National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

National Oceanography Centre

Cruise Report No. 29

RRS *Discovery* Cruise DY017

20 OCT - 06 NOV 2014

Outer Hebrides process cruise

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2015

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ABSTRACT

The continental shelf region immediately west of the UK and North of Ireland is thought to be a key region for the exchange of nutrients, carbon and water between the NW European continental shelf and the open North Atlantic Ocean yet it remains comparatively under sampled. Within the context of the NERC/DEFRA co-funded Shelf Sea Biogeochemistry programme, which aims to improve our understanding of the role of shelf seas in the global carbon cycle, this cruise undertook a regional scale survey to determine the distribution and concentrations of dissolved inorganic carbon, inorganic nutrients, trace metals, and other ancillary data on the Malin and Hebridean Shelves. Of the seven planned transects, six were completed with the seventh abandoned due to poor weather but a rich dataset of key biogeochemical parameters has been collected which will enable work on the stoichiometry of dissolved nutrients and exchange with the open ocean to be undertaken.

KEYWORDS

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Preface

The data presented in this Cruise Report are provisional and should not be used or reproduced without permission. In some cases they are fully calibrated and in other cases not. Further details can be obtained from the originators (see Scientific Reports). In due course the full data set will be lodged with the British Oceanographic Data Centre.

ACKNOWLEDGMENTS

We thank the Master, the officers and the crew of RRS *Discovery* for their excellent support and assistance throughout the cruise, particularly given the technical problems experienced.

Excellent support was provided by NMFSS staff on board and also prior to departure.

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NOC – National Oceanography Centre
- OBE – Ocean Biogeochemistry and Ecosystems
- NMFSS – NERC Marine Facilities Sea Systems
- OES – Ocean and Earth Science

SBR – Station Biologique de Roscoff
NIOZ – Royal Netherlands Institute for Sea Research
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PML - Plymouth Marine Laboratory
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ABSTRACT

The continental shelf region immediately west of the UK and North of Ireland is thought to be a key region for the exchange of nutrients, carbon and water between the NW European continental shelf and the open North Atlantic Ocean yet it remains comparatively under sampled. Within the context of the NERC/DEFRA co-funded Shelf Sea Biogeochemistry programme, which aims to improve our understanding of the role of shelf seas in the global carbon cycle, this cruise undertook a regional scale survey to determine the distribution and concentrations of dissolved inorganic carbon, inorganic nutrients, trace metals, and other ancillary data on the Malin and Hebridean Shelves. Of the seven planned transects, six were completed with the seventh abandoned due to poor weather but a rich dataset of key biogeochemical parameters has been collected which will enable work on the stoichiometry of dissolved nutrients and exchange with the open ocean to be undertaken.

1. INTRODUCTION

RRS *Discovery* cruise DY017 was a UK National Capability funded cruise requested to support the scientific objectives of the NERC/DEFRA co-funded Shelf Sea Biogeochemistry (SSB) research programme (http://www.uk-ssb.org). The aim of the SSB programme is to reduce the uncertainty in our understanding of carbon and nutrient cycling within shelf seas, and to improve our understanding of the role of shelf seas in global biogeochemical cycles. As part of the SSB programme a large NW European shelf wide sampling programme has been instigated in partnership between several of the UK's leading marine research centres and national agencies responsible for both the UK's (e.g. CEFAS, Marine Scotland etc) and Irish (Marine Institute) statutory monitoring requirements. Despite this huge collaborative effort initial planning for this programme suggested that the region west of the UK, consisting of the Malin and Hebridean continental shelves would be comparatively under sampled compared to the English Channel, Celtic Sea, North Sea and waters west of Ireland. Cruise DY017 was specifically requested to fill this data gap.

The western shelf has been the focus of several NERC funded research programmes including the Shelf Edge Study conducted in the mid 1990's (Souza *et al.,* 2001), the Extended Ellett Line hydrographic section run annually since 1975 (Holliday and Cunningham 2013), and most recently the FASTNEt programme in 2013 (**Figure 1**). It remains however a comparatively less well sampled region than other areas of the NW European Shelf. Despite this, the area is recognised as being important for exchange with the open ocean and numerical models indicate that the majority of shelf edge exchange likely takes place in this region (Holt et al., 2009; Huthnance *et al.,* 2009; Wakelin *et al.,* 2012). As such, quantifying the chemical gradients and fluxes of material both onto and off of the continental shelf in this region is important for the subsequent objectives of understanding the continental shelf carbon pump and the role of the NW European shelf in the global carbon cycle.

The objectives for DY017 were to map the large-scale gradients in dissolved inorganic carbon (CO_2), iron, inorganic and organic nutrients across the Hebridean and Malin Shelves (**Figure 2**). All of these properties are central to the SSB scientific objectives and subsequent work will relate the distribution of these properties to the circulation of the region, including the prominent northward flowing shelf slope current (Souza *et al.,* 2001) and to model estimates of shelf edge exchange. Unlike other activities in the SSB programme which are repeated or on-going, cruise DY017 was a one-time affair collecting a snap-shot of the western shelf during the autumn months, a time when the seasonal breakdown of water column stratification occurs.

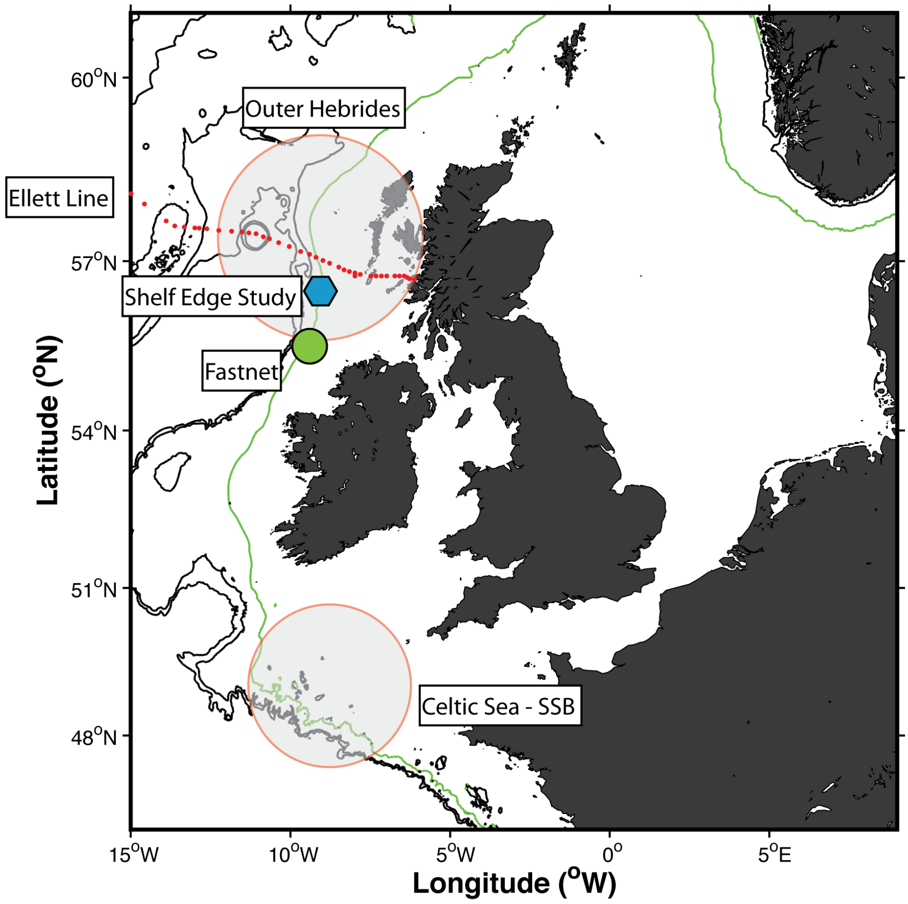


Figure 1: Chart showing the main working areas of the Shelf Sea Biogeochemistry programme research cruises in the Celtic Sea, previous NERC funded research activities on the western shelf, including the Extended Ellett Line (red diamonds), the Shelf Edge Study (blue hexagon), FastNet (green circle) and the approximate working area of the Outer Hebrides process cruise. The green line represents the 200 m bathymetric contour.

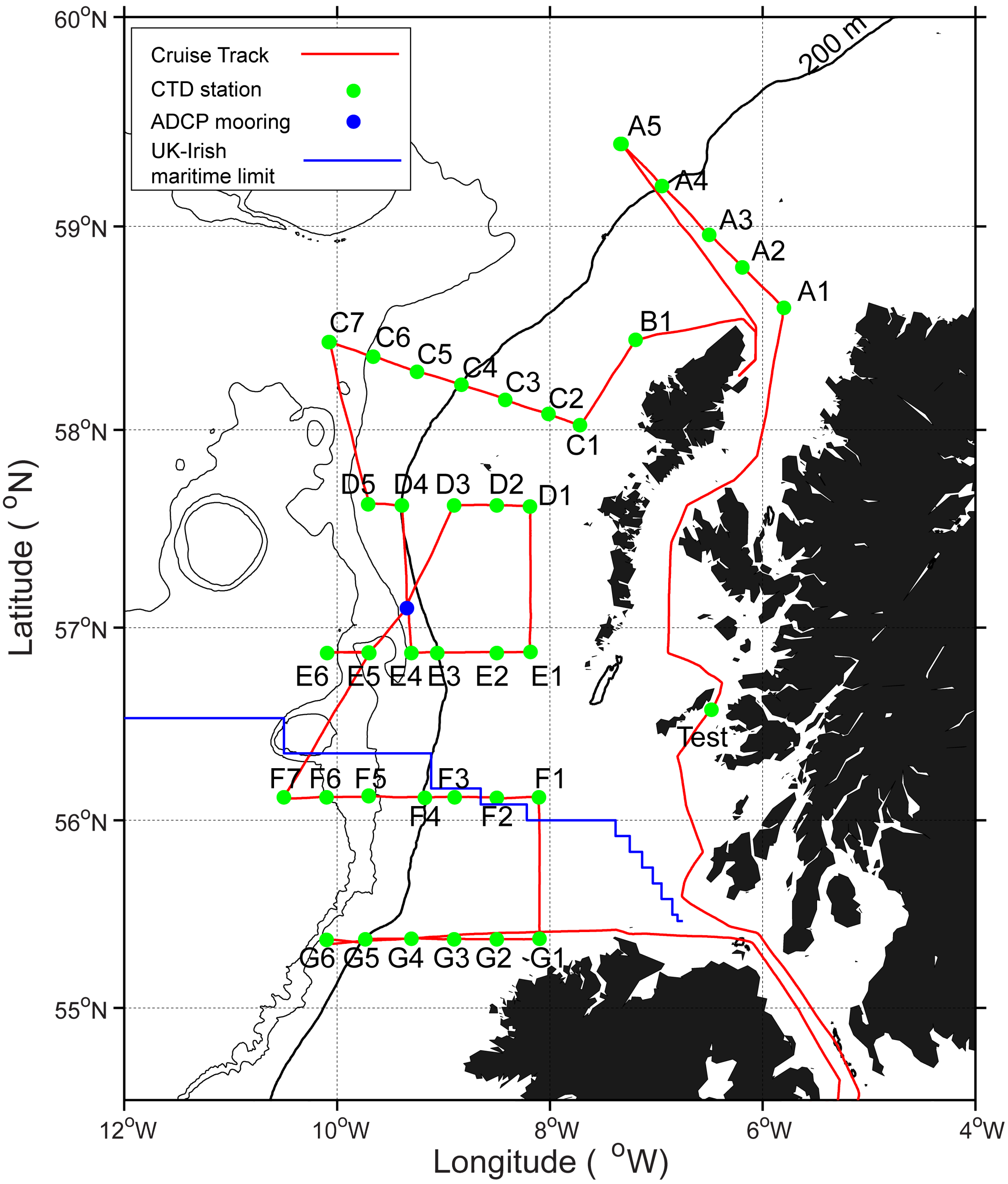


Figure 2: Chart showing Outer Hebrides work area with DY017 cruise track (red line), position of completed CTD stations (green dots), benthic ADCP lander location (blue dot), and the UK/Irish maritime limits (blue line). The thick black line represents the 200 m bathymetric contour.

2. CRUISE NARRATIVE

PSO's Diary

Monday Oct 20th (Day 293)

We departed the NOC berth in Southampton at ~0730 prepared for a 3 day transit to the work area west of the Hebrides and having been forewarned that the imminent arrival of ex-hurricane Gonzalo was likely to make conditions a little bumpy for the first few days. Weather conditions on departure were good with light winds and sunny periods and good progress was made down the Channel. Weather conditions deteriorated from early afternoon onwards with strengthening winds and a building swell throughout the evening.

Tuesday Oct 21st (Day 294)

We turned the corner around Land's End at 1am and true to predictions the sea conditions became noticeably worse leading to a rather unsettled night for most onboard. We awoke to Gale Force (GF) 10 winds but only a moderate swell yet *Discovery* proved to be a stable platform in bad weather and most of the scientific party re-emerged after a broken nights sleep. Only minor displacement of equipment due to ship movement was reported from the scientific labs with one exception. One of the working benches in the Deck Lab supporting a fume hood had partially collapsed overnight due to the continuous rocking motion of the ship. Complete collapse of this particular bench was only averted due to the fortuitous placement of another piece of scientific equipment that acted as a brace. Remedial repair work was quickly undertaken by the crew in the morning and whilst all other benches were checked for similar signs of collapse none were found to be at risk. Nevertheless precautions were taken to avoid this from happening by bracing benches where possible. It is troubling that so many of the benches were found to wobble with light pressure applied and in the opinion of this PSO this is only likely to worsen over time possibly leading to collapse when supporting heavy equipment particularly during high seas. These particular benches do not appear to be well made.

Poor weather conditions remained throughout the day with a drop in wind speed to GF6 by early afternoon however our progress north has been slowed due to the unfavourable conditions. Once in the Irish Sea and in the lee of Ireland the sea state dropped and by early evening conditions were greatly improved.

Wednesday Oct 22nd (Day 295)

Conditions were fairly calm overnight and into Wednesday morning as we finished our transit of the Irish Sea. Once out of the North Channel however both the wind speed and sea swell increased with gusts of GF 9 experienced around midday. A preliminary plan to test the acoustic releases for the UK-OSNAP benthic ADCP lander at the shelf edge was abandoned due to unfavourable conditions and instead we continued our northwards passage to station A1. Hopes of deploying the ADCP lander on our northward passage were further dashed after receiving news that the Naval Test Firing Zone situated west of the Hebrides was in use at the time of our northward passage. As fate would have it the proposed position of the lander is squarely in the middle of the firing range.

It now looks like the next opportunity to test the acoustic releases will be at the end of transect A.

Ongoing problems with the Surfmet system mean that no data has yet been collected with the underway instrumentation. Despite close scrutiny fault finding has yet to reveal a definitive cause for the lack of data. Suspicion is now on the instrument themselves rather than a communication problem.

At 1840 we stopped in the lee of Coll (56.58N 6.48W) to deploy the titanium CTD system (**CTD001**) to collect seawater to condition the bottles with prior to deploying the bottles again at station A1. The CTD was back on deck at 1936. The trace metal tow fish was prepared and deployed and we left at 2045 to continue northwards to station A1.

Thursday Oct 23rd (Day 296)

Conditions overnight were calm with greatly reduced wind speeds and we awoke to find patchy skies and the occasional sunny period as we finished our transit through the Little Minch. The forecast for the next 48 hours was promising but changeable and though wind speeds were predicted to increase to GF6-8 as we rounded the corner of the Isle of Lewis conditions looked promising for our first day of science.

We arrived at station A1 (58.60N 5.80W) at 1020 and deployed the titanium CTD (**CTD002**) for the trace metal measurements. This was followed at 1104 by the stainless steel CTD (**CTD003**), at 1228 by the plankton net (**NET001**) and finally the air-sea buoy (**BUOY001**) at 1323. As is usual at the first station a few delays were encountered including failure of the buoy electronics which terminated the deployment early but otherwise all sampled as planned. We departed for station A2 at ~1500.

On arrival at station A2 (58 48.027N 6 11.618W) at 1700 we proceeded to deploy the titanium CTD (**CTD004**) and the stainless CTD (**CTD005**). Both deployments were problem free and we departed for station A3 at 1930.

Wind speeds increased to GF8 on passage to station A3 and work was temporarily delayed on arrival at 2120. Conditions sadly did not improve and no further work was possible overnight when >40 knot south westerly winds and an 8 m swell impacted the work site.

Friday Oct 24th (Day 297)

Conditions had improved by breakfast time with winds of GF4-6 allowing a cautious deployment of the stainless steel CTD (**CTD006**) at station A3 (58 57.583N 6 30.002W) at 0852. The weather conditions were forecast to remain fairly constant with winds of GF4-6 throughout the day. We departed for station A4 at 0955.

We arrived on station A4 (59 11.92N 6 56.82W) at 1300 and deployed both CTD systems (**CTD007** & **CTD008**). A little time was lost on station due to necessary checks of the winch scrolling system but otherwise conditions were amenable to the task at hand. A large long period swell from the southwest was noticeable heralding the approach of yet another North Atlantic low pressure system which is predicted to bring with it significant wind speeds and swell. Our plan now is to head for safety behind the Isle of Lewis after completing Line A.

We departed station A4 at 1600 and headed further northwest towards station A5 arriving at 1810. We deployed the titanium CTD (**CTD009**; 59 24.05N 720.66W) undertaking a full profile to 1000 m and recovered the package at 2054. Delays were encountered during this deployment as a minor problem with the metal free winch scrolling system was identified and rectified. The stainless steel CTD was deployed at 2138 (**CTD010**; 59 23.86N 7 19.59W) and recovered at 2310. At this point the decision was made to abandon station A6 and we returned to the Isle of Lewis to wait out the approaching storm.

Saturday Oct 25th (Day 298)

We arrived in Broad Bay at ~0830 on the east side of the Isle of Lewis. Conditions were calm and sunny but ultimately misleading because by midday a noticeable increase in wind speed to F7 and above had occurred. Conditions continued to deteriorate throughout the afternoon and weather forecasts indicated GF10 winds and a >10 m swell offshore in our work area.

Sunday Oct 26th (Day 299)

We awoke to steady Force 7 winds though we were well protected from the worst of the swell by virtue of our sheltering in Broad Bay. Winds did not decrease until late in the afternoon preventing our departure. We eventually departed Broad Bay at ~1940 and cautiously headed north to test the conditions. Although a little lumpy the sea conditions were passable and we proceeded back to the survey area.

As a result of the loss of time the scientific party decided to drop Transect B and instead focus on the more southerly Transects during the remaining time. The one exception was to be station B1.

Monday Oct 27th (Day 300)

We arrived at station B1 at 0230 (58 26.79N, 7 11.620W) and proceeded to deploy both the titanium (**CTD011**) and stainless steel CTD's (**CTD012**) followed by the plankton net (**NET002**). All deployments went smoothly, helped by light winds and little swell and we left the station at ~0430.

We arrived at station C1 (58 1.36N, 7 42.94W) at 0855 and proceeded to deploy the titanium CTD (**CTD013**), the stainless steel CTD (**CTD014**) and the plankton net (**NET003**). We departed for station C2 at 1110.

At station C2 (58 4.02N, 8 0.72W) we deployed the stainless steel CTD (**CTD015**) and the air-sea buoy (**BUOY002**) forgoing an opportunity to deploy the titanium CTD due to time constraints and a desire to ensure sampling of deeper stations along Transect C. Extensive cloud covered the site and also brought with it light rain which made sampling the CTD a less than pleasant task. A moderate swell still invaded the site but wind speeds were noticeably down on recent days allowing us to work comfortably. The buoy deployment was a success with no repeat of the electronics failure that terminated deployment BUOY001 early.

On arrival at station C3 (58 5.95N, 8 25.05W) we proceeded to deploy, sample and stow the titanium CTD (**CTD016**) and steel CTD (**CTD017**) systems before moving on to station C4.

We arrived at station C4 (58 13.407N, 8 49.914W) at ~2050 and deployed titanium (**CTD018**) and steel CTD's (**CTD019**). These deployments were complete by 2300 when the plankton net was also deployed (**NET004**) before leaving this station for station C5.

On arrival at station C5 (58 17.33N, 9 14.88W) at ~0115 the titanium CTD was deployed (**CTD020**). This was successfully recovered by 0230. During the deployment of the stainless steel CTD however the deep tow cable jumped in the sheath and was crushed terminating the deployment. We were fortunate that this happened as the CTD was being raised from the deck for deployment rather than when at depth. Unfortunately this halted all science, and whilst most people on board were able to get some water from the titanium cast nothing more could be done at this station and we reluctantly steamed on to station C6 arriving at ~0430 where we waited whilst a retermination and load test was undertaken.

Tuesday Oct 28th (Day 301)

A sunny morning punctuated with cloud greeted us, which was a nice opener for the day ahead. Conditions were calm and were predicted to remain so for the next few days at least. By 0900 the retermination of the deep tow cable was complete but during the load test of the cable further problems were encountered with the winch which included slippage of the cable under tension. This necessitated further downtime to investigate and resolve. Fortunately by ~1400 a deployment was deemed possible and we cautiously deployed the steel CTD (**CTD021**) at station C6. The deployment was without issue and we departed for station C7 at ~1600.

We reached station C7 (58 26.01NM 10 4.6W) at 1810 and had the titanium CTD in the water at 1847 for cast **CTD022**. This was followed by a steel cast (**CTD023**) at 2121 and **NET005**. Due to the loss of time caused by the retermination of the deep tow cable and the need to reach the ADCP mooring location during a period of good weather, we broke the survey at this point and headed to station D5.

Wednesday Oct 29th (Day 302)

We arrived at station D5 (57 37.56N, 9 42.44W) at 0500 and deployed the steel CTD (**CTD024**) and the plankton net (**NET006**). All activities were inboard by 0700 and we departed for station D4 (57 37.18N, 9 23.45W) at the shelf edge arriving at 0840 whence we deployed the titanium CTD (**CTD025**), stainless steel CTD (**CTD026**) and plankton net (**NET007**). Due to pumping problems the trace metal tow fish was recovered and inspected. This revealed that the plastic sampling tube had been forcibly withdrawn into the tow fish by the force of the flow of water and that the screw holding the nose cone in place was dangerously loose and almost certainly would have fallen off in the near future. Remedial action was undertaken and the fish readied for redeployment at the next opportunity.

Due to loss of time at the last station, during transit to station D4 and the need to have daylight during the deployment of the ADCP mooring, we broke survey after station D4 and headed south to the proposed mooring site. A last minute change in position to a shallower inshore site (750 m water depth) saw the mooring provisionally located at 57 06.09N, 9 20.15W. The benthic mooring (**MOOR001**) was released at the surface at 1531 and sinking at a rate of 50 m min^{-1} arrived at the sea bed 15 minutes later. The release signal was sent at 1602 to allow recovery of the buoyancy parachute. Unfortunately the release did not work as planned and the buoyancy and acoustic release did not disengage cleanly from the lander. After several minutes of repeated range finding during which time the depth range remained consistently at 953-955 m it became apparent that the release was entangled. Although not clear precisely what went wrong in all likelihood one of the ropes attaching the release to the lander base failed to disengage cleanly from the acoustic release. A diagnostic test at 1608 indicated that the release was in a vertical position indicative of it being above the ADCP instrument. Sadly there was nothing more we could do.

A short 3 point survey was undertaken to correctly position the mooring on the seabed after which the trace metal tow fish (**FISH002**) was redeployed at 57 06.6N, 9 20.4W.

We transited back to station D3 (57 37.287N, 8 54.044W), to complete the inner half of Transect D and arrived on station at ~2115 where we deployed the stainless steel CTD (**CTD027**). Upon successful recovery of the CTD package we steamed on to station D2 (57 37.295n, 8 29.992w) deploying the steel CTD (**CTD028**) at 2345.

Thursday Oct 30th (Day 303)

Conditions today were grey, overcast, and frequently wet but sufficiently calm to allow us to work. We reached station D1 (57 36.958N, 8 11.140W) at 0140 and deployed the steel CTD (**CTD029**), which was safely inboard by 0218. The plankton net (**NET008**) was then deployed before we moved on to Transect E.

We arrived at station E1 at 0800 (56 52.526N, 8 10.984W) and deployed the titanium CTD (**CTD030**), the steel CTD (**CTD031**) and the plankton net (**NET009**). As it was a little early to deploy the air-sea buoy we cancelled its planned deployment at this station and moved it to the next.

We arrived at station E2 (56 56.22N, 8 30.012W) at 1055 and deployed the steel CTD (**CTD032**) which was back on deck by 1132. We then deployed the air-sea buoy (**BUOY003**), the deployment of which took longer than planned due to technical problems. By 1330 work was completed and the buoy brought back inboard.

Station E3 was moved prior to our arrival to a position closer to the shelf break (56 52.19N, 9 03.516W). On arrival at 1600 we deployed the titanium CTD (**CTD033**), steel CTD (**CTD034**), and plankton net (**NET010**). With all work completed by 1800 we proceeded to station E4.

On arrival at station E4 (56 52.186N, 9 17.917W) we deployed the titanium CTD (**CTD035**) and steel CTD (**CTD036**) systems. During deployment of the steel CTD on the deep tow winch however numerous errors were encountered and a major problem emerged in the winch room. The nature of the problem (operation of multiple winch drums simultaneously) was entirely new to the ships company and halted the deployment. A temporary resolution was found which allowed continuation of the deployment but after recovery of the package at 2330 all further use of the deep tow cable was suspended. Further guidance from Rolls Royce, Norway was immediately sought and until such guidance is received the deep two cable will remain non-operational. In response to this we have downsized from 20L Niskin bottles to 10L bottles on the steel frame and will continue the science using the metal free winch system.

Following this unwelcome turn of events we proceeded north to the position of the ADCP lander to undertake a secondary check on the acoustic releases.

Friday Oct 31st (Day 304)

On arrival at 0109 the acoustic releases were reranged. This secondary check was to confirm whether the entangled release had broken free over night and whether there had been any change to the orientation of the horizontal releases (to be used for recovery). Early on Thursday evening at 1710 a fishing trawler (*Jean Claude Coulon 2*) had been spotted fishing extremely close to the lander position and was obviously following a bathymetric contour so this opportunity to recheck that the lander was still in place allayed fears that the entangled buoyancy had made this deployment short lived. As evidenced by the choice of lander design (an anti-trawl design) it is likely however that fishing in this region may well encounter the buoyancy at some stage in future.

We arrived at station E5 at 0400 but the wind had increased to F7 and all work was suspended. In the end we chose to move on to station E6 arriving at 0700 (56 52.210N, 10 5.613W) where we deployed the steel CTD (**CTD037**). At this station a winch test of the deep tow system was also undertaken in an effort to replicate the problems seen last night. Winch test complete we then proceeded back to station E5 arriving at~1330 where we deployed the steel CTD (**CTD038**). Prior to the deployment of the air-sea buoy (**BUOY004**) electrical problems were identified with the buoy winch system. Rather than lose the station we deployed the instrument package via the starboard davit crane which seemed to be a successful alternative deployment method. A nice sunset was observed by all onboard at ~1650 – the first of the cruise – before we deployed the titanium CTD (**CTD039**) and the plankton net (**NET011**). Station completed by 2130 we then proceeded south to station F7.

<u>Saturday Nov 1st (Day 305)</u>

On arrival at station F7 at 0515 (56 07.298N, 10 29.928W) it was noted that the wind speed had increased to F7. The stainless CTD (**CTD040**) was deployed at 0530 but at a depth of only 285 m weather conditions deteriorated rapidly due to an incoming squall and the bridge ordered a halt to the deployment and the recovery of the CTD package. We maintained station for an hour before deciding to abandon this station and move on to station F6.

We arrived at station F6 at 0850 (56 07.29N, 10 06.01W) but weather conditions were still too poor to work. By 1000 the wind was blowing a steady F5 but the swell seemed to have increased. We maintained position at this station until 1800 when we deployed the steel CTD (**CTD041**). This was followed by a plankton net (**NET012**).

Information received overnight from Rolls Royce, Norway, suggests that the deep tow winch may be usable

We arrived at station F5 at 2300 and deployed the steel CTD (**CTD042**) at 2300. This was safely back on deck by 0116 and the titanium CTD was subsequently deployed (**CTD043**). With all work finished by 0400 we proceeded onwards to station F4.

<u>Sunday Nov 2nd (Day 306)</u>

On arrival at station F4 the wind had increased in intensity and it looked like a deployment of either CTD system was going to be delayed. Fortunately the decision was taken to try and we deployed the steel CTD (**CTD044**) under less than ideal conditions at 0627. The package was safely back on deck by 0653 and we proceeded to deploy the titanium CTD (**CTD045**) and plankton net (**NET013**).All work was finished by 0830 and we proceeded to the next station.

We arrived at station F3 at 0945 and deployed the steel CTD (**CTD046**) and titanium CTD (**CTD047**). All instrument packages were inboard by 1130 and we proceeded onwards.

Wind speeds continued to blow a constant F5 and on arrival at station F2 the air-sea buoy was not deployed as planned. Instead we deployed the instrument package via the aft starboard davit as had been perfected earlier at station E5 (**BUOY005**). This deployment was complete by 1450 and was followed by the deployment of the stainless steel CTD (**CTD048**). This was complete by 15:56.

Station F1 (56 07.177N, 08 06.149W) was reached at ~1730 and we immediately deployed the stainless steel CTD system (**CTD049**) and followed this with another plankton net haul (**NET014**). With this complete we departed the end of Transect F and headed south to Transect G.

We reached station G1 (55 22.236N, 08 05.864W) and deployed the stainless steel CTD (**CTD050**) just before midnight. This was followed with another plankton net haul (**NET015**) and we were soon on our way to station G2.

<u>Monday Nov 3rd (Day 307)</u>

Station G2 was reached at 0200 where we deployed the steel CTD (**CTD051**) completing the deployment by 0240.

At Station G3 we undertook a stainless steel CTD cast (**CTD052**) and the package was inboard by 0524 having taken only 20 minutes due to the shallow depth of the station (100 m).

