National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

National Oceanography Centre

Cruise Report No. 17

RRS *James Cook* Cruise 44

25 MAR - 22 APR 2010

Trinidad to Jamaica
Hydrothermal activity and deep-ocean biology of the Mid-Cayman Rise

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ABSTRACT

JC044 was a NERC funded research cruise aboard the UK Research Vessel the RRS *James Cook* the aim of the cruise was to explore the ultra-slow spreading Mid-Cayman Rise (MCR) in the Caribbean for hydrothermal activity. The MCR is the deepest spreading centre on the Earth and is isolated from the contiguous Mid-Atlantic Ridge, the closest mid-ocean spreading centre. The discovery of hydrothermal activity in this area would help us address the scientific questions related to the biogeography of hydrothermal vent organisms, the effect of high pressures on the chemistry of hydrothermal vents and the geological settings of any vents located.

We successfully identified 2 active hydrothermal systems with associated chemosynthetic communities. One site named Beebe, after William Beebe, the first man to observe deep-sea marine organisms in situ. The Beebe vent field is at a depth of around 5000m and is the deepest hydrothermal site ever discovered. The second vent site is on top of an ocean core complex, it exhibits unusual chemical properties and we have named this site the Von Damm vent field after the recently deceased Karen Von Damm, a groundbreaking hydrothermal geochemist. After extensive work in the southern area of the ridge we found no evidence of hydrothermal activity, earlier reported evidence (German et al., 2010) may be re-suspended sediment material.

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KEYWORDS

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RRS James Cook Voyage 44

www.thesearethevoyages.net

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Trinidad to Jamaica

Hydrothermal activity and deep-ocean biology of the Mid-Cayman Rise

Cruise report
Edited by Dr Douglas P. Connelly

University of Southampton

Natural Environment Research Council

National Oceanography Centre
Natural Environment Research Council

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Durham University

CONTENTS

List of Figures

List of Tables

1.1 Introduction

JC044 is the first cruise in a two-cruise programme to locate hydrothermal vents on the Mid-Cayman Rise (MCR) and to investigate the nature of those vents. The programme is multi-disciplinary, bringing together biologists, chemists, geologists, geophysicists and physical oceanographers. The over arching goal of this first cruise was to locate sites of active hydrothermal venting and to investigate the chemistry of the venting plumes, the geological setting of the plumes and to understand the control that the local hydrography has on plume distribution.

We hypothesised that hydrothermal activity should be found on the MCR based on three lines of evidence: 1) there has been evidence for hydrothermal activity located on all of the worlds' spreading centres examine to date, including the ultra-slow spreading Gakkle Ridge in the Arctic (Edmonds et al, 2001), Knipovich Ridge in the Arctic (Connelly et al, 2007) and more recently on the South West Indian Ridge (German et al, 1999, Tao et al, 2007); 2) observations and modelling of heat flow within the crust of the Cayman Trough (Rosencrantz et al, 1998; ten Brink et al, 2002); 3) the resemblance of Mount Dent, a sea mount on the western side of the MCR to oceanic core complexes (OCC) on other slow spreading ridges (Smith et al, 2006). During OCC formation lower crustal and upper mantle rocks are extruded and exposed on the seafloor, high temperature venting has been found in association with these OCC's in other ocean areas (Beltenev et al., 2005) and the serpentinisation of exposed peridotites exposed may drive hydrothermal vent systems (Lowell and Rona, 2002)

The Cayman Trough may have hydrothermal activity associated with the OCC Mt Dent, these areas have been suggested as host sites for hydrothermal systems similar to the Lost City site on the Atlantic Massif on the Mid-Atlantic Ridge. From data collected on the US cruise in October of 2009, two other possible sites of hydrothermal activity were located. One area in the north of the ridge showed a strong Light Scattering signal (LSS) with a high concentration of total iron and manganese and a high Eh signal, this is typical of a more basaltic hosted system such as that recently identified at in the Antarctic by, members of the present science team. In addition to this site there was a small amount of evidence for a site that was not only rich in particles but also had a marked methane anomaly, this resembles the type of chemical signal you find at mafic and ultramafic vent sites, such as the Rainbow hydrothermal vent field on the slow spreading MAR.

The MCR may host deep-sea vent fauna with affinities to Mid-Atlantic vents as result of present-day hydrographic connections; alternatively it may host vent fauna with eastern Pacific affinities as a consequence of a deep-water connection prior to the closure of the Isthmus of Panama, or harbour unique fauna because of its isolation and depth. The MCR therefore presents a unique opportunity to determine the influences of hydrography, geological history, bathymetry and isolation on the global biogeography of chemosynthetic ecosystems, which is a key objective of the international Census of Marine Life ChEss (Chemosynthetic Ecosystems) programme. Investigating the deep-ocean biology of the MCR will therefore advance our understanding of patterns of biodiversity.

We planned the work around a structured investigation of three main areas of suspected hydrothermal vent activity. The three areas were located on a research cruise with scientists from the United States who are associated with this present programme. The US cruise in October of 2009 involved both D. Connelly and C. Sands from this cruise. That cruise identified the three areas using a series of CTD casts with light scattering instrument and an Eh sensor to trace hydrothermal indicators, but did not identify the exact locations of the sites. The role JC044 was to identify the sites and get direct photographic and videographic evidence of the sites.

1.2 Summary and cruise track

The cruise began in Trinidad and finished in Montego Bay Jamaica, as shown in figure 1.

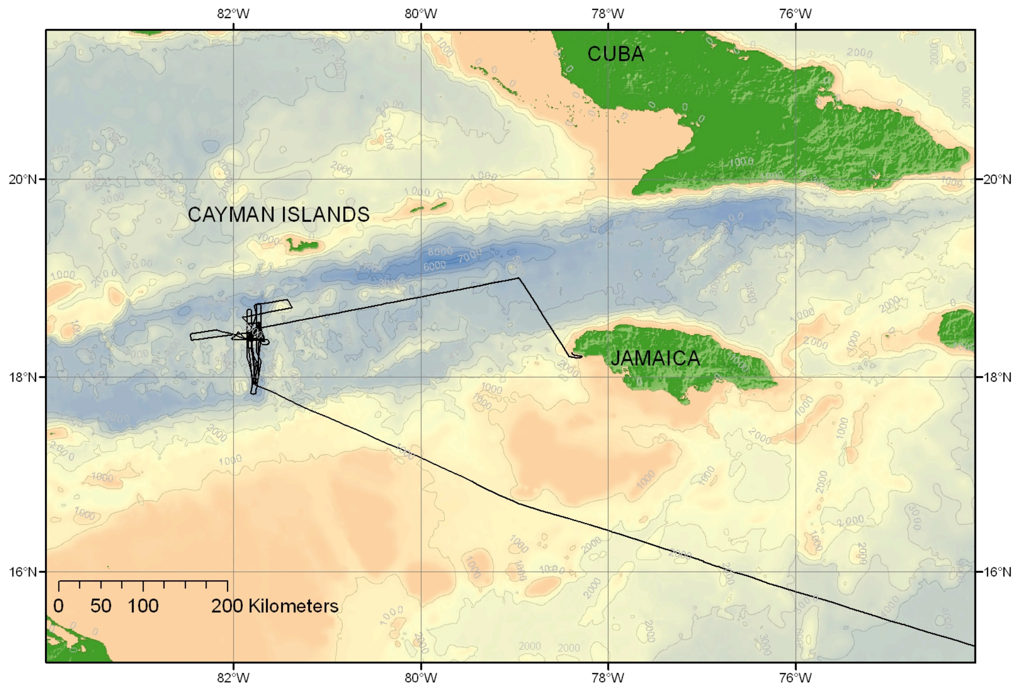


Figure 1. Cruise track of JC044.

We successfully identified 2 active hydrothermal systems with associated chemosynthetic communities. One site named Beebe, after William Beebe, the first man to observe deep sea marine organisms in situ. The Beebe vent field is at a depth of around 5000m and is the deepest hydrothermal site ever discovered. The second vent site is on top of an ocean core complex, it exhibits unusual chemical properties and we have named this site the Von Damm vent field after the recently deceased Karen Von Damm, a groundbreaking hydrothermal geochemist. After extensive work in the southern area of the ridge we found no evidence of hydrothermal activity, earlier reported evidence (German et al., 2010) may be re-suspended sediment material.

I would like to thank everyone onboard the RRS *James Cook*, Master, crew and scientific party, for their efforts and high degree of dedication that made JC044 an extremely successful cruise. We would like to thank Ko-ichi Nakamura from AIST Japan for the use of his Eh sensor, without which locating the vents would have been very difficult.

1.3 Personnel

Scientific Personnel

D. P. Connelly	NOCS	Chief Scientist
D. J. Amon	Independent	Marine Biologist
J. T. P. Copley	NOCS	Marine Biologist
N. R. Grindlay	U. N. C. U.S.A	Marine Geophysicist
N. W. Hayman	U. Texas. U.S.A	Marine Geophysicist
V. Huhnerbach	NOCS	Marine Geophysicist
M. T. Judge	Independent	Marine Geologist
T. Le Bas	NOCS	Marine Geophysicist
A. Meier	NOCS	Student Microbiologist
B. J. Murton	NOCS	Marine Geologist
V. E. Nye	NOCS	Marine Biologist
R. B. S. Pedersen	U. Bergen	Marine Geologist
C. M. Sands	NOCS	Marine Chemist
R. C. Searle	U. Durham	Marine Geophysicist
K. L. Stansfield	NOCS	Physical Oceanographer
S. L. Taws	NOCS	Physical Oceanography Student
P. A.Tyler	NOCS	Marine Biologist
S. A. Wilcox	Independent	Outreach Officer

Technical and Autosub6000 Teams

D. H.Comben	NOCS	Technical Liason Officer
M. E. Furlong	NOCS	Autosub Specialist
D. R. Matthew	NOCS	TOBI Specialist
S. D. McPhail	NOCS	Autosub Specialist
M. Pebody	NOCS	Autosub Specialist
P. Stevenson	NOCS	Autosub Specialist
D. Teare	NOCS	CTD Specialist
A. T. Webb	NOCS	TOBI/Technical specialist

Ships Personnel

R. J. Chamberlain	Master
A. Maclean	Petty Officer Deck
P. D. Gauld	Chief Officer
G. Crabb	Able Seaman
J. W. Mitchell	2nd Officer
M. S. Moore	Able Seaman
N. Norrish	3rd Officer
T. A. Jennings	Able Seaman
I. M.Slater	Chief Engineer
L. Stephens	Able Seaman
C. Kemp	2nd Engineer
L. J. Hillier	Eng Room PO
I.Maclean	3rd Engineer
J. Haughton	Head Chef
S. P.Crosby	ETO
W. C. Isby	Chef
T. E. R. Levy	Deck Eng
G. M. Mingay	Steward
A. Stevens	Purser CO
A. K. Whalen	Asst. Steward
G. A.Pook	Chf Petty off Deck
M. J. Myers	Technician
M. Minnock	CPO Scientific

1.4 Itinerary and timetable of events

March 2010

21st Most of the scientific party arrived in Port of Spain Trinidad and moved onto the ship.

23rd A visit from the High Commissioner, the FCO representative and the Political Officer. Tour of the ship followed by lunch. In the afternoon a cameraman and reporter arrived from the local news channel, D. Connelly, J. Copley and Diva Amon gave interviews.

24th Moved to a bunkering vessel offshore for fuel

25th Had to redo bunkering because of inclement weather. Finished at 0400 (local).

26th Returned to shore to drop of a member of the technical support team for TOBI and collect equipment for the ship, via a boat transfer. Started transit to the scientific study area at 1400.

27th Magnetometer and multibeam turned on and collecting data. 1700 stopped for CTD001 13°23.3N, 068°15.9W JC044/001CTD001. Streamed magnetometer, continued transit.

28th/29th Transit with magnetometer collecting data.

30th Deployed CTD 002 17°55.0 N, 081°46.0W JC044/002CTD 002 cast to 4879 m, in Southern end of study area. Moved to the TOBI deployment area. TOBI deployed for a 4 day survey.

31st March- 3rd April Recovered TOBI. Swath survey and then JC044/005 CTD003 cast to 4960 m 18°32.65 N 081°43.15 W

April 2010

4th Deployed mooring JC044 /005MOO 001, 18°22.02 N, 081°39.94 W. Hybis test cast - HYB 001 cast to 900 m, 18°42.5N, 081°42.0W, test of Hybis.

5th Autosub deployed, this was after an aborted deployment (AUV001) due to a line that had come loose. 18°32.86N, 081°43.52W, JC044/010AUV 002 CTD deployed 044/011CTD 014 cast to 4920 m, 18°33.0N, 081°43.35W CTD 015 deployed 044/012 CTD 015 cast to 4170 m, 18°33.0N, 081°43.35W

6th Autosub recovered. Hybis deployed to 4999m, JC044/013HYB002 Start 18°32.74N, 081°43.17W Finish 18°32.80N, 081°43.10W

7th Autosub deployed 18° 32.00N, 081° 43.78W: JC044/014AUV 003 CTD deployed 044/015 CTD016 cast to 4936 m, 18°32.80 N 081°43.08 W. Deployed CTD 044/016 CTD017 cast to 4955 m, 18°32.80N, 081°43.10W

8th Hybis deployed to 4999 m, JC044/017HYB 003. CTD deployed 44/018CTD018 cast to 4500 m, 18°32.85N, 081°43.20W

9th Autosub Deployed, 18°21.90N, 081°50.10W, JC044/019AUV004. Deployed Hybis, JC044/020HYB004. Deployed dredge Start18°23.2N, 081°43.5W, Finish 18° 23.2N 081°43.5W, JC044/021 DRE 001

10th Recovered Autosub. CTD deployed (TOW-YO), start 17°55.0N, 081°47.8W, finish 17°56.3N, 081°46.2W JC044/022CTD019. Autosub deployed 18°56.03N, 081°45.45W JC044/023AUV 005

11th CTD Tow Yo deployed Start 17°55.3N, 081°46.1W finish 17°55.3N, 081°45.1W JC044/024CTD051. CTD Tow Yo start 17°57.0N, 081°46.3W finish 17°57.5N, 081°45.1W JC044/025CTD 059. Recover Autosub.

12th Deploy Hybis start 18°22.2N, 081°48.7W, finish 18°22.1N, 081°48.8W JC044/026HYB005. Autosub deployed 17°55.98N, 081°45.70W JC044/027AUV006.

13th Recover Autosub. Deploy Hybis start 17°55.84N, 081°46.03W, finish 17°56.85N, 081°45.64W JC044/028HYB006.

14th Deploy CTD Tow-Yo start 18°21.3N, 081°42.4W finish 18°21.5N, 081°43.5W JC044/029CTD072. Recovered mooring MOO01. Deploy Autosub 18°23.4N, 081°50.5W JC044/030AUV007. Deploy CTD 18°42.50N, 081°40.50W JC044/031CTD073.

15th Deploy Hybis start 18°32.80N, 081°43.70W finish 18°32.8N, 081°43.3W JC044/032HYB007. Recover Autosub. Deploy Mooring 18°22.57N, 081°40.34W JC044/033MOO002. CTD deployed 18°22.70N, 081°47.86W JC044/034CTD076.

16th Autosub deployed 18°22.70N, 081°47.86W JC044/035AUV 008. CTD deployed 18°22.70N, 081°47.70W JC044/037CTD 077. Recover Autosub.

17th Deploy Hybis start 18°32.80N, 081°43.08W finish 18°32.80N, 081°43.10W JC044/038HYB008. Deploy Autosub 18°22.46N, 081°43.16W JC044/039AUV009. Deploy CTD 18°22.62N, 081°48.01W JC044/040CTD078. Deploy Hybis start 18°22.62N, 081°48.01W finish 18°22.59N, 081°47.88W JC044/041HYB 009.

18th Hybis deployed start18°22.59N, 081°47.88W finish 18°22.59N, 081°47.88W JC044/042HYB010. Autosub recovered. Problems with cable had to spend some time spooling out.

19th CTD deployed 18°22.62N, 081°48.00W JC044/043CTD079. Deployed Autosub 18°22.35N, 081°48.70W JC044/044AUV010. Deployed Hybis start 18°22.59N, 081°47.88W finish 18°22.46N, 081°47.85W JC044/045HYB011. Mooring deployed 18°32.72N, 081°43.32W JC044/046MOO003. Autosub recovered.

20th Magnetometer survey heading back to port, Montego Bay, Jamaica.

21st Arrive Montego Bay.

22nd Disembark ship.

2. Geophysical surveys.

Bram Murton, Roger Searle, Nancy Grindlay, Tim Le Bas and Nick Hayman.

2.1 Bathymetry

The EM120 multibeam echosounder was run throughout, except when on station or when other operations required acoustic silence. These data provided our basic operating map (Figure 2).

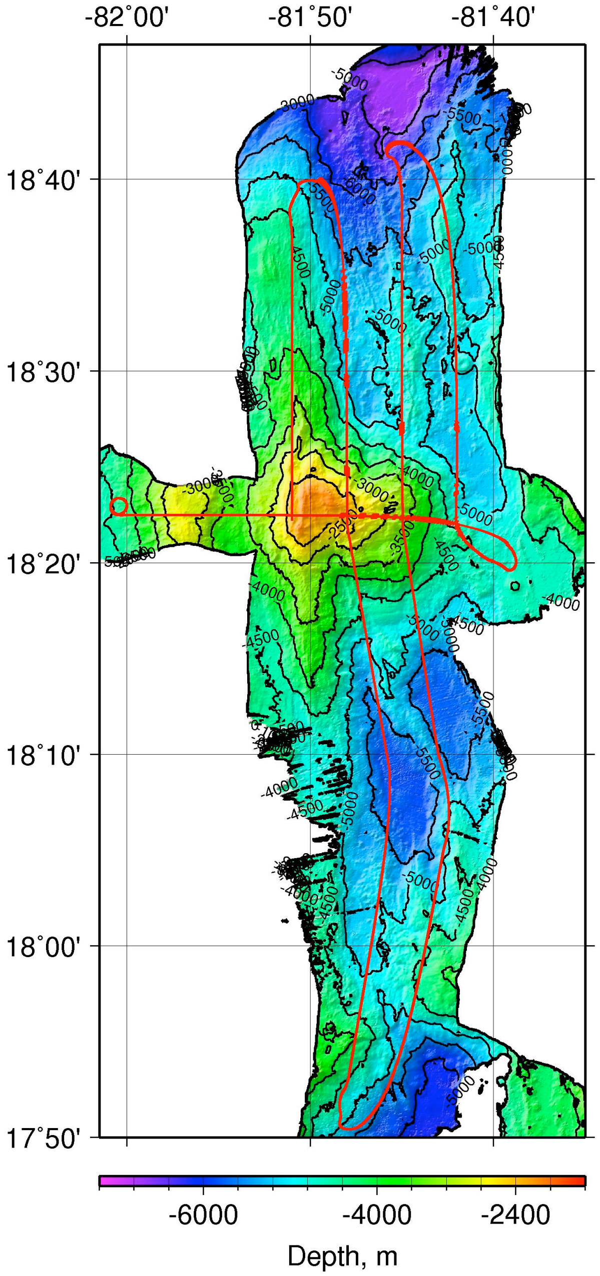


Figure 2. Bathymetric map (contour interval 500 m) showing EM 120 bathymetry of the MCSC, with TOBI tracks superimposed (red).

2.2 Gravity

The ship's Microg LaCoste Sea Land gravimeter S84 was run continuously throughout the cruise to measure accelerations related to mass distribution at the sea floor beneath the ship. Gravity measurements during the survey ranged from 9680-10,030 mGals.

Prior to departure from Port of Spain, Trinidad, gravity was measured using a portable gravimeter at the dock in a location as close to the approximate location of the Microg-Lacoste as possible to be able to reference the Microg-Lacoste value to the value at the base station. A base tie was made in Trinidad, within a few metres of what was believed to be the site of US Department of Defense station 0294-5 at the old (now dismantled) US Naval Station at Chaguaramos, some 20 km west of Port of Spain. Upon return from the base station, another gravity reading was taken at the dock. This gave an absolute gravity value of xxxxxxxx mGal at the shipboard gravimeter. It was planned to tie in at the end of the cruise to International Gravity Bureau station 04487A at the entrance to the court house in Montego.

Operation of the gravity meter was trouble-free during the entire cruise. Logging of data at 1 sec intervals was recorded by the ship's Techsas system. Daily checks were performed on the instrument to ensure that all systems were functioning properly, and watchstanders routinely checked (30 min - 1hr intervals) that the instrument was logging data.

Reduction of the gravity data consisted of: (1) merging the gravity data with GPS navigation and centerbeam bathymetry files, (2) applying the Eotvos correction and removing the reference gravity value to obtain free air anomalies, (3) smoothing the data by applying a running mean filter, (4) interpolating the data to evenly spaced 1-minute (time) values, and (5) editing the data to remove spurious points, or data recorded during turns of the ship.

2.3 Surface-Towed Magnetometer

The SeaSpy Marine Magnetometer used during this survey is a proton precession magnetometer. It uses proton precession to make a measurement of the intensity of the Earth's magnetic field. Within the survey area the field intensity ranged from 39,800 to 40,400 nT.

The SeaSpy magnetometer was towed at a distance of 200 m behind the vessel, logging at 1 second intervals using Sealink software to a laptop PC. A layback of 200m was enabled in the position calculations (with the exception of a short interval at the beginning of JC044_25.xyz GMT 0100-0200) . During operation log files were backed-up to an external hard drive by technician Mick Meyers. Watchstanders routinely checked (30 min – 1 hr intervals) data logging. A total of 26 files (JC044_01-26.xyz) were collected, some of which contain 24hrs of data, others were initiated when the magnetometer was deployed during transit between vent sites.

The magnetometer was deployed and started logging on JD 086 2034 GMT during transit to the study site. The magnetometer was deployed for the first N-S line of TOBI deployment, but recovered for the remainder of the TOBI deployment because of possible entanglement with the TOBI cable. During the cruise on JD106 1230 GMT – 2000GMT, two ~43 nm-long flow lines were run on the western flank of the ridge axis (operation MAG01). At the end of the cruise the magnetometer was deployed and logged from JD 110 0700 GMT (operation MAG02) for three E-W trending lines across the ridge axis and the transit along a flow line toward Jamaica. Logging of the magnetics data stopped on JD111 05:51GMT outside of the Jamaican Exclusive Economic Zone. Apart from occasional problems with one fish flooding and the reserve fish thus being required for the second operation, and an inability to tow at very low speeds, no problems were encountered.

Reduction of the magnetics data will include subtraction of the IGRF to obtain magnetic anomalies, smoothing the data, interpolating to 1 min intervals and editing to remove spurious points.

2.4 TOBI

2.4.1 Sidescan sonar

TOBI was launched at 1917GMT on day 089 (April 9), and towed for 4 days until recovery at 093/1620. The survey (Fig. G1) covered the whole length of the Mid-Cayman Spreading Centre (MCSC) median valley (MV), and comprised two parallel, N-S lines in the southern segment, four parallel N-S tracks over Mt. Dent and the northern segment, and one E-W track over Mt. Dent. TOBI recorded continuous 30 kHz sidescan sonar, three-component magnetic field, depth, altitude, and water temperature, conductivity and light scattering data.

Sidescan data were processed on board using the PRISM software [*Le Bas*, 2005], to yield a mosaicked image. A preliminary and partial geological interpretation is shown in Fig. 3. Appendix 1 is the TOBI log for JC044.

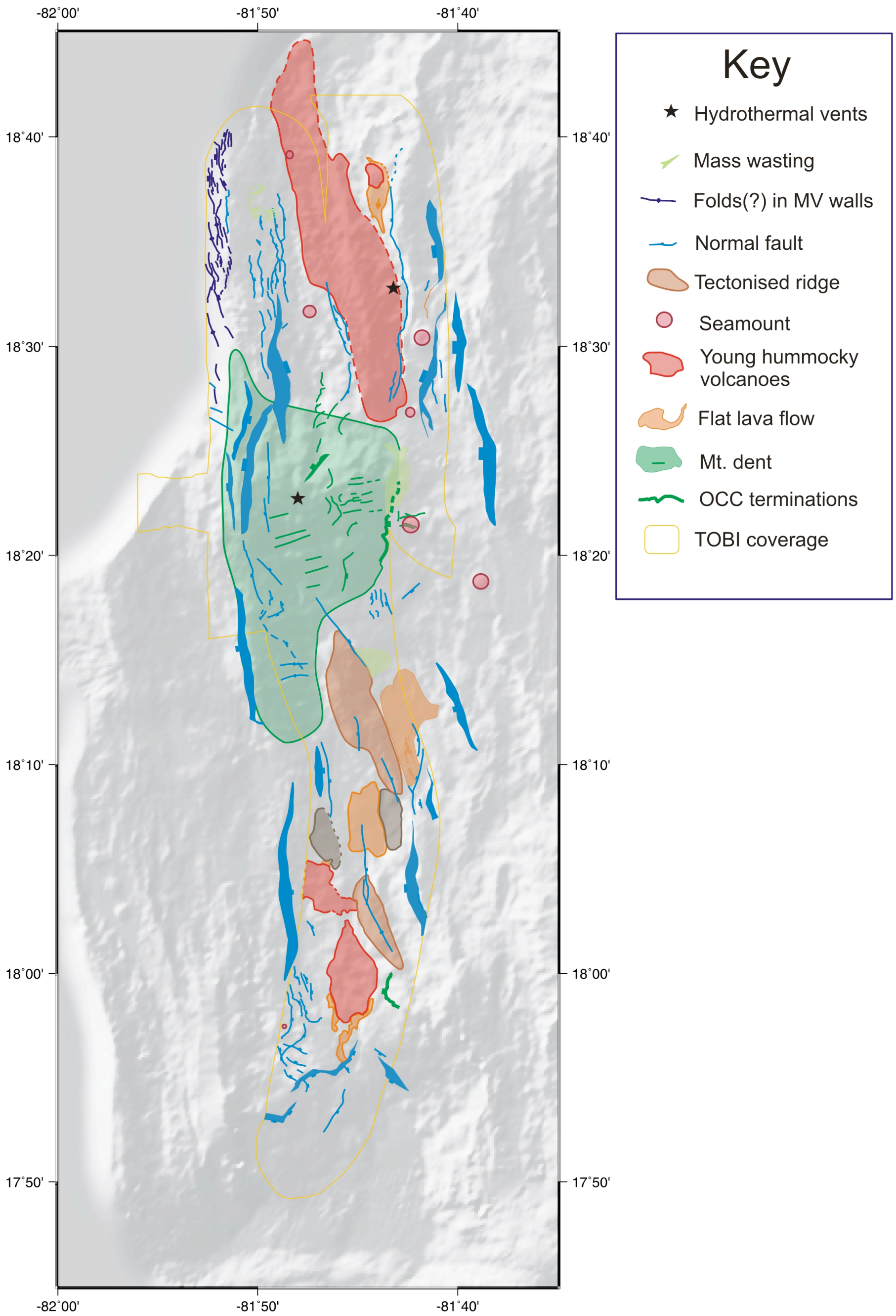


Figure 3. Preliminary interpretation of TOBI sidescan sonar data, over shaded relief bathymetry illuminated from NW. Steep slope on W side of bathymetry map is an artefact.

As previously recognised (ref), the MCSC consists of two spreading segments, the northern of which is offset some 10 km dextrally. At the junction of the two segments is a major massif, Mount Dent (ref), which has the typical spreading-parallel corrugations of an oceanic core complex (OCC, [*Cann et al.*, 1997].

Each segment contains an axial volcanic ridge (AVR) displaying typical young, hummocky volcanic terrain. The northern AVR runs the length of the segment and its southern end abuts the north flank of Mt. Dent, suggesting it is about to cut off and terminate slip on the latter [*MacLeod et al.*, 2009]. A prominent ridge to the east of the northern AVR is not, as appears from the bathymetry, a separate AVR, but a fault block in the eastern MV wall. The southern AVR occupies the southern part of the southern segment. Both AVRs, but most prominently the northern one, exhibit NE-trending volcanic spurs on their eastern flanks, which may be attributed to the action of dextral shear stresses associated with the plate boundary offsets [*Searle et al.*, 2010]. Vent site 1 is located at the foot of one of these spurs.

Between the southern AVR and Mt. Dent is a linear ridge, displaying considerable evidence of faulting but little recognisable volcanic terrain. It is flanked by two flat floored basins characterised by fairly uniform, moderate backscatter terrain typical of relatively young flat-lying lava flows. Several smaller areas of young, flat-lying lavas occur. One is to the east of the northern AVR, and is notable for being perched on an upfaulted block; it clearly has an off-axis source, and is seen cascading down the bounding fault scarp. Another arises from the southern end of the southern AVR, whence it flows south, around a small inlier of older, more sedimented seafloor, and again cascades down a fault scarp into the Swan Island Fracture Zone to the south. This flow was visited by Hybis dive xx.

