SOUTHAMPTON OCEANOGRAPHY CENTRE

CRUISE REPORT No. 31

RRS *CHARLES DARWIN* CRUISE 121
20 APR - 4 MAY 2000

Ocean Engineering Division instrument trials cruise
over the Goban Spur, Pendragon Escarpment and
Porcupine Abyssal Plain

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2000

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ABSTRACT

The objective of this cruise was to test a variety of oceanographic instruments under realistic field conditions. These instruments included:-

USBL acoustic navigation system
Inverted acoustic navigation system
SHRIMP deep-towed camera system using fibre optic tow cable
Scatterometer profiler
Chirp profiler
CLAM cable monitoring system
Autoflux meteorological measuring system
UV nitrate sensor
Fibre optic pressure and temperature sensor string
SUMOSS hyperspectral spectrometer system

Most of these instruments require a water depth of several thousand metres for normal use and this dictated the choice of work area. The Porcupine Abyssal Plain is the nearest place to Southampton offering these conditions.

All the instruments apart from SHRIMP and the scatterometer produced useful test results demonstrating the advantages of this type of cruise. Those instruments that were not successfully tested were handicapped by a lack of preparation that was aggravated by the cruise taking place earlier than initially requested.

KEYWORDS

ACOUSTIC NAVIGATION, AUTOFLUX, CAMERA. *CHARLES DARWIN*, CHEMICAL SENSOR, CHIRP PROFILER, CRUISE 121 2000, CTD, DEEP-TOWED VEHICLE, FIBRE OPTIC CABLE, FIBRE OPTIC SENSOR, FOOTPADS, HYPERSPECTRAL, INSTRUMENT TRIALS, IRRADIANCE, NITRATE, OCEANOGRAPHIC EQUIPMENT, PORCUPINE ABYSSAL PLAIN, SCATTEROMETER, SEDIMENT PROFILER, SHRIMP, SUMOSS, TRIALS CRUISE, UNDERWATER VEHICLE, USBL, VIDEO

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1. Ship's Personnel

G.M. Long	Master
P.W. Newton	Chief Officer
S. Sykes	2nd Officer
C. Vrettos	3rd Officer
A. Adams	Chief Engineer
I. Slater	2nd Engineer
G. Collard	3rd Engineer
G. Slater	3rd Engineer
G. Auld	Electrical Officer
M. Drayton	Chief Petty Officer (Deck)
M. Harrison	Petty Officer (Deck)
S. Day	Seaman
J. Dale	Seaman
D. Buffery	Seaman
G. Crabb	Seaman
J. Smyth	Motorman
E. Staite	Senior Catering Manager
D. Connelly	Chef
S. Link	Steward
W. Link	Steward
A. Duncan	Steward
S. McIver	Cadet

2. Scientific Personnel

Jon Campbell	SOC-OED	Principal Scientist
Charles Clayson	SOC-OED	
Ralf Prien	SOC-OED	
Chris Flewellen	SOC-OED	
Ian Rouse	SOC-OED	
Duncan Matthew	SOC-OED	
Dave Edge	SOC-OED	
Bob Wallace	SOC-OED	
Olivier LeBreton	SOC-OED	
Pete Mason	SOC-OED	Technical Liaison Officer
Darren Young	SOC-OED	
Lee Fowler	SOC-OED	
Paul Duncan	SOC-OED	
Matthew Mowlem	University of Southampton Optoelectronics Research Centre	
Mick Mackey	University College Cork	
Harriet Paterson	Southampton Institute	
Mark Carter	Sonardyne Ltd	

3. Itinerary

Depart Southampton 10:00 GMT on 20th April 2000 (Day 111)
Arrive Southampton 22:00 GMT on 3rd May 2000 (Day 124)

4. Cruise Objectives

The overall aim of this cruise was to test various instruments under operational conditions. The specific instruments, relevant personnel and objectives were:-

- SHRIMP (Seabed High Resolution Imaging Platform) deep towed camera system. Dave Edge, Ian Rouse, Pete Mason. To test live video and data telemetry over the main fibre-optic cable (with fibre-optic swivel). To test new floodlights.

- MSV (Mini Scatterometer Vehicle) with inverted acoustic navigation system. Chris Flewellen, Olivier LeBreton, Ian Rouse, Duncan Matthew. To test the new inverted acoustic navigation system fitted to the MSV (or TOBI), using a "tadpole" fish deployed from a boom for transmitting from the ship to the MSV.

- Sonardyne USBL (Ultra-short base line) acoustic navigation system. Mark Carter, Ian Rouse. To test the performance of this system mounted on TOBI or the MPV.

- SPV. Chris Flewellen, Olivier LeBreton, Ian Rouse, Duncan Matthew. To test the scatterometer fitted to the MSV.

- MPV (Mini Profiler Vehicle) sub-bottom profiler. Duncan Matthew, Ian Rouse, Chris Flewellen. To test the high-resolution profiler fitted to the MPV.

- AutoFlux monitoring system. Charles Clayson. To test the unattended running of this meteorological system. The system was supplied and fitted by Robin Pascal (SOC-OED) and Margaret Yelland (SOC-JRD).

- SUV-6 nitrate sensor. Charles Clayson, Ralf Prien. To test and calibrate the UV nitrate sensor attached to a CTD system. Water samples were collected for post-cruise analysis.

- FOOTPADS (Fibre Optic Observation of Temperature Profile And Depth at Sea). Charles Clayson, Ralf Prien, Matthew Mowlem. To test the FOOTPADS fibre-optic pressure/temperature sensor string in conjunction with a CTD.

- SUMOSS2 (Southampton Underwater Multi-parameter Optical-fibre Spectrographic System) optical spectrometer. Jon Campbell, Harriet Paterson, Ralf Prien. To test the operation of this profiling irradiance/transmissometer system.

- Moorings. To recover a bathysnap mooring belonging to Dr Brian Bett (SOC-GDD) located at approximately 49.0° N, 16.5° W. To check a mooring belonging to Peter Stevenson (SOC-OED) located at approximately 48.3° N, 11.9° W.

- Observations of seabirds and cetacea. Mick Mackey. Part of a wider survey being carried out by the Cetacea and Seabirds at Sea team of the Coastal Resources Centre (CRC), University College Cork.

5. Narrative

The ship sailed from Southampton docks berth 106 at 1000 GMT on 20th April (Day 111). Progress towards the deep water working area was impeded by unfavourable weather during the first 36 hours. During this period the main cable was re-terminated (mechanically, electrically and optically) to allow the optical fibre to be used.

Shortly after 0100/114 the ship slowed to 4 knots to allow interrogation of Peter Stevenson's mooring. Communication was established with both transponders on the mooring at a depth of around 2120 m.

By 0800/114 the ship had reached the test area where the water depth exceeded 4000 m. However, deteriorating weather conditions forced the ship to heave to. At 2000/114 the weather had improved sufficiently to allow a CTD dip to take place with the SUV-6 nitrate sensor attached.

Since SHRIMP and the MPVs were not yet ready to be deployed, it was decided to take advantage of the weather window to steam northwest and attempt to recover Brian Bett's mooring. The mooring site was reached at 0900/115 and the main release was successfully fired at 0913 in approximately 4800 m of water. The second Pyro was fired at 0924 for safety reasons before bringing the mooring on deck. The mooring was sighted on the surface at 1018 and the Bathysnap was on deck by 1100/115. Note that after returning to SOC, the camera was found to have operated successfully throughout the deployment duration.

Between 1200 and 1530/115 two CTD dips were taken to a depth of 40 m with FOOTPADS attached.

At 1800/115 the Sonardyne USBL head was deployed through the gate valve. A Sonardyne Supersub mini 7970 transponder was then attached to main cable with jubilee clips just above optical swivel, which was in turn attached to the depressor weight. At 1900 the depressor weight was deployed and cable paid out to 4500 m in 500 m increments with the ship steaming at 1.5 knots. The USBL operating frequency was 24 kHz and the system was able to track the transponder out to 4500m, although the position it gave seemed rather a long way off the ship's track. The ship's speed was increased to 4 knots but this caused the USBL (and the echo sounder) to struggle, presumably because of aeration under the hull.
The depressor weight was recovered around 0100/116.

In the early hours of day 116 the wind increased and by daylight a northerly force 8 was blowing, forcing the ship to remain hove-to for the remainder of the day.

Day 117 brought no respite in the weather and work continued to prepare the various instruments. At 1900/117 the decision was taken to head SE, remaining in deep water, but giving the option of steaming North at a later date, towing one of the deep-tow vehicles into the weather making it easier to handle the ship.

Day 118 saw the weather improving throughout the day. A CTD with Nitrate sensor dip was taken between 0800 and 1100/118, down to 3000m. A puzzling discrepancy was noted between the Nitrate sensor upcast and downcast data.

At 1200/118 SUMOSS2 was deployed off the starboard midships crane and measurements made at depths down to 180m over a 2 hour period.

At 1430/118 another CTD/Nitrate sensor dip commenced. During this time the PES fish was deployed over the port side for testing after a major service. No problems were noted.
At 1800/118 the depressor weight was deployed again for another test of the USBL system, using the same transponder but operating at 19 kHz instead of 24. This gave a better signal and the depressor appeared to be closely following the ship's track.

SHRIMP was deployed at 0000/119 with empty pressure housings to test the integrity of new end-caps and cable harnesses. The end caps had only been delivered to SOC a few days before the cruise began, and thus there had been no opportunity to pressure test them. SHRIMP was recovered at 0400/119 and one of the pressure tubes was found to have leaked.

At 1200/119 FOOTPADS was deployed on the CTD in worsening weather conditions. Shortly after it was recovered the ship was forced to heave-to again with wind speeds in excess of 30 knots.

Day 120 dawned with improved weather conditions but the planned deployment of the profiler MPV had to be postponed until the evening because it wasn't working. In its place, SHRIMP was deployed again at 1500/120 for another pressure test of the tubes. After recovery the same tube was found to have flooded again.
The profiler MPV was finally deployed at 1900/120 but could not be made to work because of an intermittent connection in the umbilical cable.

The profiler MPV was deployed again at 0800/121 using the spare umbilical cable and with the large Sonardyne transponder mounted in a bracket under the depressor weight. The bracket angle was about 60° to the vertical and it soon became apparent that this angle ought to be about half that amount, as the acoustic tracking stopped working after about 4000m of cable was paid out. The MPV was back on board by 1830/121 after getting a few hours of excellent profiler records recorded on the Octopus logging system.

At 0800/122 the MSV (a slightly modified MPV vehicle) was deployed to test the inverted acoustic navigation system. A "tadpole" towfish was deployed off the starboard airgun boom to transmit signals to be received on the SPV navigation array. The large Sonardyne transponder was clamped onto the wire just above the depressor weight in an effort to aim it better at the ship. The Sonardyne system worked fine out to 4000m before the signal from the transponder was lost, probably due again to unsuitable geometry. The inverted navigation system produced satisfactory results and everything was back on board by 1800/122. The USBL head was also retracted back into the gate valve.

In order to prepare the cable for future cruises, it was streamed with a swivel and small weight on the end, out to the maximum length we had used. It was then laid on the drum under minimum pressure to protect the fibre optic core, and was washed during the recovery process. This was completed by 0200/13, and the passage back to Southampton commenced.

The vessel stopped for a 2 hour SUMOSS deployment at 1300/123, and again at 1130/124.

After making good time, the ship was alongside at SOC by 2200/124.

6. Individual Instrument Reports

6.1 Mini Profiler Vehicle Overview

The MPV (mini profiler vehicle) is a deep-towed dedicated chirp sub-bottom profiler system. Using a 1kW chirp pulse sweeping between 6 and 10kHz in 26ms the profiler has a theoretical resolution of 0.25ms and can detect sediment layers over 40ms into the sea floor. A two-bodied tow system is used to decouple the vehicle from the ship's motion. The MPV was first demonstrated during the corresponding trials cruise in 1999 using a bare instrument compliment.

For this cruise the vehicle electronic systems were expanded to include a single board PC computer with a PC/104 modem. A similar computer and modem system was added to the deck electronics to enable two-way communications with the vehicle. An AML Smart pressure gauge was mounted on the vehicle to measure the tow depth of the vehicle. The frame of the vehicle was modified to mount two 17" buoyancy spheres side-by-side at the front rather than the one above and one below method used on the previous trials cruise.

An Octopus Marine Systems 360 unit was used to log and display the chirp sub-bottom profiler signals. This system had successfully been used for the same purpose on the previous trials cruise. For this cruise however, data were logged to a 1Gbyte Jazz disk instead of a DAT tape. The TOBI profiler display system was also used to give altitude information to assist the watchkeeper 'fly' the vehicle 300 – 400m above the seafloor.

This cruise represented the first opportunity to run the new modem circuitry and profiler sonar together using the 10km conducting tow cable. The modem telemetry system uses a standard PCM-3600 PC/104 modem card modified to work with the hybrid transformer-coupled signal telemetry system of the MPV.

The modem uses a frequency band of 150Hz to 4kHz. The profiler uses a frequency band of 6kHz to 10kHz. Also, in order to initiate modem telemetry a 500ms 35Hz ring tone is generated at the deck unit and transmitted down the cable to the vehicle. The proximity of the top of the modem frequency band to the bottom of the profiler band meant that high order filters had to be used to prevent crosstalk. An 8^{th} order low pass filter was used to limit the modem receiver signal and a 2^{nd} order high pass combined with a 4^{th} order bandpass filter limited the low end of the profiler deck unit receiver. Careful adjustment of the overall signal levels was also required to avoid breakthrough and clipping.

In order to reduce the attenuation of the 35Hz ring tone an increase in the value, from 1uF 400V to 22uF 400V, of the D.C. block capacitor used to couple the tow cable signals and the D.C power together was made. A consequence of this was that the cable driver and receiver electronics was more vulnerable to a tow cable short circuit due to the discharge of the coupling capacitor. This situation occurred during laboratory testing and resulted in terminal damage to the EL2099 cable driver chip. This chip was replaced in both the deck unit and the vehicle with an L165. Minor adjustments to the circuit had to be made to accommodate this chip as not only is it pin incompatible with the EL2099 but requires a gain of 10 to prevent instability, hence a simple resistive divider was placed in front of the chip to equalise the circuit gain.

The hybrid transformer matching impedance was constructed using a 1uF polyester capacitor in series with a 51ohm resistor. This circuit electrically matches the long tow-cable at the lowish frequencies employed in the MPV.

The vehicle single board computer used a Windows 3.11 operating system running Stac Reachout remote control software. The deck unit computer ran Windows 95 again with Stac Reachout software. The vehicle system was set up as a host computer with the deck unit system able to 'dial in' via the modem and, once connected, have complete control of the vehicle computer via the keyboard and mouse as well as a full screen display of the vehicle computer screen.

The AML pressure sensor was connected to the vehicle computer system's COM2 serial port. It was powered from the MPV. In order to display the pressure reading the vehicle computer ran the Windows terminal application via the remote control on the deck computer.

With all the above completed the MPV was deck tested successfully with modem communications taking place at 19,200 baud – the maximum under the software imposed limit. Little effect on the profiler signal was observed.

The MPV was launched twice during the cruise. The first launch had to be aborted due to an intermittent open circuit on the umbilical cable.

The second launch went well and the MPV was lowered to a depth of around 4500m – approximately 300m off the seafloor. Over 3 hours of profiler data were collected in a water depth of over 4800m. Good acoustic penetration was achieved with sediment boundaries visible over 25ms into the seafloor with a resolution of better than 0.5ms. Further processing should enhance this considerably. A maximum wire-out of 6634m with a vehicle depth of 4432m was achieved giving an overall lay back angle of approximately 42 degrees.

During the run the deck unit and modem link were set up in the constant temperature (CT) laboratory, the Octopus logging/display unit set up just outside the CT laboratory and the TOBI profiler display system set up in the middle of the main laboratory. The obvious conclusion to draw is that there's a pressing need to combine all these units into one system making it easier to use and more impressive to potential customers.

The sonar data logging is presently done on the Octopus 360, loaned by Octopus for this cruise, and the pressure sensor is logged on the vehicle computer system. Clearly this is not convenient and the development of a unified logging scheme based on SEGY standards is very much a priority.

Other uses of MPV equipment

Most of the MPV's electronic circuitry is contained in two pressure cases mounted onto the vehicle. One case contains the profiler sonar electronics and the other houses the power supplies, telemetry and on-board computer system. This construction makes the vehicle adaptable in its payload as well as having the flexibility to use the power and telemetry system on other vehicles.

