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Ocean Surface Mixing, Ocean Sub-mesoscale Interaction Study

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ABSTRACT

Cruise D381 was made in support of NERC's Ocean Surface Boundary layer theme action programme, OSMOSIS (Ocean Surface Mixing, Ocean Sub-mesoscale Interaction Study). The ocean surface boundary layer (OSBL) deepens in response to convective, wind and surface wave forcing, which produce three-dimensional turbulence that entrains denser water, deepening the layer. The OSBL shoals in response to solar heating and to mesoscale and sub-mesoscale motions that adjust lateral buoyancy gradients into vertical stratification. Recent and ongoing work is revolutionising our view of both the deepening and shoaling processes: new processes are coming into focus that are not currently recognised in model parameterisation schemes. In OSMOSIS we have a project which integrates observations, modelling studies and parameterisation development to deliver a step change in modelling of the OSBL. The OSMOSIS overall aim is to develop new, physically based and observationally supported, parameterisations of processes that deepen and shoal the OSBL, and to implement and evaluate these parameterisations in a state-of-the-art global coupled climate model, facilitating improved weather and climate predictions. Cruise D381 was split into two legs D381A and a process study cruise D381B. D381A partly deployed the OSMOSIS mooring array and two gliders for long term observations near the Porcupine Abyssal Plain Observatory. D381B firstly completed mooring and glider deployment work begun during the preceding D381A cruise. D381B then carried out several days of targetted turbulence profiling looking at changes in turbulent energy dissipation resulting from the interation of upper ocean fluid structures such as eddies, sub-mesoscale filaments and Langmuir cells with surface wind and current shear. Finally D381B conducted two spatial surveys with the towed SeaSoar vehicle to map and diagnose the mesoscale and sub-mesoscale flows, which, unusually, are the 'large scale' background in which this study sits.

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  - NMFSS - NERC Marine Facilities Sea Systems

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ABSTRACT

Cruise D381 was made in support of NERC's Ocean Surface Boundary layer theme action programme, OSMOSIS (Ocean Surface Mixing, Ocean Sub-mesoscale Interaction Study). The ocean surface boundary layer (OSBL) deepens in response to convective, wind and surface wave forcing, which produce three-dimensional turbulence that entrains denser water, deepening the layer. The OSBL shoals in response to solar heating and to mesoscale and sub-mesoscale motions that adjust lateral buoyancy gradients into vertical stratification. Recent and ongoing work is revolutionising our view of both the deepening and shoaling processes: new processes are coming into focus that are not currently recognised in model parameterisation schemes. In OSMOSIS we have a project which integrates observations, modelling studies and parameterisation development to deliver a step change in modelling of the OSBL. The OSMOSIS overall aim is to develop new, physically based and observationally supported, parameterisations of processes that deepen and shoal the OSBL, and to implement and evaluate these parameterisations in a state-of-the-art global coupled climate model, facilitating improved weather and climate predictions. Cruise D381 was split into two legs D381A and a process study cruise D381B. D381A partly deployed the OSMOSIS mooring array and two gliders for long term observations near the Porcupine Abyssal Plain Observatory. D381B firstly completed mooring and glider deployment work begun during the preceding D381A cruise. D381B then carried out several days of targetted turbulence profiling looking at changes in turbulent energy dissipation resulting from the interation of upper ocean fluid structures such as eddies, sub-mesoscale filaments and Langmuir cells with surface wind and current shear. Finally D381B conducted two spatial surveys with the towed SeaSoar vehicle to map and diagnose the mesoscale and sub-mesoscale flows, which, unusually, are the 'large scale' background in which this study sits.

1 INTRODUCTION

Cruise D381 was split into two D381A for mooring deployment and D381B a process study cruise. D381A sought to deploy a cluster of 9 moorings, 4 guard buoys and 2 gliders at a site in the close vicinity of the Porcupine Abyssal Plain Observatory, with the ultimate goal of measuring a full annual cycle of changes in upper-ocean properties and the physical processes underpinning those changes. The objective of D381B was to collect data to test the scaling hypotheses for Langmuir turbulence and shear spikes developed in the theoretical work packages of the OSMOSIS programme, and to make detailed surveys of mesoscale and submesoscale dynamics to complement the mooring and glider data and record the large scale boundary conditions.

The Porcupine Abyssal Plain observatory site was chosen for its physical conditions which are considered representative of the interior of mid-latitude gyres and that it hosts a NOCS-coordinated multidisciplinary observing system that has been sustained for over 20 years to investigate the response of open-ocean and deep-sea ecosystems to climatic change. It is part of the EuroSITES and OceanSITES networks of observatories. The PAP site lies in deep water ($\sim$ 4800m) with no significant complex topography nearby. Examination of existing hydrographic and velocity observations from previous PAP site cruises indicated that internal tides are locally weak and thus would not compromise the open-ocean representativeness of the site. The mixed layer depth at the site displays a significant annual cycle, typically varying from 30 - 40m in summer to 200 - 300m in winter. The PAP site also lies in the eastern edge of the North Atlantic subtropical gyre, a region of weak mean flow and relatively low eddy kinetic energy, characteristic of a substantial fraction of the global ocean. Nevertheless, the area has considerable mesoscale eddy activity: satellite altimetric measurements and in situ high-resolution surveys from research vessels reveal the regular occurrence around the site of slowly-evolving, deep, baroclinic eddies of $\sim$ 40-60km diameter and with surface velocities of $\sim$ 0.3ms^{-1}. The PAP site is well suited to studying the target 3D mixing processes. Preliminary calculations using ECMWF ERA-40 reanalysis data suggested that the site experiences a pronounced annual cycle of wind and wave forcing. Clearly the PAP site also lies close to the British isles (a 2 day transit by research vessel from Falmouth), and is thus conveniently located for servicing gliders during a year-long combined mission.

D381A departed Southampton on RRS *Discovery* on 28th August 2012. This leg of the cruises successfully deployed 8 of the 9 moorings (the remaining mooring was deployed shortly after, in leg B). The 4 guard buoys were also deployed, but one of these (the one containing meteorological sensors) sank shortly after deployment, the exact causes of this failure being unknown at the time of writing this report. The 2 gliders were eventually deployed with success, after some initial failed deployments. A further objective of leg A was to deploy a wave rider buoy, to provide spectral wave measurements for the process studies in leg B. This buoy was deployed successfully.

On the 14th September 2012, RRS *Discovery* slipped from Falmouth, at around 16:00 BST, to begin the OSMOSIS project process cruise D381B. On the way to the PAP site we stopped just off the continental shelf edge to deploy two Scottish Association for Marine Science (SAMS) gliders for another NERC programme, FASTNET. One of these would later fail after only a few depth cycles and require recovery on the return leg. The cruise was six days late leaving the UK and therefore the scientific programme was significantly cut from the start, now barely more than two weeks on site.

During the first week at the PAP site we deployed the fourth and final outer mooring of the OSMOSIS high resolution mooring array that had not been possible to deploy on the first mooring deployment leg, D381A. We deployed the NOC, Liverpool, turbulence glider, this was a Webb Slocum glider with a Rockwell Scientific turbulence sensor carried externally. In addition we carried out two separate 25+ hour duration turbulence profiling stations with an ISW MSS90 loosely tethered free fall turbulence profiler; and a 48 hour towed SeaSoar survey of an $\sim$50 nm square box centred on the OSMOSIS PAP site mooring array.

During the second week we suffered a two day period of weather down time which cut our reduced science schedule down further. We were able to carry out one further 25+ hour turbulence profiling station and just under 48 hours further towed SeaSoar surveying although this was split into two 24 hour periods due to the bad weather. In addition we recovered the turbulence glider and the SAMS wave-rider buoy that had been deployed during D381A. On our return we recovered both the failed SAMS glider and an NOC, Southampton, glider that was also taking part in the FASTNET programme.

2 NARRATIVE

PSO's Diary

Leg A - *Alberto Naveira Garabato (PSO)*

Tuesday 28th August 2012 We set off from Southampton at around 7:30 am GMT in a clear morning. We had intended to leave the previous evening, but were delayed by several incomplete deck configuration tasks. We sailed southwestward at around 10 kn toward the D381 study region in the vicinity of the PAP site, in fair seas, while preparations for the mooring and CTD operations continued.

Wednesday 29th August 2012 We continued sailing southwestward, but were slowed down by moderate winds and rough seas.

Thursday 30th August 2012 The seas started dying down overnight. In the morning, we deployed Jo Hopkins' wirewalker and ADCP mooring at the planned position, and continued our transit to the PAP site for the remainder of the day.

Friday 31st August 2012 We arrived at the position of the O-SW mooring at around 15:00 GMT, after further transit in fair seas. We conducted a full-depth CTD station (001) and tested 9 of the acoustic releases. While bottle sampling was underway, we tested the buoyancy of the two gliders, which floated.

Saturday 1st September 2012 We commenced deployment of the O-SW mooring at first light, at approximately 06:00 GMT. After completion of the deployment, we triangulated the position of the mooring, so as to check that the target overshoot distance used in deployment provided a satisfactory outcome. At around 13:00 GMT in the afternoon, we commenced deployment of the I-SW mooring, upon completion of which on-deck activities ceased for the day.

Sunday 2nd September 2012 We spent the bulk of the day constructing glass buoyancy for subsequent moorings, in fair seas. The two gliders were deployed successfully in the late afternoon. A CTD station (002) to 1000 m was conducted at the end of the day, with the primary aim of aiding in the calibration of the glider sensors.

Monday 3rd September 2012 We commenced deployment of the I-NW mooring at first light, at approximately 6:00 GMT, in fair seas. At around 13:00 GMT in the afternoon, we started the deployment of the C mooring, completed at approximately 17:30 GMT. We concluded the day with triangulation of the I-SW, I-NW and C mooring positions.

Tuesday 4th September 2012 We spent the bulk of the day winding the cable for three subsequent moorings, in fair seas. At mid-day, we recovered glider 566, the biogeochemical sensors of which had exhibited a fault seemingly related to a loose connection. The recovery was done swiftly and smoothly, in fair seas. Whilst the glider was being inspected, we conducted a full-depth CTD station (003). The remainder of the acoustic releases were tested during this station. Upon conclusion of the station, in the late afternoon, glider 566 was successfully redeployed. Subsequently, glider 510 developed what appeared to be a battery fault, and was recovered early in the evening.

Wednesday 5th September 2012 We commenced deployment of the I-NE mooring at first light, at approximately 6:00 GMT, in fair seas. At around 13:00 GMT in the afternoon, we started the deployment of the I-SE mooring, completed at approximately 19:00 GMT.

Thursday 6th September 2012 We spent the bulk of the day winding the cable and constructing buoyancy for subsequent moorings, in fair seas. In the morning, we triangulated the positions of the I-NE and I-SE moorings, and in the afternoon we conducted a full-depth CTD (004) for a final test of acoustic releases. Glider 533 was deployed at around 18:00 GMT, after a successful buoyancy test.

Friday 7th September 2012 We commenced deployment of the O-NW mooring at first light, at approximately 6:30 GMT, in fair seas. At around 12:00 GMT, we started deployment of the O-NE mooring, completed at approximately 15:00 GMT. We then proceeded to triangulate the positions of these two moorings.

Saturday 8th September 2012 The wave rider buoy was deployed in the morning (between approximately 7:00 and 11:30 GMT), in a position a few kilometres to the north of the OSMOSIS mooring array area, in fair seas. While preparations for the deployment of the first guard buoy ensued, the ship steamed to the position of the ODAS buoy in the PAP observatory, to do a visual check of that buoy, the telemetry of which had ceased. The ODAS buoy appeared to be in good condition.

Sunday 9th September 2012 The weather deteriorated overnight, such that by the morning the seas had built up considerably. At any rate, conditions were judged to be good enough to proceed with the deployment of the first (southern) guard buoy, which took place between approximately 9:30 GMT and 16:00 GMT.

Monday 10th September 2012 We commenced deployment of the northern guard buoy in the morning, at approximately 8:00 GMT, in fair seas. The deployment concluded in the early afternoon, at around 13:00 GMT. The eastern guard buoy was deployed subsequently, with operations lasting until the evening.

Tuesday 11th September 2012 The deployment of the final (western) guard buoy started in the morning, at around 7:30 GMT, in calm seas. Upon finishing in the early afternoon, we set off toward Jo Hopkins' wirewalker and ADCP mooring at the edge of the continental shelf.

Wednesday 12th September 2012 Progress toward the wirewalker / ADCP mooring site was slowed down by rough weather. Upon reaching the site at around 17:00 GMT, we successfully recovered the mooring and continued our transit to Falmouth.

Thursday 13th September 2012 We continued sailing toward Falmouth in fair seas. We finally arrived there in the mid afternoon.

Leg B - *John Allen (PSO)*

14th September (Day 258) RRS *Discovery* slipped from Falmouth at ∼15:00 GMT (16:00 BST) and headed out for the first FASTNET project glider deployment position (first of two) at 48° 13' N, 9° 37' W. The FASTNET project is another NERC funded directed project to look at the dynamics of the UK continental shelf edge using the latest ocean glider vehicles for a long term observational coverage. The pilot disembarked at 15:25 GMT and so we were at sea again. The weather had been a bit breezy but there was no significant sea until we left the western most rocky outcrops of the UK mainland behind and began to feel a significant swell from the north.

15th September (Day 259) *Discovery* rolled gently through the night as we felt the effects of Icelandic weather a long way north. By morning light the sea was very calm apart from the swell and weather forecasts set fair for a good few days, although we would have to keep our eyes on a sub-tropical storm forecast to head our way from the Azores perhaps towards the end of the next week. We had made good progress and were due on station 381005 by just after 14:00 GMT. The station number reflects the fact that 4 CTD stations were carried out on the first leg of the cruise and might need retrospectively numbering. A safety briefing and the signing on procedure began at 09:00 BST and a full practice emergency muster, proceeding to boat stations followed at 10:30 BST.

Just after lunch we received a revised position for station 381005 at which both FASTNET gliders would be deployed, 48° 9' N, 9° 41' W; the mid point between the two original positions given to us. We arrived at station 381005 at 14:25 GMT, just off the shelf in ∼ 830 m of water. The investigation of a winch alarm delayed the deployment of a shallow CTD cast which went in the water at 14:54 GMT. The CTD was deployed to 50 m just to check water density ready for glider deployment and as such it will not be recorded further. The surface density was approximately 1025.95 kg m^{-3} (sigma-t ∼ 25.95) and the pycnocline started at ∼ 40 m at a density of sigma-t ∼ 26.60. The CTD was recovered at 15:05 GMT. Problems arose trying to get a reliable iridium communications link for the 'pink' SAMS seaglider 'Talisker', but eventually, and having moved Talisker to the aft deck, a good link was achieved. Talisker was launched over the starboard quarter using the starboard pedestal crane at 16:43 GMT, at 48° 8.84' N, 9° 40.87' W, for a test dive whilst *Discovery* stood off about 2 km distant.

Following successful communications with the 'yellow' SAMS seaglider 'Ardbeg', Ardbeg was launched at 18:47 GMT at 48° 7.69' N, 9° 41.55' W. Relocating two kilometres in order to carry out a full depth CTD proved a directional challenge as NOC's slocum glider coprolite had also moved into the area, but a northerly direction seemed to be safe for all three 'needles' in the 'hay stack'. CTD cast 381005 began at 19:47 GMT at 48° 9.04' N, 9° 42.16' W. There was some discussion around what depth to achieve as we were clearly in the vicinity of several shelf edge canyons, as this was purely a calibration exercise for Talisker and Ardbeg caution was deemed the better part of valour and we chose 800 m. The CTD was recovered at 20:44 GMT and sample training for the new students began as we steamed off west in the direction of the PAP site (ETA ∼ midnight GMT Sunday).

At midnight the clocks were retarded to GMT and all times will be reported here in GMT until our return leg.

16th September (Day 260) Light winds and a calm sea *Discovery* was making good time, our ETA for the south-east outer mooring at the PAP site (**Figure 1**), nominally 48° 37.8'N, 16° 6' W, was around 23:00. We had planned some training 'master classes' for the new scientists on board and our progress allowed for a turbulence profiling practical session with the ISW MSW90 turbulence profiler. The ship slowed to ∼ 0.5 knots at 11:05 to begin buoyancy and fall rate testing for the loosely tethered profiler. The winch and deck control box had already been set up on the port quarter and therefore profiling began soon after we had slowed down. By ∼14:00 the tests and a number of training deployments had been made and *Discovery* resumed her steam towards the remaining OSMOSIS PAP outer mooring site. By late evening it was clear that *Discovery* was still making good speed and with an ETA of ∼ 00:30 we would inevitably heave to and wait for first light at around 06:30 to begin the mooring deployment.

17th September (Day 261) The surface buoyancy for the mooring began going over at 06:41 with the near surface instrumentation. A freshening wind was accompanied by a moderately increased swell, but the forecast for the week remained good. The double acoustic release mechanism was attached at 09:15 and after a 1.7 nm run into the launch site the anchor weight was released at 10:36 at 48° 37.95' N, 16° 6.43' W. By 11:07 the mooring was in position on the bottom and we headed for a point ∼ 4 km south-east for our first acoustic triangulation point and a 1000 m CTD cast, stn. 381006. After a fault with the gantry CTD 381006 went in the water at 12:06 at 48° 36.23' N, 16° 3.60' W. After a 1000 m cast, the CTD was recovered at 13:14.

Discovery then steamed to a point ∼ 4 km west of the mooring location for the second acoustic triangulation point. As we approached at ∼ 14:15, we passed passed the southern guard buoy of the OSMOSIS mooring array on our starboard side; this would place the guard buoy at the south-eastern most extremity of its slack tethered 'watch circle'. At 14:26 we began a steam to a third and final triangulation point, 4 km to the north of our outer mooring location earlier in the day; passing the southern guard buoy closely to check its position.

As we approached the third triangulation point at ∼ 15:00 we could see the eastern guard buoy of the OSMOSIS mooring array ∼ 2 miles dead ahead also south east of where it had been laid during D381A and near the south eastern limit of its 'watch circle'. This agreed with earlier satellite altimetry composites showing the presence of an anticyclonic eddy to the south/south-east of the PAP site.

At ∼ 15:10 we set off north to look for the northern guard buoy and investigate the uncommunicative meteorological package attached to it. By 16:10 after significant searching, finding the western guard buoy in the process, there was still no sign of the northern

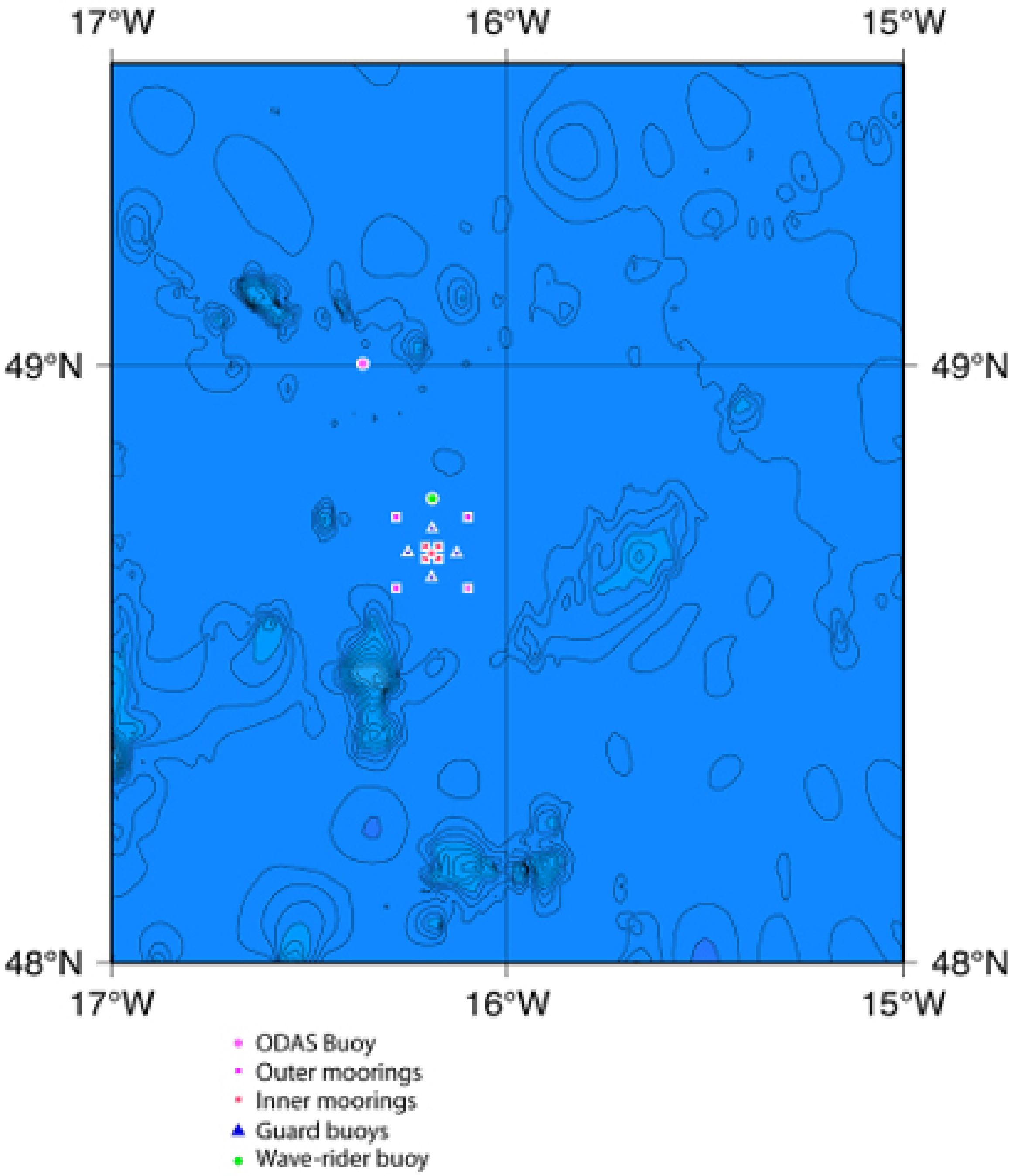

Figure 1: Diagram showing the layout of the OSMOSIS PAP site mooring array.

guard buoy. Interrogating the release gave a vertical and healthy battery diagnostic response, indicating all might be well with the mooring structure otherwise. At this point we received word that the SAMS glider, Ardbeg, that we had deployed two days ago, was now drifting on the surface following a technical problem with its buoyancy control which would make further diving impossible or to risky.

By 17:00 the conclusion was, inevitably, that the northern guard buoy had probably flooded and sunk. Whilst the searching had been going on, the NOC Liverpool turbulence glider (a Slocum glider with an externally mounted Rockwell Scientific turbulence probe) had been tested for buoyancy in a portable tank on the aft deck and was now ready for test dives. So *Discovery* set course for a position about 7 nm west of the wave-rider buoy and 4 nm west north-west of the north-west outer mooring of the OSMOSIS mooring array.

We reached the turbulence glider deployment position at ∼ 18:50. The glider was launched by 19:10, with a little gentle nudge from the crane hook in the swell!, at 48° 46.63' N, 16° 22.56' W. After a number of test dives of increasing complexity, the glider was sent off to carry out a virtual mooring pattern of repeating east-west, west-east oscillations profiling to 100 m. *Discovery* set course for a position ∼ 2 nm north to carry out CTD station 381007. The CTD was in the water at 21:17, at 48° 48.74' N, 16° 22.04' W. After a 500 m cast, the CTD was recovered and on deck by 22:00.

The ISW MSS90 turbulence profiler was connected up and a 25 plus hour microstructure profiling series began at 22:33 at 48° 48.53' N, 16° 21.52' W, with *Discovery* steaming gently north-westwards into the swell at ∼ 0.5 knots.

18th September (Day 262) At ∼ 02:45 the turbulence profiler began having data communications problems with the deck box and PC in the deck laboratory. After significant investigations it was found that the kevlar sea cable was, and probably had been for some time, flooded throughout at least 50 m or more of its length. It was clearly time to change to the new spare sea cable that we had been carrying around with the profiler equipment for a few years now. The actual cable change took little more than an hour and a half, and profiling began again at ∼ 08:00. In the meantime *Discovery* repositioned to the geographical location of the start of the profiler deployments as above.

The turbulence profiler was recovered at 15:02 and *Discovery* relocated back to the position of the start of the profiling again for a CTD stn., 381008, to obtain a nutrient sample profile for comparison with the turbulent dissipation profiles. The CTD was in the water at 15:40 at 48° 48.46' N, 16° 21.67' W. After a 500 m cast with 24 bottle resolution sampling the CTD was back on deck at 16:55. Turbulence profiling restarted within 10 minutes of the CTD recovery. As yesterday we were visited relatively frequently during the day by schools of pilot whales, and one larger whale thought to be a fin whale was observed off the ship's bow.

19th September (Day 263) We were greeted by a very calm, warm and sunny morning and the forecast remained good at least to the weekend. The turbulence profiler was recovered just after mid-day after 250 profiles. *Discovery* had drifted to about 1 nm of the Met. Office ODAS buoy to the north of the OSMOSIS mooring array; so we set off to increase our distance from the buoy to 2 nm. CTD 381009 was in the water by 12:38 at 48° 59.24' N, 16° 24.50' W. With the CTD recovered after a 1000 m cast, *Discovery* headed off to the NW corner of the first SeaSoar survey (**Figure 2**), around 49° 6.6' N, 16° 51' W.

At 16:18 we began deploying SeaSoar at 49° 6.65' N, 16° 53.28' W; to begin the first SeaSoar survey. The tow cable was all paid out by 16:43 and by 17:15 a repeatable flight path over a depth range of ∼ 350 m was achieved at a tow speed of ∼ 9 knots.

20th September (Day 264) A rather grey day with increased wind speed around 10-15 knots and a rougher but still light sea, force 4-5. The SeaSoar survey continued throughout the day reaching over half way along leg 6 by 20:45. Updated positions for OSMOSIS gliders, SeaGliders 533 and 566, had been checked closely everytime they arrived during the SeaSoar survey. Both gliders were now in the OSMOSIS array region and clear of our SeaSoar tows although the last position from 533 was now over 24 hours old at 20:20 on the 19th.

21st September (Day 265) Finally we received positions from both gliders 533 and 566, in the early hours, confirming that they were both still in the mooring region and safely out of the path of SeaSoar. The turbulence glider was also out of harm's reach having been been gently pushed east by the mean current since deployment. The failed FASTNET glider, Ardbeg, was drifting slowly towards us which would make its recovery on the return leg to Southampton simpler if that remained the best or only option. It was a lovely sunny day and, with a less than rosy forecast for early the next week, most people took advantage of the welcome autumnal sunshine.

We reached the end of SeaSoar survey 1 (south west corner) at 19:06 and began to slow down for recovery. SeaSoar was on deck and secured by 19:40. CTD 381010 was in the water by 20:20 at 48° 16.94' N, 16° 50.97' W near the south west corner of the SeaSoar survey area to begin a line of 5 CTDs up to a turbulence profiler station point near the wave-rider buoy. The CTD went to 500 m and was back on deck at 21:05.

CTD stn.381011 was deployed at 48° 24.14' N, 16° 41.06' W, at 22:23. The CTD was recovered from a 500 m cast and secured on deck by 23:10.

22nd September (Day 266) CTD stn. 381012 was deployed at 48° 31.27' N, 16° 31.19' W at 00:27. The CTD was recovered from a 500 m cast and secured on deck by 01:34.

CTD stn. 381013 was being deployed at 03:10, at 48° 37.83' N, 16° 22.00' W, when the cable parted at the traction motor and the CTD was lost into the water. The CTD was outboard over the side at the time, and no-one was close to the runaway end of the cable so thankfully no one was hurt. After some deliberation and informing both the Master and the PSO, *Discovery* set course for the turbulence station. During the early morning the spare CTD frame was taken from storage and positioned under the CTD gantry for preparation and instrument build up.

At 07:04, at 48° 51.92' N, 16° 21.67 ' W we began our second turbulence profiling station with the ISW MSS90 profiler as before; the only difference was that this time hourly, rather than four hourly, underway samples were taken.

At 10:30, a meeting was held in the library to discuss possible causes for the CTD cable failure and subsequent loss of the CTD. The winch room had been checked as usual before deployment and as commonly found, the tension compensator sheave had to be

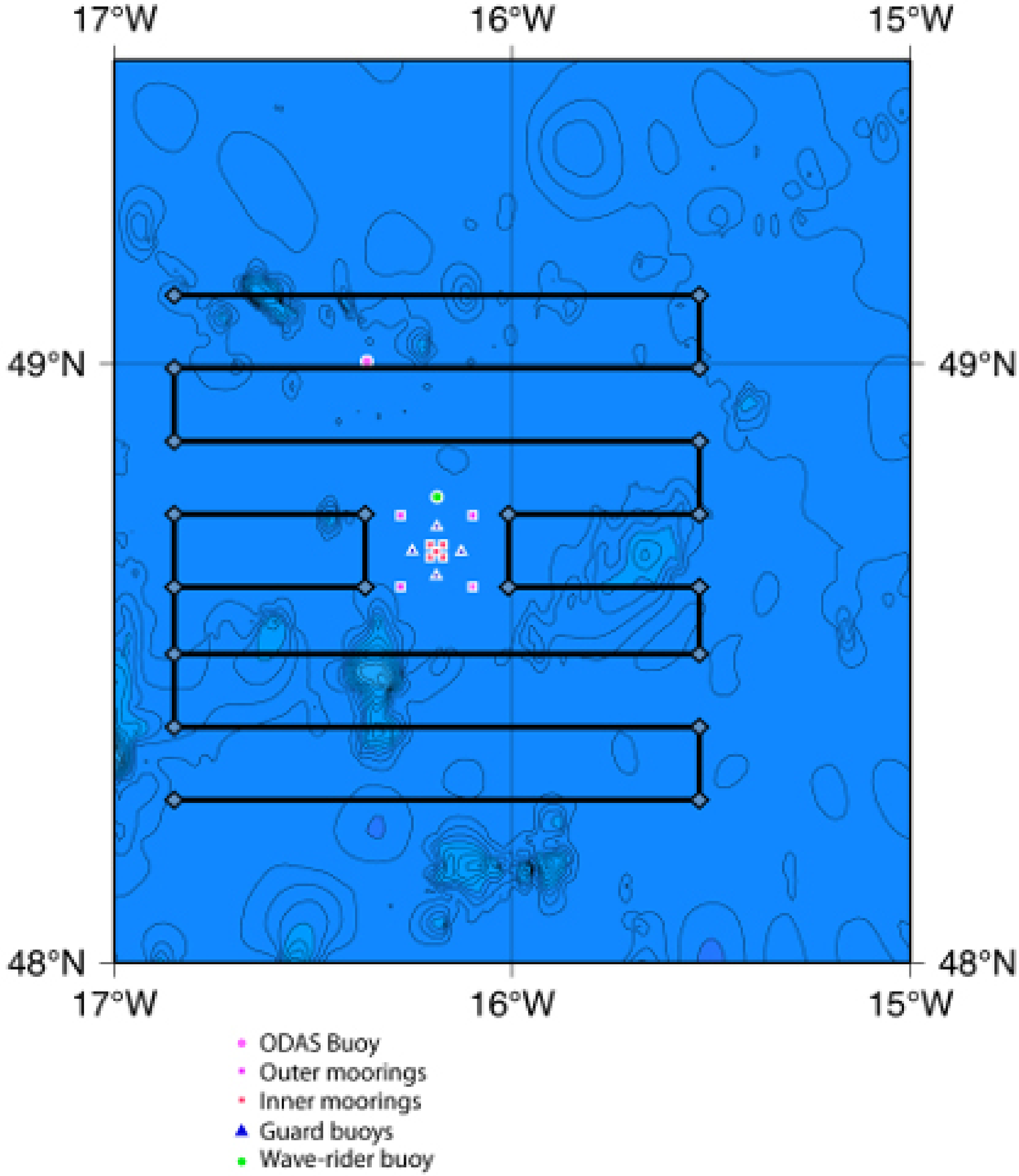

Figure 2: Diagram showing the layout of the first SeaSoar survey, legs are counted from north to south as legs 1-8, to be completed in the order 1, 2, 3, 4E, 5E, 6, 4W, 5W, 7, 8.

pushed up against the cable before starting up the winch but nothing else was seen to be out of the ordinary. During the day, a section of wire was taken off for future testing, the traction motor keeper rollers were examined, cleaned up and checked to be as close to the traction motor sheave grooves as possible, ready for afternoon and evening winch tests with a block weight.

At around 14:00, the turbulence profiler had to be recovered back on deck and 100-200 m of cable cut off the winch drum before re-termination. This followed snagging of and subsequent damage to the cable when it jumped the drum cheeks during recovery. After re-termination by our technical support team, turbulence profiling restarted at $\sim$ 16:45; during this down time *Discovery* had been repositioned back to the position of the start of this turbulence station given above.

23nd September (Day 267) By breakfast the sea state had built to a force 6 with wind speeds around 23 knots. Turbulence profiling continued with a surprisingly high level of enthusiasm. Wind and swell in opposition and now forecast to calm somewhat during the day, wet and blustery nonetheless. More dummy CTD deployments with a block weight were carried out during the morning.

The turbulence profiler was recovered and on deck at 12:57, and *Discovery* set course towards the northern guard buoy position to spend a short time looking for the mid-water buoyancy sphere on the PES (precision echo-sounder) fish. Knowing the continued existence of the buoyancy sphere and ranging its depth would help to determine if the mooring could be safely recovered; however it is a small target. Work also began reterminating the CTD cable following completion of the winch tests.

The PES survey began around 15:30, and it seemed strange and somehow scientifically difficult to justify hunting for something we no longer expect to be there; nonetheless we knew it would help in justifying any decision not to try to recover the failed mooring this trip: that is, there is insufficient positive buoyancy left, if the mid-water sphere has been carried past its failure pressure (2000 m), to be sure that the acoustic releases will rise fully to the surface and therefore if released what remains could create a submerged drifting hazard for the rest of the OSMOSIS mooring array.

The PES survey finished at $\sim$ 17:40, as expected finding no evidence of the continued existence of a submerged buoyancy sphere between 700 m and 3400 m. *Discovery* steamed to the new start point for SeaSoar survey 2, at the southern end of leg5 North (**Figure 3**).

SeaSoar was deployed at $\sim$18:45, at 48° 45.91' N, 16° 04.30' W, and the tow cable was fully paid out with *Discovery* coming up to speed at 19:08. On this northbound leg, *Discovery* was fighting to maintain 7-7.5 knots against the northerly swell.

24th September (Day 268) The sea state remained a steady force six through the night and into the morning. The forecast now indicated that things might not roughen up too badly until tomorrow. We were, and had been for some few days caught between two large converging depressions, one coming down from Iceland and now settling over the UK, the second one coming from the south and now heading into Biscay.

With 30+ knot winds for a significant time, during late morning and very early afternoon, it was surprising that mean significant wave heights were still around 3 metre. However turning points at 5-10 degrees a minute for SeaSoar were difficult; and on northerly legs *Discovery* was knocked back by the swell to ∼ 7 knots or less resulting in SeaSoar profiles not being able to reach much shallower than 30 m at times.

By 19:00, at the southern end of leg6S we decided to miss out legs 5S and 4S (**Figure 3**) to avoid making too many slow turns through the weather overnight. Instead we would head west as far as the southern end of leg 3 and attempt to do this leg overnight in a northerly direction. The wind and sea were coming from the north-west and *Discovery* was struggling to even achieve six knots against it. Although the barograph remained flat, small but violent weather cells were continuously developing around us whipping up squalls of 30-35 knot plus winds and poor visibility. Watching the pitching and the resulting rise and fall on the SeaSoar cable, and noting the very limited profile being achieved by SeaSoar, at 19:15 I decided discretion was here, we had tried but with a constant train of squalls and no great forecast for improvement it was time to recover SeaSoar in the last of the fading light.

After a skilful recovery, whilst shipping the odd splash over the aft deck, with only one gentle clang on the ship's stern, SeaSoar was on deck and tied down in the cradle before 20:00. *Discovery* hove-to till morning light: bitterly disappointing but we simply couldn't beat this weather cell.

25th September (Day 269) Morning was much the same as evening, just brighter. Turbulence profiling looked plausible for a while, at least until the forecast gale/severe gale hits us. However, on later reassessment at ∼ 09:00, the size of the swell was felt to pose too much of a risk on both the integrity of the cable and on the chance of slack being washed under the stern of the ship. Mean wave height was still ∼ 3.3 m, wind speed a steady 25-30 knots with squalls reaching over 35 knots occasionally. The barometric pressure had risen a little but was more or less stable around 998-1000 mbar.

By mid-aftrenoon the mean wave height had dropped significantly below 3 m. The wind speed had also dropped to 20-25 knots, barometric pressure still around 1000 mbar. Where was this forecast ?. At 15:00 hours we had two presentations in the bar, from Brodie Pearson and Natasha Lucas, who outlined the theory and the results so far of their work with the turbulence profiler data; this was much enjoyed by the audience and showed promising results regarding the balance between wind driven and wave driven mixing regimes and potential differences between the two turbulence profiler stations so far. We would reassess the weather at first light tomorrow, an early rise for all.

26th September (Day 270) After an uncomfortable night, by first light it was clear that the forecast had finally happened, steady 30-35 + knot force 8 winds and seas of 6-7 m mean wave height. Today would also not be workable.

By ∼ 15:00 the wind speed had begun to drop, generally force 6, and the mean wave height had decreased to ∼ 4 m although there was still the odd big peak wave. Stuart Painter suggested we could connect up the old XBT launcher and recording system and launch a few XBTs to see what had happened to the seasonal mixed layer depth. Having put the system back together and found a box of old T-7 (∼750 m) XBTs, at ∼ 15:30 a series of half hourly spaced XBT launches began as we were steaming slowly northwards whilst hove-to around 48° 26.46' N, 16° 15.87' W.

Having discovered the surface mixed layer was now ∼ 50 m thick, the fourth and final XBT was launched at ∼ 17:30.

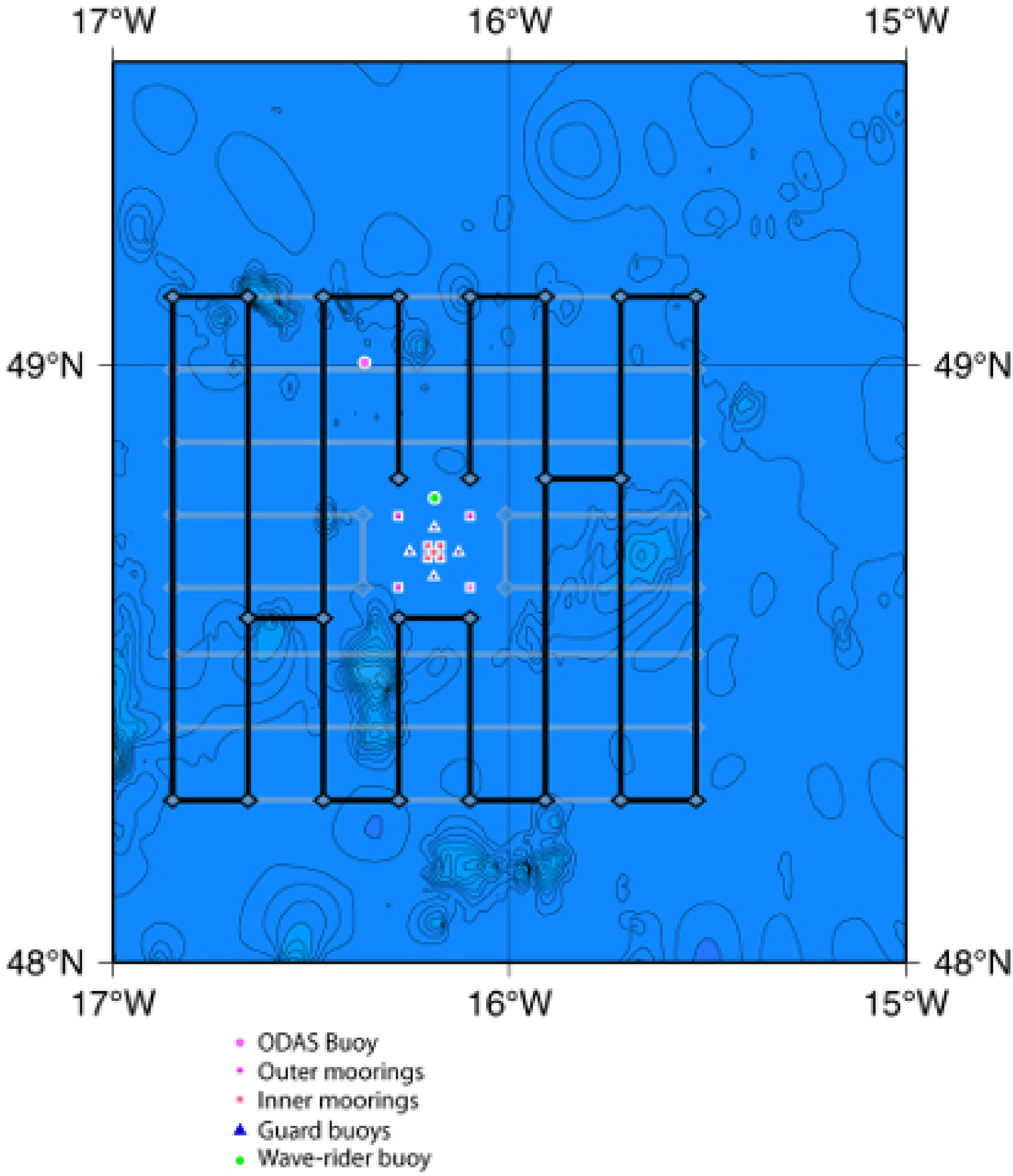

Figure 3: Diagram showing the layout of the second SeaSoar survey, legs are counted from west to east as legs 1-8, to be completed in the order 5N, 6N, 7N, 8, 7S, 6S, 5S, 4S, 3S, 2S, 1, 2N, 3N and 4N.

27th September (Day 271) By morning, seas had dropped significantly, although there were still some heavy occasional heavy swells. The wind speed had dropped to ∼16 knots and the pressure had levelled off at 1017 mbar. At 06:30 *Discovery* turned east towards the wave-ride mooring position approximately 6 miles away. By 07:45 we had spotted what we initially believed to be the wave-rider and were standing off. Sometime later we realised we were in fact looking at the yellow sub-surface buoyancy to which the wave-rider should have been loosely tethered. However, neither the wave-rider nor the bright yellow tether line could be seen. A satellite call to Mark Inall at SAMS put our minds at rest to some extent, the wave-rider was still communicating but had drifted off some 7-8 nm to the south east.

Discovery set course for 48° 43.63' N, 16° 2.75' W, the last position of the wave-rider buoy at 09:55. The buoy was spotted at 10:50 and the line hooked at 10:58. By 11:25 the wave-rider and line had been recovered, the line was still attached to its original short length of chain and astonishingly the shackle with which it was attached to the sub-surface buoyancy sphere, just without the pin. During recovery we passed a long line float indicating there was still long line fishing activity here. *Discovery* set course back to the moored remains of the mooring.

Standing just under half a mile off, the mooring was released at 12:50. The floatation glass spheres attached to the acoustic releases were spotted and grappled by 14:30. Following recovery of the glass spheres and releases, the mooring line became entangled with the PES fish and required recovery of the PES fish to release it. The mooring line and the sub-surface buoyancy sphere were fully recovered and secured on board at 17:06.

Discovery then set course for the turbulence glider position, now some 5 nm to the south east of the wave-rider mooring position. The glider was spotted at 18:05. The wind speeds were 15-20 knots and the sea-state moderate with a reduced but ever present swell. At 18:55 the glider was finally recovered in the cargo net at 48° 42.76' N, 16° 5.94' W. The cargo net had previously been prepared into a square landing frame, similar to recoveries previously made during the FASTNET programme, however, it was not an easy recovery in these seas. Although one wing was lost, and the other bent, the glider was otherwise apparently undamaged.

Discovery finally steamed ∼ 5 nm north out of the OSMOSIS mooring array area to 48° 50.50' N, 16° 9.72' W to begin a third turbulence profiling station. Turbulence profiling began at 20:31.

28th September (Day 272) At 08:19, ∼ two hourly spaced CTDs began, interspersed with the turbulence profiling. CTD stn. 381014, at 48° 58.46' N, 16° 5.13'W. A number of large whales, generally identified as Fin whales visited us at around 09:30 onwards, they were joined by a large school of Pilot whales around 10:30 and both species stayed with us for much of the day.

CTD stn. 381015 was deployed at 48° 58.56' N, 16° 3.74' W at 10:35; it was recovered from a 500 m cast at 11:19.

CTD stn. 381016 was deployed at 13:40 at 48° 58.99' N, 16° 3.76' W; and recovered from a 500 m cast at 14:28.

CTD stn. 381017 was deployed at 16:27 at 49° 0.50' N, 16° 4.09' W; and recovered from a 500 m cast at 17:16. However, whilst out at 500 m, it was noticed that there was a loose broken outer strand of wire clearly visible on the cable. CTDs would have to be abandoned until ~ 500 m of cable had been cut off and the cable re-terminated.

29th September (Day 273) After a total of 629 profiles over the three turbulence profiler stations, the turbulence profiler was recovered and secured away by 00:15 at 49° 3.56' N, 16° 4.67' W. CTD stn. 381018 was immediately deployed following load testing of the new termination at 00:24 at 49° 3.59' N, 16° 4.67' W; and recovered from a 500 m cast at 01:21.

Discovery then steamed for the north-west corner of the SeaSoar survey area (**Figure 3**), stopping twice to carry out calibration CTDs as we crossed legs 2 and 3.

CTD stn. 381019 was deployed at 03:45 at 49° 5.09' N, 16° 28.28' W; recovered from 500 m cast at 04:38.

CTD stn. 381020 was deployed at 05:44 at 49° 5.81' N, 16° 39.84' W; recovered from 500 m cast at 06:52.

SeaSoar was deployed to begin leg 1 of the 'second' SeaSoar survey (**Figure 3**) at 08:00 at 49° 9.05' N, 16° 47.42' W.

At 13:25, *Discovery* had a full power shut down following an emergency switchboard trip. For some time we lay dead in the water with the emergency generator operating. SeaSoar hung still, and the wire angle was watched carefully. After the problem was found, *Discovery's* power was restored with the main generators started up, and by 14:10 we were coming back onto the track of leg 1 near the southern end. Computing systems would take somewhat longer, but SeaSoar was up and flying again. By ~ 15:10 Yair Yaniv had restored all the data logging systems. The underway logging of data was off between 13:24:05 and 15:04:22 (100.3 minutes) in total.

30th September (Day 274) At the southern end of leg 3, at ~ 03:36, we turned to the east to tow SeaSoar along leg 8 of the 1st SeaSoar survey (**Figure 2**) to the south east corner of the SeaSoar survey area. The survey finished at ~ 07:45 and *Discovery* turned about to recover SeaSoar into the sea; 2 m mean significant wave height and 27 knot winds. SeaSoar was recovered and secured by 08:40.

CTD stn. 381021 was deployed at 08:59 at 48° 11.58' N, 15° 30.30' W. The CTD was recovered and secured on deck by 09:55.

At ~ 10:15 we set off east towards the continental shelf edge, specifically ~ 47° 59' N, 10° 59' W the most recent position of the drifting Ardbeg glider, our ETA was ~ 06:30 the next morning.

1st October (Day 275) The failed SAMS glider 'Ardbeg' was spotted at 07:04, 'lassoed' at 07:13 and safely on board on board at 07:16, at 48° 00.48' N, 10° 57.86' W. The NOCS glider 'Coprolite' had been navigated over the past 4 days to a position approximately 2 nm south east of the SAMS glider's position. At 07:23, *Discovery* set off for Coprolite's last position. Coprolite was spotted at approximately 08:20, maneuvered into the cargo net and recovered at 08:45, at 47° 59.31' N, 10° 56.61' W.

CTD stn. 381022, was immediately deployed for later inter-comparison purposes, at 09:07 at 47° 59.40' N, 10° 56.55' W. The CTD was taken to 1000 m and recovered without bottle stops at 09:55.

Discovery set course for Southampton.

3 TECHNICAL SUPPORT

CTD Operations – *James Burris*

Introduction

The following report contains the details of CTD operations for both sections of the D381 cruise.

The CTD system was a Stainless steel, 24-way frame, fitted with 10L Water Samplers. The frame was fitted with a SBE 9 Plus CTD underwater unit. (used in conjunction with an 11 plus deck unit). The CTD package consisted of 2 SBE 3P temperature sensors (for both primary and secondary), 2 SBE 4C conductivity sensors (again for primary and secondary) and also a SBE 43 dissolved oxygen sensor.

The primary temperature and conductivity sensors (and the DO sensor) were all fitted below the water sampler bottles in the main frame. The secondary temperature and conductity sensors were fitted out side of the main frame on the vane.

In addition to the core suite of sensors; a BBRT, Fluorimeter, Downward looking ADCP, altimeter and an acoustic pinger were also fitted (please see sensor sheet for further details).

During D381a, a total of 4 CTDs were carried out. (Appendix A: Sensor Information sheet). To date 8 CTDs have been successfully carried out in D381b. Unfortunately at the start of CTD 013 the wire parted as the package was being lowered to the water, and the entire CTD rosette was lost.

Appendix B contains the sensor information sheet for the second CTD frame. Appendix C contains the script for the Lowered ADCP configuration file.

Deployment comments for CTD

For all CTD casts, the package was initially lowered to a depth of 10m to allow the SBE pumps to come on and for the instruments to stabilise. Depending on sea state, the package was then either raised to just below surface and then sent down to desired max depth. If however the sea state was marginal, the package was sent straight down from 10m to target depth.

For casts up to and including cast 012, when hauling the CTD back up from depth, a pause of at least 60 seconds was used at each bottle stop to allow the water to stabilise and try and minimise the effects of entrainment.

Casts 014 onwards had the majority of the bottles fired whilst the CTD was moving upwards through the water column, this was done to reduce overall deployment time. The only bottles that had normal stops (to allow for dissipation of entrainment) were those that were below 200m and also 1 stop in the mixed layer.

CTD winch and wire

The CTD wire had to be re-terminated twice during the whole duration of the cruise.

The first occasion was due to the CTD wire becoming jammed in the winch room, which resulted in the wire parting. 80m of wire was lost with the CTD package. A further 200m (approx) was cut off to get back to good wire before re-terminating.

The CTD wire parted at 03:09:45 on 22/09/2012. The vessel position at the time of loss was 48° 37.828'N 016° 22.004'W.

The second re-termination was done due to a broken wire in the outer armour, therefore causing a potential snag point and also a reduction in strength. This re-termination resulted in 500m of wire being cut out to get back to good wire. The re-termination happened after cast 017. No further problems were noted after this, although it has been noted that the general condition of the wire is poor, with significant amounts of corrosion.

T-C duct cleaning regime

After each cast the T-C ducts (and SBE43) were flushed 2-3 times with Milli-Q and left to drain. If the next cast was due within 2-3 hrs the ducts were not capped. At all other times the caps were fitted.

Once a week the ducts were cleaned first with bleach solution, and subsequently with a Triton-X solution before flushing with Milli-Q.

Lowered ADCP

The LADCP was operated by NMF technicians. Prior to each deployment the BBtalk terminal session was logged to a file named with the format D381xxx.txt, where xxx was the CTD cast number. This was done for every cast excluding the first two. Then the following commands were sent:

TS?	time set, offset from GPS clock noted and time reset if greater than a few seconds.
RS?	to check flashcard space and RE ErAse if necessary
PA, PT200 and PC2	pre-deployment and built in self tests

About 5-10 minutes before the CTD was deployed the command file was sent and BBtalk file logging stopped. Deployment and end of pinging times were recorded on the rough log sheets.

After pinging was stopped, the number of deployments in the recorder was queried with RA?, the baud rate changed to 115200 with CB811 for download, and then the most recent file downloaded in the default RDI-xxx.000 name format. The file was then renamed to the form D381_xxx.000. All filenames were noted on the rough log sheets.

Finally CB411 was sent to change baud rate to 9600 for sending the command file for the next cast.

The battery was fully charged at 58V until it was drawing 100mA between each cast. Every week the battery was vented to release excess build up of gases caused by the operation of the lead acid battery.

CTD Cast	Station ID	Date	Start time	End time	Max Depth	Lat	Long	Comments
001	001	31/08/2012	15:13	19:24	4818m	48° 37.886'N	016° 16.922'W	Only fired 12 bottles. Used cast to wire test Ax releases
002	002	02/08/2012	18:42	19:41	1000m	48° 45.695'N	016° 6.342'W	-
003	003	04/09/2012	11:42	16:01	4805m	48° 42.048'N	016° 08.866W	Used cast to wire test Ax releases
004	004	06/09/2012	12:37	16:32	4710m	48° 41.927'N	016° 20.598'W	-
005	381005	15/09/2012	19:48	20:44	794m	48° 09.036'N	009° 42.161'W	Shelf edge
006	381006	17/09/2012	12:06	13:12	1000m	48° 36.346'N	016° 03.918'W	-
007	381007	17/09/2012	21:15	21:59	500m	48° 48.768'N	016° 27.098'W	-
008	381008	18/09/2012	15:38	16:50	500m	48° 48.462'N	016° 21.667'W	-
009	381009	19/09/2012	12:36	13:45	1000m	48° 58.847'N	016° 22.546'W	5 btls leaked
010	381010	21/09/2012	20:18	21:03	500m	48° 16.952'N	016° 50.984'W	**PAR sensor added**
011	381011	21/09/2012	22:22	23:09	500m	48° 24.132'N	016° 41.061'W	-
012	381012	22/09/2012	00:26	01:33	500m	48° 31.242'N	016° 31.205'W	
013	381013	22/09/2012	03:09	-	-	48° 37.828'N	016° 22.004'W	CTD wire parted. CTD lost
014	381014	28/09/2012	08:19	08:41	200m	48° 58.522'N	016° 05.438'W	
015	381015	28/09/2012	10:35	?	500m	48° 58.556'N	016° 03.730'W	
016	381016	28/09/2012	13:40	14:26	500m	48° 58.983'N	016° 03.763'W	
017	381017	28/09/2012	16:26	17:33	500m	49° 00.489N	016° 04.078'W	
018	381018	29/09/2012	00:23	01:18	500m	49° 03.585'N	016° 04.684'W	1st cast after re-termination

Continued on next page

Table 1 – *continued from previous page*

CTD Cast	**Station ID**	**Date**	**Start time**	**End time**	**Max Depth**	**Lat**	**Long**	**Comments**
019	381019	29/09/2012	03:45	04:36	500m	49° 05.069'N	016° 28.307'W	
020	381020	29/09/2012	05:44	06:52	500m	49° 05.833'N	016° 39.886'W	

Table 1: Summary of CTD casts.

