National
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RAPID report for Research Expedition DY146

4 February – 9 March 2022
RRS *Discovery*
Research Expedition DY146

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Abstract

The purpose of RRS *Discovery* research expedition DY146 was to refurbish the eastern boundary portion of the RAPID 26°N array of moorings that span the Atlantic from the Bahamas to the Canary Islands. The expedition started in Southampton on 4 February 2022 and ended on 9 March 2022 in Southampton, UK.

The moorings are part of a purposeful Atlantic wide array that observes the Atlantic Meridional Overturning Circulation and the associated heat and freshwater transports. The RAPIDMOCHA-WBTS array is a joint UK- US programme.

During DY146 moorings were removed at sites: EB1, EBHi and EBH4. Moorings were serviced at sites: EBH1, EBH2 and EBH3.

Moorings were equipped with instruments to measure temperature, conductivity and pressure, and a number of moorings were also equipped with current meters and/or biogeochemical sensors, including oxygen, carbon and nutrient sensors.

CTD stations were conducted throughout the cruise for purposes of providing pre- and post-deployment calibrations for mooring instrumentation (including oxygen and carbonate chemistry sampling).

Shipboard underway measurements were systematically logged, processed and calibrated, including: surface meteorology, 5m depth sea temperatures and salinities, water depth, and navigation. Water velocity profiles from 15 m to approximately 800 m depth were obtained using two vessel mounted Acoustic Doppler Current Profilers (one 75 kHz and one 150 kHz).

Keywords

Atlantic Meridional Overturning Circulation, AMOC, RAPID, moorings, mooring array, North Atlantic

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1 Scientific and Ship's Personnel

Table 1: Details of ship's and sciencific personnel.

Name	*Position*	*Affiliation*
Antonio Gatti	Master	
Robert Ovenden	Chief Officer	
Colin Leggett	Second Officer	
Graham Stringfellow	Third Officer	
Ross Weit	Chief Engineer	
Christopher Kemp	Second Engineer	
Marc Smith	Third Engineer	
Sean Rooney	Third Engineer	
Benjamin Heer	ETO	
Valerija Forbes-Simpson	Purser	
Craig Lapsley	Chief Petty Officer Scientific	
Andrew Maclean	Chief Petty Officer Deck	
Marshall Mackinnon	Chief Petty Officer Deck	
Craig Gilfillan	Petty Officer Scientific	
Harry Nicholson	SG1A	
Gary Crabb	SG1A	
Kevin Riley	SG1A	
Glyndor Henry	ERPO	
Mark Ashfield	Head Chef	
Charlotte Ray	Chef	
Carl Piper	Steward	
Kevin Mason	Assistant Steward	
Dafydd Gwyn Evans	Chief Scientist	NOC
Darren Rayner	Scientist	NOC
Brian King	Scientist	NOC
Yvonne Firing	Scientist	NOC
Alba Navarro Rodriguez	Scientist	Heriot-Watt University
Sara Fowell	Scientist	NOC
Mark Taylor	Scientist	UoS
Sevda Norouzi Alibabalou	Scientist	Heriot-Watt University
Clara Douglas	Scientist	UoS
Robert Mclachlan	Senior Technical Officer	NOC/NMF
Jason Scott	Technician	NOC/NMF
Stephen Corless	Technician	NOC/NMF
David Childs	Technician	NOC/NMF
Christian Crowe	Technician	NOC/NMF
Dean Cheeseman	Technician	NOC/NMF
Owen Foster	Technician	NOC/NMF
Timothy Powell	Technician	NOC/NMF
Emmy McGarry	SS Technician	NOC/NMF

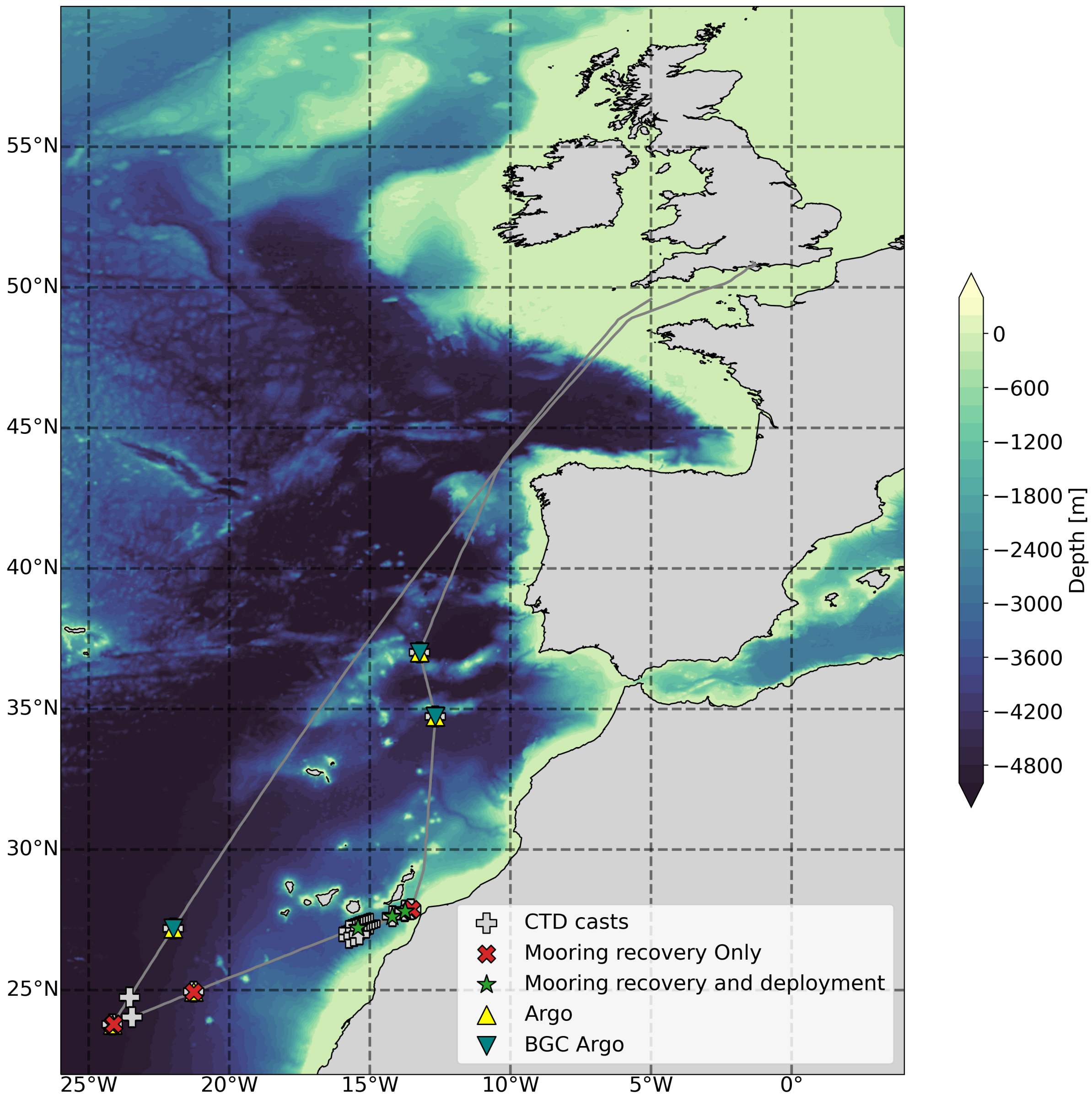


Figure 1: Cruise track for DY146

2 Cruise Narative

Times are reported in local. The cruise track is plotted in Fig. 1. See also the Event Log (§**??**)

Friday 4th February 2022 – Science party including technicians boarded in the morning. Everyone took an antigen test on arrival at the ship and a PCR test later in the morning. The PSO and two other cruise participants tested positive, but subsequently tested negative on less sensitive lateral flow tests (LFTs). As a precaution, the 3 participants that tested positive were required to isolate in their cabins with meals delivered to their doors. As the PSO had recently had COVID, they were not required to take a PCR test, and instead take LFTs in the afternoon, and on the morning of the 5th. The rest of the science party ate meals in the mess. One technician remained at home, and will join on the 5th when they will take a PCR test and isolate.

Saturday 5th February 2022 – All the science party were released from isolation in the morning, except for one NMF technician who received and inconclusive test. They were required to isolate and take an additional PCR test at the same time as the technician joining today.

All equipment was already loaded onto the ship, except for the OTE BGC sensor frames and miniboat. The science party subsequently began moving equipment into the labs. The NMF technicians setup their equipment in the deck lab, the RAPID team setup in the main lab, the DO and DIC team in the general purpose lab, OTE in the general purpose lab, and the Heriot-Watt team in general purpose lab and the temperature controlled lab.

One member of the science party were notified that they were a COVID close contact on Saturday evening. They had last interacted with their close contact on Thursday morning. The decision was made that they should isolate in their cabin until Monday morning when they would take an LFT. If that LFT was negative, they would have the all clear.

Sunday 6th February 2022 – The science party had their safety briefing at 0900, with the safety drill planned for closer to departure. Laboratory setup continued throughout the day. Had discussions with SST and NMF about challenges of mobilisation without a shore based internet connection while alongside at NOCS. Similar discussion within the RAPID team. Will plan to include a comment within the post cruise assessment. Departure confirmed for Wednesday.

Monday 7th February 2022 – Laboratory setup continued throughout the day. The OTE sensor frames and miniboat were loaded onto the ship. NMF began to construct the sections of glass spheres for the moorings. The isolating science party member tested negative this morning, but as their daughter also test positive on Saturday, it was decided that they should remain in isolation until Tuesday morning and take another LFT.

As the CTD wire was recently respooled onto CTD2 drum, the CPO Scientific requested time to spool the whole wire out to align the spooling mechanism. We'll plan to do this during the transit down to EB1. It will increase the transit slightly as the ship will have to slow to 4-6 knots, but there is sufficient time in the schedule.

Tuesday 8th February 2022 – Laboratory setup continued throughout the day, ensuring all equipment was adequately secured. The isolating science party member was released following a negative LFT in the morning. The 3 BGC Argo floats were checked by running the built-in diagnostics. All floats were good.

Wednesday 9th February 2022 – The ship departed NOCS at 1000. The crew tested the lifeboats at 1145, and we cleared the Needles at approximately 1300. Safety drill at 1630. Didn't board the lifeboats due to COVID etc. Still awaiting dip-clears for Spain and Morocco. Landside are chasing the FCDO. Expecting to receive Spanish clearance, but Morocco is uncertain. Mooring recoveries and planned additional CTDs may have to be rearranged to allow as much time to as possible to allow clearance for the recovery of EBH4.

Thursday 10th February 2022 – Continued passage through the channel and into the Bay of Biscay. Seas began to pick-up through the night with a swell from the north west from a system passing through the subpolar North Atlantic. A few of the science party members feeling the effects of the ships motion. They were looked after well by the purser and second mate. Daily briefings started today at 0830 in the main lab with the heads of department.

Friday 11th February 2022 – Rounded Finisterre during the day. Still awaiting dipclear for Spain (and Morocco) so couldn't turn on our underway system and the ADCP. Seas began to improve through the day, with the swell dying but down mixed with a wind swell from the north east. Those with sea sickness felt better today. Planning to spool the CTD2 wire on Tuesday.

Saturday 12th February 2022 – Sea conditions much improved. Planning to begin HW sampling tomorrow while in international waters. They'll deploy the Garrett Screen, collect water for the gas exchange tank and attempt to deploy their in situ gas exchange senor. The in situ gas exchange sensor is housed in a large peli-case with holes drilled into the top for a water inlet (1.5 m hose that needs to remain in the water at all times), waste water, and an air inlet. The sensor needs to remain stable at all times. We'll experiment with different methods of deployment in the morning. Have discussed the deployments with CPO-Scientific

Sunday 13th February 2022 – Weather has picked up a little, not much ship movement, however. First day during transit within international waters. At 0900 we began the HW deployments. While the crew were securing lines to the peli-case, the Garret screen was deployed and water collected using a bucket. The crew secured the peli-case with line looped around all four sides with a knot above the centre of the case. This was secured to a line fed through the yellow starboard crane. With a wave amplitude of approximately 2 m, it was challenging to keep the water inlet submerged at all times, and required constant adjustment by a crew member. We decided this wasn't a practical approach to the deployment. As an alternative we will try a longer hose and more powerful pump to draw water into the sensor which will remain on deck. We'll try this at 1400.

At 1400 we stopped again to attempt the sampling for the HW group. We used a longer hose and a peristaltic pump on deck to draw water from the sea surface, collecting a sample to run through the gas exchange sensor. We also used the same pump to draw near surface air. This worked well, and the sensor successfully measured one data point. Next they will attempt to use the peristaltic pump to draw water while continuously measuring. It's not possible however to continuously sample both near surface air and water, so a single sample of near surface air will be used.

Next stop will be the test CTD and the pre-deployment calibration cast for the deploying microcats on Thursday morning.

Monday 14th February 2022 – Improved weather, more sunshine and less wind. Ship stopped briefly in the morning to test the azimuth thruster and to lower and raise the USBL poles. Preparations continue on deck for the mooring operations.

Tuesday 15th February 2022 – Day spent unspooling and re-spooling CTD2 wire, started at 0900, completed by 1300. The weighted wire was fed through the large block on the stern A-frame. The ship was stopped while the wire was shallower than 1000 m. The ship steamed at 5-6 knots when the wire was deeper than 1000 m. The wire reached a maximum of 7500 m. Currently scheduled to enter international waters late Wednesday morning. Will perform the test CTD cast after lunch and the first MicroCat calibration cast at 0800 on Thursday morning. Arrival scheduled at EB1 for Thursday evening.

Wednesday 16th February 2022 – Received diplomatic clearance for work in Spanish waters in the morning. Crossed into international waters at 1130. Began the test CTD at 1230. This cast was planned for sampling to 2000 m, and included a full suite of sampling (DO, DIC, pH, salts, nuts, DOC and Chl). We also mounted the spare OTE sensors for TA and pH onto the empty Niskin bottle slots. These needed to be configured so that the valves remained open on the downcast, sampling began on the upcast and stopped before the surface. Timing on the downcast was tight, we estimated 50 mins, 60 would have been better. The sensors were programmed to stop an hour too early using ship time as opposed to GMT. During the CTD HW deployed their surface water pump, sampled using the Garret screen and collected surface water. When the CTD was bought on deck an Argo float and BGC float were deployed before sampling. Sampling went a little slow, typical of a first cast, but otherwise it went well. We continue onwards to EB1, and will stop for our next CTD at 0800 on Thursday.

Thursday 17th February 2022 – MicroCat calibration cast at 0800. A total of 20 MCs were attached to the CTD frame as well as 8 acoustic releases and 2 OTE sensors. The CTD was planned for 15 minute bottle stops to accommodate the OTE sensor. HW performed Garrett screens and collected water with a bucket. During the cast, failure of a cooling system within the winch electronics caused the electrical systems to overheat. Ultimately the cooling fan needed to be replaced, salvaged from the GP winch. This took about 4 hours to replace. At that point the OTE sensor had completed its mission so we reverted to 5 minute bottle stops for the MCs. The rest of the cast continued as expected, arriving on deck just before dinner. After dinner the oxygen team practiced using the remaining water in the Niskin bottles.

Friday 18th February 2022 – Arrived at EB1 during the night. The ship got into position at 200 m southwest of EB1L14. The ADCP suggested a relatively uniform flow to the northeast in the surface 500 m. EB1L14 was released just after 0600, with the release depth indicating shortly after that the lander was rising through the water column. Surfacing due for 0815. Lander spotted at 0822. It was sitting low in the water, but the makeshift hi-vis vest flag was visible above the water line with the syntactic buoyancy below. We made our approach and grappled the recover line by 0839. The recovery line was caught on one of the lander legs, which required extricating slightly. Recovery onto deck went reasonably smoothly. Upon inspection the bolts securing the acoustic releases to the top of the lander had completely corroded. Four had failed on one release, and one on the other.

With the ship positioned 250 m downwind of EB1L13 we released the lander at 0913. We had some trouble receiving replies from the releases, but we got an approximate ascent rate of 52 m/min, with an estimated surfacing time of 1050. The lander was spotted at the surface at 1052, only the recovery line, the Billings float and the shallowest packet of glass were visible at the surface. During recovery it became clear that the recovery line was tangled around the mooring line and around the pole of the Billings float. Further, the middle packet of glass had imploded.

After lunch we attempted to communicate with the EB1P and download data. This was mostly unsuccessful, communication was established, but no data was downloaded. We decided to send the release command at 1336. After the release command was received the burn wire on the release should take 15-20 mins and between 71-105 minutes to arrive at the surface, arriving at the earliest at 1503. The PIES wasn't spotted at the surface until 1540, when it surfaced off the forward quarter. We attempted to track the packages progress through the water column by listening for the 12 kHz pings produced by the PIES every 4 seconds with the single beam system on passive mode. This produced a series of slanted lines on the trace, these became more frequent about 30 mins before the PIES surfaced. At the surface there was no visible recovery line, so the crew grappled into the metal frame of the PIES and hauled it aboard by hand on the starboard side. Unfortunately, there appears to be no data on EB1P.

Pre-deployment MicroCat and pre-recovery ODO calibration CTD completed overnight with no issue. We tested the effectiveness of the active heave compensator during the 15 minute bottle stops for the mounted OTE sensors, with the AHC on for half of the bottle stop. This was the deepest a TA and pH sensor has been deployed. The TA sensor lost power near the bottom and regained power at around 3000 m.

Saturday 19th February 2022 – We released EB1 at 0800. The first release failed so the command was sent to the second release, which successfully released the anchor. The recovery line, shallowest syntactic and the steel sphere was visible at the surface a short time after release. After an hour, nothing else had surfaced. We ranged the releases to see if they were moving, which they weren't, so we made the call to go ahead and recover the mooring. Recovery went very smoothly, and it transpired that the two deepest packages of glass (x4 and x8) had imploded, preventing the majority of the mooring from surfacing. One MicroCat had flooded.

Previously we had planned to wait at EB1 to complete the post-recovery MicroCat calibration cast, but in attempt to save time, and allow us to recover EBHi on Sunday, we decided to steam towards EBHi and stop during the transit at 2000. If the weather allows (it's not looking great), by leaving EB1 earlier we will hopefully have time to recover EBHi.

Sunday 20th February 2022 – Saturday evening's CTD finished at 0230, at which point we continued our transit towards EBHi. During the night the sea state worsened, slowing our progress. Having picked up slightly again during morning, it became clear that we weren't going to make it to EBHi in time for the recovery of EBHi during the day. We adjusted our plan to recover EBHi on Monday.

Monday 21st February 2022 – On site for EBHi recovery early in the morning. We released EBHi at 0700, we estimated an accent rate of 83 m/min with a surface ETA of 0800. The buoyancy arrived at the surface out of order, with the middle glass arriving first and followed by the shallowest glass package, the deepest package and finally the billings float. Unfortunately, the recovery line was tangled with the shallowest glass, but it in the end recovery went well, but there were lots of tangled line to contend with.

We started the post-recovery CTD at 1600, during which the HW group also deployed their Garrett screen and surface pump. The CTD went smoothly, was out of the water by 2000, after which we deployed a third Argo float. We steam onwards to EBH1.

Tuesday 22nd February 2022 – Weather is much improved today. We continue to steam towards EBH1. There was a fire safety drill scheduled for 1600. However, this was postponed as we came across a small overturned boat in the water. The captain and officers decided to investigate, so deployed the small boat. They concluded that there was no one nearby. We continued to EBH1.

Wednesday 23rd February 2022 – We arrived at EBH1 overnight, releasing EBH1L12 at 0700. Recovery went smoothly despite the lander being relatively tangled. Following the recovery of EBH1L15, we released and recovered EBH1. Once again, the recovery went smoothly. We subsequently deployed EBH1L15 late morning, our first deployment of DY146! EBH1 deployment followed after lunch going well. This was the first of the moorings with the new OTE sensor frames installed. Following the deployment, we trilaterated the positions of EBH1 and EBH1L15. We deployed the post deployment CTD at 1900, this included the OTE sensors. HW sampling was also conducted during the CTD.

Thursday 24th February 2022 – We arrived at EBH2 for recovery at approximately 0800, at which point we released the mooring. The mooring reached the surface in 20 mins. The lines were slightly tangled, but recovery went smoothly. Following the recovery, we prepped the replacement EBH2 mooring for deployment. EBH2 deployment went very smoothly and finished in time for lunch. We performed the post-deployment CTD cast at EBH2 during the evening and steamed straight for EBH3 for the pre-recovery CTD cast during the early hours of Friday morning. We're still lacking diplomatic clearance to recover and deploy EBH4 and EBH4L in Moroccan waters. During the day there was discussion regarding contingency plans if we're unable to deploy moorings at EBH4. We put together a plan to adapt the mooring deployment at EBH3 to include the OTE sensors planned for deployment on EBH4, with the intention of waiting for Friday morning to make the call, and to deploy EBH3 on Sunday afternoon, giving time for the NMF team to make the necessary adjustments. Our last day available for science is Monday. If we decide to alter EBH3, but subsequently hear from the Moroccan authorities, we would plan to deploy a MicroCat only mooring at EBH4.

Friday 25th February 2022 – By the morning we had confirmation that diplomatic clearance was unlikely to arrive from Morocco. Following EBH3 recovery, which went relatively smoothly with some biofouling and tangles, we decided to adapt EBH3, adding OTE sensors from EBH3. While the NMF team adapted the moorings, we steamed back toward EBH1, where we passed a strong front in SST, with the plan to perform two high resolution CTD sections. The sections ran roughly zonally along the line of the moorings and 0.25° south of the moorings with 5 nm spacing. The aim was to capture the structure and water mass properties of the various filaments associated with the front. We began the section at 1800.

Saturday 26th February 2022 – We continued the CTD section started Friday evening, but generally the stations and steam between stations took longer than originally anticipated. By the afternoon we completed 9 stations from east to west, and returned via the section to the south. Given the plan to deploy EBH3 on Sunday afternoon, we reduced the number of stations for the second transect to 4/5 stations. We were able to complete 3 stations on the return leg prior to steaming towards EBH3

Sunday 27th February 2022 – We arrived at EBH3 for deployment at 1130. The NMF team spent the morning preparing the deck for deployment. We also spent the morning discussing alternative plans for Monday morning to keep us close to EBH4 in case Moroccan clearance arrived during the morning. We reached the conclusion to wait near EBH4 until midday on Monday, after which we would head back toward Southampton.

Deployment of EBH3 with the 4 frames went smoothly. There was some difficulty getting the first frame overboard after the 10-pack of glass, as taking back the tension onto the winch was a challenge. For the remaining frames we lowered the glass before attaching the chain between the glass and the frame. Deployment took about 2hr 15 mins, we had approximated 3 hrs with a ship speed of 1 kt. This combined with the slow speed over ground meant we had to tow the mooring for 2 hr 15 mins before dropping the anchor.

We performed the post deployment CTD for the MicroCat ODO and OTE sensors at 1900, but during the cast we realised that we had forgotten to adjust the bottle depths to match the depth of the additional frame at 1000 m. So, we performed an additional CTD cast during the night to target this depth.

Monday 28th February 2022 – During the morning while waiting in the hope that we get clearance from Morocco, the Captain called ashore to discuss the situation. It was concluded that clearance was unlikely to arrive, so the Captain made the decision 0800 to head back to Southampton. At 1000 we received clearance from Morocco to recover all the moorings left on site at EBH4 (EBH4L8, EBH4L9, EBH4 and EBH4P), and no permission to deploy any further moorings. Returning south we began recovery of EBH4L8 with 30 kt winds and a 2-3 m swell. During the recovery one of the mooring lines snagged on the starboard azimuth thruster but the Captain was able to free the snag by rotating the thruster. EBH4L8 came up very tangled, and out of order, requiring careful consideration of which lines to make safe. Once on deck, we decided that we were better off waiting until Tuesday to recover the remaining moorings. We completed the pre-recovery ODO calibration cast during the evening, and held station until the morning.

Tuesday 1st March 2022 – In the morning we released EBH4L9. The mooring arrived at the surface tangled and was recovered out of order. We released EBH4 next, which streamed out at the surface allowing a clean recovery. Some of the packages of buoyancy arrived at the surface tangled, but this didn't present much of a challenge. After lunch we attempted to communicate with the PIES lander at EBH4, with the intention of downloading the data before releasing and attempting recovery. We struggled to get the expected responses from the PIES lander to the commands sent. Therefore, we decided to release the lander, expecting a 15-20 min burn time and a 20 min ascent. After the release command was sent, the lander went into beacon mode as expected (a 12 kHz pulse every 4 secs). We were able to track this pulse using the echo sounder set to passive mode, expecting a change in gradient as the lander rose through the water column. Over the course of 2 hours we saw no change in the gradient of the PIES beacon mode trace on the echo sounder. Unsure if we were observing the PIES lander on the echo sounder or some unknown source on the ship, we moved the ship away from the expected location of the lander, which changed the gradient of the trace on the echo sounder. This told us that the origin of the trace was likely the PIES lander on the seabed. Having established that the lander had infact received the release command (the 12 kHz pulse every 4 secs) and that it had remained stationary with respect to the ship over the course of two hours, we concluded that the lander had failed to release and was stuck on the seabed. With the PIES in beacon mode, we were unable to send any further commands to the PIES lander until beacon mode had turned off, which the manual states is sometime after 3 hours. Given the time restrictions associated with our transit back to the UK, we therefore made the decision to leave the site, without recovering the PIES lander.

Wednesday 2nd March 2022 – The day was spent steaming towards the slice of international water between Madeira and Portugal for a deep MicroCat calibration cast, two Argo deployments and two BGC Argo deployments.

Thursday 3rd March 2022 – After crossing into international waters, we arrived on station for the first CTD cast to 3500 m. We attached 32 MicroCats to the CTD and sampled at 8 depths for BGC parameters to calibrate the BGC Argo measurements. Following recovery of the CTD we deployed a BGC Argo float followed by an Argo float with an experimental RBR CTD.

Friday 4th March 2022 – Following slightly slower progress than expected overnight as the wind and swell picked up, we arrived on station at 0930 and performed a CTD to 2000 m. Following this CTD we deployed a BGC Argo float followed by an Argo float with an experimental RBR CTD. With our planned operations complete we began our transit back to Southampton with an expected arrival on either the evening of the 8th or morning of the 9th.

Saturday 5th March 2022 - Tuesday 8th March 2022 – Transit

Wednesday 9th March 2022 – Arrival at NOCS

Table 2: DY146 event log. Times in GMT

Time [GMT]	Event	Latitude deg. [N]	Latitude min.	Longitude deg. [E]	Latitude min.
13/02/2022 09:13	Garret Screen / Bucket deployment	38	2.93	-14	-37.48
13/02/2022 10:10	Garret Screen / Bucket recovered	38	2.93	-14	-37.48
13/02/2022 14:03	Garret Screen / Bucket deployment	37	33.6	-14	-58.29
13/02/2022 14:43	Garret Screen / Bucket recovered	37	33.6	-14	-58.29
15/02/2022 08:38	Spooling of CTD 2 wire	31	2.29	-19	-29.03
15/02/2022 14:43	Spooling of CTD 2 wire complete	30	39.74	-19	-44.28
16/02/2022 13:43	CTD1 deployed	27	11.35	-21	-59.5
16/02/2022 14:10	HW surface water sampler deployed	27	11.35	-21	-59.5
16/02/2022 14:29	Garret Screen / Bucket deployment	27	11.35	-21	-59.5
16/02/2022 15:20	Garret Screen / Bucket recovered	27	11.35	-21	-59.5
16/02/2022 15:21	HW surface water sampler recovered	27	11.35	-21	-59.5

16/02/2022 16:10	CTD1 recovered	27	11.35	-21	-59.5
16/02/2022 16:24	BGC Argo float 1 deployed	27	11.17	-21	-59.43
16/02/2022 16:28	Argo float 1 deployed	27	11.05	-21	-59.51
17/02/2022 09:12	CTD2 deployed	24	44.19	-23	-33.15
17/02/2022 17:59	CTD2 recovered	24	44.19	-23	-33.15
18/02/2022 07:10	EB1L14 released	23	47.82	-24	-8.79
18/02/2022 08:46	EB1L14 recovered	23	47.84	-24	-8.8
18/02/2022 09:10	EB1L13 released	23	47.86	-24	-8.81
18/02/2022 12:30	EB1L13 recovered	23	48.67	-24	-7.51
18/02/2022 15:05	EB1P released	23	46.35	-24	-9.64
18/02/2022 16:56	EB1P recovered	23	46.46	-24	-9.6
18/02/2022 22:02	CTD3 deployed	23	46.4	-24	-9.69
18/02/2022 22:12	Garret Screen / Bucket deployment	23	46.4	-24	-9.69
18/02/2022 22:54	Garret Screen / Bucket recovered	23	46.4	-24	-9.69
19/02/2022 04:33	CTD3 recovered	23	46.4	-24	-9.69
19/02/2022 08:58	EB1 released	23	45.26	-24	-9.92
19/02/2022 14:09	EB1 recovered	23	47.35	-24	-6.31
19/02/2022 16:08	Argo float 2 deployed	23	45.78	-24	-9.24
19/02/2022 16:11	KES Kraken miniboat deployed	23	45.77	-24	-9.19
19/02/2022 20:56	In DP on station	24	2.24	-23	-27.61
19/02/2022 21:09	CTD4 deployed	24	2.25	-23	-27.62
19/02/2022 21:26	Garret Screen / Bucket / Surface sampler deployment	24	2.25	-23	-27.62
19/02/2022 22:18	Garret Screen / Bucket / Surface sampler recovered	24	2.25	-23	-27.62
20/02/2022 03:33	CTD4 recovered	24	2.24	-23	-27.62
21/02/2022 08:08	EBHi released	24	55.87	-21	-16.14
21/02/2022 09:54	EBHi recovered	24	56.2	-21	-16.23
21/02/2022 17:06	CTD5 deployed	24	56.2	-21	-16.23
21/02/2022 17:11	Garret Screen / Bucket deployment	24	56.2	-21	-16.23
21/02/2022 18:00	Garret Screen / Bucket recovered	24	56.2	-21	-16.23
21/02/2022 21:02	CTD5 recovered	24	56.2	-21	-16.23
21/02/2022 21:15	Argo float 3 deployed	24	56.28	-21	-16.18
23/02/2022 08:05	EBH1L13 released	27	12.79	-15	-25.8
23/02/2022 09:13	EBH1L13 recovered	27	12.54	-15	-26.79
23/02/2022 09:23	EBH1 released	27	12.54	-15	-26.8
23/02/2022 10:39	EBH1 recovered	27	12.9	-15	-26.06
23/02/2022 11:42	EBH1L15 deployment	27	13.02	-15	-26.01
23/02/2022 11:47	EBH1L15 deployed	27	13.03	-15	-26.01
23/02/2022 13:49	EBH1 deployment	27	13.06	-15	-25.21
23/02/2022 14:29	EBH1 deployed	27	13.43	-15	-25.39

23/02/2022 15:47	Trilateration complete	27	12.94	-15	-24.63
23/02/2022 20:04	Garret Screen / Bucket deployment	27	13.48	-15	-24.3
23/02/2022 20:11	CTD6 deployed	27	13.48	-15	-24.3
23/02/2022 20:44	Garret Screen / Bucket recovered	27	13.48	-15	-24.3
24/02/2022 01:23	CTD6 recovered	27	13.48	-15	-24.3
24/02/2022 08:57	EBH2 released	27	36.62	-14	-12.67
24/02/2022 10:18	EBH2 recovered	27	36.68	-14	-12.79
24/02/2022 11:39	EBH2 deployment	27	36.68	-14	-12.79
24/02/2022 12:00	EBH2 deployed	27	36.98	-14	-12.61
24/02/2022 13:18	Start trilateration	27	37.33	-14	-12.39
24/02/2022 14:00	End trilateration	27	36.77	-14	-12.12
24/02/2022 19:58	CTD7 deployed	27	37.44	-14	-11.73
24/02/2022 20:08	Garret Screen / Bucket deployment	27	37.44	-14	-11.73
24/02/2022 20:47	Garret Screen / Bucket recovered	27	37.44	-14	-11.73
25/02/2022 00:35	CTD7 recovered	27	37.44	-14	-11.73
25/02/2022 03:53	CTD8 deployed	27	48.12	-13	-45.86
25/02/2022 05:26	CTD8 recovered	27	48.12	-13	-45.86
25/02/2022 09:01	EBH3 released	27	48.22	-13	-44.94
25/02/2022 11:12	EBH3 recovered	27	49.79	-13	-44.48
25/02/2022 19:17	CTD9 deployed	27	21.55	-15	-0.03
25/02/2022 19:26	Garret Screen / Bucket deployment	27	21.55	-15	-0.02
25/02/2022 20:01	Garret Screen / Bucket recovered	27	21.55	-15	-0.02
25/02/2022 20:39	CTD9 recovered	27	21.55	-15	-0.03
25/02/2022 21:43	CTD10 deployed	27	19.67	-15	-5.63
25/02/2022 23:08	CTD10 recovered	27	19.67	-15	-5.63
26/02/2022 00:11	CTD11 deployed	27	17.75	-15	-11.27
26/02/2022 01:38	CTD11 recovered	27	17.75	-15	-11.27
26/02/2022 02:29	CTD12 deployed	27	15.84	-15	-16.86
26/02/2022 03:57	CTD12 recovered	27	15.84	-15	-16.86
26/02/2022 04:47	CTD13 deployed	27	13.94	-15	-22.43
26/02/2022 06:12	CTD13 recovered	27	13.94	-15	-22.42
26/02/2022 07:02	CTD14 deployed	27	12.04	-15	-28.04
26/02/2022 08:33	CTD14 recovered	27	12.04	-15	-28.04
26/02/2022 09:21	CTD15 deployed	27	10.12	-15	-33.6
26/02/2022 10:53	CTD15 recovered	27	10.12	-15	-33.6
26/02/2022 11:50	CTD16 deployed	27	8.18	-15	-39.26
26/02/2022 13:16	CTD16 recovered	27	8.18	-15	-39.25
26/02/2022 14:02	CTD17 deployed	27	6.27	-15	-44.84
26/02/2022 15:27	CTD17 recovered	27	6.27	-15	-44.83
26/02/2022 17:10	CTD 18 deployed	26	51.27	-15	-44.8
26/02/2022 18:43	CTD18 recovered	26	51.27	-15	-44.8
26/02/2022 20:22	CTD19 deployed	26	55.08	-15	-33.68
26/02/2022 21:55	CTD19 recovered	26	55.08	-15	-33.68

26/02/2022 23:38	CTD20 deployed	26	58.92	-15	-22.47
27/02/2022 01:14	CTD20 recovered	26	58.92	-15	-22.47
27/02/2022 13:22	EBH3 deployment	27	45.52	-13	-45.4
27/02/2022 17:44	EBH3 deployed	27	48.63	-13	-44.78
27/02/2022 17:58	Trilateration station 1	27	48.98	-13	-44.7
27/02/2022 18:21	Trilateration station 2	27	48.11	-13	-44.41
27/02/2022 18:36	Trilateration station 3	27	48.33	-13	-45.41
27/02/2022 18:40	EBH3 trilateration complete	27	48.37	-13	-45.29
27/02/2022 20:00	CTD21 deployed	27	49.53	-13	-44.94
27/02/2022 20:04	Garret Screen / Bucket deployment	27	49.53	-13	-44.94
27/02/2022 20:27	Garret Screen / Bucket recovered	27	49.53	-13	-44.94
28/02/2022 00:18	CTD21 recovered	27	49.53	-13	-44.94
28/02/2022 01:52	CTD22 deployed	27	49.53	-13	-44.94
28/02/2022 03:35	CTD22 recovered	27	49.53	-13	-44.94
28/02/2022 13:12	EBH4L8 released	27	52.52	-13	-30.83
28/02/2022 14:05	EBH4L8 recovered	27	52.9	-13	-30.53
28/02/2022 19:53	CTD23 deployed	27	52.06	-13	-32.77
28/02/2022 21:16	CTD23 recovered	27	52.06	-13	-32.76
01/03/2022 09:02	EBH4L9 released	27	51.92	-13	-30.76
01/03/2022 09:40	EBH4L9 recovered	27	52.34	-13	-30.55
01/03/2022 10:40	EBH4 released	27	50.81	-13	-32.61
01/03/2022 12:07	EBH4 recovered	27	51.57	-13	-32.25
01/03/2022 16:23	Attempted recovery of EBH4P, did not release	27	51.88	-13	-32.12
03/03/2022 13:39	CTD24 deployed	34	43.68	-12	-40.41
03/03/2022 16:59	CTD24 recovered	34	43.67	-12	-40.41
03/03/2022 17:09	BGC Argo float 2 deployed	34	43.77	-12	-40.4
03/03/2022 17:11	Argo float 4 deployed	34	43.83	-12	-40.39
04/03/2022 09:50	CTD25 deployed	37	0.93	-13	-14.2
04/03/2022 11:27	CTD25 recovered	37	0.92	-13	-14.2
04/03/2022 11:38	BGC Argo float 3 deployed	37	0.98	-13	-14.22
04/03/2022 11:43	Argo float 5 deployed	37	1.07	-13	-14.25

3 Introduction

This cruise report is for cruise DY146 conducted aboard RRS Discovery in spring 2022. The primary purpose of the cruise was to service the eastern boundary portion of the UK contribution to the RAPID-MOC/MOCHA mooring array. The RAPID-MOC/MOCHA array was first deployed in 2004 to measure the Atlantic Meridional Overturning Circulation (AMOC) at 26°N and has been maintained by regular service cruises since then. The array and associated observations are funded by NERC, NSF and NOAA. The NERC contribution to the first four years of measurements was funded under the directed programme “RAPID Climate Change”. Following an international review NERC continued funding to 2014 under the programme “RAPID-WATCH”. The servicing and redeployment of the UK moorings on this cruise are conducted under the “RAPID-AMOC” programme. NSF and NOAA have also continued funding and commitments so that the system can continue operating at the same level of activity.