Weather conditions were ideal for rapid progress with light winds and little swell and we reached station G4 at 0700 and deployed the titanium CTD (**CTD053**) which was also to be used to collect water for other participants due to our desire to maximise time on the last day of science. This was inboard by 0747.

We have made good time overnight and throughout the morning and reached the shelf break station G5 at 0940. We deployed the titanium CTD (**CTD054**), the plankton net (**NET016**) and the air-sea buoy (**BUOY006**) instrument package via the aft davit.

Due to excellent progress overnight we reached the last objective for this cruise, station G6, at 1415 and deployed the titanium CTD (**CTD055**) for the last time at 1457. This was safely inboard by 1636 and after a short delay to remove bottles and switch CTD systems the steel CTD (**CTD056**) was deployed at 1733 and recovered by 1921.To complete scientific activities for this cruise we also deployed the plankton net (**NET017**) and air-sea buoy (**BUOY007**) for good measure. All activities were completed and inboard by 2100 and this marked the end of science for this cruise.

We departed the survey area at 2110 and begun our steam back to Falmouth.

<u>Tuesday Nov 4th (Day 308)</u>

Fine weather conditions greeted us today, ideal for a smooth transit back to land and for lab break down. Good views of Ireland were encountered as we entered the North Channel.

<u>Wednesday Nov 5th (Day 309)</u>

Transit and lab break down.

We docked in Falmouth at ~1900.

Thursday Nov 6th (Day 310)

We demobilised the RRS *Discovery* throughout the morning packing equipment onto lorries for return to NOC and other home institutions. The scientific party disembarked from late morning onwards.

Identified problems

Given well publicised problems with (and anguish over) the operation of winches on RRS *Discovery* there is no point reiterating those issues here as remedial work is already planned for after DY017. The use of the deep tow winch put in place to allow DY017 to get to sea generally worked for the majority of the cruise allowing much of the planned science to be undertaken. However, following an incident on Oct 30th this winch was quarantined reducing scientific activities to use of a single winch system (the metal free winch) and also requiring a reduction in bottle volume from 20L to 10L bottles on the steel frame. This did impact the science by forcing a commensurate reduction in water requirements but thankfully did not stop any planned science. Resolution of the technical problems with the deep tow winch are ongoing as part of the wider resolution of winch problems.

Other issues which do require further investigation however concern

1. The underway surfmet instrumentation suite, which was not working at the start of the cruise and provided no sensible or usable data during the cruise. Despite efforts to unravel the wiring and debug software no solution was found. Given the poor weather experienced during parts of DY017 this loss of data will likely prove detrimental to the scientific objectives.
2. The benches in many of the scientific spaces do not look suitable for supporting heavy scientific instrumentation as the collapse of one bench supporting a fume hood on Oct 21st demonstrated. Further remedial work and/or replacement may be needed.
3. Internet communications were particularly poor for most people on board. In many instances people had more success using their mobile phones than their laptops for accessing email. Although more of an annoyance than a major problem the comms on *Discovery* appear worse than on the predecessor ship. Some improvement was made very late in the cruise but some participants were unable to access their email for the duration of the cruise which they consider to be unsatisfactory.
4. The OS75 ADCP experienced a few problems early in the cruise and was operational with a 3 beam solution for the first week. This was rectified by replacement of the ADCP deck unit and the instrument worked reliably thereafter however recognition and resolution of this problem was slow and as a result we have lost data from the first 2 transects of the cruise.

Master's Diary (Summary)

Start		End		
Date	**Time**	**Date**	**Time**	**Activity**
16/10/2014	09:00	19/10/2014	17:00	Mobilisation for DY017 incl bunkering and storing
19/10/2014	17:00	20/10/2014	07:30	Waiting to sail
20/10/2014	07:30	20/10/2014	10:12	Pilotage and Stand-by to Needles Fairway Buoy

	10:12	22/10/2014	18:35	Passage to CTD test site off the Isle of Coll. 3 generators until 13:00 22/10/14. Clocks retarded 1 hr to GMT.
22/10/2014	18:35	22/10/2014	20:43	S.S. CTD test deploymente on Deep Tow wire & deploy Tow Fish
	20:43	23/10/2014	10:12	Passage to DY017 start
23/10/2014	10:12	23/10/2014	14:52	Stn A1. SS and MF CTD. Plankton Net. Near Surface Sampling Buoy
	14:52	23/10/2014	17:10	Relocate for next station
	17:10	23/10/2014	19:30	Stn A2. SS and MF CTD
	19:30	23/10/2014	21:20	Relocate for next station
	21:20	24/10/2014	08:20	At Stn A3. Waiting on weather. Wind 40kts. Swell 5-6m
24/10/2014	08:20	24/10/2014	10:43	Stn A3. SS and MF CTD. Tow Fish issues
	10:43	24/10/2014	13:06	Relocate for next station
	13:06	24/10/2014	16:00	Stn A4. SS and MF CTD
	16:00	24/10/2014	18:30	Relocate for next station
	18:30	24/10/2014	23:21	Stn A5. SS and MF CTD & test of lander accoustic releases
	23:21	25/10/2014	08:48	To Broad Bay for shelter
25/10/2014	08:48	26/10/2014	19:30	Waiting on weather in Broad Bay
26/10/2014	19:30	27/10/2014	02:35	Return to science line at B1
27/10/2014	02:35	27/10/2014	05:15	Stn B1. SS and MF CTD. Plankton Net
	05:15	27/10/2014	09:05	Relocate for next station
	09:05	27/10/2014	11:03	Stn C1. SS and MF CTD. Plankton Net
	11:03	27/10/2014	12:18	Relocate for next station
	12:18	27/10/2014	14:38	Stn C2. SS CTD & Near Surface Sampling Buoy
	14:38	27/10/2014	16:43	Relocate for next station
	16:43	27/10/2014	19:07	Stn C3. SS and MF CTD
	19:07	27/10/2014	21:00	Relocate for next station
	21:00	27/10/2014	23:32	Stn. C4. SS and MF CTD. Plankton Net
	23:32	28/10/2014	01:20	Relocate for next station
28/10/2014	01:20	28/10/2014	03:15	Stn. C5. MF CTD. Deep Tow wire jumps out of sheave. Wire needs reterminating.
	03:15	28/10/2014	04:52	Relocate for next station
	04:52	28/10/2014	14:00	On stn at C6. Awaiting retermination and test.
	14:00	28/10/2014	16:00	Stn C6. SS CTD
	16:00	28/10/2014	18:20	Relocate for next station
	18:20	29/10/2014	00:02	Stn C7. SS and MF CTD. Plankton Net
29/10/2014	00:02	29/10/2014	05:08	Relocate for next station
	05:08	29/10/2014	07:25	Stn D5. SS CTD and Plankton Net
	07:25	29/10/2014	08:34	Relocate for next station
	08:34	29/10/2014	11:38	Stn D4. SS and MF CTD. Plankton Net. Tow Fish recovered
	11:38	29/10/2014	15:00	Reposition for Lander deployment. Flotation package not releasing

	15:00	29/10/2014	16:00	Lander deployment
	16:00	29/10/2014	18:05	Lander position calibrated/triangulation. Tow Fish deployed
	18:05	29/10/2014	21:24	Relocate for next station
	21:24	29/10/2014	22:09	Stn D3. SS CTD
	22:09	29/10/2014	23:37	Relocate for next station
	23:37	30/10/2014	00:22	Stn D2. SS CTD
30/10/2014	00:22	30/10/2014	01:36	Relocate for next station
	01:36	30/10/2014	02:35	Stn D1. SS CTD and Plankton Net
	02:35	30/10/2014	08:00	Relocate for next station
	08:00	30/10/2014	09:39	Stn E1. SS and MF CTD. Plankton Net
	09:39	30/10/2014	10:54	Relocate for next station
	10:54	30/10/2014	13:44	Stn E2. SS CTD and near surface sampling buoy
	13:44	30/10/2014	16:11	Relocate for next station
	16:11	30/10/2014	18:05	Stn E3. SS and MF CTD. Plankton Net
	18:05	30/10/2014	19:05	Relocate for next station
	19:05	30/10/2014	23:37	Stn E4. MF and SS CTD. During operation of deep tow unexplained change over to core winch. Deep Tow wire use suspended
	23:37	31/10/2014	01:10	Reposition to check lander position and status of flotation package
31/10/2014	01:10	31/10/2014	01:30	Checking position of lander
	01:30	31/10/2014	04:00	Relocate for next station
	04:00	31/10/2014	04:30	At Stn E5. Swell conditions prevent deployments
	04:30	31/10/2014	06:30	Relocate for next station
	06:30	31/10/2014	07:39	Stn E6. Waiting on reduction in swell/heave
	07:39	31/10/2014	10:12	Stn E6. SS CTD on MFCTD wire.
	10:12	31/10/2014	12:10	Tests of deep tow wire using dummy weights. Unable to replicate fault - all further CTD deployments on MFCTD wire
	12:10	31/10/2014	13:30	Relocate for next station
	13:30	31/10/2014	21:36	Stn E5. SS and MFCTD - both on MFCTD wire. Near surface sampling using crane and deck winch. Plankton net
	21:36	01/11/2014	05:00	Relocate for next station
01/11/2014	05:00	01/11/2014	07:20	Stn F7. SS CTD.
	07:20	01/11/2014	08:57	Relocate for next station
	08:57	01/11/2014	18:12	Stn F6. Waiting on weather and reduction in swell/heave
	18:12	01/11/2014	21:28	Stn F6. SS CTD and Plankton Net
	21:28	01/11/2014	23:00	Relocate for next station
	23:00	02/11/2014	04:20	Stn F5. SS and MF CTD.
02/11/2014	04:20	02/11/2014	06:22	Relocate for next station
	06:22	02/11/2014	08:33	Stn F4. SS and MF CTD. Plankton Net
	08:33	02/11/2014	09:38	Relocate for next station
	09:38	02/11/2014	11:37	Stn F3. SS and Tit CTD.
	11:37	02/11/2014	13:06	Relocate for next station
	13:06	02/11/2014	16:15	Stn F2. Near Surface sampling using crane and deck winch. SS CTD
	16:15	02/11/2014	17:40	Relocate for next station

	17:40	02/11/2014	18:47	Stn F1. SS CTD and Plankton Net
	18:47	02/11/2014	23:45	Relocate for next station
	23:45	03/11/2014	00:22	Stn G1. Tit CTD and Plankton Net
03/11/2014	00:22	03/11/2014	02:12	Relocate for next station
	02:12	03/11/2014	02:44	Stn G2. SS CTD
	02:44	03/11/2014	04:39	Relocate for next station
	04:39	03/11/2014	05:44	Stn G3. SS CTD
	05:44	03/11/2014	07:24	Relocate for next station
	07:24	03/11/2014	07:55	Stn G4. Tit CTD
	07:55	03/11/2014	09:35	Relocate for next station
	09:35	03/11/2014	13:10	Stn G5. Tit CTD. Plankton Net. Near surfce sampling
	13:10	03/11/2014	14:45	Relocate for next station
	14:45	03/11/2014	21:13	Stn G6. SS and Tit CTD. Plankton Net. Near Surface Sampling
	21:13	05/11/2014	16:00	Passage to Falmouth Pilots
05/11/2014	16:00	05/11/2014	17:12	Pilotage to berth, County Wharf

3. TECHNICAL SUPPORT

CTD Operations

Jeff Benson (with additional Deep Tow comments from A. Davies), James Burris and Julie Wood.

1) Two CTD systems were prepared. The first water sampling arrangement was a 24-way titanium frame system (s/n SBE CTD TITA1), and the initial sensor configuration was as follows:

Sea-Bird 9plus underwater unit, s/n 09P-71442-1142
Sea-Bird 3P temperature sensor, s/n 03P-5700, Frequency 0 (primary)
Sea-Bird 4C conductivity sensor, s/n 04C-4138, Frequency 1 (primary)
Digiquartz temperature compensated pressure sensor, s/n 124216, Frequency 2
Sea-Bird 3P temperature sensor, s/n 03P-5785, Frequency 3 (secondary)
Sea-Bird 4C conductivity sensor, s/n 04C-4143, Frequency 4 (secondary)
Sea-Bird 5T submersible pump, s/n 05T-3088, (primary)
Sea-Bird 5T submersible pump, s/n 05T-3090, (secondary)
Sea-Bird 32 Carousel 24 position pylon, s/n 32-60380-0805
Sea-Bird 11plus deck unit, s/n 11P-34173-0676 (main)
Sea-Bird 11plus deck unit, s/n 11P-24680-0589 (back-up logging)

2) The auxiliary input initial sensor configuration was as follows:

Sea-Bird 43 dissolved oxygen sensor, s/n 43-2055 (V0)
WETLabs light scattering sensor, s/n BBRTD-758R (V4)
Benthos PSA-916T altimeter, s/n 62679 (V5)
Chelsea Aquatracka MKIII fluorometer, s/n 088244 (V6)
Chelsea Alphatracka MKII transmissometer, s/n 161049 (V7)

3) Sea-Bird 9*plus* configuration file DY017_tita_NMEA.xmlcon was used for the initial titanium frame CTD casts.

4) The second water sampling arrangement was the Zubkov 24-way stainless steel frame system (s/n 75313), and the initial sensor configuration was as follows:

Sea-Bird 9plus underwater unit, s/n 09P-46253-0869
Sea-Bird 3P temperature sensor, s/n 03P-4782, Frequency 0 (primary)
Sea-Bird 4C conductivity sensor, s/n 04C-2231, Frequency 1 (primary)
Digiquartz temperature compensated pressure sensor, s/n 100898, Frequency 2
Sea-Bird 3P temperature sensor, s/n 03P-5495, Frequency 3 (secondary)
Sea-Bird 4C conductivity sensor, s/n 04C-3874, Frequency 4 (secondary)
Sea-Bird 5T submersible pump, s/n 05T-3085, (primary)
Sea-Bird 5T submersible pump, s/n 05T-3086, (secondary)
Sea-Bird 32 Carousel 24 position pylon, s/n 32-19817-0243
Sea-Bird 11plus deck unit, s/n 11P-34173-0676 (main)
Sea-Bird 11plus deck unit, s/n 11P-24680-0589 (back-up logging)

5) The auxiliary input initial sensor configuration was as follows:

Sea-Bird 43 dissolved oxygen sensor, s/n 43-1624 (V0)
Biospherical QCP Cosine PAR irradiance sensor, DWIRR, s/n 70510 (V2)
Biospherical QCP Cosine PAR irradiance sensor, UWIRR, s/n 70520 (V3)
Benthos PSAA-916T altimeter, s/n 59493 (V4)
WETLabs light scattering sensor, s/n BBRTD-1055 (V5)
Chelsea Alphatracka MKII transmissometer, s/n 161048 (V6)
Chelsea Aquatracka MKIII fluorometer, s/n 88-2615-124 (V7)

6) Sea-Bird 9*plus* configuration file DY017_stainless_NMEA.xmlcon was used for all stainless steel frame CTD casts.

Total number of casts – 22 titanium frame, 34 S/S frame.
Casts deeper than 2000m - 0 titanium frame, 1 S/S frame.
Deepest casts - 1862m titanium frame, 2066m S/S frame.

Appendix A: Technical detail report

Titanium CTD

Water sampler no. 8 had small leak through mounting block, replaced with no. 25 prior to cast 002. Water sampler no. 13 had small leak through upper left lanyard guide, replaced with no. 26 prior to cast 011. Water sampler no. 9 had broken centre mounting block, replaced with no. 8 prior to cast 018. Water samplers no.'s 2, 15, 26 & 11 had broken centre mounting blocks, occurred upon hard landing on deck after cast 022. Water sampler no. 10 had small leak through upper left lanyard guide, also after cast 022. Water sampler no. 12 had small leak through upper left lanyard guide, after cast 035. All samplers now repaired.

Stainless Steel CTD

Re-terminated wire because of crushed section as cable came out of over-boarding sheave. Approximately 50m removed.

Autosal

A Guildline 8400B, s/n 71126, was installed in the Salinometer Room as the main instrument for salinity analysis. A second Guildline 8400B, s/n 71185, was installed in the Salinometer Room as a spare instrument. The Autosal set point was 24C, and samples were processed according to WOCE cruise guidelines: The salinometer was standardized at the beginning of the first set of samples, and checked with an additional standard analysed prior to setting the RS. Once standardized the Autosal was not adjusted for the duration of sampling, unless the set point was changed. Additional standards were analysed every 24 samples to monitor & record drift. These were labeled sequentially and decreasing, beginning with number 999. Standard deviation set to 0.00001

Deep tow

RG-58 BNC cable to Lemo connectors installed in Main Lab at the High Voltage terminal to connect to SBE 11P deck unit. Slip-ring tray removed and inspected, (terminal torque, proper strain relief, condition of interface wires, correct labeling, etc. The interior of the drum was then observed during CTD haul and veer, at varying speeds from 5m/min up to 60m/min, to ensure no undue strain or movement of the slip-ring cabling and wire assemblies. Initial tests with the ROV team Bicotest Cable Tester indicated a fault within the first 100ft of the outboard end of the cable. This agreed with previous continuity tests in a very low resistance was measured from the outboard end (approximately 5 to 10 Ω), whilst a figure of approximately 96Ω was measured from the inboard end with the cable disconnected from the slip ring and all the ships internal wiring. The manufacture gives a resistance of 4.9Ω/km for this cable, and with 10km of wire on the drum a figure of 96Ω is consistent with a fault being very close to one end of the wire. 100m of cable was then run off and the cable cut and opened up again. The next test with the Cable Tester revealed a 'healthy' wire, indicating no further problems with the 10km on the drum. As a final confirmation an insulation resistance test was carried out on each core and this resulted in readings in excess of 3000MΩ between each core, and between each core and the metal armouring. A continuity test of each core was then carried out from both ends and a figure of approximately 95Ω was obtained in every case. The slip ring and all other connections were replaced and a final test of the entire system from Main Lab to termination was carried out to ensure no faults. Also, one core (brown/translucent sheath) is permanently bonded to earth at the Main Lab and in the Winch Room and this core is bonded to the armouring in the termination to avoid any induced voltage. The two remaining cores (green and the other brown/translucent sheath) are used as the -250VDC and +250VDC from Main Lab to termination.

RR/ODIM MFW

RG58 BNC cable of 15m length installed in JB47 next to RR/ODIM MFCTD, to connect to Junction Box Stationary in RR/ODIM container. **NB This is a temporary cable & connection, as the RR supplied 'Epic' style connector and cable cannot be located. Replacement connector ordered from RR via RR representative on board during DY008, but none has been delivered as yet to best of knowledge.** Junction Box Rotary **not** wired by RR to umbilical, nor was the slip ring wired to the Junction Box Stationary. This was completed prior to sailing by NMFSS staff using 2.5m of 4 core 0.82mm^2 stranded tinned copper wire left in place by RR post-repair. **NB Because of restricted space and access to the Rotary Junction Box, these connections are unlikely to be field serviceable once the vessel has sailed.** All BNC interconnecting and terminated cables 'megger' to >999 MOhms. The four cores were then 'meggered' to >999 MOhms; following with each pair shorted to measure internal resistance. Values for each pair varied from 198 Ohms to 202 Ohms, not comparable to the expected manufacturer's maximum of 162 Ohms (for the present umbilical length of 4250m), but within SBE recommended seacable maximum resistance of 350 Ohms. The umbilical was then connected, on each pair in sequence, to a CTD test cable to the CTD. **NB Because of the inherently large internal resistance of this seacable, the termination must be completed with only two cores, and the remaining two cores must be dead-ended.** The SBE 9+ was successfully operated on deck collecting data, firing bottles, etc. for at least 15 minutes on each pair, with no modulo or other electronic errors.

Appendix B: Configuration files

Titanium CTD frame

Date: 10/20/2014

Instrument configuration file: C:\Program Files\Sea-Bird\SeasaveV7\DY017\DY017_tita_NMEA.xmlcon

Configuration report for SBE 911plus/917plus CTD

Frequency channels suppressed : 0 Computer interface : RS-232C
Voltage words suppressed : 0

Deck unit : SBE11plus
Firmware Version >= 5.0
Scans to average : 1
NMEA position data added : Yes
NMEA depth data added : No
NMEA time added : Yes
NMEA device connected to : PC
Surface PAR voltage added : No
Scan time added : Yes

1) Frequency 0, Temperature

Serial number : 03P-5700
Calibrated on : 11 April 2014
G : 4.34159706e-003
H : 6.28508868e-004
I : 1.87468534e-005
J : 1.17132278e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 04C-4138
Calibrated on : 27 February 2014
G : -9.83474601e+000
H : 1.45187267e+000
I : -1.86002512e-003
J : 2.21735389e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 129735
Calibrated on : 12 March 2014
C1 : -6.064446e+004
C2 : 6.966022e-001
C3 : 1.971200e-002
D1 : 2.882500e-002
D2 : 0.000000e+000
T1 : 3.029590e+001
T2 : -6.713679e-005
T3 : 4.165400e-006
T4 : 0.000000e+000
T5 : 0.000000e+000
Slope : 1.00000000
Offset : 0.00000
AD590M : 1.279181e-002
AD590B : -8.821250e+000

4) Frequency 3, Temperature, 2

Serial number : 03P-5785
Calibrated on : 6 May 2014
G : 4.33666977e-003
H : 6.27870652e-004
I : 1.95435025e-005
J : 1.44731780e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number : 04C-4143
Calibrated on : 25 February 2014
G : -9.80210332e+000
H : 1.32372648e+000
I : -5.61268048e-004
J : 1.06763091e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

6) A/D voltage 0, Oxygen, SBE 43

Serial number : 43-2055
Calibrated on : 2 May 2014
Equation : Sea-Bird
Soc : 3.65900e-001
Offset : -7.06100e-001
A : -2.57000e-003
B : 1.30080e-004
C : -2.23610e-006
E : 3.60000e-002
Tau20 : 1.46000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

7) A/D voltage 1, Free

8) A/D voltage 2, Free

9) A/D voltage 3, Free

10) A/D voltage 4, Altimeter

Serial number : 62679
Calibrated on : 27 March 2014

Scale factor : 15.000
Offset : 0.000

11) A/D voltage 5, Turbidity Meter, WET Labs, ECO-BB

Serial number : BBRTD-758R
Calibrated on : 3 June 2013
ScaleFactor : 0.002903
Dark output : 0.043100

12) A/D voltage 6, Transmissometer, Chelsea/Seatech

Serial number : 161049
Calibrated on : 20 October 2010
M : 23.9408
B : -0.3507
Path length : 0.250

13) A/D voltage 7, Fluorometer, Chelsea Aqua 3

Serial number : 088244
Calibrated on : 6 August 2014
VB : 0.236800
V1 : 2.151000
Vacetone : 0.305900
Scale factor : 1.000000
Slope : 1.000000
Offset : 0.000000

Scan length : 41

Stainless CTD frame

Date: 10/20/2014

Instrument configuration file: C:\Program Files\Sea-Bird\SeasaveV7\DY017\DY017_stainless_NMEA.xmlcon

Configuration report for SBE 911plus/917plus CTD

Frequency channels suppressed : 0
Voltage words suppressed : 0
Computer interface : RS-232C
Deck unit : SBE11plus
Firmware Version >= 5.0
Scans to average : 1
NMEA position data added : Yes
NMEA depth data added : No
NMEA time added : No
NMEA device connected to : deck unit
Surface PAR voltage added : No
Scan time added : Yes

1) Frequency 0, Temperature

Serial number : 03P-4782
Calibrated on : 2 July 2013
G : 4.34988979e-003
H : 6.36411045e-004
I : 2.08372334e-005
J : 1.75345425e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 04C-2231
Calibrated on : 2 July 2013
G : -1.07805493e+001
H : 1.69843332e+000
I : -3.58275165e-003
J : 3.82993434e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 100898
Calibrated on : 6 January 2012
C1 : -4.405863e+004
C2 : -6.206030e-002
C3 : 1.337540e-002
D1 : 3.669100e-002
D2 : 0.000000e+000
T1 : 2.990734e+001
T2 : -3.493620e-004
T3 : 4.061200e-006
T4 : 3.043880e-009
T5 : 0.000000e+000
Slope : 0.99995000
Offset : -1.59900
AD590M : 1.288520e-002
AD590B : -8.271930e+000

4) Frequency 3, Temperature, 2

Serial number : 03P-5495
Calibrated on : 18 October 2013
G : 4.38224202e-003
H : 6.31062233e-004
I : 2.03280217e-005
J : 1.58958907e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number : 04C-3874
Calibrated on : 24 October 2013
G : -1.05028427e+001
H : 1.38920147e+000
I : -1.01866557e-003
J : 1.39949777e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

6) A/D voltage 0, Oxygen, SBE 43

Serial number : 43-1624
Calibrated on : 17 May 2013
Equation : Sea-Bird

Soc : 5.26900e-001
Offset : -5.08100e-001
A : -3.06370e-003
B : 1.92500e-004
C : -2.78720e-006
E : 3.60000e-002
Tau20 : 1.43000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

7) A/D voltage 1, Free

8) A/D voltage 2, PAR/Irradiance, Biospherical/Licor

Serial number : 70510
Calibrated on : 1 March 2013
M : 1.00000000
B : 0.00000000
Calibration constant : 12531000000.00000000
Multiplier : 1.00000000
Offset : -0.08126488

9) A/D voltage 3, PAR/Irradiance, Biospherical/Licor, 2

Serial number : 70520
Calibrated on : 3 February 2014
M : 1.00000000
B : 0.00000000
Calibration constant : 17574692442.90000200
Multiplier : 1.00000000
Offset : -0.05835960

10) A/D voltage 4, Altimeter

Serial number : 59493
Calibrated on : 29 November 2012
Scale factor : 15.000
Offset : 0.000

11) A/D voltage 5, Turbidity Meter, WET Labs, ECO-BB

Serial number : BBRTD-1055
Calibrated on : 13 March 2013
ScaleFactor : 0.002365
Dark output : 0.061000

12) A/D voltage 6, Transmissometer, Chelsea/Seatech

Serial number : 161048
Calibrated on : 24 July 2012
M : 23.5922
B : -0.1151
Path length : 0.250

13) A/D voltage 7, Fluorometer, Chelsea Aqua 3

Serial number : 88-2615-124
Calibrated on : 19 October 2012
VB : 0.277300
V1 : 1.956300
Vacetone : 0.356100
Scale factor : 1.000000
Slope : 1.000000
Offset : 0.000000

Scan length : 41

Stainless Steel Frame Sensor Information

Instrument / Sensor	Manufacturer/ Model	Serial Number	Channel	Casts Used
Primary CTD deck unit	SBE 11plus	11P-34173-0676	n/a	All casts
CTD Underwater Unit	SBE 9plus	09P-46253-0869	n/a	All stainless casts
Stainless steel 24-way frame	NOCS/Zubkov	75313	n/a	All stainless casts
Primary Temperature Sensor	SBE 3P	3P-4782	F0	All stainless casts
Primary Conductivity Sensor	SBE 4C	4C-2231	F1	All stainless casts
Digiquartz Pressure sensor	Paroscientific	100898	F2	All stainless casts
Secondary Temperature Sensor	SBE 3P	3P-5495 (Ti)	F3	All stainless casts
Secondary Conductivity Sensor	SBE 4C	4C-3874 (Ti)	F4	All stainless casts
Primary Pump	SBE 5T	5T-3085	n/a	All stainless casts
Secondary Pump	SBE 5T	5T-3086	n/a	All stainless casts
24-way Carousel	SBE 32	32-19817-0243	n/a	All stainless casts
Dissolved Oxygen Sensor	SBE 43	43-1624	V0	All stainless casts
Irradiance Sensor (DWIRR)	Biospherical QCP Cosine PAR	70510	V2	All stainless casts
Irradiance Sensor (UWIRR)	Biospherical QCP Cosine PAR	70520	V3	All stainless casts
Altimeter	Benthos 916T	59493	V4	All stainless casts
Light Scattering Sensor	WETLabs BBRTD	BBRTD-1055	V5	All stainless casts
Transmissometer	CTG Alphatracka MKII	161048	V6	All stainless casts
Fluorometer	CTG Aquatracka MKIII	88-2615-124	V7	All stainless casts
20L Water Samplers	OTE	1 -24	n/a	Stainless casts 001 - 036
10L Water Samplers	OTE	1D -24D	n/a	Stainless casts 037 - 056

Titanium Frame Sensor Information

Instrument / Sensor	Manufacturer/ Model	Serial Number	Channel	Casts Used
Primary CTD deck unit	SBE 11plus	11P-34173-0676	n/a	All casts
CTD Underwater Unit	SBE 9plus	09P-77801-1182 (Ti)	n/a	All titanium casts
Titanium 24-way frame	NOCS	SBE CTD TITA1	n/a	All titanium casts
Primary Temperature Sensor	SBE 3P	3P-5700 (Ti)	F0	All titanium casts
Primary Conductivity Sensor	SBE 4C	4C-4138 (Ti)	F1	All titanium casts
Digiquartz Pressure sensor	Paroscientific	129735	F2	All titanium casts
Secondary Temperature Sensor	SBE 3P	3P-5785 (Ti)	F3	All titanium casts
Secondary Conductivity Sensor	SBE 4C	4C-4143 (Ti)	F4	All titanium casts
Primary Pump	SBE 5T	5T-3088	n/a	All titanium casts
Secondary Pump	SBE 5T	5T-3090	n/a	All titanium casts
24-way Carousel	SBE 32	32-60380-0805 (Ti)	n/a	All titanium casts
Dissolved Oxygen Sensor	SBE 43	43-2055	V0	All titanium casts
Altimeter	Benthos 916T	62679	V4	All titanium casts
Light Scattering Sensor	WETLabs BBRTD	BBRTD-758R	V5	All titanium casts
Transmissometer	CTG Alphatracka MKII	161049	V6	All titanium casts
Fluorometer	CTG Aquatracka MKIII	088244	V7	All titanium casts
10L Water Samplers	OTE TMF	1T -24T	n/a	All titanium casts

RRS *Discovery* Instrumentation Overview

Jack McNeill

Introduction

The new *RRS Discovery* is broadly similar to the *RRS James Cook* and has a similar arrangement of instruments and sensors (**Figure 2**). As Discovery is a new ship this summary provides a brief overview of what's on board; where it is; what it does; what its inputs and outputs are; and gives an indication of where to get more information.