The Mini Scatterometer Vehicle (MSV) is constructed in an identical way to the MPV but has the scatterometer as a payload instead of the chirp profiler. To accommodate the larger payload an extra buoyancy sphere has been added at the rear of the vehicle, making 6 in total.

Once the MPV trials had been conducted the profiler sonar electronics chassis was fitted with electronic circuitry for the reverse USBL navigation system. The circuitry employed a Scorpion K4 micro-controller and the TOBI FM telemetry system used on the TOBI swath sonar. The K4 was connected to COM1 on the power/telemetry on-board computer and the two FM channels connected to the mixer/cable driver for transmission to the deck unit. For this experiment the TOBI deck unit was used rather than the MPV unit as it required the use of the TOBI FM demodulators.

The MSV was fitted with the MPV electronics, modified as above, the scatterometer array – blanked off – and the reverse USBL navigation array with its attendant pre-amplifiers. During the one deployment of the MSV in this configuration the power/telemetry on-board computer, instructed by the remote control from the deck unit, opened two independent Windows terminal programmes. One for the AML pressure sensor and one for the K4 controller. Instructions to either could be sent by activating the associated window. Data in the AML window was continually updated irrespective of its activity state. This scheme worked well throughout the run and contributed to the successful gathering of engineering information for the reverse USBL navigation system.

For use with the scatterometer the MPV power/telemetry electronics tube was used with the dedicated scatterometer electronics tube. This combination proved very problematic as the scatterometer electronics takes its power directly from the main tow cable and consequently imposes an impedance across the cable causing a mismatch with the hybrid cable matching impedance. It also severely reduced the level of the 35 Hz ring tone, so that transients from the scatterometer transmission produced erroneous triggers. Due to transmitter problems this combination didn't make it into the water during the cruise. However, it has highlighted three areas where further development is essential, the impedance load of the scatterometer electronics, the baseband transmission of the ring tone and the spectrum overlap of the received scatterometer signals and the modem band. Solutions to these problems were discussed during the cruise and will subsequently be implemented.

Sonardyne USBL

The MPV and MSV deployments were used to conduct range and noise tests for the Sonardyne USBL system. Two types of transponders were used during these tests: a 7823 high powered directional transponder and a 7970 super sub mini unit. The 7823 was initially mounted under the depressor weight using custom made clamps designed to angle the transponder approximately 27 degrees upwards. The 7970 was mounted onto the tow cable using a cable clamp device. Both devices gave good positional information up to a slant range of around 4000m. Beyond this, although the replies had a high SNR the number of replies declined rapidly. This indicates a failure of the transponder to detect the interrogation signal, presumably due to the directionality of the transducer. Using the units in responder mode – where a trigger signal is fed to the unit through some other channel e.g. down the cable – rather than transponder mode a significant increase in performance is predicted. This mode should be pursued especially if towing vehicles such as TOBI in deep water is required.

Ian P. Rouse

6.2 Mini Profiler Vehicle - Profiler

This was the second trial of the Mini Profiler Vehicle (MPV), a follow on from the trials cruise D240, May 1999.

The vehicle is fitted with our standard TOBI profiler transducer array but uses chirp profiler technology for operation. This operates with a 6 - 10 kHz swept frequency of 26 ms duration. A transmission rate of one 'ping' every 4 seconds was used. The vehicle had reconfigured buoyancy for better trim, based on last year's experience. Deployment was with the standard two-body towed configuration of vehicle, neutrally buoyant umbilical and depressor weight, using the ship's coaxial/fibre-optic deep-towed cable. The vehicle makes use of just the coaxial part for power, command and data transfers.

Top end (laboratory) data de-multiplexing was by in-house 'deck unit' and logging using an Octopus Marine 360 sub-bottom processor with the raw data logged to Iomega Jaz drive. Real-Time display was on the 360 system with online display processing to enhance any sub-bottom structured layers. The TOBI profiler display system was also employed in order to give flying data, using the first bottom return, for the winch drivers.

Deployment at 0800/121 (47° 35.2' N, 12° 22.7' W) was a standard smooth operation. Vehicle trim looked very good. Water depth was 4800 m and terrain was flat abyssal plain with potential deep sedimentary layering, ideal for chirp processing trials. At a height of 1400m, from the seabed, the first return appeared on the TOBI profiler display showing a very strong signal and within 1000 ms range (750m) the same signal was evident on the Octopus Marine 360 system. Logging was then initiated on the 360. The vehicle was trimmed to a comfortable 400 m 'flying' height. Once trimmed the imaging of sub-bottom layers could begin.

The survey run was of approximately 4 hours duration. Initial results, on the real time display, showed very fine structure and deep layering in the sediments. Penetration of up to 30 - 40 metres could be resolved on the 360 display. This is all before any post processing.

After each transmission oscillations on the correlated output, lasting up to 200 ms (equivalent to 150 - 200 m) was evident. This was also evident on the last trial cruise. This phenomenon is still a mystery and requires further investigation back in the laboratory. It does not affect the data, provided that the vehicle is flown at the normal surveying height of 300 - 400 m (TOBI height linked to sidescan optimisation). There are however future requirements to 'fly' closer to the seabed, in shallower applications, and use a higher ping rate in which this could be significant.

Results, similar to last year's trials, look very encouraging and deeper and finer structure in the data are likely to be revealed in the post-processing. Overall the MPV and Chirp Profiler have proved a success. The Chirp system will now be copied over to our other deep towed TOBI systems.

Duncan R. Matthew

6.3 Scatterometer

Yet again the Scatterometer did not get into the water, although the array was mounted on the MSV (Mini Scatterometer Vehicle) and was deployed for TOBI acoustic navigation tests. This at least allowed a field pressure test of the array.

The instrument had been tested at full power into dummy loads and the also into the array in the acoustic tank back at SOC. The problems arose as a result of interfacing it with the Power and Telemetry chassis developed by Ian Rouse This had been successfully used on the MPV chirp profiler and the acoustic navigation trials.

The faults we identified were :-

a) A previous rewiring arrangement brought the high voltage power in on the same connector used for signals and communications. With the power connected via a separate connector this now became an output and destroyed a signal receiver chip in the other chassis when the power was turned on.
b) Due to various re-arrangements of the wiring of the signal isolation choke it was no longer in circuit, whereas it should have been in series with the high voltage input.
c) Multiple triggering. When the previous two faults had been rectified the scatterometer was booted up again but fired off a machine-gun like burst of pulses before collapsing. Probable cause; the trigger was connected directly to the trigger logic for lab testing, but via a wiring loom running very close to wires carrying heavy currents when tested on the ship.
We should be able to solve this last problem by relocating the wiring and swapping connectors so that the trigger comes in at the end away from the high power circuitry. The power and digital grounds could also be separated.
It should then be possible to test the whole system in the dock, with the array pointing horizontally.

Chris Flewellen, Duncan Matthew and Olivier LeBreton.

6.4 TOBI Acoustic Navigation

This project looked doomed from the beginning, with crucial components arriving at the eleventh hour and circuitry built on vero-board. However, the results of one session of testing were spectacular, with useable signals being received on the MSV out to 6500m. Had there been time and the water depth we would have hoped to have got an even greater range.

System Description
A two hundred watt pulse power amplifier driving a column of 4 transducers fitted into a "tadpole" towfish. This was deployed from the air-gun boom on the starboard side with the transmitter array pivoted out of the "tadpole", to point down and backwards at around 30° from the horizontal.
A receiving array, mounted on the MSV to point forwards and upwards at 30° from the horizontal. This consists of 16 TOBI swath hydrophone elements arranged as four columns of 4 with inter-column spacing of $^1/_2$, 1, 1$^1/_2$ and 2 wavelengths. These are mounted in a plastic box in front of an aluminium and silicone rubber sandwich baffle plate. The box was filled, at sea, with castor oil.
A pre-amplifier with a pair of column selection multiplexers and voltage controlled gain. The choice of column and gain were provided by an I^2C interface.
A mixer circuit to translate the 18.5 kHz signals to 200 Hz so that they could be sent up as FM using the swath 70 kHz and 90 kHz FM channels.
An analogue/digital card installed in a PC running National Instruments Labview During the bad weather we were able to build most of the software to sample, process and log two channels of navigation data.

Results
Signal returns were weak during veering as the MSV was badly trimmed, front heavy, and we were paying out fast to get plenty of wire out in the time available. This was causing the vehicle nose to pitch down even more. Once we stopped paying out and the vehicle had settled, we were able to automatically track signals even though they were of low amplitude. We could not use the maximum gain available without instability.

Conclusions
The concept of reverse acoustic navigation of a vehicle, like TOBI, is certainly feasible. There are plenty of enhancements still to be made. The instability of high gain could be solved with better layout and additional gain added at another place. The transmitting and receiving transducers are yet to be calibrated and their beam patterns measured.

Chris Flewellen, Duncan Matthew and Olivier LeBreton.

6.5 Fibre Optic Facility

The fiber optic facility on the Charles Darwin was required for use with the SHRIMP system. This facility is a part of the standard equipment available for scientific operations from that ship.
The system comprises...

A nine kilometer conducting oceanographic cable with a single, single mode fiber, running through its center core.

An electrical swivel with fibre optic rotating joint (FORJ) mounted on the cable storage drum.

A full ocean depth mechanical swivel, which also houses an electrical swivel and a FORJ.

A termination bottle that acts as the strain member to connect the cable to the swivel, it also allows the electrical conductors and the optical fibre to be brought out to appropriate connectors.

A pair of interface boards for connecting video and serial data into the cable's fibre. These were not required for this cruise.

The overall system was tested electrically, had a load pull of 2.0 tonnes applied to the swivel and termination bottle and had the following optical insertion loss...

@ 1310 nm = 10.5dB
@ 1550 nm = 13.0dB

On testing the electrical characteristics for the system it was noticed that the two swivels had been assembled differently. One swivel was wired up pin-to-pin whilst the other one had the two wires crossed over. These swivels have just been refurbished by the manufacturers FOCAL and this matter will be taken up with them.

Unfortunately there was a problem with the SHRIMP system and this facility was never required for fibre optic operations. Having said that the rest of the system was successfully used for several deployments where the electrical properties were required.

During these deployments the fibre was routinely shot with the OTDR (optical time domain reflectometer). This showed a good fibre for most of the cruise. Towards the end of the cruise it was observed that a step in the fibre's characteristics occurred at a point close to where the deepest deployment of cable out had reached. The cable's manufacturer, Rochester, documents this phenomenon. On paying out the cable, it was observed that the attenuation step started to "repair itself" as the immediate cable lays on top of it were wound off. The cable was wound out past this point and the fault almost disappeared within a few minutes but there remained a slight step that lasted for about half an hour.

The OTDR measurements exhibited this phenomenon on one other occasion. On this occasion it was noticed that the fault started to be observed as subsequent lays were wound on top of this area of cable. It could possibly be possibly caused by a function of time or due to an accumulation of radial forces being applied from overlaying layers of cable.

The attenuation step is caused when the high cable tension from a deployed cable is next to the low cable tension of the cable that was originally wound onto the storage drum. Although this has been observed in the past, it had taken many months for it to occur. In this case the step occurred within only a few days. On the second test, it was observed to reappear almost as soon as the cable was covered by subsequent layers. The difference here being that it "healed" and was almost instantly was wound back onto the storage drum; perhaps it had not fully recovered.

At the end of the cruise the cable was deployed with just the swivel and a small weight to a point past the attenuation step. The ship was steaming about six to eight knots and the cable "flew" which reduced the tension to about 2.0 tonne. The cable was cleaned with compressed air and grease during its recovery. The attenuation step did not reoccur.

The manufacturers recommend that the cable be wound off the winch and be re-wound under a constant low tension if the cable is not going to be used for a period exceeding six months.

The cable is being monitored as a standing order every two weeks this is to ensure that the problem can be addressed should it reoccur during storage.

Pete Mason

6.6 CLAM System - (Cable Logging And Monitoring)

The CLAM system monitors and displays various parameters associated with cable parameters and winch operations. Its purpose is to aid safe winch operations and to comply with Lloyds recommendations by displaying and saving to disc certain essential parameters.

The CLAM system performs the following functions....

Displayed data....

Cable tension
The amount of cable paid out.
The speed that the cable is being operated at.
A graph of tension with the maximum peak and maximum mean tensions being displayed.
Water depth from the Simrad echo sounder.
CTD data; pressure in dbar and altimeter. (Only displayed when the CTD cable is selected.
Cable type selected.
Date and day number plus time in GMT.
All the cables physical parameters, when required.

Saved data....

The data is time stamped every second and saved to a 100 MB cyclic file for every 200 ms sample of data.
The data is sent to the ship's computer system in SMP format every second.

The CLAM system, being a recent in-house development project, had been installed on the ship prior to the previous cruise, which was also a trials cruise, where it was tested and some software enhancements were made.

A new type of solid-state (psi TFT) video display was tested to see how it performed with a PAL signal and in the marine environment. This display proved to have good contrast and was easy to read. It also produced less heat than a conventional colour monitor.

During this cruise the system was monitored to ensure that it operated correctly and that it met the requirements expected from it. This ongoing testing and monitoring was concurrent with winch operations for the various equipments deployed during the cruise.

The CTD system was different from those previously used and had to have some software written to accommodate its data string.

The cable offset function was also tested. This option would be used in the event that the cable out data became corrupt or accidentally re-set. This was tested at two km cable out on two separate occasions and worked successfully.

Pete Mason

6.7 Sonardyne USBL Navigation System

Summary
Sonardyne International Limited were requested by Southampton Oceanography Centre to demonstrate LUSBL v5.14 performance when positioning deep tow underwater vehicles with environmental and survey sensors attached. With water depths over 4000 m and approximately 1:2 slant range when towing TOBI, the largest of their underwater vehicles, slant ranges would be just under 9000 m. With the smaller Mini Profiler Vehicles (MPVs) the layback ratio was approximately 1:1 resulting in a 5600m layback.
Sonardyne anticipated that it would not be possible to position the vehicles over the maximum slant ranges to be encountered but useful information could be obtained regarding the slant range at which USBL performance became unacceptable. With this in mind Sonardyne will recommend any changes required in order to position TOBI during further deep tow operations in 2500 m of water during the summer.
The Charles Darwin is a 70 m research vessel. There is a small gate valve through which we deployed the normal head transceiver. When deployed the transceiver protrudes 1m below the ship's hull. Ship's cabling can be used to connect between the transceiver and the top unit situated in the main lab. A hippy VRU was available with a sinusoidal scale such that 10v equated to 90°. A gyro was also available but due to its age and lack of recent maintenance there was no information about its performance. Both gyro and VRU data were available in the main lab through one of the ship's junction boxes. As this was a trials trip absolute position was not important. Therefore an attitude calibration of the transceiver mounting was not required.
Transponders can either be attached to the tow wire near the depressor or on the depressor itself using a purpose made bracket. Power and responder trigger cable are not available as the

MPV is towed approximately 100 m behind the depressor weight using a separate umbilical. It is not possible to mount the beacon directly on TOBI as the acoustics would interfere with the high gain side scan sonar

System Performance

Noise Levels

The USBL system has a built in, if unsophisticated, spectrum analyser that can be used to measure the noise received at the transceiver head. Below in figure 1 is a typical noise plot taken from the RV Charles Darwin. Noise information is vital to the analysis of system performance.

