group, National Oceanography Centre, Southampton

1. CTD operations

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

1.1 Stainless steel CTD frame

The stainless steel frame configuration was as follows:

- Sea-Bird 9/11 *plus* CTD System
- 24 by 20 l Ocean Test Equipment External Spring Water Samplers
- Sea-Bird 43 Oxygen Sensor
- Chelsea MKIII Aquatracka Fluorometer
- Chelsea MKII Alphatracka 25 cm path Transmissometer
- Turner Designs Cyclops-7 Fluorometer (removed for 1000 m casts)
- Wetlabs BBRTD Back Scatter Sensor
- OED LADCP Pressure Case Battery Pack
- RD Instruments Workhorse 300 KHz Lowered ADCP (downward-looking master configuration)
- RD Instruments Workhorse 300 KHz Lowered ADCP (upward-looking slave configuration)
- Chelsea FRRF/Battery Pack/PAR/Pressure Sensor (removed for 1000 m casts)

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

1.1.1 Stainless steel CTD frame instrument configuration

The Sea-Bird CTD configuration for the stainless steel frame was as follows:

- SBE 9 *plus* Underwater unit s/n 09P-31240-0720
- Frequency 0 - SBE 3P Temperature Sensor s/n 03P-2919 (primary)
- Frequency 1 - SBE 4C Conductivity Sensor s/n 04C-2450 (primary)
- Frequency 2 - Digiquartz Temperature Compensated Pressure Sensor s/n 90573
- Frequency 3 - SBE 3P Temperature Sensor s/n 03P-4116 (secondary)
- Frequency 4 - SBE 4C Conductivity Sensor s/n 04C-2407 (secondary)
- SBE 5T Submersible Pump s/n 05T-3086
- SBE 5T Submersible Pump s/n 05T-3088
- SBE 32 Carousel 24 Position Pylon s/n 32-31240-0423
- SBE 11 *plus* Deck Unit s/n 11P-19817-0495

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

- V0 - SBE 43 Oxygen s/n 43B-0619
- V3 - Chelsea MKIII Aquatracka Fluorometer s/n 88/2960/160
- V4 - Turner Designs Cyclops 7 Fluorometer (supplied by Alex Poulton)
- V6 - WetLabs Back Scatter Sensor BBRTD s/n 167
- V7 - Chelsea MKII Alphatracka 25 cm path Transmissometer s/n 161045

The additional self-logging instruments were configured as follows:

- Chelsea FRRF s/n 182041 with PAR s/n 046-2835-012 (from FRRF 182039)
- RDI Workhorse 300 KHz Lowered ADCP (downward-looking master configuration) s/n 1881
- RDI Workhorse 300 KHz Lowered ADCP (upward-looking slave configuration) s/n 4275

1.1.2. Stainless steel CTD frame deployment notes

There were the usual occasions of the 20 l water bottles not sealing properly. There were never more than a couple per cast and the scientists sampling from these casts were informed and so did not take water from these bottles. There were a few casts where bottles that were apparently well sealed upon landing the CTD were later found to be compromised by lab analysis. It is assumed that these bottles did not seal properly then sealed at some point between closure and recovery of the CTD package. This is an unfortunate design flaw of these particular bottles and there is no method of getting 100% closures.

The FRRF and associated PAR sensor, battery and pressure sensor were removed for the 1000 m stations, during which Sam Lavender from the Scientific Party downloaded FRRF data and charged its battery.

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

The stainless steel CTD system suffered from rosette failure on cast CTD064s, a profile was obtained but no water taken. The titanium frame was then deployed at the same station for a 300 m dip and 19 water bottles fired (CTD064t). The problem was traced to a heavily corroded pin on the rosette connector of the Seabird underwater unit. The underwater unit was removed from the frame, the end-cap was removed and the bulkhead connector replaced in time for CTD066s.

1.2. Titanium CTD frame

The titanium frame configuration was as follows:

- Sea-Bird 9/11 *plus* CTD system
- 24 by 10L Ocean Test Equipment External Spring Trace-metal Water Samplers
- Sea-Bird 43 Oxygen Sensor
- Chelsea MKIII Aquatracka Fluorometer
- Chelsea MKII Alphatracka 10 cm path Transmissometer (Faulty as supplied, removed Jday 145)
- Chelsea PAR Sensor (downlooking UWIRR) – Removed for deep casts > 500 m
- Chelsea PAR Sensor (uplooking DWIRR) - Removed for deep casts > 500 m
- Wetlabs Light Scatter Sensor
- RVS 2 Second Interval Pinger – Fitted for full-depth, near bottom casts

The pressure sensor is located 30 cm from the bottom of the water samplers, and 119 cm from the top of the water samplers. This frame was used for the midday casts and was either deployed to 300 m or full ocean depth up to 6000 m.

1.2.1. Titanium CTD frame instrument configuration

The Titanium Sea-Bird CTD configuration was as follows:

- SBE 9 *plus* Underwater Unit s/n 09P-24680-0637
- Frequency 0 - SBE 3P Temperature Sensor s/n 03P-4380 (primary)

- Frequency 1 - SBE 4C Conductivity Sensor s/n 04C-2851 (primary)
- Frequency 2 - Digiquartz Temperature Compensated Pressure Sensor s/n 79501
- Frequency 3 - SBE 3P Temperature Sensor s/n 03P-4381 (secondary)
- Frequency 4 - SBE 4C Conductivity Sensor s/n 04C-2858 (secondary)
- SBE 5T Submersible Pump s/n 05T-3002
- SBE 5T Submersible Pump s/n 05T-3085
- SBE 32 Carousel 24 Position Pylon s/n 32-34173-0493
- SBE 11 *plus* Deck Unit s/n 11P-24680-0588

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

- V2 - SBE 43 Oxygen s/n 43B-0612
- V3 - Chelsea MKIII Aquatracka Fluorometer s/n 88/2960/163
- V4 - Chelsea PAR Sensor (UWIRR) s/n 04
- V5 - Chelsea PAR Sensor (DWIRR) s/n 02
- V6 - WetLabs Light Scatter Sensor s/n 338
- V7 - Chelsea MKII Alphatracka 10 cm path Transmissometer s/n 161049

1.2.2. Titanium CTD frame deployment notes

5 Niskin bottles (#11-15) damaged during overnight heavy weather before first titanium frame deployment. Damaged bottles replaced with spares and renumbered #11-15. PAR sensors removed for casts over 500 m, i.e. for all full-ocean depth 4000 – 6000 m casts, and a pinger fitted for near bottom work.

The 10 cm path-length transmissometer was faulty as supplied and was removed on Julian day 145. Hence, no transmissometer data was recorded from the titanium frame during AMT16.

2. Brooke Ocean Technology (BOT) Moving Vessel Profiler (MVP)

A total number of 273 profiles were conducted during the cruise. The sensor configuration was as follows:

- MVP300-1700 s/n 10014, with small Multi-Sensor Free-Fall Fish (MSFFF-I)
- AML Micro Sensor CTD s/n 7027
- WETLabs Flash Lamp Fluorometer s/n FLF-370S
- Seabird SBE23 Dissolved Oxygen Sensor s/n 23-0960
- Satlantic OCR 507-ICSW Irradiance Sensor s/n 0136
- Satlantic OCR 507-R10W Irradiance Sensor s/n 0074

2.1. BOT Moving Vessel Profiler deployment notes

After loss of the large Multi-Sensor Free-Fall Fish (MSFFF-II) on AMT15, Murray Eisan, a mechanical engineer from Brooke Ocean Technology attended the ship during the trials cruise D292T prior to AMT16. A new larger winch guard plate was fitted by the BOT engineer and intensive trials were undertaken. To prevent loss of the fish, the MVP was watched on deck by UKORS for every deployment during AMT16.

The system was used very intensively with the fish being deployed every 13 minutes when the ship was steaming between stations. The loss of the fish on AMT15 is now thought to be associated with considerable slack turns that can be generated on the winch drum during free-fall of the fish. Logs of the sea-state, wind, and ships speed were kept for every cast. There does not appear to be any one cause of the generated slack apart from the complex dynamics caused by the interaction of the fish, wire, winch and ship movement.

After more than 230 casts the electrical continuity of the Kevlar tow-rope was lost and over 400 m of wire had to be removed to restore functionality. The system was then used less intensively with a single cast deployment every 4 hours between the 1100 and 0400 stations. After approximately 30 more casts, the electrical continuity of the tow rope failed again and use of the MVP was ended.

A problem with the electrical continuity of the AUX1 connector on the underwater data telemetry multiplexer (DTM) was identified very near the end of MVP usage. This channel was used for the fluorometer, which was confirmed to be operating by testing on AUX4, hence no useful fluorometer data has been acquired on AUX1. The conductivity cell on the AML micro CTD became first intermittent, and then non-functional, hence salinity data was only good during the early part of the cruise. Both items are non field-serviceable. The Satlantic irradiance sensors were only fitted to the MSFFF after sufficient confidence had been generated that the fish was not going to be lost as on AMT15, hence irradiance data is only present in the later part of the MVP dataset.

3. Stand Alone Pumps (SAPs)

Three Challenger Oceanic Stand Alone Pumps were deployed simultaneously at 50, 100, and 150 m depths. The timer delay was set to 0.3 hours and the pumping time to 1.5 hours. The first deployment was aborted due to the 100 m SAP sliding down the CTD wire. Subsequently the SAPs were deployed on the core wire. On the second deployment, one SAP failed to pump and it was replaced with a spare SAP. This also did not pump. The batteries were replaced and new electronics boards fitted and subsequently all three SAPs worked reliably, pumping over 1000l on all casts for the rest of the cruise.

4. Surface sampling and meteorology (SurfMet) system

SurfMet, the UKORS surface water and meteorological suite of instrumentation was run for the duration of the cruise.

4.1. Surfmet system instrument configuration

The SurfMet system comprises:

- Transmissometer (no serial number visible)
- Fluorometer – Wetlabs W3S s/n 247
- Conductivity sensor – FSI OCM s/n1376
- Temperature sensor in bow pickup – FSI OTM s/n 1360
- Temperature sensor in TSG housing – FSI OTM s/n 1370
- Air Temperature and Relative Humidity sensor – Vaisala HMP44L s/n 1850012
- Atmospheric Pressure – Vaisala PTB100A s/n U1420016
- Port and Starboard PAR sensors – SKE510 1204 s/n's 28558 and 28557
- Port and Starboard TIR sensors – Kipp and Zonen TIR s/n's 047463 and 047462
- Wind direction – Vaisala WAV vane s/n S21214
- Wind speed – Vaisala VAA anemometer s/n P50421

The SurfMet system is controlled via a LabView program running on a desktop PC and logged at 30 second intervals to the ship's central datalogging (ABC) System. Both PAR and TIR sensors were fitted new at the start of AMT16.

4.2 SurfMet system operation notes

The system was inadvertently stopped from logging mid-cruise by an unidentified individual resulting in a loss of around 4 hours data. The transmissometer and fluorometer flow loop was stopped occasionally to clean the transmissometer lenses and take air and blank readings. *At one point after cleaning the flow through this loop appears to have stalled, even though the flowmeter indicated flow. Hence there is bad underway transmissibility and fluorometry data between Julian days 150 and 164.*

5. Salinometry

An Autosal 8400B salinometer (s/n 65764) was used on this cruise to process 153 samples either from the CTD casts or the underway non-toxic supply. The salinometer was located in the Stable Laboratory and operated at 27°C bath temperature and 25.2°C to 27°C ambient lab temperature. The samples were run using the Softsal software running on a desktop PC. All samples were processed according to WOCE standards and protocols.

Discrete samples for calibrating the SurfMet TSG were taken from the debubbler tap in the Wetlab which was left running continuously to maintain a constant flow rate. Normally samples would be drawn from the outflow from the TSG but this tap was non-functional, drawing in air instead of producing water.

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

Jan Kaiser of the science party noticed that data from the TSG 4.5 minutes earlier than the time that the discrete sample was drawn produces lower variation in the residuals from the TSG against the Autosal. This was confirmed in the UKORS produced D294_Salts.xls Excel spreadsheet. This may be caused by the different pipe-lengths and flow rates between the TSG and the debubbler supply that the discrete samples were drawn from.

One discrete salinity sample was taken from Sam Lavender's 37 PSU substandard to allow her to calibrate it. The substandard was measured at 38.023 PSU.

6. Miscellaneous

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

Determining the supply of nitrogen and phosphorus to the surface Atlantic Ocean

SARAH REYNOLDS
Department of Earth and Ocean Sciences, University of Liverpool, PO Box 147, Liverpool, L69 3BX, UK

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 and 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.

Research Objectives

Focus is on the use of organic 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 particulate phospholipids, the presence and identification of dissolved free and total hydrolysable D- and L- amino acids and the use of stable N isotopes to identify the source of N to surface waters.

In an attempt to gain preliminary estimates to the extent at which DON and DOP contribute to nutrient budgets, fluorogenic compounds to mimic labile organic nitrogen and phosphorus moieties are employed to determine the rate of turnover of DON and DOP through a series of incubations.

Methodology

Dissolved free and total hydrolysable D- and L- amino acid: 28 ml of seawater collected from CTD casts, syringe filtered through a 25 mm pre-combusted GF/F filter. Filtrate retained in a 28 ml pre-combusted glass vial and stored at -20°C until further analysis at the University of Liverpool by HPLC.

Particulate phospholipids: 2 l of seawater collected from CTD casts and filtered through a 47 mm pre-combusted GF/F filter. Filter was retained in pre-combusted foil and stored at -20°C until further analysis at the University of Liverpool by GCMS.

Stable N Isotopes: Samples collected using stand alone pumps (SAPs). On average ~1000 l of seawater filtered through a 293 mm pre-combusted GF/F filter. Filter was retained in pre-combusted foil and stored at -20°C until further analysis at International University, Florida, USA (Dr. W. Anderson) by IRMS.

Turnover rate of labile organic N and P: Seawater was collected from CTD casts and inoculated with L-leucine-7-amido-4-methylcoumarin hydrochloride and 4-methylumbelliferyl phosphate (concentrations ranging between 100 μmol l^{-1} and 750 μmol l^{-1}). The initial fluorescence was measured using a Turner Designs TD-700 Laboratory Fluorometer. The inoculated seawater was incubated at 16°C for 48 hours after which the fluorescence was re-measured.

To the data collected Michaelis-Menten kinetics will be applied and the turnover rate of the fluorogenic substrates can be determined.

Stations Sampled

Dissolved free and total-hydrolysable D- and L- amino acids

- 3 x very deep casts CTD # 18, 32 and 43
  13 depths
- 4 x 1000 m casts CTD # 24, 40, 52 and 60
  7 depths
- CTD # 1, 3, 6, 8, 15, 17, 21, 26, 33, 35, 38, 46, 50, 54, 56, 58 and 62
  One sample taken from the chlorophyll maximum

Particulate Phospholipids

- CTD # 2, 4, 5, 7, 9, 12, 14, 16, 20, 22, 24, 27, 30, 37, 39, 41, 45, 47, 49, 51, 53, 55, 57, 59, 61, 63 and 65
  6 light depths plus 225 m and 300 m

Stable N Isotopes

- See table 1

Turnover rate of labile organic N and P

- CTD # 1, 3, 6, 8, 13, 15, 21, 25, 28, 31, 35, 38, 40, 42, 46, 48, 50, 52, 54, 56, 58, 60 and 62
  One to four light depths

Results

No results are available for submission as the analyses of the samples collected will take place after the cruise. Data is due to be submitted to BODC within a year.

Table 1. SAP Stations

Sample	Date	Latitude	Longitude	Depth (m)	Volume (l)
SAP1	29/05/2005	27°31.80'S	013°26.57'W	50	1124
				100	122
				150	1121
SAP2	01/06/2005	22°52.81'S	25°00.03'W	50	1216
				100	2
				150	1473
SAP3	04/06/2005	12°24.79'S	24°59.79'W	50	1071
				100	7
				150	747
SAP4	07/06/2005	01°37.62'S	24°59.66'W	50	144
				100	248
				150	1076
SAP5	10/06/2005	07°14.94'N	28°27.26'W	50	1077
				100	1270
				150	0
SAP6	13/06/2005	15°47.75'N	32°36.10'W	50	1047
				100	1298
				150	1360
SAP7	15/06/2005	22°48.33'N	36°09.85'W	50	972
				100	1192
				150	1353
SAP8	17/06/2005	29°09.48'N	39°32.53'W	50	927
				100	1101
				150	1350

Sample	Date	Latitude	Longitude	Depth (m)	Volume (l)
SAP9	18/06/2005	31°22.99'N	42°08.65'W	50	937
				100	1100
				150	1333
SAP10	19/06/2005	33°34.68'N	45°32.4'W	50	800
				100	1282
				150	1342
SAP11	20/06/2005	34°57.17'N	42°33.57'W	50	850
				100	1211
				150	1343
SAP12	22/06/2005	37°20.92'N	33°39.63'W	50	767
				100	1317
				150	1320
SAP13	25/06/2005	44°44.11'N	22°52.4'W	50	702
				100	1325
				150	1164

References

Herut, B., Collier, R., Krom, M.D. 2002. The role of dust in supplying nitrogen and phosphorus to the southeast Mediterranean. Limnology and Oceanography 47(3), 870-878.

Karl, D, Letelier, R., Tupas, L., Dore, J., Christian, J., Hebel, D. 1997. The role of nitrogen fixation in biogeochemical cycling in the subtropical North Pacific Ocean. Nature 388(6642), 533-538.

Mahaffey, C., Williams, R.G., Wolff, G.A., Mahowald, N., Anderson, W., Woodward, M. 2003. Biogeochemical signatures of nitrogen fixation in the eastern North Atlantic. Geophysical Research Letters 30(6), art.1300.

Montoya, J.P., Carpenter, E.J., Capone, D.G. 2002. Nitrogen fixation and nitrogen isotope abundances in zooplankton of the oligotrophic North Atlantic. Limnology and Oceanography 47(6), 1617-1628.

Owens, N.J.P., Galloway, J.N., Duce, R.A. 1992. Episodic atmospheric nitrogen deposition to oligotrophic oceans. Nature 357(6377), 397-399.

Williams, R.G., Follows, M.J. 2003. Physical transport of nutrients and the maintenance of biological production. In: Fasham M. (Ed.). The role of the ocean carbon cycle in global change: Springer. p.19-51.

Collection of micosporin-like amino acid (MAA) samples.

ISOBEL COOK
Plymouth Marine Laboratory, Prospect Place, Plymouth, PL1 3DH, UK

Micosporin-like amino acid samples were collected each day in triplicate from the underway pumped water supply at the time of the midday cast. These samples are detailed in the Underway Sampling Master Log (Appendix 4). MAA samples were also taken from the midday cast at each light depth (97, 55, 33, 14, 1%) and down to max of 225 m.

Method

Samples were filtered onto 25 mm MF 300 Fisherbrand filter papers and then frozen.

Table 1. Details of casts and depths sampled for MAAs

CTD no.	Depth (m)	MAA
5	2	y
5	16	y
5	30	y
5	70	y
5	100	y
5	150	y
20	2	y
20	18	y
20	33	y
20	61	y
20	130	y
20	140	y
27	2	y
27	10	y
27	18	na
27	33	y
27	70	na
27	75	y
27	100	y
27	150	y
30	2	y
30	9	y
30	16	y
30	28	y
30	65	y
30	70	y
30	90	y
30	150	y
57	2	y
57	8	y
57	15	y
57	27	y
57	55	na
57	62	y
57	70	na
57	100	y
57	150	y
57	225	y
58	3	y
37	2	y
37	11	y
37	20	y
37	36	y
37	75	na
37	82	y
37	87	na
37	100	y
37	150	y
45	2	y
45	19	y
45	35	y
45	63	y
45	110	na
45	140	y
45	145	na
45	150	y
45	180	y
51	2	y
51	9	y
51	16	y
51	28	y
51	60	na
51	65	y
51	70	na
51	100	y
51	150	y
51	225	y

Appendix 1. Timetable of cruise sampling events D294/AMT16

Date	Local Time	GMT	Event
20/5/05	**1100**	**0900**	Depart Cape Town for anchorage to test deep-tow Winch
	1330	1130	Undertook virtual CTD (practice) run on deck
	1630	1430	Boat transfer - disembark Winch Engineers and deliver chemicals.
	1700	1500	Underway towards WP at **30°S, 016°E** to enable sampling in upwelling water.
21/5/05		**0000**	**32°25.5'S, 17°12.2'E**
	0430	0230	Hove-to, **Station #1, 31°58.2'S, 016°58.4'E**
	0435	0235	Bucket sample taken
	0440	0240	CTD O/B (1) **31°58.2'S 016°58.4'E**
	0523	0323	CTD I/B **31°57.6'S, 016°58.3'E**
	0535	0335	Deployed PES fish.
	1030	0830	Emergency muster and boat drills
	1107	0907	Hove-to, **Station #2, 31°00.5'S, 016°29.6'E**
	1112	0912	Bucket sample taken
	1116	0916	CTD O/B (2)
	1130	0930	FRRF O/B stbd quarter using crane
	1140	0940	FRRF I/B
	1142	0942	PRR O/B stbd qtr using crane
	1155	0955	PRR I/B
	1203	1003	CTD I/B **30°59.8'S, 016°29.2'E**
	1206	1006	Station complete, towards Saldana Bay CO 154^{o}(T) for boat transfer
	1901	1701	PES fish I/B
22/5/05		**0000**	**32°32.2'S, 017°22.6'E**
	0600	0400	approaching Saldana Bay
	1042	0842	boat transfer complete, underway toward WP1, CO 282°(T)
	1115	0915	deep tow Winch trial started
	1154	0954	deep tow wire I/B
	1200	1000	noon position 33°04.2'S, 017°22.5'E
	1212	1012	PES and TM fishes O/B
	1224	1024	TMF redeployed
	1700	1500	Reduced speed due to adverse weather
	2315	2115	vessel hove to secure MVP davit
	2330	2130	Davit secure, CO 282° (T)
23/5/05		**0020**	**32°44.8'S, 15°45.6'E**
	0200	0100	clocks retarded 1hr to GMT + 1
	0955	0855	MVP O/B
	1200	1100	noon position 32°43.6'S, 013°56.9'E
	1403	1303	MVP I/B
	1408	1308	MVP O/B
	1802	1702	MVP I/B for checks
	1822	1722	MVP O/B
	2200	2100	MVP recovered and re-deployed
24/5/05		**0000**	**32°00.3'S, 011°14.1'E**
	0224	0124	MVP recovered and re-deployed
	0336	0236	MVP I/B
	0430	0330	Vessel hove-to **Station #3, 31°50.0'S, 010°30.1'E**
	0437	0337	CTD O/B, 31°50.0'S, 010°30.0'E

