ABSTRACT

This report documents the scientific activities on board the Royal Research Ship (RRS) *James Clark Ross* (JCR) during the eighth Atlantic Meridional Transect (AMT-8), 24 April to 7 June 1999. There are three objectives of the AMT program. The first is to derive an improved understanding of the links between biogeochemical processes, biogenic gas exchange, air-sea interactions, and the effects on, and responses of, oceanic ecosystems and climate change. The second is to investigate the functional roles of biological particles and processes that influence ocean colour in ecosystems dynamics. The third is the algorithm development and validation of remotely sensed observations of ocean colour.

1 INTRODUCTION

The Atlantic Meridional Transect (AMT) programme, Robins and Aiken (1996), exploits the passage of the Royal Research Ship (RRS), *James Clark Ross* (JCR) through the Atlantic Ocean latitudinally from 50°N to 52°S, between the U.K. and the Falkland Islands, a distance of over 13,500 km. In September the JCR sails southward, sampling the N. Atlantic during the boreal fall and the S. Atlantic during the austral spring); the following April it returns to the UK, sampling the S. Atlantic during the austral fall and the spring conditions in the Northern Hemisphere. The ship's track crosses a range of ecosystems and physico-chemical regimes, within which conditions vary from sub-polar to tropical and from eutrophic shelf seas and upwelling systems to oligotrophic mid-ocean gyres. The JCR provides the ideal platform to measure physical, biological and bio-optical properties and processes through these diverse ecosystems of the North and South Atlantic Ocean.

The AMT programme scientific objectives are:

1. To test and refine hypotheses on the impact and the responses of oceanic circulation, marine ecosystems and the coupled marine atmosphere of the Atlantic Ocean to anthropogenically forced environmental change by assessing measurements of key marine and atmospheric variables over spatially extensive scales covering seasonal and inter-annual timescales.
2. To improve our knowledge of marine biogeochemical processes, ecosystem dynamics, food webs and fisheries and characterise physical and biogeochemical provinces.
3. To develop a holistic research strategy, integrating shipboard measurements with autonomous and novel techniques, remote sensing and modelling, exploiting the time and space series provided by the AMT.
4. To provide calibration and validation of satellite sensors of ocean colour, sea surface temperature, and solar radiation from high to low latitudes over the Atlantic Ocean, 50°N to 52°S.
5. To quantify oceanic ecosystem responses to changes in abundance of radiatively and chemically active trace gases.
6. To develop coupled physical-biological models of production and ecosystem dynamics.

Taken together, the goals and objectives form a holistic research strategy to provide an improved understanding of the links between biogeochemical processes, biogenic gas exchange, air sea interactions and the effects on, and responses of, oceanic ecosystems (biogeochemical provinces) to climate change. A key element of the strategy is to provide an improved understanding of the functional roles of biological particles and processes of ecosystem dynamics which can be related to the measurement of ocean colour.

The thrust of the AMT programme has been the acquisition of data for the development of remote sensing algorithms, the development of whole-water column algorithms, the interpretation of remotely sensed imagery, the determination of phytoplankton characteristics and photosynthetic parameters by Fast Repetition Rate Fluorometry (FRRF) for productivity studies. Additional to these are the development of climatologies of key parameters for regional and basin-scale productivity and ecosystem dynamics models, the measurement of zooplankton community structure and distribution, nutrient recycling and the exchange of atmospheric gases. The development of models of global primary production, ecosystem dynamics and air-sea interaction are the ultimate objectives of the programme. The specific objectives have been to produce calibrated, quantitative satellite measurements of oceanic biological properties, parameter values and contemporaneous data for tuning models that exploit satellite data.

The dates of the first 7 AMT cruises are: AMT-1 Sept./Oct. 1995; AMT-2 April/May 1996; AMT-3 Sept./Oct. 1996; AMT-4 April/May 1997; AMT-5 Sept./Oct. 1997; AMT-6 May/June (Cape Town to UK on JCR) (1998b); AMT-7 Sept./Oct. 1998.

