D333: Multidisciplinary Equipment TRIals Cruise (METriC)

14-23 October 2008, Canary Islands

Cruise report

Principle Scientist

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Participating Organisations

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2 Disclaimer

All data in this Cruise Report are provisional; some are fully calibrated whereas others are not. No data from this report should be published or otherwise presented without the express permission of the originators (see **Individual Scientific Reports**).

3 Acknowledgements

We would like to thank the Master, Roger Chamberlain and all of the officers, engineers and crew of RRS *Discovery* for their support during an extremely professional cruise. Please refer to the post cruise assessment report which details the exceptional contribution made by the ship's crew and NMFD personnel to the success of the cruise. Thanks is also due to the other members of the, NOC, POL and SAMS staff who enabled and undertook the hardwork that delivered an extensive test of an impressive range of equipment.

4 Cruise objectives

The objectives of this equipment trials cruise was to provide opportunities for test and verification of technology under development at the Proudman Oceanographic Laboratory (POL), the Scottish Association for Marine Science (SAMS) and the National Oceanography Centre, Southampton (NOC,S). This included equipment developed during the first year of funding under OCEANS 2025 (theme 8). Testing technology in the ocean environment is invaluable in assessing fitness for purpose. To maximise impact, all technologies were extensively tested and characterised in the lab prior to the cruise. The aim was to enable METriC to be economically prudent by meeting a number of laboratories requirements in a single cruise. In addition the risk of equipment failure on subsequent science deployments is significantly reduced. The aim of this testing is to enable validation and data for the progression of technologies up the Technologies Readiness Level (TRL) scale (see Table 1). In particular transition from the early prototype technology readiness levels (4,5) to testing and demonstration in representative and operational environments (6,7 and 8). This progression requires validation of component and systems survival *and* operation to required performance standards in progressively more harsh environments and deployment scenarios. The aim of this cruise was to provide a range of test environments in which technology deployment, diagnostic data collection, and validation could be achieved.

Specifically, the aim of the cruise was to test: A Spar wave buoy (NOC,S) biogeochemical sensors (NOC,S); the Io UAV system (NOC,S); A video rock grab system “HyBis” (NOC,S), A benthic Multicore (NOC,S), A benthic lander and associated torroidal Telemetry buoy (POL), and a shallow tow towfish (POL). SAMS contributed to these objectives by engineering support provided by John Bass.

The exact geographical location for these trials was not important, though access to deep water was required. In addition a greater range of testing would be enabled by calm seas. This was particularly important for equipment deployed for the first time.

To maximise the value of the data available to each technology under test each was given a number of deployment opportunities distributed in date and time for the duration of the cruise. This enabled data gained from early tests to be used to refine further testing and also gave the opportunity for reparations should failures occur in initial testing.

Table 1 Technology Readiness Levels

TRL	Description (adapted from the NASA definitions)
1. Basic principles observed and reported	Scientific research begins to be translated into applied research and development. Example might include paper studies of a technology's basic properties.
2. Technology concept and/or application	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and

formulated	there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.
3. Analytical and experimental critical function and/or characteristic proof of concept	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard validation in laboratory environment	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of 'ad hoc' hardware in a laboratory.
5. Component and/or breadboard validation in relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include 'high fidelity' laboratory integration of components.
6. System/subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated operational environment.
7. System prototype demonstration in an operational environment	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle or space. Examples include testing the prototype in a test bed platform.
8. Actual system completed and 'flight qualified' through test and demonstration	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended system to determine if it meets design specifications.
9. Actual system 'flight proven' through successful mission	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last "bug fixing" aspects of true system development. Examples include using

operations	the system under operational mission conditions.

5 Cruise Narrative

Following successful mobilisation (Sunday 12/10/2008) disembarkation was delayed by two successive fuel spill incidents in Santa Cruz harbour. This prevented bunkering until the morning of Tuesday 14/10/2008 when service was obtained from a fuel barge. In many respects this delay was advantageous. In particular it enabled assembly and testing of the various pieces of equipment in the absence of ship motion. The result was that there were a number of instruments ready to go immediately once at sea and this resulted in very little wasted ship time during the cruise. The delay also enabled more detailed planning of the testing schedule to reflect the readiness of each technology and to respond to the weather conditions. The long term forecast (which was accurate) predicted North Easterly winds from F2-F6. Though this is well within the ships capability it was agreed to be prudent to seek shelter when deploying instruments for the first time or in the initial stages of testing of more complex technologies. The Master suggested a region to the southwest of the foot of Fuerteventura which afforded deep (~1600m) water, access to deeper water within a days steaming (>2500m) and gave access to swell outside the defined lee of the island (e.g. for testing the spar wave buoy). This region was selected as the primary test site for the duration of the cruise. In addition opportunistic deployments were to be made on passage to and from this location. An overview of the ship's track can been seen in Figure 1. Ships time was maintained at BST; all times hereafter are reported as such unless otherwise stated. A list of stations occupied and details of technology tested is shown in Table 3. In addition onboard sensors for Ammonia and pH were also tested throughout the cruise (see §7.7). An overview of the geographic locations of stations is shown in Figure 2 whilst details of locations in the lee of Fuerteventura are shown in Figure 3. The station codes letter (suffix) used for each station is shown in Table 2. Only daylight deck operations were undertaken to minimise the risk of equipment damage and injury (especially important with prototype and unfamiliar equipment). This maximised available light and the number of hands available during operations.

The first opportunistic deployment on the outbound passage to Fuerteventura was made at 11:33 on the 14/10/2008 when HyBIS was deployed (station 16446#A). After an unsuccessful attempt to gain permission to deploy on a Seamount within the traffic separation scheme (TSS) to the west of Gran Canaria, a suitable site was located outside the TSS but still in the vicinity of a seamount and previously reported seismicity. Details of the deployment are given in the appropriate scientific report (§7.1). On conclusion of the test at 15:55 the towfish was prepared and deployed (16:40) and towed at a range of speeds. The intention was to tow for the duration of the passage to Fuerteventura. However at 10knts the vehicle broke the surface indicating that operation was not possible at cruise speed (~12knts). The vehicle was recovered and secured on deck at 19:12 when the passage was continued.

On arrival in the test area the predictions of sheltered conditions were bourn out. To gain familiarity with the launch and recovery procedures and to provide initial test data the Spar Buoy was deployed in the lee of Fuertaventura from 08:30-10:14 on the 15/10/08. The deployment and recovery were achieved without difficulty enabling deployment in more testing conditions to be permitted. This approximate location was maintained for testing of the benthic telemetry systems (attached to the coring wire in approximately 1600m of water) followed by redeployment of the Spar Buoy and testing of the Multicorer. The Spar Buoy was monitored visually, on ship's Radar and using Argos position fixes (via the communications link on the Spar Buoy). A constant and predictable drift rate was observed. After informing the appropriate authorities, the Spar Buoy was left unattended to enable a long duration test, and to enable testing of other equipment in deeper water. Overnight on the 15-16/10/2008 a passage to deeper water to the south of Gran Canaria was completed. HyBis and the multicorer were tested in this location. Overnight passage to the preferred testing area to the SW of Fuerteventura was completed 16-17/10/2008 whereupon the Spar Buoy was relocated.

The first ever flight of the NOC unmanned aeronautical vehicle (UAV) from a research ship was achieved on the morning of 17/10/2008. This was followed by testing of Satellite and benthic telemetry systems with the torroidal communications buoy(with drogue) drifting over the location of the lander on the seabed prior to retrieval of both systems. The Spar Buoy was then sought, located visually and maintained within sight until daybreak. The Spar Buoy was recovered at 08:27 on the 18/10/2008. A short passage leg to the south of this location was undertaken to gain deeper water, flatter topography (in contrast to earlier tests) and an area of reduced shipping activity. HyBis completed two dives in this location testing the performance of two different configurations.

A second deployment of the benthic lander for tests of acoustic communications and release system was undertaken in the morning of 19/10/2008 (deployed at 09:08). Whilst other equipment was being prepared the Spar Buoy was deployed. The position of the lander on the seabed was determined during this period using acoustic triangulation. Acoustic communications were also tested with over the side equipment. The torroidal buoy was then deployed such that it drifted over this location whilst testing satellite and acoustic communication systems. A drogue was not used as the previous trial concluded that the drogue did not significantly reduce the drift rate yet was hard to deploy.

HyBis was deployed at 08:55 on the 20/10/2008 to attempt to locate and image the lander thus testing if this system could navigate to a known location on the seabed. After successfully completing this test HyBis was recovered at 12:35. At 13:24 acoustic communication with the benthic lander was attempted to initiate release and return to the surface. This was not successful and the lander remained on the seabed. An attempt was made to initiate a data capsule release from the lander which was similarly unsuccessful. Whilst options were explored the Spar Buoy was deployed (16:30). Following completion of a risk assessment (see Appendix (§8)), HyBis was deployed to attempt recovery of the lander which remained on the seabed. This was successful with the lander being secured on deck at 22:02.

The Spar Buoy was recovered in the morning of the following day (21/10/2008) at 8:48. Two deployments of biogoechemical sensors connected to the CTD frame (for reference measurements and concurrent bottle sampling) were made interspersed with redeployment of the Spar Buoy (whilst samples were processed and the CTD reconfigured for the next test). CTD operations ended at 18:12 and the spar buoy was recovered at 18:50.

The penultimate science day was used to attempt a fault finding test for the acoustic communication system used on the lander (deployed at 09:00), a deployment (14:10) and recovery (19:39) of the spar buoy, and two deployments of lab-on-a-chip chemical sensors on the CTD. That night passage was made to a location immediately to the south of Gran Canaria. The final day started and ended with the deployment and recovery of the Spar Buoy. During this test HyBis made its seventh and final dive and the biogeochemical sensors were tested on the CTD.

The cruise completed repeated testing of all the equipment except the towfish (for which sufficient data was obtained in the first deployment). Valuable technical data for fault finding and performance improvement was gained for all systems. In addition the cruise was invaluable for gaining and increasing experience of using these technologies in the marine environment.

The operation of the ship was exemplary throughout. There was one near miss (NM076 "Stb'd aft Effer crane contacts aft Gantry") which was dealt with through the appropriate channels

Table 2 Station Codes (suffix) indicating type of technology under test

station code	Equipment tested	PI	Report location Section (page)
#A	HyBIS	Murton	7.1 (17)17
#B	Spar Buoy	Pascal	7.2 (36)
#C	Torroid Buoy	Balfour	7.4 (44)
#D	Benthic lander	Hargreaves	7.5 (49)
#E	Benthic Telemetry and data systems	Balfour	7.4 (44) and 7.5 (49)
#F	Multicore	Sherring	7.3 (42)
#G	Towfish	Smithson	7.6 (54)
#H	CTD +biogeochemical sensors	Mowlem	7.8 (60)
#I	UAV	Waugh	7.10 (71)
#J	RIB deployment	Chamberlain	na

Table 3 D333 equipment trials stations

Station number	APPROXIMATE POSITION						date	time (Ship = BST)	DESCRIPTION
	LATITUDE			LONGITUDE					
	deg	Min	N/S	deg	min	E/W			
16446#A	28	3.5	N	16	5.5	W	14/10/2008	11:33:00	Equipment trials of the HyBIS video grab system. Location is a sea mount in approximately 1900-1600m water. Maneouverability and sampling (with swing jaw bucket grab) functionality were tested. Station 16446#A, 10:33-14:55 (GMT), 14/10/2008
16446#G	28	3.9	N	16	5.5	W	14/10/2008	16:40:00	Equipment trials of ADCP equiped towfish (POL). Shallow tow for vehicle stabililty analysis.Station 16446#G,15:40-18:12 (GMT), 14/10/2008
16447#B	28	5.815	N	14	10.342	W	15/10/2008	08:30:00	Equipment trials of wave height measuring (15Hz) spar buoy with video and stills images for breaker identification. Station 16447#B, 07:30-9:14 (GMT), 15/10/2008
16448#E	27	59.9	N	14	0.2	W	15/10/2008	11:32:00	Equipment trials of acoustic modem systems for benthic lander. Station 16448#E, 10:32-14:12 (GMT), 15/10/2008
16449#B	27	58.6	N	13	57.5	W	15/10/2008	15:45:00	Equipment trials of wave height measuring (15Hz) spar buoy with video and stills images for breaker identification. Station 16449#B, 14:45 (GMT), 15/10/2008 - 7:27 (GMT) 18/10/08 at 27 51.6 N, 14 48.5 W
16450#F	27	59.7	N	13	58.3	W	15/10/2008	16:35:00	Equipment trials of benthic multicorer (multiple 50cm cores fired simultaneously in single location). Images of cores recorded. No cores retained. Station 16450#F, 15:35 -17:20(GMT), 15/10/2008
16451#A	27	7.3	N	15	19.3	W	16/10/2008	08:12:00	Equipment trials of the HyBIS video grab system. Station 16451#A, 10:33-14:55 (GMT), 14/10/2008
16452#F	27	7.8	N	15	18.3	W	16/10/2008	15:26:00	Equipment trials of benthic multicorer (multiple 50cm cores fired simultaneously in single location). Images of cores recorded. No cores retained. Station 16452#F, 14:26-17:22 (GMT), 16/10/2008
16453#I	28	2.3	N	14	11.1	W	17/10/2008	09:30:00	Equipment trials of ship launched Unmanned Aeronautical Vehicle. Vehicle performance data, photographs and air temperature recorded. Station 16453#I, 8:30-10:05 (GMT) 17/10/2008
16453#J	28	2.3	N	14	11.1	W	17/10/2008	09:35:00	RIB launched for recovery of UAV and photography

16454#C	28	0.2	N	14	1.3	W	17/10/2008	12:16:00	Equipment trials of acoustic modem systems and satellite communications system on a drifting torroidal buoy for communication with benthic lander. Station 16454#C, 11:16-15:00 (GMT), 17/10/2008
16454#D	27	59.9	N	14	2	W	17/10/2008	13:30:00	Equipment trials of acoustic modem systems and releases on a benthic lander. Station 16454#D, 12:30-16:38 (GMT), 17/10/2008
16455#A	27	41.9	N	14	47.2	W	18/10/2008	13:00:00	Equipment trials of the HyBIS video grab system. Station 16455#A, 12:00-19:51 (GMT), 18/10/2008
16456#D	27	59.67	N	14	0.99	W	19/10/2008	09:08:00	Equipment trials of acoustic modem systems and releases on a benthic lander. Station 16456#D, 08:08 (GMT), 19/10/2008 -21:02 (GMT) 20/10/2008 (releases failed, recovered by HyBIS see 16462#A)
16457#B	27	59.2	N	14	1.7	W	19/10/2008	09:50:00	Equipment trials of wave height measuring (15Hz) spar buoy with video and stills images for breaker identification. Station 16457#B, 08:50-18:10 (GMT), 19/10/2008 recovered at 27 55.5N, 14 05.3 W
16457#C	27	59.1	N	14	2.2	W	19/10/2008	10:53:00	Equipment trials of acoustic modem systems and satellite communications system on a drifting torroidal buoy for communication with benthic lander. Station 16457#C, 09:53-14:00 (GMT), 19/10/2008
16458#C	28	0.5	N	13	59.8	W	19/10/2008	14:38:00	Equipment trials of acoustic modem systems and satellite communications system on a drifting torroidal buoy for communication with benthic lander. Station 16458#C, 13:38-15:55 (GMT), 19/10/2008
16460#A	27	59.2	N	14	1.6	W	20/10/2008	08:55:00	Equipment trials of the HyBIS video grab system. Station 16460#A, 07:55-11:35 (GMT), 20/10/2008
16460#D	27	59	N	14	1	W	20/10/2008	13:24:00	attempted communication with benthic lander
16461#B	27	59	N	14	1	W	20/10/2008	16:30:00	Equipment trials of wave height measuring (15Hz) spar buoy with video and stills images for breaker identification. Station 16461#B, 15:30(GMT), 20/10/2008 recovered at 27 57.4N, 14 11.5 W 07:48 (GMT) 21/10/2008
16462#A	27	59.6	N	14	1.2	W	20/10/2008	18:23:00	Recovery of lost benthic lander with HyBIS video grab system. Video recording. Station 16462#A, 17:23-21:06 (GMT), 20/10/2008
16464#H	27	56.9	N	14	12.4	W	21/10/2008	10:06:00	Equipment trials of idronaut CTD with pH sensors. data retained. 9:06-12:30 (GMT), 21/10/2008
16465#B	27	59.6	N	14	1	W	21/10/2008	15:15:00	Equipment trials of wave height measuring (15Hz) spar buoy with video and stills images for breaker identification. Station16463#B, 14:15 - 17:50 (GMT), 21/10/2008 recovered at 27 59.6N, 14 03.9 W
16466#H	28	0.8	N	14	1.4	W	21/10/2008	16:12:00	Equipment trials of Lab on a chip nitrite sensor with CTD as reference. CTD data retained. Sensor failed at depth. Station 16466#H 15:12- 17:12 (GMT), 21/10/2008

16468#D	27	59.3	N	14	0.7	W	22/10/2008	09:00:00	Equipment trials of acoustic modem systems for benthic lander. Station 16468#E, 08:00- 10:28 (GMT), 22/10/2008
16469#B	27	57.34	N	14	4.13	W	22/10/2008	14:10:00	Equipment trials of wave height measuring (15Hz) spar buoy with video and stills images for breaker identification. Station16469#B, 13:10 - 18:39 (GMT), 22/10/2008 recovered at 27 55.5N, 14 07.6 W 18:39 (GMT)
16470#H	27	58.6	N	14	2.52	W	22/10/2008	14:37:00	Equipment trials of Lab on a chip nitrate sensor with CTD as reference. CTD data retained. Station 16470#H 13:37- 14:50 (GMT), 22/10/2008
16471#H	27	58	N	14	4.9	W	22/10/2008	16:58:00	Equipment trials of Lab on a chip nitrate sensor with CTD as reference. CTD data retained. Station 16471#H 15:58- 17:54 (GMT), 22/10/2008
16473#B	27	36.2	N	14	42.6	W	23/10/2008	09:04:00	Equipment trials of wave height measuring (15Hz) spar buoy with video and stills images for breaker identification. Station16473#B, 08:04 (GMT), 23/10/2008 recovered at 16:18 (GMT) at 27 34.6 N, 15 42.1 W
16474#A	27	34.2	N	15	44.6	W	23/10/2008	09:30:00	Equipment trials of the HyBIS video grab system. Station 16474#A, 08:30-12:30 (GMT), 23/10/2008
16475#H	27	34.5	N	15	41.2	W	23/10/2008	14:15:00	Equipment trials of Lab on a chip nitrate sensor with CTD as reference. CTD data retained. Station 16475#H 13:15- 15:26 (GMT), 23/10/2008

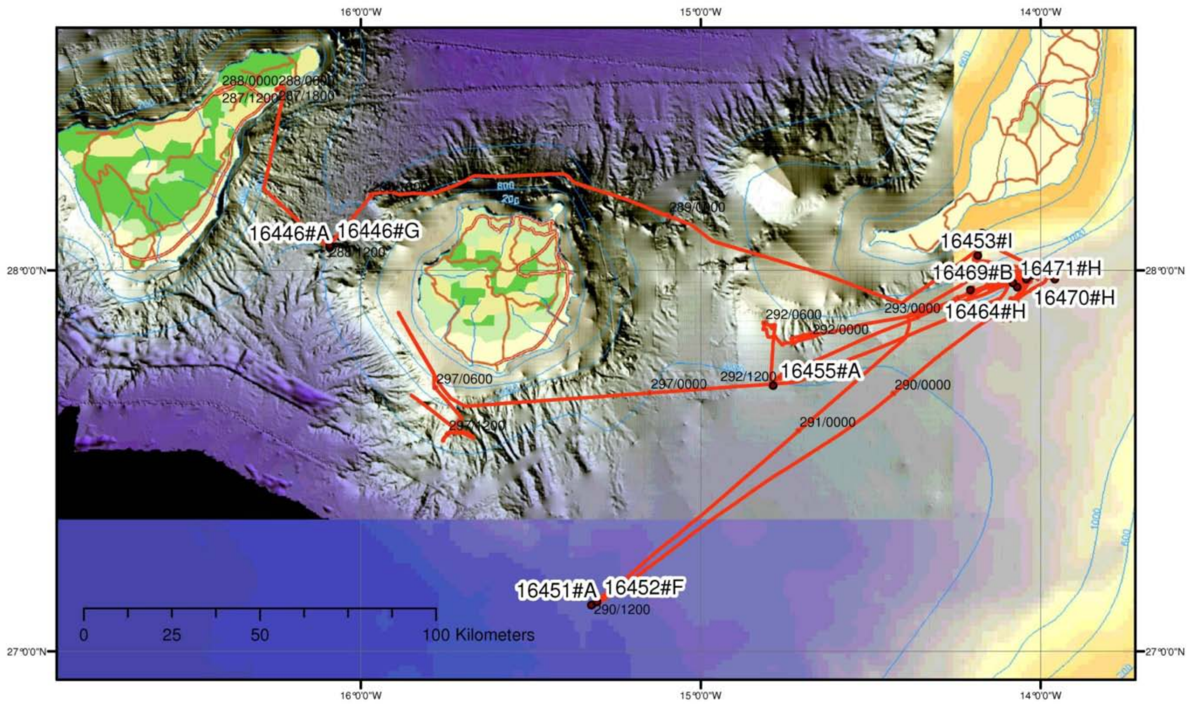


Figure 1 Cruise Track

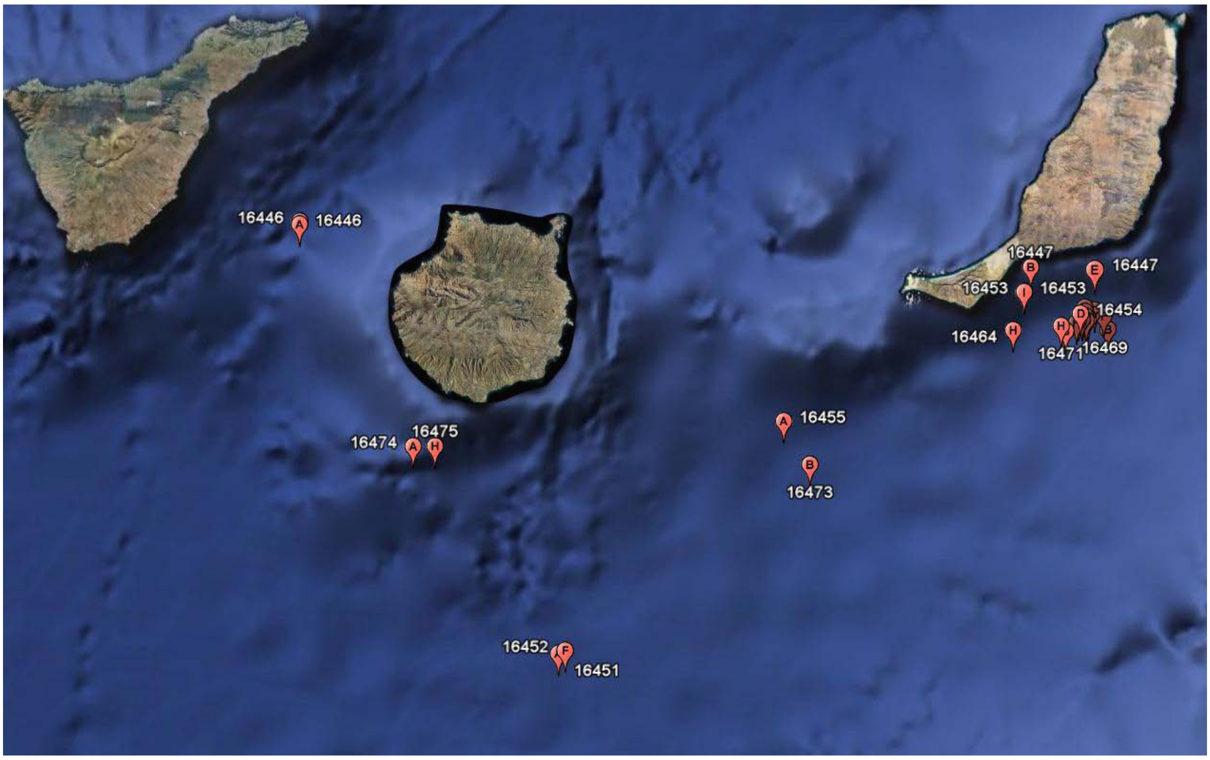


Figure 2 Overview of station locations

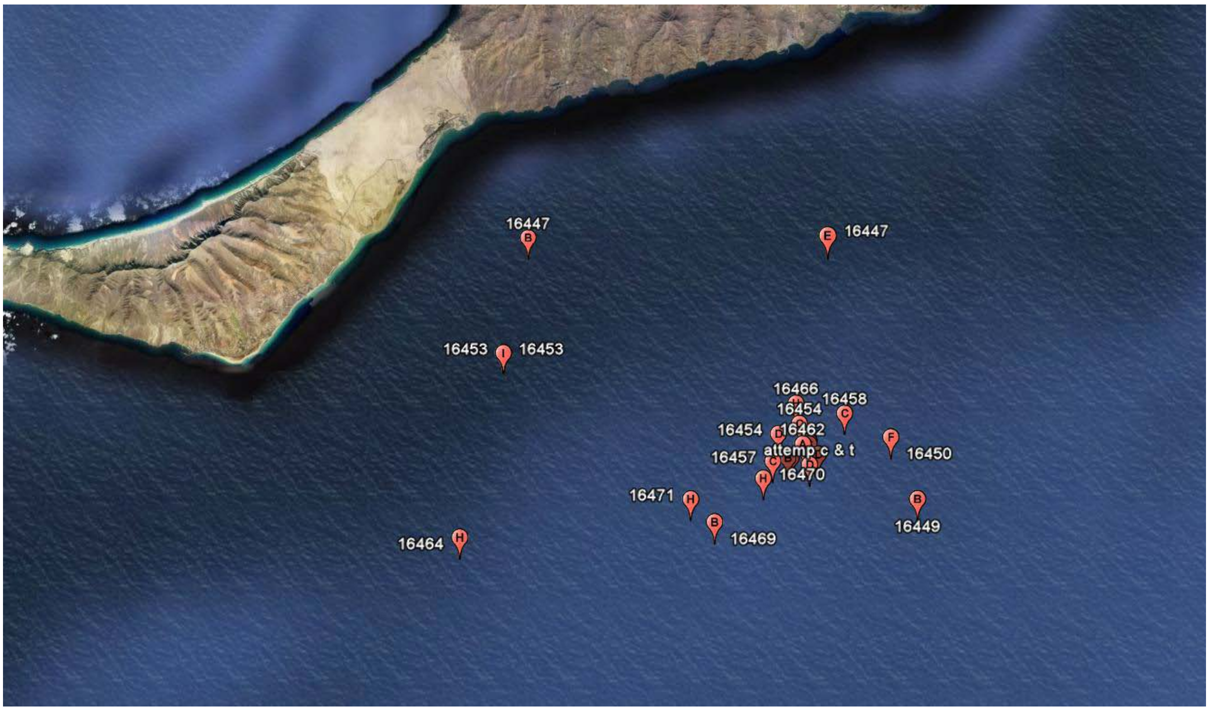


Figure 3 Detail of station locations SE of Fuerteventura

6 D333: General hydrographic and meteorological observations

Fine weather was experienced for the majority of the duration of D333. Consistent with the location and time of year the seawater temperature was in the range 22.5 to 24.5 ^oC and was declining (see Figure 4). Pressure variations were primarily diurnal though a weak low passed in the early hours of Julian day 294 (see Figure 5) resulting in some cloud during the day and thus reduced sunlight (see Figure 8). Wind was as much a function of location as time (as predicted, and used to acquire sheltered conditions) but was predominantly from the NE (Figure 7) with a mean wind speed 11.6 m/s (Figure 6). The air temperature was a degree or so lower than sea temperature (20.5 – 23.5 ^oC see Figure 10) and humidity was typically in the ranger 60-80% (see Figure 9). No wave measurement data is available at this time but conditions were generally very calm except on passage outside the shelter of Fuerteventura (where slight swell was evident).