Date	Local Time	GMT	Event
	0518	0418	CTD I/B, 31°50.4'S, 010°29.9'E
	0536	0436	TMF I/B, resumed Co & speed
	1054	0954	Hove-to on **Station # 4, 31°37.5'S, 09°19.6'E**
	1105	1005	Clean CTD O/B 31°34.9'S, 009°19.7'E
	1107	1007	PRR optical profiler O/B
	1110	1010	CTD recovered and re-deployed to set misfired bottle
	1118	1018	PRR I/B, FRRF O/B
	1136	1036	FRRF I/B
	1140	1040	Bucket deployed for surface water
	1207	1107	CTD I/B 31°34.3'S, 009°19.4'E, resume course
	1838	1738	MVP O/B
	2210	2110	MVP O/B, checked and re-deployed
25/05/05		**0000**	**31°02.5'S, 006°27.0'E**
	0206	0106	MVP O/B, checked and re-deployed
	0341	0241	MVP I/B
	1055	0955	Hove-to **Station # 5, 30°38.0'S, 04°13.4'E**
	1058	0958	CTD O/B plus PRR optics, 30°38.1'S, 004°13.3'E
	1109	1009	PRR I/B
	1111	1011	FRRF O/B
	1136	1036	FRRFI/B and bucket sample
	1149	1049	CDT I/B 30°38.5'S, 004°12.5'E, resume course
	1200	1100	Noon position, 30°38.7'S, 004°12.1'E
	1939	1839	MVP O/B
	2200	2100	MVP I/B checked and re-deployed
	2330	2230	MVP I/B
	2338	2238	MVP O/B
26/05/05		**0005**	**30°03.4'S, 001°22.6'E**
	0205	0105	MVP I/B checked and re-deployed
	0342	0242	MVP I/B
	0428	0328	Hove to on **Station # 6, 29°58.0'S, 00°42.0'E**
	0435	0335	CTD O/B 29°58.0'S, 00°42.0'E
	0518	0418	CTD I/B 29°57.8'S, 00°41.9'E, resume passage
	0540	0440	MVO O/B
	0855	0755	vessel hove to deploy TMF
	0926	0826	vessel underway on course (282^{o})
	1200	1100	Noon position, 29°42.8'S, 00°37.2'W
	1336	1236	MVP I/B for checks and re-deployed
	1726	1626	MVP shortened for inspection and re-deployed
	2220	2120	MVP recovered, checked and re-deployed
27/05/05		**0000**	**29°10.8'S, 03°27.0'W**
	0200	0100	clocks retarded 1 hour to GMT
		0158	MVP I/B for checks and re-deployed
		0550	MVP I/B
		0712	MVP O/B
		1057	hove to on **Station # 7, 28°44.6'S, 05°45.5'W**
		1059	FRRF O/B
		1102	Clean CTD O/B, 28°44.6'S, 05°45.4'W
		1139	FRRF recovered and PRR optics deployed
		1148	CTD I/B 28°44.6'S, 05°45.1'W
		1150	PRR recovered

Date	Local Time	GMT	Event
		1152	underway to next Station
28/05/05		**0000**	**28°12.4'S, 08°31.6'W**
		0428	hove to on **Station # 8, 28°04.2'S, 09°14.9'W**
		0432	CTD 8 O/B 28°04.2'S, 09°14.9'W
		0514	CTD I/B
		0525	Surface net O/B
		0552	Net I/B
		0607	SAPS O/B
		0617	SAP 2 lost down wire, recovering
		0629	SAPS aborted, resume passage
		1200	Noon position, 27°50.4'S, 10°28.3'W
		1219	Hove to on **Station, # 9, 27°49.8'S, 10°30.9'W,** PRR optics O/B
		1222	CTD 9 O/B 27°49.8'S, 10°30.9'W
		1226	PRR Optics O/B
		1230	FRRF O/B
		1314	FRRF I/B
		1318	CTD I/B resume passage
29/05/05		**0100**	**27°21.1'S, 12°57.5'W**
		0335	Hove to on **Station # 10, 27°15.3'S, 13°27.0'W,** CTD 10 O/B
		0400	CTD failed, I/B for re-termination
		0444	SAP1 O/B using trawl wire
		0446	winch alarm on trawl winch fails
		0518	Resume SAPS
		0526	SAP2 O/B
		0532	SAP3 O/B
		0721	SAP3 I/B
		0726	SAP2 I/B
		0757	CTD 11 O/B, 27°13.8'S, 13°26.6'W
		0840	CTD 11 I/B, 27°13.5'S, 13°26.7'W, resume passage
		1059	Vessel hove to on **Station # 11, 27°09.9'S, 13°49.7'W**
		1102	CTD 12 O/B, 27°09.9'S, 13°49.7'W, PRR optics O/B
		1247	CTD 12 I/B, 27°10.0 'S, 13°49.6'W
		1200	Noon position, 27°10.0'S 13°49.5'W
30/05/05		**0014**	**27.04.1'W, 14°25.2'E**
	0100	0200	clocks retarded to GMT-1
	0335	0435	Hove to on **Station 12, CTD # 13 O/B 26°31.6'S, 17°13.7'W** to 1000m
	0353	0453	Surface net O/B
	0419	0519	Net I/B
	0449	0549	CTD I/B 26°31.9'S, 17°13.4'N and resume passage towards 25°S, 25°W
	1100	1200	Hove to on **Station 13, 26°17.1'S, 18°27.7'W,** FRRF O/B
	1103	1103	CTD # 4 O/B, 26°17.1'S, 18°27.7'W
	1150	1250	CTD I/B, 26°16.9'S, 18°27.8'W, FRRF I/B
	1158	1258	completed station and resume course
31/05/05		**0100**	**25°44.3'S, 21°00.8'W**
	0427	0527	Hove to on **Station 14, 25°36.3'S, 21°56.0'W**
	0431	0531	CTD # 15 O/B to 300m, 25°36.4'S, 21°56.0'W
	0514	0614	CTD I/B, 25°36.0'S, 21°55.9'W, resume passage
	1057	1157	Hove to on **Station 15, 25°28.9'S, 23°04.7'W, optics O/B**
	1107	1207	CTD # 16 to 300m O/B, 25°23.1'S, 23°04.7'W
	1145	1245	CTD I/B, 25°23.1'S, 23°04.8'W

Date	Local Time	GMT	Event
	1155	1255	optics recovered
	1200	1300	Noon position 25°22.7'S, 23°05.4'W
	1857	1957	24°22.2'S, 23°57.7'W MVP O/B
	2000	2100	24°11.4'S, 24°07.1'W MVP I/B
01/06/05		**0119**	**23°32.1'S, 24°40.9'W**, MVP I/B (launch not recorded)
	0246	0346	A/C 000°T
	0426	0526	Hove to on **Station 16, 22°52.8'S, 25°00.1'W**
	0435	0535	CTD # 17 O/B, 22°52.8'S, 25°00.0'W
	0447	0547	CTD at 300m, surface net O/B
	0508	0608	Net I/B
	0520	0620	CTD I/B, 22°52.7'S, 25°00.0'W
	0608	0708	1st SAP O/B, 22°52.6'S, 24°59.8'W
	0617	0717	2nd SAP O/B, 22°52.6'S, 24°59.7'W
	0622	0722	3rd SAP O/B, 22°52.6'S, 24°59.6'W
	0825	0925	SAPS I/B, 22°52.6'S, 24°58.7'W, resume passage
	1054	1154	Hove to on **Station 17, 22°27.2'S, 25°00.2'W**
	1057	1157	Optics O/B
	1106	1206	Optics I/B
	1108	1208	CTD # 18 O/B to 5000m, 22°27.3'S, 25°00.0'W, optics 2 O/B
	1113	1213	Optics I/B, FRRF O/B
	1142	1242	FRRF I/B,
	1525	1652	CTD I/B, 22°27.6'S, 24°58.9'W
	2205	2305	MVP deployed
	2220	2320	MVP recovered
02/06/05		**0100**	**20°50.1'S, 25°00.1'W**
	0220	0320	MVP O/B
	0241	0341	MVP I/B
	0332	0432	Hove to on **Station 18,** CTD #19 O/B to 1000m **20°11.9'S, 24°59.8'W**
	0352	0452	Surface net O/B
	0535	0635	Completed sampling, resumed passage (000°T)
	1053	1153	Hove to on **Station 19, 19°14.2'S, 25°00.1'W**
	1058	1158	CDT # 20 and FRRF O/B, 19°14.2'S, 25°00.0'W
	1141	1241	CTD I/B 19°14.5'S, 25°00.0'W
	1158	1258	FRRF recovered
	1200	1330	Noon position 19°14.7'S, 24°59.9'W
	1230	1330	Station completed, Co 000° (T)
	2022	2122	MVP deployed
	2040	2140	MVP recovered
03/06/05		**0100**	**17°05.4'S, 24°59.9'W**
	0145	0245	MVP O/B
	0200	0300	MVP I/B
	0425	0525	Hove to on **Station 20, 16°16.8'S 25°00.0'W**
	0442	0452	CTD # 21 O/B to 300m, 16°16.7'S, 24°59.9'W
	0524	0624	CTD I/B, 16°16.5'S, 24°59.7'W
	0613	0713	Completed water sampling, resume course
	1055	1155	Vessel hove to on **Station 21, 15°24.5'S, 25°00.1'W,** FRRF O/B
	1100	1200	CTD # 22 O/B to 300m, 15°24.5'S, 25°00.0'W
	1135	1235	FRRF I/B
	1140	1240	CTD I/B 15°24.7'S, 25°00.0'W
	1200	1300	Noon position 15°24.7'S, 25°00.01'W

Date	Local Time	GMT	Event
	1222	1322	Completed sampling, underway 000^{o} (T)
	1953	2053	MVP O/B
	2015	2115	MVP I/B
04/06/05		**0100**	**13°15.05'S, 24°59.9'W**
	0024	0124	13°10.3'S, 25°00.0'W MVP O/B
	0046	0146	MVP I/B
	0425	0525	Hove to for **Station 22, 12°24.8'S, 24°59.9'W**
	0436	0536	CTD #' 23 O/B 12°24.7'S, 24°59.7'W
	0517	0617	CTD I/B, 12°24.6'S, 24°59.5'W
	0601	0701	1st SAP O/B
	0607	0707	2nd SAP O/B
	0708	0808	3rd SAP O/B
	0815	0915	SAPS I/B
	0825	0925	Vessel proceeding off station, course 000^{o} (T)
	1054	1154	Vessel hove to on **Station 23, 11°56.9'S, 25°00.0'W**
	1056	1156	optics O/B
	1103	1203	CTD # 24 O/B, 11°57.0'S, 25°00.4'W, optics I/B
	1108	1208	FRRF O/B
	1135	1235	FRRF I/B
	1146	1246	CTD I/B
	1200	1300	Noon position, 11°56.9'S, 25°00.0'W
	1224	1324	Station completed, course 000^{o} (T)
	1644	1744	NVP O/B
	1704	1804	MVP I/B
	1946	2046	MVP OB
	2005	2105	MVP I/B
	2356	0056	MVO O/B
05/06/05		**0011**	**09°41.2'S, 25°00.3'W**, MVP I/B
	0333	0433	Hove to for **Station 24, 09°04.8'S, 24°59.8'W**, CTD # 25 O/B to 1000m
	0447	0547	CTD I/B, 09°04.1'S, 24°59.5'W [wire twisted – so cropped for re-termination]
	0546	0646	resumed passage
	1030	1130	Vessel hove to on **Station 25, 08°10.5'S, 25°00.0'W**, to commence load test on CTD termination.
	1050	1150	Optics O/B
	1126	1226	Optics I/B
	1128	1228	CTD aborted because of winch problems
	1200	1300	Noon position 08°09.7'S, 25°00.0'W, resume passage
	1700	1800	MVP O/B
	1721	1821	MVP I/B
	2000	2100	MVP O/B
	2025	2125	MVP I/B
06/06/05		**0126**	**05°48.2'S, 25°00.6'W,** MVP O/B
	0043	0143	MVP I/B
	0400	0500	Vessel hove to on **Station 26, 05°09.8'S, 25°00.2'W**
	0420	0520	CTD # 26 O/B, 05°09.8'S, 25°00.1'W
	0513	0613	CTD I/B
	0607	0707	Completed sampling, resumed course
	1058	1158	Vessel on **Station 27, 04°15.1'S, 24°59.8'W**, optics O/B
	1101	1201	CTD # 27 to 300m, 04°15.1'S, 24°59.8'W

Date	Local Time	GMT	Event
	1108	1208	Optics I/B
	1113	1213	FRRF O/B
	1143	1243	FRRF I/B
	1152	1252	CTD I/B, 04°14.9'S, 25°00.0'W, resume passage
	1200	1300	Noon position 04°14.2'S, 25°00.3'W
	1609	1709	MVP O/B
	1627	1727	MVP I/B
	1820	1920	reduced to 9kts to improve sampling over equatorial region.
	2005	2105	MVP O/B
	2019	2119	MVP I/B
	2320	0020	MVP O/B
	2340	0040	MVP I/B
07/06/05		**0100**	**02°10.1'S, 24°59.9'W**
	0400	0500	Hove to on **Station 28, 01°37.6'S, 24°59.6'W**
	0402	0502	CTD # 28 O/B to 300m, 01°37.7'S 24°59.6'W
	0446	0546	CTD I/B, 01°38.2'S, 24°59.7'W
	0539	0639	SAP 1 O/B
	0544	0644	SAP 2 O/B
	0548	0648	SAP 3 O/B
	0603	0703	Surface net O/B
	0631	0731	Surface net I/B
	0743	0843	SAPS recovered, resume passage 9kts
	1155	1255	MVP O/B
	1200	1300	Noon position, 01°02.0'S, 25°00.0'W
	1550	1650	MVP O/B
	1709	1809	MVP I/B
	1844	1944	Crossed line and A/C to 335^{o} (T)
	1930	2030	MVP O/B
	1946	2046	MVP I/B
08/06/06		**0100**	**00°44.7'N, 25°05.0'W**
	0307	0407	Vessel hove to on **Station 29, 01°10.3'N, 25°33.8'W,** CTD O/B to 1000m
	0424	0524	1000m CTD I/B, 01°10.6'N, 25°34.3'W, resumed passage.
	1054	1154	Vessel hove to on **Station 30, 02°03.5'N, 25°58.9'W**
	1058	1158	CTD O/B to 300m 02°03.5'N, 25°58.9'W, optics O/B
	1145	1245	CTD I/B 02°03.4'N, 25°59.6'W
	11 53	1253	Optics I/B
	1158	1258	Proceeding to next Station
	1200	1300	Noon position, 02°03.5'N, 25°59.8'W
	1616	1716	MVP O/B
	1633	1733	MVP I/B
	2015	2115	MVP O/B
	2027	2127	MVP I/B
	2553	0053	MVP O/B
09/06/05		**0100**	**03°44.4'N, 26°46.8'W**
	0008	0108	MVP I/B
	0354	0454	Vessel hove to on **Station 31, 04°16.1'N, 27°01.8'W**
	0502	0402	CTD # 31 O/B to 300m, 04°16.32'N, 27°01.6'W
	0409	0509	Surface net O/B
	0434	0534	Net I/B
	0502	0602	CTD I/B, 04°16.9'N, 27°01.2'W

Date	Local Time	GMT	Event
	1100	1200	Vessel hove to on **Station 32, 05°01.1'N, 27°23.7'W**
	1115	1215	CTD # 32 O/B to 4360m 05°09.2'N, 27°26.5'W
	1118	1218	Optics O/B
	1125	1225	Optic I/B
	1130	1230	FRRF O/B
	1200	1300	Noon position, 05°09.5'N 27°25.8'W
	1209	1309	FRRF I/B
	1437	1537	CTD I/B, resume passage course 335^{o} (T)
	1644	1744	MVP O/B
	1729	1829	MVP I/B
	1952	2052	MVP O/B
	2020	2120	MVP I/B
10/06/05		**0100**	**06°38.2'N, 28°05.2'W**
	0024	0124	MVP O/M
	0039	0139	MVP I/B
	0357	0457	vessel hove to on **Station 33, 07°14.9'W, 28°27.3'W**
	0404	0504	CTD # 33 O/B to 300m 07°15.0'N, 28°27.2'W
	0413	0513	Surface net O/B
	0441	0541	Net I/B
	0455	0555	CTD I/B, 07°14.8'N, 28°26.8'W
	0548	0648	SAP1 O/B
	0553	0653	SAP 2 O/B
	0558	0658	SAP 3 O/B
	0756	0856	SAPs completed, resume passage.
	1100	1200	Vessel hove to on **Station 34, 07°41.7'N, 28°40.8'W**
	1105	1205	CTD # 34 O/B to 300m, 07°41.7'N 28°40.7'W, optics O/B
	1112	1212	Optics recovered
	1116	1216	FRRF O/B
	1148	1248	CTD I/B, 07°41.8'N, 28°40.4'W, FRRF I/B
	1150	1250	Vessel resuming passage
	1225	1325	Deep tow trial O/B
	1439	1539	Deep tow trial completed
11/05/05		**0100**	**09°32.3'N, 29°23.6'W**
	0305	0405	Vessel on **Station 35**, CTD #35 O/B to 1000m, **10°00.4'N, 29°47.6'W**
	0328	0428	Surface net O/B
	0351	0451	Net I/B
	0428	0528	CTD I/B, 10°00.8'N, 29°47.7'W, resume passage
	1055	1155	Vessel hove to in position for **Station 36, 10°58.8'N, 30°15.8'W**
	1057	1157	CTD O/B, optics O/B
	1100	1200	CTD cast aborted due to wire jumping sheave wire stopped off.
	1130	1230	CTD recovered
	1132	1232	Optics completed and I/B
	1142	1242	Station completed, resume passage at 6kts
	1200	1300	Noon position, 11°00.1'N, 30°17.1'W
12/06/05		**0100**	**12°10.0'N, 30°50.5'W**
	1055	1155	Vessel hove to on **Station 37, 13°11.6'N, 31°15.9'W**
	1059	1159	CTD 37 O/B to 300m, 13°11.6'S, 31°20.6'W & optics O/B
	1101	1201	Optics I/B
	1110	1210	FRRF O/B
	1144	1244	CTD I/B, 13°11.7'N, 31°20 .7'W

Date	Local Time	GMT	Event
	1147	1247	FRRF I/B
	1152	1252	Vessel resume passage
	1200	1300	Noon position: 13°12.7'N, 31°21.3'W
13/06/07		**0100**	**15°11.9'W, 32°20.2'W**
	0336	0436	**On Station 38 15°45.8'N, 32°36.1'W**, CTD 38 O/B to 300m
	0348	0448	Surface net O/B
	0412	0512	Net I/B
	0425	0525	CTD I/B 15°46.0'N, 32°35.7'W
	0516	0616	SAP 1 O/B
	0520	0620	SAP 2 O/B
	0524	0624	SAP 3 O/B
	0728	0828	All SAPs recovered, resume passage.
	1055	1155	Vessel hove to on **Station 39, 16°19.3'N 32°53.2'W**, optics O/B
	1059	1159	CTD O/B 16°19.4'N, 32°53.2'W
	1141	1241	CTD I/B, 16°19.6'N, 32°53.2'W
	1147	1247	Optics I/B
	1152	1252	Resume passage.
14/06/05		**0100**	**18°27.8'N, 33°57.4'W**
	0302	0402	On **Station 40, 18°57.9'N, 34°12.4'W**, CTD # 40 O/B to 1000m
	0336	0436	Net O/B
	0357	0457	Net I/B
	0432	0532	CTD I/B, 18°58.1'N, 34°12.4'W
	1057	1157	Vessel hove to at **Station 41, 20°04.9'N, 34°46.4'W**, Optics O/B
	1059	1159	CTD # 41 O/B to 300m 20°04.9'N, 34°46.4'W
	1105	1205	Optics I/B
	1107	1207	FRRF O/B
	1140	1240	CTD I/B, 20°05.6'N, 34°46.5'W
	1155	1255	FRRF I/B, resume passage
	1200	1300	Noon position, 20°06.0'N, 34°46.5'W
15/06/05		**0100**	**22°24.0'N, 35°57.7'W**
	0332	0442	On **Station 42, 22°48.3'N, 36°09.8'W**, CTD # 42 O/B to 300m
	0418	0518	CTD I/B 22°48.1'N, 36°09.6'W (misfires at 14m) –no data
	0534	0634	SAP 1 O/B
	0538	0638	SAP2 O/B
	0542	0642	SAP3 O/B
	0732	0832	All SAPS recovered, resume passage
	1056	1156	Vessel hove to on **Station 43, 23°21.6'N 36°27.4'W**
	1100	1200	CTD # 43 O/B to 5900m, 23°21.6'N, 36°27.4'W
	1107	1207	FRRF O/B
	1148	1248	FRRF I/B
	1450	1550	CTD I/B, 23°21.7'N, 36°27.2'W, Co 335°(T)
16/06/05		**0100**	**25°01.0'N, 37°19.2'W**
	0354	0454	Vessel hove to on **Station 44, 25°40.9'N, 37°40.3'W**
	0401	0501	CTD O/B to 300m, 25°40.9'N, 37°40.2'W
	0409	0509	CTD aborted and recovered
	0431	0531	Net O/B
	0450	0550	Net I/B, resume passage
	1216	1316	On **Station 45, 26°50.4'N, 38°17.6'W** Optics O/B
	1224	1324	Optics rig I/B
	1229	1329	FRRF O/B