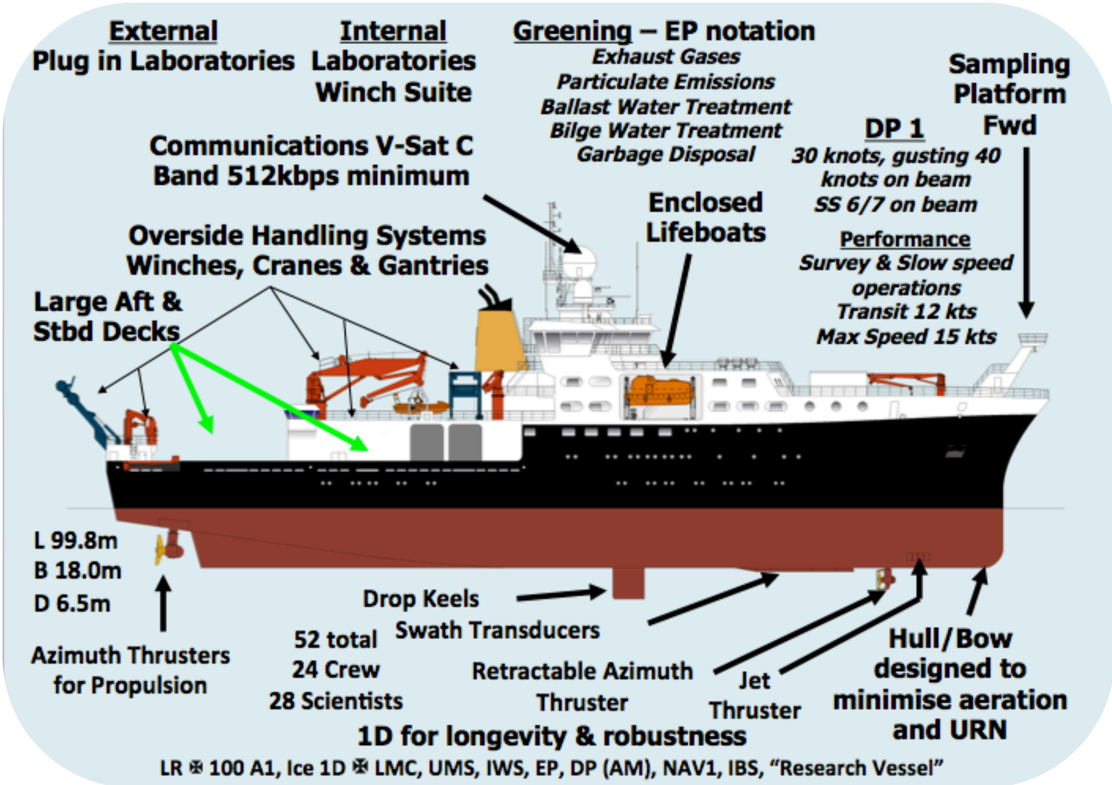


Figure 3: RRS *Discovery* instrumentation suite

Datalogging & Data Storage

Datalogging software and storage is provided on a platform common to both *RRS* vessels managed by the NOC: RRS *Discovery;* and RRS *James Cook*.

TechSAS

TechSAS is an integrated technical and scientific sensors acquisition system and is the primary datalogger on both vessels. The system allows monitoring and accurate time-stamping of each individual instrument with a graphical output.

TechSAS saves data in the self describing NetCDF (Network Common Data Format) format that can be easily read via MatLab or using freely available NetCDF libraries. TechSAS also broadcasts the logged data across the ship's network in UDP pseudo-NMEA0183 (i.e.: "NMEA-like") packets. Separate NetCDF documentation is available that explains the logged variables.

RVS Level C

Level-C is a data management programme, written in C for its Sun SPARC environment.

The Level-C system logs the TechSAS UDP packets in the Level-C binary format as flat files (colloquially known as "streams").

Level-C has a number of little programmes inside it that allow the flat files to be viewed, edited, and exported rapidly in a range of formats, e.g.: CSV; ASCII text file, at custom intervals and averaging periods.

Another feature is the display of meteorological, depth, and navigation data (as with the SSDS software running on the wall-mounted HP touchscreens around the ship).

The NMFSS Science Systems Technician will be able to generate the necessary reports from the Level-C system for you.

Positioning & Attitude Sensors

The new *RRS Discovery* has some of the same sensors as the *RRS James Cook*, and some new ones.

Applanix POS MV V4 (Primary Science GNSS and Attitude Sensor)

A combined GNSS receiver and attitude (i.e.: gyrocompass, and conventional motion) sensor that provides data about: attitude; heave; position; and velocity. The GNSS aspect is for use with Multibeam Echosounder systems.

The POSMV is logged to the TechSAS Datalogger. The datalogger produces two files for its configured file period (usually 24hrs).

These files are:

- POSMVPOS.POS - NetCDF File Containing Positional Data (Heading, Latitude, Longitude)
- POSMVATT.ATT - NetCDF File Containing Attitude data (Roll, Pitch, Heave)

Please note that the position output is the position of the ship's common reference point (the cross on the top of the POSMV MRU in the gravity room).

Specifications: Posmv_datasheet.pdf

Location: dy###_data_disc/cruise_reports/instrument_data_sheets/

Kongsberg Seapath DPS330 (Secondary Science GNSS and Attitude Sensor)

This is a secondary Science GNSS and attitude sensor. The position output is the position of the ship's common reference point (the cross on the top of the POSMV MRU in the Gravity Meter Room).

Specifications: Seapath330.pdf

Location: dy###_data_disc/cruise_reports/instrument_data_sheets/

iXSea PhINS (Photonic Inertial Navigation System)

A surface inertial navigation system that uses a FOG (Fibre-Optic Gyro) to output accurate position, attitude, and velocity data.

Specifications: br-phins-2013-06-web.pdf

Location: dy###_data_disc/cruise_reports/instrument_data_sheets/

CNav 3050 GPS, GLONASS, Galileo GNSS

GNSS and RTCM Satellite Corrections Receiver. The position output is the position of the antenna. This GPS is not referenced to any other systems. It is primarily used to provide RTCM differential corrections to the other GPS systems. Please note that the position output is the position of the antenna. This GPS is not referenced to any other systems.

Specifications: CNav3050Brochure.pdf

Location: dy###_data_disc/cruise_reports/instrument_data_sheets/

Hydroacoustics

RRS Discovery has both vessel-mounted and smaller deployable transponders.

Kongsberg-Simrad

Simrad, now part of Kongsberg, is the supplier of the heavy artillery of echosounders.

EM122 Deep Water Multibeam Echosounder

This echosounder is rated to 11,000m, but probably up to 8,000m for good quality data. The EM122 it is viewed and operated via SIS (Seafloor Information Service).

Specifications: Em122_product_description.pdf

Location: dy###_data_disc/cruise_reports/instrument_data_sheets/

EM710 Shallow Water Multibeam Echosounder

This echosounder is rated to 2,000m, but in reality you might consider switching to the EM122 between 600-1500 metres. Within this range, the EM710 gives a broader swathe, with less detail, so which one you use depends on what data you need to generate.

Specifications: Em710_product_specification.pdf

Location: dy###_data_disc/cruise_reports/instrument_data_sheets/

SBP120 Sub-Bottom Profiler

The SBP120 is an extension to the EM122 Deep Water Echosounding Profiler (the receiver part).

Specifications: Sbp120_product_specification_lr.pdf

Location: dy###_data_disc/cruise_reports/instrument_data_sheets/

EA640 Single-beam Echosounder

The EA640 is a special version of the EA600 commissioned for the *RRS Discovery*, pretty much identical to the EA600 and can operate at either 12kHz or 10kHz as required. The performance of each varies with output power (e.g.: 1kW or 2kW) and pulse lengths. They both have a wide bandwidth that overlaps, and can be run at the same time.

Specifications: EA640_data_sheet_lr.pdf

Location: dy###_data_disc/cruise_reports/instrument_data_sheets/

EK60 Multi-Frequency Echosounder ("Fish Finder")

The EK60 has 18, 38, 70, 120, 200, and 333 kHz transducers fitted to the starboard drop keel. Equipment to calibrate the system is carried onboard.

Specifications: Ek60_brochure_english_reduced.pdf

Location: dy###_data_disc/cruise_reports/instrument_data_sheets/

Kongsberg-Simrad SU16 Synchronisation Unit (K-Sync)

Running several acoustic systems simultaneously on ships with several acoustic instruments can cause interference between the systems, which may reduce the data quality. This unit and associated software lets you synchronise the pings of different acoustic equipment, (providing that they operate at different frequencies!). This system lets the SST control the timing of the instruments and by controlling the triggering of each instrument's transmission.

Specifications: Operator Manual.pdf

Location: dy###_data_disc/cruise_reports/instrument_data_sheets/k-sync/

Sonardyne Transponder Beacons & Software

There are two hull-mounted transponders on the *RRS Discovery*. The Starboard side USBL is a 7000 directional bis head for improved performance in deeper water; the Port side USBL is a 5000 standard head. The USBL transponder spars are extensible & retractable and project more or less vertically down from the aft half of the hull between the Drop Keels and the Propellers. The software used is ***Ranger 2***.

Inputs: Vertical Reference Units (VRUs), Gyro Compass; DGPS (Surface Positioning); GPS (Time Synchronisation). Transponders (1km-depth Wide-band Sub-Mini – WSM), and 3km-depth DP Transponder

Outputs: it logs data itself into a file that can be taken away; can also output a data string to TechSAS (in this case, you only get the position of one beacon at a time in the water, you can put this info into the Level-C system and plot some data from it; it outputs to the OLEX 3D-seafloor mapping software that provides a visual display). It can also output DP telegram format data.

Specification Operator Manual.pdf

Location: dy###_data_disc/cruise_reports/instrument_data_sheets/USBL Pole/

Teledyne-RDI Ocean Surveyor Acoustic Doppler Current Profilers

The ADCP transducers are located in the hull, in blisters, in a forward-aft configuration approximately 6m below the water line. There are two systems that operate at two frequencies: 75 kHz; and 150kHz. Both the heads have a rotation relative to the ship's centre line of -45°. The software used for configuring and datalogging with the ADCP is called ***VmDAS*** (Vessel Mounted Data AcquisitionSystem). ***VmDAS*** gets data from the ship's attitude sensor and uses that to convert ship velocities into earth co-ordinates.

VmDAS can be configured either by loading or editing a command file; or by changing settings on the interface. Users should be aware that it's possible to simultaneously load and use a command file, and adjust settings using the interface, which can lead to command conflicts, in which case the interface overrides the command file. Data is logged to local hard-disc, and then create a back-up on the server. Set-up file is editable when starting the ***VmDAS*** software.

Specification: OS_TM_Apr14.pdf

Location: please ask the SST for assistance.

75KHz Vessel Mounted ADCP (VMADCP)

Inputs: GPS; Gyrocompass; *iXSea* PhINS so it can calculate accurate speed and direction of currents.

Range: 520-650m (Long-range/Low quality); 310-430m (Short range/High quality)

150 kHz Vessel Mounted ADCP (VMADCP)

Inputs: the same as for the 75kHz

Range: 325-350m or 375-400m (Long Range/Low Quality); 200-250m or 220-275m (Short Range/High Quality)

Sound Velocity Sensors

Discovery has a hull-mounted *AML SmartSV Probe*, and a portable *Valeport Midas SV* Profiler. The Valeport uses *DataLogExpress* datalogger software and have a maximum depth of 5000m.
The *Kongsberg SIS* software has a new application called **MDM** for bringing the saved profiles in.

Specifications: valeport_datalogexpress.pdf; valeport_midas_svp_profiler_hardware_manual.pdf

Location: dy###_data_disc/cruise_reports/instrument_data_sheets/

Meteorological

RRS Discovery has the same meteorological instruments and sensors as the *RRS James Cook*.

OceanWaves WaMoS II Wave Radar

WaMoS is an X-Band nautical RADAR with a range of 100m to 4km. It can only generate data in above a minimum wind speed of $3ms^{-1}$. It detects open wave spectra. Sea state is calculated from detected backscatter of μwave "sea clutter" in real time. The system can detects wavelengths from 15 m – 600 m and covers periods from 4 sec-20 seconds. At coastal sites, WaMoS II can only measure the spatial wave field beyond the wave breaking zone. There is a WaMoS computer in the Met Lab, where it stores processed radar images. Data is logged in WaMoS's own format. Summary wave information is available in one of the ASCII files generated.

Specifications: WaMoSII_geninfo_2010.pdf

Location: dy###_data_disc/cruise_reports/instrument_data_sheets/wamos/

Manufacturer: http://www.oceanwaves.org/

NMFSS SurfMet (Surface Water System and Meteorological Monitoring System)

SurfMet comprises two sets of scientific instruments: Meteorological; and Surface Water Sampling, along with ADCs and a PC hosting SurfMet data conversion software that passes data to the Data Systems for event logging.

Meteorological Instruments (Met)

The Meteorological part of the system comprises a range of instruments located near the forward mast about 10 metres above sea level (**Table 1**).

The instrument called the...	**...measures...**	**...in...**	**...to calculate...**
Vaisala HMP45A Temperature & Humidity Sensor	Thermal radiation and water vapour	Sunlight; Air	Ambient air temperature and Relative humidity
Gill Windsonic Anemometer	Ultrasonic sound waves via ultrasound transceivers	Air	Wind speed and direction
Vaisala BaroCap PTB100A Barometric Pressure sensor	Change in electrical resistance via a deflectable diaphragm strain gauge within a pressure transducer	Air	Air pressure
Kipp & Zonen CM6B Pyranometer	Electromagnetic radiation flux density by converting solar radiation into heat, and thence into a voltage	Sunlight	Total Irradiance (Solar energy)
Skye Instruments SKE510 PAR (Photosynthetic Active Radiation) Pyranometer	Electromagnetic radiation flux density by converting solar radiation into heat, and thence into a voltage, passed through a bandpass filter	Sunlight	Total Irradiance (Solar energy) within a fixed range of wavelengths for photosynthesis

Table 1: Meteorological instrument suite on RRS *Discovery*

Surface Water Sampling Instruments (SWS)

The Surface Water part of the SurfMet system collects seawater (known as “non-toxic" or "underway" water) from the upper 5.3 metres of the ocean, and passes it through a suite of instruments (**Table 2**)

The instrument called the...	...measures...	...in...	...to calculate...
SeaBird 45 Thermosalinograph	Temperature and conductivity	Seawater	Salinity
SeaBird 38 Digital Oceanographic Thermometer	Change in resistance via a thermistor	Seawater	Temperature
WetLabs WetStar WS3S Fluorometer	Reflected light frequency difference between beams of light passed through water	Seawater	Marine floral density
WetLabs WetStar CST Transmissometer	Photon quanta (received light)	Seawater	Particulate density

Table 2: Surface water sampling instrument suite on RRS *Discovery*

TSG flow is approx 1.6 litres per minute whilst fluorometer and transmissometer flow is approx **20** l/min. Flow to instruments is degassed using a debubbler (outlet) with **10** l/min inflow; waste flow is usually around **8-10** l/min (adjusted to maintain balance, but at a low rate to keep the TSG flow rate to around 1.6 l/min).

DartCom HRPT L-Band Polar Orbiter Satellite Imaging System

The DartCom system comprises a 1.2m Parabolic Dish enclosed in a Radome. It receives signals from satellites that take images of cloud coverage. These images can be used to see the type of atmospheric and weather conditions nearby.

Specifications: l_band_polar_orbiter.pdf

Location: dy###_data_disc/cruise_reports/instrument_data_sheets/dartcom/

Data Displays

Software for displaying useful science-related information is provided around the ship.

SSDS (Ship Scientific Display Screens)

These touchscreens located around the ship display a range of data from scientific and non-scientific systems: Gyro information; GPS information from CNAV; sensor information from SurfMet; Depth from EA640; and winch information. Waypoints to stations can also be entered on the ETA tab, and propagated around the network to the other screens.

OLEX 3D Seafloor Mapping and Visualisation Software

OLEX is a 3-D seafloor map visualisation software that has a shared seafloor data files, and installed on a dedicated PC. OLEX receives data from navigation, depth, multibeam, and ship positioning systems (it can also position data from USBL). Olex provides rapid visualisation of multibeam data, as well as showing where in the world the ship is.

Specifications: Olex_engelsk.pdf

Location: dy###_data_disc/cruise_reports/instrument_data_sheets/olex/

Manufacturer: http://www.olex.no/index_e.html

Computing and Instrumentation

Jack McNeill

Overview

This is the first full science cruise for RRS *Discovery*. The main activities are ADCP work (including the first full configuration of the ADCPs), deployment of CTDs, and the deployment of a towfish and a lander.

Deployed Equipment

This is the first full science cruise. The equipment deployed was as follows:

- Networking:
  Servers, Computers, Displays, Printers,, Network Infrastructure
  A public network drive for scientists, updated via Syncback
- Datasystems:
  IFREMer TechSAS logged data and converted it to **NetCDF** format
  NetCDF Format given in: **DY017_netcdf_description.docx**
  Logged Instruments given in: **DY017_ship_fitted_information_sheet_dy.doc**
  Data was also logged to NERC/RVS Level-C format, also described in: **netcdf_description.docx**
  NERC software: Level-C; SurfMet Express; CLAM 2014; SSDS3
  Olex
- Hydroacoustics
  Kongsberg echosounders (EM122, EM710, EA640)
  Teledyne/RDI ADCPs
- Telecommunications
  GPS & DGPS (POS MV, PhINS; KB Seapath 330; CNAV 3050)
  OceanWaves WaMoS II
  DartCom Polar Ingester
  NESSCo V-Sat; Thrane & Thrane Sailor 500 Fleet BroadBand
- Instrumentation
  DartCom Live pCO_2
  SWS Underway & Met Platform instrumentation

Requested Services

150 kHz hull mounted ADCP system [Hydroacoustics]

75 kHz hull mounted ADCP system [Hydroacoustics]

Meteorology monitoring package [SurfMet]

Pumped sea water sampling system [SurfMet]

Sea surface monitoring system [SurfMet]

Ship scientific computing systems [Ship Scientific Datasystems]

Data Acquisition Performance

All times given are in UTC.

Ship Scientific Data systems

Data was logged and converted into NetCDF file format by the TechSAS datalogger.

The format of the NetCDF files is given in the file: **NMFSS_NetCDF_Description_Discovery.docx**

The instruments logged are given in DY017_Ship_fitted_information_sheet_DY.docx. Data was additionally logged in the RVS Level-C format, which is also described in:

NMFSS_NetCDF_Description_Discovery.docx

Position & Attitude

All GPS and attitude measurement systems were run throughout the cruise.

Kongsberg Seapath 330

The Seapath is the vessel's primary GPS, it outputs the position of the ship's common reference point in the gravity meter room. Seapath position and attitude was used by the EM710, EM122 and SBP120.

Applanix POSMV

The POSMV is the secondary scientific GPS, and is used on the SSDS displays around the vessel. TechSAS and Level-C only attitude data from the POSMV was logged. A TechSAS data logging module for the iXSea PHINS and Seapath 330 is under development.

Instrumentation

SurfMet

Malfunctions in the system led to unreliable data being displayed and logged. All SurfMet data from this cruise should be disregarded.

Extensive efforts have been made to faultfind the system, to no avail.

Please see the separate BODC information sheet dy017_surfmet_sensor_information_sheet.docx for details of the sensors used and the calibrations that need to be applied. The calibration sheets are included in the directory Ship_Systems\Met\SURFMET\calibrations. The non-toxic water supply was active from YYYYMMDDHHMM to YYYYMMDDHHMM.

SurfMet: Surface Water System

Malfunctions in the system led to unreliable data being displayed and logged. All SurfMet data from this cruise should be disregarded.

SurfMet: Met Platform System

Malfunctions in the system led to unreliable data being displayed and logged. All SurfMet data from this cruise should be disregarded.

SurfMet: PC Express

Malfunctions in the system led to unreliable data being displayed and logged. All SurfMet data from this cruise should be disregarded.

WaMoS II Wave Radar

Not requested, but logged occasionally. The WAMOS wave radar was run throughout the cruise. All data was logged and a summary of its output is given in the **PARA*.ems** files.

Gravity Meter

Not installed on the ship for this cruise.

Hydroacoustics

Generally worked OK.

Kongsberg EA640

10kHz run; 12kHz run for a while, but not needed, so turned off.

Kongsberg EM710

Not requested, but some data logged. May be a transposition error in the ".all" files.

Used until on station north of Lewis on Friday the 24th, then switched to the EM122, as it seemed the EM710 needed some faultfinding.

Kongsberg EM122

Not requested, but some data logged.

Used after the EM710 had a hiccup.

Kongsberg SBP120

Not requested, but some data logged.

Kongsberg EK60

Not requested; not switched on; no data logged.

Sound Velocity Profiles

Not used, just a manual setting of 1500m/s

Teledyne/RDI ADCP

I set a new command file for both ADCPs at the start of the cruise, and got a copy of the latest manual, as the previous one was from 2012.

This was a main focus of the cruise, and Stuart Painter and Sam Jones spent a fair bit of time adjusting the settings and also setting a new configuration file for the 75kHz, which had never been set.

75kHz

Fault noticed where beam 4 was faulty. The system was tested and the deck unit replaced on the 29th of October at approximately 11.20am, and the system worked fine after that.

150kHz

Worked fine throughout the cruise.

Sonardyne USBL

Not requested; no data logged.

Third Party Instrumentation

DartCom Live PCO2

Used, and looked after by PML PhD student Richard Sims on this cruise. A flow meter failed, but Richard found it to be clogged up, and cleaned it out. All enquiries about this system should be directed to Dr Vas Kitidis (vak@pml.ac.uk).

4. SCIENTIFIC INVESTIGATIONS

Lowered CTD data processing and calibration

Stuart Painter

A total of 56 CTD casts were completed during DY017 (**Table 3**). These comprised both stainless steel (34 casts) and titanium (22 casts) CTD rosette frames. Both CTD systems worked reliably throughout the cruise with only minimal problems reported.

Deployment of the stainless steel system was initially conducted with 20 L Niskin bottles (up to CTD036) using the Deep Tow winch and cable but following isolation of this winch for safety reasons, the remaining casts (from CTD037 onwards) were conducted with 10 L bottles using the trace metal free winch system.

Only provisional examination of the data was undertaken at sea. The final data processing and calibration was undertaken immediately after the cruise and details are included here for the formal record.

CTD No.	Survey Line / Station No.	Date	DOY	Time	Lat (N)	Lon (W)	Cast types (TiT – titanium, StS – steel)
CTD001	Test	22.10.2014	295	19:15	56.5758	-6.4813	TiT
CTD002	A1	23.10.2014	296	10:25	58.6021	-5.8023	TiT
CTD003	A1	23.10.2014	296	11:04	58.6022	-5.8023	StS
CTD004	A2	23.10.2014	296	17:20	58.8004	-6.1936	TiT
CTD005	A2	23.10.2014	296	18:12	58.8004	-6.1936	StS
CTD006	A3	24.10.2014	297	08:52	58.9597	-6.5001	StS
CTD007	A4	24.10.2014	297	13:38	59.1962	-6.9492	TiT
CTD008	A4	24.10.2014	297	14:59	59.1962	-6.9493	StS
CTD009	A5	24.10.2014	297	18:43	59.3977	-7.3381	TiT
CTD010	A5	24.10.2014	297	21:38	59.3971	-7.3242	StS
CTD011	B1	27.10.2014	300	03:18	58.4466	-7.1935	TiT
CTD012	B1	27.10.2014	300	03:53	58.4466	-7.1936	StS
CTD013	C1	27.10.2014	300	09:17	58.0227	-7.7157	TiT
CTD014	C1	27.10.2014	300	09:58	58.0227	-7.7157	StS
CTD015	C2	27.10.2014	300	12:36	58.0804	-8.012	StS
CTD016	C3	27.10.2014	300	16:46	58.1492	-8.4177	TiT
CTD017	C3	27.10.2014	300	17:37	58.1492	-8.4177	StS

CTD018	C4	27.10.2014	300	21:09	58.2235	-8.8319	TiT
CTD019	C4	27.10.2014	300	22:08	58.2234	-8.8318	StS
CTD020	C5	28.10.2014	301	01:31	58.289	-9.248	TiT
CTD021	C6	28.10.2014	301	14:10	58.3638	-9.6627	StS
CTD022	C7	28.10.2014	301	18:47	58.4335	-10.0758	TiT
CTD023	C7	28.10.2014	301	21:21	58.4334	-10.0706	StS
CTD024	D5	29.10.2014	302	05:12	57.6261	-9.7077	StS
CTD025	D4	29.10.2014	302	08:45	57.6196	-9.3894	TiT
CTD026	D4	29.10.2014	302	10:13	57.6196	-9.3895	StS
CTD027	D3	29.10.2014	302	21:29	57.6218	-8.9006	StS
CTD028	D2	29.10.2014	302	23:45	57.6216	-8.4999	StS
CTD029	D1	30.10.2014	303	01:47	57.6159	-8.1855	StS
CTD030	E1	30.10.2014	303	08:08	56.8755	-8.1831	TiT
CTD031	E1	30.10.2014	303	08:49	56.8755	-8.1831	StS
CTD032	E2	30.10.2014	303	11:00	56.8704	-8.5002	StS
CTD033	E3	30.10.2014	303	16:10	56.8699	-9.0586	TiT
CTD034	E3	30.10.2014	303	17:05	56.8699	-9.0587	StS
CTD035	E4	30.10.2014	303	19:19	56.8698	-9.2987	TiT
CTD036	E4	30.10.2014	303	21:50	56.8698	-9.2986	StS
CTD037	E6	31.10.2014	304	07:39	56.8702	-10.0928	StS
CTD038	E5	31.10.2014	304	13:40	56.8725	-9.7039	StS
CTD039	E5	31.10.2014	304	16:10	56.8687	-9.696	TiT
CTD040	F7	01.11.2014	305	05:30	56.1216	-10.4987	StS
CTD041	F6	01.11.2014	305	18:12	56.1217	-10.0998	StS
CTD042	F5	01.11.2014	305	23:01	56.125	-9.7017	StS
CTD043	F5	02.11.2014	306	02:03	56.1288	-9.7048	TiT
CTD044	F4	02.11.2014	306	06:27	56.1193	-9.1768	StS
CTD045	F4	02.11.2014	306	07:42	56.1193	-9.1768	TiT
CTD046	F3	02.11.2014	306	10:00	56.1215	-8.8978	StS

CTD047	F3	02.11.2014	306	11:08	56.1215	-8.8979	TiT
CTD048	F2	02.11.2014	306	15:24	56.1191	-8.5015	StS
CTD049	F1	02.11.2014	306	17:44	56.1196	-8.1025	StS
CTD050	G1	02.11.2014	306	23:52	55.3706	-8.0977	StS
CTD051	G2	03.11.2014	307	02:14	55.3687	-8.5016	StS
CTD052	G3	03.11.2014	307	05:03	55.37	-8.8997	StS
CTD053	G4	03.11.2014	307	07:30	55.3709	-9.303	TiT
CTD054	G5	03.11.2014	307	09:51	55.3693	-9.7356	TiT
CTD055	G6	03.11.2014	307	14:57	55.3669	-10.1008	TiT
CTD056	G6	03.11.2014	307	17:33	55.3669	-10.1009	StS

Table 3: Summary table of CTD deployments during DY017. See **Figure 2** for position of CTD stations.

CTD data processing (post cruise addendum)

All CTD data were processed and calibrated in Matlab using the 'mstar' data processing environment (Brian King, NOC) as has become common on a number of recent NOC-led cruises. Mstar is an alternative to the Unix based 'Pstar' data processing system that has been heavily used on UK research ships in the past and is entirely based around NetCDF file formats. The description below mainly follows similar procedures used by Penny Holliday (on JC086) and Adrian Martin (on JC087).

SeaBird Data Processing

SeaBird Data Processing was restricted to three stages for compatibility with other cruises using mstar:

Data Conversion – This was run **with** the hysteresis correction for oxygen and ensuring conductivity was in units of mS/cm (**n.b**. The hysteresis correction can also be handled directly in mstar in the script mctd_02b.m – see below. If this option is followed then it is essential that the hysteresis correction is **not** applied here).

Align CTD – using a value of 6 sec (consistent with prior cruises e.g. JC86 and JC87)

Cell Thermal Mass - using standard SeaBird recommendations of alpha=0.03 and 1/beta=7.0 for both primary and secondary conductivities

Translate - Convert from binary to ascii format.

At this stage the CTD data is transferred to mstar.

mstar processing

To begin, a set of ascii template files were created containing a full list of all variables and their units required in the final CTD and bottle data files. These template files are used to generate blank mstar NetCDF files and it is important that the names of variables and their units are consistently adhered to across different file types. These template files were created based on previous cruises and initially included

sam_DY017_varlist.csv	A list of variables coincident with sampling stops on the up cast (e.g. temp, salinity, nitrate, alkalinity etc)
ctd_dy017_renamelist.csv	A list of variables in ctd profile data streams
dcs_DY017_varlist.csv	A list of variables related to sampling times, positions etc

After creation of the template files the following processing routines were run

ctd_all_part1.m: A batch script which calls a variety of mstar routines including

msam_01.m: which creates an empty sample file of name *sam_DY017_NNN.nc* based on the template file *sam_DY017_varlist.csv*

(input : *sam_DY017_varlist.csv;* Output *: sam_DY017_NNN.nc*)

mctd_01.m: reads 24Hz SeaBird data (in ascii format) into netcdfd format.

(Input : 24Hz SeaBird data; Output : *ctd_DY017_NNN_raw.nc*)

mctd_02a.m: renames some variables in the raw input file

(input : *ctd_DY017_NNN_raw.nc; Output : ctd_DY017_NNN_raw.nc*)

mctd_02b.m: This script can replicate and apply the oxygen hysteresis correction that can also be implemented in the seabird software. The user must choose whether to include or omit the hysteresis correction. For DY017 the oxygen hysteresis correction was applied in the seabird software and omitted in the script mctd_02b.