Appendix A - CTD First Frame Sensor Information

SHIP: RRS DISCOVERY	CRUISE: D381

FORWARDING INSTRUCTIONS / ADDITIONAL INFORMATION:
AS SET UP ON BOARD FOR D381

Checked By: J. WYNAR	DATE: 16th August 2012

Instrument / Sensor	Manufacturer/ Model	Serial Number	Channel	Casts Used
Primary CTD deck unit	SBE 11plus	11P-34173-0676	n/a	1 – 13
CTD Underwater Unit	SBE 9plus	09P-67371-1082	n/a	1 – 13
Stainless steel 24-way frame	NOCS	1415	n/a	1 – 13
Digiquartz Pressure sensor	Paroscientific	121341	F2	1 – 13
Primary Temperature Sensor	SBE 3P	3P-5277	F0	1 – 13
Primary Conductivity Sensor	SBE 4C	4C-3920	F1	1 – 13
Secondary Temperature Sensor	SBE 3P	3P-4105	F3	1 – 13
Secondary Conductivity Sensor	SBE 4C	4C-3580	F4	1 – 13
Dissolved Oxygen Sensor	SBE 43	43-2262	V0	1 – 13
Primary Pump	SBE 5T	5T-2279	n/a	1 – 13
Secondary Pump	SBE 5T	5T-3002	n/a	1 – 13
24-way Carousel	SBE 32	32-37898-0518	n/a	1 – 13
Altimeter	Benthos 916T	874	V3	1 – 13
Salinometer	Guildline 8400B	60839	n/a	N/A
10L Water Samplers	OTE	1 -24	n/a	1 – 13
BBRTD Light Scatter Sensor	Wetlabs	167	V2	1 – 13
Transmissometer	CTG MKII Alphatracka	161050	V6	1 – 13
Fluorimeter	CTG Aquatracka MKlll	09-7117-001	V7	1 – 13
WHM 300kHz LADCP	TRDI	12919	n/a	1 – 13

Appendix B - CTD Second Frame Sensor information

SHIP: RRS DISCOVERY	CRUISE: D381

FORWARDING INSTRUCTIONS / ADDITIONAL INFORMATION:
REPLACEMENT FRAME AS BUILT ON-BOARD FOR D381b After Total Package Loss (22/09/2012, 03:10, 48º 37.828'N, 016º 22.004'W)

Checked By: J.BURRIS / D.MOUNTIFIELD	DATE: 23rd September 2012

Instrument / Sensor	Manufacturer/ Model	Serial Number	Channel	Casts Used
Primary CTD deck unit	SBE 11plus	11P-34173-0676	n/a	14 on
CTD Underwater Unit	SBE 9plus	09P-46253-0869	n/a	14 on
Stainless steel 24-way frame	NOCS	SBE CTD 6	n/a	14 on
Digiquartz Pressure sensor	Paroscientific	100898	F2	14 on
Primary Temperature Sensor	SBE 3P	3P-5494	F0	14 on
Primary Conductivity Sensor	SBE 4C	4C-3698	F1	14 on
Secondary Temperature Sensor	SBE 3P	3P-5495	F3	14 on
Secondary Conductivity Sensor	SBE 4C	4C-3874	F4	14 on
Dissolved Oxygen Sensor	SBE 43	43-2055	V0	14 on
Primary Pump	SBE 5T	5T-3085	n/a	14 on
Secondary Pump	SBE 5T	5T-3088	n/a	14 on
24-way Carousel	SBE 32	3219817-0243	n/a	14 on
Altimeter	Benthos 916T	47597	V3	14 on
Salinometer	Guildline 8400B	60839	n/a	N/A
10L Water Samplers	OTE	1A -24A	n/a	14 on
BBRTD Light Scatter Sensor	Wetlabs	758R	V2	14 on
Transmissometer	CTG MKII Alphatracka	07-6075-001	V6	14 on
Fluorimeter	CTG Aquatracka MKlll	088095	V7	14 on
WHM 300kHz LADCP LADCP	TRDI	13329	n/a	14 on
Aluminium Battery Pack	NMF-SS	WH007	n/a	14 on

Appendix C - Lowered ADCP configuration file.

```
CR1
    CF11101
    EA00000
    EB00000
    ED00000
    ES35
    EX11111
    EZ0111111
    TE00:00:05.00
    TP00:00.00
    WM15
    LD111100000
    LF176
    LN27
    LP1
    LS400
    LV175
    LJ1
    LW1
    LZ30, 220
    SM1
    SA001
    SI0
    SW0
    CK
    CS
```

Appendix D - Con file for the first CTD set up (prior to CTD loss)

PSA file:
C:\Program Files\Sea-Bird\SeasaveV7\D381\D381_SS_NMEA.psa
Date: 09/25/2012
Instrument configuration file:
C:\Program Files\Sea-Bird\SeasaveV7\D381\D381_NMEA_PAR.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-5277
Calibrated on : 8 May 2012
G : 4.37793729e-003
H : 6.38304908e-004
I : 2.22471665e-005
J : 2.01586552e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000
2) Frequency 1, Conductivity
Serial number : 04C-3920
Calibrated on : 7 March 2012
G : -1.02435488e+001
H : 1.37820698e+000
I : -6.04468726e-004
J : 1.18827899e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000
3) Frequency 2, Pressure, Digiquartz with TC
Serial number : 121341
Calibrated on : 6 March 2012
C1 : -4.817191e+004
C2 : -2.790175e-001

C3 : 1.471600e-002
D1 : 3.995300e-002
D2 : 0.000000e+000
T1 : 3.031710e+001
T2 : -3.320637e-004
T3 : 3.758500e-006
T4 : 4.062020e-009
T5 : 0.000000e+000
Slope : 1.00000000
Offset : 0.00000
AD590M : 1.282700e-002
AD590B : -9.212862e+000
4) Frequency 3, Temperature, 2
Serial number : 03P-4105
Calibrated on : 8 May 2012
G : 4.39448443e-003
H : 6.48450043e-004
I : 2.36074914e-005
J : 2.15806109e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000
5) Frequency 4, Conductivity, 2
Serial number : 04C-3580
Calibrated on : 8 May 2012
G : -9.68070578e+000
H : 1.16862145e+000
I : -1.37195778e-003
J : 1.45468590e-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 : 43-2262
Calibrated on : 6 March 2012
Equation : Sea-Bird
Soc : 4.08900e-001
Offset : -5.03700e-001
A : -2.69180e-003
B : 1.25350e-004
C : -1.83090e-006
E : 3.60000e-002
Tau20 : 1.53000e+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, Turbidity Meter, WET Labs, ECO-BB
Serial number : 167
Calibrated on : 6 July 2011
ScaleFactor : 1.000000
Dark output : 0.000000
9) A/D voltage 3, Altimeter
Serial number : 874
Calibrated on : 10 Mar 2010
Scale factor : 15.000
Offset : 0.000
10) A/D voltage 4, PAR/Irradiance, Biospherical/Licor
Serial number : 46-2835-09
Calibrated on : 16 December 2011
M : 0.42671000
B : 2.26532000
Calibration constant : 10000000000.00000000
Multiplier : 1.00000000
Offset : 0.00000000
11) A/D voltage 5, Free
12) A/D voltage 6, Transmissometer, Chelsea/Seatech
Serial number : 161-050
Calibrated on : 29 Feb 2012
M : 23.8318
B : -0.5171
Path length : 0.250
13) A/D voltage 7, Fluorometer, Chelsea Aqua 3
Serial number : 09-7117-001
Calibrated on : 20th June 2011
VB : 0.217800
V1 : 2.096300
Vacetone : 0.393000
Scale factor : 1.000000
Slope : 1.000000
Offset : 0.000000
Scan length : 41

Pump Control
This setting is only applicable to a custom build of the SBE 9plus.
Enable pump on / pump off commands: YES
Serial port for 911 pump control: COM3

Data Acquisition:

Archive data: YES
Delay archiving: NO
Data archive:
C:\Program Files\Sea-Bird\SeasaveV7\D381\raw data\D381_010.hex
Timeout (seconds) at startup: 10
Timeout (seconds) between scans: 10

Instrument port configuration:
Port = COM1
Baud rate = 19200
Parity = N
Data bits = 8
Stop bits = 1

Water Sampler Data:
Water Sampler Type: SBE Carousel
Number of bottles: 32
Port: COM3
Enable remote firing: NO
Firing sequence: User input
Tone for bottle fire confirmation uses PC internal speakers.

Header information:
Header Choice = Prompt for Header Information
prompt 0 = Ship: RRS Discovery
prompt 1 = Cruise: D381
prompt 2 = Station ID:
prompt 3 = CTD Cast:
prompt 4 = Date:
prompt 5 = Julian Day:
prompt 6 = Time (GMT):
prompt 7 = Latitude:
prompt 8 = Longitude:
prompt 9 = Depth (uncorrected):
prompt 10 = Prinicpal Scientist: John Allen
prompt 11 = Operator: NMFSS Tech party

TCP/IP - port numbers:
Data acquisition:
Data port: 49163
Status port: 49165
Command port: 49164
Remote bottle firing:
Command port: 49167
Status port: 49168
Remote data publishing:

Converted data port: 49161
Raw data port: 49160

Miscellaneous data for calculations
Depth and Average Sound Velocity
Latitude when NMEA is not available: 53.500000
Average Sound Velocity
Minimum pressure [db]: 20.000000
Minimum salinity [psu]: 20.000000
Pressure window size [db]: 20.000000
Time window size [s]: 60.000000
Descent and Acceleration
Window size [s]: 2.000000
Plume Anomaly
Theta-B: 0.000000
Salinity-B 0.000000
Theta-Z / Salinity-Z 0.000000
Reference pressure [db] 0.000000
Oxygen
Window size [s]: 2.000000
Apply hysteresis correction: 1
Apply Tau correction: 1
Potential Temperature Anomaly
A0: 0.000000
A1: 0.000000
A1 Multiplier: Salinity

Serial Data Output:
Output data to serial port: NO

Mark Variables:
Variables:
Digits Variable Name [units]
----
0 Scan Count
4 Depth [salt water, m]
7 Conductivity [S/m]
5 Salinity, Practical [PSU]

Shared File Output:
Output data to shared file: YES
File name:
Seconds between updates: 0.000000
Variables:
Digits Variable Name [units]
----

0 Scan Count
5 Temperature [ITS-90, deg C]
7 Conductivity [S/m]
4 Pressure, Digiquartz [db]
4 Depth [salt water, m]
6 Oxygen, SBE 43 [ml/l]
6 Oxygen, SBE 43 [% saturation]
6 Oxygen Saturation, Weiss [ml/l]
5 Salinity, Practical [PSU]
———————————————
TCP/IP Output:
Raw data:
Output raw data to socket: YES
XML wrapper and settings: YES
Seconds between raw data updates: 0.000000
Converted data:
Output converted data to socket: YES
XML format: YES
Seconds between converted data updates: 0.000000
Variables:
Digits Variable Name [units]
—————————
0 Scan Count
7 Conductivity [S/m]
5 Temperature [ITS-90, deg C]
4 Pressure, Digiquartz [db]
4 Depth [salt water, m]
6 Oxygen, SBE 43 [ml/l]
6 Oxygen, SBE 43 [% saturation]
5 Salinity, Practical [PSU]
4 Time, Elapsed [seconds]
6 Oxygen Saturation, Weiss [ml/l]
———————————————
SBE 11plus Deck Unit Alarms
Enable minimum pressure alarm: NO
Enable maximum pressure alarm: NO
Enable altimeter alarm: NO
———————————————
SBE 14 Remote Display
Enable SBE 14 Remote Display: NO
———————————————
PC Alarms
Enable minimum pressure alarm: NO
Enable maximum pressure alarm: NO
Enable altimeter alarm: NO
Enable bottom contact alarm: NO

Alarm uses PC sound card.

Options:
Prompt to save program setup changes: YES
Automatically save program setup changes on exit: NO
Confirm instrument configuration change: YES
Confirm display setup changes: YES
Confirm output file overwrite: YES
Check scan length: YES
Compare serial numbers: NO
Maximized plot may cover Seasave: NO

Appendix E - Con File for Second CTD frame

PSA file:
C:\Program Files\Sea-Bird\SeasaveV7\D381\D381_2ND_CTD_SS_NMEA.psa
Date: 09/25/2012
Instrument configuration file:
C:\Program Files\Sea-Bird\SeasaveV7\D381\D381_2ND_CTD_B__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 : 03F-5494
Calibrated on : 09-May-12
G : 4.32432899e-003
H : 6.26209304e-004
I : 1.95955803e-005
J : 1.51713616e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000
2) Frequency 1, Conductivity
Serial number : 04C-3698
Calibrated on : 08-May-12
G : -1.01569849e+001
H : 1.43967267e+000
I : -3.44059820e-003
J : 3.39351246e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000
3) Frequency 2, Pressure, Digiquartz with TC
Serial number : 0869
Calibrated on : 06-Jan-12
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 : 06 July 2012
G : 4.38224268e-003
H : 6.31026077e-004
I : 2.02985691e-005
J : 1.58183621e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000
5) Frequency 4, Conductivity, 2
Serial number : 04C-3874
Calibrated on : 12 July 2012
G : -1.05030174e+001
H : 1.38921915e+000
I : -1.00129763e-003
J : 1.37088089e-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 : 27 June 2012
Equation : Sea-Bird
Soc : 3.60000e-001
Offset : -7.01700e-001
A : -2.36690e-003
B : 7.10770e-005
C : -1.52550e-006
E : 0.00000e+000
Tau20 : 2.01000e+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, Turbidity Meter, WET Labs, ECO-BB
Serial number : 758R
Calibrated on : 18 May 2010
ScaleFactor : 0.003255
Dark output : 0.063000
9) A/D voltage 3, Altimeter
Serial number : 47597
Calibrated on : 10 Mar 2010
Scale factor : 15.000
Offset : 0.000
10) A/D voltage 4, Free
11) A/D voltage 5, Free
12) A/D voltage 6, Transmissometer, Chelsea/Seatech
Serial number : 07-6075-001
Calibrated on : 08 May 2012
M : 23.8616
B : -0.2331
Path length : 0.250
13) A/D voltage 7, Fluorometer, Chelsea Aqua 3
Serial number : 088-095
Calibrated on : 25 July 2012
VB : 0.300000
V1 : 2.787000
Vacetone : 0.393000
Scale factor : 1.000000
Slope : 1.000000
Offset : 0.000000
Scan length : 41

Pump Control
This setting is only applicable to a custom build of the SBE 9plus.
Enable pump on / pump off commands: YES
Serial port for 911 pump control: COM3

Data Acquisition:
Archive data: NO
Delay archiving: NO
Data archive: C:\Program Files\Sea-Bird\SeasaveV7\D381\raw data\D381_013.hex
Timeout (seconds) at startup: 10
Timeout (seconds) between scans: 10

Instrument port configuration:

Port = COM1
Baud rate = 19200
Parity = N
Data bits = 8
Stop bits = 1

Water Sampler Data:
Water Sampler Type: SBE Carousel
Number of bottles: 32
Port: COM3
Enable remote firing: NO
Firing sequence: User input
Tone for bottle fire confirmation uses PC internal speakers.

Header information:
Header Choice = Prompt for Header Information
prompt 0 = Ship: RRS Discovery
prompt 1 = Cruise: D381
prompt 2 = Station ID:
prompt 3 = CTD Cast:
prompt 4 = Date:
prompt 5 = Julian Day:
prompt 6 = Time (GMT):
prompt 7 = Latitude:
prompt 8 = Longitude:
prompt 9 = Depth (uncorrected):
prompt 10 = Prinicpal Scientist: John Allen
prompt 11 = Operator: NMFSS Tech party

TCP/IP - port numbers:
Data acquisition:
Data port: 49163
Status port: 49165
Command port: 49164
Remote bottle firing:
Command port: 49167
Status port: 49168
Remote data publishing:
Converted data port: 49161
Raw data port: 49160

Miscellaneous data for calculations
Depth and Average Sound Velocity
Latitude when NMEA is not available: 53.500000
Average Sound Velocity
Minimum pressure [db]: 20.000000

Minimum salinity [psu]: 20.000000
Pressure window size [db]: 20.000000
Time window size [s]: 60.000000
Descent and Acceleration
Window size [s]: 2.000000
Plume Anomaly
Theta-B: 0.000000
Salinity-B 0.000000
Theta-Z / Salinity-Z 0.000000
Reference pressure [db] 0.000000
Oxygen
Window size [s]: 2.000000
Apply hysteresis correction: 1
Apply Tau correction: 1
Potential Temperature Anomaly
A0: 0.000000
A1: 0.000000
A1 Multiplier: Salinity

Serial Data Output:
Output data to serial port: NO

Mark Variables:
Variables:
Digits Variable Name [units]
------ ---------------------
0 Scan Count
4 Depth [salt water, m]
7 Conductivity [S/m]
5 Salinity, Practical [PSU]

Shared File Output:
Output data to shared file: YES
File name:
Seconds between updates: 0.000000
Variables:
Digits Variable Name [units]
------ ---------------------
0 Scan Count
5 Temperature [ITS-90, deg C]
7 Conductivity [S/m]
4 Pressure, Digiquartz [db]
4 Depth [salt water, m]
6 Oxygen, SBE 43 [ml/l]
6 Oxygen, SBE 43 [% saturation]
6 Oxygen Saturation, Weiss [ml/l]

5 Salinity, Practical [PSU]

TCP/IP Output:
Raw data:
Output raw data to socket: YES
XML wrapper and settings: YES
Seconds between raw data updates: 0.000000
Converted data:
Output converted data to socket: YES
XML format: YES
Seconds between converted data updates: 0.000000
Variables:
Digits Variable Name [units]
------ ---------------------
0 Scan Count
7 Conductivity [S/m]
5 Temperature [ITS-90, deg C]
4 Pressure, Digiquartz [db]
4 Depth [salt water, m]
6 Oxygen, SBE 43 [ml/l]
6 Oxygen, SBE 43 [% saturation]
5 Salinity, Practical [PSU]
4 Time, Elapsed [seconds]
6 Oxygen Saturation, Weiss [ml/l]

SBE 11plus Deck Unit Alarms
Enable minimum pressure alarm: NO
Enable maximum pressure alarm: NO
Enable altimeter alarm: NO

SBE 14 Remote Display
Enable SBE 14 Remote Display: NO

PC Alarms
Enable minimum pressure alarm: NO
Enable maximum pressure alarm: NO
Enable altimeter alarm: NO
Enable bottom contact alarm: NO
Alarm uses PC sound card.

Options:
Prompt to save program setup changes: YES
Automatically save program setup changes on exit: NO
Confirm instrument configuration change: YES
Confirm display setup changes: YES
Confirm output file overwrite: YES

Check scan length: YES
Compare serial numbers: NO
Maximized plot may cover Seasave: NO

SeaSoar Operations –*Dougal Mountifield*

Summary

The Seasoar system was used to survey a ∼50 nm square grid across the OSMOSIS mooring array field during the cruise with 2 survey deployments. The line-spacing was ∼7 nm. The first survey had E-W main legs, and the second N-S. The science party took hourly discrete salinity samples from the underway system (∼6 m depth) throughout the tows. After the first survey an inter-calibration CTD transect was planned across the tow-lines, but was curtailed by the unfortunate total loss of the CTD package when the wire parted on the traction winch. The second survey was curtailed approximately half-way through by unworkable sea-conditions which unfortunately continued for over 48hrs. Eventually the western half of the second survey was completed as a third tow.

Distances and Time On-Survey

97 hrs (4 days) was spent undulating on survey covering ∼850 nm. No trial-towing opportunities were available due to time constraints. The deployment time from system power-up, to first dive, was approximately 40 minutes. The recovery time was of similar duration. Hence, each tow had a nominal overhead of 1 hour 20 minutes not profiling. For the three multi-day tows, a total of 4hrs was lost in deployment and recovery, a total of 4% of total Seasoar operation time. Note that in comparison, over the 30 short deployments of D369, 8% of total Seasoar operation time was lost in deployment and recovery.

Flight Characteristics

On D369, problems were encountered with a depth limitation of 200m. This was assessed to be caused by the fish inverting, due to roll instability, as the proximity of the Turner Cyclops optics sensors to the rudder was preventing positive roll control. During D369, the Cyclops sensors were relocated from the top of the top tail-fin to the aft end of the top cover. Also on D369 the LOPC was removed and the fish was then towed successfully at 8.5 - 9 knts on 750m of faired cable, undulating between the surface and ∼390m.

For D381b, the Turners were left on the top cover but the LOPC was refitted on the underside of the lower tail-fin. The vehicle towed well at 8-8.5knts, between the surface and ∼370m, with ∼700m of deployed tow-cable. This confirms that the current location of the LOPC does *not* significantly compromise the flight behaviour of Seasoar. During the heavy weather (F6-F7) experienced during the second tow, vessel speeds were often down to 6-6.5knts which limited minimum fish depths to ∼40-50m due to reduced hydrodynamic lift. It is thought that this would not improve greatly had the LOPC not been fitted.

The wing-trim was left as set on D369 with a 1 degree up-wing bias set on the push rods. This yields a range of 16 degrees up to 14 degrees down wing angle. Over a few hundred hours in the water over the past few cruises, this trim has proven to be optimally suited to the vehicle with its current payload.

Winch, Wire and Fairing

The winch has had its HPU motor and bell-housing replaced due to excessive corrosion and has had a new scroll chain fitted. The winch electrical system was inspected and certified safe by IME prior to the cruise. A dedicated lifting bridle was procured with colour-coded ferrules to match colour-coded lifting points on the winch due to each leg being a different length.

The scroll-bearer shafts and lead-screw were protected with Denso tape prior to the cruise. This was removed and the shafts and screw cleaned and greased onboard prior to use. The load-cell panel meter current loop transmitter was re-configured to 4-20mA to allow detection of deck cable failure by the topside interface equipment. The deck-cable junction box on the winch has now had its back-plate bonded to the tow-cable armour to adequately earth the deck-cable connector mounting bolts.

Prior to D381B a further 20m of tow cable was removed for destructive testing, which now yields only ∼700m of deployable wire. A new electrical splice was made to the sea-cable pig-tail prior to the cruise. The tow-cable and fairing is now ∼5 years old and although it passed destructive testing prior to the cruise (5.96T) it is now overdue for replacement.

Adequate seawater cooling flow through the winch oil cooler could not be established during the cruise. It is suspected that the cooler tubes are scaled up and require de-scaling. The cooler performance requires further assessment and rectification post-cruise.

The winch scrolled the faired cable well, but the plough requires a very small adjustment to prevent it from striking the aluminium ferrules on the wire. Some ferrules have worked loose, and although this is likely to be as a result of the slight waisting of the wire due to corrosion, the impact of the plough is unlikely to be helpful.

Instrumentation

SeaSoar Tow-fish Configuration Including Spares

Sensors deployed bracketed in bold. Please refer to the deployment history table at the end of this report for details of sensor changes.

Senor	**Serial Numbers**
PENGUIN Submersible Linux Computer	s/n's [**PENGUIN1**] & PENGUIN2
Chelsea TG Minipack CTD-f	s/n 210011, [**210012**], [**210035**], 210039 & 04-4330-003
Chelsea TG Fastracka-II FRRF-II	s/n [**07-6139-001**] & 07-6480-002
Chelsea TG Glowtracka Bioluminescence sensor	s/n 07-6244-001 & [**07-6244-002**]
Maurer Instruments Ltd Flow Meter Model SR150	s/n 2885 & [**2886**]
Chelsea TG 2π Hemispherical PAR sensor (Seasoar/FRRF)	s/n [**46/2835/08**] & 46/2835/09
Turner Cyclops mini fluorimeter – Chlorophyll "C"	s/n [**2100432**]

Senor	**Serial Numbers**
Turner Cyclops mini fluorimeter – Phycocyanin “P”	s/n 2100433
Turner Cyclops mini fluorimeter – Phycoerythrin “E”	s/n [**2100594**]
Turner Cyclops mini fluorimeter – CDOM “U”	s/n [**2100595**]
Chelsea TG Unilux Nephelometer 2125-021-PL-D	s/n [**005**] & 006
Aanderaa Optode 3975 Dissolved Oxygen	s/n [**891**]
Seabird SBE43 Dissolved Oxygen Sensor	s/n [**2061**] & 2068
NOC/Valeport SUV-6 UV Nutrient Sensor	s/n TBCF
New Valeport SUV-6 UV Nutrient Sensor	s/n [**17395**]
Evaluation Valeport SUV-51 UV Nutrient Sensor	s/n [**41426**]
ODIM LOPC Optical Plankton Counter (660m pressure case)	s/n [**10690**] & 10693

SeaSoar PENGUIN Instrument Configuration

The following instruments were logged using the four serial ports in PENGUIN:

/dev/ttyS0	Chelsea TG Minipack CTD-f (9600 baud)
/dev/ttyS1	ODIM LOPC Optical Plankton Counter (115, 200 baud)
/dev/ttyS2	NOC/Valeport SUV-6/51 UV Nutrient Sensor (9600/19, 200 baud)
/dev/ttyS3	Chelsea TG Fastracka-II FRRF-II (115, 200 baud)

All the remaining instruments were logged using the auxiliary 0-5VDC inputs of the Chelsea Minipack CTD-f as follows:

Y-Cable A

Cable #	**Minipack Channel**	**Instrument**
1	10	UNUSED
1	11	UNUSED
2	12	Cyclops CDOM
3	13	Cyclops Phycoerythrin
4	14	Chelsea TG Unilux Turbidity
5	15	Cyclops Chlorophyll

Y-Cable B

1	17	Optode Oxygen Conc
1	18	Optode Oxygen Temperature
2	19	SBE43 Oxygen
3	20	Chelsea Glowtracka
4	21	Chelsea PAR
5	22	UNUSED

Dissolved Oxygen

The SeaSoar system was configured as on D369 (2011) but the SBE 43 Dissolved Oxygen now has an associated SBE 5T pump to control flow. The power to the pump can be switched by software remotely from the topside using the i2C switchable power in PENGUIN. The Aanderaa Optode optical oxygen sensor failed to produce any useable data in spite of comprehensive pre-cruise complete system testing. The Optode instrument cable was replaced between the two tows, but the outputs still flatlined mid-scale. No spare Optode was available. However, the pumped oxygen sensor proved to be very effective, so good oxygen data was obtained in spite of the Optode failure.

Minipack CTD-f

The CTG Minipack is now powered directly from the tow-cable voltage (∼56V) via its HV (18-72V) power input as CTG state that the auxiliary instruments cannot be adequately powered when the instrument is powered from the 15V battery input as used in the past. All five NMEP Minipacks were returned once again to CTG prior to the cruise in an attempt once more to rectify their reliability, accuracy and stability issues. Minipack 210011 was not available for use after suffering damage by a faulty bench PSU whilst on test at the NOC.

Following the considerable problems were experienced with the CTG Minipack CTD-f's during D350/1, and D369 they were returned to CTG once again for rectification and stress-testing, prior to final calibration. Minipack s/n 210012 was deployed for the first tow and displayed a conductivity offset of 0.3mS/cm which created a positive salinity offset of ∼0.25PSU. For the second tow, Minipack s/n 210035 was fitted and surprisingly showed negligible offset.

Due to the unacceptable performance of the CTG Minipacks since their incorporation into the NMEP, and the issues still experienced in spite of the frequent return of the instruments to CTG over the past few years, we are now convinced that they are no longer supportable. We are also concerned about the dependence of all the auxiliary instruments (optics and DO) on the functioning and stability of the Minipack.

Valeport UV Absorption Spectrophotometer Nitrate Sensors

In addition to the two Valeport SUV6 Nitrate Sensors (one of which was deployed), a Valeport SUV51 Nitrate sensor was trialled on Seasoar during the cruise.

Valeport SUV-6 s/n 17395 was fitted for the first tow with the mirror configured to sample internally for 15 seconds every minute (i.e. 45 seconds of external measurement followed by 15 seconds of internal reference). The instrument was configured to output 1Hz averaged data of the 8Hz raw sampling. Unlike the older SUV-6 (19, 200) baud, this newer SUV6 has been changed in firmware (Valeport state that someone at the NOC requested this) to 9600 baud. This required editing the baud rate in the DAPS suv6.icp file to enable successful parsing. The SUV-51 that was trialled during the second tow had a baud rate of 19, 200 which required re-editing the DAPS suv6.icp file. This instrument has no mirror mechanism, and uses a different lamp referencing technique.

Seasoar Optics Suite

The Turner Cyclops instruments were used at a gain of 10. Once again a small noisy signal was produced in Chlorophyll and a very small and very noisy signal was obtained on Phycoerythrin. It is thought that the light sources on these instruments are insufficiently intense for use in open ocean water. The CDOM signal had a long period oscillation (several minutes) of unknown origin as experienced in the past. This oscillation was also observed during deck testing with the sensor over 2m away from the SUV6 (which emits UV) and with the SUV6 lamp switched off, so it is not interference from adjacent instruments. During the second tow, a similar but shorter period oscillation was observed on the chlorophyll and phycoerythrin Cyclops sensors.

The CTG Unilux turbidity meter as before was noisy and is also suspected to have insufficient sensitivity for blue water work. Prior to the second tow, the instrument was found to have a zero output, the cable is suspect intermittent, but some data was obtained during the second tow.

The CTG Seasoar PAR sensor s/n 46/2835/08 flooded shortly after deployment on the first tow. Initial inspection indicates crevice corrosion of the housing at the first (HP) 'O'-ring on the optic bulkhead. The second backup 'O'-ring is either the incorrect size (0.3mm smaller measured OD), is old and distorted or failed due to the sudden presence of pressure. It is recommended that all NMEP 316 stainless cased PAR sensors should be dismantled for inspection of 'O'-ring surfaces to prevent further failures. CTG Seasoar PAR s/n 46/2835/09 was deployed on the CTD package and was lost with it on cast 13.

No useful signal was observed from the CTG Glowtracka Bathyphotometer Bioluminescence sensor. During daylight hours, a small signal was observed near the surface (which certainly indicates that the instrument is functional). This is probably sunlight leaking through the less than optimal light baffle created by an 'S' bend in the flow-through hose. Due to their being no pump and no flow-measurement, the flow, or perhaps lack of flow through the system is uncertain. The 8Hz measurement and 1Hz averaging of the Minipack may also be causing significant attenuation of any intense but short-lived flashes that are often emitted by bioluminescent organisms.

Rolls-Royce Naval Marine (ODIM BOT) LOPC-660

Numerous LOPC software crashes were experienced as before. In spite of considerable correspondence with Rolls Royce Naval Marine (who have acquired ODIM since they acquired Brooke Ocean Technology), they have yet to acknowledge the problem or propose a solution. The system crashes regardless of the PC (3 systems tested), operating system (Windows XP and Windows 7 tested), or serial port used (one integrated port, one PCMCIA port and one Express port adapter tested). Four different versions of the LOPC software present the same issue, and the issue is also experienced when on the bench with the manufacturers deck unit and also when integrated with the MVP system. Rolls Royce have recently asked NMF to supply some data files and the laptop system used with Seasoar for investigation. We trust that this frustrating issue can be resolved. LOPC software version 1.39 was used for D381b. The instruments had firmware version 2.48 and DSP version 2.32 during the cruise.

CTG FASTtracka-II FRRF

Following problems with both CTG FASTtracka-II FRRFs on D369 (one instrument with battery backup and RTC issues, the second flooded on first deployment since new), both instruments were returned to CTG for rectification. A new version (2.5.1) of the CTG FASTpro software was used on D381b, and no problems were experienced with the instrument or the software aside from one crash, which is tolerable and a significant improvement. FASTpro was configured to output hourly files. PMT eht (receiver sensitivity) and LED drive (lamp intensity) were occasionally adjusted to suite the in-situ conditions. A PMT eht value of 540V and an LED drive of 26 offered good dynamic range through most of the chlorophyll conditions encountered. Instrument s/n 07-6480-002 was not deployed but was bench tested ok after the flood damage was repaired by CTG post-D369. Both Fasttracka-II instruments now have the same firmware version.

System Operation

Flight Control System

The new NMF-SS Seasoar Controller topside system and software was used for the second time during D381. After successful trials on D369, the old hardware and software system has now been retired.

As before, peak control currents were < 2mA and most of the time the current was of the order of 0.1 mA. Tow cable tensions were smooth and peak tension was approx 1300kg, apart from in higher seas where vessel pitching created occasional peak loads of $\sim$1500-1700kg.

PENGUIN

The netcat service for control system pressure and socat serial port bridging for FRRF2 and LOPC logging has now been automated by using Linux init. Init is also configured to respawn the netcat and socat services should they fail or the user accidentally kill them. No user intervention is required and as soon as PENGUIN has booted, the LOPC and FRRF2 loggers can be started. As soon as DAPS is running the Minipack process, pressure data is available to the control system.

The pre-logging testing of PENGUIN and its network services have also been automated. All the user is required to do upon power up of PENGUIN is to reboot to bring up the NFS and NTP network services properly (due to PENGUIN booting quicker than the SHDSL modems can establish a link), then login again and run the *penguin* script.

The *penguin* script waits for NTP time synch with Emperor, checks for NFS mount of the data area, and does a write test. It then sets the Minipack clock to system time, powers up the Minipack aux instruments and starts its data streaming. Finally the *penguin* script displays an Xclock of PENGUIN time on the Emperor desktop, and starts DAPS.

The user is then able to start the minipack and suv6 processes in DAPS.

SeaSoar Deployment Notes

The Lebus deployment snatchblock was hung from the pendulum arm on the after gantry and the pendulum ram was extended to give more headroom during deployment and more clearance from the transom during recovery.

The topside PSU voltage was set at ∼80-85 V to yield approximately the PENGUIN PSU clamping voltage of ∼60V at the fish end. The resistance of the power conductor loop in the tow cable was approximately 30 Ω including the deck cable. Total power supply current was found to be 0.8 A with 700m of wire streamed and the SBE5T pump switched on, yielding a tow-cable voltage drop of ∼20V. During system testing at the NOC the supply current was measured at 1A with the pump submerged in a bucket of water with no loading from tubing or instruments. It is presumed that the in-situ loading of the SBE43 and associated plumbing has reduced the current required by the pump.

DAPS Minipack Data-Logging Issues

Early in the first tow two data quality issues were observed with the Minipack data-stream from DAPS.

Firstly, occasional spiking, followed by ringing was seen on the Minipack conductivity channel. This may be an instrument issue or could plausibly be caused by biological matter (jellies were observed in the water at the time) passing through and temporarily fouling the inductive conductivity cell. The problem was also observed on the second Minipack fitted to the vehicle during the second tow, however it was less frequent. Our feeling is that it is unlikely to be an instrument fault.

Secondly, and more frequently, a series of data corruption or parsing errors were observed. This always followed the same progression, first on pressure, then Minipack fluorescence, then Minipack voltage. It did not affect any other Minipack channels, nor was it observed in the SUV data stream.

The characteristic was a multi-stable series of values including a correctly recorded one. This will be useful in data processing as there are good values interspersed amongst the bad records. The pressure problem lasted about two minutes, which then returned to normal. During the pressure problem, the control system often had to be put into emergency up mode to prevent large control valve currents. The problem then moved to fluorescence. The values were observed to amplify or scale any change in the measurand. I.e. small measurand values yielded small differences between real and bad values, whilst conversely larger pressure or fluorescence values gave disproportionately larger errors. Once the fluorescence data series had returned to normal, the problem moved to Minipack voltage. On one occasion, the problem was seen to start on the C channel, and progress through T, D, f, V and I.

Close inspection of the data files will hopefully provide enough information to diagnose the origin of the problem. It does look like a parsing error on the part of DAPS, but why it has not been observed before, and is not present in the suv6 data files is uncertain.

Seasoar Tow Summary

Julian Day	Date	Time	Comment
263	19/09/2012	16:13	Start logging on Flight Controller and DAPS **minipack311.000** **suv6312.000**
		16:15	LOPC started
		16:22	FRRF2 started – LED drive 36, PMT eht 360V
		16:24	Steady on 090T Fish in Water Load-cell indicates that fish weighs ~350kg in air
		16:43	700m wire deployed, vsl speed increasing to survey speed
		16:52	FRRF2 taken offline briefly to change to optimise LED drive and PMT eht LED 36, PMT eht 480V, then LED 45, PMT eht 480V then LED 40, PMT eht 480V
		16:54	Vsl at survey speed 9knts Fish on surface, start undulation
		17:20	Reduce vsl speed to 8.5knts, to increase fish max depth
		17:42	FRRF2 taken offline briefly to change to optimise LED drive and PMT eht LED 38, PMT eht 480V
		18:44	LOPC software crash
		19:01	LOPC software crash
		21:17	LOPC software crash
		21:31	LOPC software crash
		22:05	Commence turn to 180T @ 5 deg/min
		22:24	Steady on 180T
		22:50	Commence turn to 270T @ 5 deg/min
		23:08	LOPC software crash
		23:09	Steady on 270T
264	20/09/2012	00:04	LOPC software crash
		02:09	Off-track detour to South of old PAP mooring site foul ground marked on chart as "submerged moorings"
		02:18	LOPC software crash
		03:57	DAPS minipack file cycled to provide data for processing **minipack578.000** started
		03:58	Steady on 270T
		04:29	LOPC software crash

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Table 2 – *continued from previous page*

Julian Day	Date	Time	Comment
		04:33	Commence turn to 180T @ 5 deg/min
264	20/09/2012	04:41	DAPS suv6 file cycled to provide data for processing **suv6621.000** started
		04:53	Steady on 180T
		05:14	Commence turn to 090T @ 5 deg/min
		05:15	DAPS minipack file cycled in attempt to clear parsing error **minipack644.000** started
		05:38	Steady on 090T
		06:32	FRRF2 taken offline briefly to change to optimise LED drive and PMT eht LED 35, PMT eht 540V
		06:40	LOPC software crash
		06:51	DAPS minipack file cycled in attempt to clear parsing error **minipack689.000** started
		06:55	LOPC software crash
		08:32	FRRF2 taken offline briefly to change to optimise LED drive and PMT eht LED 30, PMT eht 540V
		09:22	LOPC software crash
		09:34	LOPC software crash
		10:13	LOPC software crash
		10:41	Commence turn to 180T @ 5 deg/min
		11:00	Steady on 180T
		11:02	LOPC software crash
		11:27	Commence turn to 270T @ 5 deg/min
		11:32	LOPC software crash twice in quick succession
		11:43	LOPC software crash
		11:45	Steady on 270T
		12:40	LOPC software crash
		13:36	Commence turn to 180T @ 5 deg/min
		13:55	Steady on 180T
		14:20	Commence turn to 090T @ 5 deg/min
		14:41	Steady on 090T
		14:57	LOPC software crash
		16:16	Commence turn to 180T @ 5 deg/min
		16:35	Steady on 180T
		17:00	Commence turn to 270T @ 5 deg/min
		17:15	LOPC software crash
		17:21	Steady on 270T

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Table 2 – *continued from previous page*

Julian Day	**Date**	**Time**	**Comment**
		19:06	LOPC software crash
		19:37	LOPC software crash
		20:31	LOPC software crash
		21:12	LOPC software crash
		22:56	Commence turn to 000T @ 5 deg/min
		23:15	Steady on 000T
		23:52	LOPC software crash
265	21/09/2012	00:25	Commence turn to 090T @ 5 deg/min
265	21/09/2012	00:38	LOPC software crash
		00:42	Steady on 090T
		02:21	LOPC software crash
		02:30	Commence turn to 180T @ 5 deg/min
		02:47	Steady on 180T
		03:14	Commence turn to 270T @ 5 deg/min
		03:32	Steady on 270T
		03:56	LOPC software crash
		04:15	DAPS suv6 file cycled to provide data for processing **suv61152.000** started
		04:16	DAPS minipack file cycled to provide data for processing **minipack1153.000** started
		04:25	LOPC software crash
		04:40	LOPC software crash
		04:45	LOPC software crash
		05:15	Commence turn to 180T @ 5 deg/min
		05:34	Steady on 180T
		06:17	LOPC software crash
		06:21	LOPC software crash
		06:41	Commence turn to 090T @ 5 deg/min
		06:59	Steady on 090T
		07:50	LOPC software crash
		08:40	LOPC software crash
		10:12	LOPC software crash
		11:02	LOPC software crash
		12:21	Commence turn to 180T @ 5 deg/min
		12:39	Steady on 180T
		13:01	Commence turn to 270T @ 5 deg/min
		13:19	Steady on 270T
		13:49	LOPC software crash
		14:03	LOPC software crash

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Table 2 – *continued from previous page*

Julian Day	Date	Time	Comment
		16:10	LOPC software crash
		16:42	LOPC software crash
		16:45	LOPC software crash
		19:07	End Undulation – System on Emergency up for recovery Vsl slowing to recovery speed
		19:14	Commence hauling with ∼380kg outboard load
		19:38	Fish out of water
		19:41	All inboard and secure
		19:44	FRRF2 stopped – 53 files acquired
		19:46	LOPC stopped – 43 bin and dat (ASCII) files acquired
		19:48	DAPS logging stopped – 5 minipack and 3 suv6 files acquired
		19:52	End Flight Controller logging and power down

Table 2: Details of SeaSoar Tow 1. Main survey lines oriented E-W through OSMOSIS mooring field.

Julian Day	Date	Time	Comment
267	23/09/2012	18:12	Start logging on Flight Controller and powering up
		18:21	Start logging on DAPS **minipack265.001** **suv6266.000**
		18:25	LOPC started
		18:29	FRRF2 started – LED drive 26, PMT eht 540V
		18:46	Steady on 320 Mag, head to wind for deployment Fish in Water Load-cell indicates that fish weighs ∼350kg in air
		19:03	700m wire deployed, vsl speed increasing to survey speed and turning to 000T @ 5 deg/min
		19:07	LOPC software crash
		19:17	Steady on 000T, Vsl at survey speed 9knts Fish on surface, start undulation
		20:00	LOPC software crash
		21:24	Commence turn to 090T @ 5 deg/min
		21:42	Steady on 090T
		21:43	LOPC software crash
		22:04	LOPC software crash

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Table 3 – *continued from previous page*

Julian Day	Date	Time	Comment
		22:07	Commence turn to 180T @ 5 deg/min
		22:26	Steady on 180T
268	24/09/2012	00:01	Commence turn to 090T @ 5 deg/min
		00:10	LOPC software crash
		00:19	Steady on 090T
		00:45	Commence turn to 000T @ 5 deg/min
		01:00	Steady on 000T
		02:04	LOPC software crash
		02:43	Commence turn to 090T @ 5 deg/min
		02:50	LOPC software crash
		03:04	Steady on 090T
		03:27	Commence turn to 180T @ 5 deg/min
		03:47	Steady on 180T
		04:06	DAPS suv6 file cycled to provide data for processing **suv6509.000** started
		04:07	DAPS minipack file cycled to provide data for processing **minipack510.000** started
		04:23	LOPC software crash
		06:24	LOPC software crash
268	24/09/2012	07:39	LOPC software crash
		09:00	Commence turn to 270T @ 5 deg/min
		09:17	Steady on 270T
		09:52	Commence turn to 000T @ 5 deg/min
		10:09	LOPC software crash
		10:10	Steady on 000T
		11:22	LOPC software crash
		13:09	LOPC software crash
		14:08	Commence turn to 270T @ 5 deg/min
		14:27	Steady on 270T
		14:40	LOPC software crash
		15:13	Commence turn to 180T @ 5 deg/min
		15:20	LOPC software crash
		15:25	Steady on 180T
		16:16	LOPC software crash
		17:56	LOPC software crash
		18:41	Commence turn to 270T @ 5 deg/min
		19:00	Steady on 270T
		19:17	Commence turn to ~305 Mag (head to wind) @ 5 deg/min for recovery

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Table 3 – *continued from previous page*

Julian Day	Date	Time	Comment
		19:22	End Undulation due to unworkable sea conditions – System on Emergency up for recovery Vsl slowing to recovery speed
		19:27	Commence hauling with ∼380kg outboard load
		19:30	Steady head to wind @ 305 Mag
		19:44	Fish out of water Load-cell indicates that fish weighs ∼350kg in air
		19:46	All inboard and secure
		19:51	LOPC stopped – 18 bin and dat (ASCII) files acquired
		19:52	FRRF2 stopped – 26 files acquired
		19:53	DAPS logging stopped – 2 minipack and 2 suv6 files acquired
		19:56	End Flight Controller logging and power down

Table 3: Details of SeaSoar Tow 2. Main survey lines oriented N-S through OSMOSIS mooring field.

Julian Day	Date	Time	Comment
273	29/09/2012	05:18	SUV51 (mirrorless) Evaluation Unit s/n 41426 2Hz averaged data from 8Hz Minipack s/n 210035 No PAR sensor (flooded on first tow). Powering up
		07:48	Start logging on DAPS **Minipack356.000** **suv6355.000**
		07:50	FRRF2 started – LED drive 26, PMT eht 540V
		07:51	LOPC started
		07:52	Flight Controller Started – Vsl steady on 270M 3knts for deployment
		08:00	Fish in Water
		08:20	Vsl speed 6knts increasing to 8.5knt survey speed.
		08:22	700m wire deployed, vsl turning to 150M @ 5 deg/min. Start undulation.
		08:32	SBE43 Pump switched on
		08:47	Steady on 150M, Vsl at survey speed 8.5knts
		08:55	LOPC software crash
		08:58	Commence turn to 180T @ 5 deg/min

Continued on next page

Julian Day	**Date**	**Time**	**Comment**
		09:04	Steady on 180T Now on survey line. FRRF2 taken offline briefly to change to optimise LED drive and PMT eht LED 20, PMT eht 560V
		09:05	LOPC software crash
		09:20	FRRF2 taken offline briefly to change to optimise LED drive and PMT eht LED 16, PMT eht 560V
		09:29	DAPs Minipack 'Parsing' error that started with C, then T, then D, then f, then V, then I.
		09:52	Increase vsl speed by 0.5knts to ∼9knts as fish not making surface and low peak tension of 1200kg.
		10:22	LOPC software crash
		12:01	LOPC software crash
		13:24	**Vessel Blackout** – All files stopped due to loss of power.
		14:09	Power restored, powering up fish again.
		14:18	LOPC and DAPS logging started **minipack278.000** started **suv6279.000** started
273	29/09/2012	14:21	FRRF2 started
		14:22	SBE43 Pump switched on
		14:25	Start undulation – Vsl heading 170M due to drifting off the survey line during the blackout.
		14:30	LOPC software crash
		14:47	Vsl A/C again to 190M to get back on the survey line prior to the next turn
		15:08	Vsl heading 190M and commencing turn to 090T @ 5 deg/min
		15:25	Steady on 090T
		15:41	LOPC software crash
		15:55	Commence turn to 000T @ 5 deg/min
		16:07	Steady on 000T
		17:49	LOPC software crash
		18:15	LOPC software crash
		18:31	LOPC software crash
		19:48	LOPC software crash
		20:59	LOPC software crash
		21:14	Commence turn to 090T @ 5 deg/min
		21:24	LOPC software crash
		21:32	Steady on 090T
		21:56	Commence turn to 180T @ 5 deg/min

Continued on next page

Table 4 – *continued from previous page*

Julian Day	Date	Time	Comment
		22:16	Steady on 180T
		23:46	LOPC software crash
274	30/09/2012	02:14	LOPC software crash
		03:21	Commence turn to 090T @ 5 deg/min
		03:40	Steady on 090T
		04:03	LOPC software crash
		05:11	LOPC software crash
		06:17	LOPC software crash
		07:26	LOPC software crash
		04:43	**Techsas ships' data logger power supply failure**, main navigation files off-line. Note that the Seastar GPS is logged directly by the Seasoar Flight Controller, hence the Flight tow files will provide a navigation source during the Techsas gap.
		07:36	End of line, Commence turn to ∼230M(head to wind) @ 5 deg/min for recovery
		08:06	Continuing turn. End Undulation. System on Emergency up for recovery
		08:12	Steady head to wind on 230M reducing speed for recovery.
		08:16	Commence hauling with ∼300kg outboard load
		08:36	Fish out of water Load-cell indicates that fish weighs ∼350kg in air
		08:41	All inboard and secure
		08:43	End Flight Controller, LOPC, FRRF2 and DAPS logging and power down 20 LOPC bin and dat (ASCII files), 25 FRRF2 files, 2 minipack and 2 suv6 files acquired.

Table 4: Details of SeaSoar Tow 3. Main survey lines oriented N-S through OSMOSIS mooring field – completion of western part of second survey.

Computing and Instrumentation – *Yair Yaniv*

Echo sounder 10kHz (10/12 kHz fish and hull mounted system)

Whilst recovering a mooring buoy the mooring rope tangled with the fish cable. As a result a small area of the green outer layer plastic was damaged. The fish seems to work fine but the cable needs to be properly sealed. To fix it I used the same method the mooring guys terminate their CTD cable. The PES fish is more accurate than the hull transducer as it is capable of being deployed deeper and is also decoupled from the noise of the ship. The transducer outputs its data to a stream called ea500 on the Level C System. The hull mounted transducer worked reasonably well considering its limitations. We had to switch the transducer from active to passive mode every time mooring recovery was in operation.

150 kHz hull mounted ADCP system.

The RDI Ocean Surveyor was setup based on the previous cruise with a bottom track and water track file that is included with the dataset. The Ocean surveyors are fed with data from the ships GPS, Gyro and ADU systems in order that the system can calculate true speeds and direction of the currents below the ship.

During the passage from Southampton to the survey area no data was recorded by Bm1 and Bm2. I replayed data from previous days and everything looked ok then. I run the diagnostic test commands (as per RDI troubleshooting manual) the results showed "pass". I checked for air in the top hat, we opened and closed the valve it made no different.

I contacted RDI (ref 00009161) they suggested the following;

1. To send them xx.ens file and based on the file output they asked me to run tests on the cable, below are the results.

Description	From	To	Actual Resistance	Resistance
BEAM 1 XMIT to XMIT RTN	A	W	OL	> 4.5 Mohms
BEAM 2 XMIT to XMIT RTN	D	C	OL	> 4.5 Mohms
BEAM 3 XMIT to XMIT RTN	G	F	OL	> 4.5 Mohms
BEAM 4 XMIT to XMIT RTN	K	J	OL	> 4.5 Mohms
BEAM 1 RCV HI to BEAM 1 RCV LOW	e	M	5 ohms	< 15 ohms
BEAM 2 RCV HI to BEAM 2 RCV LOW	f	N	7 ohms	< 15 ohms
BEAM 3 RCV HI to BEAM 3 RCV LOW	g	P	9 ohms	<15 ohms
BEAM 4 RCV HI to BEAM 4 RCV LOW	h	R	10 ohms	<15 ohms
SHIELD to SHIELD	d	q	3 ohms	< 5 ohms
SHIELD to SHIELD	r	s	6 ohms	< 5 ohms
SHIELD to SHIELD	d	r	OL	> 20 Mohms
RCV ENABLE to VXDC GND	S	T	100 kohms	4.7 kohms

Description	From	To	Actual Resistance	Resistance
TEMP to TEMP RTN	i	j	14 kohms	11.3 kohms
VXDC to VXDC GND (see note 6)	U	T	0.545VDC diode drop and OL reverse leads	Diode Check
SDAT B to VXDC GND (see note 7)	k	T	no at all reading	5.9 kohms
SDAT A to VXDC GND (see note 7)	m	T	OL	> 20 Mohms
SHIELD to ALL	B	ALL	OL	> 20 Mohms
SHIELD to ALL	E	ALL	OL	> 20 Mohms
SHIELD to ALL	H	ALL	OL	> 20 Mohms
SHIELD to ALL	V	ALL	OL	> 20 Mohms

1. To check if the problem comes from the deck box or from the Transducer. I tested the voltage on the Power board.

TP1-TP0	4.97VDC
TP2-TP0	11.96VDC
TP3-TP0	47.7VDC
TP4-TP0	10.2VDC

These confirmed that there is a problem with the transducer and maintenance is required therefore the transducer will be sent to RDI for repair.

75 kHz hull mounted ADCP system.

The RDI Ocean Surveyor 75 kHz VM-ADCP was setup by the science party on the cruise with a bottom track and water track file that is included with the dataset. The Ocean surveyors are fed with data from the ships GPS, Gyro and ADU systems in order so that the system can calculate true speeds and direction of the currents below the ship. The 75 kHz VM-ADCP worked well all cruise.

Meteorology monitoring package.

The meteorology component consists of a suite of sensors mounted on the foremast at a height of approx 10m above the waterline. Parameters measured are wind speed and direction, air temperature, humidity and atmospheric pressure. There is also a pair of optical sensors mounted on gimbals on each side of the ship. These measure total irradiance (TIR) and photo-synthetically active radiation (PAR). I had to reset the power supply to the mast during the cruise because of a problem with the Windsonic Anemometer. It indicated a wind speed of between 50 and 0 m/s. At the time the weather was too bad so resetting the power to the mast was the only option to get it working again. During the next few days the windsonic intermittently gave very high wind speed.

Maintenance is required to replace the windsonic anemometer with the spare unit and to send the faulty unit to Gill to repair.