Date	Local Time	GMT	Event
	1232	1332	CTD 45 O/B to 300m, 26°50.5'N, 38°17.8'W
	1304	1404	FRRF I/B
	1322	1422	CTD I/B, 26°50.6'N, 38°18.3'W, resume passage, course 335°(T)
17/06/05		**0100**	**28°48.0'N, 39°20.5'W**
	0337	0447	On **Station 46, 29°09.5'N, 39°32.5'W**, CTD #46 O/B to 1000m
	0350	0450	Surface net O/B from stbd quarter
	0412	0512	Net I/B
	0456	0556	CTD I/B, 29°08.9'N, 39°32.4'W
	0603	0703	SAP 1 O/B
	0607	0707	SAP 2 O/B
	0610	0710	SAP 3 O/B
	0805	0905	SAPs recovered, resume passage.
	1015	1115	Vessel a/c to investigate object in water
	1048	1148	Object identified as Nav. Buoy, possibly adrift from Azores.
	1114	1214	Vessel on **Station 47, 29°27.3'N, 39°48.8'W**, optics O/B
	1116	1216	CTD O/B to 300m, 29°27.3'N, 39°48.9'W
	1206	1306	CTS and optics I/B, 29°27.2'N, 39°48.9'W
	1344	1444	CTD wire streamed astern at 8kts
	1600	1745	Emergency drill and lifeboat muster
	1725	1825	CTD wire recovered, resumed full speed.
18/06/05		**0100**	**30°52.7'N, 41°32.0'W**
	0345	0445	Vessel hove to on **Station 48, 31°23.0'N, 42°08.8'W**
	0401	0501	CTD O/B to 300m, 31°23.0'N, 42°08.6'W
	0416	0516	Surface net O/B
	0440	0540	Surface net I/B
	0446	0456	CTD I/B 31°23.2'N, 42°08.1'W
	0541	0641	SAP 1 I/B
	0545	0645	SAP 2 O/B
	0549	0649	SAP3 O/B
	0738	0838	SAPS recovered, resume passage
	1054	1154	Vessel on **Station 49, 31°43.4'N, 42°39.0'W**
	1055	1155	CTD O/B to 3300m, 31°43.4'N, 42°39.0'W, optics O/B
	1105	1203	optics I/B
	1107	1207	FRRF O/B
	1135	1235	FRRF I/B
	1140	1240	CTD I/B 31°43.2'N, 42°39.2'W
	1145	1245	Vessel resumes passage
	1200	1300	Noon position, 31°44.7'N, 42°41.6'W
19/06/05		**0100**	**33°09.5'N, 44°52.6'W**
	0354	0454	Vessel hove to on **Station 50, 33°47.7'N, 45°32.3'W**
	0402	0502	CTD O/B, 33°34.6'N, 45°32.3'W
	0442	0542	CTD I/B 33°34.5'N, 45°31.8'W
	0531	0631	SAP 1 O/B
	0535	0635	SAP 2 O/B
	0539	0639	SAP 3 O/B
	0730	0830	All SAPS recovered, resume passage.
	1105	1205	Vessel hove to on **Station 51, 33°55.6'N, 46°04.5'W**
	1107	1207	CTD O/B to 300m 33°55.6'N, 46°04.5'W, optics O/B
	1112	1212	Optics I/B
	1151	1251	CTD I/B 33°55.3'N, 46°94.8'W

Date	Local Time	GMT	Event
	1200	1300	Noon position, 33°55.3'N, 46°04.8'W
20/06/05		**0100**	**34°39.6'N, 43°26.0'W**
	0354	0454	Vessel on **Station 52, 34°51.1'N 42°44.7'W**
	0400	0500	CTD O/B to 1000m 34°54.1'N, 42°33.6'W
	0508	0608	CTD I/B 34°54.9'N, 42°32.8'W
	0607	0707	SAP 1 O/B
	0612	0712	SAP 2 O/B
	0716	0816	SAP 3 O/B
	0800	0900	SAPs I/B resume passage
	1056	1156	Vessel hove to on **Station 53, 35°05.9'N, 41°50.7'W**, optics O/B
	1104	1204	Optics I/B,
	1105	1205	CTD O/B to 330m, 35°05.9'N, 41°50.7'W
	1110	1210	FRRF O/B
	1144	1244	FRRF I/B
	1152	1252	CTD I/B, 35°05.6'N 41°50.0'W
	1200	1300	Noon position 35°05.5'N, 41°49.7'W
21/06/05		**0100**	**35°55.7'N, 38°50.9'W**
	0335	0435	**On Station 54, 36°03.3'N, 38°24.5'W**, CTD # 54 O/B to 300m
	0422	0522	CTD I/B, 36°03.8'N, 38°20.6'W
	1058	1158	Vessel hove to on **Station 55, 36°26.6'N, 36°55.2'W**, optics O/B
	1101	1201	CTD O/B to 300m, 36°27.6'N, 36°55.2'W
	1109	1209	FRRF O/B
	1136	1236	Optic I/B, CTD I/B 36°27.4'N, 36°55.2'W
	1200	1300	Noon position, 36°28.00'N, 36°53. 5'W
22/06/05		**0100**	**37°10.8'N, 34°17.0'W**
	0312	9412	**On Station 56, 37°20.9'N, 33°39.6'W** CTD O/B to 300m
	0401	0501	CTD I/B 37°20.8'N, 33°39.7'W
	0452	0552	SAP 1 O/B
	0456	0556	SAP 2 O/B
	0500	0600	SAP 3 O/B
	0647	0747	SAPs recovered, resume passage
	1056	1156	Vessel hove to on **Station 57, 37°34.4'N, 32°50.2'W**, optics O/B
	1057	1157	CTD # 57 O/B, 37°34.4'N, 32°50.2'W
	1102	1103	optics I/B
	1107	1207	FRRF O/B
	1136	1236	FRRF I/B
	1139	1239	CTD I/B, 37°34.1'N, 32°50.5'W
	1147	1247	Vessel resuming passage
	1200	1300	Noon position, 37°34.7'N, 32°48.0'W
	1336	1446	Vessel hove to for CTD Winch tests
	1436	1536	test completed, Co 071° (T)
23/06/07		**0100**	**38°12.4'N, 30°15.1'W**
	0202	0302	**Station 58, CTD O/B to 300m 38°18.4'N, 30°03.8'W**
	0209	0309	Surface net O/B
	0231	0331	Net I/B
	0251	0351	CTD I/B 38°17.9'N, 30°03.8'W, resume Co 055^{o} (T)
	0318	0418	38°20.0 30°00.0'W A/C 045^{o} (T)
	1055	1155	Vessel on **Station 59, 39°15.8'N, 28°49.3'W**, optics O/B
	1059	1159	CTD O/B, 39°15.8'N 28°49.3'W
	1142	1242	Optics I/B

Date	Local Time	GMT	Event
	1145	1245	CTD I/B, 39°15.9'W 28°49.6'W
	1200	1300	Noon position 39°17.0'N, 28°48.2'W
24/06/05		**0100**	**40°53.2'N, 26°42.3'W**
	0211	0311	**Station 60, 41°08.3'N, 26°22.6'W,** CTD # 60 O/B to 1000m
	0220	0320	Surface net O/B
	0242	0342	Net I/B
	0332	0432	CTD I/B, 41°08.6'N, 26°22.7'W, Co 045^{o} (T)
	1057	1157	Vessel on **Station 61, 42°06.7'N, 25°04.2'W**, optics O/B
	1103	1203	CTD O/B to 300m, 42°06.7'N, 25°04.2'W, optics I/B
	1108	1208	FRRF O/B
	1138	1238	FRRF I/B
	1143	1243	CTD I/B, 42°06.4'N, 25°04.1'W, resume passage
	1715	1815	Reduced speed to 9.5knots
25/05/05		**0100**	**43°34.7'N, 23°05.1'W**
	0132	0232	**Station 62, 43°44.1'N, 22°52.4'W**, CTD # 62 O/B
	0143	0143	Surface net O/B
	0205	0305	Net I/B
	0216	0316	CTD I/B, 43°44.2'N, 22°52.3'W
	0304	0404	SAP 1 O/B
	0308	0408	SAP 2 O/B
	0312	0412	SAP 3 O/B
	0506	0606	SAPS recovered, resume passage
	1051	1151	Vessel on **Station 63, 44°22.1'N, 21°59.7'W**
	1055	1155	Optic O/B
	1102	1202	Optics I/B, CTD # 63 O/B to 300m, 44°22.1'N, 21°59.8'W
	1105	1205	FRRF O/B
	1136	1236	FRRF I/B
	1140	1240	CTD I/B, 44°22.3'N, 21°59.9'W
	1200	1300	Noon position, 44°23.8'N, 21°58.0'W
26/06/05		**0100**	**45°42.1'N, 20°07.0'W,** Clocks fwd to GMT
		0405	**Station 64, 45°01.1'N, 19°40.1'W,** CTD O/B to 1000m
		0448	Surface net O/B
		0449	Recovering CTD from 1000m – unable to fire bottles
		0509	Net I/B
		0516	Aborted CTD I/B, prep Titanium CTD unit
		0541	Ti CDT # 64t O/B to 300m 45°02.1'N, 19°40.2'W
		0622	CTD I/B 46°02.3'N, 19°40.0'W resume passage
		0844	Vessel A/C to 075° (T) at 46°16.9'N, 19°17.1'W
		1052	Vessel hove to on Station **65 46°21.9'N, 18°51.0'W** Optics O/B
		1057	Optics rig I/B
		1105	CTD # 65 O/B to 300m, 46°21.9'N, 18°51.2'W, FRRF O/B
		1129	FRRF I/B
		1145	CTD I/B 46°22.1'N, 18°51.5'W
		1152	Vessel resuming passage
		1200	Noon position, 46°22.3'N, 18°50.2'W
27/06/05		**0100**	**46°54.7'N, 15°55.1'W**
		0355	Vessel hove to on **Station 66 47°02.0'N 15°15.6'W**
		0403	CTD # 66 O/B to 300m 47°02.0'N 15°15.5'W
		0412	Surface net O/B
		0439	Net I/B

Date	Local Time	GMT	Event
		0500	CTD I/B 47°01.8'N 15°14.5'W, resume passage
		1054	Vessel hove to on **Station 67 47°16.5'N 13°50.0'W**; optics O/B
		1100	Optic I/B
		1109	FRRF O/B
		1131	FRRF I/B
		1140	CTD I/B, 47°16.9'N, 13°58.2'W
		1145	Vessel resuming passage
		1200	Noon position 47°17.4'N, 13°55.3'W
28/06/05		**0100**	**47°42.0 11°17.4**, clocks fwd to BST
	0732	0632	48°00.0'N, 10°00.0'W, A/c to 061^{o} (T)
	1612	1512	PES fish recovered
	1800	1700	End of underway sampling; completed science
29/06/05		**0718**	Embarked pilot; entering Falmouth UK

Appendix 2. D294 AMT16 summary of CTD casts

Date	Lat	Lon	Time (UTC)	Station #	CTD Cast #	T °C	S PSU	Fluor Mv	No_3+ um	Chlor Mg/m^3	Mix l depth m	DCM Depth m	Total Depth m
21/05/05	31°58.23'S	16°58.42'E	0226	1	1	18.9	35.42	0.263	1.64	2.66	50		260
	31°00.39'S	16°29.55'E	0907	2	2	16.8	35.18	0.125	no data	0.84	30		286
24/05/05	31°49.98'S	10°30.01'E	0329	3	3	19.18	35.51	0.157	0.64	0.47	96		4900
	31°34.88'S	09°19.66'E	1003	4	4	19.6	35.70	0.039	0.15	0.25	115		4918
25/05/05	30°38.01'S	04°13.38'E	0958	5	5	19.99	35.71	0.049	0.09	0.18	85		5103
26/05/05	29°57.97'S	00°42.15'E	0332	6	6	20.07	35.84	0.069	<0.03	0.14	95		2811
27/05/05	28°44.59'S	05°45.41'W	1102	7	7	20.12	35.95	0.009	0.05	0.07	80	100	4456
28/05/05	28°04°18'S	09°14.89'W	0431	8	8	20.96	36.11	0.022	0.07	0.070	80	110	3868
	27°49.81'S	10°30.81'W	1217	9	9	20.93	36.09	0.011	<0.03	0.071	90	125	3556
29/05/05	27°13.80'S	13°26.57'W	0752	10	11	22.45	35.54	0.025	<0.03	0.095	95	130	3500
	27°09.99'S	13°49.72'W	1100	11	12	22.46	36.52	0.007	<0.03	0.112	110	130	2974
30/05/05	26°31.59'S	17°13.68'W	0431	12	13	23.07	36.72	0.022	<0.03	0.089	100	~110	4300
	26°17.02'S	18°27.70'W	1200	13	14	22.79	36.58	0.012	<0.03	0.093	100	130	3932
31/05/05	25°36.26'S	21°55.97'W	0526	14	15	22.72	36.41	0.025	<0.03	0.072	80	120	4722
	25°23.04'S	23°04.69'W	1203	15	16	23.90	36.76	0.016	<0.03	0.095	85	120	5141
1/06/05	22°52.81'S	25°00.03'W	0532	16	17	25.11	37.12	0.027	<0.03	0.07	80	130	5706
	22°27.26'S	25°00.00'W	1205	17	18	25.19	37.12	-0.013	<0.03	0.07	?	135	5412
02/06/05	20°11.96'S	24°59.84'W	0429	18	19	25.47	37.28	0.019	0.09	0.06	90	150	4846
	19°14.23'S	25°00.03'W	1155	19	20	25.25	37.21	0.014	<0.03	0.07	95	145	5372
03/06/05	16°16.74'S	24°59.96'W	0537	20	21	25.74	37.28	0.024	<0.03	0.07	90	150	5235
	15°24.50'S	25°00.06'W	1158	21	22	25.68	37.22	0.008	<0.03	0.07	90	140	5044
04/06/06	12°24.79'S	24°59.79'W	0527	22	23	26.61	37.02	0.028	0.10	0.07	90	135	5388
	11°56.98'S	25°00.51'W	1154	23	24	26.89	36.96	0.014	0.09	0.09	70	125	5535
05/06/05	09°04.82'S	24°59.81'W	0429	24	25	27.64	36.31	0.0397	<0.03	0.13	90	100	5700
				25	FAIL					0.20			
06/06/05	05°09.85'S	25°00.14'W	0510	26	26	27.76	35.77	0.041	<0.03	0.15	85	90	5388

Date	Lat	Lon	Time (UTC)	Station #	CTD Cast #	T °C	S PSU	Fluor Mv	No_3+ um	Chlor Mg/m^3	Mix l depth m	DCM Depth m	Total Depth m
	04°15.07'S	24°59.87'W	1202	27	27	27.91	35.77	-0.029	<0.03	0.15	60	80	5046
07/06/05	01°37.62'S	24°59.66'W	0458	28	28	25.97	35.99	0.051	<0.03	0.23	70	70	4805
08/06/07	01°10.30'N	25°33.73'W	0404	29	29	28.37	35.10	0.027	<0.03	0.17	80	50	3600
	02°03.51'N	25°58.88'W	1155	30	30	28.46	35.06	0.072	<0.03	0.15	40	70	3961
09/06/05	04°16.18'N	27°01.68'W	0458	31	31	28.24	35.22	0.028	<0.03	0.15	75	85	4246
	05°19.13'N	27°27.10'W	1204	32	32	28.89	35.36	-0.029	0.07	0.20	~	90	4361
10/06/05	07°14.94'N	28°27.26'W	0500	33	33	28.41	35.33	0.033	0.07	0.16	25	60	4207
	07°41.68'N	28°40.74'W	1201	34	34	28.60	35.28	-0.029	0.07	0.13	30	50	4555
11/06/05	10°00.40'N	29°47.60'W	0359	35	35	27.61	36.20	0.023	0.04	0.13	40	100?	5333
				36	FAIL								
12/06/05	13°11.66'N	31°20.57'W	1155	37	37	26.28	36.26	-0.029	0.06	0.11	40	85	5727
13/06/05	15°45.75'N	32°36.10'W	0431	38	38	25.65	36.67	0.0258	0.14	0.08	35	100	5384
	16°19.31'N	32°53.16'W	1157	39	39	25.51	36.92	0.0128	0.14	0.12	35	100	5161
14/06/05	18°57.89'N	34°12.40'W	0359	40	40	25.36	36.84	0.0173	0.06	0.08	40	130	4931
	20°04.97'N	34°46.37'W	1158	41	41	25.71	37.24	0.009	0.09	0.07	60	~	5298
15/06/05	22°48.33'N	36°09.85'W	0430	42	42	24.81	37.47	0.0202	0.07	0.05	~	130	4760
	23°21.60'N	36°27.44'W	1200	43	43	24.90	37.49	-0.029	0.09	0.04			5920
16/06/05				44	FAIL								
	26°50.45'N	38°17.74'W	1327	45	45	24.19	37.03	0.007	no data	0.05	20	145	4637
17/06/05	29°09.48'N	39°32.53'W	0431	46	46	24.02	36.91	0.0232	<0.03	0.03	~	140	4155
	29°27.25'N	39°48.83'W	1214	47	47	24.10	36.93	0.003	0.04	0.04	30	135	3244
18/06/05	31°22.99'N	42°08.65'W	0503	48	48	24.99	36.80	0.028	0.03	0.03	20	115	3513
	31°43.44'N	42°38.93'W	1152	49	49	22.76	36.69	0.01	0.06	0.06	25	90	3316
19/06/05	33°34.68'N	45°32.40'W	0456	50	50	22.51	36.53	0.024	0.08	0.08	25	80	4896
	33°55.55'N	46°04.51'W	1205	51	51	20.42	36.47	0.033	0.11	0.11	40	65	4879
20/06/05	34°54.17'N	42°33.57'W	0501	52	52	22.05	36.61	0.0203	0.07	0.07			4279
	35°05.96'N	41°50.64'W	1201	53	53	21.82	36.6	0.007	0.07	0.07			3889
21/06/05	36°04.13'N	38°20.54'W	0435	54	54	20.79	36.45	0.026	0.08	0.08			2932
	36°27.59'N	36°55.24'W	1157	55	55	20.62	36.37	0.009	0.09				3350

Date	Lat	Lon	Time (UTC)	Station #	CTD Cast #	T °C	S PSU	Fluor Mv	No_3+ um	Chlor Mg/m^3	Mix l depth m	DCM Depth m	Total Depth m
22/06/05	37°20.93'N	33°39.63'W	0414	56	56	20.05	36.19	0.029	0.10				1444
	37°34.35'N	32°50.20'W	1156	57	57	19.67	36.10	0.0137	0.12				1590
23/06/05	38°18.32'N	30°03.83'W	0304	58	58	19.31	36.18	0.033	0.14				1055
	39°15.75'N	28°49°31'W	1157	59	59	18.66	36.05	0.020					1520
24/06/05	41°08.32'N	26°22.61'W	0312	60	60	18.87	36.05	0.049					2829
	42°06.66'N	25°04.20'W	1202	61	61	17.79	35.99	0.022					3682
25/06/05	43°44.11'N	22°52.40'W	0233	62	62	17.69	35.88	0.156					1919
	44°22.14'N	21°59.17'W	1157	63	63	17.30	35.89	0.044					3500
26/06/05	46°02.00'N	19°40.20'W	0542	64	64t	16.98	35.73	0.223					4429
	46°21.94'N	18°51.18'W	4589	65	65	16.88	35.79	0.131					4580
27/06/05	47°02.04'N	15°15.43'W°	0404	66	66	16.66	35.80	0.256					4778
	47°16.45'N	13°58.02'W	4774	67	67	16.63	35.72	0.156					4774

DEEP CTDS see Key in 'read me' files because bottles fired out of sequence
FAIL = no CTD samples – possibly some data - usually due to conductor breakage

Appendix 3. CTD cast bottle mis-fires and non-seal

CTD No.	Bottles
01	15 not sealed
02	4 not sealed
03	OK
04	OK
05	OK
06	3 not sealed
07	OK
08	OK
09	OK
10	Aborted
11	1 not sealed
12	4 not sealed
13	4 compromised
14	4 not sealed
15	OK
16	1 not sealed
17	1 compromised
18	3,5,7
19	2,4,6 compromised
20	OK
21	12 not sealed
22	OK
23	OK
24	15 not sealed
25	OK
26	2,4 & 24 not sealed
27	OK
28	4 & 24 not sealed
29	12 not sealed
30	OK
31	OK
32	OK
33	OK
34	OK

CTD No.	Bottles
35	24 not sealed, 1 not closed
36	OK
37	OK
38	OK
39	OK
40	17 & 5 not sealed (+20?)
41	OK
42	17 not sealed
43	OK
44	Aborted
45	12 not sealed
46	4 not closed
47	OK
48	4 & 1 not sealed, 10 not closed
49	OK
50	OK
51	OK
52	10 not sealed
53	OK
54	3 not sealed
55	OK
56	OK
57	OK
58	1 not sealed
59	OK
60	8 not sealed, 1 slight leak
61	
62	10 not closed, 1 slight leak
63	
64	
65	
66	
67	

Appendix 4. Underway sampling Master Log Sheet

Key

DIC is dissolved inorganic carbon sampling –undertaken by Trish Frickers
PIC, CC and BiSi are particulate inorganic carbon, cell counts and biogenic silica, respectively, -collected by David Drapeau
Tchl, HPLC, POC are total chlorophyll, HPLC pigments and particulate organic carbon, respectively, taken by Alex Poulton and Isobel Cook
MAAs are micosporin-like amino acids collected by Isobel Cook

Date	Time	ID	Lat	Lon	DIC (B)	DIC (A)	PIC	CC	BiSi	T Chl	HPLC	POC	MAA
23/05/2005	13:00	A	32°37.26'S	13°33.85'E			Y	Y	Y	Y	Y	Y	
	17:00	B	32°22.56'S	12°45.55'E			Y	Y	Y	Y	Y	Y	
	20:00	C	32°12.87'S	12°06.90'E			Y	Y	Y	Y	Y	Y	
24/05/2005	3:00	D	31°51.08'S	10°35.24'E			Y	Y	Y	Y	Y	Y	
	3:45		31°49.98'S	10°30.00'E	1	429							
	8:30	E	31°38.92'S	9°01.00'E			Y	Y	Y	Y	Y	Y	
	9:59	UWCO4	31°34.91'S	9°19.67'E						Y	Y	Y	Y
	13:00	F	31°30.21'S	8°54.97'E			Y	Y	Y	Y	Y	Y	
	16:11	G	31°22.46'S	8°11.57'E			Y	Y	Y	Y	Y	Y	
	20:30	H	31°11.24'S	7°13.93'E			Y	Y	Y	Y	Y	Y	
25/05/2005	5:07	I	30°49.64'S	5°16.98'E			Y	Y	Y	Y	Y	Y	
	8:00	J	30°42.58'S	4°37.97'E			Y	Y	Y	Y	Y	Y	
	10:30	UWCO5	30°38.29'S	4°12.97'E						Y	Y	Y	
	10:47		30°38.07'S	4°13.28'E	2	508							
	13:40	K	30°30.78'S	3°36.47'E			Y	Y	Y	Y	Y	Y	
	17:11	L	30°22.03'S	2°50.02'E			Y	Y	Y	Y	Y	Y	
	20:00	M	30°15.37'S	2°13.82'E			Y	Y	Y	Y	Y	Y	
26/05/2005	3:49		29°57.92'S	0°42.01'W	3	430							
	8:03	N	29°49.76'S	0°03.66'W			Y	Y	Y	Y	Y	Y	
	10:14	N1	29°44.98'S	0°25.66'W						Y			
	11:25	O	29°41.73'S	0°43.04'W			Y	Y	Y	Y			