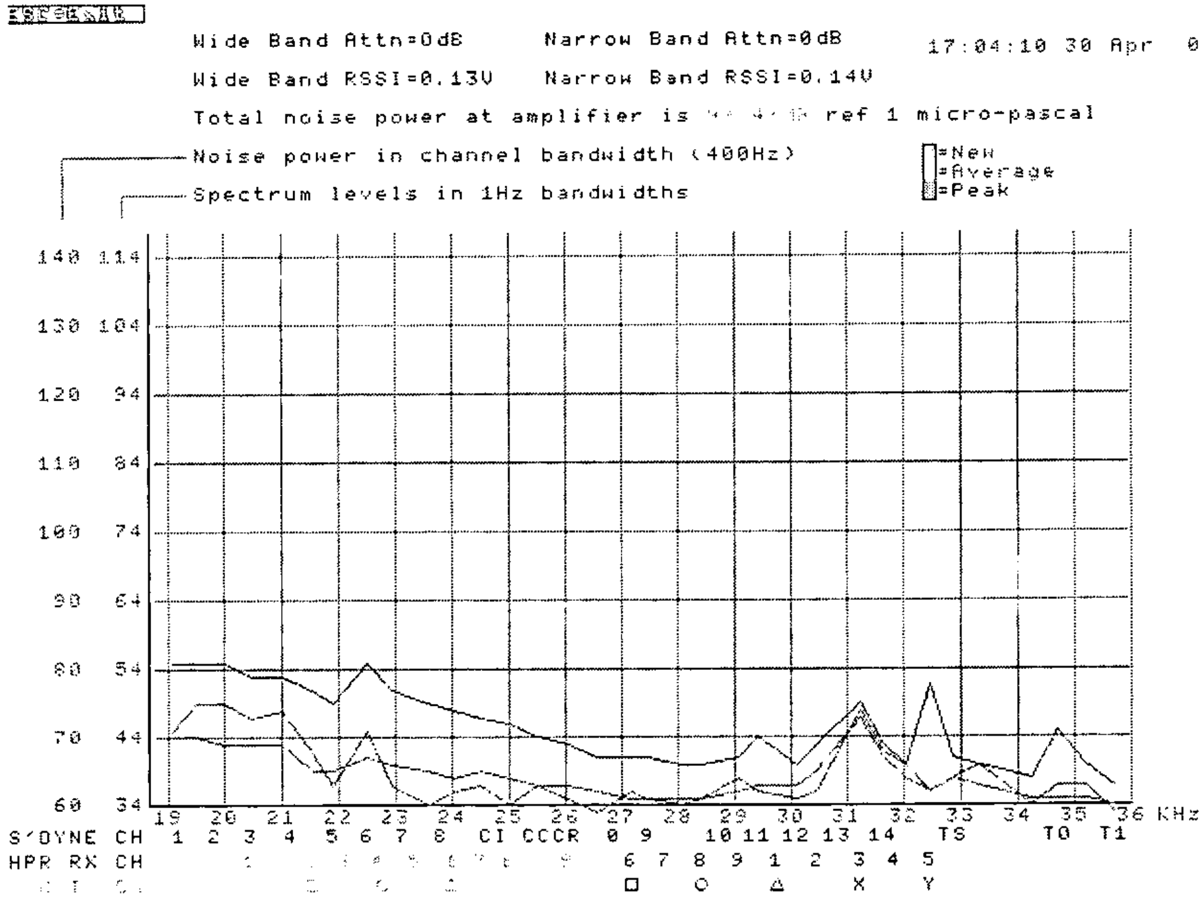


Figure 1 : Noise plot taken at 1.5 knots in calm weather conditions 30-04-00

Noise information taken from figure 1 indicates a maximum average noise (grey line) of 70 dB in the frequency range we intend to operate, 19 to 25 kHz (Sonardyne channels 1 to CIF). This value is quite low and will not significantly degrade system performance.

Velocity Profile

A CTD probe was used to collect data to provide a velocity profile through the water column. This data was used to calculate the mean sound speed through the water column that was programmed into the LUSBL system.

At the Transceiver: 1500.00 ms-1

Through the water column: 1502.00 ms-1

System Configuration

We had two beacon options available to us; a 7970 Super Sub Mini and a 7823 high power directional beacon.

7970 Super Sub Mini

The 7970 Super Sub Mini is a versatile high-powered beacon that can be mounted on small MPVs without significantly altering the weight distribution or towing characteristics. It can also be attached to cables without specialist mounting equipment so is an ideal beacon for positioning during towing and coring operations. Interrogation set to a 10 second interval would give a battery life of just under a week and using the Type 7972 charger the battery can be re-charged from flat in 2 hours. Alternatively the beacon can be connected to a DC power supply if available and set to work in responder mode if a suitable cable core can be dedicated to the transponder interrogation.

The standard frequency options are Simrad HPR , these settings interrogate low and reply high (27 - 32 kHz). However the beacon tested was a modified version tuned to Sonardyne Pairs channels with the range benefits of lower reply frequencies but still with the option to use higher reply frequencies for shallow water high precision work if required. The frequencies available are outlined in the table below.

Channel	Tx channel (kHz)	Rx channel (kHz)
66	6 (22.5)	12 (30.1)
77	7 (23.1)	13 (30.9)
88	8 (23.8)	14 (31.6)
95	1 (19.2)	7 (23.1)
96	2 (19.8)	8 (23.8)
97	5 (21.9)	6 (22.5)
98	7 (23.1)	8 (23.8)

Channels are easily changed using dial switches on the back of the beacon.

During periods of good weather when the MPVs were not operational the Super sub mini was deployed attached to the cable just above the depressor weight. Due to the 600kg weight of the depressor it was not possible to replicate the laybacks encountered with the vehicles attached. However at 15° off the vertical reliable positioning at slant ranges over 4000 m was achieved.

The USBL system has a built in logging system which logs to the hard disk on a rolling file system and outputs ASCII data through a serial port as a “Surveyor’s Output” string. Using a Sonardyne utility program position and attitude information can be analysed. Using raw transceiver data and a second Sonardyne utility program signal to noise data can also be monitored. Figure 2 below shows the typical performance of the 7970 Super Sub Mini using the results of the analysis programs.

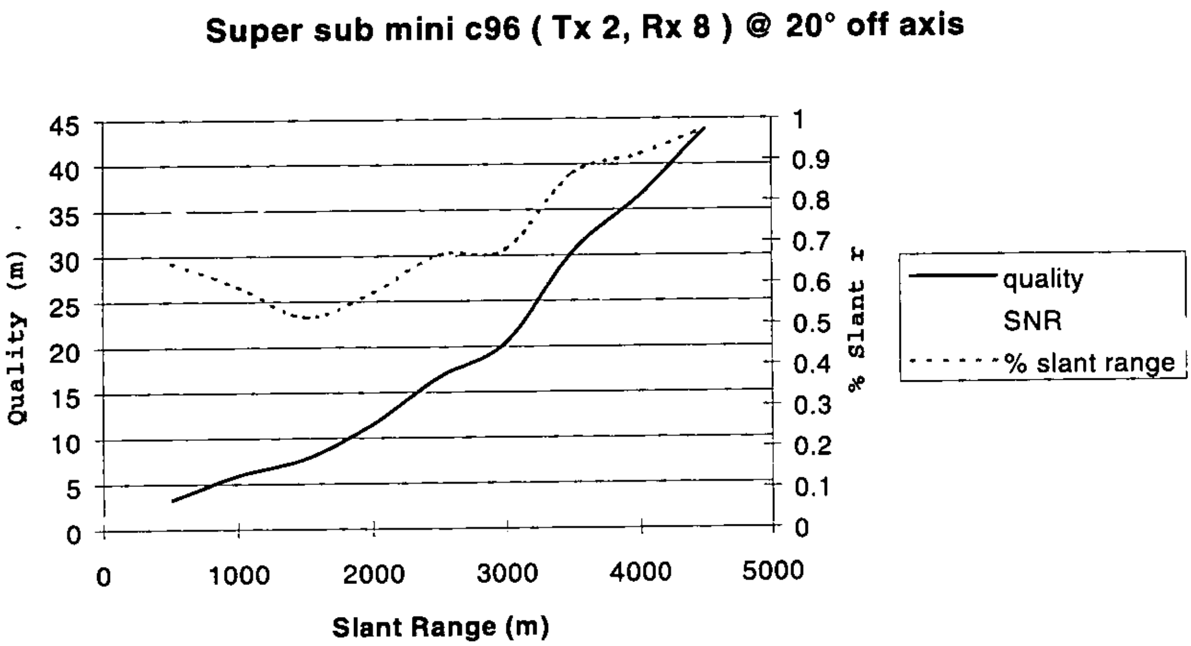


Figure 2 : Typical performance of 7970 Super Sub mini

7823 High Powered Transponder / Responder

The 7823 is a super high powered, long life directional beacon designed to get maximum range from the USBL system. Power output is 208 dB ref 1μ Pascal compared with 196 dB of the Super Sub Mini. Due to its long battery life it is more cumbersome due to the batteries size and weight. Therefore it is suited to larger vehicles such as TOBI or alternatively can also be mounted onto a cable if a special bracket is fabricated. Due to its directionality it is important the beacon it pointing towards the transceiver. If power is available the 7823 - 04 can be used, identical to the 7823 but without a battery. Due to its light weight the 7823-04 will have less effect on the towing characteristics of the vehicle and would require little or no ballasting. However should the umbilical break it would not be possible to continue positioning to aid recovery of the vehicle.

It is common to use a responder mode with this type of beacon as the omni directional interrogation pulse is 196 dB, 12dB less than the reply when the transceiver is transmitting on high power. Also the Sonardyne common interrogation frequency (CIF) of 24.7 kHz is not suitable for long ranges. This means the interrogation is the limiting factor on range when in transponder mode.

In practice the 7823 was first deployed on a frame mounted below the depressor angled at 60° off the vertical towards the vessel. A MPV was towed behind the depressor at approximately 1 to 1.5 knots resulting in a layback angle of 30 to 35° off the vertical. The beacon position remained stable until 4000 m slant range. Results are shown below in figure 3.

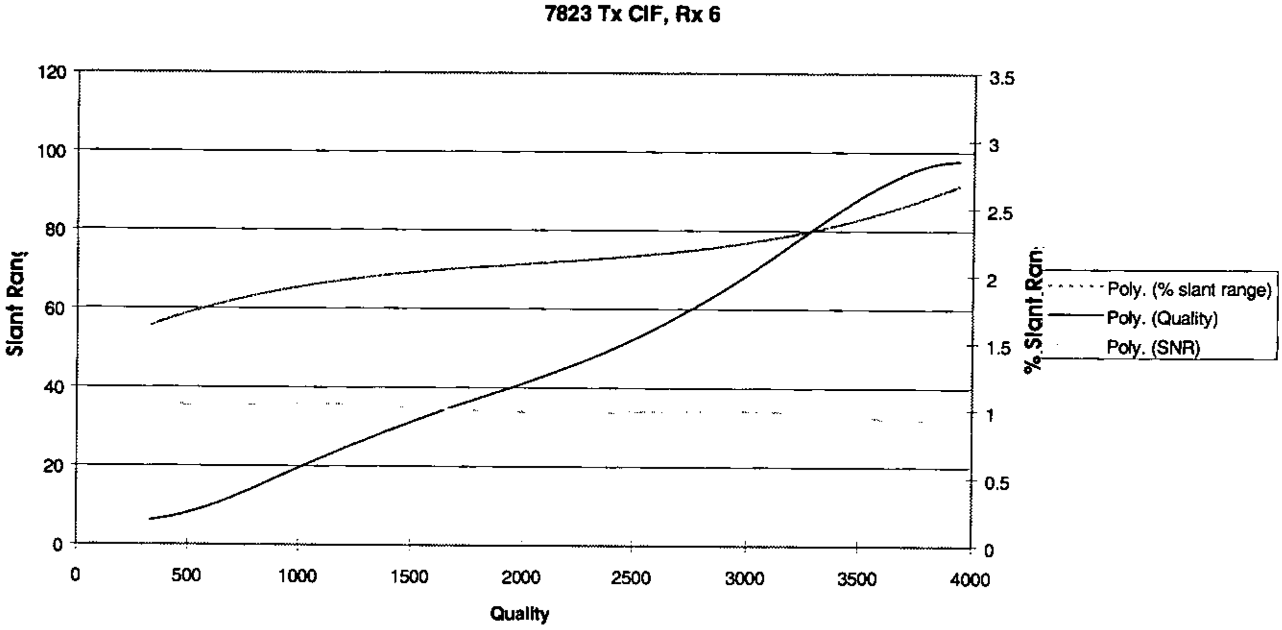


Figure 3 : 7823 typical performance

The performance of reply channel 6 was outside the system specification. As there is no straightforward explanation as to why this is the specific hardware will be analysed upon its return to the office.

The graph above shows that the maximum slant range is just under 4000 m. However at the point where positioning becomes unacceptable the Signal to Noise Ratio (SNR) of the reply is over 30 dB. This suggests that failure of the interrogation caused the positioning to become intermittent. A Sonardyne prediction program indicates that approximately 4000 m is the maximum to be expected for CIF at this angle to the vertical. A second possibility is the mounting angle of the beacon. With the beacon mounted at 60° and the incoming reply at 30° off vertical the interrogate is received and the reply transmitted towards the outer edge of the beacon beam pattern.
A later attempt to mount the beacon on the cable also proved unsuccessful as the depressor was towing at 45° behind the vessel with the beacon anticipated to be pointing vertically towards the surface once 3000m of cable had been paid out

Recommendations
For future projects this summer water depths are to be shallower at around 2500 m with a 5000 m maximum slant range. Positioning of TOBI is required to +/- 50m. More accurate positioning will also be required for coring operations.

USBL Calibration
In order to achieve the required accuracy in absolute position a Casius (calibration of attitude sensors in USBL) is recommended. This removes attitude and heading offsets introduced during the mounting of the transceiver as well as providing a check on antenna offsets and sound velocity. The vessel manoeuvres around a beacon deployed on the sea bed whilst logging USBL and DGPS data simultaneously. Post processing reduces a correction for pitch, roll and heading and an associated quality estimation. The corrections are entered into the USBL system and applied in real time to all displayed and output measurements. For a vessel of this type in 2000m of water a calibration should take around 6 hours including calibration verification and deployment and recovery of the seabed beacon.

Transponder options
During this trials trip we reached the limit of transponder mode and particularly CIF interrogation. To achieve the slant ranges required for future operations responder mode is strongly recommended. This should increase the range of the 7823 to over 5000m at a 1:2 layback ratio provided it can be mounted pointing towards the vessel. With previous beacons mounted on TOBI the acoustic reply has interfered with the side scan sonar system resulting in unusable records. The Sonardyne USBL system can take an external trigger into the top unit and use it to interrogate the beacon. The beacon transmits 61.3ms after the positive edge of the trigger pulse. Therefore it would be possible to trigger both the transponder and side scan simultaneously hopefully avoiding interference. The default delay of 61.3ms can be extended or reduced if required providing notice is given in advance.

For coring operations the 7970 Super Sub mini is ideal. Operating in transponder mode on channel 95, position repeatability of 0.6% slant range was achieved during these trials at 2500m vertically down .

Transceiver Deployment
Due to the low noise conditions it would be beneficial to tilt the transceiver towards the towed vehicle at an angle of approximately 20° off the vertical providing it is possible to maintain a low noise environment. This would not be possible through the gate valve but would be feasible with an over the side mount deployed mid - ships. A longer pole would also ensure the transceiver was as far away from vessel noise and propeller wash as is possible. The current deployment depth, 1m below the hull is not ideal. Tilting the head reduces the off axis signal strength loss caused by decreasing transceiver sensitivity towards the horizontal. It often proves beneficial in deep tow positioning applications on vessels with low noise characteristics. Due to the size of the vessel, fabricating a suitable o.t.s.m. would be difficult as would deployment and recovery. With this in mind a tilted transceiver head should only be required at ranges in excess of 5000m.

Data Output
There were a number of data output formats from the USBL. During the trials cruise a Surveyor's Output format was used to output Time, and X, Y, and Z vectors from the vessel CRP to the beacon. Any processing software would need the capability to take in the vessel antenna position, convert to UTM co ordinates, and apply the X, Y, and Z offset relative to the vessel CRP using gyro information.

Mark Carter

6.8 FOOTPADS (Fibre-Optic Ocean Temperature Profile And Depth Sensor)

The development of this system was funded under the NERC/DTI Seasense LINK Programme; it uses an array of fibre-optic Bragg gratings to sense temperature and/or strain induced by pressure.

A fibre-optic Bragg grating consists of a small (~mm sized) region of optical fibre over which a periodic axial refractive index variation is induced by exposure to a high energy laser via a phase mask. This results in a narrow reflection resonance at a wavelength which is controlled by the angle of the mask during exposure. The resonances of the sensor gratings in the array were spaced over the range 1530 - 1560 nm. The resonant wavelengths of the temperature sensors varied by about 13 ppm per degree C and that of the pressure sensor by about 13 ppm per dbar.

The gratings were spliced into the lower part of an 83 metre length of optical fibre, using junction boxes to protect the splices. The array was interrogated, using a wavelength-agile source and detection system with computer control and processing (the interrogator), giving a temperature profile of the upper ocean.

The interrogator system consisted of a PC-controlled narrow band acousto-optic tuned filter (AOTF) in series with a broadband infrared source. The AOTF is controlled by a frequency in the range 81 – 87 MHz, generated by a direct digital frequency synthesiser. Light selectively reflected by the sensors was detected and digitised by an A-D card in the PC. Software algorithms were used to identify the peaks of the individual sensor reflection resonances. Two reference gratings, held at constant temperature, were used to compensate for drift in the optoelectronic system. Output data, which are the block average of several readings of the frequency synthesiser control word, were stored to disk at 1 second intervals.