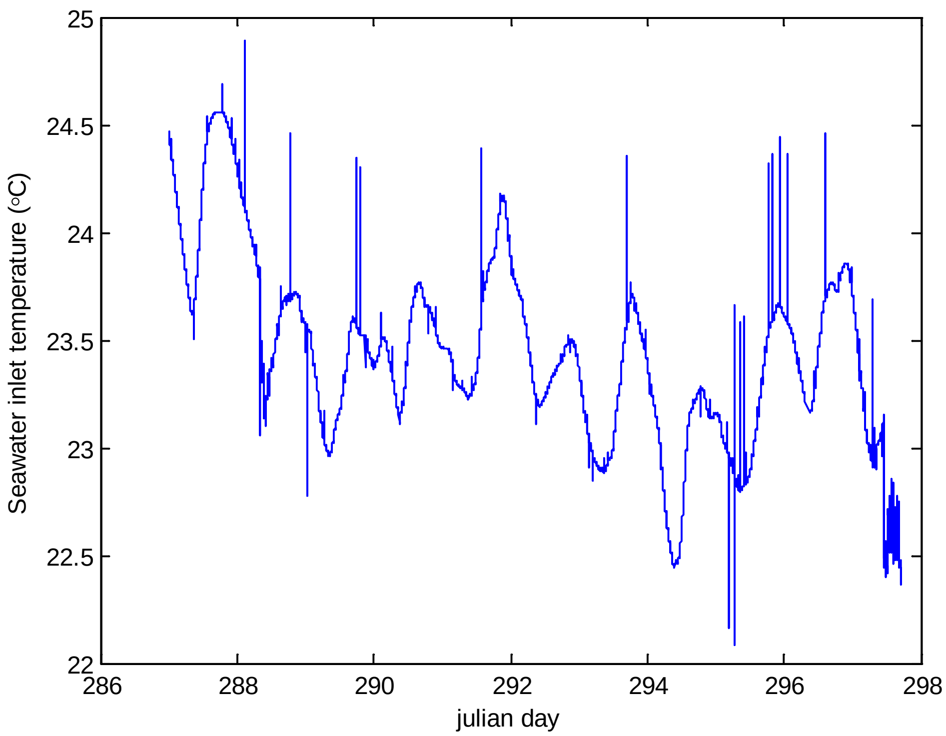


Figure 4 Near surface sea temperature during cruise

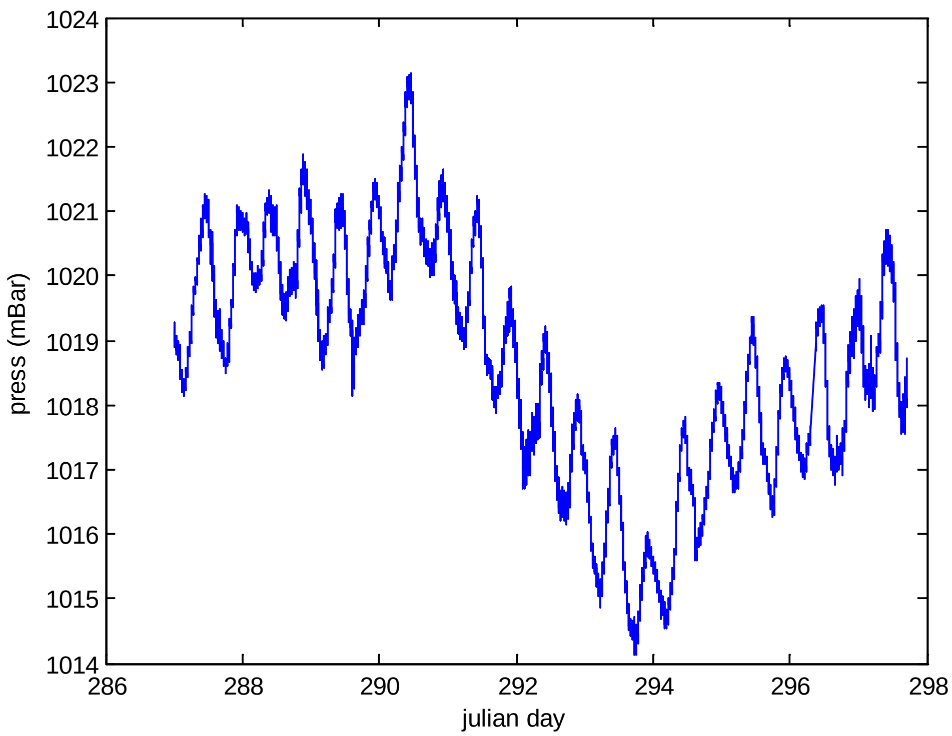


Figure 5 Atmospheric pressure during cruise

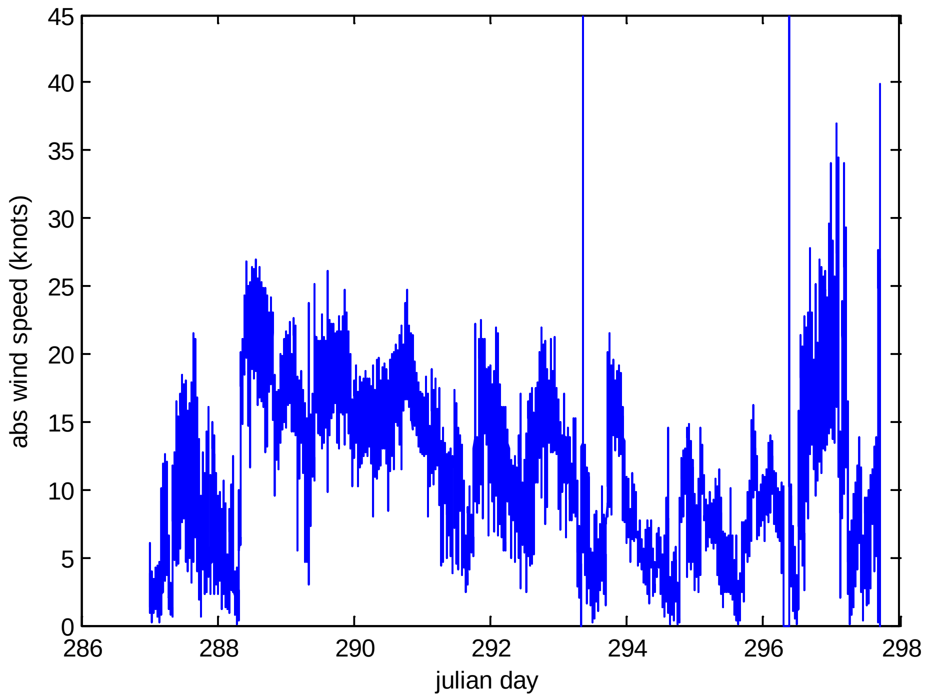


Figure 6 Absolute wind speed during cruise

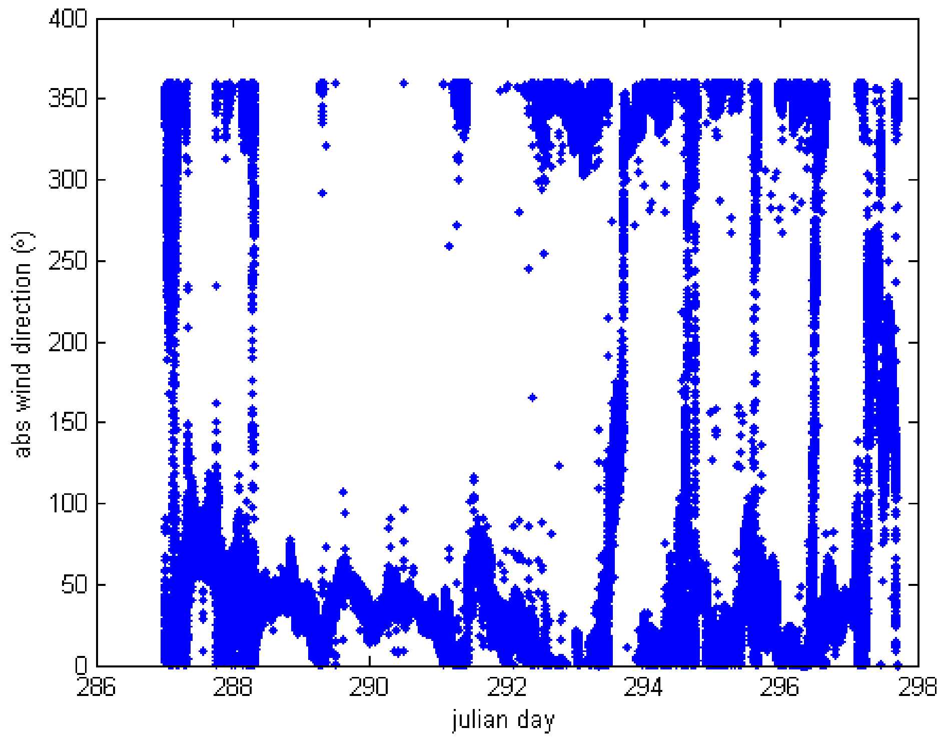


Figure 7 Absolute wind direction during cruise

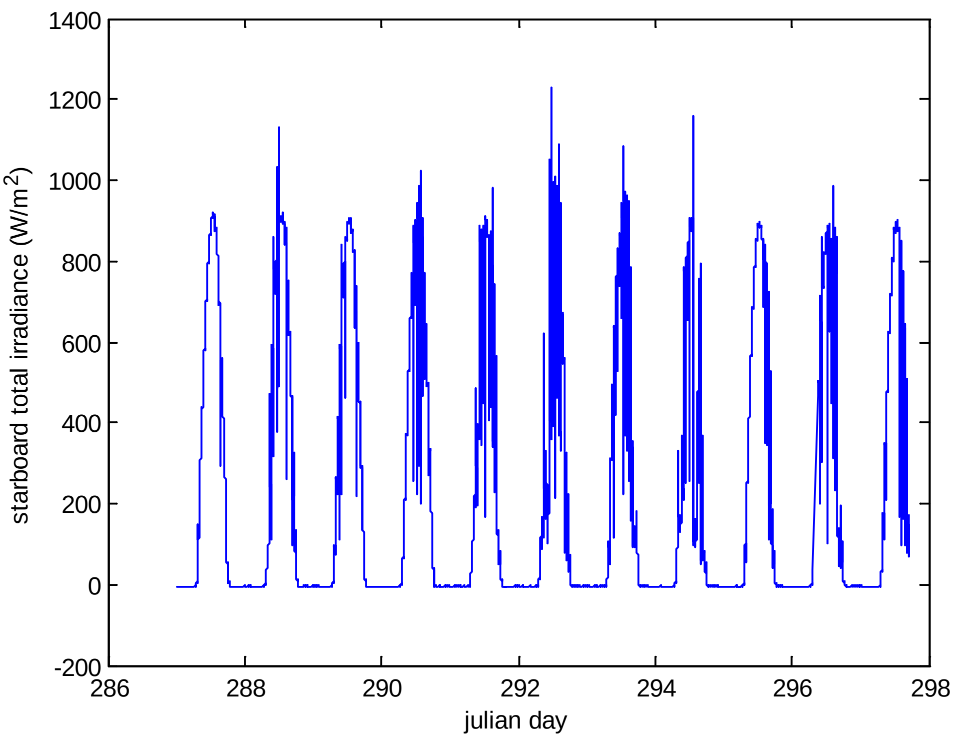


Figure 8 Starboard side measurement of total irradiance during cruise

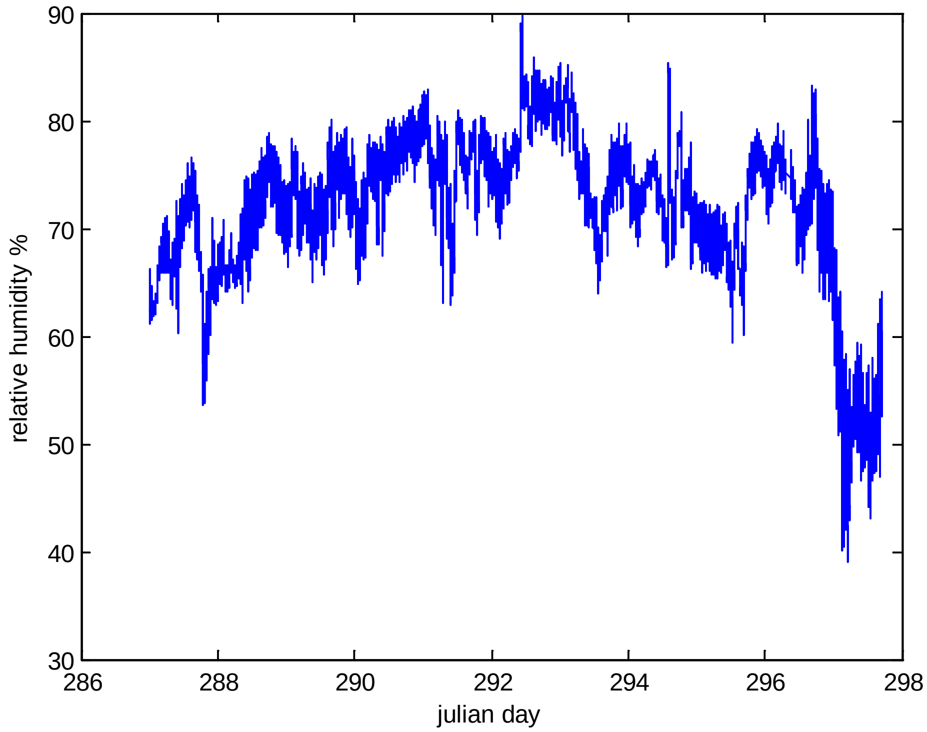


Figure 9 Relative humidity during cruise

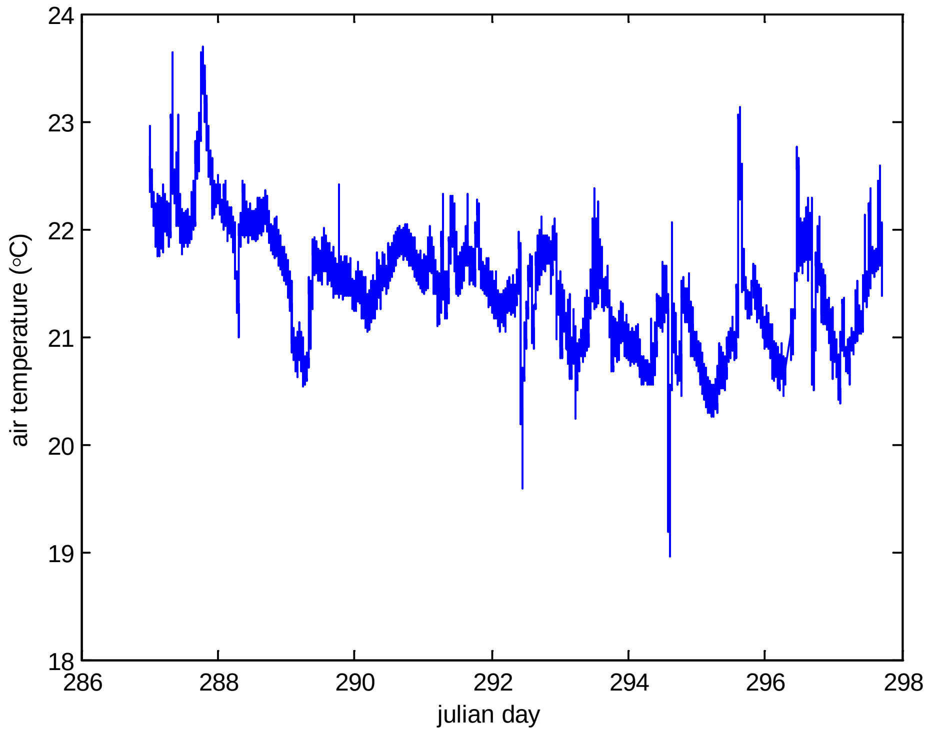


Figure 10 Air temperature during cruise

7 Scientific Reports

7.1 HyBIS (Hydraulic Benthic Interactive Sampler)

Bramley Murton

HyBIS is an RO-TVG (Remotely Operated TV-Grab) that is designed to be a versatile, easy-to-use platform for seafloor survey, intervention and instrument package deployment.

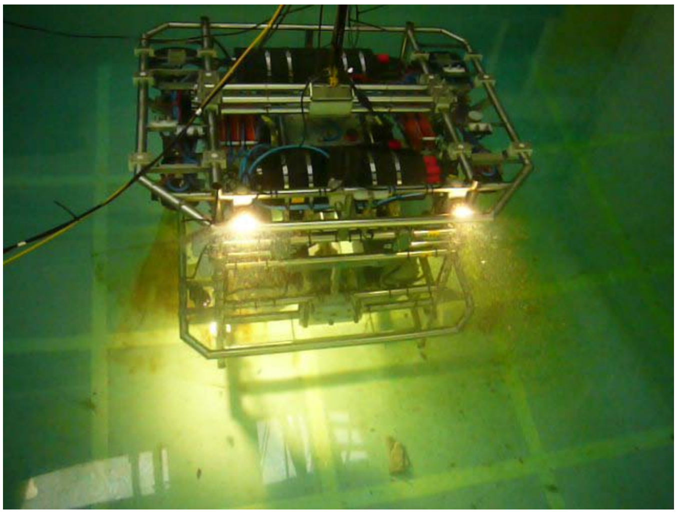
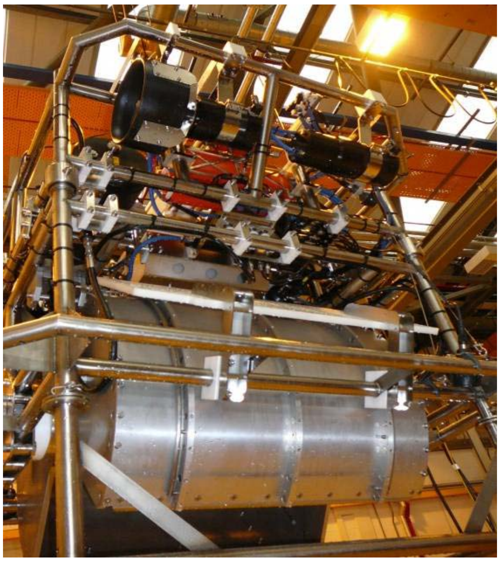


Figure 11 HyBIS vehicle in NOC acoustic test tank

The concept was originated by Bramley Murton and Pete Mason to bridge the capability gap between blind sampling and full ROV operations. It was funded through an NOCS technology initiative fund. The vehicle was built in 2007 by Hydro-Lek, an off-shore engineering company that specializes in remotely controlled sub-sea vehicle systems.

HyBIS currently has six serial channels and three colour video channels. It has enough hotel power to supply a CTD, chemical and optical sensors and a variety of sonars. It is powered through the standard NMFD fibre-optic-electrical cable, delivering 7kvA at 1500V ac, with 5 KW available at the vehicle.



HyBIS has a command module for power, lights, and telemetry, and a swappable tool module for sampling. The command module has twin colour cameras and over 1000W of lights - all rated to 6000m. The command module also has hydraulic power packs, 140Bar water pump and electric thrusters producing 100 kg of thrust. The sampling module currently comprises a 0.3 cubic meter clam-shell grab.

The modules are separated by hydraulic release pins, enabling the tool module to be jettisoned or a pay-load to be deployed. In the future, it can be tooled with manipulators, push-cores, a slurp-gun or a rotary drill.

Figure 12 Underside view of HyBIS

7.1.1 Pre-dive set-up and tests:

The RO-TVG 'HyBIS' was positioned on the after deck of the RRS Discovery and mounted on its deck frame which, in turn, was mounted to the screw fixture matrix on the ship's deck. The vehicle was attached via a termination bottle (supplied by NOCS' Deep Platforms Group) to a 4700m length of 17mm electrical fibre-optic umbilical cable wound on a portable winch. The winch (a Macartney portable electric winch) required 120Amps of 3 phase electrical supply plus a continuous flow of cooling water from the ship's non-toxic supply. All operations of the vehicle were done according to the procedures described in the risk assessment presented to the ship's master and operators prior to the start of the trials cruise.

Figure 13 The HyBIS vehicle mounted on its deck stand, on the after deck of the RS Discovery

7.1.1.1 Connection issues:

The first problem was encountered when trying to connect the vehicle to the deep-tow cable. It was found that the D G O'Brian fibre optic bulkhead, fitted to the termination bottle, was badly corroded and came apart when fitted into the bottle's end-cap. Luckily, HyBIS had a spare bulkhead that was fitted in place of the old one.

The second problem was the insufficient length of the termination bottle. This caused a tight bend in the fibre optic connections inside the bottle, resulting in an intermittent loss of optical signal. After some rearrangement of the connections inside the bottle, we were able to limit these losses to 10-15dB of the transmitted signal strength.

Figure 14 Joe Garrard (HydroLek contractor) and Lee Fowler (NOCS) work on the fibre optic connections inside the umbilical termination bottle

Once the connection problems were overcome, communications and power to the vehicle were established. No electrical power, voltage or earth leakage faults were detected (see figure) and the fibre-optic communications were robust. All vehicle functions were tested on deck and found to be working correctly.

7.1.1.2 Vehicle data:

7.1.1.2.1 Pressure sensors:

The vehicle's depth and hydraulic pressure sensors gave erratic readings on deck. Pressures readings from both sensors varied by 5%. Both the depth and hydraulic pressure sensors yield a 1 to 5 volt DC output across 0-10000 psi and 0-1000 psi ranges respectively. Tests on the sensor bottle connections were made by connecting a 1.5V dry cell to the depth sensor output, connected to the 10bit A to D converter on the 'SeaEye Marine Ltd.' compass board inside the vehicle's main electronics pressure pod. The erratic values remained, ruling out the sensor as the probable cause. As a check, a spare depth sensor was connected to a 24V, clean, DC power supply in the lab, and found to yield a clean 1V output at one atmosphere. An oscilloscope was attached to the depth sensor output voltage on the vehicle and was found to have a 100kHz carrier frequency. It was thought that this might be a cause of the erratic sensor reading so a 22 nano-farraday capacitor was attached to both the input supply and output voltages from the depth sensor to surpress the high-frequency noise. This failed to have a discernable effect, so a further smoothing circuit was added, inside the dry sensor bottle, to the sensor output but to no avail.

7.1.1.2.2 Orientation sensors:

The digital compass on board the vehicle was also found to suffer some erratic behaviour of about 1% of its 360° range. In addition, the compass was not calibrated for the vehicle's inherent magnetic field. A calibration was made subsequently on the first dive, initially by powered rotation of the vehicle, which proved to induce magnetic effects from the vehicle's electric thrusters. A second calibration was made without thruster assistance, completing two 360° turns in 90 seconds. The resulting compass calibration was acceptable, although a further calibration might improve the performance of the compass. It was noted that the compass is not pitch and roll corrected, which might account for a component of the heading errors.

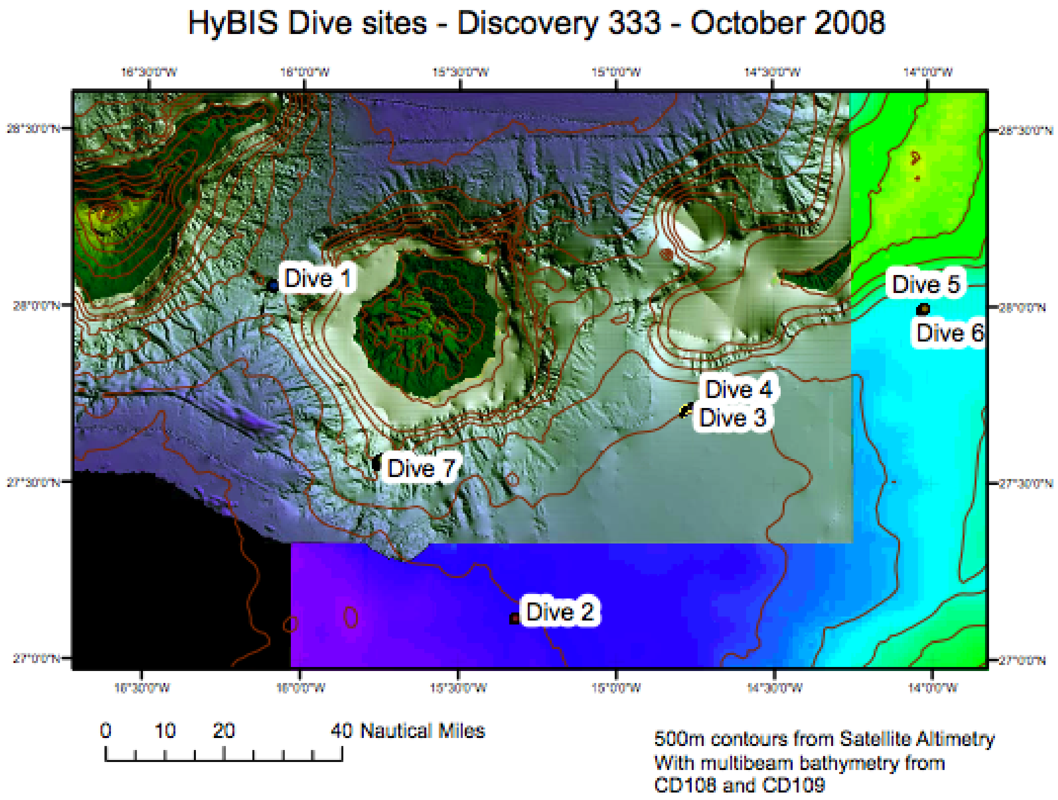


Figure 15 Chart showing all dive sites during HyBIS trials on cruise D333. Background data are multibeam bathymetry and GEBCO bathymetry

7.1.2 HyBIS Dive 1

Date: 14th October, 2008. Station Number: 16446#A. Location: 28° 03.5'N; 16° 05.5'W; depth 1891m.

Target: Seamount 14 nautical miles due west of Gran Canaria. The seamount lies within a zone of seismicitty and is thought to be possibly active.

Sea-state moderate 4, wind 15-20 kts from the NE.

Figure 16 HyBIS launched (left) and recovered (right) over the stern of the RRS Discovery on its first trials dive.

7.1.2.1 Dive summary:

At 1400 GMT HyBIS was launched and descended at 30 metres per minute. The vehicle was fitted with a Sonardine USBL beacon inside the vehicle 's frame. At 1458 GMT the vehicle was at 1850m depth and in sight of the bottom. The sea floor was found to be extremely rugged with steep scarps and rocky outcrops covered in coral. A sample of mixed dead and live was taken at 1351GMT and the vehicle returned to the surface at 40m/min.