Date	Time	ID	Lat	Lon	DIC (B)	DIC (A)	PIC	CC	BiSi	T Chl	HPLC	POC	MAA
	15:01	P	29°32.97’S	1°32.97’W			Y	Y	Y	Y	Y	Y	
	20:30	Q	29°18.72’S	2°42.17’W			Y	Y	Y	Y	Y	Y	
27/05/2005	5:03	R	28°58.39’S	4°31.12’W			Y	Y	Y	Y	Y	Y	
	7:00	S	28°53.83’S	4°56.03’W			Y	Y	Y	Y	Y	Y	
	9:00	T	28°49.26’S	5°21.56’W			Y	Y	Y	Y	Y	Y	
	10:48		28°44.6’S	5°45.30’W	4	504							
	15:00	U	28°37.29’S	6°22.67’W			Y	Y	Y	Y	Y	Y	
	18:15	V	28°29.15’S	7°05.14’W			Y	Y	Y	Y	Y	Y	
	20:46	W	28°23.16’S	7°37.91’W			Y	Y	Y	Y	Y	Y	
28/05/2005	4:42		28°4.23’S	9°15.06’W	5	505							
	9:00	X	28°57.65’S	9°49.01’W			Y	Y	Y	Y	Y	Y	
	12:24	UWCO9	28°57.65’S	9°49.01’W						Y	Y	Y	Y
	13:09		27°74.49’S	10°31.43’W	6	506							
	16:40	Y	27°41.00’S	11°12.49’W			Y	Y	Y	Y	NA	NA	
	21:00	Z	27°30.70’S	12°08.35’W			Y	Y	Y	Y	Y	Y	
29/05/2005	8:30		27°13.81’S	13°26.56’W	7	435							
	11:00	UWC12	27°10.03’S	13°49.65’W					Y		NA	Y	Y
	11:17		27°10.03’S	13°49.65’W	8	502							
	15:23	AA	27°3.21’S	14°29.96’W			Y	Y	Y	Y	Y	Y	
	18:22	AB	26°56.16’S	15°07.09’W			Y	Y	Y	Y	Y	Y	
	21:13	AC	26°49.40’S	15°43.54’W			Y	Y	Y	Y	Y	Y	
30/05/2005	5:31		26°31.72’S	17°13.65’W	9	436							
	10:01	AD	26°21.83’S	18°04.53’W			Y	Y	Y	Y	Y	Y	
	12:01	UWC14	26°17.03’S	18°27.716’						Y	NA	Y	Y
	12:06		26°17.04’S	18°27.70’W	10	437							
	16:25	AE	26°08.61’S	19°10.47’W			Y	Y	Y	NA	Y	Y	
	19:21	AF	26°01.46’S	19°47.95’W			Y	Y	Y	Y	Y	Y	
	22:03	AG	26°54.52’S	20°22.20’W			Y	Y	Y	Y	Y	Y	
31/05/2005	0:00	AH	25°27.44’S	22°41.81’W			Y	Y	Y	Y	Y	Y	

Date	Time	ID	Lat	Lon	DIC (B)	DIC (A)	PIC	CC	BiSi	T Chl	HPLC	POC	MAA
	05:30		25°36.29’S	21°55.97’W	11	438							
	12:04	UWC16	25°23.07’S	23°04.66’W						Y	NA	Y	Y
	12:20		25°23.05’S	23°04.76’W	12	439							
	16:30	AI	24°51.93’S	23°31.97’W			Y	Y	Y	Y	Y	Y	
	20:06	AJ	24°19.28’S	24°00.21’W			Y	Y	Y	Y	Y	Y	
	21:59	AK	24°02.45’S	24°14.98’W			Y	Y	Y	Y	Y	Y	
01/06/2005	5:30		22°52.82’S	24°59.98’W	13	440							
	13:08	UWC18	21°27.63’S	24°59.80’W						Y	NA	Y	Y
	14:14		22°27.41’S	24°59.29’W	14	441							
	20:30	AL	21°41.98’S	25°00.03’W			Y	Y	Y	Y	Y	Y	
02/06/2005	5:47		20°11.06’S	24°59.75’W	15	442							
	10:00	AM	19°35.33’S	24°59.56’W			Y	Y	Y	Y	Y	Y	
	12:13		19°14.31’S	24°59.57’W	16	516							
	16:04	AN	18°46.38’S	24°59.99’W			Y	Y	Y	Y	Y	Y	
	21:15	AO	17°48.43’S	25°00.18’W			Y	Y	Y	Y	Y	Y	
03/06/2005	5:33		16°16.71’S	24°59.92’W	17	517							
	9:30	AP	15°51.35’S	25°00.10’W			Y	Y	Y	Y	Y	Y	
	12:00	UWC22	15°24.55’S	25°00.70’W						Y	Y	Y	Y
	12:14		15°24.59’S	25°00.59’W	18	510							
	16:15	AQ	14°53.30’S	25°00.05’W			Y	Y	Y	Y	Y	Y	
	21:00	AR	14°01.01’S	24°59.88’W			Y	Y	Y	Y	Y	Y	
	5:47		12°24.64’S	24°59.76’W	19	519							
04/06/2005	11:00	UWC24	11°57.11’S	25°00.52’W						Y	Y	Y	Y
	12:22		11°57.10’S	25°00.45’W	20								
	16:31	AS	11°21.86’S	25°00.03’W			Y	Y	Y	Y	Y	Y	
	19:06	AT	10°51.46’S	24°59.99’W			Y	Y	Y	Y	Y	Y	
	21:30	AU	10°23.57’S	25°00.03’W			Y	Y	Y	Y	Y	Y	
	4:39		9°04.76’S	24°59.82’W	21	512							
05/06/2005	9:30	AV	8°32.34’S	24°59.96’W			Y	Y	Y	Y	Y	Y	

Date	Time	ID	Lat	Lon	DIC (B)	DIC (A)	PIC	CC	BiSi	T Chl	HPLC	POC	MAA
	12:11	UWC26	8°10.11’S	25°00.43’W						Y	Y	Y	Y
	14:00	AW	7°59.52’S	25°00.39’W			Y	Y	Y	Y	Y	Y	
	17:03	AX	7°24.89’S	24°59.99’W			Y	Y	Y	Y	Y	Y	
	0:00	AY	6°38.62’S	25°00.03’W			Y	Y	Y	Y	Y	Y	
06/06/2005	5:15		5°09.84’S	25°00.11’W	22	521							
	9:30	AZ	4°42.69’S	25°00.20’W			Y	Y	Y	Y	Y	Y	
	11:54		4°15.07’S	24°59.88’W	23	522							
	16:30	BA	3°33.23’S	25°00.10’W			Y	Y	Y	Y	Y	Y	
	21:30	BB	2°40.99’S	24°59.87’W			Y	Y	Y	Y	Y	Y	
07/06/2005	5:12		1°37.86’S	24°09.60’W	24	523							
	12:17	BC	1°08.16’S	25°00.12’W			Y	Y	Y	Y	Y	Y	
	21:00	BD	0°10.39’N	25°05.05’W			Y	Y	Y	Y	Y	Y	
08/06/2005	4:30		1°10.40’N	25°34.10’W	25	514							
	9:30	BE	1°43.95’N	25°49.67’W			Y	Y	Y	Y	Y	Y	
	12:21		2°03.45’N	25°59.20’W	26	926							
	16:44	BF	2°35.89’N	26°14.27’W			Y	Y	Y	Y	Y	Y	
	21:00	BG	3°11.18’N	26°30.99’W			Y	Y	Y	Y	Y	Y	
09/06/2005	0:18	BH	3°38.67’N	26°44.14’W			Y	Y	Y	Y	Y	Y	
	5:00		4°16.33’N	27°01.58’W	27	940							
	9:31	BI	4°45.80’N	27°16.29’W			Y	Y	Y	Y	Y	Y	
	12:10		5°09.15’N	27°26.79’W	28	936							
	20:11	BJ	5°51.52’N	27°47.84’W			Y	Y	Y	Y	Y	Y	
10/06/2005	0:11	BK	6°29.60’N	28°27.15’W			Y	Y	Y	Y	Y	Y	
	5:00		7°14.99’N	28°27.19’W	29	941							
	12:00		7°41.75’N	28°40.67’W	30	929							
	12:29	UWC34	7°41.78’N	28°40.56’W						Y	NA	Y	Y
	16:11	BL	8°05.85’N	28°52.45’W			Y	Y	Y	Y	Y	Y	
	20:30	BM	8°47.08’N	29°12.39’W			Y	Y	Y	Y	Y	Y	
11/06/2005	1:04	BN	9°33.28’N	29°34.13’W				Y	Y	Y	Y	Y	

Date	Time	ID	Lat	Lon	DIC (B)	DIC (A)	PIC	CC	BiSi	T Chl	HPLC	POC	MAA
	4:00		10°00.42'N	29°47.59'W	31	927							
	9:00	BO	10°32.79'N	30°03.31'W			Y	Y	Y	Y	Y	Y	
	12:03	UWC36	10°58.85'N	30°15.85'W						Y	Y	Y	Y
	13:31	BP	11°03.24'N	30°18.44'W				Y	Y	Y	Y	Y	
	17:00	BQ	11°23.17'N	30°27.73'W			Y	Y	Y	Y	Y	Y	
	21:30	BR	11°49.50'N	30°40.47'W			Y	Y	Y	Y	Y	Y	
12/06/2005	0:30	BS	12°07.03'N	30°49.13'W			Y	Y	Y	Y	Y	Y	
	6:33	BT	12°41.99'N	31°06.38'W			Y	Y	Y	Y	3	Y	
	12:02		13°11.71'N	31°20.39'W	32	932							
	9:11	BU	12°56.95'N	31°20.59'W			Y	Y	Y	Y	Y	Y	
	12:09	UWC37	13°11.72'N	31°20.61'W						Y	NA	Y	Y
	17:01	BV	13°51.35'N	31°40.06'W			Y	Y	Y	Y	Y	Y	
	21:00	BW	14°31.46'N	31°59.78'W			Y	Y	Y	Y	Y	Y	
13/06/2005	0:22	BX	15°05.57'N	32°16.77'W			Y	Y	Y	Y	Y	Y	
			15°45.74'N	32°35.96'W	33	8							
	12:06	UWC39	16°15.63'N	32°53.04'W						Y	NA	Y	Y
	16:31	BY	16°57.90'N	33°12.20'W			Y	Y	Y	Y	Y	Y	
	21:00	BZ	17°45.47'N	33°36.11'W			Y	Y	Y	Y	Y	Y	
14/06/2005	0:30	CA	18°22.57'N	33°54.84'W				Y	Y	Y	Y	Y	
	4:12		18°51.91'N	34°12.89'W	35	928							
	9:02	CB	19°34.59'N	34°47.34'W			Y	Y	Y	Y	Y	Y	
	12:00		20°05.00'N	34°46.34'W	36	933							
	12:00	UWC41	20°05.00'N	36°34.00'W						Y	NA	Y	Y
	16:34	CC	20°44.01'N	35°06.30'W			Y	Y	Y	Y	Y	Y	
	20:28	CD	21°25.55'N	35°27.80'W			Y	Y	Y	Y	Y	Y	
15/06/2005	0:35	CE	22°08.97'N	35°50.01'W			Y	Y	Y	Y	Y	Y	
	5:10		22°48.12'N	36°09.58'W	37	934							
	12:00		23°21.58'N	36°27.43'W	38	930							
	12:22	UWC43	23°21.61'N	36°27.38'W						Y	NA	Y	Y

Date	Time	ID	Lat	Lon	DIC (B)	DIC (A)	PIC	CC	BiSi	T Chl	HPLC	POC	MAA
	21:30	CF	24°19.52'N	36°56.70'W			Y	Y	Y	Y	Y	Y	NA
16/06/2005	0:50	CG	24°59.17'N	37°18.42'W			Y	Y	Y	Y	Y	Y	
	4:59		25°40.52'N	37°40.09'W	39	935							
	5:22	CH	25°40.90'N	37°40.08'W			Y	Y	Y	Y	Y	Y	
	9:22	CI	26°13.97'N	37°57.77'W			Y	Y	Y	Y	Y	Y	
	13:30		26°50.46'N	38°17.77'W	40	943							
	18:09	CJ	27°28.58'N	38°37.61'W			Y	Y	Y	Y	Y	Y	
	21:40	CK	28°05.04'N	38°57.24'W			Y	Y	Y	Y	Y	Y	
17/06/2005	0:34	CL	28°34.13'N	39°13.44'W			Y	Y	Y	Y	Y	Y	
	4:40		29°09.43'N	39°32.53'W	41	948							
	12:33	UWC47	29°27.21'N	39°48.85'W						Y	NA	Y	Y
	16:30	CM	29°49.82'N	40°16.14'W			Y	Y	Y				
	21:00	CN	30°20.88'N	40°53.51'W			Y	Y	Y				
18/06/2005	0:52	CO	30°51.70'N	41°30.80'W			Y	Y	Y				
	5:05		31°22.99'N	42°08.65'W	42	939							
	12:08	UWC49	31°43.34'N	42°39.05'W						Y	NA	Y	Y
	16:53	CP	32°12.18'N	43°32.18'W			Y	Y	Y				
	21:04	CQ	32°42.59'N	44°10.18'W			Y	Y	Y				
19/06/2005	1:50	CR	33°14.95'N	45°01.32'W			Y	Y	Y				
	5:50		33°34.52'N	45°32.31'W	43	931							
	10:31	CS	33°46.11'N	45°50.33'W			Y	Y	Y				
	12:10		33°55.05'N	46°04.53'W	44	942							
	16:57	CT	34°08.39'N	45°16.28'W			Y	Y	Y				
	21:01	CU	34°23.40'N	44°22.83'W			Y	Y	Y				
20/06/2005	0:51	CV	34°39.17'N	43°27.97'W			Y	Y	Y				
	0:00	CW	35°21.44'N	40°55.30'W			Y	Y	Y				
	5:00		34°54.17'N	42°33.57'W	45	944							
	12:00	UWC53	35°05.99'N	41°50.66'W						Y	NA	Y	Y
	21:00	CX	35°37.21'N	39°58.62'W			Y	Y	Y				

Date	Time	ID	Lat	Lon	DIC (B)	DIC (A)	PIC	CC	BiSi	T Chl	HPLC	POC	MAA
21/06/2005	1:32	CY	35°54.07'N	38°57.19'W			Y	Y	Y				
	4:40		36°04.11'N	38°20.54'W	46	945							
	9:17	CZ	36°18.13'N	37°30.36'W			Y	Y	Y				
	12:13	UWC55	36°18.13'N	37°30.36'W						Y	NA	Y	Y
	17:03	DA	36°42.80'N	35°59.97'W			Y	Y	Y				
	21:00	DB	36°56.50'N	35°09.62'W			Y	Y	Y				
22/06/2005	0:54	DC	37°10.50'N	34°18.05'W			Y	Y	Y				
	4:10		37°20.94'N	33°39.62'W	47	946							
	4:10		37°20.94'N	33°39.62'W	48	949							
	4:10		37°20.94'N	33°39.62'W	49	950							
	16:00	DD	37°41.18'N	32°25.77'W			Y	Y	Y				
	20:00	DE	37°54.70'N	31°34.78'W			Y	Y	Y				
	23:59	DF	38°08.86'N	30°41.90'W			Y	Y	Y				
23/06/2005	7:55	DG	38°46.16'N	29°26.78'W			Y	Y	Y				
	12:11	UWC59	39°15.81'N	28°49.44'W						Y	NA	Y	Y
	16:10	DH	39°42.19'N	28°14.70'W			Y	Y	Y				
	20:30	DI	40°15.86'N	27°30.89'W			Y	Y	Y				
24/06/2005	0:06	DJ	40°45.45'N	26°52.47'W			Y	Y	Y				
	3:12		41°08.34'N	26°22.61'W	50	298							
	8:00	DK	41°36.08'N	25°45.04'W			Y	Y	Y				
	12:10		42°06.85'N	25°04.18'W	51	3509							
	16:26	DL	42°35.03'N	24°26.46'W			Y	Y	Y				
	20:00	DM	43°00.94'N	23°51.33'W			Y	Y	Y				
25/06/2005	0:15	DN	43°29.75'N	23°11.97'W			Y	Y	Y				
	2:40		43°44.11'N	22°52.40'W	52	3504							
	8:03	DO	43°57.77'N	22°33.41'W			Y	Y	Y				
	12:13	UWC63	44°22.20'N	21°59.89'W						Y	NA	Y	Y
	17:00	DP	44°50.26'N	21°21.15'W			Y	Y	Y				
	21:00	DQ	45°15.89'N	20°44.19'W			Y	Y	Y				

Date	Time	ID	Lat	Lon	DIC (B)	DIC (A)	PIC	CC	BiSi	T Chl	HPLC	POC	MAA
26/05/2006	0:10	DR	45°35.39'N	20°16.51'W			Y	Y	Y				
	4:43		46°01.89'N	19°40.28'W	53	3503							
	3:36	UWC65	46°21.94'N	18°51.35'W						Y	NA	Y	Y
	11:22		46°22.05'N	18°51.48'W	54	3502							
27/06/2005	4:10		47°02.03'N	15°15.30'W	55	3501							
	11:10		47°16.57'N	13°58.09'W	56	3510							

Appendix 5. Underway sampling log generated by Dave Drapeau

(a) Underway

Table 1. Ships time, measurement(s) collected.

Time (local approximate) Measurement(s)
0330 Morning CTD
0800 PIC, BSi, cell counts
1100 Optics cast
1600 PIC, BSi, cell counts
2000 PIC, BSi, cell counts
0000 PIC, BSi, cell counts

Year	Mon	Day	Time (GMT)	Cal. Day	CTD#/ UW id.	Lat (dec deg)	Lon (dec deg)	Sample #	PIC?	CC?	BSi?
2005	5	23	13:00	143	A	32.621°S	13.56417°E	15	Y	Y	Y
2005	5	23	17:00	143	B	32.376°S	12.75917°E	16	Y	Y	Y
2005	5	23	20:00	143	C	32.2145°S	12.115°E	17	Y	Y	Y
2005	5	24	3:00	144	D	31.8513°S	10.58733°E	18	Y	Y	Y
2005	5	24	8:30	144	E	31.6487°S	9.636333°E	27	Y	Y	Y
2005	5	24	13:00	144	F	31.5035°S	8.916167°E	34	Y	Y	Y
2005	5	24	16:11	144	G	31.3743°S	8.192833°E	35	Y	Y	Y
2005	5	24	20:30	144	H	31.1873°S	7.232167°E	36	Y	Y	Y
2005	5	25	5:07	145	I	30.8273°S	5.283°E	37	Y	Y	Y
2005	5	25	8:00	145	J	30.7097°S	4.632833°E	38	Y	Y	Y
2005	5	25	13:40	145	K	30.513°S	3.607833°E	45	Y	Y	Y
2005	5	25	17:11	145	L	30.3672°S	2.833667°E	46	Y	Y	Y
2005	5	25	20:00	145	M	30.2562°S	2.230333°E	47	Y	Y	Y
2005	5	26	8:03	146	N	29.8293°S	0.061°W	56	Y	Y	Y
2005	5	26	11:25	146	O	29.6955°S	0.71733°W	57	Y	Y	Y
2005	5	26	15:01	146	P	29.5495°S	1.5495°W	58	Y	Y	Y
2005	5	26	20:30	146	Q	29.312°S	2.70283°W	59	Y	Y	Y
2005	5	27	5:03	147	R	28.9732°S	4.51867°W	60	Y	Y	Y
2005	5	27	7:00	147	S	28.8972°S	4.93383°W	61	Y	Y	Y
2005	5	27	9:00	147	T	28.821°S	5.35933°W	62	Y	Y	Y
2005	5	27	15:00	147	U	28.6215°S	6.37783°W	69	Y	Y	Y
2005	5	27	18:15	147	V	28.4858°S	7.08567°W	70	Y	Y	Y
2005	5	27	20:46	147	W	28.3861°S	7.63183°W	71	Y	Y	Y
2005	5	28	9:00	148	X	28.9608°S	9.81683°W	80	Y	Y	Y
2005	5	28	16:40	148	Y	27.6833°S	11.2082°W	87	Y	Y	Y
2005	5	28	21:00	148	Z	27.5117°S	12.1392°W	88	Y	Y	Y
2005	5	29	15:23	149	AA	27.0535°S	14.4993°W	102	Y	Y	Y
2005	5	29	18:22	149	AB	26.936°S	15.1182°W	103	Y	Y	Y
2005	5	29	21:12	149	AC	26.8233°S	15.7257°W	104	Y	Y	Y
2005	5	30	10:01	150	AD	26.3638°S	18.0755°W	113	Y	Y	Y
2005	5	30	16:25	150	AE	26.1435°S	19.1745°W	120	Y	Y	Y
2005	5	30	19:21	150	AF	26.0243°S	19.7992°W	121	Y	Y	Y
2005	5	30	22:03	150	AG	26.9087°S	20.37°W	122	Y	Y	Y
2005	5	31	10:04	151	AH	25.4573°S	22.6968°W	130	Y	Y	Y
2005	5	31	12:07	151	AI	24.8655°S	23.5328°W	137	Y	Y	Y
2005	5	31	20:06	151	AJ	24.3213°S	24.0035°W	138	Y	Y	Y