RAPID-AMOC continues the measurements at 26°N and extends these to include biological and chemical measurements in order to determine the variability of the AMOC and its links to climate and the ocean carbon sink on interannual-to-decadal time scales. During this cruise new ‘lab on a chip’ sensors designed and manufactured by the Ocean Technology and Engineering group at the National Oceanography Centre were added to the array. For further information on the RAPID-MOC/MOCHA array please see previous cruise reports (detailed in Table 3.1).

Ancillary work conducted during the cruise included sampling of the ocean’s surface microlayer by a team from the Lyell Centre at Heriot-Watt university. Further, we deployed five Argo floats supplied by the UK Met Office and three biogeochemical Argo floats. All Argo data is freely available online, see `http://www.argo.net/` for further details.

3.1 Results and Data Policy

All data and data products from RAPID 26°N project are freely available. The NERC data policy may be found at `https://www.bodc.ac.uk/projects/data_management/uk/rapid/data_policy/`. Access to data and data products can be obtained via `https://rapid.ac.uk/index.php` and `https://mocha.rsmas.miami.edu/mocha/index.html`. Data may also be obtained directly from `http://www.bodc.ac.uk/`.

A full list of published papers is available on the programme website at `http://www.rapid.ac.uk/publications.php`.

3.2 Previous RAPID-MOC Cruises

Table 3: Previous RAPID cruises

Cruise	Vessel	Date	Objectives	Cruise Report
D277	RRS Discovery	Feb - Mar 2004	Initial Deployment of Eastern Boundary and Mid-Atlantic Ridge moorings.	Southampton Oceanography Centre Cruise Report, No 53, 2005
D278	RRS Discovery	Mar-04	Initial Deployment of UK and US Western Boundary Moorings.	Southampton Oceanography Centre Cruise Report, No 53, 2005

D279	RRS Discovery	Apr –May 2004	Transatlantic hydrography (125 CTD stations).	Southampton Oceanography Centre, Cruise Report, No 54, 2005
P319	RV Poseidon	Dec-04	Emergency deployment of replacement EB2 following loss.	Appendix in National Oceanography Centre Southampton Cruise Report, No. 2, 2006
CD170	RRS Charles Darwin	Apr-05	Service and redeployment of Eastern Boundary and Mid-Atlantic Ridge moorings.	National Oceanography Centre Southampton Cruise Report, No. 2, 2006
KN182-2	RV Knorr	May-05	Service and redeployment of UK and US Western Boundary Moorings and Western Boundary Time Series (WBTS) hydrography section.	National Oceanography Centre Southampton Cruise Report, No. 2, 2006
CD177	RRS Charles Darwin	Nov-05	Service and redeployment of key Eastern Boundary moorings.	National Oceanography Centre Southampton Cruise Report, No. 5, 2006
WS05018	RV F.G. Walton Smith	Nov-05	Emergency recovery of drifting WB1 mooring.	No report published
RB0602	RV Ronald H. Brown	Mar-06	Service and redeployment of UK Western Boundary moorings and WBTS hydrography section.	National Oceanography Centre Southampton Cruise Report, No. 16, 2007
D304	RRS Discovery	May - Jun 2006	Service and redeployment of Eastern Boundary and Mid-Atlantic Ridge moorings.	National Oceanography Centre Southampton Cruise Report, No. 16, 2007
P343	RV Poseidon	Oct-06	Service and redeployment of key Eastern Boundary moorings.	National Oceanography Centre Southampton Cruise Report No. 28, 2008.
P345	RV Poseidon	Nov – Dec 2006	Emergency redeployment of EB1 and EB2 following problems on P343.	National Oceanography Centre Southampton Cruise Report No. 28, 2008.
SJ-14-06	RV Seward Johnson	Sep – Oct 2006	Recovery and redeployment of WB2 and US Western Boundary moorings, and WBTS hydrography section.	Appendix G in National Oceanography Centre, Southampton Cruise Report, No 29
RB0701	RV Ronald H. Brown	Mar - Apr 2007	Service and redeployment of UK Western Boundary moorings and WBTS hydrography section.	National Oceanography Centre, Southampton Cruise Report, No 29

D324	RRS Discovery	Oct – Nov 2007	Service and redeployment of Eastern Boundary and Mid-Atlantic Ridge moorings.	National Oceanography Centre, Southampton Cruise Report, No 34
SJ0803	RV Seward Johnson	Apr-08	Service and redeployment of the Western Boundary moorings.	National Oceanography Centre, Southampton Cruise Report, No 37
D334	RRS Discovery	Oct-Nov 2008	Service and redeployment of the Eastern Boundary and Mid-Atlantic Ridge moorings.	National Oceanography Centre, Southampton, Cruise Report No. 38, 2009
RB0901	RV Ronald H. Brown	Apr – May 2009	Service and redeployment of the UK and US Western Boundary moorings and the WBTS hydrography section.	National Oceanography Centre, Southampton Cruise Report, No 40, 2009
D344	RRS Discovery	Oct – Nov 2009	Service and redeployment of the Eastern Boundary and Mid-Atlantic Ridge moorings.	National Oceanography Centre, Southampton, Cruise Report No. 51, 2010
D345	RRS Discovery	Nov – Dec 2009	Recovery and redeployment of US Western Boundary moorings, and WBTS hydrography section.	RAPID/MOCHA Program Report (W. Johns, RSMAS).
D346	RRS Discovery	Jan – Feb 2010	Transatlantic hydrography (135 CTD stations).	National Oceanography Centre Cruise Report, No 16, 2012
OC459	RV Oceanus	Mar – Apr 2010	Service and redeployment of the Western Boundary moorings.	National Oceanography Centre Cruise Report, No 01, 2010
RB1009	RV Ronald H. Brown	Nov – Dec 2010	Recovery of WB4 and WB3L3. Redeployment of WB4.	Appendix in: National Oceanography Centre Cruise Report, No -01, 2010
D359	RRS Discovery	Dec 2010 – Jan 2011	Service and redeployment of the Eastern Boundary and Mid-Atlantic Ridge moorings.	National Oceanography Centre Cruise Report, No. 09, 2011
KN200-4	RV Knorr	Apr – May 2011	Service and redeployment of Western Boundary Moorings and WBTS hydrography section.	National Oceanography Centre Cruise Report, No 07, 2011
JC064	RRS James Cook	Sep – Oct 2011	Service and redeployment of the Eastern Boundary and Mid-Atlantic Ridge moorings.	National Oceanography Cruise Report, No. 14, 2012

RB1201	RV Ronald H. Brown	Feb – Mar 2012	Service and redeployment of Western Boundary Moorings and WBTS hydrography section.	National Oceanography Centre, Cruise Report No. 19, 2012
EN517	RV Endeavor	Sep – Oct 2012	Service of US moorings in Western Boundary.	RV Endeavor Cruise EN-517 Cruise Report
D382	RRS Discovery	Oct – Nov 2012	Service and redeployment of full UK RAPID array.	National Oceanography Centre Cruise Report No. 21, 2012
AE1404	RV Atlantic Explorer	Mar-14	Service of US moorings in Western Boundary.	RV Atlantic Explorer Cruise AE-1404 Cruise Report
JC103	RRS James Cook	Apr – Jun 2014	Service and redeployment of full UK RAPID array.	National Oceanography Centre Cruise Report No. 30, 2015
EN570	RV Endeavor	Oct-15	Service of US moorings in Western Boundary.	RV Endeavor Cruise EN-570 Cruise Report
DY039	RRS Discovery	Oct – Dec 2015	Service and redeployment of full UK RAPID array.	National Oceanography Centre Cruise Report, 37
DY040	RRS Discovery	Dec -2015 – Jan 2016	Transatlantic hydrography.	National Oceanography Centre Cruise Report, XX
EN598	RV Endeavor	May, 2017	Service of US moorings in Western Boundary.	RV Endeavor Cruise EN-598 Cruise Report
JC145	RRS James Cook	Feb –Apr 2017	Service and redeployment of full UK RAPID array.	National Oceanography Centre Cruise Report, 52
JC174	RRS James Cook	Oct-Nov 2018	Service and redeployment of full UK RAPID array.	National Oceanography Centre Cruise Report, 59
JC192	RRS James Cook	Mar-20	Service and redeployment of eastern boundary of the UK RAPID array.	National Oceanography Centre Cruise Report, 71
DY146	RRS Discovery	Feb-Mar 2022	Service and redeployment of eastern boundary of the UK RAPID array.	This report

4 NMFSS Ship Systems Computing and Underway Instruments

Emmy McGarry

Ship Scientific Systems (SSS) is responsible for operating and managing the Ship's scientific information technology infrastructure, data acquisition, compilation and delivery, and the suite of ship-fitted instruments and sensors in support of the Marine Facilities Programme (MFP). All times in this report are in UTC.

4.1 Scientific computer systems

4.1.1 Underway data acquisition

The data acquisition systems used on this cruise are detailed in the table below. The data and data description documents are filed per system in the Data and Documentation directories respectively within Ship Systems folder on the cruise data disk.

Table 4: Data acquisition systems used on this cruise

Data acquisition system	Usage	Data products	Directory system name
Ifremer TechSAS	Continuous	NetCDF, ASCII pseudo-NMEA	/TechSAS/
NMF RVDAS	Continuous	ASCII Raw NMEA	/RVDAS/
Kongsberg SIS (EM122)	Discrete	Kongsberg .all	/Acoustics/EM-122/
Kongsberg SIS (EM710)	Unused	Kongsberg .all	/Acoustics/EM-710/
Kongsberg SBP	Unused	None	/Acoustics/SBP-120/
Kongsberg EA640	Continuous	None, redirected to Techsas/RVDAS RAM	/Acoustics/EA-640/
Kongsberg EK80	Unused		/Acoustics/EK-60/
UHDAS (ADCPs)	Continuous	ASCII raw, RBIN, GBIN, CODAS files	/Acoustics/ADCP/
VMDAS (ADCPs)	Unused		/Acoustics/ADCP/
Sonardyne Ranger2	Unused	None, redirected to Techsas/RVDAS RAM	/Acoustics/USBL/

Data description documents per system: `/Ship_Systems/Documentation/[System]/Data_Description`

Data directories per system: `/Ship_Systems/Data/[System]/`

Data gaps in continuous ocean monitoring data (underway, multibeam and ADCP) were due to entry into non international waters. At 17:29 23FEB2022 the scientific UPS in the bottom equipment room failed which resulted in several systems turning off unexpectedly. Power was restored at 18:16 and all systems were running again by 18:20. The datastreams running at the time and affected by this were Phins, POSMV, EM122 and EA640. The EM122 and EA640 data is not duplicated elsewhere, but the Phins and POSMV data can be replaced by the outputs of the Fugro and Seapath instruments.

4.1.2 Internet Provision

Satellite communications were provided with both the VSat and Fleet Broadband systems. While underway, the ship operated with bandwidth controls to prioritise business use.

4.2 Instrumentation

4.2.1 Position, Attitude and Time

Table 5: Navigation systems summary

System	**Navigation (Position, attitude, time)**
Statement of Capability	*/Ship_Systems/Documentation/GPS_and_Attitude*
Data product(s)	*NetCDF: /Ship_Systems/Data/TechSAS/NetCDF/* *Pseudo-NMEA: /Ship_Systems/Data/TechSAS/NMEA/* *Raw NMEA: /Ship_Systems/Data/RVDAS/NMEA/*
Data description	*/Ship_Systems/Documentation/TechSAS* */Ship_Systems/Documentation/RVDAS*
Other documentation	*/Ship_Systems/Documentation/GPS_and_Attitude*

Table 6: Navigation systems details

Component	**Purpose**	**Outputs**	**Headline Specifications**
Applanix PosMV	Primary GPS and attitude.	Serial NMEA to acquisition systems, multibeam and ADCP.	Positional accuracy within 2 m.
Kongsberg Seapath 330	Secondary GPS and attitude.	Serial and UDP NMEA to acquisition systems and multibeam	Positional accuracy within 1 m.
Oceaneering CNav 3050	Correction service for primary and secondary GPS and dynamic positioning.	To primary and secondary GPS	Positional accuracy within 0.15 m.

Fugro Seastar / MarineStar	Correction service for primary and secondary GPS and dynamic positioning.	To primary and secondary GPS	Positional accuracy within 0.15 m.
Meinberg NTP Clock	Provide network time	NTP protocol over the local network.	

4.2.2 Ocean and atmosphere monitoring systems – SURFMET

Table 7: SURFMET summary

System	**SURFMET**
Statement of Capability	*/Ship_Systems/Documentation/Surfmet*
Data product(s)	*NetCDF: /Ship_Systems/Data/TechSAS/NetCDF/* *Pseudo-NMEA: /Ship_Systems/Data/TechSAS/NMEA/* *Raw NMEA: /Ship_Systems/Data/RVDAS/NMEA/*
Data description	*/Ship_Systems/Documentation/TechSAS* */Ship_Systems/Documentation/RVDAS*
Underway events and other documentation	*/Ship_Systems/Documentation/Surfmet*
Calibration info	See Ship Fitted Sensor sheet for calibration

Table 8: SURFMET details

Component	**Purpose**	**Outputs**
Inlet temperature probe (SBE38)	Measure temperature of water at hull inlet	UDP NMEA to SBE45
Drop keel temperature probe (SBE38)	Measure temperature of water in drop keel space	UDP NMEA to Surfmet VM
Thermosalinograph (SBE45)	Measure temp, sal and conductivity at sampling board	Serial to Interface Box
Interface Box (SBE 90402)	Signals management	Serial to Moxa
Transmissometer (CST)	Measure of transmittance	Voltage output to Surfmet VM
Fluorometer (WS3S)	Measure of fluorescence	Voltage output to Surfmet VM
Air temperature and humidity probe (HMP155)	Temperature and humidity at met platform	Analogue to NUDAM
Ambient light sensors (PAR, TIR)	Ambient light at met platform	Analogue to NUDAM
Barometer (PTB210)	Atmospheric pressure at met platform	Analogue to NUDAM
Anemometer (Windsonic)	Wind speed and direction at met platform	Serial to Moxa

The NMF Surfmet system was run throughout the cruise, except times for cleaning, entering and leaving port, and whilst alongside. Please see the separate information sheet for details of the sensors used and whether their recorded data have calibrations applied or not.

4.2.3 Hydroacoustic systems

Table 9: Acoustics summary

System	**Acoustics**
Statement of Capability	*/Ship_Systems/Documentation/Acoustics*
Data product(s)	*Raw: /Ship_Systems/Data/Acoustics* *NetCDF (EA640, EM122cb): /Ship_Systems/Data/TechSAS* *NMEA (EA640, EM122cb): /Ship_Systems/Data/RVDAS*
Data description	*/Ship_Systems/Documentation/Acoustics*
Other documentation	*/Ship_Systems/Documentation/Acoustics*

Table 10: Acoustics details

Component	**Purpose**	**Outputs**	**Operation**
10/12 kHz Single beam (Kongsberg EA-640)	Primary depth sounder	NMEA over serial, raw files	Discrete / Free running
12 kHz Multibeam (Kongsberg EM-122)	Full-ocean-depth multibeam swath.	Binary swath, centre-beam NMEA, *.all files, optional water column data	Discrete / Free running
70 kHz Multibeam (Kongsberg EM-710)	Coastal/shallow multibeam swath.	Binary swath, centre-beam NMEA, *.all files.	Unused
Sub-bottom Profiler (Kongsberg SBP-120)	Multi-frequency echogram to provide along-track sub-bottom imagery.	BMP, raw files, optional water column data.	Unused
Drop keel sound velocity sensor	Provide sound velocity at transducer depth	Value over serial to Kongsberg SIS.	Continuous
Sound velocity profilers (Valeport Midas, Lockheed XBT)	Direct measurement of sound velocity in water column.	ASCII pressure vs sound velocity files. Manually loaded into Kongsberg SIS or Sonardyne Ranger2.	Unused
75 kHz ADCP (Teledyne OS75)	Along-track ocean current profiler	(via UHDAS)	Continuous / Free running
150 kHz ADCP (Teledyne OS150)	Along-track ocean current profiler	(via UHDAS)	Continuous / Free running

USBL (Sonardyne Ranger2)	Underwater positioning system to track deployed packages or vehicles.	NMEA over serial	Unused
CARIS	Post-processing	CARIS Project file. CARIS Vessel files	Unused
MB-System	Post-processing	XYZ, SegY files	Unused

4.2.4 Marine mammal protection

`/Ship_Systems/Documentation/Acoustics/MMOs`

Table 11: MMO procedures

System	**Actions taken to protect mammals in compliance with NERC and JNCC protocols**
12 kHz Multibeam (Kongsberg EM-122)	60-minute bridge observation. Marine mammal protection ramped start initiated at 45 minutes into observation if no mammals sighted. Clock restarted if mammals sighted.
Sub-bottom Profiler (Kongsberg SBP-120)	System not used.

MMO surveys were performed before use and restart of EM122 if it had been off for more than 10 minutes.

4.2.5 ADCPs

Path of ADCP data on the cruise datastore: `/Ship_Systems/Data/Acoustics/ADCP`

Table 12: ADCP details

Attribute	**Value**
Acquisition software	UHDAS
Frequencies used	75 kHz, 150 kHz
Running mode	Free-running (untriggered)
Configuration details	os150: Narrow band 40 bins, length 8m, 4m blanking, os75: narrow band, 60bins, length 16m, 8m blanking. Performance from beam 1 is currently degraded so running a 3 beam solution. Bottom tracking was run from leaving Southampon 08/12- 09/12, the rest of the cruise bottom tracking was off

4.2.6 Other systems

Cable logging and monitoring – Winch activity is monitored and logged using the CLAM system.

5 NMF CTD Operations

Tom Ballinger, Dave Childs and Tim Powell

5.1 CTD Summary

DY146 CTD work supported the turnaround of the RAPID East moorings with the CTD used for pre and post recovery calibration casts while also giving opportunity to test acoustic releases prior to deployment. Due to lack of diplomatic clearance to work in Moroccan waters an additional CTD transect was completed preventing any downtime or waste of fuel.

25 CTD casts were undertaken with an NMF 24-way Stainless Steel CTD frame with 12 off 10l Niskin water samplers. Only the odd bottles were fitted leaving 12 bottle positions free for Microcat clamps which were utilised for calibration dips. Dual SBE 43 dissolved oxygen sensors were used. The primary temperature, conductivity and dissolved oxygen sensors were fitted to the 9 plus with the secondary sensors mounted on the vane. A SBE 35 was mounted to a vertical stanchion of the CTD frame and programmed to average 8 samples which supplemented the temperature data.

The CTD was operated out of the hangar using the overhead gantry to position the CTD for deployment. The preferred method for this is to disconnect the CTD wire from the swivel and use a master link to connect the gantry hook to the swivel, this prevents subjecting the swivel to any lateral load. The CTD was deployed using CTD wire storage drum 2, this was the first use of wire 2 which required streaming prior to operations.

During the up cast of CTD 002 there was a fault with the winch drive suite, this resulted in the CTD being held at 3000m for four hours. Data collection continued and once the issue was fixed the cast continued.

The winch system Active Heave Compensation was used on all casts only showing slight improvements in package stability and no improvement in stabilising winch tension. Data was compared to previous work on the James Cook showing significant differences in effectiveness of the AHC. Further investigation found that the applied settings were wrong, these were roughly calculated and updated prior to CTD cast 024 producing a substantial improvement in both tension stability and package descent/ ascent rate through the water.

There was a fouling event during CTD009 during which the secondary sensors became noisy. Upon recovery both the primary and secondary sensors were flushed with bleach and triton-x solutions and then thoroughly flushed with MilliQ. The frame and optical sensors were also all cleaned as there were visible signs of fouling.

Between casts the whole CTD package was rinsed with fresh water with particular attention paid to the SBE 32 latch assembly. After each cast the primary and secondary sensors were flushed three times with MilliQ. Periodically the optical sensors were cleaned with MilliQ and Optic Prep wipes. The deepest cast was CTD003 at 5040m, CTD022 was the shallowest at 1025 m.

There were no major technical issues with the Stainless Steel CTD suite during the cruise and no sensors required changing. During cast 002 bottle 7 failed to seal sufficiently at the bottom cap, after this all lanyards and springs were checked and aligned where necessary. There were no other failed water collections throughout the cruise. All bottles were leak tested before the start of science and again at the end of science, no issues noticed.

5.2 CTD Configuration

5.2.1 Stainless Steel CTD Instrument Package

The sensors that were fitted to the Stainless Steel CTD frame are shown in Table 13.

Table 13: DY146 CTD sensor configuration

Instrument / Sensor	**Manufacturer / Model**	**Serial Number**	**Channel**	**Casts Used**
Primary CTD deck unit	SBE 11plus	11P-24680-0588	n/a	All casts
CTD Underwater Unit	SBE 9plus	09P-24680-0637	n/a	All stainless casts
Stainless steel 24-way frame	NOCS	SBE CTD6	n/a	All stainless casts
Primary Temperature Sensor	SBE 3P	03P-4380	F0	All stainless casts
Primary Conductivity Sensor	SBE 4C	04C-4065	F1	All stainless casts
Digiquartz Pressure sensor	Paroscientific	79501	F2	All stainless casts
Secondary Temperature Sensor	SBE 3P	03P-4782	F3	All stainless casts
Secondary Conductivity Sensor	SBE 4C	04C-4138	F4	All stainless casts
Primary Pump	SBE 5T	05T-3085	n/a	All stainless casts
Secondary Pump	SBE 5T	05T-3607	n/a	All stainless casts
24-way Carousel	SBE 32	32-31240-0423	n/a	All stainless casts
DOST	SBE 35	35-34173-0048	n/a	All stainless casts
Primary Dissolved Oxygen Sensor	SBE 43	43-2818	V0	All stainless casts
Secondary Dissolved Oxygen Sensor	SBE 43	43-3847	V1	All stainless casts
Fluorometer	CTG Aquatracka MKIII	88244	V2	All stainless casts
Altimeter	Teledyne Benthos PSA-916T	59494	V3	All stainless casts
Free			V4	
Free			V5	
Transmissometer	CTG Alphatracka MKII	CST-1719TR	V6	All stainless casts
Light Scattering Sensor	WETLabs BBRTD	BBRTD-1055	V7	All stainless casts
10L Water Samplers	OTE	Set D	n/a	All stainless casts

The SBE 9plus CTD top end cap configuration is show in Figure 2

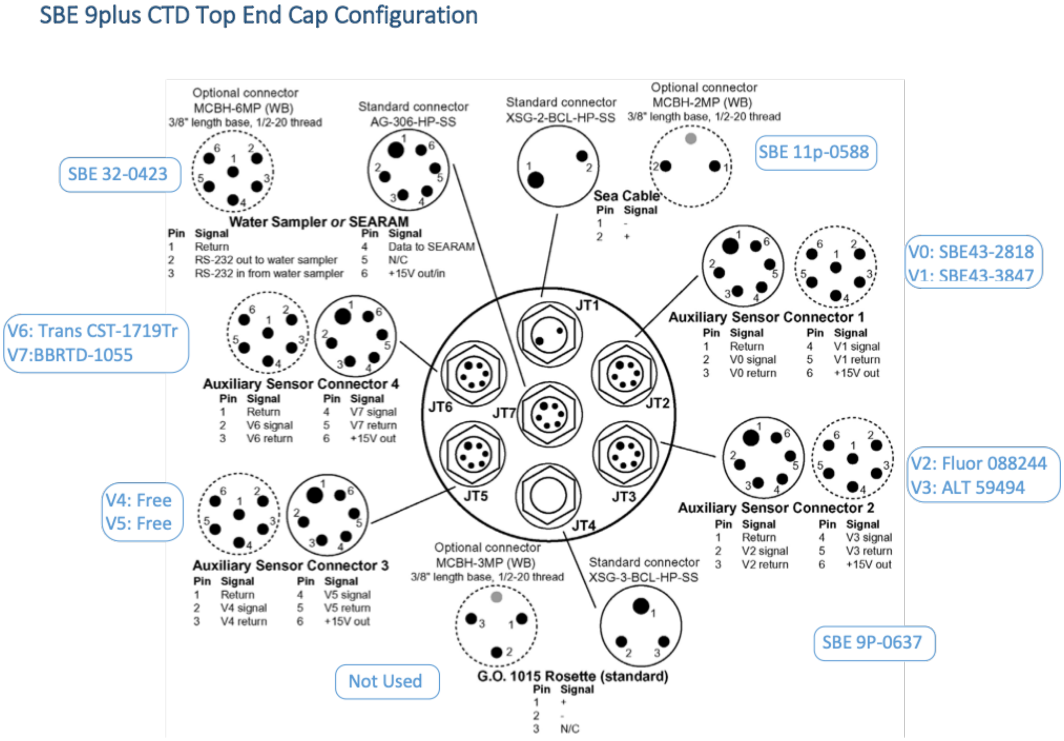


Figure 2: SBE 9plus CTD top end cap configuration

The SBE 9plus CTD bottom end cap configuration is show in Figure 3

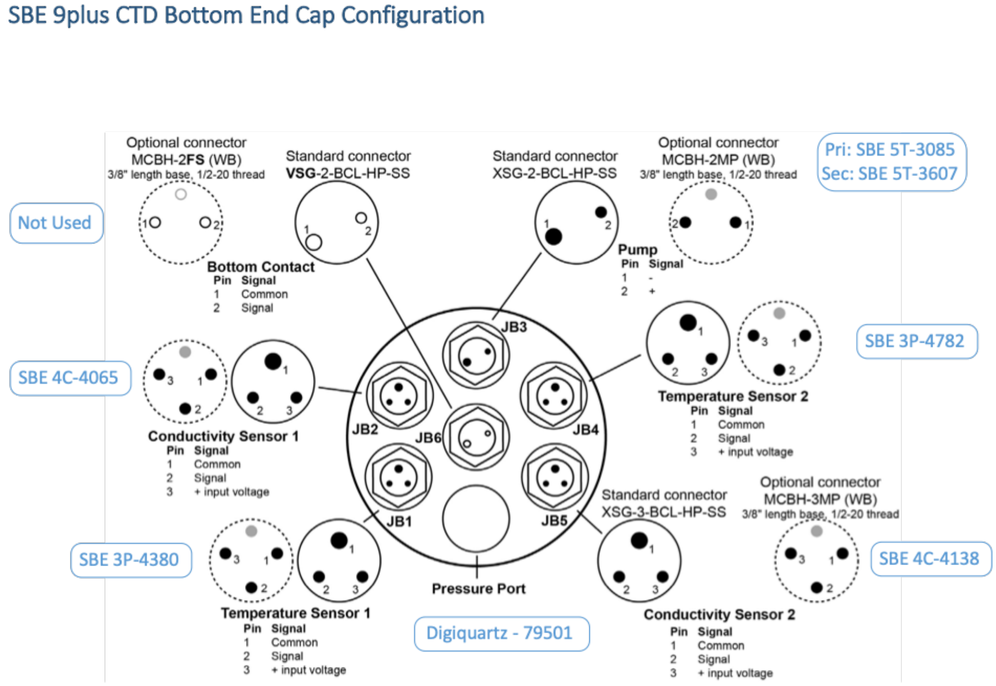


Figure 3: SBE 9plus CTD bottom end cap configuration

5.2.2 Seasave Configurations and Instrument Calibrations

Date: 03/05/2022

Instrument configuration file:

```
C:\Users\sandm\Documents\Cruises\DY146\Data\...
 Seasave Setup Files\DY146_SS_0637_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               : Yes
NMEA device connected to      : PC
Surface PAR voltage added     : No
Scan time added               : Yes

1) Frequency 0, Temperature

   Serial number : 03P-4380
   Calibrated on : 16-Feb-2021
   G             : 4.37196427e-003
   H             : 6.54764324e-004
   I             : 2.36097430e-005
   J             : 1.83938455e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

2) Frequency 1, Conductivity

   Serial number : 04C-4065
   Calibrated on : 16-Feb-21
   G             : -9.85799703e+000
   H             : 1.48882878e+000
   I             : -2.88486570e-003
   J             : 3.07913438e-004
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC
```

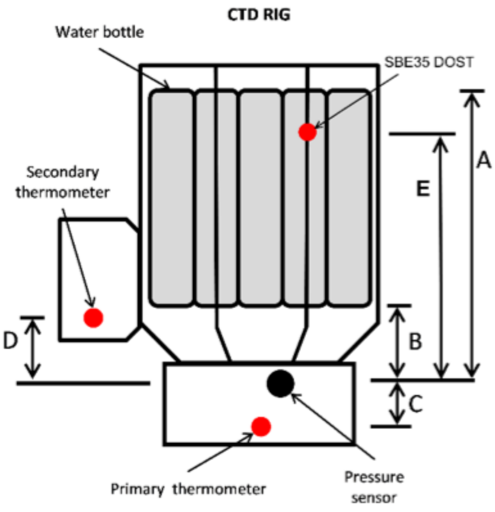
```
   Serial number : 79501
   Calibrated on : 24-Jan-2020
   C1            : -6.052595e+004
   C2            : -1.619787e+000
   C3            : 1.743190e-002
   D1            : 2.819600e-002
   D2            : 0.000000e+000
   T1            : 3.011561e+001
   T2            : -5.788717e-004
   T3            : 3.417040e-006
   T4            : 4.126500e-009
   T5            : 0.000000e+000
   Slope         : 0.99977900
   Offset        : -1.24262
   AD590M        : 1.293660e-002
   AD590B        : -9.522570e+000

4) Frequency 3, Temperature, 2

   Serial number : 03P-4782
   Calibrated on : 16-Feb-21
   G             : 4.34996027e-003
   H             : 6.36598928e-004
   I             : 2.09696633e-005
   J             : 1.78481336e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

5) Frequency 4, Conductivity, 2

   Serial number : 04C-4138
   Calibrated on : 16-Feb-21
   G             : -9.83908820e+000
   H             : 1.45290106e+000
   I             : -2.13721618e-003
   J             : 2.63858936e-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 : 43-2818
   Calibrated on : 28-Jul-2020
   Equation      : Sea-Bird
   Soc           : 4.70700e-001
   Offset        : -4.93600e-001
   A             : -4.47520e-003
```

```
   B             : 2.31120e-004
   C             : -3.48860e-006
   E             : 3.60000e-002
   Tau20         : 1.31000e+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, Oxygen, SBE 43, 2

   Serial number : 43-3847
   Calibrated on : 05-Mar-21
   Equation      : Sea-Bird
   Soc           : 3.80700e-001
   Offset        : -7.16000e-001
   A             : -5.34010e-003
   B             : 2.16650e-004
   C             : -3.22270e-006
   E             : 3.60000e-002
   Tau20         : 1.36000e+000
   D1            : 1.92634e-004
   D2            : -4.64803e-002
   H1            : -3.30000e-002
   H2            : 5.00000e+003
   H3            : 1.45000e+003

8) A/D voltage 2, Fluorometer, Chelsea Aqua 3

   Serial number : 088244
   Calibrated on : 07 August 2020
   VB            : 0.210666
   V1            : 2.032520
   Vacetone      : 0.245650
   Scale factor  : 1.000000
   Slope         : 1.000000
   Offset        : 0.000000

9) A/D voltage 3, Altimeter

   Serial number : PSA-916T 59494
   Calibrated on :
   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, WET Labs C-Star
```

```
    Serial number : CST-1719TR
    Calibrated on : 2nd April 2021
    M             : 21.2057
    B             : -0.0785
    Path length   : 0.250

13) A/D voltage 7, OBS, WET Labs, ECO-BB

    Serial number : 1055
    Calibrated on : 15/07/2019
    ScaleFactor   : 0.003639
    Dark output   : 0.043000

Scan length                  : 45
```

5.2.3 Stainless Steel CTD Frame Geometry

The geometry of the stainless steel CTD frame is shown in 4.