The system had been tested briefly in calibrations at SOC and in a short sea trial off Portland Bill, conducted by D.E.R.A. The object of the trial on CD121 was to investigate stability, noise levels, crosstalk between sensors and robustness in a realistic operating environment, with the sensor string deployed on the CTD wire.

The fibre-optic cable used for construction of the sensor array was sheathed in Fibercore LT3, which uses a layer of Aramid yarn between the polypropylene loose tube, containing the primary coated fibre, and a PVC outer sheath, with an overall diameter of 3 mm. This construction, whilst giving a degree of ruggedness, is not designed for underwater use and would be expected to collapse on the fibre at depths exceeding about 100 metres. Also, the single pressure sensor included in the string had a full scale rating of 5 bar, above which the Bragg grating could be overstrained. The deployments were, therefore, limited to the top 50 metres of the ocean. The configuration of the array is shown in figure 1.

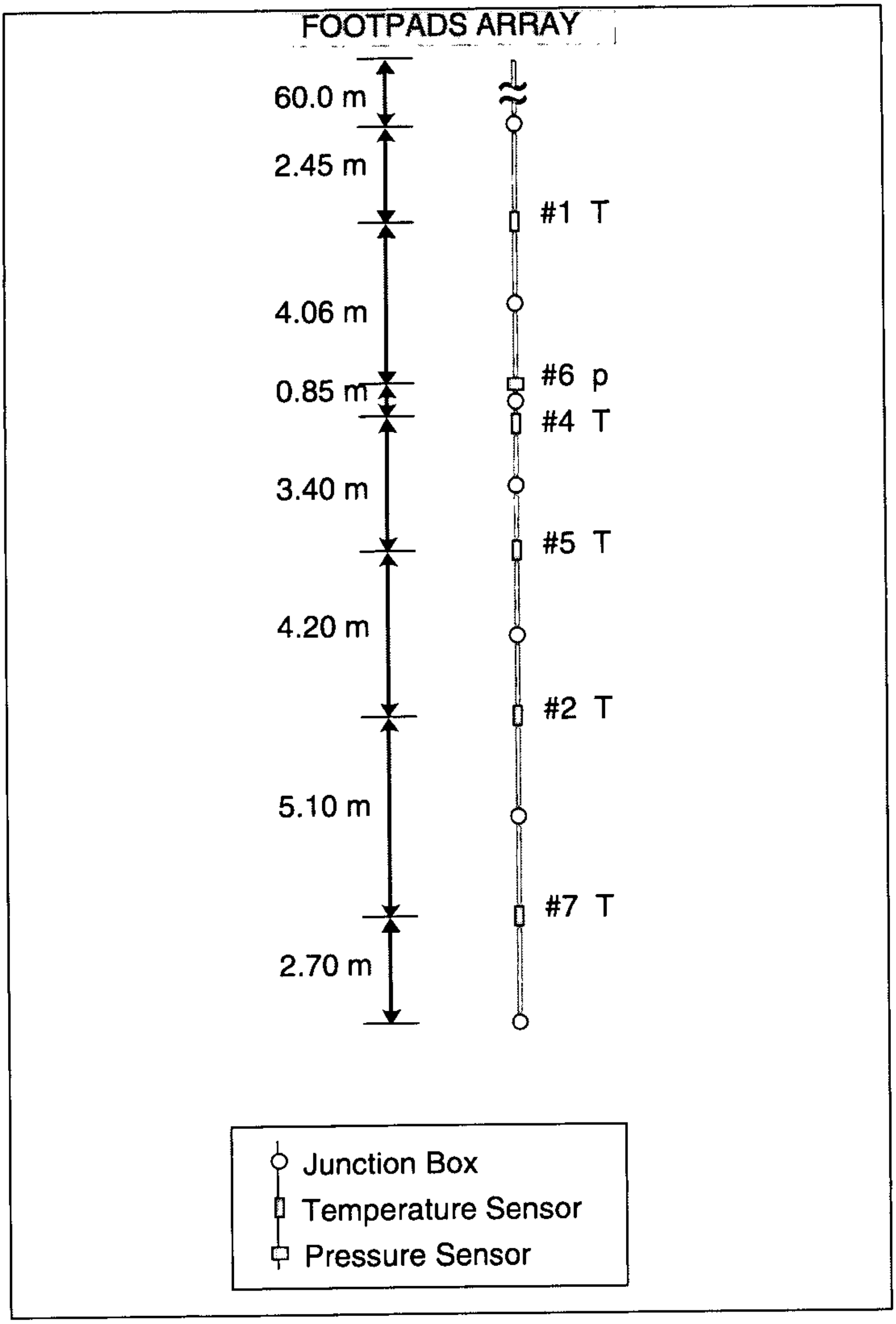


Figure 1. FOOTPADS Array Configuration

The array was connected to the interrogator system in the main lab via the fibre optic cable. For the first trial, the array sensors were attached directly to the CTD frame, as shown in figure 2, so that a common temperature was sensed by each sensor as the CTD was lowered to 50 metres depth. The CTD measured the temperature profile to an accuracy of a few millidegrees C.

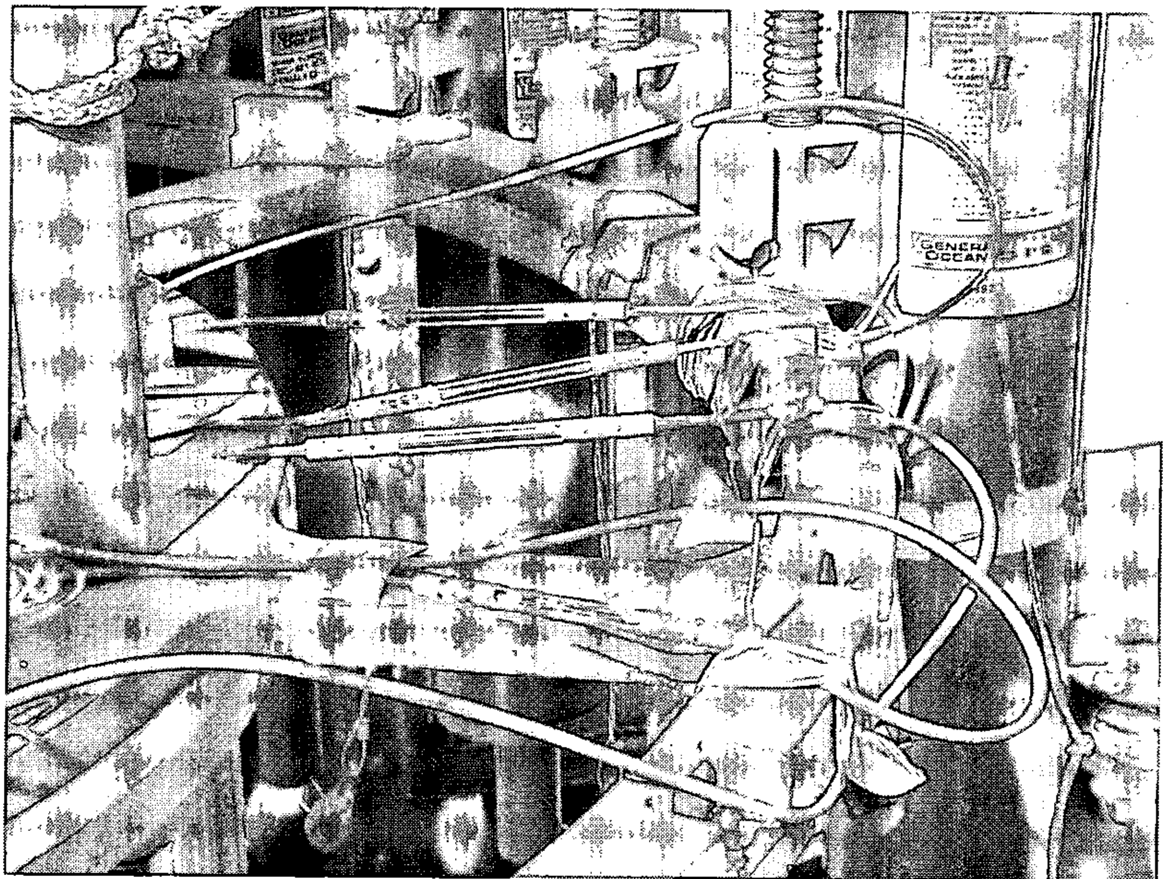


Figure 2. Part of FOOTPADS Array on CTD pylon frame

The fibre-optic cable sheath was attached to the CTD wire with cable ties as the wire was veered with the roller keeping it close to the ship's rail. The combination of these ties and the drag experienced by the cable loops caused localised "microbending" of the optical fibre which caused transmission losses due to the local angle of incidence on the interface between the core and cladding being less than the critical angle. Such microbending was, fortunately, reversible but bending at the top tie eventually caused losses large enough to prevent proper operation of the system. A bend restrictor was subsequently improvised from some lengths of plastic strip attached at the point where the fibre cable came inboard from the wire.

A CTD cast was then carried out with the array attached to the CTD wire, at intervals of approximately 2 metres, so as to give a continuous profile; this was recorded for half an hour. These tests showed up a problem with the stability of the software, which was subsequently cured successfully, and a degree of crosstalk between the sensors, which had been experienced previously. The crosstalk was thought to be due to excessive sidelobe or background level in the AOTF, although software problems were not ruled out. Further tests were made with the sensors on deck, using buckets of water at different temperatures, to narrow down the possible causes.

Detailed improvements were made to the software, but the crosstalk was found to be inherent in the present system due to the spacings of the sensor resonance wavelengths, in combination with the relatively broad AOTF bandwidth and sidelobe levels. Improvement will need the radical approach of replacement of the AOTF system, possibly by a piezo-tunable Fabry-Perot etalon or by a high-resolution spectrometer using an echelle grating in combination with a cross-dispersion grating, with a 2-D CCD array.

Acknowledgements: the participants in this trial wish to acknowledge the contributions made by the other consortium members, in particular D.E.R.A. who made the array and loaned equipment.

Charles Clayson, Matthew Mowlem and Ralf Prien

6.9 SUV-6 Nitrate Sensor

The nitrate sensors manufactured by Valeport Ltd. under licence to SOC use the absorption of UV light in the spectral range 205 to 280 nm as a measure of the concentration of dissolved nitrate and chloride in sea water. The design has undergone a number of detail improvements with the aim of improving stability of data. The most recent of these improvements has been the inclusion of a "flipping mirror" for in situ calibration by diverting the normal beam to a calibration path in air. Such calibration is necessitated by changes in the shape of the light source spectrum with age and with temperature. This modification was initially implemented over a year ago, but lack of precision of the mechanism, together with a number of lesser operating problems, lead to a further design review in September 1999. As a result of this, the deep and shallow sensors were modified by Valeport and delivered to SOC shortly before the sailing date.

Unfortunately the modified instruments suffered from a number of problems. Firstly, the bandwidths of the sensed channels appeared to be excessively wide, resulting in a smearing of the spectrum and a marked reduction in sensitivity to nitrate at the 220 nm primary wavelength. This could be due to incorrect positioning of the lenses, resulting in imperfect focussing. Secondly, the mirror mechanism did not work reliably, frequently failing to move from the normal position to the calibration position. This was diagnosed as being due to an unsatisfactory route for the helical tension spring over a sharp 90 degree bend. The operation was improved by cementing a small rounded piece of steel over the bend. Thirdly, the mirror position in the calibration mode was not sufficiently reproducible, resulting in large variations in the calibration signals with air in the sensed volume. At 250 nm, these variations were as much as 100%. This was thought to be due to a combination of play in the mirror bearings, together with the offset spring and end stop positions.

Despite these deficiencies, the deep instrument was deployed on casts to 2000 and 3000 metres depth, showing the classical hysteresis problem which the mirror was designed to correct, i.e. the up cast did not follow the profile of the down cast. It is believed that this results from the thermal time lag between the water temperature and the source tube temperature. Attempts to use the calibration signals have, so far, been only partially successful.

Figure 3, below, shows the normal and calibration mode signals obtained on a cast to 2000m; the instrument was set to measure the normal signal for 30 seconds in each minute, the remaining 30 seconds measuring in the calibration mode. The resulting plots show the calibration signals. As can be seen, the 235 nm and 250 nm calibration signals were highly variable. The 220 nm calibration signal was better, but even this had to be edited.

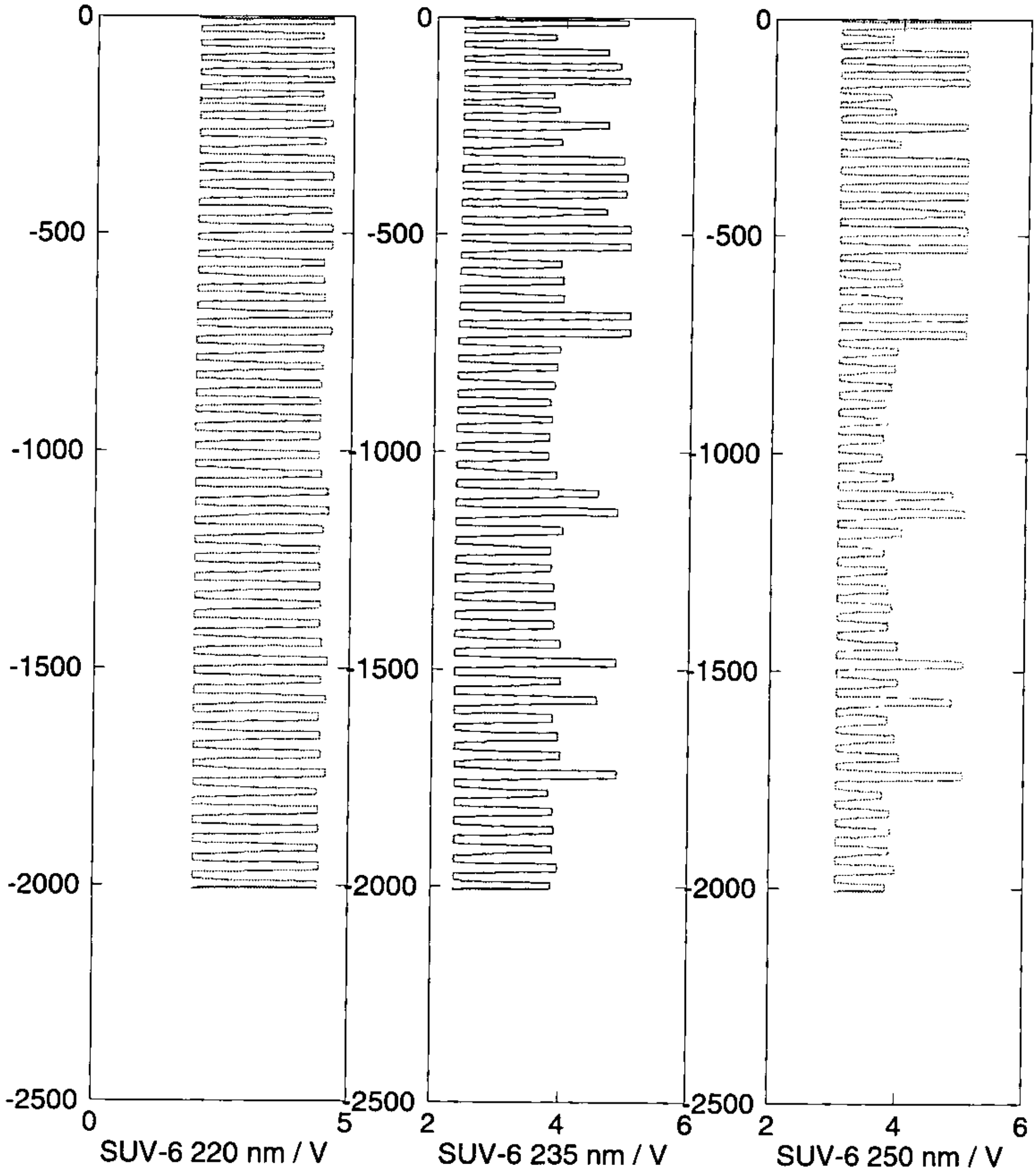


Figure 3. SUV-6 Data from Cast #6
Normal Mode Data are the lower values in each trace, Calibration Mode Data are the higher values