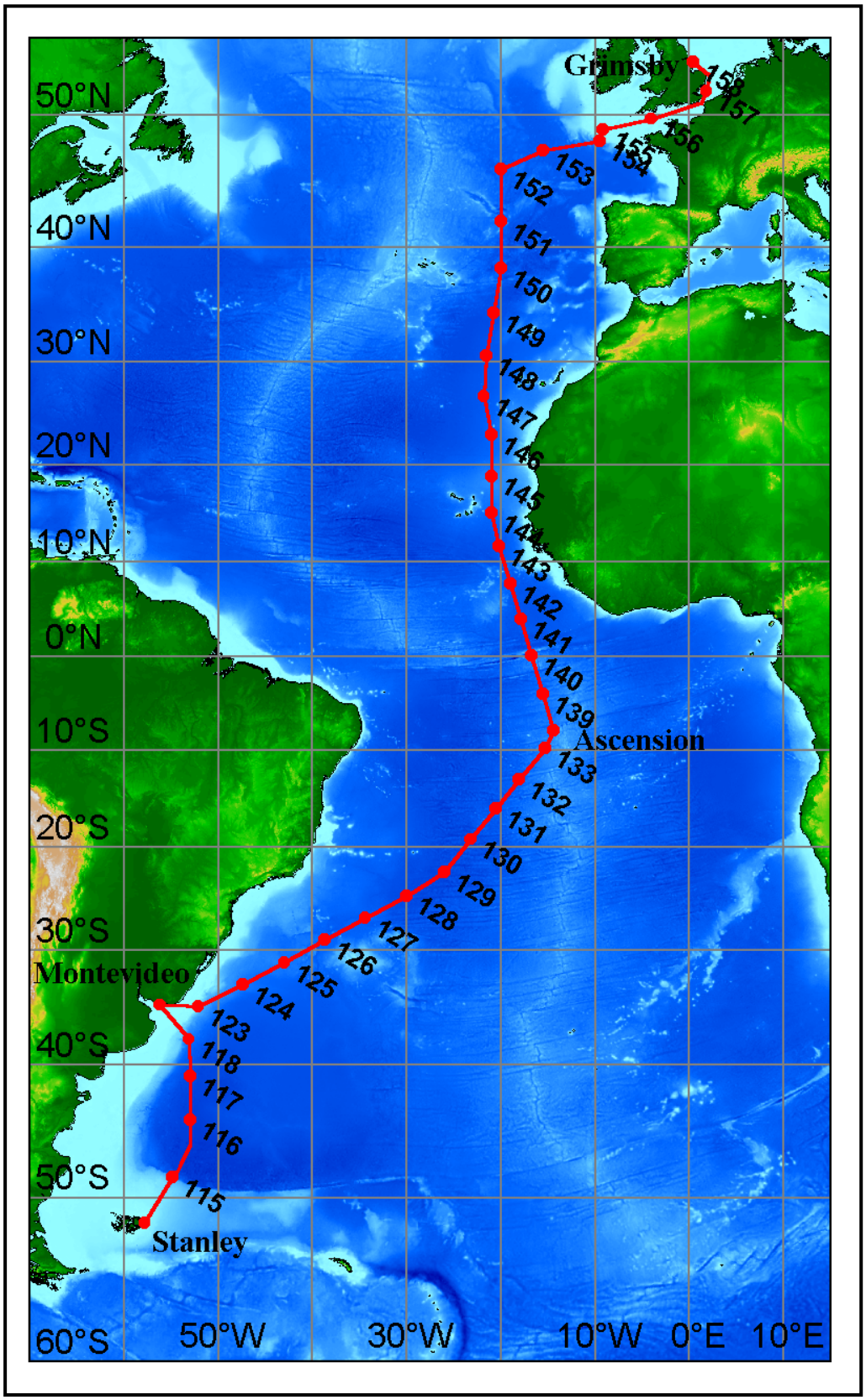

Figure 1. AMT-8 cruise track with noon positions and the sequential day of the year.

1.1 Cruise Strategy

The concept of the AMT is only marginally different from a ship of opportunity operation in that the scientific work is based on a passage either between the UK and Stanley or *vice versa.* Due to time limitations there is very little scope for deviation from the AMT track or from the present sampling routine.

The package which CCMS negotiated with BAS provides the AMT community with six days of ship time over and above the time that would be used for the direct (no science) passage. 2 days are used for the course deviations and the remainder for station time. The 'standard' AMT track (described from north to south) leaves the UK coastal shelf and head westward to 20°W, 47°N; this is a well-documented and repeated sampling area, forming a part of a series of international JGOFS stations. At 47°N the track turns south along 20°W which is an extension of the BOFS transect. This route aims to sample the edge of the Mauritanian upwelling. The track deviates slightly to avoid Madeira and Canaries territorial waters but cannot avoid either the Mauritanian or Cape Verde's EEZ for some 360 nautical miles. Diplomatic clearances for the Cape Verde's waters have been obtained from AMT4 onwards so continuous sampling has been possible. At 13°N the track heads south-west but staying outside Brazilian and Uruguayan waters until work stops off the R. Plate for a port call at Montevideo. After Montevideo the JCR shapes the best course for the Falkland Islands which avoids Uruguayan and Argentinean territorial waters.