Mount Dent has a surprisingly subdued sidescan character, with very low backscatter suggestive of significant sediment cover, and little evidence of spreading parallel striations as seen on other active OCCs [*MacLeod et al.*, 2009], although subsequent Autosub bathymetry surveys did image fine-scale corrugations, especially near the OCC toe. Some NE- and NW- trending faults occur in the western part of the massif, indicating post-emplacement deformation, while some NS trending normal faults from the adjacent median valley extend into and across it. Similar characteristics seen on OCCs on the Mid-Atlantic Ridge 13 – 14°N were taken as indicative of inactive detachment faulting[*MacLeod et al.*, 2009]. However, where such inactive faults occurred, plate separation was taken up by renewed and vigorous on-axis volcanism, but no such features are seen opposite Mt. Dent. The most probable explanation at present seems to be that Mt. Dent contains a detachment fault that is still actively accommodating the majority of plate separation, but that unusually heavy sedimentation masks the expected high reflectivity and fine-scale striations.

2.4.2 Magnetic field

At the end of the TOBI survey a 360° "calibration turn" was conducted in an area of uniform magnetic field with 500 m of cable out, in order to facilitate correction for the vehicle's magnetic field [*Korenaga*, 1995]. During the turn we alternately veered and hauled 100m to induce pitch and roll (Fig. 4). The EW TOBI magnetic field line across Mt. Dent (so far uncorrected for vehicle magnetisation) is shown in Fig. 5. The next steps will be to apply the turn correction to all the data, and upward continue the corrected field measurements to a uniform depth [*Guspi*, 1987]. We plan to invert the EW line to yield a magnetisation profile across Mt. Dent.. The other TOBI magnetic data can probably best be used by upward continuing to the sea surface, then combining with surface measurements to make a fuller grid of lines across the MCSC.

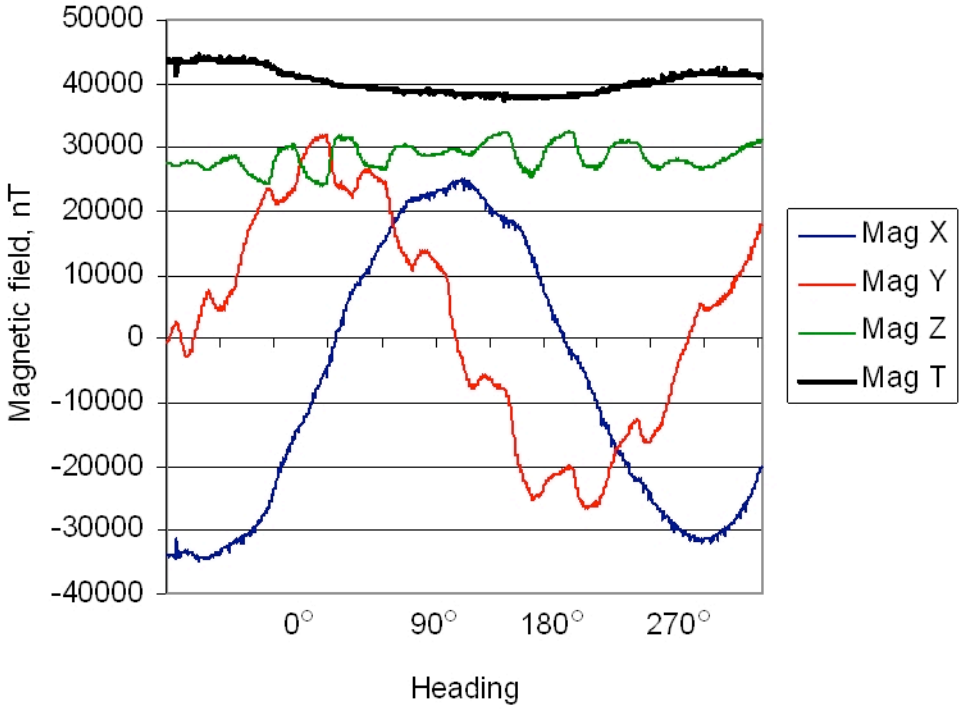


Figure 4. Magnetic field components measured during the TOBI calibration turn. Components are relative to TOBI vehicle: X, +ve to port, Y, +ve forward, Z positive down. $T = (X^2+Y^2+Z^2)^{1/2}$.

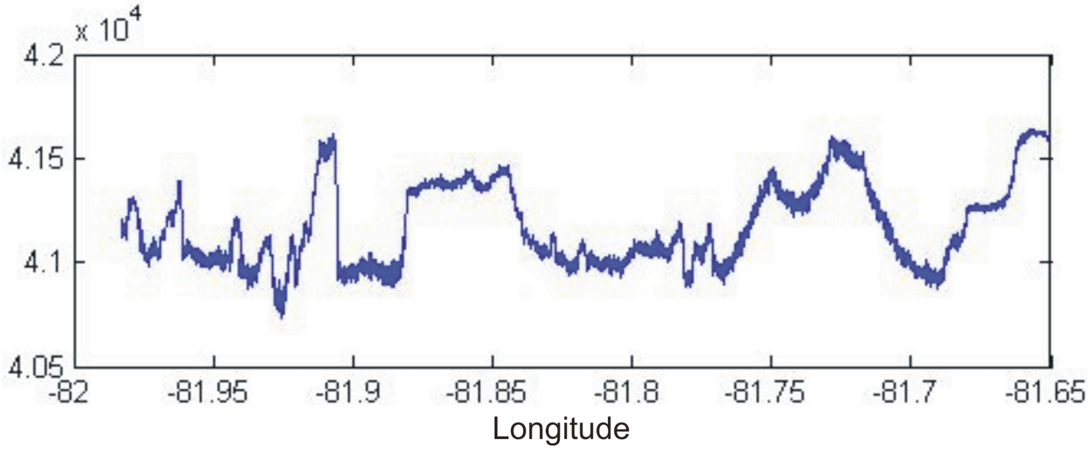


Figure 5. Uncorrected total magnetic field (nT) along the EW TOBI line over Mt. Dent.

2.5 Autosub 6000

2.5.1 Bathymetry

Autosub provides bathymetry with a resolution ~ 1m, which can show a wealth of geological information. These surveys not only contributed to the location of the vent sites (sites 1 and 2 both occur on substantial mounds that show clearly on the bathymetry, but also reveal some of the geological context: for example, site 1 clearly lies over a normal fault amid a field of young volcanoes (Fig. 6), while the survey over the toe of Mt. Dent imaged fine details of the "termination" of the OCC (junction between the footwall and hanging wall blocks) as well as the corrugations and striations that ornament the OCC surface (Fig. 7).

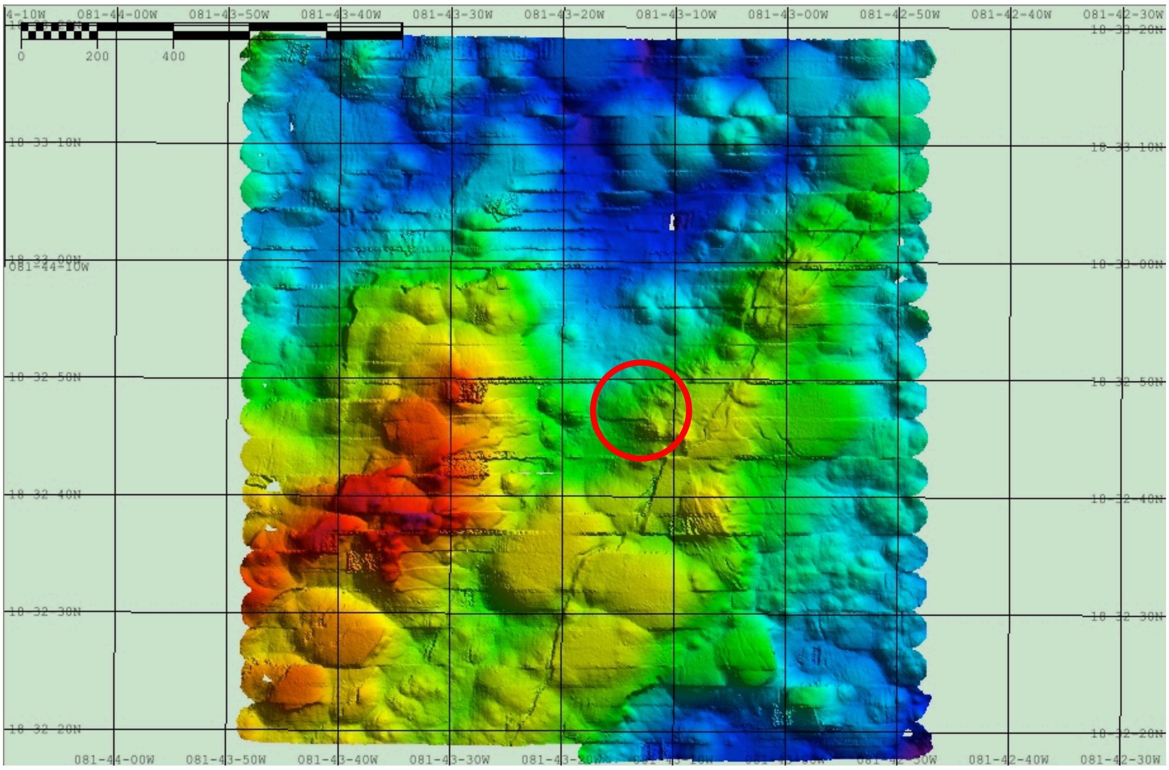


Figure 6. Autosub bathymetry around vent site 1 (circled). Note prominent volcanic domes, and fault scarp running NNE from bottom centre.

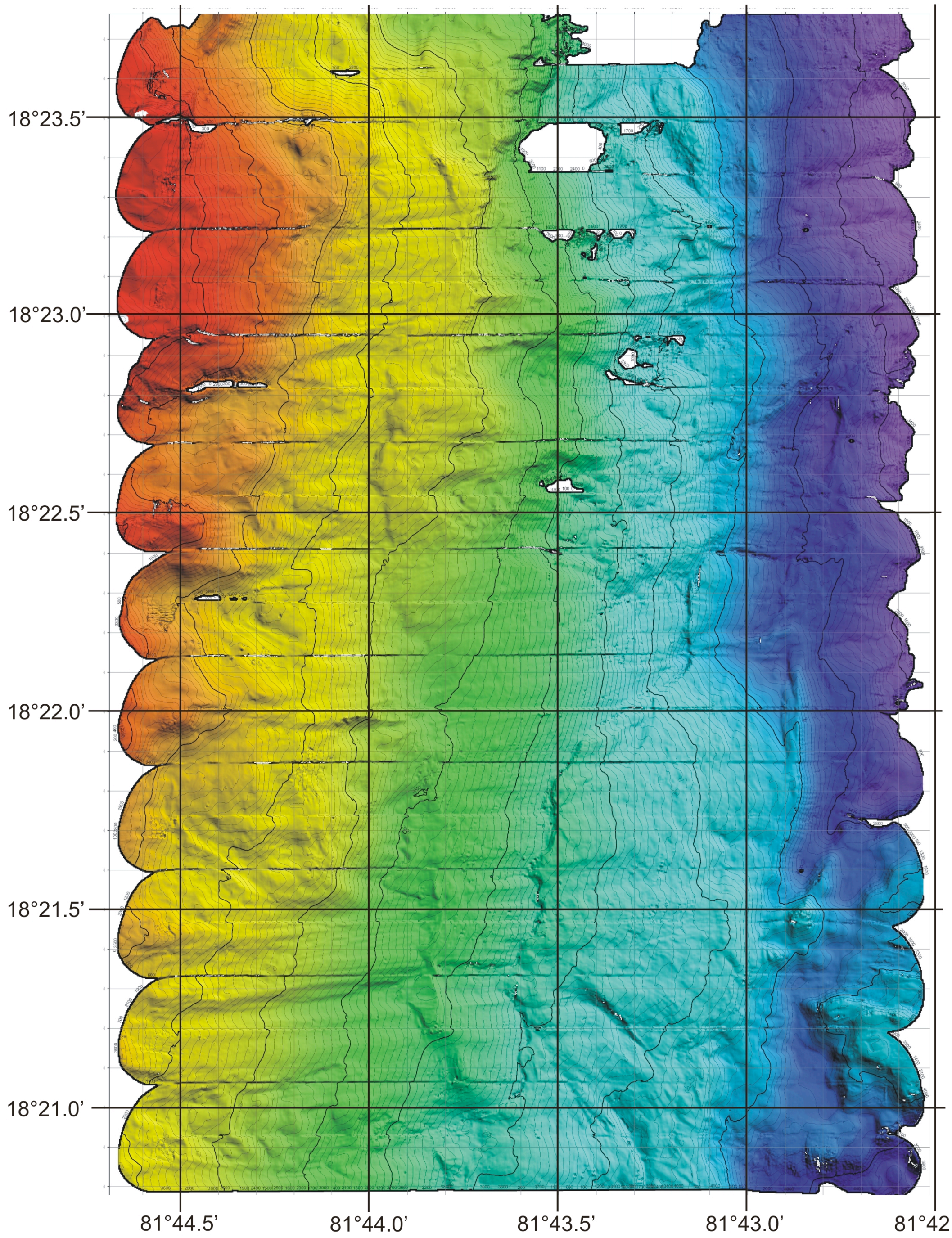


Figure 7. Autosub bathymetry over toe of Mt. Dent (2 nm by 3 nm area) showing the "termination" or "zone of emergence" as a small step trending N from bottom centre, and ENE trending corrugations that run from the footwall into the hanging wall.

2.5.2 Magnetic field

Autosub also made measurements of the magnetic field and, being much closer to the seafloor and therefore the magnetic source than TOBI, these provide a much higher resolution image of the field. The magnetic field over vent site 1 shows evidence of destruction of magnetisation around the site [*Tivey et al.*, 1993], while elsewhere the detailed magnetic maps should aid structural and lithological interpretation.

3. Autosub6000 Operations

Stephen McPhail, Peter Stevenson, Miles Pebody, Maaten Furlong

3.1 Summary of Autosub6000 missions

This was the first funded science cruise for the Autosub6000 AUV. The primary objective for the AUV was quite simply to search for and pin point the position of hydrothermal vent sites, so that they could be imaged and sampled at a later time, either on the same cruise (by the HyBIS camera grab system), or on the 2nd leg (by the ISIS ROV). In this goal, the AUV was spectacularly successful:

- 9 missions successfully completed, 3 at over 5000 m water depth the deepest at 5220 m
- Over 200 hours of mission time, with 690 km of survey line completed
- Over 100 km^2 area surveyed
- 2 vents sites found, and filmed shortly after by HYBIS
- A likely third vent site located
- The AUV coped with extreme relief including 45 degree slopes and 70 m cliffs (the correct operation of the recently developed collision avoidance system was absolutely essential)
- High resolution multibeam surveys executed for all the areas of interest
- Experimental three axis magnetometry and high altitude camera system both gave promising results
- All systems worked perfectly, with the exception of the navigation system which suffered serious accuracy degradation on 2 missions. This was linked to the extreme terrain relief.

3.2 Vent Hunting

Vent site 1. There were existing data indicating the presence of a hydrothermal vent site from WHOI CTD Tow-Yo and NEREUS AUV dives, but the exact position was unknown, and attempts to find the site with NEREUS had failed. Autosub6000 on its first dive was able to quickly tie down the position of the vent by carrying out a high resolution EH survey. Problems with navigation for this dive were mitigated by comparing the Autosub6000 high resolution bathymetry with the ship acquired bathymetry, and using this data we were able to quickly guide HYBIS to the hydrothermal vent.

Vent site 2 (Mount Dent). In Mission 30 we mapped the side of Mount Dent over an area where the geologists thought that there may be a vent site. No signals were seen in the area expected, but there was, however, a tantalising trace of a signal in the EH data in the extreme North-East corner of the survey. This signal was weak, and a subsequent HYBIS dive near the area found nothing, and so it was decided to leave this area and to use Autosub6000 to thoroughly survey a position in the south of the study area. These surveys (missions 31 and 32) came back with a null result (useful in the sense that no more time needed to be spent in that area), and it was decided to investigate the signal over Mount dent in more detail. Mission 33 was tasked to fly up and over the top of Mount Dent taking the AUV close to where the small EH signal spike had been found. This mission revealed a significant EH spike, and the high resolution multibeam data detecting, close by, a 30 m wide mound; a very plausible vent site. On Mission 34 the AUV carried out a high resolution multibeam survey of the area, confirming the mound as the source, and detecting also a 0.45 C temperature rise in the vicinity of the EH spike. It must have passed very close to the vent. HyBIS was then deployed to video the vent.

Vent Site 3. The objective of the final mission over mount Dent had been to fill in gaps in the high resolution multibeam bathymetry. An unexpected, faint, but definite EH signal was detected some 5 km south west from the site which had already been confirmed as a vent by Hybis. There was not time to investigate this further on the cruise, and this will likely be a subject for further investigation on the second cruise to the area.

3.3 Autosub6000 Specification

Autosub6000 is a deep diving, cruise mode AUV (it cannot hover), which was developed by engineers in the Underwater Systems Laboratory, National Oceanography Centre , Southampton. Its basic specifications for the JC044 cruise are detailed in the Table 1.

• Size	• 5.5 m long, 0.9 m Diameter
• Mass	• 1800 kg (dry mass). 2900 kg (flooded).
• Endurance, Range	• With current sensors and batteries (4 batteries): 27 hours, at 1.6 ms-1, is 155 km (there is space for up to 12 batteries with proportionate (x 3) increase in range and endurance).
• Speed	• 1.0 to 1.7 ms^{-1}.
• Descent / Ascent Rates	• -1.0 ms^{-1} / 1.5 ms^{-1}.
• Maximum Depth	• 6000 m (tested to 5600 m).
• Navigation	• GPS on surface • 0.1% of distance travelled when within 200 of the seabed, using the IXSEA PHINS and RDI Teledyne Workhorse Navigator ADCP (this performance is only applicable for relatively benign seabed slopes (< 20 degrees). • Range only acoustic positioning to within 20 m when at 5000 m operating depth at the start and end of the mission. We are developing techniques using multibeam data and correlation techniques to maintain the positioning accuracies to similar to that of standard GPS for periods of several days.
• Flight modes	• Constant depth, Constant altitude, Profiling between set depths. • Track Following between 2 waypoints, or head directly to a waypoint.
• Obstacle and Collision Avoidance	• Forward look obstacle avoidance based on Tritech Seaking scanning sonar. 10 m safe flying altitude in very rough terrain, 3 m in less rugged terrain. Collision Avoidance triggered when obstacle ahead cannot be cleared safely →AUV turns and tries again at a shallower depth.
• Relocation - surface	• 2 independent ARGOS satellite tracking beacons. • 2 independent Novatech ST-400 A Flashing lights.
• Coms - surface	• WiFi (IEEE 802.11g) with range of 1 km. All data can be downloaded via this link, and new missions can be uploaded.
• Coms - underwater	• LinkQuest Tracklink 1000 for USBL and two way short messages of vehicle parameters up to 7 km range. Supported by tow fish. Sonardyne Compatt 5 transponder as a positioning backup (for ships equipped with compatible equipment).
• Battery Recharge	• 8 hours.
• Payload Space	• 0.5 m^3 in the free flooded nose section of the vehicle.
• Power for sensors	• 250 W (beyond what is already supplied to standard suite (below). Power bus is at 48 volts. Other voltages can be generated.

• Current Sensor Suite	• EM2000 Multibeam Sonar. 350 m swath at 100 m altitude. 3 m resolution. • Seabird 911 dual CTD system with DO, LSS, and EH sensor • Workhorse 300 kHz ADCP Navigator with Current Profiling • Tri axis flux gate magnetometer (Applied Physics Inc., model 1540). • Survey Photographic System. 1 km^2 per day, at 10 mm resolution (mono). [system is still under development]. Imaging has been demonstrated, some work needed to improve the maximum flash repetition rate].
• Transport	• 1 of 20 foot ISO shipping container for the AUV. Also used as workshop. • 1 of 20 foot soft-top shipping container for the Launch and Recovery system.

Table 1 Specification of Autosub6000 for cruise RRS James Cook cruise 044.

3.4 Mission Details

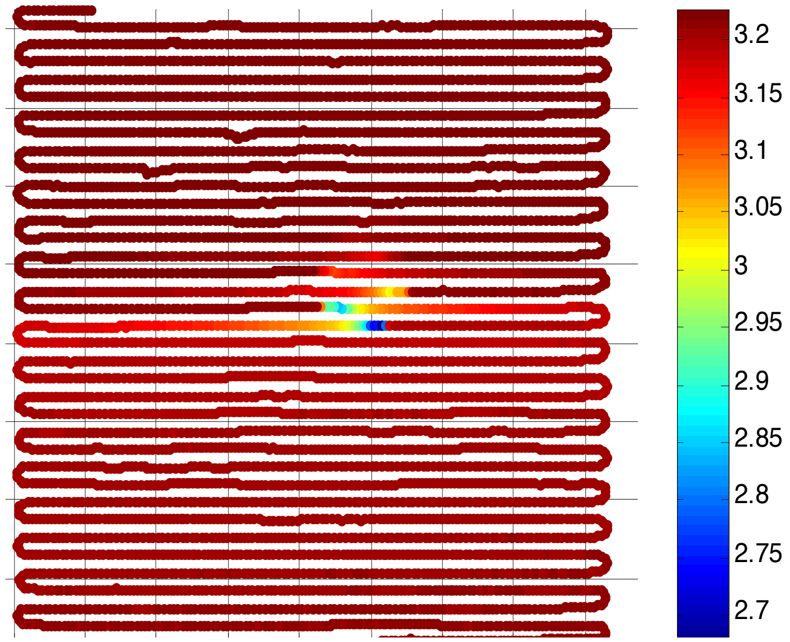
Table 2 lists the pertinent details for each mission with a brief description of the outcomes.

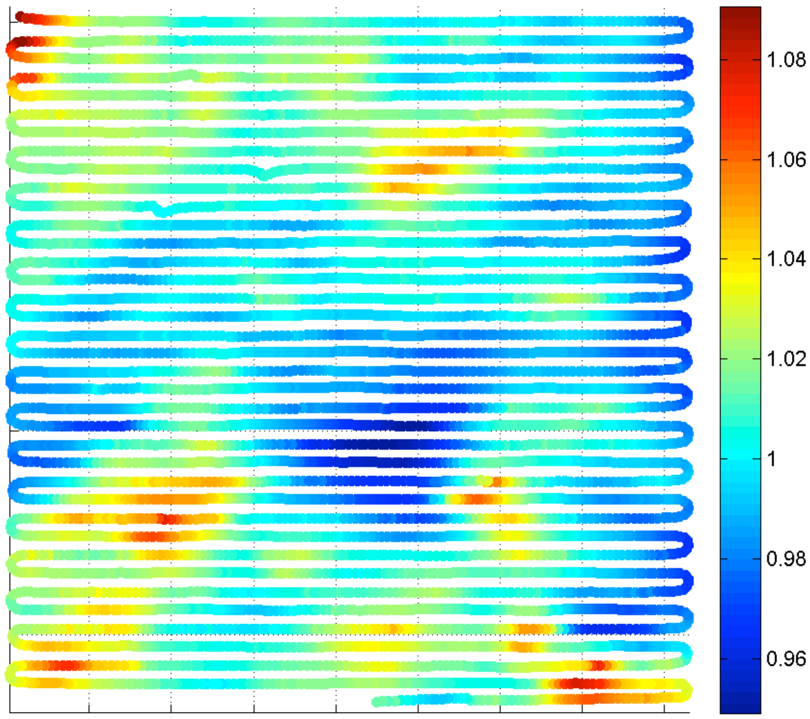
A	B	C hr	D	E km	F mm	G km^2	Notes
28	5th 00:07	27	N:18:32.75 W:81:43.35 5111 m	87	1740	1.5	Multibeam and EH survey at northern vent site. Navigation was very poor, as the drift amount per line was similar to the line spacing. Extreme terrain suspected as the cause. Mission rescued by sending position offsets demands to the AUV jumps added via 'move to' acoustic command. An EH signal was detected and this eventually lead to the location of the first vent site.
29	7th 00:15	23	N:18:32.80 W:81:43.30 5104 m	74	5060	3.7	Detailed Multibeam and EH survey of the northern vent site. There were still navigation problems (but less severe than the previous mission) , but strong EH signal detected on 5 lines. Good quality multibeam data.
30	9th 00:54	24	N:18:21.70 W:81:50.00 2941 m	86	200 100	17.2	Multibeam and EH survey of the southern top flank of Mount Dent. A small EH signal seen in the North West corner of the map.

31	10th 21:25	24	N:17:55.96 W:81:45.64 5220 m	69	50 100	3.5	Multibeam and EH survey of southern 'potential' vent site. No EH found, and navigation was not accurate. However, good quality multibeam bathymetry obtained.
32	12th 15:09	19	N:17:55.96 W:81:45.64 4805 m	61	250 NA	15.2	EH and LSS yo-yo mission between 4200-4400 and 4600-4800 in southern 'potential' vent site. No signals found, ruling out location as a real vent site. Note that the EM2000 system was disconnected for this mission (to save energy). Navigation was poor as expected, as the AUV was beyond seabed bottom tracking range with the ADCP (200 m) for almost all of the mission.
33	14th 15:41	22	N:18:22.60W:81:46.80 4482 m	74	250 100	18.6	Multibeam mission up and over flank of Mount Dent. Also to investigate further the signal found on mission 30. Good quality multibeam mapping and strong indications of vent site, with EH sensor.
34	16th 00:19	22	N:18:22.70 W:81:47.86 2658 m	85	50 60	4.2	Multibeam, EH, and camera survey over mount dent vent site. Conclusive proof of vent found. Hybis imaged the site shortly afterwards.
35	17th 12:58	25	N:18:22.50 W:81:43.50 4461 m	80	250 100	19.9	Multibeam mission on lower slopes of Mount Dent. Good quality multibeam images of slump features
36	19th 04:43	19	N:18:22.35, W:81:48.70 2685 m	74	250 100	18.6	Multibeam mission of three box survey areas to fill in mission areas on the top of mount dent. Good quality multibeam images obtained, and indications of a signal on EH sensor of a probable new vent site seen. Camera system successfully carried out a test run at 20 to 40 m altitude, obtaining images at up to 35 m altitude.

Table2. The summary details for each of the missions A: Autosub6000 mission number,. B : Date and Time, C: Mission Duration, D: Position of box centre and maximum AUV depth, E: Distance Surveyed (km), F: Survey Line Spacing (m) and Survey altitude (m), G: Area surveyed (km2).

3.5 Examples of sensor data





Figures 8a,8b. EH (volts scale), and Magnetometer (normalised scalar magnitude of field) for mission 29. The area of the survey is 1.2 km x 1.2 km.

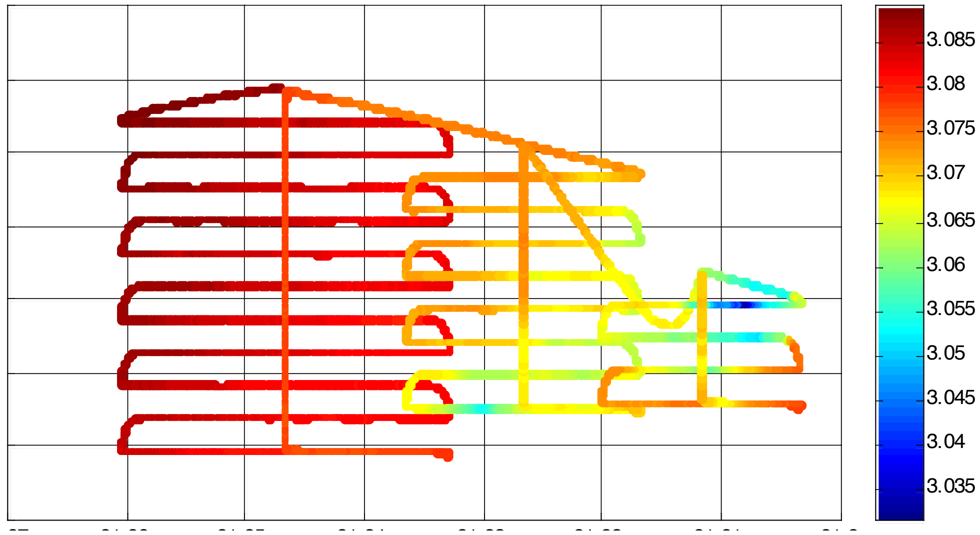


Figure 9. EH map resulting from the final AUV mission of JC 044, consisting of three boxes over the higher areas of Mount Dent. The survey area was 10 km (East West), by 7km (North-South).