Sea surface monitoring system (salinity, temperature, transmissometer, fluorimeter).

The Non Toxic system was enabled as soon as we were far enough away from land. It is also used as a coolant for the seasoar winch system. The SBE45 unit fluorometer and transmissometer was cleaned prior to sailing. All underway water sampling instruments were checked daily, and cleaned periodically, while on station.

The debubbler PVC connector broke at the same place it had previously. We stopped the water sampling for about two hours for repair. I used designated PVC adhesive to repair it.

Ship scientific computing systems.

Level C – for redundancy purpose I used a second Level C server (ENTERPRISE t5120) the standard level C system is a Sun Solaris 10 UNIX Workstation discovery1. The RVS software suite is available on these machines. This suite of software allows the processing, editing and viewing of all data within the RVS data files. The level C is receiving data from the TECHSAS System which allows real time data processing.

The Techsas data logging system is used to log the following instruments data.

1. Trimble GPS 4000 DS Surveyor (converted to RVS format as gps_4000)
2. Chernikeef EM speed log (converted to RVS format as log_chf)
3. Ships Gyrocompass (converted to RVS format as gyro)
4. Simrad EA500 Precision Echo Sounder (ea500)
5. NMFD Surface-water and Meteorology (surfmet) instrument suite
6. ASHTECH ADU-5 Altitude Detection Unit (gps_ash)
7. NMFD Winch Cable Logging And Monitoring CLAM (winch)
8. Fugro Seastar 9200 G2 XP Differential (gps_g2)
9. Seabird SBE45 MicroTSG (seabird)

The Techsas interface displays the status of all incoming data streams and provides alerts if the incoming data is lost. Techsas broadcast live data across the network via NMEA. The storage method used for data storage is NetCDF.

Data storage was run through a Dell R510 with 10TB of RAID10 Storage. Backups of running systems (ADCP's, Level C, SBWR, TECHSAS and nominated scientific areas were run on a 30 minutes schedule. Backups were transferred to the Data Archive Portable Hard Drives once every 24 hours. The entire Cruises D381 folder was also backed up to a day of the week directory. This was done so data can be recovered based on the day the data was lost. All scientific cruise data was stored on the DISCOFS server under the Cruises/D381 folder, and organized with a standard template of folders.

Pstar is a set of Unix scripts that are used to analyze raw data. It is installed on a UNIX machine discovery2ng. Because the disc space on discovery2ng was limited we moved all the script from discovery2ng to an NFS share on discofs/pstar. On discovery2ng I mounted a directory d381pstar; this enabled to use discovery2ng Unix OS without compromising disc space. To backup d381pstar I used a crontab routine on discovery2ng that run once a day. This was done because of mismatch files security between Unix and Windows.

The network worked well throughout the cruise until we had a total blackout on board. The UPS's kept the servers running long enough enabled me to shut down all the servers in a control manner. At about 1345 the power was restored to the ship. Its took me over an hour to restart all the servers, surfmet, etc making sure that all the NFS, SMB share/mount points are mapped (I had to re-mount the pstar stuff) also making sure that the GPS's NMEA, clock NMEA are all working (not until I made a reset to the combiner in the comms room). On LevelC (discovery1 and enterprise) I had to do wfset for all the streams so the fromtechsas continued to log data again. All systems ware up and running and logging data at 15:04:23 this is the gaps command output: time gap : 12 273 13:24:05 to 12 273 15:04:23.

At Jday 274 04:43:01 I got a call about level C alarm. This alarm starts when LevelC can't communicate with the techsas machine. Techsas1 had crushed, when I tried to restart techsas1 it was making strange beeping noises. I tried to get it going again but it was taking me longer than I expected. I started techsas2 and started logging data. Shortly after I got techsas1 running again at the time I thought it was the UPS (Needs more tests) I started a full data logging at 05:22:02 this is the gaps command output:

time gap : 12 274 04:43:01 to 12 274 04:59:20

time gap : 12 274 05:00:45 to 12 274 05:01:19

time gap : 12 274 05:05:14 to 12 274 05:06:30

time gap : 12 274 05:21:27 to 12 274 05:22:02

At 17:40:10 Techsas1 had crashed again, (so it's not a problem with the UPS) I took the two hard drives from techsas1 and insert them in to techsas2 box. I started techsas1 and reconfigured the IP address for et0.

Since I started to use the techsas2 hardware all seems to work ok. I am going to keep techsas running for the next few days even though we stop logging data. This is the gaps command output time gap: 12 274 17:40:10 to 12 274 18:26:32.

To fix the ship AC system another blackout was planned for the next day, the blackout started at 13:15:37 and lasted until about 1600 I used the same routine as described above to start the system and get everything running. At 16:43:14 all systems ware running ok. This is the gaps command output time gap : 12 275 13:15:37 to 12 275 16:43:14.

To improve WIFI reliability and bug fixing I upgraded the firmware on all the Linksys WIFI AP.

The Internet worked well however the modem required changing between 38W and 22W satellites and requires rebooting from time to time. The only other times we lost the internet was due to the ship heading or the weather.

The Data archive will be provided on USB Hard Drives 1 x HDD to BODC, disk to be returned once data extracted. The PSO data was copied to an external backup device that he brought with him to the cruise. 1 x HDD to NOCS held by NMFSS for 6 Months.

Mooring Operations

OSMOSIS Main Array – *Liam Brannigan, Paul Provost, Alberto Naveira-Garabato*

The moorings are a key component of the OSMOSIS observational program. The array is structured so that it will allow simultaneous measurement of the mesoscale and submesoscale velocity and density structure with high horizontal and vertical resolution.

There are nine instrumented moorings to deploy along with four guard buoys (**Figure 1**). There are four outer moorings at the vertices of a square of approximate length 14 km. These surround a further four inner moorings which form the vertices of a square of length 2 km. Finally, there is a centre mooring which is 1.5 km (along the diagonals of the square) from the inner moorings and just under 10 km from the outer moorings. The centre and inner moorings are highly instrumented in order to measure the key submesoscales. The outer moorings are less-instrumented as the objective of these is to observe the larger scale mesoscale flow field.

The guard buoys were deployed around the inner moorings in order to warn vessels that there is something in the area. These are anchored to the bottom. One of these was fitted with a meteorological package which measures [solar radiation, wind speed and direction] but this buoy suffered a major failure shortly after deployment and was not found at the site.

The decision on where to deploy the moorings was based on multi-beam surveys of the PAP site bathymetry conducted during cruises CD158, JC062, and JC071. These showed the PAP site to be largely abyssal plain of depth close to 4830 m with some isolated features rising up to 200 m above the seabed.

As well as the bathymetry, there are a number of other constraints on the mooring location. Firstly, there is the ODAS biogeochemical mooring at 49° 0.3' N 16° 22.56' W as well as the location of a Bathysnap (49° 0.36' N 16° 27.00' W), a Sediment Trap (48° 59.4' N 16° 30.48' W) and coring site (49° 50.00' N 16° 30.50' W) which form the long-term ocean observation site. Secondly, there is a communications cable which runs west-southwest through the region, about 20 km south of the ODAS buoy at the same longitude.

It was decided to deploy the moorings to the south of the existing observation locations and the communication table. This is on the edge of the area which had been surveyed and so the altimeter on the CTD was deployed upon arriving to the site (at 15.08 GMT on 31st August 2012) was used to confirm that the water depth was 4830 m. The moorings are referred to below in the obvious fashion according to their direction from the centre, and whether they are part of the inner or outer array e.g. "south-west outer" for the outside mooring in the south-west of the array.

The set-up of the instruments deployed on the moorings is set out in Section 3 below, while the details of the mooring deployments including which instruments were attached and at what depths are set out in Section 3.

Instrumentation

75 kHz ADCP

The inner and centre moorings were deployed with 75 kHz RDI Long Ranger ADCP units[1]. The objective for these units is to measure the upper ocean horizontal velocity structure across a range of depths. As such they were deployed close to 450 m depth and pointing upwards. This should allow them to measure velocities accurately until surface wave interference becomes too large. In **Table 5** below, the command file for these units is set out along with an explanation of what the setting implies.

Instrument	Workhorse Long Ranger
Beam angle	20°
Frequency	76.8 Khz
First cell range	16.62 m
Last cell range	568.62 m
Noise level	2.34 cm s^{-1}
CB411	The unit transmits data at a rate of 9600 baud; there is no parity; and the stop bit is 1 bit.
CR1	Restore the unit to factory settings before entering parameters below.
CQ255	Transmit power is set to highest value.
CF11101	The flow control unit: automatically starts new ensemble and ping cycles; provides data in binary format; has serial output disabled; and records the data.
WM1	The ADCP is set up for a dynamic sea state.
EA0	The ADCP heading alignment is uncorrected (i.e. beam 3 is the heading reference).
EB0	No correction for heading bias due to electrical or magnetic bias.
ED4500	The ADCP transducer depth is 4500 decimetres (used for speed of sound calculation).
ES35	The salinity is estimated at 35 ppt (used for speed of sound calculation).
ET+0700	The water temperature is taken as 7° C (used for speed of sound calculation).
EX00000	No coordinate transformation is applied; tilt is not used in transformation; no three-beam solutions if one beam falls below the correlation threshold; no bin-mapping.
EZ1111101	Calculate speed of sound from readings; use pressure sensor, transducer heading, internal tilt sensors and transducer temperature.
WA050	False target threshold maximum - this sets the maximum echo intensity difference between

[1] We follow oceanographic convention in rounding off the frequency when discussing the ADCPs - the exact operating frequency is listed in **Table 5**.

	beams. If this value is exceeded (normally due to passing fish) the velocity data is rejected.
WB1	Mode 1 bandwidth set to narrow-band to allow a low sampling rate and high profiling range.
WD111100000	The ADCP collects velocity, correlation, echo intensity and percent good data.
WF704	Blank after transmit set such that the first cell begins 7.04 m away from the transducer.
WN70	Data collected over 70 depth cells.
WP39	Each ensemble averages over 39 pings.
WS800	Each depth cell is 8 m thick.
WV175	The radial ambiguity velocity is set to 175 cm s^{-1}.
TE01:00:00.00	The 39 pings are averaged over 1 hour.
TP01:30.00	The minimum time between pings is set to 1 minute 30 seconds.
TF12/08/28, 12:00:00	The first ping was set to occur at noon on 28th August 2012.
CK	Store the parameters set out above in non-volatile memory.
CS	Start pinging .

Table 5: Command file specifications for the 75 kHz ADCPs

600 kHz ADCPs

The centre and north-east inner moorings were deployed with 600 kHz RDI Sentinel ADCP units. The objective for these units is to measure the small length scale (1 m) velocity field and use a structure function method to calculate the dissipation of turbulent kinetic energy. In **Table 3** below, the command file for these units is set out along with an explanation of what the setting implies.

Instrument	Workhorse Sentinel
Beam angle	20°
Frequency	614.4 Khz
First cell range	0.97 m
Last cell range	3.47 m
Noise level	0.61 cm s^{-1}
CB411	The unit transmits data at a rate of 9600 baud; there is no parity; and the stop bit is 1 bit
CR1	Restore the unit to factory settings before entering parameters below
CF11101	The flow control unit: automatically starts new ensemble and ping cycles, provides data in binary format, has serial output disabled and records the data

EA0	The ADCP heading alignment is uncorrected (i.e. beam 3 is the heading reference)
EB0	No correction for heading bias due to electrical or magnetic bias
ED2000	The ADCP transducer depth is 2000 decimetres (used for speed of sound calculation)
ES35	The salinity is estimated at 35 ppt for the speed of sound calculation
EX00000	No coordinate transformation is applied; tilt is not used in transformation; no three-beam solutions if one beam falls below the correlation threshold; no bin-mapping
EZ1111101	Calculate speed of sound from readings, use pressure sensor, transducer heading, internal tilt sensors and transducer temperature
WA50	False target threshold maximum - this sets the maximum echo intensity difference between beams. If this value is exceeded (normally due to passing fish) the velocity data is rejected
WB0	Mode 1 Bandwidth set to wide-band to allow a high sampling rate, low data variance and low profiling range
WD111100000	The ADCP collects velocity, correlation, echo intensity and percent good data
WF88	Blank after transmit set such that the first cell begins 0.88 m away from the transducer
WM5	ADCP is set up for a very low standard deviation environment
WN26	Data collected over 26 depth cells
WP1	Each ensemble averages over a single ping
WS10	Each depth cell is 0.1 m thick
WZ5	The mode 5 radial ambiguity velocity is set to 5 cm s^{-1}
TB01:00:00.00	The interval between bursts is one hour
TC00307	There are 307 ensembles per burst
TE00:00:01.00	The minimum interval between ensembles is one second
TP00:01.00	The minimum time between pings is set to one second
TF12/08/28, 12:00:00	The first ping was set to occur at noon on 28th August 2012
CK	Store the parameters set out above in non-volatile memory
CS	Start pinging

Table 6: Command file specifications for the 600 kHz ADCPs

Nortek Aquadropp

There were 61 Nortek Aquadropp current meters deployed on the moorings to give point measurements of velocity. The units were set up as shown in **Table 7**. The profilers estimate the current over 10 minute ensemble averages. They also have a diagnostic mode which works over 12 hour periods which allows the noise level of the instrument in that interval to be understood.

Instrument	Nortek Aquadropp V. 1.3
Measurement interval	10 minutes
Averaging interval	1 minute
Blanking distance	35 cm
Diagnostics interval	12 hours
Diagnostics samples	20 minutes
Vertical velocity precision	1.4 cm s^{-1}
Horizontal velocity precision	0.9 cm s^{-1}
Salinity	35 ppt
Speed of sound	Measured (m s^{-1})
Compass upload rate	1 second
Coordinate system	ENU
File wrapping	Off
Assumed deployment duration	370 days

Table 7: Nortek Aquadropp specifications

SBE 37-SM MicroCAT

There were 61 Sea-bird Electronics 37-SM MicroCAT sensors deployed on the moorings to measure temperature and salinity. While there are additional thermistors on the inner and centre moorings, the SBE-37 units are the only instruments which can record the salinity field. The units were set up as shown in **Table 8**. Note that the higher serial number units (listed first in **Table 8**) are a newer version of the instrument and were deployed on the centre and inner moorings. These perform ensemble averaging over five minutes, whereas the lower serial number units (listed second in **Table 8**) deployed on the outer moorings perform averaging over 10 minutes.

StarODDI thermistors

There were 248 StarODDI Starmon thermistors deployed, all of which were on the inner and centre moorings. The thermistors record temperature only i.e. they do not have pressure sensors. The sampling frequency is two minutes.

TRIAXYS waverider buoy

The waverider buoy was deployed with AXYS Technologies TRIAXYS Directional Wave Buoy. This mooring was only in place for the duration of the cruise and so was recovered at the end of the second leg. This instrument measured the wave height, wave period and direction (on a tri-axis basis) over the deployment and sea surface temperature. It was equipped with a satellite communications unit to report its location, though the unit must be recovered to download its data. The unit was equipped with solar panels for power.

Model name and number	SBE 37SM-RS232 v4.1
Serial numbers	9371-9399
Start time	30th August 2012 12.00
Sample interval	5 minutes
Data format	"Converted engineering"
Output	Salinity
Transmit real-time	No
Sync mode	No
Pump installed	Yes
Minimum conductivity frequency	3326.9 Hz
Model name and number	SBE 37SM-RS232 3.0h
Serial numbers	7288-8079 (non-consecutive)
Start time	30th August 2012 12.00
Sample interval	10 minutes
Data format	"Converted engineering alternate"
Output	Salinity
Transmit real-time	No
Sync mode	No
Pump installed	Yes
Minimum conductivity frequency	3000.0 Hz

Table 8: SBE 37-SM MicroCAT specifications

The data acquisition interval was 20 minutes i.e. it switched on every 20 minutes and the acquisition interval was 15 minutes i.e. it recorded for 15 minutes out over every hour (with the first cycle starting on the hour). The buoy can communicate over both the Immarsat D and Iridium satellite networks and reported back every [x] and [X]. The unit had a 100 GB memory card.

Mooring deployment

Mooring deployment operations began at 06.17 GMT on 1st September 2012 with the deployment of the SW-O mooring. All moorings were deployed from the aft deck of the *RRS Discovery* by the National Marine Facilities team led by Paul Provost.

The moorings were equipped with deployed with IXSEA Oceano 2500 acoustic releases, which were tested on the initial CTD cast. There are two releases on each mooring for redundancy with the exception of the waverider buoy which had a single release. All moorings were deployed using a NOC double barrel winch (hydraulic) and reeling winch system which was load-tested prior to commencement of operations. The moorings were deployed "top-first, anchor-last", allowing the buoyancy to stream away from the vessel during deployment. Vessel speed varied between 0.5 and 1.8 knots during the mooring deployment.

The anchors for the instrumented moorings consisted of an approx 1,750 kg eight-inch chain while for the guardbuoy moorings 3,000 kg sinker moorings were used.

The final position of the moorings was determined from the "cocked hat" triangulation method. A transducer was deployed over the side of the ship and the slant range (distance) to the mooring was obtained. The calculated horizontal distance provided an estimate of the radius from the ship location within which the mooring was located. This horizontal distance allows a circle to be defined relative to the point the triangulation was conducted from. The relative overlap of the range circles provides an estimate of the location of the mooring. In most cases the circles did not have a common full overlap area. This is due to a number of factors such as variations in the speed of sound through the water column, the relative positions of the GPS beacons and the transducer and the drift of the ship while the observations are being taken. The final estimated anchor location was in the locus of the area formed by edges of the triangulation circles.

South-west outer mooring

The target for the outer south-west mooring was 48° 37.800' N, 16° 16.800' W in approximately 4,830 m of water. The mooring consisted of five Nortek single-point current meters and five SBE 37 MicroCAT sensors as detailed in **Table 9**. In addition, a light and Argo tag were affixed at the top of the mooring. The mooring plan was adjusted for a slightly shallower depth than expected by replacing a 50 m section of cable just above 4810 m depth (on the mooring) with a 20 m section. A summary of the instruments deployed along with the time they went in the water as part of the streaming operation and their target depth below the surface is set out in **Table 9**.

The mooring operation began at 06.17 GMT on 1st September 2012. The attachment of instruments, buoyancy devices, releases and chain continued until 08:10 GMT. Steaming southwest, the ship arrived at 48° 37.59' N, 16° 17.08' W at 09:27 GMT at which

Instrument and equipment	Serial number	Time (GMT) Overside	Depth rel. to surface
Light	18664	06:17	33 m
ARGO tag	A02-013	06:17	33 m
Nortek CM	5883	06:18	50 m
SBE 37 MicroCAT	7288	06:18	51 m
Nortek CM	6178	06:24	110 m
SBE 37 MicroCAT	7289	06:24	110 m
Nortek CM	6181	06:32	224 m
SBE 37 MicroCAT	7290	06:32	225 m
Nortek CM	6182	06:38	348 m
SBE 37 MicroCAT	7291	06:38	348 m
Nortek CM	1404	06:44	511 m
SBE 37 MicroCAT	7292	06:44	512 m
Release	1469 / 1496	08:10	4816 m

Table 9: Instruments deployed on the south-west outer mooring

point the chain was released by the aft crane and the mooring was deployed. This was approximately 500 m beyond the target position to allow for fall-back.

The estimated mooring position of 48° 37.64' N, 16° 16.65' W was determined using the distance from five independent ranging locations. This required the ship to position itself at least an ocean depth horizontally away from the likely location of the mooring. A transducer was deployed over the side of the ship and the slant range (distance) to the mooring was obtained. The calculated horizontal distance provided an estimate of the radius from the ship location within which the mooring was located. The cross-over of the five range circles (the "cocked hat" method) provided an estimate of the location of the mooring. In this case the estimated position given above was the locus of the small area close to where the circles met. The estimated mooring location was 350 m south-east of the target location.

South-west inner mooring

The target for the south-west mooring was 48° 40.740' N, 16° 12.360' W in approximately 4,830 m of water. The mooring consisted of 50 Star-Oddi thermistors, one upward pointing 75 kHz ADCP, seven Nortek single-point current meters and seven SBE 37 MicroCAT sensors as detailed in **Table 3**. In addition, a light and Argo tag were affixed at the top of the mooring. The mooring plan was adjusted for a slightly shallower depth than expected by replacing a 50 m section of cable just above 4810 m depth (on the mooring) with a 20 m section. This gives the mooring a total depth of 4830 m.

Instrument and equipment	Serial number	Time (GMT) Overside	Depth rel. to surface
Thermistor	T4185	13:42	33 m
Light	W03-095	13:42	36 m
ARGO tag	A02-017	13:42	36 m

Continued on next page

Table 10 – *continued from previous page*

Instrument and equipment	Serial number	Time (GMT) Overside	Depth rel. to surface
Thermistor	T4186	13:42	47 m
Nortek CM	8059	13:42	53 m
Thermistor	T4192	13:42	54 m
SBE 37 MicroCAT	9371	13:42	54 m
Thermistor	T4193	13:43	59 m
Thermistor	T4194	13:44	64 m
Thermistor	T4195	13:44	69 m
Thermistor	T4196	13:45	74 m
Thermistor	T4197	13:47	79 m
Thermistor	T4198	13:48	84 m
Thermistor	T4199	13:49	89 m
Thermistor	T4200	13:50	94 m
Thermistor	T4201	13:51	99 m
Nortek CM	8080	13:56	110 m
Thermistor	T4202	13:56	110 m
SBE 37 MicroCAT	9372	13:56	110 m
Thermistor	T4203	13:57	115 m
Thermistor	T4204	13:58	120 m
Thermistor	T4205	13:59	125 m
Thermistor	T4206	14:00	130 m
Thermistor	T4207	14:00	135 m
Thermistor	T4208	14:01	140 m
Thermistor	T4209	14:01	145 m
Thermistor	T4210	14:02	150 m
Nortek CM	8088	14:07	159 m
SBE 37 MicroCAT	9373	14:07	160 m
Thermistor	T4211	14:07	162 m
Thermistor	T4212	14:08	171 m
Thermistor	T4213	14:09	180 m
Thermistor	T4214	14:10	189 m
Thermistor	T4343	14:11	198 m
Thermistor	T4344	14:12	207 m
Thermistor	T4345	14:13	216 m
Nortek CM	8093	14:18	228 m
Thermistor	T4346	14:18	228 m
SBE 37 MicroCAT	9374	14:18	229 m
Thermistor	T4347	14:19	234 m
Thermistor	T4348	14:24	244 m
Thermistor	T4349	14:25	254 m
Thermistor	T4350	14:26	264 m
Thermistor	T4351	14:27	274 m
Thermistor	T4352	14:29	284 m
Thermistor	T4353	14:40	293 m

Continued on next page

Table 10 – *continued from previous page*

Instrument and equipment	Serial number	Time (GMT) Overside	Depth rel. to surface
Nortek CM	8097	14:45	298 m
SBE 37 MicroCAT	9375	14:45	299 m
Thermistor	T4354	14:47	305 m
Thermistor	T4355	14:48	319 m
Thermistor	T4356	14:50	334 m
Thermistor	T4357	14:53	348 m
Nortek CM	8111	14:57	352 m
SBE 37 MicroCAT	7310	14:57	353 m
Thermistor	T4359	14:58	363 m
Thermistor	T4360	14:59	378 m
Thermistor	T4361	15:00	393 m
Thermistor	T4362	15:01	408 m
Thermistor	T4363	15:02	423 m
Thermistor	T4364	15:04	438 m
75 kHz ADCP	LR10583	15:15	452 m
Thermistor	T4365	15:15	453 m
Thermistor	T4366	15:18	465 m
Thermistor	T4367	15:20	480 m
Thermistor	T4368	15:22	495 m
Nortek CM	8351	15:26	513 m
SBE 37 MicroCAT	7311	15:26	514 m
Release	1134 / 1491	17:13	4816 m

Table 10: Instruments deployed on the south-west inner mooring

The mooring operation began at 13.41 GMT on 1st September 2012. The attachment of instruments, buoyancy devices, releases and chain continued until 17:13 GMT. The ship arrived at 48° 40.53' N, 16° 12.72' W at 18:04 GMT at which point the chain was released by the aft crane and the mooring was deployed. This was approximately 500 m beyond the target position to allow for fall-back.

The estimated mooring position of 48°40.68 ' N, 16° 12.30' W was determined from four independent ranging locations (triangulation) to the acoustic release. This required the ship to position itself at least an ocean depth horizontally away from the likely location of the mooring. A transducer was deployed over the side of the ship and the slant range (distance) to the mooring was obtained. The calculated horizontal distance provided an estimate of the radius from the ship location within which the mooring was located. The cross-over of the range circles (the "cocked hat" method) provided an estimate of the location of the mooring. In this case the estimated position given above was the locus of the small area close to where the circles met. The estimated mooring location was 350 m to the south-west from the target location.

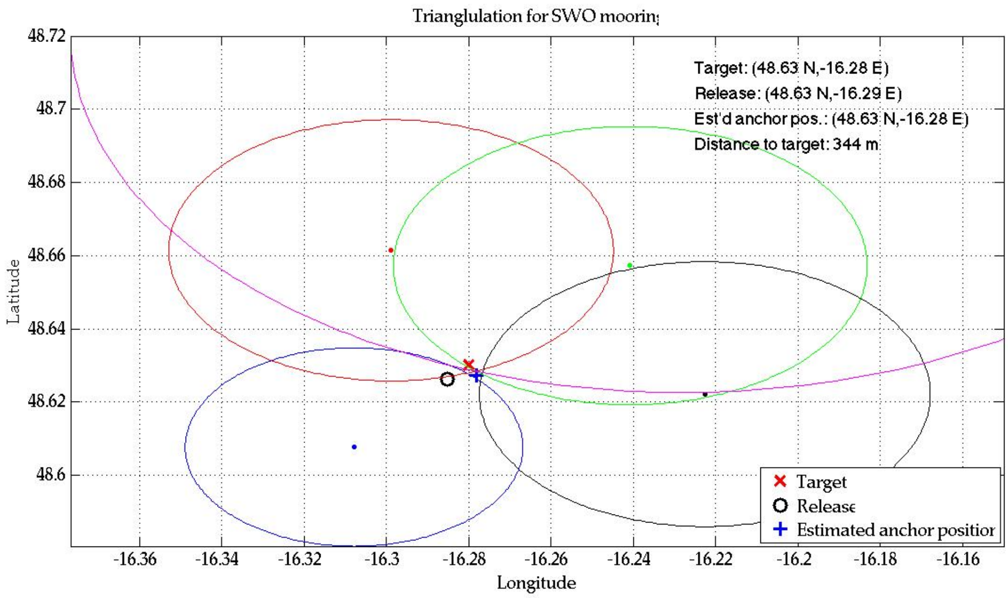

Figure 4: The triangulation data for the south-west outer mooring. Note that the ellipse generated by the furthest away triangulation point is only partially included. The anchor position has been estimated based on the relative overlaps of the triangulation ellipses.

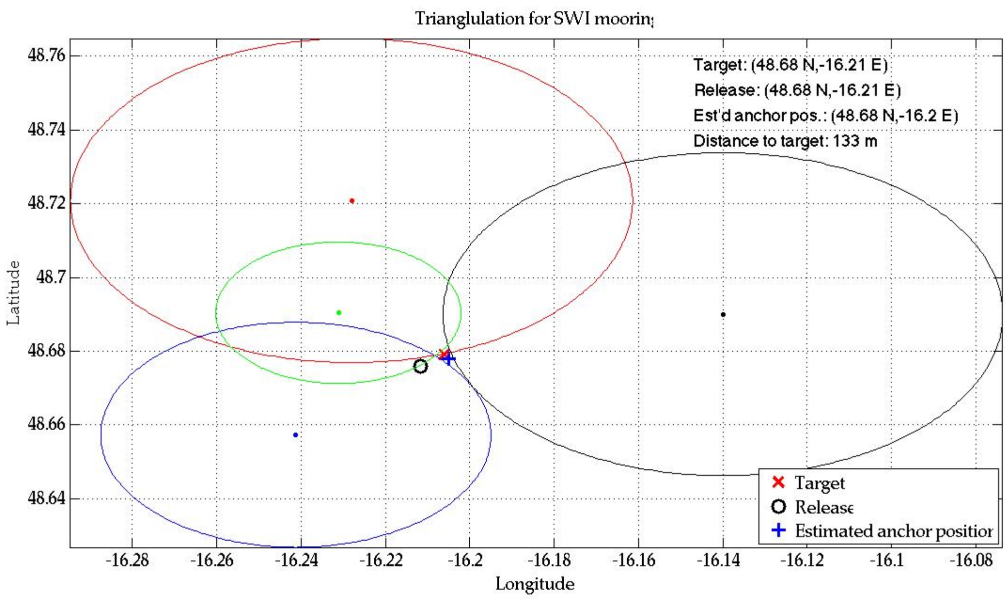

Figure 5: The triangulation data for the south-west inner mooring. The anchor position has been estimated based on the relative overlaps of the triangulation ellipses.

North-west inner mooring

The target for the inner north-west mooring was 48° 42.000' N, 16° 12.360' W in approximately 4,830 m of water. The mooring consisted of 50 Star-Oddi thermistors, one upward pointing 75 kHz ADCP, seven Nortek single-point current meters and seven SBE 37 MicroCAT sensors as detailed in **Table 3**. In addition, a light and Argo tag were affixed at the top of the mooring. The mooring plan was adjusted with the 200 m section below 4154 m replaced by two 100 m sections and also for a slightly shallower depth by replacing a 50 m section of cable just above 4810 m depth (on the mooring) with a 20 m section. This gives the mooring a total depth of 4830 m.

Instrument and equipment	Serial number	Time (GMT) Overside	Depth rel. to surface
Thermistor	T4215	06:28	33 m
Light	W06-005	06:28	36 m
ARGO tag	A02-018	06:28	36 m
Thermistor	T4216	06:29	47 m
Nortek CM	8352	06:29	53 m
Thermistor	T4217	06:29	53 m
SBE 37 MicroCAT	9376	06:29	54 m
Thermistor	T4220	06:31	59 m
Thermistor	T4221	06:32	64 m
Thermistor	T4222	06:32	69 m
Thermistor	T4223	06:33	74 m
Thermistor	T4224	06:34	79 m
Thermistor	T4225	06:35	84 m
Thermistor	T4226	06:35	89 m
Thermistor	T4227	06:36	94 m
Thermistor	T4228	06:37	99 m
Nortek CM	8355	06:42	110 m
Thermistor	T4229	06:42	110 m
SBE 37 MicroCAT	9377	06:42	111 m
Thermistor	T4230	06:44	115 m
Thermistor	T4231	06:45	120 m
Thermistor	T4232	06:45	125 m
Thermistor	T4233	06:46	130 m
Thermistor	T4234	06:47	135 m
Thermistor	T4235	06:48	140 m
Thermistor	T4236	06:49	145 m
Thermistor	T4237	06:50	150 m
Nortek CM	8360	06:53	159 m
SBE 37 MicroCAT	9378	06:53	160 m
Thermistor	T4238	06:54	162 m
Thermistor	T4239	06:55	171 m
Thermistor	T4240	06:56	180 m
Thermistor	T4241	06:57	189 m

Continued on next page

Table 11 – *continued from previous page*

Instrument and equipment	Serial number	Time (GMT) Overside	Depth rel. to surface
Thermistor	T4369	06:58	198 m
Thermistor	T4371	06:59	207 m
Thermistor	T4372	07:00	216 m
Nortek CM	8362	07:05	228 m
Thermistor	T4382	07:05	228 m
SBE 37 MicroCAT	9379	07:05	229 m
Thermistor	T4383	07:07	234 m
Thermistor	T4384	07:08	244 m
Thermistor	T4385	07:08	254 m
Thermistor	T4386	07:09	264 m
Thermistor	T4387	07:10	274 m
Thermistor	T4388	07:11	284 m
Thermistor	T4389	07:12	293 m
Nortek CM	8364	07:15	298 m
SBE 37 MicroCAT	9380	07:15	299 m
Thermistor	T4390	07:16	305 m
Thermistor	T4391	07:17	319 m
Thermistor	T4392	07:18	334 m
Thermistor	T4393	07:20	348 m
Nortek CM	8365	07:22	352 m
SBE 37 MicroCAT	7312	07:22	353 m
Thermistor	T4394	07:24	363 m
Thermistor	T4395	07:25	378 m
Thermistor	T4396	07:26	393 m
Thermistor	T4397	07:28	408 m
Thermistor	T4398	07:29	423 m
Thermistor	T4399	07:30	438 m
75 kHz ADCP	LR10584	07:45	452 m
Thermistor	T4400	07:45	453 m
Thermistor	T4401	07:46	465 m
Thermistor	T4402	07:48	480 m
Thermistor	T4403	07:49	495 m
Nortek CM	9822	07:52	513 m
SBE 37 MicroCAT	7313	07:52	514 m
Release	1136 / 1492	09:14	4816 m

Table 11: Instruments deployed on the north-west inner mooring

The mooring operation began at 06.28 GMT on 3rd September 2012. The attachment of instruments, buoyancy devices, releases and chain continued until 09:14 GMT. The ship arrived at 48° 41.746' N, 16° 12.600' W at 10:41 GMT at which point the chain was released by the aft crane and the mooring was deployed. This was approximately 500 m beyond the target position to allow for fall-back.

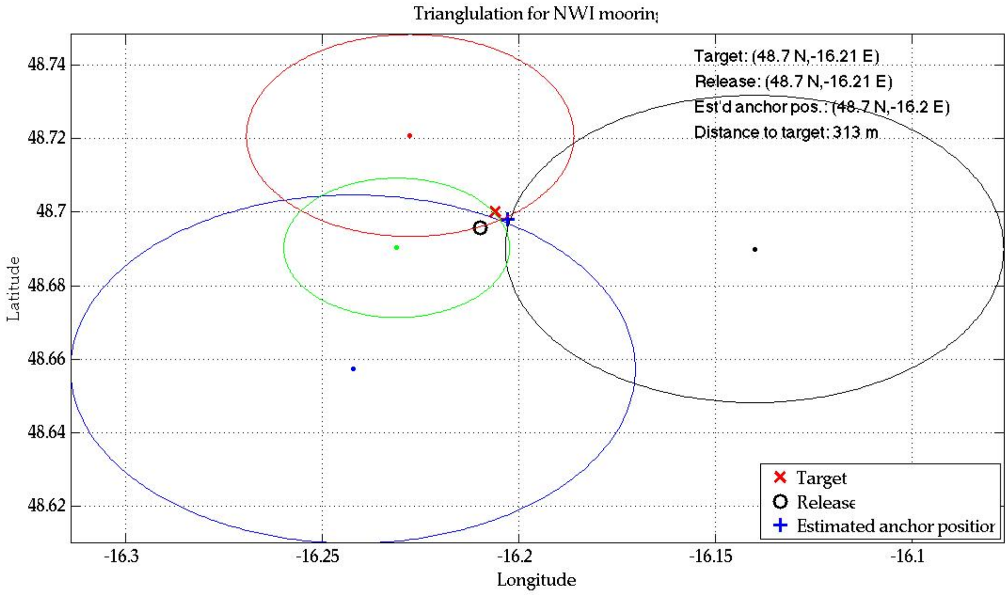

Figure 6: The triangulation data for the north-west inner mooring. The anchor position has been estimated based on the relative overlaps of the triangulation ellipses.

The estimated mooring position of 48°40.68 ' N, 16° 12.30' W was determined from four independent ranging locations (triangulation) to the acoustic release. This required the ship to position itself at least an ocean depth horizontally away from the likely location of the mooring. A transducer was deployed over the side of the ship and the slant range (distance) to the mooring was obtained. The calculated horizontal distance provided an estimate of the radius from the ship location within which the mooring was located. The cross-over of the range circles (the "cocked hat" method) provided an estimate of the location of the mooring. In this case the estimated position given above was the locus of the small area close to where the circles met. The estimated mooring location was 313 m to the south-east of the target location.

Centre mooring

The target for the centre mooring was 48° 41.340' N, 16° 11.400' W in approximately 4,830 m of water. The mooring consisted of 48 Star-Oddi thermistors, one upward pointing 75 kHz ADCP, four 600 kHz ADCPs, thirteen Nortek single-point current meters and thirteen SBE 37 MicroCAT sensors as detailed in **Table 3**. In addition, a light and Argo tag were affixed at the top of the mooring. The mooring plan was adjusted for a slightly shallower depth than expected by replacing a 60 m section of cable just above 4810 m depth (on the mooring) with a 30 m section. This gives the mooring a total depth of 4820 m.

Instrument and equipment	Serial number	Time (GMT) Overside	Depth rel. to surface
Thermistor	T2607	13:16	33 m

Continued on next page

Table 12 – *continued from previous page*

Instrument and equipment	Serial number	Time (GMT) Overside	Depth rel. to surface
Light	W10-030	13:16	35 m
ARGO tag	A02-021	13:16	35 m
Thermistor	T2608	13:16	47 m
600 kHz ADCP	WHS2390	13:18	48 m
Thermistor	T2618	13:18	50 m
Nortek CM	9956	13:18	53 m
SBE 37 MicroCAT	9391	13:18	54 m
Thermistor	T2620	13:19	57 m
Thermistor	T2622	13:20	62 m
Thermistor	T2624	13:21	67 m
Thermistor	T2846	13:27	72 m
600 kHz ADCP	WHS7301	13:27	76 m
Thermistor	T2850	13:27	77 m
Nortek CM	9957	13:27	79 m
SBE 37 MicroCAT	9392	13:28	79 m
Thermistor	T3114	13:29	84 m
Thermistor	T3725	13:30	89 m
Thermistor	T3727	13:31	94 m
Thermistor	T3728	13:31	99 m
Thermistor	T3729	13:35	104 m
Thermistor	T3730	13:35	112 m
Nortek CM	9960	13:35	113 m
SBE 37 MicroCAT	9393	13:36	113 m
Thermistor	T3731	13:36	118 m
Thermistor	T3732	13:37	123 m
Thermistor	T4294	13:38	128 m
Thermistor	T4295	13:39	133 m
Thermistor	T4296	13:42	138 m
Thermistor	T4297	13:42	145 m
Nortek CM	9962	13:42	146 m
SBE 37 MicroCAT	9394	13:43	146 m
Thermistor	T4298	13:50	151 m
Thermistor	T4299	13:50	156 m
600 kHz ADCP	WHS5807	13:50	158 m
Nortek CM	9966	13:50	161 m
SBE 37 MicroCAT	9395	13:50	162 m
Thermistor	T4300	13:52	170 m
Thermistor	T4301	13:53	178 m
Thermistor	T4302	13:54	186 m
Thermistor	T4303	13:58	195 m
Nortek CM	9968	13:58	195 m
SBE 37 MicroCAT	9396	13:58	195 m
Thermistor	T4461	13:59	203 m

Continued on next page

Table 12 – *continued from previous page*

Instrument and equipment	Serial number	Time (GMT) Overside	Depth rel. to surface
Thermistor	T4462	14:00	211 m
Thermistor	T4463	14:01	219 m
Thermistor	T4464	14:05	228 m
Nortek CM	9969	14:05	229 m
SBE 37 MicroCAT	9397	14:05	229 m
Thermistor	T4465	14:06	239 m
Thermistor	T4466	14:07	249 m
Nortek CM	9972	14:10	261 m
SBE 37 MicroCAT	9398	14:10	262 m
Thermistor	T4468	14:11	272 m
Thermistor	T4469	14:12	282 m
600 kHz ADCP	WHS3725	14:18	294 m
Thermistor	T4470	14:18	295 m
Nortek CM	9975	14:18	297 m
SBE 37 MicroCAT	9399	14:18	297 m
Thermistor	T4471	14:20	303 m
Thermistor	T4472	14:21	317 m
Thermistor	T4473	14:22	332 m
Thermistor	T4474	14:23	346 m
Nortek CM	9976	14:26	350 m
SBE 37 MicroCAT	8076	14:26	351 m
Thermistor	T4475	14:27	357 m
Thermistor	T4476	14:28	371 m
Thermistor	T4477	14:29	386 m
Nortek CM	9979	14:32	402 m
SBE 37 MicroCAT	8077	14:32	402 m
Thermistor	T4479	14:34	418 m
Thermistor	T4480	14:35	434 m
Thermistor	T4481	14:36	448 m
75 kHz ADCP	LR5575	14:49	454 m
Nortek CM	9986	14:49	458 m
SBE 37 MicroCAT	8078	14:49	459 m
Thermistor	T44482	14:52	464 m
Thermistor	T4483	14:52	479 m
Thermistor	T4484	14:53	494 m
Nortek CM	9989	14:56	512 m
SBE 37 MicroCAT	8079	14:56	512 m
Release	1137 / 1493	16:22	4816 m

Table 12: Instruments deployed on the centre mooring

The mooring operation began at 13.16 GMT on 3rd September 2012. The attachment of instruments, buoyancy devices, releases and chain continued until 16:35 GMT. The

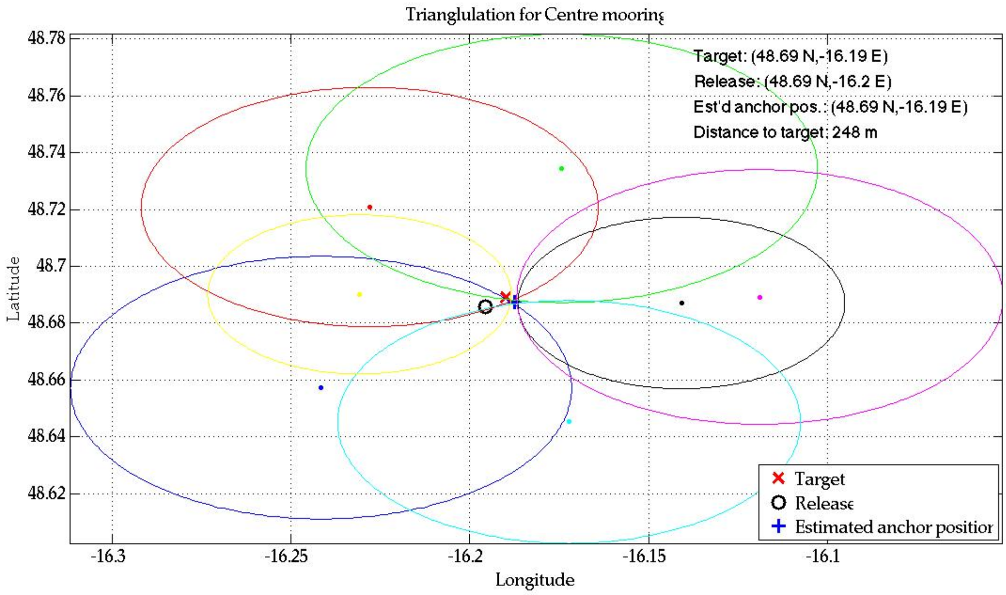

Figure 7: The triangulation data for the centre mooring. The anchor position has been estimated based on the relative overlaps of the triangulation ellipses.

ship arrived at 48° 41.142' N, 16° 11.736' W at 17:16 GMT at which point the chain was released by the aft crane and the mooring was deployed. This was approximately 500 m beyond the target position to allow for fall-back.

The estimated mooring position of 48°41.25 ' N, 16° 11.25' W was determined from seven independent ranging locations (triangulation) to the acoustic release. This required the ship to position itself at least an ocean depth horizontally away from the likely location of the mooring. A transducer was deployed over the side of the ship and the slant range (distance) to the mooring was obtained. The calculated horizontal distance provided an estimate of the radius from the ship location within which the mooring was located. The cross-over of the range circles (the "cocked hat" method) provided an estimate of the location of the mooring. In this case the estimated position given above was the locus of the small area close to where the circles met. The estimated mooring location was 250 m to the south-west from the target location.

North-east Inner mooring

The target for the north-east inner (NE-I) mooring was 48° 42.000' N, 16° 10.440' W in approximately 4,830 m of water. The mooring consisted of 50 Star-Oddi thermistors, one upward pointing 75 kHz ADCP, three 600 kHz ADCPs, seven Nortek single-point current meters and seven SBE 37 MicroCAT sensors as detailed in **Table 3**. In addition, a light and Argo tag were affixed at the top of the mooring. The mooring plan was adjusted for a slightly shallower depth than expected by replacing a 50 m section of cable just above 4810 m depth (on the mooring) with a 20 m section. This gives the mooring a total depth of 4830 m.

Instrument and equipment	Serial number	Time (GMT) Overside	Depth rel. to surface
Thermistor	T4242	06:48	32 m
Light	W06-007	06:48	35 m
ARGO tag	A02-020	06:48	35 m
Thermistor	T4244	06:48	46 m
600 kHz ADCP	WHS3644	06:49	51 m
Thermistor	T4245	06:49	52 m
Nortek CM	9853	06:49	54 m
SBE 37 MicroCAT	9381	06:49	54 m
Thermistor	T4246	06:50	59 m
Thermistor	T4247	06:51	64 m
Thermistor	T4248	06:52	69 m
Thermistor	T4249	06:52	74 m
Thermistor	T4251	06:53	79 m
Thermistor	T4252	06:54	84 m
Thermistor	T4253	06:55	89 m
Thermistor	T4254	06:55	94 m
Thermistor	T4255	06:56	99 m
600 kHz ADCP	WHS3821	07:00	108 m
Thermistor	T4256	07:00	110 m
Nortek CM	9854	07:00	111 m
SBE 37 MicroCAT	9382	07:00	112 m
Thermistor	T4467	07:01	117 m
Thermistor	T4258	07:02	122 m
Thermistor	T4259	07:03	127 m
Thermistor	T4260	07:04	132 m
Thermistor	T4261	07:05	137 m
Thermistor	T4262	07:05	142 m
Thermistor	T4263	07:06	147 m
Thermistor	T4264	07:07	152 m
Nortek CM	9859	07:11	160 m
SBE 37 MicroCAT	9383	07:11	160 m
Thermistor	T4265	07:11	163 m
Thermistor	T4266	07:12	172 m
Thermistor	T4267	07:13	181 m
Thermistor	T4268	07:14	190 m
Thermistor	T4404	07:15	199 m
Thermistor	T4405	07:16	208 m
Thermistor	T4406	07:16	217 m
600 kHz ADCP	WHS4015	07:20	228 m
Thermistor	T4407	07:20	229 m
Nortek CM	9861	07:20	230 m
SBE 37 MicroCAT	9384	07:20	231 m
Thermistor	T4408	07:22	236 m
Thermistor	T4411	07:23	246 m

Continued on next page

Table 13 – *continued from previous page*

Instrument and equipment	Serial number	Time (GMT) Overside	Depth rel. to surface
Thermistor	T4412	07:24	256 m
Thermistor	T4413	07:25	266 m
Thermistor	T4414	07:26	276 m
Thermistor	T4415	07:27	286 m
Thermistor	T4416	07:27	295 m
Nortek CM	9867	07:30	299 m
SBE 37 MicroCAT	9385	07:30	299 m
Thermistor	T4418	07:31	305 m
Thermistor	T4419	07:32	319 m
Thermistor	T4420	07:33	334 m
Thermistor	T4421	07:36	348 m
Nortek CM	9868	07:38	352 m
SBE 37 MicroCAT	7316	07:38	353 m
Thermistor	T4422	07:40	363 m
Thermistor	T4423	07:41	378 m
Thermistor	T4424	07:42	393 m
Thermistor	T4425	07:42	408 m
Thermistor	T4426	07:43	423 m
Thermistor	T4427	07:44	438 m
75 kHz ADCP	LR17825	07:52	452 m
Thermistor	T4428	07:52	453 m
Thermistor	T4429	07:54	464 m
Thermistor	T4430	07:55	479 m
Thermistor	T4432	07:56	494 m
Nortek CM	9874	07:58	512 m
SBE 37 MicroCAT	8075	07:58	513 m
Release	1138 / 1494	09:15	4816 m

Table 13: Instruments deployed on the north-east inner mooring

The mooring operation began at 06:47 GMT on 5th September 2012. The attachment of instruments, buoyancy devices, releases and chain continued until 09:15 GMT. The ship arrived at 48° 41.916' N, 16° 10.878' W at 10:38 GMT at which point the chain was released by the aft crane and the mooring was deployed. This was approximately 500 m beyond the target position to allow for fall-back.

The estimated mooring position of 48°41.64' N, 16° 10.38' W was determined from four independent ranging locations (triangulation) to the acoustic release. This required the ship to position itself at least an ocean depth horizontally away from the likely location of the mooring. A transducer was deployed over the side of the ship and the slant range (distance) to the mooring was obtained. The calculated horizontal distance provided an estimate of the radius from the ship location within which the mooring was located. The cross-over of the range circles (the "cocked hat" method) provided an estimate of the

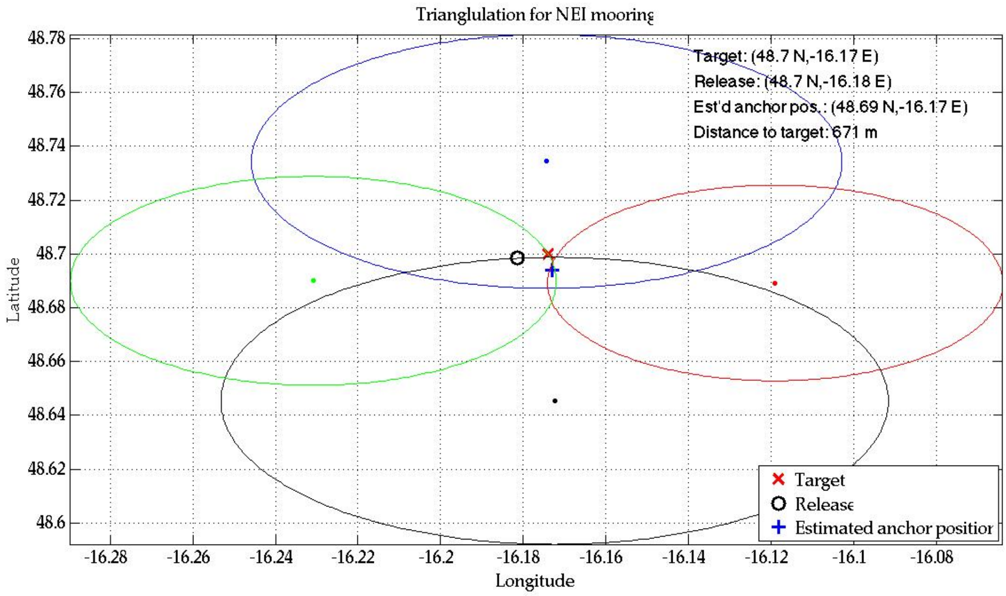

Figure 8: The triangulation data for the north-east inner mooring. The anchor position has been estimated based on the relative overlaps of the triangulation ellipses.

location of the mooring. In this case the estimated mooring location was 670 m away from the target location.

South-east Inner mooring

The target for the inner south-east mooring was 48° 40.740' N, 16° 10.440' W in approximately 4,830 m of water. The mooring consisted of 48 Star-Oddi thermistors, one upward pointing 75 kHz ADCP, seven Nortek single-point current meters and seven SBE 37 MicroCAT sensors. In addition, a light and Argo tag were affixed at the top of the mooring. The mooring plan was adjusted for a slightly shallower depth than expected by replacing a 50 m section of cable just above 4810 m depth (on the mooring) with a 20 m section. This gives the mooring a total depth of 4830 m.

Instrument and equipment	Serial number	Time (GMT) Overside	Depth rel. to surface
Thermistor	T4269	12:57	33 m
Light	W06-006	12:57	36 m
ARGO tag	A02-019	12:57	36 m
Thermistor	T4270	12:58	47 m
Nortek CM	9877	12:58	53 m
Thermistor	T4271	12:58	54 m
SBE 37 MicroCAT	9386	12:58	54 m
Thermistor	T4272	12:59	59 m
Thermistor	T4273	12:59	64 m
Thermistor	T4274	13:00	69 m

Continued on next page

Table 14 – *continued from previous page*

Instrument and equipment	Serial number	Time (GMT) Overside	Depth rel. to surface
Thermistor	T4275	13:01	74 m
Thermistor	T4276	13:01	79 m
Thermistor	T4277	13:02	84 m
Thermistor	T4278	13:03	89 m
Thermistor	T4279	13:03	94 m
Thermistor	T4280	13:04	99 m
Nortek CM	9881	13:08	110 m
Thermistor	T4281	13:08	110 m
SBE 37 MicroCAT	9387	13:08	110 m
Thermistor	T4282	13:09	115 m
Thermistor	T4283	13:09	120 m
Thermistor	T4284	13:10	125 m
Thermistor	T4285	13:11	130 m
Thermistor	T4286	13:11	135 m
Thermistor	T4287	13:12	140 m
Thermistor	T4288	13:13	145 m
Thermistor	T4289	13:13	150 m
Nortek CM	9885	13:17	159 m
SBE 37 MicroCAT	9388	13:17	160 m
Thermistor	T4290	13:21	162 m
Thermistor	T4291	13:22	171 m
Thermistor	T4292	13:23	180 m
Thermistor	T4293	13:24	189 m
Thermistor	T4433	13:25	198 m
Thermistor	T4434	13:26	207 m
Thermistor	T4437	13:26	216 m
Nortek CM	9905	13:32	228 m
Thermistor	T4439	13:32	228 m
SBE 37 MicroCAT	9389	13:32	229 m
Thermistor	T4440	13:34	234 m
Thermistor	T4441	13:34	244 m
Thermistor	T4442	13:35	254 m
Thermistor	T4443	13:36	264 m
Thermistor	T4444	13:37	274 m
Thermistor	T4445	13:38	284 m
Thermistor	T4446	13:39	293 m
Nortek CM	9909	13:42	298 m
SBE 37 MicroCAT	9390	13:42	299 m
Thermistor	T4447	13:43	305 m
Thermistor	T4448	13:44	319 m
Thermistor	T4478	13:45	334 m
Thermistor	T4450	13:46	348 m
Nortek CM	9912	13:48	352 m

Continued on next page

Table 14 – *continued from previous page*

Instrument and equipment	Serial number	Time (GMT) Overside	Depth rel. to surface
SBE 37 MicroCAT	7314	13:48	353 m
Thermistor	T4451	13:50	363 m
Thermistor	T4452	13:51	378 m
Thermistor	T4453	13:52	393 m
Thermistor	T4454	13:53	408 m
Thermistor	T4455	13:54	423 m
Thermistor	T4456	13:55	438 m
75 kHz ADCP	LR17826	14:02	452 m
Thermistor	T4457	14:02	453 m
Thermistor	T4458	14:04	465 m
Thermistor	T4459	14:05	480 m
Thermistor	T4460	14:06	495 m
Nortek CM	9926	14:08	513 m
SBE 37 MicroCAT	7315	14:08	514 m
Release	1140 / 1497	15:38	4816 m

Table 14: Instruments deployed on the south-east inner mooring

The mooring operation began at 12.57 GMT on 5th September 2012. The attachment of instruments, buoyancy devices, releases and chain continued until 15:38 GMT. The ship arrived at 48° 40.764' N, 16° 10.830' W at 18:52 GMT at which point the chain was released by the aft crane and the mooring was deployed. This was approximately 500 m beyond the target position to allow for fall-back.