A 4-day seismic cruise (JR-42) in the vicinity of Ascension Island (circa 8.7°W, 14.5°S), during AMT-8 resulted in a deviation from the 'typical' track. Figure 1 shows the full AMT-8 cruise track, Table 1 summaries the main cruise dates.

Date	Location
24/04/99 (114)	Depart Port Stanley
29/04/99 (119)	Arrive Montevideo
02/05/99 (122)	Depart Montevideo
13/05/99 (133)	Start of JR42
18/05/99 (138)	End of JR42
07/06/99 (158)	Arrive Grimsby

Table 1. AMT-8 main dates.

To accommodate the scientist involved in JR-42, the number of berths available to the AMT programme between Montevideo and Stanley was restricted. Of the 13 scientists involved in AMT-8, five were continuously on board for the complete passage from Stanley to the UK with others embarking/disembarking at Montevideo and Ascension, (appendix 1 contains the full list of cruise personnel). This impacted on scientific activities and in effect split the cruise into three distinct legs; Stanley-Montevideo, Montevideo-Ascension and Ascension-UK, each with different scientific objectives and activities.

1.2 Sampling Strategy

The daily routine consisted of continuous underway sampling of surface water using the uncontaminated sea water supply and daily stations. Where possible the research agenda and sampling location was dictated by the analysis of recent AVHRR, SeaWiFS and TOPEX imagery received on board via email. The strategy proved particularly effective in the higher latitudes with SeaWiFS imagery providing information for navigation into both a coccolithophore bloom and high chlorophyll levels at the UK shelf break.

On leg I the sampling strategy was tailored to investigate the structure of eddy systems within the Brazil/Falklands confluence. Science time was used to achieve the 53°W meridional, along which recent TOPEX imagery showed the centre of eddy activity. The CTD was deployed to coincide with the edges and the centre of the eddy systems

A 'shuffle' of scientist personnel and the arrival of the NASA optics team in Montevideo resulted in the sampling strategy on legs II and III focusing on the acquisition of optical measurements at the SeaWiFS wavebands and concurrent data on phytoplankton pigments and species, zooplankton, hydrographic properties, Productivity-Irradiance (PI) curves, biogases and nutrients. The primary station commenced at approximately 1030 (ship's time), coinciding with the recovery of the undulating oceanographic recorder.

The main instruments deployed were as follows:

1. Sea-Bird electronics (SBE) 911 plus CTD (conductivity, temperature and depth) sensor deployments from the dedicated mid-ships gantry, with fluorometer, transmissometer, and photosynthetically available radiation (PAR) instruments, plus a 12x30 l bottle water sampler for phytoplantkton pigments.
2. SeaFALLS and LoCNESS optical free-fall profilers deployed from the stern; and
3. Repeated zooplankton net deployments from the forward crane.

For much of leg II and virtually all of leg III, an afternoon optics station was performed to coincide, within +/- one hour of the SeaWiFS overpass. A total of 61 stations, were completed during AMT-8, with 38 (successful) CTD casts, XX Optics profiles, YY zooplankton nets. An inventory of measurements made on station are summarised in Table 2.

Table 2. A summary of station work executed during AMT-8. Station activities are denoted by C – CTD, Z – Zooplanton, O – Optics. Bold station indicate CTD failure. The HPLC column gives the chlorophyll *a* pigment concentration (mg m^{-3}) at 7m. The times are in Greenwich Mean Time (GMT).