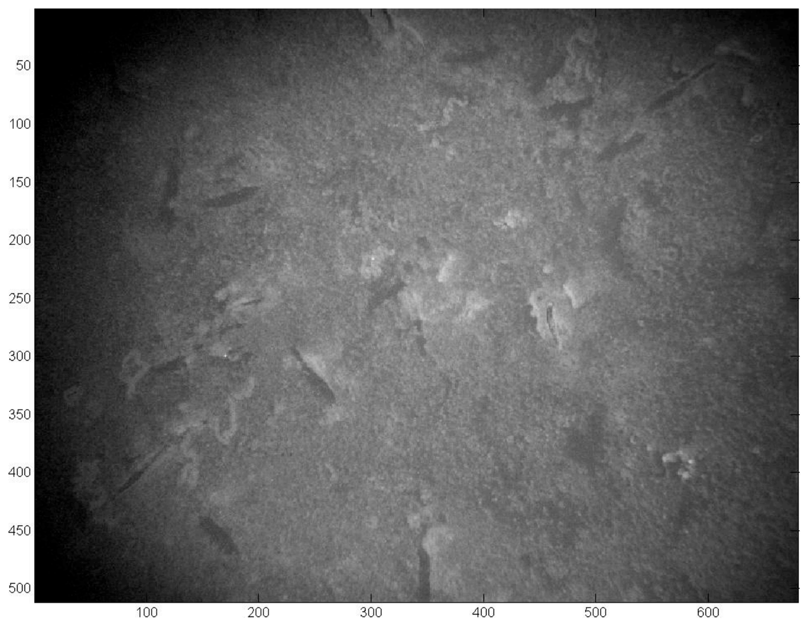


Figure 10. A seabed image taken by Autosub6000 at an altitude of 25m while flying over the summit area of Mount Dent. The horizontal extent is 17m, with a pixel resolution of 25 mm. Illumination is from the left, the AUV is travelling to the right , and the flash gun is 4 m aft of camera.

3.6 Autosub Sensor Configuration

The sensor suite fitted to Autosub6000 are listed in Table 1. Photographs 1 to 5 show the installation of the CTs, Oxygen, EH, camera and flash. Each CT assembly was mounted on the inside of the nose panel with a 40mm (i.e. short) length of tube plumbing the water outside the vehicle to the temperature sensor. Each CT assembly was lagged with open cell foam to minimise the effects of any temperature difference between water outside and water inside the vehicle.

The magnetometer was mounted on top of the nose frame using plastic Tie Wraps, cradles and screws to eliminate the magnetic fields in the immediate vicinity of the instrument (however a plot of total field showed that this was not very successful as the stray field due to the vehicle was approximately 10% of the total field). Fortunately is was possible to remove the vast majority of this field by having the AUV, for ten minutes each mission, to execute a tight circle while pitching up and down. Using this data , and a suitable calibration routine, it was possible to substantially remove this offset field.

The EM2000 Multibeam transmitter and receiver were mounted outside GFRP panels beneath the rear of the nose section, the same arrangement as proved on cruises JC027 and D343.

Description	Part No.	Source	Serial No.
CTD Port Temp	90565	Sea Bird	03P5009
CTD Port Cond'	90468	Sea Bird	043499
CTD Stbd Temp	90465	Sea Bird	03P5071
CTD Stbd Cond	90468	Sea Bird	043566
Oxygen sensor	90599.2	Sea Bird	431582
CTD Pump Port	90544	Sea Bird	055125
CTD Pump Port	90544	Sea Bird	055238
CTD Logger	90538.042	Sea Bird	09P52764-0930
EH Sensor		Ko-ichi Nakamura	
Magnetometer		Applied Physics Inc. (NOCS-USL integration)	
Light Scattering Sensor (LSS)		Sea Point	
300 kHz ADCP		RDI-Teledyne	
Depth sensor	NOC dwg No A5952	Digiquartz Inc.	
Camera	GE1380	Prosilica Inc. (NOCS-USL integration of Camera and Flash gun).	
Flash	Canon 580	Canon (NOCS-USL integration)	
Multibeam	EM2000	Kongsberg	

Table 3. Autosub sensor suite for JC044

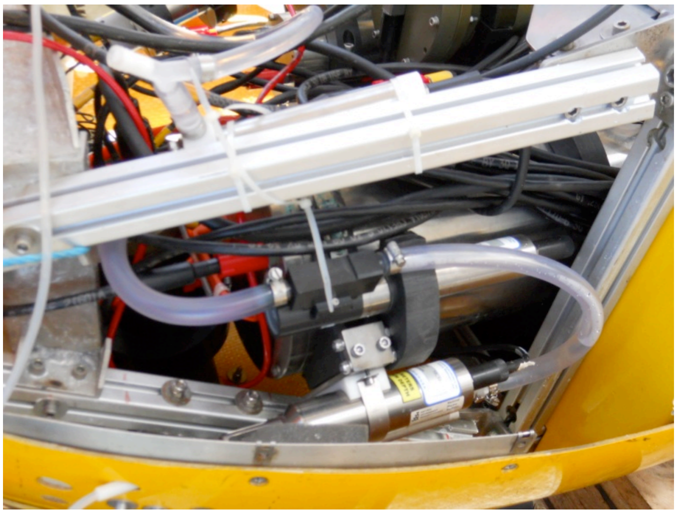


Figure 11. Port CT (mounted below the panel split line) and Oxygen sensor uppermost

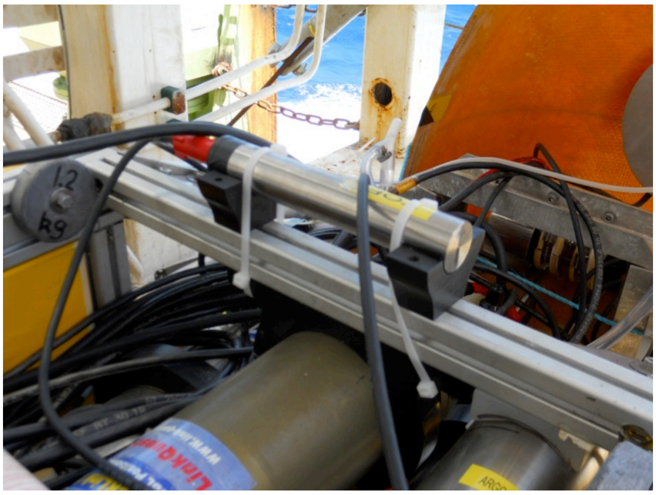


Figure 12. Magnetometer mounted on top of nose frame, avoiding magnetic materials where possible

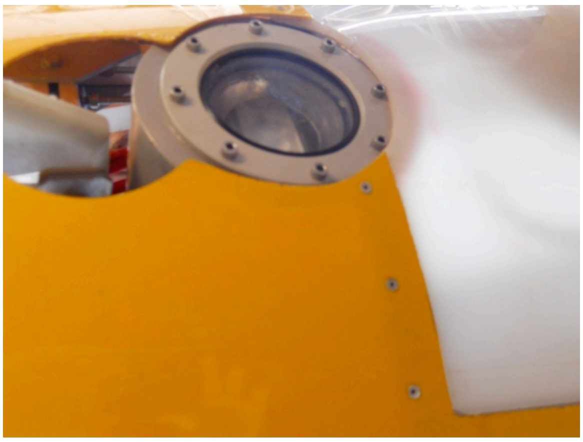


Figure 13. Looking upwards at the flash unit in the tail section

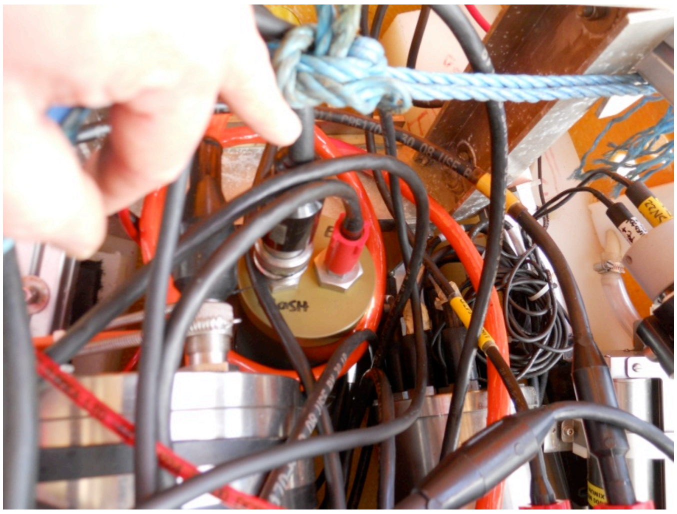


Figure 14. Looking down into the nose section at the camera unit (at end of finger)

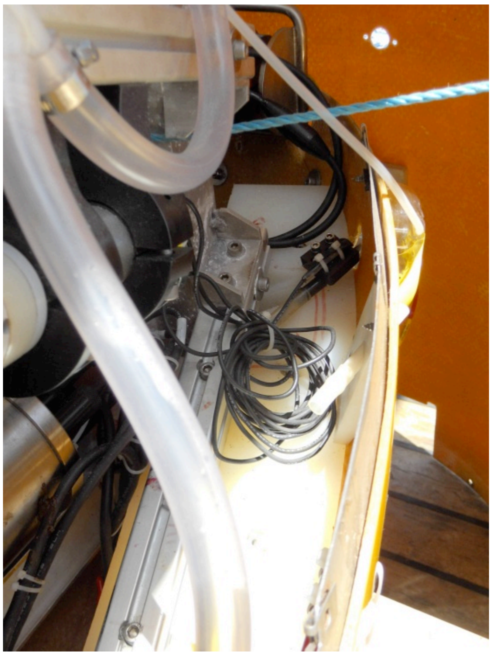


Figure 15. Eh sensor on starboard side protruding through panel

3.6.1 Sensor maintenance

The coiled wire section of the Eh sensor protruding through the panel was protected with a cap taped to the panel while on deck. The CTs and oxygen sensors were flushed through with Millipore water after each mission and kept wet with Millipore water by means of a U tube arrangement. After the final mission, these were flushed through with a 20% bleach/water mix, flushed with Millipore water, drained and plugged, i.e. the same procedure as used on the CTD carousel.

3.6.2 Launch and recovery

The Autosub launch and recovery gantry was installed just aft of the ship's parallelogram on the starboard side using the 5 Tonne rated 0.5metre M24 matrix sockets. This location had a very noticeable reduction in pitching motion which made the recovery operation very much easier compared with stern recoveries.

In order to avoid problems of the Autosub stern-planes being knocked during the launch operation, the AUV was launched approximately at 30 degrees to the ship pointing aft. The launch was timed so the propeller would be running shortly after it hit the water ensuring the AUV would propel itself away from the ship. Good use was made of the ship's manoeuvrability during the recoveries and with the calmer mid-ships location, all the recoveries were carried out with minimal drama.

4. CTD Operations

Kate Stansfield and Sarah Taws

4.1 CTD Processing and Calibration

4.1.1 Initial Processing Using SeaBird

The files output by Seasave (Version 7) have the appendices: .hex, .HDR, .bl, .CON. The .CON files for each cast contain the calibration coefficients for the instrument. The .HDR files contain the information in the header of each cast file. The .hex files are the data files for each cast and are in hex format. The .bl files contain information on bottle firings of the rosette.

Initial data processing was performed on a PC using the Seabird processing software SBE Data Processing, Version 7. We used the following options in the given order:

Data Conversion - turns the raw data into physical units. It takes the .CON files and .hex files. The input files were named jc044_NNN.hex where NNN refers to the three-digit station number.

Align CTD - takes the .cnv file and applies a temporal shift to align the sensor readings. The offsets applied were zero for the primary and secondary temperature and conductivity sensors as the CTD deck unit automatically applies the conductivity lag to the conductivity sensors. An offset of 5 was applied to the oxygen sensor.

Cell Thermal Mass - takes the .cnv files output from Align CTD and makes corrections for the thermal mass of the cell, in an attempt to minimize salinity spiking in steep vertical gradients due to a temperature/conductivity mismatch. The constants applied were; thermal anomaly amplitude α= 0.03; thermal anomaly time constant $1/\beta$= 7.

Output files were copied to *nosea1*, and symbolic links were created for each file named ctd_jc044_NNN_ctm.cnv, and ctd_jc044_NNN.bl, where NNN is the station number.

4.1.2 Mstar CTD Processing

The entire *Mstar* software suite is written in MATLAB and uses NetCDF file format to store all the data. There are four principal types of files:

- SAM files: store all information about rosette bottles samples, including upcast CTD data from when the bottles were fired. Data from chemistry samples corresponding with each bottle are uploaded into this file as well. Other information about the station is stored too.
- CTD files: store all data from CTD sensors. There are five CTD files: raw, 24Hz, 1Hz, psal and 2db. The program averages and interpolates the raw data until it has 2db resolution.

- DCS files: store information necessary to know CTD downcast (for e.g. start, bottom and end points of the cast). It is also used to merge in latitude and longitude.
- FIR files: keep information about CTD data in points when each rosette bottle was fired. Also stores information about winch work.

4.2 Processing Procedure Used on JC044

After having converted CTD with the SBE processes, there were two files to work on: *ctd_jc044_NNN_ctm.cnv* and *ctd_jc044_NNN.bl*. The first one contains all raw CTD data including cast information. The other one contains information about the firing of each bottle on the cast.

To start the CTD data processing, run *m_setup* in MATLAB to add Mstar tools and information needed for the processing. The following scripts were then run:

msam_01: creates an empty SAM file to store all information about rosette bottle samples. The set of variables are available in the /TEMPLATES directory and can be changed according to what it needs to store. This file, named as *sam_jc044_NNN.nc*, contains space to store data for each sample bottle, their flags, and some CTD data at firing time.

mctd_01: reads the raw data (*ctd_jc044_NNN_ctm.cnv*) and stores it in a NetCDF file named *ctd_jc044_NNN_raw.nc*, which becomes write protected.

mctd_02a: copies *ctd_jc044_NNN_raw.nc* into *ctd_jc044_NNN_24hz.nc* renaming the variables for the SBE sensor.

mctd_02b: using the 24Hz data (ctd_jc044_NNN_24hz.nc), applies oxygen hysteresis correction to variable oxygen_sbe to create new variable oxygen.

mctd_03: using 24Hz data (*ctd_jc044_NNN_24hz*) it averages to 1Hz data. Then, using the 1Hz file (*ctd_jc044_NNN_1hz*) it calculates potential salinity and potential temperature (*ctd_jc044_NNN_psal*). Also calls mctd_sensor_choice.m, which records the first choice CT sensor pair for each station. First choice sensor data is then stored in the variables temp and cond (which are subsequently used to calculate variables potemp and psal).

mdcs_01: creates empty file named as *dcs_jc044_NNN* to store information about the start, bottom and end of the cast.

mdcs_02: populates *dcs_jc044_NNN* with information from the bottom cast. It takes the highest pressure point as bottom.

Dependant on whether the CTD station involved a classic downcast/upcast profile, or a TOWYO, the next step of the processing would differ as follows:

For regular up/downcasts, the normal mdcs_03 and mctd_04 scripts are used:

mdcs_03: selects and shows surface data < 20db (*ctd_jc044_NNN_surf*) then the analyst chooses the positions of the start and end scan numbers.

The start is selected by scrolling from the top of data printed out by *mdcs_03.* The operator identifies where the CTD went from being on deck (zero/negative pressure) to roughly 10 db and then the point where is it was brought back to the surface for start the downcast. The scan number at which the pressure begins to increase, and temperature, salinity and oxygen data show reasonable values is selected as the start point of the downcast.

To find the end of upcast, scroll the data up from the bottom and identify where the CTD came back onboard. The operator chooses the last available point where the sensor values are reasonable before an abrupt change in measurements occurs as the CTD is lifted out of the water.

mctd_04: using information on *dcs_jc044_NNN* it selects the CTD downcast data from *ctd_jc044_NNN_psal* file and averages it into 2db resolution (*ctd_jc044_NNN_2db*).

<u>For CTD casts involving TOWYOs: the script mtow_04 is used:</u>

mtow_04: Extracts data from the psal file using the index information in *towyo_limits_jc044* file, sort and average to 2dbar (ctd_jc044_XXXXXX_2db), interpolate gaps and recalculate pot.temp. XXXXXX represents the index number associated with the TOWYO cast (see below). TOWYO files contain multiple casts and part casts. Code is run using details of TOWYO 'profile number', CTD file number from which data are to be extracted, and range of scan numbers to be included in the TOWYO profile.

The format of the *towyo_limits_jc044* file is as follows:

003001 1.37405e+04 1.66308e+05
004001 0 2.40125e+04

The first number on each line is an index of the profile. The index number is *(CTD_file_number*1000)+ profile_number*, e.g. 13003 for CTD file 013, sequential profile 3. The next two numbers are the lower and upper limits of scan number to be extracted. The scan number range is used by DATPIK to extract scans within the range. Thus to extract from the 'start of file' you can use scan number zero, and to extract to 'end of file' you can use a large number such as 1e10.

Regular processing returned to normal after this additional step:

mdcs_04: loads position from navigation file and merges it on the cast's points previously defined on mdcs_03 and store it on *dcs_jc044_NNN_pos.nc*.

<u>Only CTD stations during which bottle samples were taken involved the next four scripts being implemented.</u>

mfir_01: extracts information about fired bottles from *ctd_jc044_NNN.bl* and copies them into a new file named *fir_jc044_NNN_bl.nc*.

mfir_02: using *fir_jc044_NNN_bl* and *ctd_jc044_NNN_1hz* it merges the time from the CTD using scan numbers and puts it into a new file (*fir_jc044_NNN_time.nc*).

mfir_03: stores the CTD data at each bottle firing time in *fir_jc044_NNN_ctd*. The CTD data are taken from *ctd_jc044_NNN_psal* and selected according to the firing time information stored in *fir_jc044_NNN_time*.

mfir_04: copies information of each bottle from *fir_jc044_NNN_ctd* onto *sam_jc044_NNN*.

<u>Regular processing returned to normal afterwards.</u>

mwin_01: creates a new file named *win_jc044_NNN.nc* to store information about winch working (for e.g. angles, rate and tension).

<u>Only CTD stations during which bottle samples were taken involved the next four scripts being implemented.</u>

mwin_03: using time stored in *fir_jc044_NNN_time*, it selects wire-out from *win_jc044_NNN* at each bottle firing location to *fir_jc044_NNN_winch*.

mwin_04: pastes wire-out information from *fir_jc044_NNN_winch* into *sam_jc044_NNN.nc*.

mbot_01: creates a bottle file (*bot_jc044_NNN*) to store information regarding the state of each Niskin bottle. It uses a text file named as *bot_jc044_01.csv* (on BOTTLE_FILE/directory) that must be always updated after each station with the number of the bottle, position on rosette, and a flag number. For e.g. *101 1 1 1 2* represents: 101 (Bottle 1 of station 1) 1 (Station 1) 1 (Bottle 1) 1 (Position 1 on Rosette) 2 (Flag Number).

mbot_02: copies information from *bot_jc044_NNN* to *sam_jc044_NNN.nc*.

<u>Regular processing returned to normal afterwards.</u>

mdep_01: applies full water depth into all files. The depth is taken from the LDEO processing of the LADCP.

mdcs_05: applies positions from *dcs_jc044_NNN_pos.nc* to all files. If a file on the set doesn't exist yet it won't be uploaded.

<u>Please refer to 'PROCESSING LOGSHEETS' for a summary of the CTD processing commands completed for each station.</u>

4.3 CTD Files

CTD Stations 71-75 were subject to spurious data error whilst the CTD was underwater. As much as 100 modular errors (over 200 for station 75) were observed per CTD station, resulting in approximately 4 seconds of data being lost each cast. These errors resulted in a re-termination of the CTD wire, following casts 74 and 75. Additional SBE processing ('*White Flag'*) was carried out to omit the bad data prior to the Mstar processing in MATLAB (during '*White Flag*' processing, bad data are flagged as *-9e-29*; they were subsequently converted to NaNs within the jc044_NNN_ctm.cnv file). Salinity profiles for CTD stations 72 and 75 still exhibit numerous spikes despite the above processing (i.e. '*White Flag*') being carried out (Figure 3); potential temperature profiles show no spikes. Further processing is therefore required to remove these additional flaws. Other problems were also encountered when processing horizontal transects associated with the CTD casts (i.e. for stations 74, 76-77). A slight modification of the mtow_04 command maybe required to process these casts correctly, or the user should use the un-averaged data stored within the ctd_jc044_NNN_psal file. Additional processing to clean the data files may also be required. The latest calibrated CTD data for the Cayman Basin are saved to file within the *cruise/data/ctd* directory.

4.4 Niskin Bottles

During sampling the bottles were checked for problems such as firing, leaking and dribbling. Any issues were noted on the deck log. During the processing of the data, Quality Control (QC) Flags were assigned and are as follows:

Flags	
2	No Problems Noted
3	Leaking profusely when taken from water (rejection)
4	Did not fire (rejection)
4	Bad bottles from salinity/temperature measurements (rejection)
9	Samples not drawn from bottle (duplicates)
10	Slight drip/water leak when top valve opened

Table 4. Niskin Bottle Flags

In order to maximize the number of bottles sampled and the limited probability of contamination, bottles with minor leaking problems were generally sampled, and given a QC Flag 10. Bottles were only immediately rejected if they were seen be leaking when the CTD was removed from the water (QC Flag 3), or if the bottle did not fire (QC Flag 4). The bottle was also rejected if temperature measurements revealed an unusually high temperature conducive with the Niskin bottle failing to seal correctly at its original depth but fully sealing higher within the water column (QC Flag 4). Where no problems were noted and samples taken, a QC Flag of 2 was awarded. QC Flags 2, 3 and 9 are taken from the WOCE operations manual.

4.4.1 Bottle Performance

Bottle 22 was not present on the rosette throughout the cruise. It was removed to make space for the SVP. Bottles 6-9 were also removed from the rosette on station 15 to make way for SAPS experiments. Bottles 5, 7-9 and 12 were also removed from the rosette at station 18 for the same reason. The bottles largely performed well. The total percentage of Niskin bottles during the cruise given a flag of 3-4 was 9%.

4.5 Preliminary Analysis

The following section illustrates some of the initial figures generated from the CTD analysis.

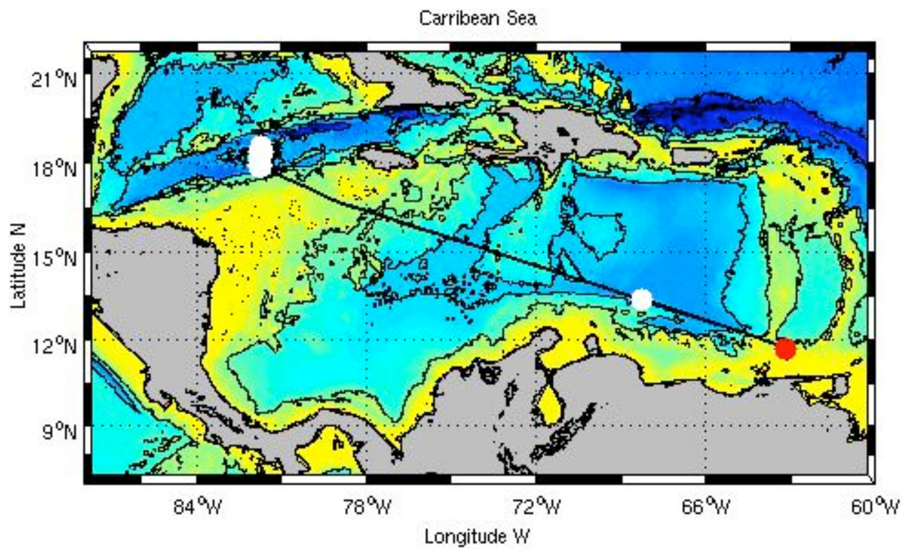


Figure 16. Map of the Caribbean showing transect to study site in the Cayman Basin, and locations of CTD casts (white dots). The red dot illustrates the location where TECHSAS data was first collected (i.e. start of the data)

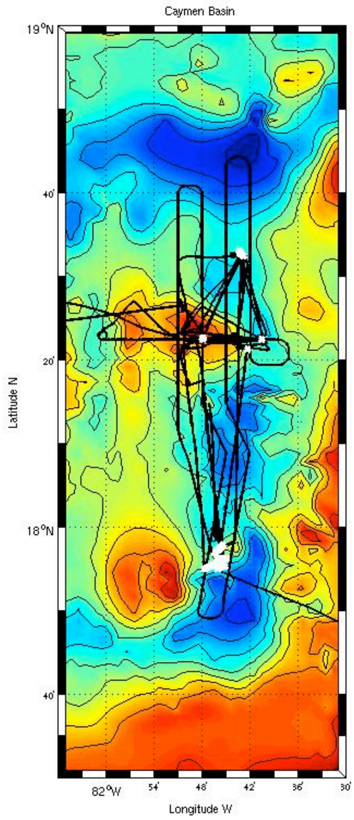


Figure 17. Map of the Cayman basin showing ships transect and associated CTD study sites (white dots)

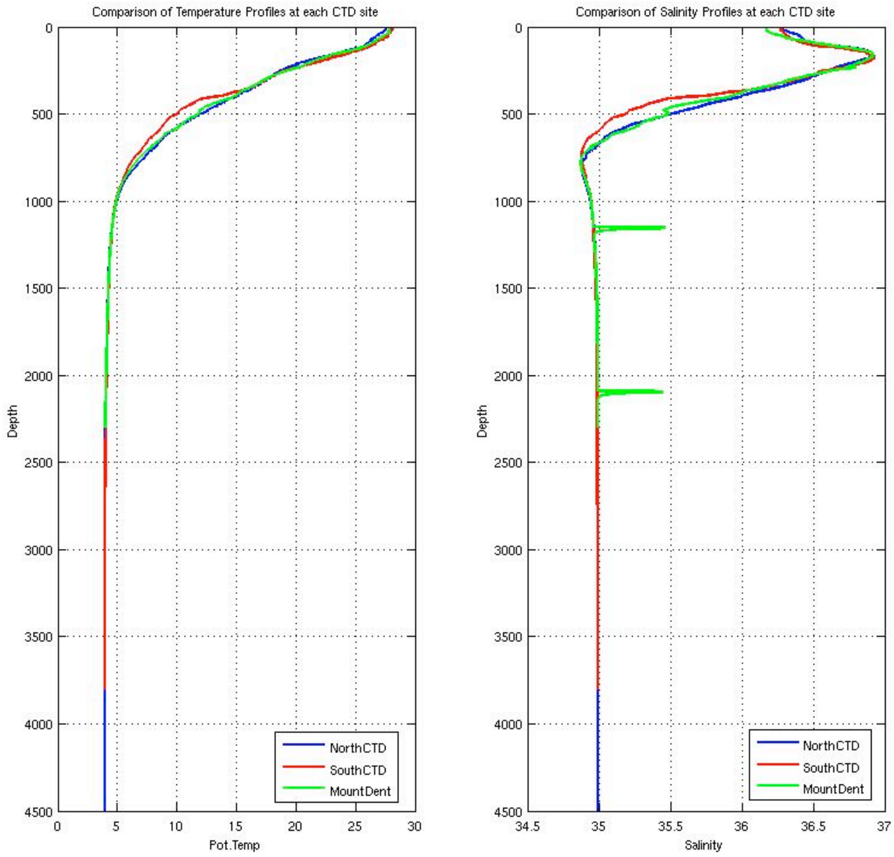


Figure 18. Mean potential temperature and salinity profiles of the three principle study sites (North Study Site, South Study Site, and Mount Dent) analysed in the Cayman Basin. Note the spikes evident in the Mount Dent salinity profile. These reflect modular error in the data resulting from re-termination.

