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NOC Liverpool report for the Wirewalker underwater profiler deployment for the RidgeMix research programme

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ABSTRACT

This report provides a review of a ‘wirewalker’ underwater profiler that was used for high resolution water quality and turbulence measurements as part of a mid-Atlantic ocean based scientific survey. The profiler utilised wave energy and buoyancy to generate automated, cyclic underwater vertical measurements. A drifting supporting surface buoy and mooring configuration was used that moved horizontally in response to underwater currents, surface wind and waves, while generating repeated sub-surface vertical scientific measurements.

The profiler instrumentation payload included a high-resolution chlorophyll-a fluorimeter, a fast sampling, precision conductivity, temperature and depth sensor (CTD) and a fragile, high resolution oceanic microstructure and turbulence sensor. A bespoke guard was used to help protect the fragile microstructure and turbulence sensors from damage. The mooring surface buoy instrumentation included telemetered GPS at nominally 30 minute intervals, a backup telemetered position indication, a VHF radio beacon based position locator and a solar powered night time light.

The experiment was designed to resolve time-variability of upper-ocean mixing and chlorophyll-a fluorescence over the Mid-Atlantic underwater Ridge, an internal wave generation hotspot. Typically more than three wave driven descents to 200 metres and subsequent buoyancy driven ascents to close to the sea surface were achieved per hour during a 22 day deployment, whilst continuously sampling. This represents the first time the UK National Oceanography Centre (NOC) have used this type of underwater profiling system for high resolution oceanic microstructure and turbulence measurements to support a scientific campaign.

Information to support a series of developing operational best practices for the use of this delicate and precision sensing arrangement with a wirewalker underwater profiler is provided. Recommendations relating to the future development of this versatile measurement system are also discussed.

KEYWORDS:

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Terms and Definitions

wirewalker™	An automated wave and buoyancy driven underwater profiler originally developed by the Ocean Physics Group at Scripps Institution of Oceanography in America that is now produced commercially by Del Mar Oceanographic. The device is typically used to undertake repeated, automated vertical profiles underwater with a configurable scientific sensor payload.
MicroRider	An internally recording oceanic microstructure profiler manufactured by Rockland Scientific International (RSI), Canada. The sensor system is capable of high resolution measurements of underwater pressure, temperature, conductivity and it includes a fast sampling high fidelity accelerometer. A pair of shear sensors may be used measure underwater velocity fluctuations. The instrument can be used to derive estimates turbulent kinetic energy dissipation rates.
RRS James Clark Ross	Royal Research Ship James Clark Ross is a scientific research vessel owned by the UK Natural Environment Research Council (NERC) that went into service in 1990. The ship is 99.04m in length, has a beam of 18.85m and has 11 officers in addition to 15 crew. Accommodation is provided for up to 50 scientific personnel on-board and the ship has an operational endurance of up to 57 days.
Iridium	Wireless data transfer based upon the Iridium low earth orbit satellite constellation.
Argos	Wireless data transfer based upon the Argos low earth orbit satellite constellation.

Abbreviations

NERC	Natural Environment Research Council
RidgeMix	A nutrient and carbon pump over mid-ocean ridges research project NERC Reference: NE/L003449/1 (http://gtr.rcuk.ac.uk/projects?ref=NE/L003449/1)
NOCL	National Oceanography Centre, Liverpool, UK
NOCS	National Oceanography Centre, Southampton, UK
VHF	Very high frequency
VMP	Vertical Microstructure profiler
ADCP	Acoustic Current Doppler Profiler
CTD	Conductivity, temperature and depth sensor
GPS	Global Positioning System
GMT	Greenwich Mean Time
SAP	Standalone seawater/water pump
OMG	Teledyne Webb Research Slocum Electric Glider with a RSI oceanic microstructure and turbulence sensor

Contents

1. Scientific survey overview, objectives and basic wirewalker operation

The wirewalker underwater vertical profiler was deployed as part of the RidgeMix nutrient and carbon pump over mid-ocean ridges project suite of scientific measurement systems. The overall project aim was to investigate the hypothesis that underwater waves generated over the mid-Atlantic sub-surface ridge cause turbulence, mixing nutrients upward. The dissolved nutrients are then transported along upper underwater regions of uniform water density. These nutrients subsequently emerge in the well mixed upper regions of the underwater column that form part of a large system of circulating currents, close to the tropics, that are referred to as the western subtropical gyre. This process is suspected as supporting simple marine life growth in the form of phytoplankton. Marine life growth such as this causes oceanic carbon capture and acts as an important greenhouse gas control mechanism.

Within the RidgeMix project the RRS James Clark Ross (JCR) JR15007 research cruise was commissioned from 24th May to 10th July 2016 to undertake a scientific survey around a region of the mid-Atlantic underwater ridge. A schematic of the JR15007 CTD survey is shown in fig.1. A drifting wirewalker measurement system and mooring was deployed close to the main mooring R1 site, shown in fig. 1. Super stations indicated in fig. 1 refer to key locations that were identified for an extended survey period. As shown by the bathymetry information included in fig. 1, the research cruise survey stations were both along, adjacent to and off the Mid-Atlantic ridge. The reported GPS position of the wirewalker surface buoy on 21st June 2016 is denoted by a yellow star. This was located to the top right of the JR15007 survey grid, just north of the R1 mooring site. In general the wirewalker mooring stayed within a reasonably close proximity to a series of separate sub-surface moorings that were deployed at the ‘on-ridge’ site R1 in October 2015. The moorings comprised of a sequence of spatially distributed underwater lines maintained in a vertical orientation using seabed based anchor weights and sub-surface floats. These lines were used to mount various water quality instruments such as CTDs, temperature recorders and underwater water velocity measuring instruments such as ADCPs. The moorings were deployed in advance of the JR15007 research cruise to undertake an extended survey of the local conditions and seasonal variations at the R1 survey site.

A simplified functional diagram of the basic operation of the wirewalker underwater profiler operation is shown in fig. 2. A 200 metre long steel wire was attached to the underside of a spherical surface buoy via a series of mechanical couplings. The steel wire was maintained under tension vertically below the surface buoy using a sub-surface weight. Rotating couplings were used to reduce the risk of the mooring motion introducing twisting of the steel cable along which the profiler traverses. The steel mooring wire was passed through the centre of the wirewalker mechanism that used a rotating cam and tapered steel plate arrangement, which had two distinct modes of operation. In the wave driven mode, as the mooring moved in sync with surface waves, the wirewalker mechanism locked onto the mooring wire in one direction only. This caused the profiler to move downwards in progressive steps until the lower neoprene hose at the end of the mooring wire was reached. At this stage the cam based mechanism disengaged and the profiler subsequently ascended vertically to near to the sea surface along the mooring wire, using its inherent positive buoyancy. At the top of the mooring wire, when the upper neoprene hose was reached, the wave driven phase of the mechanism operation was re-engaged and the profiling sequence repeated. In the drifting configuration the entire profiler mooring will move horizontally in response to the effect of surface waves, wind and underwater currents, while generating vertical underwater measurement profiles.

It is common practice and strongly recommended to undertake a series of underwater test profiles with the wirewalker, typically in close proximity to where the profiler will be deployed. Adding or removing a series of buoyant foam blocks used by the profiler allows adjustments to the level of positive buoyancy. Subsequently the ascent rate of the profiler can be set to preferred levels. The ascent rate is assessed by analysing the recorded pressure change reported by the profiler scientific sensors after each test deployment.

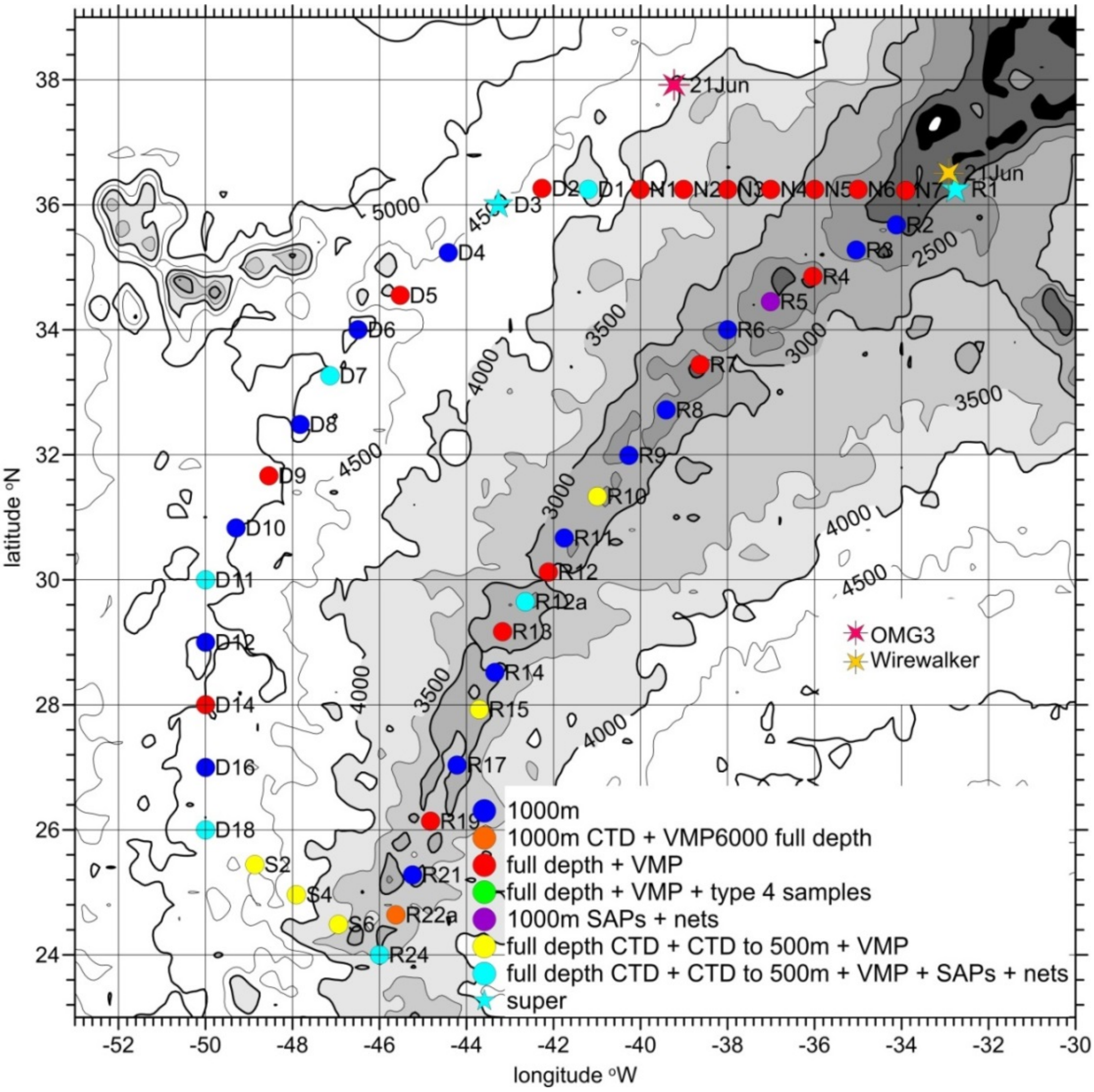


Fig. 1. The JCR JR15007 research cruise CTD survey grid

Plot courtesy of Professor Jonathan Sharples, principal scientist for the JR15007 research cruise

Table 1 provides a list of the internally recording underwater profiler scientific sensor system basic specifications. The MicroRider microstructure and turbulence sensor is a precision instrument that is sensitive to parasitic vibrations. This sensor was not able to generate useful scientific measurements as the profiler moved down the mooring wire in discrete steps during the wave driven phase of profiling. During these descents the parasitic vibrations occurring contaminated the sensitive oceanic microstructure and underwater turbulence signals generated by the MicroRider.

Table. 1 – Wire Walker underwater profiler instrumentation

Rockland Scientific International (RSI) **MicroRider 1000** **Serial number 043**	An internally recording underwater microstructure and turbulence sensor including two fast sampling temperature sensors, a microstructure conductivity sensor, high resolution pressure measurement, a high speed high fidelity accelerometer and two underwater velocity shear sensors. A measurement sample rate of up to 512Hz may be used.
RBR Concerto CTD **Serial number 060048**	Fast sampling underwater conductivity, temperature and depth sensor (CTD) set to a maximum measurement rate of 6Hz.
WetLabs Eco fluorimeter **Serial number 777**	A self-recording fluorimeter configurable for a maximum measurement rate of up to 20Hz. A custom data recording and external power system was added to allow for several weeks of measurements to be recorded at this data rate.