Year	Mon	Day	Time (GMT)	Cal. Day	CTD#/ UW id.	Lat (dec deg)	Lon (dec deg)	Sample #	PIC?	CC?	BSi?
2005	5	31	21:59	151	AK	24.0408°S	24.2497°W	139	Y	Y	Y
2005	6	1	20:30	152	AL	21.6997°S	25.0005°W	154	Y	Y	Y
2005	6	2	10:00	153	AM	19.5888°S	24.9927°W	163	Y	Y	Y
2005	6	2	16:04	153	AN	18.773°S	24.9998°W	170	Y	Y	Y
2005	6	2	21:15	153	AO	17.8072°S	25.003°W	171	Y	Y	Y
2005	6	3	9:30	154	AP	15.8558°S	25.0017°W	179	Y	Y	Y
2005	6	3	16:15	154	AQ	14.8883°S	25.0008°W	186	Y	Y	Y
2005	6	3	21:00	154	AR	14.0168°S	24.998°W	187	Y	Y	Y
2005	6	4	16:31	155	AS	11.3643°S	25.0005°W	201	Y	Y	Y
2005	6	4	19:06	155	AT	10.8577°S	24.9998°W	202	Y	Y	Y
2005	6	4	21:30	155	AU	10.3928°S	25.0005°W	203	Y	Y	Y
2005	6	5	9:30	156	AV	8.539°S	24.9993°W	212	Y	Y	Y
2005	6	5	14:00	156	AW	7.992°S	25.0065°W	213	Y	Y	Y
2005	6	5	17:03	156	AX	7.41483°S	24.9998°W	214	Y	Y	Y
2005	6	5	21:00	156	AY	6.64367°S	25.0005°W	215	Y	Y	Y
2005	6	6	9:30	157	AZ	4.7115°S	25.0033°W	223	Y	Y	Y
2005	6	6	16:30	157	BA	3.55383°S	25.0017°W	230	Y	Y	Y
2005	6	6	21:30	157	BB	2.68317°S	24.9978°W	231	Y	Y	Y
2005	6	7	12:17	158	BC	1.136°S	25.002°W	240	Y	Y	Y
2005	6	7	21:00	158	BD	0.173167°N	25.0842°W	241	Y	Y	Y
2005	6	8	9:30	159	BE	1.7325°N	25.8278°W	250	Y	Y	Y
2005	6	8	16:44	159	BF	2.598167°N	26.2378°W	257	Y	Y	Y
2005	6	8	21:00	159	BG	3.186333°N	26.5165°W	258	Y	Y	Y
2005	6	9	0:18	160	BH	3.6445°N	26.7357°W	259	Y	Y	Y
2005	6	9	9:31	160	BI	4.763333°N	27.2715°W	268	Y	Y	Y
2005	6	9	20:11	160	BJ	5.858667°N	27.7973°W	275	Y	Y	Y
2005	6	10	0:11	161	BK	6.493333°N	28.4525°W	276	Y	Y	Y
2005	6	10	16:11	161	BL	8.0975°N	28.8742°W	291	Y	Y	Y
2005	6	10	20:30	161	BM	8.784667°N	29.2065°W	292	Y	Y	Y
2005	6	11	1:04	162	BN	9.554667°N	29.5688°W	293	Y	Y	Y
2005	6	11	9:00	162	BO	10.5465°N	30.0552°W	301	Y	Y	Y
2005	6	11	13:31	162	BP	11.054°N	30.3073°W	302	Y	Y	Y
2005	6	11	17:00	162	BQ	11.38617°N	30.4622°W	303	Y	Y	Y
2005	6	11	21:30	162	BR	11.825°N	30.6745°W	304	Y	Y	Y
2005	6	12	0:30	163	BS	12.11717°N	30.8188°W	305	Y	Y	Y
2005	6	12	6:33	163	BT	12.69983°N	31.1063°W	306	Y	Y	Y
2005	6	12	9:11	163	BU	12.94917°N	31.3432°W	307	Y	Y	Y
2005	6	12	17:01	163	BV	13.85583°N	31.6677°W	314	Y	Y	Y
2005	6	12	21:00	163	BW	14.52433°N	31.9963°W	315	Y	Y	Y
2005	6	13	0:22	164	BX	15.09283°N	32.2795°W	316	Y	Y	Y
2005	6	13	16:30	164	BY	16.965°N	33.2033°W	331	Y	Y	Y
2005	6	13	21:00	164	BZ	17.75783°N	33.6018°W	332	Y	Y	Y
2005	6	14	0:30	165	CA	18.37617°N	33.914°W	333	Y	Y	Y
2005	6	14	9:02	165	CB	19.5765°N	34.789°W	342	Y	Y	Y
2005	6	14	16:34	165	CC	20.7335°N	35.105°W	349	Y	Y	Y
2005	6	14	20:28	165	CD	21.42583°N	35.4633°W	350	Y	Y	Y
2005	6	15	0:35	166	CE	22.1495°N	35.8335°W	351	Y	Y	Y
2005	6	15	21:30	166	CF	24.32533°N	36.945°W	366	Y	Y	Y

Year	Mon	Day	Time (GMT)	Cal. Day	CTD#/ UW id.	Lat (dec deg)	Lon (dec deg)	Sample #	PIC?	CC?	BSi?
2005	6	16	0:50	167	CG	24.98617°N	37.307°W	367	Y	Y	Y
2005	6	16	5:22	167	CH	25.68167°N	37.668°W	368	Y	Y	Y
2005	6	16	9:22	167	CI	26.23283°N	37.9628°W	369	Y	Y	Y
2005	6	16	18:09	167	CJ	27.47633°N	38.6268°W	376	Y	Y	Y
2005	6	16	21:40	167	CK	28.084°N	38.954°W	377	Y	Y	Y
2005	6	17	0:34	168	CL	28.56883°N	39.224°W	378	Y	Y	Y
2005	6	17	16:30	168	CM	29.83033°N	40.269°W	393	Y	Y	Y
2005	6	17	21:00	168	CN	30.348°N	40.8918°W	394	Y	Y	Y
2005	6	18	0:52	169	CO	30.86167°N	41.5133°W	395	Y	Y	Y
2005	6	18	16:53	169	CP	32.203°N	43.5363°W	409	Y	Y	Y
2005	6	18	21:04	169	CQ	32.70983°N	44.1697°W	410	Y	Y	Y
2005	6	19	1:50	170	CR	33.24917°N	45.022°W	411	Y	Y	Y
2005	6	19	10:31	170	CS	33.7685°N	45.8388°W	419	Y	Y	Y
2005	6	19	16:57	170	CT	34.13983°N	45.2713°W	426	Y	Y	Y
2005	6	19	21:01	170	CU	34.39°N	44.3805°W	427	Y	Y	Y
2005	6	20	0:51	171	CV	34.65283°N	43.4662°W	428	Y	Y	Y
2005	6	20	16:56	171	CW	35.35733°N	40.9217°W	443	Y	Y	Y
2005	6	20	21:00	171	CX	35.62017°N	39.977°W	444	Y	Y	Y
2005	6	21	1:32	172	CY	35.90117°N	38.9532°W	445	Y	Y	Y
2005	6	21	9:17	172	CZ	36.30217°N	37.506°W	453	Y	Y	Y
2005	6	21	17:03	172	DA	36.71333°N	35.9995°W	460	Y	Y	Y
2005	6	21	21:00	172	DB	36.94167°N	35.1603°W	461	Y	Y	Y
2005	6	22	0:54	173	DC	37.175°N	34.3008°W	462	Y	Y	Y
2005	6	22	16:00	173	DD	37.68633°N	32.4295°W	477	Y	Y	Y
2005	6	22	20:00	173	DE	37.91167°N	31.5797°W	478	Y	Y	Y
2005	6	22	23:59	173	DF	38.14767°N	30.6983°W	479	Y	Y	Y
2005	6	23	7:55	174	DG	38.76933°N	29.4463°W	487	Y	Y	Y
2005	6	23	16:10	174	DH	39.70317°N	28.245°W	494	Y	Y	Y
2005	6	23	20:30	174	DI	40.26433°N	27.5148°W	495	Y	Y	Y
2005	6	24	0:06	175	DJ	40.7575°N	26.8745°W	496	Y	Y	Y
2005	6	24	8:00	175	DK	41.60133°N	25.7507°W	504	Y	Y	Y
2005	6	24	16:26	175	DL	42.58383°N	24.441°W	511	Y	Y	Y
2005	6	24	20:00	175	DM	43.01567°N	23.8555°W	512	Y	Y	Y
2005	6	25	0:15	176	DN	43.49583°N	23.1995°W	513	Y	Y	Y
2005	6	25	8:03	176	DO	43.96283°N	22.5568°W	521	Y	Y	Y
2005	6	25	17:00	176	DP	44.83767°N	21.3525°W	528	Y	Y	Y
2005	6	25	21:00	176	DQ	45.26483°N	20.7365°W	529	Y	Y	Y
2005	6	26	0:10	177	DR	45.58983°N	20.2752°W	530	Y	Y	Y

(b) CTD Stations

Table 2. Stations (CTD cast number) sampled and measurement(s) made. Abbreviations used are BSi (particulate biogenic silica), PIC (particulate inorganic carbon), and CC (cell counts,coccolithophores and coccoliths).

Year	Mon	Day	Time (GMT)	Cal. Day	CTD#/ UW id.	Lat (dec deg)	Lon (dec deg)	Sample #	PIC?	CC?	BSi?
2005	5	21	2:40	141	1	31.97°S	16.97333°E	1	Y	Y	Y
2005	5	21	2:40	141	1	31.97°S	16.97333°E	2	Y	Y	Y
2005	5	21	2:40	141	1	31.97°S	16.97333°E	3	Y	Y	Y
2005	5	21	2:40	141	1	31.97°S	16.97333°E	4	Y	Y	Y
2005	5	21	2:40	141	1	31.97°S	16.97333°E	5	Y	Y	Y
2005	5	21	2:40	141	1	31.97°S	16.97333°E	6	Y	Y	Y
2005	5	21	2:40	141	1	31.97°S	16.97333°E	7	Y	Y	Y
2005	5	21	2:40	141	1	31.97°S	16.97333°E	8	Y	Y	Y
2005	5	21	9:30	141	2	31.0065°S	16.4925°E	9	Y	Y	Y
2005	5	21	9:30	141	2	31.0065°S	16.4925°E	10	Y		Y
2005	5	21	9:30	141	2	31.0065°S	16.4925°E	11	Y		Y
2005	5	21	9:30	141	2	31.0065°S	16.4925°E	12	Y		Y
2005	5	21	9:30	141	2	31.0065°S	16.4925°E	13	Y		Y
2005	5	21	9:30	141	2	31.0065°S	16.4925°E	14	Y		Y
2005	5	24	3:40	144	3	31.833°S	10.3335°E	19	Y	Y	Y
2005	5	24	3:40	144	3	31.833°S	10.3335°E	20	Y	Y	Y
2005	5	24	3:40	144	3	31.833°S	10.3335°E	21	Y	Y	Y
2005	5	24	3:40	144	3	31.833°S	10.3335°E	22	Y	Y	Y
2005	5	24	3:40	144	3	31.833°S	10.3335°E	23	Y	Y	Y
2005	5	24	3:40	144	3	31.833°S	10.3335°E	24	Y	Y	Y
2005	5	24	3:40	144	3	31.833°S	10.3335°E	25	Y	Y	Y
2005	5	24	3:40	144	3	31.833°S	10.3335°E	26	Y	Y	Y
2005	5	24	10:13	144	4	31.579°S	9.325833°E	28	Y	Y	Y
2005	5	24	10:13	144	4	31.579°S	9.325833°E	29	Y		Y
2005	5	24	10:13	144	4	31.579°S	9.325833°E	30	Y		Y
2005	5	24	10:13	144	4	31.579°S	9.325833°E	31	Y		Y
2005	5	24	10:13	144	4	31.579°S	9.325833°E	32	Y		Y
2005	5	24	10:13	144	4	31.579°S	9.325833°E	33	Y		Y
2005	5	25	10:00	145	5	30.6347°S	4.221333°E	39	Y	Y	Y
2005	5	25	10:00	145	5	30.6347°S	4.221333°E	40	Y	Y	Y
2005	5	25	10:00	145	5	30.6347°S	4.221333°E	41	Y	Y	Y
2005	5	25	10:00	145	5	30.6347°S	4.221333°E	42	Y	Y	Y
2005	5	25	10:00	145	5	30.6347°S	4.221333°E	43	Y	Y	Y
2005	5	25	10:00	145	5	30.6347°S	4.221333°E	44	Y	Y	Y
2005	5	26	3:35	146	6	29.9988°S	0.699833°E	48	Y	Y	Y
2005	5	26	3:35	146	6	29.9988°S	0.699833°E	49	Y	Y	Y
2005	5	26	3:35	146	6	29.9988°S	0.699833°E	50	Y	Y	Y
2005	5	26	3:35	146	6	29.9988°S	0.699833°E	51	Y	Y	Y
2005	5	26	3:35	146	6	29.9988°S	0.699833°E	52	Y	Y	Y
2005	5	26	3:35	146	6	29.9988°S	0.699833°E	53	Y	Y	Y
2005	5	26	3:35	146	6	29.9988°S	0.699833°E	54	Y	Y	Y
2005	5	26	3:35	146	6	29.9988°S	0.699833°E	55	Y	Y	Y
2005	5	27	11:00	147	7	28.6935°S	5.7545°W	63	Y	Y	Y

Year	Mon	Day	Time (GMT)	Cal. Day	CTD#/ UW id.	Lat (dec deg)	Lon (dec deg)	Sample #	PIC?	CC?	BSi?
2005	5	27	11:00	147	7	28.6935°S	5.7545°W	64	Y	Y	Y
2005	5	27	11:00	147	7	28.6935°S	5.7545°W	65	Y	Y	Y
2005	5	27	11:00	147	7	28.6935°S	5.7545°W	66	Y	Y	Y
2005	5	27	11:00	147	7	28.6935°S	5.7545°W	67	Y	Y	Y
2005	5	27	11:00	147	7	28.6935°S	5.7545°W	68	Y	Y	Y
2005	5	28	4:34	148	8	28.0705°S	9.24933°W	72	Y	Y	Y
2005	5	28	4:34	148	8	28.0705°S	9.24933°W	73	Y	Y	Y
2005	5	28	4:34	148	8	28.0705°S	9.24933°W	74	Y	Y	Y
2005	5	28	4:34	148	8	28.0705°S	9.24933°W	75	Y	Y	Y
2005	5	28	4:34	148	8	28.0705°S	9.24933°W	76	Y	Y	Y
2005	5	28	4:34	148	8	28.0705°S	9.24933°W	77	Y	Y	Y
2005	5	28	4:34	148	8	28.0705°S	9.24933°W	78	Y	Y	Y
2005	5	28	4:34	148	8	28.0705°S	9.24933°W	79	Y	Y	Y
2005	5	28	12:24	148	9	27.8295°S	9.484°W	81	Y	Y	Y
2005	5	28	12:24	148	9	27.8295°S	9.484°W	82	Y		Y
2005	5	28	12:24	148	9	27.8295°S	9.484°W	83	Y		Y
2005	5	28	12:24	148	9	27.8295°S	9.484°W	84	Y		Y
2005	5	28	12:24	148	9	27.8295°S	9.484°W	85	Y		Y
2005	5	28	12:24	148	9	27.8295°S	9.484°W	86	Y		Y
2005	5	29	7:58	149	11	27.2302°S	13.4427°W	89	Y	Y	Y
2005	5	29	7:58	149	11	27.2302°S	13.4427°W	90	Y	Y	Y
2005	5	29	7:58	149	11	27.2302°S	13.4427°W	91	Y	Y	Y
2005	5	29	7:58	149	11	27.2302°S	13.4427°W	92	Y	Y	Y
2005	5	29	7:58	149	11	27.2302°S	13.4427°W	93	Y	Y	Y
2005	5	29	7:58	149	11	27.2302°S	13.4427°W	94	Y	Y	Y
2005	5	29	7:58	149	11	27.2302°S	13.4427°W	95	Y	Y	Y
2005	5	29	10:54	149	12	27.1672°S	13.8275°W	96	Y	Y	Y
2005	5	29	10:54	149	12	27.1672°S	13.8275°W	97	Y	Y	Y
2005	5	29	10:54	149	12	27.1672°S	13.8275°W	98	Y	Y	Y
2005	5	29	10:54	149	12	27.1672°S	13.8275°W	99	Y	Y	Y
2005	5	29	10:54	149	12	27.1672°S	13.8275°W	100	Y	Y	Y
2005	5	29	10:54	149	12	27.1672°S	13.8275°W	101	Y	Y	Y
2005	5	30	4:40	150	13	26.5268°S	17.2278°W	105	Y	Y	Y
2005	5	30	4:40	150	13	26.5268°S	17.2278°W	106	Y	Y	Y
2005	5	30	4:40	150	13	26.5268°S	17.2278°W	107	Y	Y	Y
2005	5	30	4:40	150	13	26.5268°S	17.2278°W	108	Y	Y	Y
2005	5	30	4:40	150	13	26.5268°S	17.2278°W	109	Y	Y	Y
2005	5	30	4:40	150	13	26.5268°S	17.2278°W	110	Y	Y	Y
2005	5	30	4:40	150	13	26.5268°S	17.2278°W	111	Y	Y	Y
2005	5	30	4:40	150	13	26.5268°S	17.2278°W	112	Y	Y	Y
2005	5	30	12:03	150	14	26.284°S	18.4617°W	114	Y	Y	Y
2005	5	30	12:03	150	14	26.284°S	18.4617°W	115	Y		Y
2005	5	30	12:03	150	14	26.284°S	18.4617°W	116	Y		Y
2005	5	30	12:03	150	14	26.284°S	18.4617°W	117	Y		Y
2005	5	30	12:03	150	14	26.284°S	18.4617°W	118	Y		Y
2005	5	30	12:03	150	14	26.284°S	18.4617°W	119	Y		Y
2005	5	31	5:30	151	15	25.6052°S	21.9327°W	123	Y	Y	Y
2005	5	31	5:30	151	15	25.6052°S	21.9327°W	124	Y	Y	Y

Year	Mon	Day	Time (GMT)	Cal. Day	CTD#/ UW id.	Lat (dec deg)	Lon (dec deg)	Sample #	PIC?	CC?	BSi?
2005	5	31	5:30	151	15	25.6052°S	21.9327°W	125	Y	Y	Y
2005	5	31	5:30	151	15	25.6052°S	21.9327°W	126	Y	Y	Y
2005	5	31	5:30	151	15	25.6052°S	21.9327°W	127	Y	Y	Y
2005	5	31	5:30	151	15	25.6052°S	21.9327°W	128	Y	Y	Y
2005	5	31	5:30	151	15	25.6052°S	21.9327°W	129	Y	Y	Y
2005	5	31	12:07	151	16	25.3845°S	23.0777°W	131	Y	Y	Y
2005	5	31	12:07	151	16	25.3845°S	23.0777°W	132	Y		Y
2005	5	31	12:07	151	16	25.3845°S	23.0777°W	133	Y		Y
2005	5	31	12:07	151	16	25.3845°S	23.0777°W	134	Y		Y
2005	5	31	12:07	151	16	25.3845°S	23.0777°W	135	Y		Y
2005	5	31	12:07	151	16	25.3845°S	23.0777°W	136	Y		Y
2005	6	1	5:37	152	17	22.8803°S	24.9997°W	140	Y	Y	Y
2005	6	1	5:37	152	17	22.8803°S	24.9997°W	141	Y	Y	Y
2005	6	1	5:37	152	17	22.8803°S	24.9997°W	142	Y	Y	Y
2005	6	1	5:37	152	17	22.8803°S	24.9997°W	143	Y	Y	Y
2005	6	1	5:37	152	17	22.8803°S	24.9997°W	144	Y	Y	Y
2005	6	1	5:37	152	17	22.8803°S	24.9997°W	145	Y	Y	Y
2005	6	1	5:37	152	17	22.8803°S	24.9997°W	146	Y	Y	Y
2005	6	1	5:37	152	17	22.8803°S	24.9997°W	147	Y	Y	Y
2005	6	1	12:07	152	18	22.4547°S	24.9995°W	148	Y	Y	Y
2005	6	1	12:07	152	18	22.4547°S	24.9995°W	149	Y	Y	Y
2005	6	1	12:07	152	18	22.4547°S	24.9995°W	150	Y	Y	Y
2005	6	1	12:07	152	18	22.4547°S	24.9995°W	151	Y	Y	Y
2005	6	1	12:07	152	18	22.4547°S	24.9995°W	152	Y	Y	Y
2005	6	1	12:07	152	18	22.4547°S	24.9995°W	153	Y	Y	Y
2005	6	2	4:37	153	19	19.8012°S	24.9805°W	155	Y	Y	Y
2005	6	2	4:37	153	19	19.8012°S	24.9805°W	156	Y	Y	Y
2005	6	2	4:37	153	19	19.8012°S	24.9805°W	157	Y	Y	Y
2005	6	2	4:37	153	19	19.8012°S	24.9805°W	158	Y	Y	Y
2005	6	2	4:37	153	19	19.8012°S	24.9805°W	159	Y	Y	Y
2005	6	2	4:37	153	19	19.8012°S	24.9805°W	160	Y	Y	Y
2005	6	2	4:37	153	19	19.8012°S	24.9805°W	161	Y	Y	Y
2005	6	2	4:37	153	19	19.8012°S	24.9805°W	162	Y	Y	Y
2005	6	2	11:59	153	20	19.2373°S	25°W	164	Y	Y	Y
2005	6	2	11:59	153	20	19.2373°S	25°W	165	Y	Y	Y
2005	6	2	11:59	153	20	19.2373°S	25°W	166	Y	Y	Y
2005	6	2	11:59	153	20	19.2373°S	25°W	167	Y	Y	Y
2005	6	2	11:59	153	20	19.2373°S	25°W	168	Y	Y	Y
2005	6	2	11:59	153	20	19.2373°S	25°W	169	Y	Y	Y
2005	6	3	5:42	154	21	16.2785°S	24.9987°W	172	Y	Y	Y
2005	6	3	5:42	154	21	16.2785°S	24.9987°W	173	Y	Y	Y
2005	6	3	5:42	154	21	16.2785°S	24.9987°W	174	Y	Y	Y
2005	6	3	5:42	154	21	16.2785°S	24.9987°W	175	Y	Y	Y
2005	6	3	5:42	154	21	16.2785°S	24.9987°W	176	Y	Y	Y
2005	6	3	5:42	154	21	16.2785°S	24.9987°W	177	Y	Y	Y
2005	6	3	5:42	154	21	16.2785°S	24.9987°W	178	Y	Y	Y
2005	6	3	12:04	154	22	15.4253°S	25.0012°W	180	Y	Y	Y
2005	6	3	12:04	154	22	15.4253°S	25.0012°W	181	Y	Y	Y