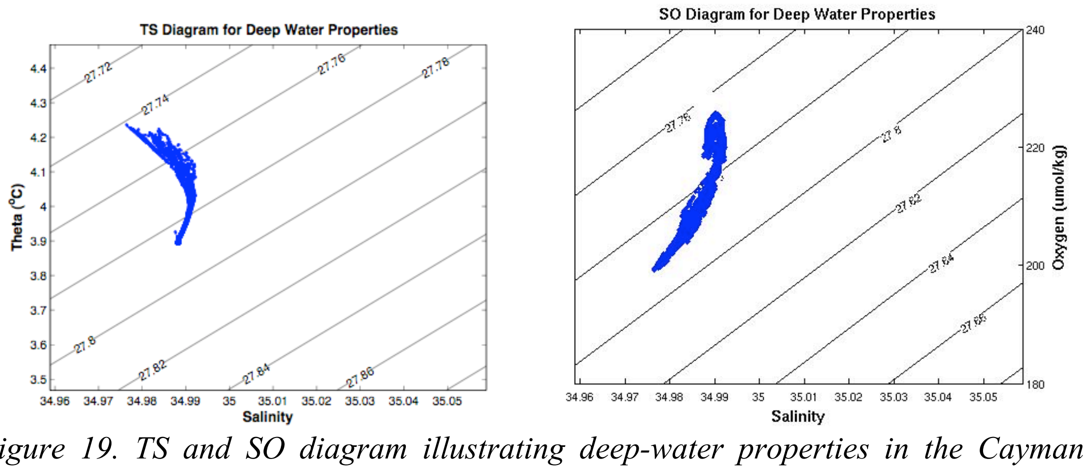


Figure 19. TS and SO diagram illustrating deep-water properties in the Cayman Basin for stations 1-78

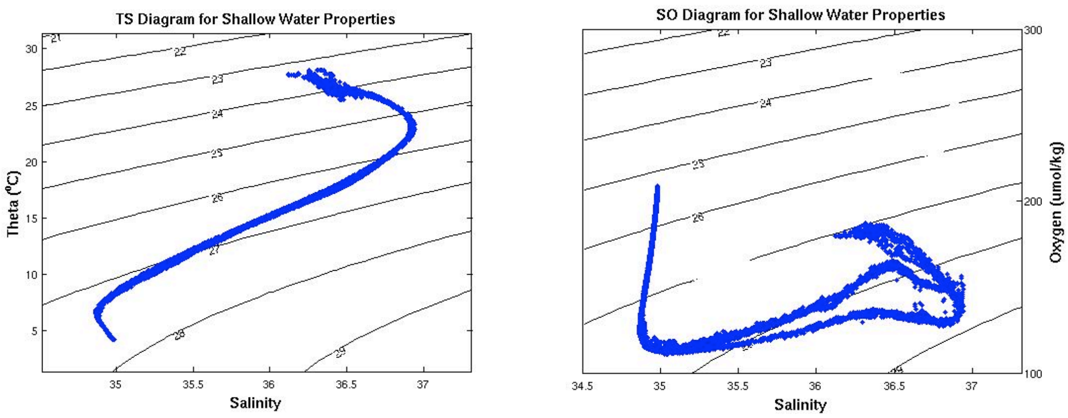


Figure 20. TS and SO diagram illustrating shallow-water properties in the Cayman Basin for stations 1-78

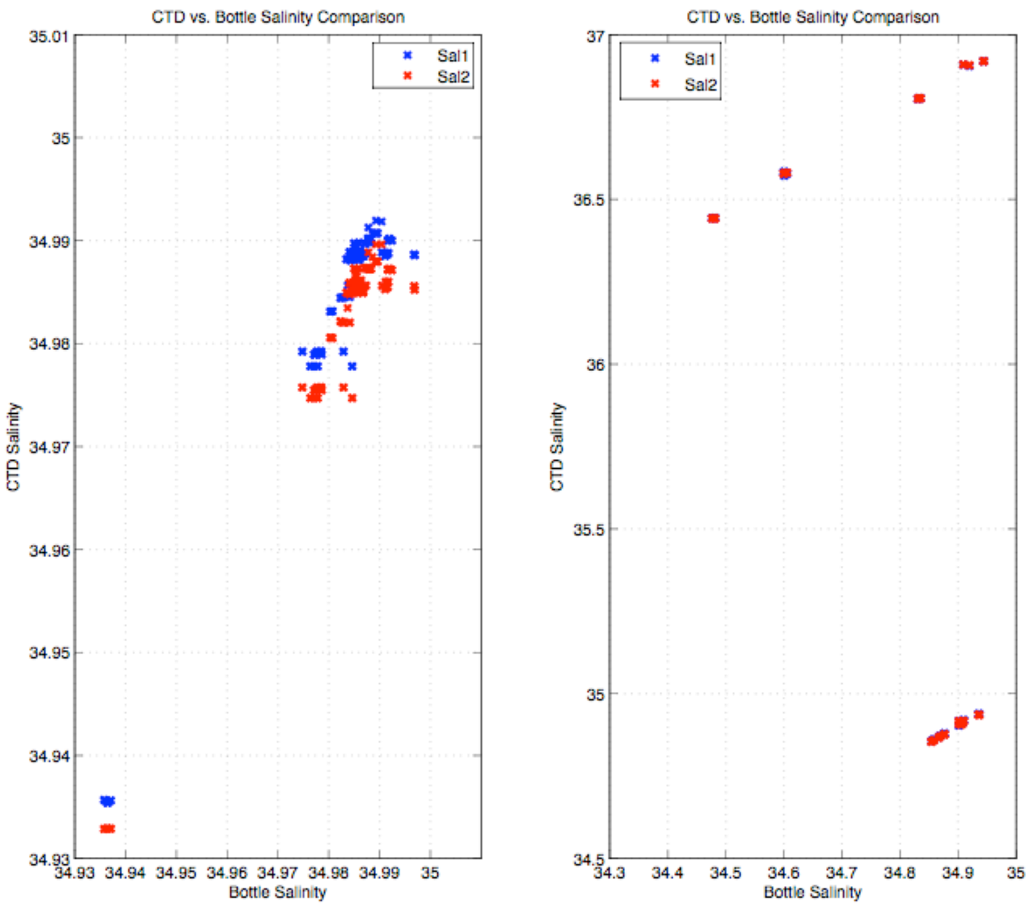


Figure 21. Comparison between bottle salinities and CTD salinities for stations 1-78

5. Water sampling *Douglas Connelly, Carla Sands and Alexandra Meier*

The majority of the water samples collected were done using a Seabird CTD. The CTD system used is a Seabird +911 on a titanium frame with up to 24 externally sprung Niskin bottles. This is a clean system, specifically designed for the sampling of waters with low levels of trace metals and nutrients. The bottles are Teflon lined, with Teflon taps and non-metallic parts, any metallic components are titanium or high quality stainless steel.

5.1 Water Analyses

5.1.1 Biogeochemical samples

The CTD Carousel Niskin and ROV mini-Niskin bottles were sampled for (in order):
1) Methane (125ml, poisoned with HgCl for analysis at the NOC, Southampton)
2) Dissolved inorganic carbon (DIC) (250ml, poisoned with HgCl for analysis at the NOC)
3) Total dissolved organic carbon (tDOC) (20ml, filtered through 0.2µm filter and acidified with HCl for analysis at the NOC)
4) Trace metals (filtered through 0.2µm filter into an 500ml acid cleaned Teflon bottle, analysis at NOC)
5) Metal speciation (filtered through 0.2µm filter into duplicate 250ml bottles and frozen for analysis at NOC)
6) Siderophores - remaining volume for Mini-Niskins, usually 10L for large Niskins - filtered and sucked through an Isolute ENV+ column (frozen) for characteristion at NOC

The Filters were all washed for salts with pH8 MilliQ water and stored frozen for analysis at NOC)

Description	Volume/ ml	Onboard processing
Gases (CH_4)	125	Sampled to exclude air. Most samples poisoned with mercuric chloride for analysis back onshore; a few samples analysed onboard by GC.
DIC	250	Sampled to exclude air and poisoned with mercuric chloride for analysis back onshore.
DOC	20	Sample filtered through 0.2 µm filter and preserved for analysis back onshore by acidifying with HCl.
Trace metals	500	Sample filtered through 0.2 µm filter and stored in an acid-cleaned HDPE bottle. Sample preserved for analysis back onshore by acidifying with HNO_3.
Metal speciation	2 × 250	Sample filtered through 0.2 µm filter stored in an acid-cleaned HDPE bottle. Sample preserved by freezing for analysis back onshore.
Siderophores	Remainder	Sample filtered through 0.2 µm filter and passed through a column packed with Isolute ENV+ resin. The column was then frozen for analysis back onshore.
Plume particulate material	Filters	0.2 µm filters were washed to remove sea salt with Milli-Q water adjusted to pH8, and frozen for analysis back onshore.

Table 5 Onboard sub-sampling and processing of Niskin bottle samples for chemical studies.

5.1.2 Methane analysis

The first samples to be drawn from the Niskin bottles were for methane. These samples were collected in 100 ml glass vials, capped with a rubber stopper and crimped with an aluminium seal to ensure no loss of the water or gas occurred. The samples were taken to the laboratory where 20ml of UHP nitrogen was added and the bottles were left to equilibrate as they warmed to room temperature. A sample of the headspace gas was taken for each vial and analysed using a 7850 Agilent Gas Chromatograph. We had two 7850 systems on board, the first combines an FID (Flame ionisation detector) for C1-C6 detection with a HID (Hydrogen ionisation detector) for the determination of hydrogen. The second system has an FID with built in methaniser for the determination of carbon dioxide in addition to methane. From the beginning of the cruise the HID did not function, towards the end of the cruise the methaniser malfunctioned. The samples were poisoned with 20 µl of mercuric chloride and stored.

5.2 Stand Alone Pumps (SAPS)

SAPS are designed to allow the high volume sampling of particles from the water column. On this cruise we used 293 mm Nuclepore filters with a nominal pore size of 1µm. The SAPS are designed to be mounted on either a line or modified to fit directly onto a CTD frame. We successfully mounted the SAPS system onto HyBis sampled from within the rising buoyant plume. We obtained samples at both the Beebe vent site and the Von Damm vent site. The filter from Beebe was particularly impressive and indicates that we were well positioned in the plume for sampling.

5.3 Microbiology Samples of JC044

Microbiology samples were taken on the cruise JC044 for characterisation of the microbial communities in the Cayman Trough and examine a possible relationship between the planktonic and biofilm microbial communities. Samples were collected by filtering seawater collected during CTD dives at different depths and from geological specimens brought on board using the ROV HyBIS. Some DNA extractions were done directly on board while some samples were stored at -80°C for later analysis.

Several materials were also exposed for 10 days on the deep sea mooring in order to examine their susceptibility to biofouling. The materials used in the exposure experiment were Polymethyl methacrylate (PMMA), Glass, Cyclic Olefin Copolymer (COC), Stainless Steel 316 grade, Cyclic Olefin Polymer (COP), Copper and Delrin.

A second long-term mooring was deployed with the same materials with the samples to be collected at a later point.

5.3.1 CTD – Seawater filtration

Seawater samples were collected at several different depths and location to analyse the planktonic microbial community.

Some samples were taken where no indication of hydrothermal activity could be detected in to determine the background. Other samples were taken from within, above and below hydrothermal plumes.

Two Glass fibre filters of different pore size were used in sequence, 3 µm and 0.7µm. All these samples were stored at -80°C for later DNA extraction and subsequent molecular analysis.

Position	Sampling Depth [m]	CTD #	approx. Sample Vol.[l]	Sample Label	Comments
17°54.998N; 81°46.001W	4876	2	15	JC044 CTD002 I 0.7µm; JC044 CTD002 I 3µm	Background samples
17°54.998N; 81°46.001W	4550	2	50	JC044 CTD002 II 0.7µm; JC044 CTD002 II 3µm	Background samples
17°54.998N; 81°46.001W	4000	2	50	JC044 CTD002 III 0.7µm; JC044 CTD002 III 3µm	Background samples
17°54.998N; 81°46.001W	2000	2	50	JC044 CTD002 IV 0.7µm; JC044 CTD002 IV 3µm	Background samples
17°54.998N; 81°46.001W	750	2	25	JC044 CTD002 V 0.7µm; JC044 CTD002 V 3µm	Background samples
18°32.996N; 81°43.351W	4090	14	49	JC044 CTD014 II 0.7µm; JC044 CTD014 II 3µm	samples mid-plume
18°32.996N; 81°43.351W	3509	14	49	JC044 CTD014 III 0.7µm; JC044 CTD014 III 3µm	samples above plume
18°32.835N; 81°43.080W	4940	16	50	JC044 CTD016 I 0.7µm; JC044 CTD016 I 3µm	Background samples
18°32.791N; 81°43.080W	4966	17	35	JC044 CTD017 I 0.7µm; JC044 CTD017 I 3µm	Samples taken in hot water plume
18°32.791N; 81°43.080W	4950	17	25	JC044 CTD017 II 0.7µm; JC044 CTD017 II 3µm	Samples taken in hot water plume
18°32.745N; 81°43.088W	4093	18	50	JC044 CTD018 I 0.7µm; JC044 CTD018 I 3µm	Sample @ vent site
18°22.498N; 81°40.503W	4967	75	36	JC044 CTD075 I 0.7µm; JC044 CTD075 I 3µm	Sample near short term mooring site
18°22.498N; 81°40.503W	4867	75	36	JC044 CTD075 II 0.7µm; JC044 CTD075 II 3µm	Sample near short term mooring site
18°22.498N; 81°40.503W	4367	75	36	JC044 CTD075 III 0.7µm; JC044 CTD075 III 3µm	Sample near short term mooring site
18°22.498N; 81°40.503W	3967	75	36	JC044 CTD075 IV 0.7µm; JC044 CTD075 IIV3µm	Sample near short term mooring site
18°22.498N; 81°40.503W	750	75	50	JC044 CTD075 V 0.7µm; JC044 CTD075 V 3µm	Sample near short term mooring site
18°22.618N; 81°47.806W	2220	78	50	JC044 CTD078 I 0.7µm; JC044 CTD078 I 3µm	sample mid-plume; immediate filtration
18°22.618N; 81°47.806W	2220	78	50	JC044 CTD078 II 0.7µm; JC044 CTD078 II 3µm	sample mid-plume; stored overnight @ 20°C

Table 6 Seawater samples collected for microbiological analysis

5.3.2 HyBIS Samples

Swaps of biofilms on geological samples brought to the surface from the bottom by HyBIS were taken. Also some sediment samples were used for direct DNA extraction.

Position	Sampling Depth	HyBIS Dive#	No. of samples taken	Sample Label	Comments
18°32.753N; 81°43.034W	4962	3	8	JC044 HYBIS003 Swap	swaps of different parts of old chimney
18°32.753N; 81°43.034W	4962	3	8	JC044 HYBIS003 Swap E	swaps of different parts of old chimney; DNA extraction on board
18°32.753N; 81°43.034W	4962	3	7	JC044 HYBIS003 Mat	Filaments collected with Tweezers of the chimney
18°32.753N; 81°43.034W	4962	3	7	JC044 HYBIS003 Mat E	Filaments collected with Tweezers of the chimney: DNA extraction on board
18°32.811N; 81°43.332W	4962	7	4	JC044 HYBIS007 Swap	Swaps taken from Debris material inside the shrimp trap
18°32.811N; 81°43.332W	4962	7	4	JC044 HYBIS007 Swap E	Swaps taken from Debris material inside the shrimp trap; DNA extraction on board
18°32.811N; 81°43.332W	4962	7	6	JC044 HYBIS007 Sed	Sediment from Shrimp trap after being filtered through 50µm Nylon mesh and washed with MilliQ Water; stored in 15ml Tubes
18°32.811N; 81°43.332W	4962	7	10	JC044 HYBIS007 Sed	Sediment from Shrimp trap after being filtered through 50µm Nylon mesh and washed with MilliQ Water; stored in 2ml CryoTubes
18°32.811N; 81°43.332W	4962	7	8	JC044 HYBIS007 Sed E	Sediment from Shrimp trap after being filtered through 50µm Nylon mesh and washed with MilliQ Water; DNA extraction on board using Soil Extraction Kit
18°22.555N; 81°47.883W	2337	9	7	JC044 HYBIS009 Swap	Swaps of rocks from bottom of slope @ new vent site
18°22.555N; 81°47.883W	2337	9	7	JC044 HYBIS009 Swap E	Swaps of rocks from bottom of slope @ new vent site; DNA extraction on Board
18°22.606N; 81°47.877W	2290	10	11	JC044 HYBIS010 Swap	Swaps of rocks from top of slope @ new vent site
18°22.606N; 81°47.877W	2290	10	11	JC044 HYBIS010 Swap E	Swaps of rocks from top of slope @ new vent site; DNA extraction on board

Table 7 Material samples collected for microbiological analysis

5.3.3 Mooring Samples

Exposed materials were recovered after 10 days and divided. One half was swapped using sterile cotton swaps for molecular analysis of the microbial community and the second half was fixed with 100% Ethanol for microscopic analysis of the spatial distribution of the biofilm.

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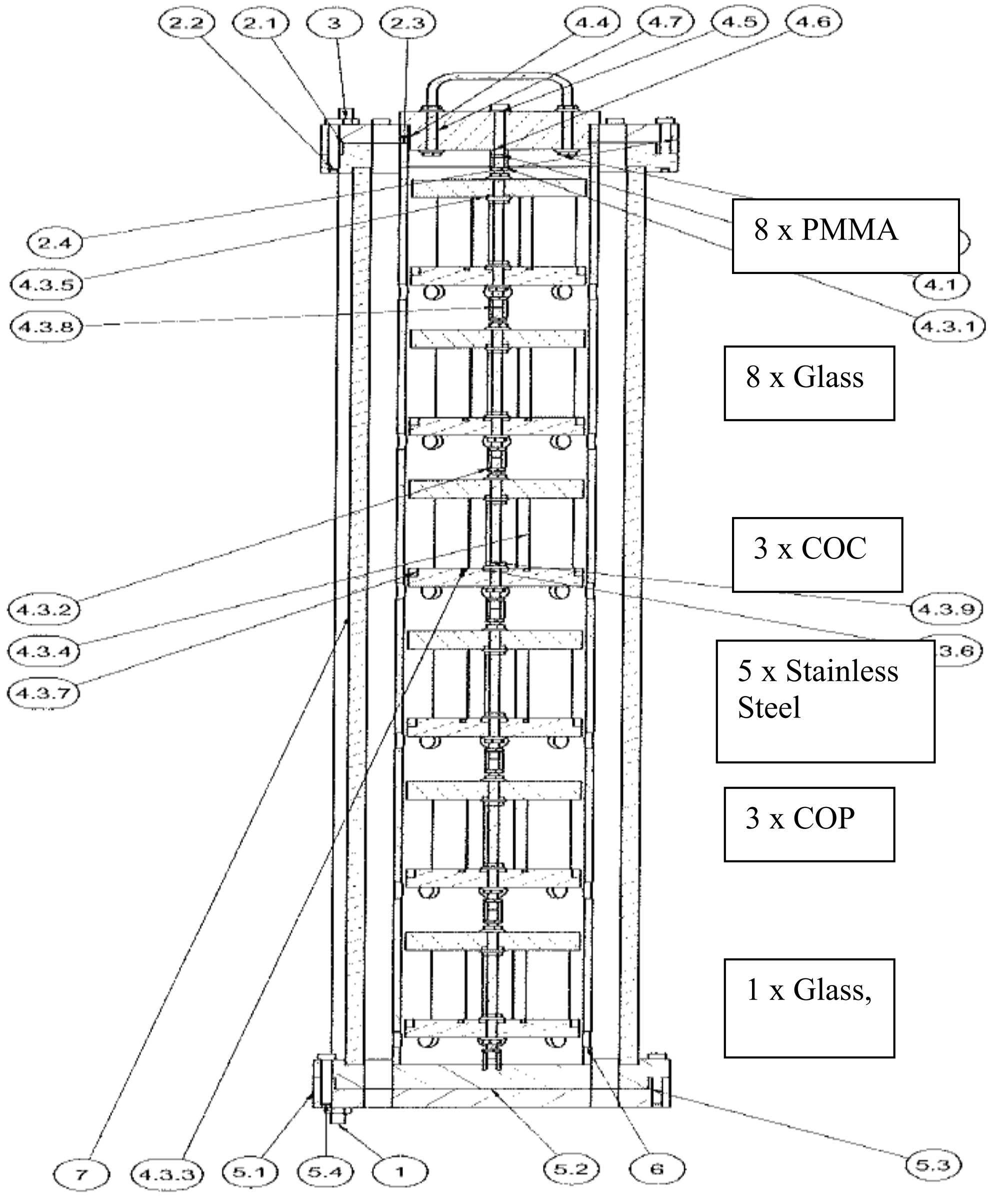

*Figure 22. Sample Positions inside the Biofouling Tube, Mooring I (*Serial No. RCM 100m: #400)

Position	Depth of Samples [m]	Material	No. of Samples	Sample Label	Comments	Positon of Slides
18°22.033N; 81°39.927W	100m off Bottom @ 4690	Glass	2	JC044 MOOI-Glass T -20	Slides preserved for Microscopy; frozen	Biofouling Tube
18°22.033N; 81°39.927W	100m off Bottom @ 4690	Glass	2	JC044 MOOI-Glass T EtOH	Slides preserved for Microscopy; dipped in Ethanol	Biofouling Tube
18°22.033N; 81°39.927W	100m off Bottom @ 4690	Glass	2	JC044 MOOI-Glass T	Slides preserved for Microscopy; Petridish with wet towel	Biofouling Tube
18°22.033N; 81°39.927W	100m off Bottom @ 4690	Glass	3	JC044 MOOI-Glass T	DNA Extraction on Board	Biofouling Tube
18°22.033N; 81°39.927W	100m off Bottom @ 4690	Glass	2	JC044 MOOI-Glass B -20	Slides preserved for Microscopy; frozen	Biofouling Box
18°22.033N; 81°39.927W	100m off Bottom @ 4690	Glass	2	JC044 MOOI-Glass B EtOH	Slides preserved for Microscopy; dipped in Ethanol	Biofouling Box
18°22.033N; 81°39.927W	100m off Bottom @ 4690	Glass	2	JC044 MOOI-Glass B	Slides preserved for Microscopy; Petridish with wet towel	Biofouling Box
18°22.033N; 81°39.927W	100m off Bottom @ 4690	Glass	3	JC044 MOOI-Glass B	DNA Extraction on Board	Biofouling Box
18°22.033N; 81°39.927W	100m off Bottom @ 4690	PMMA	1	JC044 MOOI-PMMA T -20	Slides preserved for Microscopy; frozen	Biofouling Tube
18°22.033N; 81°39.927W	100m off Bottom @ 4690	PMMA	2	JC044 MOOI-PMMA T EtOH	Slides preserved for Microscopy; dipped in Ethanol	Biofouling Tube
18°22.033N; 81°39.927W	100m off Bottom @ 4690	PMMA	2	JC044 MOOI-PMMA T	Slides preserved for Microscopy; Petridish with wet towel	Biofouling Tube
18°22.033N; 81°39.927W	100m off Bottom @ 4690	PMMA	3	JC044 MOOI-PMMA T	DNA Extraction on Board	Biofouling Tube
18°22.033N; 81°39.927W	100m off Bottom @ 4690	PMMA	3	JC044 MOOI-PMMA B	DNA Extraction on Board	Biofouling Box
Position	**Depth of Samples [m]**	**Material**	**No. of Samples**	**Sample Label**	**Comments**	**Positon of Slides**
18°22.033N; 81°39.927W	100m off Bottom @ 4690	Steel	3	JC044 MOOI-Steel	DNA Extraction on Board	Biofouling Tube
18°22.033N; 81°39.927W	100m off Bottom @ 4690	Delrin	2	JC044 MOOI-Delrin -20	Slides preserved for Microscopy; frozen	Biofouling Box
18°22.033N; 81°39.927W	100m off Bottom @	Delrin	2	JC044 MOOI-	Slides preserved for Microscopy;	Biofouling Box

	4690			Delrin EtOH	dipped in Ethanol	
18°22.033N; 81°39.927W	100m off Bottom @ 4690	Delrin	2	JC044 MOOI-Delrin	Slides preserved for Microscopy; Petridish with wet towel	Biofouling Box
18°22.033N; 81°39.927W	100m off Bottom @ 4690	Delrin	3	JC044 MOOI-Delrin	DNA Extraction on Board	Biofouling Box
18°22.033N; 81°39.927W	100m off Bottom @ 4690	Copper	2	JC044 MOOI-Copper -20	Slides preserved for Microscopy; frozen	Biofouling Box
18°22.033N; 81°39.927W	100m off Bottom @ 4690	Copper	2	JC044 MOOI-Copper EtOH	Slides preserved for Microscopy; dipped in Ethanol	Biofouling Box
18°22.033N; 81°39.927W	100m off Bottom @ 4690	Copper	2	JC044 MOOI-Copper	Slides preserved for Microscopy; Petridish with wet towel	Biofouling Box
18°22.033N; 81°39.927W	100m off Bottom @ 4690	Copper	3	JC044 MOOI-Copper	DNA Extraction on Board	Biofouling Box
18°22.033N; 81°39.927W	100m off Bottom @ 4690	COC	3	JC044 MOOI-COC T	DNA Extraction on Board	Biofouling Tube
18°22.033N; 81°39.927W	100m off Bottom @ 4690	COP	3	JC044 MOOI-COP T	DNA Extraction on Board	Biofouling Tube

Table 8 Samples collected from the mooring for microbiological analysis

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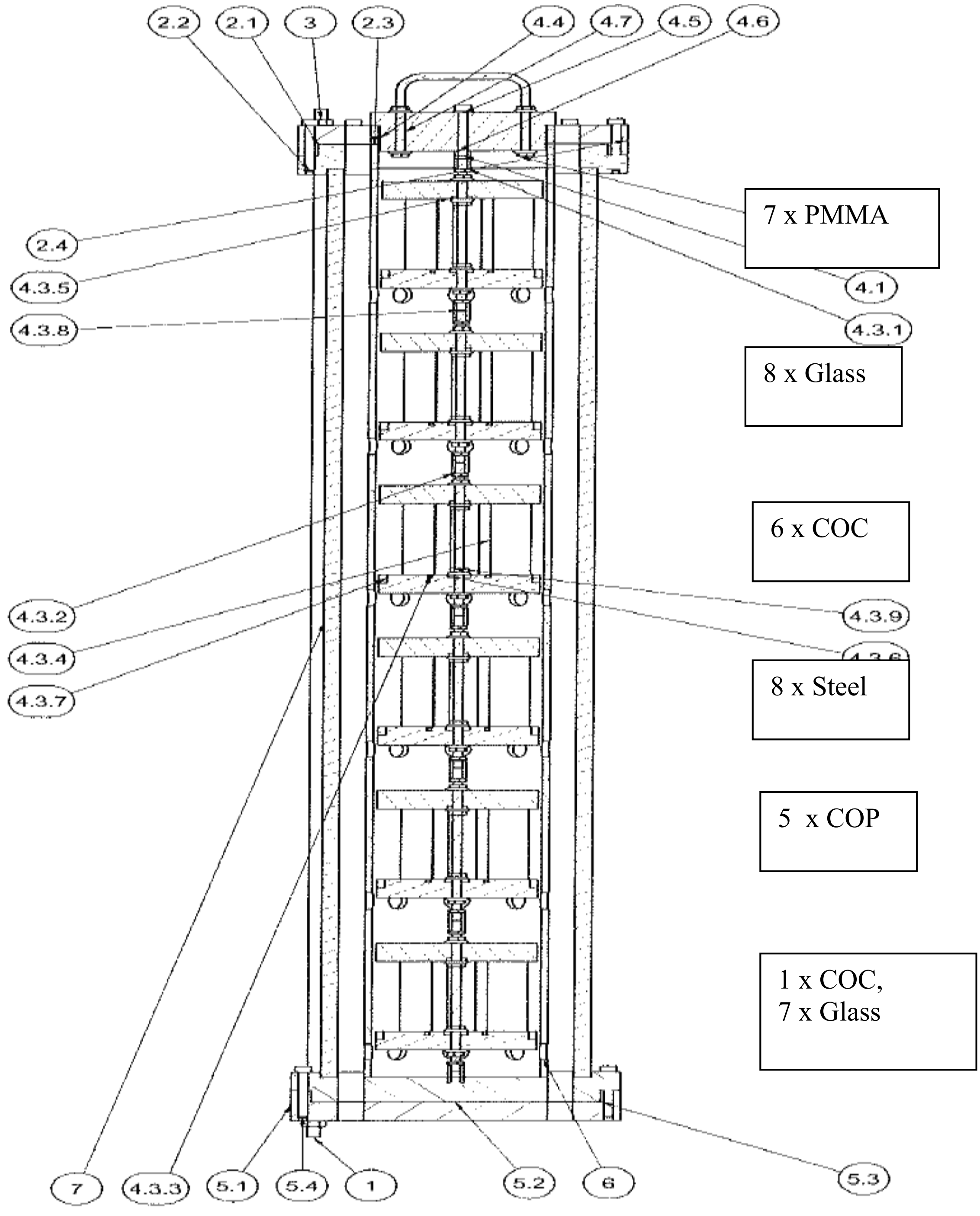


Figure 23. Sample Positions inside the Biofouling Tube, Mooring II (long term):(Sensors placed directly on top of the biofouling Tube/Box:Serial No. CTD 100m: #3279 Serial No. RCM 100m: #400)

6. HyBIS Operations

Bramley Murton, Veit Huhnerbach and Maria Judge

6.1 Background

HyBIS is a remotely operated, tethered vehicle that has a depth capability of 6000m. It was designed and operated by Bramley Murton and built by Hydro-Lek UK. Modular in design, HyBIS comprises a command and power module and a sampling module. The command module provides electrical and hydraulic power, thrusters, lights and cameras. Telemetry is via a single-mode fibre optic link and provides 3 channels of real-time standard-definition colour video plus vehicle attitude data. Power is supplied through a single-phase 1500V ac, 8kVA umbilical and converted to 3 phase 120V on the vehicle by two silicon motor controllers, 120V ac for the lights, and 24 to 12 V dc for onboard instruments. The sampling module comprised a 0.5 cubic metre clam-shell grab with a pay-load capacity of 1000kg and closure force of 4 tonnes.