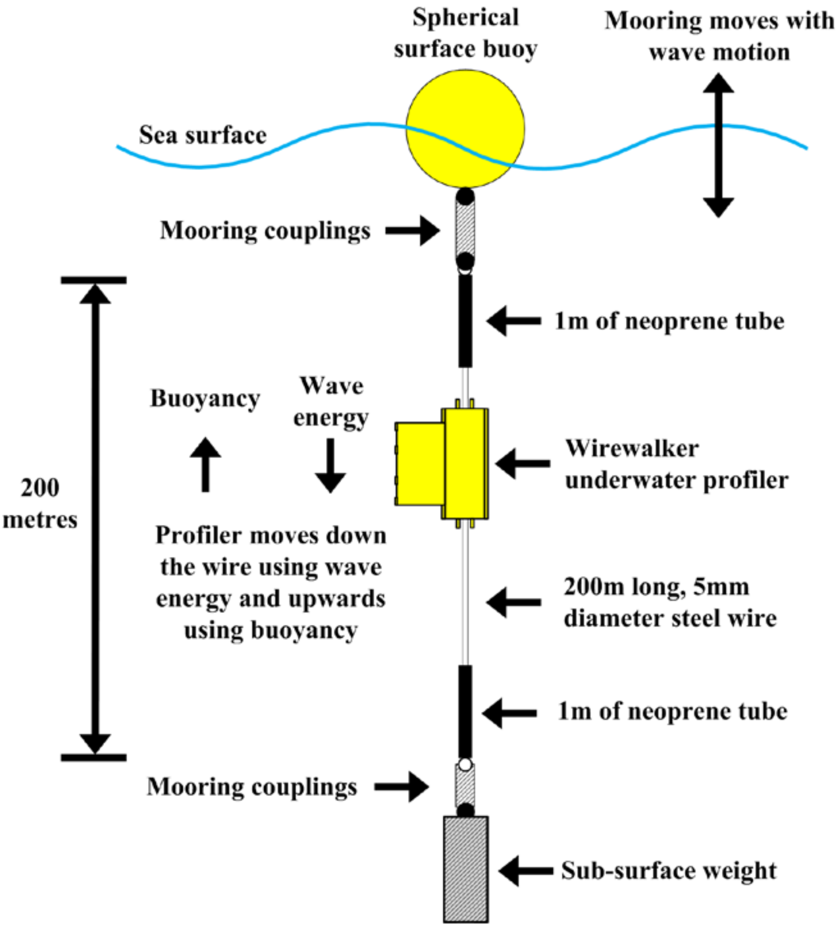


Fig. 2. Simplified functional diagram of the wirewalker and mooring

The list in table 2 provides some details of the buoy mounted position indication and recording systems. The primary location system was a Pacific Gyre Globeacon transmitter. This was a battery powered beacon that uses the iridium constellation of low earth orbit satellites to transfer the GPS position of the surface buoy to the internet at regular intervals in near real time. In case of a failure of the Globeacon a marine mammal tracking tag was fitted to the buoy. This was a self-contained, encapsulated battery powered transmitter that was used to provide estimates, typically several positional fixes per day to within 500 metres, of the buoy location using the Argos constellation of low earth orbit satellites. A VHF radio beacon was also fitted to the buoy to broadcast a periodic signal burst to help to locate the buoy with a typical range of 3-5 nautical miles. A custom GPS recorder was used to allow a high resolution position track to be downloaded after the buoy was recovered at the end of the deployment. The one second update rate of GPS information recorded was prohibitively expensive to transmit in near-real time from the buoy via the iridium satellite constellation.

Table. 2 – Surface buoy based instrumentation

Pacific Gyre Globeacon	An iridium beacon with integrated GPS receiver for surface buoy location tracking. A nominal position transmission update rate of 30 minutes was used.
Novatech Minibeacon 7500	A VHF radio beacon for locating the surface buoy with a typical range of up to 3-5 nautical miles.
Argos Tag	A Wildlife Computers SPOT-100 inline fin mount, 258A tag with a 90s transmission rate for backup locational information.
Carmanah M650 light	A solar powered, rechargeable light for night time buoy positon indication.
High resolution GPS recorder	This was a custom built GPS recording system in a pressure case. This battery powered system internally logged to memory GPS fix information at a nominal 1 second interval and had an operational endurance of several weeks.

A labelled picture of the wirewalker underwater profiler key components is shown in fig. 3, as the profiler was being prepared for the deployment during the JR15007 research cruise.

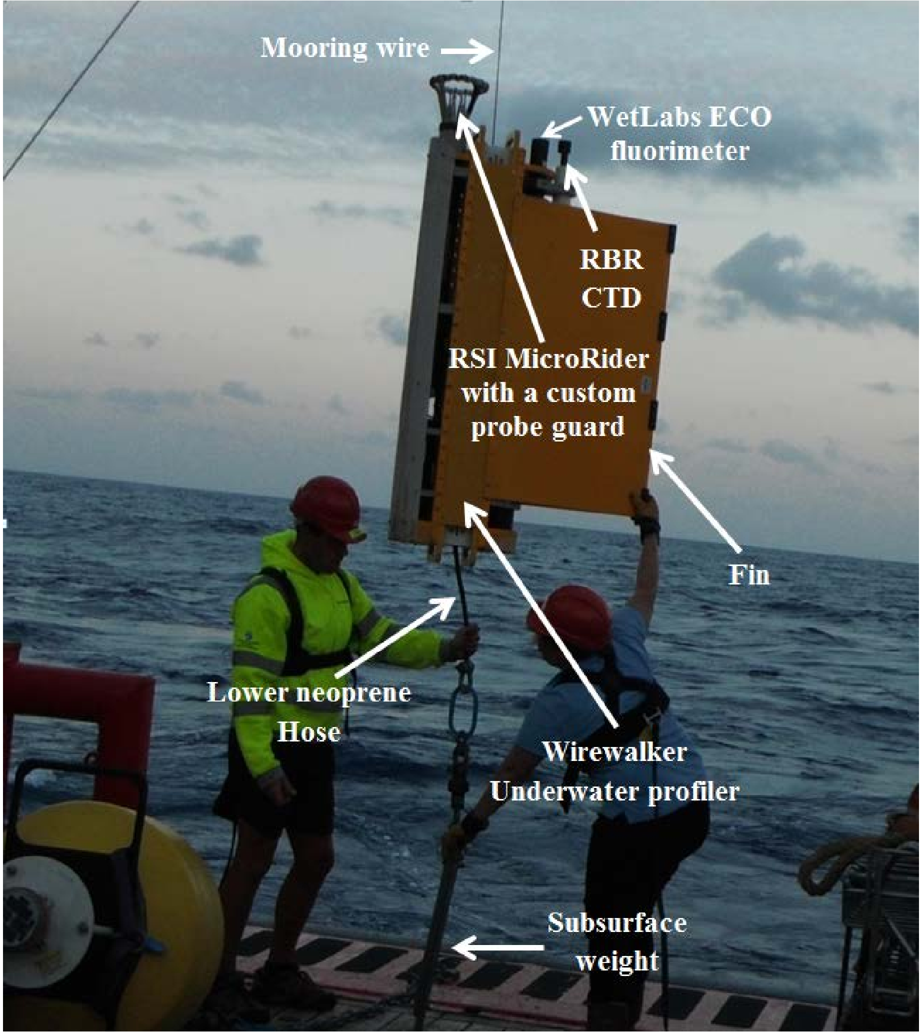


Fig. 3. Wirewalker key components

A fin was attached to the opposite side of the MicroRider sensor to align the profiler underwater with the MicroRider facing into oncoming underwater currents. This was used to minimise turbulent wake from the profiler and sensors interfering with the microstructure and turbulence measurements. A custom plastic guard was installed around the fragile MicroRider sensor probes to provide some level of protection from damage, particularly during the deployment and recovery of the profiler. The leading edge of the guard had a line installed in a cross helix pattern to discourage the onset of vortex shedding that, if left unchecked may disturb the MicroRider measurements during underwater profiling. A labelled picture of the key surface buoy components is provided in fig.4. The layout and location of the buoy based iridium plus GPS beacon, high resolution GPS recorder, VHF radio beacon, Argos backup positional tracking tag and the solar powered night time light are shown.

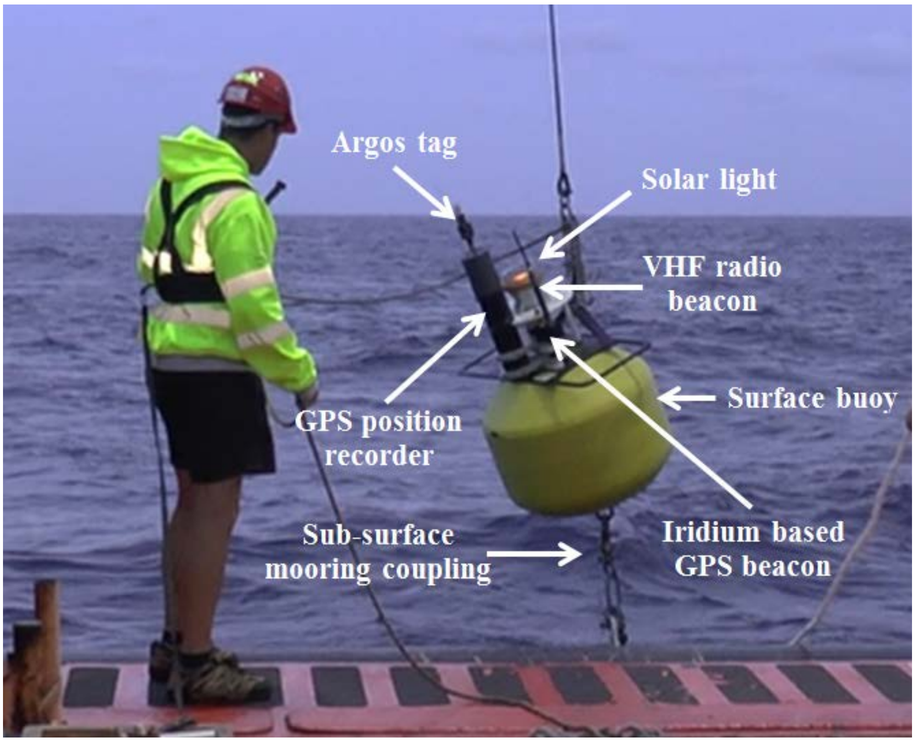


Fig. 4. Wirewalker surface buoy key components

Prior to deploying a wirewalker profiler and its associated moorings it is good practice to verify the ballasting and correct mass distribution of the profiler, as described by the tank tests in appendix A. It is highly recommended that a series of test profiles underwater are then undertaken after a ballasting check. This testing may be performed multiple times and is usually to a limited underwater depth with a shorter mooring wire. Analysis of the scientific data generated during these tests allows a rapid check of the profiler performance in the intended deployment area. If required, final adjustments may be made to the profiler buoyancy and setup before committing to a scientific survey. Details of this are provided in appendix B. If the ballasting, mass distribution and ascent rate checks are omitted before a deployment then this introduces the risk of the profiler not operating as intended. Poorly balanced and ballasted profilers may not operate in the preferred vertical orientation and may not produce the intended smooth vertical profiles while taking measurements at a desired or target ascent rate.

This concludes a basic overview of the wirewalker system and the RidgeMix research project. A review of the use of the profiler, the mooring options, the scientific data return, servicing and a discussion are provided in the subsequent sections of this document.

2. Profiler usage from different vessel sizes and capacities

The scale of the wirewalker and mooring system is such that it is possible to carefully and directly deploy and recover the profiler from small vessels with a low or limited freeboard. This approach allows direct handling of the fragile sensing systems during ballasting testing, deployment and recovery and is particularly applicable to coastal scientific surveys. For larger research vessels with an increased freeboard that may be operating in more remote locations, with potentially more challenging conditions and sea states, this level of direct control of the profiler operational use may not be possible. Progressive and carefully controlled operational procedures are required to limit the risk of damage to the profiler when direct handling is not possible. Hazards include lifting, moving, snatching, impacts or collisions with the deployment vessel and motion of the ship towing or dragging the profiler and its associated mooring system.

3. Ship based operations, mooring alternatives and scientific data interpretation

This section reviews the wirewalker and mooring deployment and recovery operations during JR15007. The key mooring configurations that may be used are described and the potential impact of this with respect to scientific data interpretation is discussed.

3.1 wirewalker deployment

As shown in fig. 5, a drifting mooring arrangement was used, which is the preferred mooring configuration from an operational perspective. A series of pictures depicting the mooring deployment sequence during JR15007 are provided in fig. 6.

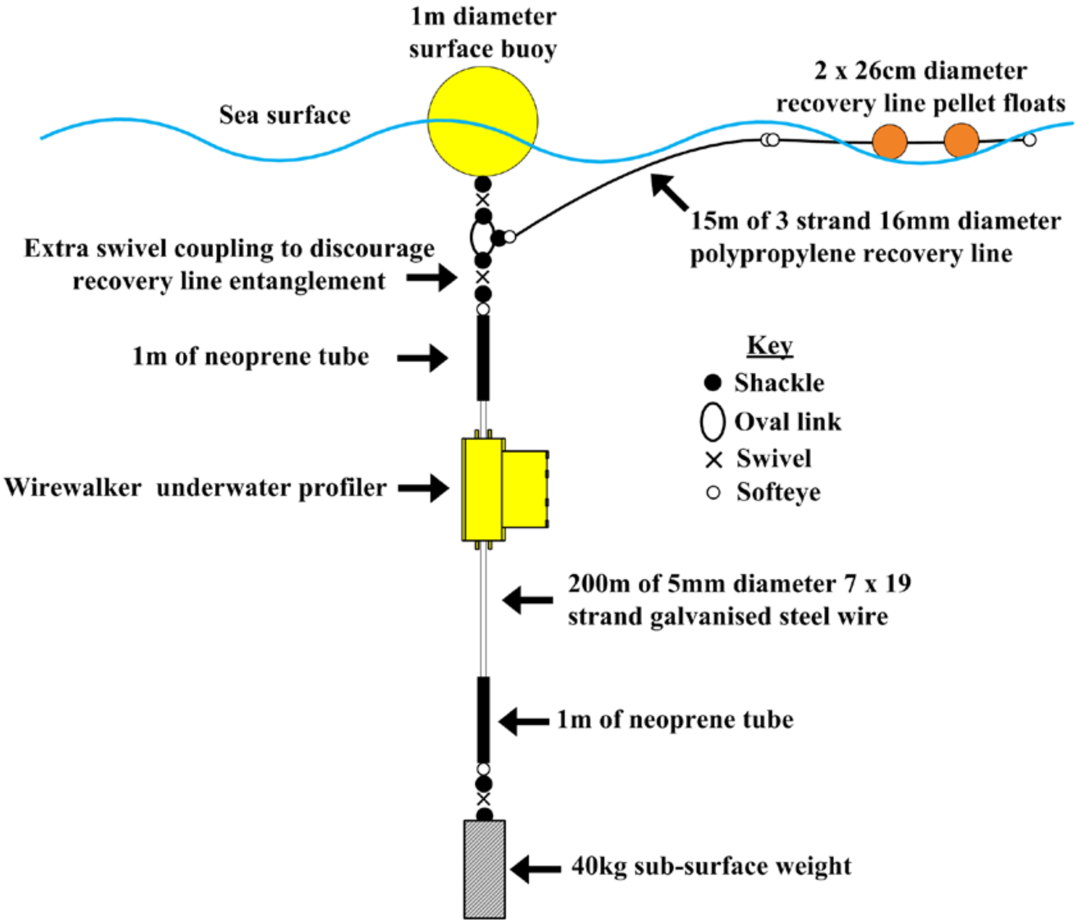


Fig. 5. Wirewalker mooring diagram

For the deployment, the wirewalker was attached to the mooring wire and rested on the lower 1m long neoprene tube end stop. The profiler and the subsurface weight were lifted and deployed first using the ship’s stern based A-frame and a winch. The mooring wire was routed through a wide sheave block that was suspended from the A-frame. JCR was aligned to allow for underwater currents to encourage the profiler to be moved away from the stern of the ship and the ship’s propulsion systems. The ship also moved slowly away from the profiler to further reduce the risk of entanglement. After the majority of the 200 metre long mooring wire was deployed via a winch, the upper part of the wire was stopped off to a fixed point on deck. The surface buoy plus recovery line were coupled to the wire via the upper mooring oval link. A winched line with a quick release sea catch attached was coupled to a lifting strop on the upper part of the buoy. This arrangement was then used to lift the buoy and mooring off the deck and then lower the buoy close to the sea surface, with the A-frame extended outwards, before releasing the buoy. As the ship subsequently travelled away from the surface buoy the buoyant recovery line plus pellet floats were deployed from the stern of the ship to complete the required operations.