ID	Vertical distance from pressure sensor (m positive-up)
A	1.2 (Top of water samplers)
B	0.34 (Bottom of water samplers)
C	-0.075 (Primary T mounted on 9p)
D	0.085 (Secondary T mounted on Vane)
E	1.025 (SBE35 DOST probe sheath tip)

Figure 4: Stainless steel CTD frame geometry

5.2.4 Sea-Bird SBE35 DOST Configuration

The SBE35 was connected to the SBE9plus underwater unit and the SBD32 carousel using its ‘y’ – cable. It was configured to take 8 temperature samples each time that a bottle was fired.

```
* SBE35 V 2.0a    SERIAL NO. 0048
* number of measurement cycles to average = 8
* number of data points stored in memory = 8
```

```
* bottle confirm interface = SBE 911plus

* S>
* SBE35 V 2.0a    SERIAL NO. 0048
* 02-dec-21
* A0 =  4.601160270e-03
* A1 = -1.251567940e-03
* A2 =  1.885855280e-04
* A3 = -1.049558840e-05
* A4 =  2.240998470e-07
* SLOPE =  0.999989
* OFFSET =  0.000280
```

5.3 Technical Report

5.3.1 Stainless Steel CTD Wire CTD2

All stainless steel casts were carried out using wire CTD2, which was terminated using the scotch kote method during the mobilisation for DY146. The CTD wire was electrically tested after terminating and had an insulation resistance of >999 MΩ at 250 V. The wire stream gave the opportunity to test the electrical termination prior to the test cast, the insulation resistance was checked periodically throughout the stream with results of >999 MΩ at 250 V.

The mechanical termination was load tested as per the standard CTD load test of 5 minutes at 0.5 T, 1.0 T, 1.5 T and 10 minutes at 2.0 T. The mechanical termination did not slip under load. The mechanical termination was checked periodically throughout the cruise with no slipping noticed.

5.3.2 Altimeter

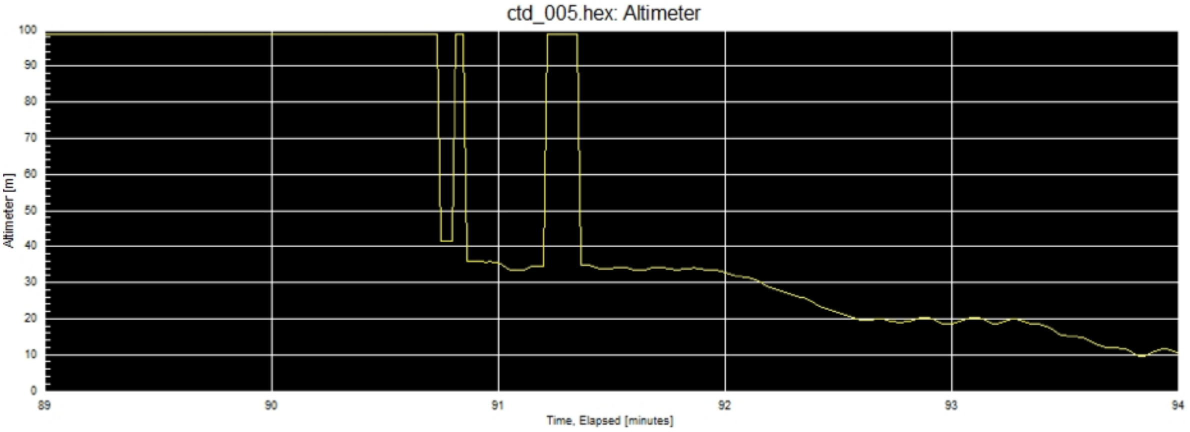


Figure 5: Cast 005 near bottom Altimeter plot

A Teledyne Benthos PSA-916T altimeter was used for DY146, as can be seen in the figure above the Altimeter did not get a consistent fix until the CTD was less than 35m off the seabed.

During DY138 a user supplied Valeport VA500 altimeter was fitted to the CTD for all casts, this reliably found the seabed from at least 90m every cast including a number of casts working on steep slopes. From this recent experience it would be highly beneficial to consider purchasing a number of Valeport Altimeters for the national marine equipment pool.

5.3.3 AUTOSAL

A Guildline 8400B, s/n 71185 was installed in the Salinometer Room as the main Autosal for salinity analysis. The bath temperature was set to 21°C with the lab ambient temperature ranging between 18°C – 18.5°C. The salinometer was standardised during the mobilisation, then again prior to the start of analysis.

The Autosal was standardised using IAPSO Standard Seawater batch P164 (K15 = 0.9985, 2 x K15 = 1.99970. There was no requirement to standardise the Autosal again during the cruise. The Autosal salinities agreed with the CTD data. In total 12 crates were analysed by Sensors and Moorings Technicians, 9 CTD crates and 3 Underway crates.

5.4 Sea-Bird Data Processing

Table 14 lists the Sea-Bird processing routines run by Sensors and Moorings Technicians. Note this is only the modules that were run by NMF, not by scientific staff.

Table 14: SBE data processing steps

Module	**Run?**	**Comments**
Configure	N	
Data Conversion	Y	**As per BODC guidelines Version1.0 October 2010 (Oxygen Concentration umol/l and umol/kg, Latitude and Longitude (degrees), Scan Count, Time and Pressure Temperature)**
Bottle Summary	Y	**As per BODC guidelines Version1.0 October 2010, with above variables added (except not averaging Scan Count and Time)**
Mark Scan	N	
Align CTD	Y	As per BODC guidelines Version1.0 October 2010 (dissolved oxygen advanced 6 seconds) (appended file name)
Buoyancy	N	
Cell Thermal Mass	Y	As per BODC guidelines Version1.0 October 2010 (appended file name)
Derive	Y	As per BODC guidelines Version1.0 October 2010 (appended file name)
Bin Average	Y	As per BODC guidelines Version1.0 October 2010 (1 metre depth bins) (appended file name)
Filter	N	As per BODC guidelines Version1.0 October 2010 (appended file name)
Loop Edit	N	As per BODC guidelines Version1.0 October 2010 (appended file name)
Wild Edit	N	**Not applicable.**

Window Filter	N	
ASCII In	N	
ASCII Out	N	
Section	N	
Split	N	
Strip	Y	As per BODC guidelines Version1.0 October 2010 (appended file name)
Translate	N	
Sea Plot	N	
SeaCalc II	N	

Software Used

- SeaBird SeaTerm 1.59
- SeaBird SeaSave 7.26.7.121
- SeaBird SBE Data Processing 7.26.6.28

6 Underway Measurements

Brian King, Yvonne Firing

Underway measurements for navigation, bathymetry, surface seawater, were routinely processed in daily batches using, for example, days = 50; `m_daily_proc`.

Underway data were processed to the end of day 064, and not for the remainder of the passage back to the UK.

6.1 Navigation

Navigation data were read in from the POSMV, CNAV, FUGRO, SEAPATH, GYRO streams. PHINS data were available in RVDAS but were not read into exec.

The POSMV was regarded as the primary navigation stream.

The PHINS did not provide heading and pitch/roll in a single RVDAS table. PHINS heading and pitch/roll were loaded from RVDAS at the end of the cruise and saved alongside attitude from POSMV and SEAPATH in matlab files in the nav/phins directory. These data were used for the study of heading transients.

6.2 Bathymetry

In order to be more generic across ships, the EM122 and EA640 streams were renamed to multib and singleb for multibeam and singlebeam depth measurements. The multibeam was not operated for much of the cruise, but was used as a backup depth measurement when CTDs were in progress. The single beam was of a generally high quality and required very little cleaning. Depth corrected for speed of sound was calculated, but no other postprocessing was carried out.

There are several data messages that provide water depth below surface or water depth below transducer. Some of the data in RVDAS is water depth below transducer, some is water depth below surface. Work remains to be done on getting complete metadata and message descriptions into the JSON files that set up the RVDAS database. The following fragment from the mrnames table indicates the mexec abbreviations for depth below surface (no suffix) and depth below transducer (suffix `_t`). The multibeam transducer depth was assumed to be 5 metres below the surface.

`multib_t`	`em122_depth_kidpt`
`singleb`	`em640_depth_sddbs`
`singleb_t`	`em640_depth_sddpt`

6.3 Surface ocean and meteorology

Data from the pumped seawater supply were logged in directory met/tsg. At the end of the cruise, underway salinity was compared with 62 surface bottle samples analysed by Autosal standardised with P164 standard seawater. A smoothed adjustment to TSG salinity was applied, varying between + 0.013 and +0.021. After applying the smoothed adjustment, the residuals between bottle salinity and TSG salinity had a mean value smaller than 0.001 and standard deviation 0.0015. The bottle salinity samples are in file `tsgsal_dy146_all.nc`. The final calibrated salinity is in file `tsg_dy146_01_medav_clean_cal.nc`.

Data periods for underway TSG are as follows

2022/02/09 1900 – start of data

2022/02/10 0858-0905 – flow off

2022/02/21 1318-1327 – flow off

2022/03/04 1238 – end of data

6.4 Other SURFMET calibrations

Calibration constants for fluoromter, transmissometer, PAR, TIR were entered in `opt_dy146` and applied in daily processing. Absolute wind speed and direction was calculated and is found in file `surfmet_dy146_01_trueav.nc`.

Note that the SURFMET RVDAS stream contains the wind speed and direction data, PAR, TIR, humidty, atmospheric pressure, also the fluorometer, transmissometer and flow rate. An extra temperature sensor on the drop keel is logged into a channel used for flow rate, and renamed in `mexec` to `watertemperature`. This measurement was used in a study of sea surface temperature reported under its own heading.

7 Vessel mounted Acoustic Doppler Current Profiler (ADCP)

Yvonne Firing

The 75 kHz and 150 kHz vessel mounted ADCPs were configured and run using the University of Hawaii Data Acquisition System (UHDAS, `http://currents.soest.hawaii.edu/docs/adcp_doc/index.html`). Configuration parameters are given in Table 15. Bottom tracking data was obtained on the track out the Channel but subsequently both ADCPs were configured for watertrack pings only.

Table 15: VMADCP instrument configurations

Instrument	**OS150**	**OS75**
Mode	Narrowbeam (nb)	Narrowbeam (nb)
Bins	40	60
Bin length (m)	8	16
Blanking distance (m)	4	8
Minimum ping time (s)	1.1	1.8
Maximum depth for bottom tracking (m)	500	1000
Bottom tracking	No except first day	No except first day
Beams	3-beam solution (beam 4 bad)	4-beam solution

Preliminary processing of UHDAS data happens automatically using CODAS, a set of programs written in Python and C which perform automatic editing on single-ping data, combine the VMADCP and navigation data to produce earth-referenced ocean velocities, and construct ensemble averages (with additional automatic editing and diagnostics at this stage). The default heading alignment and scale factors for each instrument were set at the start of the cruise based on examination (by the UHDAS group) of previous cruises' watertrack and bottomtrack data. Around 18 February, the UHDAS group pointed out dropouts in the Seapath heading stream being used for ship velocities, and sent a new configuration file for switching to the Posmv. Processing parameters are given in Table 16.

Table 16: VMADCP navigation sources and processing parameters

Cruise segment	**DY146**	**DY146_1**
Dates	09/02/2022-20/02/2022	20/02/2022-03/04/2022
Position (gps) instrument	Seapath	Posmv
Heading instrument	Gyro	Gyro
Heading correction instrument	Posmv	Posmv
Heading alignment (degrees)	-45.95	-46.59
Scale factor	1.01	1.02
Transducer (dx, dy) (m)	(0, 25)	(0, 25)
Ensemble length (s)	300	300

Postprocessing, again using CODAS, was performed on workstation koaekea (installation of a miniconda environment and CODAS is described in the Computing section). Processing steps are:

1. At the start of the trip, create text file `/local/users/pstar/cruise/data/vmadcp/cruise_segments`, containing one line, DY146; when the ADCPs are stopped and restarted with the new configuration, add another line, `DY146_1` (the name of the new segment).
2. Sync data from the UHDAS computer to a mirror on koaekea and to a postprocessing directory:

```
$ uhdas_00_syncraw
$ uhdas_02_sync_postprocessing_from_raw
```

3. View the latest data (for whichever cruise segment segment):

   ```
   $ conda activate pycodas
   $ cd /local/users/pstar/cruise/data/vmadcp/postprocessing/{segment}/
   proc_editing
   $ dataviewer.py -c os75nb os150nb
   ```

   Brings up the CODAS dataviewer GUI showing vector and contour (track section) plots of both instruments, for a first look and comparison.

4. Edit the data from both instruments (and possibly multiple segments) one after another:

   ```
   $ uhdas_03_copy_asclog_for_editing
   ```

   In case edits have previously been made and copied to `proc_archive` (see below) and overwritten by running the sync scripts above, brings them back into the `proc_editing` directory and applies them to the database there.

   ```
   $ dataviewer.py -e {instrument}
   ```

   Where `{instrument}` is os75nb or os150nb, brings up the editing version of the GUI, allowing bad or questionable data not picked up by the automatic processing to be removed.

5. Create a `.nc` file from the edited data and sync the data to `proc_archive` to preserve them:

   ```
   $ uhdas_04_export_nc
   $ uhdas_05_sync_edited_to_archive
   ```

The editing and comparison steps are done repeatedly and iteratively. Data range and quality was generally good other than the previously-identified probably-electrical noise that reduces the range of both ADCPs on this ship. As has been noted, this should be addressed during a shipyard period. Otherwise, the main issues visible in postprocessing were:

1. The 150-kHz had increased signal amplitude all through the water column most of the time on station, presumably reflecting noise from the ship's dynamic positioning thrusters. However, there was generally at most a small decrease in average correlation as measured by percent good (producing a slight reduction of the depth at which data failed the percent good cutoff). The 75-kHz only exhibited this noise in stripes (at all depths, so reflecting long pulses) sometimes, mostly on day 59.

2. Scattering layers were detected in the 75-kHz data, with a persistent higher amplitude around 400-450 m as well as occasional shallower layers exhibiting diel migration, through much of the cruise. The expected effect is to bias forward velocities at the top and bottom of the layer when the ship is underway. Sometimes this was clearly visible; sometimes no effect was visible; and sometimes a velocity anomaly associated with the scattering layer persisted both off and on station (i.e. with zero ship velocity). Data were edited out where the biasing effect of the scattering layer was clear, but not otherwise.

3. A tendency for the os75 to have larger forward and lower port velocity than the os150, on or off station. This was more consistent during the main mooring work segment (as opposed to the segments farther north).

4. Bad data in the bin above the bottom of the os75 record at the start (in shallow water) was edited out.
5. In some short stretches the top bin of the 150-kHz appeared to be an outlier; it was only edited out when this was very obviously wrong or large enough to produce a difference in the (averaged over 2 150-kHz bins) comparison with the 75-kHz.
6. Isolated bad profiles or larger discrepancies between the two instruments. Where it was clear which one (or both) instrument was showing bad data, either because of a sudden shift in velocity particularly associated with large heading changes or reduced signal amplitude or percent good, or because of elevated error velocity for the 75-kHz, the data were edited out. For some discrepancies between the two instruments, e.g. around decimal day 58.4-58.55, it was not clear which was correct, so both were left in. (A more conservative approach might have been to remove that stretch from both.)

After editing all data, `uhdas_03_copy_asclog_for_editing` is rerun to recalculate the heading alignment, scale factor, and transducer offset calibrations. Solutions for these coefficients are computed from bottom tracking (difference between apparent ship velocity over the bottom and known ship velocity over the earth) and from water tracking (change in apparent ocean velocity when the ship changes heading or speed, as when moving on and off station). Because we only collected bottom tracking for a short stretch at a single heading, water tracking was most useful for this cruise.

Table 17: Derived (additional) calibration coefficients: median (standard deviation)

Instrument (segment)	WT points	Heading alignment (degrees)	Scale Factor	Xducer [dx,dy] (m)
OS75nb (DY146)	8	-0.0020 (0.1717)	0.9995 (0.0071)	[1, 9]
OS75nb (DY146_1)	41	0.0430 (0.2734)	0.9990 (0.0059)	[1, 11]
OS150nb (DY146)	8	0.2380 (0.2597)	1.000 (0.0058)	[2, 10]
OS150nb (DY146)	41	0.0450 (0.5555)	0.9990 (0.0089)	[2, 13]

Only the transducer offsets were large enough relative to uncertainty to be worth applying. This was done by running `quick_adcp.py`, with the same coefficients for both segments (and different for the two instruments):

```
$ cd /local/users/pstar/cruise/data/vmadcp/postprocessing/DY146/os75nb
$ quick_adcp.py {steps2rerun rotate:apply_edit:navsteps:calib...
 --rotate_angle --rotate_amplitude --xducer_dx 1 --xducer_dy 12 --auto
$ cd /local/users/pstar/cruise/data/vmadcp/postprocessing/DY146/os75nb
$ quick_adcp.py {steps2rerun rotate:apply_edit:navsteps:calib...
 --rotate_angle --rotate_amplitude --xducer_dx 2 --xducer_dy 12 --auto
$ cd /local/users/pstar/cruise/data/vmadcp/postprocessing/DY146_1/os75nb
$ quick_adcp.py {steps2rerun rotate:apply_edit:navsteps:calib...
 --rotate_angle --rotate_amplitude --xducer_dx 1 --xducer_dy 12 --auto
$ cd /local/users/pstar/cruise/data/vmadcp/postprocessing/DY146_1/os75nb
$ quick_adcp.py {steps2rerun rotate:apply_edit:navsteps:calib...
 --rotate_angle --rotate_amplitude --xducer_dx 2 --xducer_dy 12 --auto
```

Alignment and scale factor calculations were only insignificantly changed by applying these additional transducer offsets. Finally, `uhdas_04_export_nc` and `uhdas_05_sync_edited_to_archive` were rerun to extract and sync the final, edited, calibrated data. Vectors in the reference layer from the OS150 and a depth-time contour plot of velocity from the OS75 from the main part of the cruise are shown here.

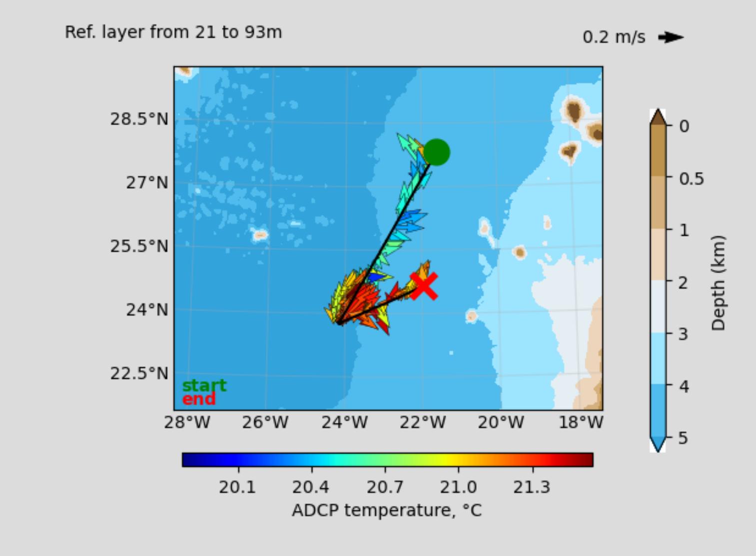


Figure 6: ADCP os150 vector plot part 1

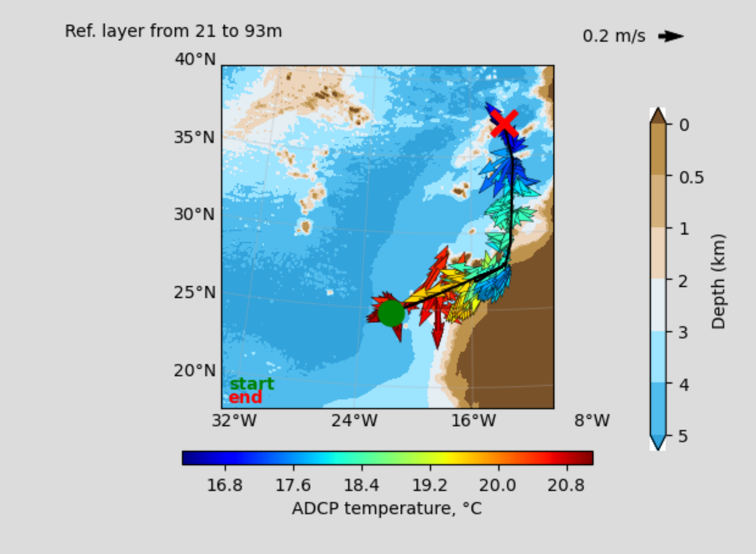


Figure 7: ADCP os150 vector plot part 2

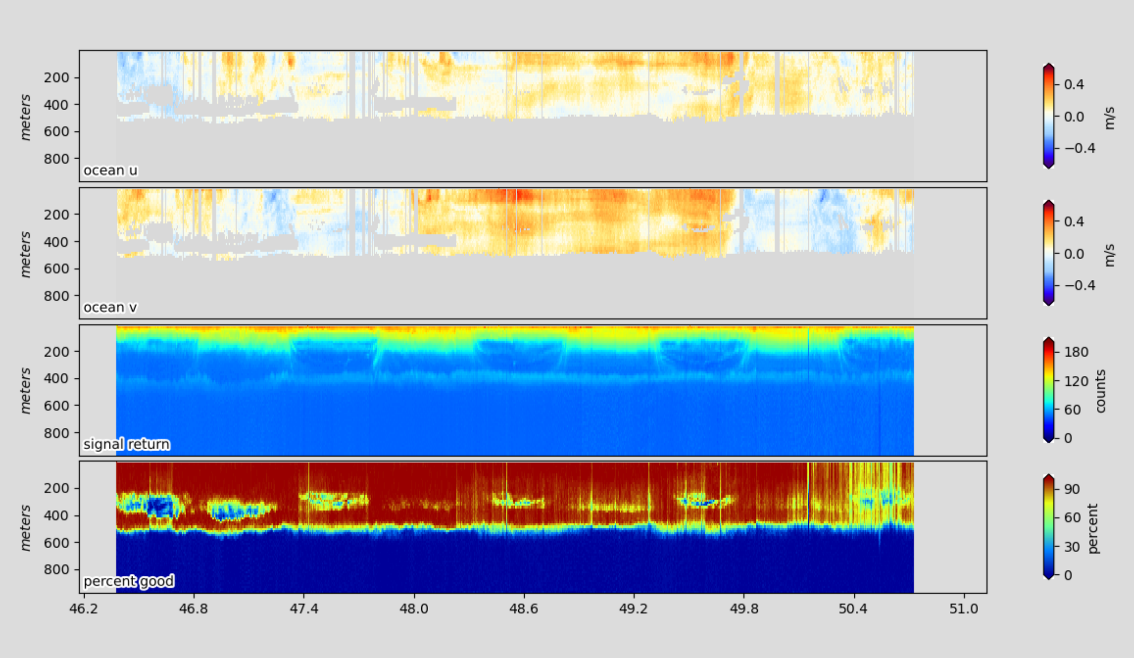


Figure 8: ADCP os75 contour plot part 1

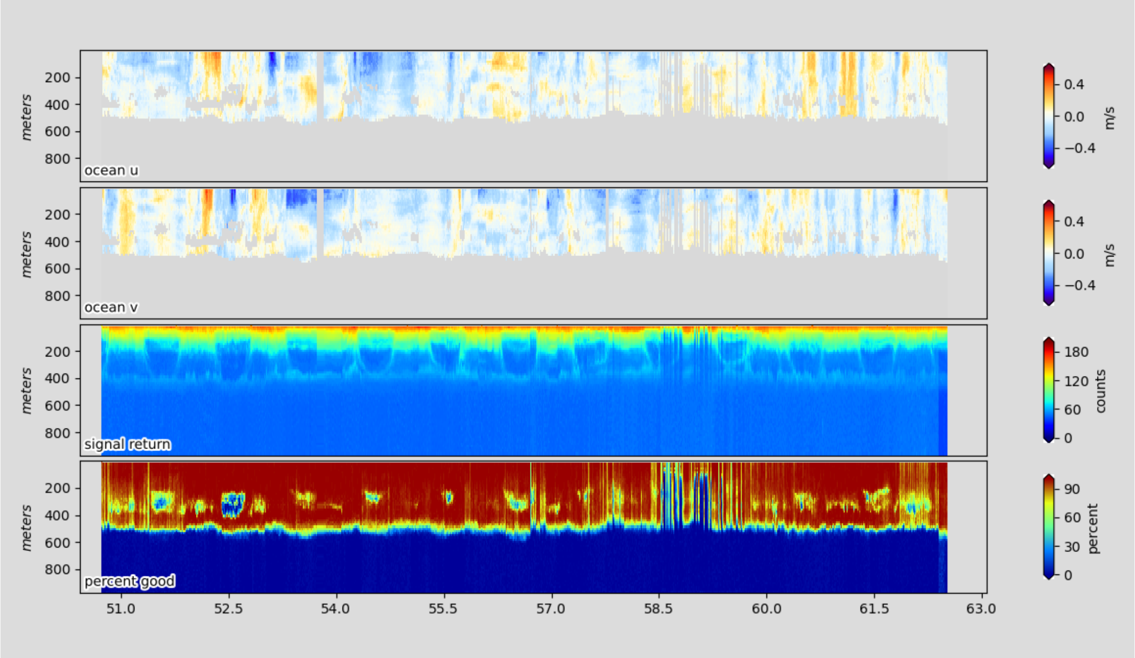


Figure 9: ADCP os75 contour plot part 2

8 Heading transients

Brian King and Yvonne Firing

A study was undertaken of heading from three intertial/motion reference sources: PHINS: reference for absolute heading is Fibre Optic Gyro POSMV: reference for absolute heading is satellite navigation antennas SEAPATH: reference for absolute heading is satellite navigation antennas

Each of the three heading sources, hereafter PHINS, PMV and SEA is supposed to be accurate at all times to 0.1 degrees from true north or better. Substantial transients were found, as illustrated in the following figures.

The heading sources were examined by inspecting differences, PMV-PHINS, PHINS-SEA, SEA-PMV. The heading sources were interpolated onto a common timebase, with an attempt to determine lags of a fraction of a second so that spurious transients were not generated when merging two oscillating signals with a time offset.

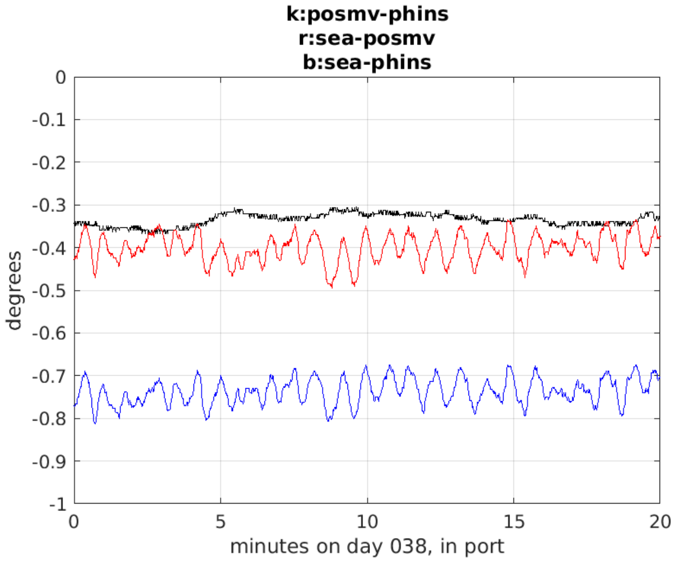


Figure 10: 20 minutes data from start of cruise while in port. The blue and red lines, SEA-PHINS and SEA-PMV show transients on timescales of minutes and order 0.1° or more. PHINS-PMV does not show this, so it is clearly a transient in SEA with a timescale of order 1 minute.

We did not note any obvious correlation between the PHINS-PMV difference and other properties of the ship that might influence one or other instrument: speed, heading, latitude. But that does not mean that no such correlation is present.

Summary: All three absolute heading sources claim accuracy of 0.1 degrees or better. At least two of them, and possibly all three, fail to deliver that accuracy.

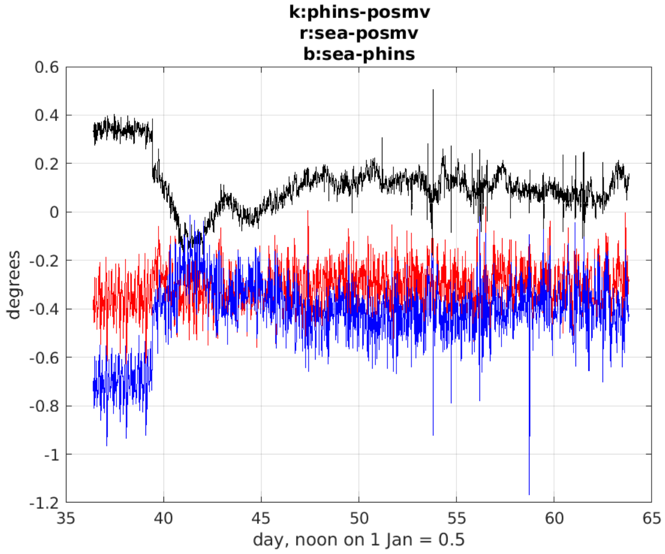


Figure 11: Data from 30 days, in port and at sea. Data have been smoothed with 15-minute averaging before plotting. The two curves that involve SEA still show transients of several tenths of a degree, which can surely be attributed to SEA. But the large scale offset between SEA and PMV is stable over time. PMV and PHINS show good agreement over timesclaes up to 1 day, but have transients of up to 0.5 degrees over days. SEA-PMV does not show that behaviour. However, SEA and PMV both take their absolute reference from GNSS antennas, whereas PHINS uses a different FOG technology. It is tempting to ascribe the PHINS-PMV transients to PHINS, but that is not proven. SEA and PMV could be subject to the same errors, if there was some aspect of GNSS antenna geometry that was imperfect.

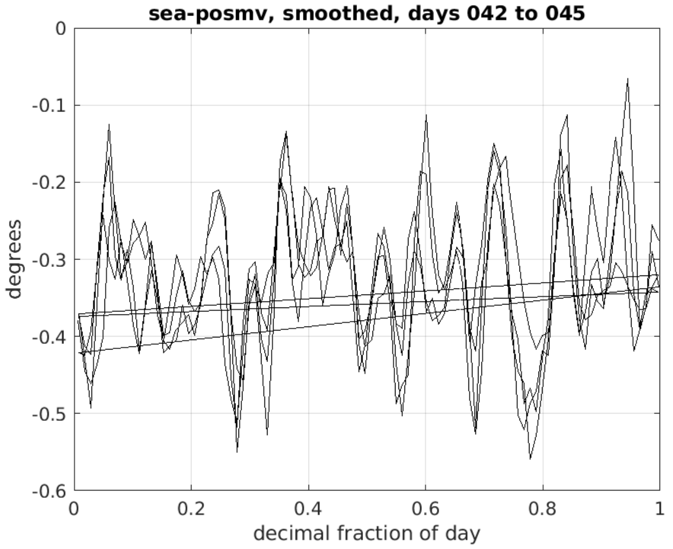


Figure 12: Shows 4 days of the SEA-PMV smoothed transient overplotted as a function of fractional time of day. The transient is clearly reproducible. The GNSS constellations also tend to be seen at recurring times of day. It is therefore very likely that the transient that we attribute to SEA is a consequence of a repeatable error in calculating the geometry of the antennas relative to the geometry of the GNSS constellations.

9 Scientific computing systems

Yvonne Firing

9.1 Configuration of the workstation

Scientific data processing was done on Linux workstation ‘koaekea’, a Dell T5820 running Centos 7. Configuration before packing included: Installing available software and Centos updates Updating MATLAB to 2021b Installing an updated python environment for VMADCP processing (using miniconda) as well as updating the CODAS VMADCP processing software. There were some mismatches between versions specified in the instructions (at the time, early November 2021) from `http://currents.soest.hawaii.edu/docs/adcp_doc/index.html` which could be avoided either by specifying python=3.8 when creating the pycodas environment:

```
conda env create -n pycodas python=3.8 ...
  --file ~/bin/adcpcode/codas_processing.yml
```

or by installing packages after creating a python=3.9 environment:

```
conda create --name pycodas python=3.9

conda install -n pycodas mercurial pip pyflakes numpy flake8 ...
  matplotlib ipython ipyparallel qtconsole pyqt pytest-qt ...
  basemap basemap-data-hires netcdf4 scipy
```

For future versions, the default installation path may work, or these modified steps may need to be updated appropriately.

Setting up cruise directories for CTD and underway data processing using `mexec_exec` shell script `conf_script_dy146`, and organising programs and software in `/local/users/pstar/bin` (compiled software not installed via Centos: Matlab, miniconda, and CODAS adcpcode) and `/local/users/ptar/programs` (mostly Matlab libraries, including the MEXEC software, and GSW, gamma_n and SW toolboxes in `/local/users/pstar/programs/others/`). Workstation ‘akeake’, a Dell T3420, was configured the same way as koaekea before shipping, but was not unpacked during the cruise.

Once on the ship, the external mounts were set up. The cruise network data directory (`current_cruise`) was mounted using cifs in `/mnt/data`, linked to by `/local/users/pstar/mounts/mnt_cruise_data`. The public directory was mounted separately in `/mnt/public`, linked to by `/mounts/public`,

but unfortunately this means it is readable but not writeable. Finally, the UHDAS mirror was mounted using nfs in `/mnt/uhdas_data`, linked to by `~/mounts/uhdas_data`. Unlike on some previous cruises, the Sensors and Moorings computer was not mounted directly but data were synced from `current_cruise` (using `ctd_syncscript`). The commands used are stored in `/local/users/pstar/mounts/mount_commands_dy` (which can be run as root following any reboots to set up the mounts again).

Updates to rapid data and scripts that had been copied to an external hard drive from `/noc/mpoc/rpdmoc` were synced to `/local/users/pstar/rpdmoc`.

Two backup disks were set up; this required first using a Mac to reformat as FAT so they would be recognised by koaekea, then reformatting as EXT4 for use with koaekea and other Linux workstations.

The latest versions of MEXEC libraries `mexec_exec`, `mexec_processing_scripts`, and `mexec` were pulled from `git.noc.soton.ac.uk/MEXEC`, each set up as a new branch for cruise DY146.

For access to the RVDAS database of ship underway data, `psql` was installed, and a private/public key pair was set up in `/local/users/pstar/.pgpass`.

Shell scripts in `mexec_exec` were updated to point to the current cruise's data and name formats: `ctd_syncscript` (replacing `ctd_linkscript`) and the five `uhdas_*` scripts.