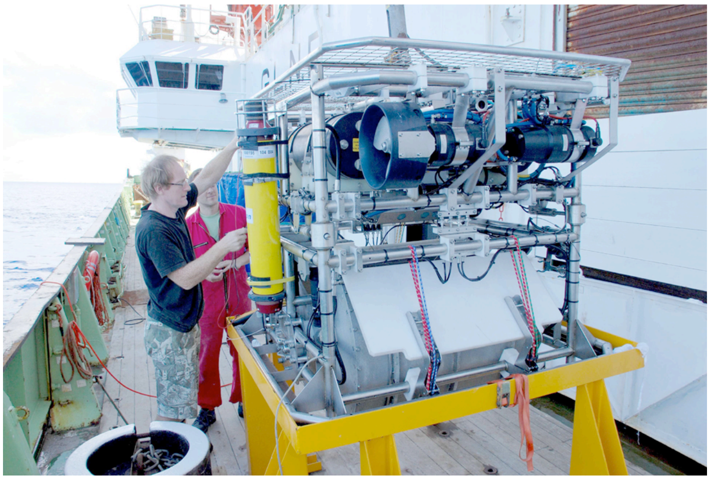


Figure 24. HyBIS in its deck frame being prepared for a deployment by Veit Huehnerbach (red boiler suit) and Bramley Murton. The yellow cylinder is the USBL subsea navigation beacon.

For cruise JC044, HyBIS was modified to operate with maximum efficiency at depths as great as 6000m. Modifications included the fitting of a secondary hydraulic power pack, installed in parallel with the primary power pack, and the use of a low-viscosity hydraulic oil (Q8 Hella-15) in the high-pressure circuit. These modifications were designed to overcome sluggish operation induced by high environmental pressures (up to 600 bar) at 6000m water depth.

Other modifications and additions included the design and manufacture of a high-definition video and stills camera, the addition of extra lights (totalling 2kW), three lasers for scale (620nm, 3 milliwatts), a sector scanning sonar, and brackets to carry a stand-alone pump, CTD, niskin bottle and a biological slurp-gun.

6.2 The HyBIS set-up on JC044

HyBIS was deployed from the amidships starboard gantry, and located closed to the Autosub 6000 launch gantry and CTD system. The top-side control centre was established in the main lab, on the starboard side, towards the aft and next to the high-voltage bulk-head connections. This minimised the length of trailing high-voltage leads across the lab. The vehicle's primary control box (HyBox) was supplemented with additional monitors and a relay of the USBL navigation screen. A video-extended Cat5 cable was used to relay the forward-looking camera's video stream to a 42 inch flat screen on the forward bulkhead of the main lab to enable group viewing. A dedicated GPS aerial was mounted on an out-rigger over the starboard side and provided a continuously recorded GPS string to the Garmin GPS navigation system in the HyBox. Winch controls were established adjacent to the vehicle pilot's position, allowing synchronisation between winch operator and pilot.

Video was recorded digitally as DV and AVI formats on 1.5 Tb hard-discs. All three cameras (forward and downward SD and forward HD) were recorded in standard definition. The forward camera was recorded continuously with vehicle attitude data overlain. The HD camera was also recorded continuously while the downward looking camera only recorded when the downward lights were on. Full HD video (1080i, PAL, 30fps, AVCHD format), super-slow motion HD video, and stills (both 8 and 12 megapix, jpeg format) was down-loaded from the vehicle's HD camera after each dive and copied to the 1.5Tb hard drives. Back-ups of all dive data and videos were then made before the end of each dive watch. All GPS navigation data were recorded on the HyBox and copied to the 1.5Tb drives. Time codes were all set and synchronised to GMT.

Acoustic navigation was provided by the 'Sonardyne' USBL system on the RRS *James Cook* and a 10kHz transponder on the HyBIS vehicle. Tracking was good at the start of the cruise but deteriorated with time. Transponder battery conditions were good throughout the mission and the cause of the deterioration in sub-sea navigation remains unknown. All available SBL navigation data were recorded to the 1.5Tb discs and backed up at the end of each dive.

6.3 Operational protocols

HyBIS was operated under the full safety and best-practice protocol established for the safe deployment of the ROV. The ship was on DP at all times. All risk-assessment procedures were strictly adhered to, especially those involving 'live' operations on deck. The HyBIS team comprised Dr Bramley Murton, Miss Maria Judge and Mr Veit Hunherbash. All three scientist/operators managed the maintenance, piloting, data acquisition and data back-up. These were complex and integrated tasks requiring close cooperation between team members. Log-keeping and general navigation was provided by normal scientific watch active during the dives. Mechanical services and modifications to the vehicle during the cruise were provided by Andy Webb and Dan Combden.

6.4 Dive Summaries

Dive logs are available as an appendix to this report. For JC044, dive numbers are numbered consecutively preceded by the cruise name, followed by the accumulated HyBIS dive number (in parentheses). The dates and time refer to when the vehicle was on the bottom.

6.4.1 JC044-HyBIS-1 (Dive 20)

Target: northern Mid-Cayman Rise vent site: location and discovery.

Start location	18°32.728 N, 81°43.178 W
Start depth	5009m
Start time	07:48 GMT, 06/4/2010
End location	18°32.780 N, 81° 43.098 W
End depth	4948m
End time	20:30 GMT, 06/4/2010

Table 9 Summary information JC044-HyBIS-1 (Dive 20)

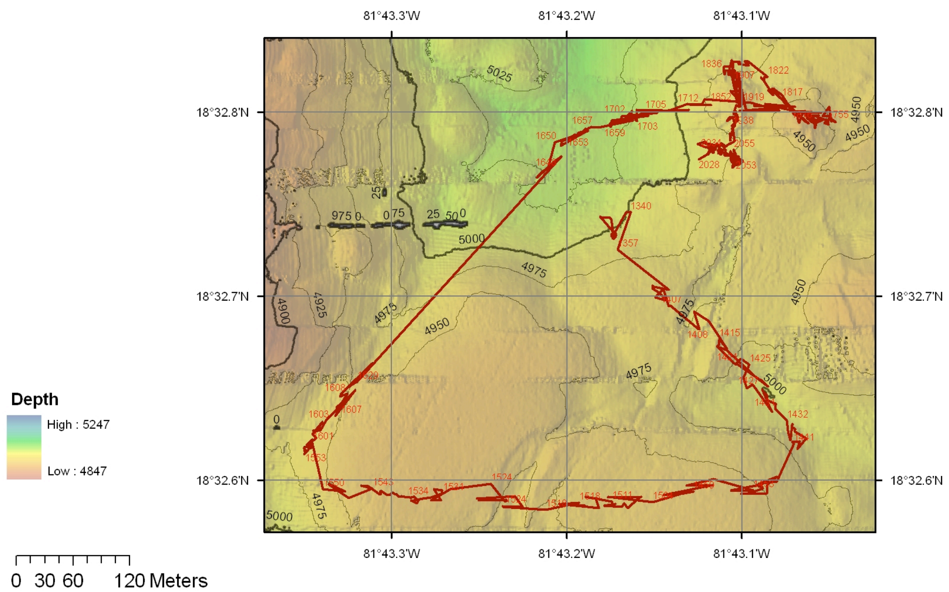


Figure 25. Location map showing HyBIS track (USBL navigation) with time annotation


Figure 26. Digital still image of black smoker at 5000m water depth, taken by HyBIS.

6.4.2 JC044-HyBIS-2 (Dive 21)

Target: northern Mid-Cayman Rise vent site: survey and sampling

Start location	18°32.792 N, 81°43.105 W
Start depth	4977m
Start time	02:48 GMT, 08/4/2010
End location	18°32.71 N, 81° 43.035 W
End depth	4954m
End time	11:50 GMT, 08/4/2010

Table 10 Summary information JC044-HyBIS-2 (Dive 21)

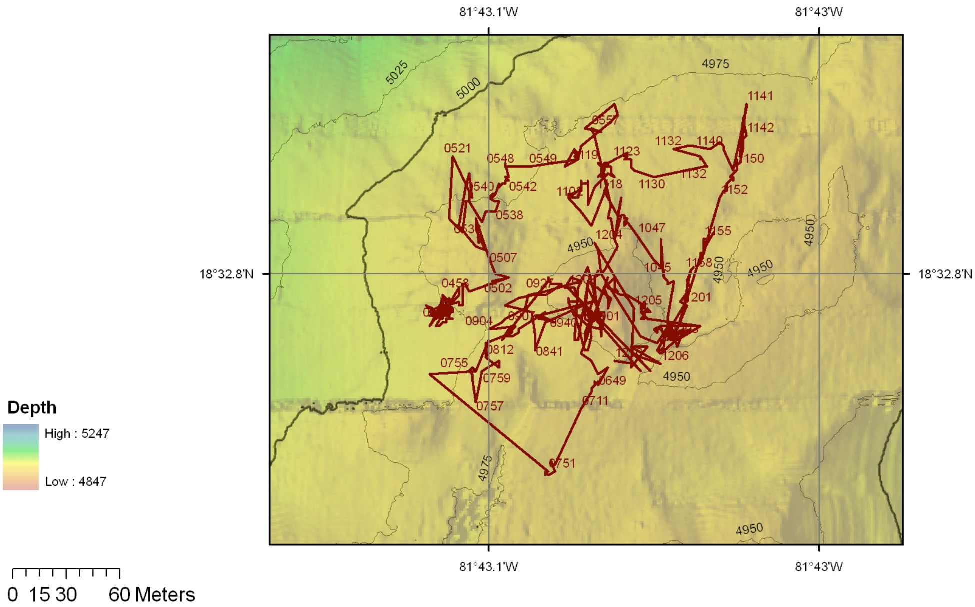


Figure 27. Location map showing HyBIS track (USBL navigation) with time annotation.

Figure 28. Digital still image of beehive diffusers, at 5010m, taken by HyBIS

6.4.3 JC044-HyBIS-3 (Dive 22)

Target: northern Mid-Cayman Rise vent site: plume sampling by SAPS

Start location	18°32.790 N, 81°43.106 W
Start depth	4967m
Start time	06:50GMT, 09/4/2010
End location	18°32.79 N, 81° 43.149 W
End depth	4930m
End time	11:31 GMT, 09/4/2010

Table 11 Summary information JC044-HyBIS-3 (Dive 22)

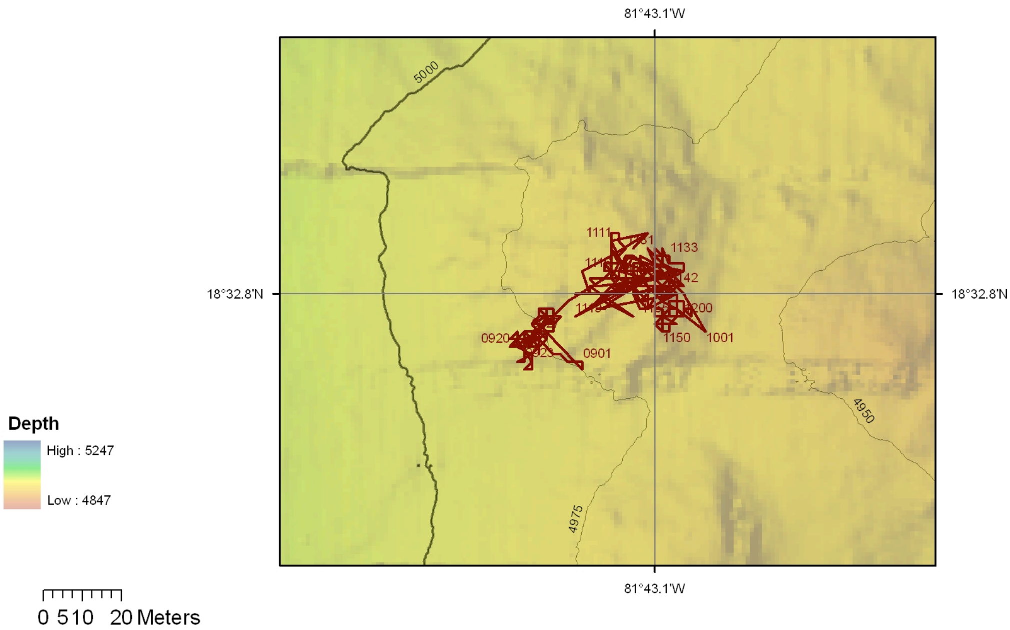


Figure 29. Location map showing HyBIS track (USBL navigation) with time annotation.

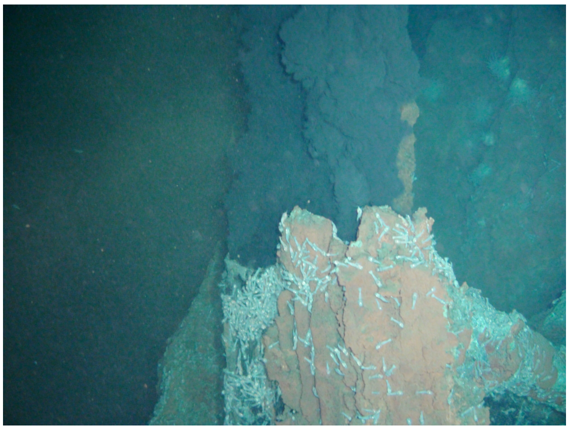


Figure 30. Digital still image from HyBIS showing black smoker emissions from vents.

6.4.4 JC044-HyBIS-4 (Dive 23)

Target: Southern flank of Mt Dent: Eh plume vent source search.

Start location	18°22.225 N, 81°48.701 W
Start depth	2263m
Start time	03:07MT, 12/4/2010
End location	18°21.092 N, 81° 48.828 W
End depth	2454m
End time	09:31 GMT, 12/4/2010

Table 12 Summary information JC044-HyBIS-4 (Dive 23)

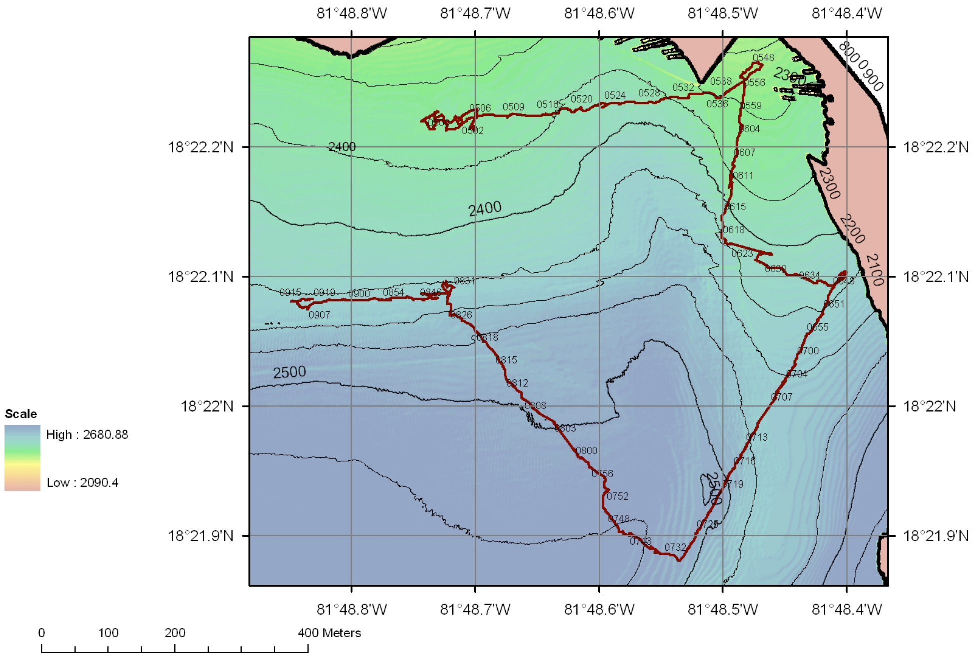


Figure 31. Location map showing HyBIS track (USBL navigation) with time annotation.

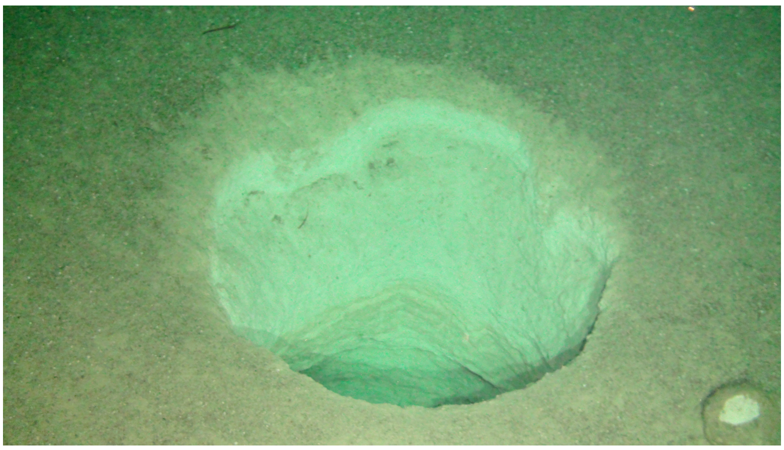


Figure 32. HD still image from HyBIS showing a 60cm diameter 'pock mark' on the southern upper flank of Mt Dent.

6.4.5 JC044-HyBIS-5 (Dive 24)

Target: Southern segment of Mid-Cayman Rise. Nephel plume vent source search.

Start location	17°55.8 N; 81'46.0 W
Start depth	4733m
Start time	12:25 GMT, 13/4/2010
End location	17°56.4 N, 81' 45.6 W
End depth	5131m
End time	19:35 GMT, 13/4/2010

Table 13 Summary information JC044-HyBIS-5 (Dive 24)

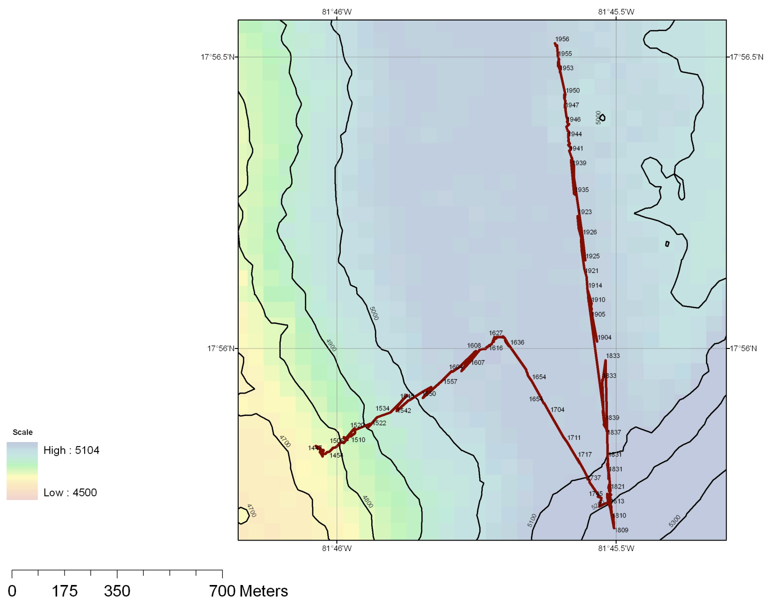


Figure 33. Location map showing HyBIS track (USBL navigation) with time annotation.

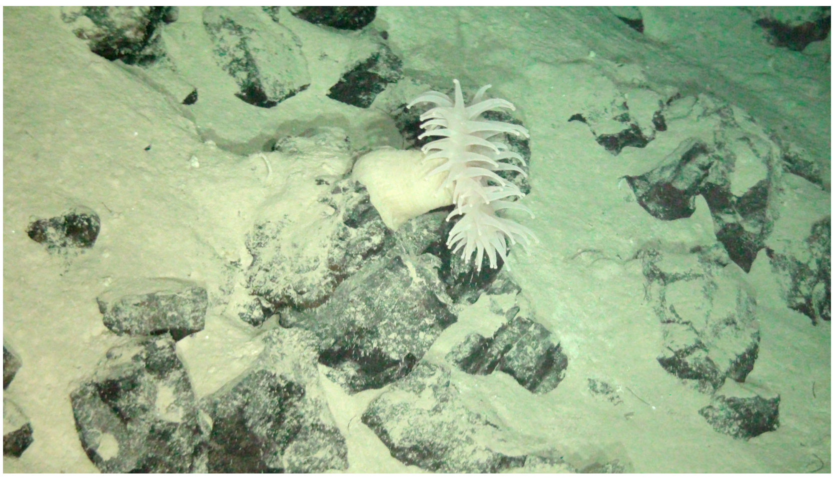


Figure 34. HD still image from HyBIS showing a 20cm diameter anemone.

6.4.6 JC044- HyBIS -6 (Dive 25)

Target: Northern MCR vent site: Slurp-gun and net deployment to collect fauna from active chimneys.

Start location	18°32.7 N, 81'43.0 W
Start depth	4955m
Start time	02:00 GMT, 14/4/2010
End location	18°32.8 N, 81'43.0 W
End depth	4925m
End time	07:04 GMT, 14/4/2010

Table 14 Summary information JC044-HyBIS-5 (Dive 25)

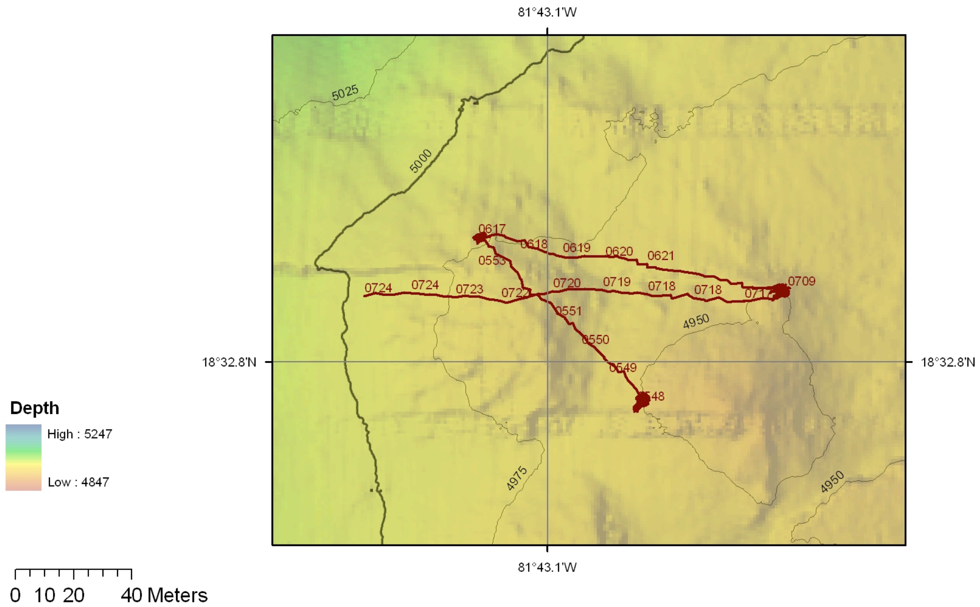


Figure 35. Location map showing HyBIS track (USBL navigation) with time annotation.

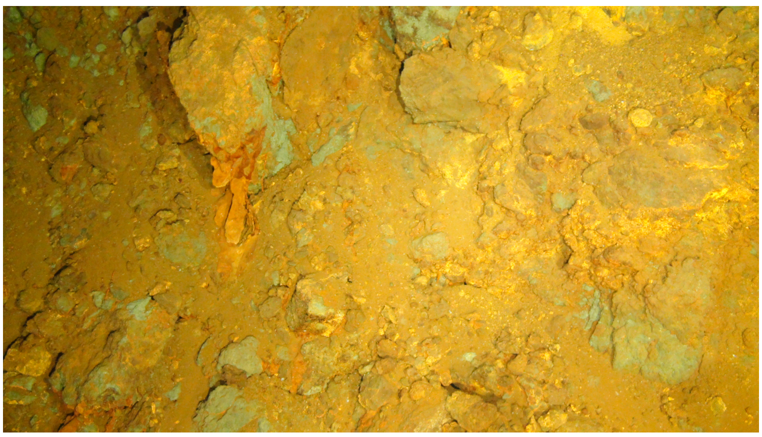


Figure 36. HD still image from HyBIS showing iron and copper mineralisation.

6.4.7 JC044- HyBIS -7 (Dive 26)

Target: Northern MCR vent site: SAPS plume filtration and niskin bottle for vent fluid collection.

Start location	18°32.810 N, 81°43.129 W
Start depth	4957m
Start time	01:27 GMT, 17/4/2010
End location	18°32.810 N, 81°43.108 W
End depth	4950m
End time	06:35 GMT, 17/4/2010

Table 15 Summary information JC044- HyBIS -7 (Dive 26)

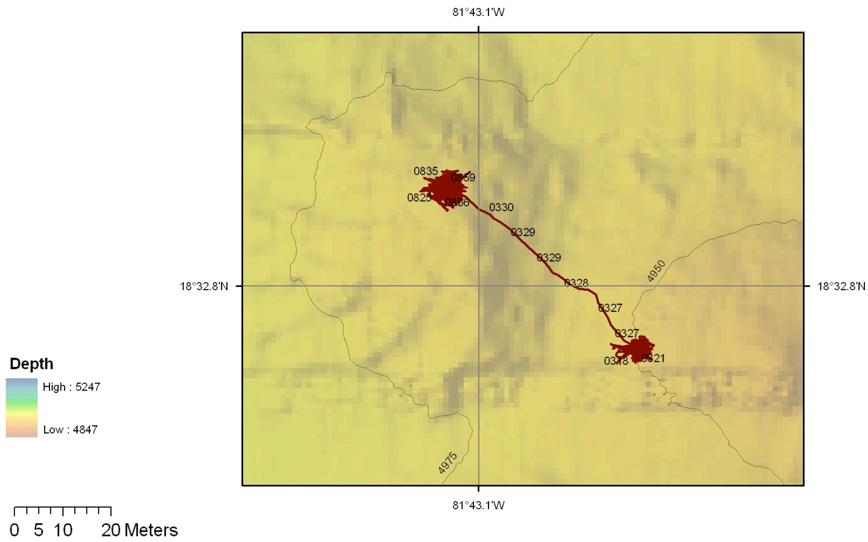


Figure 37. Location map showing HyBIS track (USBL navigation) with time annotation.

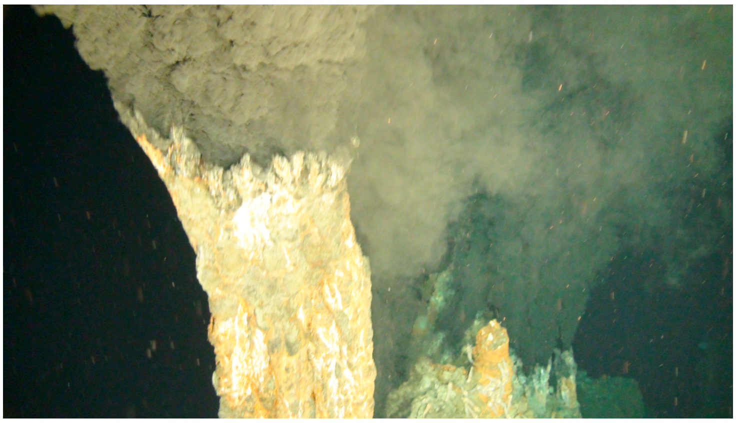


Figure 38. HD still image from HyBIS showing black smoker emissions.

6.4.8 JC044- HyBIS -8 (Dive 27)

Target: Southern flank of Mt Dent: vent site search.

Start location	18°22.616 N, 81°48.011 W
Start depth	2330m
Start time	23:11 GMT, 16/4/2010
End location	18°22.559 N, 81° 47.885 W
End depth	2336m
End time	04:31 GMT, 17/4/2010

Table 16 Summary information JC044- HyBIS -8 (Dive 27)

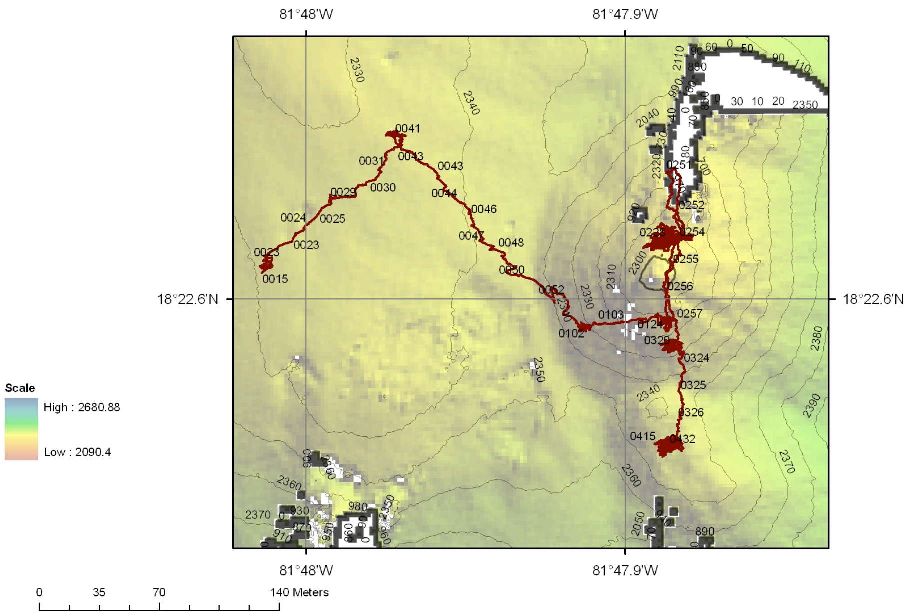


Figure 39. Location map showing HyBIS track (USBL navigation) with time annotation.