a Profiler and subsurface weight

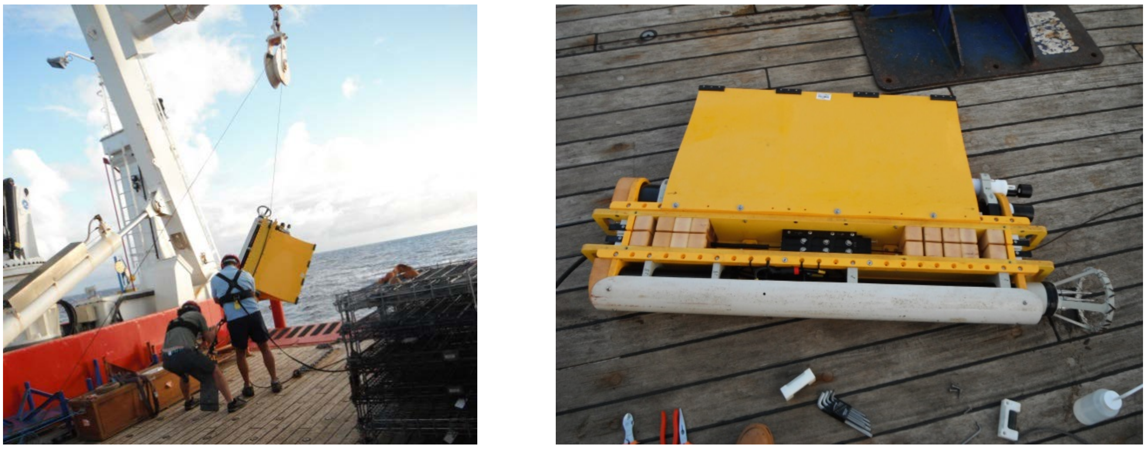
b Surface buoy

c Deployed drifting mooring surface buoy with recovery line and pelett floats

Fig. 6. Mooring deployment sequence

3.2 wirewalker recovery

A sequence of photographs of the subsequent mooring and profiler recovery after the 22 day survey are shown in fig.7. Essentially the reverse of the deployment sequence was used. The mooring recovery line was captured with a grapnel deployed close to the stern of the ship and a winched line was then used to haul the buoy on-board. The link on the underside of the buoy was then used to temporarily stop off the mooring to a fixed point on the JCR deck. The surface buoy and stray line were then de-coupled and a wide sheave block and line were used with the A-frame extended astern to winch the mooring, wirewalker and subsurface weight upwards in a vertical orientation. When the subsurface weight was raised above the stern of the ship the A-frame was moved inwards. The weight plus profiler were then placed on deck with careful winch based control of the mooring wire to complete the recovery operations.



a Subsurface weight, wire and wirewalker profiler recovery

b No significant biofouling or sedimentation was evident with the recovered profiler

c The recovered MicroRider probes were clean and free of contamination and the MicroRider was still running and recording data after the recovery

Figure 7 – Recovery of the Wirewalker and mooring

The photographs in fig. 7 illustrate that after the recovery, no significant biofouling other than a fine film of algal growth with a light brown hue was present. The scientific sensors were intact and the fragile MicroRider sensor probes were clean and free from any noticeable damage. This provided a preliminary indication that the deployment had been successful.

3.3 Mooring configuration alternatives

For coastal deployments, in regions with high underwater tidal currents and hazards such as local shipping, the mooring may need to be held in position. A seabed based cast anchor weight, swivel link, length of chain plus a length of negatively buoyant rope attached to the lower part of the subsurface weight can be used to keep the mooring on station, as shown in fig. 8. The length of the mooring wire along which the wirewalker travels would be adjusted to suit the intended working or profiler underwater operational depth limit. Potential drawbacks with the anchored mooring configuration shown in fig. 8 are that as the mooring drifts the subsurface rope and chain will be under tension from time to time. Effectively the seabed anchor keeps the mooring operating in an underwater current, wave and surface wind driven restricted area or watch circle. The scale of the watch circle is primarily determined by the length of the subsurface rope connection to the seabed based mooring anchor. This rope connection and mooring design must allow for any depth variations due to tides. As and when the mooring is under tension the steel wire along which the wirewalker travels will tend to slope and possibly curve or snatch rather than maintaining the desired vertical orientation below the surface buoy. This can interrupt the profiler operation and possibly increase wear and tear of the wirewalker mooring cable guides and movement rectifying cam based mechanism. For these reasons, when practicable, the drifting mooring configuration is preferred to ease the task of deployment and recovery and to limit mechanical wear.

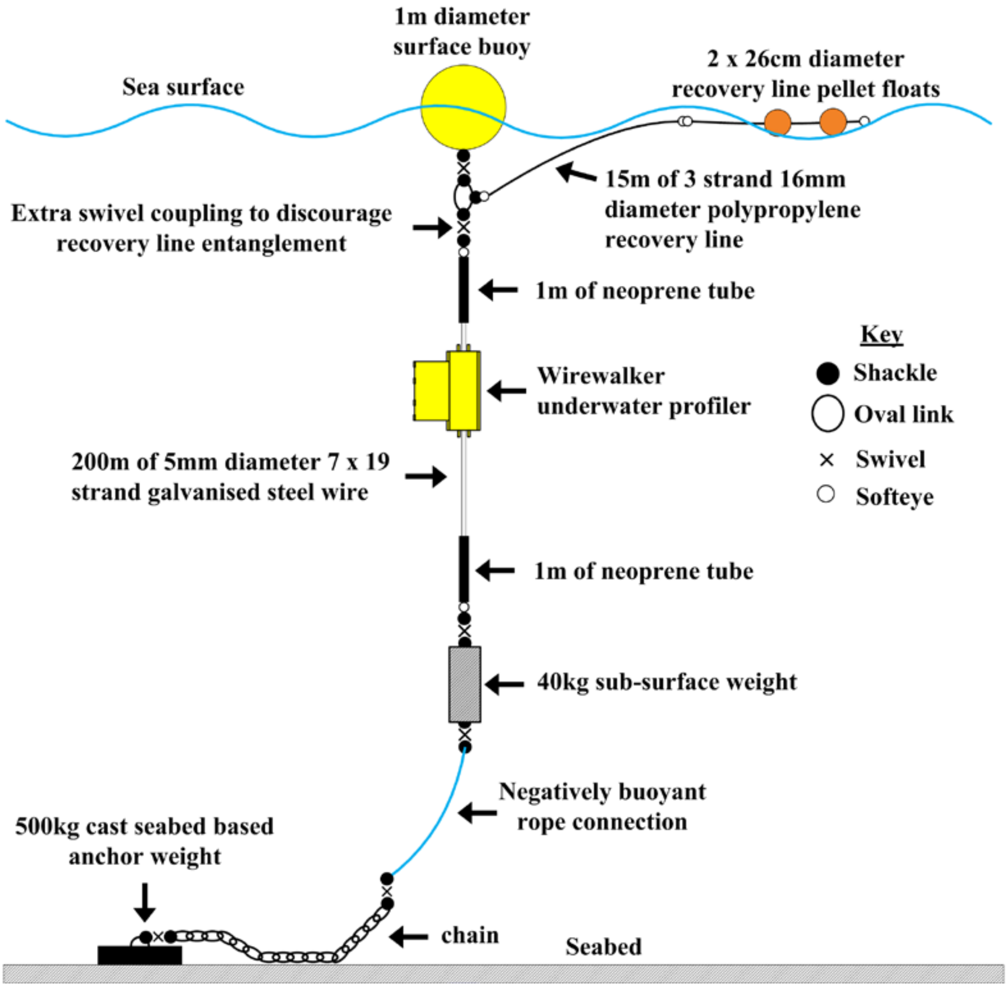


Fig. 8. Wirewalker mooring with a seabed based cast anchor functional diagram

3.4 Scientific data interpretation

It must be noted that from a scientific data processing and interpretation perspective the anchored mooring configuration is preferred. Holding the profiler on station in a particular survey area limits the horizontal spatial variability in the measured values. This provides repeated measurements over a limited study area. While anchor weights and long mooring ropes are possible for deeper waters, this type of arrangement tends to be expensive and time consuming to deploy and recover and was not used for JR15007.

This concludes a review of the profiler deployment, recovery, mooring options and scientific data interpretation considerations. The next section of this document provides a brief overview of the scientific data return from the underwater profiling system.

4. Scientific measurements and results

To assess the wirewalker performance, a series of 20 metre deep test profiles with the wirewalker were undertaken. During these tests the surface buoy was tethered to the starboard side of JCR and an ascent rate of approximately 0.4m/s under buoyancy was configured. As described during the latter part of appendix B, this was achieved by adjusting the number of foam blocks in the mechanism compartment. As anticipated, this ascent rate under buoyancy closely matched the measured MicroRider ascent rates provided by the preliminary microstructure data review in appendix C. The wirewalker mooring was then subsequently deployed at 21:38 on Sunday 5th June 2016 at a GPS location 36° 14.743N, 32° 45.303W with a water depth of 2183 metres. A plot of the track the surface buoy as reported by the predominantly 30 minute GPS positional update rate from the iridium satellite beacon is shown in fig. 9.

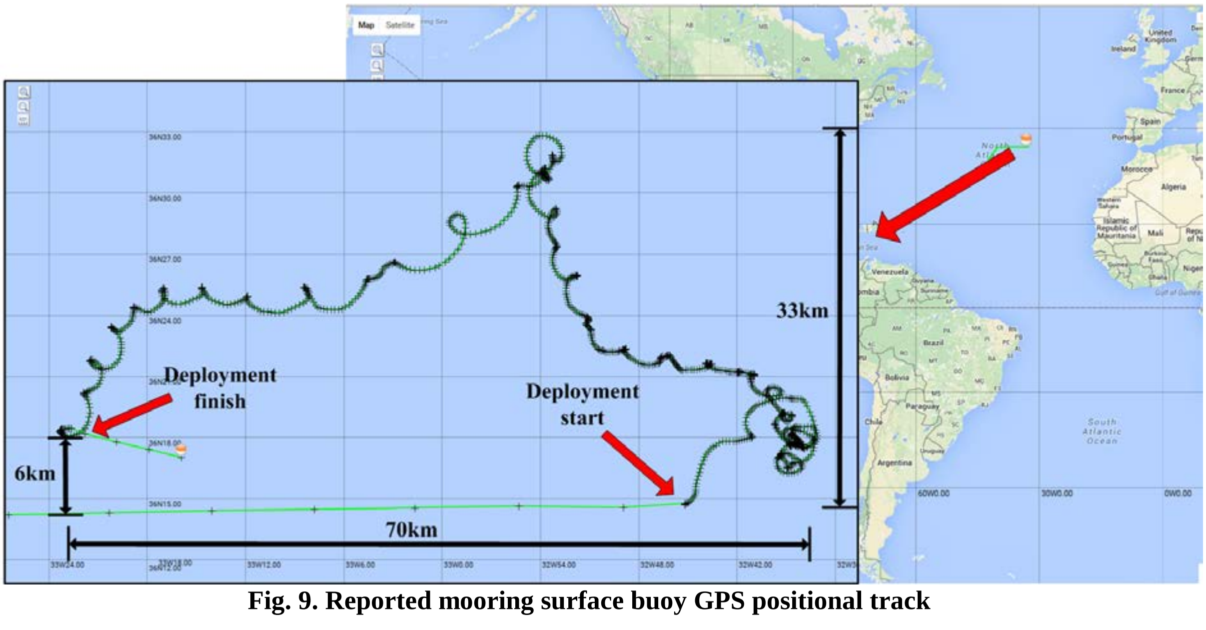


Fig. 9. Reported mooring surface buoy GPS positional track

The nearest post deployment sensor calibration CTD using the JCR over the side carousel was event number 24, CTD cast and station 9 at 23:58 GMT on Sunday 5th June 2016. This calibration CTD occurred at a GPS location of 36° 13.261N, 32° 45.788W to a depth of 2300 metres. During this CTD profile an underwater temperature of 20°C with a salinity reading of 36.3 PSU occurred to a depth of approximately 50m, indicating well mixed waters to this depth. From 50m to 200m the temperature reduced to 14.5°C and the salinity reduced to 35.8

PSU. This corresponded to an approximate density near the sea surface of 1026 kg/m^3 increasing to a density of approximately 1027.5 kg/m^3 at a depth of 200m.This indicated that the seawater was well mixed in the upper 50m of the water column and stratified below this. The wirewalker and its associated mooring were then subsequently recovered at 20:00 GMT on Monday 27th June 2016 at a GPS location of 36° 18.4243N, 32° 23.0228W, following a deployment of approximately 22 days. The deployment and recovery locations and some distance markers have been added to fig. 9. As shown the surface buoy tended to head in a north easterly direction after the initial deployment. A series of spirals in position then occurred in a north westerly direction before the buoy headed in a south westerly direction. From the perspective of the JR15007 survey grid in fig. 1, the wirewalker drifted north of the main R1 mooring station for the bulk of the deployment. The profiler then headed in a south westerly direction before a recovery between the N7 and R1 survey stations.