The backup script used on previous RAPID cruises, which uses rsync's backup mode to both sync and create a space-efficient record of changes, was combined with the hydro backup script into `mexec_exec/cruise_backup` (and calls `mexec_exec/backup_core_local`). The crontab file was edited to do backups to the two disks at alternating times, as well as syncing the VMADCP data from the UHDAS computer to koaekea regularly:

```
10 1,13 * * * /local/users/pstar/programs/mexec_exec/uhdas_00_syncraw ...
 > /dev/null
20 2,8,14,20 * * * /local/users/pstar/programs/mexec_exec/ ...
  backups_syncs/cruise_backup dy146a > /dev/null
20 4,10,16,22 * * * /local/users/pstar/programs/mexec_exec/ ...
  backups_syncs/cruise_backup dy146b > /dev/null
```

9.2 Working on the workstation

The workstation was set up with an external monitor, but for the most part users interacted either via ssh or by mounting its drive and working on their own laptops. Several users ran into a problem with working in Matlab on koaekea using ssh -X (or ssh -Y) from a Mac using XQuartz, where windows displayed with a black background and text was not visible most of the time (changing the background or text color setting did not help). The problem appeared with both XQuartz 2.8.1 and XQuartz 2.7 on a Mac running OSX 11.6 but not on one running 11.6.2; and with Matlab 2021b but not Matlab 2015b. This appears to be a known but unsolved problem (not limited to Matlab, and possibly having something to do with the use of Java).

Besides the data areas `/local/users/pstar/rpdmoc/rapid` and `/local/users/pstar/rpdmoc/dy146`, `/local/users/pstar/rpdmoc/users` was used for working directories. These three areas plus `/local/users/pstar/programs` were included in the automatic backups.

9.3 MEXEC software for processing CTD, bottle sample, and underway data

The MEXEC software, particularly `mexec/` and `mexec_processing_scripts/`, was updated throughout the cruise, with changes tracked via git and a record of committed changes available from `git.noc.soton.ac.uk/MEXEC` under the dy146 branch for each repository. This started from an offshoot of the JC211 branch, but before and during the cruise a number of differences with the JC192 and DY129 branches were reconciled. During DY146, some reorganisation of `mexec` and `mexec_processing_scripts` was done so that functions that interact with mstar files directly are in mexec, and those which work in the Matlab workspace and load from or write to mstar files using mexec functions are in `mexec_processing_scripts`. Other significant updates were:

`mexec_exec` – `ctd_linkscript` replaced with `ctd_syncscript` (and rather than making symbolic links to standardised file names, `opt_{cruise}.m` tells the processing steps what file name form to look for and load, for CTD data as for bottle sample data).

`mexec` – RVDAS underway metadata added from json tables for dy146 – this means there is a set of metadata for both the Cook and the Discovery

`mexec` – new function `timeunits_mstar_cf.m` converts time units and origins between mstar format and CF format; `m_commontime.m` was updated to use this function.

`mexec_processing_scripts` – modified organisation of CTD processing steps with almost all calculations taking place in the Matlab workspace rather than via repeated reading/writing of mstar files. These steps are summarised below.

`mexec_processing_scripts/underway` – Underway data processing wrapper `m_daily_proc.m` modified to call `m_uway_append.m`, which merges on sample number so that if a given day is added again it will be overwritten not stuck on the end. `mnav_best.m` combines previous `mbest_*.m`; `mtsg_medav_clean_cal.m` includes code formerly contained in `mtsg_cleanup.m` and uses syntax similar to `mctd_02.m` for applying calibrations.

`mexec_processing_scripts/bottle_samples` – `msal_01.m` and `moxy_01.m` load all data in one step, from .csv or .xlsx files, using (new) `load_samdata.m`, as well as `hdata_flagnan.m` (imported from `MEXEC/hydro_tools/`), and write both to `sal_{cruise}_{nnn}_01.nc/`, `oxy_{cruise}_{nnn}_01.nc` and `sam_{cruise}_all.nc`.

9.3.1 The basic steps for CTD processing following a cast in the dy146 branch

`$ ctd_syncscript` –

Copies `.hex`, `.cnv`, `_align_ctm.cnv`, and `.bl` files from SM computer to koaekea.

`>> stn = {N}; ctd_all_part1` –

`ctd_all_part1.m` calls:

`mctd_01.m` loads and (new) renames variables and saves in `ctd_{cruise}_{nnn}_raw.nc`.

`mctd_02.m` does conversions, edits, and corrections, calling (new) `ctd_apply_autoedits.m`, `ctd_apply_oxyhyst.m`, `select_calibrations.m`, and `apply_calibrations.m` to produce `_raw_cleaned.nc` and `_24hz.nc` files. The syntax for specifying edits, corrections, and calibrations in `setdef_cropt_ctd.m` and `opt_{cruise}.m` was also modified, allowing (among other things) `ctd_apply_oxyhyst` to apply different corrections for different sensors.

`mctd_03.m` selects primary sensors, computes derived variables and averages to 1 Hz, using (new) `grid_profile.m`, producing `_psal.nc`. Note that `grid_profile.m` replaces a variety of averaging/interpolating/filling behaviour using (old) `merge_avmed.m`, `mintrp2.m`, and other code in previous versions, calling (new) `gp_smooth.m`, `gp_fillgaps.m`, `gp_binav.m`, and `gp_intav.m`.

`mdcs_01.m` guesses start and bottom of cast and saves in `dcs_{cruise}_{nnn}.nc`.

```
>> stn = {N}; mdcs_03g –
```

`mdcs_03g.m` brings up a gui for selection or confirmation of cast start, bottom, and end based on P, T, C, and pumps flag; any modifications are added to `dcs_{cruise}_{nnn}.nc`.

```
>> stn = {N}; ctd_all_part2 –
```

`ctd_all_part2.m calls`:

`mctd_04.m` separates down and up casts, optionally applies `m_loopedit.m` to the downcast data, and averages to 2 dbar, producing `_2db.nc` and `_2up.nc`.

`mfir_01.m` gets times and scans of Niskin bottle firing from `.bl` file and puts in `fir_{cruise}_{nnn}.nc`.

`mfir_03.m` gets CTD data from these scans from the 1-Hz `_psal.nc` file, either by interpolation or by averaging over a few seconds as set in `opt_{cruise}.m`, and adds to `fir_{cruise}_{nnn}.nc`.

`mwin_01.m` gets winch information from the underway stream and saves in `win_{cruise}_{nnn}.nc`.

`mwin_to_fir.m` adds it to `fir_{cruise}_{nnn}.nc`.

`mfir_to_sam.m` puts bottle firing data from `fir_{cruise}_{nnn}.nc` into appended `sam_{cruise}_all.nc`.

`station_summary.m` adds position, start and end time, depth obtained by calling `best_station_depths.m`, and information from `sam_{cruise}_all.nc` for this station to `station_summary_{cruise}.nc` and table `station_summary_{cruise}.txt`. Rather than storing station depths in a text file, they are calculated by `best_station_depths.m`, and if they cannot be calculated by CTD+altimeter are read from `opt_{cruise}.m` (which should be filled in for non full-depth casts).

`mdep_01.m` adds the depths to the various `ctd_{cruise}_{nnn}_*.nc` files.

```
>> stn = {n}; mctd_checkplots –
```

`mctd_checkplots.m` produces a set of plots to check for sensor drift or other problems.

```
>> stn = {n}; mctd_rawshow –
```

`mctd_rawshow.m` allows inspection of 24 Hz data. If this reveals editing needed, there are two options: specify automatic edits (based on scan ranges, data ranges, behaviour if pumps go off, and despiking) in `opt_{cruise}.m` under `mctd_02.m` case; and/or

```
>> stn = {n}; mctd_rawedit –
```

`mctd_rawedit.m` brings up a GUI for selecting and deleting spikes in the data

If automatic edits were added or `mctd_rawedit` was used,

```
>> stn = {n}; ctd_all_postedit –
```

`ctd_all_postedit.m` reruns `mctd_02`, `mctd_03`, `mctd_04`, `mfir_03`, and `mfir_to_sam` to propagate changes to the `_raw_cleaned.nc` file through to other files.

9.3.2 Steps for ingestion of calibration data

Temperature data –

> `>> msbe35_01` – `msbe35_01.m` produces `sbe35_{cruise}_{nnn}.nc` and adds to `sam_{cruise}_{nnn}.nc`

Oxygen data –

> Sync oxygen calculation excel spreadsheet file(s) to `~/cruise/data/ctd/BOTTLE_OXY/`, add file names `opt_{cruise}.m`, and if necessary variable names (if they differ from the defaults in `moxy_01.m` or `setdef_cropt_sam.m`).
>
> `>> moxy_01` – `moxy_01.m` loads multiple files/sheets to produce `oxy_{cruise}_{nnn}.nc` and, after converting from umol/l to umol/kg and averaging duplicates, add to `sam_{cruise}_{nnn}.nc`.

Salinity data –

> Sync `.xls` files (which are actually `.csv` not spreadsheet files) produced by Autosal-connected computer to `~/cruise/data/ctd/BOTTLE_SAL/`. By reference to sample collection logsheets (and eventlog), edit to add `sampnum` column containing the `sampnum = 100*{cast_number} + {niskin_position}` corresponding to each salinity sample bottle. Standards get sample numbers of the form `999NNN`, where `NNN` increments sequentially. TSG samples get sample numbers of the form `yyyymmddHHMM`. Rename or link to files with the name form `sal_{cruise}_n.csv` where n puts them in the order in which they were run.
>
> By inspection of the standards values compared to the nominal 2*K15 values for a given batch, select standards offsets to be applied to sets of samples (by interpolation across a given crate, or as a constant offset for each crate), and add to `opt_{cruise}.m`.
>
> `>> msal_01` – `msal_01.m` loads multiple files, applies offsets, calculates salinity from conductivity ratio, saves in `sal_{cruise}_01.nc` and adds to `sam_{cruise}_all.nc`.

9.3.3 Steps for inspection and comparison of calibration data

`>> mctd_evaluate_sensors(temp1)` –

> Produces plots of differences between CTD temp1 and temp2 and SBE35 data

`>> mctd_evaluate_sensors(temp2)` –

> Same for CTD temp2

`>> mctd_evaluate_sensors(cond1)` –

> Produces plots of ratio between CTD cond1 and cond2 (adjusted for temp1 vs temp2) and conductivity from bottle salinity (and CTD temp1)

`>> mctd_evaluate_sensors(oxygen1, 'useoxyratio',1)` –

> Produces plots of ratio between CTD oxygen1 and oxygen2 and bottle oxygen – this is useful for a first-pass comparison

`>> mctd_evaluate_sensors(oxygen1)` –

> Produces plots of differences between CTD oxygen1 and oxygen2 and bottle oxygen – this is useful after an initial calibration has been applied and the comparison is closer.

`mctd_evaluate_sensors.m` also has the option to inspect large CTD-cal differences profile-by-profile to determine which ones indicate suspect Niskin closures, suspect sample analysis, or just large gradients or variance in the CTD trace.

Calibration coefficients are set in `opt_{cruise}.m` under the `mctd_02` case and applied by running `ctd_all_postedit.m` for each station (see above and Section ***).

9.4 RAPID software

The RAPID software is found in `/local/users/pstar/rpdmoc/rapid/data/exec/`. Versions for a number of past cruises are stored there. On DY146, the version for this cruise (`/local/users/pstar/rpdmoc/rapid/data/exec/dy146/`) was made a git repository for the first time, and old versions started to be moved into subdirectory `ref_not_on_path` (which, as the name suggests, was specifically excluded from the Matlab startup path) to reduce confusion. We suggest that in future git is used to track changes, and old versions are kept only in their respective cruise backups (which are also preserved on the seagoing workstation as well as at NOC), with only the most recently-used or relevant copied to the current cruise's directory. Other significant changes were: Modified `rapid_widgit*` scripts to work with mrvdas as well as mtechsas, along with corresponding variable name changes New `rapid_basedir.m` function replaces code in various scripts testing for base directory depending on setup (e.g. working on koaekea, on Mac mounting koaekea, at NOC).

Initial processing of moored data includes data loading and conversion; inspection and setting of deployment start and end times and (for BPR data) selection of pressure drift function; and conversion to output .use files along with noting any issues with the data (e.g. sensor drifts, sensor fouling, P spikes, etc.). For cal dip data it includes loading and conversion, comparison with CTD data to check the T and C values are within range at the deepest, most stable stops, and the P values are within range at the just-completed or planned deployment depth, and note any deviations or other issues affecting either later data processing or planning for future use of the instrument.

These processing steps are carried out using Matlab scripts:

Moored MicroCat (and ODO) –

`mc_call_2.m` and `microcat_raw2use_003.m`

BPR –

`seagauge2rdb_003.m` and `seagauge_processing_003.m`

MicroCat cal dips –

`mc_call_caldip_v4.m`

Before running for each cast or mooring, the scripts must be edited to change the cast or mooring name, and possibly the cruise and time base or range for plotting. Raw data copied from the download PCs to `koaekea:/local/users/pstar//rpdmoc/rapid/data/moor/raw/{cruise}/{instrument_type}`. Text files containing mooring/cast information, found in `~/rpdmoc/rapid/data/moor/proc/{mooringname}_{deploynumber}_{deploydate}/orproc_calib/{cruise}/cal_dip/`, are also used.

10 Sequence of steps to configure mrvdas on dy146 on workstation koaekea

Brian King and Yvonne Firing

The sequence below employs the json files used to describe the RVDAS database. This pathway is a legacy from the start of jc211. When RVDAS is fully finished and includes significant metadata, everything required for `mexec` could be interrogated out of the database itself rather than the `json` files. At present however we take variable name/unit pairs from the json files. The present sequence also requires some manual editing of files. This is largely a case of one set of edits for each ship. We envisage in due course having a single set of codes, with case switches for each ship: James Cook, Discovery, Sir David Attenborough. This will be streamlined as experience on each ship evolves.

The steps taken below were centred in the `~/data/rvdas` directory on mexec workstation koaekea. Most of the scripts are in `~/programs/mexec/source/mrvdas`.

1. Create a rvdas data directory; copy the original json files from the rvdas machine; make a list of the json file names. Create a directory that will later be used for temporary csv files as data are read from rvdas into mexec.

   ```
   mkdir -p ~/cruise/data/rvdas/original_json_files
   mkdir -p ~/cruise/data/rvdas/rvdas_csv_tmp

   cd ~/cruise/data/rvdas/original_json_files
   rsync -a rvdas@192.168.62.12:///home/rvdas/ingester/sensorfiles/dy/
   ```

   This copies the original json files to

   ```
   ~/cruise/data/rvdas/original_json_files/dy

   cd ~/cruise/data/rvdas/original_json_files/dy
   ls *.json > list_json.txt
   ```

   to create a list of the .json files

   On dy146 there were 25 original json files:

   ```
   10_at1m
   air2sea_gravity
   air2sea_s84
   at1m_u12
   cnav_gps-dy
   ea640_depth-dy
   em122_depth-dy
   env_temp-dy
   fugro_gps-dy
   nmf_surfmet-dy
   nmf_winch-dy
   phins_att-dy
   posmv_att
   ```

```
posmv_gyro
posmv_pos-dy
ranger2_usbl-dy
rex_wave-dy
sbe45_tsg-dy
seapath_att-dy
seapath_pos-dy
seaspy_mag-dy
ships_gyro-dy
ship_skipperlog-dy
u12_at1m
wamos_wave-dy
```

Each json file contains a number of 'sentences' associated with a set of rvdas tables. Each sentence corresponds to a data message to unpack, such as an NMEA navigation message. For example, `posmv_pos-dy.json` recognises 8 messages, GPGGA, GPHDT, GPVTG, GPRMC, GPZDA, PASHR, GPGLL, GPGST. Note that this json file declares the number of sentences to be 7. This is an error, but doesn't seem to matter. The later script `mrshow_json.m` counts the actual number of sentences.

2. Convert the json files to matlab

   In matlab, script `mrjson2mat_all.m` calls `mrjson2mat.m` for each of the files in `list_json.txt`, thus

   ```
   >> cd ˜/cruise/data/rvdas/original_json_files/dy
   >> mrjson2mat_all('list_json.txt')
   ```

   This calls `jsondecode` to convert .json to .mat. Function `jsondecode` was not available in Matlab2015 on jc211, but was available in Matlab2018a and later.

   The .mat files contain struct variable `js`, with fieldname `js.sentences` with dimension equal to the number of sentences found by `jsondecode`.

3. Produce a listing of all the json sentences, which will be used to select which data mexec wishes to access.

   In matlab, script `mrshow_json_all.m` calls `mrshow_json.m` for each of the files in `list_json.txt`, thus

   ```
   >> cd ˜/cruise/data/rvdas/original_json_files/dy
   >> mrshow_json_all('list_json.txt')
   ```

   This unpacks all the json structures and produces a list to the screen. That full list is copied and pasted into `mrtables_from_json.m`.

   On dy146 this process produced 91 possible tables extracted from 25 json files.

4. Select tables that mexec wishes to access: edit the file `mrtables_from_json.m`.

   On jc211 and dy146 this process required significant manual intervention. Many tables are not required at all. The section of the listing corresponding to those tables can be commented out. In other tables, not all variables are required. Variables not required can be commented out, for example

```
%posmv_pos-dy  8  sentences

%"GPGGA { Global Positioning Fix Data"
rtables.posmv_pos_gpgga = {  % from posmv_pos-dy.json
    ’posmv_pos_gpgga’ 14  % fields
    ’utcTime’                             ’’
    ’latitude’  ’degrees and decimal minutes’
    ’latDir’                             ’’
    ’longitude’  ’degrees and decimal minutes’
    ’lonDir’                             ’’
    ’ggaQual’                             ’’
    ’numSat’                             ’’
    ’hdop’                             ’’
    ’altitude’                             ’’
    %     ’unitsOfMeasureAntenna’                             ’’
    %     ’geoidAltitude’                             ’’
    %     ’unitsOfMeasureGeoid’                             ’’
    %     ’diffcAge’                      ’seconds’
    %     ’dgnssRefId’                             ’’
    };
```

The variables that remain will be read in to mexec by later scripts. Variables with non-numeric values, eg some quality flags, should be commented out at this stage.

5. If interested, compare the tables described in the json files with the tables actually present in rvdas. The script

   ```
   >> cd ˜/cruise/data/rvdas/original_json_files/dy
   >> js = mrshow_json_all(‘list_json.txt’);
   >> jslist = fieldnames(js);
   >> whos jslist;
   ```

   returns a list of all the sentences unpacked from the json files. On dy146 there were 91 sentences unpacked.

   The matlab script

   ```
   >> t = mrgettables;
   >> tlist = fieldnames(t);
   >> whos tlist
   ```

   generates a `psql \dt` query to list all the rvdas tables in the database. On dy146 there were 90 tables.

   There were 89 common tables. The difference between the lists was that rvdas has a table

   ```
   {‘logta’}
   ```

   and the json files defined sentences for

   ```
   {’seaspy_mag_3rr0r’}
   {’seaspy_mag_inmag’}
   ```

that were not not found as rvdas tables

6) Script `mrnames.m` maintains a list of shortcut names between names that mexec uses and the full rvdas table names.

```
tablemap = {

    ’winch’        ’nmf_winch_winch’
%
    ’hdtgyro’      ’ships_gyro_hehdt’
%
    ’attpmv’       ’posmv_pos_pashr’
    ’hdtpmv’       ’posmv_pos_gphdt’
    ’pospmv’       ’posmv_pos_gpgga’
    ’vtgpmv’       ’posmv_pos_gpvtg’
%
    ’posfugro’     ’fugro_gps_gpgga’
    ’vtgfugro’     ’fugro_gps_gpvtg’
    ’dopfugro’     ’fugro_gps_gngsa’
%
    ’attphins’     ’phins_att_pashr’
    ’hdtphins’     ’phins_att_hehdt’
    ’posphins’     ’phins_att_pixsegpsin0’ % phins lat and lon
    ’hssphins’     ’phins_att_pixseheave0’ % phins surge sway heave
    ’prophins’     ’phins_att_pixseatitud’ % phins pitch and roll
    ’prdphins’     ’phins_att_prdid’
%
    ’poscnav’      ’cnav_gps_gngga’
    ’vtgcnav’      ’cnav_gps_gnvtg’
%     ’dopcnav’      ’cnav_gps_gngsa’  % available on jc211

%     ’posdps’       ’dps116_gps_gpgga’ % available on jc211

    ’posranger’    ’ranger2_usbl_gpgga’
%
    ’attsea’       ’seapath_att_psxn23’
    ’hdtsea’       ’seapath_pos_inhdt’
    ’possea’       ’seapath_pos_ingga’
    ’vtgsea’       ’seapath_pos_invtg’
%     ’dopsea’       ’seapath_pos_ingsa’  % available on jc211
%
    ’surfmet’      ’nmf_surfmet_gpxsm’
%     ’windsonic’    ’windsonic_nmea_iimwv’
    ’multib_t’     ’em122_depth_kidpt’
    %     ’em120’        ’em120_depth_kidpt’    on jc211
    ’singleb’      ’em640_depth_sddbs’
    %     ’ea600’        ’em600_depth_sddbs’    on jc211
    ’singleb_t’    ’em640_depth_sddpt’
    ’envtemp’      ’env_temp_wimta’
    ’envhumid’     ’env_temp_wimhu’
    ’rex2wave’     ’rex2_wave_pramr’
    ’wamos’        ’wamos_wave_pwam’
```

```
    'tsg'          'sbe45_tsg_nanan'
%     'logchf'       'ships_chernikeef_vmvbw'  % available on jc211
    'logskip'      'ships_skipperlog_vdvbw'
    'gravity'      'u12_at1m_uw'
    'mag'          'seaspy_mag_inmag'
    'magerror'     'seaspy_mag_3rr0r'
    };
```

6. Edit the script which renames variables as they are read in to mexec.

   Script `mrrename_tables.m` allows the renaming of variables and units as they are read out of rvdas and into mexec. This allows for consistent and simple names for variables like heading, lat, lon, depth.

   It is probably easiest to start with a version of `mrrename_tables.m` from a previous cruise, and make any small edits required. Some differences occur between jc and dy. New entries may be required for rvdas tables for new datastreams.

   The contents of `mrrename_tables.m`, starts with the list of contents in `mrtables_from_json.m`. Some entire tables, and some variables are already commented out. In `mrrename_tables.m`, variables which are not having renamed names or units can be further commented out. For example

```
%posmv_pos-dy  8  sentences

%"GPGGA { Global Positioning Fix Data"
renametables.posmv_pos_gpgga = {  % from posmv_pos-dy.json
    %     'posmv_pos_gpgga' 14  % fields
    'utcTime'                             '' 'utctime'  'hhmmss_fff'
    'latitude' 'degrees, minutes and decimal minutes' 'latdegm' 'dddmm'
    %     'latDir'                             ''
    'longitude' 'degrees, minutes and decimal minutes' 'londegm' 'dddmm'
    %     'lonDir'                             ''
    %     'ggaQual'                             ''
    %     'numSat'                             ''
    %     'hdop'                             ''
    %     'altitude'                             ''
    %     'unitsOfMeasureAntenna'                             ''
    %     'geoidAltitude'                             ''
    %     'unitsOfMeasureGeoid'                             ''
    %     'diffcAge'                      'seconds'
    %     'dgnssRefId'                             ''
    };


%"GPHDT { Heading { True Data"
renametables.posmv_pos_gphdt = {  % from posmv_pos-dy.json
    %     'posmv_pos_gphdt'  2  % fields
    'headingTrue'                      'degrees' 'heading' 'degrees'
    %     'trueHeading'                             ''
    };
```

   In this example, ‘latitude’ is renamed to ‘latdegm’ because latitude is not a decimal latitude but a composite of degrees and minutes. Latitude will be calculated later for this data stream. The units ‘dddmm’ are assigned. In the second example, ‘headingTrue’ is renamed to ‘heading’ but the units are kept as degrees.

7. If all is well, the following commands should display sensible results in matlab

```
>> mrnames
>> mrlookd
>> mrlookd f
>> mrload pospmv
>> mrlast pospmv % with lat and lon now converted to decimal degrees
>> mrposinfo pospmv [050 12 0 0]
```

8. A note about navigation tables in rvdas.

   There are json files that would allow the same NMEA navigation message to be ingested into several rvdas tables. For example the set of 8 POSMV messages appear in each of

```
posmv_att.json
posmv_gyro.json
posmv_pos-dy.json
```

   And each of these rvdas tables exists, so there are 8 x 3 = 24 rvdas tables for posmv:

```
posmv_att_gpgga
posmv_gyro_gpgga
posmv_pos_gpgga
```

   However, the att and gyro rvdas tables are empty. Only the

```
posmv_pos_gpgll
posmv_pos_gpgst
posmv_pos_gphdt
posmv_pos_gprmc
posmv_pos_gpvtg
posmv_pos_gpzda
posmv_pos_pashr
```

   tables are filling with data. So the mexec shortnames

```
 'attpmv'  ->     'posmv_pos_pashr'
 'hdtpmv'  ->     'posmv_pos_gphdt'
 'pospmv'  ->     'posmv_pos_gpgga'
 'vtgpmv'  ->     'posmv_pos_gpvtg'
```

   are all mapped to `posmv_pos` tables in rvdas.

11 CTD Temperature, Salinity, Oxygen data processing

Brian King

Routine CTD data processing followed previous cruises. A collection of scripts gathered in `ctd_all_part1.m` to read in data from SBE `.cnv` files, manual selection of the start and end of the cast using `mdcs_03g.m`, and a second collection in `ctd_all_part2.m` to reduce data to 1Hz, extract and average down and up casts, and prepare the CTD data and winch data corresponding to bottle closures.

11.1 Initial files from datcnv, and Oxygen hysteresis

After a few false starts that required reprocessing, data were converted to SBE cnv files with the following algorithms applied in SeaSoft datcnv:

```
advance primary conductivity  0.073 seconds (applied in deck unit)
advance secondary conductivity  0.073 seconds (applied in deck unit)
# datcnv_ox_hysteresis_correction = no
# datcnv_ox_tau_correction = yes
# alignctd_adv = sbeox0V 6.000, sbox0Mm/Kg 6.000, sbeox1V 6.000,...
 sbox1Mm/Kg 6.000
# celltm_alpha = 0.0300, 0.0300
# celltm_tau = 7.0000, 7.0000
```

Certain variables or units that are not always output by NMF, but are required outputs for mexec processing include

```
# name 0 = timeS: Time, Elapsed [seconds]
# name 1 = latitude: Latitude [deg]
# name 2 = longitude: Longitude [deg]
# name 7 = c0mS/cm: Conductivity [mS/cm]
# name 8 = c1mS/cm: Conductivity, 2 [mS/cm]
# name 11 = sbeox0V: Oxygen raw, SBE 43 [V]
# name 12 = sbox0Mm/Kg: Oxygen, SBE 43 [umol/kg]
# name 13 = sbeox1V: Oxygen raw, SBE 43, 2 [V]
# name 14 = sbox1Mm/Kg: Oxygen, SBE 43, 2 [umol/kg]
# name 19 = scan: Scan Count
# name 20 = pumps: Pump Status
```

Note preferred units for Conductivity and Oxygen, and the output of lat and lon, scan and pumps.

Oxygen hysteresis was not applied in datcnv, so that we could explore and change hysteresis parameters.

A script not really part of the usual mexec suite was brought up from a dy040 archive: toxy.m. This allows experimenting with different hysteresis parameters until optimum up/down agreement is achieved.

Default hysteresis parameters, which are applied in mcoxyhyst, are

```
[H1, H2, H3] = [ -0.033 5000 1450];
```

Experimentation found that better up/down agreement could be achieved by letting H3 vary with depth. Accordingly the following lookup tables for H3 were devised and entered in `opt_dy146.m`.

```
h3tab1 =[
    -10 500
    2000 500
    2001 3000
    9000 3000
    ];
h3tab2 =[
    -10 500
    2000 500
    2001 3000
    9000 3000
    ];
```

Also `castopts.oxyhyst.H1 = {-0.038 -0.033};` to set H1 to -0.038 for sensor 1

These numbers were determined after the last station and re-applied to the whole cruise.

These values provided good upcast/downcast agreement throughout, with up-down differences generally of order 1 umol/kg for much of the water column.

11.2 Processing scripts

Changes and departures from standard scripts in place at the start of the cruise:

`ctd_all_part1` – Options were added, controlled by `opt_jdy146`, to apply temp, cond, oxy cals as part of `ctd_all_part1`. This meant that once calibrations had been determined, they could be applied as data were processed.

11.3 Sensors and calibrations, selection of datastream, SBE35

Throughout this report we will refer to primary and secondary sensors as 1 and 2. This is different from the SBE convention of using 0 and 1. The sensors in the SBE primary channel were mounted below the water bottle rosette, and the sensors in the SBE secondary channel were mounted on the vane. The secondary sensors produced the best data and that data stream will be reported as the cruise dataset for T, S, O for all stations, except station 9, which had a fouling on the downcast. The primary sensor data are reported for that station.

11.3.1 Temperature calibration

Data from temp1 and temp2 were compared with SBE35 data at bottle stops. For each sensor a small residual offset of order 0.5 mK with small pressure dependence was inferred. These were adjusted in `mctd_02` with

```
castopts.calstr.temp1.dy146 = ’dcal.temp1 =...
 d0.temp1 + interp1([-10 0 2000 4500 6000],[ 5  5  5 0 0]/1e4,d0.press);’;
castopts.calstr.temp2.dy146 = ’dcal.temp2 =...
 d0.temp2 + interp1([-10 0 2000 4500 6000],[-4 -4 -4 4 4]/1e4,d0.press);’;
```

11.3.2 Conductivity and salinity calibration

The same C1, C2 sensors were used throughout, and were stable compared with bottle salinity samples.

After adjusting temp1 and temp2, the conductivity data cond1 and cond2 were compared with the corresponding conductivities from salinity bottles. A pressure dependence was found for each cell, and determined with a by-eye fit to the conductivity residuals. Adjustment was applied in `mctd_02` with the following

```
castopts.calstr.cond1.dy146 = ’dcal.cond1 =...
 d0.cond1.*(1 + interp1([-10 0 500 1000 2000 3500 4500 8000],...
 1*[-12 -12   0  10 18 4 -5 -5]/1e4,d0.press)/35);’;
castopts.calstr.cond2.dy146 = ’dcal.cond2 =...
   d0.cond2.*(1 + interp1([-10 0 500 1000 2000 3500 4500 8000],...
 1*[-35 -35 -17  -6  6 2 -5 -5]/1e4,d0.press)/35);’;
```

For cond1, the equivalent salinity adjustment was everywhere less than 0.0020, except in the upper 500 dbar.

There were 83 bottle salinities deeper than 1000 dbar. After applying the adjustments, the standard deviation of residuals between reported CTD salinity and bottle salinity for those samples was 0.0014, with mean 0.0002.

11.3.3 SBE35

SBE35 data were collected and used to adjust the CTD temperatures by up to 0.5 mK.

11.3.4 Oxygen calibration

A single pair of primary and secondary oxygen sensors were used throughout the cruise. An initial calibration for oxygen was determined after station 005, and this was revised after station 025. A new calibration was re-applied to the whole cruise dataset.

After all the oxygen bottle data were available, the pressure dependence for each sensor was determined. A single empirical pressure dependence was found for each sensor, and used for the whole cruise. The residuals of bottle minus CTD for the whole cruise then looked stable over most of the cruise, with both sensors reading a little higher on the first few stations. Ie the suggestion was of both sensors losing a bit of sensitivity between stations 1 and 5. Accordingly, a further factor was introduced for each sensor interpolated linearly on station number form 1 to 5. The calibration equations in `opt_dy146` were

```
castopts.calstr.oxygen1.dy146 = ['dcal.oxygen1 = d0.oxygen1.*'...
  'interp1([-10      0    1000    3000  5400   6000],...
[1.027 1.027  1.033   1.038 1.055 1.055],d0.press).*'...
'interp1([1 5 25],[0.988 1 1],d0.statnum);'];

castopts.calstr.oxygen2.dy146 = ['dcal.oxygen2 = d0.oxygen2.*'...
'interp1([-10      0    1000    3000  5400   6000],...
 [1.045 1.045  1.052   1.062 1.075 1.075],d0.press).*'...
'interp1([1 5 25],[.992  1 1],d0.statnum);'];
```

In those entries, the first interp1 calculats the pressure dependence, and the second interp1 ramps the further factor up from 0.988 (oxygen1) or 0.992 (oxygen1) at station 1 to 1.000 at station 5.

There were 62 bottle oxygens deeper than 1000 dbar and 79 shallower. After applying those calibrations, the mean and standard deviation of the reported CTD oxygen for the deeper set were (0.06,0.98) and for the upper ocean set were (0.53,0.94) μmol/kg.

11.3.5 Station depths and positions

Station depths were taken from the single beam bathymetry record, corrected water depths at the time the CTD was at the bottom of the cast.

Values were entered into `opt_dy146`.

11.3.6 Other sensors, fluor, transmittance, backscatter

In addition to T, S, O sensors, the CTD frame was equipped with chlorophyll fluorescence, transmittance and backscatter. These data had no extra processing on the cruise, beyond applying the manufacturer's calibration in the SBE processing, but are carried through the files, and may be of value for comparison with BGC floats. The group from Heriot-Watt collected and filtered some samples from the shallowest two bottles on several stations for chlorophyll analysis ashore.

12 mexec handling of bottle salinity for CTD and underway TSG

Brian King

Bottle salinity samples were analysed by NMF on a Guildline Autosal 8400B operated at 21C.

The Standard Seawater batch was P164, K15 = 0.99985, 2*K15 = 1.99970.

The SSW values were assessed from the autosal log sheets, and an offset value for each standard was entered into `opt_dy146`. The adjustments to Guildline ratio varied from -6 to +6 over 24 SSW standards and 12 crates of samples.

The .xls autosal logs were converted to .csv, and sample numbers added.

Standards were assigned sample numbers 999001 and following. CTD samples were assigned sample numbers 101 to 2513 for (station 001, niskin 1) to (station 025, niskin 13). Underway TSG samples were assigned sample numbers based on time of collection, eg 202203022112, in the format yyyymmddHHMM. Times were cut and pasted from the event log, with excel reformatting the times into the format that mexec expected.

Bottle salinity csv files were placed into mexec directory `ctd/BOTTLE_SAL`, and linked with a sequential convenient file name, e.g.

```
sal_dy146_001.csv -> DY146 CRATE 15 21 Feb 2022.csv
sal_dy146_002.csv -> DY146 CRATE 14 23 Feb 2022.csv
```

Bottle sample data were read into mexec using `msal_01`. `msal_01` identified and read all the `sal_dy146_nnn.csv` files. It then found SSW offsets in the `opt_dy146` file. For a single run of `msal_01`, CTD samples were adjusted for SSW and output into the CTD `sam_dy146_all.nc` file. Underway samples were adjusted for SSW and output into file `tsgsal_dy146_all.nc`.

13 Sea surface temperature comparison

Brian King

The measurement of underway sea surface temperature has been a topic of concern and debate for a considerable time. It was investigated extensively on DY040, because of the sensitivity of calculations of air-sea gas exchange on sea surface temperature.