7.1.2.2 Results:

All systems functioned, although the USBL fixes were poor. Vehicle manoeuvrability was good, especially it yaw control with 3° per second lateral roation. Both forward and reverse thrusters function worked well enabling a radius of manoeuvre of about 30-50m at a speed of 0.3 kts. Both forward and downward lights provided an even illumination with a viewing range of 10 to 20 m. It was difficult to see the contents of the grab when it closed due to sediment clouds inside the bucket. Once cleared, the sample was evenly illuminated and clearly visible. The vehicle suffered minor impact damage to its bottom frame from rocks and requires some form of impact protection.

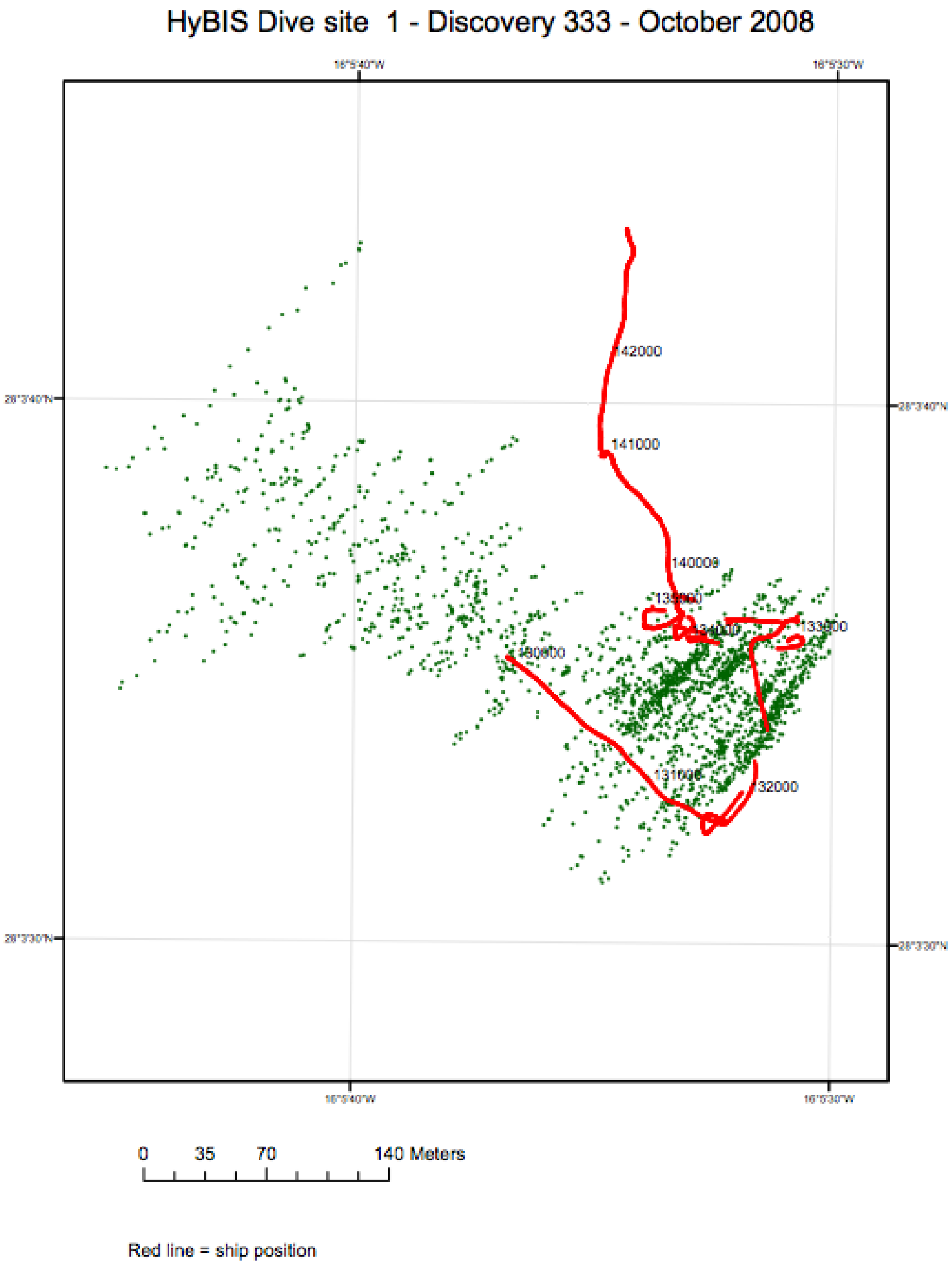


Figure 17 HyBIS dive site 1. Green dots are acoustic USBL navigation or HyBIS. The positions are poor due to a location of the beacon inside the vehicle causing interference

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7.1.3 HyBIS Dive 2

Date: 16th October, 2008. Station Number: 16451#A

Location: 27° 07.30'N; 15° 19.31'W; depth 2987m.

Target: Flat sea floor 8 nautical miles due south of Fortevetura Island.

Sea-state calm 1, wind 5-10 kts from the NE.

Figure 18 HyBIS is launched into a calm sea, south of the Island of Lanzerote, Canaries.

7.1.3.1 Dive summary:

At 0800 GMT HyBIS was launched and descended at 30 metres per minute. The vehicle was fitted with a Sonardine USBL beacon inside the vehicle 's frame. At 0953 GMT the vehicle was at 2987m depth and in sight of the bottom. The sea floor was found to be fat and covered in clay ooze. At 1100 GMT a large sponge, rooted into the seafloor, was taken. The vehicle then followed the ship at 0.2 kts for 400m without any detrimental affects on its heave or manouverability. At 1206 GMT we dumped the coral and sampled a clean piece of seafloor to test sample integrity. The vehicle returned to the surface at 40m/min and was secured and powered off at 1343 GMT.

7.1.3.2 Results:

All systems functioned, although the USBL fixes remained poor with an error of 50 to 100m at 2900m water depth. Vehicle manoeuvrability was good achieving a radius of manoeuvre of about 50m at a speed of 0.3 kts. The sample was cored using a push core at the surface, on deck. The cores was relatively homogeneous but not disturbed, although the surface of the sample was.

Figure 19 HyBIS Sediment sample taken using an improvised push core. Results of push cores: minimally disturbed sediment profiles.

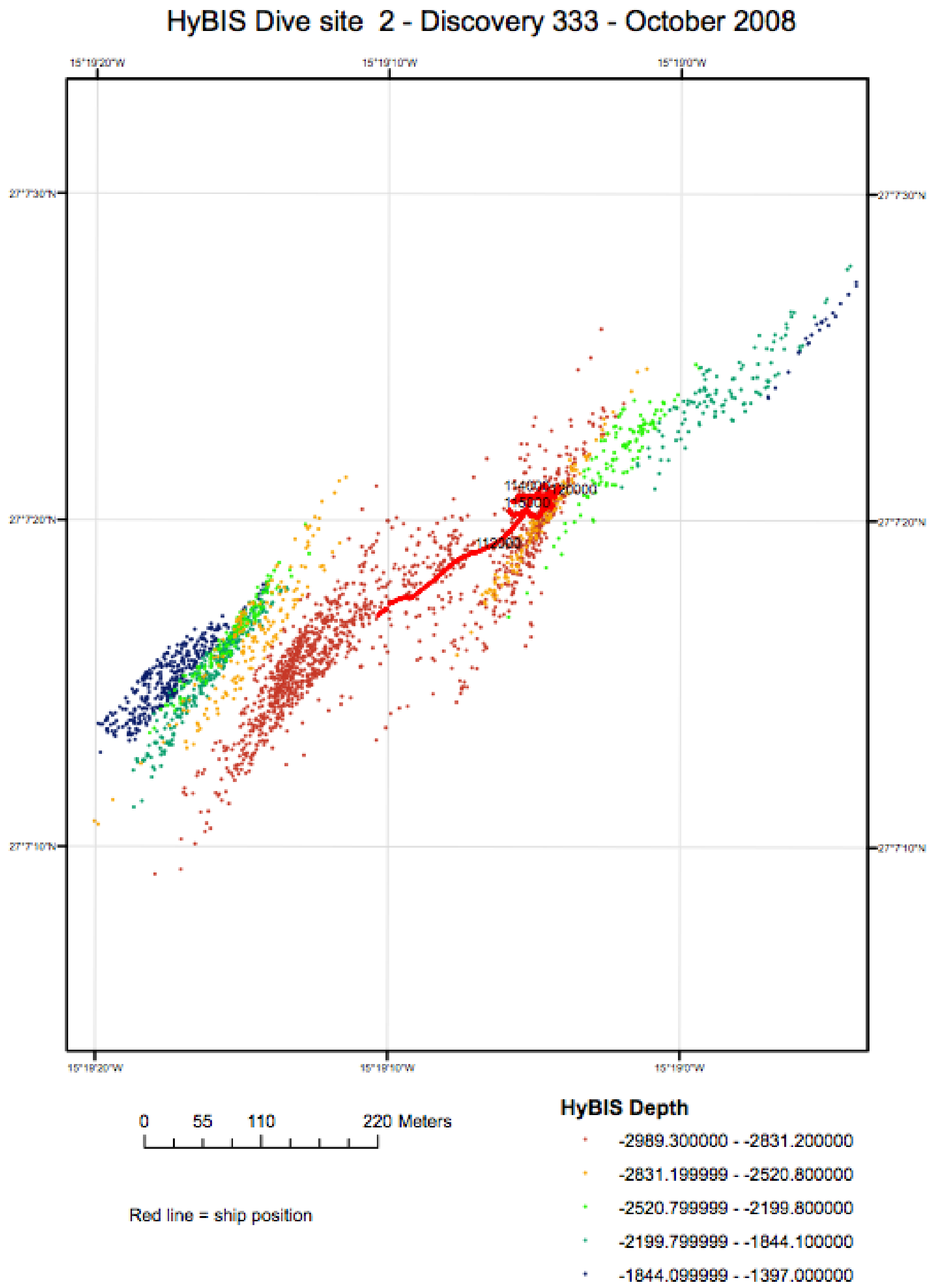


Figure 20 HyBIS dive 2 coloured dots are acoustic USBL navigation of HyBIS. The positions are poor due to a location of the beacon inside the vehicle causing interference.

7.1.4 HyBIS Dive 3

Date: 18th October, 2008.

Station Number: 16455#A

Location: 27° 42.10'N; 14° 47.20'W; depth 2340m.

Target: Flat sea floor 8 nautical miles due south of Fortevetura Island. The vehicle was deployed in command module configuration, with 50kg of payload plus 30m of cord marked off every 2 metres with a piece of weighted white rag and without its grab. The objective was to test payload delyment (via the emergency release bolts) and to measure the manoeuvrability range with a calibrated line. The end of the line was attached to the 50kg payload and a 5kg depressor weight.

Sea-state calm 1, wind 10-15 kts from the NE.

7.1.4.1 Dive summary:

At 1230 GMT HyBIS was launched and descended at 30 metres per minute. The vehicle was fitted with a Sonardine USBL beacon outside the vehicle's frame and another beacon 50m up on the umbilical wire. At 1333 GMT the vehicle was at 2325m depth and in sight of the bottom. The sea floor was found to be fat and covered in clay ooze. Vetical visibility was at least 18m. USBL position fixes were god from both vehicle and wire (error ±5m). At 1348 GMT the package was released, but one of the tag lines failed to let go. It was found to have been wrongly fastened.

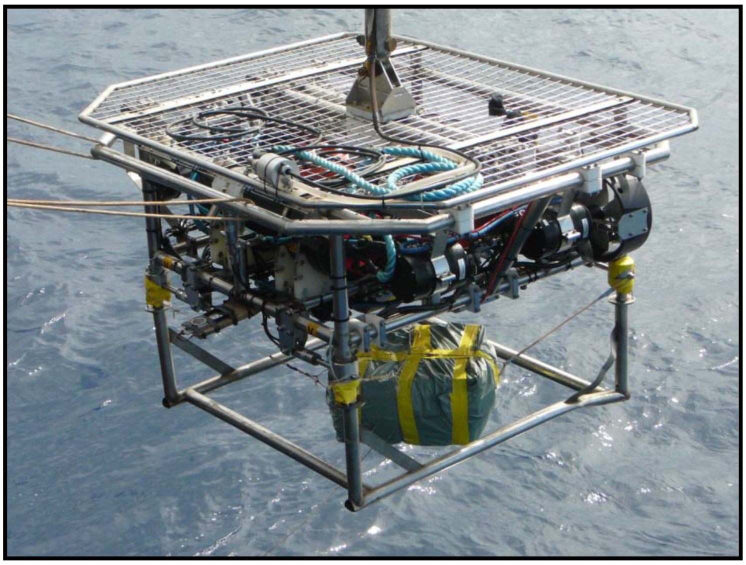


Figure 21 HyBIS configured as a payload delivery vehicle. A 50kg payload was slung under the vehicle and suspended on lines attached to the hydraulic release bolts.

The vehicle returned to the surface at 40m/min and was secured and powered off at 1450 GMT.

7.1.4.2 Results:

All systems functioned and the USBL fixes were found to be very good (especially depth (±1m) with an error of ±5m at 2240m range. Vehicle manoeuvrability was good achieving a radius of manoeuvre of about 50m at a speed of 0.3 kts.

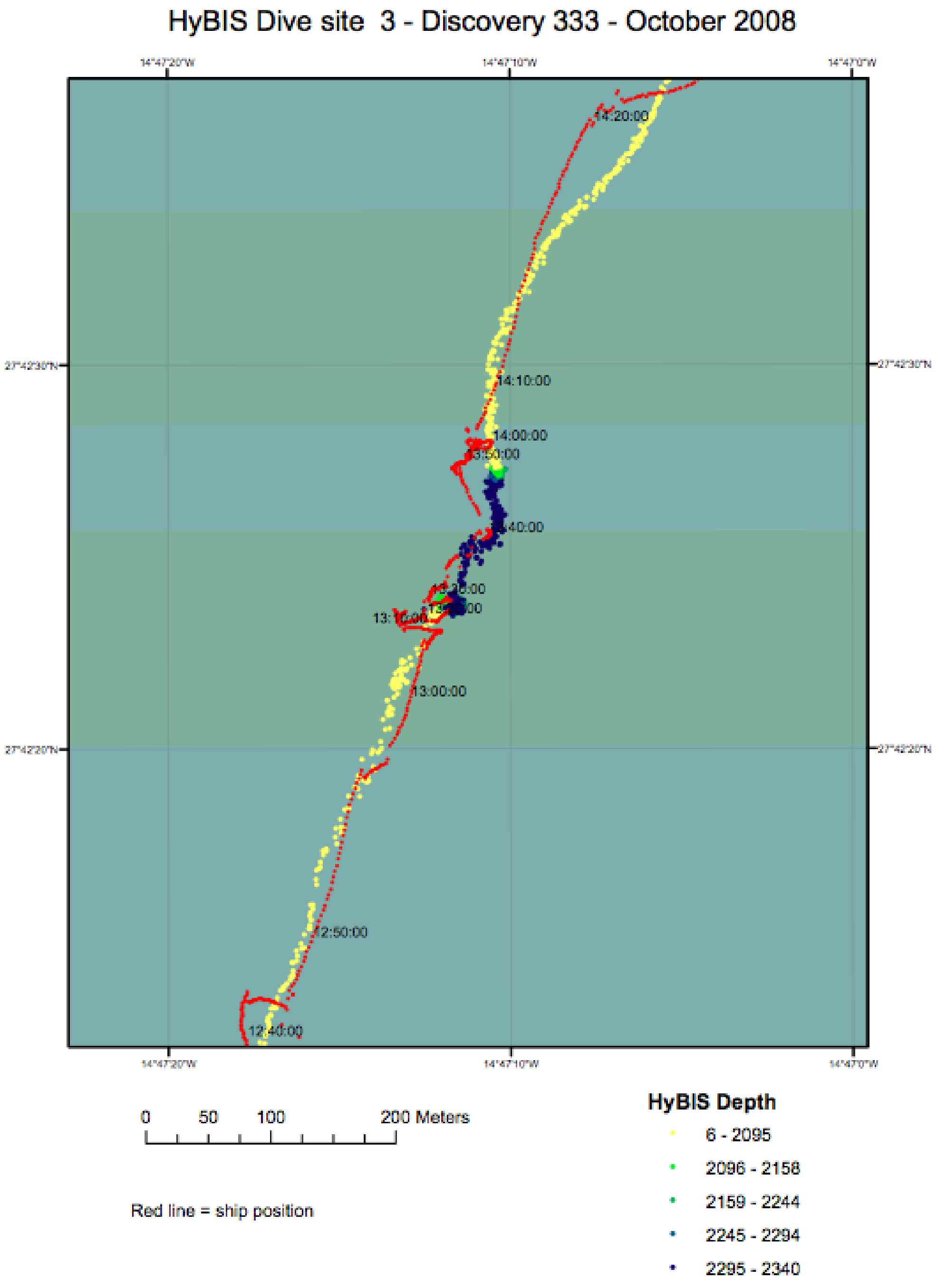


Figure 22 HyBIS dive site 3 depth coloured dots are acoustic USBL navigation or HyBIS. The positions are good to within ±3m due to a location of the beacon on the outside the vehicle.

7.1.5 HyBIS Dive 4

Date: 18th October, 2008.

Station Number:

Location: 27° 42.10'N; 14° 47.20'W; depth 2340m.

Target: Flat sea floor 8 nautical miles due south of Fortevetura Island. The vehicle was deployed in command module configuration, with 10kg of payload plus 30m of cord marked off every 2 metres with a piece of weighted white rag and without its grab. The objective was to test payload deployment (via the emergency release bolts) and to measure the manoeuvrability and range with a calibrated line. The end of the line was attached to the 10kg payload and a 2kg depressor weight.

Sea-state calm 1, wind 10-15 kts from the NE.

7.1.5.1 Dive summary:

At 1603 GMT HyBIS was launched and descended at 30 metres per minute. The vehicle was fitted with a Sonardine USBL beacon outside the vehicle's frame and another beacon 50m up on the umbilical wire. At 1725 GMT the vehicle was at 2300m depth and had deployed the payload after puling the calibrated line tight. The sea floor was found to be fat and covered in clay ooze. Vetical visibility was at least 18m and horizontal visibility 15m-20m. USBL position fixes were god from both vehicle and wire (error ±5m). At 1840 GMT the vehicle returned to the surface at 40m/min and was secured and powered off at 2000 GMT.

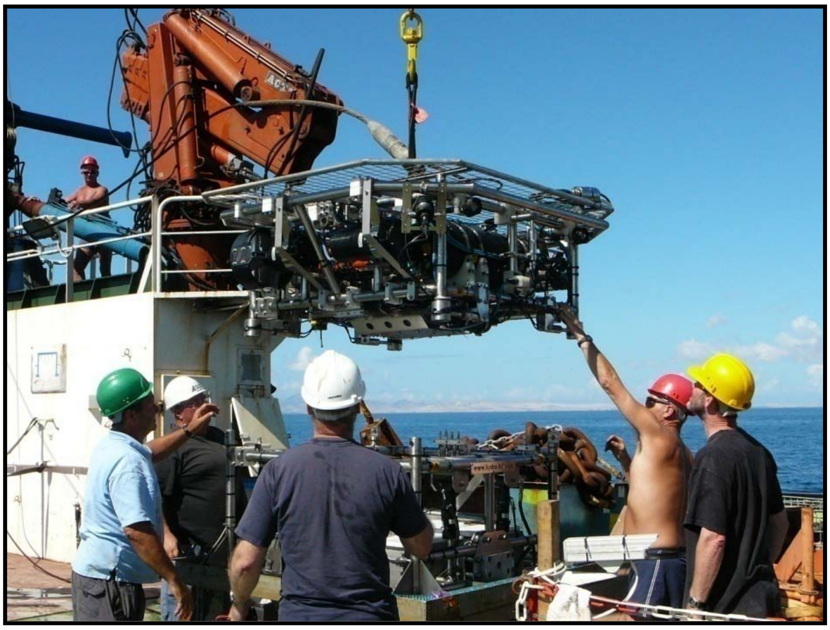


Figure 23 HyBIS being split in preparation for its configuration as a payload delivery vehicle. The command module readily pulls apart from the bottom sampler

7.1.5.2 Results:

All systems functioned and the USBL fixes were very good (depth ±1m and lateral position ±5m at 2240m range). Vehicle manoeuvrability was better with a lighter configuration achieving a radius of manoeuvre of about 80m at a speed of 0.3 kts. This confirmed the view that some vehicle buoyancy (and umbilical buoyancy) would increase range and decouple ships heave.

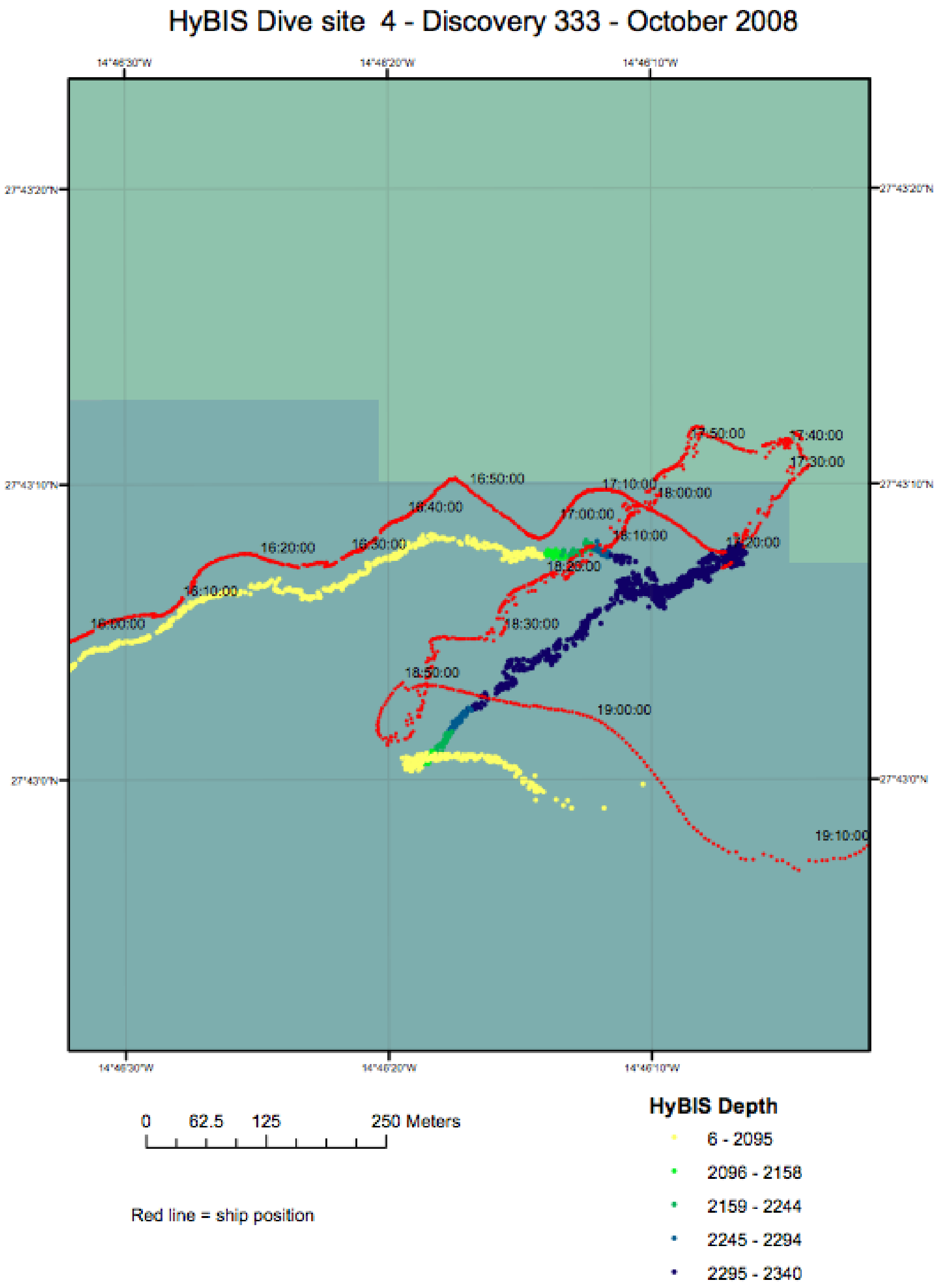


Figure 24 HyBIS dive site 4. Depth coloured dots are acoustic USBL navigation of HyBIS. The vehicle was able to manoeuvre within a 50-100 metres radius from the ship.

7.1.6 HyBIS Dive 5

Date: 20th October, 2008.

Station Number: 16460#A

Location: 27° 59.664'N; 14° 01.032'W; depth 1698m.

Target: Flat sea floor 6 nautical miles due south of Fortevetura Island. The objective was to search and locate a lander, deployed earlier by POL. The lander was fitted with a blinking green LED flashing unit. Ranges to the acoustic releases had yielded at position with in an area of 32 x 38 metres square. The vehicle was deployed in its normal sampling grab configuration.

Sea-state calm 1, wind 10-15 kts from the NE.

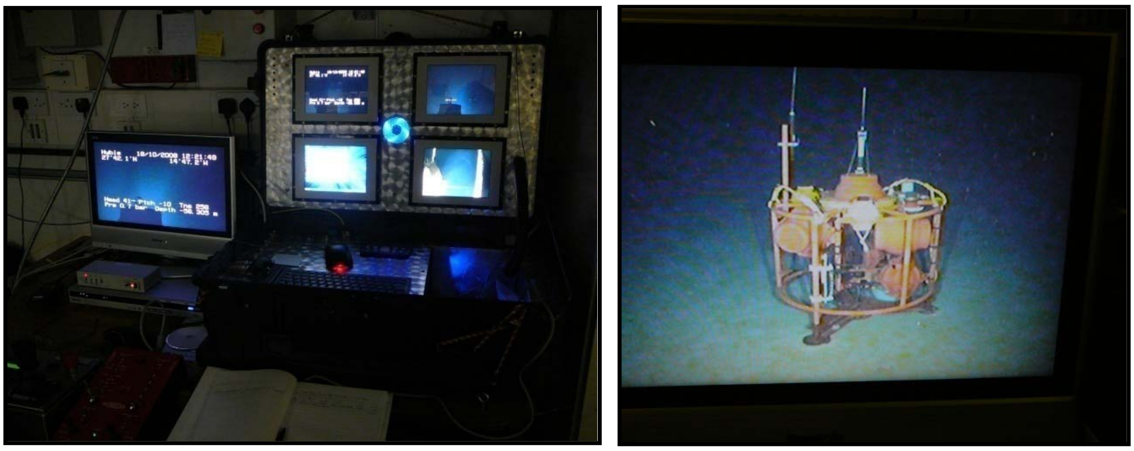


Figure 25 Left: HyBIS control consol, digital video recorder and display screens (built by Ed Waugh and Robin Brown). Right: POL lander, located on seabed in 1698m of water.

7.1.6.1 Dive summary:

At 0754 GMT HyBIS was launched up-current with a range to the target of 1200m. It then descended at 30 metres per minute. The vehicle was fitted with a Sonardine USBL beacon outside the vehicle's frame. At 0923 GMT the vehicle was at 1606m depth and 100m SW of the target. Ship's speed was 0.8 kts over the ground. At 0938 GMT the bottom was sighted and the vehicle was at a depth of 1652m. The sea floor was found to be fat and covered in clay ooze. Heading NE towards the target under full thrust at 0.3 kts, the ship was 180m to the NNE and slowed to 0.2 kts. Current of ~0.3kts from the north east. USBL position fixes were god from the vehicle (lateral error ±5m, vertical depth error ±1m). At 0956 GMT the Lander was sighted and video footage taken as we circled the target. At 1030 GMT an insitu stalked sponge was sampled, including its roots in the sediment, and the vehicle returned to the surface at 40m/min. The sample remained undisturbed until it broke clear of the surface. The vehicle was secured and powered off at 1130 GMT.