DATE	SDAY	TIME	STATION		POSITION		HPLC
25 Apr.	**115**	**1311**	**A800**	**CZ**	**47°59.9'S**	**54°18.2'W**	
	115	1800	A801	C	47°36.7'S	53°57.1'W	
26 Apr.	116	0040	A802	CZ	46°30.0'S	53°00.0'W	
	116	1639	A803	CZ	43°30.0'S	53°00.0'W	
	116	2310	A804	CZ	42°29.8'S	53°00.0'W	
27 Apr.	117	0958	A805	CZ	41°11.9'S	53°00.4'W	
	117	1534	A806	CZ	40°12.0'S	53°00.0'W	
	117	2247	A807	CZ	39°00.7'S	52°59.9'W	
28 Apr.	118	1003	A808	CZ	38°00.1'S	52°59.9'W	
3 May	123	1400	A809	OCZ	35°04.6'S	51°40.3'W	0.142
4 May	**124**	**1356**	**A810**	**OCZ**	**32°57.7'S**	**47°01.1'W**	**0.045**
	124	**1728**	**A811**	**OCZ**	**32°41.7'S**	**46°27.1'W**	**0.067**
5 May	125	1546	A812	OCZ	30°44.1'S	42°16.1'W	0.087
6 May	126	1400	A813	OCZ	28°51.0'S	38°19.1'W	0.073
7 May	127	1258	A814	OCZ	26°53.6'S	34°15.1'W	0.075
8 May	128	1446	A815	OCZ	24°33.2'S	29°33.6'W	0.027
9 May	129	1347	A816	OCZ	22°13.7'S	25°49.0'W	0.029
10 May	130	1128	A817	OCZ	19°12.7'S	23°13.2'W	0.037
	130	1401	A818	OC	18°59.7'S	23°03.5'W	0.066
11 May	**131**	**1200**	**A819**	**OCZ**	**16°02.8'S**	**20°31.9'W**	**0.03**
	131	1405	A820	O	15°51.1'S	20°24.1'W	0.026
12 May	132	1030	A821	OCZ	13°10.2'S	18°07.5'W	0.039
	132	1330	A822	O	12°53.4'S	17°54.7'W	0.057
13 May	133	1030	A823	OCZ	09°51.6'S	15°23.9'W	0.086
	133	1301	A824	O	09°36.4'S	15°12.7'W	0.082
18 May	138	1332	A825	OCZ	07°38.5'S	14°31.0'W	0.072
19 May	**139**	**1030**	**A826**	**OCZ**	**04°07.1'S**	**15°31.8'W**	**0.161**
	139	1300	A827	OZ	03°52.3'S	15°36.8'W	0.184
20 May	140	1030	A828	OCZ	00°04.6'S	16°42.6'W	0.139
	140	1301	A829	OZ	00°13.9'N	16°47.9'W	0.11
21 May	141	1030	A830	OCZ	03°53.9'N	17°53.0'W	0.152
	141	1400	A831	OC	04°18.8'N	18°00.7'W	0.113
22 May	142	1028	A832	OCZ	07°37.2'N	18°59.3'W	0.168
	142	1245	A833	O	07°50.8'N	19°03.2'W	0.136
23 May	143	1028	A834	OCZ	11°33.8'N	20°09.1'W	0.237
	143	1332	A835	O	11°55.0'N	20°15.6'W	0.145
24 May	144	1035	A836	OCZ	15°09.0'N	21°00.2'W	0.414
	145	1028	A837	OCZ	18°48.1'N	21°00.2'W	0.814
25 May	145	1401	A838	O	19°18.5'N	21°00.0'W	0.412
26 May	146	1028	A839	OCZ	22°55.0'N	21°00.9'W	0.117
	146	1331	A840	O	23°16.7'N	21°03.9'W	0.145
27 May	**147**	**1030**	**A841**	**OCZ**	**26°41.6'N**	**21°48.4'W**	**0.079**
	147	1331	A842	OZ	27°03.1'N	21°52.2'W	0.094
28 May	148	1022	A843	OCZ	30°28.0'N	21°33.8'W	0.048
	148	1403	A844	O	30°57.3'N	21°29.9'W	0.037
29 May	149	1026	A845	OCZ	34°22.0'N	20°47.3'W	0.054
	149	1301	A846	OZ	34°33.0'N	20°41.5'W	0.052
30 May	150	1028	A847	OCZ	38°10.7'N	20°00.7'W	0.036
	150	1359	A848	O	38°38.5'N	20°00.2'W	0.079
31 May	151	1030	A849	OCZ	41°51.0'N	20°00.7'W	0.124

	151	1259	A850	O	42°15.8’N	20°00.5’W	0.137
1 June	152	1008	A851	OCZ	45°56.6’N	19°58.7’W	
	152	1330	A852	O	46°22.7’N	20°00.1’W	
	152	1750	A853	CZ	47°00.0’N	20°00.0’W	0.661
2 June	153	1032	A854	OCZ	47°27.2’N	15°39.8’W	
	153	1450	A855	O	47°32.4’N	14°46.3’W	0.852
3 June	154	1036	A856	OCZ	48°08.9’N	09°39.9’W	0.514
	154	1236	A857	O	48°12.8’N	09°24.5’W	1.9-2.9
	154	1500	A858	OCZ	48°15.2’N	09°14.1’W	2.028
4 June	155	1030	A859	OCZ	48°58.9’N	09°15.0’W	0.932
	155	1244	A860	OC	48°59.0’N	09°10.7’W	0.942
	155	1458	A861	O	49°01.9’N	08°51.9’W	0.647
5 June	156	1008	A862	OCZ	49°42.1’N	04°27.5’W	1.5-2.4

2 NARRATIVE

Monday 19 April - Thursday 22 April (110), UK to Falkland Islands

An inauspicious beginning.