SST is traditionally reported from a sensor near the intake of the pumped seawater supply at a nominal depth of around 5 metres. It has been noted in the past that this temperature is often a tenth to a few tenths of a degree warmer than temperature at 5 metres reported by CTD casts. This has been observed on several ships: Discovery, James Cook, James Clark Ross, in a variety of ocean temperatures.

An extra sensor was recently installed on one of Discovery's drop keels. It is logged into the surfmet stream on RVDAS

```
{'surfmet'  }    {'nmf_surfmet_gpxsm'     }
```

and known in mexec as 'surfmet'. The variable uses one of the flow channels in RVDAS and is renamed to `watertemperature` in mexec.

The figure shows a startling result, showing comparisons between the traditional TSG remote temperature, the dropkeel remote temperature and CTD data from 5 metres, recorded on the CTD downcast. The ship underway measurements were extracted at the time of the start of the CTD station.

The continuous blue curve is the TSG intake minus the dropkeel temperature. The red symbols are the TSG minus CTD at 25 stations, and the black symbols are dropkeel minus CTD. The dropkeel and CTD are in remarkable agreement, near perfect, with mean offset smaller than 0.001 K, and standard deviation 0.005 K.

The conclusion is inescapable: The dropkeel sensor is doing a good job and reports the same water temperature as the CTD. As expected, and despite the best efforts to introduce lagging and remove bias, the TSG remote temperatures are higher than the CTD. The TSG remote sensor is only a short distance inside the point of hull intake, but it is nevertheless the case that the water passes down some pipework before the temperature measurement is made. The pipework passes through a water tank, in which the water level fluctuates. There is a clear excursion, lasting about 2 days, in which the TSG temperature is more than 0.5K warmer than the dropkeel temperature. The water level in the ship's water tank fluctuates between 38 and 97 m^3, but the rises, falls and extremes of level are not correlated with the excursions in temperature sensor difference. The large anomaly between days 045 and 050 remains unexplained. It corresponds to a mid-level in the ship water tank, as judged from data supplied by the Ch Officer.

The median value of (TSG minus dropkeel) is 0.07 K and the 75th percentile is 0.10 K. So the bias of 0.10 K is exceeded 25% of the time. It is expected that the statistics of the amount by which the TSG reports biased temperatures would vary with temperature in which the ship is operating.

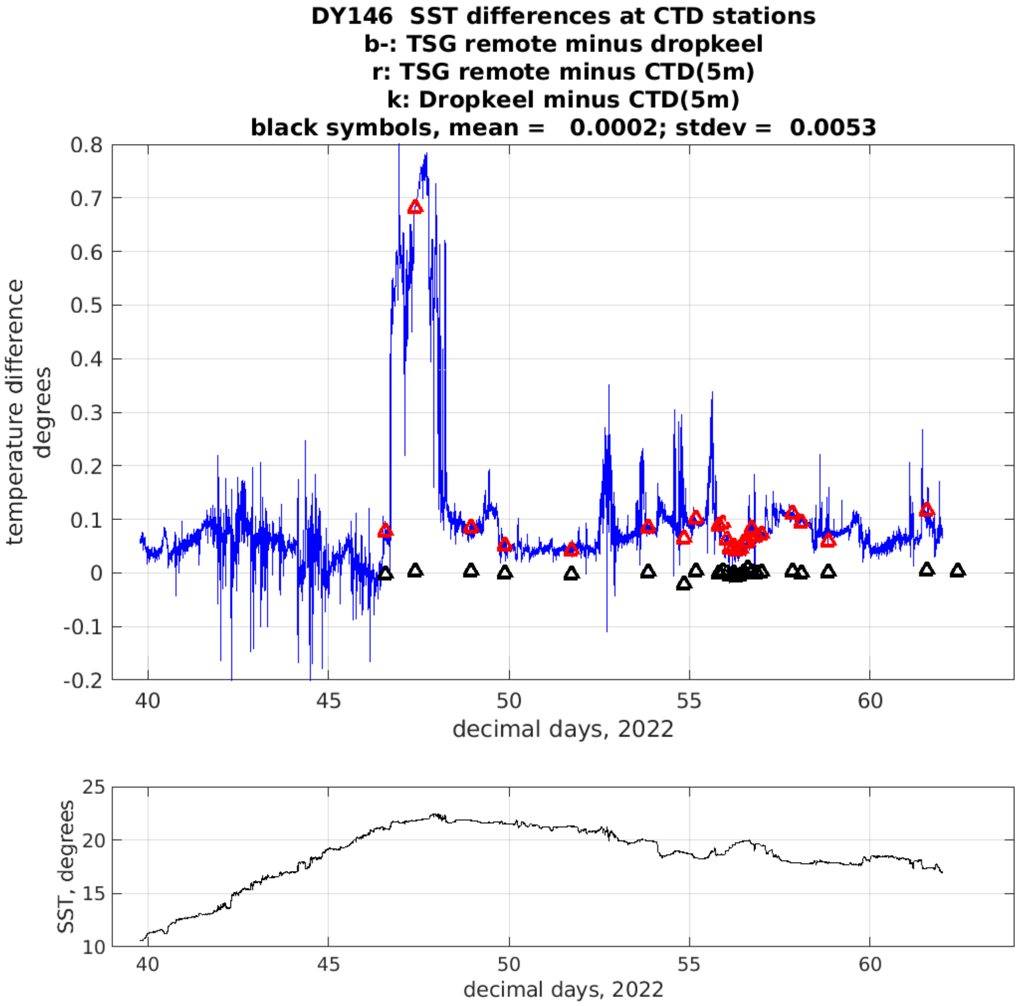


Figure 13: DY146 SST comparison

14 Winch MRU offsets and active heave compensation

Brian King, Craig Lapsley

The investigation of active heave compensation on DY146 led to the exposure of major errors in the setup of the system, and an eventual temporary workable solution that provided good active heave compensation on stations 24 and 25.

This investigation, identification of errors of setup, temporary workable solution and pathway to permanent solution, depended strongly on the cooperation, patience and awareness of Craig Lapsley (CPOS) and the deck crew operating the winches. We on DY146, and all the scientists who will benefit from an effective heave compensation system in the future, are indebted to their contributions.

Since anecdotal evidence is that the heave compensation has 'never worked very well on DY' and not as well as recent performance on James Cook (JC), it is assumed that these errors have been present in the system for a long time, possibly since it was first commissioned.

This report is in two parts. First, the detective work that illustrates how 'good' or 'poor' heave compensation can be diagnosed and illustrated, and Second, a summary of the errors in the system that need to be corrected, presumably with the manufacturer's assistance.

14.1 Diagnosis of heave compensation and its affect on the CTD package

The effect of heave compensation is illustrated with a series of figures showing the JC system, with heave compensation disabled and enabled, then the DY system disabled, enabled with wrong MRU offsets, and enabled with improved MRU offsets.

Data were analysed on DY146 in a Matlab program `analyse_winch.m`, with data from DY146 and JC211.

The winch and CTD behaviour were analysed when the winch was stopped to allow sampling by the CTD instrument package. At these stops, the winch would be set to zero speed. If heave compensation is disabled, the winch is indeed stationary, and the cableout is constant during the stop. The CTD package moves up and down in the water as the ship moves. This movement is detected by the CTD pressure/depth sensor. Even with several thousand metres of cable out, the CTD package is very tightly attached to the ship, and the CTD package motion exactly matches the motion of the sheave that supports the cable. If heave compensation is enabled, the winch moves a small amount in and out, to compensate for the motion of the ship. The intention is that the motion of the CTD package will be much reduced.

Each study of a 'CTD stop' has several diagnostics. During the time when the winch is 'stopped', the heave/pitch/roll motion of the ship is analysed from the scientific Seapath MRU in the gravity room. This is a similar unit to the winch MRU in the winch drive suite. Using the scientific MRU, an estimate is made of the likely motion of the final overside sheave. The motion of either the CTD, or the way the winch heave compensator chooses to move the winch, can then be decomposed onto the three components of ship motion: heave, roll, pitch. (The technical detail is that there is a least squares fit between the time series of the CTD vertical speed or winch rate, and the equivalent time series of sheave motion due to heave, roll and pitch. The reported heave component of CTD motion is the total motion with roll and pitch removed, and equivalent for the other two components.)

Moving from top to bottom, the panels for each 'CTD stop' consist of the following: Top: CTD vertical speed decomposed onto heave, roll, pitch. The red diagonal lines show the 1:1 correspondence. If the scattered dots fall on the diagonal lines, it means the CTD vertical speed decomposed onto ship heave, after removal of roll and pitch, exactly matches the ship heave reported by the MRU. Similarly for roll and pitch. The next panel down shows the rate of paying out or hauling in with the winch, distributed into the response to the ship heave, roll and pitch. In the third panel down, the cyan line shows the amount of wire paid out by the winch, which is either fixed if the winch is truly stopped, or oscillates if the heave compensation is active. In the lowest panel, the black line shows the vertical displacement of the CTD, in metres, while the winch is supposed to be stopped. Behind the black line, the red line shows the motion that the CTD would have had if the heave compensation was not active. If the winch is truly stopped, there is no red line in the lowest panel, because it is identical to the black line and hidden behind it.

The horizontal axis is time, measured by decimal day number in the year.

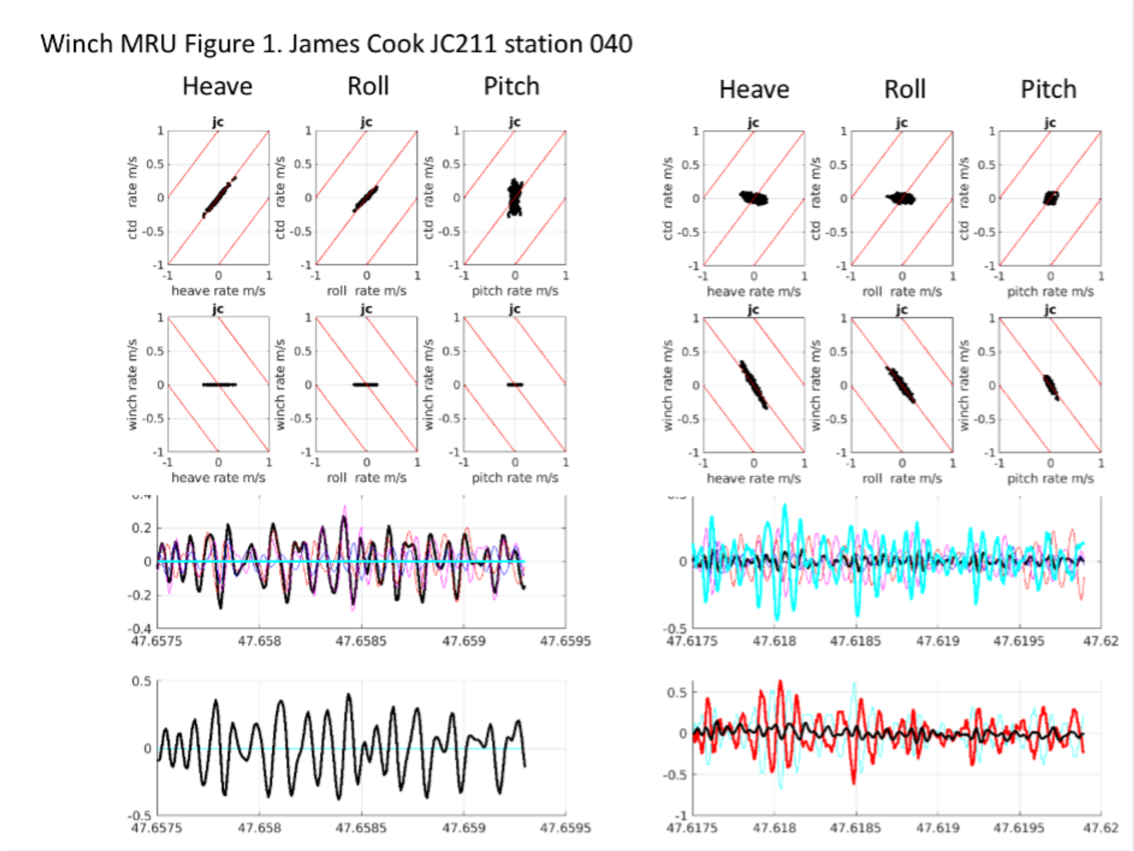


Figure 14: Left panels, JC211, station 40: a CTD stop shallower than 100 metres, heave compensation disabled. Second row has no motion; the winch is stopped. Row 1, the CTD vertical speed is almost perfectly predicted by heave and roll of the ship. The response to pitch is small. When JC pitches, the CTD sheave doesn't move much, there is no significant correlation. Row 3: cyan line horizontal, the winch is stopped. Row 4: the CTD moves up and down in the water while the winch is stopped. Right panels, JC211, station 40: a deeper CTD stop with heave compensation enabled. Second row, the winch is correctly moving almost exactly equal and opposite to the motion of heave, roll, pitch of the ship. Row 1, the CTD now has very little motion. Row 3, the cyan line shows the winch moving in and out while the package is 'stopped'. Row 4: If the winch was stopped without heave compensation, the CTD would move up and down with the red line. Because of heave compensation, the CTD moves with the black line. Around 70% of the CTD package motion has been removed.

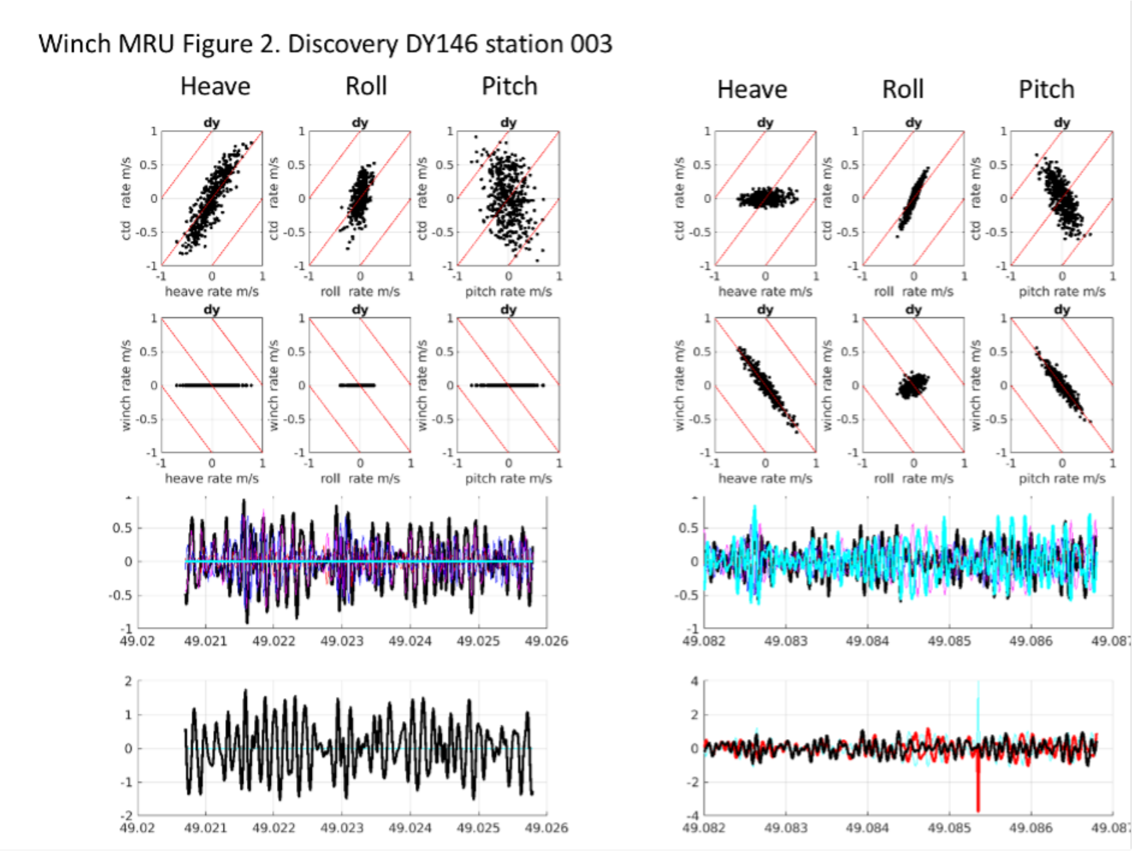


Figure 15: Left panels, DY146, station 3: winch stopped, heave compensation disabled. Similar to Figure 14 JC left panels. Winch has no motion, CTD motion is well predicted as the response to ship heave and roll. No strong correlation with ship pitch. Right panels, DY146, station 3, winch stopped, heave compensation enabled. Rows 1 and 2: Left pair: the winch is correctly moving in response to the ship heave, and that component of CTD motion is removed. Centre pair: The winch is not moving correctly to compensate for roll. The CTD motion is still affected by roll. Right pair, the winch is moving strongly but unnecessarily in response to pitch, and introduces CTD motion correlated with pitch, which was not there when heave compensation is disabled. Row 3: the winch moves in and out. Row 4, although the winch is moving a lot, and compensating for heave, it is not compensating for roll. The black line is the same amplitude as the red line behind it.

After altering the setup of the winch heave compensation, which is discussed in the next section, two successful stations were conducted, with CTD stops shown in Figure 16.

14.2 Faulty setup of the heave compensation offsets in the winch control system

Once we knew that the winch was correctly responding to the ship heave, but not responding to roll, and responding wrongly to pitch, there were a number of possibilities, of which one or more must have been the cause. These were

1. The MRU was not sending correct roll and pitch data.
2. The winch was not receiving correct roll and pitch data.
3. The winch was receiving data but not decoding it correctly.

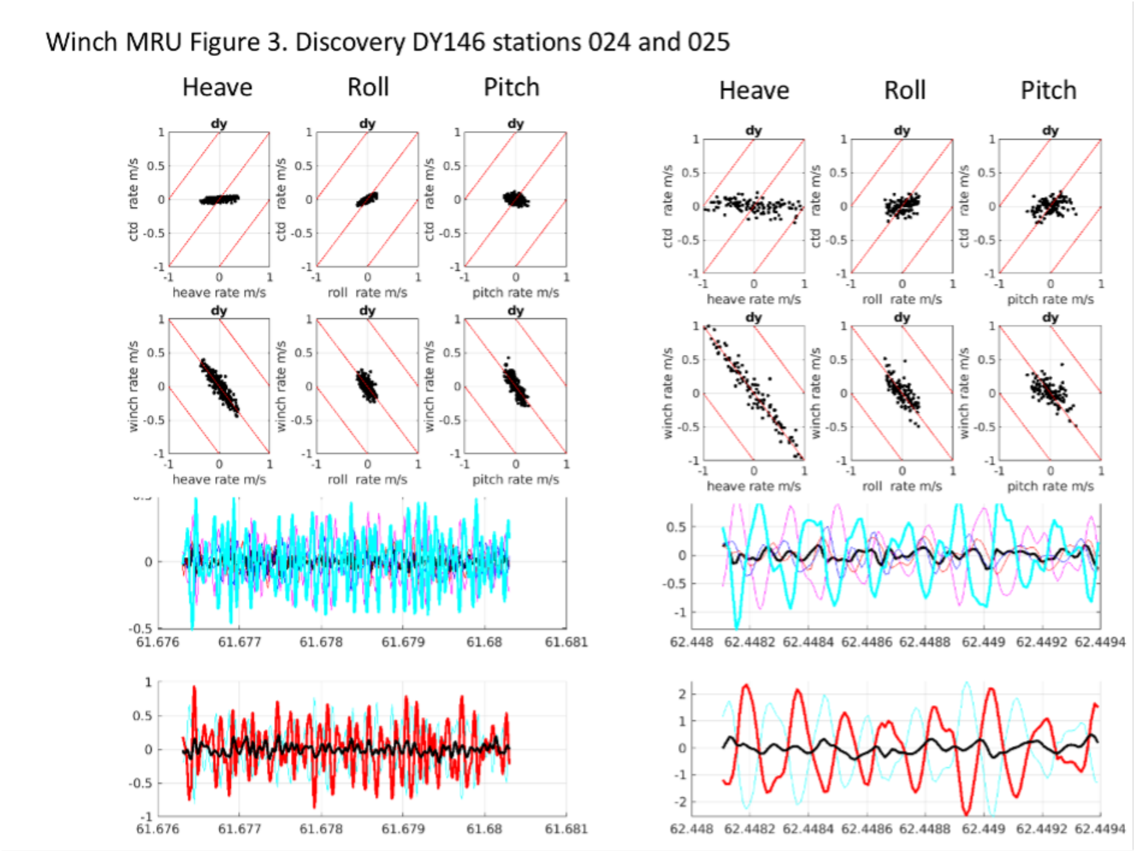


Figure 16: Left panels, DY146, station 24, winch stopped, heave compensation enabled. Right panels, station 25, winch stopped, heave compensation enabled. In each case, the rate at which the winch moves the cable in response to the ship heave, roll and pitch is correct, and the CTD package motion is mostly removed. In the lowest panel, the black line has much lower amplitude oscillations than the red line. The CTD package motion is reduced by 70 to 80 percent. This performance is comparable to the JC.

4. The winch was decoding correct and valid MRU data, but the controller made wrong calculations of how to move the drum in response.
5. The winch controller calculated correctly how it should move the drum, but was failing to move the drum correctly.

We could not think of any other steps from MRU to correctly compensated CTD motion, so the problem must have been in one of those steps. Some of them would be easier to test and rectify than others. It turns out that step (4) was the reason the heave compensation was failing to work properly.

Once the winch controller has valid heave, roll and pitch data, it needs to decide how much to move the drum. Heave we will not consider further, since it is working correctly. In order to translate pitch and roll angles to motion of the sheave that supports the wire outboard, the winch controller needs to know the 'lever arm' offsets between the sheave, and the point at which heave, roll and pitch are reported by the MRU. Notice that I wrote 'reported by' the MRU. It is possible for the MRU to measure heave, pitch, roll at one location translate them and report data that are valid at a different location. So the winch needs to know distance offsets from a winch point of interest to the point at which the MRU data are valid.

Once we knew what to look for, an investigation was begun by Brian King (scientist) and Craig Lapsley

(CPOS). The winch control system has offsets installed that define distances in X,Y,Z directions for each winch 'Point', for the P-Frame, A-Frame and BullHorn, inboard, moving, and fully extended. It turns out that more than half these offsets are simply wrong or do not vary correctly as 'dynamic' points. This meant the winch could not calculate the correct drum motion to compensate for the ship motion.

The table below shows the X, Y, Z offsets for various points on the A-Frame (AF), BullHorn (BH), P-Frame (PF). The P-Frame has 'CTD' and GC' sheaves. The BullHorn has only one sheave, but used to have distinct CTD and GC sheaves, and these are both still entered in the winch system. The A-Frame has only one sheave.

In the table, X is fore/aft, and it appears that positive numbers describe the offset for a point more aft. Y is port/stbd, and it appears that positive numbers describe the offset for a point more towards stbd. Z is up/down, and it appears that negative numbers describe a point upwards, further from the centre of the earth.

Each sheave has a 'fixed' point corresponding to fully extended (100% tilt on the articulating frames, and 100% extended on the BH), and a 'dynamic' point, at which the offsets are supposed to vary in response to the movement of each gantry. Every single one of these 'dynamic' points is wrongly configured.

The following analysis provides commentary on the numbers shown in the table

A-Frame: Point 2, fixed 100% tilt

X = 54.89, well aft Y = 0.34, near the centreline Z = -8.51, we conclude -9 is the height of the top of the A-frame. Negative numbers are upwards.

A-Frame: Point 1, dynamic

X and Z report 'NaN'. In computing terms this means 'Not A Number'. It means a calculation has been provided with some invalid numbers, and can't compute an answer. The display doesn't change while the A-Frame is moved from 0% to 100% extended

BH, Points 3 and 4, fixed 100% extension

The X,Y,Z are similar for points 3 and 4. There is only one sheave now. X = 15.57 means this is fwd of the AF and aft of the PF, which is sensible. Y = 12.44, seems OK for extended over the stbd rail Z = -6.99, not quit as high as the AF sheave. OK

BH, Points 1 and 2, dynamic

X = 15.57 Y = 9.48 (at 0% extension) Z = -6.99 We expect X and Z to remain the same while the BH extends. Only Y should change. At zero extension, Y for Point 2 is 2.96 metres inboard of Point 4. But as the BH extends, Y does not change. It remains as 9.48. Therefore if Point 2 is selected, it is correct at zero extension, and wrong at 100% extension. Point 1 behaves in the same wrong way. It doesn't move when the BH extends. However, the Y-value can fluctuate by up to 3 cm when a dynamic point is selected and the BH is not being extended.

P-Frame, Points 3 and 4, fixed 100% tilt The X and Y values for Points 3 and 4 are reasonable. Around 4 metres fwd of the BH, with Point 4, the CTD sheave, around 14 metres outboard of the centreline when at full tilt.

The Z values for points 3 and 4 are 5.02 and 9.25. By eye, these sheaves are a little higher than the BH sheave. So these values should be around -7.5, not +5 or +9. And apart from small differences in sheave diameter, they should be the same value. Fortunately, this error is not of major importance, because the winch compensation is not sensitive to Z.

P-Frame, Points 1 and 2, dynamic

It is for Point 2 that the most important errors are found. This is unfortunate, because it is Point 2 that is the logical choice for a CTD over the P-Frame, and Point 2 that has commonly been used.

X = -5.20, whereas +10.81 seems more likely. X = -5.20 for all values of tilt. Y = 8.30 when the PF is fully inboard, about right, but changes in the wrong direction and becomes Y = 2.17 at 100% tilt. Z = 2.78 at 0% tilt, moves through 1.41 at the midpoint, which is in the correct direction, to move a bit higher as the PF arcs over from inboard to outboard, and ends at 2.46.

At point 1, the Y value also changes by wrongly moving 6 metres inboard as the tilt increases from 0% to 100%.

The PF dynamic points therefore both move the wrong way, when the PF is deployed outboard toward 100% tilt. Something is backwards.

At Point 2 and 100% tilt, the system thinks the sheave is only 2 metres outboard, and takes no action to compensate for roll.

14.3 Summary of why things were so wrong on DY146, and makeshift fix for upcoming cruises

For most of DY146, and presumably for many prior cruises, the heave compensation was selected to be P-Frame dynamic Point 2. This is the logical and previously recommended selection, for the moving P-Frame. Unfortunately, it is the worst possible choice, as all the X,Y,Z numbers are wrong. When the PF is fully outboard, the Z number is 16 metres wrong, and the Y number is about 12 metres wrong. That is why the winch responded so wrongly to pitch and roll. Figure 4 shows the screen displaying the wrong numbers for P-Frame Point 2 100% tilt.

Once we had an understanding of why the heave compensation was so wrong in pitch and roll, we could make a different choice. For stations 24 and 25, P-Frame Point 4 was selected. This has plausible values for X and Y. The wrong value in Z does not greatly affect the movement of the winch drum. The result was good compensation for the CTD package.

This has several benefits:

- The CTD descent and ascent rate is much smoother – the CTD operator noticed it immediately when the heave compensation was activated at 100 metres. This is very good for the data.
- The wire tension is much more even – the winch operator noticed it immediately when the heave compensation was activated at 100 metres. This means the winch can pay out safely at 60 metres/minute more or less as soon as the heave compensation is activated. Without effective heave compensation, the wire tension fluctuates and the winch speed needs to be kept low until there is greater load on the wire, to ensure the load does not go close to zero at the sheave. This is also very good for the wire termination at the CTD, preventing slack wire there and kinks and other damage.

14.4 Recommendations for short-term use

It looks as though P-Frame points 3 and 4 could be used effectively, and BH points 3 and 4. Probably also A-Frame Point 2.

P-Frame points 1 and 2, and BH points 1 and 2, and A-Frame point 1 should not be used until the manufacturer has sorted out the many problems and errors.

14.5 Strategy for fixing the problems of offsets

Clearly some input is required from someone with a very detailed knowledge of the MRU, ship survey distances, the winch interface, and the sensors that detect the dynamic position of the A-Frame, BullHorn and P-Frame. If the problem is to be fixed, the following issues need to be considered/addressed. They all need to be considered together. If the solution includes a manufacturer visit, whoever visits or advises will need to consider all of the points below, not just some of them.

1. Discover the details of the MRU output. What are the conventions of MRU output ? Is positive heave closer to the earth or further away ? Is positive pitch bow up or bow down ? Is positive roll stbd side up or stbd side down ?

2. Does the MRU send messages about heave, roll and pitch that are valid at the point where the MRU measures them ? Or does the MRU adjust them to be valid at a reference point somewhere else on the ship, eg on the centreline ? No amount of suggesting or assuming that the MRU ‘could have been’, ‘might have been’, ‘should have been’, ‘is usually’ or ‘once was’ set up in a certain way is good enough. There are too many things wrong in the system to allow any assumptions. It is imperative that the MRU is interrogated to establish how it is configured and what it actually sends out. Where is the point at which the offsets are X = 0, Y = 0, Z = 0 ? The winch point offsets must also be measured from this MRU reference point.

   The answer to the location of the point at which the MRU data are valid will determine whether the offsets entered in the winch interface should be (a) offsets between the winch points and the MRU location, or (b) offsets between the winch points and the MRU reference point. Whoever is fixing the system will need to be able to check and if necessary adjust the setup of the MRU, as well as the setup of the winch interface.

3. Make sure the positive/negative convention for XYZ offsets is known, not guessed or inferred from what is in the system already. The manufacturer must confirm whether the system expects that positive X means the reference point is fwd of the winch point, Y means more port or more stbd, Z means higher up the ship or lower down. The A-Frame cannot be -8.51 if the P-Frame is +9.25. The convention for X,Y,Z positive or negative has to match whether pitch and roll are positive for bow up/down and stbd side up/down.

   The offsets screen carries this text next to the offset values: “X, Y and Z offsets are distance from aft left of Crane Frame to Docking Head Sheave”. We didn’t know what that meant.

4. The manufacturer or whoever is fixing the system will need access to the ship survey data to know the correct distances between (i) the winch points, (ii) the centre of the MRU, and (iii) the reference point at which the MRU data are valid (if that is different from the centre of the MRU). The correct offsets should be checked against survey for the fixed points (100%) and 0% dynamic points. The BH should be reduced to a single Point, since there is now only one sheave. Or identical, corrected, offsets should be entered for CTD and GC Points on the BH.

5. The sensor actions and outputs for 0%, intermediate, and 100% tilt/extension need to be checked and corrected for each gantry. At present they are all wrong. The A-Frame returns Not-A-Number, the BullHorn doesn’t change its numbers, and the P-Frame reports numbers moving inwards as tilt increases.

6. Once the offsets have been entered correctly, and behaviour of the dynamic points corrected, a document should be provided as a check and for future reference that is essentially a copy of the table included here, but with the correct entries. The numbers should be checked by reading the screen as the gantries are moved, and not as 'theoretical' values that 'should have been entered'.

If the offsets can be entered correctly, there is a good chance that the winch will provide good heave compensation.

Table 18: RRS Discovery MRU offsets for winch points, 2 March 2022 - Numbers copied from the winch control screen. Numbers highlighted in red are almost certainly wrong, or indicate wrong action for dynamic points. Points highlighted in green are OK or close to OK. Points highlighted in yellow appear to have errors in Z but will provide OK compensation.

Winch type	X	Y	Z	Point	Position
A-Frame/GC	NaN	0.34	NaN	Point 1	Dynamic, fully inboard
	Does not change			Point 1	Dynamic, midpoint
	NaN	0.34	NaN	Point 1	Dynamic, fully deployed
	54.89	0.34	-8.51	Point 2	100% tilt
BH/GC	14.8	8.91	-6.92	Point 1	Dynamic, fully inboard
	Does not change			Point 1	Dynamic, midpoint
	Does not change			Point 1	Dynamic, fully outboard
	14.8	11.87	-6.92	Point 3	100% extension
BH/CTD	15.57	9.48	-6.99	Point 2	Dynamic, fully inboard
	Does not change			Point 2	Dynamic, midpoint
	Does not change			Point 2	Dynamic, fully outboard
	15.57	12.44	-6.99	Point 4	100% extension
P-Frame/GC	10.63	11.9	5.02	Point 1	Dynamic, fully inboard
	10.63	8.5	3.65		Dynamic, midpoint
	10.63	5.77	4.7		Dynamic, fully outboard
	10.63	11.78	9.25	Point 3	100% tilt
P-Frame/CTD	-5.2	8.3	2.78	Point 2	Dynamic, fully inboard
	-5.2	5.27	1.41	Point 2	Dynamic, midpoint
	-5.2	2.17	2.46	Point 2	Dynamic, fully outboard
	10.81	14.2	5.02	Point 4	100% tilt

15 Dissolved Oxygen Analysis

Clara Douglas, Mark Taylor, Yvonne Firing

Dissolved oxygen (DO) samples were collected during DY146 to calibrate both CTD DO sensors (primary and secondary), correct for drift, temperature and pressure influences. The calibrated CTD oxygen in turn will be used to calibrate oxygen sensors deployed on moorings. Samples were taken from every cast at the beginning and end of the cruise in case of drift in the CTD DO sensors, with every Niskin bottle being sampled excluding known misfires and those observed obviously leaking on CTD recovery. Details of all the DO sampling are given in Table 19 and discrete sample depths are shown in Table NN.# (after DIC/nutrient section). Duplicates were taken from a minimum of 1 Niskin when all 12 bottles were fired. During the CTD transect, when fewer bottles were fired, a 10% duplicate rate was aimed for. Discrete water samples collected were subsequently analysed by automatic Winkler titration using a Metrohm Ti-Touch titration system and amperometric endpoint detection.

15.1 Metrohm Ti-Touch set-up and de-bubbling

Of the two titration machines brought on board, the machine with the external stirrer (used on previous RAPID/ABC-Fluxes cruises as well as JC211) was used for the duration of DY146. The thiosulphate solution was made (by adding one vial of pre-weighed thio crystals to 1 L of deionized water), and the titration system and dosing devices were set-up at the start of the cruise. The ti-touch was preloaded with programs for running blanks, standards, and samples. The system was tested by running blanks and standards (see method below). However, initial results were both too high (for blanks) and too variable. Changes were made to some of the settings, and a process of de-bubbling the dosing units was carried out, which resulted in more consistent and acceptable readings for the blanks and standards:

- To get the bubbles off the dosing units, press the hand button from the icons, select Dosing and use manual dosing, dosing fixed vol (with automatic filling switched off) to partially empty the dosing unit. Remove the draw straw from liquid while refilling the dosing unit to draw up a larger air bubble that will subsume the smaller ones. Importantly, return the draw straw to the liquid (reattach unit to bottle) before the end of the filling period. This is to ensure that liquid is fully drawn up the draw straw, and there are no bubbles left in that portion of the device. Start dosing again, then, plugging both vent ports, invert the dosing unit, tap it to dislodge the large bubble to the bottom of the dosing unit (currently the top), rotate so the outlet valve is at the top and dose so the bubble is pushed out the outlet valve, down the straw and out of the burette tip – this will hopefully collect any bubbles within the tubing as well as the bubbles in the piston. Ensure you have righted the dosing unit and bottle before refilling to ensure the base of the draw straw is submerged. This seemed to be successful at removing all bubbles except in some cases one tiny one. However, the dosing unit barrels accumulated more bubbles over the course of hours to a day (whether the machine is in use or not). It was not clear whether they were coming out of solution or being let into the barrel possibly due to uneven greasing of seals as found on JC159. The pistons and to some extent the corresponding cups at the bottoms of the barrels appear to be somewhat adhesive to bubbles.
- To avoid (or reduce) drawing in new bubbles, reduce the maximum dosing and fill speeds from maximum (estimate this is 20-50 mL/min) to 5 mL/min or less. This will need to be done in various parts of various programs, wherever dosing parameters are specified.