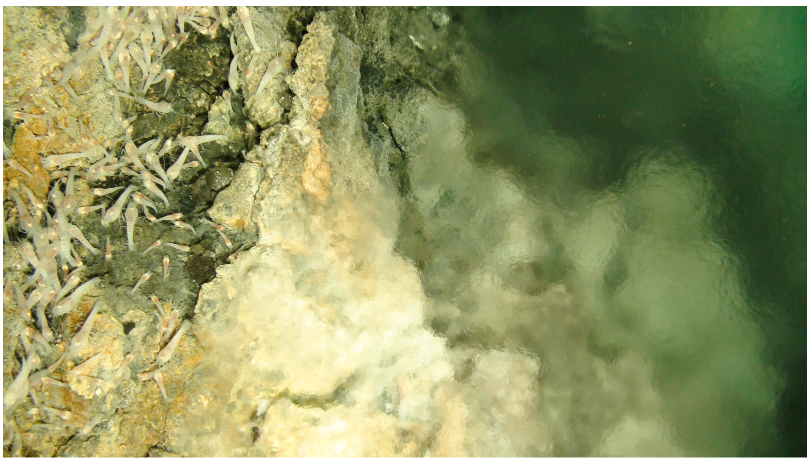


Figure 40. HD still image from HyBIS with shrimp and shimmering water.

6.4.9 JC044- HyBIS -9 (Dive 28)

Target: Southern flank of Mt Dent: vent sulphide sampling.

Start location	18°22.594 N, 81°47.981 W
Start depth	2329m
Start time	07:48 GMT, 18/4/2010
End location	18°22.605 N, 81° 47.850 W
End depth	2289m
End time	08:50 GMT

Table 17 Summary information JC044- HyBIS -9 (Dive 28)

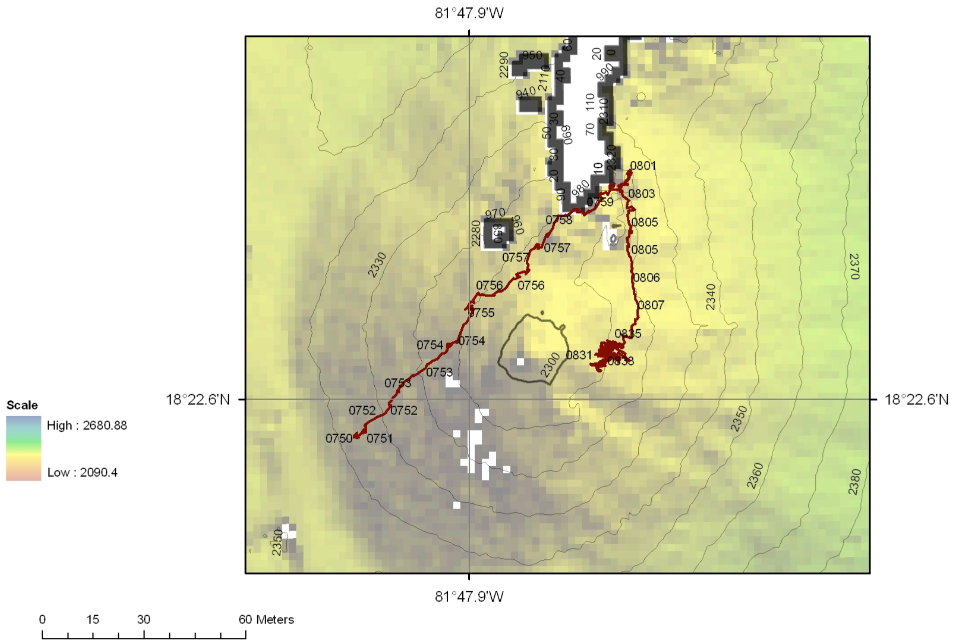


Figure 41. Location map showing HyBIS track (ship' navigation) with time annotation.

Figure 42. HD still image from HyBIS of shrimp and shimmering water.

6.4.10 JC044- HyBIS -10 (Dive 29)

Target: Southern flank of Mt Dent: vent fluid sampling.

Start location	18°22.615 N, 81°47.880 W
Start depth	2302m
Start time	09:35 GMT, 19/4/2010
End location	18°22.456 N, 81° 47.859 W
End depth	2283m
End time	12:00 GMT

Table 18 Summary information JC044- HyBIS -10 (Dive 29)

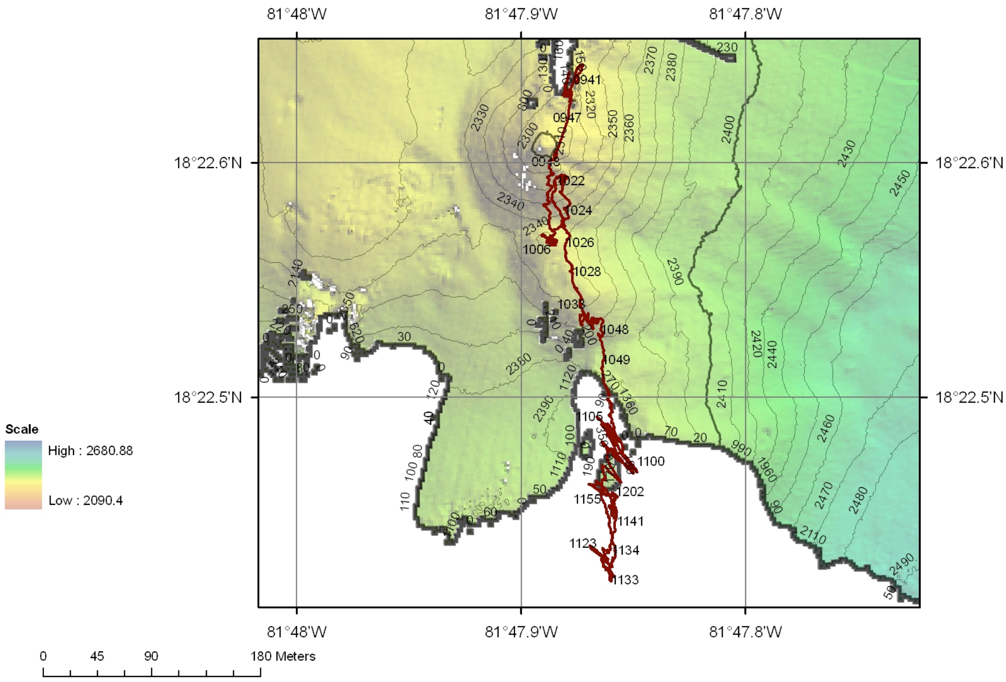


Figure 43. Location map showing HyBIS track (ship' navigation) with time annotation.

7. BIOLOGY

Jon Copley, Paul Tyler, Verity Nye and Diva Amon

7.1 Collection of faunal samples

7.1.2 Deep vent field

Vent shrimp were sampled from the deep vent field (18º 32.785' N 81º 43.080' W, depth 4950 m) during HyBIS dive #25 (JC44-33-HYB008) on 15/04/2010. Specimens were collected using a suction sampler constructed from a Stand-Alone Pump drawing water through a push-core barrel into two nested buckets adapted to form a sample chamber.

The suction sampler was used to collect shrimp from the sides of one of the chimneys encountered at the deep vent field. The baffle (vinyl disk weighted by a push-rivet) used to close the sampling tube after deactivation of the pump proved unsuccessful in preventing egress of shrimp; during the ascent of HyBIS from the dive, at least 40 shrimp were counted swimming out of the sample chamber. However, 43 shrimp remained in the chamber after HyBIS was recovered.

Carapace length and total lengths were recorded for ten specimens that were subsequently frozen at -80ºC for future molecular analyses (although one specimen was damaged and could not be measured). Fourteen specimens, including three juveniles, were preserved in molecular-grade ethanol for future molecular work. The remaining 19 specimens were preserved in 10% seawater-buffered formalin for morphological and taxonomic analyses.

Initial shipboard examination of specimens indicates that the shrimp resemble the genus *Rimicaris*, but exhibit some apparent morphological differences to the only known North Atlantic species, *Rimicaris exoculata*. In particular, there are some differences in the morphology of the dorsal photoreceptor organ, with the species here exhibiting twin "pores" on the posterior lobes of the organ in adult specimens.

Two shrimp traps, constructed from 5-litre white plastic buckets, were deployed on the upper NE slope of the mound, but could not be recovered by HyBIS during JC44. Recovery of these traps is planned for the second cruise of this research programme, using the Isis ROV.

7.1.2 Shallow vent field

Fauna were collected from the shallow vent field (18º 22.606' N 18º 47.877' W, depth 2287 m) in the grab sample taken by HyBIS during dive #28 (JC44-42-HYB010) on 18/04/2010. This faunal sample was comprised of 9 shrimp superficially resembling the species found at the deep vent field, 36 small coiled gastropods, and 82 amphipods, living on the sulphides collected in the grab.

Three shrimp were frozen at -80ºC, and three specimens preserved in molecular-grade absolute ethanol, for future molecular analyses. The remaining three shrimp were preserved in 10% seawater-buffered formalin for morphology and taxonomy. Ten gastropods were similarly frozen, and ten preserved in ethanol, while the remainder were preserved in formalin for taxonomy and reproductive biology. All gastropods had their shells gently cracked to enable penetration of fixative, apart from nine individuals that were preserved with shells intact for morphology. Thirty amphipods were frozen, and the remainder preserved in ethanol.

Specimen numbers	Taxon	Site	Preservation
JC44-BIO-1 to 10	Shrimp	Deep vent field	-80ºC
JC44-BIO-11 to 21	Shrimp	Deep vent field	Ethanol
JC44-BIO-22 to 40	Shrimp	Deep vent field	Formalin
JC44-BIO-41 to 43	Shrimp (juveniles)	Deep vent field	Ethanol
JC44-BIO-44 to 46	Shrimp	Shallow vent field	-80ºC
JC44-BIO-47 to 49	Shrimp	Shallow vent field	Ethanol
JC44-BIO-50 to 52	Shrimp	Shallow vent field	Formalin
JC44-BIO-53 to 62	Gastropods	Shallow vent field	-80ºC
JC44-BIO-63 to 72	Gastropods (shells cracked)	Shallow vent field	Ethanol
JC44-BIO-73 to 79	Gastropods (shells cracked)	Shallow vent field	Formalin
JC44-BIO-80 to 87	Gastropods (shells intact)	Shallow vent field	Formalin
JC44-BIO-88 to 107	Amphipods	Shallow vent field	-80ºC
JC44-BIO-108 to 159	Amphipods	Shallow vent field	Ethanol
JC44-BIO-160	Gastropod (shell intact)	Shallow vent field	Formalin
JC44-BIO-161 to 170	Amphipods	Shallow vent field	-80ºC

Table 19. Faunal sample collection summary

7.2 Videographic observations of vent biota

In addition to the species sampled, other fauna were observed at both vent fields, and their distributions noted as described below during HyBIS dives.

7.2.1 Deep vent field

Dense aggregations of shrimp were observed in patches on the vent chimneys, and around crevices in the mound issuing visible diffuse flow. A lower density of shrimp was also observed on sulphides surrounding such areas. High abundances of anemones, superficially resembling the genus *Maractis*, were observed elsewhere in the central region of the mound. Small gastropods appeared to be present in sediment pond areas. Macrourid fish were occasionally observed in the vent field. Solitary galatheids were present on the talus slope of the mound, and hydroids observed on sulphide rubble at its periphery, with sparse "non-vent" anemones where the sulphides grade into pillow basalts.

7.2.2 Shallow vent field

The fauna at the shallow vent field are visually dominated by aggregations of shrimp towards the tops of the vent edifices. The most abundant shrimp resemble the genus *Rimicaris*, but two other shrimp taxa were observed in lower numbers: one putatively resembling *Chorocaris* in crevices lower down on the vent edifice, and specimens of an as-yet unidentified shrimp with stalked orange eyes.

Numerous zoarcid fish resembling the genus *Pachycara* were observed among the shrimp aggregations. Small gastropods were seen on sulphide surfaces, along with amphipods, which were also found swimming above sources of diffuse flow. No anemones were observed in the vent field. Branching octocorals were present in the periphery at the base of the mound.

7.3 Deployment of whale bone and wood colonisation experiments

To investigate the colonisation of biological substrates at depths greater than 4000 m, whale bones and pine wood planks were attached to the bottom of the two moorings deployed during JC44. The whalebones were obtained by Dr Adrian Glover of the Natural History Museum from a putative fin whale carcass beached in Cardiff Bay in September 2009. Two vertebrae and wrist bones from one flipper were attached to the first mooring deployed during JC44. Two vertebrae were attached to the second mooring that was deployed during the cruise. Untreated pine wood planks were also attached to both moorings. All the colonisation substrates were attached to the lowermost section of each mooring, immediately above the acoustic release.

8. JC044 Outreach

Jon Copley and Sally Wilcox

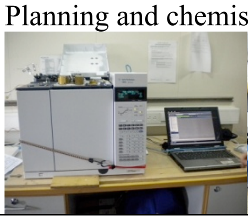
The outreach programme started as we joined the ship, with the website 'going live' and contact being made with a number of organisations. The NOCS communications team handled all the pre-cruise media contact and press release process.

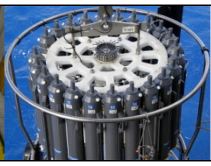
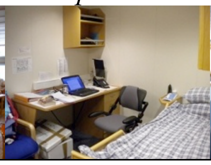
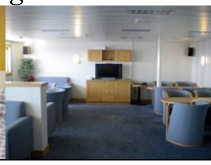
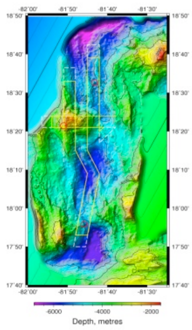
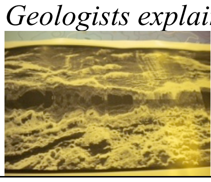
The website received positive feedback via the comments section on the dairy page and hearsay via the team on board. Using the visitor statistics to the site, we have been successful in extending the reach of science to a broader community. See section below : web activities.

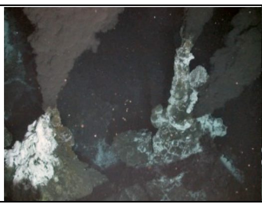
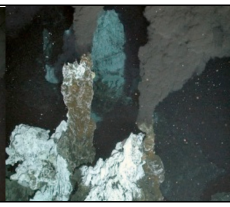
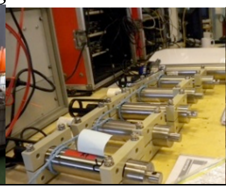
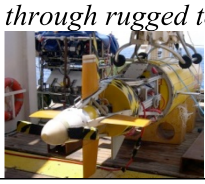
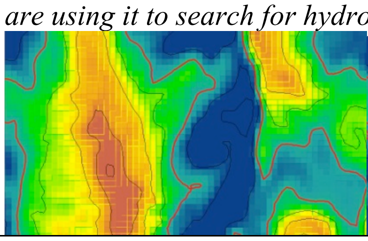
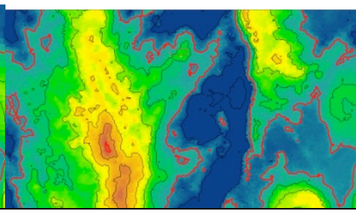
This is the first time that an outreach programme has been constructed in this way i.e. a dedicated person being responsible for developing a programme with the scientists. We know there are lessons to be learnt if a similar approach is to be taken in the future. Specifically, pre-cruise activities and a schools programme. Timing of this cruise was affected the interaction with schools, it being Easter.

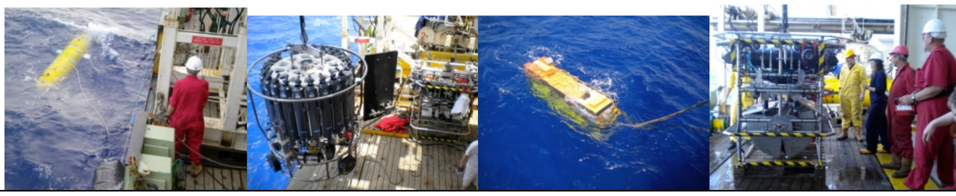
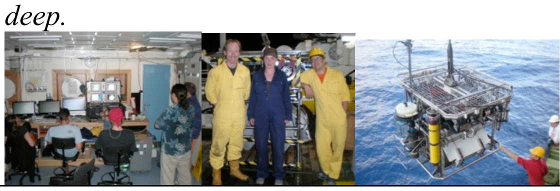
8.1 Summary of diary entries on www.thesearethevoyages.net

This section gives a summary of the diary page for each day, including a selection of the pictures used.

Date	**Summary of Content**
Mar 21 Sun	Arrival
Mar 22 Mon	Mobilisation
Mar 23 Tues	Pre-expedition checks
Mar 24 Wed	Leaving Port of Spain, emergency drill
Mar 25 Thur	Planning and chemistry lab    
Mar 26 Fri	Bunkering, bridge, navigation, checking all the instruments for logging 
Mar 27 Sat	Starting the science! First CTD, HyBIS checks, magnetometer

	 
Mar 28 Sun	Life on board *RSS: In today's diary: a tour of our vessel, and Sunday inspection, as we continue heading towards our expedition target area in the Cayman Trough.*   
Mar 29 Mon	Galley *RSS: Take a trip around the galley with Head Chef John to see how he and his team feed the forty-nine people aboard the RRS James Cook.* 
Mar 30 Tues	Arrival at target area, CTD, TOBI *RSS: TOBI - Towed Ocean Bottom Instrument, was launched today on a four-day mission to map the Cayman Trough and help our hunt for deep-sea vents.*  
Mar 31 Wed	TOBI, logging *RSS: TOBI - Towed Ocean Bottom Instrument - maps new terrain and has a near-miss when flying over uncharted young volcanoes.*   
Apr 1 Thur	Geology, TOBI *RSS: First TOBI images show young volcanoes in this previously unmapped area. Geologists explain why.* 
Apr 2 Fri	Chemistry, TOBI *RSS: The TOBI survey continues and we get an insight into the chemistry of hydrothermal vents.*

	 
Apr 3 Sat	TOBI finished, sea systems, planning *RSS: TOBI completes its mission, bringing images for planning our next stage. But who brings the technology together on our expedition?*   
Apr 4 Sun	Captain, purser, mooring, CTD, HyBIS test dive *RSS: The missions are drawing us closer to vent sites in the hidden depths of the Cayman Trough. Autosub6000 is soon to be sent out.*    
Apr 5 Mon	Autosub6000 *RSS: Autosub6000 is launched on its first mission laden with sensors and a camera; gliding along the rugged terrain at depths never seen before.* 
Apr 6 Tue	Autosub6000 *RSS: Watch Autosub6000 return from its deepest and most daring mission yet, through rugged terrain, it travels collecting valuable information.* 
Apr 7 Wed	Bathymetry – Tim Le Bas *RSS: An interview with Tim Lebas, the mystery of bathymetry explained; and how we are using it to search for hydrothermal vents.*  
Apr 8 Thur	2 x CTD's, safety – Diva *RSS: Autosub6000 heads off on a second mission for a detailed survey of Mount Dent. Back on the ship, we discuss safety with Diva Amon, marine biologist and resident of Trinidad.*

	
Apr 9 Fri	Engine room and engineer, Captain *RSS: Low-tech solution used for sampling the seafloor; and a tour, with the chief engineer, of previously unseen parts of the ship.* 
Apr 10 Sat	CTD, Dredge, Bucket *RSS: Confirmed peridotite on seafloor, Autosub6000 sent on third mission and eleven hours of CTD probing for active hydrothermal vent minerals.* 
Apr 11 Sun	Press announcement
Apr 12 Mon	How we did it.... *RSS: Its official we have discovered the deepest hydrothermal vent, finds out how we did it.* 
Apr 13 Tues	Autosub6000 & Hybis missions *RSS: Autosub6000 on its most dangerous mission yet and HyBIS heads to into the deep.* 
Apr 14 Wed	Moorings, maintenance, CTD *RSS: Mooring recovered and off for analysis; why is physical oceanography so important and climbing to the top of the mast.* 
Apr 15 Thur	HyBIS, Autosub6000 technology, Bramley, whale bones *RSS: Autosub6000 brings back vital information, a mooring is deployed with whale bones and HyBIS is sent on another mission.* 

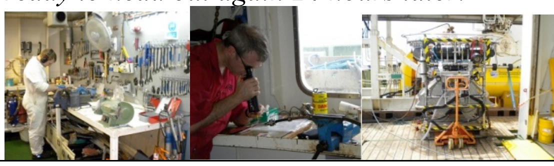
Apr 16 Fri	Mending, fixing and Paul *RSS: Cable snaps and HyBIS mission aborted, no damage to people or machine; and ready to head out again 24 hours later.* 
Apr 17 Sat	Night shift diary *RSS: A night with the HyBIS team as they dive into the deep....* 
Apr 18 Sun	Mechanical engineering, electrical engineering, mooring, Kate *RSS: Untwisting 6 miles of cable. A chat with mechanical engineer, Pete; and electrical engineer, Steve.* 
Apr 19 Mon	New vents *RSS: Scientists found 'diffuse' hydrothermal vents in a chaotic setting, 2300 metres deep at the base of Mount Dent.* 
Apr 20 Tues	Packing and final science *RSS: Science coming to an end, collecting magnetic information and Sarah analyses her samples.* 
Apr 21 Wed	Final thoughts *RSS: Our last day on board RRS James Cook and a summary of the journey.* 

Table 20 Summary of Web pages displayed on www.thesearethevoyages.net

8.2 Web activity

As part of our project studying deep-sea vents in the Cayman Trough, we delivered a successful programme of public engagement and media outreach from the research ship *James Cook*. Our expedition website received more than 50 000 unique visits from people in at least 89 countries, while our YouTube channel carrying video from the ship received more than 100 000 views and was the 38th most-viewed YouTube channel during the week of April 12th. Our discovery of the world's deepest known hydrothermal vents was covered by more than 520 print, broadcast and online media outlets worldwide, and is currently mentioned on more than 10 000 webpages.

This report presents a summary of our engagement and outreach activites and their impact, including details of visitor traffic to our project website. The following conclusions may be informative for future outreach efforts:

· An integrated strategy, using media coverage to publicise the project website, was highly successful in generating visitor traffic to our online engagement resources;

· Only three print and online media outlets included independent comment in their coverage, and fewer than a dozen sought original quotes through interviews; the vast majority of outlets simply adapted press release material;

· Newswire services were key to achieving widespread online media coverage and publicising the project website; in particular an article by Associated Press was carried by Yahoo.com, which generated 40% of visitor traffic to the project website;

· Use of interactive "Web 2.0" resources, rather than traditional static webpages, enabled dialogue and engagement with the public about our research, rather than one-way communication;

· Our network of "Web 2.0" resources (Twitter, Facebook and YouTube) drew more visitors to the website than links in coverage by National Geographic or Discovery;

· Social bookmarking by website visitors (using linkshare websites such as digg.com and stumbleupon.com) generated more additional traffic to our webpages than links in online coverage by the *Daily Mail* and Nature.com

· The link from the University of Southampton webpages generated 4% of traffic to the website, more than any other non-media outlet and surpassed only by the BBC, CNN and Yahoo.

8.3 Summary of the media activity

We appeared in over 370 media outlets in 69 countries and had 21,000 unique visitors to the web site. The video clip posted on YouTube received over 47,000 registered visits.

Date	Media	Time spent
26/3/10	Various Trinidad newspapers	From press release, sent by Sally
23/3/10	Trinidad CNC3 TV	Live interview with Doug, Jon & Diva
12/4/10	BBC radio 4 Today programme	Live interview with Doug
12/4/10	BBC world service	Live interview with Doug
12/4/10	Radio Toronto, pre-record for show	Interview with Doug
12/4/10	CNN.com	Interview with Doug
12/4/10	SUT	Sally sent photos and press release via email to John Howard (editor)
12/4/10	Times Online	Press release coverage
12/4/10	BBC radio 2 – hourly news bulletin, covered clip from R4 interview	
12/4/10	Daily Mail online	Press release coverage
12/4/10	BBC website – Home page (science)	Press release coverage
12/4/10	Daily Telegraph – online	Press release coverage
12/4/10	Daily Telegraph – hard copy	Press release coverage
12/04/10	Dutch daily NRC Handelsblad	Interview with Doug
12/4/10	Nautilus International – Andrew Linington (editor)	Sally sent press release and photos
12/4/10	Wolverhampton – Peter Rhodes http://www.expressandstar.com/news/2010/04/14/roger-has-hot-seat-for-volcano-mission/	Sally sent press release and photos
12/4/10	Radio Solent -drivetime	Interview with Doug
12/4/10	BBC World Service different channel to earlier -	Interview with Doug
12/4/10	BBC Scotland interview	Rachel James Live interview
12/4/10	New Round	Press release coverage
12/4/10	Christian Science Monitor at MIT http://www.csmonitor.com/Science/2010/0413/At-deepest-hydrothermal-vent-yet-found-an-awe-inspiring-view	Paul Tyler interview
12/4/10	Trojan channel CBBC	Press release coverage
12/4/10	National Geographic – online	Press release coverage
12/4/10	Cayman Free Press – front page	Sally sent to press release to journalist
12/4/10	German online Spiegil magazine	Press release coverage
12/4/10	Nature	Doug comments via email
14/4/10	Physics Today May issue	Doug comments via email
14/4/10	Ireland...	Maria interview
14/4/10	The World Today -radio CKNW Vancouver	Doug gave an interview
14/4/10	Discovery channel TV -Canada	Pre-interview with Jon and Doug
16/4/10	HyBIS manufacturers issuing press release	Hydro-lek with Bramley
16/4/10	Trinidad Express http://www.trinidadexpress.com/index.pl/nart?id=161633747	Questions for Diva as part of article on Sunday
22/4/10	Discovery channel TV – Canada – extended programme	On board video and interviews

Table 21 Summary of direct media outreach

8.4 Impact

8.4.1 Visitor traffic to the cruise website and other online resources

Between March 25th and April 25th, the cruise website received **56 641 unique visits**, and a total of **139 319 page views**.

Our YouTube channel carrying video from the cruise received **104 278 views**, and was the **38th most viewed channel on YouTube** during the week of April 12th (incidentally surpassing the Conservative Party's WebCameronUK channel during the first full week of the UK election campaign).

8.4.2 Media coverage

Our first press release, announcing the start of the cruise and the launch of the website, drew coverage in IT outlets *The Register* and *Gizmodo*, tech website *Nouvo* in Switzerland, the *Caymanian Compass*, and *CNC3* television in Trinidad.

The second press release, reporting our discovery of the world's deepest known hydrothermal vents, resulted in coverage by **at least 520 media outlets** (tracked via Google News), including *The Times*, *Metro*, *BBC News Online*, *ITN*, *The Daily Mail*online, *New Scientist*, *Nature*, NationalGeographic.com, CNN.com and Time.com. Broadcast interviews by PSO Connelly included BBC World Service, BBC Radio 4 *Today* programme and Discovery Channel Canada's *Daily Planet*.

The video that we released to *BBC News Online* was the **most viewed video on *BBC News Online*** on April 12th, and the accompanying news story was the most read Science/Nature story of that day, receiving **more than 400 000 hits** according to an email from its author, Alasdair Cross.

Associated Press produced a newswire story that was also carried by many outlets around the world. International coverage included the *New York Times*, *Washington Post*, *Seattle Post Intelligencer*, and *Boston Globe* in the US, *Stern* in Germany, and *La Stampa* in Italy. Follow-up media contact targeting publications local to cruise participants resulted in additional coverage in the *Trinidad Express* (featuring cruise participant Diva Amon) and *Irish Times* (featuring cruise participant Maria Judge).

Coverage spread rapidly across the internet via the blogosphere, and a Google search of "world's deepest vents Cayman Southampton" on 29th April returned **more than 10 000 webpages**. We have also since been contacted by Sylvia Earle's office to create georeferenced links to our outreach materials from Google Oceans.

9. RTVS Ship Systems

Mike Myers

9.1 RVS LEVEL C System

9.1.1 Ifremer TECHSAS System

The Ifremer TECHSAS system is the primary data logger for all navigation, surfmet and winch data. The TECHSAS software is installed on an industrial based system with a high level of redundancy. The operating system is Centos Linux 5.2. The system itself logs data on to a RAID 0 disk mirror and also logs to the backup logger. The TECHSAS interface displays the status of all incoming data streams and provides alerts if the incoming data is lost. The ability exists to broadcast live data across the network via NMEA.

The storage method used for data storage is NetCDF (binary which is a self describing file and is OS independent) and also pseudo-NMEA (ASCII). The NetCDF data files are currently manually parsed through an application in order to convert them to RVS Format for data processing.