4.1 Profiler instrumentation data return summary

Details of the wirewalker scientific sensor data return after the recovery are provided in table 3. The MicroRider and fluorimeter were still running on battery power when the profiler was recovered, with space for further measurements remaining in their internal recording systems. The RBR concerto CTD had filled its 21.5 day capacity internal data recorder.

Table 3 – Wire Walker underwater profiler instrumentation measurement summary

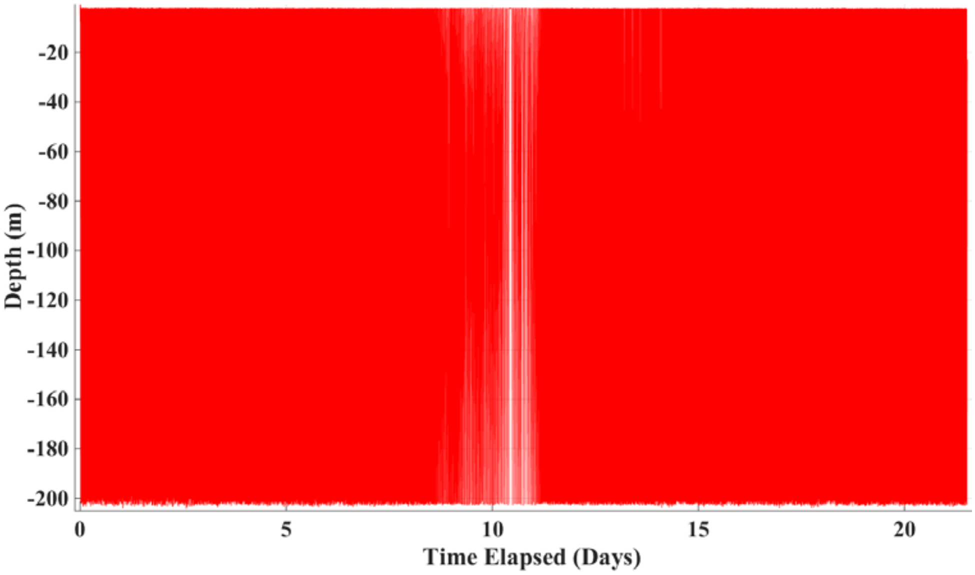
Deployment from Sunday 5th June to Monday 27th of June 2016	
Sensor	**Summary of data return**
MicroRider	A full, continuously sampled measurement data return was achieved at close to the endurance of the 128Ah battery capacity.
CTD	Measurements were recorded continually at 6Hz until the 21.5 day memory capacity of the CTD was reached.
Fluorimeter	Data was recorded throughout the deployment at less than the maximal 20Hz sample rate. The fluorimeter was still running when the mooring was recovered.

4.2 RBR Concerto CTD and WetLabs Eco Fluorimeter data visualisation

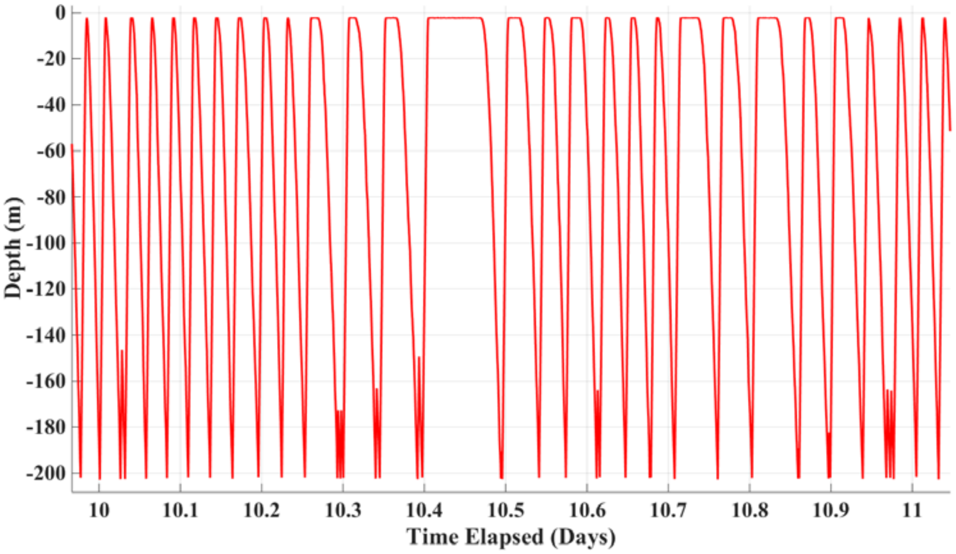
It is likely that the CTD and fluorimeter data will feature in future scientific publications. Coloured surface plots that could be used to visualise the preliminary data from these sensors and indicate salient features in these data have been omitted. This is to avoid potentially compromising future scientific publications.

4.3 CTD computed depth record

To illustrate that the required profiler operation was achieved, fig. 10 provides plots of the RBR concerto CTD recorded depth measurements. This shows that the wirewalker was repeatedly profiling to the intended depth of 200 metres for the majority of the 22 day deployment. In excess of 1700 underwater measurement profiles were generated during this time. An average of 3.2 descents to 200 metres using wave energy and subsequent ascents to close to the sea surface using buoyancy were completed per hour by the profiler. The plot in fig. 10a shows the pressure sensor based measured depth record for the entire deployment. What is noticeable is the more sparse profiling density between 10 and 11 days into the deployment. A plot of this area of the measured depth record is provided in fig. 10b. What is evident in fig. 10b is the time the wirewalker has spent close to the sea surface shown by the flat edges in the upper part of the plot, with the longest period being in the order of 2.5 hours. The most likely cause of this would probably be a benign sea state whereby there is insufficient wave energy generated to operate the downward phase of the profiler operation. The earlier and latter stages of the data record do not show this anomaly, meaning that the slowed profiler operation rate occurred temporarily. In addition to this, during the slowed profiler rate period shown in fig. 10b, some ascents of the profiler have terminated early between depths of approximately 150 and 180 metres. The wirewalker has intermittently interrupted buoyancy driven ascents and returned, under wave energy, to the maximum depth of close to 200 metres. The exact reasons for this are unclear. A possible cause could be that, under low wave energy conditions, the cam based mechanism for wave energy driven descents does not disengage properly when the lower neoprene hose end stop is reached at the bottom of the mooring wire. Subsequent buoyancy driven ascents of the profiler are then interrupted when the cam based wirewalker mechanism intermittently re-engages, causing an early termination to a profiler ascent.



a Recorded 22 day CTD computed depth with sparser profiling evident close to the centre of the record

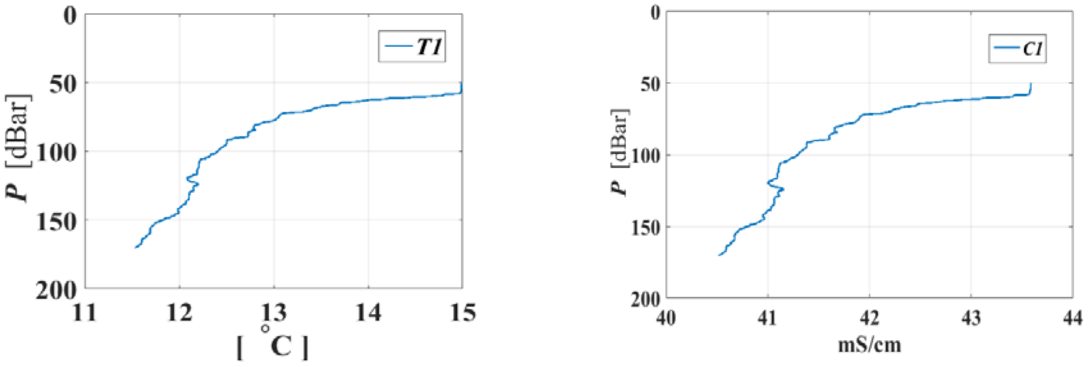


b Plot of the depth readings between days 10 and 11 of the deployment

Fig. 10. Plots of the computed depth record from the RBR concerto CTD

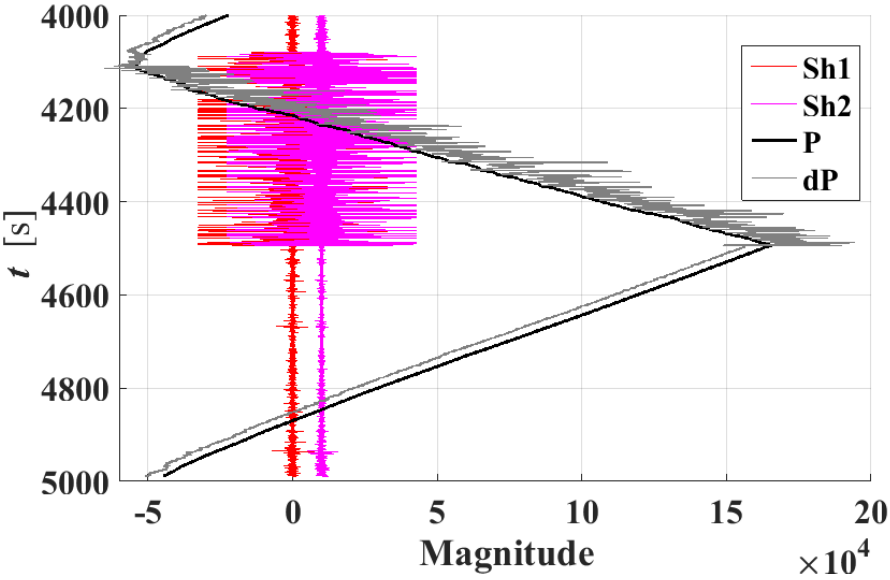
4.4 MicroRider microstructure and turbulence sensor data plots

A selection of preliminary plots from the MicroRider oceanic microstructure and turbulence sensor are shown in fig 11. Uncalibrated plots of microstructure temperature and conductivity are shown in fig 11a and fig 11b. These plots are for the bulk of a terminal velocity or steady ascent rate of the profiler underwater. While the absolute values of microstructure temperature and conductivity need to be calibrated against a precision, slower sampling reference CTD such as the RBR Concerto on the wirewalker platform, the fine detail or variance in the underwater temperature and conductivity has been measured. There was no obvious contamination, slowed response or distortion of the measured values. This provides some level of confidence that the microstructure profiler was operating correctly. Based on a profiler nominal terminal ascent rate of 0.4m/s and a MicroRider microstructure signal sampling rate of 64Hz, a spatial resolution of (0.4/64) 0.006m is achievable, with a similar resolution possible for the microstructure conductivity. The subsequent calibrated data sets that will be generated therefore provide the basis for providing sub-centimetre measurement resolutions. This allows the capturing of oceanic microstructure in the form of fine scale changes in temperature and conductivity for the 200 metre depth profiles generated during the 22 day wirewalker deployment. This oceanic microstructure resolution allows study of the water quality and physical properties in an extremely high level of detail, as required by the RidgeMix research project.



a Uncalibrated microstructure temperature

b Uncalibrated microstructure conductivity



c Normalised shear, presure and change in pre-emphasized pressure signal magnitude versus time

Fig. 11. Preliminary oceanic microstructure and shear signal plots from 6th June 2016

The analysis and processing of the underwater velocity fluctuations from the two shear sensors, Sh1 and Sh2 is in general quite a complex process. Typically an assessment of the signals is made in the frequency domain. A series of processing steps are then applied to deduce an estimate of the underwater turbulent kinetic energy dissipation rates. This more complex scientific analysis is beyond the scope of this document and will be utilised for subsequent scientific measurement processing for the RidgeMix research programme. To gain confidence in the shear measurement signal quality and illustrate the effect of profiler oscillations during the wave driven underwater descent phase of profiling, fig 11c was generated. This shows the magnitude of the oceanic microstructure pressure (P), the pre-emphasized pressure (dP), shear sensor channel 1 (Sh1) signal and the shear channel 2 (Sh2) sensor signal. Pre-emphasis is a signal processing derivative technique that is used to improve the signal to noise ratio of key frequencies and signals of interest. Pre-emphasised signals can be particularly susceptible to contamination by sources of electrical noise and mechanical vibration. The time elapsed is shown by the vertical y axis in fig. 11c and the x axis represents the magnitude of the raw sensor signal sampled and digitised by the MicroRider. From approximately 4100 to 4500 seconds elapsed the profiler was implementing a wave energy driven descent using a series of stepped discrete movements. The noise envelope and contamination of all of the signals is evident in the graphs. Between approximately 4500 and 5000 second elapsed the profiler was ascending under buoyancy and the comparatively lower electrical noise and uncontaminated signals are evident. This provides some level of confidence that, during buoyancy driven wirewalker ascents underwater, the oceanic microstructure and velocity shear measurements are relatively devoid of parasitic host platform vibration. This reduces the likelihood of contamination of the measured values during this phase of the profiler operation. To provide a review of the integrity of the microstructure measurements over the entire data set the basic plots shown in appendix C have been generated. These plots indicate no obvious corruption of the MicroRider measurements from vibration, biofouling or sedimentation during buoyancy driven 200 metre underwater profiles for the entire duration of the 22 day deployment. This initial assessment was achieved by examining subsets of the MicroRider sensor data from near to the beginning, the middle and the end of the deployment.

This completes a preliminary review of what has been indicated to be a very high quality 22 day long scientific data set comprising of 6Hz measurements from the RBR CTD, in conjunction with a high resolution record of oceanic temperature, conductivity and underwater velocity shear. In addition to this a high resolution data set of chlorophyll-a measurements as a proxy for phytoplankton activity has been attained. The next section of this document reviews wear and tear and the recommended routine servicing of the wirewalker mooring wire guide and wave energy utilisation mechanism.

5. Wear, tear and wirewalker system maintenance

Key considerations when operating an underwater scientific vertical profiling system, with a mechanical coupling to a mooring wire, are the operational endurance of the system and the wear and tear associated with moving parts in seawater. Energetic sea states may also result in additional wear on mechanical couplings. Prior to the deployment on 5th June the wire guide mechanism had been refurbished. The wire guide cams were replaced and the cam engagement tapered metal plate edges had been smoothed to remove any uneven edges or wear. The plastic faces on either side of the mooring wire in the wire guide mechanism were smooth and clear of any signs of wear. The plastic rollers that were installed at the top and bottom of the wirewalker to route the wire into and out of the profiler were also replaced.