Year	Mon	Day	Time (GMT)	Cal. Day	CTD#/ UW id.	Lat (dec deg)	Lon (dec deg)	Sample #	PIC?	CC?	BSi?
2005	6	3	12:04	154	22	15.4253°S	25.0012°W	182	Y	Y	Y
2005	6	3	12:04	154	22	15.4253°S	25.0012°W	183	Y	Y	Y
2005	6	3	12:04	154	22	15.4253°S	25.0012°W	184	Y	Y	Y
2005	6	3	12:04	154	22	15.4253°S	25.0012°W	185	Y	Y	Y
2005	6	4	5:36	155	23	12.412°S	24.9955°W	188	Y	Y	Y
2005	6	4	5:36	155	23	12.412°S	24.9955°W	189	Y	Y	Y
2005	6	4	5:36	155	23	12.412°S	24.9955°W	190	Y	Y	Y
2005	6	4	5:36	155	23	12.412°S	24.9955°W	191	Y	Y	Y
2005	6	4	5:36	155	23	12.412°S	24.9955°W	192	Y	Y	Y
2005	6	4	5:36	155	23	12.412°S	24.9955°W	193	Y	Y	Y
2005	6	4	5:36	155	23	12.412°S	24.9955°W	194	Y	Y	Y
2005	6	4	12:03	155	24	11.9505°S	25.0068°W	195	Y	Y	Y
2005	6	4	12:03	155	24	11.9505°S	25.0068°W	196	Y	Y	Y
2005	6	4	12:03	155	24	11.9505°S	25.0068°W	197	Y	Y	Y
2005	6	4	12:03	155	24	11.9505°S	25.0068°W	198	Y	Y	Y
2005	6	4	12:03	155	24	11.9505°S	25.0068°W	199	Y	Y	Y
2005	6	4	12:03	155	24	11.9505°S	25.0068°W	200	Y	Y	Y
2005	6	5	4:35	156	25	9.07933°S	24.9973°W	204	Y	Y	Y
2005	6	5	4:35	156	25	9.07933°S	24.9973°W	205	Y	Y	Y
2005	6	5	4:35	156	25	9.07933°S	24.9973°W	206	Y	Y	Y
2005	6	5	4:35	156	25	9.07933°S	24.9973°W	207	Y	Y	Y
2005	6	5	4:35	156	25	9.07933°S	24.9973°W	208	Y	Y	Y
2005	6	5	4:35	156	25	9.07933°S	24.9973°W	209	Y	Y	Y
2005	6	5	4:35	156	25	9.07933°S	24.9973°W	210	Y	Y	Y
2005	6	5	4:35	156	25	9.07933°S	24.9973°W	211	Y	Y	Y
2005	6	6	5:15	157	26	5.16217°S	25.0057°W	216	Y	Y	Y
2005	6	6	5:15	157	26	5.16217°S	25.0057°W	217	Y	Y	Y
2005	6	6	5:15	157	26	5.16217°S	25.0057°W	218	Y	Y	Y
2005	6	6	5:15	157	26	5.16217°S	25.0057°W	219	Y	Y	Y
2005	6	6	5:15	157	26	5.16217°S	25.0057°W	220	Y	Y	Y
2005	6	6	5:15	157	26	5.16217°S	25.0057°W	221	Y	Y	Y
2005	6	6	5:15	157	26	5.16217°S	25.0057°W	222	Y	Y	Y
2005	6	6	12:02	157	27	4.25117°S	24.998°W	224	Y	Y	Y
2005	6	6	12:02	157	27	4.25117°S	24.998°W	225	Y	Y	Y
2005	6	6	12:02	157	27	4.25117°S	24.998°W	226	Y	Y	Y
2005	6	6	12:02	157	27	4.25117°S	24.998°W	227	Y	Y	Y
2005	6	6	12:02	157	27	4.25117°S	24.998°W	228	Y	Y	Y
2005	6	6	12:02	157	27	4.25117°S	24.998°W	229	Y	Y	Y
2005	6	7	5:03	158	28	1.62917°S	24.993°W	232	Y	Y	Y
2005	6	7	5:03	158	28	1.62917°S	24.993°W	233	Y	Y	Y
2005	6	7	5:03	158	28	1.62917°S	24.993°W	234	Y	Y	Y
2005	6	7	5:03	158	28	1.62917°S	24.993°W	235	Y	Y	Y
2005	6	7	5:03	158	28	1.62917°S	24.993°W	236	Y	Y	Y
2005	6	7	5:03	158	28	1.62917°S	24.993°W	237	Y	Y	Y
2005	6	7	5:03	158	28	1.62917°S	24.993°W	238	Y	Y	Y
2005	6	7	5:03	158	28	1.62917°S	24.993°W	239	Y	Y	Y
2005	6	8	4:13	159	29	1.173°N	25.5667°W	242	Y	Y	Y
2005	6	8	4:13	159	29	1.173°N	25.5667°W	243	Y	Y	Y

Year	Mon	Day	Time (GMT)	Cal. Day	CTD#/ UW id.	Lat (dec deg)	Lon (dec deg)	Sample #	PIC?	CC?	BSi?
2005	6	8	4:13	159	29	1.173°N	25.5667°W	244	Y	Y	Y
2005	6	8	4:13	159	29	1.173°N	25.5667°W	245	Y	Y	Y
2005	6	8	4:13	159	29	1.173°N	25.5667°W	246	Y	Y	Y
2005	6	8	4:13	159	29	1.173°N	25.5667°W	247	Y	Y	Y
2005	6	8	4:13	159	29	1.173°N	25.5667°W	248	Y	Y	Y
2005	6	8	4:13	159	29	1.173°N	25.5667°W	249	Y	Y	Y
2005	6	8	11:58	159	30	2.058333°N	25.982°W	251	Y	Y	Y
2005	6	8	11:58	159	30	2.058333°N	25.982°W	252	Y	Y	Y
2005	6	8	11:58	159	30	2.058333°N	25.982°W	253	Y	Y	Y
2005	6	8	11:58	159	30	2.058333°N	25.982°W	254	Y	Y	Y
2005	6	8	11:58	159	30	2.058333°N	25.982°W	255	Y	Y	Y
2005	6	8	11:58	159	30	2.058333°N	25.982°W	256	Y	Y	Y
2005	6	9	5:06	160	31	4.273°N	27.026°W	260	Y	Y	Y
2005	6	9	5:06	160	31	4.273°N	27.026°W	261	Y	Y	Y
2005	6	9	5:06	160	31	4.273°N	27.026°W	262	Y	Y	Y
2005	6	9	5:06	160	31	4.273°N	27.026°W	263	Y	Y	Y
2005	6	9	5:06	160	31	4.273°N	27.026°W	264	Y	Y	Y
2005	6	9	5:06	160	31	4.273°N	27.026°W	265	Y	Y	Y
2005	6	9	5:06	160	31	4.273°N	27.026°W	266	Y	Y	Y
2005	6	9	5:06	160	31	4.273°N	27.026°W	267	Y	Y	Y
2005	6	9	12:11	160	32	5.1525°N	27.4382°W	269	Y	Y	Y
2005	6	9	12:11	160	32	5.1525°N	27.4382°W	270	Y	Y	Y
2005	6	9	12:11	160	32	5.1525°N	27.4382°W	271	Y	Y	Y
2005	6	9	12:11	160	32	5.1525°N	27.4382°W	272	Y	Y	Y
2005	6	9	12:11	160	32	5.1525°N	27.4382°W	273	Y	Y	Y
2005	6	9	12:11	160	32	5.1525°N	27.4382°W	274	Y	Y	Y
2005	6	10	5:06	161	33	7.250167°N	28.4525°W	277	Y	Y	Y
2005	6	10	5:06	161	33	7.250167°N	28.4525°W	278	Y	Y	Y
2005	6	10	5:06	161	33	7.250167°N	28.4525°W	279	Y	Y	Y
2005	6	10	5:06	161	33	7.250167°N	28.4525°W	280	Y	Y	Y
2005	6	10	5:06	161	33	7.250167°N	28.4525°W	281	Y	Y	Y
2005	6	10	5:06	161	33	7.250167°N	28.4525°W	282	Y	Y	Y
2005	6	10	5:06	161	33	7.250167°N	28.4525°W	283	Y	Y	Y
2005	6	10	5:06	161	33	7.250167°N	28.4525°W	284	Y	Y	Y
2005	6	10	12:07	161	34	7.745833°N	28.6778°W	285	Y	Y	Y
2005	6	10	12:07	161	34	7.745833°N	28.6778°W	286	Y	Y	Y
2005	6	10	12:07	161	34	7.745833°N	28.6778°W	287	Y	Y	Y
2005	6	10	12:07	161	34	7.745833°N	28.6778°W	288	Y	Y	Y
2005	6	10	12:07	161	34	7.745833°N	28.6778°W	289	Y	Y	Y
2005	6	10	12:07	161	34	7.745833°N	28.6778°W	290	Y	Y	Y
2005	6	11	4:06	162	35	10.007°N	29.7932°W	294	Y	Y	Y
2005	6	11	4:06	162	35	10.007°N	29.7932°W	295	Y	Y	Y
2005	6	11	4:06	162	35	10.007°N	29.7932°W	296	Y	Y	Y
2005	6	11	4:06	162	35	10.007°N	29.7932°W	297	Y	Y	Y
2005	6	11	4:06	162	35	10.007°N	29.7932°W	298	Y	Y	Y
2005	6	11	4:06	162	35	10.007°N	29.7932°W	299	Y	Y	Y
2005	6	11	4:06	162	35	10.007°N	29.7932°W	300	Y	Y	Y
2005	6	12	12:10	163	37	13.195°N	31.3432°W	308	Y	Y	Y

Year	Mon	Day	Time (GMT)	Cal. Day	CTD#/ UW id.	Lat (dec deg)	Lon (dec deg)	Sample #	PIC?	CC?	BSi?
2005	6	12	12:10	163	37	13.195°N	31.3432°W	309	Y		Y
2005	6	12	12:10	163	37	13.195°N	31.3432°W	310	Y		Y
2005	6	12	12:10	163	37	13.195°N	31.3432°W	311	Y		Y
2005	6	12	12:10	163	37	13.195°N	31.3432°W	312	Y		Y
2005	6	12	12:10	163	37	13.195°N	31.3432°W	313	Y		Y
2005	6	13	4:43	164	38	15.76233°N	32.5993°W	317	Y	Y	Y
2005	6	13	4:43	164	38	15.76233°N	32.5993°W	318	Y	Y	Y
2005	6	13	4:43	164	38	15.76233°N	32.5993°W	319	Y	Y	Y
2005	6	13	4:43	164	38	15.76233°N	32.5993°W	320	Y	Y	Y
2005	6	13	4:43	164	38	15.76233°N	32.5993°W	321	Y	Y	Y
2005	6	13	4:43	164	38	15.76233°N	32.5993°W	322	Y	Y	Y
2005	6	13	4:43	164	38	15.76233°N	32.5993°W	323	Y	Y	Y
2005	6	13	4:43	164	38	15.76233°N	32.5993°W	324	Y	Y	Y
2005	6	13	12:02	164	39	16.3245°N	32.8863°W	325	Y	Y	Y
2005	6	13	12:02	164	39	16.3245°N	32.8863°W	326	Y	Y	Y
2005	6	13	12:02	164	39	16.3245°N	32.8863°W	327	Y	Y	Y
2005	6	13	12:02	164	39	16.3245°N	32.8863°W	328	Y	Y	Y
2005	6	13	12:02	164	39	16.3245°N	32.8863°W	329	Y	Y	Y
2005	6	13	12:02	164	39	16.3245°N	32.8863°W	330	Y	Y	Y
2005	6	14	4:11	165	40	18.96533°N	34.2153°W	334	Y	Y	Y
2005	6	14	4:11	165	40	18.96533°N	34.2153°W	335	Y	Y	Y
2005	6	14	4:11	165	40	18.96533°N	34.2153°W	336	Y	Y	Y
2005	6	14	4:11	165	40	18.96533°N	34.2153°W	337	Y	Y	Y
2005	6	14	4:11	165	40	18.96533°N	34.2153°W	338	Y	Y	Y
2005	6	14	4:11	165	40	18.96533°N	34.2153°W	339	Y	Y	Y
2005	6	14	4:11	165	40	18.96533°N	34.2153°W	340	Y	Y	Y
2005	6	14	4:11	165	40	18.96533°N	34.2153°W	341	Y	Y	Y
2005	6	14	12:00	165	41	20.08333°N	34.7723°W	343	Y	Y	Y
2005	6	14	12:00	165	41	20.08333°N	34.7723°W	344	Y		Y
2005	6	14	12:00	165	41	20.08333°N	34.7723°W	345	Y		Y
2005	6	14	12:00	165	41	20.08333°N	34.7723°W	346	Y		Y
2005	6	14	12:00	165	41	20.08333°N	34.7723°W	347	Y		Y
2005	6	14	12:00	165	41	20.08333°N	34.7723°W	348	Y		Y
2005	6	15	4:33	166	42	22.80517°N	36.1638°W	352	Y	Y	Y
2005	6	15	4:33	166	42	22.80517°N	36.1638°W	353	Y	Y	Y
2005	6	15	4:33	166	42	22.80517°N	36.1638°W	354	Y	Y	Y
2005	6	15	4:33	166	42	22.80517°N	36.1638°W	355	Y	Y	Y
2005	6	15	4:33	166	42	22.80517°N	36.1638°W	356	Y	Y	Y
2005	6	15	4:33	166	42	22.80517°N	36.1638°W	357	Y	Y	Y
2005	6	15	4:33	166	42	22.80517°N	36.1638°W	358	Y	Y	Y
2005	6	15	4:33	166	42	22.80517°N	36.1638°W	359	Y	Y	Y
2005	6	15	12:00	166	43	23.35967°N	36.4572°W	360	Y	Y	Y
2005	6	15	12:00	166	43	23.35967°N	36.4572°W	361	Y		Y
2005	6	15	12:00	166	43	23.35967°N	36.4572°W	362	Y		Y
2005	6	15	12:00	166	43	23.35967°N	36.4572°W	363	Y		Y
2005	6	15	12:00	166	43	23.35967°N	36.4572°W	364	Y		Y
2005	6	15	12:00	166	43	23.35967°N	36.4572°W	365	Y		Y
2005	6	16	13:33	167	45	26.841°N	37.2962°W	370	Y	Y	Y

Year	Mon	Day	Time (GMT)	Cal. Day	CTD#/ UW id.	Lat (dec deg)	Lon (dec deg)	Sample #	PIC?	CC?	BSi?
2005	6	16	13:33	167	45	26.841°N	37.2962°W	371	Y		Y
2005	6	16	13:33	167	45	26.841°N	37.2962°W	372	Y		Y
2005	6	16	13:33	167	45	26.841°N	37.2962°W	373	Y		Y
2005	6	16	13:33	167	45	26.841°N	37.2962°W	374	Y		Y
2005	6	16	13:33	167	45	26.841°N	37.2962°W	375	Y		Y
2005	6	17	4:40	168	46	29.15717°N	39.5422°W	379	Y	Y	Y
2005	6	17	4:40	168	46	29.15717°N	39.5422°W	380	Y	Y	Y
2005	6	17	4:40	168	46	29.15717°N	39.5422°W	381	Y	Y	Y
2005	6	17	4:40	168	46	29.15717°N	39.5422°W	382	Y	Y	Y
2005	6	17	4:40	168	46	29.15717°N	39.5422°W	383	Y	Y	Y
2005	6	17	4:40	168	46	29.15717°N	39.5422°W	384	Y	Y	Y
2005	6	17	4:40	168	46	29.15717°N	39.5422°W	385	Y	Y	Y
2005	6	17	4:40	168	46	29.15717°N	39.5422°W	386	Y	Y	Y
2005	6	17	12:18	168	47	29.4545°N	39.8142°W	387	Y	Y	Y
2005	6	17	12:18	168	47	29.4545°N	39.8142°W	388	Y		Y
2005	6	17	12:18	168	47	29.4545°N	39.8142°W	389	Y		Y
2005	6	17	12:18	168	47	29.4545°N	39.8142°W	390	Y		Y
2005	6	17	12:18	168	47	29.4545°N	39.8142°W	391	Y		Y
2005	6	17	12:18	168	47	29.4545°N	39.8142°W	392	Y		Y
2005	6	18	4:05	169	48	31.383°N	42.1437°W	396	Y	Y	Y
2005	6	18	4:05	169	48	31.383°N	42.1437°W	397	Y	Y	Y
2005	6	18	4:05	169	48	31.383°N	42.1437°W	398	Y	Y	Y
2005	6	18	4:05	169	48	31.383°N	42.1437°W	399	Y	Y	Y
2005	6	18	4:05	169	48	31.383°N	42.1437°W	400	Y	Y	Y
2005	6	18	4:05	169	48	31.383°N	42.1437°W	401	Y	Y	Y
2005	6	18	4:05	169	48	31.383°N	42.1437°W	402	Y	Y	Y
2005	6	18	11:56	169	49	31.7235°N	42.6497°W	403	Y	Y	Y
2005	6	18	11:56	169	49	31.7235°N	42.6497°W	404	Y		Y
2005	6	18	11:56	169	49	31.7235°N	42.6497°W	405	Y		Y
2005	6	18	11:56	169	49	31.7235°N	42.6497°W	406	Y		Y
2005	6	18	11:56	169	49	31.7235°N	42.6497°W	407	Y		Y
2005	6	18	11:56	169	49	31.7235°N	42.6497°W	408	Y		Y
2005	6	19	5:02	170	50	33.57717°N	45.5388°W	412	Y	Y	Y
2005	6	19	5:02	170	50	33.57717°N	45.5388°W	413	Y	Y	Y
2005	6	19	5:02	170	50	33.57717°N	45.5388°W	414	Y	Y	Y
2005	6	19	5:02	170	50	33.57717°N	45.5388°W	415	Y	Y	Y
2005	6	19	5:02	170	50	33.57717°N	45.5388°W	416	Y	Y	Y
2005	6	19	5:02	170	50	33.57717°N	45.5388°W	417	Y	Y	Y
2005	6	19	5:02	170	50	33.57717°N	45.5388°W	418	Y	Y	Y
2005	6	19	12:08	170	51	33.92583°N	46.0755°W	420	Y	Y	Y
2005	6	19	12:08	170	51	33.92583°N	46.0755°W	421	Y		Y
2005	6	19	12:08	170	51	33.92583°N	46.0755°W	422	Y		Y
2005	6	19	12:08	170	51	33.92583°N	46.0755°W	423	Y		Y
2005	6	19	12:08	170	51	33.92583°N	46.0755°W	424	Y		Y
2005	6	19	12:08	170	51	33.92583°N	46.0755°W	425	Y		Y
2005	6	20	5:00	171	52	34.90167°N	42.5595°W	429	Y	Y	Y
2005	6	20	5:00	171	52	34.90167°N	42.5595°W	430	Y	Y	Y
2005	6	20	5:00	171	52	34.90167°N	42.5595°W	431	Y	Y	Y

Year	Mon	Day	Time (GMT)	Cal. Day	CTD#/ UW id.	Lat (dec deg)	Lon (dec deg)	Sample #	PIC?	CC?	BSi?
2005	6	20	5:00	171	52	34.90167°N	42.5595°W	432	Y	Y	Y
2005	6	20	5:00	171	52	34.90167°N	42.5595°W	433	Y	Y	Y
2005	6	20	5:00	171	52	34.90167°N	42.5595°W	434	Y	Y	Y
2005	6	20	5:00	171	52	34.90167°N	42.5595°W	435	Y	Y	Y
2005	6	20	5:00	171	52	34.90167°N	42.5595°W	436	Y	Y	Y
2005	6	20	12:06	171	53	35.09867°N	41.8433°W	437	Y	Y	Y
2005	6	20	12:06	171	53	35.09867°N	41.8433°W	438	Y		Y
2005	6	20	12:06	171	53	35.09867°N	41.8433°W	439	Y		Y
2005	6	20	12:06	171	53	35.09867°N	41.8433°W	440	Y		Y
2005	6	20	12:06	171	53	35.09867°N	41.8433°W	441	Y		Y
2005	6	20	12:06	171	53	35.09867°N	41.8433°W	442	Y		Y
2005	6	21	4:35	172	54	36.0685°N	38.3423°W	446	Y	Y	Y
2005	6	21	4:35	172	54	36.0685°N	38.3423°W	447	Y	Y	Y
2005	6	21	4:35	172	54	36.0685°N	38.3423°W	448	Y	Y	Y
2005	6	21	4:35	172	54	36.0685°N	38.3423°W	449	Y	Y	Y
2005	6	21	4:35	172	54	36.0685°N	38.3423°W	450	Y	Y	Y
2005	6	21	4:35	172	54	36.0685°N	38.3423°W	451	Y	Y	Y
2005	6	21	4:35	172	54	36.0685°N	38.3423°W	452	Y	Y	Y
2005	6	21	12:01	172	55	36.45983°N	36.9197°W	454	Y	Y	Y
2005	6	21	12:01	172	55	36.45983°N	36.9197°W	455	Y		Y
2005	6	21	12:01	172	55	36.45983°N	36.9197°W	456	Y		Y
2005	6	21	12:01	172	55	36.45983°N	36.9197°W	457	Y		Y
2005	6	21	12:01	172	55	36.45983°N	36.9197°W	458	Y		Y
2005	6	21	12:01	172	55	36.45983°N	36.9197°W	459	Y		Y
2005	6	22	4:05	173	56	37.349°N	33.6617°W	463	Y	Y	Y
2005	6	22	4:05	173	56	37.349°N	33.6617°W	464	Y	Y	Y
2005	6	22	4:05	173	56	37.349°N	33.6617°W	465	Y	Y	Y
2005	6	22	4:05	173	56	37.349°N	33.6617°W	466	Y	Y	Y
2005	6	22	4:05	173	56	37.349°N	33.6617°W	467	Y	Y	Y
2005	6	22	4:05	173	56	37.349°N	33.6617°W	468	Y	Y	Y
2005	6	22	4:05	173	56	37.349°N	33.6617°W	469	Y	Y	Y
2005	6	22	4:05	173	56	37.349°N	33.6617°W	470	Y	Y	Y
2005	6	22	11:59	173	57	37.57217°N	32.8372°W	471	Y	Y	Y
2005	6	22	11:59	173	57	37.57217°N	32.8372°W	472	Y		Y
2005	6	22	11:59	173	57	37.57217°N	32.8372°W	473	Y		Y
2005	6	22	11:59	173	57	37.57217°N	32.8372°W	474	Y		Y
2005	6	22	11:59	173	57	37.57217°N	32.8372°W	475	Y		Y
2005	6	22	11:59	173	57	37.57217°N	32.8372°W	476	Y		Y
2005	6	23	3:02	174	58	38.305°N	30.0638°W	480	Y	Y	Y
2005	6	23	3:02	174	58	38.305°N	30.0638°W	481	Y	Y	Y
2005	6	23	3:02	174	58	38.305°N	30.0638°W	482	Y	Y	Y
2005	6	23	3:02	174	58	38.305°N	30.0638°W	483	Y	Y	Y
2005	6	23	3:02	174	58	38.305°N	30.0638°W	484	Y	Y	Y
2005	6	23	3:02	174	58	38.305°N	30.0638°W	485	Y	Y	Y
2005	6	23	3:02	174	58	38.305°N	30.0638°W	486	Y	Y	Y
2005	6	23	12:00	174	59	39.2595°N	28.8223°W	488	Y	Y	Y
2005	6	23	12:00	174	59	39.2595°N	28.8223°W	489	Y		Y
2005	6	23	12:00	174	59	39.2595°N	28.8223°W	490	Y		Y