The flight transporting the AMT personnel to the Falkland Islands was delayed overnight at Ascension Island, with the RAF providing accommodation in *bunk bed city.* In the evening we visited the Mountain View Club, where to keep up morale Greg was allowed to organise and win the AMT-8 pool competition. Phone calls to the UK confirmed that the airfreight was still at Brize Norton. After consultation the airfreight was re-organised by Malcolm Woodward to meet the JCR in Montevideo.

We arrived in Stanley on the Wednesday evening, and the following morning the JCR docked. We were able to scrounge enough equipment from both BAS and UEA (thanks to David Blake and Dave Stevens) to be able to complete our basic work until we got to Montevideo.

Friday 23 April (113), Falkland Islands

We boarded the ship at 1300 in the middle of a snowstorm. The officers and crew had done a good job, unloading the PML container and putting equipment in the correct lab spaces. That left adequate time to set-up equipment ready for departure the following afternoon.

Saturday 24 April (114), South Atlantic Shelf

The day was spent completing the set-up of equipment. After consulting with the Captain a rapid transect of 14 knots, on a bearing 31°, to the waypoint of 46° 30’S 53°W was agreed. Underway work began at 0000 hours.

Sunday 25 April (115), South Atlantic

The JCR crossed the shelf break at 1200 and by 1400 we were in the over 5000m of water. Hourly XBT deployment began at 1300. At circa 1330 the Sub Antarctic front was crossed notable by a sharp increase in the Sea Surface Temperature (from 5 to 11°C within 20 km). The shakedown station was performed at 1500, problems with the configuration of the BAS CTD lead to an early abandonment. The first successful CTD (A801) was completed at 1900.

Monday 26 April (116), South Atlantic

After the morning CTD (A802) the JCR turned north and proceeded along the 53°W meridian at the standard passage speed (11.5 knots). The third station was performed at the edge of a warm core eddy and the forth (A804) in the core of the eddy. During A804 the CTD in-water pumps turned off for 30 seconds before recovering. The secondary system appeared to suffer flow problems, and the in-line fluorometer in the secondary system failed to give any sensible readings. Post cast the fluorometer was examined and it was discovered that the internal glass chamber was broken.

Tuesday 27 April (117), South Atlantic

CTD casts continued with main and secondary temperature and conductivity sensors and the transmissometer.

Wednesday 28 April (118), South Atlantic

The final CTD cast (A808) on leg I was performed at the edge of the Uruguayan EEZ. All sampling stopped after the station.

Thursday 29 April – Saturday 1 May, Montevideo

There were major changes in personnel on board, a change-over in officers and crew, the AMT personnel were ‘shuffled’, and the scientists and technicians of JR42 joined the vessel. Several sets of equipment arrived, with the notable exception of the airfreight left behind at Brize Norton.

Most of the science party took time to sort out their equipment, however a good couple of nights in Montevideo were possible. The local produce was heavily sampled, with the ‘meat market’ enjoying much of our custom.

Sunday 2 May (122), River Plate

After many, many inexplicable delays our airfreight arrived, 4 hours before the JCR sailed. A manic 24 hours ensued, as equipment was set-up.

Monday 3 May (123), South Atlantic

For the first time on an AMT Uruguay had granted permission to sample in her waters and a mid morning full station of Zooplanton nets, CTD (A809) and Optics rockets was performed.

Tuesday 4 May (124), South Atlantic

The CTD developed intermittent spikes on the data streams – this appeared to be a termination problem, however 3 re-terminations failed to cure the problem. No CTD cast was possible. Poor weather condition and a continual battle to get equipment working meant the optics team restricted themselves to a morning only cast.

Wednesday 5 May (125), South Atlantic

The BAS CTD was decommissioned, and seawater was found in the main power in plug. The NASA CTD was built as a replacement, and was successfully deployed (A812). Weather still poor.

Thursday 6 May (126), South Atlantic

Guy discovered half of the liquid nitrogen on board had evaporated (leaving approx. 100 l). Leonie reported that PI curves were limited to 4 station pre-Ascension, due to the small number of filters on board. An XBT calibration exercise post station was conducted. During the station (A813) Alex's drift net rips. Weather worsens.

Friday 7 May (127), South Atlantic

At the station (A814) Chris loses his rig and zooplankton net. We are in the clear blue waters of the South Atlantic Gyre, with a deep chlorophyll maximum and low chlorophyll concentrations. Weather still poor.

Saturday 8 May (128), South Atlantic

Weather conditions had eased but it was still too cloudy for good optics. Chris deployed the replacement zooplankton nets.