During the use of the wirewalker system some mechanical degradation of the mooring wire guide and wave energy utilisation mechanism was observed. A photograph of the wirewalker profiler with the wire guide mechanism access plate removed is shown in fig. 12. This was shortly after the recovery on Monday 27th June, following the 22 day deployment. A small amount of algal biofouling was present. It is suspected that the profiler operating to depths of 200 metres, where natural light from the sea surface is heavily supressed, slowed down the rate of marine life growth on the profiler from that which may be expected for warmer mid-Atlantic waters. The photograph in fig. 12 also shows the position of the buoyancy adjustment foam blocks in the wire guide mechanism compartment.

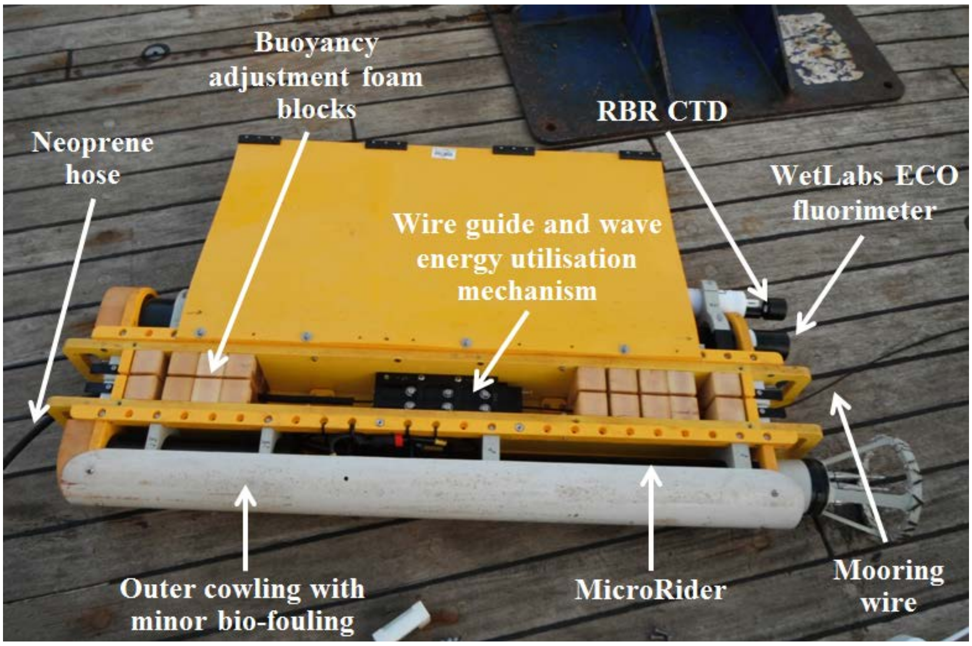


Fig. 12. Recovered wirewalker with the mechanism access upper cover removed

The recovered wirewalker wire guide and wave energy utilisation mechanism is shown in the photographs in fig. 13 and fig. 14. There was some evidence of corrosion of the mainly stainless steel components of the mechanism, as indicated.

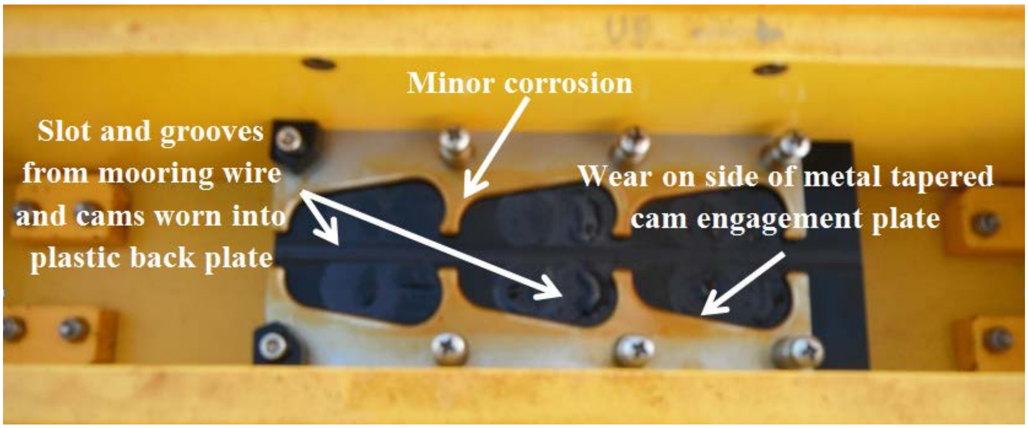


Fig. 13. wear and corrosion of lower wire guide mechanism components

On a related note the galvanised steel mooring wire along which the profiler operates was intact, had no burrs, broken fibres, significant corrosion, biofouling or obvious damage along the full 200m profiling length. It is suspected that the repeated operating of the wire guide cams along the mooring wire prevented the onset of bio-fouling or deposits of particulate from building up on the wire. This appears to have prevented any interference with the wirewalker operation or stalling of the profiler from occurring. What is evident in fig. 13 and fig. 14 is that a groove has been worn into the upper and lower plastic faces that enclose around the mooring wire when the mechanism was assembled. Grooves such as this may introduce a space by which the mooring wire can move or oscillate around during profiling, subsequently increasing frictional wear and possibly introducing increased parasitic profiler vibrations or oscillations. Wear was also evident on the side of the tapered metal back plate that causes the cams to engage and momentarily lock on the mooring wire during wave driven descents of the profiler. While some corrosion was observed on the actual cams, this was only minor and there was not any significant erosion of the base material. The grooves that are slotted into the edges of the cams, through which the mooring wire passes, did not show any noticeable signs of wear and were in good condition when the wirewalker was recovered after the 22 day deployment.

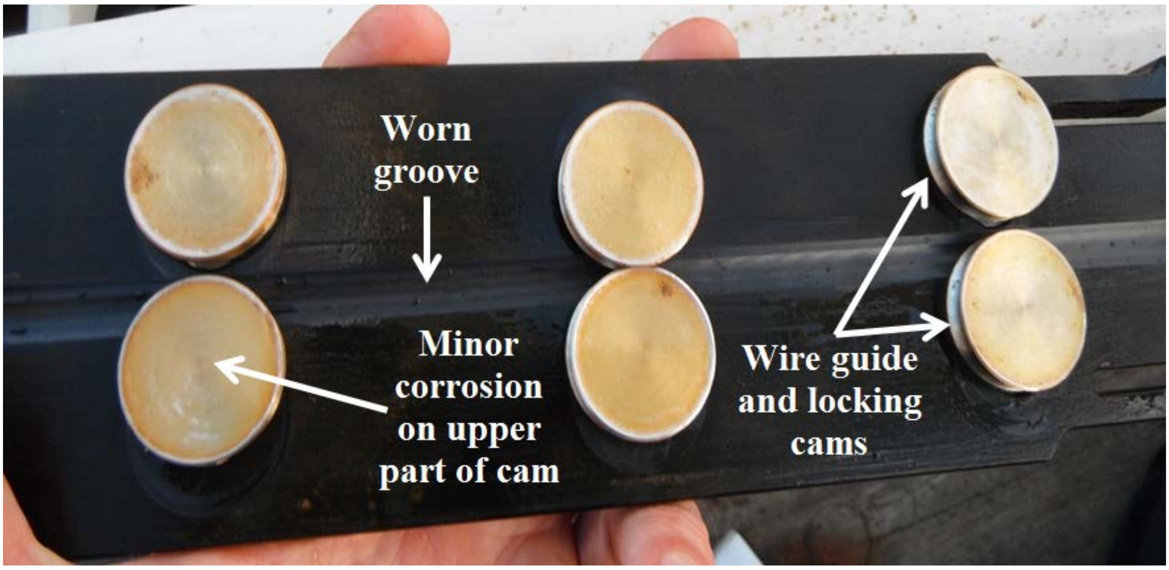


Fig. 14. Wear of the upper plate and wire guide cams after a 22 day drifting mooring deployment

For deployments of the wirewalker underwater profiling system using an anchored mooring configuration, an increased level of mechanical wear can occur, as shown in the labelled picture in fig. 15. It must be noted that this was from a deployment of several weeks in a coastal area with strong tidal currents of between 0.5m/s and 1 m/s. The high underwater currents, possible curvature of the mooring wire as the profiler mooring to seabed cast anchor weight repeatedly tensioned, and energetic sea states are suspected to have accelerated the mechanical wear observed. Metal burrs had started to form on the section of the tapered cam engagement metal plate where the cams lock onto the mooring wire. The slots where the mooring wire locates on the actual cam edges had also experienced wear, with burrs starting to form on the cam edges. An understandable concern, with such mechanical component degradation and burr formation being evident, is the impact this may have on the integrity of the mooring wire along which the profiler operates. Burrs in particular can affect the strength and structure of the strands of the mooring wire. This may lead to accelerated mechanical wear, possible stalling of the profiler and ultimately a subsequent failure of the mooring system. A close up picture of a worn cam is provided in fig. 15 that illustrates how flat edges have started to form on a cam edge through which the mooring wire passes.

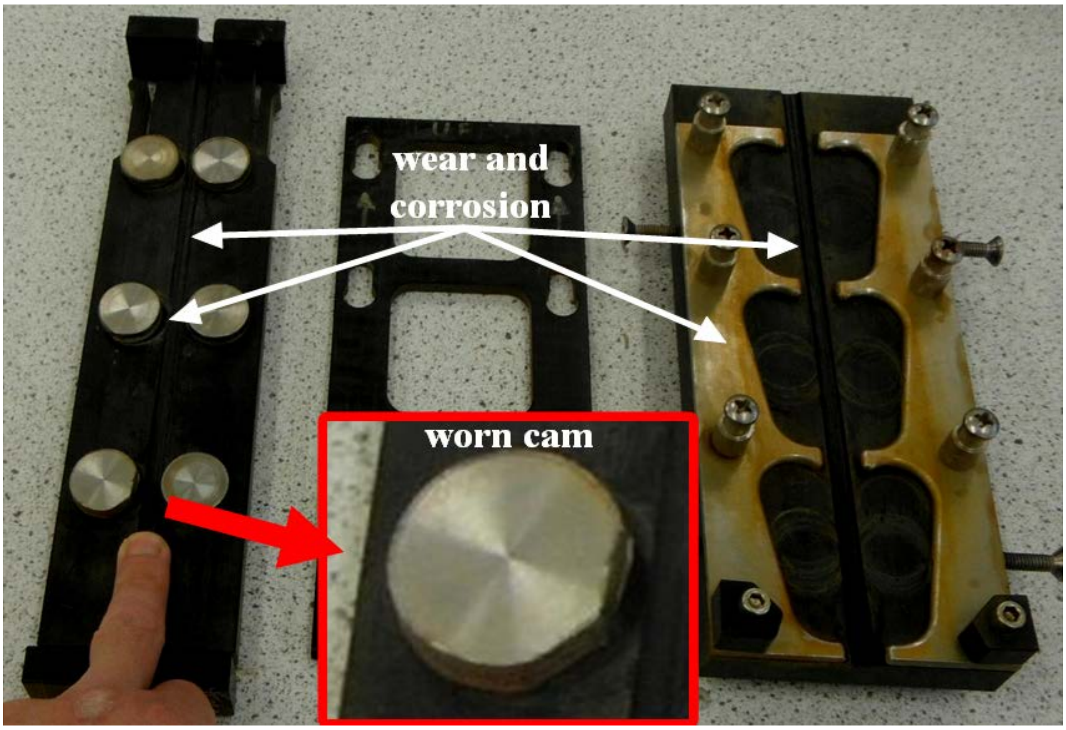


Fig. 15. Wear of the wirewalker mechanism after a costal deployment with an anchored mooring

This concludes a brief review of the mechanical degradation of the wirewalker mooring wire guide and wave energy utilisation mechanism. The next section of this report reviews the operational use of the wirewalker and summarises some future recommendations based upon the experienced gained to date with this system.

6. Discussion and summary

An operational overview of the use of the wirewalker to gather high resolution vertical profiles of temperature, salinity, chlorophyll fluorescence and turbulent kinetic energy dissipation has been provided in this report. This work has contributed to the overall success of the RRS James Clark Ross JR15007 scientific research cruise for the NERC funded RidgeMix research programme. The high resolution CTD, chlorophyll-a concentration, oceanic microstructure and oceanic turbulence scientific measurements will be used to assess the time-variability of upper-ocean mixing processes over the Mid-Atlantic Ridge, with a particular focus on tidal timescales.

During the wirewalker deployment described in this report a significant amount of raw and unprocessed scientific measurement data was gathered. Typically more than three 200 metre deep profiles of wave driven descents, followed by ascents under buoyancy to near the sea surface were completed per hour, while the scientific sensors were sampling continuously. More than 1700 high resolution scientific measurement profiles were generated for the 22 day deployment. In line with scientific data management best practices, this information will be processed and calibrated using precision reference sensors. Salient metadata such as instrument configurations, how the measurements were gathered, when and where calibration reference measurements occurred and any exceptions, anomalies or unusual features of these data will be documented. This information will be duplicated and securely backed up along with the other outputs from this research to form an evolving and expanding resource of high quality scientific information. The backed up wirewalker scientific measurements will be traceable back to the raw or initial data that was gathered when the profiler was recovered after the 22 day deployment.

Progressive, careful handling procedures were used for operations with the profiler and mooring system to reduce the chances of damage to the delicate scientific sensors. The use of a bespoke plastic guard for the fragile MicroRider sensor probes reduced the risk of damage to this sensor system. If precautions such as this are not observed then it is considered to be likely that damage to the profiler scientific sensor payload can occur, ultimately leading to a failure to generate the required scientific measurements.

It is highly advisable to undertake a series of ballasting tests to ensure the profiler operates correctly and the ascent rate under buoyancy is within the required constraints. It is common practice to reserve about half a day of ship time to complete the required tests and possible buoyancy adjustments before committing to a deployment of the profiler.