(input : *ctd_DY017_NNN_raw.nc;* Output *: ctd_DY017_NNN_24hz.nc*)

mctd_03.m: averages the 24Hz data to 1Hz and calculates derived variables (e.g. salinity, potential temperature etc)

(input : *ctd_DY017_NNN_24hz.nc; Output : ctd_DY017_NNN_1hz.nc*

ctd_DY017_NNN_psal.nc)

mdcs_01.m: creates an empty file based on template file (*dcs_DY017_varlist.csv*) which will later hold info on start and end of up and down casts

(input : *dcs_DY017_varlist.csv;* Output *: dcs_DY017_NNN.nc*)

mdcs_02.m: Calculates position of deepest datapoint in CTD file and adds information (time, scan number, position) to the dcs file

(input : *dcs_DY017_NNN.nc;* Output *: dcs_DY017_NNN.nc*)

At this point the user must manually obtain the first and last good data points in each CTD profile. This is done via

mdcs_03g.m: which is a graphical interface which allows the user to choose the first and last good points of data in the downcast and upcast respectively. After both points have been identified the scan numbers are saved to the dcs file. Generally the first good data point is the shallowest data point after the CTD has soaked and all pumps are on, and the last good data point is the last data point for which there is good oxygen, salinity, temperature and conductivity data.

(input : *ctd_DY017_NNN_psal.nc;* Output *: dcs_DY017_NNN.nc*)

ctd_all_part2.m: Another batch script which calls a variety of mstar routines including

mctd_04.m: extracts downcast data using information in dcs file and averages to 2db intervals

(input : *ctd_DY017_NNN_psal.nc;* Output *: ctd_DY017_NNN_2db.nc*)

mdcs_04.m: adds positions of profile start, bottom and end from the navigation file into dcs file

(input : *dcs_DY017_NNN.nc;* Output *: dcs_DY017_NNN.nc*)

mfir_01.m: create mstar NetCDF file with info from SeaBird bottle (.bl) file

(input : *Seabird bottle (.bl) file;* Output *: fir_DY017_NNN.nc*)

mfir_02.m: add time from CTD file to firing information file

(input : *: fir_DY017_NNN.nc;* Output *: fir_DY017_NNN_time.nc*)

mfir_03.m: Locate and extract CTD data from upcast and paste into fir file

(input : *fir_DY017_NNN_time.nc;* Output *: fir_DY017_NNN_ctd.nc*
ctd_DY017_NNN_psal.nc)

mfir_04: Paste CTD data from fir file into sample file

(input : *: fir_DY017_NNN_ctd.nc;* Output *: sam_DY017_NNN.nc*)

mwin_01.m: create NetCDF file to hold winch data extracted from Techsas NetCDF files

(input : *Techsas NetCDF file;* Output *: win_DY017_NNN.nc*)

mwin_03.m: Merges winch data onto fir file

(input : *win_DY017_NNN.nc;* Output *: fir_DY017_NNN_winch.nc*)

mwin_04.m: Pastes winch data from fir file into the sam file

(input : *fir_DY017_NNN_winch.nc;* Output *: sam_DY017_NNN.nc*)

At this point all data were examined and edited for spikes using

mctd_rawedit.m: This is a graphical interface which allows you to remove spikes in temperature, conductivity and oxygen. All editing is performed on the raw data files (ctd_DY017_NNN_raw.nc) but a backup is made first (ctd_DY017_NNN_raw_original.nc) and the edited file saved as ctd_DY017_NNN_raw_corrected.nc.

(input : ctd_DY017_NNN_raw.nc*;* Output *:* ctd_DY017_NNN_raw_original.nc

ctd_DY017_NNN_raw_corrected.nc)

Once edits are complete it is necessary to re-run some of the early stages to correct derived variables accordingly. This is done by running the batch script

Smallscript.m: This batch script reruns mctd_02b, mctd_03, mctd_04, mfir_03 and mfir_04.

Bottle sample data

A separate ascii file is first created for each CTD cast and for each bottle sample data type (i.e. salinity, oxygen, nutrients, CO_2, chlorophyll etc). The format of the ascii file is dependent upon the data type, for example, the salinity file format looks like the standard output file from the salinometer (i.e. a file with the same number of header lines but containing less data), whilst the nutrient file consists of several columns of data (one for each nutrient) and the a data quality flag. It is best to find and modify existing template files before starting and rigidly ensuring that all formats are strictly adhered to. Once the various ascii files were created the following scripts were used to read the data into mstar netcdf and to subsequently merge the data with the sam file.

Salinity

msal_01.m: convert the ascii file into NetCDF. This routine will ask you for the salinometer bath temperature and whether you want to apply a conductivity ratio offset. The offset was set to zero throughout. Tweak script for changes to variable names before use.

(input : *ascii csv file e.g. sal_DY017_NNN.csv;* Output *: sal_DY017_NNN.nc*)

msal_02.m: paste the bottle salinity data into the sample file

(input : *sal_dy017_NNN.nc;* Output *: sam_DY017_NNN.nc*)

Nutrients

mnut_01.m: Read in the csv ascii file and convert to NetCDF. Tweak script for changes to variable names before use.

(input : *ascii csv file e.g. nut_DY017_NNN.csv;* Output *: nut_DY017_NNN.nc*)

mnut_02.m: paste the bottle nutrient data into the sample file

(input : *nut_dy017_NNN.nc;* Output *: sam_DY017_NNN.nc*)

Oxygen

moxy_01.m: Read in the csv ascii file and convert to NetCDF. Tweak script for changes to variable names before use.

(input : *ascii csv file e.g. oxy_DY017_NNN.csv;* Output *: oxy_DY017_NNN.nc*)

moxy_02.m: paste the bottle oxygen data into the sample file

(input : *oxy_dy017_NNN.nc;* Output *: sam_DY017_NNN.nc*)

Conductivity and Oxygen calibration

A set of residual values were generated by running the script

msam_02.m: This script calculates a series of residual values between bottle samples and CTD sensor measurements to aid the calibration process. The standard version of this script generates

1) bottle salinity – CTD salinity (Channel 1)

2) bottle salinity - CTD salinity (Channel 2)

3) bottle oxygen – CTD oxygen

in addition, following the derivation of bottle conductivity, were calculated

4) bottle conductivity – CTD conductivity (Channel 1)

5) bottle conductivity – CTD conductivity (Channel 2)

6) bottle conductivity / CTD conductivity (Channel 1)

7) bottle conductivity / CTD conductivity (Channel 2)

8) bottle salinity / CTD salinity (Channel 1)

9) bottle salinity / CTD salinity (Channel 2)

10) CTD temp (channel 1) – CTD temp (Channel 2)

(input : *sam_DY017_NNN.nc;* Output *: sam_DY017_NNN_resid.nc*)

Residual files were then grouped by CTD type (stainless steel or titanium frame) and appended together (using mapend.m) to create two master files. The master files were examined in a series of plots (mplotxy) to identify outlier values in the residual variables (particularly No. 6 and 7 above), which were removed from sequential versions of the master files using either mdatpik or mplxyed.

Stainless steel CTD calibration

The calibration of the two Seabird conductivity channels to the salinometry results revealed a good agreement in both cases. Plots of conductivity difference against station number (i.e. time) revealed no drift with time, indicating that both sensors were stable.

SeaBird claim that the correct in-situ calibration for their conductivity sensors is a linear function of conductivity with no offset. Plots of conductivity difference against conductivity added support to this and therefore the calibration coefficients A and B were calculated as

$$conductivity = A*(primary\ conductivity)$$

$$conductivity = B*(secondary\ conductivity)$$

where

$$A = \frac{\sum Cond_{bot}Cond_{ctd}}{\sum (Cond_{ctd})^2} = \frac{\overline{Cond_{bot}Cond_{ctd}}}{\overline{(Cond_{ctd})^2}}$$

and

$$B = \frac{\sum Cond2_{bot}Cond2_{ctd}}{\sum (Cond2_{ctd})^2} = \frac{\overline{Cond2_{bot}Cond2_{ctd}}}{\overline{(Cond2_{ctd})^2}}$$

and $cond2_{bot}$ is the sample bottle conductivity determined with the secondary temperature variable.

Coefficient A was determined to be 1.000002 and coefficient B was determined to be 0.999946. Corrected Seabird conductivities were calculated through the application of coefficient A to primary conductivity and coefficient B to the secondary conductivity channel. All derived variables were then recalculated.

Residual conductivity differences calculated as bottle conductivity – corrected Seabird conductivity were typically better than ±0.003 mS/cm for both channels but some scatter was present within the data. On conductivity channel 1 the mean residual was calculated as -0.00019 mS/cm and the standard deviation was 0.00444. On conductivity channel 2 the mean residual was 0.00007 mS/cm and the standard deviation was 0.00447. Final salinity offsets, derived from calibrated conductivities, are shown in **Figure 4**.

The linear regression between Seabird 43 oxygen concentrations (in mmol/l) and manual titrations produced a regression equation of

$$y = 1.1428 * CTDoxy - 12.638$$

where y = corrected oxygen concentration (μmol/l).

The typical range of residual oxygen values (i.e. corrected Seabird oxygen concentration – bottle titration estimate) was ±4 μmol/l but the majority of observations were better than ±2 μmol/l (**Figure 5**). The mean residual was 0.0051 μmol/l with a large standard deviation of 2.31 μmol/l due to the spread within the data.

Titanium CTD calibration

Following the same approach as for the stainless steel CTD, Coefficient A was determined to be 1.000141 and coefficient B was determined to be 1.000114. Corrected Seabird conductivities were again calculated through the application of coefficient A to primary conductivity and coefficient B to the secondary conductivity channel. All derived variables were then recalculated.

Residual conductivity differences calculated as bottle conductivity – corrected Seabird conductivity were generally better than ±0.004 mS/cm for both channels but some scatter was present within the data. On conductivity channel 1 the mean residual was calculated as 0.0003 mS/cm and the standard deviation was 0.0044. On conductivity channel 2 the mean residual was -0.0011 mS/cm and the standard deviation was 0.0031. Final salinity offsets, derived from calibrated conductivities, are shown in **Figure 4**. It should be noted that the final salinity offsets obtained for the titanium CTD appear poorer than those obtained from the stainless steel CTD, which most likely reflects the reduced number of bottle salinity samples collected from the titanium CTD.

The linear regression between Seabird 43 oxygen concentrations (in mmol/l) and bottle titrations produced a regression equation of

$$y = 1.1535 * CTDoxy - 14.647$$

where y = corrected oxygen concentration (μmol/l).

The typical range of residual oxygen values (i.e. corrected Seabird oxygen concentration – bottle titration estimate) was ±5 μmol/l (**Figure 5**). Relative to the stainless CTD the calibration for the titanium system appears poorer with a number of calibrated data points outside the ±2 μmol/l range (**Figure 5**). Despite the greatly reduced number of bottle titrations collected from the titanium CTD the mean residual (0.0029 μmol/l) and standard deviation

(2.087 μmol/l) were comparable to the results obtained from the stainless CTD system suggesting comparable accuracies have been obtained from both systems.

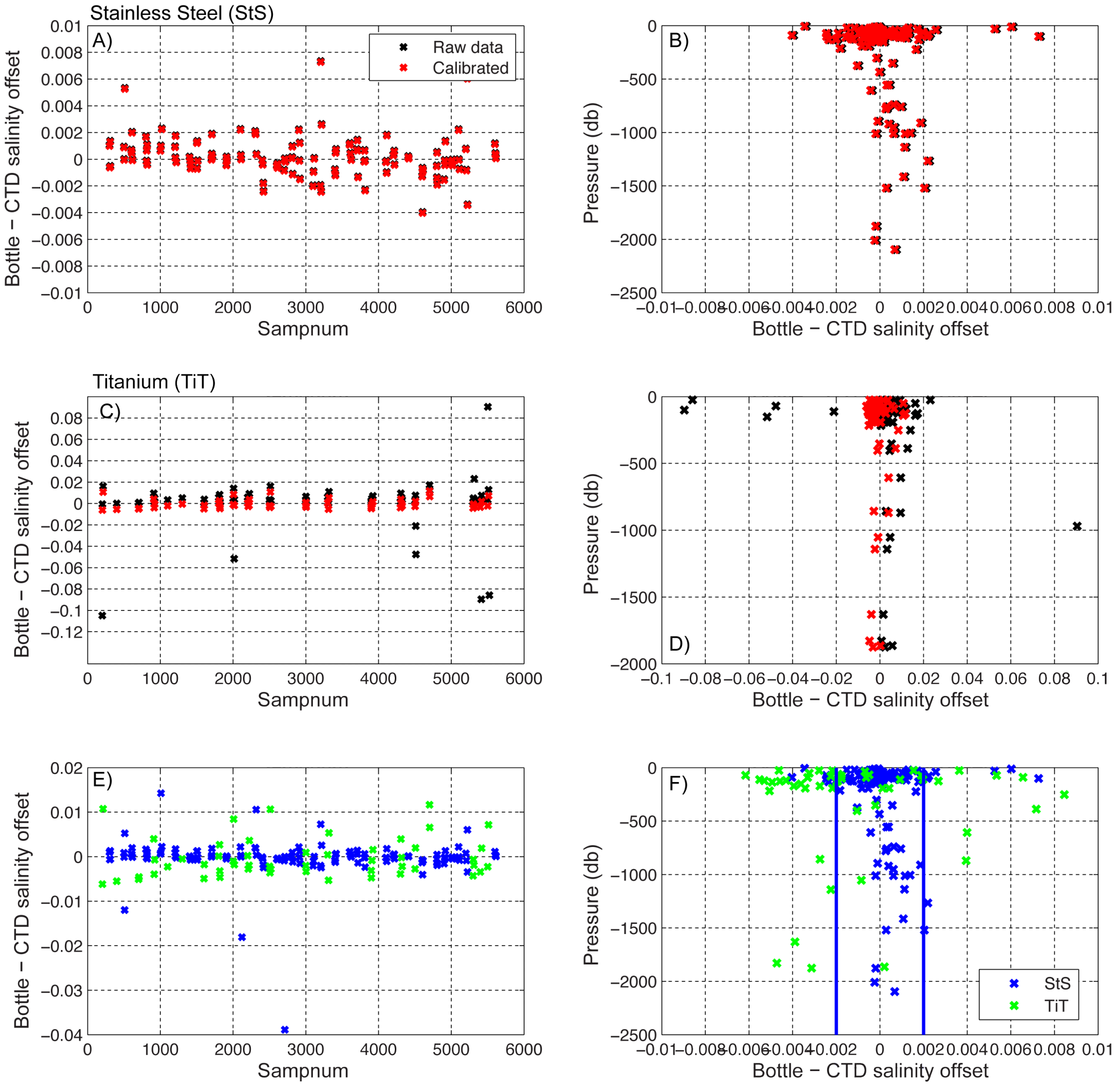


Figure 4: Summary of CTD salinity calibrations. Panels a) and c) show temporal salinity residuals for the stainless and titanium CTD systems respectively, whilst panels b) and d) show the vertical (pressure) residuals. Panels E) and F) show final residuals after calibration. Vertical blue lines in panel f) indicate ±0.002 offset range.

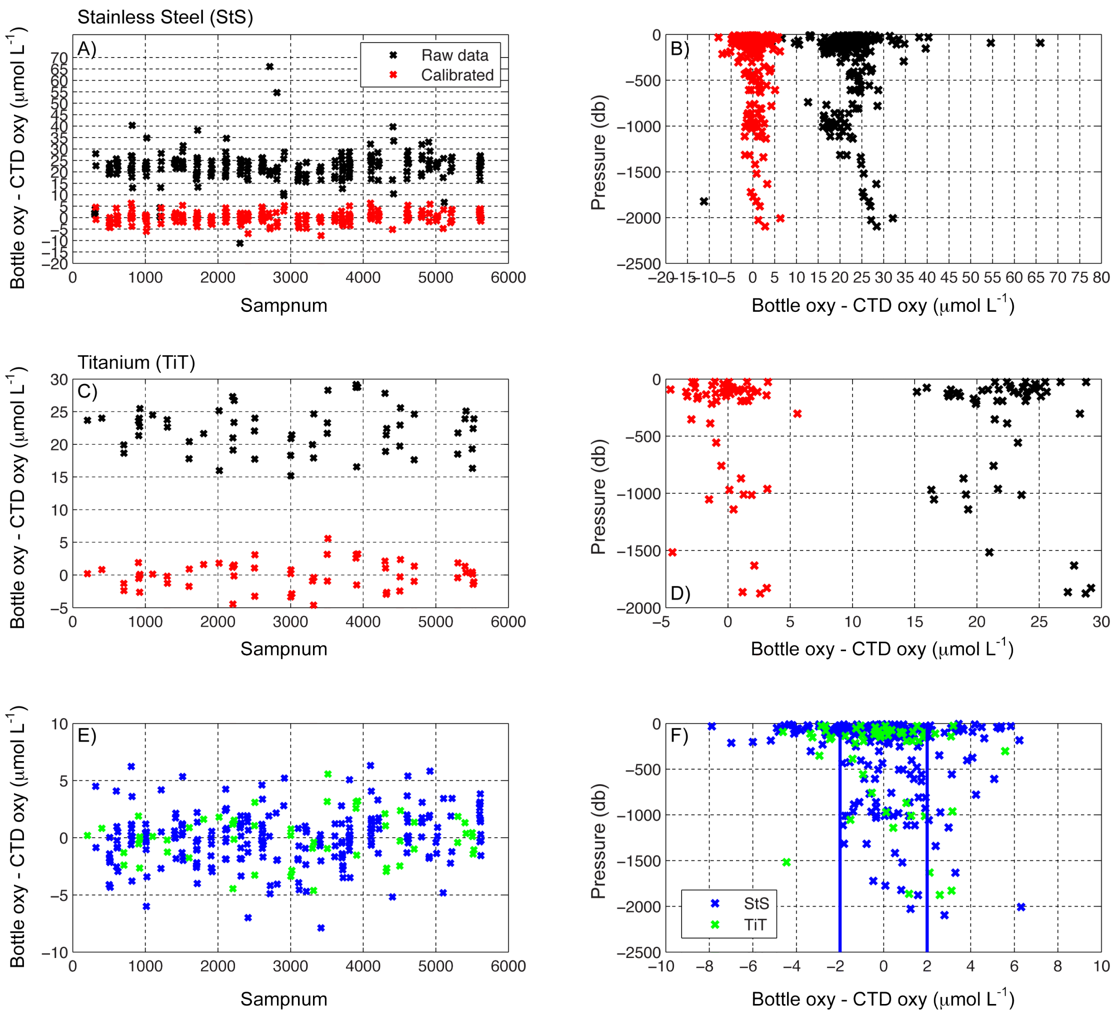


Figure 5: Summary of CTD oxygen calibrations. Panels a) and c) show temporal oxygen residuals for the stainless and titanium CTD systems respectively, whilst panels b) and d) show the vertical (pressure) residuals. Panels E) and F) show final residuals after calibration. Vertical blue lines in panel f) indicate ±2 μmol L^{-1} offset range.

Surfmet underway data – *Stuart Painter*

Continued problems with the surfmet/TSG system during DY017 were thought to have rendered all underway data streams unusable. Provisional examination of the data however suggests that some underway salinity and temperature data may be recoverable but no other data stream will be functional. This will be investigated post cruise.

Vessel mounted ADCP (VMADCP) processing using an RDI OS75, RDI OS150 and PosMV positioning

Sam Jones

Adapted from JC88 & JR239 cruise reports

- For those hoping to access processed VMADCP data, you are most likely to require file type: CRUISE_000_000000_zz_abs.mat; detailed in section 4.5.8. Dates and times covered by files are given in section 5.1.

- For cruises on *Discovery* in the near future, it is recommended that you read section 1.1 which outlines the specific issues we encountered (some of which probably easily rectified by a skilled operator)

- A 'quick start' guide to setting up the Matlab software on another machine is included in section 4.3.

OS75 and OS150 configuration

RRS *Discover*y is fitted with RD Instruments 75kHz and 150 kHz Ocean Surveyor ADCPs. The instruments are mounted in the ship's hull in a forward – aft configuration, approximately 6 m below the waterline. Their nominal rotation relative to the centreline of the ship is -45°, but fine-tuning of this value is performed by the water-track or bottom-track calculations in the Matlab routines. The exact determination of this rotation offset is crucial to removing ship velocity from the data.

Positional and attitude information is provided via a PosMV multi-receiver GPS attitude sensor. Ship's heading information from the vessel's Gyro, though streamed to and saved by the logging PC, was not used in the processing steps described here. The RDI proprietary software VMDAS was used to configure the ADCP and perform velocity mapping to the reference frame of the vessel. Bottom tracking was enabled for the majority of the cruise though most good calibration data were acquired during the long transits at the beginning and end of the cruise.

A suite of MATLAB routines were used to perform data screening and transformation to absolute velocities in Earth coordinates: A summary of configuration and the processing steps during DY017 is given below.

OS75 basic VMDAS configuration

ADCP Setup

Number of bins: 60

Bin size: 16 m

Blank distance: 8 m

Transducer depth: 6 m

Processing mode: low-resolution (long range) – recommended by Brian King (NOC)

Bottom track: on

Ensemble time: fast as possible

Recording

Number: start at 1 but allow VMDAS to increment automatically (otherwise files are overwritten)

Max Size: 10 Mb - rolls over to new ‘sub-file’ automatically. Setting the file size to very large can cause it to crash

NAV

NMEA ship position sources: NMEA1

Transform

Heading / tilt source: PRDID; NMEA2

Custom NMEA from C:\RDI\VmDas

ADCP alignment correction: Heading -45

Averaging

First time interval: 120 seconds

Second time interval: 600 seconds

Data screening

All unchecked

OS150 basic VMDAS configuration

ADCP Setup

Number of bins: 96

Bin size: 4 m

Blank distance: 4 m

Transducer depth: 6 m

Processing mode: low-resolution (long range)

Bottom track: on

Ensemble time: fast as possible

Recording

Number: start at 1 but allow VMDAS to increment automatically (otherwise files are overwritten)

Max Size: 10 Mb - rolls over to new 'sub-file' automatically. Setting the file size to very large can cause it to crash

NAV

NMEA ship position sources: NMEA1

Transform

Heading / tilt source: PRDID; NMEA2

Custom NMEA from C:\RDI\VmDas

ADCP alignment correction: Heading -45

Averaging

First time interval: 120 seconds

Second time interval: 600 seconds

Data screening

All unchecked

Discussion of data acquisition during DY017 and (more generally) on-board *Discovery*

During the cruise the ADCP-VMDAS system presented numerous challenges, due variously to relatively untested systems, equipment failure and incorrect setup. Below is a brief discussion of the problems we encountered (and mostly overcame) in the hope that some might be avoided on future cruises.

Using (and misusing) VMDAS

The RDI VMDAS software looks intimidating but is in fact quite easy to use. It is recommended that future users download and at least skim-read the user manual prior to embarkation! A key feature of VMDAS is the ability to import command files for the ADCP and processing setup, or to manually dictate settings using the configuration panels and tick-boxes.

A potential stumbling-block is that you can simultaneously have a command file loaded and alter the settings via tick-boxes, leading to a conflict. The manual states that in this situation, the command file is loaded first so is effectively overridden by the tick-boxes. The preferable option is always to load a reliable command file from a previous cruise – VMDAS can read command files from other ships but be aware that some settings are ship-specific.

We were thrown by the fact that, on loading a command file, the tick boxes are not automatically updated to reflect the settings therein. We took this as meaning that the command file was not being read, whereas actually the tick-boxes simply override the command file. On arrival on the ship, we therefore recommend loading a command file from a previous cruise on the same vessel (one which generated good VMADCP data!) and starting with most boxes in the configuration menu unchecked. Specify only what is necessary for your requirements (bin size, bottom tracking, etc) and, if necessary, test the effect of other settings through trial-and-error outside the scientific portion of the cruise, processing the output daily to monitor changes.

Command files to immortalise your settings can be generated through Options/Save as. Two types of command file have been generated by previous cruises; one is four A4 pages long and lists all ADCP and VMDAS settings. The other is much shorter and commented. The difference between the two, and their intended functions, is slightly unclear. Suspect the commented command files (text format) are supplied by RDI to get the user started in various modes, whereas the long version (.ini) is the user-generated settings output which specify exactly how you want it set up.

Command files were generated from DY017 and will be saved with the final data suite. Be aware that these will load settings made by relatively inexperienced VMDAS operators and should be checked and amended sooner rather than later!

OS150 ADCP misalignment

The majority of the ship velocity is automatically removed by VMDAS in the 'raw' processing stages (though truly raw velocities are also output). For this it needs information on the rotation of the ADCPs relative to the ship's hull, specified in the VMDAS setup.

On arrival on *Discovery* it was found that the OS150 ADCP was still configured with factory settings and had probably not been used in anger. The ADCP settings were mostly copied from the OS75 machine, but the ADCP alignment in the hull was set at 0° initially rather than -45° as with the OS75. On post-processing the data it was discovered that the correct misalignment was in fact -45° as well. The Matlab routines are able to correct for this, but after email discussion with Brian King (NOC) we decided to correct it to avoid any unknown errors creeping in. The output files of the OS150 are therefore divided into those requiring a ~45° correction at the beginning of the cruise, and those requiring a ~0.5° correction for the rest of the cruise.

OS75 beam failure

Early in the cruise it was discovered that the fourth beam of the OS75 was not working. With the VMDAS display set to 'real-time', this was seen as a persistent absence of velocity returns (occasional gaps are normal and are averaged out). The software can perform '3-beam solutions' but parts of the QC in the Matlab routines had to be suppressed as they check for a threshold 'percentage good' in all beams.

After email discussion with NOC, the deck unit handling the OS75 feed was swapped with a spare, which rectified the problem. Detailed description in the Ship Technician's report.

Range and noise issues

Throughout the cruise, the range of both instruments fluctuated and was generally poorer than expected, as was the amount of noise in the return signal. This seemed to be unrelated to the weather or movement of the vessel, and should investigated by a skilled operator. Presumably the cause could be one of the following; poor choice of setting in some obscure part of the ADCP setup, instrument problems or acoustic features inherent to the new *Discovery*.

Though it pains me to write this, when the return signal became particularly poor, sometimes closing and re-opening the VMDAS software solved the problem.

Bottom tracking

Bottom-tracking is an option which can be enabled on the VMDAS setup and provides data on the ship's heading in shallow waters, from the ADCP pings reaching the sea floor. Water tracking is performed in the Matlab post-processing steps and uses relatively stable water from a specified depth as a velocity reference frame. The original intention was to switch bottom tracking on for the steam through the Irish Sea to the Malin Shelf to provide a calibration period in shallow waters, then switch it off for the rest of the cruise. However, when it was switched off in shallow waters it was found that the VMDAS processing no longer stripped the seabed reflection from the data, resulting in profiles with echoes and interference below the seabed. We therefore kept bottom tracking switched on for the rest of the cruise.

Not sure whether this is to be expected; there is a 'strip seabed data' tickbox in the setup panels but as this was not enabled in previous cruises we decided not to venture into the unknown.

Output data format

The filenames of the VmDas data are of the general structure CRUISE_xxx_yyyyyy.END where CRUISE is the name set in the recording tab of VmDas (see above), xxx is the number set in the same tab and changed before every restart of recording, and yyyyyy is a number automatically set by VmDas starting at 0 and increasing when the file size becomes larger than max size and a new file is created. END is the filename extension, denoting the different files that are created for each recording. The following list shows all the different file types that were created during DY017 and their content.

-.ENR: binary; raw ADCP data file.

-.STA: binary; average ADCP data, using the short time period specified in VmDas Data Options.

-.LTA: binary; average ADCP data, using the long time period specified in VmDas Data Options.

-.ENS: binary; ADCP data after screening for RSSI and correlation, either by VmDas or adjusted by user, and navigation data from .NMS file.

-.ENX: binary; : ADCP single-ping data and navigation data, after having been bin-mapped, transformed to Earth coordinates and screened for error velocity, vertical velocity and false targets.

-.N1R: ASCII text; raw NMEA data, see section 3.

-.N2R: ASCII text; raw NMEA data, see section 3.

-.NMS: binary; navigation data after screening and pre-averaging.

-.VMO: ASCII text; option setting used for collection the data.

-.LOG: ASCII text; all logging output and error messages.

More options are available and information about the data files and their format is available in the various OS user guides. Here, a short overview about the structure of the binary data files is given. The structure varies slightly depending on whether only narrowband OR broadband mode are turned on or both are on.

-**Header**: header ID, data source ID, number of data types (i.e. fixed leader, variable leader, etc.) and their offsets;

-**Fixed leader data**: fixed leader ID, ADCP hardware configuration, number of beams, cells, and pings per ensemble, depth cell length, blank after transmit, signal processing mode (narrow- or broadband), output controls, amount of time between ping groups, coordinate transform parameters, heading alignment, heading bias, sensor source, sensors available, distance to middle of first depth bin, length of transmit pulse, distance between pulse repetitions;

-**Variable leader data**: variable leader ID, ping ensemble number, date and time, speed of sound, transducer depth, heading, pitch and roll, salinity and temperature;

-**Variable data**: velocity, correlation magnitude, echo intensity, and status data

-Bottom track (BT): BT ID, BT number of pings, correlation magnitude, evaluation amplitude, BT mode, error velocity maximum, BT range, BT velocity, BT correlation magnitude, BT evaluation amplitude, BT maximum depth, receiver signal strength indicator, gain level for shallow water, most significant byte of the vertical range from the ADCP to the sea bottom;

-Attitude: fixed and variable attitude data. Fixed attitude data includes the command settings and is the same for all pings. Variable attitude data changes with every ping and consists of heading, pitch and roll;

-Navigation (ENS, ENX, STA, and LTA-files only): navigation ID, UTC date and time, PC clock offset, latitude and longitude received after the previous ADCP ping, UTC time of last fix, last latitude and longitude received prior to the current ADCP ping, average navigation speed, true navigational ship track direction and magnetic navigation ship track direction, speed made good, direction made good, flags, ADCP ensemble number, date and time, pitch, roll and heading, number of samples average since the previous ADCP ping for speed, true track, magnetic track, heading, pitch and roll;

-Checksum: modulo 65536 checksum (sum of all bytes in the output buffer excluding the checksum). If data storing by VmDas is interrupted by e.g. a software crash and/or the data files are not closed properly by VmDas, the checksum can be incorrect and the check in the post processing can fail.