Sunday 9 May (129), Tropical South Atlantic

The first calm day, the clouds cleared for the first station – all instruments were deployed successfully. The carboys were filled with low nutrient water @ 21°57.7 S 25°34.8 W.

Monday10 May (130), Tropical South Atlantic

The ship placed the sun was on the port side for station A817. The afternoon station cast was to 3000m to obtain waters from the southerly flowing NADW for the bio-gas work. A good optics station.

Tuesday 11 May (131), Tropical South Atlantic

The CTD wire was twisted during A818 (the deep cast), to untwist the wire, a cast was performed to 3,000m with a weight attached as a replacement for the CTD. The re-termination took until 1900 hours – and the CTD cast was abandoned for the day. The first afternoon optics station was performed.

Wednesday 12 May(132), Tropical South Atlantic

All instruments working. Two good optics stations in clear conditions during SeaWiFS overpass.

Thursday 13 May (133), South of Ascension

A full casts in the morning, and a good optics station in the afternoon. At 1800 cruise JR42 takes over use of the ship. The main pump for the Stephen's Gas Chromatograph finally dies on him.

Friday 13 May – Monday 17 May JR42Cruise around Ascension

Proposal writing, paper chasing, catching up on work and sleep.

Tuesday 18 May (138), North of Ascension

We say good bye to the JR42 personnel and welcome back on board Adrian, Tony and Murielle. They bring some vital supplies, the UK papers, extra filters and replacement equipment. One station (A825) was performed north of Ascension in the afternoon. Swift sub-surface currents cause the delay of rocket deployments, but the station was successfully completed. The primary conductivity sensor on CTD (A825) has anomalous reading near surface on the up cast – on investigation the tube taking the water to the sensor was loose. Replacement equipment for Stephens GC was fitted successfully. Guy reports problems with the FRRF bench system as it appears to give low readings, and there are intermittent power failures from the battery packs.

Wednesday 19 May (139), Tropical South Atlantic

We start early morning UOR tows to compare the FRRF measurements with the PI curves obtained at the morning station. During the morning station a hydraulic hose on the CTD unit bursts, spraying the deck and CTD unit with oil, the cast was aborted (A826). The CTD was taken apart and the bottles are thoroughly cleaned, and the unit was washed down with soap and water. By evening the CTD was rebuilt and a new hydraulic hose was fitted. Zooplankton and

Optics work continued as normal as the spill was dealt with. For the first time on the cruise Toby measures significant levels of *Trichodesmium*.

Thursday 20 May (140), Equator

The morning station was performed just 6 miles south of the equator. A strong undercurrent sees both the zooplankton net and CTD wires pay out at sharp angles to starboard. It appears that the Bio-gas work has suffered heavily from (oil) contamination and Stephen begins a long battle with his machine that was destined to lasts until Grimsby.

In the evening we celebrate crossing the line with an equatorial BBQ.

Friday 21 May (141), North Equatorial Atlantic

During the morning station the clouds clear to give good optical conditions. On the afternoon station the Turner fluorometer was cleaned and checked – readings appear to be okay – and the levels on leaving the station are noted to rise slightly. Optics casts in the afternoon produce good data. Calm and hot.

Saturday 22 May (142), North Equatorial Atlantic

Experiments with UOR to determine optimum wire and speed to achieve good depth ranges begin. The ocean was like a millpond.

Sunday 23 May (143), North Equatorial Atlantic

Calm waters again, Fluorescence level rises throughout the day, accompanied by a fall in temperature as the influence of the upwelling off the African coast was felt. Calm conditions allow a good cast but there was intermittent haze. Waiting on imagery to decide the exact location for tomorrow's stations.

Monday 24 May (144), 200 miles off Senegal

A large increase in the level of fluorescence was recorded by the in-line Turner fluorometer, from 0730 to a maximum at 0830, circa 21°N 15°09'W. The UOR was recovered at 0930 by which time the levels of fluorescence had started to fall. The ship was turned around and headed back to the maximum and was on station by 1030. A 3 and a half-hour station (A836) was performed, during which time the surface fluorescence levels increase. A bonus for the optical work was the stability of the illumination field caused in part by the haze from the Saharan dust

SeaWiFS imagery downloaded to ship from the web was low quality and resolution it appears to show 'fingers' of chlorophyll heading offshore from the upwelling – one of which we may have sampled today. Hopefully the same can be repeated tomorrow. On leaving the station the UOR was towed again.

Tuesday 25 May (145), 200 miles off Mauritania

A large peak in fluorescence was recorded at 0300 but was not noticed until 0800 – frustratingly to far to turn around and sample. The weather conditions have deteriorated slightly there was a small swell and 'marble cloud' cover. The fluorescence levels on station are twice those at A836.