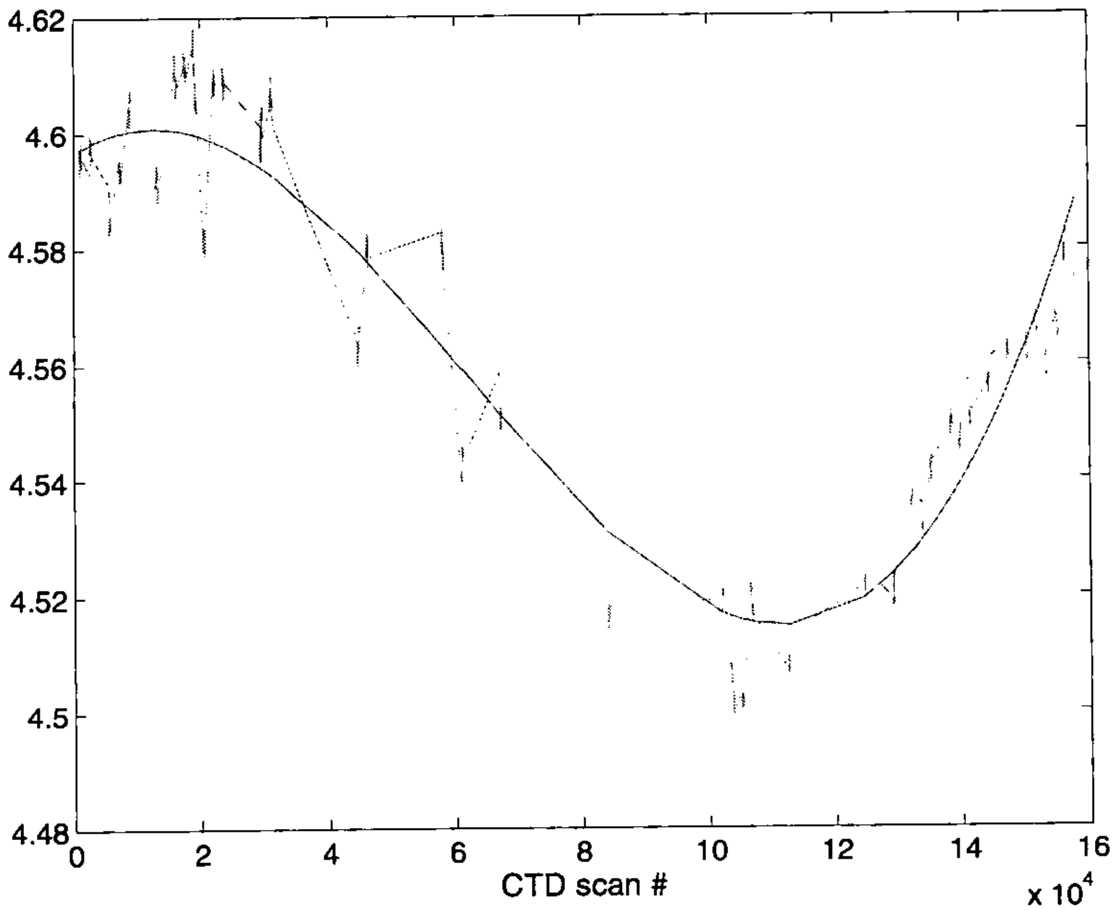


Figure 4. 3[rd] Order polynomial fit to edited 220 nm calibration values

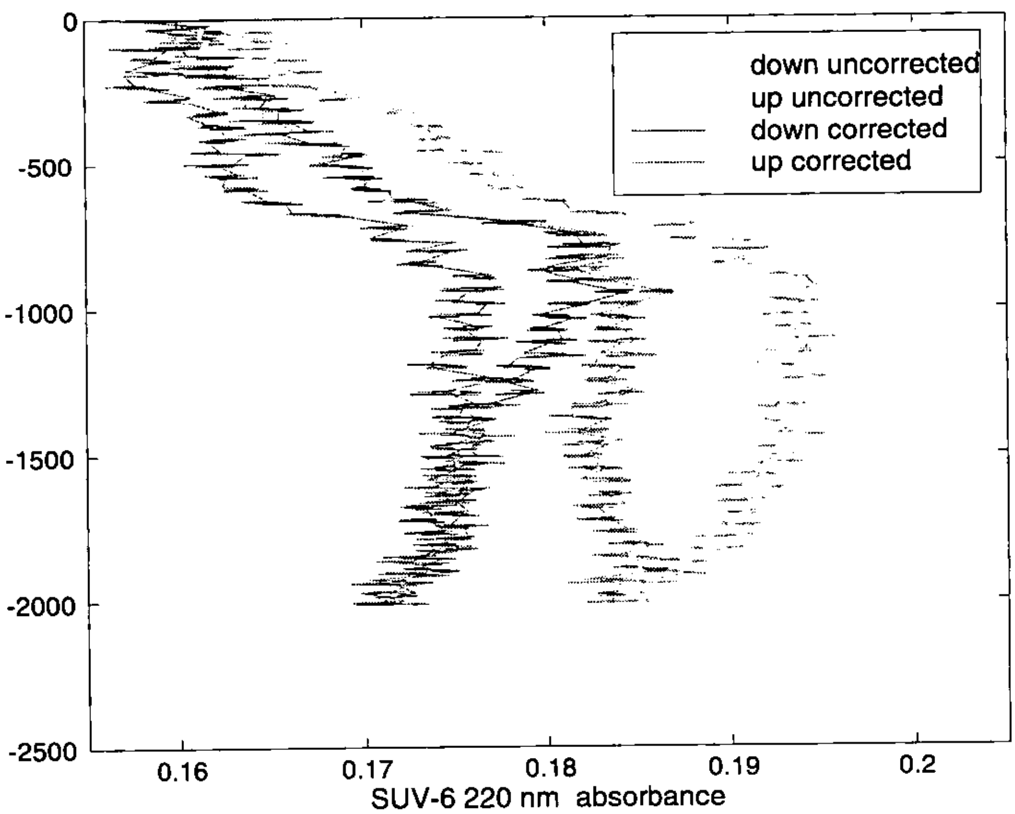


Figure 5 SUV-6 220 nm Data, corrected using the mean value of the noisy calibration data

The SUV-6 was powered by a 35 Ah secondary battery, kindly loaned by the SHRIMP project, since it proved impossible to power it from the designated 24 V supply from the CTD (figure 6). The 220, 235 and 250 nm analogue signals were acquired by the CTD. The CTD binary data files were decoded and analysed using a Matlab program written by Ralf Prien.

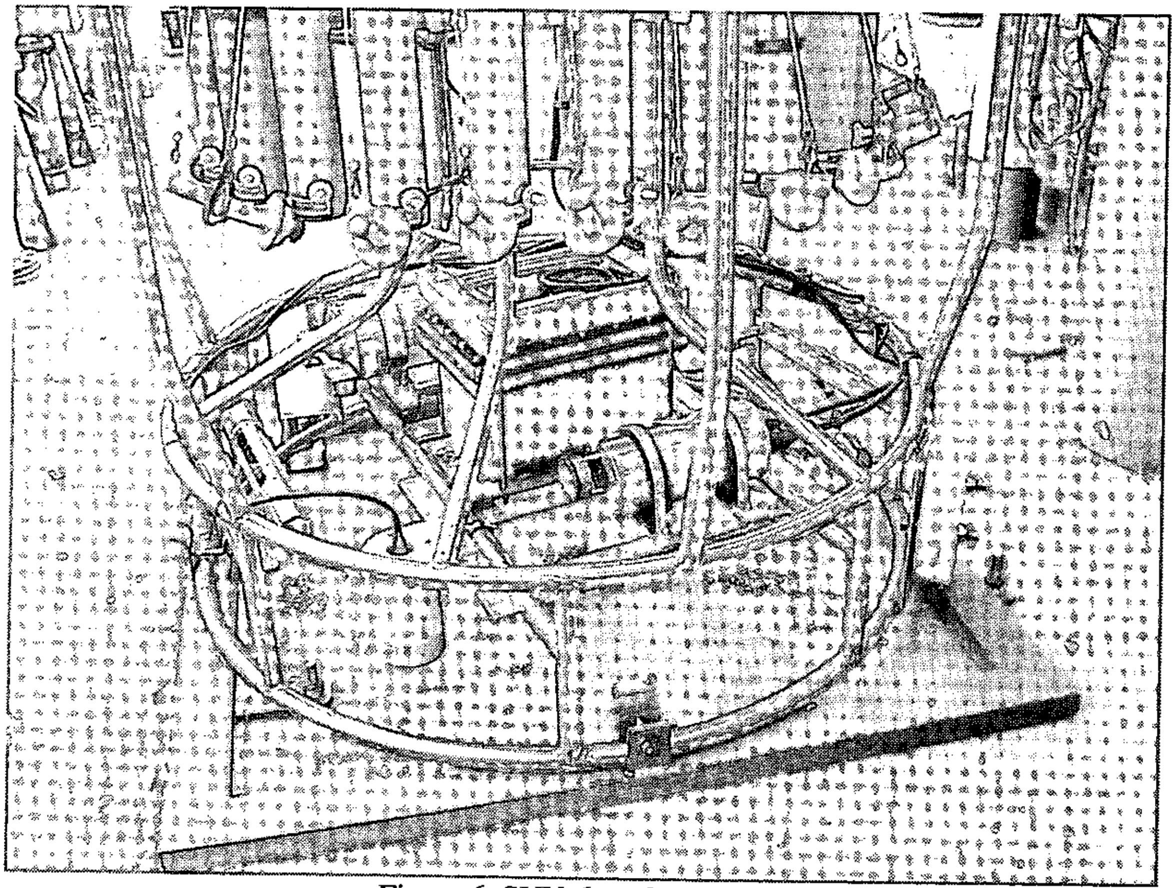


Figure 6. SUV-6 on CTD frame

Acknowledgements: thanks are due to John Smithers for providing and setting up the CTD system, to Dave Edge for loan of the battery and connectors, and to Bob Wallace for fitting a temporary battery mount to the CTD frame.

Charles Clayson and Ralf Prien

6.10 AUTOFLUX Met System

The system had been set up by Robin Pascal et al. prior to the cruise for a test under operational conditions (as an unattended system). Its operation was monitored at least daily and some of the data were worked up for examination during the cruise.
Problems experienced included two failures of the GPS receiver, which latched up drawing excessive current from its power supply. These were cured simply by switching it off and on again.
The dry bulb thermometers (PRTs) in the port and starboard psychrometers suffered from occasional problems with water drips, depressing their temperatures. All psychrometer signals suffered from intermittent spikes, due to buffer problems. In spite of increasing buffer time out duration, it was not possible to eliminate these completely.
SST data acquired from the RVS SurfMet system were also affected by timing problems and atmospheric pressure readings were sometimes absent.

In contrast, the three fast sampling systems performed reliably, with no problems apart from incorrect directory and file naming, which was corrected, and a date problem in the Sonic Temperature system.

Charles Clayson

6.11 SHRIMP

Objectives

- Prove communications with the deep tow fibre optic cable.
- Prove operation of High Intensity Discharge (HID) Daylight and Thallium Iodide underwater lighting for use with both CCD and SIT cameras. Obtain video records of seabed images to identify optimum operational altitudes when combining these devices.

Results

The first week of the cruise was devoted to rewiring the SHRIMP electronics to incorporate a new electronic chassis and end-caps. The late delivery of these items a few days before sailing, delayed the wiring schedule and prevented in-house pressure testing of the end-caps and connectors. By the end of the first week the SHRIMP electronics was prepared and tested in the laboratory ready for deployment.

To simplify the scheduling of trials equipment onboard and associated winch cables, SHRIMP was deployed over the stern as opposed to the preferred operational position at mid-ships. The only optical swivel available for attaching the vehicle to the fibre optic cable was one designed for another instrument named 'DASI'. Its size and weight proved very cumbersome and during the trials caused damage to SHRIMP when they collided near the surface due to ship heave.

The initial deployment was to prove the watertight integrity of the end-caps and connectors. This test proved crucial as it was found on recovery that the main pressure vessel contained approximately 10 litres of water. All connectors and blanking plugs were removed and all 'O' rings inspected, cleaned and reassembled. The second deployment showed no improvement with the same quantity of water captured. After much deliberation and connector replacing a final deployment achieved the same results.

It was decided to wipe down SHRIMP and conduct further tests back at SOC.

On return to SOC, one week of exhaustive testing in the pressure tank found the cause.

With only the small pressure tank operational a short pressure housing was produced for mounting the end-caps. The leak was finally traced to a hard-anodized aluminum blanking plug containing a fissure through its full length. This blanking plug was the only one of four used during the trials cruise that proved faulty.

Conclusion

This exercise has shown that development and testing of new instruments can be time consuming and frustrating. It is clear that good preparation prior to sea trials pays dividends and late delivery of essential components is not welcomed. This cruise provided the opportunity to focus purely on instrument development and not be pressurized by other scientific demands.

For future operations it would be beneficial to have an alternative fibre optic swivel available more suited in size to the application.

Dave Edge

6.12 SUMOSS2

Introduction

SUMOSS2 is an instrument for studying ocean colour developed with funding from the NERC Technical Innovation Fund and the MAST BIOCOLOR project. The objectives on this cruise were;

1. To improve the deployment technique
2. To test a new type of strain termination on the dunking cable
3. To produce a user manual
4. To use the photodiode light sensor to automatically determine the correct exposure for the CCD
5. To obtain some irradiance and transmission profiles
6. To gain experience of data gathering and processing

Deployment Log

SUMOSS2 was deployed on three occasions, in a variety of water depths.

Day 118 (27 April)
Overboard from 1200 to 1415Z at 48° 20.14' N, 14° 25.89' W. Water depth 4800m, broken sunshine and large swell.

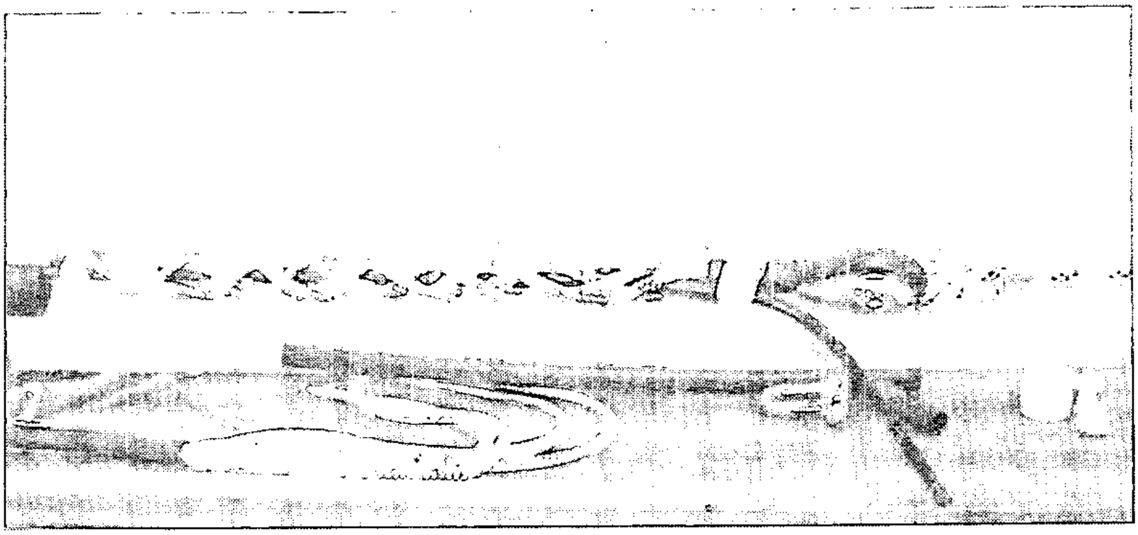
Day 123 (2 May)
Overboard from 1300 to 1415Z at 48° 36.54' N, 8° 22.97' W. Water depth 170m, hazy sunshine.

Day 124 (3 May)
Overboard from 1130 to 1330Z at 50° 12.23' N, 3° 1.80' W. Water depth 55m, overcast.