Note: The date recorded by VmDas is given as Julian day. VmDas takes 1st Jan to be day no. 0, different from the ship clock and the other data logging systems!

Navigation data in the VmDas output files

There are two NMEA (nav) feeds into the VmDas software. The NMEA1 stream is normally written to the N1R-files, the NMEA2 stream to the N2R-files. They are also included in the binary (.ENX) data files. NMEA2 gives the messages used by the processing software. In both files, a message from VmDas is stored in the PADCP line at every ADCP ping.

Note: Depending on the way the feeds to VMDAS are configured, the data relevant to the Matlab routines (pitch, roll, heading etc) may be either stored in the N1R or N2R files, so this is an important thing to check. In DY017, the file read in was N2R. To change the file read by the post-processing software, amend the variable 'extension' in read_nmea_att_disc2.m. The line headings containing this data also vary depending on the device and software used to supply the nav data.

This version of the post-processing only reads the PADCP and PRDID messages. The 'PRDID' header might change, but the line to look for looks like this:

$PRDID,-000.76,+002.03,259.94*7E

This contains the pitch roll and heading values, and a couple of digits which might be a checksum from VMDAS and are not needed.

Processing in Matlab

The Matlab routines

For the post-processing of the VmDas data, we used a set of Matlab routines. They were first obtained from IfM Kiel by Mark Inall and adapted for use on the RRS James Clark Ross by Deb Shoosmith. During JR165, Mark Brandon and Angelika Renner cleaned up large parts of the routines and added comments throughout. Since JR165, some further debugging and refinement have been done by numerous operators. The structure, general processing, and in- and output formats remain the same. The following description of the routines and the output data files are adapted from the JR235 cruise report.

Remarks and Glossary

Whenever it says 'run a routine/program/function', it means type in the function name in the Matlab command window and hit enter... A few terms should be clear:

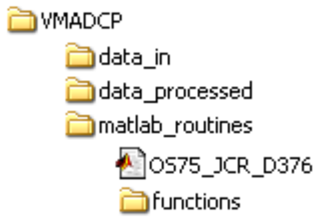
-file sequence: all files for which in the filename CRUISE_xxx_yyyyyy.END the number at position xxx is the same. These files have been recorded without stopping the ADCP in between and the same setting was used.

-amplitude, scaling factor, A: Throughout the routines, the factor by which the ADCP data has to be scaled for calibration is called either amplitude, scaling factor or A.

-misalignment (angle), phi: synonyms for the angle by which the ADCP is misaligned in addition to the physical misalignment set in the command files.

Quick'n'dirty

How to get processed ADCP data



- Create a file structure as shown above.

- The master function (OS75_DY017.m) lives in 'matlab_routines', all others go in the subfolder 'functions'.

- Depending on your version of Matlab, you may need the **signal processing** and **stats** toolboxes.

-There are a few things that have to be set for each cruise in file OS75_DY017.m. These are:

1. Add the correct path to the 'functions' subfolder (line ~54).

2. Point Matlab variable '*RAWPATH*' to 'data_in' and '*PATH*' to 'data_processed' (Remember the 'forward slash' character!). Lines ~62 – 70.

3. The expected VMDAS output: '*filename*'. Line ~73. Note that both the length and the position of file numbers has to be correct or the program will not get very far! If file length/numbering is different, there's also a bit of tinkering to be done at line ~287… (hint: the program counts backwards from the end of the filename).

3. The cruise name: variable '*cruise*'. The name is used when reading in raw data and saving processed data, and appears in the plots. Line ~74.

4. The file sequences: variable '*files*'. This determines which of the file sequences are to be processed. 'Files' can be a single number or a vector containing the numbers of several file sequences (**A new file sequence is begun each time you switch the VMDAS on / off).** Line ~105

5. The averaging interval: variable '*superaverage*'. '*superaverage*' sets the interval over which ping ensembles will be averaged. Unit is seconds. **Leave as is if unsure.** Line ~117.

6. The year: variable '*YYYY*'.

7. A switch for which lat/lon fix to be used (see below, 5.4): variable '*which_prdid_fix*'. Options are a) 1 to use the fix directly after the previous ADCP ping, or b) any other number to use the fix directly before the current ADCP ping. **Set it to 1 presently and has negligible impact on the resultant data.**

8. The upper and lower limit of the reference layer: variables '*ref_uplim*' and '*ref_lowlim*'. Those are needed for calculation of a reference velocity which is used when doing calibration by water tracking. Unit is meters. Useful if a particular layer of water is known to be particularly good / bad as a reference level due to tides, etc. **Leave as is if unsure**.

9. The misalignment angle and the scaling factor: variables '*misalignment_nb / misalignment_bb'*, and '*amplitude_nb / amplitude_bb'*.

When running *OS75_DY017.m* the first time, set the misalignment to 0 and amplitude to 1. (Currently Line ~ 183). While the '_nb' and '_bb' suffixes refer to the 'narrowband' and 'broadband' setting in VMDAS, regardless of which setting you use, keep the _nb and _bb settings the same as each other. In the convoluted path through this code, I'm not sure whether one or both is seen by the QC routines, so it's best to change both.

After the first run, to correct for the angle and the scaling, set the variables to the mean, median, mode or whichever value is preferred, and run OS75_DY017.m again. The Mean, median, and standard deviation are displayed in the plot *adcp_calib_calc.ps*. (The commented out values used on DY017 should give a ballpark value *for Discovery*). To keep track of which values were used, it is a good idea to note down which file sequences require which correction factors.

That is all that should be set. All that needs to be done then is:

1. Put raw files into 'data_in' folder. Note the Matlab suite only requires .N1R, .N2R and .ENX files to run, just make sure you get the whole file sequence (on DY017 max file size was set at 10 Mb after which a new file was started by the VMDAS).

2. Run OS75_DY017.m.

3. Check which values for misalignment angle and scaling factor are derived.

4. Set 'misalignment_xx' and 'amplitude_xx' in OS75_DY017.m to these values. Note: setting these values other than 1 and 0 invokes some additional statistical routines which increase the processing time…

5. Run OS75_DY017.m again.

Existence of files in 'data_processed' and 'data_in' folders

If the program encounters files or plots of the current working name in the 'data_processed' folder, it skips much of the processing, assuming them to be completed. Therefore until you are happy with the outputs it is best to regularly delete the contents of the 'data_processed' folder, or at least move them elsewhere.

<u>Brief description of Matlab processing steps</u>

1. RDI binary file with extension ENX (single-ping ADCP ship referenced data from VMDAS) and extension N2R (ascii NMEA output from PosMV saved by VMDAS) read into MATLAB environment. NB: The N2R file consists of ADCP single ping time stamps ($PADCP string) and PosMV pitch, roll and heading information ($PRDID string).

2. Ensembles with no ADCP data removed

3. Ensembles with bad or missing PosMV GPS heading data identified and adjusted GYRO heading substituted

4. Attitude information time-merged with single ping data

5. Heading data used to rotate single ping ADCP velocities from vessel centreline reference to True North reference

6. Transducer mis-alignment error corrected for (derived from the mis-alignment determination)

7. Ship velocity derived from PosMV positional information

8. Further data screening performed:

    -Max heading change between pings (10 degrees per ping)

    -Max ship velocity change between pings (>2ms^{-1}pingrate^{-1})

    -Error velocity greater than twice Stdev of error velocities of single ping profile

9. All data averaged into 120-second super-ensembles (user selectable)

10. Determine absolute water velocities from either bottom track derived ship velocity or PosMV GPS derived ship velocity, dependent on depth.

Detailed description of the processing functions

The master function: OS75_DY017.m

The main function for the processing is OS75_DY017.m. In there, the environment and variables are set, and the subfunctions are called. **Figure 6** gives an overview of the processing routines, their order and the output. In the first part the work environment is defined: the paths to the processing routines are added to the Matlab search path, the directory with the raw data and the directory for the processed data are declared, the file- and cruise names are defined, and the vector containing the numbers of the file sequences that are to be processed is created. Several choices can be made for the processing: the variable *superaverage* is used to define the interval over which pings will be averaged in time, unit is seconds; which $PASHR string sets, i.e. the first $PASHR fix after the previous $PADCP string or the last one before the current $PADCP string. The values for *ref_uplim* and *ref_lowlim* give the upper and lower limits of the reference layer of which a velocity is calculated and used as reference velocity. This is of importance mostly for water track calibration in cases where no bottom track data is available or the bottom track calibration is not satisfactory.

Then, during the first run through OS75_DY017.m, where no data are processed yet and no calibration data are available, the correction values for the misalignment angle (*misalignment_xb*) and the scaling factor (*amplitude_xb*) are set to 0 and 1 respectively (x=n for narrowband mode, x=b for broadband mode). For the second run, when values for *misalignment_xb* and *amplitude_xb* have been calculated, they should be set to the median, mean, mode or whichever value works best (i.e. gives the smallest angle and amplitude after the second run). To keep a record of the settings used to process a set of ADCP data, the settings and the text displayed on screen during the processing are written to a diary called *adcp_proc_log_runX.txt*. X will be 1 for the first run (when *misalignment_xb* and *amplitude_xb* are equal to 0 and 1, resp.) and 2 for the second run (*misalignment_xb* and *amplitude_xb* unequal 0 and 1, resp.).

After this introductory part, the processing starts. Arrays are declared for later use when calling some of the subroutines, and the file containing calibration point data is deleted if it exists in the processed data directory. Then, the loop through all file sequences specified above starts. First, the filename is set. Its general structure is *CRUISE_xxx_yyyyyy*. At this point, *xxx* is set to the file sequence number that is the current in the loop and *yyyyyy* is 000000. After the initialisations, the run through the subroutines begins! This includes all routines described in 4.4.2 to 4.4.11. Once all files have been passed through these routines and the loop is finished, the functions described in 4.4.12 to 4.4.16 are called. After that, all data is processed and saved in the specified directory. The last thing in the main function is a plot of velocities: cross sections of the zonal and meridional velocities against time are produced and the plots are saved in *adcp_vel_contours.ps*.

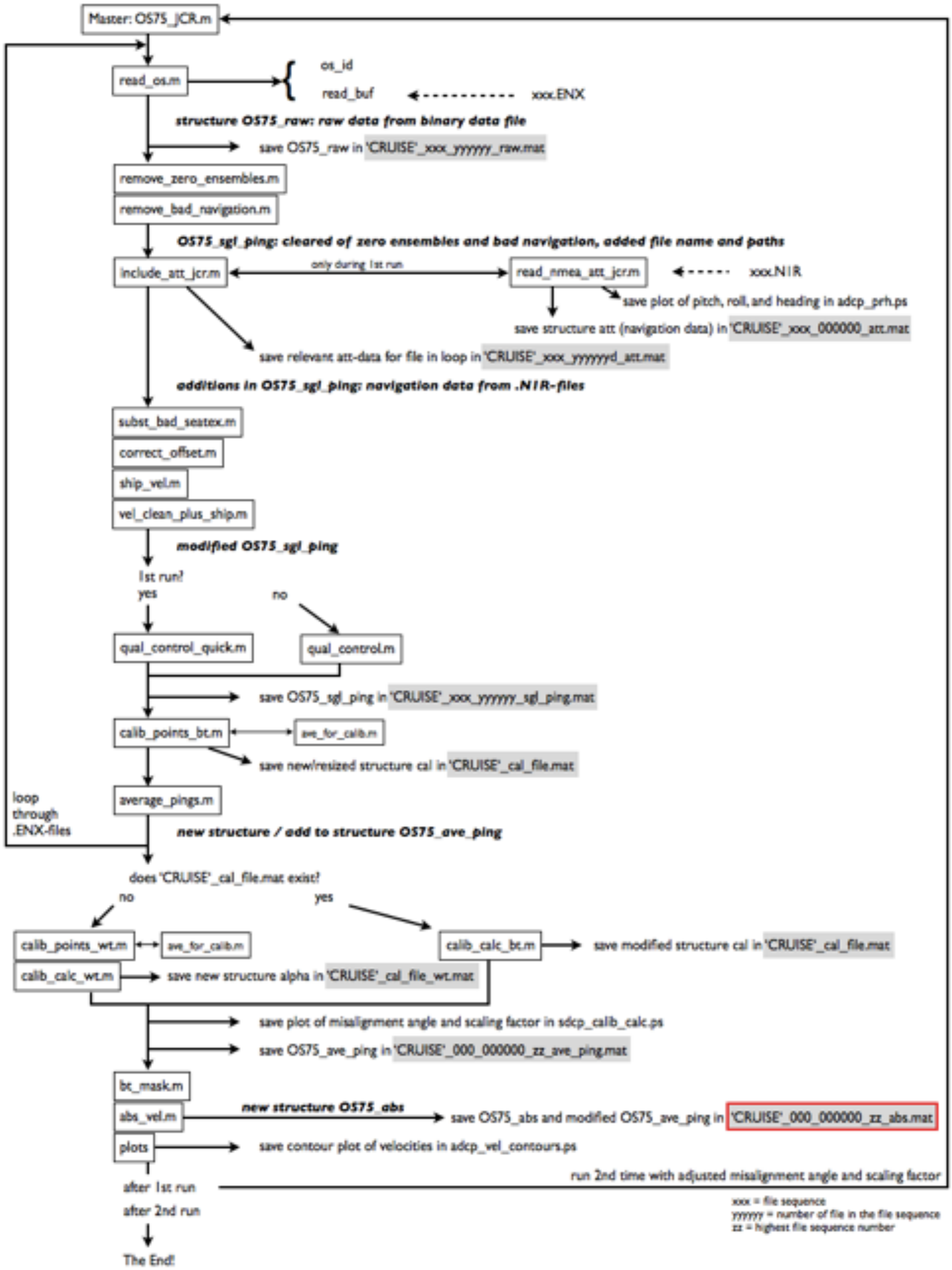


Figure 6. Schematic of the master processing script for DY017 (OS75_DY017.m)

read_os.m In this routine, the raw binary data from VmDas are read. In case of DY017, we used the .ENX files, which contain ADCP single-ping and navigation data. The ADCP single-ping data has already been bin-mapped, transformed to Earth coordinates, and screened for error velocity, vertical velocity and false targets (see VmDas User's Guide).

read_os.m is called with the file name variable and optional arguments. The latter define which part of the raw data is read:

-'ends': ???

-'ens list': list of ensemble numbers

-'yearbase': start year

-'second set': read narrow band mode data when both broad and narrow band are collected.

-'vel': read velocity.

-'cor': read correlation magnitude.

-'amp': read echo intensity.

-'pg': read percent good.

-'ts': read pitch, roll, and heading.

-'bt': read bottom track data.

-'nav': read navigation data

-'all': includes vel, cor, amp, ts, bt, and pg.

More than one argument can be passed on to read_os.m. Arguments can also be numbers. After the switches are set, the subroutine os_id, which is within read_os.m, is called with the argument *id_arg*. The value of *id_arg* depends on the offset of the positions of the data. If both narrowband and broadband data are collected in broadband mode, this also decides which data are read. If *id_arg*=1, the narrowband data is extracted. os_id returns the structure id with the positions/identifiers of the data fields in the binary data files. The next step is the first call to the subroutine read_buf, also within read_os.m.

read_buf This is the part where the binary data is read. During the first call with only one argument, the configuration of the OS75 ADCP is extracted from the fixed leader data and stored in the structure config. If one of the checks on number of bytes, header or data source ID or checksum fails, an error message will be returned to read_os.m. Otherwise, information about ADCP hardware and setup that remains the same for all pings is read. After that and during the second call (with two arguments), the variable, bottom track, attitude, and navigation data is extracted. After the first call to read_buf, the configuration data is used to set up the variables and the reading loop. During the second call, the data requested by using the various switches is stored. Before returning to the main routine, variables are adjusted for negative numbers or NaNs. All raw data read in is stored in the structure OS75_raw and returned to the main function and written to the file *CRUISE_xxx_yyyyyy_raw.mat*.

remove_zero_ensembles.m The structure OS75_raw is handed over to remove_zero_ensembles.m. A search for all ensembles whose ensemble number

(OS75_raw.ens_num) is not zero is done and only those are kept and handed back to the main routine as *OS75_sgl_ping*.

remove_bad_navigation.m Depending on *which_prdid_fix*, *OS75_sgl_ping.nav.txy1* or *2* is checked for time (first row), longitude (second row) and latitude (third row) duplicates. The number of rejected data cycles is printed on screen and saved as bad and good (=number of data cycles - number of rejected cycles) in the file *CRUISE_bad_nav.mat*. The rejected data cycles are then removed from *OS75_sgl_ping* and the structure handed back to the main routine.

include_att_disc2*.m* Arguments passed on to this routine are *OS75_sgl_ping*, *add_to_ensnum* (for the correction of ensemble numbers; see below) and *which_prdid_fix*. If no file *CRUISE_xxx_000000_att.mat* exists yet in the processed data directory (i.e. the navigation data in the .N2R-files has not been read yet), *OS75_sgl_ping* is passed on to read_nmea_att_disc2.m which is called to read the .N2R-files.

read_nmea_att_disc2.m (Works on the new *Discovery* file output. Also versions named …_jcr and …jc). The routine goes through all .N2R-files in a file sequence. The number of lines to be read in one go is limited to a maximum of 160000, the loop will go on until all lines are read. The text in the .N2R-file is read into a matrix. Then lines containing the $PADCP or the $PRDID string are extracted. If two $PADCP-lines are consecutive, the first of them is discharged (no attitude data available for this ping ensemble!). From the $PRDID-lines the one following the $PADCP-line are extracted, the others discharged. Pitch, roll and heading are read from the remaining $PRDID-lines and stored. If heading is missing (=999), pitch and roll are set to 999 as well. From $PADCP-lines, the ping ensemble number and the PC time of the ping ensembles (converted to decimal Julian days) are extracted. After all files are read, the ping ensemble number is checked and corrected for duplicates, which can appear due to the splitting of the files after the maximum number of lines is read. The data is stored in the structure *att* which is written to *CRUISE_xxx_000000_att.mat*. Pitch, roll and heading are plotted and the figures saved to *adcp_prh.eps*. (Figures need to be improved!) After that, return to include_att_disc2.m.

The file *CRUISE_xxx_000000_att.mat* with the att-structure is loaded in. If the structure contains data, the following is done: For further processing the ping ensemble number has to be increasing. When the ADCP times out while waiting for a response and resets, the ensemble number goes back to 1. Here, the ensemble numbers are modified so that they increase throughout the file (for *att*) and throughout the files of a file ensemble in *OS75_sgl_ping.ens_num*. There is already attitude data in the structure *OS75_sgl_ping* which comes from the .ENX-file. To extract pitch, roll, heading, and PC clock offset which are relevant for the current .ENX-file, a vector is created for each variable of the length max (highest ensemble number in *att*, highest ensemble number from the .ENX attitude data) and filled with NaNs. Then, the attitude information from *att* is written into the vector and on the data points corresponding to the ensemble numbers from the .ENX-file are stored. If *att* is empty, heading, pitch, roll, and PC clock offset are set to NaN.

The extracted attitude data is written to *OS75_sgl_ping.att*. The attitude data relevant to the current .ENX- file is also saved in the new structure *att* in *CRUISE_xxx_yyyyyyd_att.mat*. The modified OS75_sgl_ping is returned to the main routine.

subst_bad_seatex.m The arguments *OS75_sgl_ping.att,* and *sea_file* are handed over. In *sea_file* the number of accepted and rejected (due to bad Seatex data) data points will be stored. A search on *OS75_sgl_ping.att* data is done for ensembles where:

-heading = 0;

-heading = 999;

-pitch and roll = 0;

-the second differential of heading = 0.

The total number of those ensembles is printed on screen and saved as bad in *'CRUISE'_bad_heading.mat*. *OS75_sgl_ping* contains two headings: *OS75_sgl_ping.heading* which comes from the .ENX-file and *OS75_sgl_ping.att.heading* from the .N2R-file. Both are from the same instrument (Seapath Seatex), but maybe slightly different due to a (very) small time difference in when they are recorded. Therefore, the velocities in OS75_sgl_ping are rotated by the difference. To get bottom track velocities in the correct orientation, *OS75_sgl_ping.bt.vel* is multiplied by -1. *OS75_sgl_ping* with the modified values is returned to the main routine.

correct_offset.m Using the helper routine *uvrot.m*, this routine scales the water and bottom track velocities and corrects them for misalignment. From the main routine, the arguments *OS75_sgl_ping, misalignment_xb* and *amplitude_xb* are passed on, x=n or b depending on whether the current file ensemble is in narrow- or broadband mode. The horizontal velocities are multiplied by the scaling factor *amplitude_xb* and rotated by the specified misalignment angle *misalignment_xb*. The heading is adjusted by subtracting the misalignment angle. The modified structure *OS75_sgl_ping* is returned to the main routine.

ship_vel.m The routine is called with the arguments *OS75_sgl_ping* and *which_prdid_fix*. The latter decides which navigation fix is used for the calculation of the ship velocity: either *txy1* or *txy2*. With the help of the routine ***sw_dist.m*** from the CSIRO Seawater toolbox, the distance and the direction between the fixes is calculated and then converted to distance in east- and northward direction in meters and time difference in seconds. Dividing distance by time difference results in ship velocity in m/s, which is written to *OS75_sgl_ping.ship_velocity*. If bottom tracking was on, the horizontal bottom track velocities *OS75_sgl_ping.bt.vel(1:2,:)* should contain values other than NaN. If that is the case, the ship velocity is set to *OS75_sgl_ping.bt.vel(1:2,:)*.The structure *OS75_sgl_ping* is then handed back to the main routine.

vel_clean_ship_vel.m This routine was added by Hugh Venables during JR218 to filter out spikes in the GPS data. It is called with the arguments *OS75_sgl_ping* and *which_prdid_fix* and returns the modified structure *OS75_sgl_ping*.

qual_control.m Several criteria are used in this routine for further quality control. Therefore, the arguments *OS75_sgl_ping, beam, heading_change* and *ship_velocity_change* are included in the call. *beam* is the number of beams of the ADCP instrument, *heading_change* is the maximum change in heading allowed at any one time step, and *ship_velocity_change* is the maximum change in ship velocity allowed at any one time step. Large changes lead to less reliable ADCP data.

The first step of quality control uses the error velocity provided through the fourth beam *(vel(:,4,:))*. A variable *err_vel* is set to 2 times standard deviation of the error velocity, and the velocities of all ping ensembles where the absolute value of this velocity exceeds *err_vel* are set to NaN.

Then, if *beam* = 0, a check using *percent good* is performed: velocities of ping ensembles with percentage of good four beam solutions equal to zero are set to NaN.

The two following steps look at the heading changes. First, a smoothed version of the heading change *(diff(heading)),* created using a Hamming-window based, second order filter is checked for values exceeding heading change, and the velocities of affected ping ensembles (i.e. the two ensembles in between which the change is large) are set to NaN. The same is done for the unfiltered heading change.

NOTE: for mfilter.m and the therein used Matlab function filtfilt.m, the data needs to have a minimum length of 3 times the filter order! **This means that files with less than 5 minutes of data will crash.**

Velocities are set to NaN if the change in ship speed exceeds ship velocity change.

A last control is done on absolute horizontal velocities in a reference layer: The eastward and northward velocities in the ninth depth bin are chosen and the ship velocity is added to obtain absolute velocities. Then, velocities of ping ensembles between which the change of either of these reference velocities is larger than 2m/s are set to NaN.

The structure with the modified velocity array is returned to the main routine.

Hugh Venables modified the call to the quality control routine such that in the first run, a quicker, less thorough quality check is done using the routine qual_control_quick.m to allow faster processing for quick data checks. During the second run, the above quality control is done.

calib_points_bt.m In this routine, calibration points are extracted using 2-minute averages of ADCP data and various criteria these points have to fulfill. It is called with the arguments *OS75_sgl_ping*, *cal_file, which_prdid_fix, ref_*uplim and *ref_lowlim*. *cal_file* specifies where the data for calibration extracted here will be written to, *which_prdid_fix* does the same as in ship_vel.m.

To average the ADCP data over 2 minutes, the routine ave_for_calib.m is called with the arguments *OS75_sgl_ping, av_time* (set to 120 seconds), *ref_uplim, ref_lowlim,* and *which_prdid_fix*.

ave_for_calib.m This routine is a reduced version of average_pings.m (see 4.4.13), including only variables required by calib_points_bt.m. The possibility of missing out ping ensembles in the averaging process when several .ENX-files exist in a file sequence is ignored here (for more about that issue see 4.4.13).

After the averaging, a check is done whether bottom track velocities are available or not. If all bottom velocities are NaNs, the routine stops and returns to the main program.

The principle used is based on a comparison of ADCP bottom track data and GPS tracks. The bottom velocity recorded by the ADCP should be the same as the GPS derived ship velocity. Therefore, the value GPS ship speed/ADCP bottom track speed gives the scaling factor to adjust ADCP velocities, and −(GPS ship heading − ADCP bottom track heading) is the misalignment angle. As velocities from bottom tracking are crucial for the calibration, ping ensembles with NaNs in either zonal or meridional bottom velocity are discharged. The ship velocity is derived from navigation data in *OS75_sgl_ping.nav* and *which_prdid_fix* sets which fix is used. Ship velocity is then calculated as in ship_vel.m as distance in east- and northward direction divided by time difference. The criteria potential calibration points have to fulfill are:

-the change in ship heading is small;

-the change in ship speed is small;

-the ship speed is within the interval average ship speed ± standard deviation;

-the ship heading is within the interval average ship heading ± standard deviation;

-the bottom speed is larger than a specified minimum speed;

-there are a minimum number of possible calibration points in a row that fulfill the criteria.

Relevant data at the calibration points are extracted and saved in the structure cal. This includes bottom velocity, speed, heading and range, ADCP velocities and heading, ship speed and heading, and the navigation data. The scaling factor at the calibration points is calculated as is the misalignment angle. To enable quality control of the intervals of calibration points (interval=row of successive calibration points) and possible filtering by hand after the processing, some statistics are done and included in the structure: average and standard deviations of ship velocity and heading, bottom velocity and heading, scaling factor and misalignment angle, and the number of 2-minute averages in the interval. If the cal_file does not exist yet, it is created, otherwise, the data is added to the existing file.

average_pings.m The routine is called with the arguments *OS75_sgl_ping*, *d_missed, OS75_ave_ping, superaverage, ref_uplim, ref_lowlim,* and *which_prdid_fix*.

The time in seconds over which the ping ensembles are averaged is given by *superaverage*. As the ping ensembles in a file of a file sequence are not necessarily divisible into the specified time intervals without remainder, the structure d_missed is used to carry on the surplus ensembles and add them to the ping ensembles of the next file in the same file sequence. If there are ping ensembles left at the end of a file sequence, they will not be included in the averaging.

First, a check is done whether any ping ensembles from the previous file were carried forward. If that is the case, and the bin depth is the same in both files, they are added to the current file in the loop. A depth range for the reference layer velocity is set as is the maximum number of depth bins.

Pings are averaged in intervals determined by *superaverage* and using the time stamps in *OS75_sgl_ping.nav.txyX* where *X* is either 1 or 2 depending on *which_prdid_fix*.

Throughout the routine, there are various occasions where (usually) three dimensional arrays are split up into several 2d-arrays. This is done using the reshape-command and the size of the velocity fields. To avoid problems when the original velocity field is 2d instead of 3d, a check is introduced and the variable containing the size of the field is adjusted.

Several variables are extracted and derived: the reference layer velocity (zonal and meridional) as mean of the horizontal velocities in the depth range specified by *ref_uplim* and *ref_lowlim*; absolute velocities by adding the ship velocity to the horizontal velocities; percent good from the fourth beam; a value for bottom range for each ping ensemble with the condition that it is between 50 and 1200 m depth and using the median of the four beams; the difference between the headings from the .ENX- and from the .N2R-file (set to NaN if the .ENX-heading does not change for two successive ping ensembles); pitch and roll (set to NaN if data is missing, i.e. > 998); the PC clock offset; the echo intensity as mean over all beams.

The navigation data is set to NaN for ping ensembles where there is no velocity data in any of the beams and any of the depth bins. For the averaging, the heading is broken up into components (-cos and sin) and reconverted to angles in degrees afterwards.

Of the extracted variables, the ones included in the averaging are: absolute velocity (all three directions), reference velocity, heading, difference in .ENX- and .N3R-heading, PC clock offset, echo intensity, percent good, and bottom range. Additionally, ship velocity and navigation data (time, longitude, latitude) are averaged. For pitch and roll, the standard deviation is calculated.

The data from ping ensembles that were remainders after the averaging is written to *d_missed* and returned to the main routine. The averaged absolute velocity is converted back to velocity relative to the ship by subtracting the averaged ship velocity. The reference layer velocity is then recalculated from the resulting averaged (relative) velocity. The averaged variables are added to the structure *OS75_ave_ping* as are the variables depth and *ref.bins* (=numbers of the bins in the reference layer). The structure is then returned to the main routine.

average_pings.m is the last routine called within the loops through all files in a file sequence and through all file sequences specified. At the end of the loops, the structure *OS75_ave_ping* contains averaged data for all files included in the processing. Before the loops are left, the array *bindepth* containing bin depths for each of the averaged velocity profiles is created.