The estimated mooring position of 48°40.82 ' N, 16° 10.44' W was determined from four independent ranging locations (triangulation) to the acoustic release. This required the ship to position itself at least an ocean depth horizontally away from the likely location of the mooring. A transducer was deployed over the side of the ship and the slant range (distance) to the mooring was obtained. The calculated horizontal distance provided an estimate of the radius from the ship location within which the mooring was located. The cross-over of the range circles (the "cocked hat" method) provided an estimate of the location of the mooring. In this case the estimated mooring location was 160 m away from the target location.

North-west outer mooring

The target for the north-west outer mooring was 48° 44.940' N, 16° 16.800' W in approximately 4,830 m of water. The mooring consisted of five Nortek Aquadropp single-point current meters and five SBE 37 MicroCAT sensors. In addition, a light and Argo tag were affixed at the top of the mooring. The mooring plan was adjusted for a slightly shallower depth than expected by replacing a 50 m section of cable just above 4810 m depth (on the mooring) with a 20 m section. This gives the mooring a total depth of 4830 m.

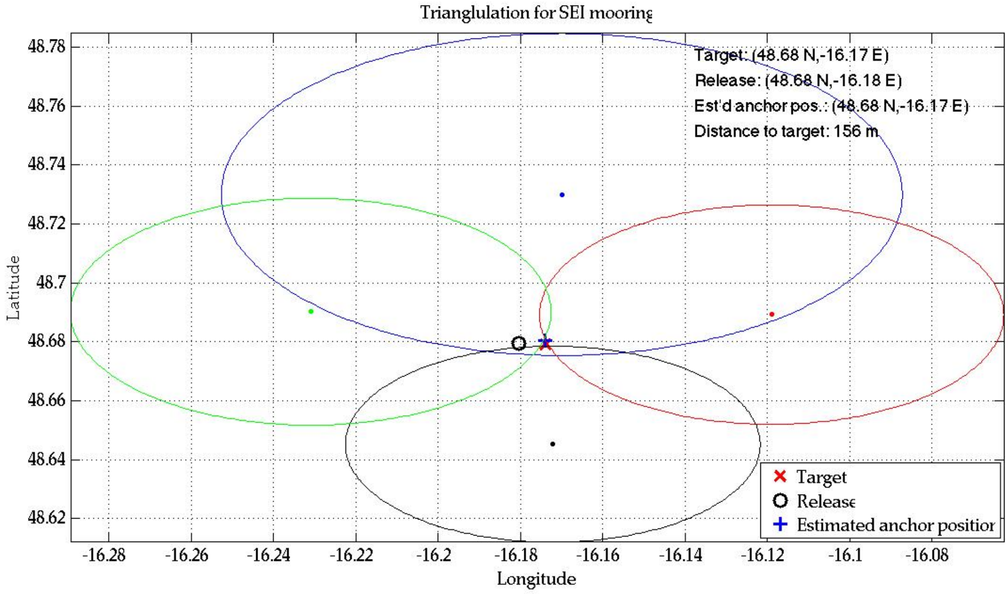

Figure 9: The triangulation data for the south-east inner mooring. The anchor position has been estimated based on the relative positions of the triangulation ellipses.

Table 15: Instruments deployed on the north-west outer mooring

Instrument and equipment	Serial number	Time (GMT) Overside	Depth rel. to surface
Light	A1554	06:44	33 m
ARGO tag	A02-014	06:44	33 m
Nortek CM	6203	06:45	50 m
SBE 37 MicroCAT	7293	06:45	51 m
Nortek CM	6212	06:50	110 m
SBE 37 MicroCAT	7294	06:50	110 m
Nortek CM	6213	06:55	224 m
SBE 37 MicroCAT	7295	06:55	225 m
Nortek CM	6224	07:01	348 m
SBE 37 MicroCAT	7296	07:01	348 m
Nortek CM	1415	07:10	511 m
SBE 37 MicroCAT	7297	07:10	512 m
Release	831 / 1270	08:46	4816 m

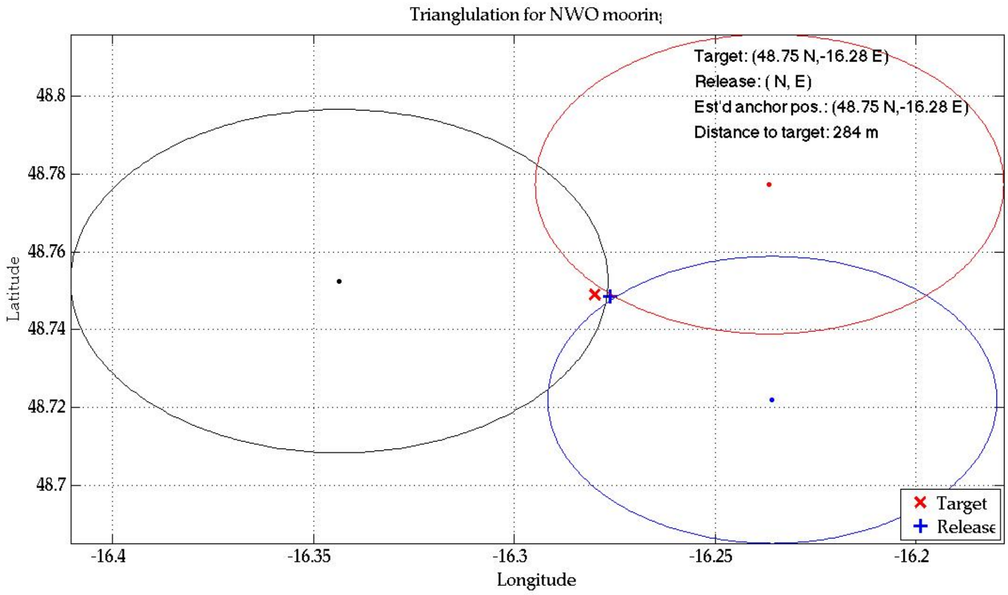

Figure 10: The triangulation data for the north-west outer mooring. The anchor position has been estimated based on the relative overlaps of the triangulation ellipses.

The mooring operation began at 06.44 GMT on 7th September 2012. The attachment of instruments, buoyancy devices, releases and chain continued until 08:46 GMT. The ship arrived at 48° 44.737' N, 16° 16.450' W at 09:47 GMT at which point the chain was released by the aft crane and the mooring was deployed. This was approximately 500 m beyond the target position to allow for fall-back.

The estimated mooring position of 48°44.91' N, 16° 16.57' W was determined from three independent ranging locations (triangulation) to the acoustic release. This required the ship to position itself at least an ocean depth horizontally away from the likely location of the mooring. A transducer was deployed over the side of the ship and the slant range (distance) to the mooring was obtained. The calculated horizontal distance provided an estimate of the radius from the ship location within which the mooring was located. The cross-over of the three circles (the "cocked hat" method) provided an estimate of the location of the mooring. In this case the estimated mooring location was 280 m east/south-east from the target location.

North-east outer mooring

The target for the north-east outer mooring was 48° 44.940' N, 16° 6.000' W in approximately 4,830 m of water. The mooring consisted of five Nortek Aquadropp single-point current meters and five SBE 37 MicroCAT sensors. In addition, a light and Argo tag were affixed at the top of the mooring. The mooring plan was adjusted for a slightly shallower depth than expected by replacing a 50 m section of cable just above 4810 m depth (on the mooring) with a 20 m section. This gives the mooring a total depth of 4830 m.

The mooring operation began at 12.22 GMT on 7th September 2012. The attachment

Table 16: Instruments deployed on the north-east outer mooring

Instrument and equipment	Serial number	Time (GMT) Overside	Depth rel. to surface
Light	B1335	12:22	33 m
ARGO tag	A02-015	12:22	33 m
Nortek CM	6225	12:23	50 m
SBE 37 MicroCAT	7298	12:23	51 m
Nortek CM	6242	12:29	110 m
SBE 37 MicroCAT	7299	12:29	110 m
Nortek CM	6244	12:35	224 m
SBE 37 MicroCAT	7302	12:35	225 m
Nortek CM	6260	12:41	348 m
SBE 37 MicroCAT	7303	12:41	348 m
Nortek CM	1420	12:46	511 m
SBE 37 MicroCAT	7304	12:46	512 m
Release	1142 / 1272	14:16	4816 m

of instruments, buoyancy devices, releases and chain continued until 14:16 GMT. The ship arrived at 48° 44.791' N, 16° 5.616' W at 14:44 GMT at which point the chain was released by the aft crane and the mooring was deployed. This was approximately 500 m beyond the target position to allow for fall-back.

The estimated mooring position of 48°44.88' N, 16° 5.67' W was determined from three independent ranging locations (triangulation) to the acoustic release. This required the ship to position itself at least an ocean depth horizontally away from the likely location of the mooring. A transducer was deployed over the side of the ship and the slant range (distance) to the mooring was obtained. The calculated horizontal distance provided an estimate of the radius from the ship location within which the mooring was located. The cross-over of the range circles (the "cocked hat" method) provided an estimate of the location of the mooring. In this case the estimated mooring location was 420 m east/south-east from the target location.

South-east outer mooring

The target for the south-east outer mooring was 48° ' N, 16° 6.000' W in approximately 4,830 m of water. The mooring consisted of five Nortek Aquadropp single-point current meters and five Sea Bird Electronics (SBE) 37 MicroCAT sensors. In addition, a light and Argo tag were affixed at the top of the mooring. The mooring plan was adjusted for a slightly shallower depth than expected by replacing a 50 m section of cable just above 4810 m depth (on the mooring) with a 20 m section. This gives the mooring a total depth of 4830 m.

The mooring operation began at 06.41 GMT on 17th September 2012 (i.e. on the second leg of the cruise). The attachment of instruments, buoyancy devices, releases and chain continued until 09:22 GMT. The ship arrived at 48° 24.77' N, 16° 14.25' W at 09:22 GMT at which point the chain was released by the aft crane and the mooring

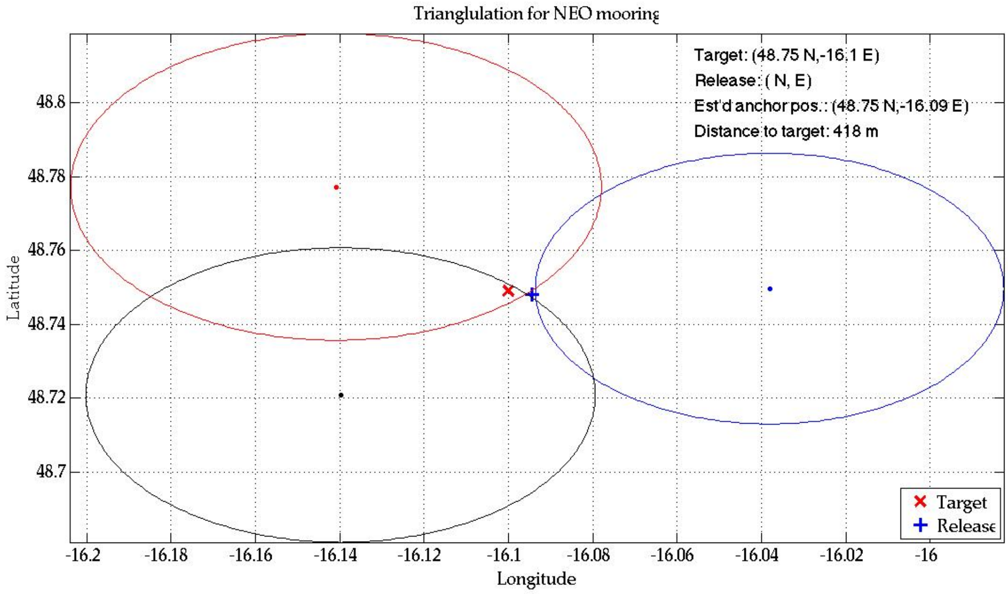

Figure 11: The triangulation data for the north-east outer mooring. The anchor position has been estimated based on the relative overlaps of the triangulation ellipses.

Table 17: Instruments deployed on the south-east outer mooring

Instrument and equipment	Serial number	Time (GMT) Overside	Depth rel. to surface
Light	J12-028	06:41	33 m
ARGO tag	A02-016	06:41	33 m
Nortek CM	6262	06:48	50 m
SBE 37 MicroCAT	7305	06:48	51 m
Nortek CM	6273	06:55	110 m
SBE 37 MicroCAT	7306	06:55	110 m
Nortek CM	6275	07:02	224 m
SBE 37 MicroCAT	7307	07:02	225 m
Nortek CM	6276	07:10	348 m
SBE 37 MicroCAT	7308	07:10	348 m
Nortek CM	1430	07:17	511 m
SBE 37 MicroCAT	7309	07:17	512 m
Release	1135 / 1495	09:14	4816 m

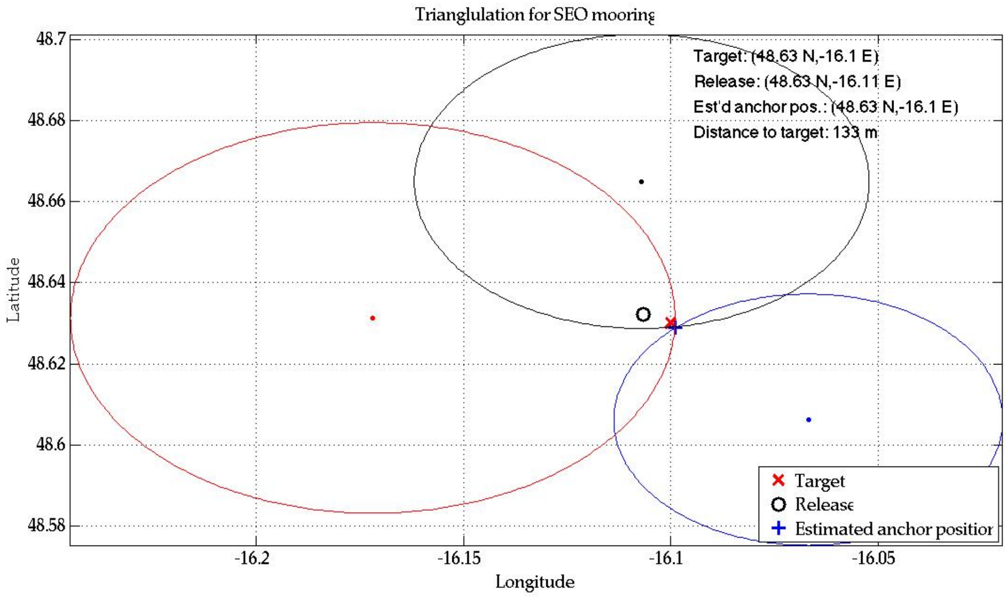

Figure 12: The triangulation data for the south-east outer mooring. The anchor position has been estimated based on the relative overlaps of the triangulation ellipses.

was deployed. This was approximately 500 m beyond the target position to allow for fall-back.

The estimated mooring position of 48°37.74' N, 16° 5.94' W was determined from three independent ranging locations (triangulation) to the acoustic release. This required the ship to position itself at least an ocean depth horizontally away from the likely location of the mooring. A transducer was deployed over the side of the ship and the slant range (distance) to the mooring was obtained. The calculated horizontal distance provided an estimate of the radius from the ship location within which the mooring was located. The cross-over of the range circles (the "cocked hat" method) provided an estimate of the location of the mooring. In this case the estimated mooring location was 130 m south-east from the target location.

Waverider buoy

The waverider buoy was deployed with AXYS Technologies TRIAXYS Directional Wave Buoy. This will measure the wave height, wave period and direction (on a tri-axis basis) over the year as well as SST. It is equipped with satellite communications unit, so it will be able to upload its data throughout the year. The unit is equipped with solar panels for power.

The acquisition interval is 20 minutes i.e. it switches on every 20 minutes and the acquisition interval is 15 minutes i.e. it records for 15 minutes out over every hour (with the first cycle starting on the hour). The buoy can communicate over both the Immarsat D and Iridium satellite networks and reports back every [x] and [X] at SAMS collects the data. [All of the data recorded is uploaded]. The unit has a 100 GB memory card.

There was no watch circle enabled for this deployment. The mooring was designed such that there is an anchor in place on the sea bed which is connected by wire to a large buoy on the surface. This buoy is then attached to the waverider with a negatively buoyant rope for 95 m, a positively buoyant rope for 225 m, 10 m of 32 mm bungee rope and finally 0.5 m of long-link chain attached to the unit itself.

The noise levels for the unit are [X cm], [X s^{-1}] and [X °] for the height, frequency and direction respectively.

Further information on the buoy can be found in the TRIAXYS Directional Wave Buoy Manual Version 12.

The mooring operation for the waverider buoy began on 8th September 2012 at 08:10 GMT. The deployment of the buoy and the attachment of buoyancy devices and acoustic release continued until 10:00 GMT. The ship arrived at 48° 46.532' N, 16° 11.211' W at 11:10 GMT at which point the chain was released by the aft crane and the mooring was deployed.

Guard buoys

The array was equipped with four guard buoys to make ships aware that equipment and has been deployed in the area. They were deployed along the 'faces' of the square formed by the inner moorings. Additionally, one of the buoys was fitted with a meteorological package to measure the [solar radiation and surface winds]. This was the buoy in the northern position.

The buoys were given 700 m fall-back allowance, apart from the first buoy (in the southern position) which was allowed 800 m fall-back.

Table 18: Guard buoy deployment

Position	Ship deploy. latitude	Ship deploy. longitude	Time Overside (GMT)
Southern	48° 38.719' N	16° 11.932' W	16:23 09/09/2012
Northern (Met. Office)	48°43.789' N	16° 11.967' W	12:44 10/09/2012
Eastern	48°41.526' N	16° 8.285' W	18:10 10/09/2012
Western	48°41.604' N	16° 14.591' W	11:42 11/09/2012

Approximately one and a half hours after deployment, the guard buoy with the meteorological sensors ceased transmitting data. This was investigated on the second leg after a replacement buoy was ordered and collected in Falmouth.

Wirewalker – *Jo Hopkins and Terry Doyle*

Introduction

Three short term moorings were deployed at 48° 38.91'N, 9° 6.366'W on 30/08/2012 in nominally 145m of water: a bedframe housing a Flowquest 150 kHz ADCP and a Seabird 16+; an in-line mooring with a profiling platform, the Wirewalker; and a guard buoy with light and radar reflector. The Wirewalker is a wave-powered autonomous profiler, developed at Scripps Institute of Oceanography, and was kindly loaned to us by Andrew.

J. Lucas for use in the FASTNEt project. Following deployment problems in June 2012 this was our second attempt at data collection. The Wirewalker uses the surface wave field to power continual vertical profiling. Internally powered and recording instrumentation attached to the profiler collects a two-dimensional depth-time record. Coupled with the co-located ADCP bedframe the main aim of deployment was to allow calculation of on- and off-shelf fluxes of mass, heat and salt driven by the internal tide. The moorings were deployed at the site named ST4 in cruise D376 in order to take advantage of two long-term ADCPs already in place further towards the shelf edge. The tables below detail exact locations and date/times of deployment/recovery.

Deployment					
	Latitude	**Longitude**	**Date**	**Time (GMT)**	**Nominal depth (m)**
Bed frame	48° 38.886 N	9° 06.344 W	30/08/2012	07:42	145
Wirewalker	48° 38.965 N	9° 06.372 W	30/08/2012	08:53	145
Guard buoy	48° 39.039 N	9° 06.901 W	30/08/2012	10:08	145
Recovery					
	Latitude	**Longitude**	**Date**	**Time (GMT)**	**Nominal depth (m)**
Bed frame	48° 38.703 N	9° 06.382 W	12/09/2012	19:08	145
Wirewalker	48° 38.797 N	9° 06.444 W	12/09/2012	17:29	145
Guard buoy	48° 38.730 N	9° 07.149 W	12/09/2012	18:39	145

Table 19: Details of WireWalker mooring deployment and recovery.

The Wirewalker mooring

Briefly, the mooring itself includes a surface buoy, a wire suspended from the buoy, a weight at the end of the wire, and the profiler attached to the wire via a cam mechanism. A mooring diagram is included below. The wire and weight follow the surface motion of the buoy. The wave-induced motion of the water is reduced with increasing depth, and the relative motion between the wire and the water is used to propel the profiler. The cam engages the wire as it descends and releases it as it ascends, pulling the profiler downwards. At the bottom of the wire, the wirewalker hits a mechanical stop that causes the cam to remain open and the

profiler free floats to the surface. At the top of the wire, the cam is reset and the wirewalker is ratched downwards again.

Instrumentation

A TRDI Citadel CTD-NV measuring temperature, conductivity and pressure, an Aanderra optode for oxygen concentration, and a Wetlabs ECO Triplet recording Chlorophyll-a, CDOM and Phycoerthrin fluorescence were all mounted on the Wirewalker. The CTD

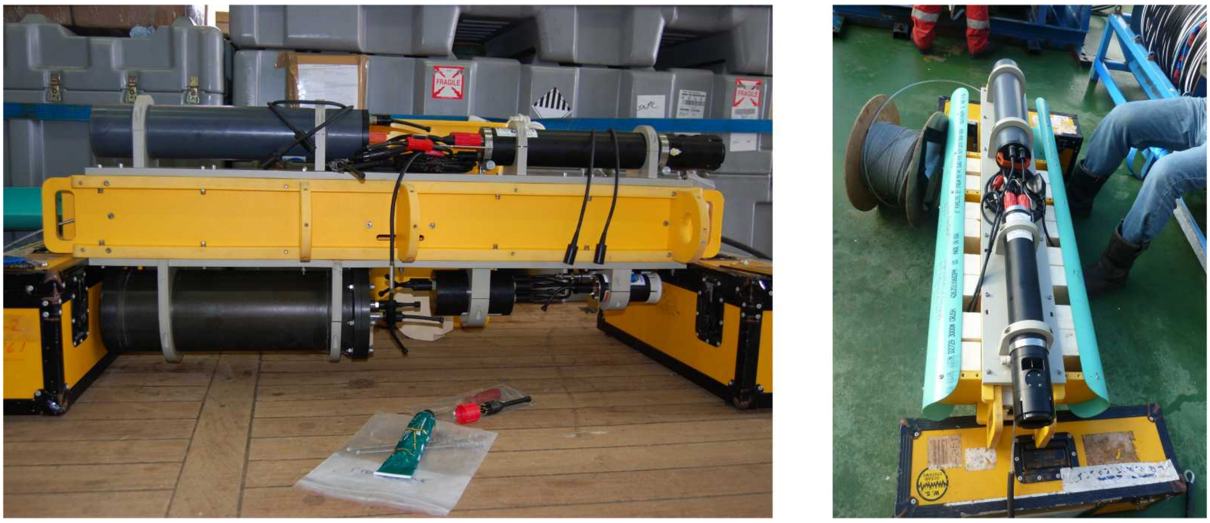

Figure 13: Wirewalker setup without side guards and floats (left). Wirewalker setup on mooring wire and ready for deployment (right).

and oxygen sensor were both powered by a custom made external battery pack and logged to the CTD internal memory. The Triplet was connected to a Wetlabs DH4 data logger and both were powered by an external Wetlabs battery.

The bedframe contained a 150 kHz Flowquest ADCP and a Seabird 16+. The setup details are provided in the tables below.

Calibration

The following manufacturer's calibrations are applied to the Triplet data:

Chlorophyll
CHL (µg/l) = scale_factor x (output - dark_counts)
scale_factor = 0.0121 µg/l/count
dark_counts = 51 counts

CDOM
CDOM (ppb) = scale_factor x (output - dark_counts)
scale_factor = 0.0906 ppb/counts
dark_counts = 50 counts

Phycoerthrin
PHYCO (ppb) = scale_factor x (output - dark_counts)
scale_factor = 0.0426 ppb/counts
dark_counts = 54 counts

The following conversion was applied to the optode:

Oxygen
(µM/l) = (oxygen voltage / 5) x 500
oxygen voltage = (oxygen counts / saturation count) x full scale voltage
saturation count = 65535
full scale voltage = 5

Instrument	Serial number	Sampling rate	Logging started (GMT)	Logging stopped (GMT)	Drift (sec)
Wetlabs ECO Custom TRIPLET 600m (Chlorophyll-a, CDOM and Phycoerthrin)	2560	4 Hz	07:27:30 30/08/2012	19:24:05 12/09/2012	+17
TRDI Citadel CTD-NV	2277	4 Hz	07:45:58 30/08/2012	19:31:05 12/09/2012	+17
Aanderra Optode	1126	4 Hz	07:27:30 30/08/2012	19:31:05 12/09/2012	+17
Wetlabs DH4 data logger *	161	n/a	07:27:30 30/08/2012	19:24:05 12/09/2012	+17
Wetlabs battery (model BPA50B)	175	n/a	n/a	n/a	n/a

*A 2 minute warm up period was programmed for the DH4-Triplet set up which started at 07:25:30 on 30/08/2012.

Table 20: Details of instrumentation mounted on the Wirewalker mooring.

Serial Number	Delayed start (GMT)	Stopped (GMT)	Sampling interval (secs)	Measurements per sample	Drift (secs)
4848	12:00:00 28/08/2012	07:51:50 13/09/2012	120	4	+13

Table 21: WireWalker bedframe Seabird 16+ (70 cm above seabed) setup details.

Bin size:		2 m
Ensemble length:		60 seconds
Pings per ensemble:		60
Max working distance:		180 m
Blanking distance:		280 cm
Serial Number	**Delayed start (GMT)**	**Stopped (GMT)**
011043	12:00:00 28/08/2012	08:36:58 13/09/2012

Table 22: WireWalker bedframe Flowquest 150 kHz ADCP (95 cm above sea bed) setup details.

It was not possible to take in-situ samples for calibration on this cruise. The bottle samples taken on D376 will therefore be used for further calibration.

Results

Unfortunately the mooring failed to operate as designed. Instead of profiling continually up and down the wire the profiler remained trapped at the bottom (approx. 90). This was potentially due to a problem with the buoyancy and will need to be investigated. A time series of temperature, conductivity, oxygen, chlorophyll, CDOM and phycoerthrin was therefore collected at approx. 90 m.

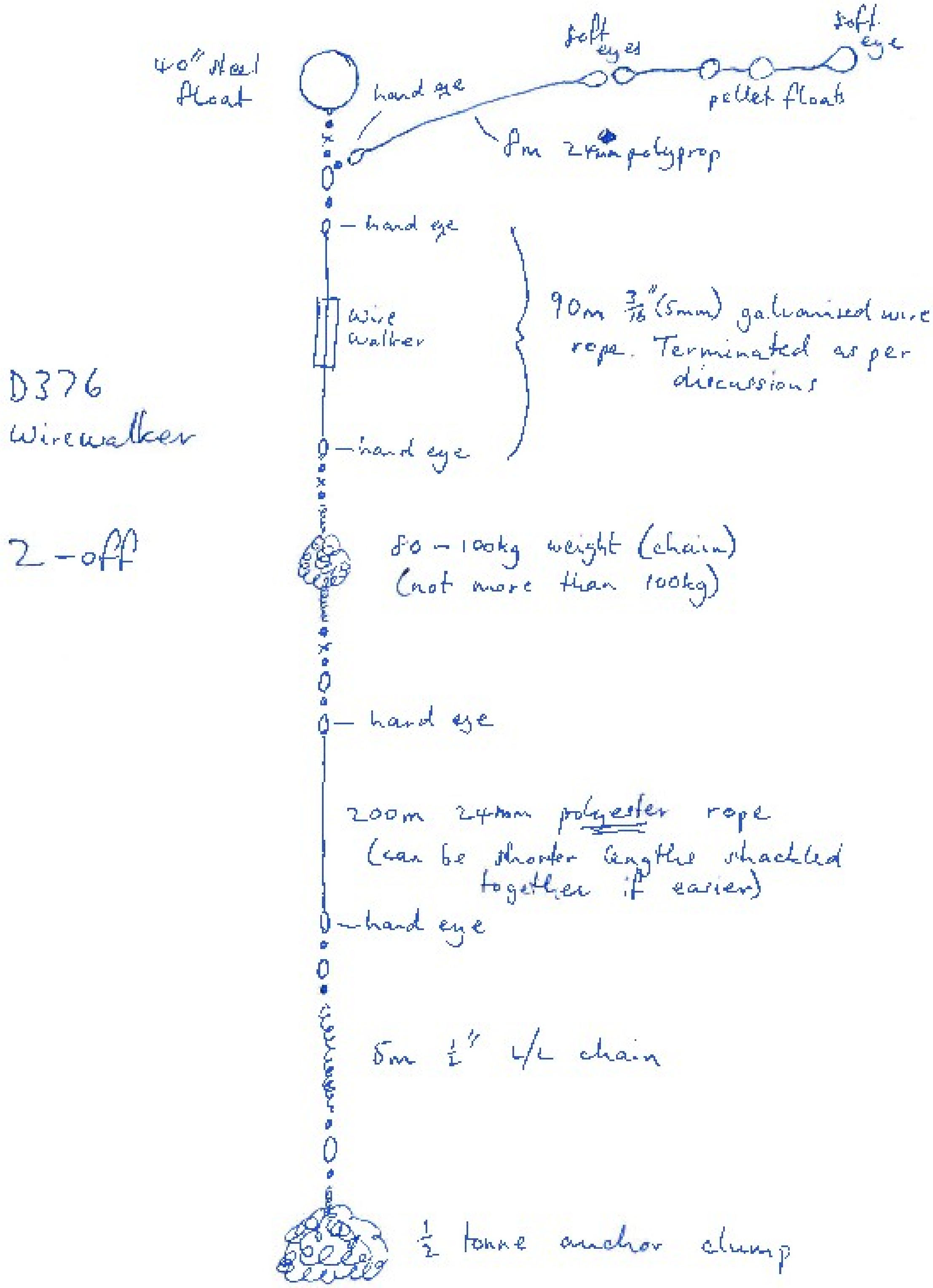

Figure 14: WireWalker mooring diagram.

Turbulence Glider Operations – *Chris Balfour*

This section provides a brief overview of the Teledyne Webb Research Slocum Electric Glider operations during the *RRS Discovery* Based D381B research cruise. This cruise was commissioned to support the Ocean Surface Mixing, Ocean Submesoscale Interaction Study (OSMOSIS) research project. The glider used had a specialist turbulence probe attached that was supplied by Rockland Scientific International. This system was used to provide millimetre scale resolution of changes to the physical properties of the water column such as temperature, shear force and conductivity. The glider was used in conjunction with more established turbulence measurements from a MSS vertical profiler. The vertical profiler was operated from *RRS Discovery* to establish comparative measurements during key surveys within the cruise schedule. The survey work occurred above the Porcupine Abyssal Plane area of the Celtic Sea at an initial GPS location of 48° 46.731'N, 16° 22.816'W and a nominal water depth of approximately 4800 metres.

Glider Deployment Operations

A labelled diagram of the turbulence glider is shown in **Figure 15**. The turbulence probe is the black tube mounted above the front hull of the glider. A custom guard has been fitted close to the delicate turbulence sensor probes. This is designed to provide some level of protection of the probes from damage, particularly during glider deployment and recovery operations. During the deployment of the glider the high volume of data generated by the micro-Rider turbulence probe is stored internally inside the sensor. The glider provides power to the turbulence sensor and a signal to turn on or off turbulence data recording. The mounting of a sensor such as this on the turbulence glider means that great care must be taken to correctly ballast and configure the vehicle for a deployment. To assess the ballasting of the glider a portable water tank was used on *RRS Discovery*. This purpose of using the tank was to verify the glider ballasting in near surface sea water from the intended glider survey area. This test confirmed that the glider was suitably ballasted to attempt a deployment. Comparisons were also made between the ship's CTD measurements of temperature, salinity and density and the parameters used to ballast the glider. This confirmed that the glider 200 meter buoyancy pump had sufficient range to operate correctly in the intended survey area.

Following the completion of the glider testing in the wet lab the glider was transported to the starboard deck of *RRS Discovery*. After final communications checks were completed the glider was lifted using a ship based crane and dual strop arrangement. Stay lines were used to keep the strops in tension around the glider fore and aft hull sections prior to deployment. The stay lines also provided a mechanism to stop the glider moving excessively due to the ship's motion. One side of the strops supporting the glider were connected to a quick release hook.

A safety pin and pull line was installed to prevent a premature release of the hook from occurring. This safety pin was removed from the release hook once the crane had positioned the glider over the side of the ship. As the glider was lowered to the sea surface the stay lines were then removed. The turbulence glider was then subsequently deployed at a GPS location of 48° 46.731'N, 16° 22.816'W at a water depth of approximately 4800 metres at 19:14 GMT on Monday 17th September 2012. The selected deployment location was approximately 14km to the west of the wave rider buoy at the northern part of the OSMOSIS moorings at the PAP survey site. A sequence of pictures that illustrate the glider deployment operations are shown in Fig. 2. Once the glider was buoyant at the sea surface the release hook was then operated and the crane lifted the strops away from the glider to complete the deployment. A sea surface swell occurred during the glider deployment operations that caused the deployed glider to move vertically on the sea surface relative to the ship. Before the crane lifting arm could be retracted the release hook impacted with the rear plastic cowling over the glider air bladder and below the tail section. No damage was evident to the cowling although this does illustrate the potential risk of using this type of deployment mechanism in anything other than a flat calm sea state. Two long fending off poles were on standby to prevent the glider from straying too close to the outer hull of *RRS Discovery* during the early phases of the deployment. When the glider was approximately 300m to 500m from the ship the pre deployment glider dive testing operations commenced.

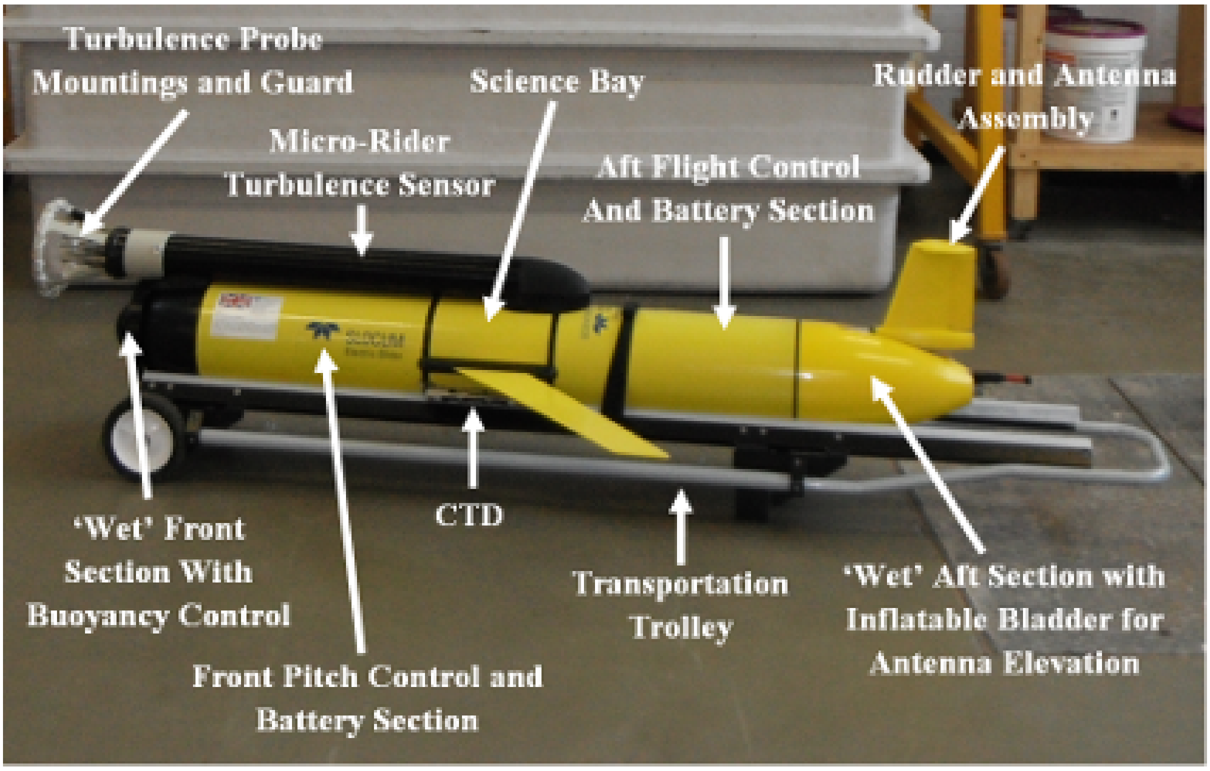

Figure 15: Turbulence Glider Key Features.

Following the glider deployment a series of tests were then undertaken using FreeWave wireless communications to the glider. This was achieved using an antenna mounted on the ship at an elevated position close to the CTD winch. These tests involved checking the status of the vehicle, performing incremental test dives to 3 metres, and then 50 metres. After each test dive the recorded glider data was downloaded and plotted to assess the vehicle status and check for problems such as seawater ingress. The dive profile was also trimmed by adjusting the position of the pitch control battery pack at the start of dives and climbs. After successfully completing a set of 50 metre profiling dives of 30 minutes in duration the recorded sensor data from the glider was downloaded to the ship and a series of checks were undertaken. The glider climb pitch angle was adjusted for a steeper climb angle of closer to 53°. No problems were evident and at 20:39 GMT the glider survey mission to 100m depth profiles with the glider CTD and turbulence sensor operating were initiated. This completed the glider deployment operations. Casts from the *RRS Discovery* based CTD carousel prior to and after the glider deployment were used to provide the required reference calibration readings for the glider CTD sensor calibration. The glider operation was then closely monitored using the ship's internet connection as and when possible. Standby pilots were available at NOC Liverpool during normal working hours. A satellite phone was used to liaise with shore based glider pilots regarding the turbulence glider status when the *RRS Discovery* internet connection was inoperative for significant periods of time.

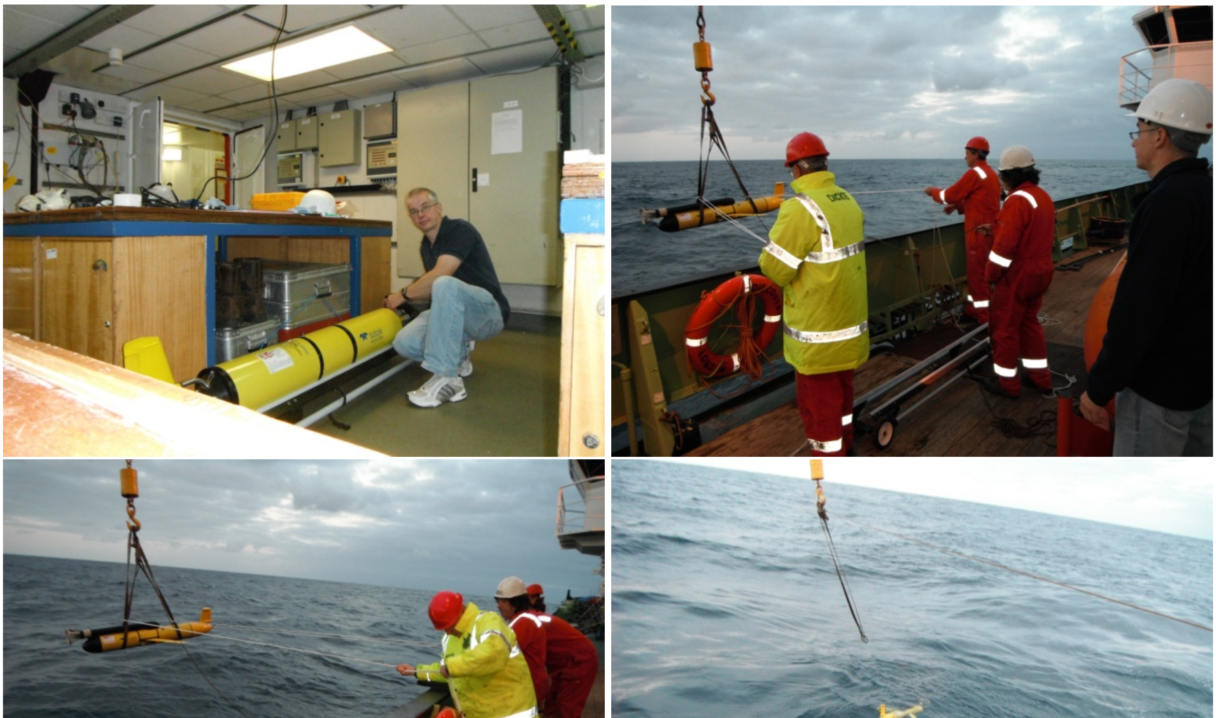

Figure 16: Turbulence glider preparation and deployment. Glider preparation in the wet lab of *RRS Discovery*. All of the glider communication systems were tested (FreeWave, Iridium, Argos, GPS) and a mission simulation was run before the deployment. The glider hull seals and zinc anodes were also replaced before the deployment (top right).Glider lifting for deployment using the starboard deck, a crane, dual strops. Stay lines are used to keep the glider stable and the strops in tension around the glider hull prior to release of the glider (top left).Lowering of the glider towards the sea surface (bottom right). Glider deployment (bottom left).

Turbulence Glider Piloting

The turbulence glider was configured to only make adjustments to the buoyancy pump or pitch control forward battery position motor during dive to climb or climb to dive inflections. The normal settings that automatically adjust the forward pitch battery position to optimise the glider dive and climb angles for maximum propulsion are turned off. This is essential to minimise electrical and mechanical interference with the operation of the highly sensitive turbulence measurement sensor. Progressive adjustments are required to trim the glider pitch battery control parameters to the desired settings for turbulence profiling in a particular survey area as the vehicle attitude will be affected by the properties of and any variations in the water column. The early phases of piloting of the turbulence glider for the OSMOSIS project deployment involved adjusting the dive and climb angles to 35°. This represents a steeper angle than the optimal 26° normally used. The general intention was to sacrifice forward propulsion efficiency for steeper survey profile angles. This is required from a science perspective to use the turbulence sensor as close to vertical profiling as possible. If a dive and climb angle steeper than 35° is used it is estimated that this may cause problems with the operation of the glider attitude sensor. Therefore the selected profiling angle represents the closest reasonable value to the desired vertical turbulence profiling that can be reliably achieved with the glider. A sample depth profile from the OSMOSIS project turbulence glider deployment is shown in **Figure 17**. This illustrates a symmetrical dive and climb profile at the required pitch angle.

Figure 17: Sample Glider Underwater Depth and Pitch Profile

The glider was diving to a depth of 100m and then inflecting towards the sea surface. An upper inflection point of 3 metres was used and suspected vehicle momentum resulted in an inflection close to the sea surface. This produced turbulence measurements along the full length of the dive and climb profile as required. During the deployment the glider was kept as close as possible to the moorings array, particularly when additional turbulence measurements were undertaken using a ship based vertical MSS profiler. The MSS profiling system consisted of a long cable attached to the profiling instrument with a small winch that was located at the stern of *RRS Discovery* to drive the cable. The winch was used to pay out the cable at rate that allows the MSS profiler to freefall through the water column to a typical depth of 150 metres while making turbulence measurements. At the same time the ship moves at a speed of approximately 0.5 knots repeatedly along a 5-8km long profiling transect that was to the north west of the glider survey area. The measurements from the MSS system are transferred to a signal conditioning and data recording system on the ship by the long power and data cable that is connected to the profiler through the winch system. The instrument is then returned to the surface using the winch to haul the cable and subsequently the profiler. This process repeats to generate the required measurements. A series of stations were then undertaken whereby the MSS system generated vertical turbulence profiles in close proximity to the turbulence glider. The intention was to generate two sets of independent turbulence measurements in the same general work area close to the moorings array. The use of a more established MSS vertical turbulence profiling system from the ship was intended to act as a reference for comparison to assess the performance of the glider turbulence sensors. With the glider located at least several kilometres away from the ship during MSS profiling a further aim of the experiments was to see if any of the MSS generated water column turbulence features are not evident in the glider generated turbulence data. This would provide some level of indication of how the ship based turbulence profiles are being disturbed by the actual motion or propulsion of the ship. During the turbulence glider deployment a strong west to east underwater current was evident. The glider was deployed approximately 14km to the west of the mooring array and the effect of this current was to drive the glider to the east. A plot of the reported glider positions for the 10 day deployment is shown in **Figure 18**.

The large red crosses represent the locations of the OSMOSIS moorings in the PAP survey site. The mooring were positioned within a rectangle of approximately 14km in width and 17km in length, with a centre mooring at a GPS location of 48° 44.340'N, 16° 11.400'W. The green rectangles in **Figure 18** represent the reported glider positions and the effect of the water current and surface currents driving the glider to the west can be seen.

The actual piloting of the glider was undertaken aboard *RRS Discovery* using the ship's internet connection. This allowed communication with the glider using the iridium global satellite service. Basically, when the glider surfaces at timed intervals it tries to connect to the iridium satellite service and communicate with a server based in the NOC Liverpool laboratory. The *RRS Discovery* internet service was used to monitor the glider

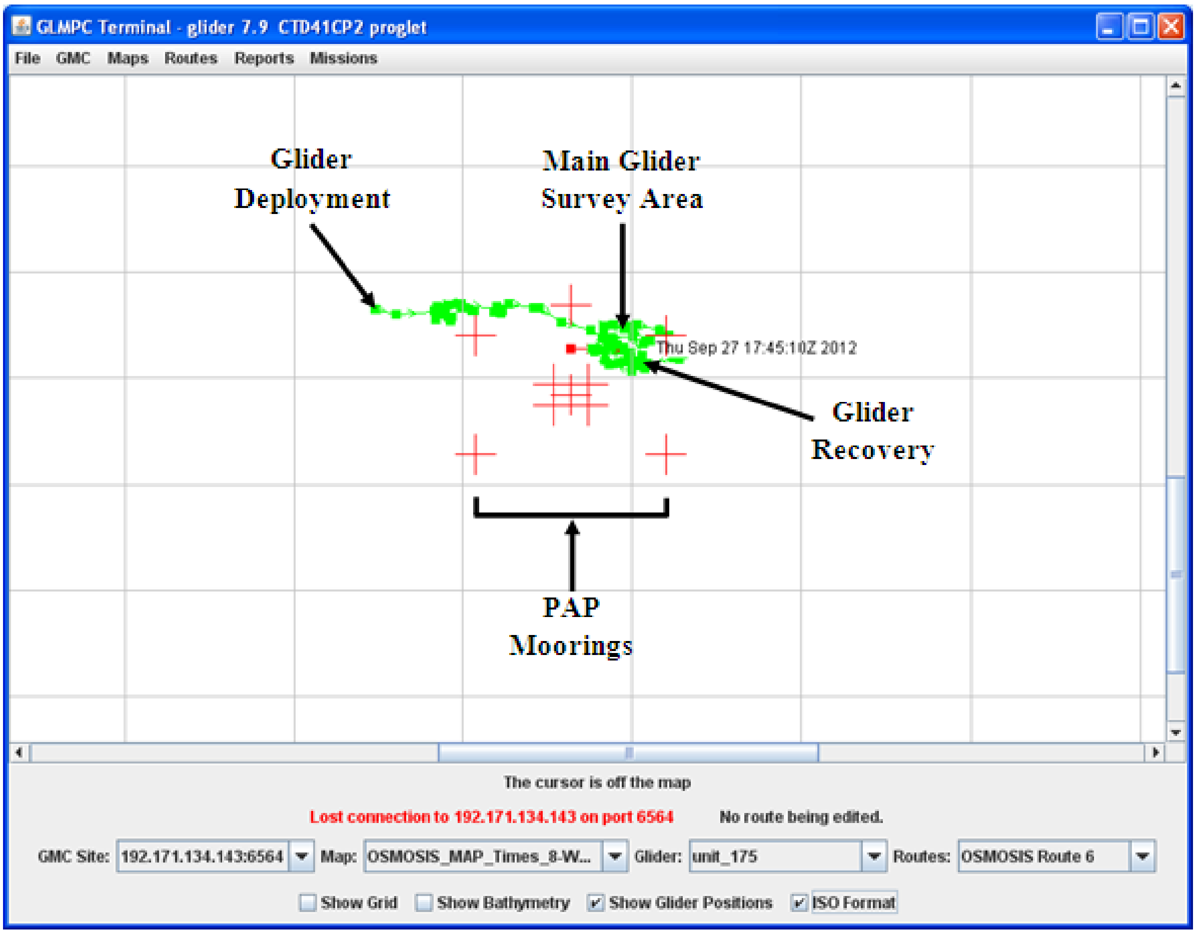

Figure 18: Plot of The Reported Turbulence Glider Surfacing Positions Relative to the PAPMoorings

progress by communicating with the NOCL Liverpool glider server computer. This allows data or files to be transferred to or from the glider computer via the server.

Throughout the deployment an underwater current was flowing with the main component from west to east. When the glider was surfacing to transfer near real time data over iridium it was losing ground and being driven eastwards. For the first MSS profiler survey the glider was holding its position very well during the MSS profiling from Monday 17th to Wednesday 19th September. During the second MSS survey from Saturday 22nd to Sunday 23rd September the turbulence glider had drifted to ∼10-20km away from the MSS profiling. This was a little disappointing, although it was fortunate to select a good location to the west of the moorings to initially deploy the glider. Throughout the second MSS vertical profiling sequence of transects the glider managed to sustain a position approximately 3km south east of the upper right mooring location shown in Fig. 4. The glider aborted its profiling mission several times, due to suspected intermittent EMC problems. These aborts were managed successfully by close monitoring of the glider performance. As and when required pilot intervention occurred to deal with technical problems with the glider and resume the glider turbulence survey mission as soon as possible. Following the initial turbulence glider deployment, once the glider dive and climb profiles had been trimmed to the correct pitch angles, the mission configuration has been altered to keep the glider underwater profiling for longer periods of time that were typically 3 hours in duration. Near real time data transfer using iridium of the glider flight and science sensor status data was been turned off. The glider simply surfaced, reported its GPS position and then resumed profiling. This limited the glider time on the sea surface and allowed the glider to maintain its position at the north east of the OSMOSIS PAP site mooring array, close to the moorings.

If the ship's internet connection failed then a satellite phone was used during daytime working hours to contact NOC Liverpool to monitor the status of the glider. Standby pilots were also available at Liverpool to intervene in the turbulence glider piloting process throughout the turbulence glider deployment.

Turbulence Glider Recovery

During the cruise, a combination of bad weather and time constraints for the remainder of the scientific measurement programme resulted in an earlier than planned turbulence glider recovery attempt. The sea state was not ideal with a significant amount of swell and it was questionable if a recovery could or should be attempted. After consulting the deck crew and the senior crew in the bridge a decision was made to attempt a glider recovery. If the sea state was suitable and the current phase of mooring recoveries could be completed in time at least two hours before nightfall then a recovery attempt would be made. The mooring recoveries were completed at 17:10 GMT on Thursday 27th September and the glider was re-configured to 30 minute surfacing. At 17:25 GMT the glider was held on the surface and GPS updates from the glider were provided. Once the glider was within FreeWave wireless communications range the ship was manoeuvred into position with the glider approximately 100m ahead of the ship. After further consultation with the deck crew a recovery attempt was made. A sequence of photographs of the turbulence glider recovery operations are shown in **Figure 19**. During the first recovery attempt the glider snagged one of the stay lines and then overshot the recovery net. Further attempts to drag the glider back to the net resulted in the loss of the port wing. *RRS Discovery* was re-aligned with the glider and during the second attempt the glider was manipulated onto the recovery net. The sea swell made this operation very difficult and long fending off poles were used to hold the glider in the net until the crane on the side of the ship could lift the glider clear of the water and back onto deck. The glider was successfully recovered at 18:46 GMT on Thursday 27th September at a GPS location of 48° 43.274'N, 16° 07.023'W. After the recovery the glider was washed down with fresh water, dried and returned to the wet lab. An initial inspection revealed that there was no damage to the glider hull or main components although both wings were lost or damaged during the recovery. The micro-Rider was de-mounted and initial tests showed that the correct volume of data had been recorded. Preliminary tests showed that the glider was operational and the internal vacuum had been sustained. This indicated that no significant damage or seawater ingress had occurred during the recovery process. The glider was then subsequently disassembled and the hull seals were cleaned and re-greased. A copy of the flight and science data recorded by the glider was then made. Following this a preliminary assessment of the glider science data was, undertaken as summarised in appendix C. Initial checks showed that the micro-Rider had recorded 7.27GB of science data and that all of the microstructure probes had been working correctly throughout the 10 day deployment. A preliminary evaluation of the glider CTD data showed that a problem with the science computer had caused the loss of approximately 1.5 days of CTD data. While this was disappointing, more than 8 days of precision CTD measurements had been recorded by the glider. The general feedback from the turbulence data scientists is that the micro-Rider turbulence data can be adequately calibrated with the existing data set to compensate for the interruption in the main glider CTD recording. This loss of glider CTD data occurred between day 8 and day 9 of the 10 day glider deployment (am on Wednesday 26th September to around midday on Thursday 27th September).