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

1) Applanix POSMV System
2) Applanix POSMV System Heading
3) Chernikeef EM speed log (converted to RVS format as log_chf)
4) Ships Gyrocompass (converted to RVS format as gyronmea)
5) Simrad EA600 Precision Echo Sounder (Converted to RVS Format as ea600)
6) NMFD Surface-water and Meteorology instrument suite (Converted to RVS as sm_surf, sm_met and sm_light)
7) ASHTECH ADU-5 Altitude Detection Unit Converted to RVS Format as adu5pat and adu5pos)
7) NMFSS Cable Logging and Monitoring (Converted to RVS as winch)
8) MircroTsg SBE45

9.2 Data Processing

9.2.1 Applanix POSMV System

The Ships primary GPS System for scientific data and also part of the Dynamic Positioning system is the Applanix POSMV. The POSMV includes a intertial measurement unit capable of providing heading pitch and roll data to the bridge, logged by the techsas system and displayed in the main lab. The POSMV data is also used by the ADCP systems in order to account for ships motion.

The Applanix IMU is located at the ships centre point and is used as reference for all offsets for instruments on board the RRS *James Cook* The GPS antenna positions are held within the POSMV and the GPS position is corrected for the position of the MRU and so the GPS position that is recorded is the position of the MRU itself.

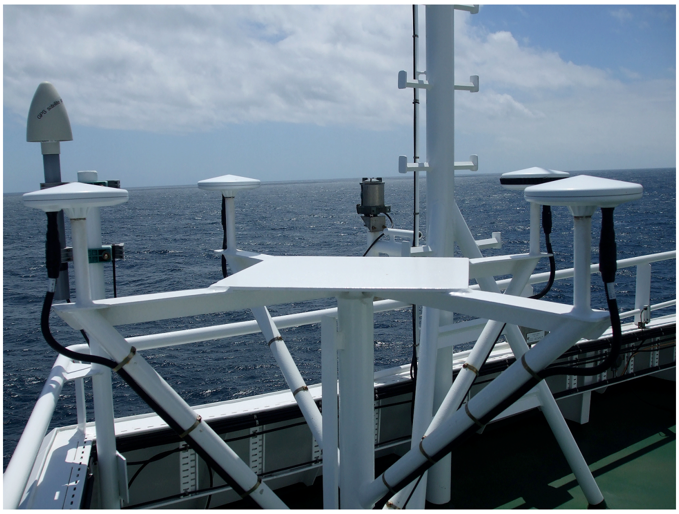
System Specifications

	Specification (With Differential Correction	During GPS Outages
Roll, Pitch Accuracy	0.02 º (1 sigma with GPS or DGPS	0.02 º
Heave Accuracy	5cm or 5% whichever is greater for periods of 20 seconds or less	5cm or 5% whichever is greater for wave periods of 20 seconds or less
Heading Accuracy	0.02 º with 2m antenna baseline	Drift less than 1 º per hour (negligible for outages < 60 seconds)
Position Accuracy	0.5 – 2m (1 sigma) dependant on differential correction quality	Ddegredation 2.5m (1 sigma for outages < 30s) <6m (1 sigma for outages < 60s)
Velocity Accuracy	0.03 m/s horzontal	

Table 22 System specifications for the Applanix POSMV system

9.2.2 Magellan Ashtech ADU-5

This is a four antenna GPS system that can produce attitude data from the relative positions of each antenna and is used to correct the VMADCP for ship motion. The antenna array is located on the port side of the ships monkey island. The ADU-5 system worked reliably throughout the cruise with some gaps that are quite usual with this system due to the amount of calculations necessary and the roll of the ship causing bad satellite communication. No Large data gaps are present. The ADU-5 forms part of the bestnav system which is an assembly of multiple GPS signals including the gyronmea and emlog stream in order to calculate the best possible position, speed heading pitch and roll of the ship.



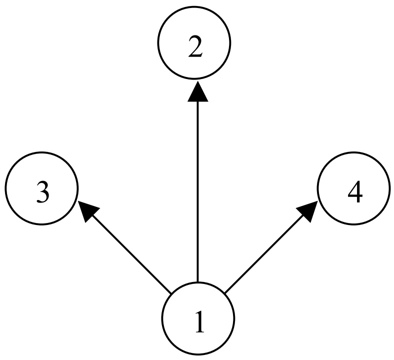


Figure 44 The ADU5 Platform on the Starboard Side. Black surrounded Antenna indicates AFT. This is the primary antenna which sits behind all 3 other antennas.

ADU5 Offsets with reference to Antenna 1 (used internally by ADU5 for HPR Calculations

Vector	X(Right Positive)	Y(Forward Positive)	Z(Up Positive)
1-2	0.000	1.203	0.010
1-3	-0.599	0.600	0.010
1-4	0.597	0.598	0.012

Antenna Position on *James Cook* From MRU (0,0,0)

Antenna	X (Positive Starboard)	Y (Positive Forward)	Z (Positive Up)
1	9.265	1.541	19.416
2	10.463	1.537	19.419
3	9.863	0.932	19.426
4	9.870	2.138	19.419

Table 23 System information for the Magellan Ashtech ADU-5

9.2.3 Ships Gyrocompass

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

9.2.4 Chernikeef EM log

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

The EM log system was not showing the correct data following the last calibration attempt. The system has been highly unreliable since its installation within the ship and continues to be an ongoing issue that we are attempting to get support from the manufacturer for, however they are not so forth coming.

9.2.5 Simrad EA600 Precision Echo Sounder (PES)

The EA600 Precision Echo Sounder is the ships primary depth readout. The EA600 output is passed to TECHSAS and also to the green display screens in the main lab. The EA600 is mounted on the port drop keel. The keel was kept flush throughout the cruise and the system produced reasonably useable data in all but the worst sea conditions.

9.2.6 Kongsberg EM120 Multibeam Echo Sounder

Operating frequency and coverage sector.
The nominal sonar frequency is 12 kHz with an angular coverage sector of 150 degrees and 191 beams per ping as narrow as 1 degree.

Achievable swath width on a flat bottom will normally be approximately six times the water depth. The angular coverage sector and beam pointing angles may be set to vary automatically with depth according to achievable coverage. This maximizes the number of usable beams. The beam spacing is normally equidistant with equiangle available.

Transmission

The transmit fan is split in several individual sectors with independent active steering according to vessel roll, pitch and yaw. This place all soundings on a "best fit" to a line perpendicular to the survey line, thus ensuring a uniform sampling of the bottom and 100% coverage.

The sectors are frequency coded (11.25 to 12.60 kHz), and they are all transmitted sequentially at each ping. The sector steering is fully taken into account when the position and depth of each sounding is calculated, as is the refraction due to the sound speed profile, vessel attitude and installation angles. Pulse length and range sampling rate are variable with depth for best resolution, and in shallow waters due care is taken to the near field effects. The ping rate is mainly limited by the round trip travel time in the water up to a ping rate of 5 Hz.

Transducer arrays
The EM 120 transducers are linear arrays in a Mills cross configuration with separate units for transmit and receive.

The Multibeam was used extensively throughout the cruise with Replay/Neptune being employed to produce ascii xyz files for further processing. The system performed as expected with the data becoming virtually useless when heading into the sea due to the well known aeration problems, but improving markedly when the sea was from astern.

9.2.7 Surfmet System

This is the NMFD surface water and meteorology instrument suite. The surface water component consists of a flow through system with a pumped pickup at 5.5m depth. TSG flow is approx 18 litres per minute whilst fluoriometer and transmissometer flow is approx 1.5 l/min. Flow to instruments is degassed using a debubbler with 24 l/min inflow and 10/l min waste flow.

The meteorology component consists of a suite of sensors mounted on the foremast at a height of approx 16.4m above the waterline. Parameters measured are wind speed and direction, air temperature, humidity and atmospheric pressure. There is also a pair of optical sensors mounted on gimbals on each side of the ship. These measure total irradiance (TIR) and photo-synthetically active radiation (PAR). The gimbals were cleaned at the beginning of the cruise.

9.2.8 ADCP's

The 75Khz and 150Khz ship mounted ADCPs were used for the majority of the cruise with the data being collected for post-cruise processing and analysis. Both appeared to perform satisfactorily throughout.

9.2.9 Network Services

The network worked well without any issues, the wireless system also performed well throughout the cruise

9.2.10 Data Storage

Throughout the cruise data was stored in Data32. A Raided data store attached to Cook3. This performed well throughout. The Level C data was backed up to LTO daily.

9.2.11 VSAT

The VSAT functioned well throughout the cruise.

9.2.12 Gravity

Recorded throughout the cruise on Micro & Lacoste AirSeaII at 1hz worked well throughout. Base station tie-ins conducted at Trinidad and Jamaica.

9.2.13 Magnetics

SeaSpy magnetometer used whenever opportunity allowed, recorded on manufacturer supplied sealink software again at 1Hz

10. Technical C.T.D. report

Dave Teare

The trace metal free titanium CTD system comprised of the following equipment:
Seabird 911+ CTD with dual pumped temperature and conductivity sensor pairs; a Seabird SBE43 dissolved oxygen sensor; Seabird SBE32 carousel with twenty-three OTE, externally sprung, ten litre water bottles; a downward looking TRDI 300 KHz workhorse ADCP; Chelsea Instruments Alphatracka (transmissometer) and Aquatracka (fluorometer); a Benthos 916T altimeter; an IOS 10 KHz pinger Sonardyne location beacon; Seatech LSS back-scatter sensor; Wet-Labs BBRTD back-scatter sensor and a user supplied eH chemical sensor.

One pair of temperature\conductivity sensors (secondary pair) were mounted on the stabilisation vane, the other pair, with the oxygen sensor, were mounted conventionally onto the CTD body (primary pair).

Overall the system worked well, problems worthy of note are; throughout the cruise the altimeters gave very poor bottom returns this problem was overcome by fitting the IOS 10Khz pinger to the stabilisation vane; water bottle 22 was not used as the latching mechanism had failed. The second sea cable, CTD1 was used after water was found to have penetrated up the centre core of the CTD2.

The CTD operations fell into three main categories.

1) Conventional physics deployment, of a down cast followed by an up cast.
2) Tow-Yo casts. Initially a down cast was performed. An area of interest was then identified and multiple up casts and down casts performed through the area, whilst towing the CTD slowly through the water.
3) Pumping stations. For these stations, three of the water bottles were removed and a Challenger Oceanics Stand Alone Pump (S.A.P.) was fitted. A downcast was performed to identify an area of interest and the pump was left in position for one to two hours whilst filtering up to two hundred litres of water.

The ADCP was used on all casts, no problems were reported. The S.A.P. were used, occasionally, on the CTD and also on the remotely operated vehicle IBIS. No problems were reported on these two units.

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12. Acronyms

ADCP Acoustic Doppler Current Profiler
AUV Autonomous Underwater Vehicle
BBRTD Backscatter sensor
ChEsSO Chemosynthetically-driven Ecosystems South of the Polar Front: Biogeography and Ecology consortium programme
CTD Conductivity-Temperature-Depth
GPS Global Positioning System
HyBIS Hydraulic Benthic Interactive Sampler
LSS Light scatting sensor
MAR Mid-Atlantic Ridge
MCR Mid-Cayman Rise
NMF National Marine Facilities
NMFD National Marine Facilities Division
NOCS National Oceanography Centre, Southampton
OCC Ocean Core Complex
PES Precision echo sounder
SCS Shipboard Computing System
SSU Simrad Sequencing Unit
STCM Shipboard Three-Component Magnetometer
TOPAS TOpographic PArametric Sonar
TVG Time variable gain
SBE Seabird electronics corp
SVP Sound Velocity Probe/Profile
WHOI Woods Hole Oceanographic Institute

Appendix 1. TOBI log

JC044 TOBI Log

Julian	Time	Lat N		Water		Hdg depth	Total depth	Gyro	Alt	LSS	Cable	Cable	Veer	Layback	1 mm= Layback	Water depth		
day	GMT	deg	min	deg	min				field				out	rate	haul	m	nm	@tobi
89	20:43						2589						4381			3634	1.962	
89	21:30	18	12.990	81	51.000	4884	368	0.1	40092	7.5	0	0.0960	571	30.1	V	537	0.290	
89	22:00	18	13.960	81	51.000	4375	877	354	51197	3.3	0	0.0930	1432	30.2	V	1232	0.665	
89	22:30	18	14.990	81	51.000	4225	1464	354	40168	0.9	0	0.0910	2315	30.5	V	1893	1.022	
89	23:00	18	15.972	81	50.990	4074	1934	354	40278	0.6	0	0.0890	3199	30.0	V	2648	1.430	
90	23:30	18	16.998	81	51.000	3845	2435	354	40286	0.4	0	0.0880	4165	30.5	V	3479	1.879	
90	00:00	18	17.990	81	51.000	3689	2919	355	40270	2.2	0	0.0880	4999	0.0	V	4158	2.245	
90	00:04																0.054	
90	00:30	18	19.000	81	51.000	3386	2928	354	40445	0.4	0	0.0880	5224	15.2	V	4426	2.390	
90	01:00	18	19.980	81	51.000	3009	2972	354	40454	360.0	0	0.0860	5379	0.0		4583	2.475	
90	01:30	18	20.990	81	51.000	2678	2796	355	40501	1.6	0	0.0870	5137	0.0		4409	2.381	
90	02:00	18	22.030	81	51.000	2319	2553	355	40217	2.0	0	0.0590	4664	30.0	H	4003	2.162	
90	02:30	18	22.980	81	51.000	2369	2118	354	40382	0.6	0	0.0600	3845	20.0	H	3309	1.787	
90	02:43	18		81		2334	1910				0		3441	0.0		2962	1.599	
90	03:00	18	24.022	81	51.000	2411	1832	357	40345	4.2	0	0.0610	3275	0.0		2815	1.520	
90	03:30	18	25.063	81	51.000	2583	1851	355	40181	2.3	0	0.0600	3222	20.2	H	2737	1.478	
90	04:00	18	26.005	81	51.000	3202	1823	354	40325	1.0	0	0.0600	3227	0.0		2763	1.492	
90	04:30	18	26.973	81	51.000	3386	1922	354	40552	0.6	0	0.0596	3394	0.0		2897	1.564	

90	05:00	18	28.004	81	51.000	3560	2125	354	40440	0.8	0	0.0601	3785	20.3	V	3232	1.745
90	05:30	18	28.904	81	51.000	3655	2589	355	40476	1.7	0	0.0593	4381	20.4	V	3634	1.962
90	06:00	18	29.846	81	51.000	3657	2814	355	40442	1.3	0	0.0588	4693	0.0		3856	2.082
90	06:30	18	30.769	81	51.003	3931	2750	354	40733	0.6	0	0.0592	4708	15.0	V	3921	2.117
90	07:00	18	31.760	81	51.001	4214	3029	354	40981	1.0	0	0.0592	5268	20.4	V	4410	2.381
90	07:30	18	32.776	81	51.001	4309	3008	349	41336	0.6	0	0.0593	5361	0.0		4538	2.450
90	08:00	18	33.781	81	51.004	4298	3279	350	41145	1.6	0	0.0588	5883	20.5	V	4984	2.691
90	08:30	18	34.784	81	51.001	4331	3475	350	41037	0.3	0	0.0582	6271	10.1	V	5320	2.873
90	09:00	18	35.785	81	51.002	4338	3614	351	40979	1.0	0	0.0585	6566	0.0		5582	3.014
90	09:30	18	35.828	81	51.001	4422	3567	352.2	40367	0.5	649	0.0566	6566	0.0		5613	3.031
90	10:00	18	37.814	81	51.001	4540	3583	353.2	40433	1.2	645	0.0583	6566	0.0		5602	3.025
90	10:30	18	38.799	81	51.001	4762	3406	352	40551	0.7	862	0.0587	6275	15.4	H	5370	2.900
90	11:00	18	39.847	81	51.001	4969	3370	352.7	40704	0.8	960	0.0592	6184	0.0		5285	2.854
90	11:30	18	40.648	81	50.529	5247	3448	353.6	40622	1.9	975	0.0576	6184	0.0		5234	2.826
90	12:00	18	40.799	81	49.644	5832	3731	358	40311	8.4	896	0.0576	6184	0.0		5032	2.717
90	12:30	18	40.613	81	48.413	6131	3937	16.7	39480	33.0	953	0.0576	6184	0.0	-	4869	2.629
90	13:00	18	39.730	81	48.000	6096	4213	35	38940	60.1	753	0.5760	6184	0.0	-	4627	2.498
90	13:30	18	38.703	81	48.000	5939	4653	57.7	38250	87.9	730	0.0579	6184	0.0		4173	2.253
90	13:32	-	-	-	-	-	-	-	-	-	-	-	6184	15.0	v	#VALUE!	#VALUE!
90	14:00	18	37.690	81	48.000	5714	4848	86.7	37870	129.0	8.81	0.0576	6639	20.0	v	4636	2.503
90	14:30	18	36.773	81	48.001	5643	4992	109.1	37910	180.9	785	0.0565	7300	20.3	v	5426	2.930

90	15:00	18	35.769	81	48.001	5500	5121	127.7	37924	161.6	695	0.0563	7856	20.1	v	6058	3.271	
90	15:30	18	34.722	81	48.000	5324	5186	157.7	37764	168.4	554	0.0568	8287	15.1	h	6564	3.544	
90	15:52												8300	0.0				
90	16:00	18	33.700	81	48.000	5343	4948	158.8	38318	172.9	689	0.0563	8300	0.0		6764	3.652	
90	16:32	18	32.500	81	48.000	5314	4757	165	38008	176.0	892	0.0556	8300	0.0		6902	3.727	5649
90	17:00	18	31.520	81	48.001	5194	4418	166.1	37785	176.9	840	0.0557	8300	0.0		7126	3.848	5258
90	17:30	18	30.358	81	48.001	5107	4251	169.2	37957	179.1	877	0.5550	8300	0.0		7229	3.903	5128
90	18:00	18	29.180	81	48.000	5063	4170	170	38070	180.0	962	0.0560	8301	0.0		7278	3.930	5132
90	18:30	18	28.073	81	48.000	4786	4185	170.5	38225	179.8	984	0.0555	8300	0.0		7268	3.924	5169
90	19:00	18	26.933	81	47.998	4365	4193	170.3	38614	179.4	944	0.0553	8300	0.0		7263	3.922	5137
90	19:30	18	25.847	81	48.001	3861	4105	173.2	38575	181.1	889	0.0556	8100	10.1	h	7083	3.824	4994
90	20:00	18	24.813	81	48.001	3218	3929	172.3	38312	180.1		0.0560	7735	15.1	h	6763	3.652	3929
90	20:30	18	23.604	81	48.000	2442	3594	174.1	38366	181.1	769	0.0550	7227	25.1	h	6370	3.440	4363
90	21:00	18	22.360	81	48.000	2402	3118	175	38330	181.2	455	0.0550	6420	30.2	haul	5712	3.084	3573
90	21:30	18	20.946	81	48.000	2896	2252	176	38310	181.3	15	0.0550	5212	90.0	h	4800	2.592	2267
90	22:00	18	19.310	81	48.000	3937	1854	173.2	38005	180.6	613	0.0560	4628	0.0	-	4340	2.344	2467
90	22:30	18	18.029	81	48.000	4370	2060	173.8	38092	180.4	794	0.0550	5110	20.0	V	4776	2.579	2854
90	23:00	18	16.850	81	48.000	4350	2669	173.5	38047	181.5	832	0.0550	5756	20.8	veer	5200	2.808	3501
90	23:30	18	15.864	81	48.000	4760	3239	160.1	37858	179.1	917	0.0550	6433	15.2	veer	5658	3.055	4156
	23:50																	
90	00:00	18	14.935	81	47.956	4888	3640	166.1	37659	180.6	708	0.0550	6865	15.0	V	5921	3.197	4348

91	00:30	18	14.060	81	47.528	5240	3768	167.9	38055	177.0	535	0.0550	6824		30.1	H	5789	3.126	4303
91	01:00	18	13.104	81	47.052	5482	3817	144.9	38042	171.9	903	0.0550	6931		20.2	veer	5885	3.178	4720
91	01:30	18	12.228	81	46.613	5558	4082	142.5	37891	164.7	802	0.0550	7312	-		-	6167	3.330	4884
91	02:00	18	11.347	81	46.176	5667	4308	127.2	37913	159.9	712	0.0550	7724		10.1	V	6511	3.516	5020
91	02:30	18	10.474	81	45.735	5772	4586	124.3	37802	158.3	736	0.0550	8168		10.2	V	6859	3.704	5322
91	03:00	18	9.636	81	45.320	5806	4765	122.8	37947	156.6	677	0.0550	8464		10.1	v	7095	3.831	5442
91	03:12	18	9.230	81	45.115												100	0.054	0
91	03:30	18	8.714	81	45.052	5817	4867	123.3	38282	155.7	635	0.0550	8633		0.0		7230	3.904	5502
91	04:00	18	7.850	81	45.212	5733	4943	125.5	38163	155.2	600	0.0544	8633		0.0		7178	3.876	5543
91	04:30	18	6.697	81	45.424	5753	4880	140.5	37901	162.1	840	0.0545	8633		0.0		7221	3.899	5720
91	05:00	18	5.709	81	45.610	5585	4757	156.2	37724	171.3	974	0.0544	8633		0.0		7304	3.944	5731
91	05:30	18	4.610	81	45.809	5299	4646	168.8	37753	177.6	1000	0.0540	8633		0.0		7376	3.983	5646
91	06:00	18	3.645	81	45.988	5184	4625	177.3	38006	183.8	1000	0.0541	8633		0.0		7390	3.990	5625
91	06:11																100	0.054	0
91	06:30	18	2.263	81	46.174	5057	4629	181.1	38057	185.4	1000	0.0541	8633		0.0		7387	3.989	5629
91	07:00	18	1.674	81	46.352	5172	4645	184.3	38188	187.4	753	0.0544	8633		0.0		7377	3.983	5398
91	07:30	18	0.598	81	46.549	5080	4399	188.8	38095	188.6	790	0.0549	8290		0.0		7127	3.848	5189
91	08:00	17	59.491	81	46.755	5090	4336	189.9	438419	190.1	748	0.0540	8290		0.0		7166	3.869	5084
91	07:12	17	58.367	81	46.960	4913	4128	188.6	38304	190.4	777	0.0543	8037		15.2	H	6996	3.777	4905
91	08:58	17	57.387	81	47.140	4775	4043	189.5	38137	190.1	976	0.0547	7970				6968	3.763	5019
91	09:30	17	56.315	81	47.386	4469	4082	191.6	38163	191.7	910	0.0545	7970				6945	3.750	4992

91	10:00	17	55.310	81	47.522	4040	4003	191.7	38235	191.7	1000	0.0536	7785		0.0		6777	3.659	5003
91	10:30	17	54.225	81	47.722	4256	3858	187.3	38016	190.1	9430	0.0542	7558		10.2	H	6599	3.563	13288
91	11:00	17	53.112	81	47.927	4484	3675	187.3	38143	189.7	891	0.0542	7251		10.2	H	6351	3.429	4566
91	11:30	17	52.041	81	48.124	4789	3504	186.3	38137	189.2	456	0.0543	6763		10.0	H	5884	3.177	3960
91	12:00	17	50.871	81	48.340	4885	3377	235.1	47504	188.7	803	0.0541	6660		20.1	h	5840	3.154	4180
91	12:20	-	-	-	-	-	-	-	-	-	-	-	-	-					
91	12:30	17	49.716	81	48.498	5249	3230	191.2	38288	190.4	1000	0.0543	6490		10.1	v	5729	3.093	4230
91	13:00	17	49.105	81	47.563	5717	3588	198.8	38503	191.6	1000	0.0543	6836		10.2	v	5919	3.196	4588
91	13:30	17	49.179	81	46.241	5768	3861	155.2	37824	174.2	838	0.0541	6838		0.0	-	5744	3.101	4699
91	14:00	17	50.120	81	45.290	5936	4064	111.2	37766	144.2	1000	0.0540	6838		0.0	-	5599	3.023	5064
91	14:30	17	51.619	81	45.203	5658	4248	76.7	38298	103.2	1000	0.0536	6838		0.0	-	5458	2.947	5248
91	14:34		-	-	-	-	-	-	-	-	-	-	-		15.0	V	#VALUE!	#VALUE!	#VALUE!
91	14:55		-	-	-	-			-	-	-			-					#VALUE!
91	15:00	17	52.733	81	44.997	5509	4280	41.3	38812	60.7	1000	0.0541	7304		20.2	v	6019	3.250	5280
91	15:30	17	53.803	81	44.799	5599	4514	23.1	39145	36.8	1000	0.0539	8056		25.4		6773	3.657	5514
91	16:00	17	54.861	81	44.607	5365	4759	15.9	39378	25.5	933	0.0538	8667		0.0		7344	3.965	5692
91	16:30	17	55.824	81	44.428	5147	4606	10.1	39646	19.6	858	0.0536	8667		0.0		7442	4.018	5464
91	17:00	17	56.757	81	44.256	4661	4550	7	39778	15.8	802	0.0537	8623		10.1	h	7425	4.009	5352
91	17:00			-	-	-	-	-		-	-	-		-			#VALUE!	#VALUE!	#VALUE!
91	17:30	17	57.815	81	44.061	4434	4367	5.6	39606	13.3	772	0.0537	8330		10.1	h	7194	3.884	5139
91	18:00	17	58.934	81	43.857	4482	4218	4.6	39967	12.4	999	0.0535	8182		0.0		7111	3.840	5217

91	18:21												8182		15.0	h				0
91	18:30	18	0.050	81	43.650	4446	4090	3.8	39638	11.3	752	0.0535	8067		15.0	h		7053	3.808	4842
91	19:00	18	1.098	81	43.456	4587	3830	3	39988	10.2	614	0.0537	7612		15.2	h		6678	3.606	4444
91	19:11	-	-	-	-	-	-	-	-	-	-	-	-	-				#VALUE!	#VALUE!	#VALUE!
91	19:30	18	2.171	81	43.257	4906	3751	3.5	40050	10.7	646	0.0533	7458		0.0	-		6546	3.535	4397
91	19:48	-	-	-	-	-	-	-	-	-	-	-	-		15.0	h		#VALUE!	#VALUE!	#VALUE!
91	20:00	18	3.260	81	43.058	5157	3782	2.6	39930	10.2	798	0.0540	7322		0.0	-		6370	3.439	4580
91	20:30	18	4.335	81	42.860	5101	3713	3.3	39861	11.0	817	0.0530	7346		5.1	V		6439	3.477	4530
91	21:00	18	5.430	81	42.657	5057	3783	3.4	39966	10.3	864	0.0530	7471		10.1	V		6542	3.533	4647
91	21:30	18	6.515	81	42.460	4964	4136	2.7	39995	11.3	994	0.0530	7905		15.2	V		6837	3.691	5130
91	22:00	18	7.536	81	42.269	5003	4190	2.7	40031	9.9	961	0.0530	8145		0.0	-		7085	3.825	5151
91	22:30	18	8.500	81	42.009	5426	4270	2.8	40220	11.1	719	0.0530	8207		0.0		0	7109	3.838	4989
91	23:00	18	9.479	81	42.240	5604	4352	2.8	40329	10.3	557	0.0530	8164		0.0			7007	3.784	4909
91	23:30	18	10.469	81	42.741	5576	4235	0.4	40148	6.7	704	0.0520	7901		10.1	H		6770	3.656	4939
91	00:00	18	11.458	81	43.233	5710	4204	351.9	40420	357.5	872	0.0520	7895		0.0			6783	3.662	5076
92	00:30	18	12.370	81	43.687	5665	4553	346	40661	350.5	783	0.0530	8415		20.1			7177	3.875	5336
92	01:00	18	13.279	81	44.141	5632	4655	340.1	40731	343.0	703	0.0530	8636		0.0			7374	3.982	5358
92	01:30	18	14.183	81	44.595	5417	4688	339.3	40852	340.3	685	0.0530	8738		10.1	V		7474	4.036	5373
92	02:00	18	15.113	81	44.997	5026	4702	336.6	40904	338.2	764	0.0520	8765		0.0			7497	4.048	5466
92	02:30	18	16.147	81	45.002	4974	4744	334.6	41036	337.0	753	0.0520	8765		0.0			7470	4.034	5497
92	03:00	18	17.129	81	45.002	4804	4750	337.9	40955	341.1	798	0.0530	8759		10.1	H		7459	4.028	5548