Cable Termination

Shortly before the cruise, Ian Waddington and his team in OED had developed a new method of terminating the cable at the instrument, based on the ancient "Chinese finger" design. The original cable termination used a special moulding to attach the strain bearing kevlar in the cable to a special stainless steel fork fitting which was in turn secured to the instrument with a pin. This arrangement was expensive and impossible to repair in the field. Ian's termination method, known as "The Gripper", uses kevlar braid to transfer the load from an attachment eye to the stain bearing kevlar in the cable as shown in fig. 1. The braiding is plaited around the cable then covered with heat shrink tubing for protection and to hold it in position. After performing successfully on the OED load test facility, the termination was used for the first time on this cruise.
Although SUMOSS2 only weighs 120 kg in air and around half that in water, it has significant drag which means it can be subject to quite high snatch loading when deployed from a rolling ship. This was especially apparent during the first of the 3 deployments when a large swell was running. The termination was carefully inspected after each deployment but no evidence of movement was found. "The Gripper" thus seems to be a reliable and cost effective solution to the problem of strain termination for kevlar cables.

Figure 1 "The Gripper" Under Construction



Deployment Procedure

As on the 1999 trials cruise, SUMOSS2 was deployed using the RVS SR3 slip-ring winch. The winch was mounted on the starboard side, just outside the main lab. In this position, the large crane situated on the next deck up can be used to lift the instrument over the side and can then extend to hold it away from the ship. This is particularly important given the proximity of the ship's main propeller. The cable runs over a large sheave, which should ideally have a narrow "V" section to stop the cable sliding around. Fig.2 shows the deployment arrangement with the instrument in the water.

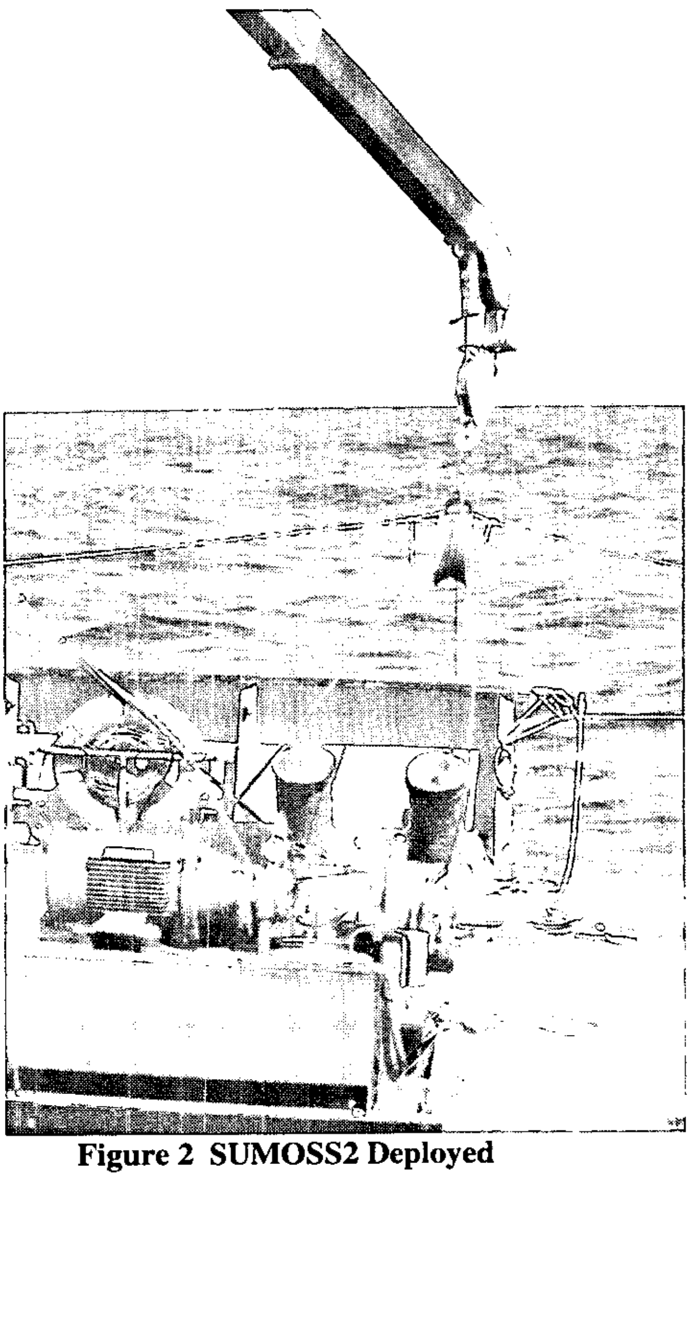


Figure 2 SUMOSS2 Deployed

Instrument Movement

It is desirable that the upwelling and downwelling irradiance sensors remain in the horizontal plane while measurements are made, and in order to monitor the stability of SUMOSS, a pitch, roll and compass sensor is installed. This sensor is oriented such that when viewed from above, the struts holding the irradiance sensors are deemed to point forwards. Thus a positive pitch angle means the struts are angled down, whilst a positive roll angle means the "port" side of the instrument is angled down.

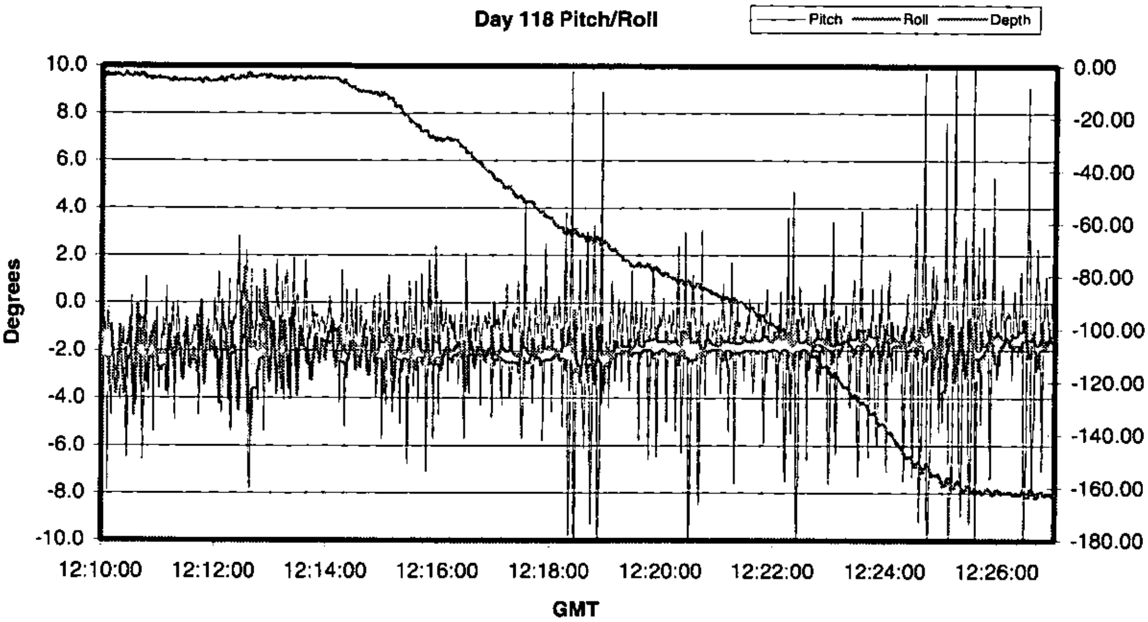


Figure 3 Pitch, Roll and Depth on Day 118

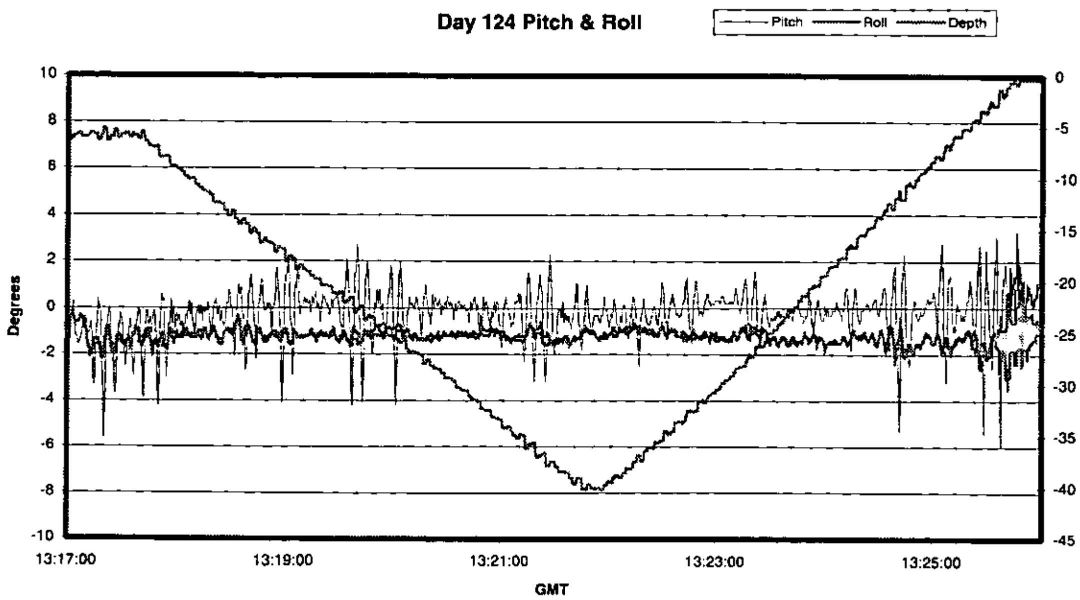


Figure 4 Pitch, Roll and Depth on Day 124

Figures 3 and 4 show some data from these sensors under fairly rough (day 118) and fairly calm (day 124) conditions. As the ship heaves up and down the motion is transmitted to SUMOSS as can be seen in the depth data. However, the struts have significant drag causing

this motion to be translated into pitching which can exceed 6108 in bad weather. The roll stability is much better, rarely exceeding 618, even in poor weather.
It is worth noting the difference in the depth records in the two examples shown above. When the ship motion is large it is impossible obtain anything like a constant downward velocity because of the drag and inertia of SUMOSS.
The heading of the struts carrying the irradiance sensors is also of interest and figure 5 shows some data from day 123, including the ship's heading. Note that the SUMOSS heading is magnetic, and is uncorrected for deviation or variation.

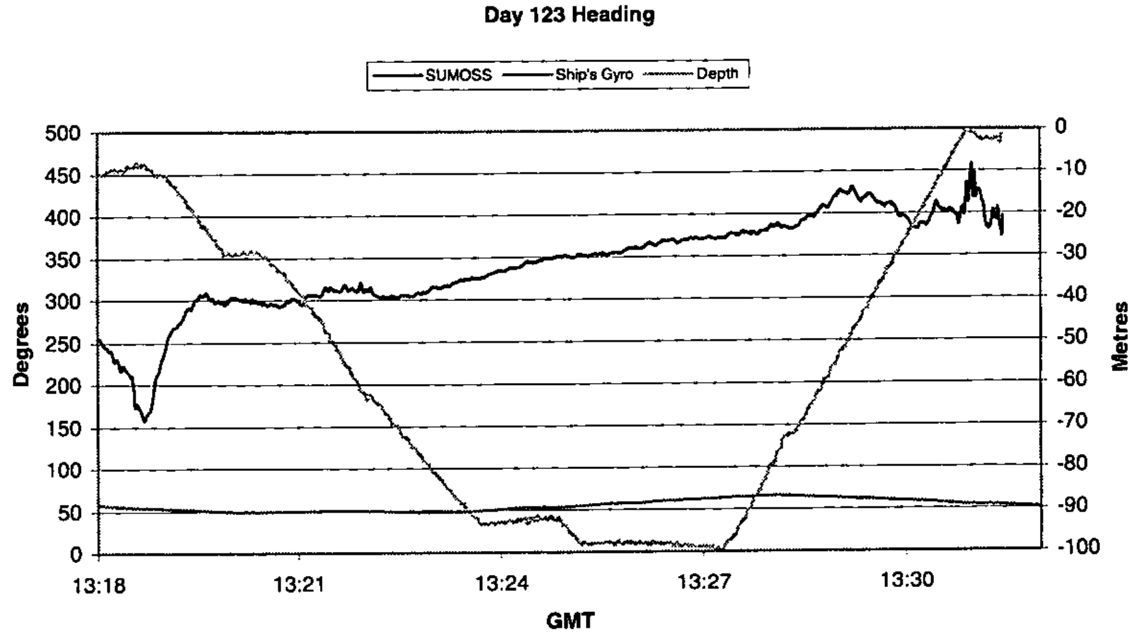


Figure 5 SUMOSS Heading on Day 123

Photodiode Light Sensor

A small photodiode with an integrated amplifier is situated close to the top of the SUMOSS spherical pressure housing, and is intended to provide a method for quickly determining the correct CCD exposure time when measuring irradiance. The signal from the photodiode is digitised using a 12-bit analogue to digital converter board. The photodiode amplifier has two gain settings, which are automatically switched under computer control to increase its dynamic range. However, the switching process appears to be unreliable so that on some occasions the program failed to switch to the more sensitive setting, and on others the circuit failed to respond to a command to switch gains. The algorithm for converting output voltage into Watts m^{-2} was derived from the photodiode datasheet and has not been verified by calibration.
Figure 6 shows how the measured irradiance varied with depth in the 3 deployment locations. Since these measurements have not been corrected for variations in the surface irradiance, it is not possible to estimate the role of water clarity in producing observed differences between the deep ocean (day 118) and the English Channel (day 124). The wide variations in the data for day 118 reflect variations in the surface irradiance caused by clouds. The data for day 123 appears to be incorrect below 45 m, and this was probably caused by a failure of the gain switching mechanism to change to the more sensitive setting.

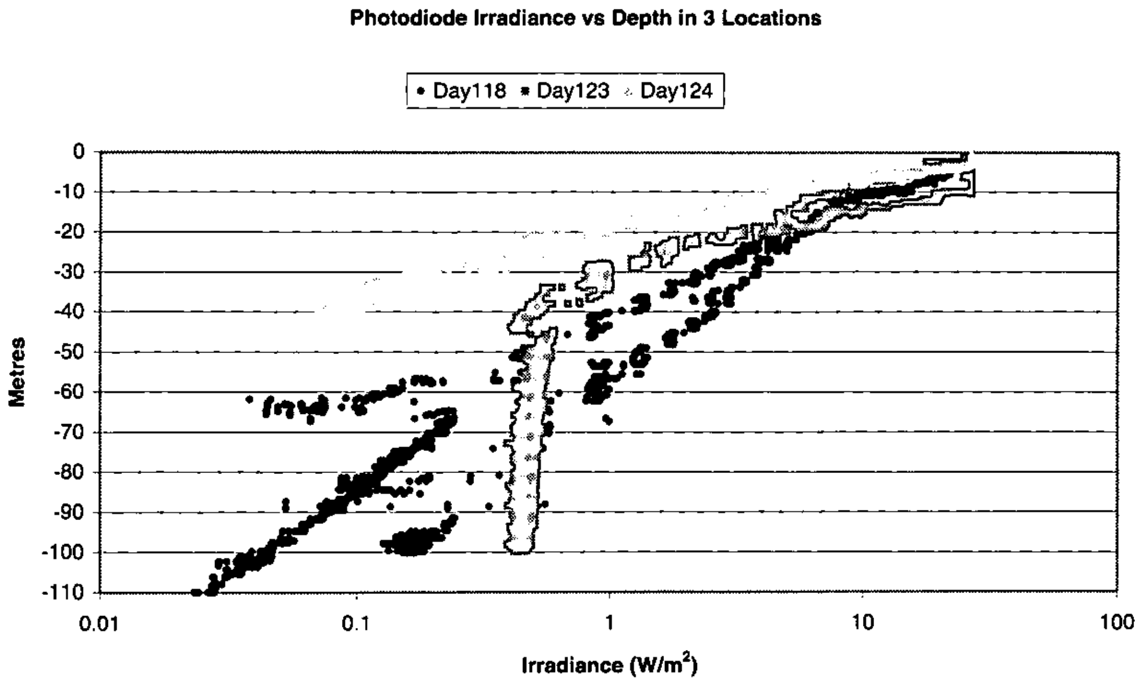


Figure 6 Photodiode Irradiance

In order to obtain a relationship between photodiode irradiance and CCD exposure time, correctly exposed spectra were selected from those recorded on day 118, and the corresponding exposures and irradiances were plotted in figure 7. The equation shown in the figure was then incorporated into the ccd3.c program to automatically set the exposure time. This produced results that were consistently underexposed, so the multiplier in the equation was doubled as shown in the "Double" line. This gave better results.