Next steps are the final part of the calibration, blanking the bottom, and removing the ship velocity from the ADCP velocity data.

calib_points_wt.m   If there is no bottom track data available, the calibration is done using water track. Again, the search for possible calibration points is done using 2 minute averages produced by ave_for_calib.m. First differences are calculated from the average data for the reference velocities (i.e. the water velocities in the reference layer specified by *ref_uplim* and *ref_lowlim*) du and dv, and the ship velocities dsu and dsv. Of those, only differences were considered for when ship speed exceeded 3 m/s between ensembles not more than 5000 m or 3600 s apart. Using the Matlab function fminsearch.m, the following function was minimized for phi and A:

$$f(A,\alpha) = \left(Adu\cos\alpha - Adv\sin\alpha + dsu\right)^2 + \left(Adu\sin\alpha + Adv\cos\alpha + dsv\right)^2$$

Values for A and phi are written to the array alpha together with relevant heading, navigation, and velocity data, and alpha is handed back to the main routine.

calib_calc_wt.m After alpha has been created in calib_points_wt.m, it is passed on to this subroutine. Here, average, median, and standard deviation for phi and A are calculated and written to *cal_file_wt*. The average or the median should then be used during the second run of OS75_DY017.m for misalignment and amplitude correction. Several plots of the misalignment and the scaling are also produced and stored in *adcp_correction_stats.ps*.

calib_calc_bt.m During the first run of OS75_DY017.m, the misalignment angle and the scaling factor which are to be used for the second run are calculated here. In the second run, the results for phi and A should be closer to zero and one, respectively, than before.

The arguments handed over are *cal_file*, which specifies the file with the calibration point data, cruise, *misalignment_xb* and *amplitude_xb*, which are used for the plots created in this routine. After *cal_file* is read in, scaling factors and misalignment angles outside the interval average ± standard deviation are sorted out.

From the remaining points, the average, the median and the standard deviation for A and phi are calculated and added to the structure *cal*. The median is less affected by outliers which might have survived the screening in calib_points_bt.m and calib_calc_bt.m and should therefore be used as correction value in the second run.

Before returning to the main routine, a plot showing the distribution of the misalignment angles and the scaling factors and their temporal evolution is produced. (After returning to the main program, the plot is written to the file *adcp_calib_calc.ps*.)

bt_mask.m *OS75_ave_ping* and *bindepth* are passed on to this routine. Here, a mask is created using the bottom range *bt.range*. With this mask, velocity data below 86% of the bottom range (= water depth) is set to NaN. The structure containing the modified velocity fields is returned to the main routine.

abs_vel.m *OS75_ave_ping* and *bindepth* are handed over from the main routine. In order to derive absolute water velocities independent of the ship movement, the east- and northward ship velocity is added to the horizontal water velocity (*OS75_ave_ping.vel*). The same is done for the velocity in the reference layer (*OS75_ave_ping.ref.vel*). The resulting absolute velocities, the navigation data and the depth array (set to *bindepth*) are handed back to the main routine within the structure *OS75_abs*.

Helper routines: julian.m, sw_dist.m, uvrot.m, rot_fun_1.m, mfilter.m These routines are called on various occasions during the processing. sw_dist.m is part of the CSIRO Seawater toolbox.

Overview of output files

CRUISE_xxx_yyyyyy_raw.mat

Note: there are a few instances where structures in the OS150 output still have the prefix 'OS75'. The same Matlab scripts are used for both, and I have not yet managed to iron

out all of these instances. It's only a naming convention and the files concerned are not otherwise affected.

The structure *OS75_raw* in this file contains the raw, unedited data from the .ENX-file as read in in include_att_disc2.m and read_nmea_att_disc2.m. The structure consists of:

- vel, cor, amp, pg (arrays of size [number of bins x number of beams x number of ensembles]): velocity, correlation magnitude, echo intensity and percent good for the four beams.

- heading, pitch, roll as [1 x number of ensembles]-array.

- temperature, soundspeed: [1 x number of ensembles]-array. The temperature here is the temperature of the water at the transducer head. It is either set manually or measured. The soundspeed is calculated or set manually.

- dday, ens_num,num pings: [1 x number of ensembles-]array. dday is decimal day, ens_num the ensemble number of the pings, and num ping the number of pings in each ensemble.

- bt: structure containing the bottom track data:

    - vel, range, cor, amp, rssi (arrays of size [4 x number of ensembles]): bottom track velocity, range, correlation magnitude, echo intensity and receiver signal strength indicator for the four beams

- nav: structure containing navigation data:

    - sec pc minus utc: [number of ensembles x 1]-array containing the PC clock offset in seconds;

    - txy1, txy2: [3 x number of ensembles]-arrays; first row: time in decimal Julian days, second row: longitude, third row: latitude. txy1 is data from the first $PRDID -fix after the previous ADCP ping, txy2 is

    from the last $PRDID -fix before the actual ADCP ping.

- config: structure containing the setup information about the OS75 and VmDas

- depth: [1 x number of bins] array. The array contains the depth of the bins in the configuration used for the actual file sequence.

- error: if reading of data fails, an error message will be stored here, otherwise it should be empty. There is one such file for each .ENX-file in a file sequence.

CRUISE_xxx_000000_att.mat

In this file, the structure *att* contains the attitude information from all .N2R-files of a file sequence, read during read_nmea_att_disc2.m. This includes the following [1 x number of ensembles]-arrays:

• heading, pitch, roll;

• pc_time: time from the ADCP PC clock;

• pc_time_offset: offset of the ADCP PC clock from UTC in seconds;

• ens_num: the ping ensemble number.

Per file sequence, one file CRUISE_xxx_000000_att.mat is produced.

CRUISE_xxx_yyyyyyd_att.mat

For each file in a file sequence, attitude data is extracted and saved in CRUISE_xxx_yyyyyyd_att.mat. It contains a structure *att* which consists of the following arrays of size [1 x number of ensembles] per .ENX-file:

- att_heading, att_pitch, att_roll: heading, pitch and roll from the .N2R-files for the ping ensembles in the corresponding .ENX-file;

- heading_orig: heading from the .ENX-file;

- ens_num: the ping ensemble number;

- lat: latitude of the ping ensemble.

The difference between att_heading and heading_orig should be small and therefore negligible.

CRUISE_xxx_yyyyyy_sgl_ping.mat

Again, one file with single ping data is produced for each .ENX-file. In the structure *OS75_sgl_ping*, after several steps of quality control, filtering and correcting for misalignment and scaling (after final processing), data from the four beams, bottom track data, navigation data, configuration data and information about the

processing environment are stored:

- all variables that exist in *OS75_raw* in the file CRUISE_xxx_yyyyyy_raw.mat are included;

additional variables:

- filename: CRUISE_xxx_000000;

- path, rawpath: paths to the directories where the processed data is written to (path) and where the raw data files are stored (rawpath);

- att: structure containing heading, pitch, roll, and PC clock offset;

- heading_orig: [number of ping ensembles x 1]-array, heading from the .ENX-file;

- ship velocity: [2 x number of ping ensembles]-array, containing the eastward (first row) and the northward (second row) ship velocity.

CRUISE_cal_points.mat

In this file, all information at bottom track calibration points needed for the calculation of misalignment angle and scaling factor are stored. This includes:

- bt: structure with bottom track data: arrays vel ([2 x number of calibration points]), speed, heading, and range ([1 x number of calibration points]);

- vel: [number of bins x 2 x number of calibration points]-array of east- and northward velocity heading: [1 x number of cal. points]-array; heading from .N1R-data; nav: structure containing txy1 data at the calibration points;

- ship speed, ship heading: [1 x number of cal points]-arrays;

- scaling, phi: scaling factor and misalignment angle at each calibration point; [1 x number of cal. points]-array;

- intervals: stats for each interval of successive calibration points; see description of routine calib_points_bt.m;

- mode: [1 x number of cal points]-array. 1 or 10 for each calibration point depending on broadband or narrowband mode.

- which file: [number of cal points x 16]-character array with file name of the file the calibration point is from.

- stat: structure with values for the scaling factor (a) and the misalignment angle (phi) as calculated in the routine calib_calc_bt.m; the values stored here after the first run of the main routine OS75_DY017.m are the ones that should be used for the second run!

Only one file for all file sequences processed in a run is created.

CRUISE_cal_points_wt.mat

If no bottom track data is available, calibration is done using water track. For this, the array alpha is created. From data in alpha, the misalignment angle phi and the scaling factor scaling are derived and alpha, phi, and scaling are stored in this file.

CRUISE_000_000000_zz_ave_ping.mat

(zz=highest file ensemble number included in the processing)

The structure *OS75_ave_ping* contains data after averaging over a chosen time interval (xyz = number of velocity profiles after averaging):

- vel: [number of bins x 3 x xyz]-array of average velocity (zonal, meridional and vertical);

- amp, pg: [number of bins x xyz]-arrays; echo intensity and percent good;

- ship velocity: [2 x xyz]-array of zonal and meridional ship velocity; if bottom track velocity is available, then the ship velocity equals the bottom track velocity;

- heading: [1 x xyz]-array;

- nav: structure containing txy1: [3 x xyz]-array of time (decimal Julian days), longitude and latitude;

- att: structure containing:

  - heading difference: [1 x xyz]-array of the difference between heading from .ENX and .N2R (hopefully equal to zero);

  - pitch, roll, pc time: [1 x xyz]-arrays;

- ref: structure with velocity ([2 x xyz]-array): average over the reference layer, and bins: vector containing the depth bins that lie within the reference layer;

- bt: structure containing range: [1 x xyz]-array of bottom track range;

- depth: [1 x number of bins]-array (bin depths of the setting of the last file sequence processed).

CRUISE_000_000000_zz_abs.mat

(zz=highest file ensemble number included in the processing) In this file, both *OS75_abs* and *OS75_ave_ping* are saved. The latter contains the same fields as in

CRUISE_000_000000_zz_ave_ping.mat, where only the values in the velocity field are changed.

Additionally, the variable bindepth is included.

OS75_abs includes (xyz = number of velocity profiles after averaging):

- vel: [number of bins x 2 x xyz]-array of absolute velocity (zonal, meridional), i.e. horizontal velocities are corrected for ship velocity;

- nav: structure containing txy1: [3 x xyz]-array of time (decimal Julian days), longitude and latitude;

- ref: structure with velocity ([2 x xyz]-array): average over the reference layer, and bins: vector containing the depth bins that lie within the reference layer;

- depth: [number of bins x xyz]-array (bin depths corresponding to the settings used for the velocity profiles).

<u>DY017 File generation and calibration</u>

Typically, a new file was generated daily to keep track of the ADCP behaviour. This is good practice as problems with the ADCP can develop which are hard to diagnose using only the VMDAS display.

Raw data files and processed data files in MATLAB format will be logged with BODC after the cruise, the approximate total quantity of data will be 6GB. Raw data for the 75 kHz ADCP are divided into around 20 series (**OS075_DY017003_000000** to **OS075_DY017024_000000**), with some gaps. Raw data for the 150 kHz ADCP are divided into around 20 series (**OS150_DY017000_000000** to **OS150_DY017023_000000**), with some gaps. Within each series files are subdivided into files of maximum 10MB in size. Series number is incremented each time VMDAS is stopped and restarted; the number of sub-files per series is therefore variable.

DY017 operated both on and off the shelf, but bottom tracking was switched on for the majority of the cruise. Alignment and amplitude corrections were calculated for the whole cruise period and were as follows:

OS150 files 3-11

misalignment_xb = 45.3847º

amplitude_xb = 1.0020

OS150 files 12-23

misalignment_xb = 0.3847º

amplitude_xb = 1.0020

OS75 files 5-24

misalignment_xb =0.8262 º

amplitude_xb = 1.007092

File sequences during DY017

OS75 Raw Data Files

Date	Time	Filename	File open/closed	Comments
20/10/2014	18:57	OS075_DY017003_000000	opened	**NOTE BEAM 4 MISSING
20/10/2014	19:52	OS075_DY017003_000000	closed	
20/10/2014	19:55	OS075_DY017004_000000	opened	commence test run of VMADCP around Land's end and thru Irish Sea
21/10/2014	15:42	OS075_DY017004_000000	closed	
21/10/2014	15:42	OS075_DY017005_000000	opened	Routine daily processing
22/10/2014	11:02	OS075_DY017005_000000	closed	
22/10/2014	11:02	OS075_DY017006_000000	opened	Routine daily processing
22/10/2014	20:25	OS075_DY017006_000000	closed	END BOTTOM TRACK
22/10/2014	20:28	OS075_DY017007_000000	opened	START WATER TRACK
23/10/2014	08:39	OS075_DY017007_000000	closed	
23/10/2014	08:39	OS075_DY017008_000000	opened	Routine daily processing
23/10/2014	11:18	OS075_DY017008_000000	closed	
23/10/2014	11:18	OS075_DY017009_000000	opened	Restarted to try to solve data screening problem
23/10/2014	13:04	OS075_DY017009_000000	closed	END WATER TRACK
23/10/2014	13:04	OS075_DY017010_000000	opened	START BOTTOM TRACK
23/10/2014	14:43	OS075_DY017010_000000	closed	
23/10/2014	14:43	OS075_DY017011_000000	opened	
23/10/2014	18:43	OS075_DY017011_000000	closed	Closed to check ADCP setup - nothing altered
23/10/2014	18:44	OS075_DY017012_000000	opened	
24/10/2014	08:54	OS075_DY017012_000000	closed	
24/10/2014	08:54	OS075_DY017013_000000	opened	Routine daily processing
25/10/2014	10:12	OS075_DY017013_000000	closed	Remaining 3 beams noted as very short range and flaky. Noticeable now in deep water.
25/10/2014	10:12	OS075_DY017014_000000	opened	Routine daily processing
26/10/2014	09:21	OS075_DY017014_000000	closed	
26/10/2014	09:21	OS075_DY017015_000000	opened	Routine daily processing
27/10/2014	09:05	OS075_DY017015_000000	closed	
27/10/2014	09:05	OS075_DY017016_000000	opened	Routine daily processing
27/10/2014	09:40	OS075_DY017016_000000	closed	CLOSED TO INSTALL ALTERNATE DECK UNIT (attempt to resolve beam 4 dropout)
28/10/2014	11:20	OS075_DY017017_000000	opened	RESTARTED USING ALTERNATE DECK UNIT Beam 4 dropout appears to be resolved
29/10/2014	07:42	OS075_DY017017_000000	closed	**NOTE file _002 breaks the processing. Date var wroing length
29/10/2014	07:42	OS075_DY017018_000000	opened	Routine daily processing
30/10/2014	10:20	OS075_DY017018_000000	closed	
30/10/2014	10:20	OS075_DY017019_000000	opened	Routine daily processing
31/10/2014	11:00	OS075_DY017019_000000	closed	
31/10/2014	11:00	OS075_DY017020_000000	opened	Routine daily processing
01/11/2014	10:40	OS075_DY017020_000000	closed	
01/11/2014	10:40	OS075_DY017022_000000	opened	Routine daily processing - file skipped as restarted to try to improve poor penetration
02/11/2014	08:25	OS075_DY017022_000000	closed	
02/11/2014	08:25	OS075_DY017023_000000	opened	Routine daily processing
03/11/2014	08:20	OS075_DY017023_000000	closed	
03/11/2014	08:20	OS075_DY017024_000000	opened	Routine daily processing
05/11/2014	09:30	OS075_DY017024_000000	closed	

Table 4: List of OS75 raw data files collected during DY017

OS150 Raw Data Files

Time	Filename	File open/closed	Comments
18:47	OS150_DY017000_000000	opened	
18:49	OS150_DY017000_000000	closed	
18:49	OS150_DY017001_000000	opened	
19:53	OS150_DY017001_000000	closed	
19:53	OS150_DY017002_000000	opened	commence test run of VMADCP around Land's end and thru Irish Sea
15:42	OS150_DY017002_000000	closed	
15:42	OS150_DY017003_000000	opened	Routine daily processing
11:03	OS150_DY017003_000000	closed	
11:03	OS150_DY017004_000000	opened	Routine daily processing
20:31	OS150_DY017004_000000	closed	END BOTTOM TRACK
20:34	OS150_DY017005_000000	opened	START WATER TRACK
08:39	OS150_DY017005_000000	closed	
08:39	OS150_DY017006_000000	opened	Routine daily processing
11:17	OS150_DY017006_000000	closed	
11:17	OS150_DY017007_000000	opened	Restarted to try to solve data screening problem
13:04	OS150_DY017007_000000	closed	END WATER TRACK
13:04	OS150_DY017008_000000	opened	START BOTTOM TRACK
14:43	OS150_DY017008_000000	closed	
14:43	OS150_DY017011_000000	opened	Serial cable failure on files 9 and 10
18:39	OS150_DY017011_000000	closed	CHANGE CALIBRATION - TRANSDUCER ROTATION SET TO -45 DEGREES IN VmDas.
18:43	OS150_DY017012_000000	opened	File 12 has new calibration applied.
08:54	OS150_DY017012_000000	closed	
08:54	OS150_DY017013_000000	opened	Routine daily processing
10:12	OS150_DY017013_000000	closed	75kHz noted as short range and flaky; not entirely sure about 150 either. Monitor.
10:12	OS150_DY017014_000000	opened	Routine daily processing
09:21	OS150_DY017014_000000	closed	
09:21	OS150_DY017015_000000	opened	Routine daily processing
09:05	OS150_DY017015_000000	closed	
09:05	OS150_DY017016_000000	opened	Routine daily processing
09:55	OS150_DY017016_000000	closed	
09:55	OS150_DY017017_000000	opened	Routine daily processing
07:45	OS150_DY017017_000000	closed	
07:45	OS150_DY017018_000000	opened	Routine daily processing
10:20	OS150_DY017018_000000	closed	
10:20	OS150_DY017019_000000	opened	Routine daily processing
11:00	OS150_DY017019_000000	closed	
11:00	OS150_DY017020_000000	opened	Routine daily processing
10:40	OS150_DY017020_000000	closed	
10:40	OS150_DY017020_000000	opened	Note penetration was particularly poor this morning; restarting vmdas seemed to improve slightly
08:25	OS150_DY017021_000000	closed	
08:25	OS150_DY017022_000000	opened	Routine daily processing
08:20	OS150_DY017022_000000	closed	
08:20	OS150_DY017023_000000	opened	Routine daily processing
09:30	OS150_DY017023_000000	closed	

Table 5: List of OS150 raw data files collected during DY017

Processed data

It was initially hoped that it would be possible to generate one large file from the post-processing for each ADCP, but as different ADCP alignments were used in the early stages of the cruise the final processed file structure is as follows:

OS075_DY01700x_000000_23_abs; series 5-24, 75 kHz; 18:43 15:42 21/10/14 – 09:30 05/11/14 Majority of cruise. First few days are poor quality due to beam 4 failure.

OS150_DY01700x_000000_11_abs; series 4-11, 150 kHz; 11:03 22/10/14 to 18:39 23/10/14 (Steam across Malin Shelf towards Minch). The misalignment adjustment in this file is ~45° to account for the misalignment in ADCP setup.

OS150_DY01700x_000000_23_abs; series 12-23, 150 kHz; 18:43 23/10/14 to 09:30 05/11/14 Remainder of cruise to southern Irish Sea. The misalignment adjustment in this file is ~0° to account for the misalignment in ADCP setup.

Dissolved oxygen measurements

Victoria Hemsley

Cruise objectives

The objectives of the dissolved oxygen analyses were to provide calibration data for the oxygen sensors mounted on the CTD frames used during cruise DY017. For this, Winkler titrations were performed on water samples collected from the Niskin bottles mounted on the CTD frame.

Methods

Dissolved oxygen samples were taken from the stainless steel and titanium CTD casts and were the first samples to be drawn from the Niskin bottles. Up to twelve oxygen samples were collected in duplicate from stainless steel CTD casts but a maximum of five duplicate samples were collected from the titanium CTD casts due to water constraints. The depths sampled were decided by examination of the oxygen trace during the downcast and samples were generally collected from regions without rapid changes in dissolved oxygen concentration. All samples were drawn through short pieces of silicon tubing into clear, precalibrated narrow necked borosilicate flasks. The temperature of each water sample was measured using an electronic thermometer probe and used to calculate any temperature dependant changes in the sample bottle volumes.

Each sample was fixed immediately using 1 ml of manganese chloride and 1 ml of alkaline iodide. The samples were shaken thoroughly and then left to settle before being shaken again. Samples were typically analysed within a few hours of collection but in cases where samples were collected overnight analysis could have occurred up to 12 hours after collection.

All samples were analysed following the procedure outlined in Holley and Hydes (1995). Samples were first acidified with 1 ml of sulphuric acid immediately before titration against sodium thiosulphate and continuously stirred using a magnetic stirrer. The Winkler whole bottle titration method with amperometric endpoint detection (Culberson and Huang, 1987), using a Metrohm titrino was used to determine the oxygen concentration.

The normality of the sodium thiosulphate titrant was checked every few days using a potassium iodate standard. This was done four times throughout the cruise. Thiosulphate standardisation was carried out by adding 10 ml of 5 N iodate solution after the other reagents had been added in reverse order to a sample of milli-Q water. Results from this standardisation check were used in the calculation of final dissolved oxygen concentrations. The volume of sodium thiosulphate needed to titrate the 10 ml potassium iodate standard can be seen in **Figure 7**.

The amount of dissolved oxygen in the reagents was also checked by performing a blank correction. This was also done using potassium iodate. The reagents were added to a sample of milli-Q water in reverse order, as with the thiosulphate standardisation method, and then 1 ml of 5 N iodate was added. This was titrated to completion and this process repeated 5 times. The blank was calculated as the average of all five blanks (or remaining samples once outliers were excluded). This mean value was then also used in the calculation of the final dissolved oxygen concentrations.

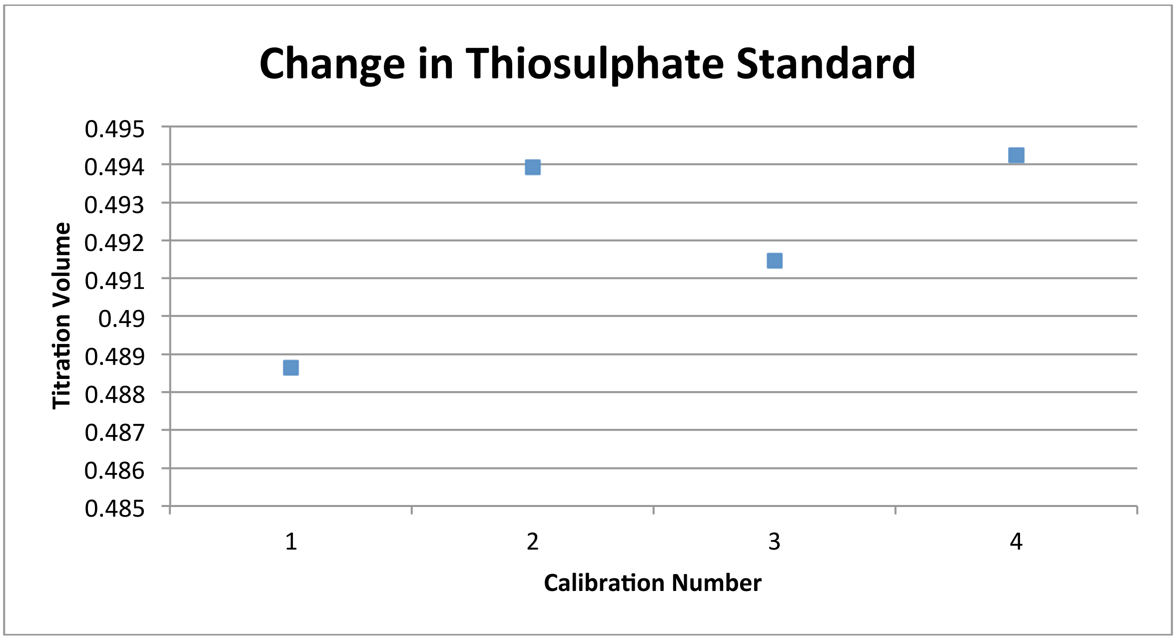


Figure 7: Sodium thiosulphate standardization results.

Sampling

A summary of all sampling during DY017 is presented in **Table 6**.

CTD cast	Number of depths sampled	Niskin bottle sampled
1	0	-
2	2	3, 6
3	10	1, 3, 5, 7, 9, 15, 17, 19, 21, 23
4	3	1, 4, 6
5	8	2, 4, 6, 8, 10, 12, 14, 16
6	8	1,3,7,9,13,15,21,23
7	4	1, 5, 10, 12
8	12	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23
9	5	4, 25, 17, 21, 24
10	11	1, 3, 5, 7, 9, 10, 11, 15, 17, 19, 22
11	3	1, 4, 6
12	7	1, 3, 7, 10, 14, 18, 20
13	3	1, 3, 6
14	8	1, 3, 7, 9, 13, 15, 20, 23

15	11	2, 3, 5, 7, 9, 11, 13, 15, 17, 20, 21
16	0	-
17	12	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23
18	0	-
19	7	4, 7, 9, 11, 13, 15, 19
20	0	-
21	12	1, 3, 5, 6, 7, 11, 12, 13, 16, 17, 18, 21
22	0	-
23	12	3, 5, 7, 9, 10, 12, 14, 15, 16, 17, 18, 22
24	6	1, 2, 7, 8, 12, 15
25	0	-
26	12	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 21
27	5	1, 7, 13, 17, 21
28	5	1, 11, 13, 15, 17
29	4	3, 5, 7, 15
30	0	-
31	6	1, 3, 5, 10, 15, 19
32	6	1, 5, 9, 15, 17, 21
33	0	-
34	6	1,5 ,7, 9, 17, 19
35	0	-
36	4	8, 10, 13, 15
37	12	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23
38	12	1, 3, 5, 7, 8, 9, 11, 12, 14, 15, 16, 19
39	0	-
40	0	-
41	12	1, 3, 5, 7, 9, 11, 12, 13, 14, 15, 17, 19
42	5	1, 5, 7, 14, 20
43	0	-
44	4	2, 10, 18, 20
45	0	-
46	12	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23
47	0	-
48	6	1, 5, 7, 9, 11, 13
49	6	1, 3, 7, 11, 15, 19
50	4	3, 11, 23, 24
51	3	1, 6, 15
52	4	2, 8, 21, 24
53	0	-
54	0	-
55	0	-
56	12	1, 3, 5, 7, 9, 11, 12, 13, 15, 17, 19, 21

Table 6: Summary of all sampling for dissolved oxygen

Dissolved Inorganic Carbon, Total Alkalinity

Nikki Clargo, Sue Hartman, Caroline Kivimäe, Lesley Salt

Methodology

Sampling and analysis for carbonate system parameters broadly followed the standard operating procedures outlined by Dickson et al., 2007. Water samples of 0.6 L were collected from the CTD niskin bottles into borosilicate sample bottles with plastic caps, using tygon tubing. Samples were collected from every station occupied during the cruise, except F7 where no bottles were fired. Samples were collected from the stainless steel CTD except on station C5, G4 and G5 where only the titanium CTD was deployed. In general one duplicate sample was collected on each station.

No. depths sampled	
Transect A	56
Transect B	6
Transect C	99
Transect D	65
Transect E	93
Transect F	83
Transect G	74
Total	476

Sample analysis commenced immediately after collection and analysis of profiles was in all cases completed within 24 hours after sampling (most often within 12 hours). All analyses were performed on two VINDTA 3C (Versatile INstrument for the Determination of Total Alkalinity, designed and built by Dr. L. Mintrop, Marine Analytics and Data, Kiel, Germany). These instruments were slightly modified: the peristaltic sample pump was replaced with an overpressure system (~0.5 bar overpressure) and a 1 m long (though coiled) 1/8" stainless steel counter-flow heat exchanger that was placed between the sampling line and the water bath circulation circuit. This setup allows for the rapid, convenient and bubble-free loading of the pipettes with sample of 25 ºC (± 0.1 ºC), irrespective of the samples' initial temperature.

There were also underway samples collected from the ship's seawater system, often once a day but more often during transit to and from the study region. These samples were poisoned with 50 µl 50% mercuric chloride solution. About half of these samples were analyzed onboard while the rest will be analyzed back at NOC. Salinity samples were collected together with the DIC/TA samples until the 4th of Nov to calibrate the thermosalinograph.

The analysis and correction of the raw data is in progress. Final results will be available within one month.

Dissolved inorganic carbon (DIC)

Dissolved inorganic carbon (DIC) was determined by coulometric titration. An automated extraction line takes a 20 mL subsample which is subsequently purged of CO_2 in a stripping chamber containing ~1 mL of ~8.5% phosphoric acid (H_3PO_4). A stream of nitrogen carries the CO_2 gas into a coulometric titration cell via a condenser, to strip the gas flow of any water.

The CO_2 reacts with the cathode solution in the cell to form hydroxyethylcarbamic acid, which is then titrated with hydroxide ions (OH^-) generated by the coulometer. The current of the coulometer is then integrated over the duration of the titration to obtain the total amount of carbon titrated. The power to the two coulometers were stabilized with a UPS.

Total Alkalinity (TA)

Determinations of total alkalinity (TA) were performed by acid titration that combines aspects from both the commonly used 'closed cell' method and the 'open cell' method, following the VINDTAs standard settings. A single 20 L batch of acid of ~0.1M and salinity 35 was prepared to be used by both VINDTAs. Potential drift in acid strength due to HCl-gas loss to acid vessel headspace is not accounted for.

Certified reference material (CRM, Batch #140) obtained from Dr. Andrew Dickson at Scripps Institute of Oceanography (San Diego, California) was used for calibration purposes and quality control for both DIC and TA.

Organic nutrients and stable isotopes

Nealy Carr and Carl Springys

Aims during DY017

The aims of the organic nutrient biogeochemistry team were to (a) identify gradients in organic nutrients across the shelf edge of the Malin and Western Irish Shelf and (b) collect seawater samples to determine the stable nitrogen and oxygen isotope composition of nitrate (δ15N and δ18O-nitrate) in deep waters.

Sampling

A series of sampling regimes were followed: (a) four cross shelf transects consisting of 5 -7 stations (Transect A, C, E and F), and (b) sampling surface water from the uncontaminated seawater supply (**Table 7).**

Analytical methods

Dissolved organic nutrients: Seawater was collected in 1L pre-cleaned (10% HCl) HDPE bottles and filtered through a pre-combusted glass fibre filter (nominal pore size 0.7 μm) using a pre-cleaned glass filtration rig. Filtered seawater samples were collected into acid-washed HDPE bottles and frozen immediately at -20°C. The concentration of dissolved organic carbon and dissolved organic nitrogen will be determined by high temperature catalytic oxidation, and dissolved organic phosphorous using UV digestion .