- More vigorous stirring than previously programmed, i.e., with the external stirrer on a speed of 7, appeared to be required before and between reagent additions and also during iodate addition (or else between adding iodate and starting to titrate). The effect is most visible in blanks. Some flasks cause the flea to jump around the base of the flask on the transition from add iodate to titration on the blank program, which produces enough stirring, but others don't, requiring the stirrer to be turned up to 7. (4 or 5 during titration is sufficient)

15.2 Sample collection

Water sampling was carried out according to the guidelines by Langdon (2010) with seawater being collected directly into pre-calibrated Pyrex iodine titration bottles (approximately 140 ml flasks with flared necks). This protocol is analogous to previous cruises (see RAPID cruise reports No. 30, 37, 52 for more details). The key steps were:

- Prior to sampling each station, the reagent dispensers (Brand dispensettes set to 1 mL) were emptied and refilled 2-3 times to remove any bubbles that had formed in the chemical lines. This minimizes the risk of bubble injection into samples. This process was repeated if bubbles were noticed.
- Silicon Tygon tubing (S3 E-3603 - 8mm [5/16"] ID x 11.2mm [7/16"] OD) was attached to the Niskin spigot to transfer water to the flask. (The tubing was kept submerged in sea water between stations to reduce the tendency of bubbles to form within it.) The spigot was pushed in only after attaching the tubing, and the tap opened after that to allow checking for leaks.
- Bottles and stoppers were rinsed three times with Niskin water.
- Bottles were filled slowly, from the bottom, to minimize turbulence and bubble formation, with water flow decreased by pinching the tubing. The bottles were overflowed by three flask volumes of water (approximately 15 seconds at full flow).
- The bottles were held at the neck to minimise transferal of heat to the water.
- During overfilling, the temperature of the sample was measured using a digital thermometer (RS 206-3738 calibrated chromel alumel thermocouple thermometer S/N 63001993) whilst the bottle was being overflowed. This temperature is used to correct the bottle volume due to glass expansion/contraction, and to convert the oxygen concentration measured from μmol/L to μmol/kg.
- 1mL of manganese chloride was carefully added to the bottle, immediately followed by 1mL of alkaline iodide solution. Dispenser tips were lowered beneath the water surface to eliminate the loss of chemical through splashing, and the entrainment of bubbles into the sample.
- Stoppers were inserted slowly and at an angle to stop bubbles getting trapped beneath.
- Bottles were vigorously shaken for 15-30 seconds (twisted about 20 times) to facilitate the mixing and formation of the precipitate (manganese hydroxides). A second shake was performed after 30 min.
- Deionised water was added to the necks of the conical flasks to act as an additional gas-tight seal. This was maintained until analysis. All bottles were kept in the dark in their crates until analysis.
- Each stopper is uniquely matched to a volume-calibrated flask. Regular checks were made to ensure each stopper/flask pair had the same number attached to them. Cracks and chips in both the bottles and stoppers were regularly checked for.

Table 19: Summary of CTD casts sampled for oxygen

CTD cast	Date	Total Samples	Replicates	Questionable	Date analysed	Not Analysed
1	16-Feb	16	4	0	17-Feb	
2	17-Feb	19	8	2	17/02 and 21/02	
3	19-Feb	14	2	3	21-Feb	
4	21-Feb	15	3	2	21-Feb	
5	21-Feb	14	2	2	22-Feb	
6	24-Feb	7	1	2	27-Feb	
7	24-Feb	8	2	2	27-Feb	
8	25-Feb	8	2	3	27-Feb	
9	25-Feb	3	0	1	27-Feb	
12	26-Feb	4	1	0	28-Feb	
14	26-Feb	3	0	0	28-Feb	
17	26-Feb	3	0	0	28-Feb	
18	26-Feb	3	0	1	28-Feb	
19	26-Feb	3	0	1	28-Feb	
20	27-Feb	4	1	0	28-Feb	
21	28-Feb	14	1	1	28-Feb	1
22	28-Feb	3	0	0	28-Feb	
23	28-Feb	14	2	0	04-Mar	
24	03-Mar	10	2	0	04-Mar	
25	04-Mar	10	2	0	04-Mar	1
Total		175	33	20	Analysed:	173
Percent of total			19	11		

15.3 Blank analysis

Prior to the analysis of seawater samples, the system blank was measured and calculated. This represents the signal produced by the addition of the chemical reagents. Bottles were 3/4 filled with deionized water and a stirrer bead, and chemicals were added in reverse order with thorough stirring in between (1mL sulphuric acid, 1mL alkaline iodide solution, 1mL manganous chloride). 1mL of iodate standard solution (1.667 mol/L, OSIL) was then added by the ti-touch dosing unit and titrated with thiosulphate solution up to an endpoint of current $0.1\text{x}10^{-6}$ A; this endpoint was recorded. The titration of 2-3 further additions of 1mL iodate standard was carried out. The blank is the difference between the average of these and the first titre value – that is, a single blank estimate comes from 1-4 standard additions and titrations in a single flask with a single initial does of reagents. Additional (new) blanks were run until four acceptable estimates were obtained (<0.004). Due to bubbles in the system at the start of the cruise, and improvements to procedure, the first two days of blanks (and standards), before bubbles were removed, were not used in subsequent analysis. Values >0.004 or <0 were also excluded from further calculations. Figure 17 shows the blanks during DY146 from 17/02/2022, when oxygen sample analysis began. A median value calculated from all the suitable blank titres during the cruise, 0.0030, was used in the oxygen calculations. The blank values were generally either consistent or clear outliers, and it was found that using specific medians for each analysis set instead of a whole-cruise median made negligible difference to the final oxygen concentrations.

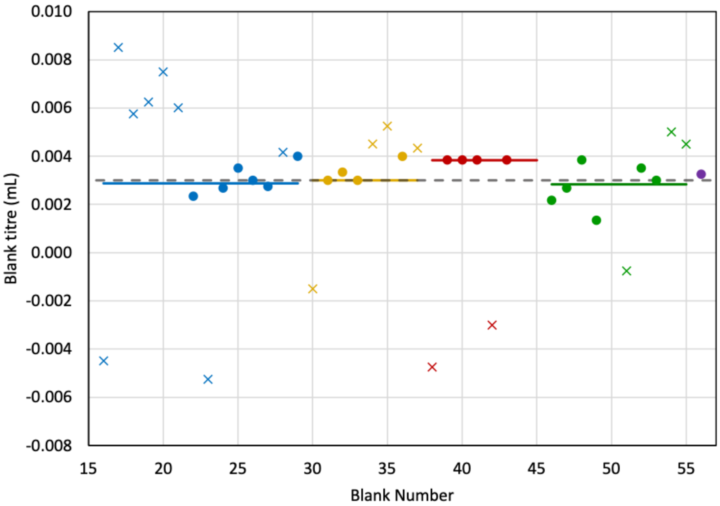


Figure 17: Output of blank analyses during DY146. Unique colours indicate different days of analysis. 'x' marks analyses that were classified as outliers (values >0.004 or <0) and not used to calculate the blank median. The median for each analysis set is shown with the corresponding colours, and the cruise median is displayed as the grey dashed line. The first two days of blank values have been excluded due to the large variability in results caused by bubbles/mixing, as described in 1.1 Metrohm Ti-Touch Set-Up and De-Bubbling.

15.4 Standard Analysis

After the blanks were measured, the thiosulphate molarity was checked against an iodate certified iodate standard of known molarity (1.667 mM, OSIL Scientific). The procedure is similar to that of the Blank measurements except that exactly 5 mL of potassium iodate standard was added to a bottle in one injection and then titrated, once. Two repeats in new flasks (or more if needed) were performed per standardization set. After discarding obvious outliers, values were still inconsistent at some times. Values that were more than 0.8% from the median for a given run were excluded (producing standard deviations of 0.2-0.25% of the median for each analysis set). Previous cruises have aimed for values that were no more than 0.5% from the mean/median, but that was not achieved here, and a large number of values had to be discarded. For runs 3 and 4, values also appeared to change across a run of samples, with different clusters observed at the start and end. As the clusters at the start were more self-consistent and to keep to standard practice of determining the standard (and blank) before running samples, the most consistent standards from before each run were used. Figure **??** shows the output of the standard analyses throughout DY146 and the average blank and standard titres per analysis set is shown in Table 20. On the second analysis, standards values increased from immediately after debubbling; we considered the first few values to represent the solution still settling and did not use them. On the final analysis set, the standard value increased for standards 2-6, then became steady for the next few; these latter consistent standards were used. Given the solutions had been left to settle for longer before running any standards in this case, we were uncertain of the cause of the variability. There were potentially two clusters of (internally) consistent standard values in the final set; the first was chosen because we recognized that it is more conventional to run standards at the beginning of analysis and not run standards at the end. The uncertainty in the standards equates to a fraction of a percent when translated into uncertainty in oxygen concentrations. The very largest uncertainties, relevant to the analysis of CTDs 23-25 (final analysis set), would result in 1.9 μmol/L higher concentrations if the later (lower) standards had been used instead of the earlier (higher) set. Using a median standard value for each analysis set reduced the scatter between the bottle and CTD values relative to using a single standard median value for the whole cruise.

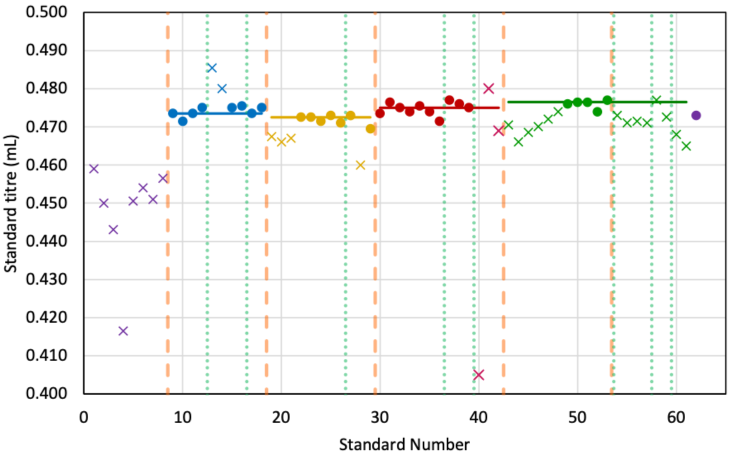


Figure 18: Output of 5mL iodate standard analyses during DY129. Unique colours indicate different days of analysis. ‘x’ marks analyses that were not used to calculate the standard median for each analysis set (corresponding horizontal lines). The orange dashed lines indicate where de-bubbling took place before/between oxygen analyses. The green dotted lines indicate where a round of CTD cast analysis had taken place, and standards were measured after.

Table 20: Mean and standard deviation values for blanks and standards used in oxygen calculations over the course of the cruise.

Analysis Set	Day	Whole Cruise Blank Median	Blank Median (per run)	Standard Median	CTDs analysed
1	17/02/2022	0.0030 ± 0.00084	0.0029 ± 0.0006	0.4742 ± 0.0012	01-Feb
2	21/02/2022 - 22/02/2022		0.0030 ± 0.0020	0.4725 ± 0.0012	02-May
3	27/02/2022 - 28/02/2022		0.0038 ± 0.0012	0.4750 ± 0.0011	Jun-22
4	04/03/2022		0.0028 ± 0.0008	0.4765 ± 0.0010	23-25

15.5 Sample analyses

Samples were stored for between several hours and 3 days, based on the determination of Langdon [2010] that storage produces no change in analysed values. Analysis in batches of stations is more time, titrant and standard efficient. Before running each batch of samples, blanks and standards were run until satisfactory stability was achieved. Between each flask (blank, standard, or sample), the burette tips, electrode and stirrer were rinsed with Milli-Q and the electrode tip carefully dried with a Kimwipe, checking for any contamination.

Batches of samples typically came from 2-3 days of stations at a time. When ready to titrate, the Milli-Q water seal was poured away, the neck dried, and the stopper of the flask carefully removed. A 1 ml aliquot of 5 M sulfuric acid was dispensed, immediately followed by a clean magnetic stirrer. The flask was placed on the stir plate and the electrode and thiosulfate burette were carefully inserted to place the tips in the lower-middle depth of the sample flask. The initial volume of sodium thiosulphate for each sample was 0.3 ml before continuing to be titrated at 0.0005 ml intervals using the amperometic end-point detection electrode [Culberson and Huang, 1987] to the end current of 0.1 x 10^{-6}) A. The resultant volume of titrant was recorded both by manual logging and automatically on the Ti-Touch. Following this the value was converted to a DO concentration within an Excel file, using bottle volumes, expansion coefficients and sample temperatures, blank and standard titres, and standard volume, and saved as `oxygen_calculation_newflasks_dy146.xlsx`. Preliminary quality code flags were assigned to the data (2=Good, 3=Dubious, 5=Not analysed, 4=Bad, 9=Missing). Figure 19 shows a summary of the vertical profile of oxygen concentrations measured on DY146 and Figure 20 shows the concentrations at the discrete depths sampled at each CTD.

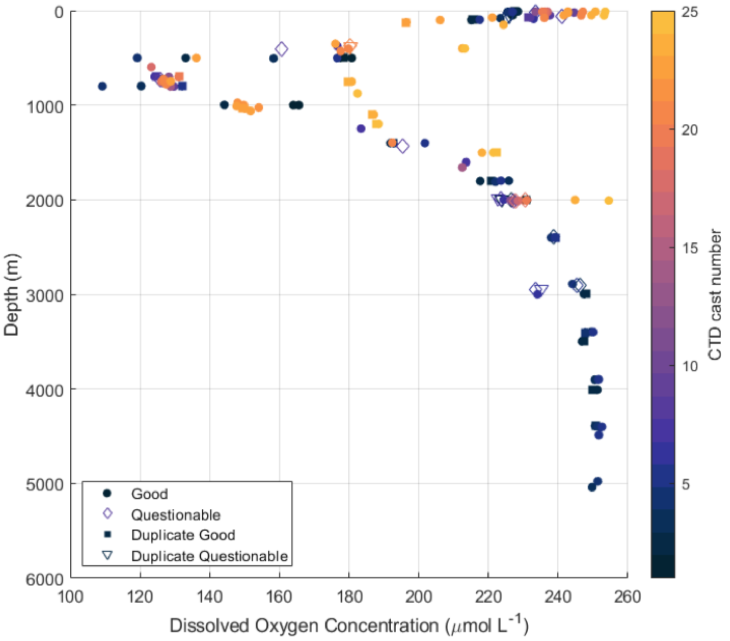


Figure 19: DY146 dissolved oxygen concentration profile. Colour scale represents the CTD cast number.

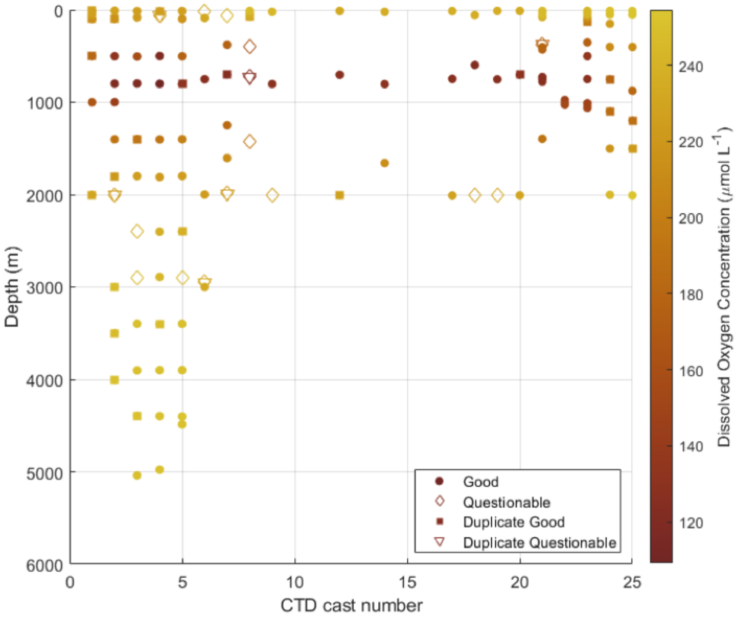


Figure 20: Dissolved oxygen concentrations at the sampled depths per CTD cast.

15.6 Precision and accuracy

A total of 33 replicates were taken from 31 Niskin bottles, two of which were triplicates. The differences between sample and duplicate bottle results are shown in Figure 21. There were 9 samples where either the first draw or duplicate bottle were flagged as questionable during sampling and/or analysis. These bottle values will not be included in averages. For duplicate samples where the difference is greater than 1 μmol L^{-1}, both bottles will be ignored/removed from the dataset when the sample results are used to calibrate the CTD oxygen sensors. The absolute mean difference between samples and duplicates was 0.7402 μmol L^{-1} and the absolute standard deviation was 0.7478 μmol L^{-1}. Differences were fairly evenly distributed between positive and negative, such that the mean difference was close to zero (-0.1397 μmol L^{-1}). The standard deviation was ±1.0513 μmol L^{-1}.

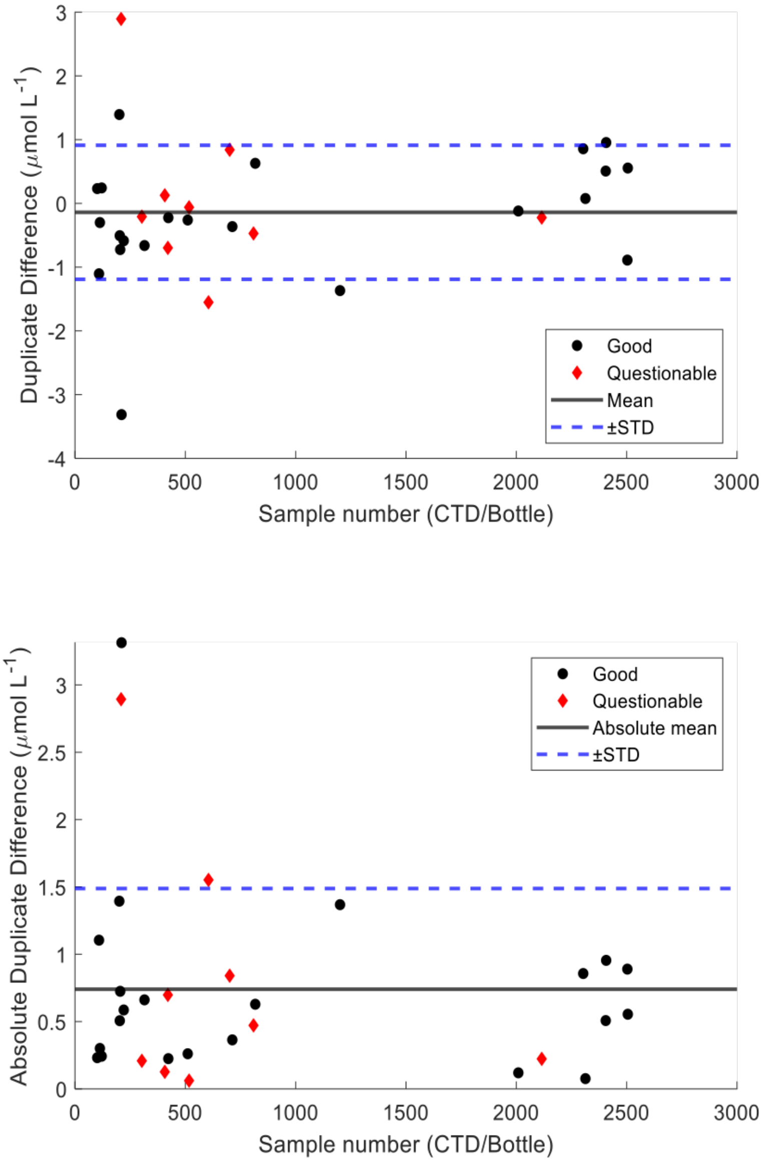


Figure 21: (a) Differences between replicate oxygen concentrations on DY146. (b) Absolute differences between replicate oxygen concentrations on DY146. In both figures, the diamonds represent samples where either one, or both, of the bottles were flagged as questionable during the sampling/analysis process.

16 Discrete chemical sampling

Clara Douglas, Mark Taylor

Table 21: Summary of CTD casts sampled for carbon/nutrients

CTD cast	Date	Total Carbon	Carbon Duplicates	Total Nutrients	Nutrient Duplicates	Total pH	pH Duplicates	Carbon Notes
1	16-Feb	8	2	7	1	6	0	
2	17-Feb	0	0	0	0	0	0	
3	19-Feb	0	0	0	0	14	2	
4	21-Feb	0	0	0	0	0	0	
5	21-Feb	0	0	0	0	0	0	
6	24-Feb	14	2	14	2	13	1	
7	24-Feb	14	2	14	2	0	0	Pipette tip in one sample bottle
8	25-Feb	0	0	0	0	0	0	
9	25-Feb	4	0	8	4	0	0	
10	25-Feb	1	0	1	0	0	0	
11	25-Feb	2	0	2	0	0	0	
12	26-Feb	5	0	5	0	0	0	
13	26-Feb	3	1	3	1	0	0	
14	26-Feb	7	0	7	0	0	0	
15	26-Feb	4	0	4	0	0	0	
16	26-Feb	4	0	4	0	0	0	
17	26-Feb	5	0	5	0	0	0	
18	26-Feb	7	0	7	0	0	0	
19	26-Feb	9	2	9	2	0	0	
20	27-Feb	6	0	6	0	0	0	Loose pipette tip - spilt some water back into a sample
21	28-Feb	14	2	14	2	14	2	
22	28-Feb	3	0	3	0	3	0	
23	28-Feb	0	0	0	0	0	0	
24	03-Mar	9	1	9	1	0	0	
25	04-Mar	9	1	9	1	0	0	
Total		128	13	131	16	50	5	
Percent of total			10		12		10	

Discrete bottle samples were collected for the later analysis of dissolved inorganic carbon (DIC), inorganic nutrients, and organic nitrogen and pH (the latter collected for analysis within OTE) at a subset of CTD stations. DIC and nutrient samples were collected from post-EBH# (EBH1-3) deployment casts, BGC-Argo deployment casts and at selected depths of the transect casts. The transect casts were carried out across a front south of the Canary Islands, and the bottle stops targeted warm/cold filaments in the depth profile as well as the surface, deepest stop, and oxygen minimum. pH samples were taken as part of the OTE sensor calibration, which were deployed on the moorings and CTD frame. Details of the stations sampled are displayed in

Table 21, and further details of discrete sample depths are given in Figure 23 and 24.

16.1 Dissolved Inorganic Carbon and pH

A total of 17 stations were sampled for dissolved inorganic carbon (DIC) (110 samples in total) and 5 stations (50 samples) for pH. Details of these are given in Table 21.

In each case borosilicate glass bottles were used to collect seawater from the rosette immediately after oxygen samples were taken. This was typically within 30 minutes of the CTD being secured in the hangar. A short piece of Tygon tubing was attached to the Niskin spigot and used to draw water into the pre-washed bottles. The tubing was pre-soaked in MilliQ water to keep supple and to reduce the build-up of bubbles. Bottles were rinsed once, filled slowly with the tubing at the bottom and then overflown by at least one full bottle volume. The bottle stopper was washed using overflowing water before being inserted into the bottle. Care was taken to avoid introducing any bubbles throughout this process.

Samples were fixed in the general-purpose laboratory. A Pasteur pipette was used to create a headspace in each sample (removing approximately 1% of bottle volume) prior to preserving with saturated mercuric (II) chloride (HgCl2) (for more details see Dickson et al., 2007). The ground glass of the bottle neck and stopper were then dried with a lint free highly absorbent wipe. Apiezon grease was applied to the stopper before it was inserted completely into the bottle. The stopper was twisted to remove residual air from the grease and to ensure a complete seal was made. Finally, a securing elastic band was placed on the bottle and the sample preservative mixed through by inverting the bottle 3 – 4 times. pH samples were secured with tape instead of clips and elastic bands (as were the last few DIC samples, because many of the elastic bands were perished). DIC and pH samples were stored in boxes in the chemistry lab ($\sim$21°C). DIC sample bottles were labelled as follows: DY146_CTD#_nisken#_depth. The bottle number for each of the pH samples was recorded on the CTD sample record sheet.

16.1.1 Some useful laboratory set-up tips

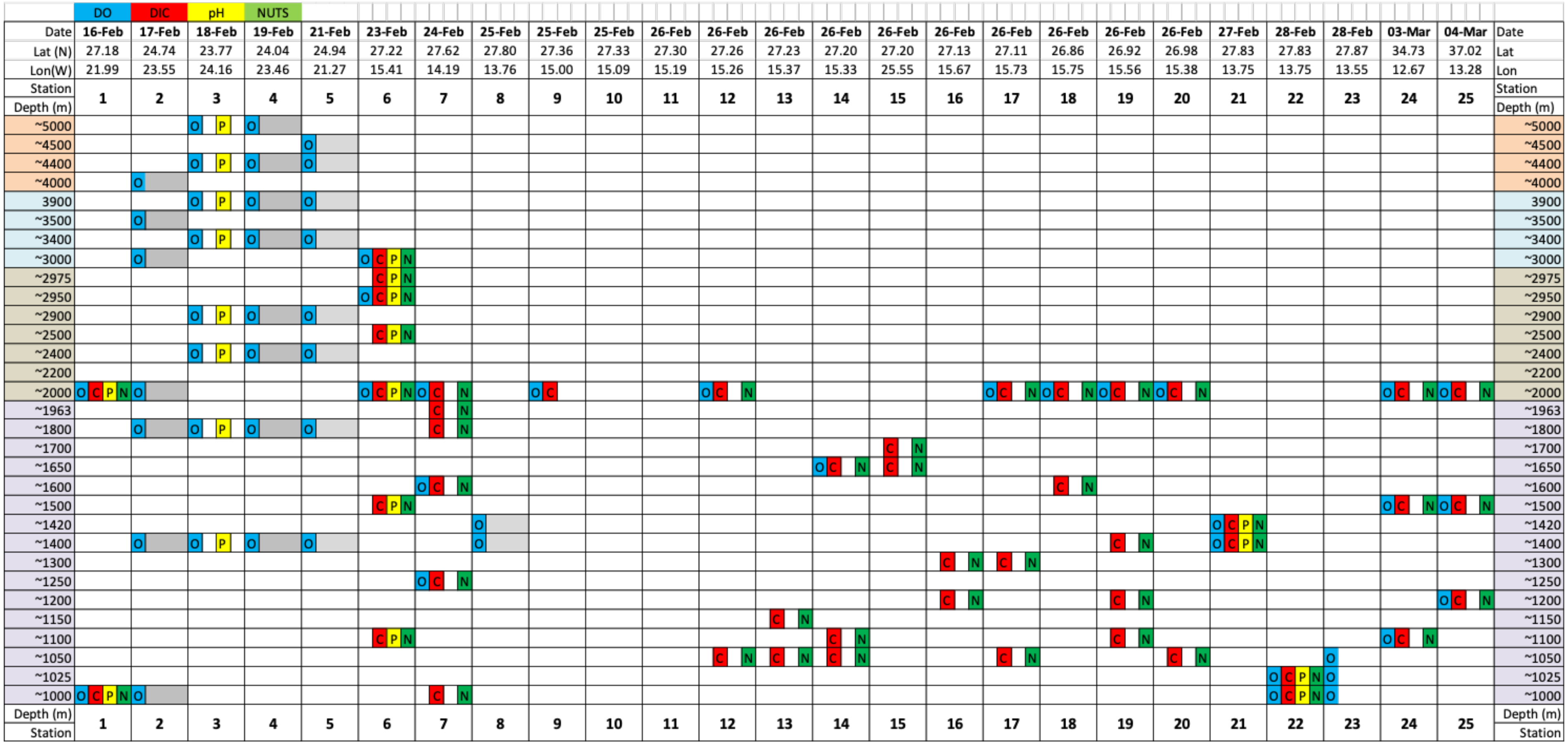
- The mercuric chloride was brought on board in a relatively large glass bottle. In order to minimise the risk of spilling the $HgCl_2$ during sample poisoning, 5ml was transferred into a smaller bottle (one of the 125ml Nalgene plastic screw-top nutrient sample bottles) using a 5ml Pasteur pipette. This meant that the bottle could be opened and held in place with one hand while the dose was pipetted from the $HgCl_2$ bottle to the sample. During the rest of the sample preservation process, the lid remained on the $HgCl_2$ bottle, which sat within a plastic bag. This was further contained within the base of a plastic water bottle which had been cut down to size and taped to the fume hood to provide a base for the $HgCl_2$ to sit (Figure 22). When not in use, the small $HgCl_2$ bottle was placed in two zip-lock bags and stored in the same box as the main $HgCl_2$ bottle. Gloves and tissues that were used during the poisoning were kept in a HG waste zip-lock bag for disposal on land.

- The pipette used for $HgCl_2$ was placed within as small zip-lock bag when not being used during the preservation process to minimise surface contact with $HgCl_2$. Placing it into the zip-lock bag was identified as a potential weak point in the procedure, so thought could be given to improving this for the future – in calm seas, it may be fine to rest the pipette tip over some blue roll (which is easier than dealing with the opening of the zip-lock bag) and dispose of this as Hg waste. However, in rougher conditions, a dedicated and stable stand may be more suitable.

Figure 22: Photographs of the fume hood set-up and examples of how bottles were sealed with tape (left bottle) and clip and band (right bottle).

16.2 Nutrients

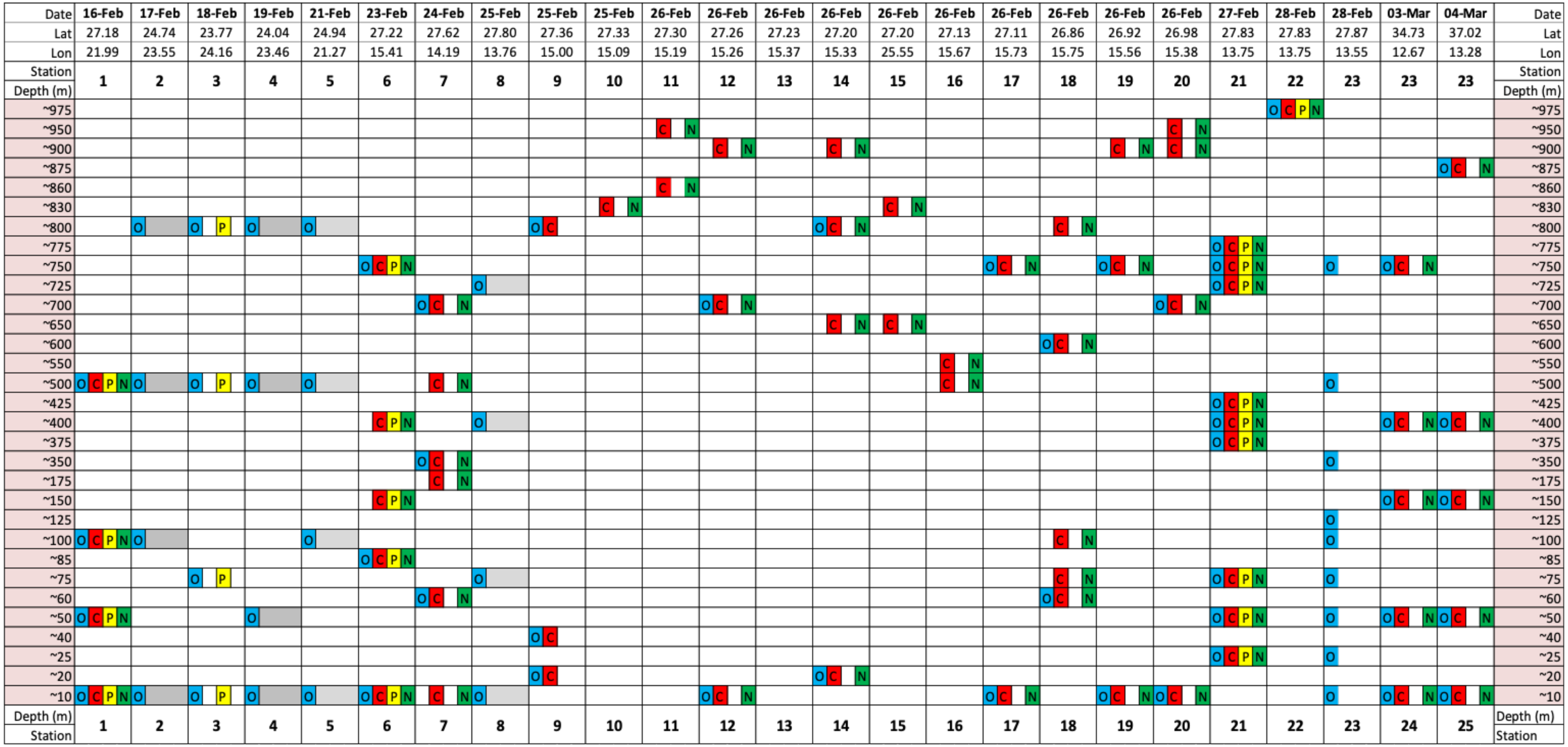
As with DIC, a total of 17 stations were sampled (113 samples in total) for inorganic/organic nutrients (Table 21). Samples were collected directly (without Tygon tubing) into 125 mL (4 oz) Nalgene plastic screw-top bottles. Each bottle was rinsed out 2-3 times before being filled to approximately 75% full and immediately frozen at -20°C for later analysis ashore at NOC facilities. Nutrient samples were labelled: DY146_CTD#_nisken#_depth.