Preliminary Turbulence Glider Recorded Scientific Data Assessment

This section provides a brief overview of an initial quality check undertaken on the turbulence glider and micro-Rider recovered data. This scientific data was generated during the OSMOSIS project deployment from *RRS Discovery* between Monday 17th September and Thursday 27th September 2012. The glider was operating within the Celtic Sea PAP mooring site location.

Glider CTD Data Assessment

A time series of the glider CTD recorded temperature and salinity data is shown in **Figures. 20** and **21**.

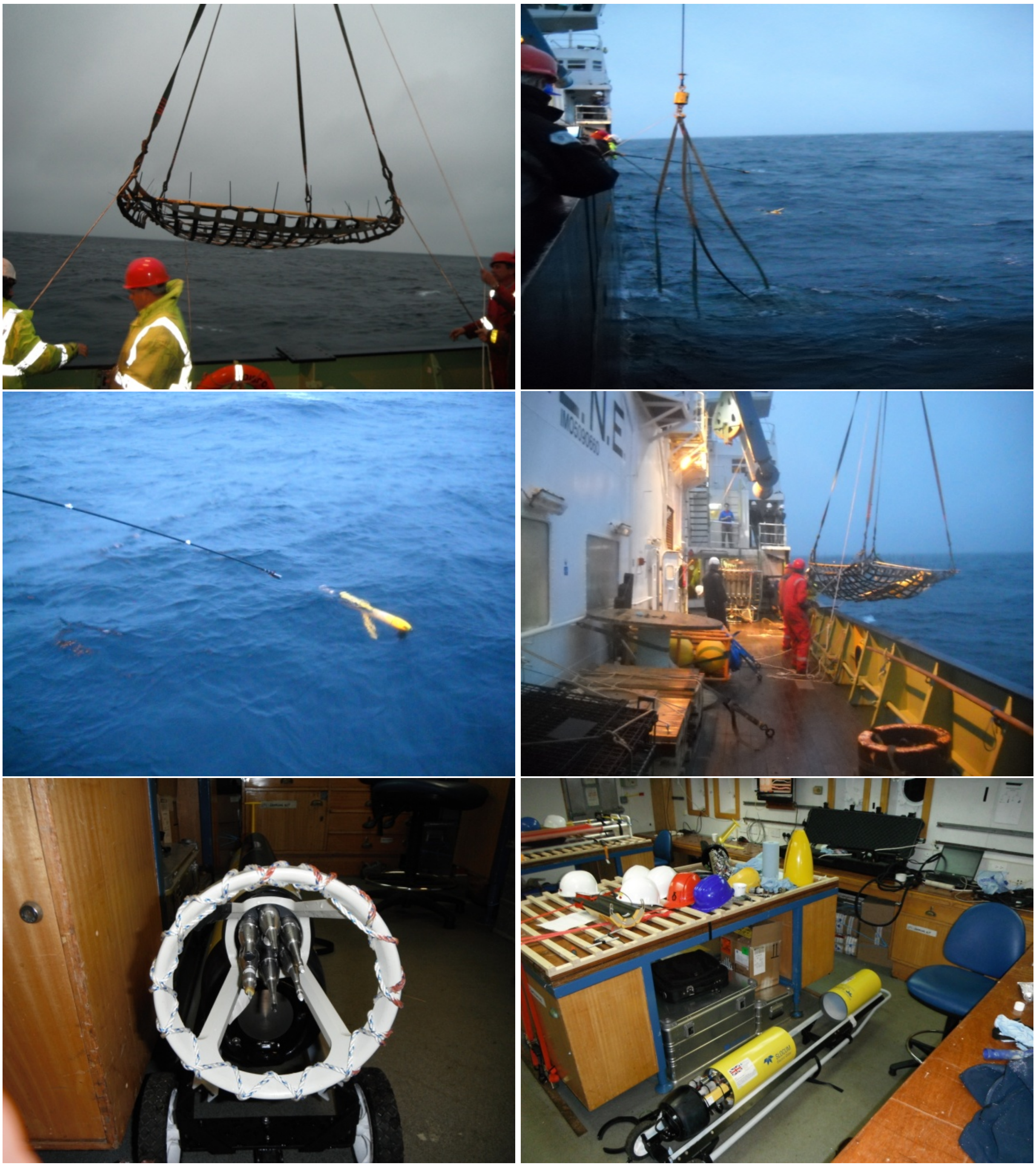

Figure 19: Turbulence glider recovery operations. Recovery net deployment (top right). Glider alignment for recovery (top left). Port wing lost after first recovery attempt (middle right).Glider recovery. The sea swell and white cap can be seen in this picture just below the recovery net (middle left). Turbulence probes clean and intact after the recovery (bottom right). Servicing of the recovered glider (bottom left).

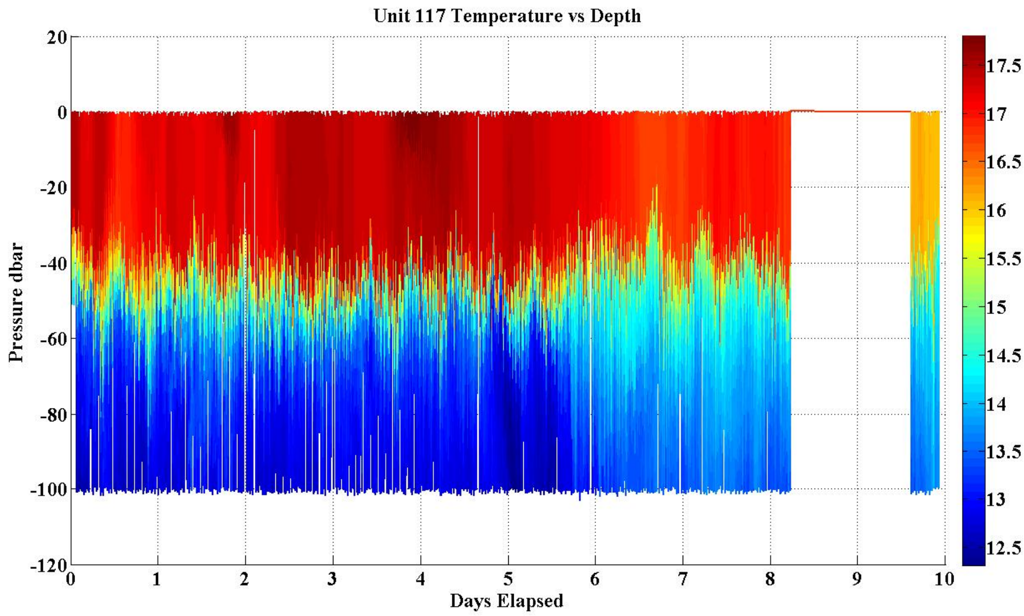

Figure 20: Plot of Temperature Versus Depth for the 10 Day deployment. The CTD has stopped logging data for ∼1.5 days from ∼8.25 to 9.75 days into the 10 day deployment.

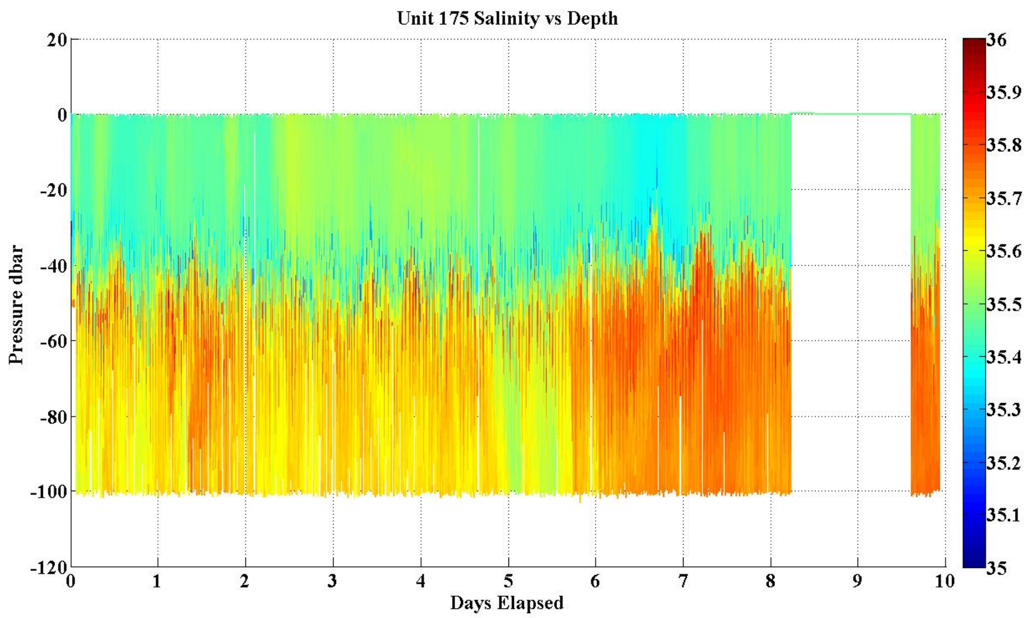

Figure 21: Plot of Salinity Versus Depth for the 10 Day deployment. The CTD has stopped logging data for ∼1.5 days from ∼8.25 to 9.75 days into the 10 day deployment.

Initial Turbulence Glider Micro-Rider Data Assessment

Data quality checks for file Dat004.p that was recorded on 17th September 2012. This was generated by the micro-Rider near the start of the data set during 50m test dives. Up-cast (climb phase) measurements have been generated and all channels appear to be working correctly. **Figures 22** to **26** show some thumbnail plots of the general form of the recorded data.

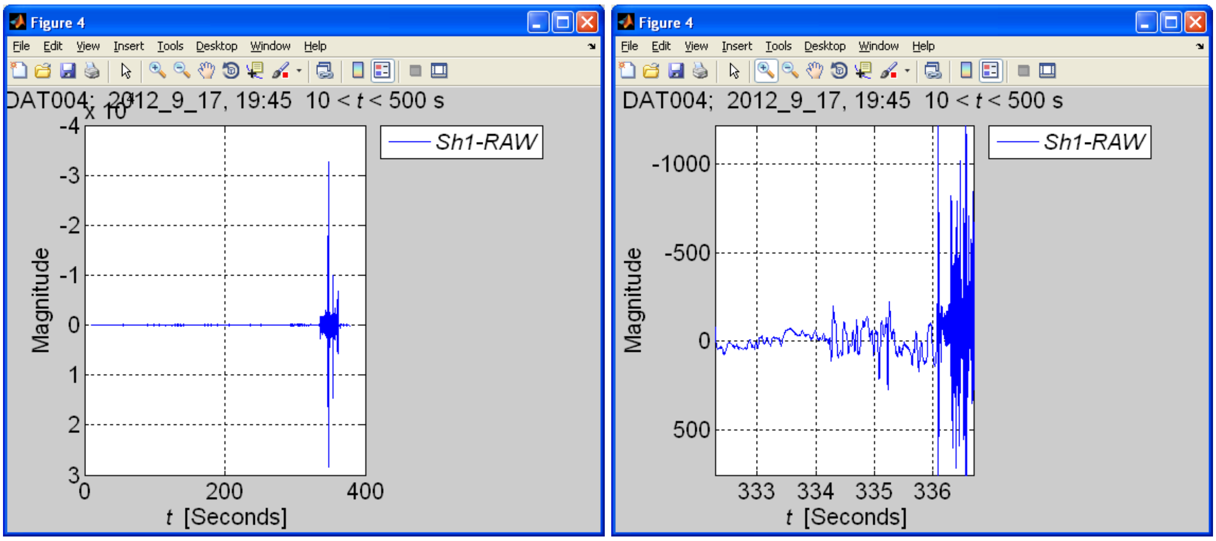

Figure 22: Dat004p Shear Channel 1. Raw signal (right hand). Expanded view. The dynamic measurement range up to an inflection (glider motor noise) is shown (left hand).

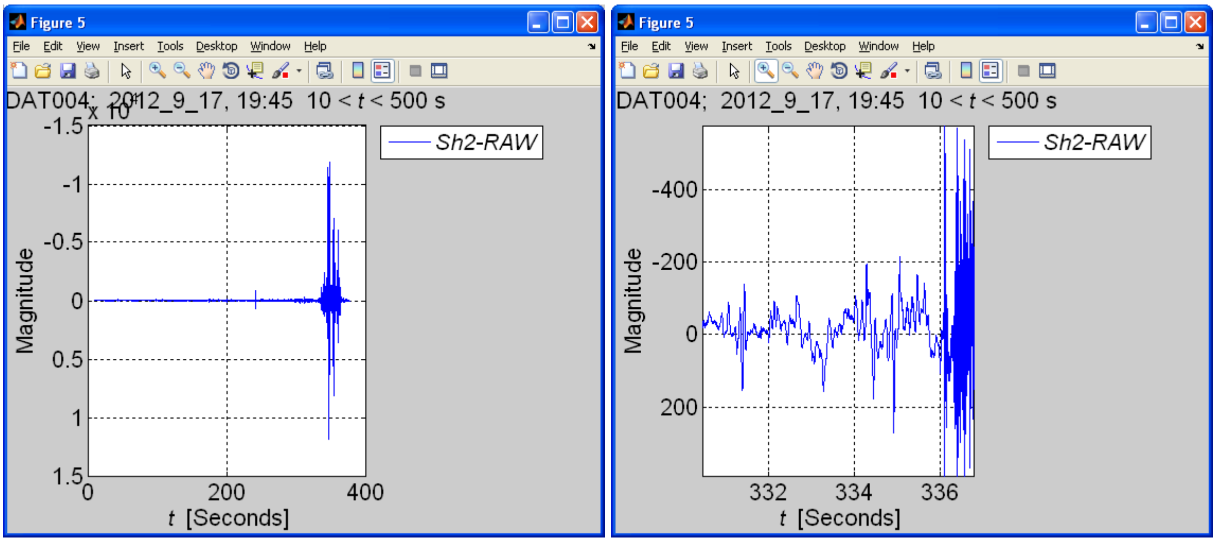

Figure 23: Dat004p Shear Channel 2. Raw signal (right hand) Expanded view. The dynamic measurement range up to an inflection (glider motor noise) is shown (left hand).

Similar results were obtained for tests of the turbulence data during and at the end of the deployment. The indications are that the data measurement quality from the micro-Rider turbulence sensor has been sustained throughout the deployment.

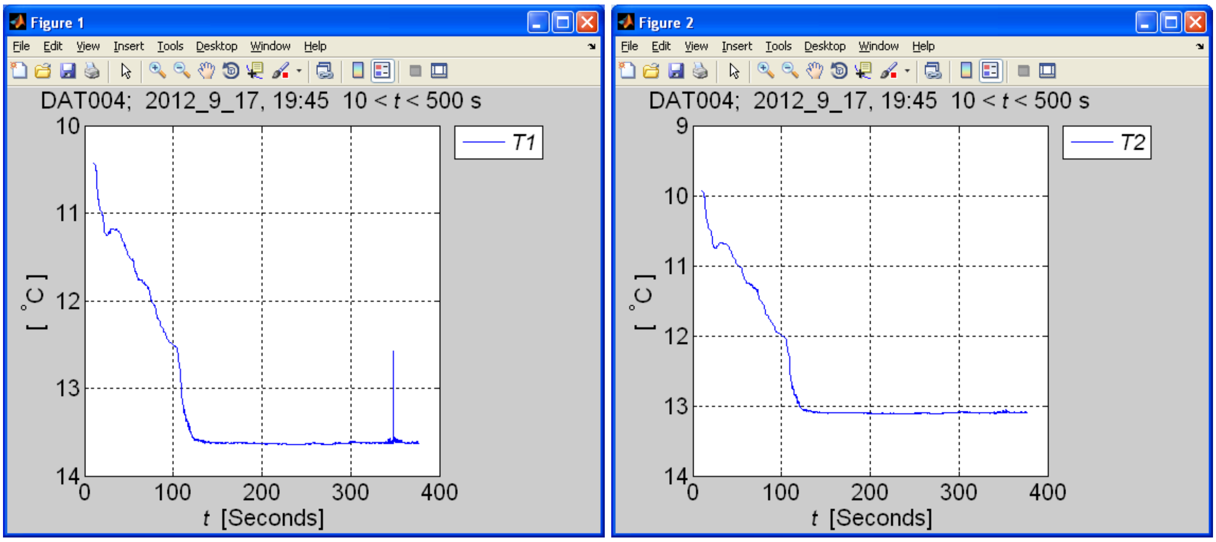

Figure 24: Dat004p Temperature channels.Temperature Channel 1 (right hand). Temperature channel 2 (left hand).

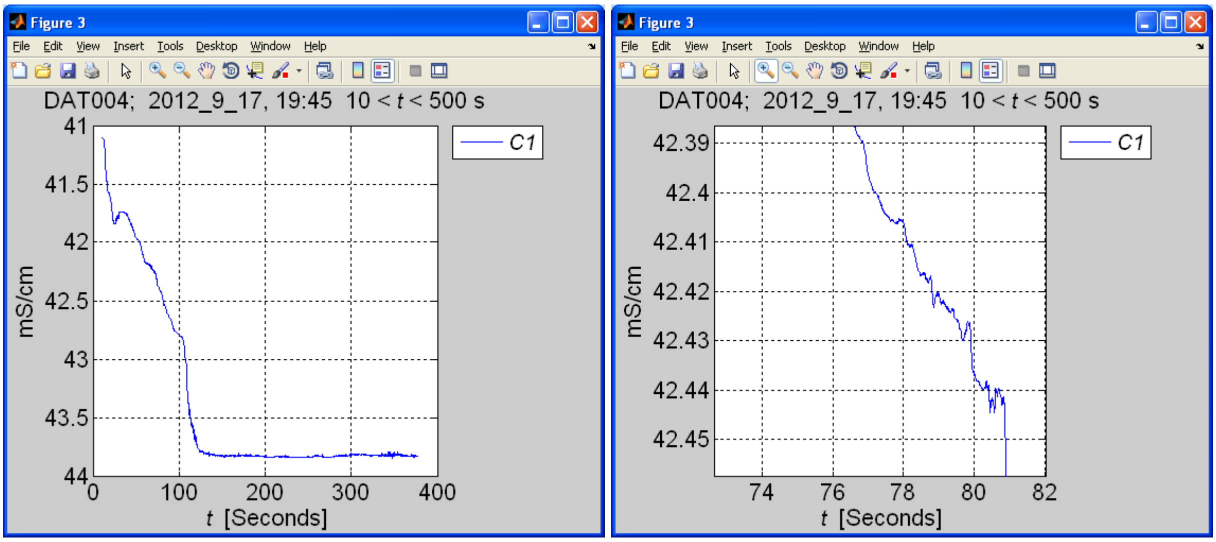

Figure 25: Dat004p micro conductivity. Full profile (right hand). Expanded view. The micro-conductivity probe response seems to be correct without any evidence of sensor fouling (left hand).

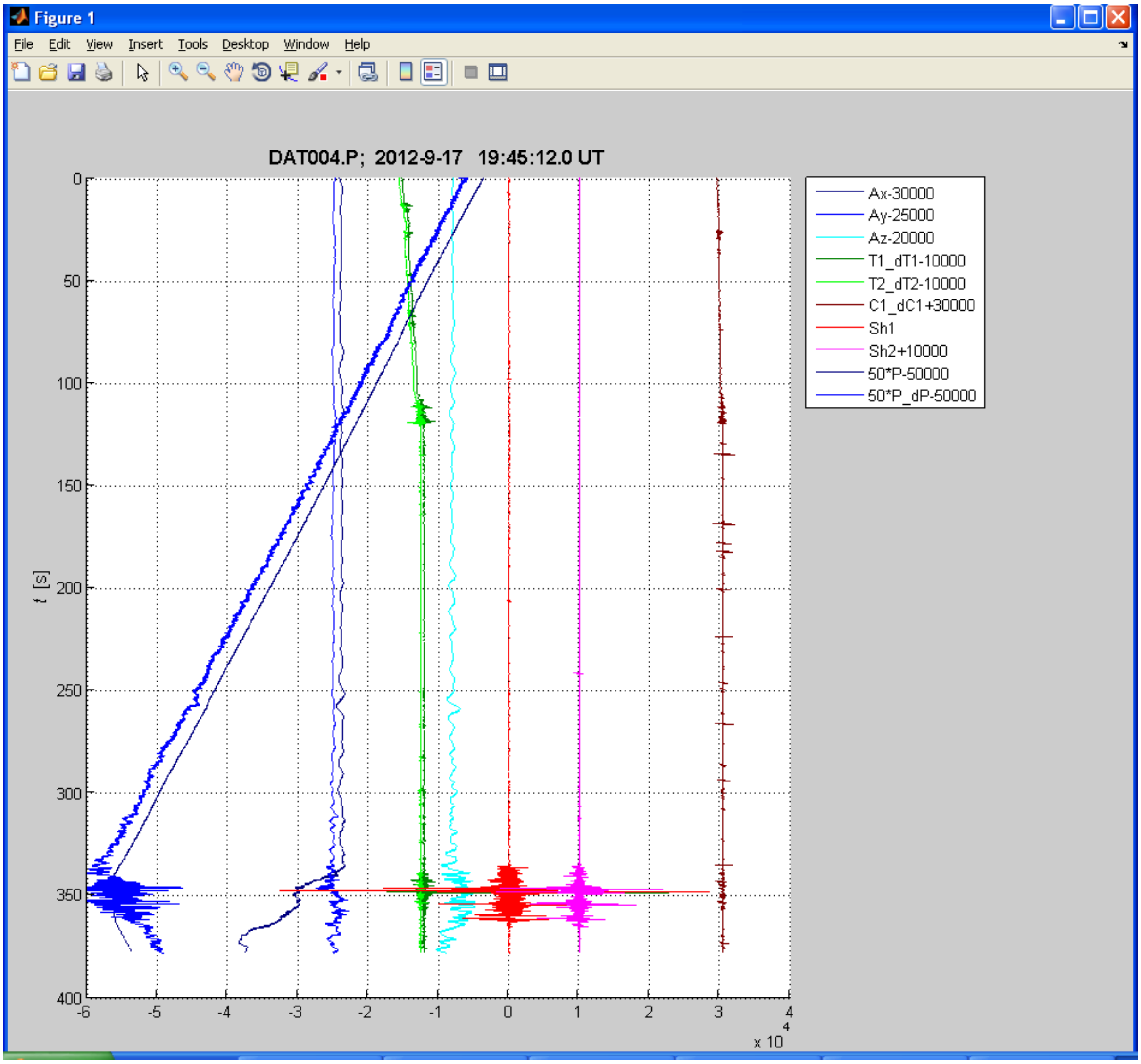

Figure 26: Dat004p Plot VMP Function. This is a plot with the raw measurements from the micro-Rider turbulence probe normalised onto a common x axis. The pressure record, all of the turbulence probe channels and the accelerometer measurements seem to be operating correctly.

Terms and Definitions

Turbulence Glider	A 200 metre depth rated generation 1 or G1 type Slocum Electric Glider. This is small AUV that is designed for oceanographic survey work. The glider is manufactured by Teledyne Webb Research, America. The turbulence glider has a Seabird Electronics non pumped CTD sensor and a Rockland Scientific International micro-Rider turbulence sensor installed.
FreeWave	Wireless short range radio link based glider communications
Iridium	Wireless data transfer based upon the Iridium low earth orbit satellite constellation.
Argos	Wireless data transfer based upon the Argos low earth orbit satellite constellation.

Abbreviations

NOCL	National Oceanography Centre, Liverpool, UK
AUV	Autonomous Underwater Vehicle
TWR	Teledyne Webb Research
RSI	Rockland Scientific International
MSS	A turbulence sensor manufactured by Sea & Sun Technology GmbH, Germany
CTD	Conductivity, temperature and depth sensor
ADCP	Acoustic Doppler Current Profiler
ODAS Buoy	A buoy provided by the UK Met Office with a standard metrological instrumentation package.
PAP	Celtic Sea Porcupine Abyssal Plane
GPS	Global Positioning System
GMT	Greenwich Mean Time
EMC	Electromagnetic compatibility

Seaglider Operations - *Andrew Thompson and Gillian Damerell*

The plan for OSMOSIS is to deploy ocean gliders in pairs for a period of a full year. Each glider deployment will last for four months. Careful monitoring and planning will be required to maintain sufficient battery power throughout the four months. Initial estimates seem to show that the 10V science battery will most likely be the limiting factor.

Deployment Timeline

27th August	Arrived on ship, removed SG510 and SG566 from their crates, checked contents, began running self-tests.
28th - 31st	Self-tests and simulated dives for SG510 and 566.
31st	Assembled SG510 and SG566, carried out initial, slightly inconclusive buoyancy tests.
1st September	Prepared initial science, targets and cmdfiles for SG510 and SG566.
2nd	Pre-launch procedures, final buoyancy checks, LAUNCH SG510 and SG566.
3rd	Initial piloting, correcting flight parameters, filling in logsheets, etc. Gliders in virtual mooring mode at central mooring.
4th	Recovered SG566, tightened cables, re-deployed SG566. Recovered SG510.
5th	Tested SG510, shorted PAR cable, etc. Decision was taken not to re-deploy SG510.
6th	SG533 brought up from hold, tested, updated, assembled, tested more, buoyancy checked, LAUNCHED!
7th	Washed and disassembled SG510, and returned it to its crate.

Preparation

The plan for the D381a leg of the cruise was to deploy one UEA glider (SG510, Orca) and one Caltech glider (SG566, Tashtego). SG566 was purchased earlier in the year and was shipped directly to NOCS. David White received shipment of the glider. NOCS also provided a glider (SG533) to be used as a spare in case of any problems with the gliders to be deployed. PAR sensors were purchased from iRobot to be installed on SG510 and SG533. This was carried out by David White, Gareth Lee and Stephen Woodward in Southampton. Ballasting of both SG510 and SG533, required due to the installation of the PAR sensors, was carried out by David White at Southampton. David White also replaced the SatCom SIM card in SG566 with the new JouBeh card, and the SatCom SIM card in SG510 with the new CLS card.

Gillian and Andy arrived in Southampton on the 26th of August and the gliders were already loaded on the Discovery when we boarded on the morning of the 27th. SG510 and SG566 were in the hangar and SG533 was in the hold. Both UEA and Caltech have RUDICS accounts, but we were unable to call through to the Caltech basestation. Therefore SG510 is set up to use RUDICS as the primary phone number and PSTN as the alternative number. SG566 was set up to have UEA's PSTN number as both the primary and secondary phone number. We were able to successfully call through to the UEA basestation with SG566 on the 27th of August. Andy will investigate moving SG566 over to RUDICS upon his return to Caltech. The appropriate numbers are:

UEA RUDICS	881600005196
Caltech RUDICS	881600005206
UEA PSTN	441603597331

Departure from Southampton was delayed until the 28th of August and a full three days was required to steam to the PAP site. During these three days multiple self-tests and sim dives were carried out on the gliders. The only errors that were encountered involved bathymetry maps and the ability to pick up a GPS signal. The former is not relevant for this project and the latter is an expected error due to the short period of time that is allowed to obtain a GPS fix during the self test (see Seaglider manual). The files from SG566 were not processing on the basestation which we determined was due to the fact that the glider had not been shipped with the latest software update, version 66.07.13. Andy had a copy of the latest software on his laptop and we were able to successfully update the software following instructions from iRobot. TeraTerm had to be downloaded and installed on Gillian's laptop before we could do this.

There were no problems sending and receiving information between the basestation and the gliders. Communications were generally good on the back deck and could be achieved with the glider lying flat on the deck with the antenna propped up vertically. Upon going through the iRobot provided checklist of the self tests and sim dives, we noticed that SG566's VBD was pumping at a rate of 4 to 5 AD/sec, whereas rates greater than or equal to 7 AD/sec are expected. Following correspondence with iRobot, it was suggested that both $D_BOOST and $T_BOOST were set to 0, which allows both the standard buoyancy engine (SBE) and the enhanced buoyancy engine (EBE) to work in tandem. In subsequent self tests the pumping rate was increased to about 9 AD/sec. All self tests were screen logged on either Andy or Gillian's laptop. Note that for a Mac, we had to (the -L option logs the screen to the current directory)

```
ln /dev/tty.usbserial
screen -L /dev/tty.usbserial 9600
```

The gliders were brought inside to make room on the deck for the first mooring deployments. In the main lab we attached the wings, rudder and antenna to the glider. We interrogated the glider with the acoustic deck box and received a good reading from each glider. The interrogation and return frequencies for each glider are:

SG510	Interrogate	15.0	Respond	10.5
SG533	Interrogate	13.0	Respond	11.5
SG566	Interrogate	13.0	Respond	11.5

The first buoyancy tests were carried out on the 31st of August. The gliders were moved to the aft of the back deck where the starboard aft crane was used to lift the glider over the side and into the water, while still attached to a single line under the rudder. A second line was used to keep the strop off the antenna, but the gliders persistently drifted back towards the ship making it difficult to allow the glider to float freely in the water. All subsequent deployment and recoveries were carried out alongside mid-ship where there appeared to be less drift. The first buoyancy tests were rather inconclusive. Although we were fairly confident that the gliders would not sink we were unsure how high they would sit in the water and actually deployed. We resolved to attempt another buoyancy test before deployment. We also note that this method of performing a buoyancy test would be very difficult in rough seas -we carried this test out in relatively calm water.

On the 1st of September we went through a complete review of the command file. The initial cmd values are given in the Appendix A (Section 3). We also cleaned out the sg566 and sg533 folders on the basestation using the following command:

```
sudo su /usr/local/basestation/movedata.sh <FolderName>
```

We established a targets file that enabled the two gliders to carry out a butterfly pattern between the outer edge of the mooring array and the center mooring. Glider SG510 was set to cover the east/west edges of the array and SG566 to cover the north/south edges of the array. The targets file for SG566 is:

```
/OSMOSIS Cruise, August 2012-September 2013
SE_OUT  lat=4837.80 lon=-1606.00  radius=1000 goto=SW_OUT
NE_OUT  lat=4844.94 lon=-1606.00  radius=1000 goto=NW_OUT
NW_OUT  lat=4844.94 lon=-1616.80  radius=1000 goto=CENTERb
SW_OUT  lat=4837.80 lon=-1616.80  radius=1000 goto=CENTERa
CENTERa  lat=4841.34 lon=-1611.40  radius=1000 goto=NE_OUT
CENTERb  lat=4841.34 lon=-1611.40  radius=1000 goto=SE_OUT
```

We established a science file that will hopefully allow continuous sampling between deployment and the recovery some time in early January. We expect that we will need to make changes to this science file during the course of the study, especially after monitoring battery consumption during the first week or two. The science sensors (see below) refer to CT, Wetlabs, O2, PAR (on SG566 and SG533, on SG510 the order of O2 and Wetlabs is switched). The last column is for guidance and control (G&C)

```
// Science for OSMOSIS
/For 566 glider w/ CT, Wetlabs, Aanderaa oxy, PAR
/depth  time  sample  gcint
100  5  1122  60
300  5  1224  180
500  10  1030  180
1000  10  1060  180
```

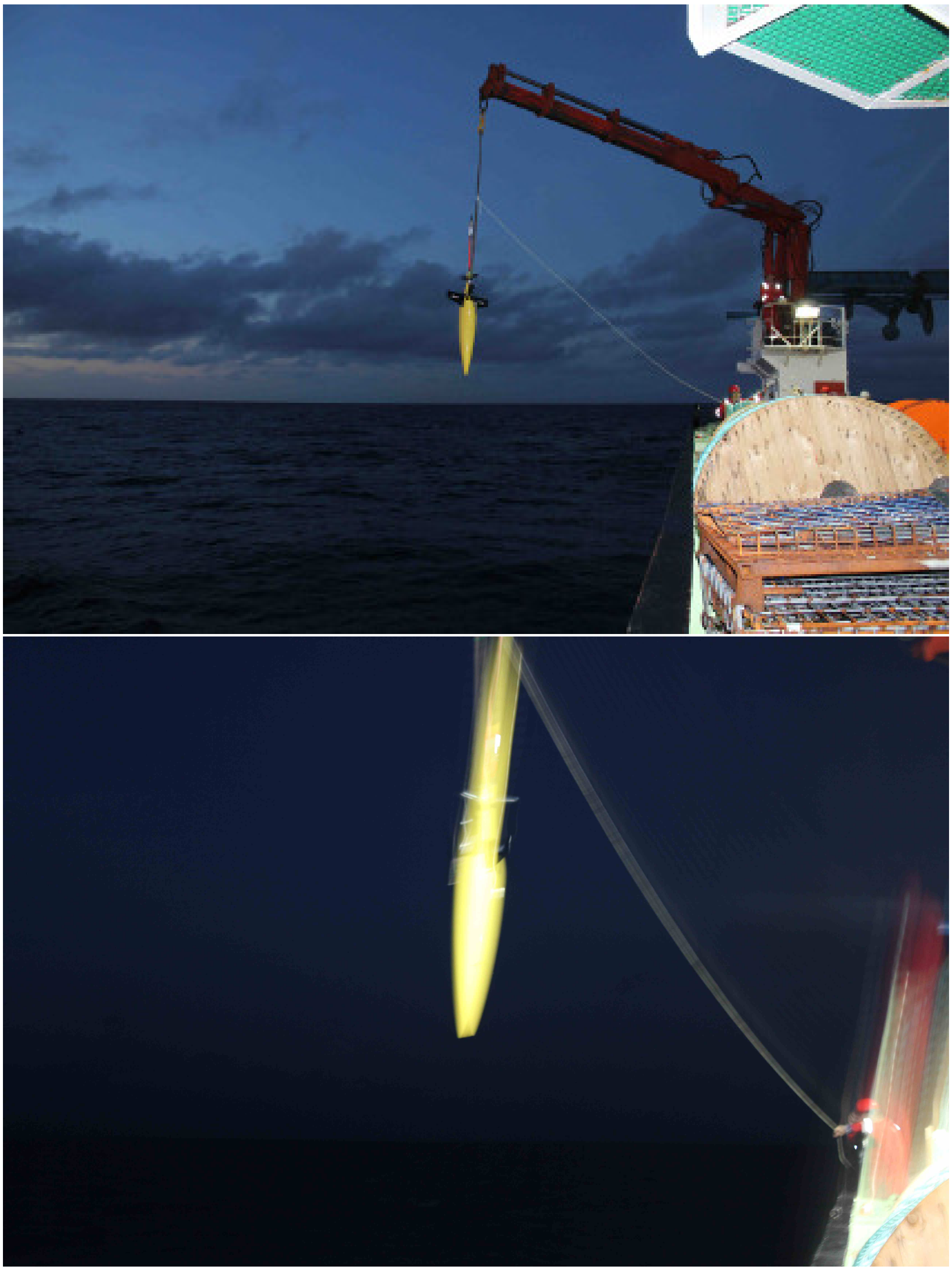

Figure 27: Photos of the first buoyancy tests carried out on in the last light of August. (a) SG510 is lifted over the side using the aft starboard crane. (b) A new technique, “The Rocket” is used for SG566 . . . (do not try this at home).

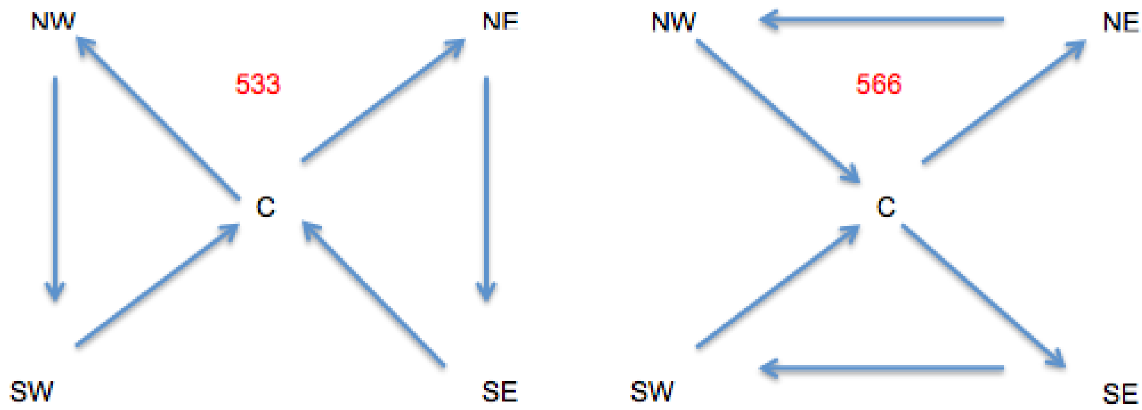

Figure 28: Butterfly pattern described by the gliders targets file.

as of the 10th of September the science file has been updated to:

```
// Science for OSMOSIS
/For 566 glider w/ CT, Wetlabs, Aanderaa oxy, PAR
/depth  time  sample  gcint
100  5  1222  60
200  5  1320  120
300  5  1020  180
1000  5  1030  180
```

A google docs spreadsheet has been created for both SG510 and SG566 which will allow entry of command, science and target file changes. Piloting duties will be shared between Caltech and UEA; there is a google docs calendar for which we can sign up (full day). The pilot should at least check the gliders once in the morning and at the end of the day and record any changes in the spreadsheet.

Argos tags were affixed to the antenna of both gliders. Andy was unable to locate the Argos tag for SG566. This is because Andy did not realize that the Argos tag kit purchased from iRobot does not actually include an Argos tag (truth in advertising!). The screws in that kit were also too short for use with the new, short, fat antenna, so we had to use screws supplied by the ship. Therefore we took the tag from SG533 and attached it with stainless steel screws (after the first screws supplied by the ship started to rust). Later when we had to recover SG510 and put SG533 in the water, we took the UEA Argos tag off and put it on the NOCS glider. The Argos tag IDs are:

SG533	155801	(NOCS glider, UEA tag)
SG566	120186	(Caltech glider, NOCS tag)

During the course of the first deployment, both SG510 and SG566 had to be recovered. It was determined that SG510 could not be re-deployed (see recoveries section). Therefore we had to get SG533 ready as a replacement. The preparation of SG533 was carried out in a single day and we feel the following will be a useful checklist for future deployments. Preparations for SG533 included:

Figure 29: Close-up photo of the Argos tag attached to the antenna of SG510. The string was used to keep the antenna upright during comms testing.

- Remove from crate and check all parts and contents of the toolkit (wings, rudder, antenna, sensor caps, PAR shield).
- Move Argos tag from SG510 to SG533.
- Open SG533's hatch (replace PAR cable!) and CHECK ALL CABLE CONNECTIONS.
- Update software on SG533 (update to 66.07.13).
- Update phone numbers to use UEA's PSTN number as both primary and alternate number.
- Assemble wings, rudder and antenna.
- Take outside to check comms and GPS.
- Run interactive self-test and check output of the self-test thoroughly.
- Update the complete list of parameters using SG533's trim sheet (this needed some work because of the change in parameters like $MASS, $RHO due to the addition of the PAR sensor).
- Set up cmdfile, science and targets on the UEA basestation.
- Delete old data, log files and bathymetry maps from SG533.
- Run at least three simulated dives on SG533 using the parameters given in the manual (e.g. SIM_PITCH, SIM_W).

- Thoroughly check the output of the simulated dives (be sure all the sensors are turned on!).
- After checking the self tests and sim dives, clear the sg533 folder on the basestation using the movedata.sh command.
- Prepare new sg_calib_constants.m from the trim sheet.
- Set up piloting log sheet for SG533 on google docs.
- Run the sea launch routine checking closely for errors.
- Remember to remove sensor caps, place the PAR shield in the correct position, switch on Argos tag.
- Buoyancy test
- LAUNCH!

Sensors

Each of the three gliders were equipped with an unpumped CT sensor, a Wetlabs ECO puck, an Aanderaa optode disolved oxygen sensor and a spherical PAR sensor. A photo of the sensor placement is shown below. Details of the sensors are listed below:

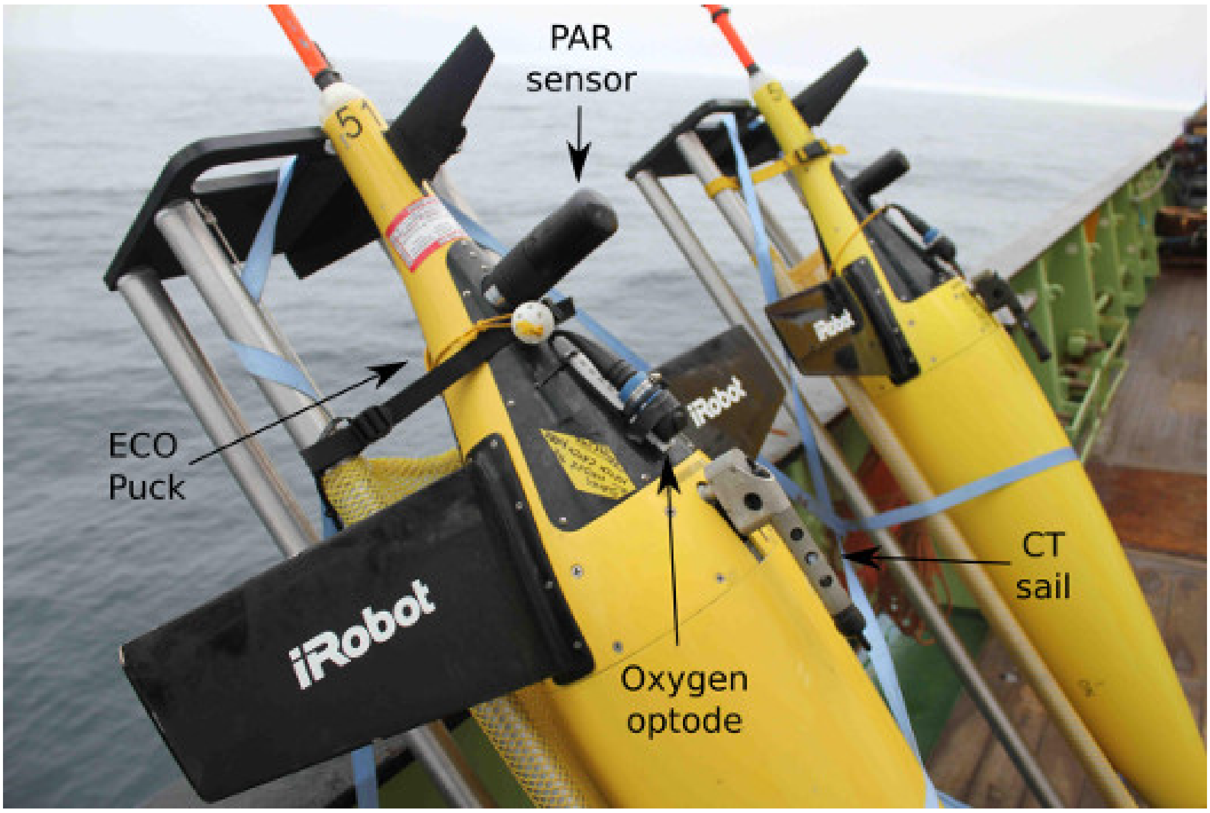

Figure 30: Position of the four sensors on the gliders.

SG566		
Paine Electronics pressure sensor Part number: 211-75-710-05	Serial No. 269510	Calibration date 9 September, 2011
Sea-Bird Electronics CT sensor	Serial No. 0204	Calibration date 1 April, 2012
Aanderaa Oxygen Optode 4330F	Serial No. 806	Calibration date 8 October, 2011
WetLabs Triplet BBFL2-VMT Configuration 863		Calibration date 28 December, 2011 Scattering wavelength: 650 nm CDOM and Chla fluorometers.
Biospherical Instruments PAR sensor Model number: QSP2150	Serial No. S50139	Calibration date 17 January 2012

Calibration constants for SG566 were included in the sg_calib_constants.m file. SG510 and SG533 were both missing calibration data for the PAR sensor. We note that SG533 did not recognize the PAR sensor following the update to software version 66.07.13. Following a re-installation of the PAR software and an assignment of a port, the glider was able to use the PAR sensor.

Upon re-deployment of SG566, both the dives and the sensors worked well for the first seven dives. On the eighth dive, there was a significant offset over part of the upcast in the conductivity sensor. The data then gave reasonable values for the next four dives. Following this, however, a significant offset in salinity (about 0.9 psu) was found for all subsequent dives. The data was noiser than the early dives, but structure was still visible. We initially tried to do a series of fast dives in order to dislodge what we believed to be a particle or some biology stuck on or around the conductivity sensor (see piloting section for details). This was unsuccessful and consumed battery so we returned to the original deep dive sampling. However, the noise in the salinity sensor became progressively worse. On Monday, 10 September we decided that it would be worth recovering SG566 in order to visually inspect and to clear the conductivity cell. We alerted the captain that we would like to do this recovery and on the next call in from the glider . . . the sensor had righted itself. All other dives up until 12 September have given sensible salinity readings.

The raw optical signals from the Wetlabs EcoPuck are in counts. The Chla fluorescence values were calibrated into Chla concentration ([Chla]; mg m^{-3}), the CDOM fluorescence into CDOM (CDOM; ppb) and the volume scattering of particles at 530 m into particulate backscattering coefficient (bp_p; m^{-1}). This was done by substracted the darkcount (provided by the manufacturer) from the raw signal and multiplied by the scaleFactor (provided by the manufacturer). For both gliders, the Chla and the bp_p values are in a good order of magnitude considering the area and the time of the year. The CDOM values are too high. For both gliders, the vertical shape of the Chla and the bp_p corresponds to what is expected considering the area and the time of the year: A shallow DCM (not an artifact of non-photochemical quenching) occurs around 25 m, following by a decrease with depth from 25 m to 150 m for both Chla and bp_p. The CDOM profile shows a monotonous profile, furthers investigations are required for the CDOM. There are is offset between the gliders for the Chla and the bp_p values. A post-calibration

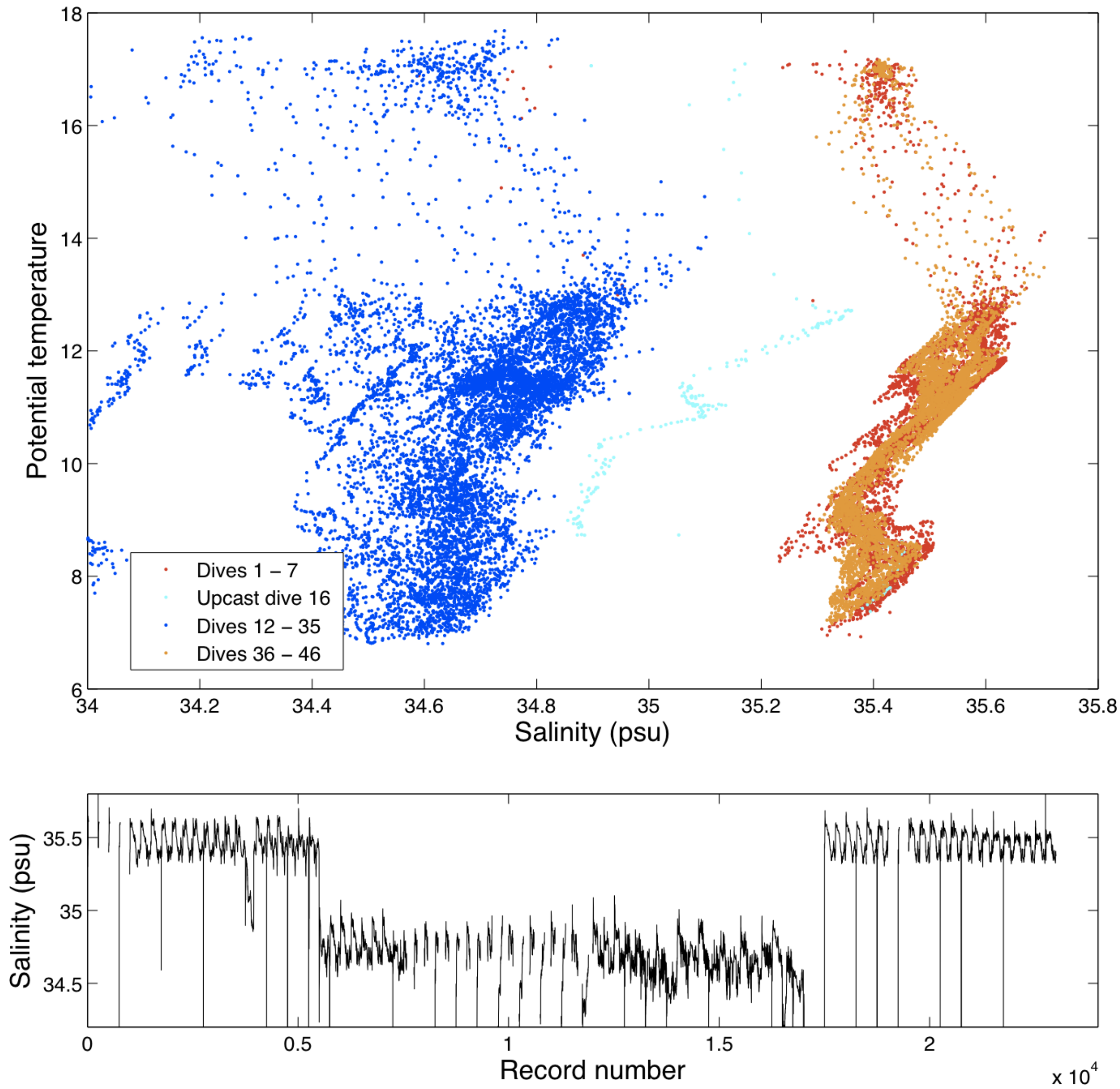

Figure 31: (top) Potential temperature-salinity diagram for the initial dives of SG566. The dives in red indicate the first dives before failure of the conductivity cell. The cell recovered following dive 35.

is required with data obtained from the CTD as well as accurate estimations of Chla by HPLC obtained during gliders deployment.

The raw PAR values are in mV. They were calibrated into PAR (uE.cm^{-2}s^{-1}) by subtracted the darkcount (provided by the manufacturer) from the raw signal and divided by the scaleFactor (provided by the manufacturer). The manufacturer (Biospherical) had confirmed that the calibrated data correspond to what it is expected considering the area and the time of the year. Furthers investigations are in progress to estimate the effect of the angle of the glider (between the up and down cast) on the PAR values.

I would recommend for the rest of the mission to ensure a good data quality:

1. To limit the sampling resolution to 1 point every 3 meter for the Ecopuck and the PAR sensor.

2. To monitor the darkcount as much as possible, with deep profile for the Ecopuck and deep profile or night profile for the PAR sensor.

3. The sampling depth should be adapted to the seasonal evolution of the depth of the optical baseline.

Figure 32: Photograph of the PAR shield attached before deployment.

Deployments

The first set of glider deployments was carried out on Sunday, 2 September. We awoke to a very foggy morning with visibilty on the order of a few tens of meters. We agreed that it would be too difficult to keep an eye on the gliders if these conditions persisted (similar to deploying at night), but proceeded on the assumption that the weather would clear later in the day. In the morning the gliders were taken out on the back deck (10:30 BST) and a final self test was carried out. The final sef-tests, sim dives and pre-launch routine were completed on SG510 by 1400. We then discussed with Martin Harrison (the CPO(Science)) our method of deployment using a strop and line with a daisy chain knot that was effective during the GENTOO cruise.

Buoyancy tests were carried out once again, this time using the midship crane. The conditions were extremely calm and we were able to have a much more accurate estimate of the gliders ballast. Both SG566 and SG510 appeared to be sitting comfortably in the water so they were brough back on deck in preparation for deployment. The following is a description of the deployment technique from GENTOO:

A strap was cinched onto the crane to shorten it sufficiently for the glider to clear the railing. A long line (20m +) was used for the release. On one end, a loop was spliced (not pictured here) to prevent it catching in the rudder. The long-line's loop was passed through the strap's loop as opposed to tied on so that the glider would not end up suspended on a long line going from the ship to the crane. The long-line was passed around the aft end of the glider below the rudder and a bight pulled through the loop. Another bight was then pulled through this newly created one from the long-line to create another link. This was repeated 3 to 4 times to create a series of links. The link closest to the glider gets pulled tight by the weight so it is important to leave the following links fairly loose (as pictured). The final link can be tightened more to prevent the bight from slipping out. This was only ever a risk when the winds were slightly stronger and cause the glider to spin, catching the rope on the wings and pulling at the release.

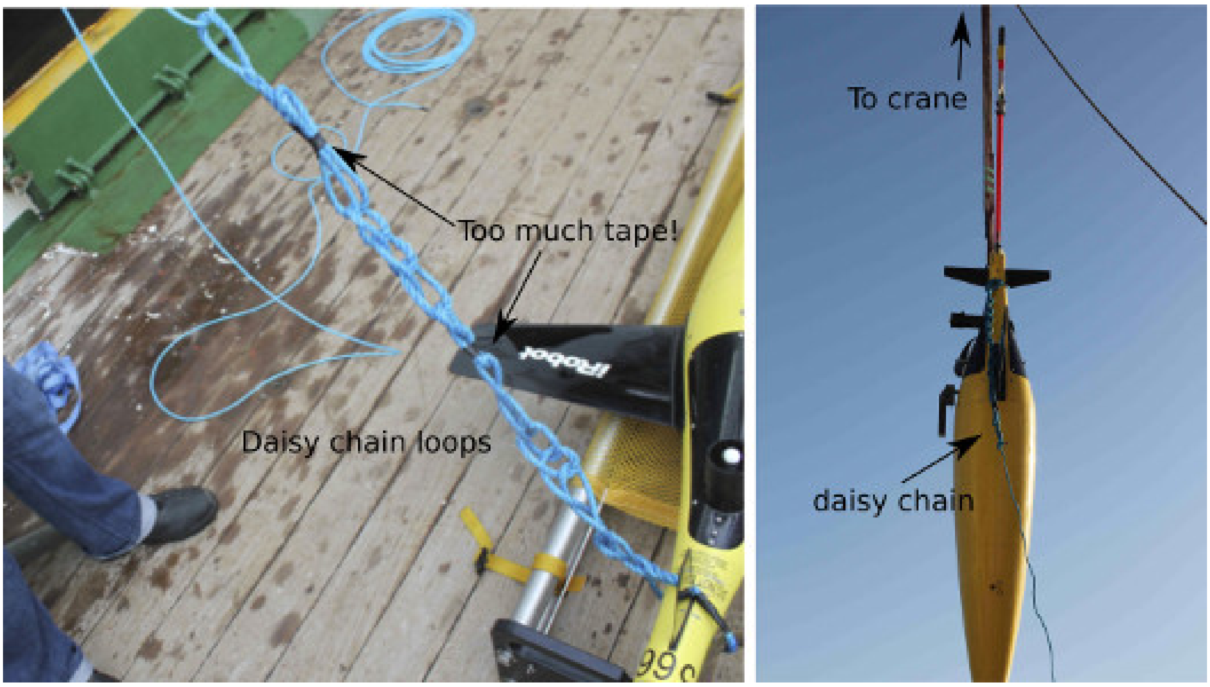

Figure 33: (Left) Photograph of the daisy chain line prior to deployment. (Right) SG533 immediately before release.