Year	Mon	Day	Time (GMT)	Cal. Day	CTD#/ UW id.	Lat (dec deg)	Lon (dec deg)	Sample #	PIC?	CC?	BSi?
2005	6	23	12:00	174	59	39.2595°N	28.8223°W	491	Y		Y
2005	6	23	12:00	174	59	39.2595°N	28.8223°W	492	Y		Y
2005	6	23	12:00	174	59	39.2595°N	28.8223°W	493	Y		Y
2005	6	24	3:10	175	60	41.139°N	26.3767°W	497	Y	Y	Y
2005	6	24	3:10	175	60	41.139°N	26.3767°W	498	Y	Y	Y
2005	6	24	3:10	175	60	41.139°N	26.3767°W	499	Y	Y	Y
2005	6	24	3:10	175	60	41.139°N	26.3767°W	500	Y	Y	Y
2005	6	24	3:10	175	60	41.139°N	26.3767°W	501	Y	Y	Y
2005	6	24	3:10	175	60	41.139°N	26.3767°W	502	Y	Y	Y
2005	6	24	3:10	175	60	41.139°N	26.3767°W	503	Y	Y	Y
2005	6	24	12:05	175	61	42.11083°N	25.0697°W	505	Y	Y	Y
2005	6	24	12:05	175	61	42.11083°N	25.0697°W	506	Y		Y
2005	6	24	12:05	175	61	42.11083°N	25.0697°W	507	Y		Y
2005	6	24	12:05	175	61	42.11083°N	25.0697°W	508	Y		Y
2005	6	24	12:05	175	61	42.11083°N	25.0697°W	509	Y		Y
2005	6	24	12:05	175	61	42.11083°N	25.0697°W	510	Y		Y
2005	6	25	2:35	176	62	43.73533°N	22.8732°W	514	Y	Y	Y
2005	6	25	2:35	176	62	43.73533°N	22.8732°W	515	Y	Y	Y
2005	6	25	2:35	176	62	43.73533°N	22.8732°W	516	Y	Y	Y
2005	6	25	2:35	176	62	43.73533°N	22.8732°W	517	Y	Y	Y
2005	6	25	2:35	176	62	43.73533°N	22.8732°W	518	Y	Y	Y
2005	6	25	2:35	176	62	43.73533°N	22.8732°W	519	Y	Y	Y
2005	6	25	2:35	176	62	43.73533°N	22.8732°W	520	Y	Y	Y
2005		25	12:00	176	63	44.36833°N	21.9968°W	522	Y	Y	Y
2005	6	25	12:00	176	63	44.36833°N	21.9968°W	523	Y		Y
2005	6	25	12:00	176	63	44.36833°N	21.9968°W	524	Y		Y
2005	6	25	12:00	176	63	44.36833°N	21.9968°W	525	Y		Y
2005	6	25	12:00	176	63	44.36833°N	21.9968°W	526	Y		Y
2005	6	25	12:00	176	63	44.36833°N	21.9968°W	527	Y		Y
2005	6	26	5:43	177	64	46.0335°N	19.6702°W	531	Y	Y	Y
2005	6	26	5:43	177	64	46.0335°N	19.6702°W	532	Y	Y	Y
2005	6	26	5:43	177	64	46.0335°N	19.6702°W	533	Y	Y	Y
2005	6	26	5:43	177	64	46.0335°N	19.6702°W	534	Y	Y	Y
2005	6	26	5:43	177	64	46.0335°N	19.6702°W	535	Y	Y	Y
2005	6	26	5:43	177	64	46.0335°N	19.6702°W	536	Y	Y	Y
2005	6	26	5:43	177	64	46.0335°N	19.6702°W	537	Y	Y	Y
2005	6	26	11:06	177	65	46.36567°N	18.8537°W	538	Y	Y	Y
2005	6	26	11:06	177	65	46.36567°N	18.8537°W	539	Y		Y
2005	6	26	11:06	177	65	46.36567°N	18.8537°W	540	Y		Y
2005	6	26	11:06	177	65	46.36567°N	18.8537°W	541	Y		Y
2005	6	26	11:06	177	65	46.36567°N	18.8537°W	542	Y		Y
2005	6	26	11:06	177	65	46.36567°N	18.8537°W	543	Y		Y

Appendix 6. Discrete samples taken from underway system for calibration of O_2/Ar and N_2/Ar ratios as well as $^{17}O/^{16}O$ and $^{18}O/^{16}O$ isotope ratio measurements of dissolved O_2

Flask	Station	Cast	Niskin	Date	Time	Lat	Long
82	9	9	23	05/28/05	13:14:52	27°50'S	10°31'W
96	11	12	23	05/29/05	11:44:43	27°10'S	13°50'W
108	12	13	21	05/30/05	5:44:03	26°32'S	17°13'W
804	14	15	21	05/31/05	6:10:04	25°36'S	21°56'W
812	15	16	23	05/31/05	12:44:14	25°23'S	23°05'W
829	18	19	23	06/02/05	5:46:35	20°12'S	25°00'W
842	21	22	23	06/03/05	12:39:15	15°25'S	25°00'W
890	24	25	10	06/05/05	5:30:59	09°04'S	25°00'W
889	24	25	21	06/05/05	5:45:07	09°04'S	25°00'W
909	28	28	21	06/07/05	5:44:15	01°38'S	25°00'W
937	34	34	23	06/10/05	12:47:34	07°42'N	28°40'W
982	37	37	23	06/12/05	12:39:35	13°12'N	31°21'W
1006	43	43	23	06/15/05	15:44:26	23°22'N	36°27'W
1025	46	46	21	06/18/05	5:38:40	31°23'N	42°08'W
1019	46	46	22	06/17/05	5:50:13	29°09'N	39°32'W
1036	50	50	21	06/19/05	5:37:28	33°35'N	45°32'W
1044	52	52	21	06/20/05	6:04:27	34°55'N	42°33'W
1051	54	54	21	06/21/05	5:16:09	36°04'N	38°21'W
1062	56	56	21	06/22/05	4:57:29	37°21'N	33°40'W
1072	59	59	23	06/23/05	12:43:13	39°16'N	28°50'W
1076	60	60	21	06/24/05	4:27:46	41°09'N	26°23'W
1080	62	62	23	06/25/05	3:13:08	43°44'N	22°52'W
1092	65	65	21	06/26/05	11:44:25	46°22'N	18°52'W
2	underway			05/22/05	17:39:00	32°51'N	16°21'E
4	underway			05/22/05	23:30:00	32°44'N	15°44'E
6	underway			05/23/05	6:07:00	32°49'N	14°50'E
9	underway			05/23/05	13:00:00	32°37'N	13°34'E
10	underway			05/23/05	18:01:00	32°19'N	12°33'E
11	underway			05/24/05	2:33:00	31°53'N	10°41'E
12	underway			05/24/05	7:38:00	31°42'N	09°50'E
14	underway			05/24/05	12:07:30	31°32'N	09°07'E
21	underway			05/24/05	18:11:30	31°17'N	07°44'E
22	underway			05/24/05	23:19:30	31°04'N	06°36'E
28	underway			05/25/05	6:58:00	30°45'N	04°52'E
32	underway			05/25/05	11:58:30	30°36'N	03°59'E
33	underway			05/25/05	18:14:30	30°20'N	02°36'E
52	underway			05/25/05	22:27:00	30°10'N	01°43'E
61	underway			05/26/05	4:51:30	29°57'N	00°36'E
65	underway			05/26/05	10:52:00	29°43'N	00°36'E
66	underway			05/26/05	15:59:30	29°30'N	01°43'W
67	underway			05/26/05	22:26:00	29°15'N	03°07'W
68	underway			05/27/05	7:14:00	28°53'N	04°59'W
71	underway			05/27/05	12:39:30	28°43'N	05°52'W
73	underway			05/27/05	18:17:00	28°29'N	07°05'W
74	underway			05/27/05	23:32:00	28°16'N	08°13'W

Flask	Station	Cast	Niskin	Date	Time	Lat	Long
78	underway			05/28/05	8:03:00	28°00’N	09°36’W
80	underway			05/28/05	13:03:30	27°50’N	10°31’W
84	underway			05/28/05	18:09:30	27°38’N	11°33’W
88	underway			05/29/05	1:23:30	27°20’N	13°02’W
91	underway			05/29/05	7:15:30	27°14’N	13°27’W
93	underway			05/29/05	11:58:30	27°10’N	13°50’W
98	underway			05/29/05	17:16:00	26°59’N	14°53’W
99	underway			05/29/05	23:15:30	26°44’N	16°10’W
100	underway			05/30/05	5:46:00	26°32’N	17°13’W
111	underway			05/30/05	11:30:30	26°18’N	18°23’W
112	underway			05/30/05	18:20:30	26°04’N	19°35’W
117	underway			05/30/05	23:34:00	25°51’N	20°42’W
807	underway			05/31/05	6:30:00	25°36’N	21°58’W
809	underway			05/31/05	12:52:00	25°23’N	23°05’W
813	underway			05/31/05	23:29:30	23°49’N	24°27’W
820	underway			06/01/05	8:17:00	22°59’N	24°59’W
822	underway			06/01/05	17:59:00	22°10’N	25°00’W
825	underway			06/01/05	23:51:30	21°03’N	25°00’W
826	underway			06/02/05	5:38:30	20°12’N	25°00’W
827	underway			06/02/05	17:19:30	18°32’N	25°00’W
833	underway			06/02/05	23:28:00	17°22’N	25°00’W
834	underway			06/03/05	7:56:30	16°09’N	25°00’W
836	underway			06/03/05	12:34:00	15°25’N	25°00’W
856	underway			06/03/05	18:41:00	14°26’N	25°00’W
863	underway			06/03/05	23:29:00	13°32’N	25°00’W
874	underway			06/04/05	9:57:00	12°18’N	25°00’W
876	underway			06/04/05	13:10:00	11°57’N	25°01’W
879	underway			06/04/05	17:57:00	11°05’N	25°00’W
880	underway			06/04/05	23:34:30	10°00’N	25°00’W
887	underway			06/05/05	5:33:00	09°04’N	25°00’W
891	underway			06/05/05	15:33:30	07°42’N	25°00’W
894	underway			06/05/05	23:36:00	06°09’N	25°00’W
896	underway			06/06/05	8:28:00	04°55’N	25°00’W
899	underway			06/06/05	16:59:30	03°28’N	25°00’W
902	underway			06/06/05	23:39:00	02°22’N	25°00’W
903	underway			06/07/05	5:38:00	01°38’N	25°00’W
910	underway			06/07/05	11:36:00	01°14’N	25°00’W
912	underway			06/07/05	18:07:30	00°15’N	25°00’W
914	underway			06/07/05	23:15:00	00°29’N	25°14’W
915	underway			06/08/05	5:12:00	01°11’N	25°34’W
919	underway			06/08/05	11:21:30	01°59’N	25°58’W
920	underway			06/08/05	17:46:00	02°44’N	26°18’W
922	underway			06/08/05	23:30:30	03°32’N	26°41’W
926	underway			06/09/05	7:21:30	04°28’N	27°07’W
928	underway			06/09/05	11:46:30	05°09’N	27°27’W
933	underway			06/09/05	19:16:30	05°43’N	27°44’W
935	underway			06/09/05	23:48:00	06°27’N	28°05’W
936	underway			06/10/05	7:42:00	07°14’N	28°26’W
953	underway			06/10/05	12:52:30	07°42’N	28°40’W

Flask	Station	Cast	Niskin	Date	Time	Lat	Long
941	underway			06/10/05	20:24:00	08°46'N	29°12'W
954	underway			06/10/05	23:43:00	09°19'N	29°28'W
959	underway			06/11/05	7:04:00	10°15'N	29°55'W
962	underway			06/11/05	11:16:00	10°54'N	30°14'W
970	underway			06/11/05	17:17:00	11°25'N	30°29'W
972	underway			06/11/05	23:32:00	12°01'N	30°46'W
974	underway			06/12/05	7:21:30	12°47'N	31°08'W
980	underway			06/12/05	12:52:30	13°12'N	31°21'W
986	underway			06/12/05	21:48:30	14°39'N	32°04'W
992	underway			06/13/05	7:52:00	15°47'N	32°35'W
993	underway			06/13/05	12:38:00	16°20'N	32°53'W
994	underway			06/13/05	17:52:00	17°12'N	33°20'W
995	underway			06/13/05	23:39:00	18°14'N	33°50'W
996	underway			06/14/05	5:17:00	18°58'N	34°12'W
997	underway			06/14/05	11:35:00	20°02'N	34°45'W
999	underway			06/14/05	17:41:00	20°56'N	35°12'W
1002	underway			06/14/05	23:06:00	21°54'N	35°42'W
1003	underway			06/15/05	8:28:30	22°48'N	36°09'W
1004	underway			06/15/05	15:23:00	23°22'N	36°27'W
1008	underway			06/15/05	23:39:30	24°46'N	37°12'W
1010	underway			06/16/05	8:33:00	26°07'N	37°54'W
1012	underway			06/16/05	14:14:30	26°51'N	38°18'W
1013	underway			06/16/05	23:45:30	28°26'N	39°09'W
1017	underway			06/17/05	5:23:00	29°09'N	39°32'W
1016	underway			06/17/05	23:39:30	30°42'N	41°19'W
1024	underway			06/18/05	5:39:00	31°23'N	42°08'W
1026	underway			06/18/05	11:20:30	31°41'N	42°34'W
1027	underway			06/18/05	16:55:00	32°13'N	43°24'W
1033	underway			06/18/05	23:06:30	32°56'N	44°32'W
1034	underway			06/19/05	5:27:00	33°35'N	45°32'W
1038	underway			06/19/05	12:37:30	33°55'N	46°05'W
1040	underway			06/19/05	17:18:00	34°10'N	45°12'W
1041	underway			06/19/05	23:31:00	34°34'N	43°47'W
1042	underway			06/20/05	5:35:30	34°55'N	42°33'W
1045	underway			06/20/05	18:09:00	35°26'N	40°39'W
1047	underway			06/20/05	23:28:00	35°46'N	39°25'W
1048	underway			06/21/05	5:04:00	36°04'N	38°21'W
1057	underway			06/21/05	14:04:30	36°32'N	36°39'W
1059	underway			06/21/05	23:19:30	37°05'N	34°39'W
1061	underway			06/22/05	4:28:00	37°21'N	33°40'W
1064	underway			06/22/05	14:02:00	37°30'N	32°35'W
1067	underway			06/22/05	23:42:00	38°08'N	30°46'W
1071	underway			06/23/05	8:17:30	38°49'N	29°24'W
1074	underway			06/23/05	21:02:30	40°20'N	27°25'W
1077	underway			06/24/05	11:25:30	42°03'N	25°09'W
1078	underway			06/24/05	20:30:00	43°04'N	23°47'W
1083	underway			06/25/05	13:22:30	44°26'N	21°54'W
1091	underway			06/26/05	0:11:00	45°37'N	20°15'W
1094	underway			06/26/05	23:02:30	46°50'N	16°21'W

Appendix 7. Aerosol Sampling

Sample name	Sampling Start time	Start date	Latitude Start	Longitude Start	Sampling End date	End time	Latitude End	Longitude End	Notes
AMT16M01 (MOTOR BLANK)	20/05/05	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
AMT16M02 (CASSETTE BLANK?)	21/05/05	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
AMT16M03	22/05/05	08:18:00	33°07.38'S	17°40.76'W	24/05/05	09:15:00	31°36.85'S	9°28.38'W	1
AMT16M04	25/05/05	08:57:00	30°40.25'S	04°25.21'W	27/05/05	15:35:00	28°35.68'S	6°31.18'W	
AMT16M05	27/05/05	16:00:00	28°34.42'S	06°37.53'W	29/05/05	14:00:00	27°05.50'S	14°12.80'W	
AMT16M06	29/05/05	15:15:00	27°01.77'S	14°37.91'W	30/05/05	15:00:00	not recorded	see underway data	2
AMT16M07	02/06/05	17:47:00	18°27.14'S	24°59.92'W	04/06/05	?	11°21.55'S	25°00.02'W	
AMT16M08 (Exposure Blank)	04/06/05	18:45:00	N/A	N/A	05/06/05	19:00:00	N/A	N/A	
AMT16M09	06/06/05	19:44:00	2°57.68'S	25°59.87'W	08/06/05	15:37:00	2°26.15'N	26°09.63'W	3
AMT16M10	08/06/05	19:07:00	2°55.10'N	26°23.50'W	10/06/05	16:30:00	8°07.33'N	28°53.18'W	4
AMT16M11	10/0605	18:21:00	8°36.76'N	29°07.06'W	12/06/05	16:46:00	13°48.83'N	31°38.85'W	5
AMT16M12	12/06/05	19:29:00	14°16.41'N	31°52.38'W	14/06/05	16:18:00	20°41.21'N	35°04.75'W	6
AMT16M13	14/06/05	20:08:00	21°21.63'N	35°25.90'W	16/06/05	16:59:00	27°16.73'N	38°31.53'W	7
AMT16M14	16/06/05	18:17:00	27°50.61'N	38°49.63'W	13/06/05	17:32:00	32°17.52'N	43°31.26'W	8
AMT16M15	18/06/05	18:42:00	32°39.97'N	44°06.36'W	21/06/05	15:11:00	36°36.31'N	36°24.04'W	
AMT16M16	21/06/05	16:22:00	36°40.48'N	36°08.47'W	24/06/05	14:42:00	42°21.65'N	36°08.47'W	9
AMT16M17	24/06/05	19:39:00	42°58.68'N	23°54.38'W	27/06/05	09:08:00	47°12.32'N	14°20.03'W	

Notes

1. V. Clean
2. Tail Wind - Pump turned off when indicated but filter remained in sampler until 02/06/05

3-6 Strong colour grey or red colour

7. Less colour
8. Wind very calm at start of sampling - Less colour
9. Possibly contaminated crew painting monkey island!!