Wednesday 25 May (146), 200 miles off Mauritania

The effects of the upwelling had diminished. Two stations are performed in extremely calm waters and very stable clear skies.

Thursday 26 May (147), 200 miles off Canaries

Electrical problems strike. A malfunction in the cable-out metering causes the cancellation of the CTD cast. The oceanlogger system appears to have noise on the scientific temperature and the Themosalinograph channels. A replacement PC partially solves the problem but data was still noisy. Good clear skies and the calmest conditions seen at sea by many on-board. Stunning sunset.

Friday 28 May (148), Southwest of Madeira

The NASA spare CTD (SeaCat) system was used on deck with water from the non-toxic supply as a backup system, although the underway logger system appears to be 'settling down'.

Saturday 29 May (149), North Atlantic

Weather worsens slightly – regular casts. Scientist verses the crew at darts and crib in the crew bar.

Sunday 30 May (150), North Atlantic

Heading into a big swell all day, (light winds). During the morning station (A847) SeaFalls optics rocket makes contact with the hull of the ship, and damages its wings. The afternoon station was performed with Locness.

Monday 31 May (151), NE Atlantic

Still in a large swell – stations pass without any major problems

Tuesday 1 June (152), NE Atlantic

Weather improves overnight – we wake to a flat sea, blue skies and high fluorescence levels! 3 stations today including one at 20°W, 47°N, after which the ship turns east and head towards the English Channel, the weather starts to worsen as a low pressure follows us in towards the south-west. SeaWiFS images for the last week show

high chlorophyll on the shelf break, fortunately, just between French and Irish territorial waters and a coccolithophore bloom to the north of it.

Wednesday 2 June (153), NE Atlantic

An early morning UOR tow provides good data. The Sea State worsens, with squalls on and off all day, the optics team manages to dodge the showers and produce two good stations. Fluorescence levels continue to rise. Imagery received in the evening showed high chlorophyll staying on the shelf break, no new imagery showing coccolithophores.

Thursday 3 June (154) UK Shelf Break

At 1030 there was high chlorophyll and blue skies, 2 hours later the fluorescence levels are off the Turner fluorometer lower scale. The sea was virtually black. Three stations (A856, A857, and A858) are performed and the UOR was towed at all other times. At 1800 the JCR goes into an overnight grid pattern to map the coccolithophores bloom. At 2010 the ship entered the bloom, and the entire scientific party turn out to marvel at the milky blue seas. The UOR was being towed as we entered the bloom.

Friday 4 June (155), Shelf Break

The swell increased overnight, a contour of the overnight grid shows the lowest levels of light transmittance were in the northern section of the grid. The ship returns to northern section and two full stations are performed (A859, A860). There was an opportunistic optics stations later in the afternoon and the UOR was towed out of the bloom. The swell was increasing and was driving us up the channel.

Saturday 5 June (156), South of Cornwall

A dull dark day with heavy rain in other words a typical West Country summer weather, we are back. The final station begins under leaden skies but a large sudden (blue) rent in the clouds lets through the sun enough for a final optics cast in sunshine – a good way to finish. Underway sampling was completed after the morning station and the underway non-toxic water supply was turned off in the afternoon. Everyone tries to conclude their work in time for the end of cruise meal.

3 PROVINCES

Traditionally, oceanographers have partitioned the oceans on the basis of physical and biological characteristics: e.g., topography, geostrophic flows, wind-driven circulation, gyres, fronts, upwelling zones and patterns of seasonal stratification, biological productivity, as well as phytoplankton and zooplankton assemblages and community structure. Taken together, this bio-physical partitioning provides the descriptors of regional ecosystems or biogeochemical provinces, each with discrete boundaries and each having distinct flora and fauna. More recently, the concept of biogeochemical provinces has been promoted by Longhurst et al. (1995) particularly as a means of evaluating patterns of basin- to global-scale productivity from remotely sensed measurements of ocean colour, making use of province-specific physical and biological parameterisations (climatological values of the key variables).

The AMT cruise track crosses 10 provinces proposed by Longhurst (1998). For reference Figure 2 shows a plot of the along-track temperature, salinity and raw fluorometery recorded during AMT-8, with the approximate province boundaries overlaid. Each province appears to have distinct fluorescence characteristics, however the surface physical characteristics are variable within the larger provinces.

Longhurst concentrated his work on distinguishing regions on marine ecology, rather than the physical structure. Hence the fronts at 30°South (Brazil Current front), and 36°North (Azores Front) are not viewed by as province boundaries. The equatorial region (ETRA) contains the banded structure of the equatorial currents, North Equatorial Current, the North Equatorial Counter Current (NECC), and the South Equatorial The NECC is a particularly distinct feature, seen as a drop in salinity water at circa 4°North.