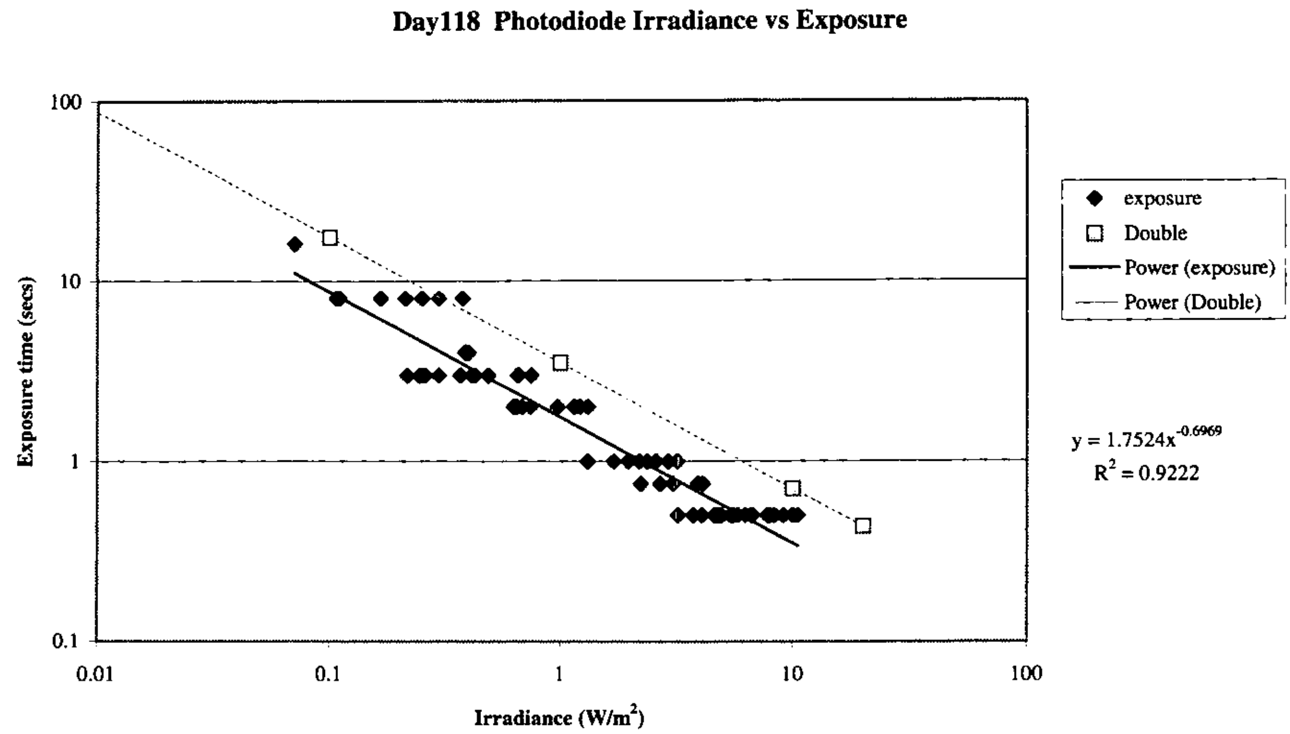


Figure 7 CCD Exposure Time as a function of Irradiance

Although the principle of automatically determining exposure time has been demonstrated, its practical application was marred by the problems with the photodiode irradiance measurements. The accuracy of the photodiode output would also be improved by positioning it away from the pressure housing, clear of any shading.

Irradiance Measurements

SUMOSS2 has a pair of twin upwelling/downwelling irradiance sensors located a metre apart at the ends of the struts. The Eu1/Ed1 sensor is located above the Eu2/Ed2 sensor. There is also a scalar irradiance sensor located half way between these two.

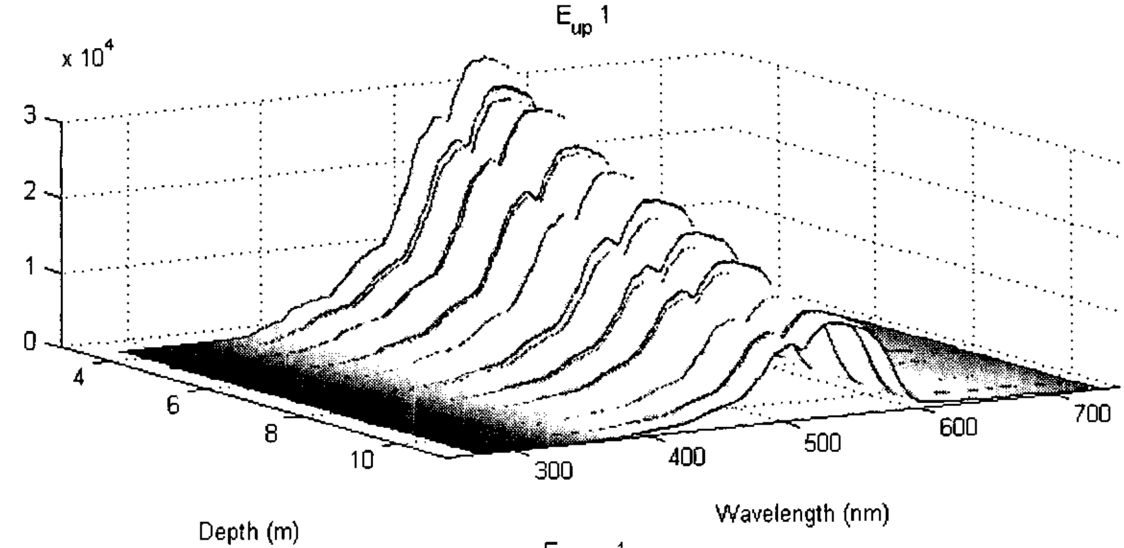
Figure 8 shows a typical irradiance profile with uncorrected outputs from the top upwelling/downwelling sensor and the scalar sensor. Note that the downwelling spectra are overexposed in the 4 to 6 m range, resulting in flat-topped spectra. This situation could be improved by attenuating the downwelling signals so that their level is closer to that of the upwelling signals, making it easier to judge the correct exposure time.

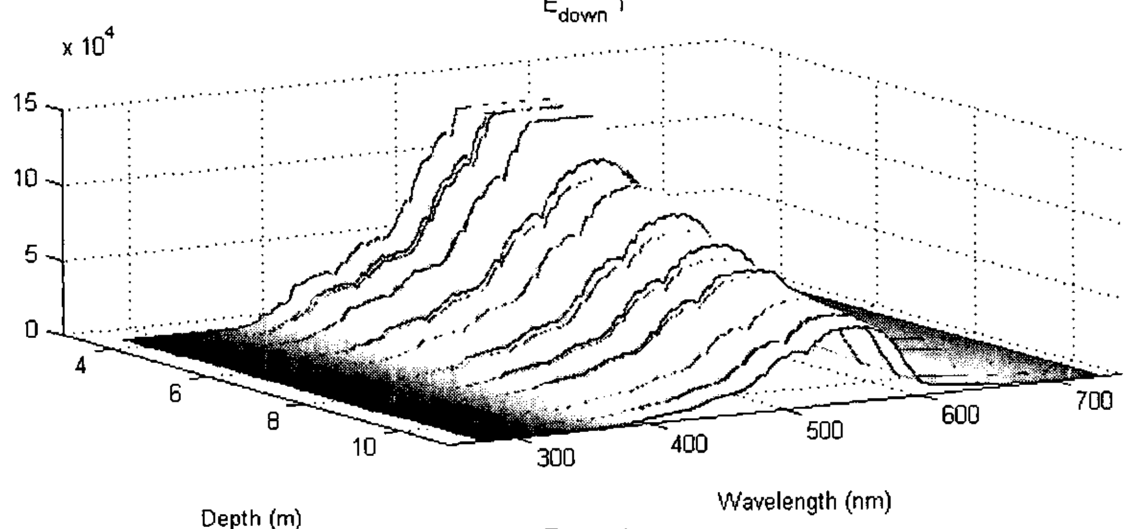
Transmission Measurements

Although the transmissometer has two light sources, a laser diode and a xenon flash, it was not possible to use the laser during these trials as it was too bright for even the minimum exposure time. The xenon flash produced some results as shown below, but in contrast to the laser the signal levels were on the low side. Furthermore the N.D. filter placed in the reference signal path to attenuate the laser brightness rendered the xenon reference signal too small to be usable. This meant that the transmission results could not be compensated for variations in output energy from the xenon flash.

Figure 9 is a profile of transmission measurements recorded on day 124, as SUMOSS was lowered from 3 m to 33m. In the lower of the two plots, the data has been normalised relative to the deepest spectra in order to highlight small variations. Despite the rather noisy data, a general trend of transmission reducing with depth is apparent.

Figure 10 shows a similar normalised profile recorded on day 123, as SUMOSS was raised from 53 m to 2 m. Here the transmission appears to reach a pronounced minimum at around 30 m before increasing again. This is roughly coincident with the thermocline visible in the SUMOSS CTD data from this station (see figure 13).
Although these results demonstrate the potential of the SUMOSS transmissometer for profiling, several adjustments and calibrations need to be carried out before it can produce scientifically valid data.





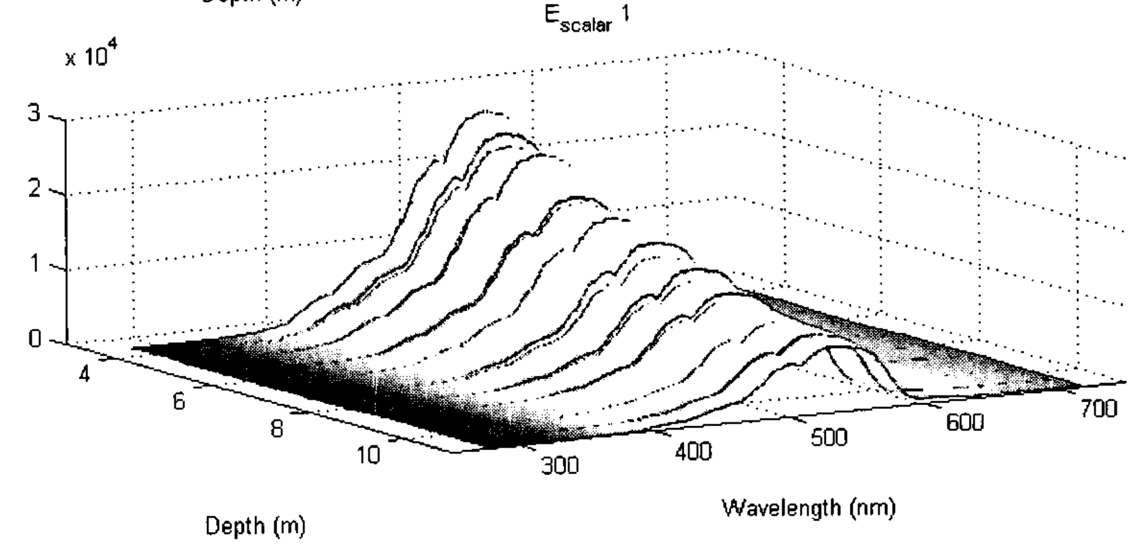
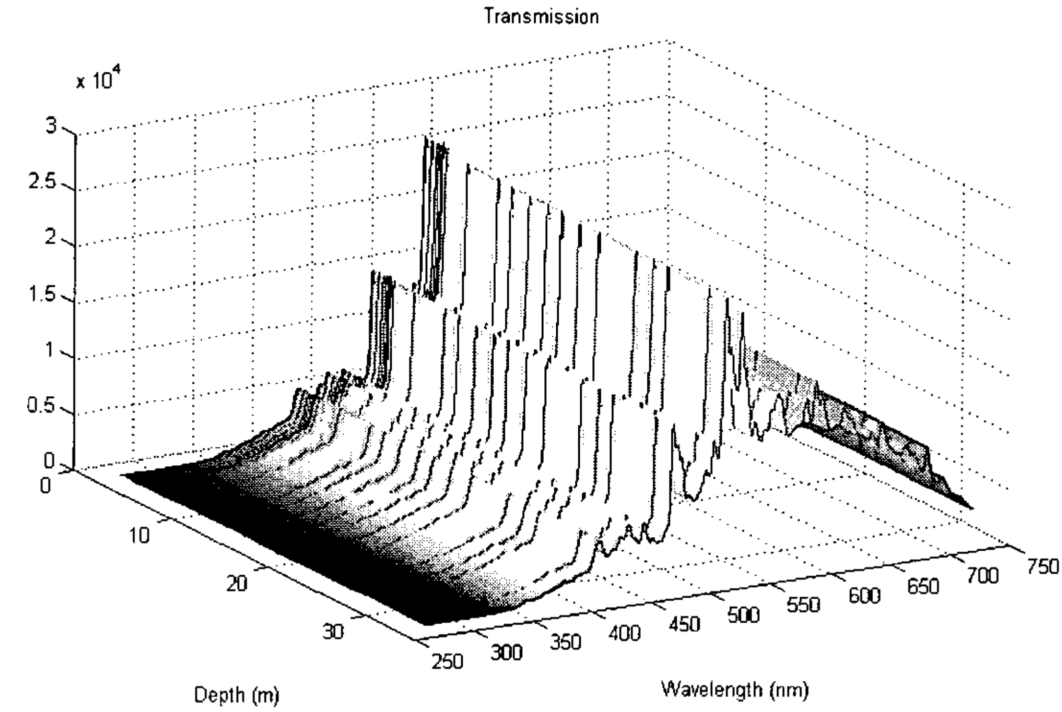


Figure 8 Irradiance profiles from Day 124



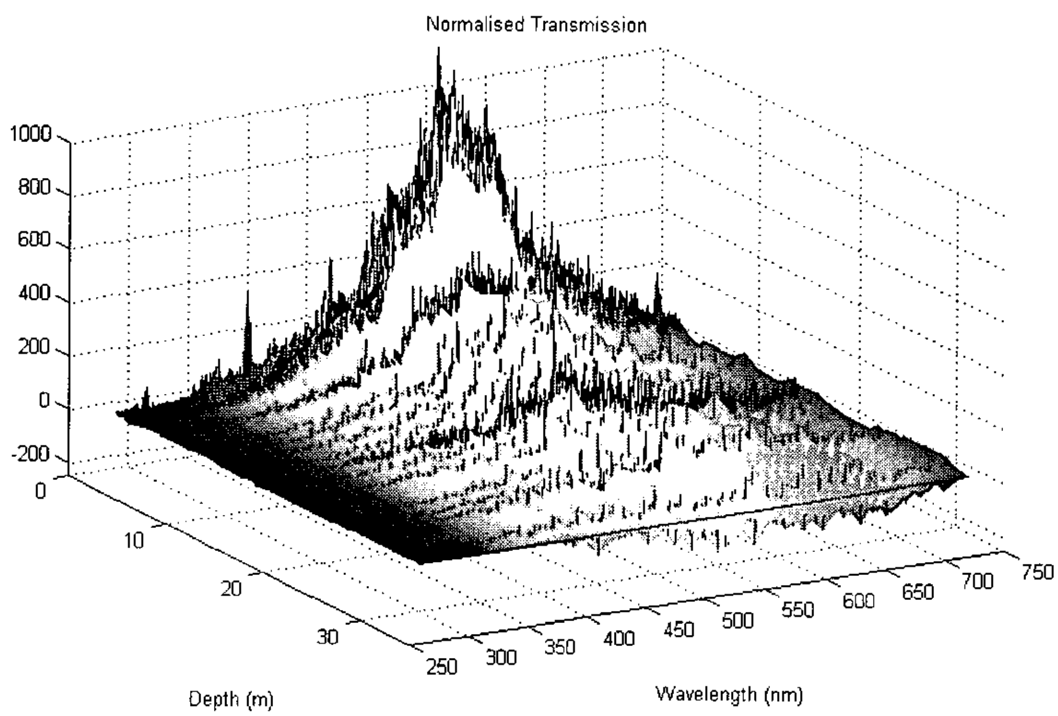


Figure 9 Transmissometer Profile Day 124

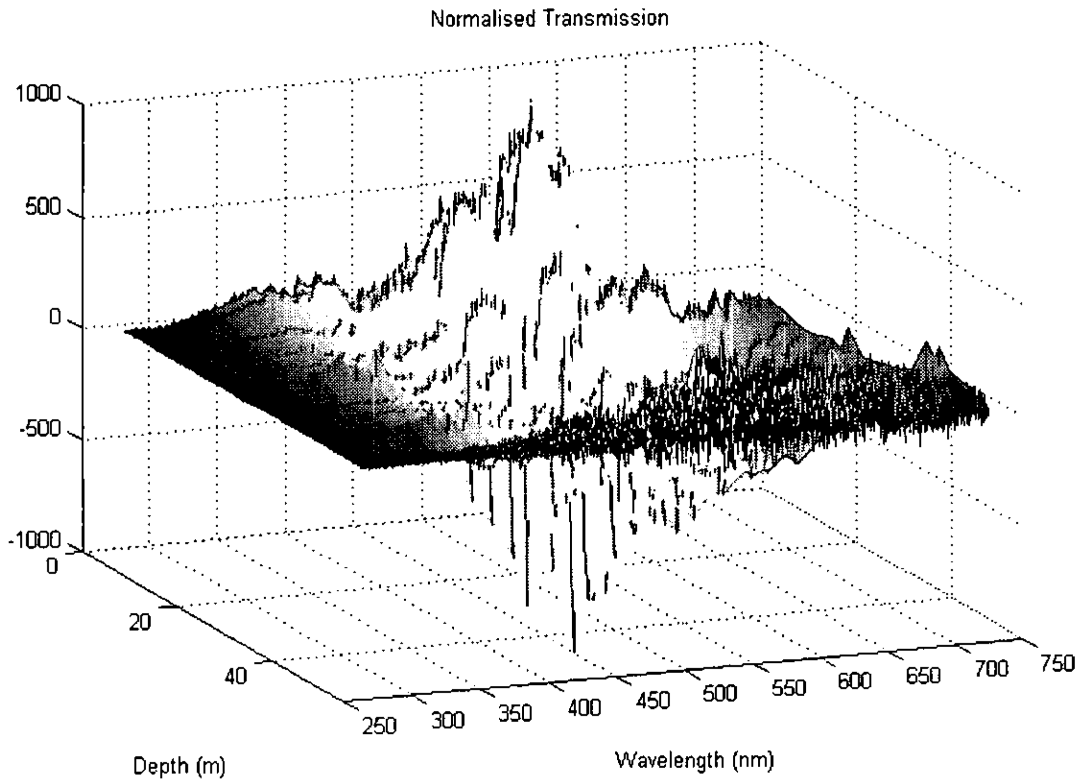


Figure 10 Transmissometer Profile Day 123

Conductivity and Temperature Profiles

SUMOSS2 is equipped with an FSI C-T sensor module and a pressure gauge. On Day 118 the ship's main CTD (a GO/Neil Brown MkIIIC) was used approximately 3 hours before SUMOSS (cast #5) and 3 hours after SUMOSS (cast #6). This afforded the opportunity to compare data from the SUMOSS CTD with a standard instrument.