Appendix 8. Water samples for nitrate and dissolved organic nitrogen isotope analysis

Nalgene #	Station	Cast	Niskin	Date	GMT	Lat.	Long.	z_{approx}m	Light level	Remarks
S-G 973	1	1	23	5/21/05	02:30	31°58'S	16°58'E	2	97%	
S-G 974	1	1	19	5/21/05	02:30	31°58'S	16°58'E	10	55%	
S-G 975	1	1	13	5/21/05	02:30	31°58'S	16°58'E	30	14%	
S-G 976	1	1	12	5/21/05	02:30	31°58'S	16°58'E	40	upslope	
S-G 977	1	1	10	5/21/05	02:30	31°58'S	16°58'E	50	1%	
S-G 978	1	1	8	5/21/05	02:30	31°58'S	16°58'E	65	downslope	
S-G 979	1	1	6	5/21/05	02:30	31°58'S	16°58'E	85	0.1%	
S-G 980	1	1	5	5/21/05	02:30	31°58'S	16°58'E	100		
S-G 981	1	1	4	5/21/05	02:30	31°58'S	16°58'E	125		
S-G 982	1	1	3	5/21/05	02:30	31°58'S	16°58'E	175		
S-G 983	1	1	2	5/21/05	02:30	31°58'S	16°58'E	225		
S-G 984	1	1	1	5/21/05	02:30	31°58'S	16°58'E	250		
S-G 985	4	4	23	5/24/05	10:13	31°35'S	09°20'E	2	97%	
S-G 986	4	4	21	5/24/05	10:13	31°35'S	09°20'E	13	55%	
S-G 987	4	4	19	5/24/05	10:13	31°35'S	09°20'E	23	33%	
S-G 988	4	4	17	5/24/05	10:13	31°35'S	09°20'E	42	14%	
S-G 989	4	4	15	5/24/05	10:13	31°35'S	09°20'E	90	upslope	maybe contaminated (black particles)
S-G 990	4	4	14	5/24/05	10:13	31°35'S	09°20'E	95	1%	
S-G 991	4	4	10	5/24/05	10:13	31°35'S	09°20'E	100	downslope	
S-G 992	4	4	9	5/24/05	10:13	31°35'S	09°20'E	110	0.1%	
S-G 993	4	4	6	5/24/05	10:13	31°35'S	09°20'E	125		
S-G 994	4	4	5	5/24/05	10:13	31°35'S	09°20'E	150		
S-G 995	4	4	3	5/24/05	10:13	31°35'S	09°20'E	225		
S-G 996	4	4	1	5/24/05	10:13	31°35'S	09°20'E	300		
S-G 997	6	6	23	5/26/05	03:37	29°58'S	00°42'E	2	97%	
S-G 998	6	6	21	5/26/05	03:37	29°58'S	00°42'E	5		
S-G 999	6	6	19	5/26/05	03:37	29°58'S	00°42'E	13	55%	
S-H 886	6	6	13	5/26/05	03:37	29°58'S	00°42'E	23	33%	

Nalgene #	Station	Cast	Niskin	Date	GMT	Lat.	Long.	z_{approx}m	Light level	Remarks
S-H 887	6	6	11	5/26/05	03:37	29°58'S	00°42'E	42	14%	
S-H 888	6	6	10	5/26/05	03:37	29°58'S	00°42'E	70	upslope	
S-H 889	6	6	9	5/26/05	03:37	29°58'S	00°42'E	95	1%	
S-H 892	6	6	6	5/26/05	03:37	29°58'S	00°42'E	110	downslope	
S-H 893	6	6	4	5/26/05	03:37	29°58'S	00°42'E	145	0.1%	
S-H 894	6	6	3	5/26/05	03:37	29°58'S	00°42'E	180		Niskin bottle did not seal properly
S-H 895	6	6	2	5/26/05	03:37	29°58'S	00°42'E	240		
S-H 896	6	6	1	5/26/05	03:37	29°58'S	00°42'E	300		
S-H 897	10	11	23	5/29/05	07:58	27°14'S	13°27'W	2	97%	
S-H 898	10	11	21	5/29/05	07:58	27°14'S	13°27'W	5		
S-H 899	10	11	19	5/29/05	07:58	27°14'S	13°27'W	17	55%	
S-H 900	10	11	15	5/29/05	07:58	27°14'S	13°27'W	31	33%	
S-H 901	10	11	13	5/29/05	07:58	27°14'S	13°27'W	56	14%	
S-H 902	10	11	11	5/29/05	07:58	27°14'S	13°27'W	90		
S-H 903	10	11	10	5/29/05	07:58	27°14'S	13°27'W	120	upslope	
S-H 904	10	11	6	5/29/05	07:58	27°14'S	13°27'W	140	downslope	
S-H 905	10	11	4	5/29/05	07:58	27°14'S	13°27'W	195	0.1%	
S-H 906	10	11	3	5/29/05	07:58	27°14'S	13°27'W	220		
S-H 907	10	11	2	5/29/05	07:58	27°14'S	13°27'W	250		
S-H 908	10	11	1	5/29/05	07:58	27°14'S	13°27'W	300		Niskin bottle may have leaked
S-H 909	15	16	23	5/31/05	12:02	25°23'S	23°05'W	2	97%	
S-H 910	15	16	21	5/31/05	12:02	25°23'S	23°05'W	16	55%	
S-H 911	15	16	19	5/31/05	12:02	25°23'S	23°05'W	29	33%	
S-H 912	15	16	18	5/31/05	12:02	25°23'S	23°05'W	52	14%	
S-H 913	15	16	17	5/31/05	12:02	25°23'S	23°05'W	80		
S-H 914	15	16	10	5/31/05	12:02	25°23'S	23°05'W	120	1%	
S-H 915	15	16	6	5/31/05	12:02	25°23'S	23°05'W	160		
S-H 916	15	16	5	5/31/05	12:02	25°23'S	23°05'W	200		
S-H 917	15	16	3	5/31/05	12:02	25°23'S	23°05'W	250		
S-H 918	15	16	1	5/31/05	12:02	25°23'S	23°05'W	300		
S-H 919	17	18	23	6/1/05	12:07	22°28'S	25°00'W	2	97%	
S-H 920	17	18	21	6/1/05	12:07	22°28'S	25°00'W	17	55%	

Nalgene #	Station	Cast	Niskin	Date	GMT	Lat.	Long.	z_{approx}m	Light level	Remarks
S-H 921	17	18	20	6/1/05	12:07	22°28'S	25°00'W	31	33%	
S-H 922	17	18	18	6/1/05	12:07	22°28'S	25°00'W	57	14%	
S-H 923	17	18	6	6/1/05	12:07	22°28'S	25°00'W	95		
S-H 924	17	18	15	6/1/05	12:07	22°28'S	25°00'W	130	1%	
S-H 925	17	18	12	6/1/05	12:07	22°28'S	25°00'W	150		
S-H 926	17	18	10	6/1/05	12:07	22°28'S	25°00'W	170		
S-H 927	17	18	9	6/1/05	12:07	22°28'S	25°00'W	225		
S-H 928	17	18	8	6/1/05	12:07	22°28'S	25°00'W	300		
S-H 929	17	18	16	6/1/05	12:07	22°28'S	25°00'W	500		sampled in clean container by Ed Mawji
S-H 930	17	18	11	6/1/05	12:07	22°28'S	25°00'W	750		sampled in clean container by Ed Mawji
S-H 931	17	18	3	6/1/05	12:07	22°28'S	25°00'W	1000		sampled in clean container by Ed Mawji
S-H 932	17	18	7	6/1/05	12:07	22°28'S	25°00'W	2000		sampled in clean container by Ed Mawji
S-H 933	17	18	1	6/1/05	12:07	22°28'S	25°00'W	3500		sampled in clean container by Ed Mawji
S-H 934	17	18	4	6/1/05	12:07	22°28'S	25°00'W	4400		sampled in clean container by Ed Mawji
S-H 935	17	18	2	6/1/05	12:07	22°28'S	25°00'W	5390		sampled in clean container by Ed Mawji
S-H 936	18	19	23	6/2/05	04:37	20°21'S	25°00'W	2	97%	
S-H 937	18	19	21	6/2/05	04:37	20°21'S	25°00'W	5		
S-H 938	18	19	19	6/2/05	04:37	20°21'S	25°00'W	20	55%	
S-H 939	18	19	15	6/2/05	04:37	20°21'S	25°00'W	36	33%	
S-H 940	18	19	13	6/2/05	04:37	20°21'S	25°00'W	65	14%	
S-H 941	18	19	12	6/2/05	04:37	20°21'S	25°00'W	105		
S-H 942	18	19	11	6/2/05	04:37	20°21'S	25°00'W	125	upslope	
S-H 943	18	19	8	6/2/05	04:37	20°21'S	25°00'W	150	1%	
S-H 944	18	19	6	6/2/05	04:37	20°21'S	25°00'W	225	0.1%	
S-H 945	18	19	4	6/2/05	04:37	20°21'S	25°00'W	275		Niskin bottle compromised
S-H 946	18	19	2	6/2/05	04:37	20°21'S	25°00'W	500		Niskin bottle compromised
S-H 947	18	19	1	6/2/05	04:37	20°21'S	25°00'W	1000		
S-H 948	21	22	23	6/3/05	12:04	15°25'S	25°00'W	2	97%	
S-H 949	21	22	20	6/3/05	12:04	15°25'S	25°00'W	33	33%	
S-H 950	21	22	15	6/3/05	12:04	15°25'S	25°00'W	80		
S-H 951	21	22	14	6/3/05	12:04	15°25'S	25°00'W	110		
S-H 952	21	22	9	6/3/05	12:04	15°25'S	25°00'W	140	1%	

Nalgene #	Station	Cast	Niskin	Date	GMT	Lat.	Long.	z_{approx}m	Light level	Remarks
S-H 953	21	22	6	6/3/05	12:04	15°25'S	25°00'W	175		
S-H 954	21	22	3	6/3/05	12:04	15°25'S	25°00'W	225		
S-H 955	21	22	1	6/3/05	12:04	15°25'S	25°00'W	300		
S-H 956	23	24	23	6/4/05	12:03	11°57'S	25°01'W	2	97%	
S-H 957	23	24	20	6/4/05	12:03	11°57'S	25°01'W	29	33%	
S-H 958	23	24	15	6/4/05	12:03	11°57'S	25°01'W	75		
S-H 959	23	24	14	6/4/05	12:03	11°57'S	25°01'W	90		
S-H 960	23	24	9	6/4/05	12:03	11°57'S	25°01'W	120	1%	
S-H 961	23	24	6	6/4/05	12:03	11°57'S	25°01'W	170		
S-H 962	23	24	3	6/4/05	12:03	11°57'S	25°01'W	225		
S-H 963	23	24	1	6/4/05	12:03	11°57'S	25°01'W	300		
S-H 964	24	25	21	6/5/05	04:35	09°05'S	25°00'W	2	97%	
S-H 965	24	25	15	6/5/05	04:35	09°05'S	25°00'W	25	33%	
S-H 966	24	25	14	6/5/05	04:35	09°05'S	25°00'W	46	14%	
S-H 967	24	25	12	6/5/05	04:35	09°05'S	25°00'W	75		
S-H 968	24	25	10	6/5/05	04:35	09°05'S	25°00'W	105	1%	
S-H 969	24	25	5	6/5/05	04:35	09°05'S	25°00'W	158	0.1%	
S-H 970	24	25	4	6/5/05	04:35	09°05'S	25°00'W	200		
S-H 971	24	25	3	6/5/05	04:35	09°05'S	25°00'W	300		
S-H 972	24	25	2	6/5/05	04:35	09°05'S	25°00'W	500		
S-H 973	24	25	1	6/5/05	04:35	09°05'S	25°00'W	1000		
S-H 974	27	27	23	6/6/05	12:02	04°15'S	25°00'W	2	97%	
S-H 975	27	27	20	6/6/05	12:02	04°15'S	25°00'W	18	33%	Niskin bottle compromised
S-H 976	27	27	15	6/6/05	12:02	04°15'S	25°00'W	50		
S-H 977	27	27	10	6/6/05	12:02	04°15'S	25°00'W	75	1%	
S-H 978	27	27	8	6/6/05	12:02	04°15'S	25°00'W	100		
S-H 979	27	27	5	6/6/05	12:02	04°15'S	25°00'W	150		
S-H 980	27	27	3	6/6/05	12:02	04°15'S	25°00'W	225		
S-H 981	27	27	1	6/6/05	12:02	04°15'S	25°00'W	300		
S-H 001	28	28	23	6/7/05	05:03	01°38'S	25°00'W	2	97%	*Trichodesmium* "puffs"
S-H 002	28	28	20	6/7/05	05:03	01°38'S	25°00'W	10	55%	*Trichodesmium* "puffs"
S-H 003	28	28	11	6/7/05	05:03	01°38'S	25°00'W	30	14%	*Trichodesmium* "puffs"

Nalgene #	Station	Cast	Niskin	Date	GMT	Lat.	Long.	z_{approx}m	Light level	Remarks
S-H 004	28	28	9	6/7/05	05:03	01°38'S	25°00'W	55	upslope	*Trichodesmium* "puffs"
S-H 005	28	28	5	6/7/05	05:03	01°38'S	25°00'W	85		*Trichodesmium* "puffs"
S-H 006	28	28	3	6/7/05	05:03	01°38'S	25°00'W	105	0.1%	*Trichodesmium* "puffs"
S-H 007	28	28	2	6/7/05	05:03	01°38'S	25°00'W	200		
S-H 008	28	28	1	6/7/05	05:03	01°38'S	25°00'W	300		
S-H 009	29	29	23	6/8/05	04:13	01°11'N	25°34'W	3	97%	*Trichodesmium* "puffs"
S-H 010	29	29	13	6/8/05	04:13	01°11'N	25°34'W	22	14%	*Trichodesmium* "puffs"
S-H 011	29	29	10	6/8/05	04:13	01°11'N	25°34'W	48	1%	*Trichodesmium* "puffs"
S-H 012	29	29	6	6/8/05	04:13	01°11'N	25°34'W	75	0.1%	*Trichodesmium* "puffs"
S-H 013	29	29	4	6/8/05	04:13	01°11'N	25°34'W	100		
S-H 014	29	29	3	6/8/05	04:13	01°11'N	25°34'W	150		
S-H 015	29	29	2	6/8/05	04:13	01°11'N	25°34'W	300		
S-H 016	29	29	1	6/8/05	04:13	01°11'N	25°34'W	1000		
S-H 017	32	32	23	6/9/05	12:11	05°09'N	27°27'W	2	97%	
S-H 018	32	32	21	6/9/05	12:11	05°09'N	27°27'W	10	55%	Niskin tap not sealed
S-H 019	32	32	19	6/9/05	12:11	05°09'N	27°27'W	20	33%	
S-H 020	32	32	18	6/9/05	12:11	05°09'N	27°27'W	35	14%	
S-H 021	32	32	15	6/9/05	12:11	05°09'N	27°27'W	50		
S-J 127	32	32	14	6/9/05	12:11	05°09'N	27°27'W	65		
S-J 128	32	32	5	6/9/05	12:11	05°09'N	27°27'W	80	1%	
S-J 129	32	32	10	6/9/05	12:11	05°09'N	27°27'W	90		
S-J 130	32	32	9	6/9/05	12:11	05°09'N	27°27'W	120	0.1%	
S-J 131	32	32	8	6/9/05	12:11	05°09'N	27°27'W	200		
S-J 132	32	32	3	6/9/05	12:11	05°09'N	27°27'W	300		
S-J 133	32	32	16	6/9/05	12:11	05°09'N	27°27'W	500		sampled in clean container by Ed Mawji
S-J 134	32	32	11	6/9/05	12:11	05°09'N	27°27'W	850		sampled in clean container by Ed Mawji
S-J 135	32	32	7	6/9/05	12:11	05°09'N	27°27'W	1500		sampled in clean container by Ed Mawji
S-J 136	32	32	4	6/9/05	12:11	05°09'N	27°27'W	2400		sampled in clean container by Ed Mawji
S-J 137	32	32	2	6/9/05	12:11	05°09'N	27°27'W	3500		sampled in clean container by Ed Mawji
S-J 138	32	32	1	6/9/05	12:11	05°09'N	27°27'W	4310		sampled in clean container by Ed Mawji
S-J 139	34	34	23	6/10/05	12:07	07°42'N	28°41'W	2	97%	
S-J 140	34	34	18	6/10/05	12:07	07°42'N	28°41'W	22	14%	

Nalgene #	Station	Cast	Niskin	Date	GMT	Lat.	Long.	z_{approx}m	Light level	Remarks
S-J 141	34	34	14	6/10/05	12:07	07°42'N	28°41'W	50	1%	
S-J 143	34	34	8	6/10/05	12:07	07°42'N	28°41'W	100		
S-J 144	34	34	5	6/10/05	12:07	07°42'N	28°41'W	150		
S-J 145	34	34	3	6/10/05	12:07	07°42'N	28°41'W	225		
S-J 147	34	34	1	6/10/05	12:07	07°42'N	28°41'W	300		
S-J 149	35	35	23	6/11/05	04:06	10°00'N	29°48'W	2	97%	
S-J 150	35	35	14	6/11/05	04:06	10°00'N	29°48'W	30	14%	
S-J 151	35	35	10	6/11/05	04:06	10°00'N	29°48'W	68	1% / F_{max}	
S-J 152	35	35	7	6/11/05	04:06	10°00'N	29°48'W	95	downslope	
S-J 153	35	35	5	6/11/05	04:06	10°00'N	29°48'W	132	0.1%	
S-J 154	35	35	4	6/11/05	04:06	10°00'N	29°48'W	200		
S-J 157	35	35	3	6/11/05	04:06	10°00'N	29°48'W	350		
S-J 158	35	35	15	6/11/05	04:06	10°00'N	29°48'W	16	33%	
S-J 159	37	37	23	6/12/05	12:02	13°12'N	31°21'W	2	97%	
S-J 160	37	37	20	6/12/05	12:02	13°12'N	31°21'W	20	33%	
S-J 161	37	37	18	6/12/05	12:02	13°12'N	31°21'W	36	14%	
S-J 162	37	37	14	6/12/05	12:02	13°12'N	31°21'W	75		
S-J 163	37	37	10	6/12/05	12:02	13°12'N	31°21'W	82	1% / F_{max}	
S-J 164	37	37	8	6/12/05	12:02	13°12'N	31°21'W	100		
S-J 165	37	37	3	6/12/05	12:02	13°12'N	31°21'W	225		
S-J 166	37	37	1	6/12/05	12:02	13°12'N	31°21'W	300		
S-J 167	39	39	23	6/13/05	12:02	16°20'N	32°53'W	2	97%	
S-J 168	39	39	20	6/13/05	12:02	16°20'N	32°53'W	24	33%	
S-J 169	39	39	18	6/13/05	12:02	16°20'N	32°53'W	44	14%	
S-J 170	39	39	14	6/13/05	12:02	16°20'N	32°53'W	60		
S-J 171	39	39	12	6/13/05	12:02	16°20'N	32°53'W	100	1% / F_{max}	
S-J 172	39	39	5	6/13/05	12:02	16°20'N	32°53'W	150		
S-J 173	39	39	3	6/13/05	12:02	16°20'N	32°53'W	225		
S-J 174	39	39	1	6/13/05	12:02	16°20'N	32°53'W	300		
S-J 175	40	40	23	6/14/05	04:11	18°58'N	34°12'W	2	97%	
S-J 176	40	40	15	6/14/05	04:11	18°58'N	34°12'W	36	33%	
S-J 177	40	40	12	6/14/05	04:11	18°58'N	34°12'W	80		

Nalgene #	Station	Cast	Niskin	Date	GMT	Lat.	Long.	z_{approx}m	Light level	Remarks
S-J 178	40	40	10	6/14/05	04:11	18°58'N	34°12'W	140	1% / F_{max}	
S-J 179	40	40	6	6/14/05	04:11	18°58'N	34°12'W	225		
S-J 180	40	40	4	6/14/05	04:11	18°58'N	34°12'W	300		
S-J 181	40	40	3	6/14/05	04:11	18°58'N	34°12'W	400		
S-J 182	40	40	2	6/14/05	04:11	18°58'N	34°12'W	600		
S-J 183	40	40	1	6/14/05	04:11	18°58'N	34°12'W	1000		
S-J 184	43	43	23	6/15/05	12:00	23°22'N	36°27'W	2	97%	
S-J 185	43	43	21	6/15/05	12:00	23°22'N	36°27'W	17	55%	
S-J 186	43	43	20	6/15/05	12:00	23°22'N	36°27'W	31	33%	
S-J 187	43	43	18	6/15/05	12:00	23°22'N	36°27'W	57	14%	
S-J 188	43	43	6	6/15/05	12:00	23°22'N	36°27'W	75		
S-J 189	43	43	15	6/15/05	12:00	23°22'N	36°27'W	100		
S-J 190	43	43	12	6/15/05	12:00	23°22'N	36°27'W	130	1% / F_{max}	
S-J 191	43	43	10	6/15/05	12:00	23°22'N	36°27'W	180		
S-J 192	43	43	9	6/15/05	12:00	23°22'N	36°27'W	225		
S-J 193	43	43	8	6/15/05	12:00	23°22'N	36°27'W	300		
S-J 194	43	43	3	6/15/05	12:00	23°22'N	36°27'W	500		
S-J 195	43	43	16	6/15/05	12:00	23°22'N	36°27'W	850		sampled in clean container by Ed Mawji
S-J 196	43	43	11	6/15/05	12:00	23°22'N	36°27'W	1500		sampled in clean container by Ed Mawji
S-J 197	43	43	7	6/15/05	12:00	23°22'N	36°27'W	2250		sampled in clean container by Ed Mawji
S-J 198	43	43	4	6/15/05	12:00	23°22'N	36°27'W	3500		sampled in clean container by Ed Mawji
S-J 199	43	43	2	6/15/05	12:00	23°22'N	36°27'W	4500		sampled in clean container by Ed Mawji
S-J 200	43	43	1	6/15/05	12:00	23°22'N	36°27'W	5900		sampled in clean container by Ed Mawji
S-J 201	45	45	23	6/16/05	13:33	26°51'N	38°18'W	2	97%	
S-J 202	45	45	18	6/16/05	13:33	26°51'N	38°18'W	63	14%	
S-J 203	45	45	14	6/16/05	13:33	26°51'N	38°18'W	110		
S-J 204	45	45	9	6/16/05	13:33	26°51'N	38°18'W	145	1% / F_{max}	
S-J 205	45	45	6	6/16/05	13:33	26°51'N	38°18'W	180		
S-J 206	45	45	3	6/16/05	13:33	26°51'N	38°18'W	225		
S-J 209	46	46	23	6/17/05	04:40	29°09'N	39°32'W	2	97%	
S-J 210	46	46	21	6/17/05	04:40	29°09'N	39°32'W	18	55%	
S-J 211	46	46	17	6/17/05	04:40	29°09'N	39°32'W	32	33%	

Nalgene #	Station	Cast	Niskin	Date	GMT	Lat.	Long.	z_{approx}m	Light level	Remarks
S-J 212	46	46	13	6/17/05	04:40	29°09'N	39°32'W	80		
S-J 213	46	46	11	6/17/05	04:40	29°09'N	39°32'W	135	1% / F_{max}	
S-J 214	46	46	6	6/17/05	04:40	29°09'N	39°32'W	202	0.1%	
S-J 215	46	46	5	6/17/05	04:40	29°09'N	39°32'W	285		
S-J 216	46	46	3	6/17/05	04:40	29°09'N	39°32'W	600		
S-J 217	46	46	2	6/17/05	04:40	29°09'N	39°32'W	1000		
S-J 218	51	51	23	6/19/05	12:08	33°56'N	46°05'W	2	97%	
S-J 219	51	51	18	6/19/05	12:08	33°56'N	46°05'W	28	14%	
S-J 220	51	51	10	6/19/05	12:08	33°56'N	46°05'W	65	1% / F_{max}	
S-J 221	51	51	8	6/19/05	12:08	33°56'N	46°05'W	100		
S-J 222	51	51	5	6/19/05	12:08	33°56'N	46°05'W	150		
S-J 519	51	51	3	6/19/05	12:08	33°56'N	46°05'W	225		
S-J 522	51	51	1	6/19/05	12:08	33°56'N	46°05'W	300		
S-J 532	60	60	23	6/24/05	03:00	41°09'N	26°23'W	2	97%	
S-J 534	60	60	19	6/24/05	03:00	41°09'N	26°23'W	10	55%	
S-J 535	60	60	14	6/24/05	03:00	41°09'N	26°23'W	35	14%	
S-J 543	60	60	10	6/24/05	03:00	41°09'N	26°23'W	75	1% / F_{max}	
S-J 545	60	60	6	6/24/05	03:00	41°09'N	26°23'W	120	0.1%	
S-J 547	60	60	4	6/24/05	03:00	41°09'N	26°23'W	200		
S-J 550	60	60	3	6/24/05	03:00	41°09'N	26°23'W	400		
S-J 553	60	60	2	6/24/05	03:00	41°09'N	26°23'W	800		
S-J 558	60	60	1	6/24/05	03:00	41°09'N	26°23'W	1000		