In terms of the deployment of the wirewalker and its associated mooring system, when possible, the drifting or unanchored configuration is preferable. This arrangement promotes stable, progressive vertical profiling and reduces wear of the wire guide and wave energy utilisation mechanism. Regular maintenance is advised to mitigate the problems of wear and tear of the wire guide cams, plastic mechanism faces and the tapered stainless steel cam engagement plates. It is recommended to smooth any wear that may be evident on the tapered cam engagement plate edges before a deployment. Any cams and mechanism plastic faces that show signs of wear should also be replaced before a deployment. The plastic rollers that guide the wire into the upper part and out of the lower part of the profiler should be replaced if signs of wear are evident.

Although not always possible, from a scientific data measurement perspective it is usually preferable to anchor the mooring system in place. This can ease the task of data processing and interpretation by restricting horizontal spatial variability and confining the recorded measurements to one particular study location.

Based upon experiences to date, it is considered advisable that if such an underwater profiler is to be used regularly from large research vessels, then scaling up of the engineering may be required to implement a more robust system. The general aim would be to use a larger diameter, higher load tolerant mooring wire with heavier gauge mooring couplings. A more rugged wire guide and wave energy capture mechanism would probably be appropriate. This mechanism would have an increased load bearing capability and would be more tolerant to mechanical wear and tear. Perhaps a larger profiling frame to support an increased volume of scientific sensors, cables and power sources would also be applicable. Such a system could provide increased protection from damage to delicate scientific sensors, particularly during ballasting testing, deployment and recovery operations. A higher capacity surface expression will probably be required to support a more rugged, increased scale mooring system and a profiler that can accommodate an increased scientific payload. Such a measurement system would probably be more able to withstand the rigours of sustained deployments in dynamic coastal regions and more energetic sea states.

In terms of the remote monitoring of the profiler and mooring system operation then some form of data telemetry system would be desirable. A wireless communications link such as underwater acoustic modems could be added to the system. This could allow regular information exchange between an underwater profiler and the associated mooring surface buoy instrumentation during a scientific survey. Remote monitoring of the deployed profiler could then be implemented by using satellite based data telemetry systems fitted to the surface buoy. Such an approach could also allow remote re-configuration of the deployed scientific sensors. A potential application of this could be to manage the sensor battery power budget for longer deployments by only recording measurements in key study areas or at particular times of interest.

For longer deployments of days to weeks or beyond, depending on the environment in which the system is deployed, steps to mitigate the effects of marine bio-fouling or sedimentation of the scientific sensors may be required. There are various techniques such as localised chlorination, UV lighting, automated cleaning and biocides to address these problems and a detailed discussion of this is beyond the scope of this report. It is important to consider and perhaps take steps to mitigate the risk of these potential drawbacks if longer deployments of the underwater profiling system are being considered or planned.

This report has served to summarise what has been an excellent example of the use of new and emerging scientific sensors, systems and their supporting infrastructure for the automated, cost effective gathering of sensitive, precision scientific measurements. The wirewalker has been demonstrated to be a capable and powerful system for the automated collection of CTD, oceanic microstructure and oceanic turbulence in addition to monitoring phytoplankton activity in the upper parts of the water column. It has been particularly rewarding that this has been successfully achieved in remote and challenging conditions.

Acknowledgements

Thanks are due to excellent help and assistance from the officers and crew of RRS James Clark Ross with support from NMF. Their outstanding level of professionalism and support was crucial for the successful completion of the required careful and progressive deployment and recovery of the fragile, precision oceanic sensing system described in this document. Thanks are also due to Drew Lucas and Tyler Hughen from the Ocean Physics Group at Scripps Institution of Oceanography and Del Mar Oceanographic. The rapid response to technical enquiries in addition to the subsequent provision of the required spares is appreciated. This was essential to support the express preparation of the wirewalker underwater profiler for a mid-Atlantic deployment at short notice, as part of the revised JR15007 research cruise scientific survey programme. Thanks are also due to Emma Murowinski, Haruno Sugita, Sandra Flower and Louise Legacy at RSI for the rapid help and support with the MicroRider sensor setup and the subsequent procurement of the required spares for the JR15007 research cruise, under very tight deadlines. The authors also thank the University of Liverpool based Department of Engineering for the provision of the excellent facilities within the Hydraulics Laboratory. These facilities were fully exploited for the ballasting tank based initial wirewalker setup and surface buoy testing that was required, at short notice, as part of the preparations for JR15007.

Appendix A – Wirewalker ballasting and surface expression testing

Prior to a deployment, initial testing of the wirewalker and the associated mooring system was undertaken in a laboratory environment. The profiler and instrumentation were assembled and tested for buoyancy and a suitable mass distribution using a salt water test tank, as shown in fig. A1. The key objective was to demonstrate that the wirewalker could be ballasted to be positively buoyant with a reasonably level or balanced scientific payload. Two wirewalker buoyancy foam blocks were fastened to the base of the profiler with one mounted on either side. A further 11 foam blocks were then fitted inside the wire guide and wave energy utilisation mechanism compartment for the ballasting test. This formed the maximum of 13 permitted buoyancy blocks for a standard configuration of the profiler.

a lowering of the profiler into the ballasting tank

b Profiler positive buoyancy confirmed

Fig. A1. University of Liverpool based ballasting tank test

In addition to ballasting the profiler to be positively buoyant, a key requirement was to try to assess and ensure the mass of the scientific payload and associated cables, clamps and fastenings was reasonably well distributed and balanced on either side of the profiler. The intention is to maintain a stable, balanced vertical orientation during buoyancy driven ascents underwater to collect precision scientific measurements. To test the profiler configuration, a ballasting tank with synthetic sea salt added that was located in the University of Liverpool Hydraulics Laboratory was used. A precision oceanographic CTD immersed in the tank determined that the ballasting tank water had a temperature of 15.66°C, a salinity of 31.78PSU and a density of 1023.36 kg/m^3 during the tests. The profiler was confirmed as being positively buoyant. Approximately 1.6kg of negatively buoyant ballast or the removal of two foam blocks from the wire guide compartment would cause the profiler to sink. Unfortunately the profiler was too tall to stay underwater in the desired vertical orientation in the ballasting tank. If the profiler was stood upright then approximately two thirds of the wirewalker was submerged in the tank. If a support to keep the profiler stationary and upright in the tank was removed, and the ballasting tank water was calm and still, then the profiler tended to stay upright. This provided some preliminary indication, within the limits of the ballasting test facilities and tank used, that the masses fitted to either side of the wirewalker that formed the scientific payload were reasonably evenly distributed. At this stage the configuration of the wirewalker was considered satisfactory for ballasting and profile rate testing form a chartered or research vessel, in advance of its use for a scientific survey.

If the wirewalker underwater profiler is to be deployed in less saline waters than the configuration used for the ballasting tank tests, then extra buoyancy may be required. To accommodate this, custom side pods and mountings were fabricated, as shown in fig. A2.

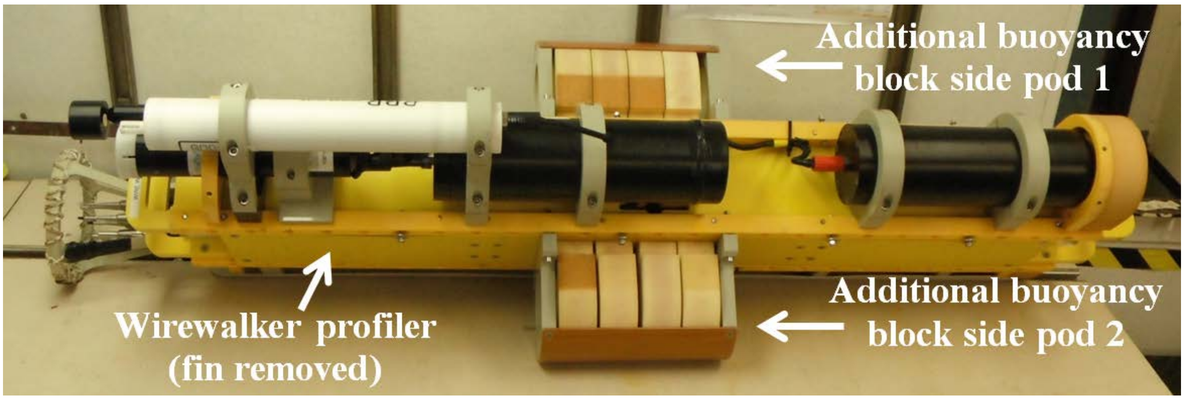
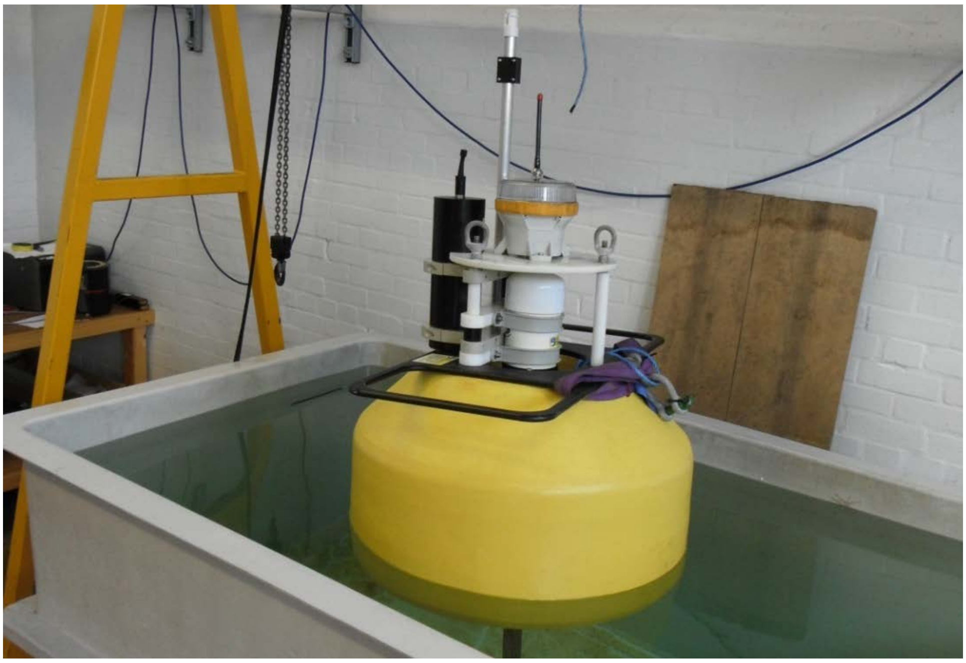


Fig. A2. Labelled photograph of the additional buoyancy side pods installed with four foam blocks in each pod and the underwater orientation fin temporarily removed

The general idea is to install one of the pods on opposite sides of the profiler and add even numbers of buoyancy blocks, distributed evenly on either side of the profiler. For example, the minimum balanced extra buoyancy, using standard wirewalker foam blocks and the side pods, would be one fitted to either side of the profiler. Each block provided approximately 0.5kg to 0.8kg of additional buoyancy in the test tank, with two blocks adding in the order of 1.5kg of additional positive buoyancy. The maximum extra, balanced additional buoyancy that could be added would be four foam blocks mounted in each side pod, providing a total of eight additional foam blocks, as shown in the configuration in the photograph in fig. A2.

A test was then conducted to ensure that, with all of the required instrumentation and the subsurface weight attached to the mooring surface buoy, the buoy was not unduly laden, did not list and it was suitable for a deployment. Attaching the subsurface weight to the underside of the buoy was deemed to be a reasonable representation of how the buoy will perform after a deployment. As shown in fig. A3 the fully instrumented buoy orientation, when floating in the ballasting tank with the subsurface weight attached underneath the buoy was confirmed as suitable for a deployment.

a lowering of the instrumented buoy and mooring subsurface weight into the ballasting tank



b buoy orientation and displacement confirmed as acceptable

Fig. A3. Surface buoy, instrumentation and subsurface weight test in the ballasting tank

Appendix B – Ballasting tests from RRS JCR and deployed profiler ascent rate

In advance of deploying the wirewalker to undertake 200 metre deep repeated underwater profiles to gather scientific measurements, a 20 metre long mooring wire was used. This allowed shorter underwater vertical profiles to be generated for testing and evaluation. The primary purpose of this was to rapidly assess the ballasting of the profiler, close to the intended deployment location, and modify if necessary the profiler ascent rate. When the profiler ascends under buoyancy a certain level of friction between the mooring wire and the wire guides and wave energy capture mechanism may occur. Therefore a simple ballasting tank test, as described in appendix A, is not considered sufficient to evaluate the wirewalker performance underwater. It is strongly advisable to assess the ballasting and subsequent ascent rate of the profiler when it is coupled to a mooring and under an appreciable depth of water. This water needs to be representative in terms of density of the intended scientific survey area. The aim is to simulate the operational conditions of a deployment as accurately as possible within a reasonable time frame. This can be an iterative process, typically close to the intended deployment location, involving multiple deployments, recoveries, recorded scientific data evaluation and profiler performance assessments before a suitable configuration is established. Fig. B1 shows a picture of the deployment of the subsurface weight, 20 metre long test wire, and the wirewalker profiler from the side of JCR.