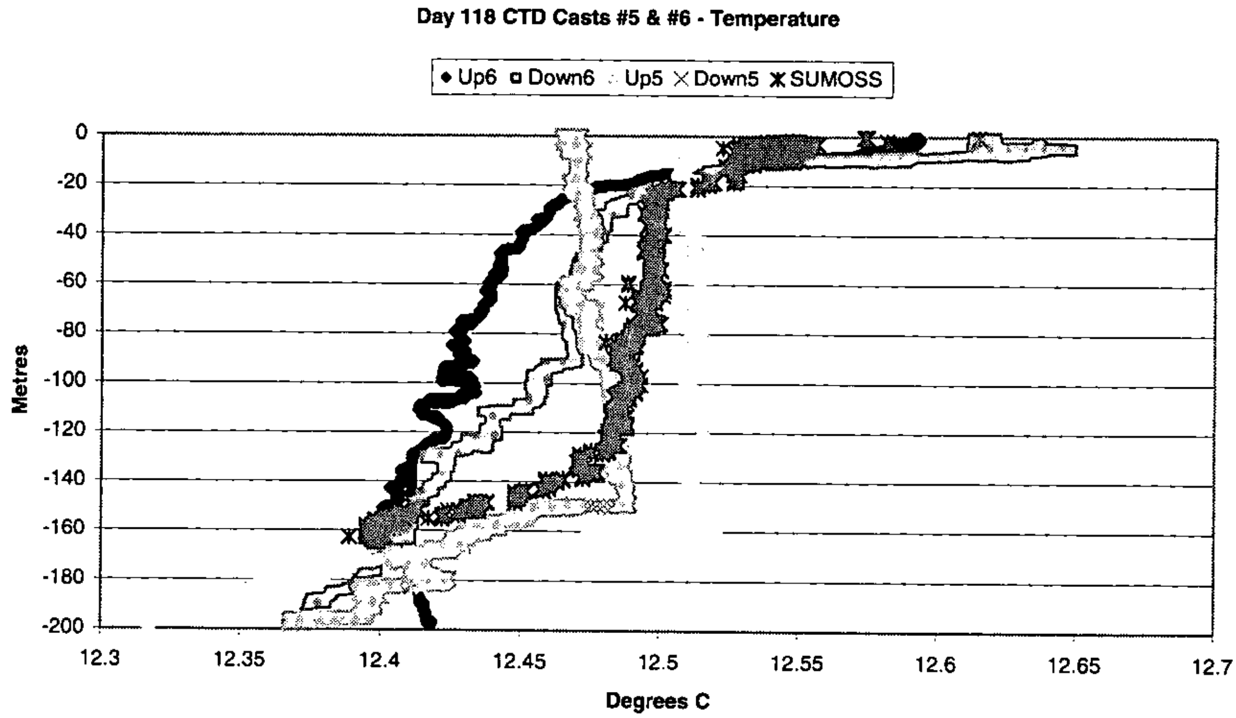


Figure 11 CTD Comparison - Temperature

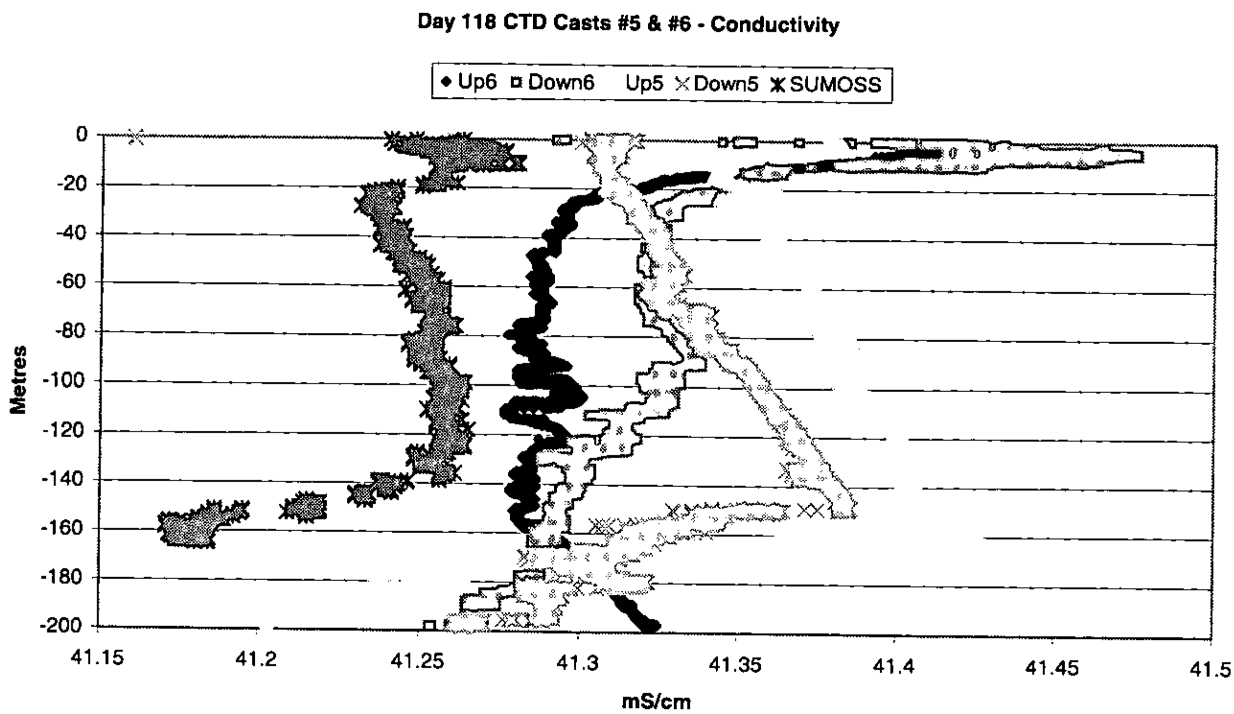


Figure 12 CTD Comparison - Conductivity

Figures 11 and 12 show how the SUMOSS CTD data compares with the Neil Brown CTD. Although the temperature is in good agreement, the SUMOSS conductivity sensor appears to be reading about 0.1 mS/cm low, which may be due to the relatively close proximity of the steel basket under SUMOSS.
Figure 13 gives the temperature profile on days 123 and 124 to assist in the interpretation of the transmissometer results.

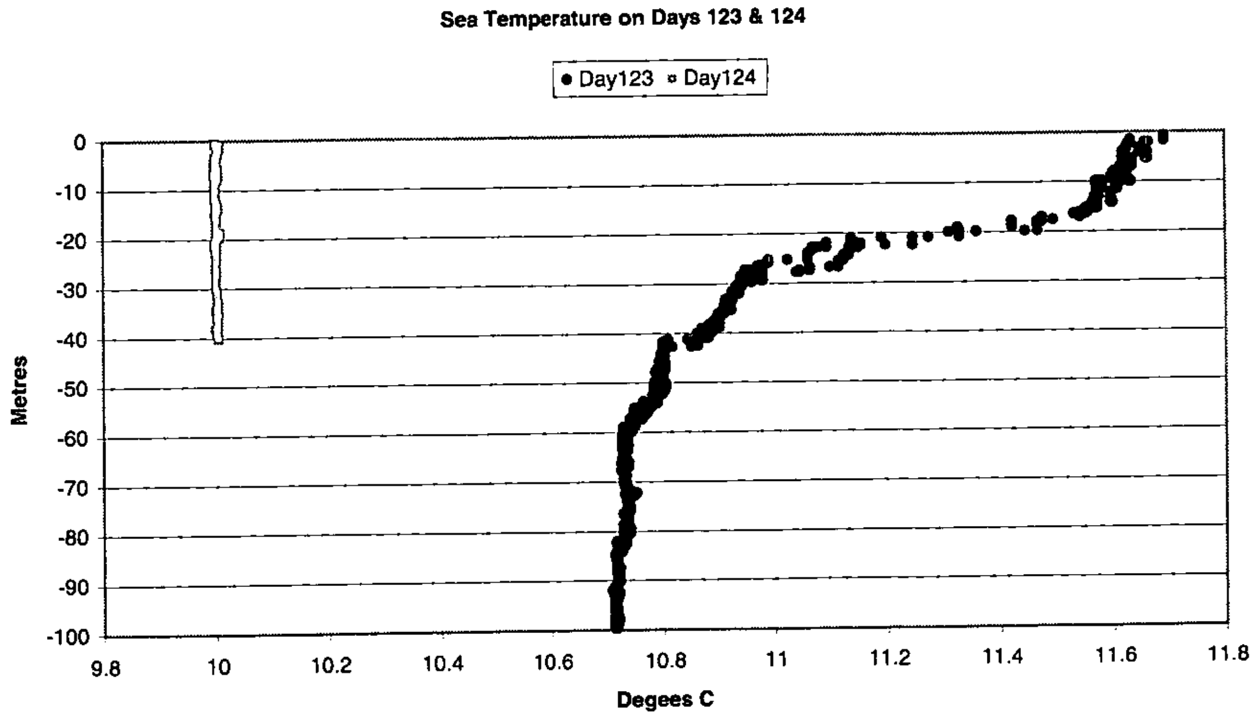


Figure 13 Water Column Structure on Days 123 & 124

Logging Software
During this cruise two programs were used for recording SUMOSS data; "ccd3" recorded spectra from the CCD together with spot values from the other sensors, while "ss_test" recorded sensor data continuously without any spectra.
Both programs were modified to record the time at which they were started in a special event-logging file called "sumoss2.evt". This event file becomes a record of the sequence of events during a cruise, which can prove useful afterwards when processing and analysing the data.
"ccd3" underwent further modifications to enhance its profiling capabilities. An auto-exposure option was added as described earlier, and the user can now specify the number of spectra to take when profiling, if desired. Because profiling can generate large numbers of files, "ccd3" was altered to automatically create a separate directory for each new profile. This strictly defined directory structure proved to be a useful way of organising the data.
The thermoelectric cooler in the CCD head is now controlled by "ccd3", which demands a preset temperature (08C was used throughout this cruise) and displays the actual temperature. Further enhancements to "ccd3" included displaying the temperature of the PC inside SUMOSS and the status of the leak detector located in the bottom of the pressure housing.

Processing software
A new program called "ss2prof" has been developed for listing the header values from spectra files generated by "ccd3". By specifying a directory, a user can create a listing of over 20 parameters from each spectral file in that directory and all subdirectories. This is a useful data management tool, making it an easy task to produce an overall picture of a deployment

showing exactly when and where each spectrum was taken. An example of this for day 124 is shown in figure 14.

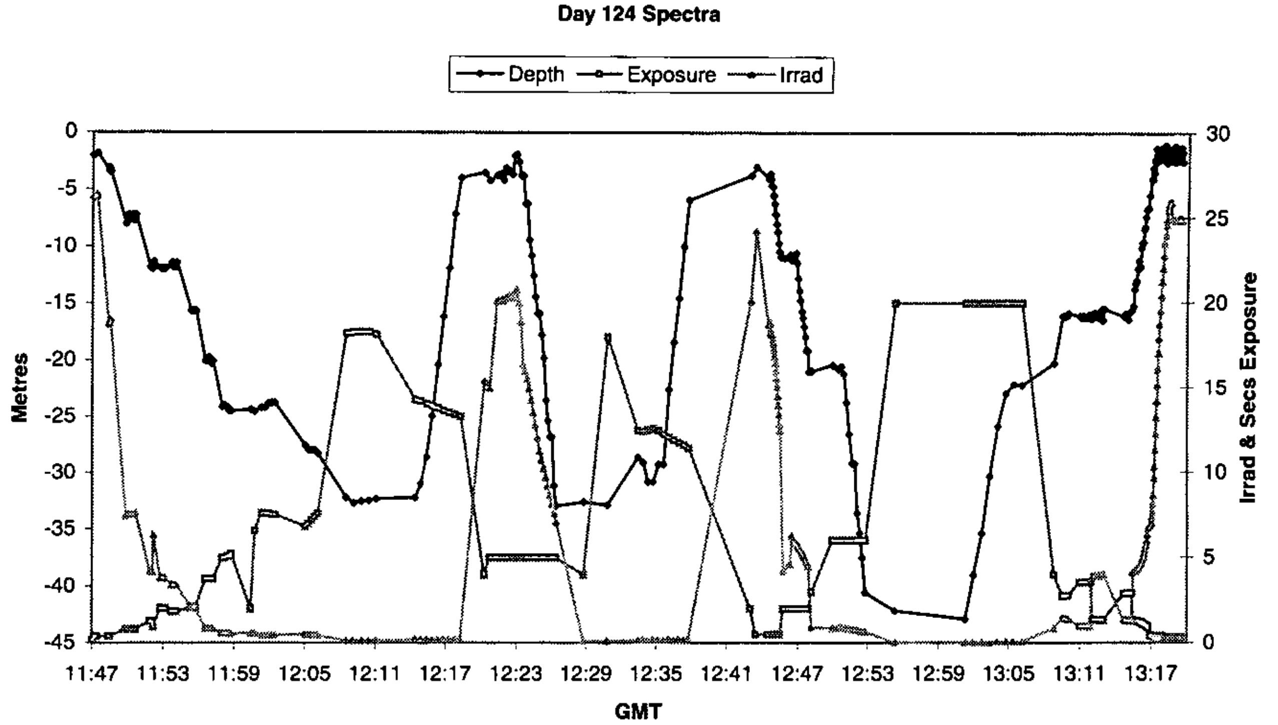


Figure 14 Summary of all Spectra from Day 124

Jon Campbell

7. Summary

The successful trial of the majority of the instruments taken on this cruise vindicated the decision to accept a cruise date that was somewhat earlier in the year than that which had been requested. However, it is likely that had the cruise taken place later in the year, instruments such as SHRIMP and the scatterometer would have been in a far better state of readiness. It is also likely that less time would have been lost due to bad weather.
The failure of the SHRIMP trials due to an extremely unusual manufacturing defect in a blanking plug were especially disappointing in view of the exciting potential offered by live video from the seafloor.

8. Acknowledgements

We would like to thank the ship's master, Geoff Long, and all his officers and crew for their help and support throughout this cruise.

9. Track Plot for Charles Darwin Cruise 121