We followed the same technique on OSMOSIS. During the first deployment of SG510, we only put four or five bights in the long line. As the glider went out over the deck a few of the bights fell out due to contact with the glider and the fact that it was a heavy line and was pulling out some of the bights under its own weight. SG510 was lowered quickly towards the surface and was released without any problems. It began to drift back towards the ship and was kept off the ship with a long pole. It eventually drifted off towards the aft of the ship. It was difficult to keep the glider off the ship in this area because of the mooring equipment on the deck. The glider eventually drifted off behind the ship and successfully picked up a `$RESUME` command and began diving.

After SG510 we began preparing SG566 for deployment. Unfortunately we were unable to get good comms on SG566 and we spent almost two hours trying to complete the pre-launch routine and upload the .prm file. At some point we realized that the capture file had become far too long—at one point we put through 60 blocks of 1024 before it eventually dropped the call. At this point we had moved the glider onto the back deck for better comms and decided to delete the THISDIVE.KAP file. This had the desired effect and we were able to get the files uploaded after much huffing and puffing.

The same procedure was carried out for the deployment of SG566. The buoyancy test was much more conclusive and the glider was brought back on deck to attach the release line. This time we created a daisy-chain of perhaps 10 loops, and applied a bit of tape to a couple of the loops to prevent a premature release. On this occasion we perhaps used too much tape as we had to tug very hard to break the band. This tugging again brought the glider up towards the ship, but we were successfully able to keep it off the ship with long poles. During the deployment the fog had raced back in, so we were unable to keep sight of it before it actually picked up the $RESUME command and started to dive. The glider was ballasted well and completed its first dive without any problems. The deployment of SG566 was completed around 1800 UTC (1900 BST).

Recoveries

Within the first few dives, it became apparent that there was a problem with the Wetlabs sensor on SG566. There were occasional good values, but most data points were either NaN or 9999 (assumed to be a fill value for missing/bad data). The occasional good values made it seem likely that the problem was a loose cable rather than a malfunctioning sensor. We therefore decided to recover the glider on 4th September and check the cables. A $QUIT command was put in the cmdfile, the glider was on the surface in recovery mode by 10.30am on the 4th, and the ship headed for the location of the glider's most recent GPS fix. The glider was spotted from the bridge by 10.45am. The seas were very calm, so the glider was relatively easy to spot.

The recovery method was similar to that employed on the GENTOO cruise. We used a 10-12 m extendable pole, a Streamline Ecoline pole, with a machined end (as pictured below) bolted onto the pole. The rope used was slightly negatively buoyant so as to sink around the glider. A large noose was held open by being lightly taped to the pole about a metre behind the machined end. Once the noose was around the glider's rudder, the noose was pulled tight (breaking the tape), and a knot tied in the rope for attachment to the starboard midships crane (the same crane as used for deployment). The glider was hoisted out of the water and brought inboard, and guided into the cradle on deck. We did not need to use another pole to hold the glider off the ship as recovery was carried out in very calm seas. The recovery was slightly complicated by the presence of so much equipment (for the moorings) on deck. We could only reach the side of the ship along a short section midships, so could not lift the glider with the aft crane as was done on GENTOO. It was also necessary to have an additional person to collapse the extendable pole once the glider had been noosed, as otherwise the pole would collide with the CTD or the guard buoys as the glider was lifted. We therefore needed four people for recoveries – one manouvering the pole, one to tighten the noose, one to assist in manouvering the pole and hold onto the safety line on the pole to guard against losing it over the side, and one to collapse the pole.

Figure 34: Close up of the end of the recovery pole, showing the machined end, and a noose taped open against the pole about 1 metre behind the end.

Once SG566 was back on deck, we opened the hatches and discovered the Wetlabs cable was noticably loose. We undid it entirely, cleaned off a little gunk with blue roll, sprayed the cable end and the socket with silicon spray, then replaced the cable and tightened carefully. Once it was fully hand-tightened, we tightened it for a further quarter-turn using pliers, as recommended by iRobot. This process was repeated for all the other cables. Subsequent self-tests showed all sensors giving good values, so SG566 was re-deployed at 5.30pm on the 4$^{\text{th}}$.

After dinner on the 4$^{\text{th}}$, we discovered that SG510 was also in recovery mode due to a reading of 7.1 V on the 10 V battery. It seemed most unlikely that this was an accurate battery voltage after so short a deployment, but the glider would not dive again, and the cause of the low reading had to be investigated. We therefore recovered SG510 at around 7pm on the 4$^{\text{th}}$. The same recovery method was used as for SG566, and was equally successful. Realising that we would not be able to re-deploy SG510 before it got dark, we brought it inside the main lab for further investigation the next day. A self-test performed that evening showed the 10 V battery with a voltage of 10.42 V, and the 24 V battery with a voltage of 26.31 V. No problems were detected with the PAR sensor during that self-test because it was switched off. The self-test detected no problems (apart from the lack of bathymetry maps, which was expected since we had deleted them before deployment).

On the 5$^{\text{th}}$, a round of email discussion suggested that the PAR sensor might be causing the problems. We ran some hardware self-tests of the PAR sensor and were

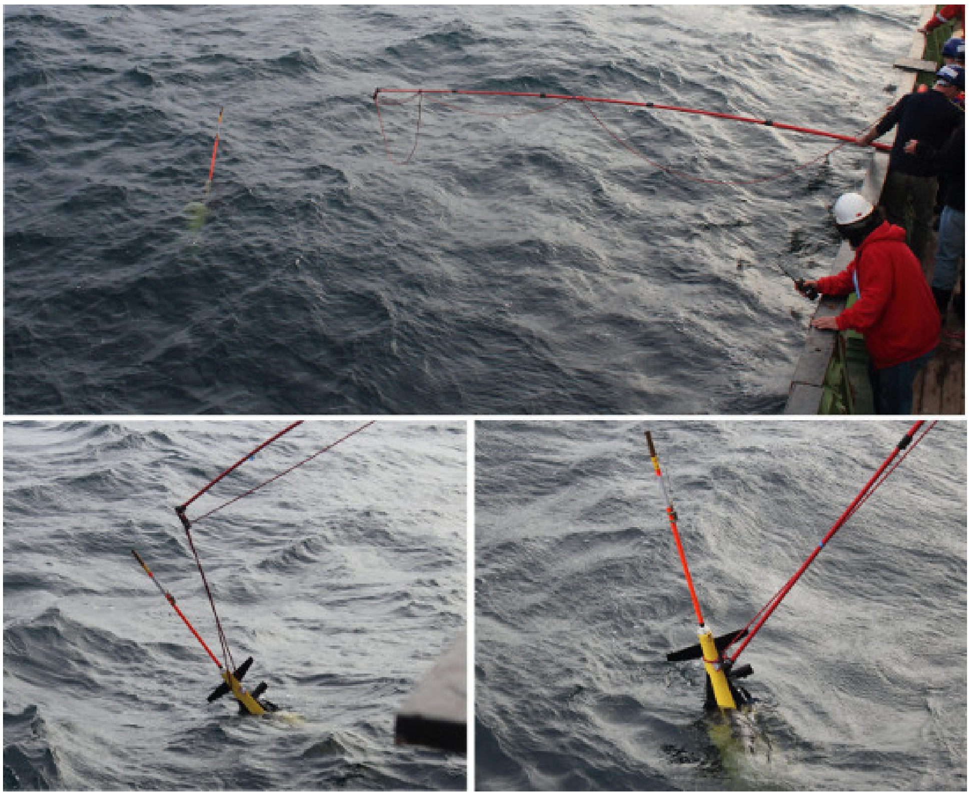

Figure 35: The recovery sequence. Top, the pole has been prepared, and the ship manouvered to bring the glider alongside midships. Bottom left, the noose has been positioned beneath the glider's rudder. Bottom right, the noose is pulled tight beneath the rudder before the rope is attached to the crane.

unable to communicate with it. Upon opening the hatch, we discovered the PAR cable itself was extremely loose, even though the grey screw-on connector was still done up. We cleaned and re-attached the cable as with SG566 on the 4th. It proved difficult to screw the grey connector on as far as on the other cables, so Andy tried to tighten it using pliers until he realised that that the cable was beginning to twist as he turned the connector, rather than the connector and the cable rotating independently. After this, additional hardware self-tests gave good results, but when we started direct comms with the sensor in order to obtain the diagnostic information, there was a loud 'pop' sound, and we lost communication with the sensor. Upon detaching the PAR cable again, we found the results of an electrical short – part of the end of the cable was burnt and snerged, there was a smell of burnt rubber, and two pins were missing in the bulkhead socket (which was also hot to the touch for a minute or so). We reported this to UEA, and were told that there was another alternative socket which could be used for the PAR sensor if we took the sensor cable from SG533, but it would be necessary to waterproof the socket with the missing pins. The broken socket was cleaned as before, with additional cleaning, carried out by John Beaton, using electrical contact cleaner and an old toothbrush. It was then coated with silicon grease and sealed with a dummy plug. We took the PAR sensor cable from SG533, attached it to the alternative socket, cleaned and re-attached all the other cables as on SG566 (above), ran successful hardware self-tests on all sensors and a full, successful, self-test.

Figure 36: (Left) Photograph of melted plug after blown cable. (Right) Photograph of partially corroded socket.

However, by this time the email discussions between UEA, iRobot, and other glider experts, had moved on. Even though our repair of the damaged socket would probably be waterproof at the surface, it was feared that the heat generated by the short might have caused additional damage to the bulkhead connector. This could compromise the integrity of the pressure hull, and it was considered too risky to re-deploy SG510. We therefore put SG510 in travel mode and switched it off. On the 7th, (having spent the 6th preparing and deploying SG533) we washed SG510 as described in the manual – a full freshwater rinse, plus rinsing of all sensors with de-ionised water, and a further cleaning of the conductivity cell with a mild bleach solution to reduce the risk of the growth of micro-organisms. SG510 was then returned to its crate.

Piloting

Internet availability has been sporadic on the cruise making piloting difficult at times. Piloting duties have been shared with UEA with lots of help from Karen Heywood, Bastien Queste and Sunke Schmidtko. Both SG510 and SG533 had piloting issues at first. SG510 was initially deployed with `$PITCH_ADJ_DBAND`, `$PITCH_ADJ_GAIN`, `$ROLL_ADJ_DBAND` and `$ROLL_ADJ_GAIN` set to the nominal values given in the manual. However, these were found to cause very large overcorrections in both pitch and roll, so were subsequently set to zero, turning off this functionality. SG533 initially appeared, upon deployment, to be sitting nicely in the water, looking to have a good ballast. We put in a `$RESUME` command and watched it sink off the surface. We had gone back into the Main Lab when we had a call from the bridge saying that the glider was still at the surface. Upon looking at it with binoculars, the glider was seen to be lying horizontal in the water. After about 10 to 15 minutes it righted itself. The value for `$C_VBD` was far too low, such that the glider only achieved a depth of about 5 m in its first couple of dives. Some aggressive trimming helped to fix this, mostly a large change in `$C_VBD` from 2150 to 2500, and within the first three to four dives, we had SG533 flying to an appropriate depth.

During the problems with the salinity sensor on SG566, (see discussion in Sensors section above) we attempted a few `very fast' dives in an attempt to dislodge what we think was a particle stuck on the conductivity cell. This amounted to increasing `C_VBD`, `MAX_BUOY` and `GLIDE_SLOPE` and reducing `T_DIVE` (following suggestions from Maritime Support at iRobot). The most aggressive dive had the following parameters:

```
$D_TGT, 600
$T_DIVE, 50
$T_MISSION, 100
$GLIDE_SLOPE,60
$C_VDB,3300
$MAX_BUOY,600
```

This unfortunately did not solve the problem and since these dives were using a lot of battery power, we reverted to the trimmed settings. Details of the piloting changes for both SG566 and SG533 can be found on the Google Docs spreadsheet.

As of 12 September, the radius of the target locations has been increased from 1km to 2km. The target radius is indicated in the figure below showing the glider positions as of midday 12 September.

Stuff we found ourselves wanting

- spare caps for all sensors, not just CT
- toolkit containing (we borrowed most of this stuff from various people during the cruise):

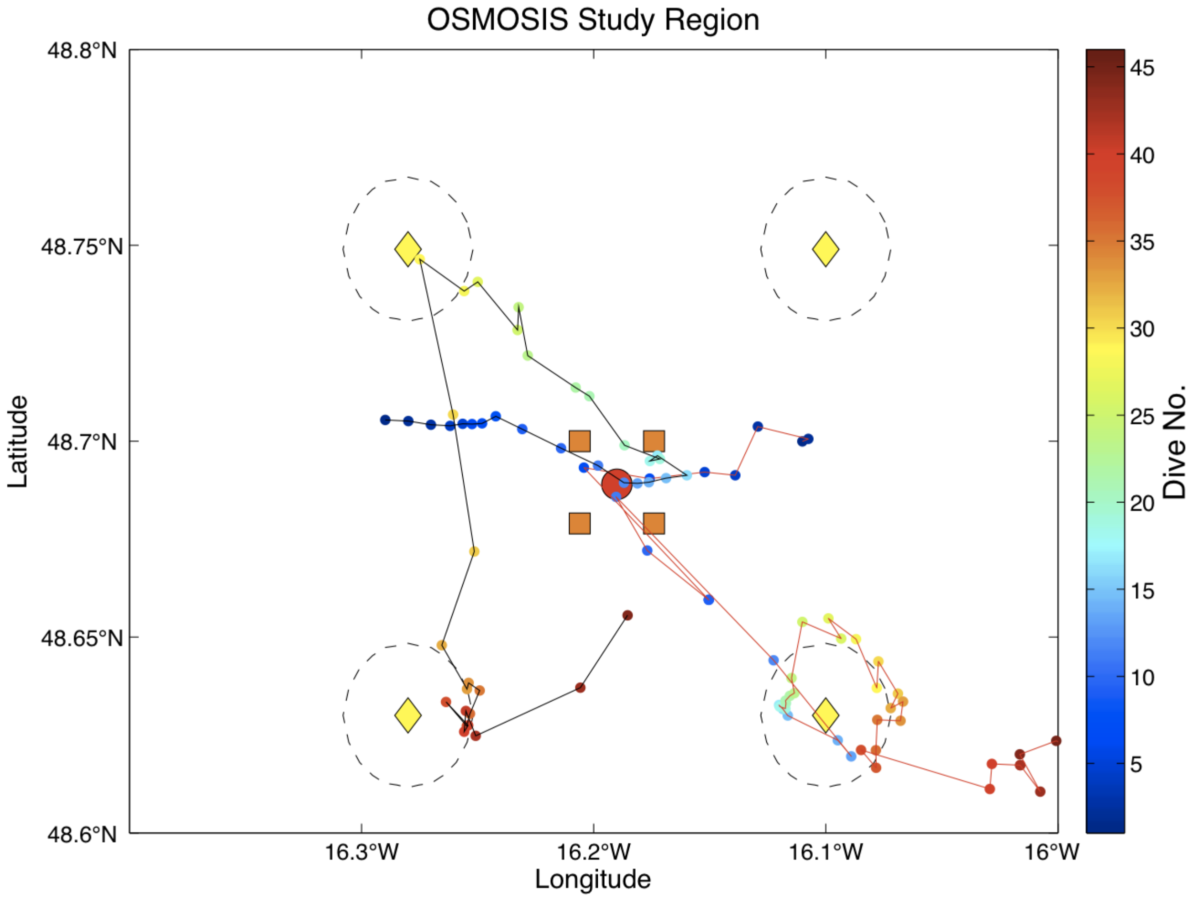

Figure 37: Glider positions as of 12 September, 2012. SG533 (black) and SG566 (red) will make a butterfly pattern around the outer moorings (yellow diamonds) and the center mooring (red circle). A two kilometre radius around each outer mooring is given by the dashed line.

  - adjustable wrenches/spanners
  - screwdrivers – phillips and flathead
  - allen keys
  - pliers
  - electrical tape
  - duct tape
  - craft/stanley knife
  - rubber hammer
  - file
  - side snips
  - cable ties of different sizes
  - headtorch
  - sizable tube of silicon grease
  - silicon spray
  - electrical contact cleaner
  - old toothbrush
  - the goop that's on the gliders' screws – might be lithium grease?

It might also be worth considering, for future deployments:

- spare screws of all types used on the glider, not just a few types
- spare wings/rudder/antenna/antenna shoe – all quite breakable

Science

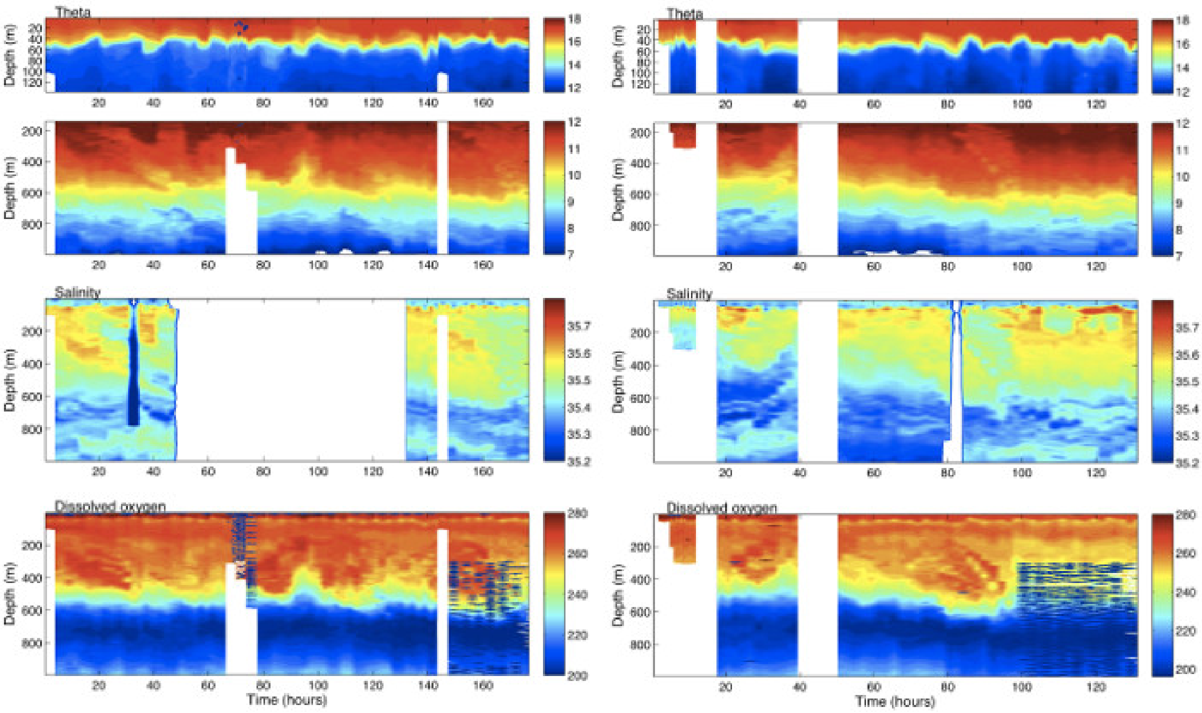

Figure 38: Initial sections of potential temperature (top two panels), salinity (third panel) and dissolved oxygen (bottom panel) for SG566 (left) and SG533 (right).

Appendix A

Log file for SG566 from the first dive, showing how all parameters were set:

```
version: 66.07.13
glider: 566
mission: 2
dive: 1
start: 9 2 112 18 9 44
data:
$ID,566
$MISSION,2
$DIVE,1
$D_SURF,3
$D_FLARE,3
$D_TGT,45
$D_ABORT,1025
$D_NO_BLEED,200
$D_BOOST,0
$T_BOOST,0
$T_BOOST_BLACKOUT,0
$D_FINISH,0
$D_PITCH,0
$D_SAFE,0
$D_CALL,0
$SURFACE_URGENCY,0
$SURFACE_URGENCY_TRY,0
$SURFACE_URGENCY_FORCE,0
$T_DIVE,15
$T_MISSION,25
$T_ABORT,1440
$T_TURN,225
$T_TURN_SAMPINT,5
$T_NO_W,60
$T_LOITER,0
$USE_BATHY,0
$USE_ICE,0
$ICE_FREEZE_MARGIN,0.30000001
$D_OFFGRID,100
$T_WATCHDOG,10
$RELAUNCH,1
$APOGEE_PITCH,-5
$MAX_BUOY,150
$COURSE_BIAS,0
$GLIDE_SLOPE,30
$SPEED_FACTOR,1
$RHO,1.0276999
```

```
$MASS,54031
$LENGTH,1.8
$NAV_MODE,1
$DIRECT_CONTROL,0
$FERRY_MAX,45
$KALMAN_USE,0
$HD_A,0.0038360001
$HD_B,0.010078
$HD_C,9.8500004e-06
$HEADING,-1
$ESCAPE_HEADING,90
$ESCAPE_HEADING_DELTA,10
$FIX_MISSING_TIMEOUT,0
$TGT_DEFAULT_LAT,4844.9399
$TGT_DEFAULT_LON,-1606
$TGT_AUTO_DEFAULT,0
$SM_CC,650
$N_FILEKB,4
$FILEMGR,0
$CALL_NDIVES,1
$COMM_SEQ,0
$KERMIT,0
$N_NOCOMM,1
$N_NOSURFACE,0
$UPLOAD_DIVES_MAX,-1
$CALL_TRIES,5
$CALL_WAIT,60
$CAPUPLOAD,1
$CAPMAXSIZE,2048
$HEAPDBG,0
$T_GPS,15
$N_GPS,20
$T_GPS_ALMANAC,0
$T_GPS_CHARGE,-1512.0055
$T_RSLEEP,5
$STROBE,0
$RAFOS_PEAK_OFFSET,1.5
$RAFOS_CORR_THRESH,60
$RAFOS_HIT_WINDOW,3600
$PITCH_MIN,94
$PITCH_MAX,3850
$C_PITCH,3100
$PITCH_DBAND,0.0099999998
$PITCH_CNV,0.003125763
$P_OVSHOOT,0.039999999
$PITCH_GAIN,30
```

```
$PITCH_TIMEOUT,16
$PITCH_AD_RATE,175
$PITCH_MAXERRORS,1
$PITCH_ADJ_GAIN,0.02
$PITCH_ADJ_DBAND,1
$ROLL_MIN,153
$ROLL_MAX,3749
$ROLL_DEG,40
$C_ROLL_DIVE,2100
$C_ROLL_CLIMB,2100
$HEAD_ERRBAND,10
$ROLL_CNV,0.028270001
$ROLL_TIMEOUT,15
$R_PORT_OVSHOOT,46
$R_STBD_OVSHOOT,47
$ROLL_AD_RATE,350
$ROLL_MAXERRORS,1
$ROLL_ADJ_GAIN,0
$ROLL_ADJ_DBAND,0
$ROLL_GAIN_P,0.5
$VBD_MIN,411
$VBD_MAX,3961
$C_VBD,3026
$VBD_DBAND,2
$VBD_CNV,-0.245296
$VBD_TIMEOUT,720
$PITCH_VBD_SHIFT,4.9999999e-05
$VBD_PUMP_AD_RATE_SURFACE,5
$VBD_PUMP_AD_RATE_APOGEE,4
$VBD_BLEED_AD_RATE,8
$UNCOM_BLEED,60
$VBD_MAXERRORS,1
$CF8_MAXERRORS,20
$AH0_24V,150
$AH0_10V,100
$MINV_24V,19
$MINV_10V,8
$FG_AHR_10V,0
$FG_AHR_24V,0
$PHONE_SUPPLY,2
$PRESSURE_YINT,-82.611328
$PRESSURE_SLOPE,0.0001165365
$AD7714Ch0Gain,128
$TCM_PITCH_OFFSET,0
$TCM_ROLL_OFFSET,0
$COMPASS_USE,0
```

```
$ALTIM_BOTTOM_PING_RANGE,0
$ALTIM_TOP_PING_RANGE,0
$ALTIM_BOTTOM_TURN_MARGIN,0
$ALTIM_TOP_TURN_MARGIN,0
$ALTIM_TOP_MIN_OBSTACLE,1
$ALTIM_PING_DEPTH,0
$ALTIM_PING_DELTA,0
$ALTIM_FREQUENCY,13
$ALTIM_PULSE,3
$ALTIM_SENSITIVITY,2
$XPDR_VALID,2
$XPDR_INHIBIT,90
$INT_PRESSURE_SLOPE,0.0097660003
$INT_PRESSURE_YINT,0.33500001
$DEEPGLIDER,0
$DEEPGLIDERMB,0
$MOTHERBOARD,4
$DEVICE1,2
$DEVICE2,83
$DEVICE3,101
$DEVICE4,118
$DEVICE5,-1
$DEVICE6,-1
$LOGGERS,7
$LOGGERDEVICE1,-1
$LOGGERDEVICE2,-1
$LOGGERDEVICE3,-1
$LOGGERDEVICE4,-1
$COMPASS_DEVICE,33
$COMPASS2_DEVICE,-1
$PHONE_DEVICE,48
$GPS_DEVICE,32
$RAFOS_DEVICE,-1
$XPDR_DEVICE,24
$SIM_W,0
$SIM_PITCH,0
$SEABIRD_T_G,0.0042688316
$SEABIRD_T_H,0.00061706884
$SEABIRD_T_I,2.136217e-05
$SEABIRD_T_J,2.1618002e-06
$SEABIRD_C_G,-9.8912401
$SEABIRD_C_H,1.1324019
$SEABIRD_C_I,-0.0016651552
$SEABIRD_C_J,0.00020771979
$EBE_ENABLE,1
```

Most parameters were the same for the other gliders, except for glider specific parameters such as the $ID, $MASS, and calibration coefficients, the `$PITCH_ADJ_GAIN` and `$PITCH_ADJ_DBAND`, which were set to 0 for SG533 from the start, and `$D_BOOST` and `$T_BOOST`, which were set to 120 and 5 respectively for SG533, at the request of David White at NOCS.

4 SCIENTIFIC INVESTIGATIONS

Vessel Mounted ADCP (VM-ADCP) and navigation data – *Liam Brannigan and John Allen*

Introduction

The RRS *Discovery* is equipped with two hull-mounted Ocean Survey broadband ADCPs. An RDI broad-band 150 kHz (Ocean Surveyor) phased-array style VM-ADCP is mounted in the hull 1.75 m to port of the keel, 33 m aft of the bow at the waterline, at an approximate depth of 5.3 m. A 75 kHz ADCP is also mounted in the hull, in a second well 4.15 m forward and 2.5 m to starboard of the 150 kHz well.

Both of the units were operating upon departure from Southampton on 28th August. However, the 150 kHz unit did not function properly from 30th August as only two of its beams were reporting velocities, which is not enough to generate the three-dimensional velocity vector. The on-screen real-time outputs indicated that the energy levels in beams 1 and 2 were only about half those in beams 3 and 4. We ran diagnostic tests on the unit which did not reveal the problem. The 75 kHz VM-ADCP hull well automatic bleed pipe was opened and re-sealed to check the issue had nothing to do with trapped air behind the transducer, however, this had no impact on its performance. After communicating with RDI it was decided that the unit has a serious problem and will need to be returned to RDI. The 150 kHz unit was finally switched off on the second leg after all options had been tried.

This section describes the operation and data processing paths for the 75 kHz VM-ADCP. The navigation data processing is described first since it is key to the accuracy of the ADCP current data. All integrated underway data were logged using the Ifremer TechSAS data logging system.

Navigation

The ship's primary position instrument is a Fugro SeaStar 9200G2 system. The positional accuracy for the SeaStar 9200 system, tested whilst tied up alongside during cruise D365, was ± 0.14 m S.D. For this cruise, our back up system was the Ashtech ADU5 3-D GPS system the positional accuracy of which was, in parallel on cruise D365, determined to be ± 0.9-1.5 m S.D.

Both the SeaStar 9200 and the Ashtech ADU5 systems have sufficient precision to enable the calculation of ship's velocities to much better than 1 cm s^{-1} over 2 minute ensemble periods and therefore below the instrumental limits (∼ 1 cm s^{-1}) of the RDI VM-ADCP systems. Using the Fugro SeaStar 9200G2 system as its primary navigation source, the NMFSS Bestnav combined (10 second) cleaned navigation process was operational and working well on D381.

Navigation and gyro data were transferred regularly from the RVS format file streams to pstar navigation files, e.g. abnv38102, gpC38101, gyr38101 or ash38101. Note that the labelling system was not entirely consistent across the data types. The navigation file for the entire first leg was abnv38101 while the respective file for the second leg was abnv38102. The gpC datafile for the first leg was gpC3811 while the file for the second leg was gpC3812. The gyro file for the first leg was gyr38101 while for the second leg it was gyr38102. The ashtech file for the first leg was ash38101 while for the second leg they were labelled in sequence as ash38102, ash38103 and so on. The latter each correspond to about one day's worth of data.

Scripts:

navexec0 transferred data from the RVS *bestnav* stream to PSTAR, calculated the ship's velocity, appended onto the absolute (master) navigation file and calculated the distance run from the start of the master file. Output: abnv3811, abnv3812.

gyroexec0 transferred data from the RVS *gyro* stream to Pstar, a nominal edit was made for directions between 0-360° before the file was appended to a master file. Output: gyr38101, gyr38102.

gpCexec0 transferred data from the RVS *gps_g2* stream to Pstar, edited out pdop (position dilution of precision) greater than 7 and appended the new file to a master file. The master file was averaged to create an additional 30 second file and distance run was calculated and added to both.

Heading

The ships attitude was determined every second with the ultra short baseline 3D GPS Ashtech ADU5 navigation system. The Ashtech data were used to calibrate the gyro heading information as follows:

ashexec0 transferred data from the RVS format stream *gps_ash* to pstar.

ashexec1 merged the ashtech data from ashexec0 with the gyro data from gyroexec0 and calculated the difference in headings (hdg and gyro-Hdg); ashtech-gyro (a-ghdg).

ashexec2 edited the data from ashexec1 using the following criteria:
heading $0 < hdg < 360$ (degrees)
pitch $-5 < pitch < 5$ (degrees)
roll $-7 < roll < 7$ (degrees)
measurement RMS error $0.00001 < mrms < 0.01$
baseline RMS error $0.00001 < brms < 0.1$
ashtech-gyro heading $-10 < a\text{-}ghdg < 10$ (degrees)

The heading difference (a-ghdg) was then filtered with a running mean based on 5 data cycles and a maximum difference between median and data of 1 degree. The data were then averaged to 2 minutes and further edited for:

$$-2 < pitch < 2$$
$$0 < mrms < 0.004$$

The 2 minute averages were merged with the gyro data files to obtain spot gyro values. The ship's velocity was calculated from position and time, and converted to speed and direction. The resulting a-ghdg should be a smoothly varying trace that can be merged with ADCP data to correct the gyro heading. Diagnostic plots were produced to check this. During ship manoeuvres, bad weather or around data gaps, there were spikes which were edited out manually (plxyed, **Figure 39**).

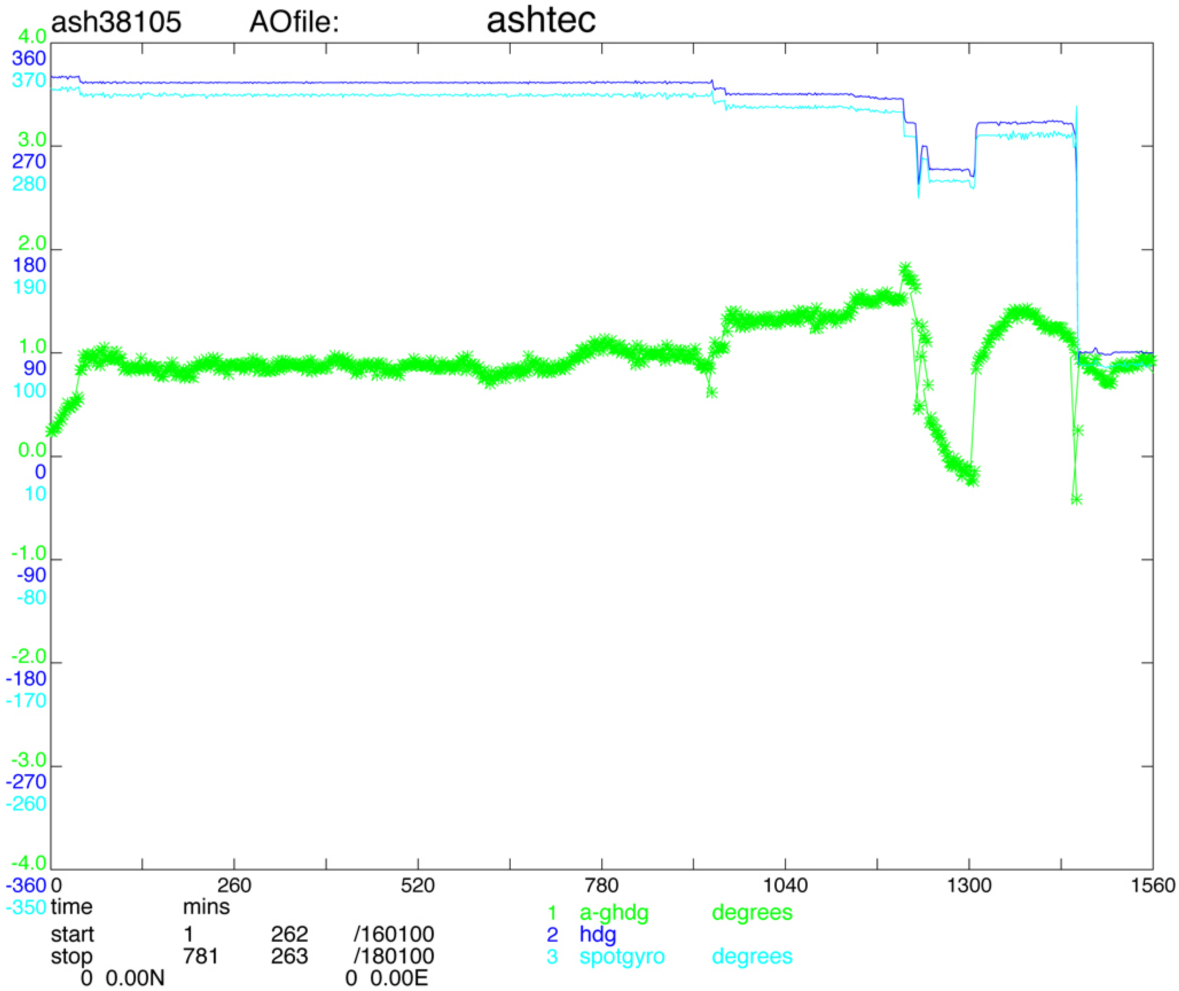

Figure 39: Example of the onscreen output of daily heading (hdg) data generated by gyro (light blue line), ashtech ADU5 (dark blue line) and the difference between them (green line).

COM PORT	Baud Rate	Data Stream
COM1	9600	ADCP
COM2	4800	NMEA1 ($GPGGA – Position) ($HEHDT – Gyro)
COM3	9600	NMEA2 ($GPPAT – Ashtech)

Table 23: COM ports in use during D381

75 kHz VM-ADCP data processing

This section describes the operation and data processing paths for the VM-ADCP, and closely follows that used on RRS *Discovery* 365 but with a different selection of vertical bin length and number of bins.

The RDI Ocean Surveyor 75 kHz Ocean Surveyor VM-ADCP was configured to sample over 120 second intervals with 96 bins of 8 m length and a blank beyond transmit distance of 8 m. The instrument is a broad-band phased array ADCP with 76.8 kHz frequency and a 30° beam angle.

The deck unit had firmware upgrades to VMDAS 23.17 following the March 2008 refit. The controlling PC ran RDI software VmDAS v1.46.

Changes to the network COM ports on *RRS Discovery* occurred during the 2010 refit and the following is now applicable for both ADCPs when in operation (**Table 23**)

Gyro heading, and GPS Ashtech heading, location and time were fed as NMEA messages into the serial ports of the controlling PC and VmDAS was configured to use the gyro heading for co-ordinate transformation. VmDAS logs the PC clock time, stamps the data (start of each ensemble) with that time, and records the offset of the PC clock from GPS time. This offset was applied to the data in the PSTAR processing path, see below, before merging with navigation.

The 2 minute averaged data were written to the PC hard disk in files with a .STA extension, e.g. D381OS075001_000000.STA etc. Sequentially numbered files were created whenever data logging was stopped and re-started. The software was set to close the file once it reached 100 MB in size, though on D381 files were closed and data collection restarted typically daily, such that the files never became that large. All files were transferred to the unix directory /os75 on the ship's Dell file server. This transfer included the plethora of much larger ping by ping data files, these can be useful in the event of major failure of the ship's data handling systems as they record all the basic navigation and ships heading/attitude data supplied by NMEA message.

The VM-ADCP was configured to run in 'Narrowband' range over resolution mode. Bottom tracking was used when leaving Falmouth (U.K). The ship was on the shelf for the following 24 hours and this data was used to calibrate the unit (file sbt381). At the time of writing it is expected that bottom tracking will be used as we return to port.

The VM-ADCP processing path followed the same route to that developed in 2001 (RRS *Discovery* cruise 253). In the following script descriptions, "##" indicates the sequential file number.

s75exec0 Data read into Pstar format from RDI binary file (psurvey2). Water track velocities written into "sur" files, bottom track into "sbt" files if in bottom track mode. Velocities were scaled to cm/s and amplitude by 0.45 to db. The time variable was corrected to GPS time by combining the PC clock time and the PC-GPS offset. An offset depth for the depth bins was provided in the user supplied information, 13 m for the 75 kHz instrument, this equated to the sum of the water depth of the transducer in the ship's hull (∼5 m in RRS *Discovery*) and the blank beyond transmit distance used in the instrument setup (see earlier). Output Files: (sur381##.raw, sbt381##.raw).

s75exec1 Data edited according to status flags (flag of 1 indicated bad data). Velocity data replaced with absent data if variable "2+bmbad" was greater than 25% (% of pings where >1 beam bad therefore no velocity computed). Time of ensemble moved to the end of the ensemble period (120 secs added with pcalib). Output files: (sur381##, sbt381##).

s75exec2 This merged the adcp data (both water track and bottom track files, where they existed) with the ashtech a-ghdg created by ashexec2. The adcp velocities were converted to speed and direction so that the heading correction could be applied and then returned to east and north. Note the renaming and ordering of variables. Output files: (sur381##.true, sbt381##.true).

s75exec3 applied the misalignment angle, ø, and scaling factor, A, discussed below, to both files. Variables were renamed and re-ordered to preserve the original raw data. Output Files: (sur381##.cal, sbt381##.cal).

s75exec4 merged the adcp data (both files) with the bestnav (10 sec) NMFSS combined navigation imported to pstar through navexec0 (abnv3812). Ship's velocity was calculated from spot positions taken from the abnv3812 file and applied to the adcp velocities. The end product is the absolute velocity of the water. The time base of the ADCP profiles was then shifted to the centre of the 2 minute ensemble by subtracting 60 seconds and new positions were taken from abnv3812. Output Files: (sur381##.abs, sbt381##.abs).

75 kHz VM-ADCP calibration

A calibration of the 75 kHz VM-ADCP was achieved using bottom tracking data available from our departure from Falmouth (U.K.), during the passage over the shelf (file sbt38125.abs). No further calibration was deemed necessary from inspection of the processed data during the cruise: however data were recorded over the shelf on our return passage. Using straight, steady speed sections of standard two minute ensemble profiles over reasonably constant bottom depth the following calibrations for mis-alignment angle, ϕ, and necessary amplification (tilt), A, were derived by comparing GPS derived component vectors of the vessel speed and direction with processed VM-ADCP bottom track determined component vectors of the vessel speed and direction:

75 kHz	ϕ	A
mean	3.5600	0.9966
s.d	±0.5255	± 0.0055

This was reassuringly similar to the calibration used on D379.

Results and Discussion

Initial data inspection included absolute velocity vectors at 25m. Water track files were appended regularly, averaged in a 1 km regular grid, and plotted along the ship track. Visual comparison of these plots allowed rough assessment of the data consistency. Altimetry measurements were downloaded regularly and compared with ADCP velocities at 25 metres. These showed broad agreement with altimetry; which indicated that an anti-cyclonic eddy dominated the south of the area. There was a region of apparent large negative relative vorticity in the south half of the area (**Figure 40**).

The first leg of the first survey (along 49.11° N) displayed cyclonic vorticity with the current rotating anti-clockwise by 180 degrees between the middle and end of the leg. The second and third legs included a region where the flow was convergent, flowing south-east of the second leg at 49° north and north-east along the third leg. The second leg included a kink to avoid the ODAS buoy.

The southern part of the survey, on the other hand, featured a strong anti-cyclonic feature (velocities up to 66 cm s^{-1}), which is most visible in the eastern part of the two southern-most legs.

The ADCP data was also used to investigate processes which generate spikes in shear across the seasonal thermocline. This was done over the course of the MSS turbulence profiling in order to compare it with the direct dissipation observations. The slow speed of the ship during these stations (less than 1 knot) meant that the distance travelled was relatively small and so the data can be treated as a virtual mooring.

The shear data did not, however, display evidence of major spikes across the seasonal thermocline as shown in **Figure 41**.

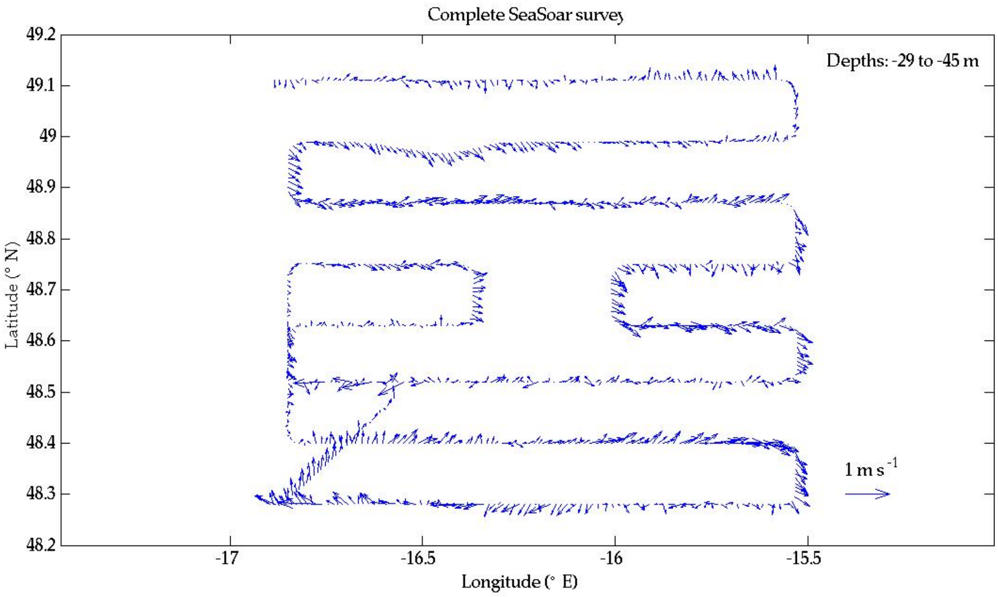

Figure 40: ADCP velocity between 29-45 m depth for survey 1 averaged over 1 km along the track with the velocity vector scale shown on the bottom right.

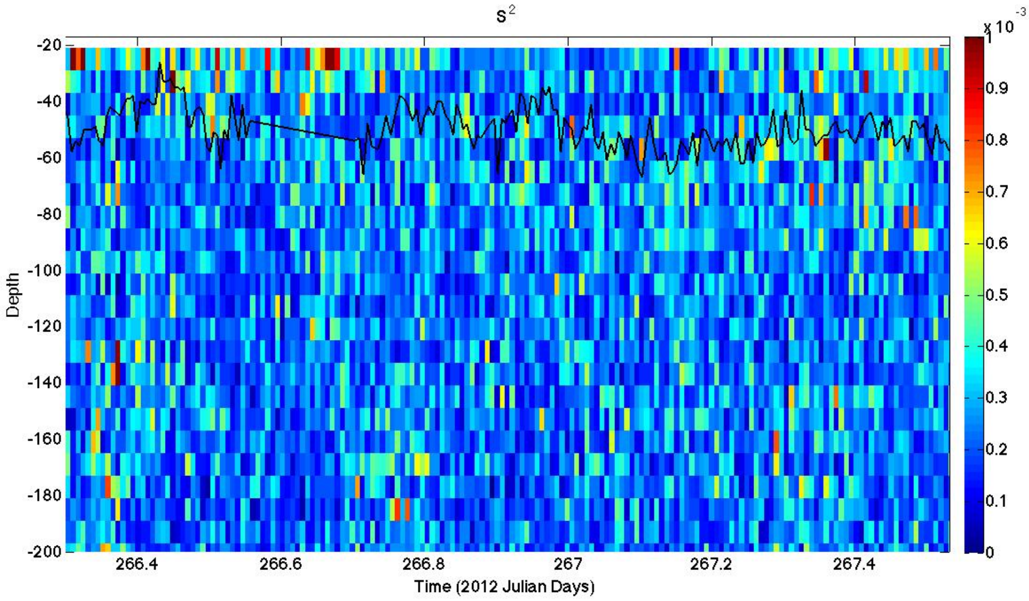

Figure 41: The shear squared and depth of maximum stratification (black line) during the second MSS station. The shear data are calculated from the ADCP observations while the stratification is derived from the temperature and conductivity sensors on the MSS profiler. The black line is the depth of maximum stratification to indicate the location of the seasonal thermocline in the upper panel. The straight section of the black line near T=266.7 is a linear interpolation over a period when there was a gap in the MSS profiling due to instrument problems.

Lowered CTD Sampling, Processing, and Calibration -

Tim Boyd, Matt Toberman, Sophie Wilmes

Objectives

CTD casts were conducted at several stations together with water sampling in order to:

1. provide reference points for calibration/validation of both moored time series measurements and autonomous glider measurements

2. provide water and supporting hydrography for biogeochemical (e.g. nutrients, chlorophyll, dissolved oxygen) studies of the upper ocean for use in conjunction with turbulence profiler to derive and interpret fluxes into the surface mixed layer

3. provide salinity data for comparison to/validation of SeaSoar towed salinity transects.

Methodology

The CTD was mounted on a stainless steel frame outfitted with a vane to minimize rotation and reduce twisting of the CTD wire. The configuration was built around a SeaBird Electronics (SBE) 9Plus CTD, with dual SBE-3 temperature (T) and SBE-4 conductivity (C) sensors, SBE-43 dissolved oxygen sensor, Chelsea Techonologies AquaTracka III fluorometer and AlphaTracka II transmissometer, and WET Labs BB single angle scattering sensor. The 'primary' set of C and T sensors are mounted bottom within the frame at the bottom, and the 'secondary' set of C and T sensors are mounted toward the lower edge of the external vane. The primary C-T sensor pair are mounted in line with the SBE dissolved oxygen sensor, and used in the correction of those measured values. Otherwise, the values from secondary pair of sensors are used here for the computation of salinity and density, for reasons that will be described in greater detail below. Details of the instrument configurations, including copies of the SBE configuration files, are shown in the section on CTD operations. The C and T sensors are calibrated by SBE every six months.

The system was deployed from the CTD winch on the starboard side. The usual procedure was to first lower the CTD to about 12m deep for the pumps to switch on and for the system to equilibrate. The system was then brought back up to within about 3m of the surface before starting the cast. Casts were primarily conducted to depths of 500m and 1000m during the second leg (D381B) of the OSMOSIS cruise (casts 5-21). Full depth profiles (casts 1, 3, 4) were conducted during the first leg (mooring deployment, D381A). Data was recorded on and SBE 11 deck unit.

Twenty-four 10 litre Niskin bottles were fitted on the CTD rosette. Water was collected at a variety of depths for nutrient and POC/HPLC/chlorophyll analysis, as well as for salinity calibration of the CTD sensors. During the later CTD casts (CTDs 14-21), water was collected at 10m intervals from the surface to 200m depth, including typically four depths within the surface mixed layer, followed by four samples in relatively constant salinity patches between 200m and the bottom of the cast. Depths of water samples during the earlier CTD casts are more variable, and are described in detail elsewhere in the cruise report. Ordinarily, CTD bottles are fired on the upcast while the CTD is held stationary. During the later casts, the four deep bottle samples and one bottle depth from within the mixed layer were sampled while stationary, but otherwise the bottles were fired 'on the fly' at a nominal ascent rates of 20-30 m/min. The various stationary and 'on the fly' bottle depths are identified in **Table 24**. Salinity of CTD cast bottle data were processed on board during the cruise. Results associated with that processing are discussed separately within the cruise report, and are used below to form separate corrections for each of the CTD used on the cruise.

CTD Cast Number	Date	Stationary Bottle Nominal Depths (m)	'on the fly' Bottle Nominal Depths (m)
018	29/09/2012	30, 340, 384, 430, 480	10, 20, 40:10:200
019	29/09/2012	30, 300, 400, 445, 495	10, 20, 40:10:200
020	29/09/2012	10, 250, 340, 375, 450	20:10:200
021	30/09/2012	20, 250, 300, 375, 480	30:10:200

Table 24: List of depths for which bottle samples were acquired as stationary and 'on the fly' samples. Light-grey shaded CTD was acquired at the end of MSS series C.

CTD Cast Locations

CTD cast locations, time, and maximum depths are shown in **Table 25**. Note that casts 1-4 (highlighted) were conducted during the mooring leg (cruise D381A). Note also that the CTD wire parted in the winch room at the start of cast 13. At the time, the CTD was suspended over the water in preparation for descent into the water. The CTD was consequently lost, and no data returned for that CTD cast. A complete rebuild and test of the CTD system using a second rosette was conducted using backup CTD and sensors following the failed cast, as described elsewhere in this data report, accounting both for the large time lag between CTD casts 13 and 14 and the shallow maximum depth (200m) on cast 14. The two light-grey shaded series of CTD casts in **Table 25** were conducted in conjunction with MSS turbulence microstructure time series A and C, which are described elsewhere in this data report.

CTD Cast Number	Filename	Date	Start Time (UTC)	Max. Depth (m)	Latitude	Longitude
001	D381_001	31/08/2012	15:13	4818	48° 37.886'N	016° 16.922'W
002	D381_002	02/08/2012	18:42	1000	48° 45.695'N	016° 6.342'W
003	D381_003	04/09/2012	11:42	4805	48° 42.048'N	016° 08.866W
004	D381_004	06/09/2012	12:37	4710	48° 41.927'N	016° 20.598'W
005	D381_005	15/09/2012	19:48	794	48° 09.036'N	009° 42.161'W
006	D381_006	17/09/2012	12:06	1000	48° 36.346'N	016° 03.918'W

Continued on next page

Table 25 – *continued from previous page*

CTD Cast Number	Filename	Date	Start Time (UTC)	Max. Depth (m)	Latitude	Longitude
007	D381_007	17/09/2012	21:15	500	48° 48.768'N	016° 27.098'W
008	D381_008	18/09/2012	15:38	500	48° 48.462'N	016° 21.667'W
009	D381_009	19/09/2012	12:36	1000	48° 58.847'N	016° 22.546'W
010	D381_010	21/09/2012	20:18	500	48° 16.952'N	016° 50.984'W
011	D381_011	21/09/2012	22:22	500	48° 24.132'N	016° 41.061'W
012	D381_012	22/09/2012	00:26	500	48° 31.242'N	016° 31.205'W
013		22/09/2012	03:09		48° 37.828'N	016° 22.004'W
014	D381_014	28/09/2012	08:19	200	48° 58.522'N	016° 05.438'W
015	D381_015	28/09/2012	10:35	500	48° 58.556'N	016° 03.730'W
016	D381_016	28/09/2012	13:40	500	48° 58.983'N	016° 03.763'W
017	D381_017	28/09/2012	16:26	500	49° 00.489'N	016° 04.078'W
018	D381_018	29/09/2012	00:23	500	49° 03.585'N	016° 04.684'W
019	D381_019	29/09/2012	03:45	500	49° 05.069'N	016° 28.307'W
020	D381_020	29/09/2012	05:44	500	49° 05.833'N	016° 39.886'W
021	D381_021	30/09/2012	09:00	500	49° 11.737'N	015° 30.022'W

Table 25: CTD cast times and locations. The two light-grey shaded series of CTD casts were conducted in conjunction with MSS turbulence microstructure time series A and C, which are described elsewhere in this data report. The series of darker-grey shade casts were acquired during the mooring leg (D381A). The CTD was lost overboard during cast 013, due to parted wire in the winch room.

Data Processing

The CTD data were processed using Seabird Data Processing version 7.21a and Matlab version R2010a. It was our intention to process these CTD data according to the standards described in the SAMS CTD data Processing Protocol (Dumont and Sherwin, 2008, SAMS internal report No 257), however the significant effects of ship heave on the data led us to deviate from that process in the details of the Matlab processing. Furthermore, the SBE data processing sequence used here is more akin to the 'Special Procedure' used for processing of casts conducted with the titanium rosette during cruise D321B. The processing used here can be outlined in several steps:

- Step 1. Use of SBE Data Processing modules Data Conversion, Bottle Summary, Wild Edit, Align CTD, Filter, Derive, and ASCII Out. The initial conversion from binary to ascii data results in 24Hz raw data files that have minimally processed, with the exception of removing outliers in Wild Edit and filtering the pressure in Filter. The Data Conversion module processes only the downcast data for the purposes of subsequent processing and analysis. The Data Conversion module is run separately to process both the downcasts and upcasts (upcasts only is not an option) in order to generate data from the bottle depths.