Chromophoric/Fluorescent dissolved organic matter (CDOM/FDOM): Seawater from up to 11 depths was filtered from the same sample in the same manner as above for dissolved organic nutrients. The filtrate was then filtered through Durapore membrane filters (0.22 μm), collected in pre-cleaned 125 mL HDPE bottles and stored in the dark at 4°C until analysis. Samples were analysed on-board within 5 days of collection using a Shimadzu spectrophotometer (UV-1650 PC) and Horiba scanning spectrofluorometer (Fluoromax 4).

Emission excitation matrices and spectral absorbance indices will be employed to determine the likely source of organic matter on the Malin Shelf and Western Irish Sea shelf.

Stable nitrogen and oxygen isotope composition of nitrate: Seawater from up to 11 depths was filtered from the same sample in the same manner as above for dissolved organic nutrients. The filtrate was collected in pre-cleaned (10% HCl) 60 mL HDPE bottles and immediately frozen at -20°C. The stable nitrogen and oxygen isotope composition of nitrate ($\delta^{15}N$ and $\delta^{18}O$ of nitrate, respectively) will be analysed according to methods described and updated by McIlvin and Casciotti (2011) using a Gas Bench attached to a Thermo Finnigan isotope ratio mass spectrometer. This stable isotope approach will provide insight into the source and cycling of nitrate at the shelf edge.

Amino Acids: Seawater from up to 11 depths was filtered from the same sample in the same manner as above for dissolved organic nutrients. The filtrate was collected in pre-cleaned (10% HCl) and combusted 22 mL glass vials, capped and immediately frozen at -20°C. Isomeric ratios of amino acids present will be determined using high performance liquid chromatography and will provide insight into the degradation state and lability of DOM across the shelf region.

Particulate Organic Matter (POC, PON and POP): Up to 3 L of seawater from between 4 to 11 depths were filtered through pre-combusted acid rinsed (10% HCl) fibre filter (nominal pore size 0.7 μm) using a pre-cleaned triple-port filtration rig. The filter was collected onto muffled foil in a pre-cleaned petri dish and immediately frozen at -20°C. POC and PON will be determined using standard methodology on a CHN analyser. POP will be measured following combustion and acid hydrolysis; lipid and pigment biomarkers and amino acids will be used to determine particle sources and degradation state.

Station	Latitude (N)	Longitude (W)	Water Depth (approx m)	Date Sampled	CTD Number
A1	058° 36.130'	005° 48.138'	118	23/10/2014	003
A2	058° 48.026'	006° 11.617'	121	23/10/2014	005
A3	058° 57.58'	006° 30.00'	107	24/10/2014	006
A4	059° 11.770'	006° 56.960'	234	24/10/2014	008
A5	059° 23.827'	007° 19.454'	1000	24/10/2014	010
B1	058° 26.796'	007° 11.617'	90	27/10/2014	012
C1	058° 01.360'	007° 42.940'	90	27/10/2014	014
C2	058° 4.820'	008° 0.710'	126	27/10/2014	015
C3	058° 8.951'	008° 25.061'	144	27/10/2014	017
C4	058° 13.406'	008° 19.912'	201	27/10/2014	019
C5	058° 17.330'	009° 14.880'	406	28/10/2014	020
C6	058° 21.826'	009° 39.760'	1323	28/10/2014	021
C7	058° 26.006'	010° 04.237'	1880	28/10/2014	023
E1	056° 2.529'	008° 10.985'	140	30/10/2014	031
E2	056° 52.223'	008° 30.013'	133	30/10/2014	032
E3	056° 52.192'	009° 3.518'	200	30/10/2014	034
E4	056° 52.187'	009° 17.917'	1415	30/10/2014	036
E5	056° 52.348'	009° 43.233'	1870	31/10/2014	038

E6	056° 52.211'	010° 5.401'	2100	31/10/2014	037
F1	056° 07.177'	008° 06.149'	120	02/11/2014	049
F2	056° 7.147'	008° 30.90'	129	02/11/2014	048
F3	056° 7.290'	008° 53.870'	139	02/11/2014	046
F4	056° 07.156'	009° 10.609'	205	02/11/2014	044
F5	056° 07.466'	009° 42.089'	1629	02/11/2014	042
F6	056° 7.298'	010° 5.988'	2002	01/11/2014	041

Table 7: Locations of cross-shelf edge stations for transects A, C, E and F, approximate water depth (metres, taken from pressure sensor during CTD casts), date sampled and corresponding CTD number.

Inorganic Nutrient Analysis

Chris Daniels

Cruise Objectives

My objective on cruise DY017 was to measure the concentrations of the inorganic nutrients: TON, silicate and phosphate using segmented flow analysis.

Method

Analysis for micro-molar concentrations of nitrate and nitrite (Total Oxidised Nitrogen or TON), phosphate and silicate was undertaken on a Skalar San+ segmented flow autoanalyser following methods described by Kirkwood (1996). Samples were drawn from Niskin bottles on the CTD into 25ml sterilin coulter counter vials and kept refrigerated at approximately 4^{o}C until analysis, which commenced within 24 hours. Overall 12 runs were undertaken with 1034 samples analysed in total: 681 from the Stainless Steel CTD, 303 from the Titanium CTD, and 50 from the Tow Fish. An artificial seawater matrix (ASW) of 40g/litre sodium chloride was used as the inter-sample wash and standard matrix. A single set of mixed standards were made up by diluting 5mM solutions made from weighed dried salts in 1 litre. The accuracy of the analyser was tested by running certified reference material (CRM) of nutrients on each run. Data processing was undertaken using Skalar proprietary software. The wash time and sample time were 90 seconds; the lines were washed daily with Milli-Q and 10% Decon.

Performance of the analyser

During the first sample run (CTDs 2 – 5), the cadmium column used in the TON line showed significant degradation, and dust entered into the detector during the analysis of CTD 3 such that the TON data for CTDs 3 – 5 was erroneous. These samples were refrigerated until the following day where they were re-run after the cadmium column was replaced.

However, post-processing of runs 2 and 3 (CTDs 3 – 10) showed large standard deviations between replicate samples for the TON line, but not for phosphate or silicate. Further investigation of the source of the variability revealed that the neoprene gloves used during the collection and handling of samples, were the source of the contamination. For the remainder of the cruise, vinyl gloves were used and no further contamination was observed.

Preliminary Data

Data were processed during the cruise and the final quality of these data will take place back at the NOC over the coming months, particularly concerning the TON data from Transect A (CTDs). The quality control process is not expected to significantly change the data from all other transects.

Below in **Figure 8** are the distributions of TON, phosphate and silicate from all Stainless Steel CTDs in transect E.

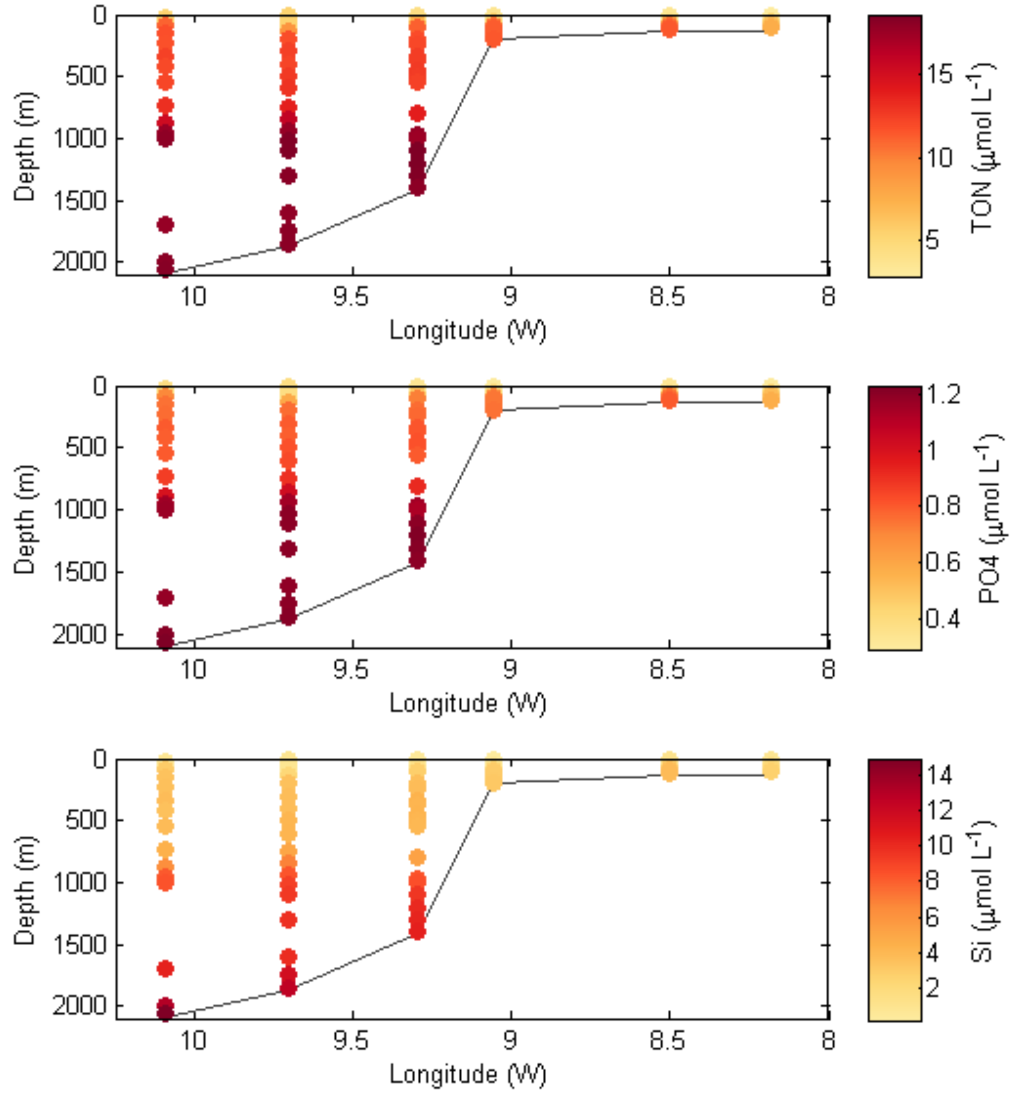


Figure 8: Depth distributions of TON, phosphate and silicate (µmol L^{-1}) for Transect E

POC/PON, POP, BSi and PIC underway and CTD sampling

Stephanie Allen and Lucie Munns

CTD Sampling

For each stainless steel CTD cast (and where necessary from some titanium CTD casts), 2 – 4 litres water from each of 6-8 depths, generally with higher resolution in the surface mixed layer was drawn into 10 L black carboys. In most cases 1 L was filtered for POC/PON, 1 L for POP, and 0.5 for Biogenic Silica and PIC. When water volumes were restricted, a reduced volume of 0.75 L were filtered for POC/PON and POP.

Underway sampling

Occasionally samples were taken from the ships underway supply in the main deck lab and filtered in a similar fashion. This was usually undertaken when the weather prevented the deployment of the CTD rosette.

Filtering of samples

Particulate Organic Carbon (POC) / Particulate Organic Nitrogen (PON)

Between 750ml and 1000ml of seawater was filtered onto an ashed GFF (0.7μm) filter. When filtering was complete the filter was rinsed with 1% HCL and then pre-filtered seawater. The filter was then stored in a labelled cryovial. The label denoted the unique sample number (described below), JDay of collection, time of CTD deployment and volume of sample seawater that was filtered. Samples were placed in an oven set at 50-60°C for 8-12 hours with the lid removed. When removed from the oven the lid was secured, and the cryovial stored.

Note: Pre-filtered seawater was produced during the transit to the Outer Herbrides by collecting underway seawater and filtering it first through ashed GFF filter and then again through a 0.4μm polycarbonate filter.

Particulate Organic Phosphate (POP)

Between 750ml and 1000ml of seawater was filtered onto pre-treated GFF (0.7μm) filters. When filtering was complete the filter was removed and stored in non pre-combusted glass tubes that were labelled. The label denoted the unique sample number (described below), JDay of collection, time of CTD deployment and volume of sample seawater that was filtered. Samples were placed in an oven set at 50-60°C for 8-12 hours without a covering. When removed from the oven parafilm was applied as a lid and the samples stored.

Note: Ashed GFF filters were first pre-treated in a 10% HCL bath for 24 hours, and then transferred to a Milli-Q bath for 12hours, emptied and then applied to another Milli-Q bath for a further 12 hours.

Biogenic Silica (BSi)

500ml of seawater was filtered onto 0.8μm polycarbonate filters with a MF300 backing filter. Once filtering was completed the filter was rinsed with pH adjusted Milli-Q, folded in quarter and stored in a labelled a 15ml centrifuge tube. The label denoted the unique sample number (described below), JDay of collection, time of CTD deployment and volume of sample seawater that was filtered. Samples were placed in an oven set at 50-60°C for 8-12 hours with the lid off. When removed from the oven the lid was secured on the sample and stored.

Particulate Inorganic Carbonate (PIC)
500ml of seawater was filtered onto 0.8μm polycarbonate filter with a MF300 backing filter. Once filtering was completed the filter was rinsed with pH adjusted Milli-Q and stored in a labelled 50ml centrifuge tube. The label denoted the unique sample number (described below), JDay of collection, time of CTD deployment and volume of sample seawater that was filtered. Samples were placed in an oven set at 50-60°C for 8-12 hours with the lid off. When removed from the oven the lid was secured on the sample and stored.

Note: Samples from stations A1 were filtered using 0.4μm polycarbonate filters, however, it was decided that due to allocated processing time it was more effective to change to 0.8μm polycarbonate filters.

Labelling of samples
All samples were labelled to a uniform system (**Table 8**). Each type of analysis, as described above, was given a unique code that is displayed in Table 1 below. This code was then used alongside the station number and niskin bottle number to provide a unique code for each sample undertaken. The code NA12, is described below in its unique parts in **Table 9** as an example.

As well as this unique code, the last three numbers of the JDay, on which the sample was processed, was logged along with the time of the CTD deployment and the volume of water that was filtered.

Sample Code	***Analysis type***
N	POC/PON
P	POP
S	BSi
C	POC

Table 8: Labelling code given to each type of analysis

N	A1	2
Analysis type	Station number	Niskin bottle number

Table 9: Description of CTD sample labelling for sample NA12

For underway samples a similar labelling technique was applied for each analysis type, an example underway code UW1N is described below in **Table 10** as an example. The numbering of underway samples was sequential, and was logged alongside the time that the sample was collected and the JDay, so that a specific coordinate could be produced from the ships logs.

UW	1	N
Underway sample	Sample number (sequential)	Analysis type

Table 10: Description of underway sample labelling for sample UW1N

	Niskin bottle																							
Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
A1		X			X						X					X				X			X	
A2	X		X			X	X		X			X	X		X									
A3	X		X				X			X				X		X			X				X	
A4	X				X				X		X		X				X		X				X	
A5	X			X						X		X			X				X			X		X
B1	X					X			X				X			X						X		
C1		X				X							X			X			X				X	
C2		X			X						X				X					X			X	
C3		X				X		X		X		X		X					X					X
C4		X					X		X			X			X				X				X	
C5	X				X				X	X				X				X						
C6	X		X	X			X				X							X			X			X
C7		X			X					X				X				X		X		X		X
D1		X			X						X				X			X				X		
D2		X									X		X			X		X					X	
D3		X				X					X				X				X				X	
D4		X								X			X				X				X		X	
D5	X				X						X		X		X			X				X		X
E1	X				X					X					X			X			X			
E2		X							X					X			X				X			X
E3		X			X						X				X					X			X	
E4	X				X				X		X					X			X		X			X
E5		X			X			X							X				X			X		X
E6		X					X								X			X		X	X	X	X	
F1		X		X		X						X						X						X
F2		X		X		X						X						X						X
F3		X				X				X				X				X				X		
F4		X							X							X				X		X		X
F5	X										X					X			X		X	X	X	X
F6		X							X			X		X				X		X		X		X
G1		X				X				X						X				X		X		
G2		X							X				X			X				X		X		
G3		X							X				X					X			X		X	
G4		X	X		X	X	X	X																
G5		X				X					X		X		X		X							
G6		X		X						X				X		X			X			X		X

Table 11: Summary table of sampling for particulate material

ADCP lander

John Beaton

Mooring description

One mooring was deployed during the cruise. On 29/10/2014 an acoustic current meter was deployed in support of the UK-OSNAP project by John Beaton for Stuart Cunningham of SAMS. The deployment was named RTADCP1.

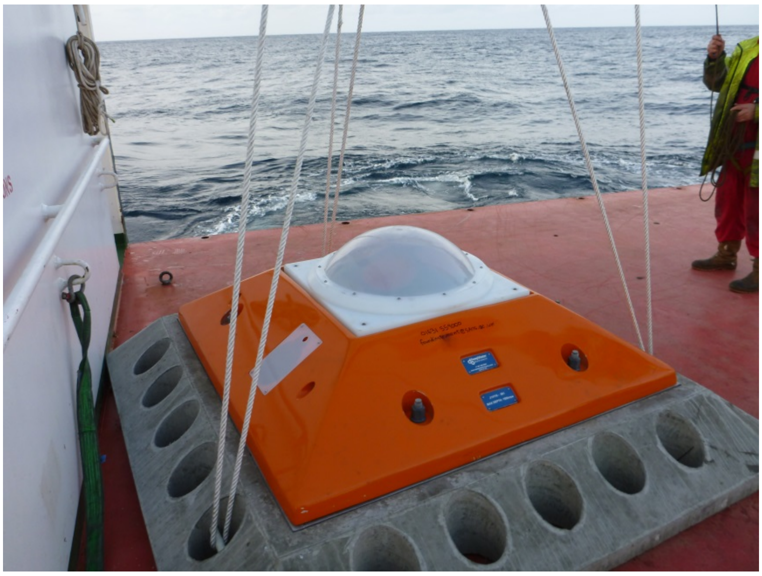


Figure 9: AL-500 with concrete base ready for deployment, ADCP heads protected by white dome.

The plan was to deploy the 75KHz ADCP in a low profile seabed mount at latitude 57.1°N and depth 750m at an expected longitude of approximately 9.33°W. The deployment consisted of a Teledyne RD Instruments 75KHz ADCP in a DeepWater Buoyancy AL-500 Trawl Resistant Bottom Mount (TRBM) with a non-recoverable concrete base (**Figure 9**).

The AL-500 was fitted with a pair of Ixsea AR861 acoustic releases to provide redundancy in the event of individual failure (**Figure 10**). Recovery aids fitted were a Novatech Iridium beacon and a Novatech strobe, both pressure activated on surfacing.

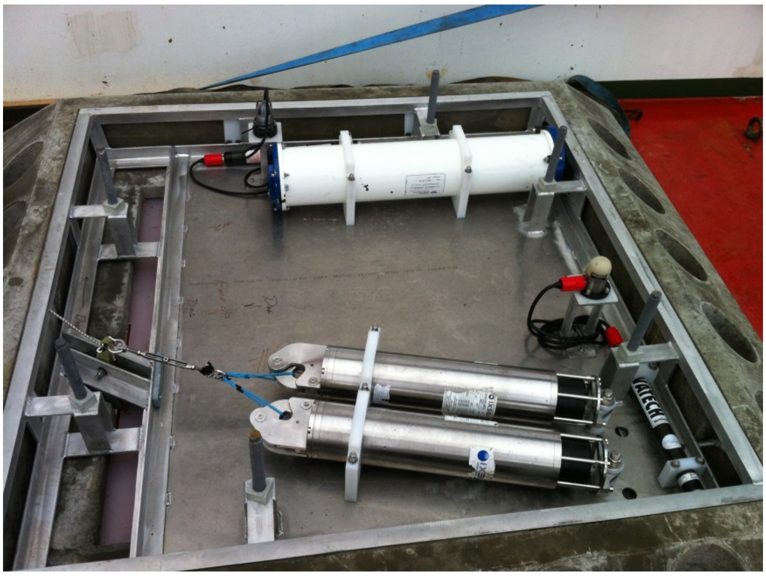


Figure 10: Internal view of Trawl Resistant Bottom Mount showing twin acoustic releases, recovery aids and ADCP battery case.

Deployment method

Deployment was by freefall from the surface with a detachable 'buoyancy parachute' consisting of three 17" Benthos glass spheres on ½" chain above an Ixsea acoustic release that could be released once the frame was confirmed on the seabed. Pre-deployment tests included a pressure and function test of all three acoustic releases by attaching to a CTD frame and lowering to 1000m then firing at 800m.

The entire package was lifted with the port-hand crane and swung out over the stern inside the extended stern gantry. With the entire package under the surface of the water a Seacatch quick release was used to release it from the crane at 1531 (57.10179°N, 9.33682°W). The TRBM and parachute were tracked, using an Ixsea TT801 deck unit, at a descent rate of about 50m/min and was on the bottom at 1546 with a slant range of 789m. Before release was attempted the vessel moved off the drop zone by several hundred meters.

Parachute failure

At 1602 the parachute was released and release confirmations received but it failed to surface maintaining a steady slant range of 935m. Multiple release attempts were made returning slight variations in range but due to the swell and position keeping it was not possible to say whether the height the parachute had changed. At 1608 a diagnostic test was made that confirmed the release was vertical and the battery voltage was 8.9V.

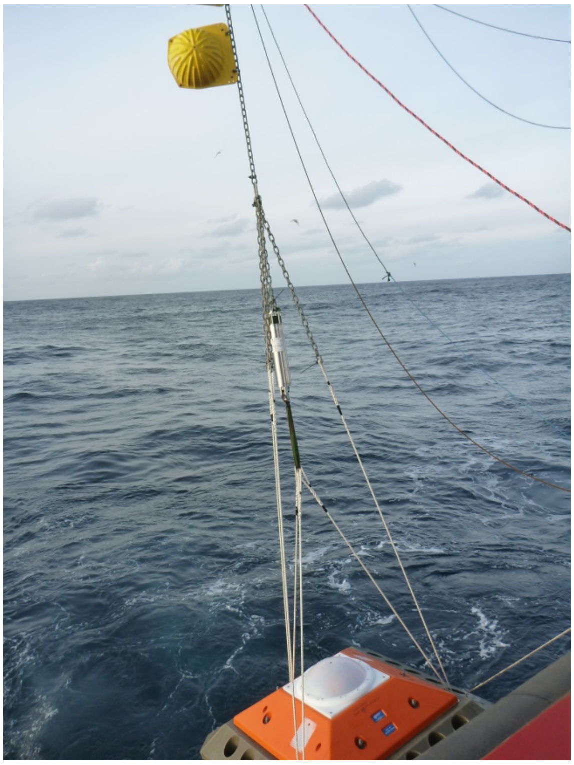


Figure 11: AL-500 showing three-legged bridle and part of buoyancy parachute (top).

It was thought the most likely reason the parachute did not detach successfully was one or more of the eyes of the three-legged bridle suspending the TRBM becoming trapped after the acoustic release was activated (**Figure 11**)

Trilateration

Confirmation of the TRBM's location was carried out by trilateration.

Position 1	57.09818°N, 9.32464°W	slant range	1227m
Position 2	57.09843°N, 9.35067°W	slant range	1184m
Position 3	57.11046°N, 9.34013°W	slant range	1110m

The position of RTADCP1 was fixed at 57.10302°N, 9.33799°W which is 147m NNW of the drop position.

Two days later at 0125 on 31/10/2014 communication was again made with the parachute acoustic release s/n 1916 from position 57.10239°N, 9.32892°W and slant range 938m. The release was confirmed as still in place and in the vertical orientation. Range and diagnostic commands were made to the TRBM's internal releases, s/n 899 & 1326, to confirm realistic ranges and correct horizontal orientations.

Instrument serial numbers

AL-500 TRBM s/n J14110-001

Teledyne RDI 75KHz ADCP s/n 20467 512Mb memory card

Ixsea AR861 acoustic release s/n 899 A:1A7A R:1A55 D:1A49

Ixsea AR861 acoustic release s/n 1326 A:18B4 R:1855 D:1849

Ixsea AR861 acoustic release s/n 1916 A:090D R:0955 D:0949

Novatech strobe beacon no serial number

Novatech Iridium beacon s/n M00146 IMEI: 300434060123920 on at 1405 29/10/2014

One email alert was received from the Iridium beacon at 1418 prior to deployment.

Recovery

The anticipated recovery date for this mooring is June 2015.

Appendix A- ADCP pre-deployment test.

```
[BREAK Wakeup B]
WorkHorse Broadband ADCP Version 50.40
Teledyne RD Instruments (c) 1996-2010
All Rights Reserved.
>DEPLOY?
Deployment Commands:
CF = 11111 --------------- Flow Ctrl (EnsCyc;PngCyc;Binry;Ser;Rec)
CK ----------------------- Keep Parameters as USER Defaults
CR # --------------------- Retrieve Parameters (0 = USER, 1 = FACTORY)
CS ----------------------- Start Deployment
EA = +00000 -------------- Heading Alignment (1/100 deg)
EB = +00000 -------------- Heading Bias (1/100 deg)
ED = 00000 --------------- Transducer Depth (0 - 65535 dm)
ES = 35 ------------------ Salinity (0-40 pp thousand)
EX = 11111 --------------- Coord Transform (Xform: Type,Tilts,3 Bm,Map)
EZ = 1111101 ------------- Sensor Source (C,D,H,P,R,S,T)
RE ----------------------- Recorder ErAsE
RN ----------------------- Set Deployment Name
TE = 01:00:00.00 --------- Time per Ensemble (hrs:min:sec.sec/100)
TF = **/**/**,**:**:** --- Time of First Ping (yr/mon/day,hour:min:sec)
TP = 01:20.00 ------------ Time per Ping (min:sec.sec/100)
TS = 14/10/20,17:46:18 --- Time Set (yr/mon/day,hour:min:sec)
WD = 111 100 000 --------- Data Out (Vel,Cor,Amp; PG,St,P0; P1,P2,P3)
WF = 0704 ---------------- Blank After Transmit (cm)
WN = 030 ----------------- Number of depth cells (1-128)
WP = 00045 --------------- Pings per Ensemble (0-16384)
WS = 1600 ---------------- Depth Cell Size (cm)
WV = 175 ----------------- Mode 1 Ambiguity Vel (cm/s radial)
>SYSTEM?
System Control, Data Recovery and Testing Commands:
```

```
AC ----------------------- Output Active Fluxgate & Tilt Calibration data
AF ----------------------- Field calibrate to remove hard/soft iron error
AR ----------------------- Restore factory fluxgate calibration data
AX ----------------------- Examine compass performance
AZ ----------------------- Zero pressure reading
CB = 411 ----------------- Serial Port Control (Baud; Par; Stop)
CP # --------------------- Polled Mode (0 = NORMAL, 1 = POLLED)
CZ  ---------------------- Power Down Instrument
FC ----------------------- Clear Fault Log
FD ----------------------- Display Fault Log
OL ----------------------- Display Features List
PA ----------------------- Pre-Deployment Tests
PC1 ---------------------- Beam Continuity
PC2 ---------------------- Sensor Data
PS0 ---------------------- System Configuration
PS3 ---------------------- Transformation Matrices
RR ----------------------- Recorder Directory
RF ----------------------- Recorder Space used/free (bytes)
RY ----------------------- Upload Recorder Files to Host
>TS?
TS 14/10/20,17:46:32 --- Time Set (yr/mon/day,hour:min:sec)
>PS0
  Instrument S/N:  20467
       Frequency:  76800 HZ
   Configuration:  4 BEAM, JANUS
     Match Layer:  10
      Beam Angle:  20 DEGREES
    Beam Pattern:  CONVEX
     Orientation:  DOWN
       Sensor(s):  HEADING  TILT 1  TILT 2  DEPTH  TEMPERATURE
PRESSURE
Pressure Sens Coefficients:
              c3 = +1.773849E-10
              c2 = -1.369659E-06
              c1 = +1.395053E+00
          Offset = -1.095539E+02
Temp Sens Offset:  -0.03 degrees C
    CPU Firmware:  50.40 [0]
   Boot Code Ver:  Required:  1.16   Actual:  1.16
    DEMOD #1 Ver:  ad48, Type:  1f
    DEMOD #2 Ver:  ad48, Type:  1f
    PWRTIMG  Ver:  85d3, Type:   6
Board Serial Number Data:
   48  00 00 07 68 CA 30  09 REC727-1004-06A
   25  00 00 07 28 4B 4E  09 HPA727-3009-00B
   3C  00 00 07 68 C9 DE  09 CPU727-2011-00E
   AB  00 00 07 68 B6 41  09 DSP727-2001-06H
   8B  00 00 07 68 DC 8F  09 TUN727-1005-06A
   5D  00 00 07 68 DF FF  09 HPI727-3007-00A
>PA
PRE-DEPLOYMENT TESTS
CPU TESTS:
  RTC......................................PASS
  RAM.....................................PASS
```

```
  ROM.....................................PASS
RECORDER TESTS:
  PC Card #0...............................DETECTED
    Card Detect............................PASS
    Communication..........................PASS
    DOS Structure..........................PASS
    Sector Test (short)....................PASS
  PC Card #1...............................NOT DETECTED
DSP TESTS:
  Timing RAM...............................PASS
  Demod  RAM...............................PASS
  Demod  REG...............................PASS
  FIFOs...................................PASS
SYSTEM TESTS:
  XILINX Interrupts... IRQ3  IRQ3  IRQ3 ...PASS
  Wide Bandwidth........................***FAIL***
  Narrow Bandwidth.........................PASS
  RSSI Filter.............................PASS
  Transmit.............................***FAIL***
SENSOR TESTS:
  H/W Operation............................PASS
>RS  ERR 005:  EXTRA PARAMETERS ENCOUNTERED
>PC1
BEAM CONTINUITY TEST
When prompted to do so, vigorously rub the selected
beam's face.
If a beam does not PASS the test, send any character to
the ADCP to automatically select the next beam.
Collecting Statistical Data...
  26  26  31  28
Rub Beam 1 = PASS
Rub Beam 2 = PASS
Rub Beam 3 = PASS
Rub Beam 4 = PASS
>CZ
Powering Down
```

Appendix B- ADCP program log file.

```
>>>>>> Function starting 10/26/14 15:28:06 >>>>>>

[BREAK Wakeup B]
WorkHorse Broadband ADCP Version 50.40
Teledyne RD Instruments (c) 1996-2010
All Rights Reserved.
>CR1
[Parameters set to FACTORY defaults]
>CQ255
>CF11101
>EA0
>EB0
>ED0
>ES35
>EX11111
```

```
>EZ1111111
>WA50
>WB1
>WD111100000
>WF704
>WN50
>WP30
>WS1600
>WV175
>TE01:00:00.00
>TF14/10/26 16:00:00
>TP02:00.00
>CK
[Parameters saved as USER defaults]
>The command CS is not allowed in this command file.  It has been ignored.
>The following commands are generated by this program:
>CF?
CF = 11101 --------------- Flow Ctrl (EnsCyc;PngCyc;Binry;Ser;Rec)
>CF11101
>RN RTAD1
>cs
```

Appendix C- Sample Iridium email.

```
> From: NOC Iridium Moorings <Iridium.Moorings@noc.ac.uk>
> Date: 29 October 2014 14:18:28 GMT
> To: NOCS_NMFSS_SM <nocs_nmfss_sm@noc.ac.uk>, "dr400@noc.ac.uk"
<dr400@noc.ac.uk>, "stuart.cunningham@sams.ac.uk"
<stuart.cunningham@sams.ac.uk>, "colin.griffiths@sams.ac.uk"
<colin.griffiths@sams.ac.uk>, "john.beaton@sams.ac.uk"
<john.beaton@sams.ac.uk>, "mark.inall@sams.ac.uk" <mark.inall@sams.ac.uk>
> Subject: FW: SBD Msg From Unit: 300434060123920
> -------------------------------------------
> From: sbdservice@sbd.iridium.com[SMTP:SBDSERVICE@SBD.IRIDIUM.COM]
> Sent: Wednesday, October 29, 2014 2:11:47 PM
> To: NOC Iridium Moorings
> Subject: SBD Msg From Unit: 300434060123920
> Auto forwarded by a Rule
>
> MOMSN: 28
> MTMSN: 0
> Time of Session (UTC): Wed Oct 29 14:11:47 2014
> Session Status: 00 - Transfer OK
> Message Size (bytes): 67
>
> Unit Location: Lat = 57.21276 Long = -9.17922
> CEPradius = 6
```

Near Surface Ocean Profiler Measurements

Richard Sims

Method

Measurements of near surface gradients were collected using the Near Surface Ocean Profiler (NSOP; **Figure 12**). The method is the same as used during DY026. An instrument cage containing two CTD models (Valeport/Seabird) giving measurements of temperature, salinity, depth and fluorescence was raised and lowered through the top 10 m of the ocean by winch attached to a floating buoy that was loosely tethered to the ship. Tubing is also connected to this cage through which water is pumped back to the ship at 4 L min^{-1} for analysis for the partial pressure of CO_2.