92	03:30	18	18.100	81	45.000	4507	4518	340	40890	347.3	661	0.0520	8326	20.4	H	7094	3.830	5179
92	04:00	18	19.219	81	45.001	3922	4139	345.6	40704	354.0	711	0.0521	7721	20.1	H	6618	3.573	4850
92	04:30	18	20.260	81	45.001	3592	3789	349.4	40536	356.7	1000	0.0523	7224			6251	3.375	4789
92	05:00	18	21.339	81	45.002	3532	3562	351.4	40626	359.2	885	0.0526	6900	15.2	H	6009	3.245	4447
92	05:30	18	22.503	81	45.001	3176	3224	353.1	40753	0.6	510	0.0523	6348	20.3	H	5568	3.007	3734
92	00:00	18	23.605	81	44.999	3229	2893	354	40102	2.2	600	0.0530	5767	20.1	H	5089	2.748	3493
92	06:30	18	24.860	81	45.006	3838	2534	352.6	40568	0.4	611	0.0523	5125	20.4	H	4555	2.459	3145
92	07:00	18	26.003	81	45.001	4710	2467	354.3	40576	1.7	711	0.0520	4971	0.0		4416	2.384	3178
92	07:30	18	27.145	81	45.001	4830	2245	355	40570	2.6	762	0.0522	5277	20.2	V	4876	2.633	3007
92	07:44															100	0.054	0
92	07:50															100	0.054	0
92	08:00	18	28.178	81	45.002	4647	2922	354.9	40709	2.4	1000	0.0520	5806	20.2	V	5117	2.763	3922
92	08:04															100	0.054	0
92	08:30	18	29.108	81	45.001	4722	3447	354.5	40944	1.6	125	0.0521	6418	20.1		5514	2.977	3572
92	09:00	18	29.980	81	45.001	4573	3879	352.4	41264	0.7	1000	0.0522	7006	20.4		5934	3.204	4879
92	09:18															100	0.054	0
92	09:30	18	30.963	81	45.001	4567	4078	351.6	41226	359.1	815	0.0520	7236	0.0		6077	3.282	4893
92	10:00	18	31.872	81	45.001	4641	4084	352.8	40869	0.3	642	0.0520	7302	0.0		6153	3.322	4726
92	10:30	18	33.064	81	45.001	4691	4068	354	40866	1.1	636	0.0517	7498	10.3	V	6399	3.455	4704
92	10:51															100	0.054	0
92	11:00	18	34.183	81	45.001	4802	3997	355.1	40494	1.8	782	0.0522	7628	15.3	V	6597	3.562	4779

92	11:30	18	35.437	81	45.001	4877	3953	353.6	40697	1.8	765	0.0526	7900	0.0		6940	3.747	4718
92	11:44															100	0.054	0
92	12:00	18	36.952	81	45.002	5554	3876	353.6	40704	1.8	836	0.0522	7900	0.0		6984	3.771	4712
92	12:30	18	37.663	81	45.000	5591	3867	353	40638	0.3	822	0.0519	7900	0.0		6989	3.774	4689
92	12:37													15.0	v	100	0.054	0
92	13:00	18	38.815	81	45.002	5628	4072	353.7	40914	1.4	899	0.0514	8250	15.0	v	7275	3.928	4971
92	13:30	18	39.887	81	45.001	5727	4201	354	40177	1.0	671	0.0519	8451	0.0		7433	4.013	4872
92	13:40													15.0	v	100	0.054	0
92	14:00	18	40.950	81	45.001	6129	4348	353.7	40229	1.5	1000	0.0523	8750	15.0	v	7693	4.154	5348
92	14:15															100	0.054	0
92	14:30	18	42.168	81	45.001	6310	4480	353.4	40430	0.7	1000	0.0522	9000	0.0		7906	4.269	5480
92	15:00	18	43.195	81	45.001	6706	4467	354.3	40466	1.2	1000	0.0516	8972	15.0	h	7881	4.255	5467
92	15:30	18	44.211	81	44.009	6559	4174	353.3	40374	0.5	1000	0.0515	8551	0.0		7563	4.084	5174
92	16:00	18	44.010	81	42.600	6004	4362	0.5	40381		>1000	0.0516	8550	0.0		7454	4.025	>5362
92	16:30	18	42.002	81	42.002	5310	4957	15.6	40081	23.5	1000	0.0512	8550	0.0		7066	3.816	5957
92	16:34															100	0.054	0
92	16:38													20.0	h	100	0.054	0
92	17:00	18	41.109	81	41.990	4961	5146	45.6	39462	52.6	961	0.0521	8088	20.0	h	6340	3.423	6107
92	17:30	18	39.648	81	42.001	4912	4253	108.6	38711	115.1	1000	0.0526	7533	0.0		6318	3.411	5253
92	18:00	18	38.318	81	42.001	4914	3713	148.1	38160	151.6	1000	0.0522	7533	0.0		6654	3.593	4713
92	18:03													20.0	v	100	0.054	0

92	18:30	18	37.118	81	41.999	4829	3780	161.6	38143	167.6	1000	0.0521	8055	20.0	v	7213	3.895	4780
92	19:00	18	35.969	81	42.000	5063	4083	168.6	38158	174.2	815	0.0521	8676	20.0	v	7755	4.187	4898
92	19:04															100	0.054	0
92	19:30	18	34.884	81	41.999	5025	4169	171.5	38027	175.8	702	0.0513	8730			7770	4.196	4871
92	20:00	18	33.840	81	42.000	4956	4260	173.9	38049	179.0	552	0.0520	8721	5.1	h	7710	4.163	4812
92	20:30	18	32.726	81	41.999	4738	4255	175.6	38175	180.1	581	0.0510	8573	5.0	h	7543	4.073	4836
92	21:00	18	31.565	81	41.999	5054	4056	178	37372	182.3	895	0.0510	8231	0.0	-	7262	3.921	4951
92	21:30	18	30.353	81	42.000	4743	4032	176.4	37979		913	0.0520	8198	5.1	H	7238	3.908	4945
92	22:00	18	29.272	81	41.999	5119	3965	176.8	38153	180.8	855	0.0520	7995	15.2	h	7043	3.803	4820
92	22:30	18	28.199	81	41.999	5116	3786	177.4	38556	181.9	1000	0.0520	7582	0.0	-	6669	3.601	4786
92	23:00	18	27.074	81	41.999	5115	3915	177.2	38604	181.3	821	0.0520	7725	0.0	-	6759	3.650	4736
92	23:30	18	25.950	81	42.000	5235	3914	176.9	38730	181.2	849	0.0520	7725	0.0		6760	3.650	4763
92	00:00	18	24.886	81	41.999	5140	4088	179	38545	181.8	911	0.0520	8046	15.0	v	7030	3.796	4999
93	00:30	18	23.805	81	41.999	4907	4320	177.7	38411	180.8	783	0.0510	8493	14.9	V	7412	4.002	5103
93	01:00	18	22.652	81	41.999	4830	4315	177.8	38368	181.6	825	0.0510	8539	0.0		7469	4.033	5140
93	01:30	18	21.573	81	42.000	4344	4217	176.6	38042	180.9	946	0.0510	8375	25.3	H	7336	3.961	5163
93	02:00	18	20.402	81	41.957	4630	3792	176	38040	180.3	1100	0.0520	7598	30.5	H	6684	3.609	4892
93	02:30	18	19.451	81	40.972	4641	3364	174.1	37920	178.7	-	0.0510	6806	20.3	h	6017	3.249	#VALUE!
93	03:00	18	19.399	81	39.432	4713	3165	156.6	38005	161.2	~1200	0.0520	6302	10.0	h	5550	2.997	#VALUE!
93	03:30	18	19.538	81	37.861	4633	2795	117.7	38305	123.7	~1400	0.0520	6179	0.0	-	5611	3.030	#VALUE!
93	04:00	18	20.631	81	37.019	4629	2786	94.6	38642	101.5	1000	0.0520	6179	0.0		5615	3.032	3786

93	04:30	18	22.081	81	37.450	4343	3004	66.1	39084	72.7	1575	0.0523	6179	0.0		5500	2.970	4579
93	04:52															100	0.054	0
93	05:00	18	22.498	81	38.950	4207	3392	26.5	39629	33.7	1000	0.0517	6179	0.0		5265	2.843	4392
93	05:30	18	22.498	81	40.450	4858	3251	330.9	40811	338.4	1300	0.0522	6179	0.0		5355	2.891	4551
93	06:00	18	22.499	81	41.780	4622	3145	291.5	41674	298.5	1450	0.0517	6484	20.3	v	5770	3.116	4595
93	06:30	18	22.498	81	41.850	4070	3489	279.9	41675	284.5	1300	0.0517	7069	20.2		6248	3.374	4789
93	07:00	18	22.498	81	43.799	3679	3733	280.2	41323	277.5	1050	0.0513	7236	0.0		6299	3.401	4783
93	07:25															100	0.054	0
93	07:30	18	22.498	81	44.850	3208	3717	270.6	40945	6193.5	953	0.0514	6921	20.2	H	5938	3.206	4670
93	08:00	18	22.498	81	45.990	2848	3373	269	41411	272.5	916	0.0512	6329	20.0	H	5455	2.946	4289
93	08:23															100	0.054	0
93	08:30	18	22.479	81	47.112	2507	3021	268.4	41357	271.8	542	0.0516	5785	20.1	H	5034	2.718	3563
93	09:00	18	22.498	81	48.361	2302	2556	266	41045	269.8	477	0.0513	5088	25.5	H	4499	2.429	3033
93	09:15															100	0.054	0
93	09:30	18	22.498	81	49.682	2203	2112	286.2	41105	271.6	386	0.0511	4289	20.3	H	3833	2.070	2498
93	10:00	18	22.498	81	51.049	2315	1778	266.6	41109	270.1	515	0.0541	3808	20.0	H	3467	1.872	2293
93	10:30	18	22.498	81	52.374	2972	1563	266.6	41454	270.2	722	0.0523	3348	0.0		3061	1.653	2285
93	10:45																	
93	11:00	18	22.499	81	53.446	3344	1763	265.3	41417	269.6	992	0.0520	3348	0.0		2946	1.591	2755
93	11:30	18	22.498	81	54.440	3555	1968	267.8	41265	271.5	1300	0.0517	3333	30.0	H	2790	1.506	3268
93	12:00	18	22.498	81	55.380	3323	1552	265.6	40985	268.8	1000	0.5170	2457	30.6	h	2005	1.082	2552

93	12:30	18	22.497	81	56.444	2905	1843	265.7	41227	269.2	>1000	0.0523	2927	9.7		2374	1.282	>2843
93	12:40	-	-	-	-	-	-	-	-		-	-	-	-		#VALUE!	#VALUE!	#VALUE!
93	13:00	18	22.498	81	57.390	2806	1606	267.1	41016	268.8	>1000	0.0516	2337	30.5	h	1798	0.971	>2606
93	13:30	18	22.499	81	58.514	3429	972	269.3	41397	273.4	>1000	0.0523	1567	10.2	h	1329	0.718	>1972
93	13:40	-	-	-	-	-	-	-	-	-	-	-	-	-		#VALUE!	#VALUE!	#VALUE!
93	14:00	18	22.498	81	59.610	4003	657	274.3	50857	273.2	700	0.0521	875	30.4	h	678	0.366	1357
93	14:17	-	-	-	-	-	-	-	-	-	-	-				#VALUE!	#VALUE!	#VALUE!
																100	0.054	0
		pitch	**roll**	**magx**												100	0.054	0
93	14:17	13.3	0.200	-			386	282.6	43910	272.1	-	-	500	0.0		418	0.226	#VALUE!
93	14:25	14.2	0.600	1868			326	272.1	43722	269.8			533	30.4	h	522	0.282	326
93	14:27	-	-	-	-	-	-	-	-	-						#VALUE!	#VALUE!	#VALUE!
93	14:29	13.6	0.300	1772			317	286.4	44010	275.0			536	29.3	h	532	0.287	317
93	14:30	14.2	0.500	4225			334	284	43785	286.5			490	30.0	h	459	0.248	334
93	14:38	13.4	0.200	22115			325	322.5	42549	326.2			550	2.0	v	544	0.294	325
93	14:40	13.4	0.500	22771			299	334.5	41213	343.1			486	30.2	h	483	0.261	299
93	14:41	13.3	0.200	26634			284	342.6	41015	349.4			451	18.7	v	450	0.243	284
93	14:45	12.7	0.500	27201			313	2	39990	12.3			546	21.0	h	547	0.296	313
93	14:48	13	0.300	24094			257	21.9	39348	35.6			455	13.9	v	475	0.257	257
93	14:53	12.5	0.600	19630			291	39.6	38944	57.0			550	14.7	h	567	0.306	291
93	14:55	12.5	0.000	11923			266	54.5	38760	76.6			452	21.2	v	465	0.251	266

93	14:59	12.7	1.600	8397			323	63.2	38657	90.0			550	6.5	h	545	0.294	323
93	15:04	12.3	0.300	-7734			327	92.1	38099	120.6			451	10.0	v	411	0.222	327
93	15:08	12.5	1.300	-12127			336	108.4	38043	134.4			550	1.1	h	535	0.289	336
93	15:20	11.6	0.300	-23023			288	218.2	38999	214.3			474	29.2	v	476	0.257	288
93	15:24	11.9	1.400	-14401			326	245.1	39843	230.0			521	30.1	h	506	0.273	326
93	15:28	14.2	0.200	-9807			298	264.3	40712	253.4			466	29.1	v	458	0.247	298
93	15:32	13.4	1.300	4286			334	291.5	41588	273.5			550	0.0		537	0.290	334
93	16:20	-		-	-	-	-	-	-	-	-	-	-	-		#VALUE!	#VALUE!	#VALUE!
93	16:00	18	23.453	82	0.394	4185	328	329.7	40978	295.3						#NUM!	#NUM!	328
93	16:30	18	23.502	82	0.330	4246												

APPENDIX 2 Summary CTD’s

CTD CAST No.	LADCP FILE	START LAT	START LONG	START TIME	END TIME	START DEPTH	END DEPTH	MISSION	SAMPLES	Crate	Bottle range	Processed
001	JC044_001m.000	13.3883	-68.2577	86.6854	86.8383	-0.2630	-0.8320	TEST CAST VENEZUELA BASIN UP-DOWN	N	23	572-583	3-Apr
002	JC044_002m.000	17.9165	-81.7667	89.5208	89.6850	-0.3570	-0.8150	CAST AT SOUTHERN END OF CAYMAN TROUGH UP-DOWN	Y	23	584-595	3-Apr
003	JC044_003m.000	18.5441	-81.7193	93.8764	94.0159	-0.30	3958.70	DOWN CAST to 4961.2m THEN PART UP CAST test acoustic releases	N	/	/	/
004	JC044_003m.000	18.5441	-81.7192	94.0306	94.0313	3958.70	3680.80	DOWN to ~4090 Time series then up to 3500 down to 4700 up to 3680	N	/	/	/
005	JC044_003m.000	18.5434	81.7201	94.1549	94.1556	3678.90	-0.93	DOWN to 4900 then UPCAST to SURFACE	Y	7	188-211	7-Apr
006	JC044_004m.000	18.5500	-81.7225	94.6339	94.6358	12.00	4905.00	DOWN CAST to 4950 then up to 4905	N	/	/	/
007	JC044_004m.000	18.5480	-81.7213	94.6339	94.6358	3739.20	4437.44	DOWN CAST from to 3739 to 4437 partial tow-yo	N	/	/	/
008	No cast							OPERATOR ERROR	N	/	/	/
009	JC044_004m.000	18.5467	-81.7199	94.7429	94.7436	4436.97	3728.45	UP CAST from 4437 to 3728 partial tow-yo	N	/	/	/
010	JC044_004m.000	18.5449	81.7182	94.7533	94.7540	3727.07	4417.99	DOWN CAST from 3728 to 4418 partial tow-yo	N	/	/	/
011	JC044_004m.000	18.5431	-81.7163	94.7641	94.7648	4417.22	3728.43	UP CAST from 4437 to 3728 partial tow-yo	N	/	/	/
012	JC044_004m.000	18.5413	-81.7145	94.7745	94.7752	3729.94	4886.37	DOWN CAST from 3729 to 4886 partial tow-yo	N	/	/	/
013	JC044_004m.000	18.5400	-81.7131	94.7974	94.7977	4887.00	1.00	UP CAST	Y	25	620-631	7-Apr
014	JC044_005m.000	18.5500	-81.7225	95.5459	95.5466	-0.34	-0.79	PHYSICS UP-DOWN to 4914.98	Y	25	631-643	7-Apr

015	JC044_015 m.000	18.5499	-81.7225	95.7833	95.7840	-0.60	-0.85	PHYSICS UP-DOWN to 4518.72 with stop at 4145 and 4165 for SAPS (~ 2 hours)	N	/	/	/
016	JC044_016 m.000	18.5466	-81.7180	97.5211	97.6789	-0.39	-0.81	PHYSICS UP-DOWN to 5025.97 50 L for ALEX (micro-biol)	Y	10	260-271	13-Apr
017	JC044_017 m.000	18.5466	-81.7181	97.6939	97.8942	-0.91	-0.85	PHYSICS UP-DOWN to 5040.56 with stop at 4937 for plume sniffing (~ 25 minutes)	N	/	/	/
018	JC044_018 m.000	18.5474	-81.7200	98.6439	98.8748	-0.324	-0.818	PHYSICS UP-DOWN to 4921.31 with stop at 4160 for SAPS (~ 1 hour)	Y	10	272-276	13-Apr
019	JC044_019 m.000	17.9166	-81.7959	100.2656	100.3314	1.00	3881.00	DOWN CAST to 3882	N	/	/	/
020	JC044_019 m.000	17.9166	-81.7959	100.3318	100.3454	3882.00	2986.00	TOWYO upcast to 2986	N	/	/	/
021	JC044_019 m.000	17.9173	-81.7939	100.3460	100.3613	2986.00	3882.00	TOWYO downcast to 3883	N	/	/	/
022	JC044_019 m.000	17.9183	-81.7915	100.3613	100.3724	3870.00	2979.00	TOWYO upcast to 2979	N	/	/	/
023	JC044_019 m.000	17.9189	-81.7896	100.3727	100.3875	2979.00	3976.00	TOWYO downcast to 3977	N	/	/	/
024	JC044_019 m.000	17.9201	-81.7875	100.3878	100.4013	3976.00	2974.00	TOWYO upcast to 2974	N	/	/	/
025	JC044_019 m.000	17.9208	-81.7853	100.4016	100.4154	2975.00	3973.00	TOWYO downcast to 3974	N	/	/	/
026	JC044_019 m.000	17.9222	-81.7832	100.4162	100.4295	3973.00	2972.00	TOWYO upcast to 2972	N	/	/	/
027	JC044_019 m.000	17.9232	-81.7811	100.4305	100.4445	2973.00	4070.00	TOWYO downcast to 4072	N	/	/	/
028	JC044_019 m.000	17.9241	-81.7788	100.4450	100.4592	4071.00	2970.00	TOWYO upcast to 2970	N	/	/	/
029	JC044_019 m.000	17.9251	-81.7766	100.4596	100.4814	2970.00	4389.00	TOWYO downcast to 4390	N	/	/	/

030	JC044_019 m.000	17.9266	-81.7733	100.4817	100.4987	4390.00	3016.00	TOWYO upcast to 3016	N	/	/	/
031	JC044_019 m.000	17.9278	-81.7705	100.5002	100.5204	3018.00	4567.00	TOWYO downcast to 4567	N	/	/	/
032	JC044_019 m.000	17.9292	-81.7672	100.5211	100.5369	4561.00	3230.00	TOWYO upcast to 3230	N	/	/	/
033	JC044_019 m.000	17.9305	-81.7647	100.5381	100.5639	3232.00	4864.00	TOWYO downcast to 4865	N	/	/	/
034	JC044_019 m.000	17.9323	-81.7606	100.5650	100.5845	4864.00	3483.00	TOWYO upcast to 3483	N	/	/	/
035	JC044_019 m.000	17.9337	-81.7575	100.5860	100.6058	3484.00	4872.00	TOWYO downcast to 4873	N	/	/	/
036	JC044_019 m.000	17.9350	-81.7544	100.6064	100.6203	4872.00	3771.00	TOWYO upcast to 3771	N	/	/	/
037	JC044_019 m.000	17.9361	-81.7520	100.6213	100.6343	3772.00	4830.00	TOWYO downcast to 4832	N	/	/	/
038	JC044_019 m.000	17.9370	-81.7499	100.6349	100.6429	4831.00	4195.00	TOWYO upcast to 4195	N	/	/	/
039	JC044_019 m.000	17.9376	-81.7489	100.6472	100.6553	4205.00	4777.00	TOWYO downcast to 4777	N	/	/	/
040	JC044_019 m.000	17.9375	-81.7504	100.6559	100.6670	4777.00	3974.00	TOWYO upcast to 3974	N	/	/	/
041	JC044_019 m.000	17.9375	-81.7523	100.6674	100.6790	3974.00	4860.00	TOWYO downcast to 4862	N	/	/	/
042	JC044_019 m.000	17.9375	-81.7544	100.6796	100.6887	4860.00	4133.00	TOWYO upcast to 4133	N	/	/	/
043	JC044_019 m.000	17.9375	-81.7561	100.6896	100.7005	4134.00	4864.00	TOWYO downcast to 4865	N	/	/	/
044	JC044_019 m.000	17.9375	-81.7578	100.7009	100.7108	4865.00	4050.00	TOWYO upcast to 4050	N	/	/	/
045	JC044_019 m.000	17.9376	-81.7598	100.7118	100.7256	4051.00	4859.00	TOWYO downcast to 860	N	/	/	/
046	JC044_019 m.000	17.9374	-81.7621	100.7259	100.7356	4859.00	4086.00	TOWYO upcast to 4086	N	/	/	/
047	JC044_019 m.000	17.9375	-81.7639	100.7364	100.7481	4087.00	4886.00	TOWYO downcast to 4886	N	/	/	/

048	JC044_019 m.000	17.9375	- 81.7659	100.748 7	100.76 94	4886.00	3566.00	TOWYO upcast to 4886	N	/	/	/
049	JC044_019 m.000	17.9375	- 81.7682	100.772 2	100.79 11	3569.31	4802.31	End of Towyo - Vertical Profile to 4700m	N	/	/	/
050	JC044_019 m.000	17.9375	- 81.7682	100.791 6	100.85 70	4802.73	-0.79	Upcast to Surface	N	/	/	/
051	JC044_051 m.000	17.9215	- 81.7683	101.114 0	101.18 71	-0.38	4593.08	Downcast to 4593.78 m Start of Towyo – Upcast to 3500m	N	/	/	/
052	JC044_051 m.000	17.9215	- 81.7655	101.187 9	101.20 45	4593.09	3485.84	Start of Towyo – Upcast to 3500m	N	/	/	/
053	JC044_051 m.000	17.9215	- 81.7640	101.206 5	101.21 98	3484.59	3754.64	TOWYO Downcast to 3952m	N	/	/	/
054	JC044_051 m.000	17.9215	- 81.7640	101.221 3	101.23 24	3755.41	2982.87	TOWYO Upcast to 3000m	N	/	/	/
055	JC044_051 m.000	17.9215	- 81.7622	101.233 2	101.26 65	2982.59	5029.85	TOWYO Downcast to 5050m	N	/	/	/
056	JC044_051 m.000	17.9215	- 81.7573	101.267 3	101.28 20	5030.22	3974.05	TOWYO Upcast to 4000m	N	/	/	/
057	JC044_051 m.000	17.9215	- 81.7547	101.283 5	101.30 36	3973.84	5176.87	End of Towyo – Downcast	N	/	/	/
058	JC044_051 m.000	17.9215	- 81.7518	101.304 1	101.38 45	5177.39	-0.86	Upcast to Surface	Y	10	277-283	13-Apr
059	JC044_051 m.000	17.9498	- 81.7720	101.428 9	101.49 72	8.88	4788.37	Downcast to 4178m	N	/	/	/
060	JC044_051 m.000	17.9500	- 81.7718	101.499 3	101.51 33	4787.42	3882.22	Start of Towyo – Upcast to 3900m	N	/	/	/
061	JC044_051 m.000	17.9517	- 81.7700	101.514 0	101.52 68	3882.20	4779.57	TOWYO Downcast to 4800m	N	/	/	/
062	JC044_051 m.000	17.9530	- 81.7685	101.527 3	101.54 06	4780.02	3775.59	TOWYO Upcast to 3800m	N	/	/	/
063	JC044_051 m.000	17.9547	- 81.7668	101.541 1	101.55 83	3775.28	4873.82	TOWYO Downcast to 4700m	N	/	/	/
064	JC044_051 m.000	17.9567	- 81.7647	101.559 5	101.57 09	4873.78	3939.20	TOWYO Upcast to 3800m	N	/	/	/
065	JC044_051	17.9580	-	101.571	101.58	3940.05	4772.18	TOWYO Downcast to	N	/	/	/

	m.000		81.7632	4	41			4800m				
066	JC044_051 m.000	17.9595	- 81.7615	101.584 6	101.59 72	4771.35	3769.91	TOWYO Upcast to 3800m	N	/	/	/
067	JC044_051 m.000	17.9610	- 81.7600	101.597 7	101.61 23	3771.00	4799.92	TOWYO Downcast to 4700m	N	/	/	/
068	JC044_051 m.000	17.9627	- 81.7582	101.612 8	101.62 40	4800.54	3968.90	TOWYO Upcast to 4000m	N	/	/	/
069	JC044_051 m.000	17.9640	- 81.7567	101.624 6	101.64 09	3969.66	4777.97	TOWYO Downcast to 4800m	N	/	/	/
070	JC044_051 m.000	17.9643	- 81.7563	101.641 8	101.65 32	4778.39	3984.25	TOWYO Upcast to 4000m	N	/	/	/
071	JC044_051 m.000	17.9647	- 81.7560	101.653 6	101.73 89	4788.22	-0.82	End of Towyo – Downcast to 4788m then Upcast to Surface	Y	9	236-259	13-Apr

Table 24 Summary of CTD casts

APPENDIX 3. Bottle sample summary for CTD's

Cast number	CTD001	CTD002	CTD005	CTD006	CTD014	CTD016	CTD018	CTD058	CTD071	CTD072	CTD075	CTD076	CTD079	CTD080
Latitude	13	17	18	18	18	18	18	17	17	18	18	18	18	18
N	23.343	54.996	32.646	32.996	32.997	32.796	32.840	55.296	57.466	21.556	22.498	22.697	22.614	37.496
Longitude	68	81	81	81	81	81	81	81	81	81 43	81	81	81	81
W	15.908	46.000	43.153	43.352	43.353	43.082	43.100	45.112	45.358	649	20.501	47.519	48.007	45.002
Samples taken	12	12	24	11	12	12	5	7	23	5	18	6	18	24
Depth 1	4319	4877	4155	4594	4915	4937	4493	5176	4733	2045	4967	2353	2322	5600
Depth 2	4319	4877	3960	4594	4915	4937	4493	5176	4733	2044	4967	2353	2322	5600
Depth 3	4319	4877	3763	996	4915	3494	4493	5176	4732	2044	4967	2253	2230	5600
Depth 4	4319	4000	3565	996	4494	3494	4493	3986	4732	1955	4967	2253	2230	5600
Depth 5	2997	4000	3367	996	4494	2493	4493	3986	3679	1630	4967	2154	2128	5600
Depth 6	2997	4000	2498	747	4494	2493	N/A	2985	3679	N/A	4967	2154	2128	5600
Depth 7	2997	2000	2498	747	835	1496	N/A	2985	3679	N/A	4967	N/A	2037	1991
Depth 8	2997	2000	2498	747	835	1496	N/A	N/A	3679	N/A	4967	N/A	2037	1991
Depth 9	1998	2000	2498	100	835	778	N/A	N/A	2676	N/A	4367	N/A	1943	1991
Depth 10	1998	750	1002	100	150	778	N/A	N/A	2676	N/A	4367	N/A	1943	1991
Depth 11	1998	750	1002	100	150	150	N/A	N/A	2676	N/A	4367	N/A	747	1991
Depth 12	1998	750	1002	100	150	150	N/A	N/A	2676	N/A	4367	N/A	747	1991
Depth 13	N/A	N/A	1002	N/A	N/A	N/A	N/A	N/A	1680	N/A	3967	N/A	747	817
Depth 14	N/A	N/A	1002	N/A	N/A	N/A	N/A	N/A	1680	N/A	3967	N/A	500	817
Depth 15	N/A	N/A	753	N/A	N/A	N/A	N/A	N/A	1680	N/A	3967	N/A	500	817
Depth 16	N/A	N/A	753	N/A	N/A	N/A	N/A	N/A	1680	N/A	3967	N/A	500	817
Depth 17	N/A	N/A	753	N/A	N/A	N/A	N/A	N/A	731	N/A	750	N/A	180	161
Depth 18	N/A	N/A	753	N/A	N/A	N/A	N/A	N/A	731	N/A	750	N/A	180	161
Depth 19	N/A	N/A	753	N/A	N/A	N/A	N/A	N/A	731	N/A	N/A	N/A		161
Depth 20	N/A	N/A	255	N/A	N/A	N/A	N/A	N/A	731	N/A	N/A	N/A		161
Depth 21	N/A	N/A	255	N/A	N/A	N/A	N/A	N/A	142	N/A	N/A	N/A		22
Depth 22	N/A	N/A	255	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		22
Depth 23	N/A	N/A	255	N/A	N/A	N/A	N/A	N/A	142	N/A	N/A	N/A		22
Depth 24	N/A	N/A	255	N/A	N/A	N/A	N/A	N/A	142	N/A	N/A	N/A		22

Table 25 Summary of bottle samples from CTD.