7.1.6.2 Results:

All systems functioned and the USBL fixes were very good (depth ±1m and lateral position ±5m at 2240m range). Ship following capability an vehicle manoeuvrability were good, achieving a radius of manoeuvre of about 50m at a speed of 0.3 kts. Ship's heave was minimal at the vehicle, although the sea states was light. The flashing LED was visible at a range of 50 to 60m in the dark and 40m with the front lights on. Heading control and compass were sufficiently stable to enable a steady course to be maintained towards the target.

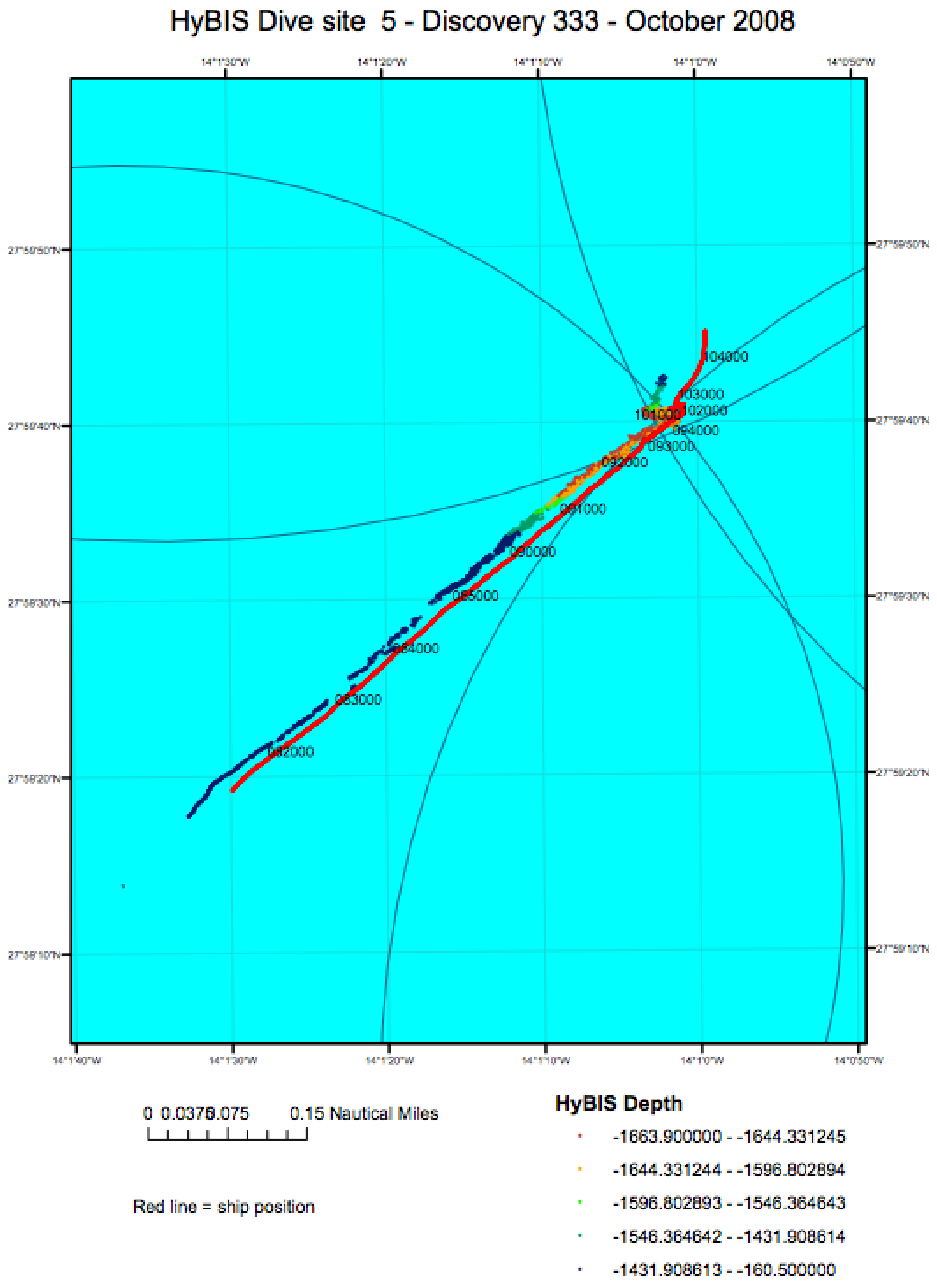


Figure 26 HyBIS dive site 5. Depth coloured dots are acoustic USBL navigation or HyBIS. The arcs describe the ranges to the POL lander made using its acoustic releases. The vehicle was able to manoeuvre within a 50 metres square, formed by the intersection of the arcs

7.1.7 HyBIS Dive 6

Date: 20th October, 2008.

Station Number: 16462#A

Location: 27° 59.6'N; 14° 01.1'W; depth 1682m.

Target: Flat sea floor 6 nautical miles due south of Fortevetura Island. The objective was to search, locate and recover the POL lander. The lander had failed to release from the sea floor and was considered lost. Its value was estimated at £50,000, its weight in water was 110kg and 360 kg in air. All acoustic release had failed to fire and the dive was in response to a request for assistance from the POL team to recover their lander. HyBIS was deployed in its normal sampling grab configuration, but with a 10m line and grapple suspended below and held fast in the grab bucket. This was to enable us the option to make a controlled jettisoning the payload, should its releases fire and become buoyant while being recovered. A full risk assessment and procedure was developed after consultation with the POL team, ship's officers, captain, deck crew and the HyBIS team (see below).

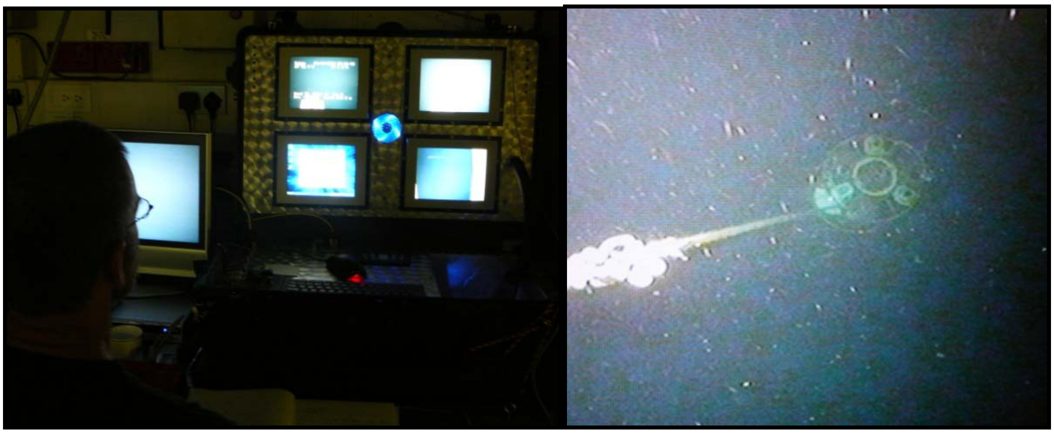


Figure 27 Joe Garrard (left) at the controls of HyBIS during the ascent, after the POL lander was recovered from the sea floor in 1700m of water (right).

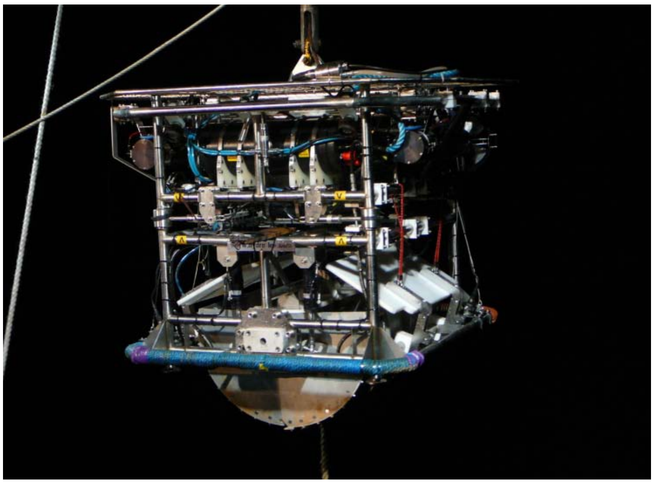
Sea-state calm 1, wind 10-15 kts from the NE.

7.1.7.1 Dive Summary:

At 1740 GMT HyBIS was launched up-current with a range to the target of 350. It then descended at 35 metres per minute. The vehicle was fitted with a Sonardine USBL beacon outside the vehicle's frame. At 1800 GMT the vehicle was at 582m depth and 300m SW of the target. Ship's speed was 0 kts over the ground. At 1842 GMT the bottom was sighted and the vehicle was at a depth of 1622m. HyBIS was under full thrust and moving at 0.3 kts towards he target position, 230m to the towards 070°. At 1850 GMT the lander was sighted and purposely nudged by HyBIS five times but to no avail. At 1854 GMT the Lander was grappled from above and both HyBIS and its payload began their ascent at 20m/min. At 2050 GMT, the vehicle was powered down, still at a depth of 150m, and surface recovery started. At 2130 GMT both the vehicle and lander were returned to the ships deck and secured.

7.1.7.2 Results:

The vehicle proved its capability to relocate a target, attach a line and recover a heavy and large payload. The method of deploying a grapple on a 10m rope below the vehicle was not optimal and would have been better loosely secured to a boom extending to the front of the vehicle. This would have enabled better control and visibility of the grapple. The method of securing the line to the grab bucket, enabling an emergency release of the payload was successful.



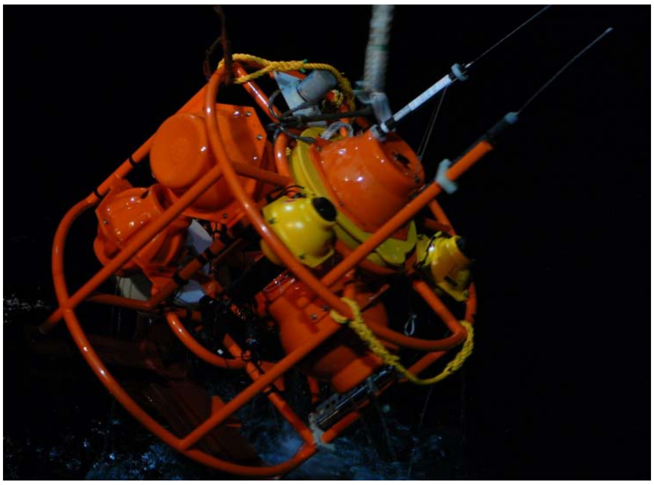


Figure 28 HyBIS and the POL lander recovered to the surface and lifted clear of the water at the end of the search and rescue mission

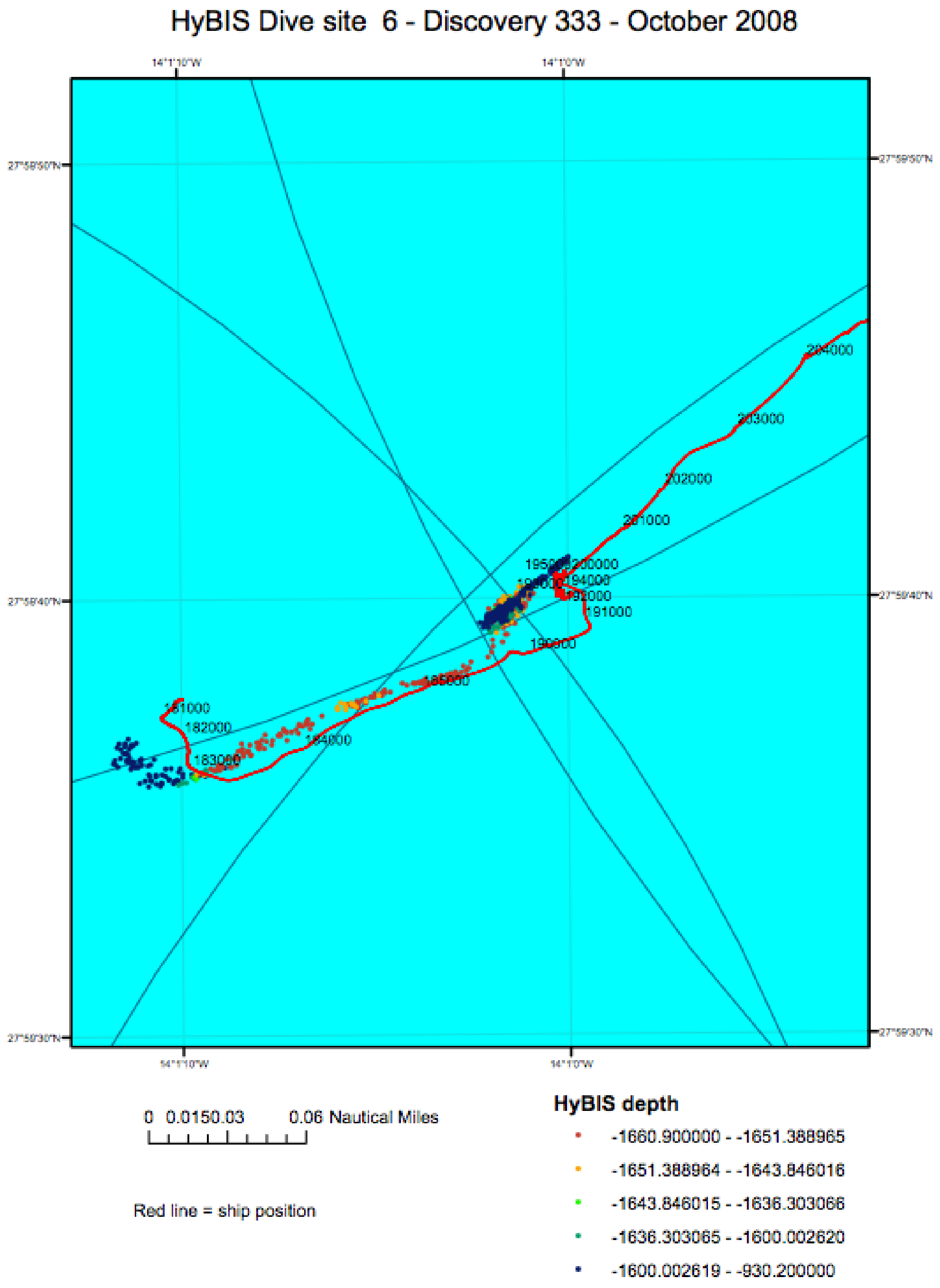


Figure 29 HyBIS dive site 6. Depth coloured dots are acoustic USBL navigation or HyBIS. The arcs describe the ranges to the POL lander made using its acoustic releases. The vehicle was able to located and recover the lander

7.1.8 HyBIS Dive 7

Date: 23rd October, 2008.

Station Number:

Location: 27° 34.6'N; 15° 44.6'W; depth 1271m.

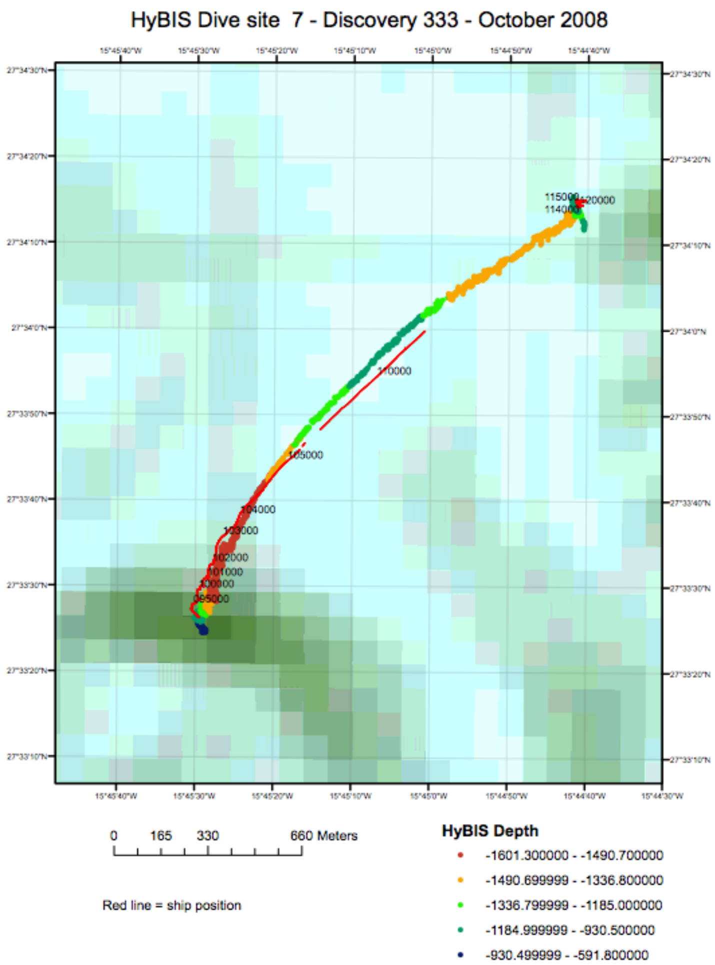
Target: Seamount, 500m high, wit bright backscatter, 12 nautical miles due south of Gran Canaria Island. The objective was to sample rocks.

7.1.8.1 Dive Summary:

At 0930 GMT HyBIS was launched up-current with a range to the target of 2350. It then descended at 35 metres per minute. The vehicle was fitted with a Sonardine USBL beacon outside the vehicle's frame. We quickly established that the vehicle was too far from the target, and towed it at 1 kt with the ship. As a result, the vehicle and umbilical streamed behind the ship. When near the bottom, the vehicle was difficult to control as the umbilical was always pulling ahead. Sampled some gravel and sand, and returned to the surface at 1330 GMT.

7.1.8.2 Results:

The vehicle proved difficult to manoeuvre which excessive cable streamed behind the ship.



7.1.9 Conclusions from testing of the HyBIS vehicle:

1. **Corrosion**: In places where aluminium components are in contact with stainless steel, there is a tendency for corrosion. This is especially apparent for the fulcrum boss at either side of the grab bucket. A solution of hard anodising, sacrificial anodes and isolation between the materials is required.
2. End-caps on the pressure pods show corrosion where the hard anodising surface has been damaged. Sacrificial anodes need to be attached to the pressure pods.
3. Corrosion of the aluminium grab bucket needs to be addressed using sacrificial anodes.
4. **SeaEye Marine Ltd. Compass board**: Depth, hydraulic pressure and heading data are erratic. Compass needs calibrating properly, probably on a turn table on land. Also needs pitch and roll correction.
5. **Hydraulic function under pressure**: The hydraulic closure f the grab is slow under pressure. This might require a thinner in the hydraulic oil, a larger flow-rate pump, or patience.
6. **Water pump seals**: These leak compensation oil when a back pressure is applied to the compensation oil. For these trials, the pump was removed and an end plate fitted. The pump may not be required as no discernable pull-out was encountered during sediment sampling. Also, the sample grab can be opened, jettisoning the ample and releasing the grab from the sea floor. In this case, the control and power functions supplying the water pump and be diverted to another system – e.g. an electric pan and tilt or slurp gun.

7.1.10 Modifications and spares:

1. **Dedicated termination bottle**. This can be a 150mm external diameter x 300mm long oil-filled bottle with dedicated optical and electric bulkheads.
2. **CTD with A to D ports and a single multiplexed serial data connection**. This would enable both accurate depth and scientific sensor functions. Make use of one of the three spare bulkhead ports on the electronics pod.
3. **Bucket closure indicator.** A simple LED and micro-switch would suffice, internally powered and visible from the camera inside the bucket.
4. **Laser scaling:** both vertical and forward looking paired parallel lasers (green).
5. **Bumpers** on lower frame to protect it from impact with hard materials.
6. **Polypropelene skids** for use on command module when in survey configuration.
7. **Floatation**: on top of command module (achieving 200-300kg of buoyancy) and floats on lower 50m of the deep-tow umbilical cable (latter similar to the detachable floats used with ISIS). This would enable more manoeuvrability and decouple some of the ship's heave from the vehicle.
8. **Third video camera**: embedded in a floatation unit attached to the umbilical cable 5 m above the vehicle. To enable contextual images of the sea floor and vehicle. Would use the spare video channel on board the vehicle.
9. **Digital stills camera and flash unit**: Either commanded or automatic, vehicle or self powered. Could be self-logging and down-loaded on deck by cable or wifi link. Prefer stand alone self powered and self logging for simplicity.
10. **Sample tray and five function sample arm**: For complete flexibility, this would make use of the five hydraulic functions available from the surplus valve pack. The sample tray would extend and retract, powered by the hydraulic function current used to supply the grab. The down-looking camera and 50W light would be attached to the wrist to enable continuous viewing of the sampling claw.

7.2 Wave Buoy (Robin Pascal)

7.2.1 Introduction

A spar buoy has been developed and instrumented at NOC to simultaneously record (by video) and measure (by capacitance wave wires) whitecap coverage and wave breaking. The aim is to develop and improve parameterisation of wave breaking and its contribution to gas exchange. The buoy has been designed to log all data internally and be independent of the ship. Maximum deployment times are approximately 5 days, but shorter deployment periods were used during the trials. The spar buoy is a unique design and its performance and systems are evaluated in the following sections.

7.2.2 The spar buoy

The spar buoy is 11 m in length and constructed of Aluminium to save weight. The buoy floated vertically in the water and uses specially aligned weights to orientate the buoy into the wind (Figure 1a). Two 12 V batteries are located at the base of the buoy and were used to power the instruments and logging systems. The buoy was ballasted by a 40 kg weight deployed 10 m below its base for all deployments (Table 2). Three 4m wave wires stretched along most of the top yellow section and were used to measure the wave height relative to the buoy. The three wave wires are perpendicular to each other and separated by a distance of 0.14 m (Figure 1b). The orange dome contained the wave wire electronics, a digital video recorder and a stills camera to record the images of the waves and identify breaking waves.

The large hoop above the dome is used for buoy recovery. To aid recovery the buoy was located by an Argos positioning system, which can also be for directional finding using the Gonio system and emails a position every hour (fig 4). In addition, for over night deployments a flashing light with RF beacon was installed.

7.2.3 Instrumentation

7.2.3.1 Wave breaking system

Wave elevations, buoy motion and compass data were logged to a 1 Gbyte flash card at 45.056 Hz and 8 Hz respectively. Data were typically written to the card in 20-minute sections. The logger system clock, video and stills camera time were set to ships time before each deployment. The wave wires were calibrated in Santa Cruise dock on day 286, before the start of the cruise. The wave wires were calibrated in Santa Cruise dock by suspending the buoy top section from a crane and taking measurement at various heights along the spar. In addition on day 295, after some circuit modifications. the system was re calibrated with a test wire in a bucket. At the same time, in an effort to ensure the there could be no water tracking across wires at the cable end joint, all wires were replaced and the joint was potted in epoxy. The calibrations applied are shown in Table 1.

	Wave wire	Height=m*(register)+c	
		m	c
Santa Cruise (Day 286)	0	0.000068912	-0.30413
	1	0.000068773	-0.19465
	2	0.000069068	-0.32167
Bucket (Day 295)	0	0.000070222	-0.35184
	1	0.000070809	-0.34926
	2	0.000070931	-0.35028

Table 1 Calibrations applied to the wave wire data.

The base of the dome is transparent allowing the camera systems to record the waves travelling past the wave wires. The JVC hard disk camcorder records video to an internal hard disk in Mpeg 2 format and will last approximately 37 hours before the disk is full. The Nikon Coolpix 5400 stills camera records 16 images (at 5 MP) over a period of 7 seconds (2.3 images per second) with a 7 second pause in-between. The images are arranged in a 4x4 matrix at a resolution of 648x486 pixels. The images will fill the 2 Gbyte card in approximately 17 hours. The cameras times are synchronised with the logger time by using LCD displays which show logger minutes and seconds and can be seen in the frames of both camera's.

The logging system and cameras were initialised in the lab and the dome sealed by a number of bolts. The system was taken out on deck and connected to the buoy. Water ingress into the dome was not encountered during the deployments, even when the dome is submerged beneath the surface during deployment or recovery.

7.2.4 Spar buoy performance

A total of seven deployments were made during the cruise. A test deployment (D333#001) was performed in the lee of Fuerte Ventura to allow the ships officers and crew to familiarise themselves with the launch and recovery of the spar. The preferred method is to deploy with ship's starboard beam facing the wind so the ship is blown away from the buoy. A summary of the deployments is contained in Table 2.1. During deployments visual inspection of the buoy was made and showed that the buoy was orientation in to the winds and seas as expected.

7.2.5 Initial Results

7.2.5.1 Wave wire system

During the test deployment (D333#001) the source wire for the wave system was broken within the dome and so no wave data was recorded. This was rectified and the buoy was then deployed for 3 days and was tracked by use of its Argos transmitted (fig4). On recovery it was found that the wave wire system and failed after nearly 2 hrs. The first 100 minutes though produce good quality data and was subsequently analysed to give the wave parameters for the period while the wires work (table2). Subsequent test of the system in the lab could not reproduce the fault that caused the wire data to fail. This became an ongoing problem throughout the cruise, where modifications to the buoy electronics failed to resolve the issue, but also that lab testing and calibrations failed to produce the fault seen when the buoy is deployed in the ocean. On day 296 the dome and 3 test wires were hung from the starboard aft crane and the serial output from the logger was monitored for over 2 hrs to see if the fault could be reproduce. During the entire test the electronic and wire data worked correctly, but on the full deployment that followed the wave wires failed as soon as the buoy entered the water. Unfortunately this fault could be identified or corrected during the period of the cruise.

7.2.6 Future improvements

Clearly the fault encountered during the trial cruise must be identified and corrected. Since the buoys initial development there have been a number modifications to the buoy electronics. It is therefore planned to rationalise the system, by removing from the design those area's, which are, not need in the future and to have all circuits professional fabricated into PCB boards.