- Step 2. (Matlab) Plotting and despiking/cleaning of the 24Hz data within Matlab to remove random noise as well as deterministic 'noise' resulting from the effects of ship heave on the otherwise relatively smooth rate of descent of the CTD rosette.

- Step 3. Use of SBE Data Processing modules Ascii In, Cell TM, Wild Edit, Loop Edit, Derive, Bin Average and Ascii Out. The final processing of the CTD data includes correction for the thermal mass of the conductivity cell (in Cell TM), another pass at removing stray outliers (Wild Edit) and the effects of variable descent rate (Loop Edit), and averaging into 2 dB bins (Bin Average).

- Step 4 (Matlab): plots of the despiked 24Hz and 2 dB-binned data (post-cruise)

- Step 5 (Matlab): calibration of salinity data on both 24Hz and 2db-bin averaged datasets (post-cruise).

Raw data processing (SBEDataProcessing)

Data Conversion converted raw data from engineering units to binary .cnv files and produced the .ros files. Variables exported were scan number, pump status, Julian day, pressure [db], temperature0 [ITS-90, deg C], conductivity0 [mS/cm], temperature1 [ITS-90, deg C], conductivity1 [mS/cm], oxygen [mg/l], beam attenuation [1/m], altimeter [m], fluorescence [μg/l], and beam transmission [%]. Note that in the SBE lexicon, the primary TC sensors were labelled 0, secondary 1. For convenience, two separate versions of the converted files were created: the primary file used for further processing contains downcast data only; a second file contains upcasts as well for the sole purpose of creating bottle files containing average values for various measured (e.g. T, C, and P) and derived (salinity and density) variables at the bottle depths.

AlignCTD was then run to compensate for sensor time-lag. The secondary conductivity is typically advanced by 0.073s in standard processing as recommended by SBE. In this case, however, a temperature step at 64.5m depth in CTD cast 008 provided an opportunity to tune the time lag in order to minimize the resulting salinity spike. The best advance of the conductivity was independently determined to be -0.015s for conductivity sensor 2 on both the CTD used for casts 1-12, (CTD1 hereafter), and for the CTD used for casts 14-21 (CTD2 hereafter).

The oxygen sensor response was advanced relative to pressure by +4s, in accordance with the value used by Dumont and Sherwin (2008).

Filter applied a low-pass filter (value of 0.15s) on the pressure and depth data, which smoothed the high frequency (rapidly changing) data. To produce zero phase (no time shift), the filter was first run forward through the data and then run backward through the data. This removed any delays caused by the filter.

At the **Derive** stage, densities sigma-theta (kg/m3) for T/C sensor pair 2, salinities (psu) for both T/C sensor pairs and depth(m) were calculated.

The data was converted from binary to ASCII format by the module **ASCII_Out**. The data had been kept in binary format up to this stage to avoid any loss in precision that could occur when converting to Ascii.

Finally, the module **BottleSum** created the ASCII bottle files (.btl) from the .ros files, for each bottle fired during a cast. These files contain mean and standard deviation values for all variables over 14 scans.

Eliminating effects of CTD heave (Matlab)

Preliminary processing of the data from Cast 005 revealed apparent intrusions in the temperature and conductivity data, with temperature excursions of up to 0.08°C (**Figure 42**). The intrusions between 140m and 160m were related to large amplitude, periodic variations in the rate of descent of the CTD and are therefore spurious. The working hypothesis for the mechanism creating this is that a slug of water entrained by the descending CTD rosette is released by the heave-induced rapid deceleration of the rosette, and subsequently passes/envelopes the sensors until the CTD descent resumes sufficient speed to escape the released wake.

Averaging across the spurious intrusions is clearly not appropriate as the water sampled in the released wake is often drawn from more than 5m above the depth at which it was sampled. The quasi-linear relationship between CTD deceleration preceding identified events and the rate of descent at the escape from the released wake (**Figure 43**) suggests an algorithm could be developed for automated detection and removal of heave-related wake event data from the CTD record.

An algorithm was developed within Matlab for identification and removal of spurious data associated with ship heave. While there is clearly a relationship between ship heave and presence of spurious intrusions in the data record, the scatter in **Figure 43** indicates that an algorithm based on this simple relationship will not completely remove the spurious data, and the remaining bad data are further removed with a de-spiking algorithm very similar to the SBE Wild Edit module, and then subsequently smoothed.

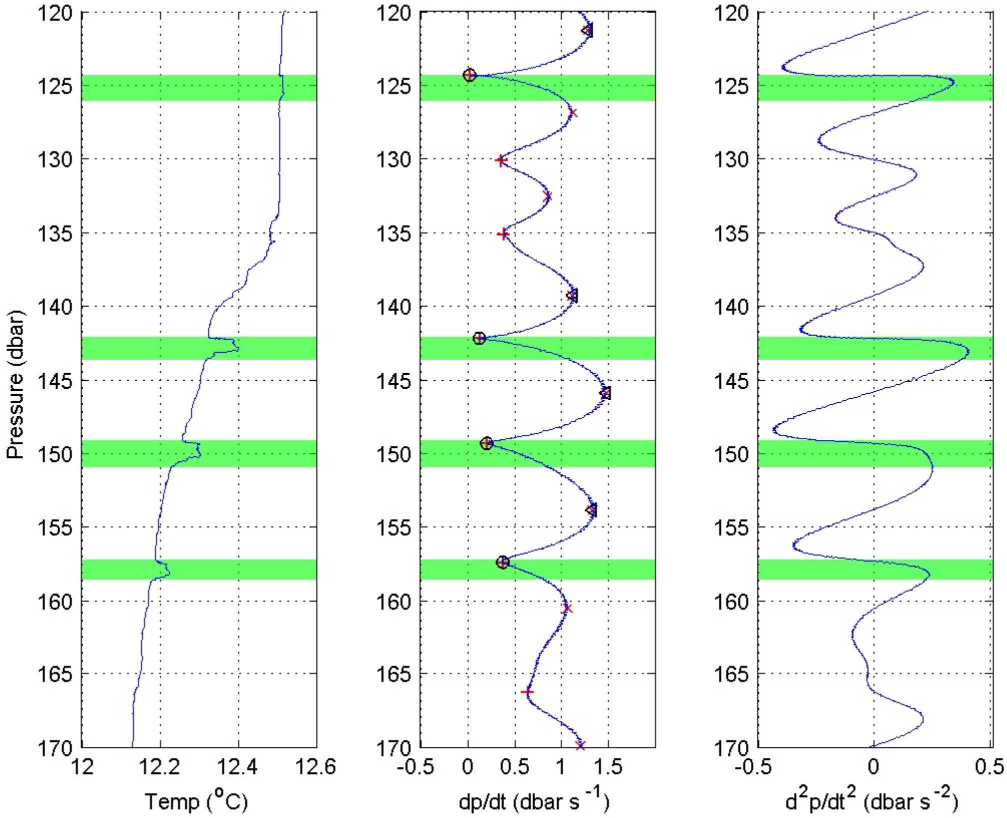

Figure 42: Temperature, CTD rate of descent (dp/dt), and acceleration (d^2p/dt^2) for Cast 005, illustrating the relationship between apparent intrusions in the temperature profile and the deceleration of the CTD. Deceleration from the locations of the triangles (maximum rate of descent) to the locations of the circles (minimum rate of descent) immediately precedes the onset of the apparent intrusions. CTD pressure has been filtered to obtain smooth rate of descent, which has been further filtered to obtain smooth acceleration.

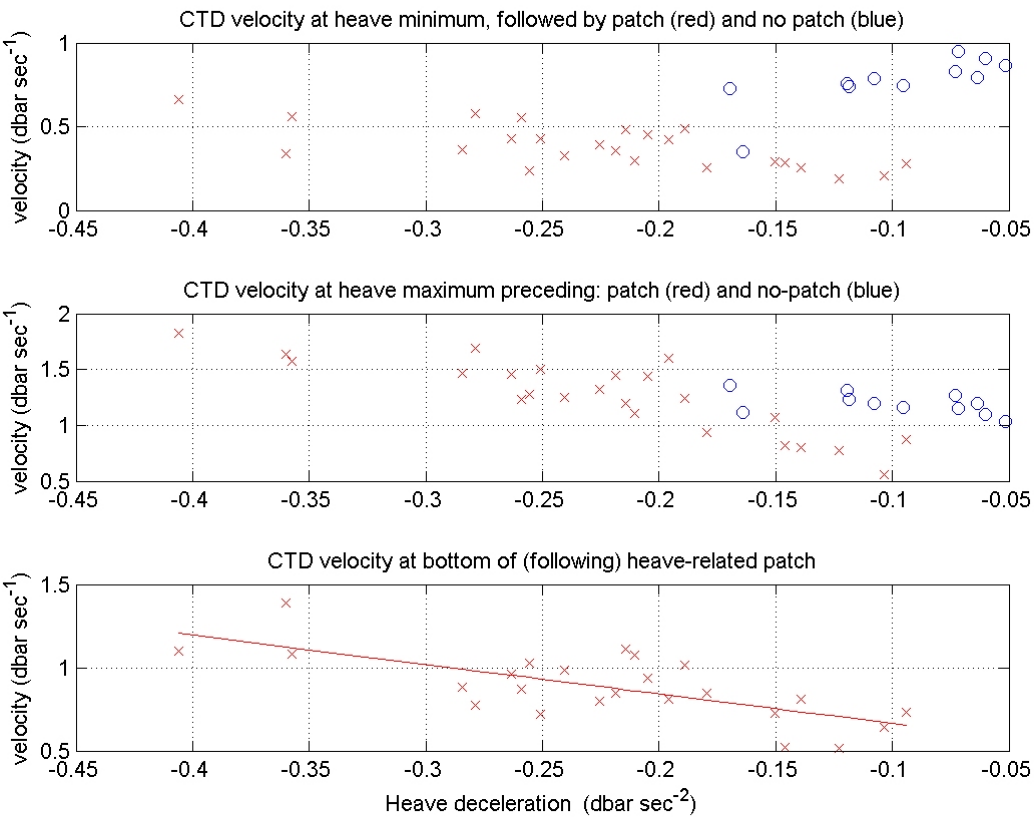

Figure 43: Relationship between the CTD rate of descent at the bottom of apparent intrusions (as identified by green patches in Figure 42) and the average preceding deceleration from the maxima (triangles in **Figure 42**) to the minima (circles).

Averaging (SBE Data Processing)

After going through Matlab, the data files need to be re-formatted to be recognised by SBE Data Processing.

In **Cell Thermal Mass**, a recursive filter was run to remove conductivity cell thermal mass effects from the measured conductivity. The constants used were the ones given by Seabird: thermal anomaly amplitude α=0.03 and thermal anomaly time constant $1/\beta$=7.

At the **Derive** stage, densities sigma-theta (kg m^{-3}) for T/C sensor pair 2, salinities (psu) for both T/C sensor pairs and depth(m) were calculated.

The module **Bin Average** averaged the 24Hz data into 2db-bins, and the module **Ascii Out** output the bin-averaged data files as ASCII (with a simplified header).

Plotting (Matlab)

Preliminary plots of the 24Hz raw temperature, conductivity and salinity data were produced for both sensor pairs. **Figures 44-47** show unfiltered 24Hz data from sensor pairs 2 for both CTD1 (used for casts 1-12) and CTD2 (used for casts 14-22). Comparison of the response during heave-related spurious intrusion events led to choice to work further only with the secondary T-C pair, located on the external fin. Data plots of 24Hz cleaned data and 2db bin-averaged cleaned will be produced post-cruise for the following variables: temperature, conductivity, salinity, density, oxygen, fluorescence, and transmittance vs. pressure. For the 2db-bin averaged data, the following plots will also be produced: potential temperature vs. pressure and salinity vs. potential temperature.

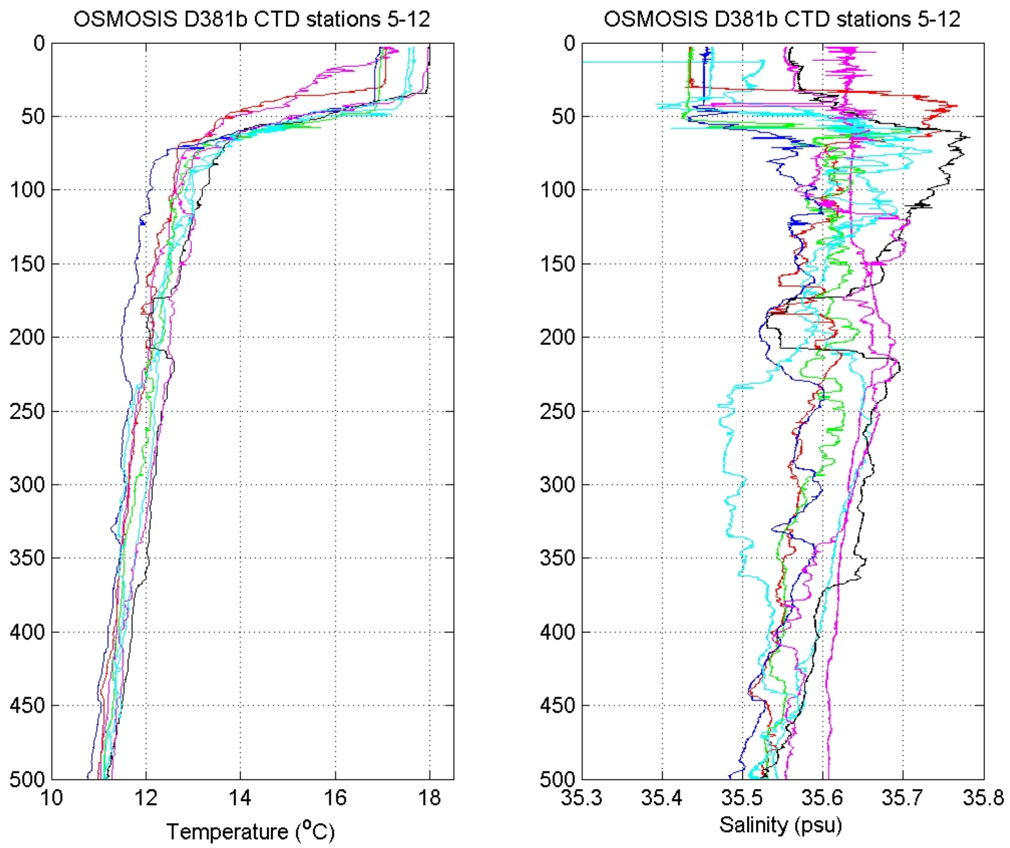

Figure 44: Temperature and Salinity profiles for CTD casts 5 through 12.

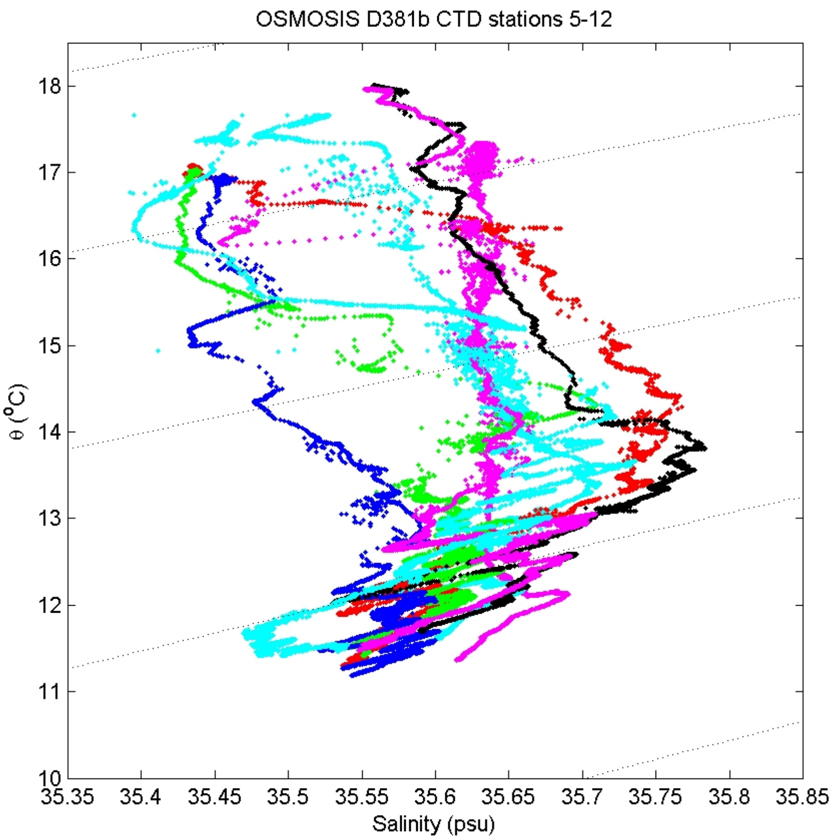

Figure 45: T/S relationship for CTD casts 5 through 12.

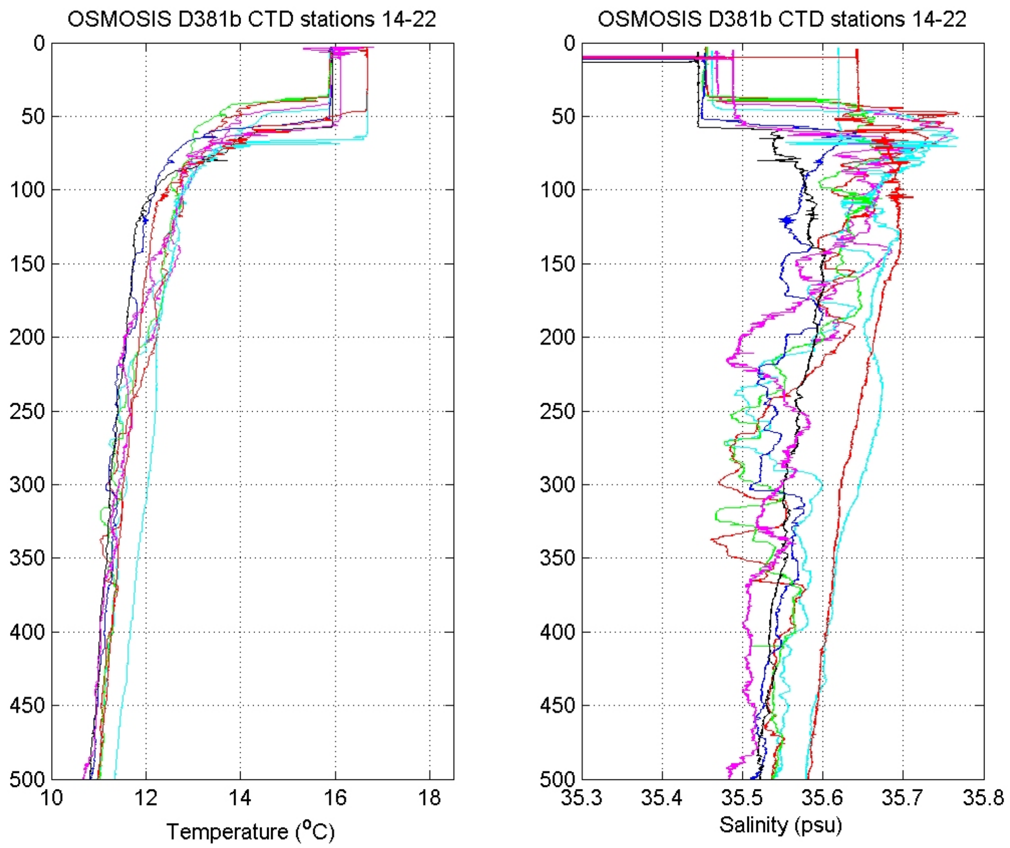

Figure 46: Temperature and Salinity profiles for CTD casts 14 through 22.

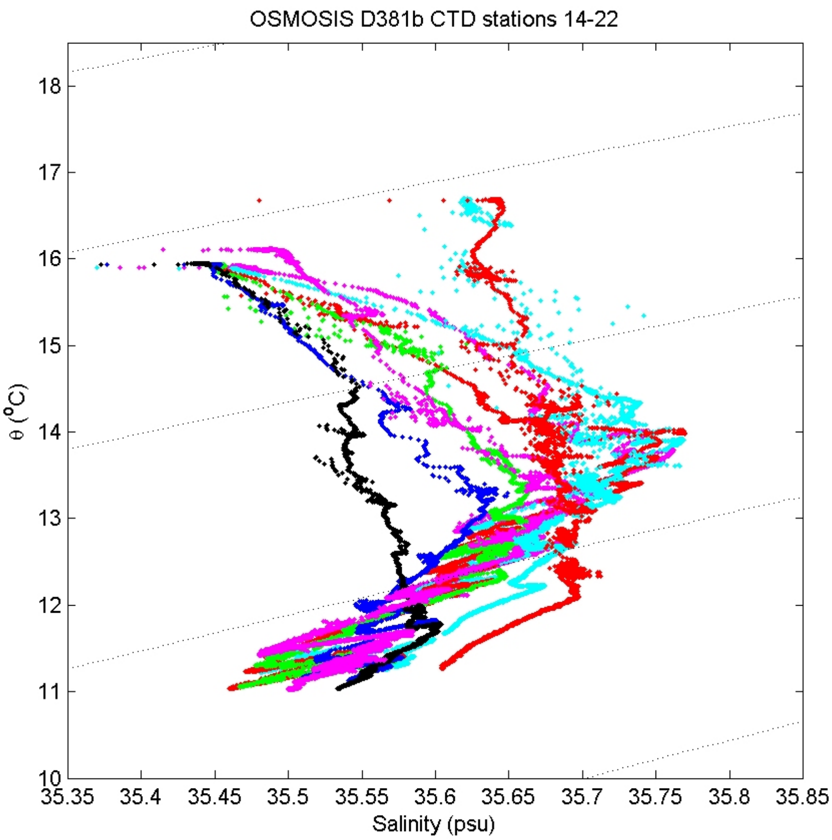

Figure 47: T/S relationship for CTD casts 5 through 12.

Salinity calibration

Linear regressions of CTD-derived salinities to Autosal-derived salinities were computed separately for all bottle data obtained during casts conducted with CTDs 1 and 2. The regression fits showed a larger offset than one would typically expect for SBE sensors that are kept in current manufacturer calibration, suggesting that further scrutiny of the bottle data is required before a firm conclusion can be drawn about the relationship between the two sets of salinities.

SeaSoar CTD Data -*Adrian Martin and John Allen*

OSMOSIS set out to explore the processes responsible for the deepening and shallowing of the oceanic mixed layer. Several such processes are associated with phenomena at the mesoscale and submesoscale e.g. frontogenesis. Gliders were deployed to provide spatial coverage over a region ∼20 km x 20 km throughout the year spanning Sept. 2012 to Sept. 2013. Additionally, the undulating profiler SeaSoar, was used on D381 to provide a high spatial resolution synoptic mapping of the upper 400m over a larger box of ∼100 km x 100 km, centred around the central mooring site 48° 41.34 N 16° 11.40 W.

Three SeaSoar surveys of the area were originally planned; each lasting 3-4 days and divided into 4 quadrants to allow surveys to be broken and interspersed with turbulence profiling or CTD stations if required. At least one of the surveys was to be carried out with transects orientated orthogonally to those of the other surveys, to minimise the effects of anisotropy in later analysis.

In practice, the delayed departure of the second leg of the cruise meant that at most 2 SeaSoar surveys would be possible. Each SeaSoar survey was designed along the standard 'radiator' format, though modified to avoid the cluster of moorings at the centre of the mapped region. Survey tracks for the two surveys are shown in **Figure 48**.

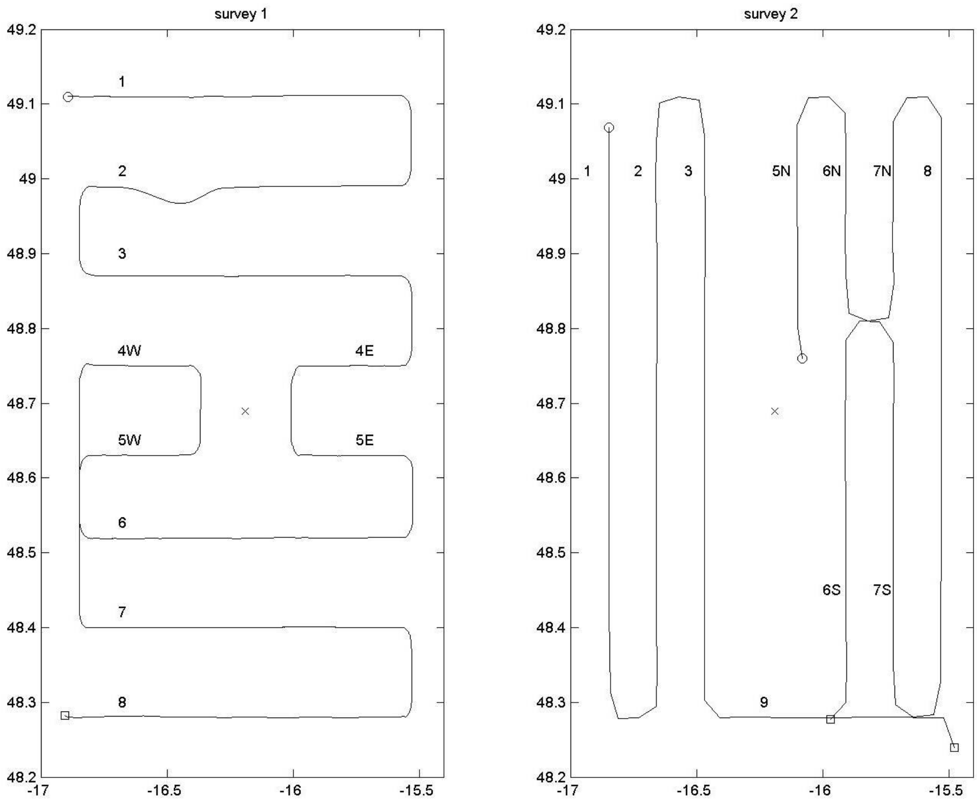

Figure 48: Tracks for the 2 SeaSoar surveys. The cross marks the central mooring position. Other moorings within the central cluster are not shown. A circle marks the start of each tow whilst a box marks the end.

Technical details on deployments and instrumentation can be found in the SeaSoar Operations section of this cruise report. It is still worth noting here that the deployments were very successful in the sense that SeaSoar was only deployed and recovered once on the first survey, at beginning and end; and that the only variation on this in survey 2 was that bad weather prompted recovery (and later redeployment) mid-way through. The only persistent problem with data coverage was due to bad weather keeping SeaSoar 's flight pattern below ~50 m of the surface for parts of the second survey. Initial concerns that a large (~ +0.2 psu) offset in salinity associated with the Chelsea Technologies Group (CTG) minipack CTDf might necessitate a non-linear correction proved groundless, in part reflecting the large variability in water properties in the area (details below). The minipack unit was swapped for the second survey due to concerns over data spiking (see SeaSoar Operations) . Spiking remained but once again salinity was stable with a constant, but now smaller, offset (details below). Deployment dates, times and notes can be found in SeaSoar Operations. **Table 26** below gives the details of individual final gridded SeaSoar surveys.

Survey 1 overview

The first survey was successfully completed but time pressures meant that, rather than being carried out in quadrants, it was carried out as a continuous survey, with the majority of transects spanning the whole region. The survey was orientated with transects running west-east. The three most northerly (legs 1, 2 and 3) and three most southerly legs (6, 7 and 8) were each ~100km long. The 4 central legs (2 either side of the central mooring: legs 4 and 5, both W and E) were of ~30km length.

Survey 2 overview

The desire to start with minimum transit time after the echosounder search for the met buoy meant that the second survey began just north east of the mooring array, rather than at one of the corners of the larger region to be surveyed by SeaSoar. Bad weather meant that the second survey was interrupted. Starting from the east of the region to be surveyed, it was curtailed just before reaching halfway at 19:44 on day 268 and only resumed at 08:00 on day 273.

For this survey, a slightly modified quadrant track was planned. Each of the 4 quadrants would be itself a smaller radiator style survey, this time with longer tracks (bar one) orientated north-south. A slight deviation from a regular division into 4 such quadrants was to extend a few of the legs to allow short segments coinciding with transects of survey 1 for comparison. Additionally, because of the length of time separating the first and second parts of survey 2, the last transect of the second part (leg 9) was west-east to repeat, albeit short, sections from the first part of survey 2. The second part of leg 2 was interrupted at 13:24 on day 273 by the power outage affecting the whole vessel.

Data

The 'C21' SeaSoar system (Allen *et al.,* 2002), used for the first time on D253 (May/June 2001), carries a Chelsea Technologies Group (CTG) Minipack CTDF (Conductivity, Temperature, Depth and Fluorescence) instrument which is considerably more compact than

Survey 1	Start date	Start datacycle	Stop Date	Stop datacycle	Total leg distance run/km		
	263	**1**	**265**	**7150**	**852**		
Leg	**Start Day**	**Start datacycle**	**Stop Day**	**Stop datacycle**	**Distance run/km**		
					Start	**End**	**Total**
1	263	1	263	900	1104	1206	102
2	263	951	264	1800	1218	1314	96
3	264	1851	264	2700	1326	1422	96
4E	264	2751	264	3050	1434	1464	30
5E	264	3101	264	3450	1476	1512	36
6	264	3501	264	4350	1524	1620	96
4W	265	4501	265	4850	1644	1680	36
5W	265	4901	265	5200	1692	1722	30
7	265	5401	265	6250	1752	1848	96
8	265	6301	265	7150	1860	1956	96
Survey 2	**Start date**	**Start datacycle**	**Stop Date**	**Stop datacycle**	**Total leg distance run/km**		
	267	**1**	**274**	**9600**	**738**		
Leg	**Start Day**	**Start datacycle**	**Stop Day**	**Stop datacycle**	**Distance run/km**		
					Start	**End**	**Total**
5N	267	1	267	400	2176	2218	42
6N	267	451	268	750	2230	2260	30
7N	268	801	268	1100	2266	2302	36
8	268	1201	268	2000	2320	2410	90
7S	268	2051	268	2550	2422	2476	54
6S	268	2651	268	3150	2494	2548	54
1	273	6501	273	7300	2956	3046	90
2	273	7351	273	8150	3058	3148	90
3	273	8201	274	9000	3160	3250	90
9	274	9001	274	9600	3256	3322	66

Table 26: final gridded survey Seasoar Legs during D381b

CTD instruments traditionally carried by the SeaSoar vehicle. A substantial payload space is available in the SeaSoar for a multidisciplinary suite of additional instruments. For RRS *Discovery* cruise D381b, the SeaSoar vehicle had been prepared to carry the (NOC/Valeport) UV Nutrient Sensor (SUV-6/SUV-51), a PAR sensor, a Brooke Ocean laser optical plankton counter (LOPC), a second generation CTG Fast Repetition Rate Fluorimeter (FRRFII), two oxygen sensors, three further fluorimetric pigment sensors, a backscatter sensor and a bioluminescence sensor. Technical details for all instruments can be found in SeaSoar Operations. Issues with the payload detrimentally affecting the flight of SeaSoar experienced on D369 appear to have been resolved with the vehicle flying well, almost to 400 m for the majority of the time.

During SeaSoar deployments data were recovered, in real time, from the PENGUIN data handling system on SeaSoar. In the case of the MiniPack and SUV-6 instruments the files were buffered for transfer in PENGUIN and the master data files were recorded on the EMPEROR Linux PC in the main lab. For the FRRFII and LOPC, the freely available software 'socat' was used to provide a virtual RS232 link bridging the instrument to their parent software on dedicated PC laptops in the main lab: all the EMPEROR and PENGUIN data handling is discussed in detail in the technical support section. Thus data were logged in four types of file: two DAPS files, one containing the CTDF measurements and its associated additional analogue channels, another containing the SUV-6 UV Nutrient Sensor data; and the 2 proprietary PC files for the FRRFII and LOPC. Only pressure, temperature and salinity (conductivity) were dealt with during the cruise.

All of the variables output by the MiniPack CTDF were calibrated using pre-set calibrations stored in the instrument firmware. The sensors are sampled in the MiniPack at 16 Hz, but the data are 1Hz averaged prior to the output data stream from the MiniPack. The variables output were:

- Conductivity ($mScm^{-1}$)
- Temperature (°C)
- Pressure (dbar)
- ΔT ($°Cs^{-1}$), temperature change over the one second averaging period.
- Chlorophyll (mgm^{-3})

Each of these were output at one second intervals and a time/date stamp was added by the DAPS handling software on PENGUIN. The time rate of change of temperature, ΔT ($°Cs^{-1}$), is the difference between the first and the last sample in the one second average of temperature.

Although technical details are left for SeaSoar Operations, it is worth noting that the, now pumped, Seabird SBE43 oxygen sensor worked well throughout (in contrast to D369 without the pump) whilst the Anderraa Optode oxygen sensor gave no usable data. It was also not clear that the CTG backscatter sensor and the CTG GlowTracker bioluminescence sensor were producing useful data.

Processing Steps

The cycling, and subsequent processing , of individual DAPS files during SeaSoar deployments was irregular in timing. Consequently the files themselves are irregular in size. The following processing route was carried out:

pgexec0: Reads raw DAPS data into a PSTAR recognisable format, sets up the dataname and header information. Copies time from Julian Day to seconds – N.B DAPS time is not necessarily an integer value of seconds thus sporadically two records may appear to have the same time. Through using the –square command in ptime, this situation is avoided.

pgexec1: Using output from pgexec0, simple editing and calibration of the data is performed. The time constant is the only calibration constant required, defined by the user according to the quality of the SeaSoar data in T/S diagrams. A number of steps are involved, primarily:

- Temperature correction applied using *pcalc*
- Interpolation of pressure to remove absent data, using *pintrp*
- Salinity and density calculated with *peos83*

plxyed: This interactive pstar editor was used in order to identify datacycles corresponding to large pressure spikes, thought to be caused by parsing errors (see SeaSoar Operations). Both surveys had such spiking. Once identified, the relevant datacycles were removed by using *pcopya* to copy all data bar these to a new file.

plpred: This interactive pstar editor was used in order to remove major salinity spikes, often associated with the pressure spikes mentioned above.

pcopya: Was used to create copies of the processed component files for each survey prior to merging them into a single survey file.

pmerge: Was used to merge the single survey file with the navigation data on time.

pgrids: A single, gridded file was produced for each survey of geolocated (merged with navigation data), interpolated data. A 6 km x 8 dbar regular gridding format was used for both surveys.

peos83: Was used following pgrids in order to recalculate potemp and sigma0, using pressure, temperature, and salinity.

pmerge: Was used once again on the resulting file, this time merging with the navigation data on distrun.

Temperature Correction

There is a small delay in the response of the temperature sensor, which must be corrected for two reasons. First, and primarily, the correction is necessary to obtain the correct temperature corresponding to conductivity measurements, to make accurate calculations of salinity. Second, it is needed to obtain an accurate determination of temperature for points in space and time.

Surprisingly, according to the Minipack users manual, the time response of the temperature and conductivity cells should be taken into account by the electronics in the CTDf unit. However, experience has shown this is rarely found to be the case. A lag in temperature is apparent in the data in two ways. There is a difference between up and down profiles of temperature (most apparent in the derived salinity) because the rate of change of temperature has opposite signs on the up and down casts. The second manifestation is the "spiking" of salinity as the sensors traverse maxima in the gradients of temperature and salinity. The rate of ascent and descent of SeaSoar is greater (up to 2-4 ms^{-1} at the beginning of descent and ascent) than that of a lowered CTD package, so the effects of the temperature lag are more pronounced. Thus, the following correction was applied to the temperature during ***pgexec1*** before evaluating the salinity

$$T_{corr} = T_{raw} + \tau\Delta T$$

where ΔT is the temperature difference over the CTD's one second averaging interval, and output as a variable, τ is the time constant, normally set to some significant fraction of the one second averaging interval.

The best value of τ was chosen so as to minimise the difference between up and down casts and noise in the salinity profile.

Thankfully the MiniPacks used on this cruise showed themselves to be more stable than on some previous cruises. The best values for τ changed between surveys (unsurprising as the MiniPack itself did too) but were consistent within surveys. The best values were found to be $\tau = 0.1$ seconds for survey 1 and $\tau = 0.12$ seconds for survey 2.

Salinity Calibration

Calibration of Minipack CTD data was clearly necessary and so comparison was made with T/S profiles from the traditional vertical CTD stations. Unfortunately, D381A had collected very few CTD profiles and though there were more opportunities on D381B the size of the CTD dataset was somewhat smaller than ideal for such calibration. Therefore, although the variability seen in profiles had been viewed with concern from the point of view of interpreting the dynamics of the region, it was considerably beneficial to the calibration of SeaSoar salinity, as the presence of several very distinctive signatures in T-S plots made diagnosis and calculation of a constant offset for each of the deployments much more straightforward than it might have been. It should be noted that salinities in CTD data had not been calibrated by the end of the cruise and so the SeaSoar calibration described here should be viewed as provisional. That said, experience with the SeaBird CTD used on the CTD frame suggests that the difference between calibrated and uncalibrated CTD data is likely to be small, particularly as the unit was calibrated just before the cruise.

Survey 1 had a relatively large but stable offset from the CTD stations. For survey 2, there was a smaller (and of opposite sign) but once again constant offset, but this offset changed slightly between deployments when survey 2 was broken by bad weather. Details of offsets are contained in **table 27** below:

Survey	Pstar file number	Offset applied
1	sa381001off	-0.22
Master File:	sa381002off	-0.22
s1bit1off	sa381003off	-0.22
Gridded File: ss1gridnavoff	sa381004off	-0.22
Survey	**Pstar file number**	**Offset applied**
2	sa381005off	+0.06
Master File:	sa381006off	+0.06
s2bit1off	sa381007off	+0.04
Gridded File: ss2gridnavoff	sa381008off	+0.04

Table 27: Calibration salinity offsets for the SeaSoar MiniPack CTD

Salinity Bottle Samples - *Anne Forbes-Brook*

Salinity samples were drawn from the Niskin bottles mounted on the CTD rosette from a selection of depths spanning the salinity range. Samples were taken using 200 mL glass sample bottles that were rinsed three times in the sample water, filled to the shoulder and sealed with a disposable plastic insert and the bottle's own screw cap. Samples were also taken from the ThermoSalinoGraph (TSG) between CTDs and every hour during SeaSoar surveys to calibrate the continual TSG measurements.

The salinometer for on-board salinity determination was sited in the constant temperature lab; a model 8400B Autosal salinometer serial no. 60839 fitted with a peristaltic pump. Once a crate of sample bottles had been filled they were moved into the constant temperature lab to stand for 24 hours prior to analysis. Standardisation was performed using IAPSO Standard Seawater batch P153 before the analysis of each crate. The salinometer operations and the recording of the salinity data were controlled by the NMFSS Autosal 2009 software, version 8.5. This created excel friendly spreadsheets.

The salinometer behaved well throughout the cruise. Problems were encountered with the results in 5 crates which it was determined were operator error. Incorrect use of the suppression switch gave salinity results which were out of the expected range for the sampling area. More training in use of the salinometer was given to the operators.

Thermosalinograph and Surfmet Data -*John Allen, Emma Heslop*

Instruments

Underway surface meteorology and thermosalinograph measurements were recorded by the RVS Surfmet system throughout *Discovery* cruise 381B. The details of the instruments used are given in the earlier computing and instrumentation section, however, the parameters measured were:

- Non-toxic supply
  - Intake water temperature (temp_m)
  - TSG housing water temperature (temp_h)
  - conductivity
  - Fluorescence (Chla)
  - Turbidity (transmissometer)
- Meteorology
  - Seal level pressure
  - Air temperature/humidity
  - Photosynthetically available radiation (PAR) - port/starboard sensors
  - Total Incident Radiation (TIR) - port/starboard sensors
  - Wind speed and direction

Processing

As this was a short cruise, processing of the underway data was undertaken once in the middle of the cruise to check the quality of the instruments conductivity and temperature measurement, through a check on salinity calibration, and then again at the end of the cruise. The processing entailed running a number of PSTAR routines as detailed below.

surfmet0: This script was used to convert the data from RVS format to PSTAR format using datapup. Resultant file was smt381**.raw

surfmet1: This ensured absent Surfmet data values were set to -999. The script also calculated TSG salinity using housing temperature, conductivity and a pressure value set to zero. Laboratory calibration of meteorological variables was applied also at this point. The Surfmet system applies the laboratory temperature sensor calibrations, as given in the earlier technical section, before the data reaches the RVS surfmet stream that we read in with*smtexec0*.

surfmet2: The master Ashtech file and navigation file were merged with smt369** at this point. This allowed accurate heading data to be incorporated into the underway dataset. The data were also averaged to 2 minute values here. This step creates the file smt381**.hdg

surfmet3: This routine computed vessel speed and subtracted it from relative winds to obtain true wind speed and direction. Resultant file was smt381**.met

Temperature calibration

A full inspection of TSG temperature against surface CTD values will be carried out later.

Salinity calibration

Salinity samples were taken from the underway source routinely approximately every hour during much of D381B, somewhat less frequently during D381A. A master Excel file of sample times and corresponding bottle salinities, as described in the previous Salinity Bottle Samples section, was read into PSTAR. The new file was then merged, using *pmerge*, with the existing smt381nn files to directly compare underway salinity (salin) and bottle salinity (botsal) in order to determine and apply a calibration to the underway salinity data. The initial comparisons were very good, suggesting zero offset in salinity. Close inspection of (**Figure 49**) suggests a possible drift in this calibration to TSG low by perhaps 0.0050 by the end of D381B. However, over all data points the mean offset is 0.0046 low with a standard deviation of 0.0105, and therefore to an expected accuracy capability of 0.01 not significantly different to zero offset. No calibration has been applied therefore at this stage.

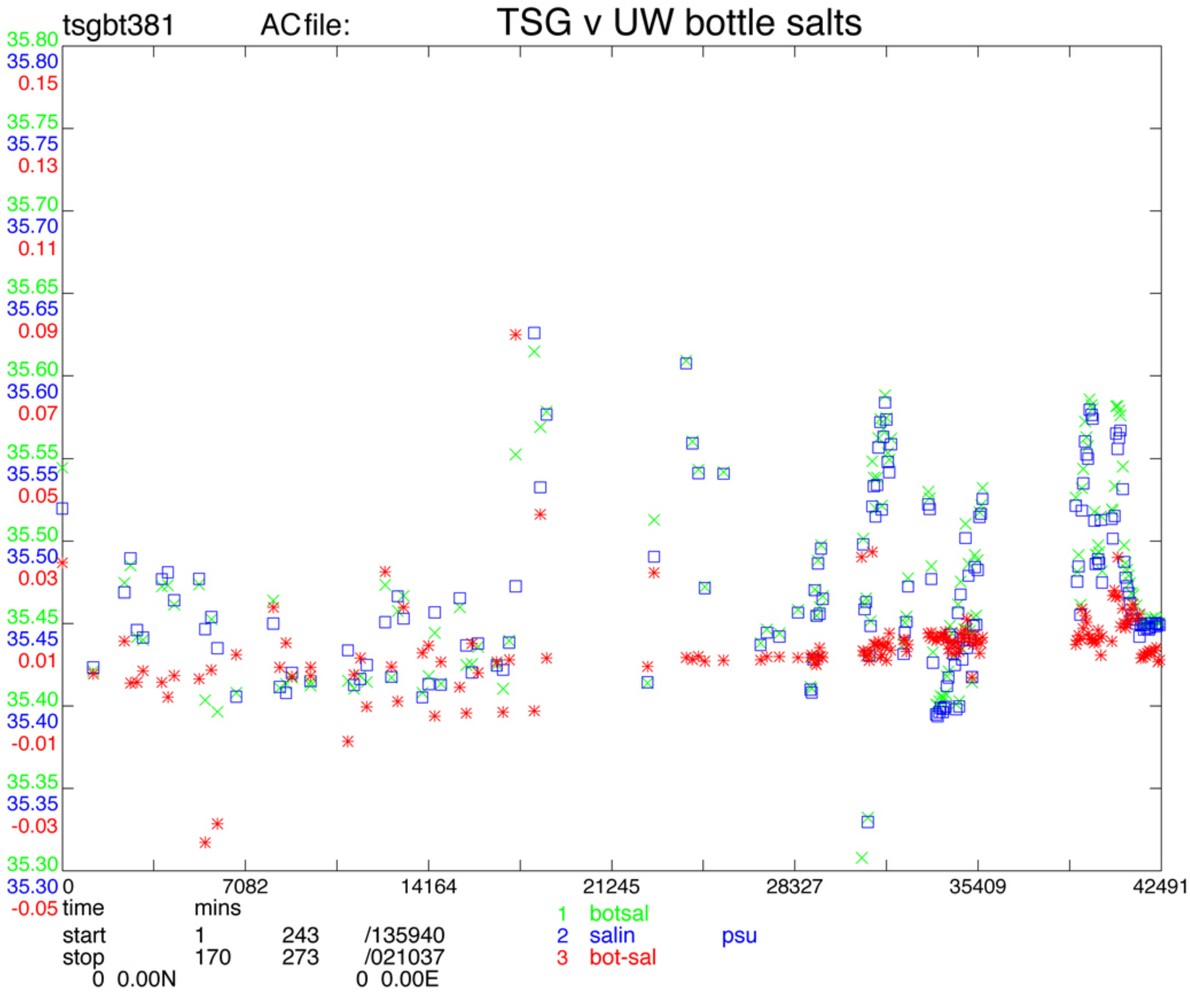

Figure 49: Salinity from TSG and underway bottle samples, TSG-bottle sample value shown in red.

Microstructure Measurements - *Tom Rippeth, Natasha Lucas, Brodie Pearson, Matthew Toberman, Adrian Martin and Tim Boyd*

Objectives

1. To provide profiles of epsilon through the surface mixed layer, seasonal thermocline and transition zone in order to test: (1) the Grant & Belcher Langmuir circulation parameterisation and (2) the hypothesis that inertial shear spikes generated by the alignment of the wind vector with the surface inertial currents leads to enhanced diapcynal mixing.

2. To provide data against which the ADCP structure function-based epsilon time-series and turbulence glider-based epsilon profiles can be tested.

Methodology

The measurements were made using a MSS90 loosely-tetherd microstructure profiler produced by Sea and Sun Technology GmbH and ISW Wassermesstechnik. The profiler is cylindrical in shape with two PNS shear probes and several other sensors, including conductivity, temperature, fast response temperature and pressure. (A back-up profiler, which was available, though not used during the sampling, was also fitted with turbidity and fluorimetry sensors). The shear probes make direct measurements of cross-axial velocity fluctuations using a piezoceramic beam. Data from the sensors are recorded continuously on a PC laptop, connected to the descending profiler via a slack tether and winch system. The profiler has a drop speed of approximately 0.85 ms^{-1}, a compromise which allows profiles to be taken as rapidly as possible whilst minimising noise effects.

The profiler was deployed from a winch mounted on the port aft gunwale and was allowed to fall to a depth of about 200m. The complete profile (ie. recorded descent and unrecorded ascent) took on average of 8 minutes thus producing 7 profiles an hour. During the deployments the ship speed relative to the water was held at 0.3-0.5 knots where possible. This was to avoid the line being drawn back under the ship and thus risking the line becoming entangled in the ship's propeller.

Although complete redundant systems were available on board, the sampling program was conducted in full using winch, motor, and cable supplied by the NOCS contingent, and the profiler and deck unit supplied by the SAMS contingent.

We aimed at obtaining profiles to around 200m thus covering the surface mixed layer, seasonal thermocline and transition layer. In order to do so, the profiler was deployed to a depth of approximately 180m with a few turns of slack cable always visible in the water. When the profiler reached 180 m, the winch operator would be instructed to begin hauling in the tether cable, and the profiler normally reached a depth of around 200 to 230m depending on how much slack cable had been paid out, and vessel speed. Temperature and conductivity sensors allow the mapping of turbulence simultaneously with the upper water column hydrography.

During the course of D381b three time series of profiler measurements were made:

A – 22:35 on 17th September to 11:54 on 19th September (238 profiles).

B – 07:05 on 22nd September to 12.47 on 23rd September (202 profiles).

C – 20:30 on 27th September to 00:05 on 29th September (175 profiles).

Two technical problems occurred during data collection, which resulted in gaps in data collection:

1. The cable failed during time series A due to long-term water ingress and was replaced, resulting in a 5.5 hour gap in the time series.

2. The cable required re-termination during time series B due to a wire snag induced cable split, resulting in a 3.5 hour gap in the time series.

Gaps of approximately 1 hour also occurred during deployments A and C to accommodate CTD profiles, taken to 500 m, predominantly to collect coincident nutrient data to enable calculation of diapcynal nutrient fluxes into the surface mixed layer.

The profiler measurements were conducted along a line between the wave rider buoy (slightly to the north of the main PAP array) and the MET Office EURDAS buoy. The direction of steaming varied according the wind/ wave conditions in order to maintain both the slow speed through the water necessary for profiler deployment and control of the ship.

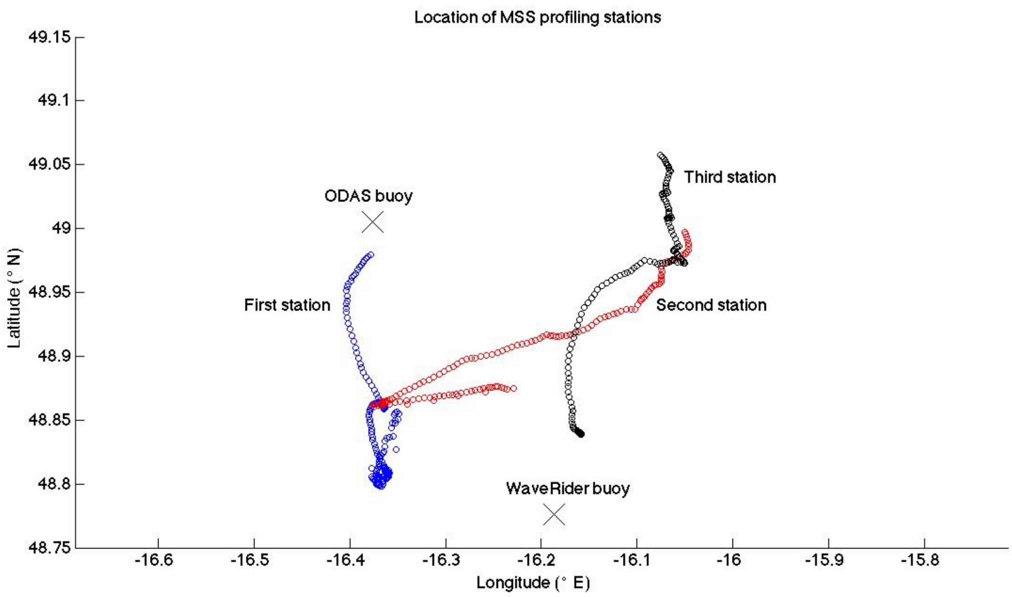

Figure 50: A map showing the locations of the three microstructure surveys

The range of wind and wave conditions sampled are shown in **Figure 51**. Full details of the deployments are given in **Tables 28, 29** and **30**.

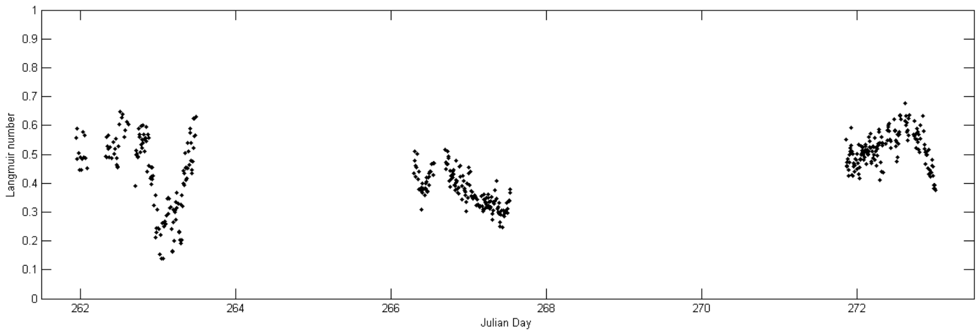

Figure 51: Estimate of Bulk Langmuir number (${L_a}^2 = U_a/U_{s_o}$) based wind measurements and ship based estimates of significant wave height and period.