DO DIC pH NUTS

Date	16-Feb	17-Feb	18-Feb	19-Feb	21-Feb	23-Feb	24-Feb	25-Feb	25-Feb	25-Feb	26-Feb	26-Feb	26-Feb	26-Feb	26-Feb	26-Feb	26-Feb	26-Feb	26-Feb	26-Feb	27-Feb	28-Feb	28-Feb	03-Mar	04-Mar	Date
Lat (N)	27.18	24.74	23.77	24.04	24.94	27.22	27.62	27.80	27.36	27.33	27.30	27.26	27.23	27.20	27.20	27.13	27.11	26.86	26.92	26.98	27.83	27.83	27.87	34.73	37.02	Lat
Lon(W)	21.99	23.55	24.16	23.46	21.27	15.41	14.19	13.76	15.00	15.09	15.19	15.26	15.37	15.33	25.55	15.67	15.73	15.75	15.56	15.38	13.75	13.75	13.55	12.67	13.28	Lon
Station Depth (m)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	Station Depth (m)
~5000			O P	O																						~5000
~4500					O																					~4500
~4400			O P	O	O																					~4400
~4000		O																								~4000
3900			O P	O	O																					3900
~3500		O																								~3500
~3400			O P	O	O																					~3400
~3000		O				O C P N																				~3000
~2975						C P N																				~2975
~2950						O C P N																				~2950
~2900			O P	O	O																					~2900
~2500						C P N																				~2500
~2400			O P	O	O																					~2400
~2200																										~2200
~2000	O C P N	O				O C P N	O C N		O C			O C N					O C N	O C N	O C N	O C N				O C N	O C N	~2000
~1963							C N																			~1963
~1800		O	O P	O	O		C N																			~1800
~1700															C N											~1700
~1650														O C N	C N											~1650
~1600							O C N											C N								~1600
~1500						C P N																		O C N	O C N	~1500
~1420								O													O C P N					~1420
~1400		O	O P	O	O			O											C N		O C P N					~1400
~1300																C N	C N									~1300
~1250							O C N																			~1250
~1200																C N			C N						O C N	~1200
~1150													C N													~1150
~1100						C P N								C N					C N					O C N		~1100
~1050												C N	C N	C N			C N			C N			O			~1050
~1025																						O C P N	O			~1025
~1000	O C P N	O					C N															O C P N	O			~1000
Depth (m) Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	Depth (m) Station

Figure 23: Location of samples collected for chemical analysis below 1000m during DY146. Key: DO – dissolved oxygen, C – DIC, p – pH, N – inorganic and organic nutrients.



Date	16-Feb	17-Feb	18-Feb	19-Feb	21-Feb	23-Feb	24-Feb	25-Feb	25-Feb	25-Feb	26-Feb	26-Feb	26-Feb	26-Feb	26-Feb	26-Feb	26-Feb	26-Feb	26-Feb	26-Feb	27-Feb	28-Feb	28-Feb	03-Mar	04-Mar	Date
Lat	27.18	24.74	23.77	24.04	24.94	27.22	27.62	27.80	27.36	27.33	27.30	27.26	27.23	27.20	27.20	27.13	27.11	26.86	26.92	26.98	27.83	27.83	27.87	34.73	37.02	Lat
Lon	21.99	23.55	24.16	23.46	21.27	15.41	14.19	13.76	15.00	15.09	15.19	15.26	15.37	15.33	25.55	15.67	15.73	15.75	15.56	15.38	13.75	13.75	13.55	12.67	13.28	Lon
Station Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	23	23	Station Depth (m)
~975																						O C P N				~975
~950											C N									C N						~950
~900												C N		C N					C N	C N						~900
~875																									O C N	~875
~860											C N															~860
~830										C N					C N											~830
~800		O	O P	O	O				O C					O C N				C N								~800
~775																					O C P N					~775
~750						O C P N											O C N		O C N		O C P N		O	O C N		~750
~725								O													O C P N					~725
~700							O C N					O C N								O C N						~700
~650														C N	C N											~650
~600																		O C N								~600
~550																C N										~550
~500	O C P N	O	O P	O	O		C N									C N							O			~500
~425																					O C P N					~425
~400						C P N		O													O C P N			O C N	O C N	~400
~375																					O C P N					~375
~350							O C N																O			~350
~175							C N																			~175
~150						C P N																		O C N	O C N	~150
~125																							O			~125
~100	O C P N	O			O													C N					O			~100
~85						O C P N																				~85
~75			O P					O										C N			O C P N		O			~75
~60							O C N											O C N								~60
~50	O C P N			O																	O C P N		O	O C N	O C N	~50
~40									O C																	~40
~25																					O C P N		O			~25
~20									O C					O C N												~20
~10	O C P N	O	O P	O	O	O C P N	C N	O				O C N					O C N		O C N	O C N			O	O C N	O C N	~10
Depth (m) Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Depth (m) Station

Figure 24: Location of samples collected for chemical analysis above 1000m during DY146. Key: DO – dissolved oxygen, C – DIC, p – pH, N – inorganic and organic nutrients..

17 Mooring and Instrumentation

Darren Rayner

17.1 Mooring recoveries

A total of 12 recovery operations were completed with 6 moorings (EB1, EBHi, EBH1, EBH2, EBH3 and EBH4), 5 landers (EB1L13, EB1L14, EBH1L13, EBH4L8 and EBH4L9) and 1 PIES (EB1P) successfully recovered. The PIES at EBH4P was unable to be recovered as it did not leave the seabed after receiving the release command (see further details later). All mooring recoveries (except EBP1) started with grappling the recovery line from the starboard deck before passing the line aft to be recovered through a block mounted on the port pedestal crane underneath the A-frame. The PIES from EBP1 did not have a recovery line attached, which made hooking on difficult. Once a pair of grapnels had a satisfactory hold of the 2-glass PIES rig it was pulled up by hand onto the starboard deck.

Table 22: Mooring recovery and target deployment locations

Mooring positions									
	Recovery location					Target deployment			
Mooring	Lat deg	Lat min	Lon deg	Lon min		Lat deg	Lat min	Lon deg	Lon min
EB1	23	45.45	24	9.65		No deployment			
EB1L13	23	47.92	24	7.74		No deployment			
EB1L14	23	47.87	24	8.64		No deployment			
EB1P	23	46.39	24	9.51		No deployment			
EBHi	24	56.08	21	15.92		No deployment			
EBH1	27	13.30	15	25.29		27	13.35	15	25.35
EBH1L13	27	13.02	15	25.97		No deployment			
EBH1L15	No recovery					27	13.00	15	26.00
EBH2	27	36.89	14	12.76		27	36.90	14	12.65
EBH3	27	48.48	13	44.83		27	48.50	13	44.80
EBH4	27	51.05	13	32.42		27	51.00	13	32.45
EBH4L8	27	52.67	13	30.73		No deployment			
EBH4P	27	52.00	13	32.05		No deployment			
EBH4L10	No recovery					27	52.50	13	30.80

The syntactic lander recovered on EB1L14 showed significant crevice corrosion as per previous deployments. This was so severe on one acoustic release bracket that all four bolts had been completely sheared. This lander was originally intended to be in the water for a further 18 months, so the corrosion would have been worse.

As with previous cruises, some of the deeper deployed Billings marker floats were tangled with other buoyancy due to the higher drag on these causing them to rise more slowly through the water column. When replacing these marker floats in future budgets they should be switched to small syntactic spheres or something akin to a submersible spar buoy so that they have lower drag.

There were several implosions of glass buoyancy on EB1 meaning much of the mooring did not rise after the main steel sphere buoyancy reached the surface. The bottom 8-pack @5050m and the 4-pack @4500m were imploded. At least one of these implosions is evident in the pressure records of the deeper

Table 23: Status of pre-recovery or post-deployment cast for mooring operations

Mooring	**Pre-recovery CTD**	**Post-deployment CTD**
EB1	Yes	Yes
EB1L13	No	No
EB1L14	No	No
EB1P	No	No
EBHi	No	Yes
EBH1	No	Yes
EBH1L13	No	No
EBH1L15	No	No
EBH2	No	Yes
EBH3	Yes	Yes
EBH4	Yes	Yes
EBH4L8	No	No
EBH4P	No	No
EBH4L10	No	No

instruments on this mooring, with a step change in pressure of 1dbar occurring in the deepest instrument in December 2020 more than 8 months after deployment (Figure 25). The increase in pressure can be attributed to the anchor clump of large link chain having a couple of links laid on the seabed when they were previously partly supported by the mooring buoyancy. This change would likely not be seen with a solid anchor.

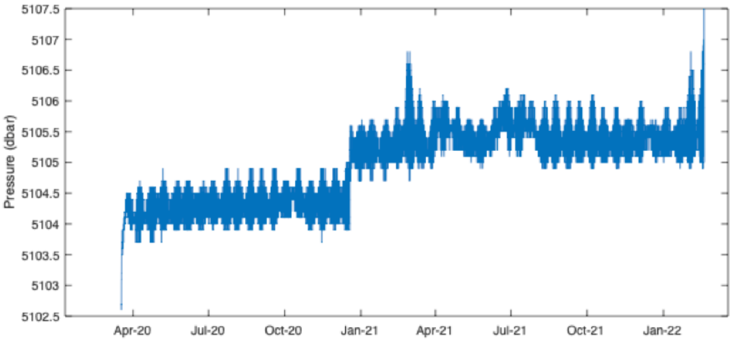


Figure 25: Pressure record from the deepest MicroCAT on mooring EB1_16_2020. Note the step change caused by glass implosions on the mooring. This same step is visible in all MicroCATs where it is not masked by depth variations from mooring knockdown.

17.2 Mooring deployments

Cutting back of the RAPID array means no moorings or landers are now deployed at the EB1 site, and problems with diplomatic clearance meant that only recoveries could be made at the EBH4 site. A total of 3 moorings (EBH1, EBH2 and EBH3) and 1 lander (EBH1L15) were deployed, with biogeochemical sensors originally planned for the not-deployed EBH4 mooring merged onto EBH3. EBH1 and EBH2 were paid out by hand from fish baskets with a crane used for the heavier lifts such as the syntactic buoyancy and instrument frame on EBH1 and the anchors on both. EBH3 was paid out by the double barrel winch and reeler setup, with the packages of glass buoyancy and instrument frames deployed by stopping off on deck and transferring loads with the winch.

Table 24: DY146 Mooring anchor drop position and trilaterated seabed position.

Mooring	Anchor drop		Anchor seabed		Fallback [m]
	Latitude [N]	Longitude [W]	Latitude [N]	Longitude [W]	
EBH1	27° 13.42’	15° 25.39’	27° 13.35’	15° 25.33’	150
EBH1L15	27° 13.02’	15° 26.01’	27° 12.97’	15° 26.04’	122
EBH2	27° 36.98’	14° 12.61’	27° 36.91’	14° 12.70’	184
EBH3	27° 48.64’	13° 44.78’	27° 48.45’	13° 44.86’	354

The design of EBH3 was also changed to use 6mm core Dyneema HS-Max rope jacketed to an outer diameter of 8mm with a braid covering. This design change was made as part of preparing for this cruise and is intended to reduce the risk of loss of moorings through drifting longline fishing line. Previously the top of moorings has been lost through the plastic jacket of wires being scraped away and exposing the galvanised core so that it corrodes through. The synthetic Dyneema ropes are of a comparable strength to the 1/4” jacketed steel wires but without the corrosion potential. A jacketed cover was chosen to try and prevent abrasion damage to the core line both when deploying and recovering, and also when clamping on instruments. This is the first deployment of these ropes on the RAPID array.

17.3 Instrument records

Two MicroCATs (sn 6811 from EB1 and sn 5766 from EBH3) were flooded, but all other recovered instruments (except for the PIES from EBP1 and a BPR from EBH4L) had full records. Details of the PIES can be seen in the later section. The SBE26 BPR from EBH4L (S/N 395) had the main battery depleted, but also the clock battery so the memory lost power and any logged data were lost. Attempts at forcing the download with the dd command (in case it was just the memory pointer that had been reset) only yielded noise. 3 other SBE26s (S/Ns 389, 396 and 397) recovered on this cruise also had flat clock batteries but the main batteries still had charge so no data were lost from these. It was however not possible to determine the clock drift as the clock response was corrupted.

Summaries of the collected record lengths along with some initial comments on the data are given in Table 25.

Table 25: Record lengths for instruments deployed during DY146

Mooring	Instrument type	S/N	Date of first record	Date of last record	Number of records	Data comments
EB1	MicroCAT	5241	17/03/2020	19/02/2022	16887	Some C spikes (dips)
	MicroCAT-ODO	14117	17/03/2020	19/02/2022	16887	
	MicroCAT	4714	17/03/2020	19/02/2022	16887	
	MicroCAT	5984	17/03/2020	19/02/2022	16887	
	MicroCAT	3206	17/03/2020	19/02/2022	16887	
	MicroCAT	4466	17/03/2020	19/02/2022	16887	
	MicroCAT	6839	17/03/2020	19/02/2022	16887	
	MicroCAT-ODO	14145	17/03/2020	19/02/2022	16887	
	MicroCAT	3212	17/03/2020	19/02/2022	16887	
	MicroCAT	6811	None - Flooded			

	MicroCAT-ODO	14146	17/03/2020	19/02/2022	16887	
	MicroCAT	3890	17/03/2020	19/02/2022	16887	
	MicroCAT	3229	17/03/2020	19/02/2022	16887	
	MicroCAT-ODO	14149	17/03/2020	19/02/2022	16887	
	MicroCAT	4722	17/03/2020	19/02/2022	16887	
	MicroCAT	6813	17/03/2020	19/02/2022	16887	
	MicroCAT-ODO	14150	17/03/2020	19/02/2022	16887	
	MicroCAT	3222	17/03/2020	19/02/2022	16887	
	MicroCAT	3224	17/03/2020	19/02/2022	16887	
	MicroCAT	10716	17/03/2020	19/02/2022	16887	P step increase in December 2020 for deeper instruments. Likely caused by glass implosion
	MicroCAT-ODO	14151	17/03/2020	19/02/2022	16887	P step increase in December 2020 for deeper instruments. Likely caused by glass implosion
	MicroCAT	5985	17/03/2020	19/02/2022	16887	P step increase in December 2020 for deeper instruments. Likely caused by glass implosion
	MicroCAT	5979	17/03/2020	19/02/2022	16887	P step increase in December 2020 for deeper instruments. Likely caused by glass implosion
	MicroCAT	3932	17/03/2020	19/02/2022	16887	P step increase in December 2020 for deeper instruments. Likely caused by glass implosion
EB1L13	SBE53 BPR	33	29/10/2018	18/02/2022	28991	
	SBE53 BPR	419	29/10/2018	18/02/2022	28991	
EB1L14	SBE26 BPR	389	17/03/2020	18/02/2022	16861	
	SBE53 BPR	29	17/03/2020	18/02/2022	16861	
EB1P	PIES	325	none - nothing logged			

EBHi	MicroCAT	3484	15/03/2020	21/02/2022	16984	
	MicroCAT	3907	15/03/2020	21/02/2022	16984	
	MicroCAT	3256	15/03/2020	21/02/2022	16984	P (and therefore S) spikes
EBH1	MicroCAT	4473	13/03/2020	23/02/2022	17084	S spike
	MicroCAT	5238	13/03/2020	23/02/2022	17804	
EBH1L14	SBE53 BPR	35	25/10/2018	23/02/2022	29200	
	SBE53 BPR	39	25/10/2018	23/02/2022	29200	
EBH2	MicroCAT	4184	12/03/2020	24/02/2022	17132	C spike near end of record
	MicroCAT	6125	12/03/2020	24/02/2022	17132	
	MicroCAT	6113	12/03/2020	24/02/2022	17132	
EBH3	MicroCAT	3234	10/03/2020	25/02/2022	17196	C (and therefore S) spikes. Probably from biofouling
	MicroCAT-ODO	10542	10/03/2020	25/02/2022	4299	C (and therefore S) spikes. Probably from biofouling
	MicroCAT	3901	10/03/2020	25/02/2022	17196	
	MicroCAT	6803	10/03/2020	25/02/2022	17196	
	MicroCAT	6122	10/03/2020	25/02/2022	17196	
	MicroCAT	6829	10/03/2020	25/02/2022	17196	
	MicroCAT	6834	10/03/2020	25/02/2022	17196	
	MicroCAT-ODO	10556	10/03/2020	25/02/2022	4299	
	Nortek Aquadopp	5590	10/03/2020	25/02/2022	17196	
	MicroCAT	5766	None - Flooded			
	MicroCAT	5777	10/03/2020	25/02/2022	17196	
	MicroCAT	3231	10/03/2020	25/02/2022	17196	
	MicroCAT-ODO	12900	10/03/2020	25/02/2022	4299	
	Nortek Aquadopp	5831	10/03/2020	25/02/2022	17196	
	MicroCAT	3253	10/03/2020	25/02/2022	17196	S spikes
	MicroCAT	3931	10/03/2020	25/02/2022	17196	
	Nortek Aquadopp	5884	10/03/2020	25/02/2022	17196	
	MicroCAT	3232	10/03/2020	25/02/2022	17196	
	Nortek Aquadopp	5885	10/03/2020	25/02/2022	17196	
	MicroCAT	5240	10/03/2020	25/02/2022	17196	
EBH4	MicroCAT	4708	11/03/2020	01/03/2022	17275	C (and therefore S) spikes. Probably from biofouling
	MicroCAT	3247	11/03/2020	01/03/2022	17275	C (and therefore S) spikes. Probably from biofouling
	MicroCAT	6332	11/03/2020	01/03/2022	17275	
	MicroCAT	6119	11/03/2020	01/03/2022	17275	

	MicroCAT	4725	11/03/2020	01/03/2022	17275	
	MicroCAT	6827	11/03/2020	01/03/2022	17275	
	MicroCAT	6118	11/03/2020	01/03/2022	17275	
	MicroCAT	4795	11/03/2020	01/03/2022	17275	
	MicroCAT	6833	11/03/2020	01/03/2022	17275	S spikes
	MicroCAT-ODO	10518	11/03/2020	01/03/2022	4318	
	MicroCAT	6835	11/03/2020	01/03/2022	17275	
	MicroCAT	4468	11/03/2020	01/03/2022	17275	
EBH4L8	SBE26 BPR	395	no date - main and clock battery failure			
	SBE53 BPR	30	23/10/2018	28/02/2022	29380	
EBH4L9	SBE26 BPR	396	11/03/2020	01/03/2022	17271	
	SBE26 BPR	397	11/03/2020	01/03/2022	17271	

17.4 Instruments deployed

In total 29 MicroCATs (11 of which were MicroCAT-ODOs) were deployed. All those without an oxygen sensor were set to log hourly whereas the ODOs were set to log 4-hourly.

Four Nortek Aquadopp current meters were deployed, with all of them being placed on EBH3. The settings for these were as previously used with sampling every hour and diagnostic measurements every 12 hours.

Two SBE-53 BPRs were deployed with the settings refined from previous deployments. As the intended deployment duration of the mooring array has increased from the previously used 18 months to what is commonly now 2 years the BPRs will be deployed for up to 4 years at a time (two consecutive deployments without a service). Checking the endurance calculations shows that using the previously selected deployment parameters the BPRs may stop logging after about 41 months. The settings were changed to have the pressure sensor not powered continuously but to use a long warm up time (30 minutes) and taking a 15 minute average per hour so the effective sleep time is only small at 15 minutes per hour. This gives a predicted endurance of 5 years.

The older SBE26 BPRs are unable to have their endurance extended significantly as the quiescent current is a significant draw on the battery. If the array continues to deploy BPRs for 4-year deployments then these instruments will not be able to be used.

The additional sensors deployed for the BGC-RAPID-East project are detailed below and in a separate section on the OTE sensors.

17.5 BGC sensor plans

For this cruise funding was obtained to add a mixture of biogeochemical sensors to several moorings. The sensors are a combination of NOC-OTE designed Lab-on-chip sensors (see separate section on these) and instruments previously used on the RAPID array as part of the ABC Fluxes project. The planned locations, depths and instrument types are given in the Table 26.

Table 26: BGC Sensor deployment plan

Depth (m)	**EBH1**	**EBH2**	**EBH3 (original plan)**	**EBH4 (original plan)**	**EBH3 (adapted and deployed)**
50			MicroCAT-ODO, Deep SeaFET-pH, Contros-pCO2		MicroCAT-ODO, Deep SeaFET-pH, Contros-pCO2, OTE-Nitrate
100				MicroCAT-ODO, Deep SeaFET-pH, OTE-Nitrate	MicroCAT-ODO, Deep SeaFET-pH
200					MicroCAT-ODO
400			MicroCAT-ODO, Contros-pCO2, OTE-Nitrate, OTE-Phosphate		MicroCAT-ODO, Contros-pCO2, OTE-Nitrate, OTE-Phosphate
750				MicroCAT-ODO	
800			MicroCAT-ODO, OTE-pH, OTE-Total Alkalinity, OTE-Nitrate		MicroCAT-ODO, OTE-pH, OTE-Total Alkalinity, OTE-Nitrate
1000				MicroCAT-ODO, OTE-Total Alkanitity, OTE-pH	MicroCAT-ODO, OTE-Total Alkanitity, OTE-pH
1400			MicroCAT-ODO		MicroCAT-ODO
1600		MicroCAT-ODO			
2000		MicroCAT-ODO			
2500	MicroCAT-ODO				

3000	MicroCAT-ODO, OTE-Total Alkanitity, OTE-pH				

Figure 26: BGC sensor frame ready to be deployed @50m on EBH3 (ignore incorrect labelling on sensor as moved from not-deployed EBH4). Sensors comprise one OTE-Nitrate sensor (dark grey plastic) with associated battery case (bottom right) and shielded waste receiver (grilled square box behind sensor), SeapHOx sensor (top left), Contros pCO2 sensor (top front) and associated battery pack (back right) and MicroCAT (front middle of frame).

Figure 27: BGC sensor frame being prepared for deployment @400m on EBH3. Sensors comprise 2 OTE sensors (dark grey plastic) with two associated battery cases (left) and shared waste receiver (grilled square box top right), Contros pCO2 sensor and battery pack (both obscured in this picture) and two MicroCATs – one with oxygen (clamped underneath the white square).

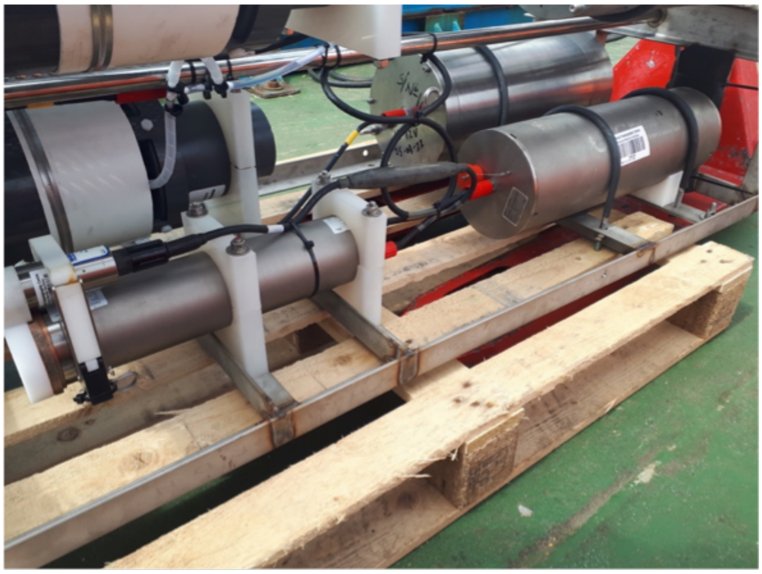


Figure 28: As in Figure 27 but showing Contros sensors on other side of frame

17.6 SeaFET pH Sensors

The Deep SeaFET-pH sensors from Sea-Bird Electronics and combined with MicroCAT-ODOs to form a SeapHOx, with an integrated flow path using the MicroCAT pump to flush the pH sensor as well as the conductivity cell. The ODO acts as a slave to the SeaFET with sampling controlled by, and data stored on, the SeaFET.

Not all the stock of RAPID/ex-ABC Fluxes MicroCAT-ODOs can be paired with the SeaFETs as they require a wet-mateable MCBH 4-pin (plus guide) connector instead of the normal 3-pin (plus guide) version. Care needs to be taken when allocating instruments in the future to ensure the correct units are available.

Both units deployed on this trip were recently calibrated at Sea-Bird, but were returned for calibration without a paired ODO. When they returned to NOC neither box contained the copper tubing usually fitted to the pH sensor end cap. This was spotted prior to loading and replacement tubes were sent from Sea-Bird. However, some small plastic adaptors were not spotted to be missing until coupling the SeaFETs to the ODOs on board. The adaptors usually fit between the pH sensor head and the ODO conductivity cell outlet, and without this the plumbing circuit cannot be completed so water would not be flushed through the pH sensor by the pumping action of the ODO. Fortunately a skilled machinist (Owen) was on board as part of the science party and a replacement pair of connectors was made on the workshop lathe. The remaining SeaFET boxes at NOC should be carefully checked and an inventory of spares maintained so that this problem can be avoided in the future. See photos below for

The SeaFET comms cable was also missing from both the shipping boxes and so one had to be made from a spare Contros cable. The two types of cable are similar in that they have a serial connector at one end and an 8-pin Subconn connector at the other with banana plugs for external power inputs, but they are wired differently and cannot be used for each other without modification. At the end of the cruise the cable was reverted to be wired for a Contros, but there were no units left on board to test the cable with, so this needs to be checked prior to future cruises. The modified comms cable did not work with the SeaBird UCI software when running on a Mac, but it was fine with a Windows laptop. Both were using the same USB-Serial adaptor, which both computers appeared to manage correctly.

The ODOs were decoupled from the SeaFETs for lowering on pre-deployment CTD casts for functionality checking, and once recovered they were reconnected to the SeaFET sensors. Prior to fitting in the BGC sensor frames the sensors were conditioned in seawater from the clean seawater supply using a plastic shipping crate in a sink in the main lab. Both sensors were left in the water for at least a week before deployment but had to be removed some hours before deployment to fit them in the frames. It is unknown how long it takes for the pH sensor to lose its conditioning, but hopefully the short time between fitting in the frame and deployment is not too much or the first few days of pH data may be compromised.

After the CTD cast the ODOs were set to use a baud rate that was incompatible with the SeaFET. The resync command can be sent through the UCI software terminal to setup the CTD to have the correct parameters for use with the SeaFET but this only works if the baud rate has already been set correctly to 9600. Any terminal program can be used for this, but it's simplest to use the Sea-Bird SeaTerm V2 software connected directly to the MicroCAT-ODO prior to changing the cabling so that the communications then pass throught the Y-cable.

The two instrument-pairs deployed (SeaFET S/N 2034 with ODO S/N 14115 @50m, and S/N 2035 with ODO S/N 14148 @100m both on EBH3) were both set to sample 4-hourly (14000 seconds) with the no real-time data transmission, external pump disabled (the ODO is not the same as the pump option) and powering of the CTD disabled (the ODO has its own batteries). The endurance calculator predicts the SeaFET will last for several years, but the prediction does not take account of the MicroCAT batteries, which will typically be drained first due to powering the pump. For this reason we match the sampling rate to that used for standalone MicroCAT-ODOs.

17.7 Contros pCO2 sensors

Two Contros Hydro-C pCO2 sensors were deployed in frames on EBH3 (S/N 1114-002 @50m and S/N 1114-001 @400m). Both are paired with Hydro-B batteries (S/N 0715-006 @50m and S/N 0715-002 @400m) to provide power and Sea-Bird SBE-5 pumps (S/N 05-8071 @50m and S/N 05-7801 @400m) to flush water through the sensor head.

Previous testing and setup of Contros sensors on cruise JC174 had confusing outcomes with some sensors not remembering their settings when using a "daily mode" sampling regime (which sets specified sleep and wake times for a 24-hour period) and therefore continuous mode having to be used (where the total time awake and asleep has to be specified). Other units also had problems with the flush settings not being used and not flush period being recorded.

On this cruise there was again confusion with the behaviour of the sensors. These have been recently calibrated at Contros prior to the cruise and both show the same firmware version (2018042401). Testing confirmed that the flush setting was not being used during either the continuous mode or day-interval mode, but confusingly it often worked during the first sample after setup.

Sensor S/N 1114-002 was initially tested and setup with "day interval" mode as otherwise the timing of reconnecting the battery determines the time of day the sampling begins (continuous mode will run through the awake cycle (warmup, flush – if it happens, measure and zero) before going to sleep for the specified time. However, after more consideration of the predicted endurance it was deemed better to aim for a 36-hour sampling interval given the longer mooring deployment planned for EBH3 (21-24 months compared to 18-month deployments for ABC-Fluxes), and this interval would not work with a schedule specifying the awake and sleep times for a repeating day. Instead continuous mode was used with the measurement time increased to account for the non-functioning flush (flush is the same operation as measure except for the inclusion of a flag in the data, so by extending the measurement duration the desired period of flushing can be cut off the front of the measurement record).

Both sensors were setup with a 36-hour schedule (awake time of 57 minutes – which is a sum of the desired warmup, measure and zero times, and a sleep time of 1 day, 11 hours and 3 minutes – which is 36 hours minus the awake time) and the batteries reconnected at 11:07 GMT on the 24th February 2022 to time the first sample at 12:00-12:02 (but with 18 minutes before this also included to replace what should have been flush), and the second at 00:00-00:02 on the 26th February 2022 and so on.

Vibrations of the sensor when measuring can be felt by putting you hand on the unit, and S/N 1114-002 was confirmed to go to sleep at 12:04 as expected after the first measurement schedule. This unit then had the pump connected and was ready to deploy.

The second unit (S/N 1114-001) did not stop vibrating and after being left till 12:30 in case there was just a timing offset the unit was stopped and checked. Reconnecting through the Contros Detect software showed that this unit now had sleep mode disabled – despite screen captures of the setup showing it had definitely been set. Bench testing with a continuous sampling set up confirmed that it was unable to retain the sleep settings, however it could when using day-interval mode. This instrument therefore could not be set to use a 36-hour sampling interval and instead was set to sample every 24 hours using day-interval mode (waking at 23:07 and sleeping at 00:07 each day). The battery may therefore run out eaely.

Bench testing the remaining units at NOCS should be a priority to see if they behave as expected or whether the sleep mode error can be replicated and if possible the root cause tracked down. A summary of the Contros settings for the two deployed units is given in Table 27.

17.8 PIES

Two Inverted Echosounders with pressure sensors (PIES) were deployed for colleagues at AOML-NOAA on cruise JC192 in 2020. Though their deployment was originally planned for several years we were asked to recover them on this trip, and so a telemetry session and recovery operation was scheduled at each of the EB1P and EBH4P sites.

At EBP1, the DS7000 deck unit was setup with the transducer deployed from the starboard deck and software from AOML running on a Linux virtual machine on a Mac to received data from the deck unit. Commands were sent to the PIES using the deck unit directly and successful ranges were obtained. The telemetry command was sent and the deck unit switched to remote mode, but no data were received by the telemetry software. Additional attempts were made using old Matlab based routines instead of the AOML software, but tweaking the gains only yielded noise. The attempt at telemetry was abandoned and the release command sent at 14:36 on 18/2/2022, which was acknowledged before the PIES entered its released beacon mode with 12kHz pings every 4 seconds. The time for the burnwire to be broke is not accurately determined, but it is predicted to be between 15-20 minutes. The predicted ascent rate is also unknown as the PIES was coupled to a data telemetry controller in a second sphere. Normally the 12kHz trace from the EA640 echosounder in passive mode should be able to detect when the PIES leaves the seabed. The 4 second pulsing from the PIES forms a line on the echogram and a change in the PIES position relative to the ship should present itself as a change in gradient of the line (steeper = approaching vessel, shallower = moving away from vessel). However, no clear deflection could be inferred as to when the PIES left the seabed and instead it was detected on the surface by the VHF beacon and a visual spotting 2 hours and 4 minutes after release. After recovery to deck the instrument sphere was rinsed and dried before opening, however the memory card held no data aside from log files

Table 27: A summary of the Contros settings for the two deployed units. *NB: value for flush entered, but sensor seems to ignore this

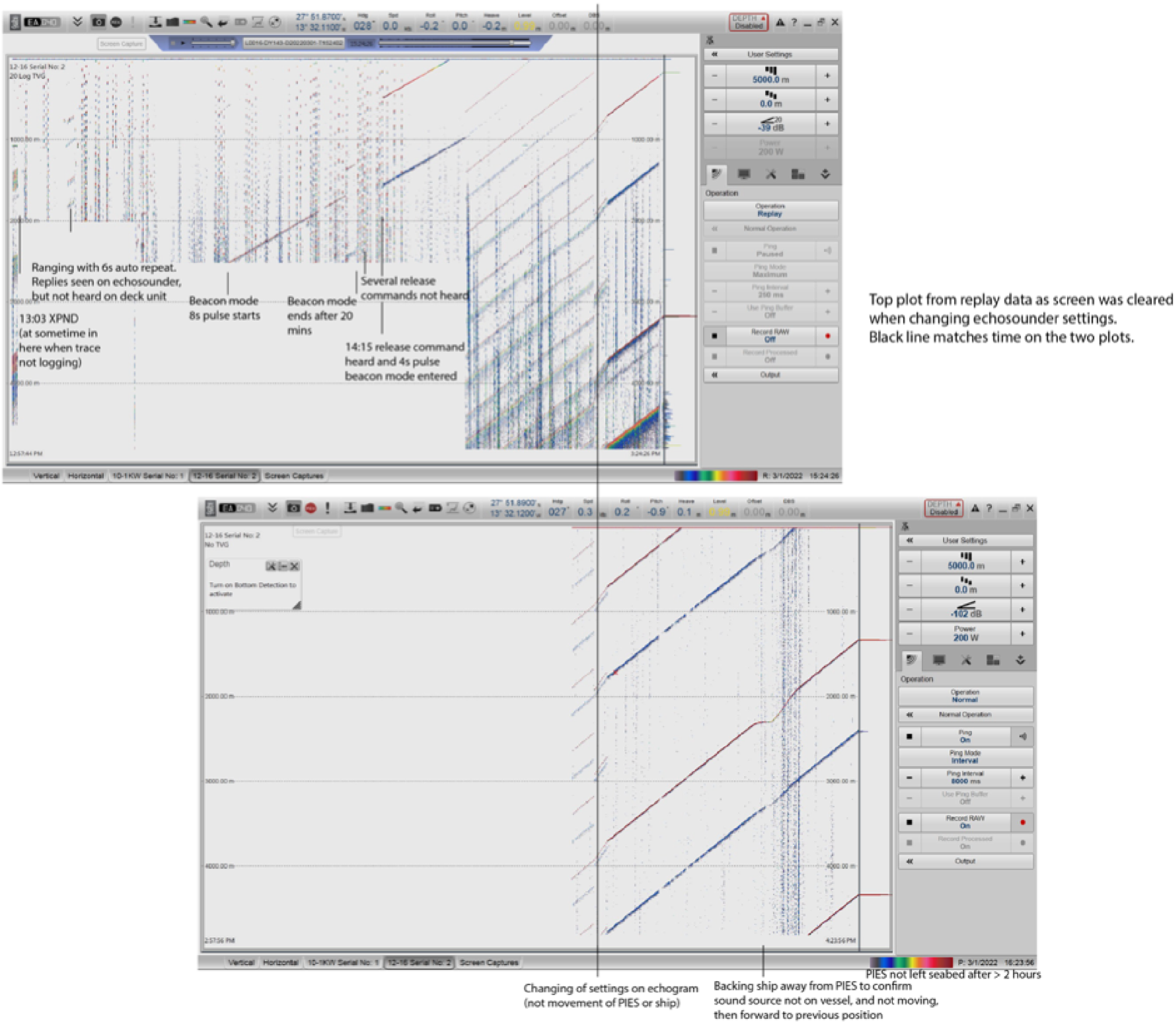
	SN 1114-001 @400m on EBH3	**SN 1114-002 @50m on EBH3**
Warmup (minutes)	35	35
Zero (minutes)	2	2
Flush (minutes)*	1	1
Measure (minutes)	20	20
Zero averaging + logging rate (seconds)	5	5
Flush averaging + logging rate (seconds)	5	5
Measure averaging + logging rate (seconds)	5	5
Sample mode	day-interval	continuous
Awake duration	n/a	57 minutes
Sleep duration	n/a	1 day 11 hours and 3 minutes
Wake time	23:07:00	n/a
Sleep time	00:07:00	n/a
Resulting sample interval	24 hours	36 hours

that showed the instrument got into a power-cycling state that reset its sampling parameters before it was deployed. This is why attempts at telemetry (both on this cruise and the deployment cruise) were unsuccessful as there were no data to send.