Table 4 Table 2 Spar Buoy deployments during the cruise

Launch No	JDay	Launch Time (GMT)	Deployment Lat (N)	Deployment Long (W)	JDay	Recovery Time (GMT)	Recovery Lat (N)	Recovery Long (W)	Comments
D333#001	289	07:37	28° 05.88	014° 10.4	289	10:12	28° 05.4	014° 10.7	Short test deployment
D333#002	289	14:49	27° 58.6	013° 57.5	292	07:25	27° 51.6	014° 48.5	Standard setup 100mins good data
D333#003	293	08:50	27° 59.2	014° 01.7	293	18:08	27° 55.5	014° 05.3	Standard setup
D333#004	294	13:42	28° 00.196	014° 00.877	295	07:53	27° 57.4	014° 11.9	Internal Batt.
D333#005	295	14:15	27° 59.6	014° 01	295	17:54	27° 59.6	014° 03.0	Internal Batt. Approx 30 mins of good data
D333#006	296	13:12	27° 57.34	014° 04.13	296	18:39	27° 55.5	014° 07.6	No Stills, No Argos, Internal Batt. Dome isolated
D333#007	297	08:06	27° 36.3.0	015° 46.6					No Stills or Video Camera's, No Argos, Internal Batt. Dome isolated
D333#cal	288	15:00	-	-	288	15:30	-	-	Calibration (Santa Cruise Dock)
D333#dome	296	09:03	27° 59.0	014°01.4	296	11:10	27° 59.0	014°01.2	Dome & wires held off crane

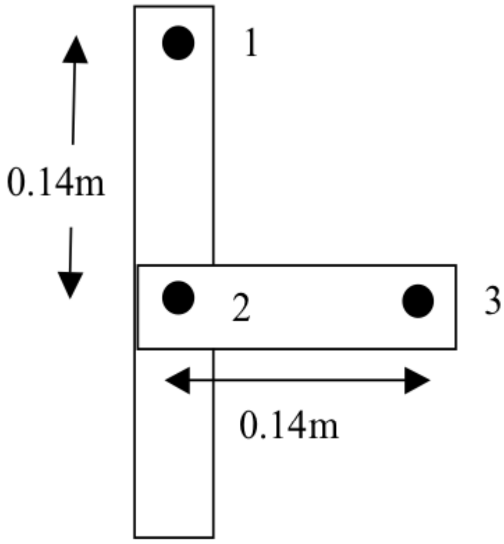


Figure 30 A breaking wave passing through the spar buoy (left) and configuration of the three wave wires

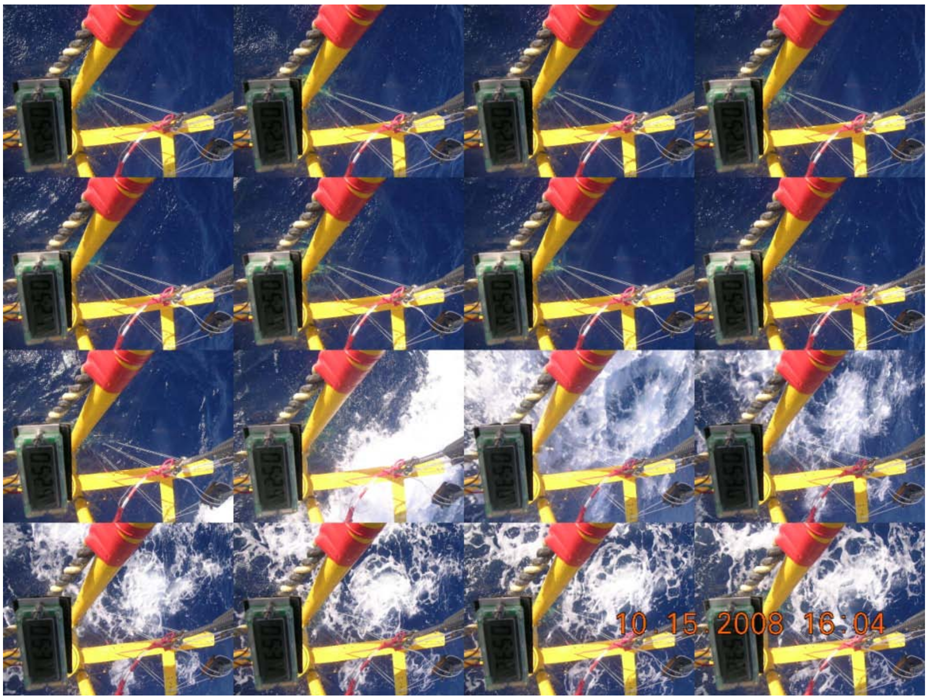


Figure 31 Spar Buoy Images from the stills camera showing the breaking wave shown in Figure 23 A breaking wave passing through the spar buoy (left) and configuration of the three wave wiresFigure 23. Each image is taken at approximately 0.5 seconds intervals.

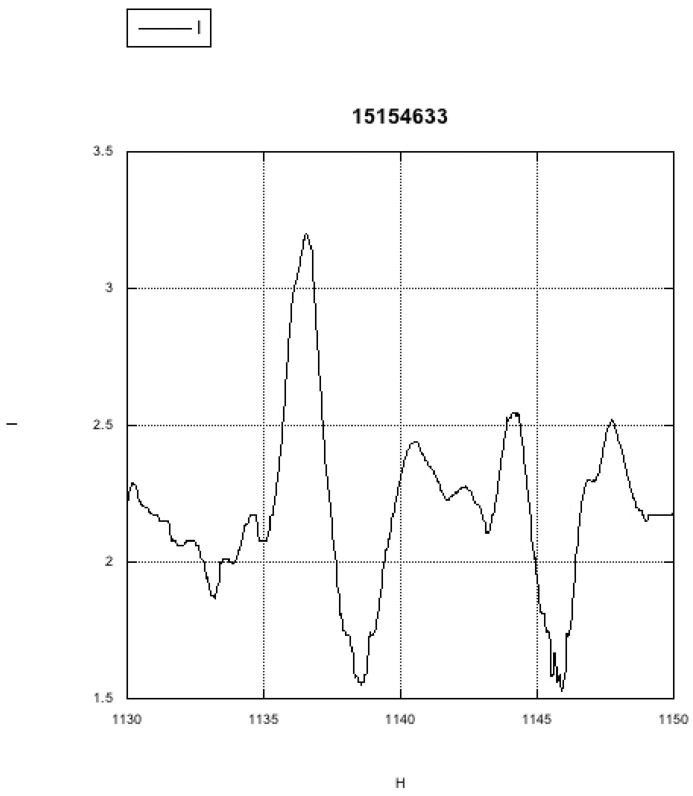


Figure 32 A 20 sec example of a wave trace from wire 0. The large wave with a steep peak coincides with the breaking wave identified in both video and stills camera images (Figure 24).

Table 5 Wave statistics from Deployment 2. Files used were 15144633.TXT and 15154633.TXT

Jday	Hs	Tz	Te	Tp
289.6260681	1.6581	4.3604	9.1930	6.9924
289.6330261	1.4064	3.8732	7.8574	5.5939
289.6399536	1.5245	4.0252	9.4479	15.809
289.6469116	1.5100	4.0530	9.5137	6.7334
289.6538391	1.4357	3.8600	8.3526	6.9924
289.6607971	1.5546	3.9448	9.3989	18.180
289.6677551	1.4923	3.8877	8.4540	6.6110
289.6746826	1.3057	3.2418	7.9783	6.8605
289.6816406	1.4797	3.6592	8.9137	7.5751

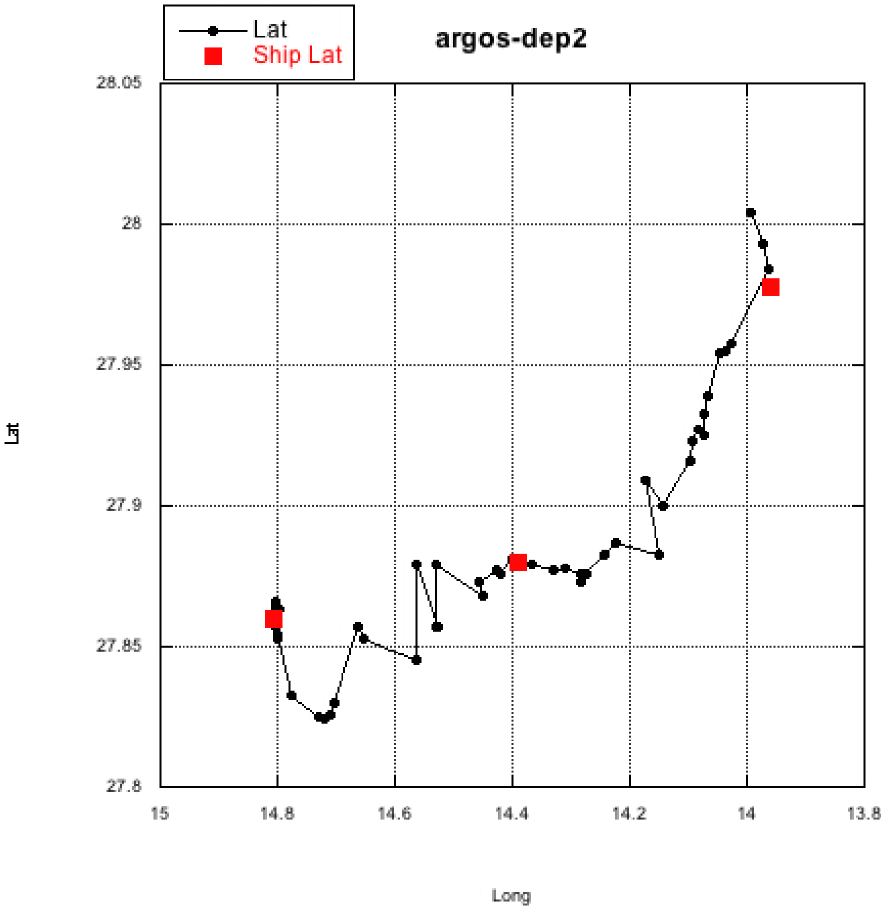


Figure 33 Track of Spar Buoy during deployment 2. Buoy Argos data (Black circles), Ship fixes (red squares).

7.3 Multi-corer Deployments – D333

Alan Sherring

The OBE-NOC Multi-corer had been fitted with a new, more compact design of external tubular frame. The purpose of sending the corer on D333 was to carry out at least one trial deployment to prove the structural integrity of the redesigned frame and its correct operation.

Two deployments were carried out, one at 1672m depth and the other at 3000m depth. Both deployments were carried out from the aft deck using the ship fitted coring winch and the aft gantry. A pinger was fitted to the wire at 50m wire out. On both deployments the corer was lowered into and pulled out of the sediment at 10m/min. Maximum speed through the water was 40m/min in both haul and veer. Both deployments were carried out in calm sea conditions.

Both deployments resulted in good samples which varied from 150mm to 210mm depth. The water sample trapped above the sediment was clear and showed little or no signs of disturbance. The external frame showed no signs of distortion of damage after deployment. The corer was washed in fresh water after the second deployment.

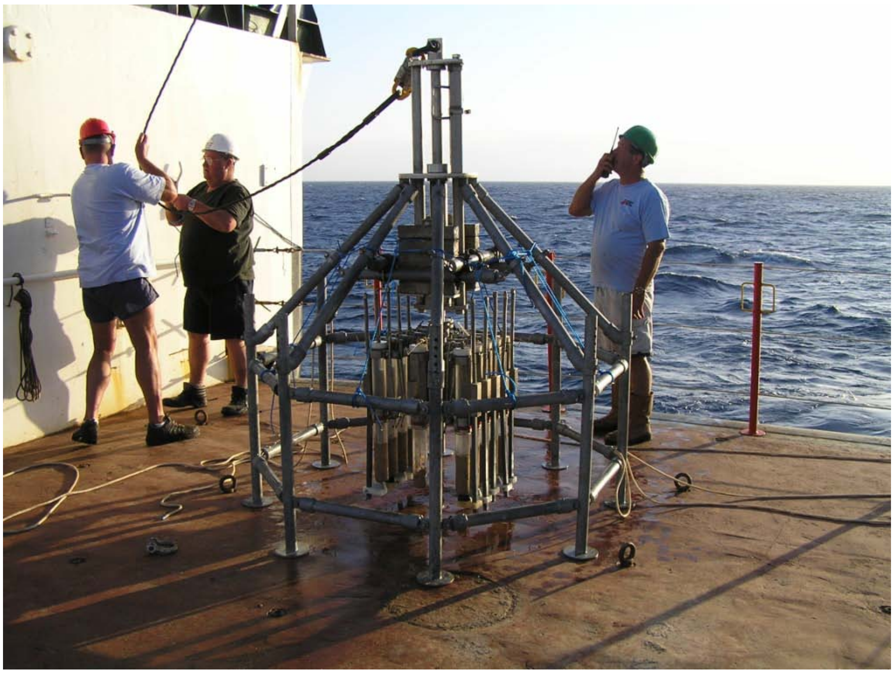


Figure 34 Multicorer on aft deck

Figure 35 Image of multicore samples showing all tubes had penetrated and sealed successfully

Figure 36 Detail of sediment water interface showing very little disturbance

7.4 POL Telemetry trials

Chris Balfour

7.4.1 Overview

This section gives a brief outline of the data telemetry trials undertaken by POL. The trials consisted of tests associated with the POL telemetry buoy to check telemetry systems for remote measurements (Orbcomm and Meteosat). These tests used a Seabird MicroCAT attached to the mini-MYRTLE lander frame to provide data to the surface buoy via LinkQuest acoustic modems. Bi-directional communication with the sea bed instrumentation was trialled to demonstrate remote instrument configuration using e-mail based commands.

7.4.2 Day 1 – Monday 13/10/08

The telemetry buoy tower was assembled with the Orbcomm units and LinkQuest acoustic modem to test the Orbcomm system and antennas. The system worked well and the MicroCAT was used to generate test data. This data was successfully transferred via Orbcomm and a test of bidirectional MicroCAT control was then attempted. An e-mail was sent from POL via Orbcomm to reconfigure the MicroCAT. This command was successfully processed indicating the correct operation of the Orbcomm system using a Quake Global data modem.

7.4.3 Day 2 – Tuesday 14/10/08

The day was spent assembling a wire test frame plus a mount for the LinkQuest surface modem. Trials of the BGAN remote internet connection modem revealed that no detectable signal could be found. Consequently it was not possible to use BGAN to provide a remote internet connection from the ship, making the trials more difficult in terms of sending e-mails to remotely reconfigure the instruments.

7.4.4 Day 3 – Wednesday 15/10/08

The ship set sail to 27° 59.942' N and 14° 0.232' W with a water depth of approximately 1600m. The test frame was lowered into the water using the coring winch and stern gantry. A pair of LinkQuest UWM4000 4000m communications range acoustic modems were used to relay measurements to the surface from a Seabird MicroCAT mounted on the test frame. The telemetry test setup and the wire test frame are shown in Figure 27.

The test began at 10:45GMT and finished at 14:00GMT. At noon a request to change the MicroCAT sample rate from 5 minutes to 15 minutes was issued. Although the Orbcomm modem received this command and processed it, the acoustic link proved to be problematic, preventing the MicroCAT sample rate from being changed. Corrupted data were regularly being transferred from the bottom modem to the surface modem, which prevented the bi-directional data transfer from operating correctly. A plot of the recorded MicroCAT data is shown in Figure 28. During the trial only one attempt was made to interrupt the MicroCAT logging. Problems associated with the acoustic link and the subsequent corruption of the data resulted in the attempts to re-configure the MicroCAT sample rate failing.

a– Telemetry tower on the after deck with antennas, battery packs and satellite modems attached

b – Wire test frame before deployment with LinkQuest and Benthos acoustics attached and a Seabird MicroCAT

Figure 37 Wire test setup

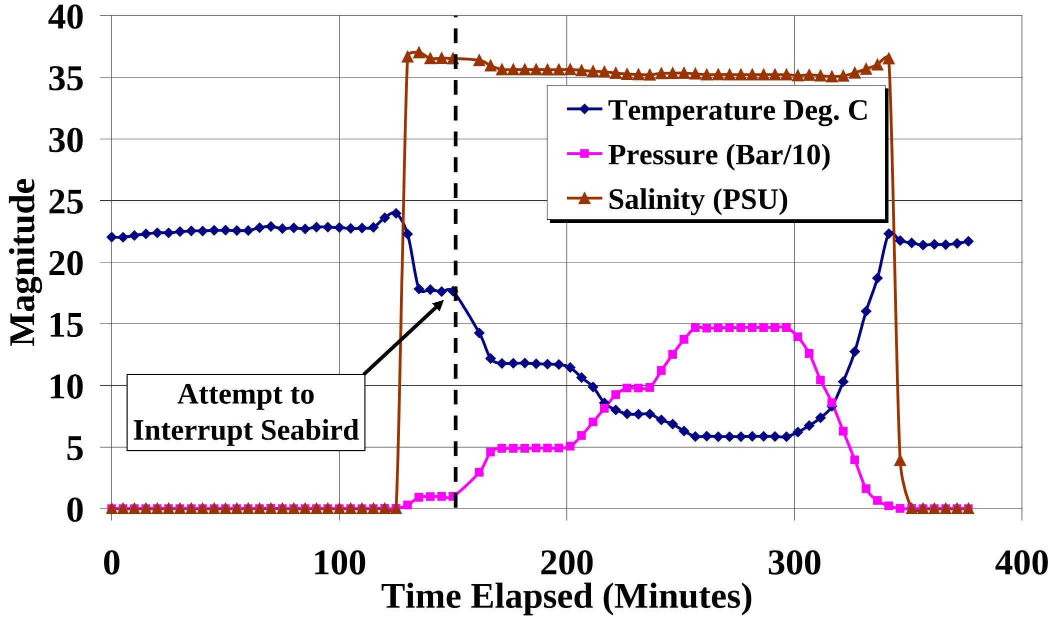
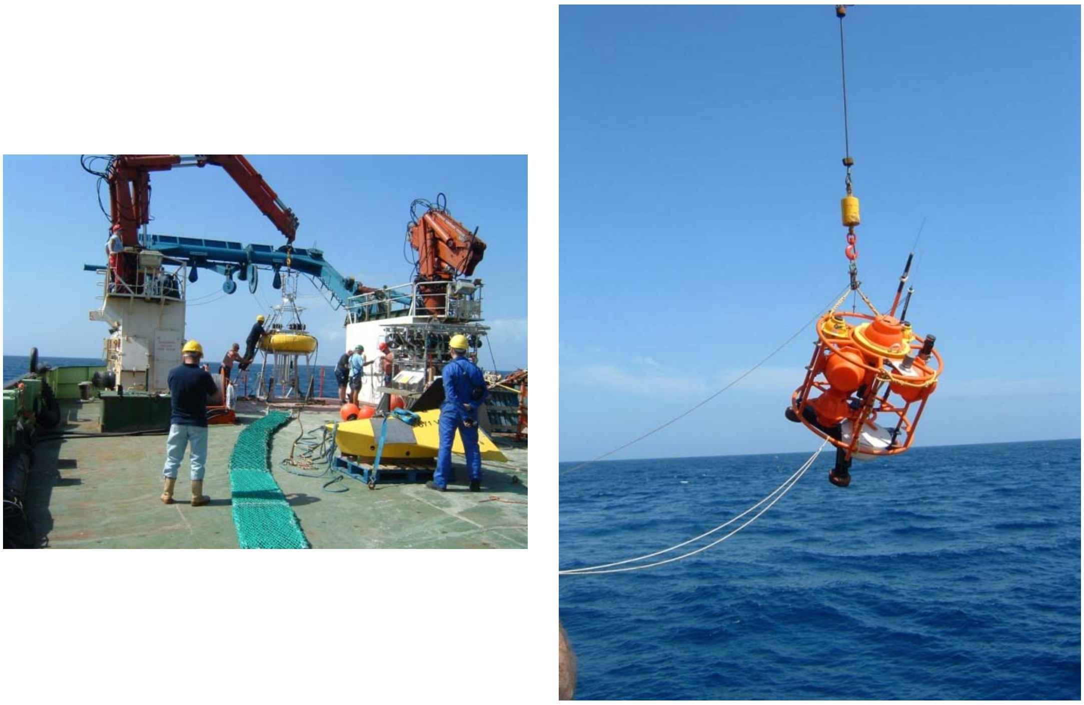


Figure 38 Recorded MicroCAT data

7.4.5 Day 5 – Friday 17/10/08

A full system test of the mini-MYRTLE lander in a similar location to the wire test was attempted in 1600m of water at 27° 59.927' N and 14° 02.095' W. Photographs of the deployment of the buoy and lander are shown in Fig. 3. The buoy used a drogue assembly to try to minimise drift.



a – Buoy and drogue Assembly b – mini-MYRTLE Deployment

Figure 39 Buoy and mini-MYRTLE deployment

Drift of the buoy meant that there was a 2 hour window to conduct the test due to the LinkQuest deep water acoustic modems having a beam angle of 70°, which corresponds to a surface range of approximately ±1km from the deployment site. During the test an e-mail command was sent from POL and although the acoustic data link was problematic an attempt was made to disturb the MicroCAT on the sea bed, as shown in the plot of the recorded data in Figure 30. It is evident is that the surface buoy has attempted to communicate with mini-MYRTLE via the acoustic link and the MicroCAT sampling has been disturbed.

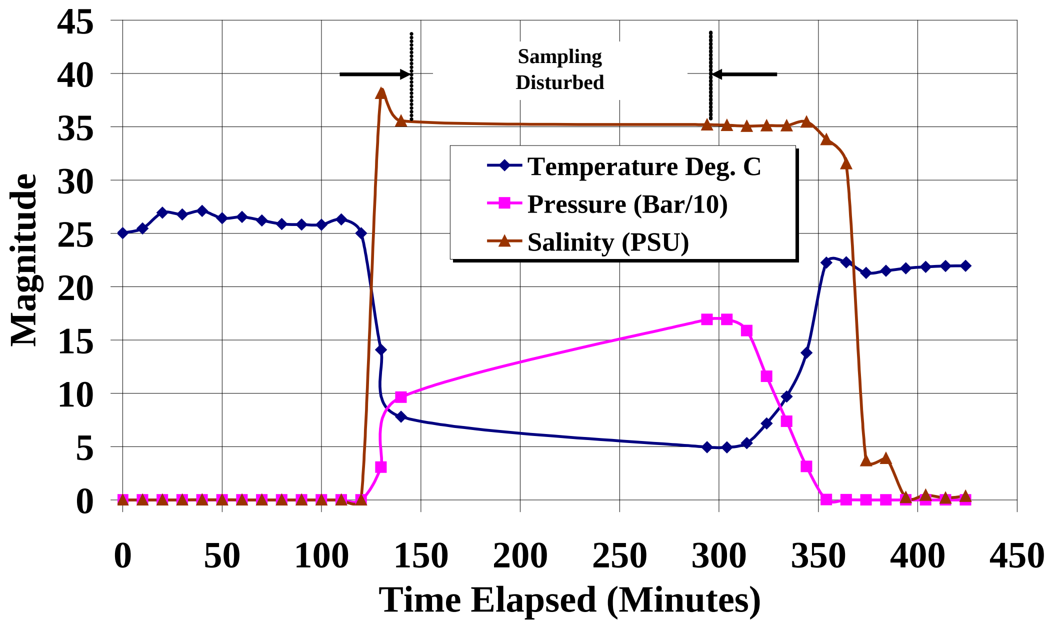


Figure 40 Recorded MicroCAT data for full deployment 1

It is likely that the system was working correctly and that the email command to the buoy was processed successfully. An acknowledgement from the buoy that the command had been sent was also received. It appears that the LinkQuest acoustic link has been problematic and corrupted the data transferred to and from the lander causing disturbance and not re-configuration of the MicroCAT.

7.4.6 Day 7 – Sunday 19/10/08

A full test of mini-MYRTLE and the telemetry buoy was undertaken. The earlier deployment had shown that the drogue assembly had little effect on the rate of drift of the buoy. Similar drift rates were observed with the spar buoy deployed during the cruise. Furthermore, the drogue was difficult to deploy and there was a risk of fouling the ships propeller. It was therefore decided to deploy the buoy without the drogue.

The frame was deployed at 27° 59.653' N, 14° 01.032' W. Reliable communications were confirmed between the surface and the various acoustic systems fitted to mini-MYRTLE during its descent and after its subsequent landing. A range of 1904 metres was reported by the LinkQuest surface modem, which corresponds to the depth of the frame plus drift of the ship from the deployment site. The ship then steamed upstream approximately 1 mile of the deployment site to perform a further communication check. The surface modem then reported a range of 3024 metres. The telemetry buoy was then deployed and allowed to drift over the mini-MYRTLE deployment site.

During the tests a series of e-mails were issued b rapid transfer using the ship's satellite communication link. These commands were then sent over the Orbcomm satellite network to the telemetry buoy data modem. The modem then decoded these emails and scripted a sample rate change to the MicroCAT at a depth of 1600 m. A command to change the sample rate to 30 minutes was issued first, followed by a command to change the sample rate to 60 seconds. A plot of the recorded MicroCAT data is shown in Figure 31.

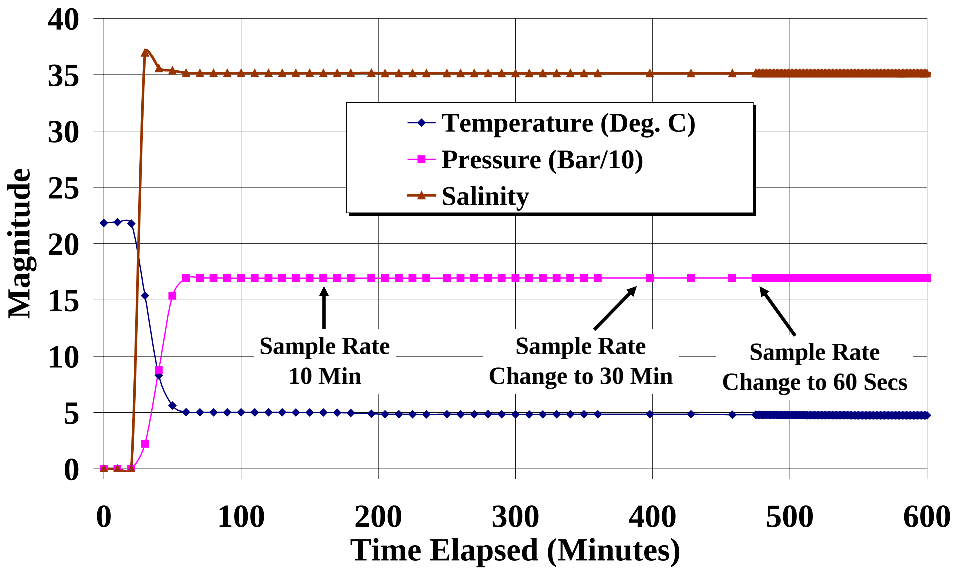


Figure 41 mini-MYRTLE re-configuration

7.4.7 Day 7 – Monday 20/10/08

Recovery of mini-MYRTLE was attempted in the morning. This was unsuccessful. Repositioning and switching off all the ship's acoustic systems had no effect. An attempt was then made to release the mini-MYRTLE data capsule using the Benthos Smart Modem After 2 hours it was clear that the data capsule had not released. After discussion with the Master, HYBIS team and crew it was decided to use HYBIS in an attempt to release the frame and if not successful, to attempt a full recovery. This is described elsewhere in the report.

7.4.8 Day 8 – Tuesday 21/10/08

Trials of Meteosat omni-directional DCP data transfer and Orbcomm data transfer using a MobiApps data modem were conducted.

7.4.9 Day 9 – Wednesday 22/10/08

An additional wire test was performed in 1500m of water. During this trial communications between the LinkQuest modems, and with the Benthos XT6001 acoustic transponder and the Benthos smart modem were all problematic. It is not clear why the acoustic conditions were so unreliable during this trial and the source of these problems will be investigated.

7.4.10 Summary

The first trial of the fully assembled POL telemetry buoy was conducted. As part of this the Orbcomm low earth orbit satellite was used for remote data transfer. Orbcomm was also used to process e-mail based commands during the buoy tests in order to interact with a Seabird MicroCAT at a depth of 1600m. Two types of Orbcomm modems were tested. For the drifting buoy communication with mini-MYRTLE a Quake Global data modem was used. During later trials a MobiApps Orbcomm data modem was used to transfer remote data. Both of the Orbcomm systems had integrated GPS receivers which were used to report the buoy location at regular intervals.

Meteosat DCP (one way measurement data transfer via a geostationary meteorological satellite) using a high power omni-directional transmitter was tested

Remote internet access was evaluated using Inmarsat BGAN This service is based upon a directional antenna communicating with a geostationary satellite and is primarily intended for land based usage. However, it was possible to achieve occasional access to internet mail when the ship was on station. This assisted with the telemetry trials during the cruise.