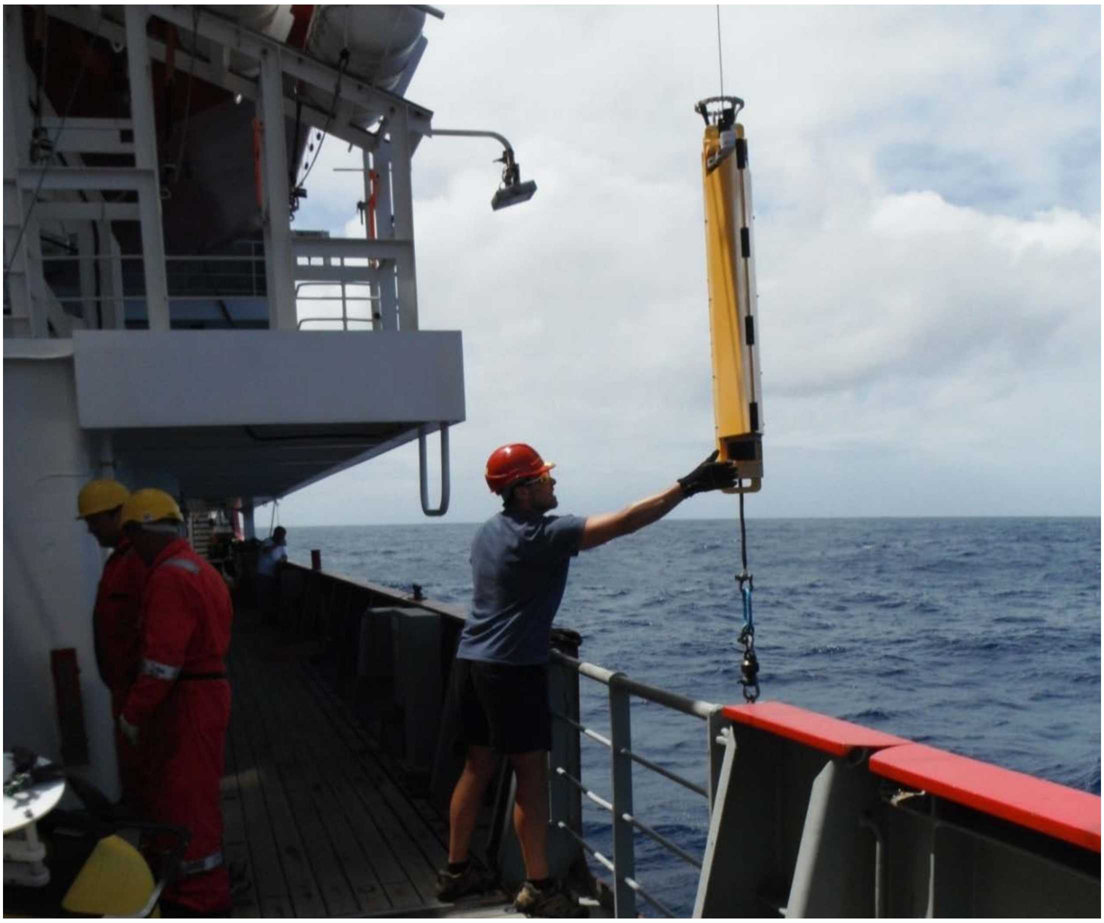


Fig. B1. Deployment of profiler, subsurface weight and a 20m test wire

The starboard CTD winch area of JCR was used for the profiler test deployments. This represented a more convenient location, away from the ship’s stern and propulsion systems, to make an initial assessment of the performance of the profiler. A picture of the profiler deployment during a 20m underwater profile ballasting test is shown in fig. B2.

Fig. B2. Test deployment of the wirewalker profiler using a 20 metre mooring wire

A reserve surface buoy without any instrumentation attached was used as the surface expression for the 20 metre depth test profiles. This surface buoy was tethered to the starboard side of JCR during the trials of the profiler as shown in fig. B3. A flexible 3m lifting strop was added as a temporary standoff between the underside mooring coupling on the buoy and the upper 20m steel mooring wire coupling. This provided increased distance between the surface buoy and the wirewalker during testing. The aim of this was to reduce the chances of the buoy impacting with the protruding sensors on the profiler, particularly during the test mooring deployment and recovery. Possible damage to the scientific sensors is a risk with operations such as this, especially if several ballasting tests are required. Each time the profiler was recovered the CTD calculated depth record and the MicroRider pressure record for the test was downloaded to assess the profiler ascent rate. A plot of a RBR CTD measured and processed data record for one of the trial deployments is shown in fig. B4.

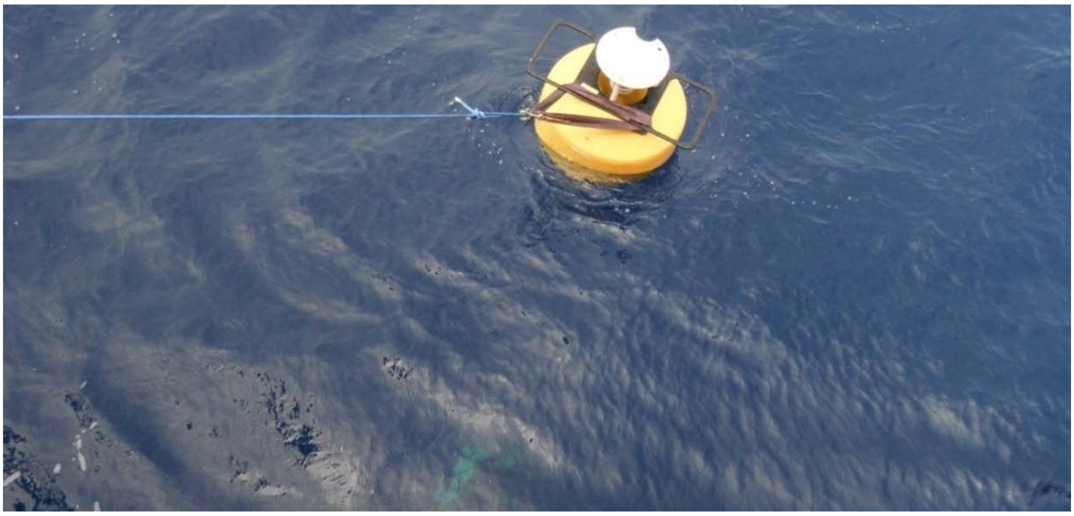


Fig. B3. Deployment of the wirewalker and a 20m test wire with a tethered surface buoy

From the expanded pressure trace in black and the computed depth plot in blue in fig. B4, the ascent change in depth from 18m to 5.5m or 12.5m depth difference was travelled from 18:36:23 to 18:36:48 at a steady or terminal velocity. Therefore, in 25 seconds the steady state ascent rate or terminal velocity under buoyancy was 12.5m/25 seconds = 0.5 m/s.

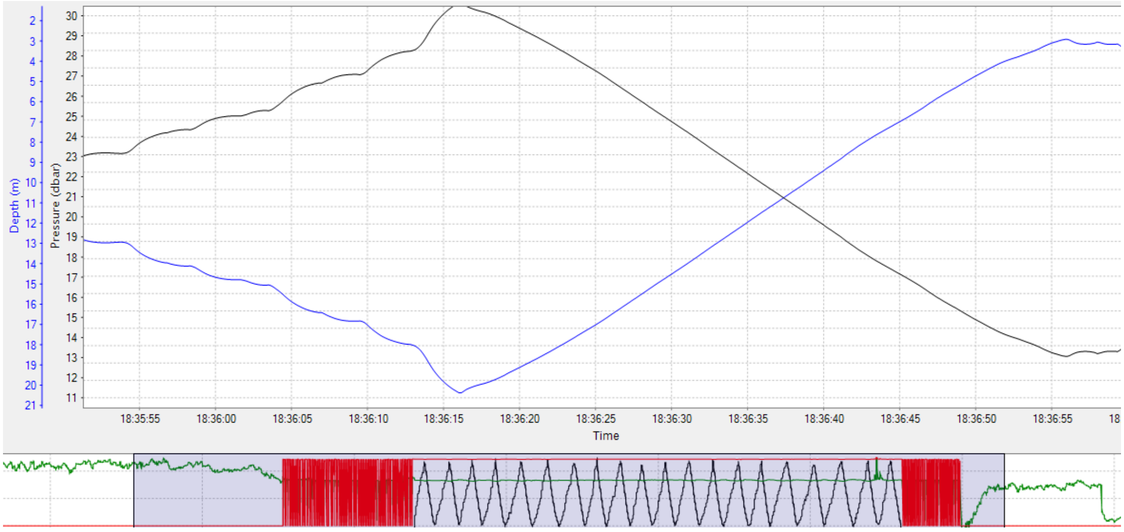


Fig. B4. Wirewalker profiler ascent rate under buoyancy for the 20m depth profiling test

While a profiler ascent rate of approximately 0.5m/s was considered acceptable, CTD surveys of the deployment location from JCR indicated an increasing density with depth beyond 20 metres. The adjustment of the wirewalker buoyancy during the pre-deployment 20 metre wire tests took account of the higher density and subsequent increased positive buoyancy at depths below 50 metres, as described in section 4 of this document. Therefore an additional buoyancy block was removed from the profiler wire guide mechanism after the 20 metre wire based ballasting tests to slow the ascent rate under buoyancy. This subsequently improved the spatial resolution of measurements from the CTD, fluorimeter and particularly the MicroRider oceanic microstructure and turbulence sensor. This reduced the buoyancy blocks to nine from an original total of eleven inside the mechanism compartment. The two outer foam blocks at the base of the profiler remained in place throughout the ballasting tests and the subsequent scientific deployment.

A screen capture of the recorded data set using the RBR Concerto CTD Ruskin software for the full 22 day deployment is shown in fig. B5. Various derived and measured parameters can be reported by the software such as the measured temperature, the derived salinity and the measured seawater pressure. What is noticeable on the predominantly green thumbnail plot of the entire data set in the lower part of the screen capture is the anomaly, in the form of a white vertical line, near to the centre of the recorded data. There seemed to be a slowing of the profiler ascent rate shortly after 10 days into the deployment. It is suspected that a calm sea state reduced the wave energy available for utilisation by the wirewalker wire guide mechanism, leading to a reduced profiling rate at this region of the data record. This is discussed in more detail in section 4 of this document that reviews the scientific results.

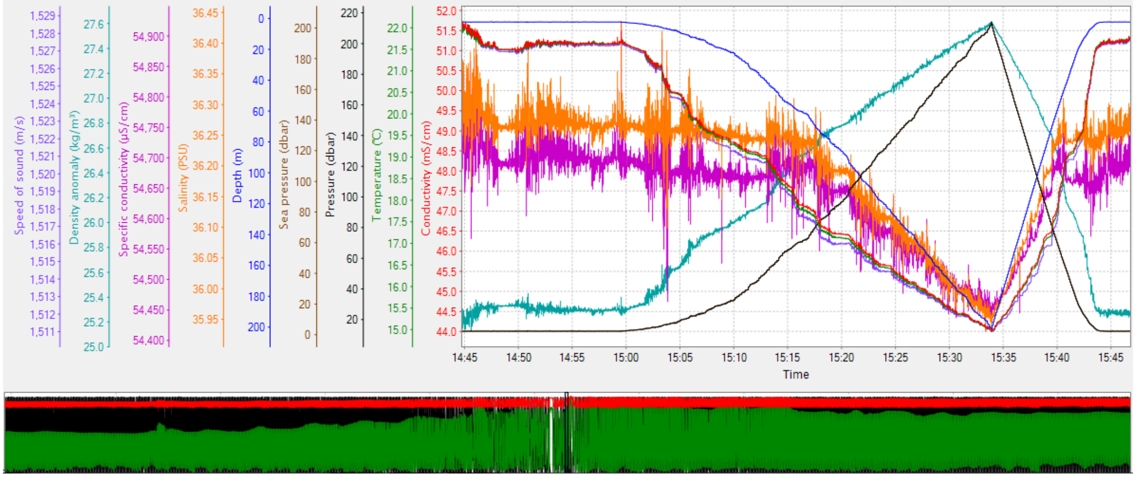


Fig. B5. Wirewalker profiler measured and computed values for the 22 day deployment from Sunday 5th to Monday 27th June 2016

A plot of a profiler ascent near the start of the deployment on Sunday 5th June 2016 using the CTD computed depth is shown in fig. B6. From 23:17 to 23:24 the profiler ascended from 180m to 15m. This represents a change in depth of 165 metres at a terminal velocity in 7 minutes or 420 seconds. The estimated profiler ascent rate was 165/420 = 0.393m/s. This ascent rate closely matches the values detailed in appendix C that were computed from the MicroRider pressure sensor readings during buoyancy driven ascents of the profiler.

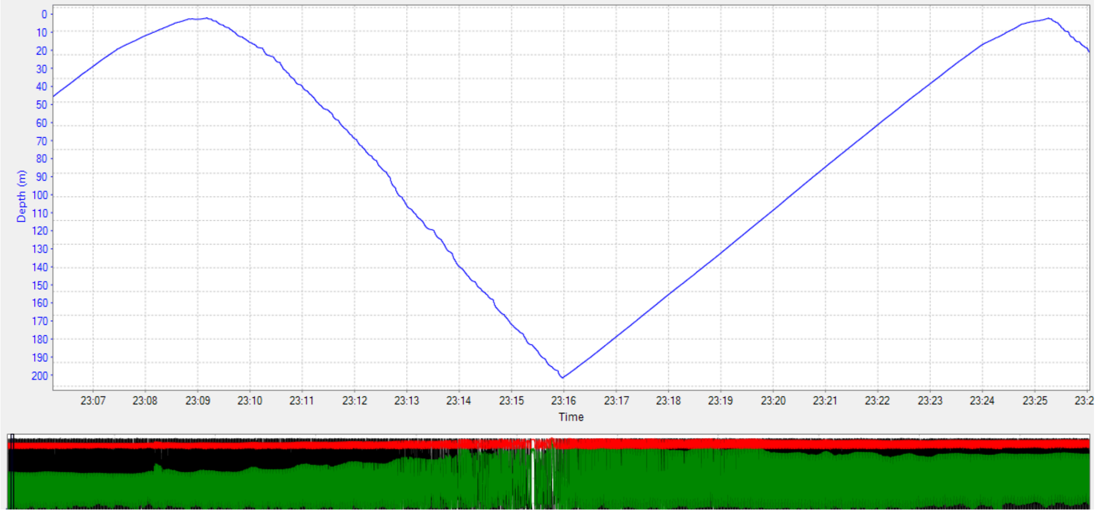
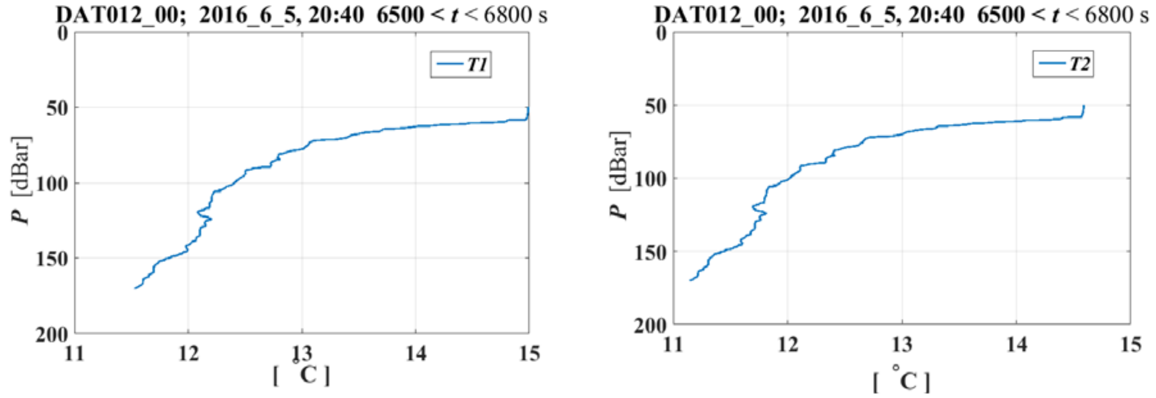