Date/ day number	Time (GMT)	Profile #	Atmospheric Pressure	Wind	Waves
17/9/12 (day 261)	22.35	D3810012	1020.3 mb	4/5 NNW	3m/ 10.5 secs
		. . . . . .			
18/9/12 (day 262)	00.09	D3810025	1020.3	4/5 N	3m/ 10.5 secs
		. . . .			
	02.45	D3810046	1020.4	4/5	2.5m/ 10 sec
** 5.25 hr break	Cable replacement required.	-	-	-	-
18/9/12 (day 262)	08.00	D3810047	1022.8	4/5 N	2.5m / 10 sec
		. . . ..			
	12.00	D3810078	1024.5	$\frac{3}{4}$ NW	2.2 m/ 9.5 sec
		. . . ...			
	14.52	D3810100	1024.9	$\frac{3}{4}$ N	2.2/ 9.8 sec
** 2 hr break	CTD	PROFILE		-	-
	17.03	D3810101	1025.2	3/4 NNW	2m / 9.5 sec
		. . . . . .			
	20.00	D3810124	1026.4	4 N	1.8m/ 9.4 sec
		. . . . . .			
19/9/12 (day 263)	00.00	D3810157	1027.4	1 variable	2.0m/ 9.8 sec
		. . . . . .			
	08.00	D3810218	1025.7	2/3 SSW	1.4m/ 9 sec
		. . . . . .			
	11.54	D3810250	1025.5	3 SW	1.2m/ 8.9 sec

Table 28: Time series A. Profile numbers and times together with atmospheric pressure, wind forcing (Beaufort scale) and direction, and wave information (significant wave height and zero crossing frequency from ships wave measuring device). Location

Date/ day number	Time (GMT)	Profile #	Atmospheric Pressure	Wind	Waves
22/9/12 (day 266)	07.05	D3810251	1014.5 mb	4 ENE	1.5m/ 7.3 secs
		. . . . . .			
	11.59	D3810289	1013.6	4 NE	1.5m/ 6.7 secs
		. . . .			
	13.19	D3810299	1013.3	4 ENE	1.2m/ 6.7 sec

Continued on next page

Table 29 – *continued from previous page*

Date/ day number	**Time (GMT)**	**Profile #**	**Atmospheric Pressure**	**Wind**	**Waves**
** 3.5 hr break	Cable snag, re-termination required.	-		-	-
	16.50	D3810300	1011.3	4 NE	1.4m/ 6.8 sec
		....			
	19.59	D3810322	1010.7	4 NNE	1.5m/ 6.3 sec
		....			
23/9/12 (day 267)	00.04	D3810356	1009.6	5 NNE	1.6m/ 6.5 sec
		....			
	03.58	D3810386	1007.2	4 N	2.2m/ 7.8 sec
		....			
	08.01	D3810416	1007.1	5/6 N	2.9m/ 7.5 sec
		......			
	12.47	D3810453	1006.5	5/6 NW	2.8/ 8.45 sec

Table 29: Time series B. Profile numbers and times together with atmospheric pressure, wind forcing (Beaufort scale) and direction, and wave information (significant wave height and zero crossing frequency from ships wave measuring device). Location

Date/ day number	**Time (GMT)**	**Profile #**	**Atmospheric Pressure**	**Wind**	**Waves**
27/9/12 (day 271)	20.30	D3810454	1016 mb	4/5 NW	1.8m/ 8.0 secs
		......			
	23.58	D3810482	1016.5	4 N	1.6m/7.4 secs
		....			
28/9/12 (day 272)	03.59	D3810511	1016.6	4 NW	1.2m/ 6.7 sec
		....			
	08.01	D3810540	1018.2	4 NNW	1.4/ 7.6 sec
50 minute break	CTD Profile				
	08.51	D3810541	1018.4	4 WNW	1.3/ 7.6 sec
		....			
	10.20	D3810553	1019.5	4 WNW	1.4m/ 7.4 sec

Continued on next page

Table 30 – *continued from previous page*

Date/ day number	Time (GMT)	Profile #	Atmospheric Pressure	Wind	Waves
1 hr break	CTD Profile				
	11.23	D3810554	1019.9	4 NW	1.2/ 7.5 sec
		……			
	12.02	D3810559	1019.7	4 NW	1.3/ 7.4 sec
		…….			
	13.23	D3810569	1020.3	5 NW	1.3/ 7.3 sec
1 hr 20min break	CTD Profile				
	14.39	D3810570	1020.1	5 NW	1.3/ 7.4 sec
		…….			
	16.00	D3810580	1020.5	5 NW	1.4m/ 7.7 sec
1 hr 15min break	CTD Profile				
	17.25	D3810582	1020.9	4 NW	1.6m/ 8 sec
		…….			
	20.15	D3810598	1022.4	4 NW	1.8m/ 9.1 sec
		…….			
29/9/2012 (day 273)	00.05	D3810629	1023.5	3 NW	2.1m/ 9 sec

Table 30: Time series C. Profile numbers and times together with atmospheric pressure, wind forcing (Beaufort scale) and direction, and wave information (significant wave height and zero crossing frequency from ships wave measuring device). Location

Profiler Details

The SAMS profiler was used throughout, MSS001. The profiler was equipped with the following sensors:

- 2 velocity microstructure shear sensors (Shear 1 – D016 and Shear 2 – D015)
- a microstructure temperature sensor (NTC)
- standard CTD sensors for precision measurements (PRESS, TEMP, COND)
- a two component tilt sensor (TILTX, TILTY) and surface detection sensor (SD)

Two shear sensors are fitted on the MSS profilers to provide both duplicate measurements, and provide a comparison in case of failure of a sensor (mode of failure is generally a lack of sensitivity).

Shear sensor calibration coefficients:

D016: $a_0 = 4.792608 \times 10^{-3}$; $a_1 = 9.585226 \times 10^{-3}$
D015: $a_0 = 6.105107 \times 10^{-3}$; $a_1 = 1.221023 \times 10^{-2}$

Data was processed from raw shear signals through to TKE dissipation rate (ε) using the MSSPRO software standard processing sequence (e.g. Venables, 2011).

Examples of Data

Examples of data collected from time series A are shown below. They are the half mixed layer depth values of the rate of dissipation of turbulent kinetic energy (**Figure 52**), the mean thermocline dissipation (**Figure 53**) and the mean dissipation in the lower part of the water column (**Figure 54**) covered by the observations.

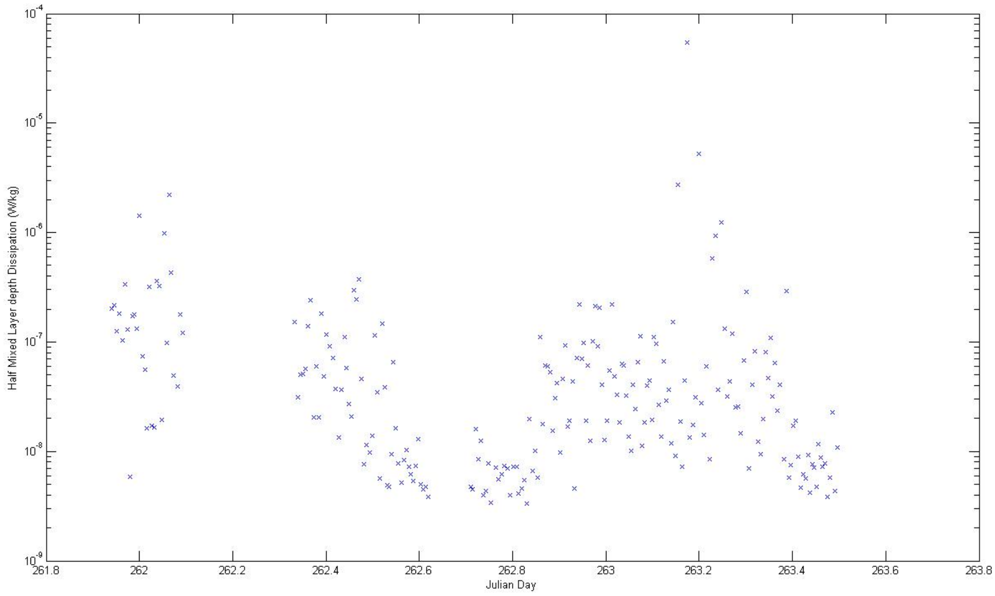

Figure 52: Time series of the rate of dissipation of turbulent kinetic energy (ε) in the middle of the surface mixed layer from deployment A

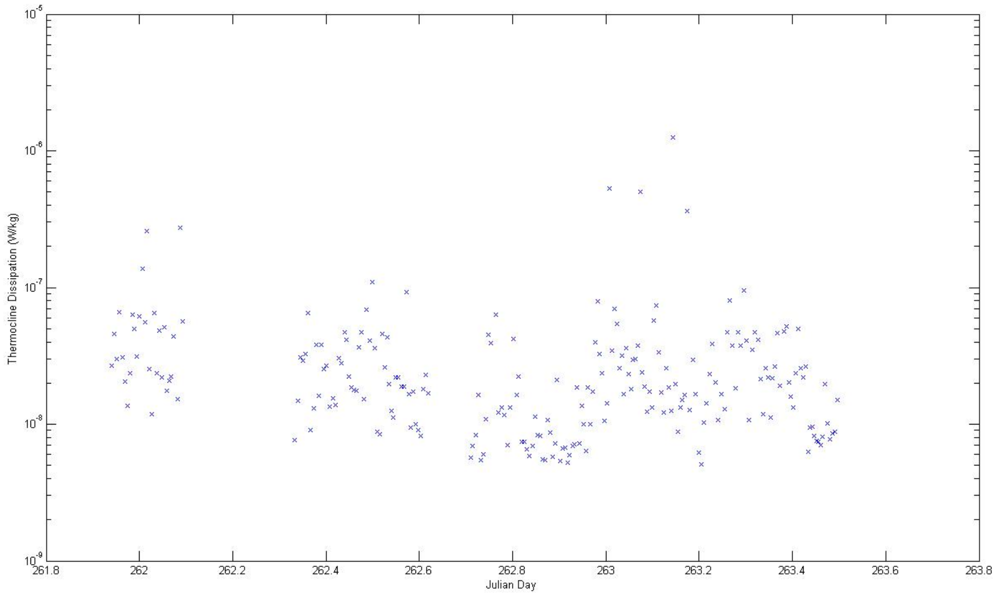

Figure 53: Time series of mean rate of dissipation over the seasonal thermocline from deployment B.

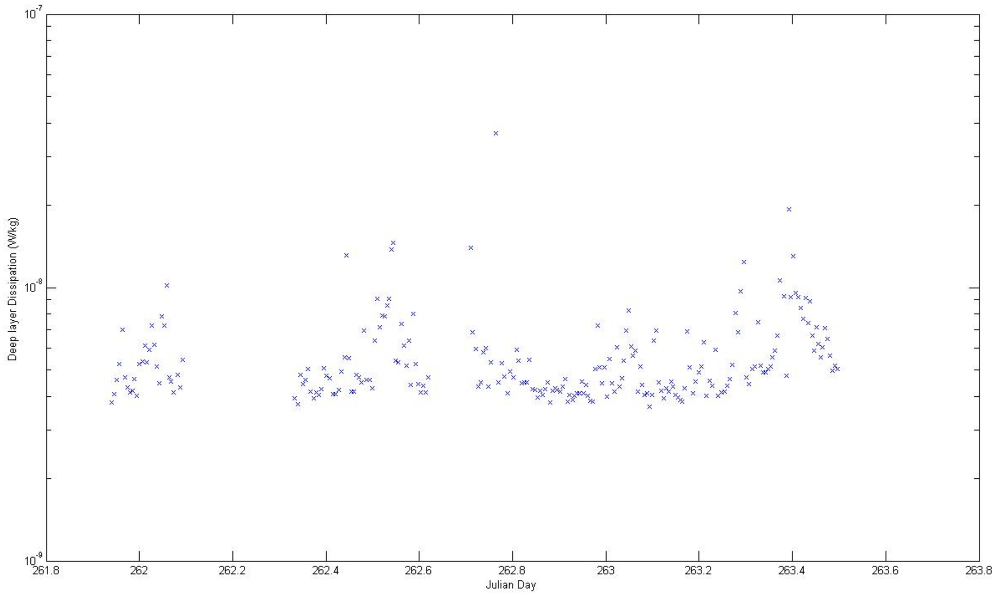

Figure 54: Time series mean dissipation between 200m and the bottom of the thermocline.

Dissolved Oxygen Concentration - *Stuart Painter, Danielle Waters, Ben Barton, Victoria Hemsley*

Dissolved oxygen concentrations were determined using the Winkler whole bottle titration method to provide accurate measurements of in-situ dissolved oxygen concentrations for calibration of the oxygen sensor deployed on the CTD, on the Seagliders deployed during the first leg, and on Seasoar which was deployed on the second leg of the cruise.

All seawater samples were drawn through short pieces of silicone tubing from CTD Niskin bottles into clear, pre-calibrated borosilicate glass bottles (approx 100 ml in volume). The temperature of each sample was measured with a handheld digital thermometer prior to the addition of 1 ml manganous chloride and 1 ml of alkaline iodide (reagents made following Dickson 1994). Glass stoppers were then inserted taking care to avoid bubbles and/or headspaces in each bottle and the bottle was shaken vigorously for 30 seconds. Typically 12 niskin bottles were sampled in duplicate from every CTD cast (**Table 32 & 33**). Samples were left for 1 hour before being shaken again and then analysed 1 hour later.

Analysis of all samples used the Winkler whole bottle titration method with spectrophotometric end-point and started with the addition of 1 ml of dilute sulphuric acid (280 ml concentrated H_2SO_4 made up to 1 L with Milli-Q water) to each sample bottle. A small magnetic stirrer bar was added to each bottle to facilitate the dissolution of the precipitate, which was aided by placing each bottle onto a magnetic stirring plate. Each bottle was titrated with sodium thiosulphate until clear. The titration volume (ml) was recorded and used with the initial fixing temperature in the calculations of Dickson (1994) to calculate the dissolved oxygen concentration.

One batch of sodium thiosulphate was made up during the cruise (50 g L^{-1}) and was tested every 3-4 days for stability. This was achieved by titrating the sodium thiosulphate against 1 ml and 10 ml of certified potassium iodate standard. The mean volume of thiosulphate required to titrate the iodate standard was then used in the calculation of dissolved oxygen concentration for all samples collected on that day. Thiosulphate stability during the cruise was generally acceptable but what be are believed to age related trends could be seen.

For each CTD cast replicates were taken from each sampled niskin. Replicate reproducibility was generally to within $\pm$ 0.5 μmol L^{-1}, but in some cases reproducibility was noticeably poorer.

Calibration

Date	Average Blank (ml)	Average Standard (ml)	Standard – Blank (ml)
8/27/2012	0.0011	0.5733	0.5722
8/31/2012	0.0031	0.5637	0.5605
9/4/2012	0.0018	0.5728	0.5711
9/9/2012	0.0026	0.5627	0.5601
9/14/2012	0.0011	0.5665	0.5654
9/18/2012	0.0029	0.5742	0.5713
9/25/2012	0.0028	0.5745	0.5717

Table 31: Thiosulphate calibration statistics.

CTD Cast	Niskin bottles sampled	Depth range (m)	Notes
1	1, 2, 5, 6, 9, 11, 13, 15, 17, 19, 21, 23	0-4800	PAP site
2	4, 6, 8, 10, 12, 13, 16, 17, 20, 22, 24	0-1000	PAP site
3	1, 3, 5, 7, 9, 11, 13, 17, 19, 21, 23	0-4800	PAP site. Results from Niskin 3 indicate bottle closed between 50 and 25 m and not at 3500
4	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23	0-4800	PAP site

Table 32: CTD casts sampled during Leg 1.

CTD Cast	Niskin bottles sampled	Depth range (m)	Location
5	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23	0-840	Shelf edge
6	1, 3, 5, 7, 9, 11, 13, 15, 17, 19	0-1000	PAP site
7	1, 3, 5, 7	0-1000	PAP site
8	1, 3, 4, 5, 6, 7, 8, 13, 17	0-500	PAP site
9	1, 3, 5, 7, 9, 11, 15, 17, 19, 21, 23	0-1000	PAP site
10	1, 5, 7, 9, 11, 13, 15, 17, 19, 21	0-500	PAP site

Continued on next page

Table 33 – *continued from previous page*

CTD Cast	Niskin bottles sampled	Depth range (m)	Location
11	1, 5, 9, 15	0-500	PAP site
14	1, 5, 10, 14, 20, 21	0-200	PAP site
15	1, 2, 4, 5, 10, 15, 20	0-500	PAP site
16	1, 3, 4, 5, 15, 18	0-500	PAP site
17	1, 2, 3, 4, 11, 18, 21	0-500	PAP site
18	1, 2, 4, 5, 10, 16, 22	0-500	PAP site
19	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23	0-500	PAP site
20	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23	0-500	PAP site
21	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23	0-500	PAP site

Table 33: CTD casts sampled during Leg 2.

Problems

Few problems were encountered during the cruise though the rather poor reproducibility of replicate samples suggests that operator procedures need to be improved. The limited number of sampling opportunities during leg D381a and the absence of people to process the CTD data on board meant that the usefulness of the oxygen data for calibration purposes was not investigated until late in the second leg.

Results

Provisional results from all CTD casts are shown in **Figure 55**. No calibration of the CTD oxygen sensor was attempted onboard and this will have to be undertaken post-cruise.

Inorganic Nutrients -*Stuart Painter, Danielle Waters, Ben Barton, Victoria Hemsley*

During leg one (Aug 28th to Sept 13th) and leg two (Sept 14th to Oct 3rd) of the D381 “OSMOSIS” cruise, sampling for inorganic nutrient concentrations was undertaken from both CTD casts and the underway non-toxic seawater supply. For technical reasons (*i.e.* the need to test acoustic releases) only a limited number of bottles could be fired on the CTD casts made during leg 1 of the cruise which reduced the number of available bottles to 12 on an individual cast (the extra weight of the acoustic releases necessitated closing fewer bottles). Regrettably this reduced the sampling resolution available to us for these full depth CTD casts. The underway system was typically sampled with a 4 hourly resolution in conjunction with other sampling requirements but this was increased to hourly sampling during the SeaSoar surveys and turbulence profiling work.

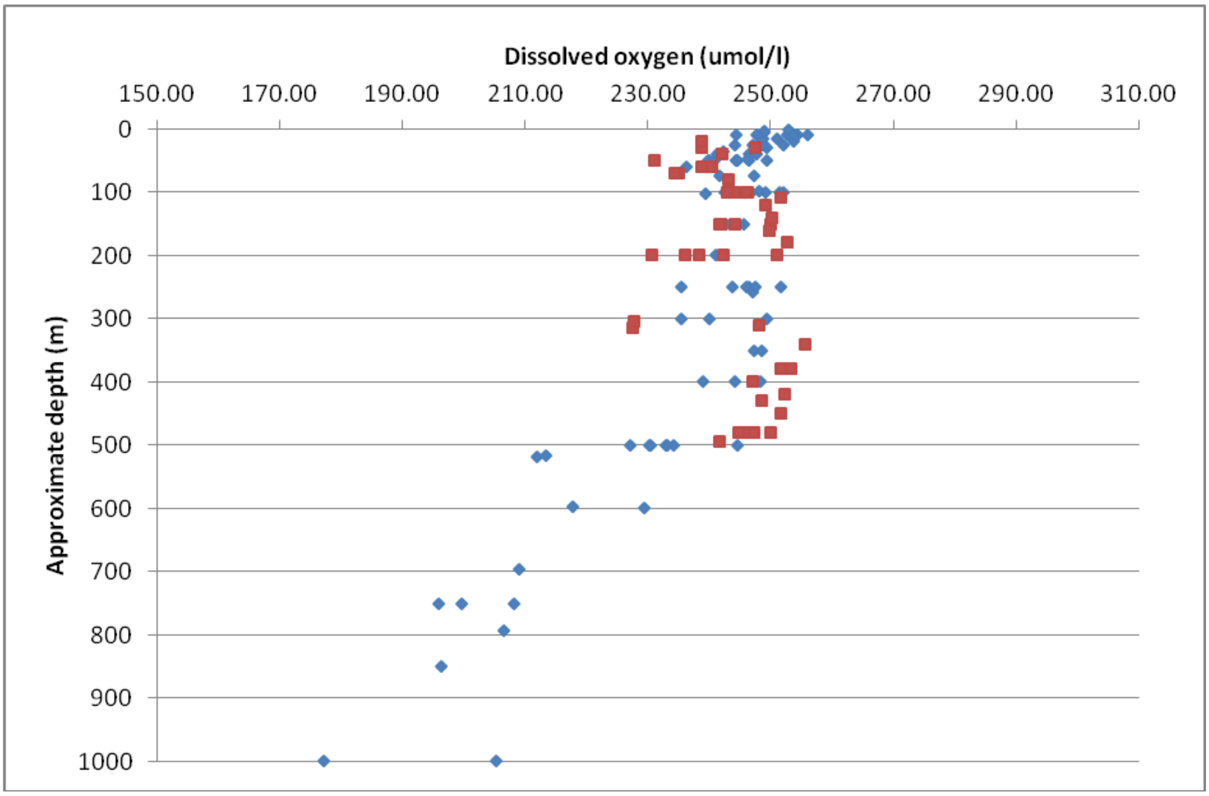

Figure 55: Profile of dissolved oxygen concentration based upon data compiled from all CTD casts (blue 1st leg, red 2nd leg). Note that sampling depths are approximate only and do not reflect actual sampling depths which will be obtained from the CTD rosette data files in due course.

Analysis for micro-molar concentrations of nitrate and nitrite (hereafter nitrate), phosphate and silicate was undertaken on a scalar sanplus autoanalyser following methods described by Kirkwood (1996). Samples were drawn from niskin bottles on the CTD and from the underway supply into 25 ml sterilin polycarbonate vials and kept refrigerated at approximately 4°C until analysis, which commenced within 12 hours. Data processing was undertaken using Skalar proprietary software and was done once each run had finished. Where necessary manual correction for the software mis-identification of peaks was performed. The wash time and sample time were 90 seconds and the lines were washed daily with 10% Decon solution and flushed with milli-Q water. All runs were preceded with standards which were used for calibration.

Date	**CTD cast**	**Niskin bottles sampled**	**Notes**
1/9/12	1	1, 2, 5, 6, 9, 11, 13, 15, 17, 19, 21, 23	Full depth cast ~4800 m, Bottle 11 leaked
2/9/12	2	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24	Shallow 1000 m cast
4/9/12	3	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23	Full depth cast ~4800 m, bottle 3 leaked
6/9/12	4	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23	Full depth cast ~4800 m
15/9/12	5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24	Shallow cast (150 m) on shelf, bottle 14 leaked
17/9/12	6	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20	bottles 6, 7 leaked
17/9/12	7	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	
18/9/12	8	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24	bottles 2, 3, 16 leaked
19/9/12	9	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24	bottles 6, 13, 14, 16, 24 leaked
21/9/12	10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24	bottles 3, 14, 18 leaked
21/9/12	11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24	bottles 18, 23 leaked
22/9/12	12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24	bottles 3, 18, 20 leaked

Continued on next page

Table 34 – *continued from previous page*

Date	CTD cast	Niskin bottles sampled	Notes
28/9/12	14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24	Bottle 12 leaked, bottle 11 did not close
28/9/12	15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24	
28/9/12	16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20, 21, 22, 23, 24	Bottle 12 leaked, bottle 19 did not close
28/9/12	17	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24	Bottle 10 did not close
29/9/12	18	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24	Bottle 15 looks suspect
29/9/12	19	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24	
29/9/12	20	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24	
30/9/12	21	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24	

Table 34: Summary list of CTD casts and Niskin bottles sampled.

Problems

A number of problems were encountered during the cruise to which satisfactory conclusions were not always found. These problems can be grouped as 1) Lack of instrument sensitivity, 2) Software and/or hardware failures and 3) Possible reagent contamination.

Instrument sensitivity

During a typical year, the water column at the PAP site in September is stratified and will have been for a number of months which results in very low nutrient concentrations in the shallow mixed layer. 2012 was no exception and against this general background our attempts to map the distribution of nutrients in the mixed layer from samples collected from the underway system were frequently thwarted by the relatively low sensitivity of the autoanalyser (detection limit of 0.1-0.2 mmol L^{-1}. In a general sense this is not a problem that can be resolved with existing instrumentation (or corrected for within the data) as this detection limit is widely recognised for such analytical instrumentation. However, it is also widely recognised that improved analytical instrumentation with greater levels of detection and sensitivity do provide enormous benefits to studying biological systems under conditions of nutrient limitation and oligotrophy. Therefore whilst we were unfortunate to find ourselves struggling with the limits of analytical detection during this cruise, future studies of the late summer mixed layer biological community at the PAP site must consider the provision of nutrient systems with nanomolar levels of detection if they are to successfully understand the variability observed in other key parameters.

Software and/or hardware failures

Despite considerable prior investigation, a number of potential solutions and the absence of similar problems on other recent cruise a recurring bug in the software operating the autoanalyser that causes the system to freeze was encountered towards the latter half of the second leg. As with previous instances of this problem the software methodology needed to be entirely rebuilt from scratch to remove the problem which resulted in a day's downtime. Fortunately the workload at the time was light such that the impact was minimal. This is a particular devious problem that appears to be related to the software operating the autoanalyser and despite regular contact with the manufacturer a permanent solution is outstanding.

Hardware problems were also encountered when the sampler started to exhibit unusual behaviour, such as stopping during a sample run, moving unexpectedly when it should not (as there is a large syringe needle attached to the sampler this random and unpredictable movement is worrying), and beeping at irregular periods. Similar problems have been encountered before and the solution is to send the unit for servicing by the manufacturer. Given the age of the system (12 years) and the software problems noted above investment in new autoanlyser capabilities would be advantageous.

Possible reagent contamination

During the initial setup for this cruise 50 litres of Milli-Q water was carried onto the ship from the NOC and used to make up initial reagent solutions and the artificial seawater solution. It soon became clear however that the NOC Milli-Q water or the carbuoys used to transport it were contaminated with silicate producing questionable results from our initial run of standards. This problem was resolved by remaking all reagents and artificial seawaters using Milli-Q water produced onboard *Discovery*. Whilst this gave improved results it was not until we had left Southampton that a possible reoccurrence of this silicate contamination was noted. For the preliminary nutrient dataset from this cruise we are unable to report any silicate concentrations within the surface mixed layer and for some particular CTD casts we are unable to report any measureable silicate in the upper 75 m of the water column! Whilst this may not be unexpected given the time of year there remains a suspicion that the sodium chloride salt used to create the artificial seawater matrix is contaminated with silicate resulting in an artificially high baseline value. As all surface nutrient samples appear to produce baseline readings below the baseline of the autoanalyser system we are unable to report any reliable silicate concentrations for the mixed layer (however concentrations of silicate and phosphate are also difficult due to the low nutrient concentrations). Confirmation of this contamination will be obtained after return to NOC where additional analyses of frozen nutrient samples will be undertaken.

Results

The final nutrient dataset will be produced in due course following post-cruise analysis of the data. Provisional results suggest that following the storm of Sept 24th/25th a pulse of nutrients was observed entering the surface mixed layer (**Figure 56**).

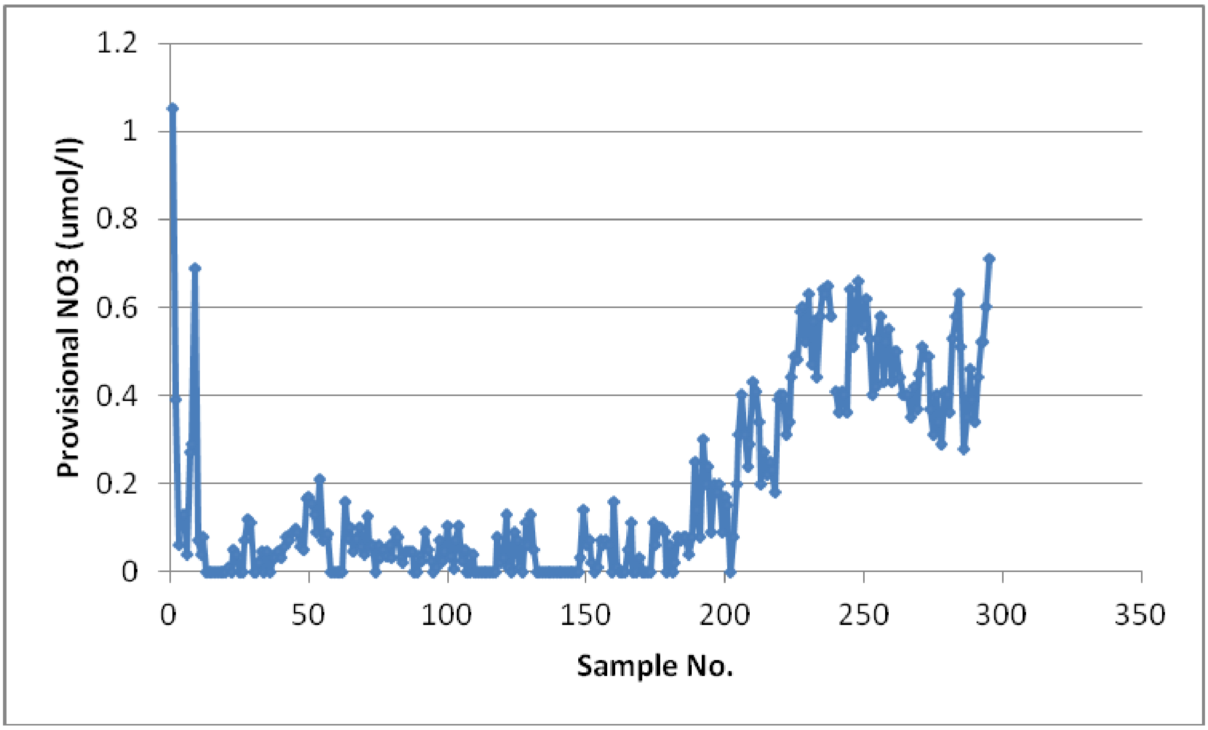

Figure 56: Provisional underway nitrate data. Note the rapid increase in surface nitrate concentrations occurring from sample 180 onwards which coincided with a period of bad weather

Chlorophyll-a, Particulate Organic Carbon/ Nitrogen (POC/PON), High Performance Liquid Chromatography (HPLC), Coccolithophores (Scanning Electron Microscope), Particulate Inorganic Carbon (PIC) and Biogenic Silica (BSi) - *Danielle Waters, Ben Barton, Victoria Hemsle, Stuart Painter*

Hypotheses

1. Autumn blooms in phytoplankton occur around the Porcupine Abyssal Plain site during September.

2. Mesoscale eddies and turbulence cause mesoscale distribution of phytoplankton.

Methods

To address these hypotheses, CTD casts were carried out intermittently during the 1st leg of the D381 cruise, primarily when gliders needed to be calibrated or acoustic releases needed to be tested. The CTD casts ranged in depths from around 4800m to 1000m depths – only the surface Niskin bottles (100m depth or less) were sampled for chlorophyll-a, POC/N, HPLC, PIC, BSi and SEM. During the 2nd leg, CTD casts were carried at intersections of the SeaSoar survey, when gliders needed to be calibrated and at 2-hourly intervals during turbulence profiling on day 272. We additionally sampled from the underway non-toxic supply to ensure greater surface resolution. The underway samples for POC/N, HPLC, PIC, BSi and SEM were taken at 4 hourly intervals starting at 0800BST and ending at 2000BST in the 1st leg and 0800GMT to 2000GMT during the 2nd leg starting from day 260 when the clocks on ship changed. Underway samples were not taken whilst CTD casts were in progress. From day 263 to day 274 we took additional underway samples for chlorophyll, nutrients and salinity every hour. In the 1st leg, there were 4 CTD casts and 54 underway samples taken for each parameter and during the 2nd leg there were 17 samples CTD casts and 245 underway samples. Details of times and positions of the CTD casts can be found in **Table 25**.

Chlorophyll-a

Chlorophyll-a samples were taken from Niskin bottles which were fired at depths between 100m and the surface. 298 samples were also collected from the underway supply. 250ml of seawater were filtered on GF/F filters on a filtration rig. The filters were then placed in 6ml of 90% acetone and left for 16-24 hours at 4°C in darkness. The fluorescence of each sample was then measured using a Turner Trilogy fluorometer. The fluorometer was initially calibrated by measuring the fluorescence of the 4 sides of a solid standard followed by measuring the fluorescence of a blank (fresh 90% acetone). Each sample was then poured into a test tube and the fluorescence was recorded.

HPLC

HPLC samples were taken from both the near-surface CTD Niskin bottles and the underway system. 2L of seawater was added to the filtration rig and the sample was filtered through a GF/F filter. Due to salp patches or the filters becoming clogged, sometimes not all the seawater filtered through. The filters were then put into cryogenic vials and immediately placed into a freezer set at -80°C. Analysis of these samples will be carried out in the NOC lab in due course.

POC/PON

POC/PON samples were taken from both the near-surface CTD casts and the underway system. Between 0.5-1L of seawater were taken and filtered through pre-ashed (at 450°C for over 6 hours) GF/F filters. Due to the filters becoming clogged, sometimes not all the seawater filtered through. A small amount of 2% hydrochloric acid was added and run through the filter once the seawater had finished. The filters were then placed in Petri-dishes and stored in a freezer set at -20°C. Analysis of these samples will be carried out in the lab at NOC in due course.

SEM

The samples that were taken to be analysed by the Scanning Electron Microscope were taken from both the underway system and CTD casts at depths from 100 m to 10 m. Between 0.24L and 1L of seawater was filtered through 0.8 µm cyclopore track etched membrane filters with a low vacuum. An analytical grade solution of 90 ml of ammonium to 500 ml of milli-Q was applied to the filters to rinse salt from them and they were then dried at 40 °C in an oven on a petrislides. The slides were then put in a plastic bag and stored in a cool dry place.

PIC

PIC samples were taken from the underway system and CTD from depths between 100 m and 10 m. As with SEM between 0.24L and 1L of seawater was filtered through 0.8 µm cyclopore track etched membrane filters with a low vacuum. An analytical grade solution of 90 ml of ammonium to 500 ml of milli-Q was used to rinse the filters of salt before they were dried in an oven at 40 °C in Eppendorf plastic vials. The vials were then stored in a cool dry place.

BSi

The samples for BSi were taken for both the underway system and the CTD depths between 100 m and 10 m. A seawater sample between 0.24L and 1L were filtered through 8 µm nuclepore track-etch membrane filters with a constant low vacuum. The filters were then put in Falcon tubes and dried in a 40 °C oven. The tubes were then stored in a cool dry place ready for analysis back at the lab at NOC.

Station No.	**Lat.**	**Long.**	Chl-a	HPLC	POC/PON	SEM	PIC	BSi	**Comments**
381001	48° 38.219N	016° 16.456W	X	X	X	X	X	X	3 depths at 100, 50 and 10m
381002	48° 45.812N	016° 05.840W	X	X	X	X	X	X	5 depths at 10m intervals in the top 50m
381003	48° 41.812N	016° 07.157W	X	X	X	X	X	X	4 depths at 118m, 58, 17 and 10m
381004	48° 41.927N	016° 20.598W	X	X	X	X	X	X	4 depths at 100, 50, 25 and 10m
381005	48° 08.9N	009° 42.5W	X	X	X	X	X	X	5 depths at 50, 25, 15, 10 and 0m
381006	48° 34.346N	016° 03.918W	X	X	X	X	X	X	5 depths at 50, 35, 25, 15 and 5m

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Table 35 – *continued from previous page*

Station No.	**Lat.**	**Long.**	CHL-A	HPLC	POC/ PON	SEM	PIC	BSI	**Comments**
381007	48° 46.764N	016° 22.109W	X	X	X	X	X	X	5 depths at 50, 35, 25, 15 and 5m
381008	48° 48.447N	016° 21.655W	X	X	X	X	X	X	6 depths at 50, 40, 30, 20, 10 and 0m
381009	48° 59.200N	016° 24.424W	X	X	X	X	X	X	5 depths at 50, 35, 25, 10 and 0m
381010	48° 17.054N	016° 51.057W	X	X	X	X	X	X	5 depths at 50, 40, 26, 10 and 4m
381011	48° 24.222N	016° 41.038W	X						5 depths at 50, 40, 25, 10 and 4m
381012	48° 31.242N	016° 31.205W	X	X	X	X	X	X	5 depths at 50, 40, 25, 10 and 0m
381013	48° 37.828N	016° 22.004W	X	X	X	X	X	X	5 depths at 50, 40, 30, 20 and 10m
381014	48° 58.522N	016° 05.438W	X		X				6 depths at 60, 50, 40, 30, 20 and 10m
381015	48° 59.559N	016° 03.773W	X	X	X	X	X	X	6 depths at 70, 50, 40, 30, 20 and 10m
381016	48° 56.9N	016° 03.67W	X	X	X	X	X	X	6 depths at 60, 50, 40, 30, 20 and 10m
381017	49° 00.49N	016° 04.12W							Test run so no samples collected
381018	49° 03.585N	016° 04.684W	X	X	X	X	X	X	6 depths at 60, 50, 40, 30, 20 and 10m
381019	49° 05.069N	016° 28.307W	X	X	X	X	X	X	6 depths at 60, 50, 40, 30, 20 and 10m

Continued on next page

Table 35 – *continued from previous page*

Station No.	Lat.	Long.	Chl-a	HPLC	POC/PON	SEM	PIC	BSi	Comments
381020	49° 05.838N	016° 39.886W	X	X	X	X	X	X	6 depths at 60, 50, 40, 30, 20 and 10m
381021	48° 11.387N	015° 30.022W	X	X	X	X	X	X	6 depths at 60, 50, 40, 30, 20 and 10m

Table 35: CTD stations, positions of when the CTD was at the bottom and the samples taken from the Niskin bottles.

Satellite Images - *Liam Brannigan*

Introduction

The OSMOSIS cruise was supplied with remote sensing images on a daily basis by NEO-DAAS in Plymouth. These images were observations of sea surface temperature (SST), true colour, chlorophyll and sea surface height (SSH). The observations covered a range of periods, with some the product of a single pass by a satellite while others were single or multi-day composites.

The images were made available on a restricted ftp server:

- ftp://neodaas15:paiPie3jie@ftp.rsg.pml.ac.uk/

Only a portion of the images made available were downloaded on the cruise. This was due to bandwidth constraints, limited periods of internet connectivity and cloud cover obscuring the images during the periods in question. One consistent issue we faced was that we were unable to adjust the colour scale on images and so their utility was on occasion hampered by an inability to focus in on features of interest.

Sea surface temperature

The SST data were derived from the AVHRR radiometer. This provides multiple daily passes over the target region. These were available to download separately or as a daily- or weekly-composite. The daily composite was typically downloaded if there had been cloud-free periods on the day covered by the image.

An example of the data which this satellite can provide is shown in **Figure 57** below with a red box added onboard to outline the overall PAP region.

Ocean colour

The ocean colour data was derived from the VIIRS remote sensor. The features of interest on the cruise were not very apparent from this data, and so it was only downloaded

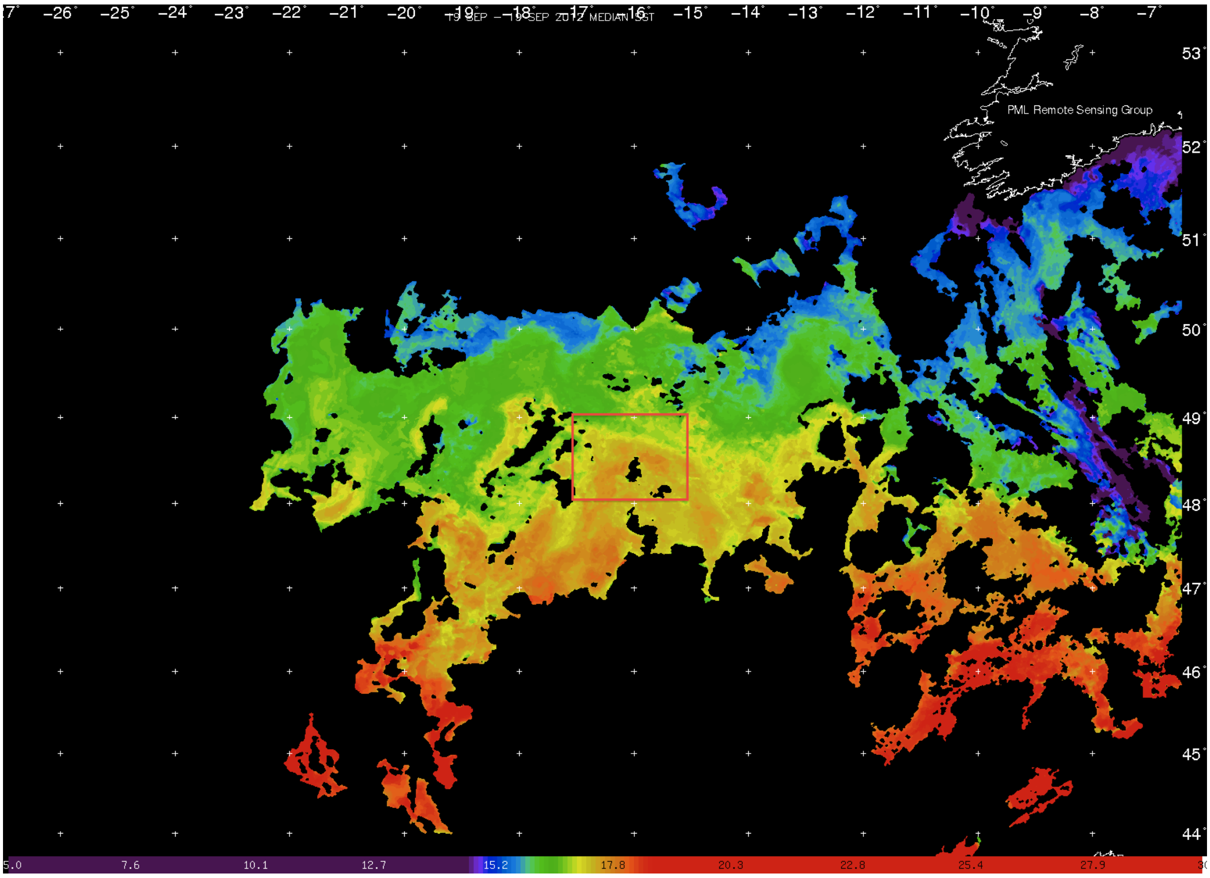

Figure 57: AVHRR daily composite for 19th September 2012. Note that the colour scale has a focus applied between 15.2 degrees and 17.0 degrees C. The red box has been added onboard and runs from 48 to 49 degrees N and -17 to -15 degrees E. The box highlights the strong temperature fronts in the region. Ireland can be seen to the upper right of the image, the remaining black areas are cloud-covered.

occasionally. An example of the data which this satellite can provide is shown in **Figure 58**.

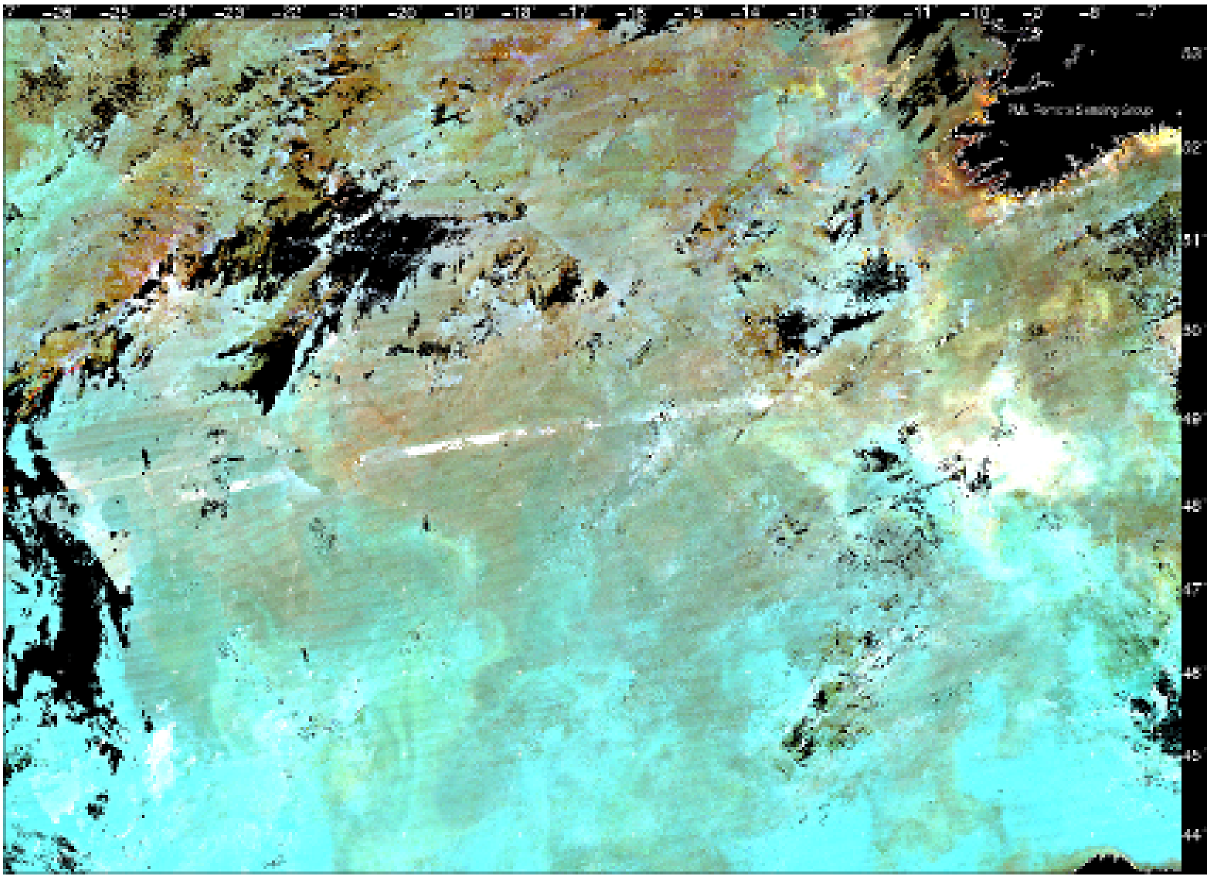

Figure 58: VIIRS ocean colour seven-day composite for 30th August to 5th September 2012. Ireland can be seen to the upper right of the image, the remaining black areas are cloud-covered.

Chlorophyll

Chlorophyll data were available from two sources: MODIS and VIIRS. The NEODASS site notes that MODIS has become unreliable in recent months, and so it should be used for indication only. The VIIRS images also displayed some banded patterns (e.g. at 53 degrees N, 16 degrees W in **Figure 59**), so these should also be used with caution.

Sea surface height

The sea surface height images were based on AVISO Global MSLA Merged Product which is a gridded composite of the currently operational altimeters. These combined sensors have a 10-day repeat cycle, meaning every image is a 10-day composite. A selection of SSH images is shown in **Figure 60**.

The SSH images revealed the site was on the northern edge of an anti-cyclonic eddy during the cruise. This likely accounts for the drift to the south-east of the gliders after

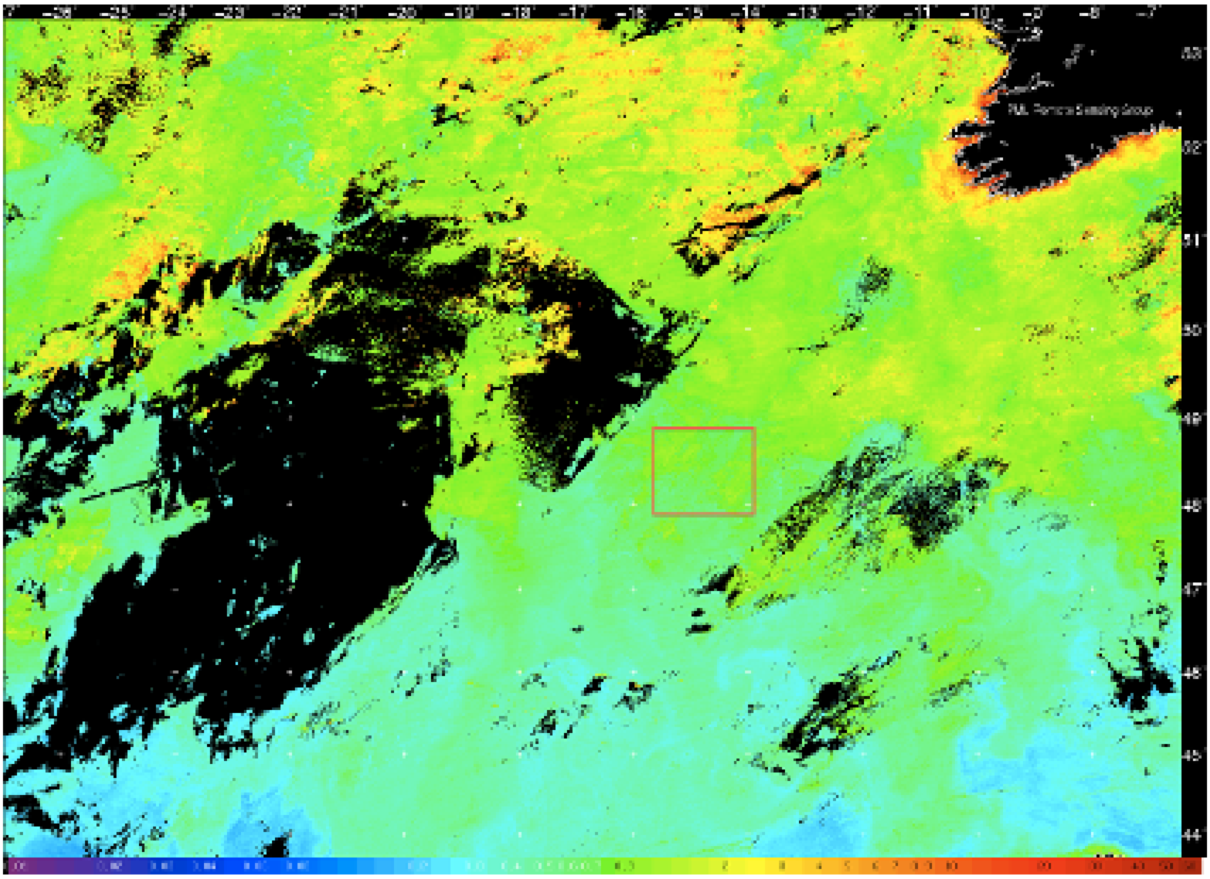

Figure 59: VIIRS Chlorophyll seven-day composite for 30th August to 5th September 2012. Ireland can be seen to the upper right of the image, the remaining black areas are cloud-covered. The colour scale is in X

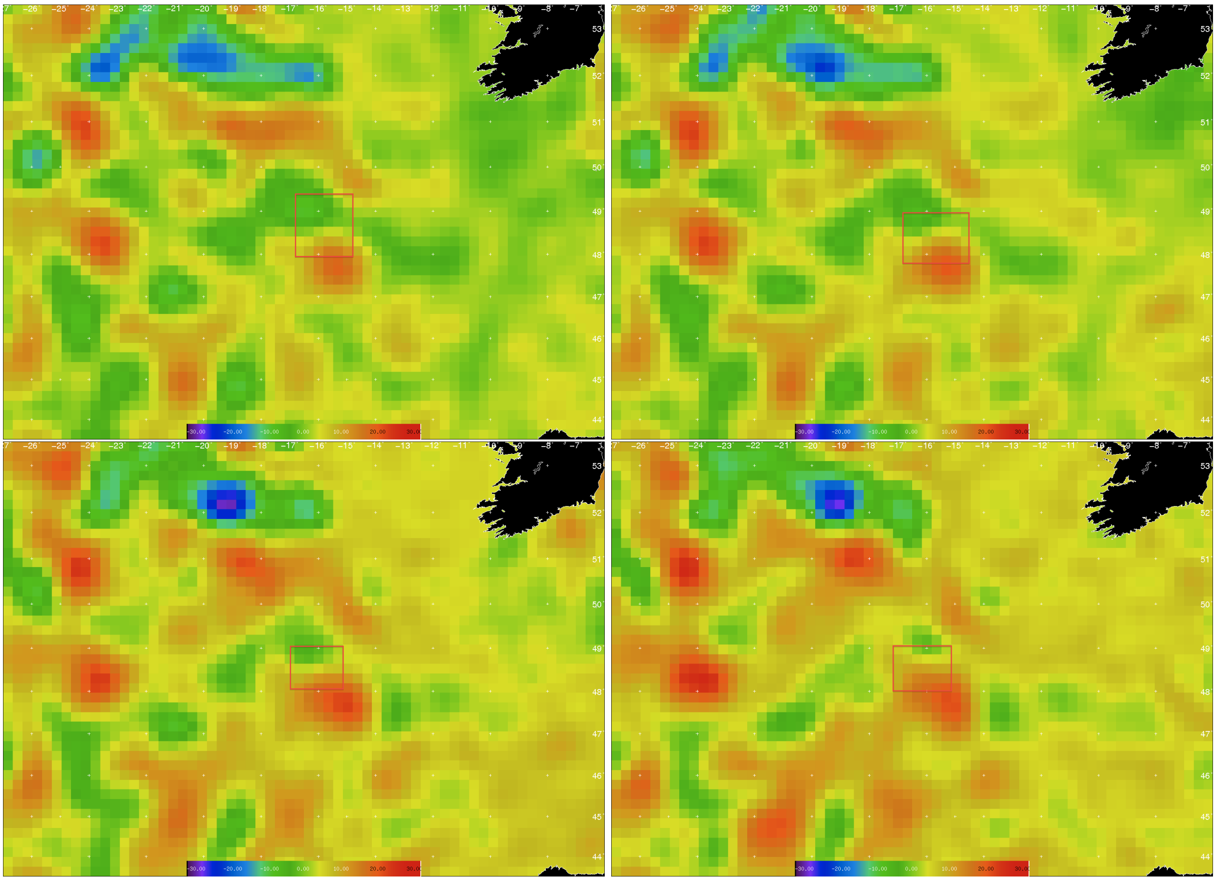

Figure 60: Examples of the sea surface height data on (left to right, top to bottom) 29th September, 6th September, 11th September and 19th September. A red box has been added onboard to aid in comparison. The colour scale is in cm and does not vary between images.

deployment and the overall tendency of the estimated mooring positions to be south-east or east of their targets.

Acknowledgements

The previous OSMOSIS mooring laying cruise D381A had been significantly late arriving in Falmouth due to a grossly underestimated time schedule at the planning stages. By the time we left Falmouth on D381B, we were already 6.5 days late and therefore we had only two thirds of out programmed time at the PAP site for the process studies. Clearly our plans had to be shortened, the number of SeaSoar surveys was hurriedly reduced by one and two turbulence profiling stations were cut out of the original plan. Nevertheless, D381B achieved virtually all of its revised objectives despite nearly two days weather downtime later on. This was achieved through the dedication of the Master, officers, crew, technicians, engineers and scientists involved, and particularly their preparedness to adapt to rapidly changing plans when necessary. My thanks is extended to them all.

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