7.5 MYRTLE X Trials

Geoff Hargreaves

7.5.1 Overview

The Proudman Oceanographic Laboratory has had two successful four year deployments of landers in the deep Southern Ocean. MYRTLE X is the next stage in the development of long term landers measuring sea level change and is designed to be deployed for up to ten years. The purpose of the trial is to test the telemetry systems that will form part of MYRTLE X, allowing data to be recovered from the deep ocean without disturbing the lander.

A series of five tests were conducted on the MYRTLE X equipment; two ‘wire tests’ (where the equipment is suspended from a wire and lowered to a certain depth) were performed and also two deployments. The final test was performed on the deck of the ship to check the performance of the Iridium satellite telemetry system.

7.5.2 Wire Test 1

A wire testing assembly was constructed from scaffold pieces, and the equipment to be tested was bolted, clamped or taped to the frame.

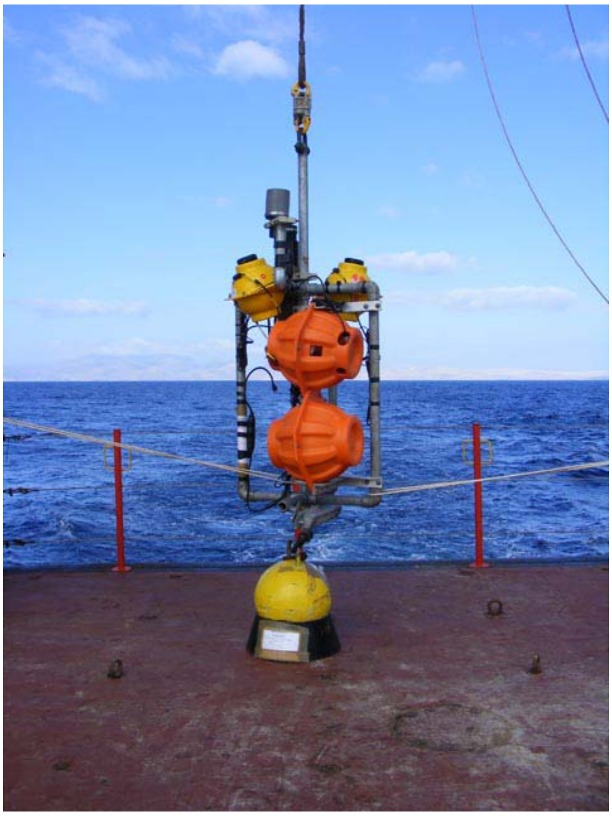


Figure 42 Acoustic release and benthos smart modem wire test assembly

The wire test assembly was lowered to a depth of 500m on 15/10/08 and then stopped. A range of tests were conducted with the Benthos XT6001 acoustic releases and also the Benthos Smart Modem. Once these tests were completed, the frame was lowered to 1000m and then stopped. The tests were repeated and then the frame lowered to 1500m. At this depth the tests were repeated again and an additional test of firing the burn wire releases was performed. All acoustic systems were responding well and giving clear indications of acting upon the commands transmitted. Once the tests were completed, the frame was brought back to the surface and when examined, the releases had successfully operated the burn wires.

7.5.3 First deployment

The mini-MYRTLE X frame was deployed at 27° 59.927′ N, 14° 02.095′ W on 17/10/08 and tracked acoustically to the seabed. A range of acoustic tests were done and all performed normally.

Figure 43 Benthic Lander (Mini-MYRTLE) deployment 1

The POL telemetry buoy was then deployed and tracked as it passed over the lander site. When it was about 1 mile past the lander position and getting further away, it was retrieved and then the frame was recovered. The acoustic conditions were good and release code D was sent to the 11.5 kHz release. The lander has two acoustic releases fitted to it as redundancy, in case a failure occurs in one of them. The release command was not transmitted to the 10.5 kHz release. It took about 45 minutes for the frame to reach the surface after releasing.

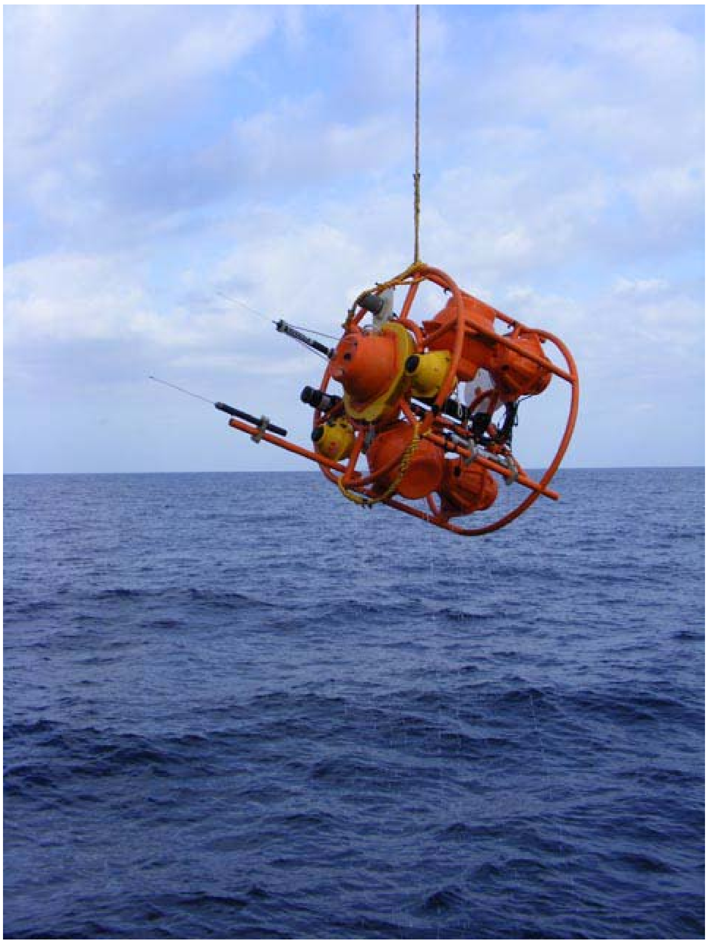


Figure 44 Benthic Lander (Mini-MYRTLE) recovery from deployment 1

7.5.4 Second Deployment

After the first successful deployment of the mini-MYRTLE X frame, a second deployment was conducted at 27° 59.653’ N, 14° 01.032’ W on 19/10/08. This was to allow further testing of the POL Telemetry Buoy. Once again, the frame was acoustically monitored to the seabed and good communication was achieved. Fitted to the frame was a hastily devised flashing beacon to aid location finding by Hybis. This was to dive on the frame and see if it could locate it in over 1600m depth of water. To narrow the search area for Hybis, slant range readings were taken from four locations and triangulation used to determine the exact location.

The next day a recovery was attempted for the frame. Acoustic reception was good, and range readings were consistent and easily obtained. Release commands were transmitted to both acoustic releases on 10.5 kHz, code D and 11.5 kHz, code D. The release command was transmitted to both acoustic releases several times and the ship moved to several different positions during the attempts. However, the frame refused to return to the surface. During the release attempts, it was possible to determine that one of the releases had received the release command, which it indicated by replying with 5 pings, every time a range reading was requested. It was not possible to determine this with the second release.

When it became clear that the frame was stuck on the seabed, an attempt was made to release the data pod via the Benthos Smart Modem. The release command was sent several times, but an acknowledge signal was never received. The ship waited for nearly two hours in case release had occurred, but no pod surfaced.

At this point, the members of the Hybis team decided to try and attempt a recovery of the frame. Hybis was set up with a grappling hook on a line of rope attached in the jaws of the sample bucket. It was lowered down to the seabed and located mini-MYRTLE X. The pod was still attached. First an attempt was made to dislodge the frame from the ballast weight. This didn't work, so an attempt was made to recover it. The team managed to manoeuvre the grapple and drop it inside the frame structure where it snagged on a section of the frame and was then hauled to the surface.

7.5.5 Second Wire Test

A wire test was conducted on 22/10/08 to test the recovered Benthos Smart Modem and also a spare Benthos XT6001 acoustic release. The wire test frame was assembled and then lowered with the CTD wire and gantry system as the trawl winch had stopped working.

Figure 45 Acoustic release and benthos smart modem wire test assembly test 2 on CTD gantry

Acoustic conditions were dreadful. It was very difficult to even obtain range readings. The release command was transmitted to the Benthos XT6001, but on recovery it hadn't activated.

7.5.6 Iridium Telemetry Test

The Iridium data transmitter was housed inside the recoverable data pod. On the MYRTLE X frame, these pods will be disposable units whereby the data is recovered via satellite telemetry.

After the Hybis recovery of the frame, the pod was removed from the frame and after an hour, the Iridium transmitter was activated. It was left to transmit for several hours before switching off. The messages have been successfully received at POL.

7.5.7 Lander Failure

On recovery of the lander, an investigation was launched to try and determine the reason why it failed to release. Prior to recovery, possible causes for the failure included; mechanical failure of the release gate, mechanical failure of the buoyancy, failure of all three independent releases. The frame has two independent acoustic releases and the pod is released by the smart modem system. This latter cause seemed the least likely.

On examining the release system on the frame, it was found that none of the burn wires had operated.

Figure 46 Detail of acoustic release that failed to release the lander at depth. The photograph was take very shortly after retrieval and indicates that mechanical failure was not the cause.

As soon as one of the burn wire modules was removed, the release gate operated, dropping the plastic end of the retaining bar. This confirmed that it wasn't mechanical failure of the release gate.

Both acoustic release systems were removed without disturbing the electrical connections to the burn wire modules and then tested. An LED load was placed across the burn wire loop and cathode connection and the release command transmitted. Both acoustic releases worked normally. The acoustic releases were left with their release cable connected and packed away for further testing back at the lab.

The smart modem was tested to determine why its release function failed. This was found to be the result of a flat battery.

7.5.8 Conclusion

The two main things to test onboard RRS Discovery Cruise 333 were the underwater telemetry and the satellite telemetry systems. Both of these systems have worked during the cruise.

However, there have also been some questions raised about components of the MYRTLE X frame that are usually very reliable. All of the acoustic releases were new, but the model type has been successfully used before, including on this cruise. Further testing is required to try and determine the possible cause of failure of both acoustic releases, which is a very rare event.

7.6 POL V-Fin trials

Mike Smithson

The V-Fin is a towed instrument platform manufactured by YSI. It is a “depressor” designed to produce a downward force while being towed in order to keep it as low as possible in the water . Its depth is controlled by a combination of towing wire length and speed. POL recently purchased a model 671 V-Fin for use in near-surface waters to measure fast sampled currents probably in association with POL’s recently developed towed thermistor-fluorometer chain.

Figure 47 YSI V-Fin Model 671

Trials of the V-Fin were not originally planned at this time but as POL was conducting other trials on this cruise it seemed a good opportunity to do some preliminary tests. These were two-fold. Firstly, to determine how well the V-Fin would “fly” and secondly, to see whether clear current information could be seen above any noise, for example from the ship’s wake.

A downward facing RDI 600kHz ADCP was fitted inside the V-Fin along with an external battery pack. These were located centrally in order to disturb the balance of the V-Fin as little as possible. A circular aperture was cut in the base plate to allow the ADCP beams to pass through. The ADCP was set up with 0.5m bins sampling at 1Hz to measure currents. It also has pressure, heading, pitch and roll sensors to determine how the V-fin is positioned as it is being towed.

Figure 48 Downward facing RDI ADCP on YSI V-Fin

The first trial was scheduled for the afternoon of Tuesday 14th. Deployment began at approximately 15:55 GMT and the V-Fin was deployed using the stern gantry and coring wire and winch. The ship made headway at about 0.5 kt and the V-Fin was lowered to the surface. It immediately positioned itself into the flow and looked balanced in the water.

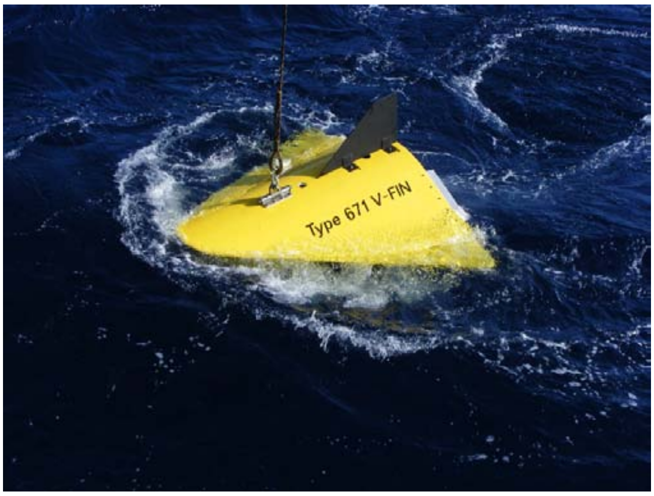


Figure 49 Deployment of V-Fin

The wire was slowly paid out to 50m, at the same time increasing speed to 1 kt to keep tension on the wire. At intervals the ship's speed was increased up to a maximum of 10 kt. Nominal speed (as indicated from the bridge), and speed and heading from the navigation display in the deck laboratory were recorded. For all these tests the length of wire paid out was kept at 50m. While increasing from 8 to 10 kt the V-Fin was seen to be breaking the surface. The ship then slowed and the V-Fin recovered. The trial ended at approximately 18:00 GMT. Data were subsequently downloaded from the ADCP.

Speed through the water, heading, pitch, roll and depth information were extracted from the ADCP data for the different nominal speeds and averaged over the period. Comparisons are shown below.

Table 6 Summary of ADCP data from V-Fin deployment

Nominal Speed (kt)	Lab Nav Display Speed (kt)	ADCP Speed through water (kt)	Lab Nav Display Heading (deg)	ADCP Heading (deg)	Depth (m)	Pitch (deg)	Roll (deg)
1	Not recorded	1.9±0.5	Not recorded	114.2	47.1	6.3	1.1
2	3.6	3.0±0.5	40.7	115.3	43.4	7.5	1.5
4	5.1	4.7±0.6	42.4	119.8	27.7	10.2	3.0
6	6.8	6.8±0.6	41.1	120.8	15.4	11.0	10.1
8	8.6	8.4±0.9	41.0	128.3	4.6	10.6	15.4

Speed through the water as indicated by the ADCP is in broad agreement with the navigation display in the laboratory, both generally higher than the nominal speed as given from the bridge. Clearly there is a large discrepancy between the heading as given by the navigation display and that from the ADCP. This is too large to be due to the attitude of the V-Fin and is likely to be in the ADCP calibration. Although field calibrations can be done on the ADCP it is not meaningful to do this onboard a steel vessel. This will be carried out when the ADCP is returned to POL. Depth readings look sensible and are useful as the likely use of the V-Fin will be in the top 5 to 15 m of the water column at speeds of around 6 to 8 kt. The V-fin pitch seems to stabilise at about 10 deg (nose up) which may be accounted for by the ADCP battery pack being mounted rear of the towing point (the V-Fin sits nose-up when being lifted in air with the ADCP fitted). Roll seems to increase (right-hand down) with speed and this seems to tally with video footage of the wire during towing – the wire was out at an angle towards the starboard side.

A detailed examination of the ADCP current data will be done at POL.

A subsequent trial which would have examined performance as a function of wire length was aborted because of a winch system failure. It was not possible to repair the fault during the cruise and no further trials were carried out.

7.7 High Resolution Shipboard Ammonium Sensor System

Samer Abi-Kaed-Beyh and Matt Mowlem

7.7.1 Introduction

Measuring Ammonium (NH_4^+) at low concentrations in the nano-molar region has always been a challenge to scientists and engineers. Historically, various methods have been used to measure NH_4^+, for example, by using Nessler's reaction, but was found to be susceptible to inorganic interference. Another method is based on the indophenol reaction, which is relatively insensitive and have poor reproducibility. Commercially available instruments such as the Technicon AutoAnalyzer and Lachat Quickchen are some of the examples using the indophenol reaction. In 1971, Roth discovered the ternary reaction of o-pthaldialdeyde (OPA), a reducing agent, and ammonia to produce a fluorescent product when excited by UV light. Since then, various sensor systems for measuring NH_4^+ have been built using the OPA, sodium sulfite and disodium tetraborate reaction, but many still lack the ability to resolve below 5nM of NH_4^+ concentrations.

7.7.2 Experimentations and Components Design

Although the OPA- NH_4^+ reaction provides more sensitivity over previous methods, the overall methodology of NH_4^+ is relatively demanding and requires continuous precise control of the system

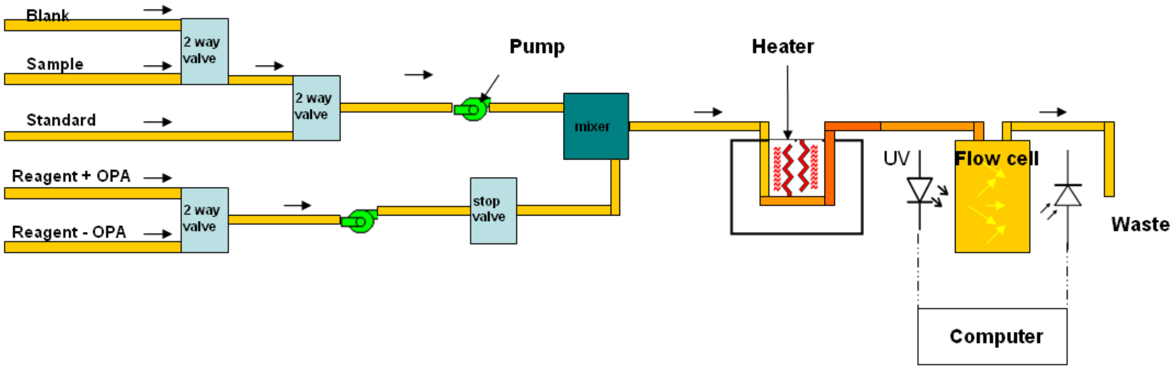


Figure 50 Schematic of the Ammonium Sensor System Components

components to achieve the desired sensitivity and repeatability. Schematic of the sensor system used is as shown in Figure 40.

During experimentations, in order to asses the quality of the gained data, five stages were followed: First, the system is flushed with a blank solution, and then a standard solution is pumped through, followed by another flush with the blank solution. The seawater sample is then mixed with the reagent without OPA (Reagent-OPA) in order to determine the background natural fluorescence as a result of the buffer and sulfite used with seawater. Finally, the seawater sample is mixed with the reagent containing OPA (Reagent + OPA) to determine the NH_4^+ amount within the sample. In each case described above, the fluid(s) will pass through the valves, pumps, mixer and the heater, where all of these components are required to operate precisely, independent of parameters such as vibration and temperature variations. In order to achieve the performance required, extensive experimentations and accurate design procedures were carried out before the cruise to optimise the involved chemistry and system components, which are briefly explained below.

7.7.3 Chemistry

To measure a wide dynamic range of NH_4^+ and decrease the background fluorescence interference, the optimum ratios of each of the reagent ingredient were obtained, in addition, the optimum dosage ratio of the reagent with respect to the seawater samples was also determined.

7.7.4 Components Design

Various components (shown in Fig.1) of the sensor system were made from scratch. This briefly includes the design of the mixer, heater, optical arrangement and detection modules choice.

7.7.4.1 Mixer

The mixer was designed at the N.O.C. taking into consideration two main factors: a small dead volume and the ability to flush easily in order to avoid cross contamination between samples/standards and to maintain a relatively fast response time for the overall sensor system. The mixer inlet/outlet flow was simulated using COSMO floworks by Solidworks to choose optimum geometry design that ensures smooth flow and avoid flow circulations. Hence, based on the simulation results, the mixer was made.

7.7.4.2 Heater

The heater was also designed at the N.O.C. based on experimentations carried out using LS55 and Ocean Optic spectrometer to find the optimum heating temperature and time required for the reaction to take place with maximum fluorescence. Based on laboratory results, a flexible heater with multiple channels was designed/machined and fitted with an accurate PID controller to maintain high temperature stability.

7.7.4.3 Optics

The optical filters and flow cell alignment with respect to the excitation light and detection modules was accomplished accurately by using a compact holder designed at the N.O.C to combine all of the above in a rugged arrangement. Experimentations were also carried out to optimise the excitation output from the low-powered Ultra-Violet LED to increase the efficiency of the detection process.

7.7.4.4 Detection Units

Two detection units, a Photodiode (PD) and compact Photon Multiplier Tube (PMT) with different performance capabilities were incorporated into the newly designed optical holders described in section 2.2.3. The reason of implementing the two different detector units is that NH_4^+ concentrations may vary widely at coastal areas (micro molar range) and deep oceans (nano molar range). Concentrations in the micro-Molar range can be picked up by a PD, where as concentrations in the nano-Molar range can be picked up using the PMT.

7.7.5 Software and Control

All of the above components/channels in addition to the pumps, valves (shown in Fig.1) and the data logging were all operated using a Labview program. Moreover, the switching between detectors based on the NH_4^+ concentrations was also included in the program to give the operator the flexibility to choose the appropriate detection module. For example, measuring 50nM of NH_4^+ was unsuccessful using a photodiode as shown in Figure 41. Signal (sea sample + (R+OPA)) was not distinguishable from other stages.

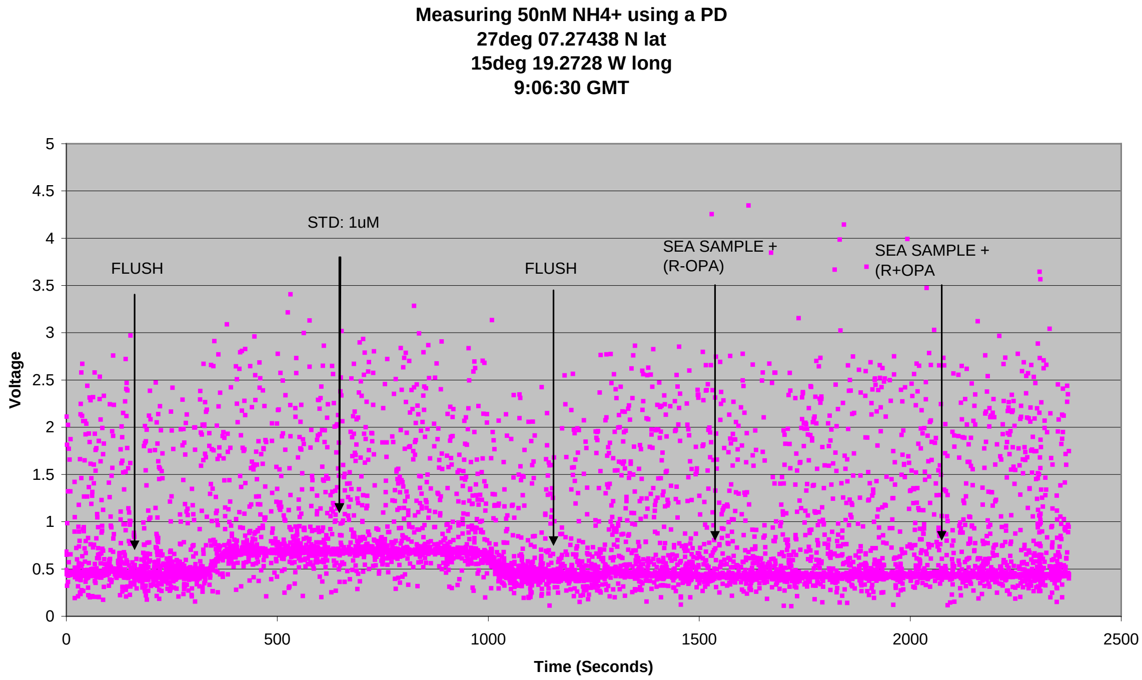


Figure 51 Resolving 50nM of NH_4^+ using a photodiode

Alternatively, when the PMT was used instead, a 50nM signal was successfully retrieved as shown in Figure 42.

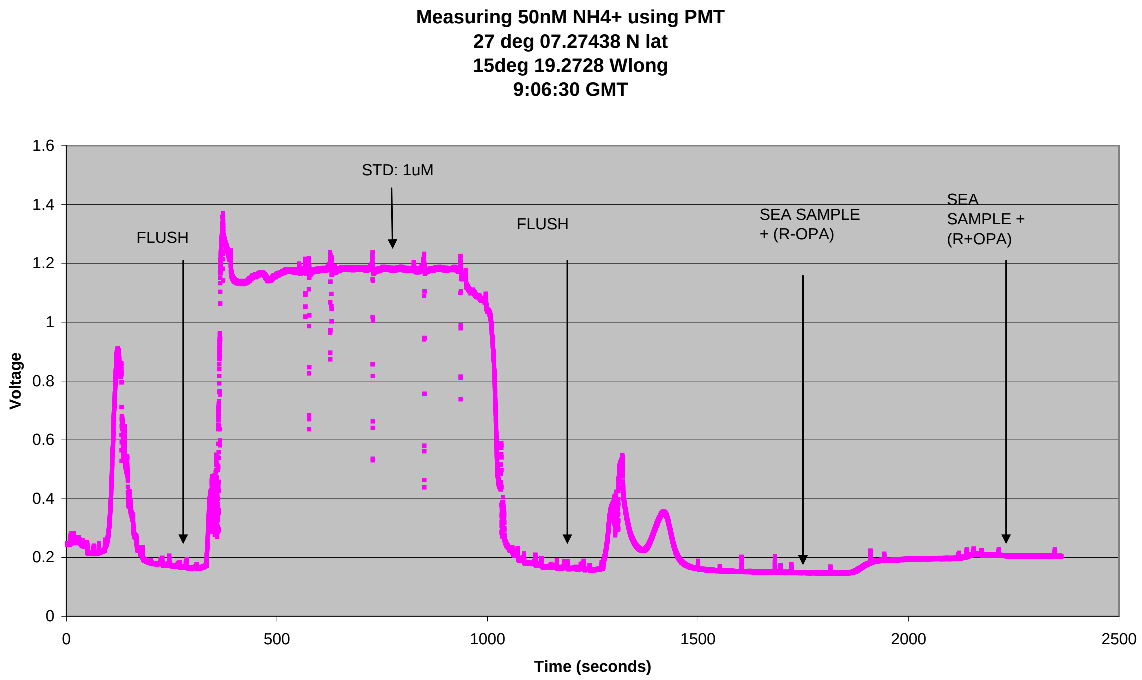


Figure 52 Resolving a 50nM of NH4+ using a PMT

7.7.6 System Performance: Results in Tenerife (Cruise D333)

The shipboard ammonium sensor system has shown successful results in resolving ammonium concentrations lower than 5nM with a limit of detection better than 10 nM. The ammonium sensor system has shown a high stability, capable of measuring ammonium with high precision, with its wide dynamic range, allows the sensor system to be used in the coastal areas. Figure 43 shows an example of a signal equivalent to 10nM (~10mV) being resolved.