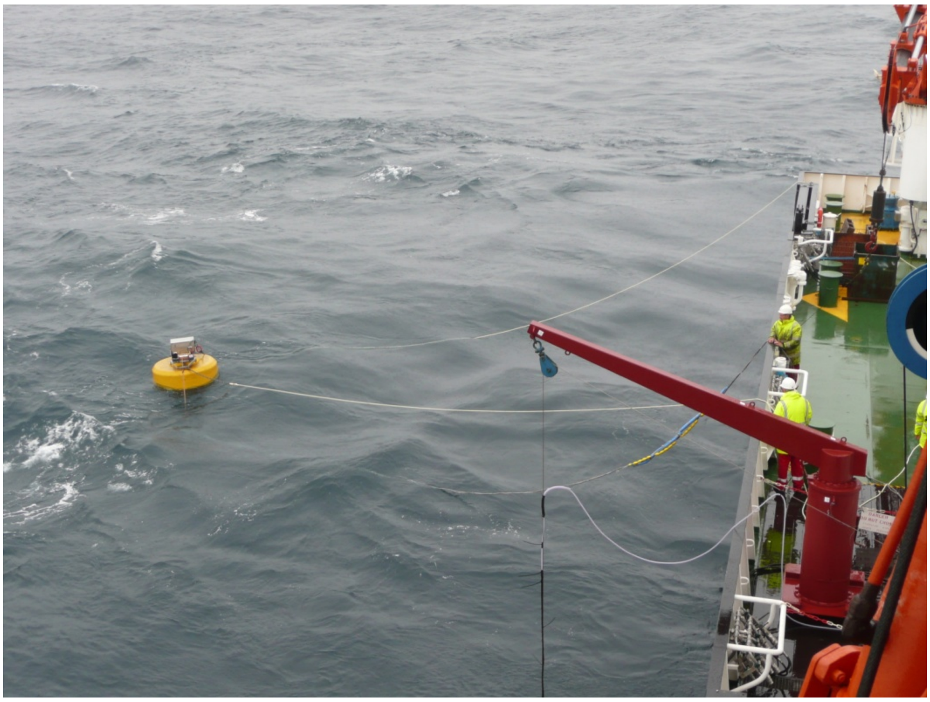


Figure 12: The Near Surface Ocean Profiler

On-board ship the water is passed through a membrane equilibrator where it was rapidly equilibrated with a counter air flow at 100 ml min^{-1}. The air flow was then dried using a nafion dryer and passed into a Licor 7000 for analysis for CO_2 content. The Licor measured a number of variables including the CO_2 partial pressure and CO_2 concentration, pressure, temperature, and water vapour content. A number of sensors were also connected including a flow meter, and separate pressure and temperature sensors.

3 Standards were also run just after the morning calibration and after the deployment was complete, the times that these standards were run was noted in the lab book.

A temperature calibration was run near the end of the cruise at 3 different temperatures to determine temperature variation between the PT1000 sensors and the two CTD's.

Issues

There were a number of technical issues relating to the NSOP deployments. These were mainly electrical and saw the winch stop working halfway through the first deployment and operate without user input midway through the cruise. It is suspected this is due to damage to the antenna of the receiver. This meant that after the first 3 deployments continued deployment of the NSOP was not possible and the decision was made to deploy the cage separately from a crane arm and to pay out a measured length of line manually. This resulted in a reduced vertical resolution but did allow deployments when the swell would have been too high for the NSOP.

Weather conditions prevented deployments on several days.

Measurements and deployment dates

The measurements for this cruise consist of the CTD, Licor, PT1000, pressure sensor, flow rate sensor data for the 3 NSOP deployments on the 23rd,27th and the 30th October and the 4 standalone cage deployments on the 2nd, 3rd and two on the 4th November (**Table 12**). The pCO_2 system was also setup to sample under way data for 1 day on the 1st November to make a direct comparison with the ships underway system.

Deployment	Date	Deployment method
1	23/10/2014	NSOP
2	27/10/2014	NSOP
3	30/10/2014	NSOP
4	2/11/2014	Davit Crane
5	3/11/2014	Davit Crane
6	4/11/2014	Davit Crane
7	4/11/2014	Davit Crane

Table 12: Summary of deployments

Phytoplankton community structure

Beatrix Siemering

Introduction

All samples were taken by Beatrix Siemering, a second year PhD student based at SAMS, the Scottish Marine Institute. Samples were taken as part of her PhD project “Advective transport of harmful phytoplankton”. The project focuses on transport of *Karenia*, *Dinophysis* and *Pseudo-nitzschia* on the Scottish west coast. The area of the Malin shelf and shelf edge is of interest for this project as it was suggested to be a spot for overwintering seed populations of harmful phytoplankton. To determine this, phytoplankton community and chlorophyll data were collected from different depths within the surface layer via CTD cast. Additional CARD-fish samples were also collected for the PhD student Ruth Patterson, also based at SAMS. Samples were collected between the 20.10.2014 and 6.11.14 on board the RRS *Discovery* and taken back to SAMS for further analysis. A summary of sampling activities is presented in **Table 13**.

Methods

All sample bottles and filtration equipment were rinsed with sample water before use.

Phytoplankton community structure

The phytoplankton community structure will be assessed via microscopy analysis of Lugol's samples collected during the cruise. For this purpose 60 ml water samples were collected from the underway seawater supply (~ 5m deep, passed through a 5mm filter) and from three depths in the surface mixed layer sampled by the stainless steel CTD from 20L bottles (until 28th October) and from 10L bottles thereafter. At one occasion, at station G5, water samples were taken from the titanium CTD. Sampled depths were different for each station and determined by the fluorescence profile. Samples were taken at depth were peaks in fluorescence were seen and at the depth on which fluorescence started to decline rapidly (often at the mixed layer depth).

Where weather conditions and time allowed additional samples were collected by deploying a phytoplankton net. Due to the dimensions (25cm diameter and ~40cm depth) and shape of the net it became also known as the "Smurf Hat". The net was lowered on a dynamar line via the metal free winch gantry. The generally windy conditions required a weight of approximately 4 kg on the bottom of the net to keep the net in an upright position and to ensure it sank. Depth of net deployment was determined by the fluorescence profile from the CTD cast. The depth of rapid fluorescence decline was picked as the maximum depth for the net. Sample volume from the net hauls was approximately 60ml.

All samples were fixed with 1 ml Lugol's Iodine solution. (a minimum of 1% Lugol's by volume is needed to fix a sample which would be 0.6ml for a 60ml sample. However 1 ml was chosen due to the minimum size of the pipette). Samples were stored in the dark at room temperature and will be returned to SAMS for community analysis using standard sedimentation chamber and light microscopy methodologies. An additional 60 ml sample taken from the underway system will be analysed by Ruth Patterson for genetic evidence of the presence of a *Azidinium*, a newly discovered harmful phytoplankton species.

Chlorophyll-a

The same depths sampled for community composition were also sampled for chlorophyll-a. 500 ml water samples were filtered through a 47 mm glass fibre filter and frozen at -20C for subsequent analysis back at SAMS.

Frozen samples will be treated with acetone, sonicated and measured for chlorophyll fluorescence using a trilogy fluorometer.

CARD-fish

Three 125 ml replicates were taken from the underway at each station. Samples were filtered through a polycarbonate filter cushioned with a glass fibre filter inside a vacuum filter holder and a syringe. Each polycarbonate filter was incubated in 5 ml saline ethanol in a 6 well plate for an hour. Saline Ethanol fixative was prepared freshly for each station from 12.5 ml ethanol, 1 ml MilliQ water and 1.5 ml SET buffer (SET buffer contains 3.75M NaCl, 25 mM EDTA and 0.5M Tris). After 1 hour saline ethanol was pipetted off and passed back through the filter. Filters were frozen at -20C and taken back to SAMS for further analyses by Ruth Patterson.

Sampling

Station	CTD No.	Cruise Event No.	Sampled Depth (m)	Niskin Bottle No.	Net haul	Cruise Event No.	Approx depth (m)	Underway sampled
A1	CTD003	4	10, 30, 50	14, 18, 22	NET001	5	0-50	Y
A3	CTD007	9	10, 30, 40	12, 15, 24	-	-	-	Y
A4	CTD008	11	10, 30, 50	18, 20, 23	-	-	-	Y
A5	CTD010	13	10. 30, 50	22, 23, 24	-	-	-	Y
X	-	-	-	-	-	-	-	Y
B1	CTD012	15	10, 30, 50	11, 16, 19	NET002	16	0-50	Y
C1	CTD014	18	30, 50, 70	3, 9, 15	NET003	19	0-70	Y
C4	CTD019	25	15, 50, 100	13, 17, 21	NET004	26	0-100	Y
C6	CTD021	28	10, 50, 90	22, 23, 24	-	-	-	Y
C7	CTD023	30	10, 50, 100	20, 22, 24	NET005	31	0-100	Y
D5	CTD024	32	10, 50, 75	21, 22, 24	NET006	33	0-80	Y
D4	CTD026	35	10, 30, 60	13, 19, 23	NET007	36	0-60	Y
D1	CTD029	41	10, 50, 100	5, 13, 23	NET008	42	0-100	Y
E1	CTD031	44	10, 50, 60	8, 12, 20	NET009	45	0-60	Y
E3	CTD034	49	10, 30, 50	16, 19, 24	NET010	50	0-50	Y
E6	CTD037	53	20, 40, 60	21,22,23	-	-	-	Y
E5	CTD038	54	10, 50, 70	18, 19, 23	NET011	55	0-70	Y
F6	CTD041	59	20, 60, 90	15, 16, 20	NET012	60	0-100	Y
F5	CTD042	61	10, 20, 50	22, 23, 24	-	-	-	Y
F4	CTD043	61	10, 20, 50	20, 22, 24	NET013	63	0-50	Y
F1	CTD049	68	20, 38, 75	5, 15, 20	NET014	69	0-80	Y
G1	CTD050	70	10, 30, 60	1, 13, 21	NET015	71	0-60	Y
G5	CTD054 (Titanium)	77	25, 50, 70	13, 15, 16	NET016	78	0-70	Y
G6	CTD056	81	50, 87, 92	16, 17, 19	NET017	82	0-100	Y

Table 13: Summary of sampling activities

Notes

Stormy weather conditions disrupted sampling. On the 25th and 26th of October the RRS *Discovery* sheltered in Broad Bay near Stornoway on the east side of Lewis to avoid adverse weather conditions. At this location (Lat 58 16.18566N, Lon 6 13.18440W) an additional underway sample was taken and sampled for phytoplankton community, chlorophyll-a and CARD fish (Labelled as station “X”).

Strong winds often made deployment and recovery of net samples difficult. Winds and surface currents often pushed the net sidewards. Consequently the length of rope deployment might not be indicative of the actual sampled depth.

Strong winds were also likely to affect the phytoplankton structure in surface layers. No clear chlorophyll maxima were apparent in the fluorescence CTD profiles as the upper ocan was well mixed. Spikes in fluorescence were present at some sites but could easily have been noise rather than true fluorescence peaks. Fluorescence profiles indicated a well mixed surface layer of phytoplankton with a rapid decline of fluorescence, commonly at the mixed layer depth between 60 and 100 m. Some shallower stations were entirely mixed throughout the water column.

Issues with the winch system onboard caused further delays in sampling and a switch from using 20 L bottles to 10 L bottles after the 28th October.

Measurements of ammonium were originally planned for the cruise but were cancelled due to technical issues with the fluorometer.

Trace Metal Sampling

Angela Milne, Antony Birchill and Dagmara Rusiecka.

Samples were collected for trace metal analysis in both the dissolved and particulate fractions using the dedicated trace metal 10 L OTE bottles mounted on a Ti-frame rosette system. Additional sample logs for all Ti-CTD casts and fish sampling are available from the authors.

The trace metal samples collected will be analysed at different institutes for differing parameters:

Total dissolvable and dissolved Iron – Antony Birchill at the University of Plymouth

Total dissolvable and dissolved Trace Metals (excluding iron) – Dagmara Rusiecka at NOCS and GEOMAR.

Ligands – Dagmara Rusiecka at NOCS and GEOMAR.

Suspended Particulate Material (SPM) – Angela Milne and Antony Birchill at the University of Plymouth.

A total of 265 depths over 21 stations were sampled, this amounted to 530 samples (265 total dissolvable and 265 dissolved) each for Iron and Trace Metal analysis. Selected depths at all stations were sampled for Suspended Particulate Material resulting in 100 samples. In addition, unfiltered samples were collected for macronutrients from all OTE bottles, and at selected depths, for oxygen and salinity. At three stations (C5, G4 and G5) unfiltered samples were also collected for DOC, DIC, macronutrient Particulates and Chlorophyll.

Underway surface samples were collected by pumping surface seawater into a trace metal clean sampling laboratory using a Teflon diaphragm pump (Almatec A-15, Germany) connected by an acid-washed braided PVC tubing to a towed fish positioned at approximately 2 - 3m depth alongside the ship. Seawater samples were filtered in-line using a 0.2 μm Sartonbran P membrane filter capsule (Sartorius). Surface seawater samples were collected at and in between stations when possible, a total of 50 surface samples were collected.

Bottle misfires and comments on sampling

Over the 21 stations sampled for trace metals, there were 3 stations where a total of 4 OTE bottles did not fire (at Stations B1, D4, and G6) and therefore these depths were not sampled.

Deployment and use of the clean tow-fish went well, however, its positioning on the starboard side of the ship needs to be re-assessed for future cruises. During this cruise the fish rode very close to the ship and during the bad weather was observed to knock the side of the ship. I think this is in part due to the ships wake pulling the fish in towards the ship.

With regards to the new clean sampling laboratory, overall the new facility has worked well and the close vicinity of the laboratory to the rosette system has aided efficient deployment and recovery of the clean OTE bottles. The general set-up in the laboratory is very good and being positioned within the ship, as opposed to a container on the aft deck, has allowed work to continue even in bad weather. However, there have been some noticeable issues that have been raised during the course of the cruise. One problem relates to a lack windows in either of the two outside doors that are used to enter the outer changing area of the clean sampling laboratory. To maintain a clean environment in the inner laboratory, these outer doors should not be opened at the same time as the inner door. This has resulted in shouting between the inner and outer doors to ensure that one is closed before the other is opened.

With regards to actual sampling, the clamps that are needed to keep the bottles closed while under pressure for sampling are difficult to attach. This is due to the positioning of the gas lines, the wall brackets that the drainage trays are attached to and the closeness of the bottles. This results in clamping, and therefore sampling, taking longer. While this did not prevent any stations from being sampled it did increase the amount of time taken to have the OTE bottles sampled and ready for the next station, this became very challenging when the station spacing was very close (1.5 h apart).

Sampling for suspended particulate material (SPM) has been a particular challenge, this is in part due to the drainage trays not being low enough and also the bottles/clamps being too close together. Though alterations can and will be made to the filtration apparatus for future cruises, it would still not be possible to collect SPM from all the OTE bottles as has been done on past UK GEOTRACES cruises. The positioning of the drainage trays also hinders the collection of filtered samples using the cartridge filter.

Finally, it is not possible to empty the OTE bottles into the drainage trays without seawater ending up on the floor as the bottles are not centred over the trays. The poor drainage in the laboratory floor (there is only one drain hole along the middle of the side wall) means that salt water often ends up behind the fridge and freezer until the ships role allows for cleaning this up.

Total dissolvable and dissolved iron

Antony Birchill

Objectives

Iron (Fe) is an essential nutrient for primary productivity in the ocean. Due to its low solubility iron can be a limiting factor for the growth of phytoplankton in the open ocean as well as in coastal seas (de Baar et al., 1990; Hutchins and Bruland, 1998; Martin and Fitzwater, 1988). It has become evident that the atmosphere (Duce and Tindale, 1991), rivers (De Baar and de Jong, 2001), hydrothermal activity (Tagliabue et al., 2010 ; Klunder et al.,2011) and advection of shelf derived sediment to the open ocean (Bucciarelli et al., 2001; Lam and Bishop, 2008) are significant transport pathways for iron to the ocean. Fe fluxes from shelf seas to the open ocean are poorly constrained, although estimates indicate they could be 2-10 times higher than atmospheric inputs (Elrod et al. 2004) and thus potentially be a major contributor to the oceanic Fe cycle. Shelf edge biogeochemical processes that result in Fe export to the ocean are not well understood and key questions remain about the magnitude and significance of Fe fluxes from the shelf to the open ocean. We aim to investigate and quantify the supply and transport of iron in the shelf region off the North West of Scotland.

Sampling protocol

On recovery, the 10 L OTE bottles were transferred into a clean sampling laboratory where they were immediately sampled for oxygen, nutrients, salinity and total dissolvable iron before being pressurised to approximately 7 psi with 0.2 μm filtered air using an oil free compressor. After the collection of particulate samples (see section on Particulate Trace Metals), a Sartobran 300 (Sartorius) filter capsule (0.2 μm) was used to collect filtered seawater samples into clean LDPE sample bottles. Bottles and caps were rinsed 3 times with the filtered sample before being filled. All samples, including underway samples, were acidified to 0.024 M (UpA HCl, Romil) and stored, double bagged, for shore based analysis.

Samples collected

Samples for total dissolvable and dissolved iron were collected at 21 stations as detailed in **Table 14**, a total of 530 samples were collected for analysis.

Station	**Samples collected from separate depths** ***Dissolvable + Dissolved***		**Station**	**Samples collected from separate depths** ***Dissolvable + Dissolved***
A1	6 + 6		E1	9 + 9
A2	6 + 6		E3	11 + 11
A4	12 + 12		E4	17 + 17
A5	19 + 19		E5	22 + 22
B1	5 + 5		F3	6 + 6
C1	6 + 6		F4	11 + 11
C3	9 + 9		F5	23 + 23
C4	12 + 12		G4	6 + 6
C5	15 + 15		G5	13 + 13
C7	24 + 24		G6	23 + 23
D4	10 + 10			

Table 14: Summary of sampling for total dissolvable and dissolved iron measurements

Sample analysis: Samples for dissolved iron will be analysed at the University of Plymouth after 2 months acidification, whereas samples for total dissolvable iron will be left for at least 6 months prior to analyses. Flow Injection with chemiluminescence detection (FI-CL) (Obata et al. 1993; de Jong 1998; Klunder et al. 2011) will be used for all sample analyses using Toyopearl AF-650-M resin for pre-concentration.

Total dissolvable and dissolved trace metals

Dagmara Rusiecka

Objectives

Iron is well established as a limiting element for phytoplankton growth, however the role and cycling of other trace elements are less understood and there is a lack of data on the concentration and distribution of these elements in the global ocean. While elements such as cadmium, zinc and cobalt have a biological role, reflected in their nutrient like profiles, other trace elements can be used as tracers of inputs to the ocean, e.g. aluminium (Al) is an indicator of aerosol deposition (Tria et al., 2007), and manganese (Mn) can indicate sedimentary or hydrothermal inputs (Johnson et al., 1992; Middag et al., 2011). As with Fe, there is a paucity of data concerning the input, and cycling, of trace metals from shelf regions. The questions surrounding the magnitude and export of Fe from the shelf to the open ocean also apply to a suite of trace metals. We aim to investigate and quantify the supply and transport of selected trace metals from the shelf off the North West of Scotland.

Sampling protocol

Following recovery of the Ti-rosette, the OTE bottles were transferred into a clean sampling laboratory where they were immediately sampled for oxygen, nutrients, salinity and total dissolvable trace metals before being pressurised to approximately 7 psi with 0.2 μm filtered air using an oil free compressor. After the collection of particulate samples (see section on Particulate Trace Metals), a Sartobran 300 (Sartorius) filter capsule (0.2 μm) was used to collect filtered seawater samples into clean LDPE sample bottles. Bottles and caps were rinsed 3 times with the filtered sample before being filled. All samples, including those from the underway system, were acidified to 0.016 M (UpA HCl, Romil) and stored, double bagged, for shore based analysis.

Samples collected

Samples for total dissolvable and dissolved trace metals were collected at 21 stations as detailed in **Table 15**, a total of 530 samples were collected for analysis.

Sample analysis

Samples will be analysed for a range of trace metals e.g. Ag, Al, Mn, Cd, Zn, Cu, by inductively coupled mass spectrometry (ICP-MS) at GEOMAR (Milne et al. 2010). For Al analysis, flow injection with fluorescence detection (Resing and Measures, 1994) will be used following the modified method of Brown and Bruland (2008). Dissolved samples will be analysed after 2 months acidification whereas dissolvable samples will be left for at least 6 months before analysis.

Station	Samples collected from separate depths *Dissolvable + Dissolved*	Station	Samples collected from separate depths *Dissolvable + Dissolved*
A1	6 + 6	E1	9 + 9
A2	6 + 6	E3	11 + 11
A4	12 + 12	E4	17 + 17
A5	19 + 19	E5	22 + 22
B1	5 + 5	F3	6 + 6
C1	6 + 6	F4	11 + 11
C3	9 + 9	F5	23 + 23
C4	12 + 12	G4	6 + 6
C5	15 + 15	G5	13 + 13
C7	24 + 24	G6	23 + 23
D4	10 + 10		

Table 15: Summary of sampling for total dissolvable and dissolved trace metal measurements

Ligands

Dagmara Rusiecka

Objectives

Understanding the biogeochemistry of Fe requires the ability to measure its oceanic chemical speciation. Fe is present in seawater as chelates with strong metal-binding organic ligands (Bruland & Lohan, 2004) which dramatically influences its' chemical behaviour. These ligands have a stabilising influence, preventing inorganic precipitation (e.g. Liu and Millero, 2002) and increasing the availability of metals for biological uptake. They are therefore an important component in understanding the cycling and distribution of Fe in any system. Ligand samples will therefore be collected at selected stations along the cruise.

Sampling protocol

On recovery of the Ti-rosette, the OTE bottles were transferred into a clean sampling laboratory where they were immediately sampled for oxygen, nutrients, salinity and total dissolvable elements before being pressurised to approximately 7 psi with 0.2 μm filtered air using an oil free compressor. After the collection of particulate samples (see section on Particulate Trace Metals), a Sartobran 300 (Sartorius) filter capsule (0.2 μm) was used to collect filtered seawater samples into clean LDPE sample bottles. Bottles and caps were rinsed 3 times with the filtered sample before being filled. All samples were double bagged and stored unacidified at -20ºC until analysis.

Samples collected

A total of 49 speciation samples were collected at 9 stations as detailed in **Table 16**:

Station	Samples collected from separate depths
A1	3
A2	3
A4	6
A5	10
B1	3
C1	3 (x 2 - duplicates)
C3	5
C4	6
C5	7

Table 16: Summary of ligand sampling

Sample analysis

The concentrations and conditional stability of Fe ligands, Fe' (soluble inorganic Fe) and free aqueous Fe will be measured at NOCS/GEOMAR by competitive ligand exchange cathodic stripping voltammetry (CLE-CSV) with the ligand TAC (Croot and Johansson, 2000).

Particulate trace metals

Angela Milne and Antony Birchill

Objectives

Particulate trace metals may occur in several forms, including stable refractory phases or as coatings on surfaces that can be rapidly recycled. Particulate behaviour is metal specific with, for instance, the majority of particulate Fe occurring in refractory phases while Zn is primarily associated with more labile phases (Hurst & Bruland, 2005). Few studies have concurrently measured trace elements in both the dissolved and particulate phases. Furthermore, labile particulate trace metals which are biologically available could be considerably higher than the dissolved phase (Berger et al., 2008). Assessment of total biologically available trace elements may thus require the determination of both dissolved and labile particulate metal phases (Lam & Bishop, 2008). A step towards a quantitative description of the cycling of trace elements between the dissolved and particulate phases required for their realistic incorporation into biogeochemical ocean models is to measure the standing stock of the particulate fraction. To address this, particulate material will be filtered on selected water samples collected using the trace metal rosette.

Sampling protocol

OTE bottles were transferred from the Ti-rosette into a clean sampling laboratory where they were immediately sampled for oxygen, nutrients, salinity and total dissolvable elements. The OTE bottles to be sampled for particulate material were inverted three times to gently mix the seawater and re-suspend particulates before being pressurised, to approximately 7 psi, with 0.2 μm filtered air using an oil free compressor. Clean filter holders (Swinnex, Millipore) containing acid washed 25 mm (0.2 μm) polyethersulfone filters (PES, Supor, Pall Gellman) were attached to the taps of the OTE bottles and up to a maximum of 7 L of seawater from selected depths was then passed over the filters. Following filtration, the filter holders were removed and placed in a laminar flow bench. Using an all polypropylene syringe attached to the top of the filter holder, residual seawater was forced through the filter using air from within the flow hood. The filter holders were gently opened and the PES filter folded in half using plastic tweezers, the filters were then placed in acid clean 2 mL LDPE vial and frozen at -20ºC until analysis. Filtration was completed in approximately three hours.

Samples collected

A total of 100 samples were collected from 21 stations as detailed in **Table 17**.

Sample analysis

Samples will be analysed for both labile and refractory particulate Fe, Mn, Al, Co, Zn, Cd, Ba, Ni, Cu, Ti and potentially other trace elements using ICP-MS at the University of Plymouth. For labile particulate trace elements the filter is subjected to a weak acid leach (25% acetic acid at pH 2) with a mild reducing agent (0.02 M hydroxylamine hydrochloride) and a heating step (20 min 90-95ºC). This approach is fully detailed in Berger et al. (2008). After the labile fraction has been determined the refractory trace elements will be determined following the method of Ohnemus and Lam (Deep Sea Research, in press). Briefly, the filters will be digested following a three step heating/dry-down process, firstly H_2SO_4 and H_2O_2 are used to digest the filter, followed by HNO_3, HCl and HF and finally HNO_3 and H_2O_2 to digest the particulate material. The final solution is dried down and the residue brought back into solution with 2 % HNO_3 for analysis by ICP-MS. The samples are then spiked with an internal reference material such as In for drift correction.

Station	Samples collected from separate depths	Station	Samples collected from separate depths
A1	2	E1	4
A2	2	E3	5
A4	5	E4	6
A5	7	E5	9
B1	3	F3	6
C1	3	F4	5
C3	4	F5	3
C4	5	G4	3
C5	5	G5	5
C7	6	G6	8
D4	4		

Table 17: Summary of sampling for particulate trace metal sampling

5. DISCUSSION

We were able to achieve the majority of the pre-cruise scientific objectives sampling both on the shelf and in deeper waters and completed 6 of the planned 7 transects. Given the time of year and the exposure of the western shelf to the open North Atlantic Ocean this should be construed as a very successful outcome. Nevertheless, time constraints and weather forced the difficult decision to drop the most westerly station at the end of each transect and transect B was almost lost in its entirety.

With good spatial coverage of the region the preliminary results are highly encouraging and have already revealed some surprises. In particular the intensity of the slope current, which was far stronger than reported by the 2013 FASTNEt cruise (Sam Jones, pers. comm.), suggests an important seasonal component and work to understand the significance of this for open ocean exchange is at an incipient stage.

The various research activities conducted on board ship will, in time, likely prove equally surprising and initial indications are that the distributions of iron, trace metals and dissolved inorganic carbon, in conjunction with inorganic nutrient fields, will be important for understanding the stoichiometry of dissolved nutrients on and off the shelf, as well as potentially resolving pathways of exchange with the open ocean.

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