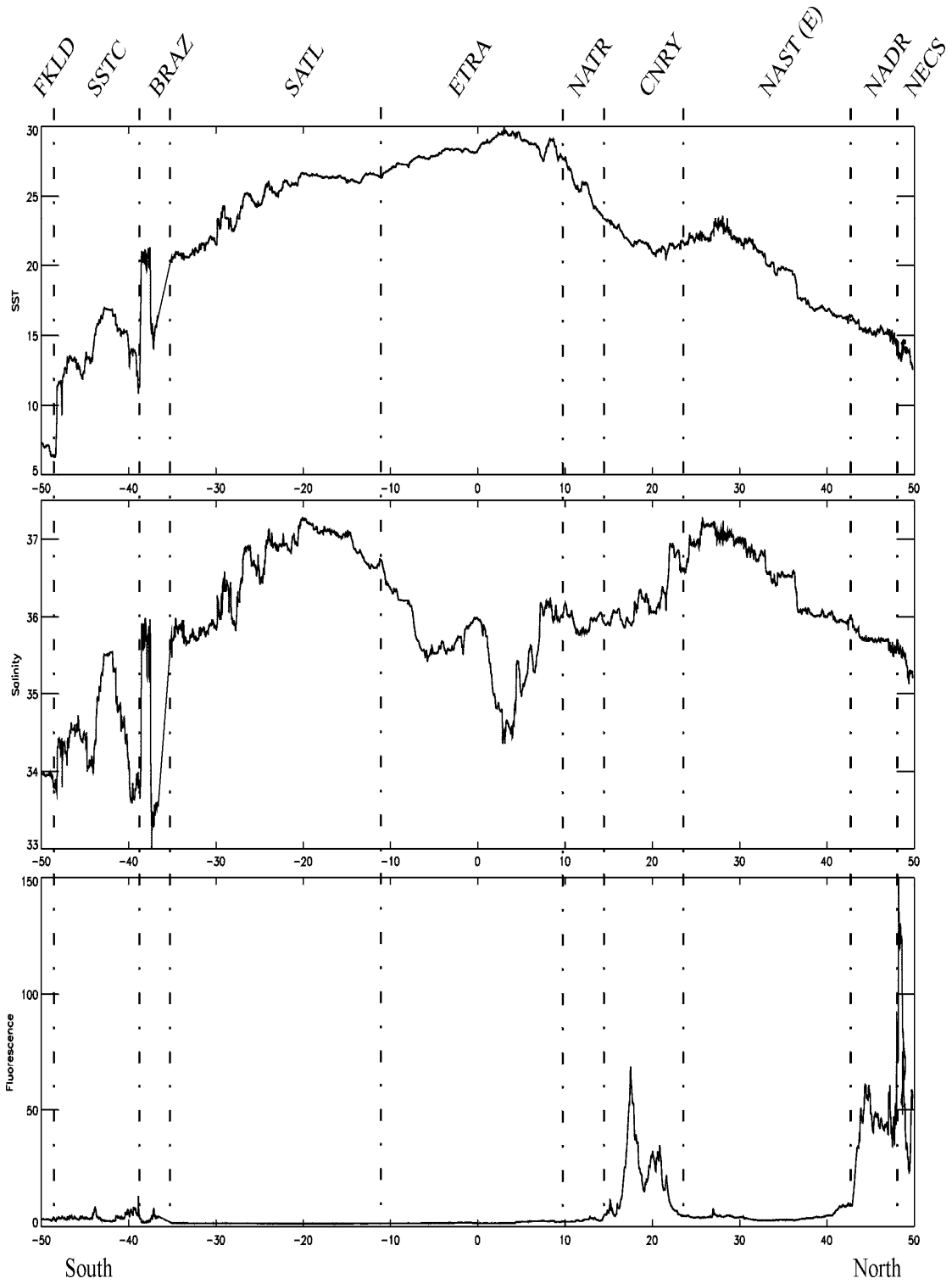

Figure 2. Temperature, Salinity and Fluorescence at 1-minute intervals recorded from waters at 7m depth during AMT-8, plotted against latitude. Provinces from Longhurst: FKLD Southwest Atlantic Shelves, SSTC South Subtropical Convergence, BRAZ Brazil Current Coastal, SATL South Atlantic Gyral, ETRA Eastern Tropical Atlantic, NATR North Atlantic Tropical Gyral, CNRY Eastern (Canary) Current Coastal, NAST (E) North Atlantic Subtropical Gyral, NADR North Atlantic Drift, NECS North Eastern Shelves.