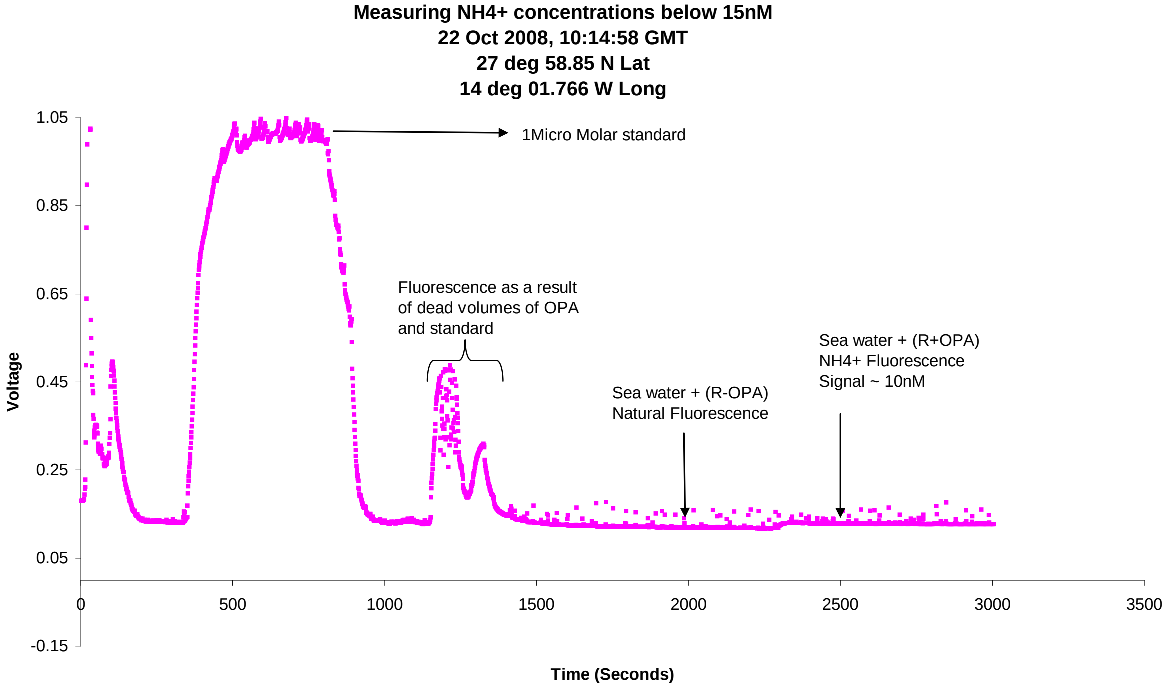


Figure 53 Measuring 10nM $NH4^+$

7.7.7 Conclusion

Experiments conducted in this cruise, have highlighted the future improvements required to enhance the continuous sampling mode of the current sensor system. In addition, a series of experiments are currently being conducted to make use of the full system potential while using only one detector unit, in which, results have already shown improvement by a factor of 2 as compared to results above.

7.8 Lab on a chip reagent based chemical sensors

Matt Mowlem and Alan Taberham

This section of the report details the testing of a microsystem wet chemical sensor for the detection of nitrite and nitrate. This is an example of a generic system which enables reagent based chemical sensing from a miniaturised platform. The platform consist of a microfluidic chip fabricated in Poly(methyl methacrylate) (PMMA) and SU8 (a photosensitive epoxy used in photolithographic masks). The purpose of the chip is to provide fluid handing, mixing of reagents, and optical detection. The latter is achieved with a dual beam spectrophotometer consisting of two absoption cells (approximately 500μm × 20mm) fabricated in SU8. One is used as the reference arm, and the other as the sample arm of the dual beam spectrophotometer system. Illumination is provided by a fibre coupled LED and detection with a fibre coupled photodiode with integrated transimpedance amplifier. A single LED is used and the light coupled into two fibres one for each arm of the spectrophotometer. This LED is modulated and lock in detection used to reduce the influence of ambient light and to enhance noise rejection. Fluid handling and mixing are provided on chip by shaped microchannels and structures. Connectors enable attachment to macro fluidics and a filter element for seawater input. The chip is supplied with reagents and sample using bespoke peristaltic pumps, and commercially available valves (Lee co. USA). Sensor control and data acquisition is performed by a bespoke onboard electronics package which is protected from pressure by hard potting (epoxy). The chip optics and electronics are enclosed in an oil filled pressure balanced tube (to protect them from seawater) with plumbing to reagent bags (medical blood bags) via bulkhead connectors on an end cap. With some adjustment (e.g. selection of suitable reagents, using LEDs and optics with the appropriate spectral characteristics) this system could be used to measure a wide range of chemical parameters. Two sensors were constructed during the cruise, Mk1 & Mk2. A total of 4 casts were conducted on a CTD frame.

7.8.1 Preparation & deployment of the Mk1 Micro chemical sensor (12th October 2008) – (21st October 2008)

The system taken on cruise had been extensively tested on the bench, but was not integrated and housed in the pressure balanced tube ready for insitu deployment. This meant that the system needed rewiring and plumbing to reconfigure and repackage it. In addition the system had been run with Instec peristaltic pumps which failed to operate when immersed in the pressure balancing oil (discovered prior to the cruise). The necessary components to construct a bespoke pump that would operate in oil were packed in preparation for the cruise, but were shipped before they could be integrated. This pump uses the Instec pump head and a stepper motor and gearbox that operates in oil (RS). Further details are given below.

- Wiring
  - The system was reconfigured with shorter wiring to enable compaction. This required cutting and hand soldering of ribbon cable. This created stress concentrators in the ribbon cable which resulted in frequent connection failures. A more robust solution was implemented using multiple braded wire connections
- Pump construction
  - Coupling RS stepper motor and gearbox to Instec pump head and verification of function on the bench.
- Pump modifications
  - A shim was inserted to improve sealing and pump pulsation characteristics. A mechanical brace was added to reduce peristaltic head movement which was causing pump variations and backflow.
- Fluidic connections
  - The system was reconfigured and plumbed to achieve efficient routing and to enable coupling of blood bags through the end cap. Initially the system was designed to use a single pump operating on the waste output of the system. This drew both seawater sample and reagents through the system. The ratio of reagent to sample in this configuration was controlled by the hydraulic resistance of each of these fluid paths if both the reagent and sample are at the same pressure. Unfortunately ship

motion created differential pressure between the sample and reagent and this technique was abandoned in favour of peristaltic pumping of both the reagent and sample at the front end of the system (i.e. before the chip). This was implemented prior to the first deployment. See results for further details.

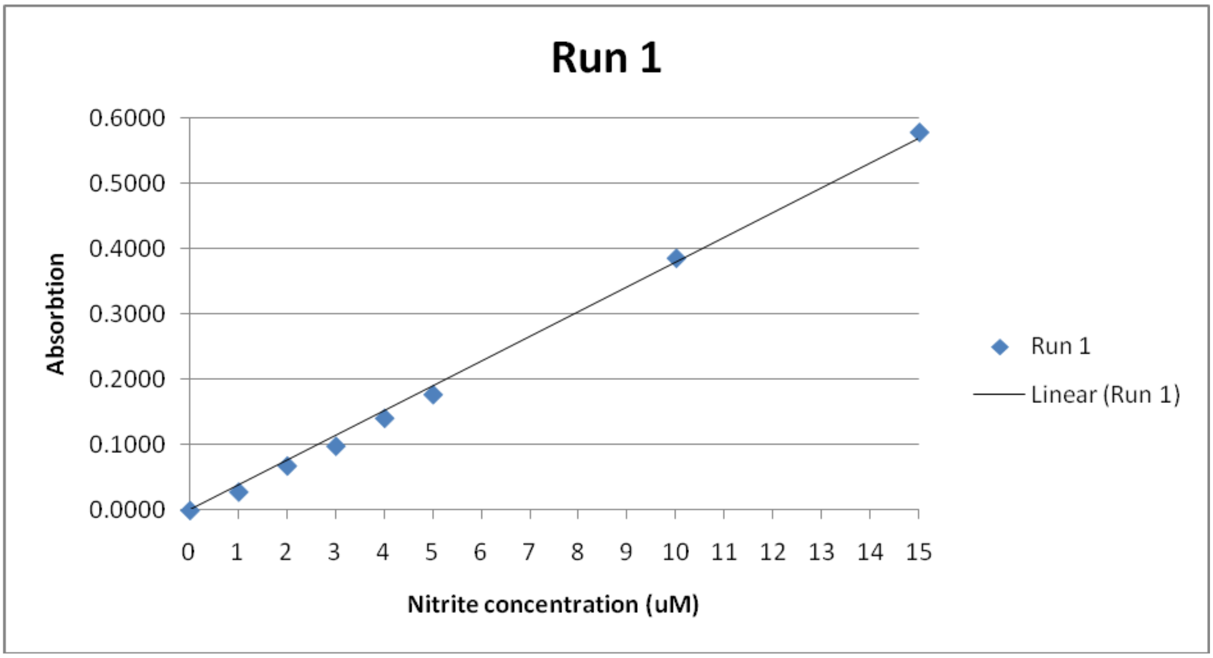
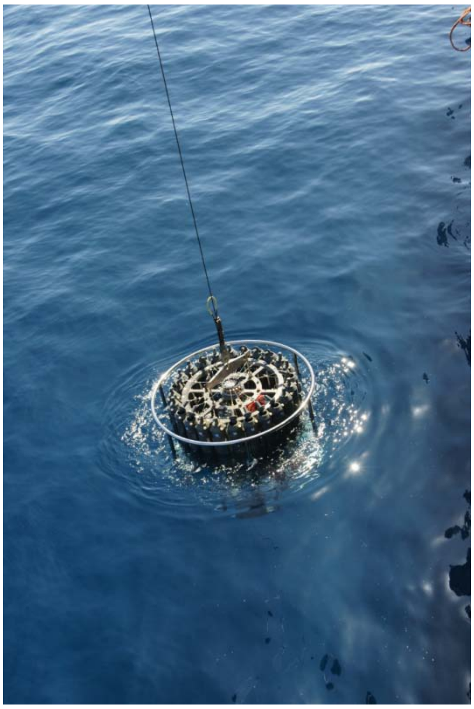


Figure 54 Example calibration data for Lab on a chip nitrite analyser

Bench top calibrations using 0uM and 25uM concentrations of nitrite were conducted before final assembly to allow a comparison of data. An example of a benchtop calibration run (0-15µM) is shown in Figure 47. The assembled system is shown in Figure 48 a).

a)



b)

Figure 55 Lab on a chip chemical analyser a) as installed on CTD frame b) entering the water

The first deployment on the 21st October at 0906 GMT was to 300m depth for approximately 2 hours at station number 16464H.On retrieval of CTD over heating of electronics and seawater ingress had caused a power surge and was responsible for the shorting of the data logging systems, two micro flow sensors, and the analogue LED drive and photodiode amplification and filter circuitry.

Overheating was suspected to be due to the Traco ±6V power supply becoming warm during initial running. Seawater ingress was also suggested because approximately 3-5ml of sweater was visible in the oil filled pressure balanced tube after the first cast. This ingress was attributed to an insufficient pressure compensation setup. The narrow bore of the fluidic connectors (0.8mm diameter) would have reduced the velocity of the fluid flowing between the compensating bladder and the sensor container, hence causing a pressure differential across the wall of the sensor container.

Preparation & deployment of the Mk2 Micro chemical sensor

After the failure of several components during the first cast the electronics were simplified. This time no electronic filtration or amplification was integrated into the design. A larger bore pressure compensation system was also integrated into the system along with a RS232 communications port for ease of data retrieval. Due to the low nitrite levels the system was converted to measure nitrate (using a miniature cadmium column).

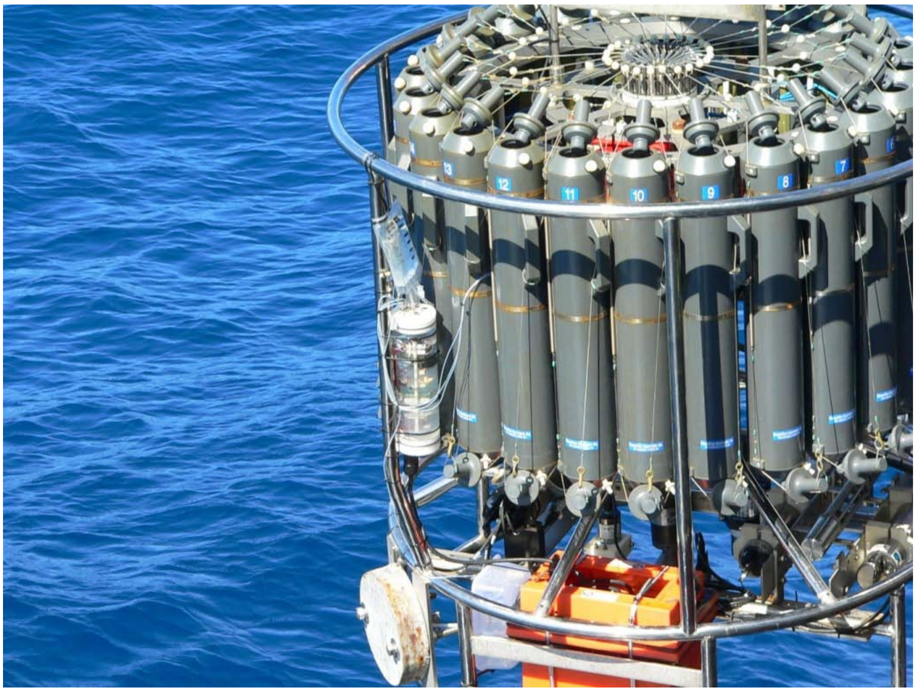


Figure 56 Reconfigured lab on a chip nitrate sensor prior to deployment

The first deployment of the Mk2 sensor was at station number 16470H on the 22nd October 2008. The sensor was tested at a depth of 30m for 60 minutes. On retrieval the sensor was still operating and communicating via RS232, and no obvious leaks had occurred. On confirmation of data download the sensor was launched again at station number 16471H. This time a depth of 1518m was reached over a total cast length of 2 hours. Another cast on the 23rd October was also taken (Station number 16475H) to a depth of 998m.

7.8.2 Results

Initial experiments using a single pump on the waste output of the system and reagent:sample ratio control reliant on the ratio of the hydraulic friction of the reagent and sample channels did not provide stable results when this configuration was tested in the ships laboratory. Ship motion was coupled into the system (by variation of pressure at the reagent and sample inlets). As the operating pressure of the peristaltic pump was limited to 0.5 bar, increasing the hydraulic resistance in the sample and reagent lines prior to the chip was unable to reduce significantly this motion induced variation. Reconfiguring the system so that both the sample and reagent were pumped into the chip on separate lines enabled improved mixing ratio control and this arrangement was used in all deployed systems. This has one negative effect in that the length of tubing between the sample inlet and the analysis chip is increased creating delay, and reducing the time response of the system. Example data from one of the CTD casts is shown in Figure 50 and Figure 51. Figure 50 shows the processed output of the reference channel of the dual beam spectrophotometer which at all times was analysing the absorption of the seawater samples. The high output levels (~5 V) at the beginning and end of the cast indicate that ambient light was entering the system causing saturation of the photodiode. This effect decreases with depth as solar illumination is attenuated. Normal operation (expected output of ~2.5 V) is only seen for ~2 minutes at the start of the deployment (on the downcast), and for ~5 minutes (on the upcast) indicating a pressure dependence in the optics. This channel stabilises at depth until approximately 50 minutes in the deployment when the light level reduces exponentially. The channel does not recover until ~ 125 minutes (during the upcast). These depth related variations are likely due to the link between the optical fibre, the LED and the absorption cell. This result demonstrates that improved methods of coupling should be developed in future work.

Figure 51 shows the output of the sample channel. Again the high (~ 5 V) output at the beginning and end of the cast indicate that ambient light was entering the system causing saturation of the photodiode. Again this effect decreases with depth as solar illumination is attenuated. Normal operation is only seen for ~50 minutes and flushing of the device, and analysis of a low (~2 V) and high (~1.5 V) standard are seen in the data. There is some noise which is related to the pump frequency indicating that the control of mixing ratio is effected by pump variation (though this can be removed by time averaging the result). The effect of increased tube length between the sample inlet and chip (caused by front end pumping) can also be seen in the long flushing (~20 minutes) and rise times (~5 minutes) observable in the data. This channel is stable at depth until approximately 50 minutes in the deployment when the light level reduces exponentially. As this feature is also seen in the reference channel this suggests a fault with the LED or the coupling between the LED and fibres. The channel does not recover until ~ 125 minutes (during the upcast). These data demonstrate that the system was able to make measurements of standards at depth but that improved methods of coupling and more pressure resitant optics should be developed in future work. Further work is also required on the pumping scheme to reduce the delay, flushing time and rise time displayed by the system.

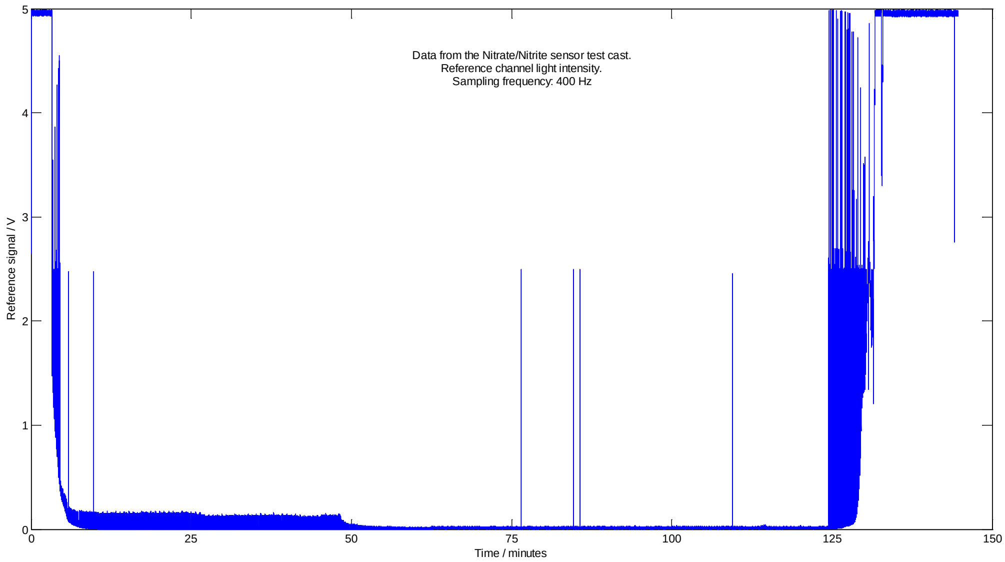


Figure 57 Double beam spectrophotometer reference channel station 16475#H

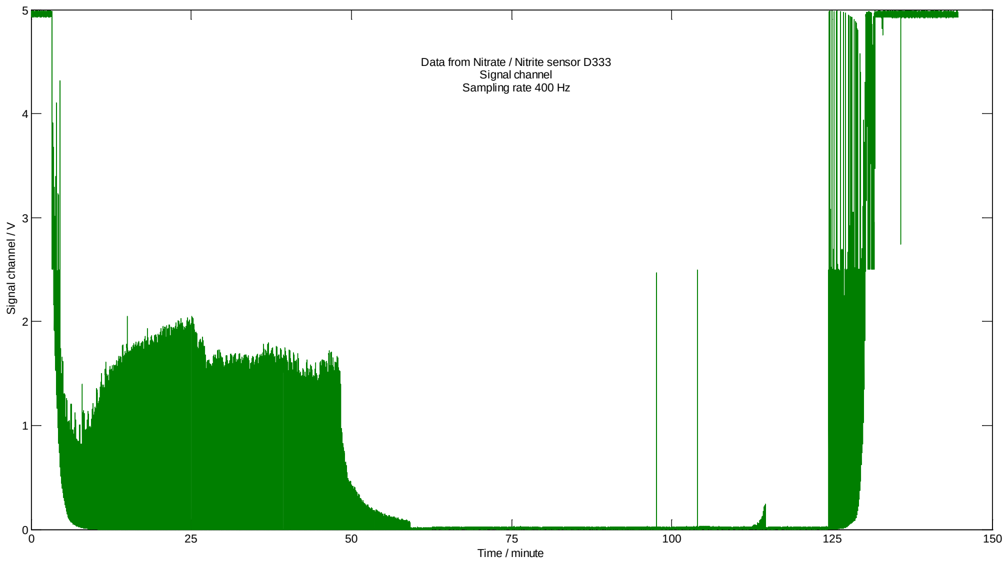


Figure 58 Double beam spectrophotometer signal channel station 16475#H

7.8.3 Conclusions

Testing of the Lab on a chip reagent based chemical sensors at sea has been invaluable in that it has shown that these systems can operate and produced data in this environment. However, a number of faults occurred and hence the testing has been invaluable for providing fault finding and performance data for these systems. Several important effects that had not been observed in the laboratory and in shore based testing were observed that require modification of the systems. The principle insights gained are

1. That ship and wave motion cause significant pressure variations between the sample and reagent making flow control using balanced hydraulic friction and a single pump on the waste of the system problematic
2. That front end pumping of the sample with peristaltic pumps causes delay and poor time response due to increased tube lengths
3. That the optics used are sensitive to ambient light
4. That pressure causes step changes in the optical performance of the system (likely due to coupling between optical elements)

The testing also showed that all elements were able to resist deployment to 1600m without breaking, the potted electronics functioned throughout without failure. In addition fouling and particulates did not cause significant performance degradation in repeated CTD deployments in oligotrophic waters. These results will be used to inform the redesign of subsequent systems and ongoing development of this technology.

7.9 Ship based biogeochemical Instrument tests

Cedric Floquet

7.9.1 Deployment and evaluation of the Idronaut In line pH module.

The In line pH module was attached to the non toxic water supply of the ship to monitor the pH of the surface seawater. The unit was initially not responding, this was fixed by changing the internal battery attached to the memory. Calibration was then carried out. The temperature sensor was working, however, the pH electrode, main aim of this evaluation, displayed a behaviour indicative of a problem with the electronics or electrode itself (figure 1). The experience was repeated three times and produced similar results. Further work on this unit was postponed until the manufacturer fixes the issues.

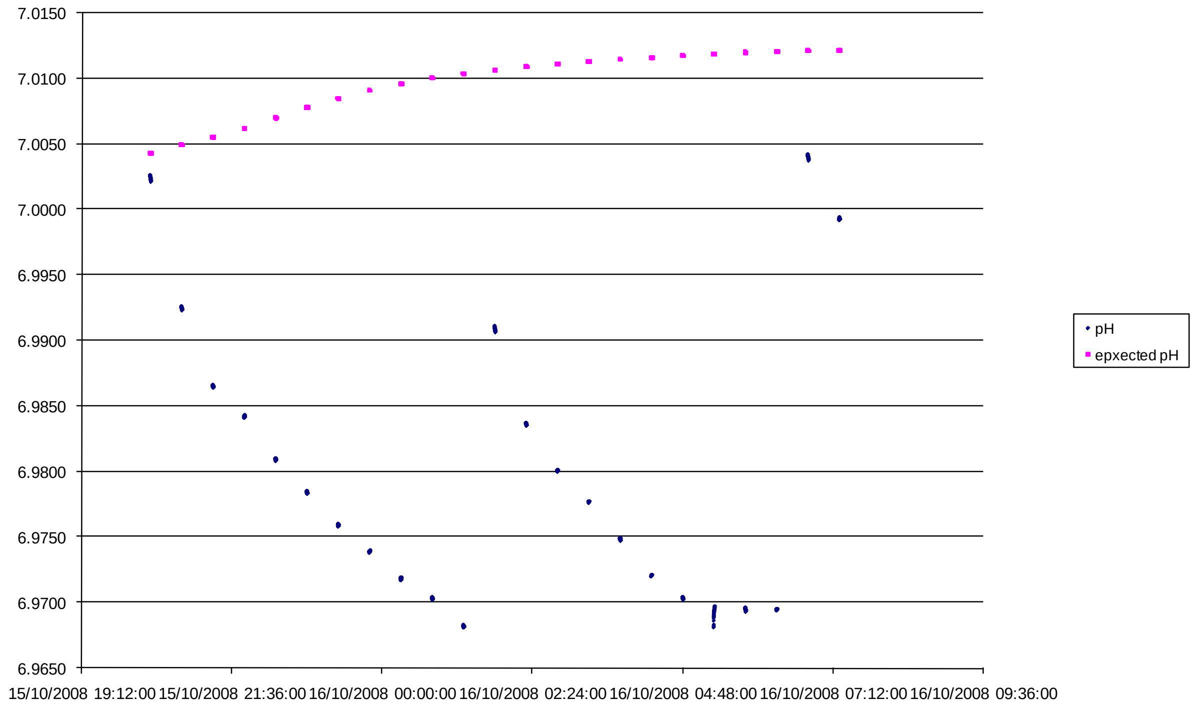


Figure 59 pH data from the long term stability test using the in line pH module. Blue are the actual data, pink are the expected pH values from the buffer vs T curve. Data collected over night using the timed data collection function: 100 points at 10 Hz every 30

7.9.2 Deployment and evaluation of the Idronaut 320plus CTD.

The Idronaut 320plus CTD was both tested in the laboratory and during CTD casts to evaluate the suitability of the pH electrode for long term monitoring and validating the calibration of the dissolved oxygen electrode, REDOX electrode, temperature sensors and conductivity (salinity) sensors. Initial results are promising, the CTD was deployed during 6 casts (figure 2) against the standard Seabird CTDs used onboard the ship and followed their trend. Further data processing will be done after having analysed the samples taken for their salinity.

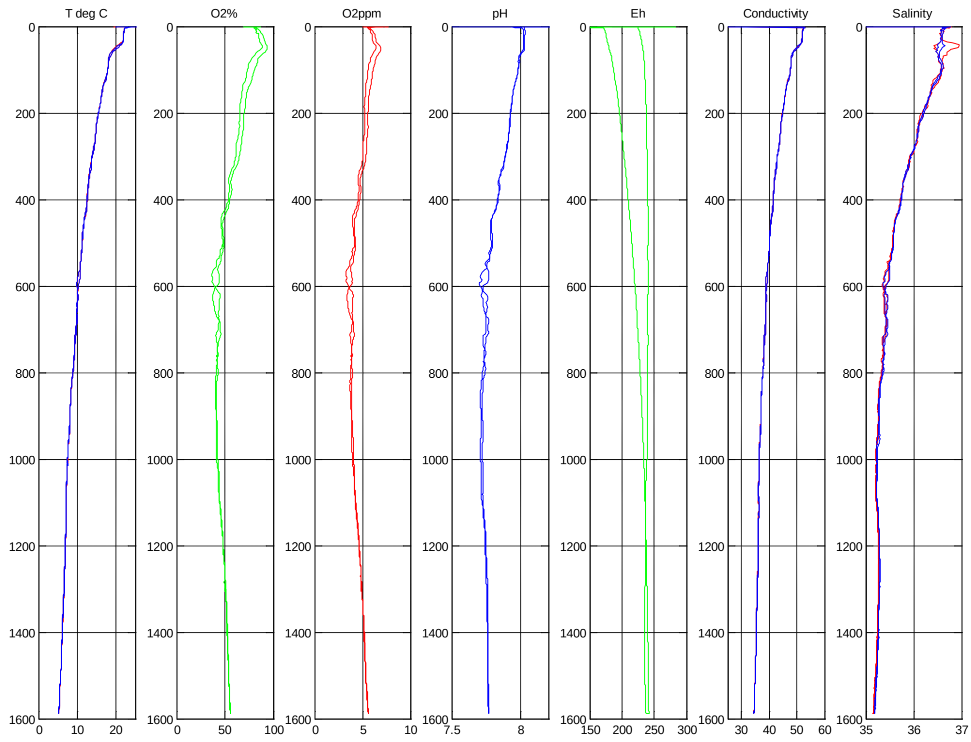


Figure 60 Example of the data obtained during a CTD cast. All the variables are plotted against pressure in dbar.