Fig. B6. Wirewalker profiler ascent rate near the start of the deployment on Sunday 5th June 2016

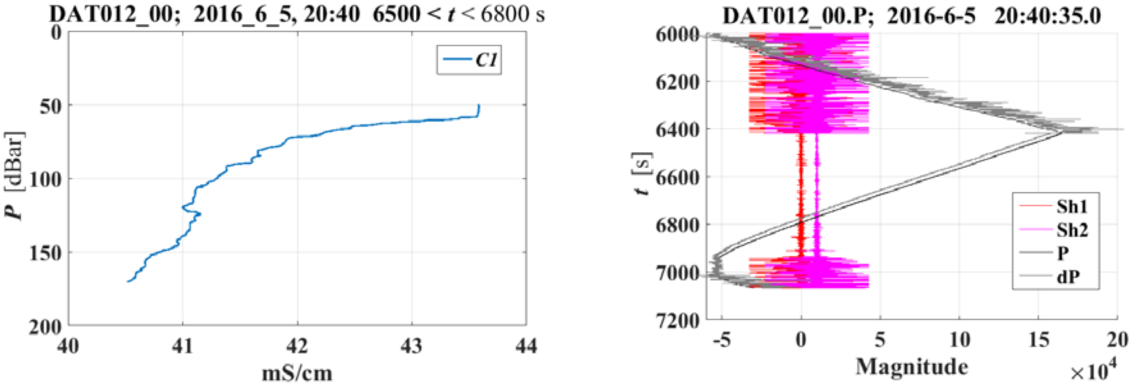
Appendix C – MicroRider preliminary data plots

To provide a degree of confidence in the integrity of the oceanic microstructure and turbulence measurements that were generated during the 22 day wirewalker deployment, a series of basic, provisional and uncalibrated data plots were generated. The purpose of this was to review the operation of the fragile MicroRider microstructure temperature, microstructure conductivity and velocity shear sensors at approximately the beginning, the middle and the end of the deployment. This was intended as a brief check for any periodic or sustained anomalies in the measured values that may have occurred during the 22 day long deployment of the profiler. The plots in fig C1 have been generated for readings close to the deployment start on Sunday 5th June 2016.



a Uncalibrated microstructure temperature T1

b Uncalibrated microstructure temperature T2

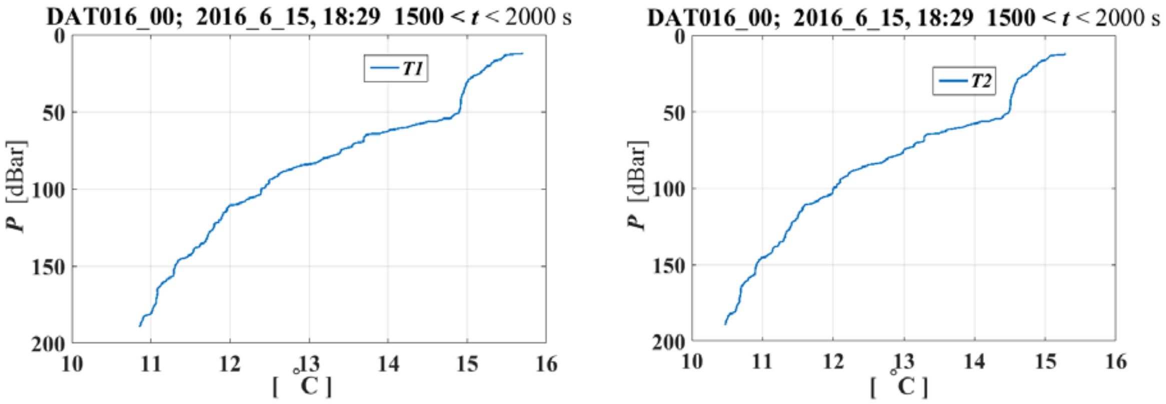


c Uncalibrated microstructure conductivity

d Normalised shear, presure and change in pre-emphasized pressure signal magnitude versus time

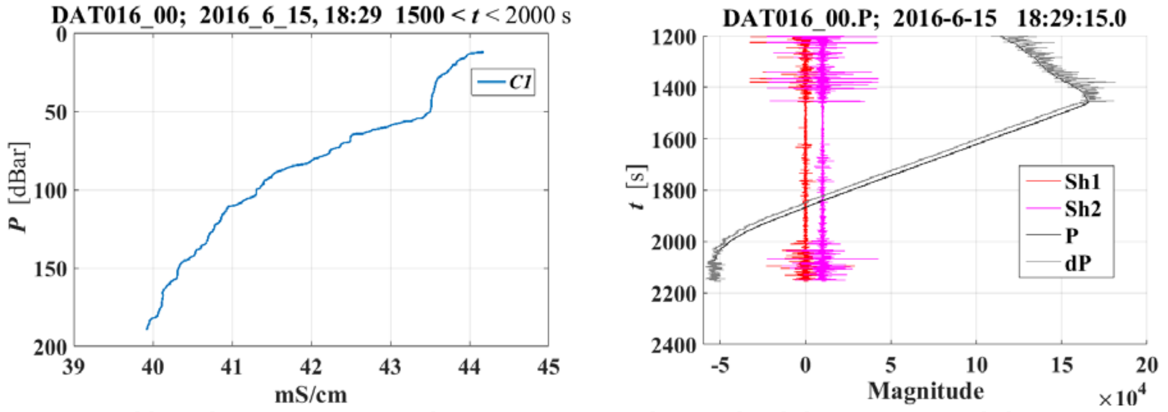
Fig. C1. Preliminary oceanic microstructure and shear signal plots near the deployment start on Sunday 5th June 2016. Graphs a to c show the readings during a buoyancy driven profiler ascent.

The graphs shown are similar to the plots in the scientific results section of this report, with the exception that the date and time information has been added and both MicroRider temperature channels are plotted. The plots in fig C1 parts a, b and c show contamination free oceanic microstructure signals for both (T1) and (T2) temperature channels and the microstructure conductivity signal, (C1). Based upon processing of the pressure sensor readings the estimated terminal velocity from approximately 200 metres in depth to near to the sea surface was 0.376m/s. This closely matches estimates in appendix B that are based on the profiler CTD pressure record. The plot of the raw measured pressure (P), the pre-emphasised pressure (dP) and the signals from shear sensor 1 (Sh1) and shear sensor 2 (Sh2) are shown in fig. C1, part d. These illustrate the signal contamination during a wave driven descent of the profiler, as shown in the upper part of the plot. The clearer, reduced noise signals during a buoyant ascent are shown in the lower part of the plot. It is anticipated that the temperature, conductivity, accelerometer, microstructure pressure and velocity shear signals are suitable for scientific analysis during the profiler ascents, as required. The actual processing of the signals, particularly the velocity shear and the estimation of turbulent kinetic energy dissipation rates, involves fairly complex steps and quality checks in the frequency domain, as mentioned in section 4.4 of this report. Such processing is beyond the scope of this document and will be used to provide measurements for future scientific publications that utilise these data. Plots of the MicroRider sensor output for a section of data from close to the middle of the deployment are shown in fig. C2. The estimated ascent rate from the MicroRider pressure sensor was 0.34m/s. As with the preliminary plots in fig C1, the microstructure temperature, conductivity, pressure and velocity shear signals are stable and do not exhibit any obvious problems during ascents of the profiler. The upper parts of the plot in fig C2, part d illustrate the signal distortion during a wave driven profiler descent, shown by a pressure slope with increasing magnitude. The buoyancy driven ascent in the lower part of this plot, with a reducing pressure slope magnitude, shows relatively low distortion and contamination in the shear and pressure signals, as required.



a Uncalibrated microstructure temperature T1

b Uncalibrated microstructure temperature T2

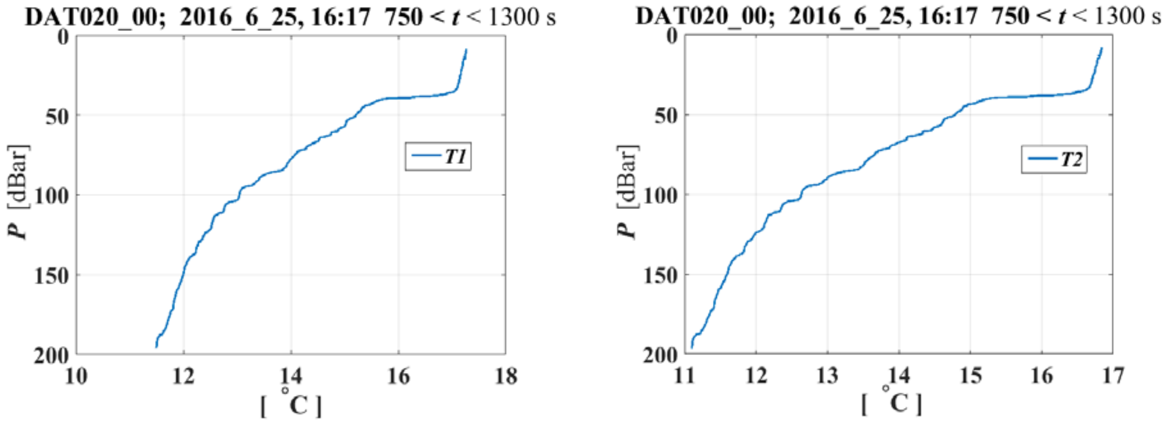


c Uncalibrated microstructure conductivity

d Normalised shear, presure and change in pre-emphasized pressure signal magnitude versus time

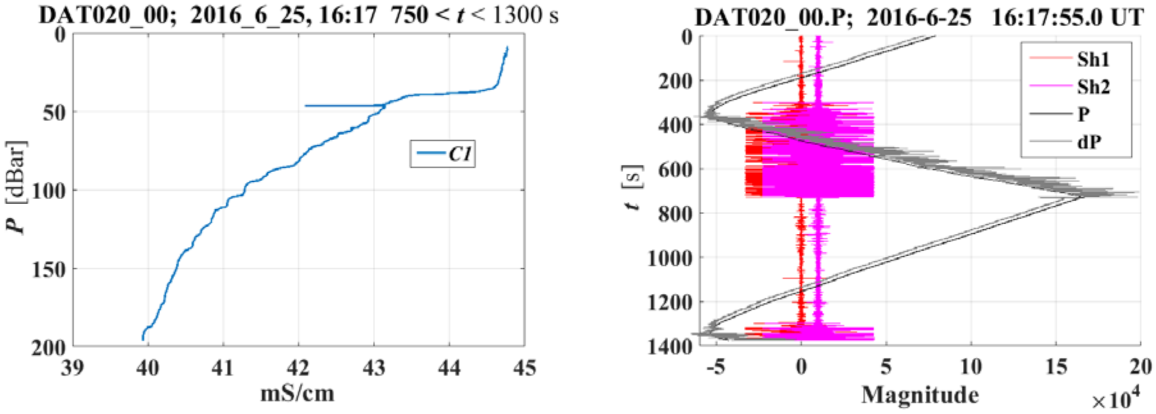
Fig. C2. Preliminary oceanic microstructure and shear signal plots near the middle of the deployment on Friday 15th June 2016. Graphs a to c show the readings during a buoyancy driven profiler ascent.

A set of similar plots of the MicroRider sensor output close to the end of the deployment are shown in fig. C3. The estimated ascent rate from the MicroRider pressure sensor signal was 0.35m/s. As with the other graphs of the oceanic microstructure temperature and conductivity the uncalibrated plots indicate that the MicroRider sensors were working correctly. At just above 50 metres in depth a noticeable impulse or spike has occurred in the microstructure conductivity measurement, as shown in fig. C3 part c, before the measurement form recovers. It is likely that the spike in the value recorded is due to some kind of particulate collision with or contamination of the microstructure conductivity sensor that has momentarily disturbed the measurement. Occasional problems such as this are relatively straightforward to filter or interpolate out of the recorded measurements during the detailed scientific analysis of the data. As with the previous profiler plots in this appendix, the shear signals and microstructure pressure graphs in fig C3, part d exhibit significantly lower parasitic noise and disturbance during the profiler ascent that is plotted in the lower section of the graph, with the pressure magnitude slope reducing in value. Based upon these observations the buoyancy driven profiler ascent based measurements would appear to be suitable for scientific analysis, and for deducing estimates of the turbulent kinetic energy dissipation rates. This is normally required at discrete depth ranges or bins underwater, at regular intervals during the wirewalker ascents from approximately 200m depth to close to the sea surface. The measurements depicted in figs C1, C2 and C3 indicate that close to the start, the middle and near to the end of the deployment the high quality of the MicroRider measurements has been sustained. This provided some level of assurance that the entire 22 day high resolution scientific record generated is likely to be of a high quality and suitable for scientific analysis.



a Uncalibrated microstructure temperature T1

b Uncalibrated microstructure temperature T2



c Uncalibrated microstructure conductivity

d Normalised shear, presure and change in pre-emphasized pressure signal magnitude versus time

Fig. C3. Preliminary microstructure and shear signal plots near the end of the wirewalker underwater profiler deployment on Saturday 25th June 2016. Graphs a to c were from a profiler ascent