The stability of the pH calibration over time was studied. A long term experiment was undertaken. The sensor was calibrated with pH8 buffer and then run with TRIS buffer overnight. The temperature and salinity dependent expected pH values were calculated from Equation 1 and Equation 2:

Equation 1

pK*=-22.5575 + 3477.5496/T + 3.32867*LN(T) -2.3755*10-2*S + 6.165*10-5*(S)2 + (6.313*S)/T

Equation 2

pH=pK* + (-9.73*10-5*S + 6.988*10-5*(S)2)*mTRIS

where; mTRIS=0.04 AND S=salinity=35psu.

Figure 46 shows the measured pH, the expected (theoretical) pH and temperature vs. time. This shows that there was likely to be an offset in the data between the measured and expected data values. The offset appears relatively constant in this data so should be able to be corrected. Furthermore as the pH decreases the temperature increases. This is an expected variation in the data. Figure 47 plots the measured pH data against the expected pH data calculated from the equations outlines above. Ideally the relationship should be in a 1:1 ratio if there were no offset in the data. Figure 46 already highlighted how there appears to be an offset in the data. Thus the application of a trend line to Figure 47 provides a solution to correct for the offset.

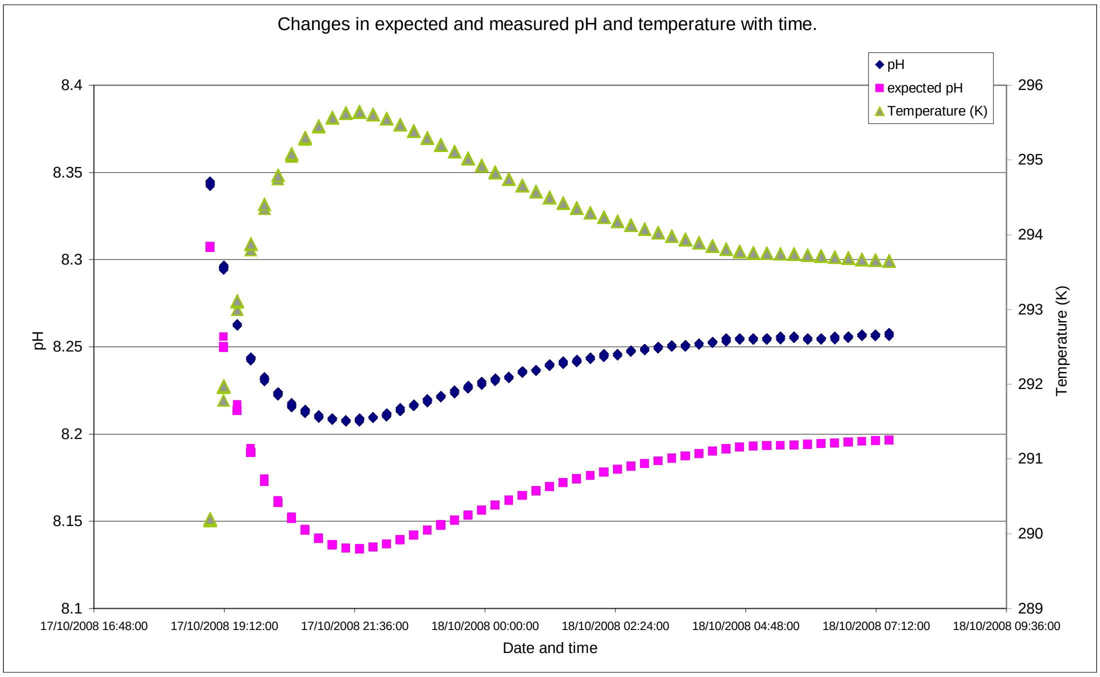


Figure 61 pH measured, pH expected and temperature vs. time

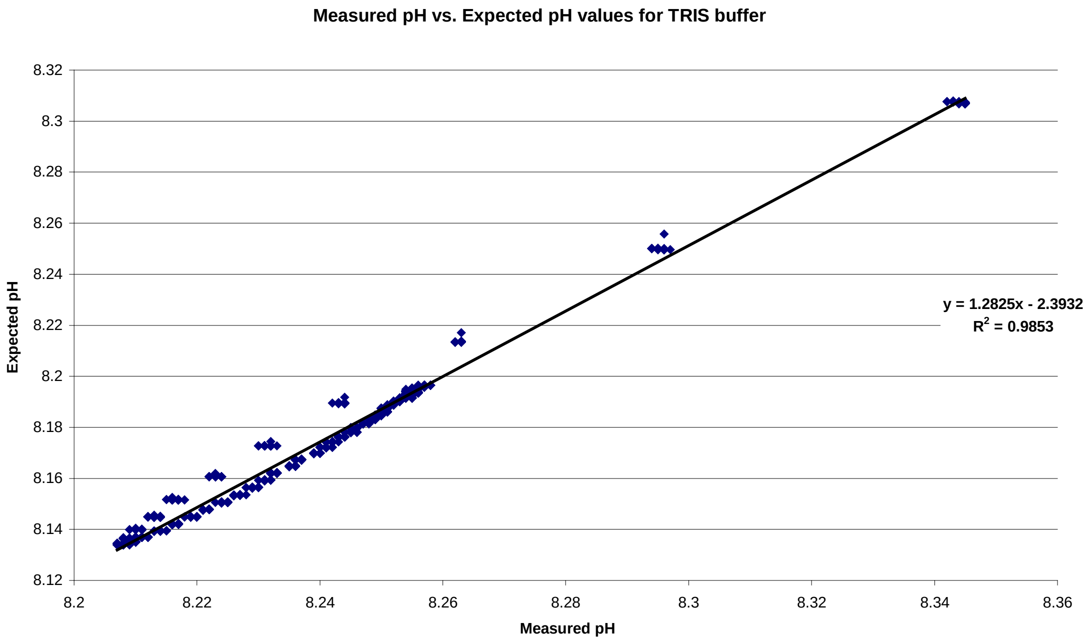


Figure 62 measured pH vs. expected pH

The equation of the trend line in graph (b) is:

Equation 3

$$y = 1.2825x - 2.3932$$

This can be used to produce a standard correction factor for the measured data:

pH corrected = =1.2825 * pH (measured) - 2.3932. Once corrected a final plot of the expected vs. corrected pH data was produced (c). This produced a trend line with the equation:

Equation 4

y = 0.9853x + 0.1204

However, if the trend line is forced through the origin then the regression has unity gradient and zero offset (as would be expected).

Thus in this case the offset between the measured data and expected data can be corrected for.

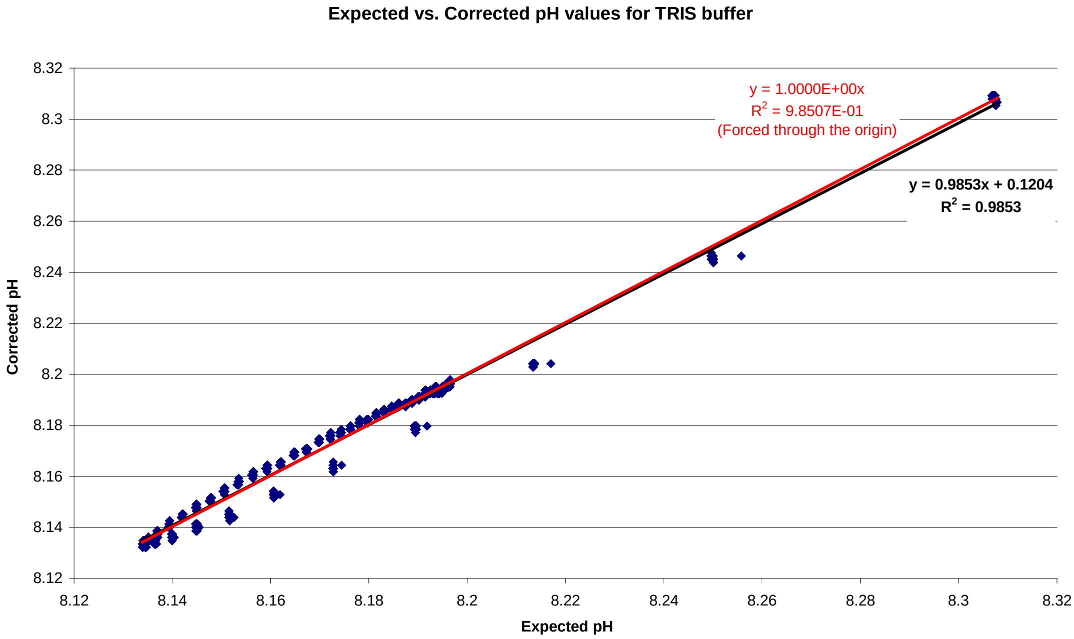


Figure 63 corrected pH data vs. expected pH data.

Initial results show that the pH electrode, once calibrated with TRIS buffer, does not display any significant drift after 48 hours including 6 casts. The pre deployment calibration and post deployment calibration compared with 48 hours interval agree within 2-4mpH units. Correct calibration is only achieved if the temperature sensor of the CTD is used as a reference when measuring the pH of the buffer solution.

7.9.3 Test of the in line fluorescence pH sensor.

The fluorescence pH instrument was deployed as an in line system during the cruise. The internals of this benchtop unit are shown in Figure 49. The aluminium flow head and temperature controller are to the left of the picture. This is attached to the optical unit (Orthogonal LED excitation and PMT detection of fluorescence). The electronics provide sensor control and high speed photoncounting required for the measurement of fluorescence lifetime in the indicator layer (Presens GmbH).

Calibration was carried out for pH6,7,8 and 9.2 buffers at different temperatures. The pH of the TRIS buffer was also measured through this system, but the sensitivity to ionic strength of the system did not allow for a conclusion to be made. Further calibration is needed with buffers of the same ionic strength that of seawater. Up to date, only 2 buffers were identified, TRIS and AMP, with pH of 8.2 and 6.8 at 25 deg C.

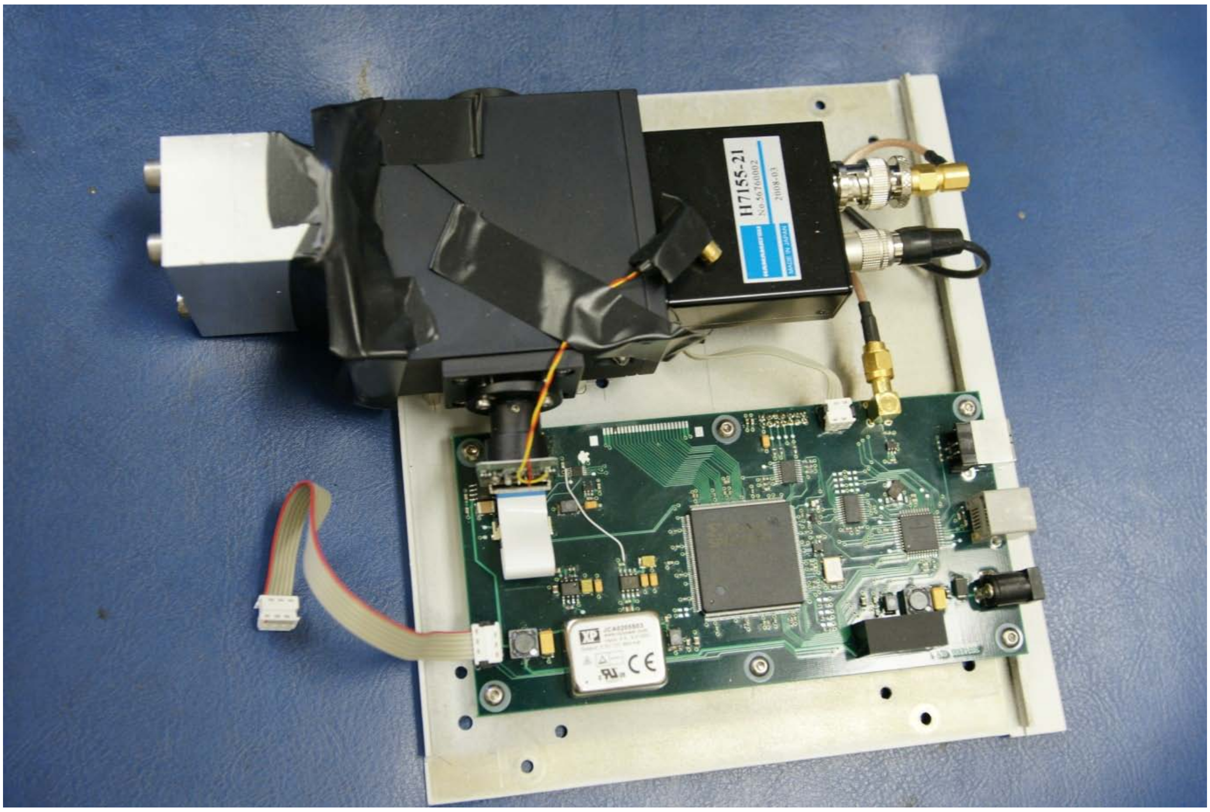


Figure 64 Fluorescence based pH sensor.

7.10 Unmanned Aerial Vehicle for Oceanographic Applications

7.10.1 Introduction

Results are presented from the recent flight tests of the Unmanned Aerial Vehicle (UAV) being developed by the National Oceanography Centre, Southampton (NOCS) as well as details of the system and its supporting hardware. The primary application for this vehicle is to provide high-resolution mapping of ocean features in support of ship operations. This allows chemical and biological sensors to be deployed and samples taken in the most suitable locations. Operating at sea creates a unique set of requirements including assisted launch and safe recovery from the water. The system will be lower cost than existing systems while providing a long endurance (>10 hours) and a high level of robustness.

7.10.2 Vehicle Specification

After discussion with the NOCS science community a set of requirements was drawn up that would allow the vehicle to be useful for a variety of applications whilst keeping costs at an acceptable level. These are:

- Range in excess of 1000 km
- Endurance longer than 8 hours
- Payload mass of 2 Kg
- Payload volume of to 10 litres

- Capable of launch from a ship
- Payload is recoverable after landing in sea water although vehicle is disposable
- Structural cost of less than £2,000 to meet total cost requirement of £5,000

These requirements were followed by a preliminary design stage which led to an approximate sizing for the vehicle. This sizing was then developed by Engineering Doctorate (EngD) and undergraduate students over a period of three years to create a detailed vehicle design. The main features of this are:

- Wing span of 3.2 metres with split flap to reduce stall speed
- Overall length of 2 metres
- Wind tunnel measured lift/drag ratio of 10 (using half scale model)
- Cruise speed of approximately 30 ms^{-1}
- Stall speed of approximately 18 ms^{-1} without flaps
- Vehicle maximum all up mass of 15 Kg
- Four-stroke 1kW petrol engine (may be replaced by diesel in future versions)
- Fuel tank volume of 6 litres

The result of this development was modelled in CAD and is shown in Figure 50.

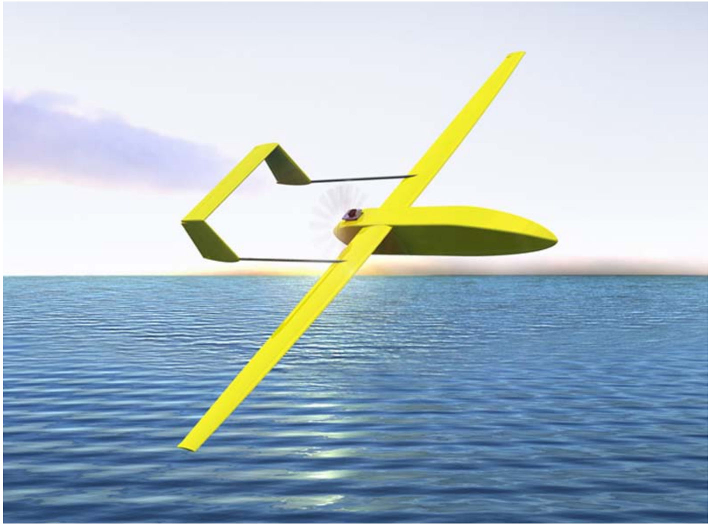


Figure 65 - Artist's rendering of the NOC UAV mk2

7.10.3 Launch and Recovery

The high stall speed of the vehicle without flaps deployed leads to the requirement for an assisted launch from the ship. This system was also developed at the NOCS and operates using a stored elastic energy technique. The UAV is fixed at the starting position and tension is wound onto a length of high performance bungee elastic using and electric winch. This tension is measured using an integrated strain gauge and once the required level is reached the shuttle is released pulling the UAV up the track. Figure 51 shows the design of the launcher with the legs set to sit on the ground.

Figure 66 - UAV launcher design

At the end of the launcher the UAV must be released from the shuttle. This performed by sequentially removing the supports which swing down flush with the shuttle body. This technique was tested using a 15 Kg lead mass to ensure it operated correctly. The results of this testing are shown in the sequence of images in Figure 52.

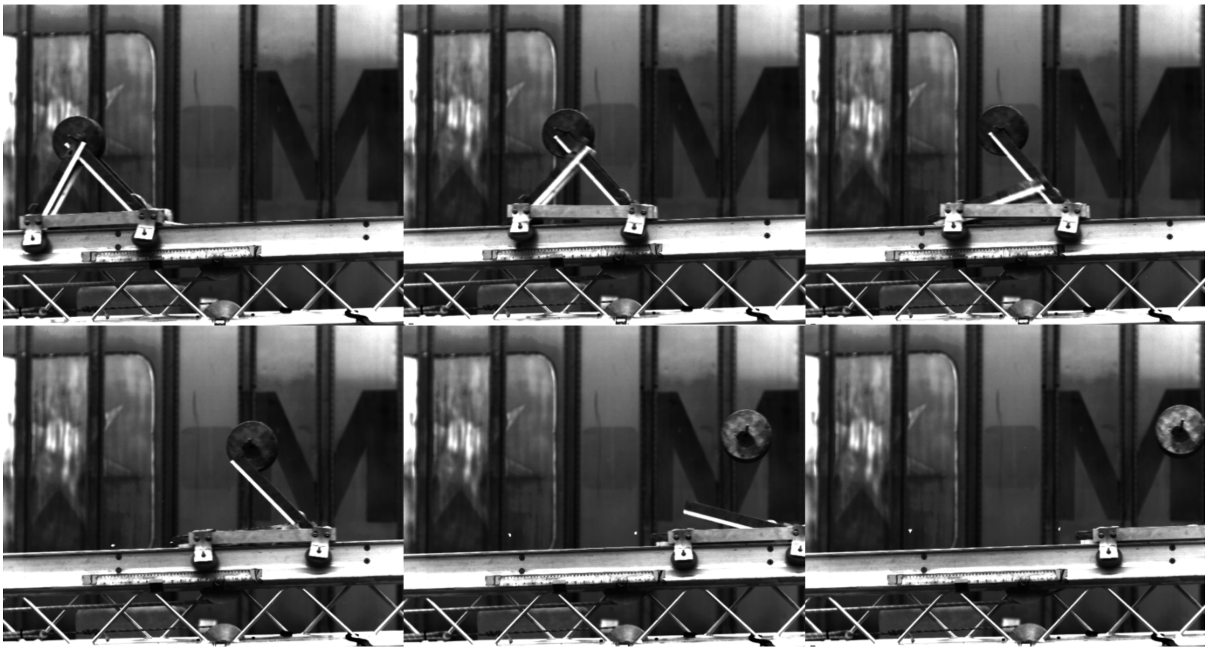


Figure 67 - UAV release mechanism in action

Recovery of the vehicle directly by the ship is very difficult, as it inevitably leads to the UAV flying at, or very close to where people are working. This is made even more difficult by adverse weather conditions. To simplify the recovery procedure, the vehicle is set down in the water and then recovered over the side of the ship using specific lifting locations. There is a great deal of experience aboard NERC research vessels of this kind of recovery and it could be performed even in very poor weather.

7.10.4 Test flight on D333

The launch catapult was assembled on the port side foredeck on Monday the 13th of October just after leaving Santa Cruz. It was easy to move the components from the Discovery hanger to the foredeck due to their lightweight construction and assembly in a calm sea, while underway was easily performed by four people. It remained in place for the duration of the cruise and did not interfere with any ship operations during this period.

The test flight took place at 9:00 GMT on Friday the 17th of October. The ship was on a heading of 12 degrees into a light breeze of around 10 knots. The UAV launched smoothly (Figure 53) and flew directly away from the ship before turning to perform laps along the port side around 200 metres off. Telemetry was streamed to the ground control system and images tagged with position and other information were recorded. The flight lasted for 7 minutes when during a slow speed flight test the engine was stalled. The pilot performed a controlled descent into the water although due to the lack of propulsion the vehicle landed more heavily than anticipated and the wing tips were broken. The vehicle floated high in the water and was recovered easily using the ship’s rigid inflatable boat.

Figure 68 - Launch of the UAV

Figure 54 shows an image captured by the UAV during the flight, this is accompanied by telemetry data detailing the position and orientation that the image was taken from. It is proposed that this data could be used to measure sea state in the local area of the ship as well as detecting plankton blooms using multi-spectral imaging. This data could be stored or partially processed onboard the vehicle and transmitted in real time to the ship.

Figure 69 - Image captured by the UAV during flight

The telemetry data is always streamed to the vehicle control system onboard the ship as well as recorded at high resolution. This allows the vehicles flight to be plotted once it is recovered as shown in Figure 55. This is helpful for vehicle development as well as accurately plotting the recorded data.

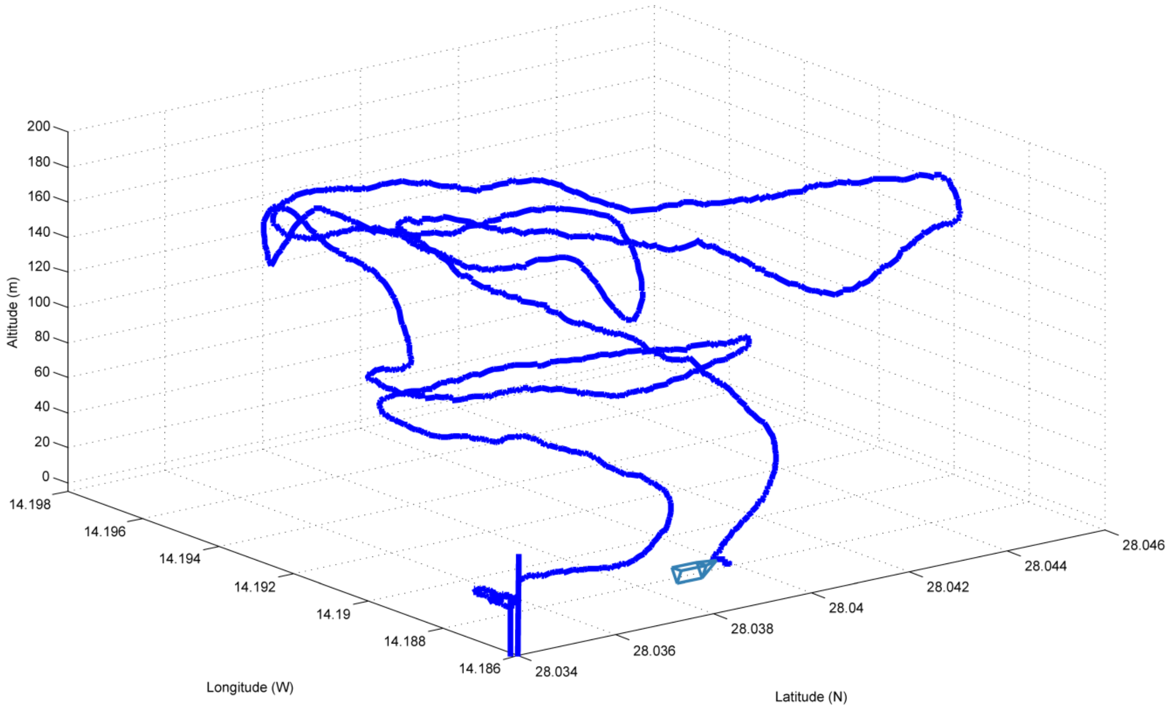


Figure 70 - Flight path of the UAV

7.10.5 Conclusions

The UAV test flight demonstrates many of the key aspects of operating this vehicle at sea. Whilst more development work is required a great deal has already been achieved on a very modest budget. The next step is to develop the vehicle to perform a specific science mission, detecting sea state, operating either from a ship or a remote coastal location.

8 Appendix A: NOCS SPECIFIC RISK ASSESSMENT FORM: LANDER RECOVERY WITH HyBIS

At Sea

Subject:	Date: 21/10/08
Benthic Lander rescue	***Location***: RV RRS Discovery
and recovery, using HyBIS TV-Grab.	
Master or Officer in charge	

Brief description of activity:

Location, rescue and recovery of POL Benthic Lander from 1700m water depth.

Locate the lander using its acoustic position and light beacon.

Approach the lander from down current direction, ship to be stationary at a position approximately 50m up current from the lander.

Nudge lander with HyBIS.

If no reaction, manoeuvre above lander with grapple line.

Grapple lander frame and haul in winch at 5 m/min. until the line is tight. Continue with a clean lift from surface.

Ensure HyBIS is on hydraulic mode to enable a rapid release of the grappl line as possible if required.

Keep the lander in view at all times during recovery until within 50m of the surface.

Steam ship at one knot up current and away from HyBIS and lander position.

At 20m depth, power down HyBIS.

Recover HyBIS, shackle grapple with line on Gilson winch and take up the strain. Release HyBS and stow on deck.

Raise lander to water line and attach recover lines to recovery loops on Lander.

Recover Lander and secure.

Secure all gear on deck.

Operational duration: Mainly short duration activity, lasting approximately 3 hours.

How could this activity:

a) ***Affect the safety of the ship/personnel***

(i) Entanglement of warp in main screw if ship was to reverse over deep-tow cable.

Action: Once the lander is grappled by HyBIS and clear of the sea bed, the ship will make up to 1 kt ahead in to the direction of the prevailing surface current.

(ii) Body strike by equipment if caused to swing by ships motion. Injury from manual handling heavy loads.

Action: Ensure tag lines are attached the HyBIS and lander as it is being recovered.

(iii) Man-over-board hazard during deployment/recovery when safety rails are lowered.

Action: Ensure life jackets are being worn if the rails are down when the equipment as it is being recovered.

Ensure operation is done under calm sea conditions with a minimum swell of 1.5m.

(iv) Electrical shock from earth leakage from the umbilical or HyBIS vehicle.

Action: ensure the vehicle is powered down before any lines are attached or anyone is within 1 metres of the vehicle. Attach earth straps when it is on deck and to be powered up.

b) Affect the environment

(i) No perceived risk.

c) Affect the equipment being used:

Scenarios:

1. Lander releases and snags the HyBIS vehicle when being nudged.

Action: Attach a 1.5 metre beam to the vehicle to nudge the lander with. Nudge the lander in an area that will not sustain damage (e.g. NOT the buoyancy spheres).

2. Lander recovered with its anchor weight, but releases during ascent. As a result the lander becomes buoyant and snags the HyBIS vehicle.

Action: Attach the grapple line to the HyBIS vehicle is such a way as it can be released. This will be done by gripping the grapple line in the closed jaws of the grab. To release the line, the jaws will be opened.

Equipment involved:	***Personnel at risk:***
Hydraulic stern A-frame	Scientific and technical
HyBIS TV-Grab	marine crew.
Macartney and Gilson winch	
USBL beacon and head.	

Signature of Assessor: B. J. Murton

Signature of Master: …………

Assessment Review

21/10/08	Originated	B. Murton