At EBH4P the same setup for the transducer was used but responses to commands were very difficult to hear in the rough weather and though showing up on the echogram they could not be detected by the deck box. There were no sensible ranges obtained with the PIES in transpond mode, either because the PIES couldn't hear the command, or more likely that the deck unit couldn't hear the replies above the background noise. Because of this telemetry would be unlikely to work, and with the pressure of running out of time on site before having to start the transit home we decided to go straight for recovering the instrument without attempting data telemetry.

The release command was sent several times before it was acknowledged, and the echogram trace confirms the first one that was accepted was at 14:15 when the PIES started in beacon mode with 4-second pings. Again the burnwire was predicted to take 15-20 minutes, and with the shallower site depth this instrument should have surfaced well before the 2 hours seen at EB1.

The settings on the echosounder were tweaked as we determined the most suitable parameters for tracking the PIES. The ping interval rate was set to 8s (but in passive mode), meaning each timestep in the echogram represented the 12kHz sounds detected in the previous 8 seconds. We had the vertical scale set from 0-5000m (relating to a 6.7s window – 2x5000m depth /1500m/s speed of sound = 6.7s), but if it had been 0-6000m then the range would have shown the whole 8 seconds. TVG was turned off to reduce noise on the plot. The output echograms can be seen below with significant events annotated.



Ranging with 6s auto repeat.
Replies seen on echosounder,
but not heard on deck unit

13:03 XPND
(at sometime in
here when trace
not logging)

Beacon mode
8s pulse starts

Beacon mode
ends after 20
mins

Several release
commands not heard

14:15 release command
heard and 4s pulse
beacon mode entered

Top plot from replay data as screen was cleared
when changing echosounder settings.
Black line matches time on the two plots.

PIES not left seabed after > 2 hours

Changing of settings on echogram
(not movement of PIES or ship)

Backing ship away from PIES to confirm
sound source not on vessel, and not moving,
then forward to previous position

Figure 29: Echogram trace from attempted recovery of PIES at EBH4

As the trace on the echogram was not level (Figure 29; as expected if the PIES and ship were stationary relative to each other) we tested moving the ship (which had been help on dynamic positioning) away from the recovery position by backing away from it. When we got to a point where the slant range was noticeably changing the gradient of the echogram trace could been seen to decrease as expected, and then we moved forwards again the gradient increased. This confirmed the sound source was definitely something external to the ship, but that it wasn't moving. The sea state and wind conditions meant that nothing could have stayed stationary on the surface, and after more than hours it was clear the PIES was not leaving the seabed. With science time having run out we abandoned the site and started the transit back to Southampton. The bridge radio was kept tuned to channel 77 whilst steaming away in case the PIES did surface whilst we were heading away, but nothing was heard.

18 Argo float deployments

Brian King, Mark Taylor, Clara Douglas

A total of 8 Argo floats were deployed as part of UK Argo, consisting of 5 Core APEX from the Met Office and 3 BGC PROVOR from NOC. The table below shows details of deployments. By the end of the cruise, the 3 BGC PROVORs and both APEX/RBRs were all returning profiles as expected.

Table 28: Argo float deployments

Float type	Serial number	WMO number	Day/time	Lat	Lon	Nearest CTD
APEX	5561		047/1631	27° 11.1' N	21° 59.5' W	1
PROVOR	21001	6904182	047/1626	27° 11.1' N	21° 59.5' W	1
APEX	9194		050/1607	23° 45.8' N	24° 09.3' W	3
APEX	9195		052/2115	24° 56.2' N	21° 16.2' W	5
PROVOR	21002	6904183	062/1710	34° 43.8' N	12° 40.4' W	24
APEX/RBR	9189		062/1712	34° 43.8' N	12° 40.4' W	24
PROVOR	21003	6904184	063/1138	37° 00.9' N	13° 14.2'W	25
APEX/RBR	9188		063/1146	37° 00.9' N	13° 14.2'W	25

18.1 APEX floats

The APEXs were all deployed by B King over the stbd aft rail with the usual lowered rope arrangement, assisted by various scientists and crew. None of the deployments were in any way unusual. All floats arrived gently in the water and streamed aft of the ship.

Three of the APEX floats were conventional APEX floats with SBE41 CTDs. Floats 9188 and 9189 carried RBR CTDs. The first 3 APEXs, 5561, 9194, 9195 were deployed in p-activated mode, as supplied by the Met Office. It seems that two worked normally, but 9194 was not heard from and is now considered overdue and is a probable float failure. It should have surfaced and broadcast after p-activation and completion of PRELUDE, but was never heard from.

After the failure of the earlier APEX, special care was taken to ensure that 9188 and 9189 started their missions. A Mac laptop was connected with USB/serial connector, sail interface and `miniterm.py` terminal program. Baud rate 19200. The floats were set to undertake a deep profile first, and missions started with `m_deploy`. The location on deck meant that the Iridium RUDICS session in the `m_deploy` self-test was only sometimes successful. A number of `modem_test` and `modem_transfer` commands were tried. After at least one successful RUDICS transfer had been achieved with each float, it was concluded that RUDICS comms was satisfactory, and the intermittency of success could be attributed to poor sky exposure on deck, which is not uncommon.

The `m_deploy` command provided results into a logged `miniterm.py` session, and left the floats in PRELUDE mode. The sail interface was disconnected, and the floats deployed at the conclusion of the relevant CTD station. Each of 9188 and 9189 was a buddy float with a PROVOR. The PROVOR was deployed first and the APEX minutes later.

18.2 PROVOR floats

DY146 had 3 of the 8 BGC PROVOR floats in stock at NOC. These were the first 3 floats from the NOC/UK Argo capital allocation, and had been delivered to NOC late in 2021. They carried CTD, DO, OCR, FLBBCD, pH and SUNA.

Communication with the floats was by Bluetooth to a Mac laptop. To establish comms, open the Bluetooth preferences control panel on the Mac. It is helpful to remove any previously paired PROVOR Bluetooth identifiers in the Bluetooth control panel.

When the arming magnet on the provor is moved from the parked position to the ‘bluetooth’ position, a Bluetooth device appears in the mac control panel, and ‘pair’ can be selected. The user then has 50 seconds in which to send commands to the float to prevent it starting its mission. A starting command of `?TI` after miniterm.py is established will interrogate the float clock time and commence comms.

Once the float was paired with the Mac, `miniterm.py` was started, and the float Bluetooth device appears in the options offered by `miniterm.py`. An example float identifier that appears in `miniterm.py` is `/dev/cu.C210216-0282-AC-SerialP` with 9600,8,N,1

Ctrl/T ctrl/E was required to establish local echo.

Each float was run through a complete set of self-tests at NOC before departure.

18.2.1 PROVOR float final checkouts and mission start

Starting one to two hours before deployment, each float had a final checkout that included interrogating and listing all mission (PM, PV) and sampling (PC) parameters and a final self-test. This included collecting any final `RUDICS_cmd.txt` file from the RUDICS server. The float was then returned to the armed state, and the Bluetooth session ended.

The float mission was then started one hour before expected deployment by removing the magnet from the armed location (do not put it on the Bluetooth location). A checklist was followed that included removal of sensor covers and listening for pump motor and valve click sounds. A test file could be found on RUDICS, and the float is ready for deployment. It was typically 30 minutes from magnet removal to data at RUDICS, and deployment within the following hour is recommended.

Note that the NKE float checklist refers to putting distilled water in the CTD cell to check the CTD pump. THIS MUST NOT BE DONE ON FLOATS WITH pH SENSOR. The pH sensor must not be exposed to either distilled water or artificial seawater.

18.2.2 PROVOR handling for testing and deployment

This cruise was the first time NOC had handled BGC PROVORs with the jumbo battery pack. The BGC PROVOR with jumbo battery pack weighs around 65kg and is too heavy for one person to handle comfortably or safely. Two people comfortable with sharing the weight can lift a float horizontally out of the box and onto a trolley.

For DY146, a gas bottle trolley was used as a float cradle. Metal parts of the trolley were padded with plastic tubing to protect the surfaces of the float from scratching. This arrangement was serviceable as a makeshift arrangement, but a proper arrangement should be designed for the future. The gas bottle trolley was laid horizontally on the deck to accept the float from the box, and was used to move the float to an upright testing location on the aft deck, and then as a cradle to position the float for deployment. Moving the float from horizontal to upright, even on the trolley, required two people to do it safely. The float was tied into the trolley until time for deployment.

Deployment was by the port aft pedestal crane. The float was laid horizontally on the cradle, by the port rail. The floats have a lifting point that consists of a rope with a small eye, attached to a bracket on the float hull. It would have been more convenient to have a larger eye in the rope. The manufacturer has been asked if the rope can be replaced in future. A small sea catch release was hung about 1.5m below the crane hook with a strop, and locked in position on the eye of the rope attached to the float. With the ship moving forward at 2 knots, the float was then lifted and swung outboard and aft, the crane telescoped down towards the water line. The float was released at the water line and in line with or aft of the transom. The float hung at a natural angle of about 45 degrees, when lifted by its rope and eye.

The deployment procedure seemed to be smooth and straightforward. The only precaution needed is for the ship to be moving well forward, so that the float moves rapidly aft and there is no risk of the float bobbing under the vessel after release.

18.2.3 PROVOR mission programming and data inspection

PROVOR 21001 was deployed with the default mission supplied by the manufacturer. Over the first few cycles, the sampling was significantly modified, selecting different sampling densities. Rather than trying to save these in 21002 and 21003 floats by typing into a `miniterm` session, a complete new set of command parameters was prepared, and loaded into the two remaining floats via RUDICS. A significant and important limitation is that a RUDICS command file is limited to 900 bytes. A complete set of PC commands requires about 5 messages to be loaded into RUDICS and then picked up by the float in response to the !SE command. This was decided to be more reliable than trying to decide which PC commands were or were not new and needed.

The PROVOR manual refers to the command file that must be placed on the RUDICS server as either `RUDICS_CMD.txt` or `RUDICS_cmd.txt`. The version with uppercase `_CMD` is wrong and is ignored by the float. Lowercase `_cmd` is correct.

The manual also makes clear that the lines in `RUDICS_cmd.txt` must be terminated with `\r\n`. The line terminators in a mac terminal window can be checked with

```
od -c RUDICS_cmd.txt
```

A matlab program was written to generate command files correctly terminated. Note however that the mac vi editor is clever in handling `\r\n`. If a file is already terminated with `\r\n`, then it can be edited in vi and any new or changed lines will also be terminated with `\r\n`, even though a new file created by vi is only terminated with `\n`.

The initial deployment mission was a 1-day cycle to 1500 metres. This can be changed after deployment to 2-days and 2000 metres, and then to longer cycles once the float and sensors are shown to be working as expected.

The float returns 2520 byte binary files. These are decoded by a manufacturer app that only runs in windows and requires administrator permission on that device. On DY146 it was run in a windows 7 vmbox on koaekea, using a windows 7 installation disk supplied by D Rayner.

19 Miniboat deployment

Dafydd Gwyn Evans

During DY146 we deployed a "miniboat" called "KES Kraken" designed by students King Edwards School in Southampton 30. The instruments and antennae were secured at NOCS prior to loading. However, the cargo hatch was not properly sealed, and there was some moisture around the gasket seals. We attempted to seal the hatch with some silicone sealant, but when we retightened the hatch this displaced the gaskets where there had previously been some water inundation. With assistance from the NMF technicians we made a new gasket seal with some spare rubber and resealed the hatch with some silicon sealant.

We launched the miniboat close to the EB1 mooring site (23° 45.77' N, 24° 9.19' W) at 16:11 on the 19th of February. Since launch the miniboat has made good progress south westward. Over the course of 13 days, 11 hours it is currently passing to the west of Cape Verde Islands (15° 3.6' N, 32° 16.2' W) having travelled 675 nm.

Figure 30: KES Kraken deployed on DY146

20 CTD Survey of SST front near EBH1

Dafydd Gwyn Evans

20.1 Overview

The region to the south of the Canary Islands has been identified as a hotspot for the formation of long-lived mesoscale eddies which propagate into the subtropical North Atlantic. These eddies are thought to act as a source of nutrients in the interior of the subtropical gyre as they entrain nutrient rich water upwelled along the African coast during their formation. During the transit between EBH1 and EBH2 we crossed a front in SST as recorded by the underway TSG (Figure 31), where we crossed from warmer subtropical waters into colder coastal waters. Maps of satellite-based estimates of SST and SLA reveal this front was part of a larger feature that subsequently formed an anticyclonic eddy. To investigate the processes that affect the entrainment of nutrient rich coastal waters into the core of mesoscale eddies in this region we conducted a high resolution CTD survey across the front.

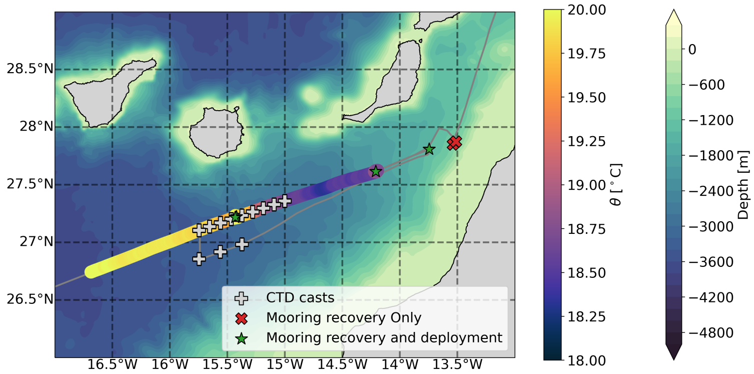


Figure 31: CTD section near EBH1 showing the TSG temperature

20.2 Sampling plan

We planned a CTD survey along our previous transect focusing on the region either side of the temperature front, with a total of 9 stations at 5 nm apart (Figure 31). CTDs were conducted to 2000 m. For the end casts we sampled for oxygens, DIC, salts and nutrients at the surface, the deep oxygen minimum and 2000 m, and additionally DIC, salts, and nutrients at the DCM. During every other cast we sampled for oxygen at the surface, deep oxygen minimum and at 2000 m. Further, we sampled for DIC, salts and nutrients within anomalous features observed during the CTD cast, with the aim of capturing the properties of submesoscale filaments associated with frontal processes.

20.3 Results

In the upper 700 m, profiles of conservative temperature and absolute salinity show a progression from warm/salty to cold/fresh across the front (Figure 32). Profiles of dissolved oxygen show less coherent change across the front at depths shallower than 700 m. Below 700 m there are distinct anomalies in

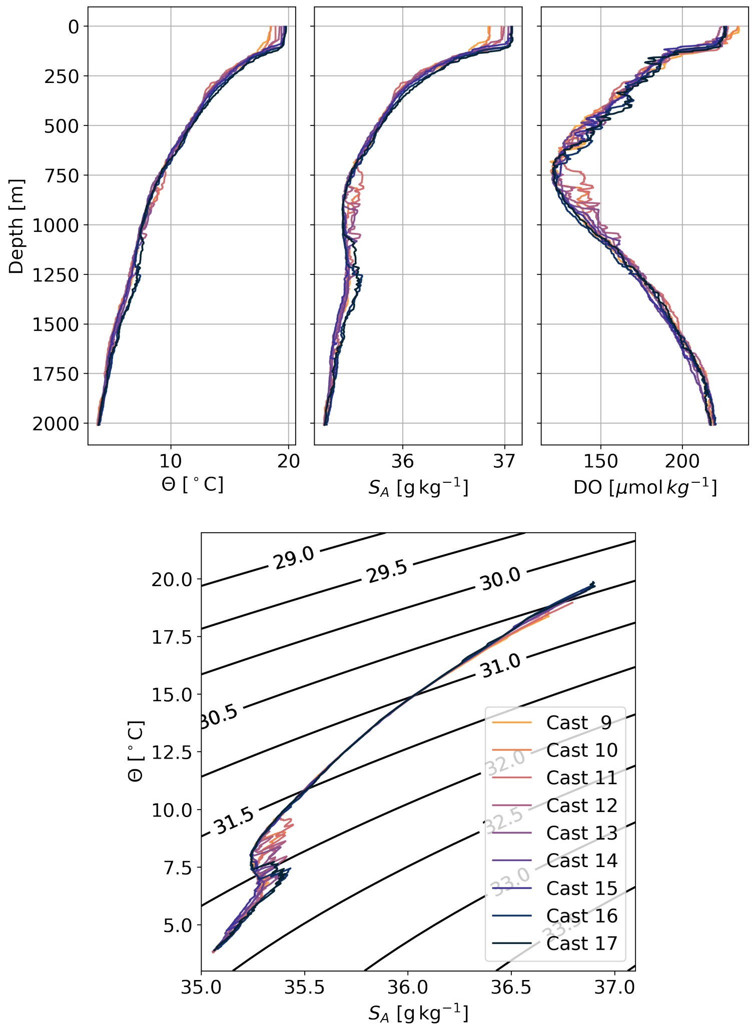


Figure 32: Profiles of conservative temperature, absolute salinity, dissolved oxygen plotted against depth. The lower panel shows absolute salinity plotted against conservative temperature, with contours showing potential density referenced to 1000 dbar. Cast 9 was conducted on the cold side of the front and cast 17 on the warm side of the front.

temperature, salinity and dissolved oxygen. These anomalies are particularly apparent when plotted in temperature and salinity space, especially between 5-10°C and 35-35.5 g/kg. These anomalies are evident in longitude-depth plots of temperature, salinity and oxygen anomaly with the strongest warm/salty anomalies on the cold side of the front close to 1000 dbar (Figure 33). An equivalent cold anomaly is evident on the warm side of the front, however its magnitude is less than the warm anomalies. Determining the relevance of these anomalies for the advection of nutrient rich water within eddies into the subtropical North Atlantic will require further analysis, including an assessment of the collected DIC and nutrient samples.

There are more subtle anomalies in the surface 500 m, with apparent exchange of warm/salty and cold/fresh water across the front, particularly between 100-200 dbar. These anomalies may be more relevant for the introduction of nutrient rich coastal water to water near the base of the mixed layer and for the subsequent advection into the subtropical gyre.

While the geostrophic velocity calculated based on the thermal wind relation (not shown) indicates a coherent southward cross sectional flow, the flow measured by the vessel mounted ADCP is more

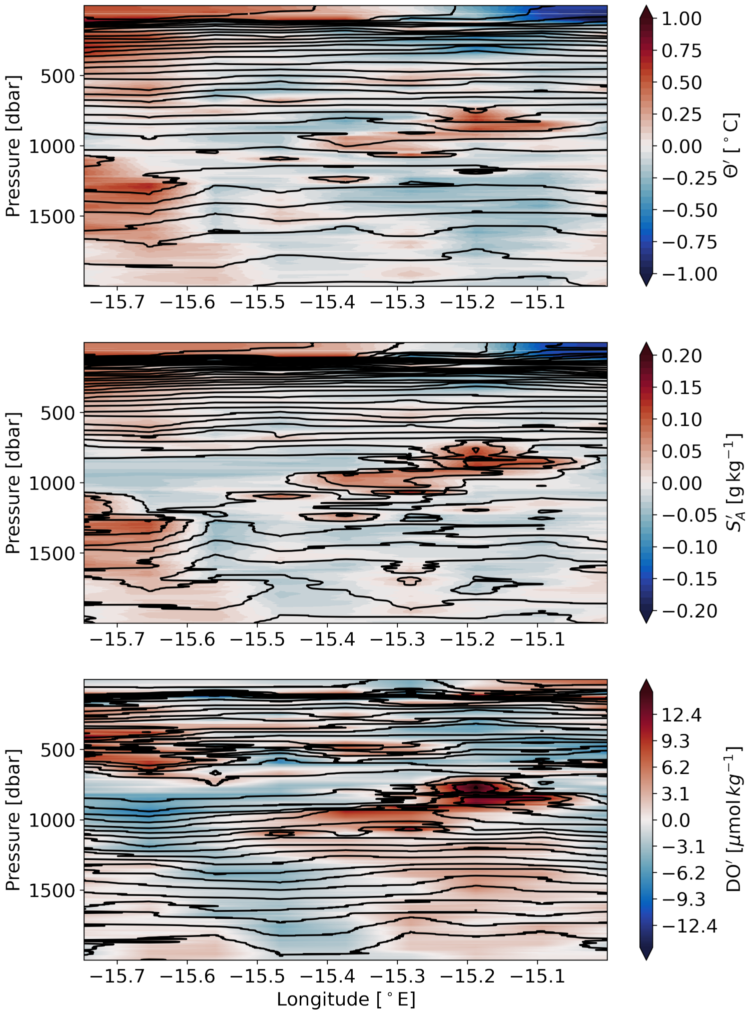


Figure 33: Zonal sections of temperature, salinity and dissolved oxygen anomaly (colours) overlayed with contours of temperature, salinity and dissolved oxygen.

complicated (Figure 34). Both the meridional and zonal velocity sections have coherent banded patterns of positive and negative flow that are deeper in the west and shallower in the east. These anomalies may correlate with the shallow anomalies of temperature and salinity shown in Figure 33, particularly in the coherent positive band of meridional velocity centred at 200 dbar.

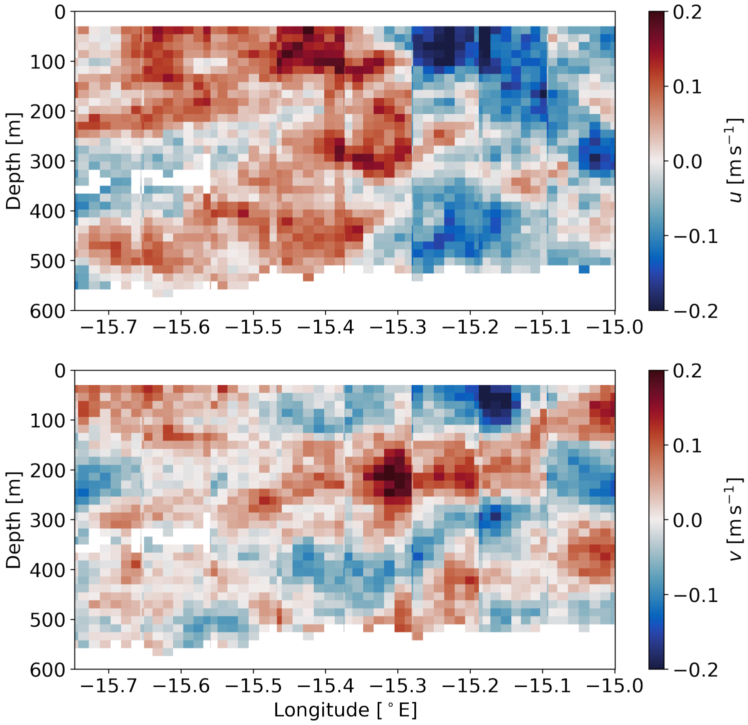


Figure 34: VMADCP measurements of zonal and meridional velocity along the CTD section plotted against longitude.

21 OTE Sensors

Sara Fowell, Owen Foster, Mark Taylor

21.1 Background

As part of BGC RAPID, the Ocean Technology and Engineering Group at NOC has produced several wet chemical autonomous lab-on-chip microfluidic sensors: pH, Total Alkalinty (TA), Nitrate+nitrite, and Phosphate. A custom designed pump and multiple solenoid valves process environmental samples, standards, and chemical reagents within the sensors. A custom electronics package controls the system, logs data, and provides communications. These sensors are operated using the WetChem software (current version 2_8_4) and a State Machine provides sensors with operating instructions. The pH is determined spectrophotometrically using purified meta-Cresol Purple indicator dye (batch p-mCP/NaCl $\sim$0.72M 110920 pH 7.890) offering high precision and high frequency measurements on the total proton scale. The TA sensor performs a single-point open cell titration with a bromophenol blue titrant (batch BPB-24) and a spectrophotometric pH measurement. The nitrate+nitrite analyser performs a colourimetric nitrate + nitrite analysis using a Griess assay and cadmium reduction on a microfluidic chip. The phosphate analyser performs a colourimetric phosphate measurement on a microfluidic chip using the Phosphate Blue method.

21.2 Underway system

Underway sensors (Figure 36) were contained in a plastic box in the sink (in the General Purpose Lab) which was filled with tap water to keep the sensors cool. Reagents and waste bags were hung above the sink, including a bag of MQ which separated the TA reference materials from the sodium hydroxide (NaOH) to prevent gas exchange into the reference materials. The sample lines of the sensors (PEEK tubing for pH, PTFE tubing for TA) were connected to filters at the bottom of a plastic tube into which the underway water flowed. A Tygon tube was connected to the end of the underway seawater tap and the opposite end was placed at the bottom of the plastic tube. The tap was opened so the water flowed at a rate where the water level in the tube remained at the height of the overflow pipe (blue elbow connection in Figure 36). The flexible tube at the bottom of the underway catchment system was cable tied in the upwards direction as a fail safe in case the underway system stopped providing water. By having the tubing in this position, the water level will remain above the green filters for a significant length of time so the sensors do not pump air. The clear plastic tube takes 2 minutes to refresh.

The sensors assigned to the underway system were TA17 and pH49 and were sampling at a resolution between continuous and every 30 minutes (depending on location) and were only operating during the times the ship was in UK or International Waters and when they were not on a CTD cast. The OTE sensors currently require external data such as temperature and salinity for data processing, which was obtained from the ship system's SeaBird45 as this instrument records the most representative temperature to that of the seawater tap because it is inside the ship (as opposed to the temperature and conductivity sensors fixed to the ship's drop keel).

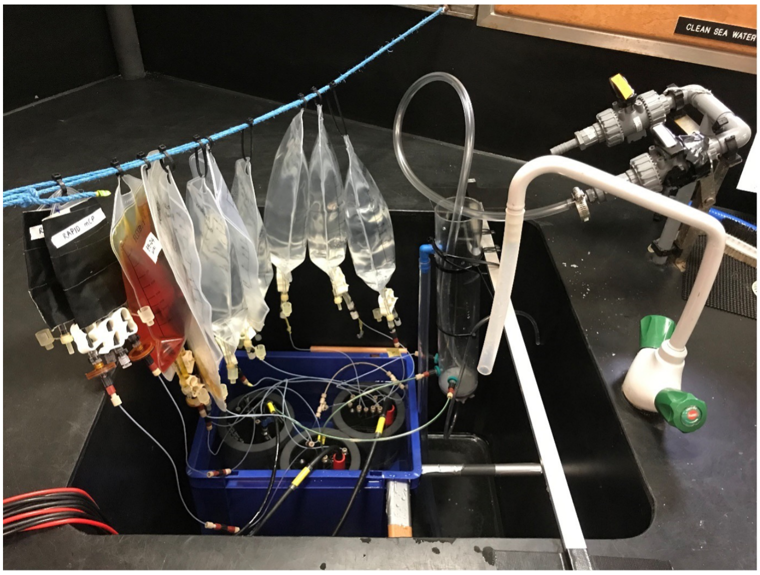


Figure 35: OTE underway sensor set up.

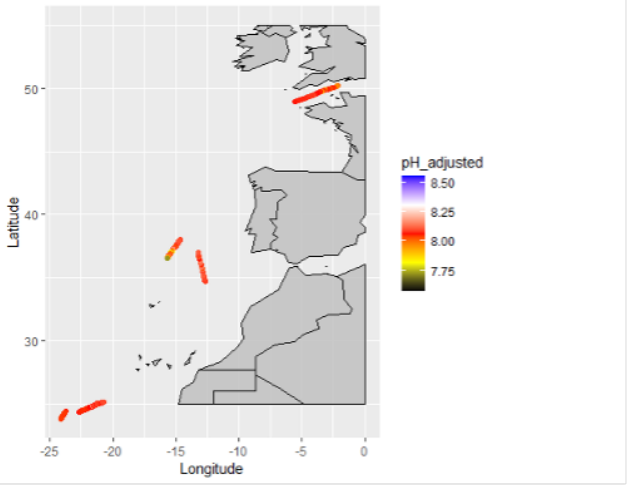


Figure 36: pH sensor data from the underway system was collected in UK and International Waters. Note that while this data has been temperature corrected, it has not yet been quality controlled.

21.3 CTD Casts

Sensors TA17 and pH49 were used on the CTD casts and were powered by either 4 x LSH20 or 4 x LS33600 batteries contained inside titanium battery housings. The battery housings were connected to the sensor using a cable made in house with a female IE55 connector at one end and a female Subconn at the other. The sensors were set to Autostart so they start operating once the battery is connected to the sensor. The automatic deployment state was State 80 (for TA) and State 12 (pH). These states tell the sensor to wait for a programmable length of time with the valves open to allow the sensor to equilibrate with the external pressure during the CTD descent. This wait time was adjusted depending on the planned maximum depth of the CTD cast, plus some extra to account for deck operations time. After this wait time, the sensors ran continuously through their State Machine until they reached their End Time on the scheduler. The End Time was estimated based on the CTD travel and wait times, and the CTD was not pulled out of the water until the end time on the sensors had been triggered to avoid pumping air into the sensors.

Figure 37: OTE sensors on the CTD.

It was requested to make the CTD stops 15 minutes long when the OTE sensors were being deployed. The total run time of pH sensor is 8 minutes, or 14 minutes for the TA sensor, so 15 minute stops allowed a replicate pH sample and a single TA sample to be collected at most bottle stops. The sensors were mounted onto the CTD frame in place of a Niskin bottle (Figure 37).

The reagent housing used on the CTD casts was not large enough to contain all the TA reagents, so some of each Reference Material was transferred from the 1L bags into 50ml bags. The 50ml bags were completely drained before they were topped up to try and ensure their composition did not drift from the main solution in the 1L bags that will be reanalysed upon return to NOC. Additionally, the 100mM NaOH solution was transferred into a 150ml bag. On CTD1, the TA titrant used was batch BPB-25A in a 150ml bag, but this leaked, so all subsequent CTDs used a 1L bag of BPB-24.

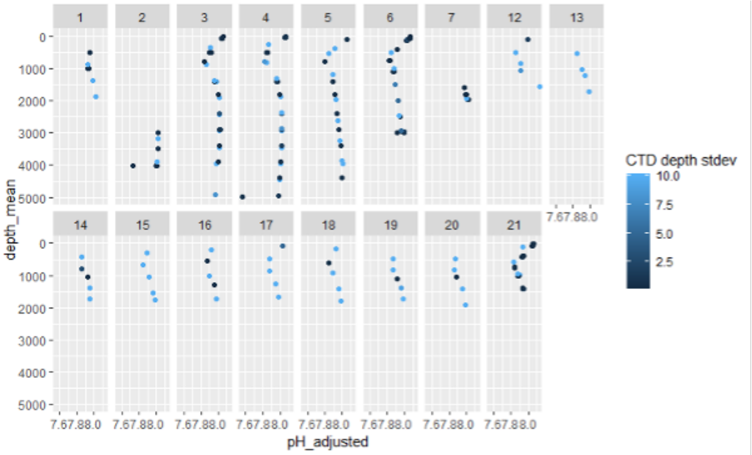


Figure 38: pH measurements from the CTD casts. pH data has been corrected for temperature but is not quality controlled. Dark blue points correspond to times when the CTD was more stationary during sample withdrawal, light blue points correspond to samples withdrawn whilst the CTD ascended significantly.

Since the sensors were measuring continuously, the CTD was not always stationary while the sensors were withdrawing their samples. To account for this in the data processing, averages of the depth, temperature, salinity, dissolved oxygen were generated for the times at which the sensor was sampling (33 seconds before the pH sensor timestamp, and 76-40 seconds before the TA sensor timestamp). As a guide, Figure 38 shows the pH data collected during the CTD casts. While the pH has been temperature corrected, this data has not yet been fully quality controlled.

During CTD2, an issue with the winch fan meant that it was possible to analyse 18 repeat samples at 3000m before the sensor reached its End Time. Additionally, CTD7 does not have a full pH profile because the batteries ran out sooner than anticipated based on the calculations.

21.4 Moorings

OTE sensors and battery packs were mounted onto stainless steel frames which were connected to the mooring line at the top and bottom. An example can be seen in Figure 39. Plastic sleeves were held around the gap in reagent housing using jubilee clips to reduce the amount of water turbulence around the tubing during the initial stage of the deployment. Ideally, the sensors would also have been covered in netting to reduce the amount of wildlife living inside the reagent housing and nibbling the tubing during the long deployment. The waste from all of the OTE sensors on the frame was directed to a centralised tube leading to a series of 10L waste bags contained inside perforated stainless steel boxes. Each sensor is powered by its own battery pack consisting of 48 x LS33600 batteries in a titanium housing pressure rated to 6000m. While a cable connects the sensor to the battery housing, there is an additional Subconn cable which allows a USB connection, enabling communication with the sensor while it is connected to the battery. During deployment, this connector is covered with a blanking plug.

pH and TA sensors were always paired on the frames (Figure 40), which allowed them to share reagent housing space. The TA sensor reagent housing contained the 3 Reference Materials listed in Table 29 (1L each) which connected into the TA chip. The pH sensor housing contained the mCP (50ml), TA titrant (1L), 100mM NaOH (1L) and NaOH waste bag (1L). These reagent bags were separated by hanging sheets of PVC to ensure there was no gas exchange between the basic NaOH and acidic dyes. The TA titrant was piped into the TA sensor using a long piece of 0.5mm PTFE tubing inserted into a Tygon tube. Initially, the NaOH to and from the gas exchange was transferred in Tygon tubing which was anticipated to be more robust. However, this was changed during the cruise and is discussed in later paragraphs.

Unlike the pH sensor, the TA sensor measures regular Reference Materials (Table 29). Due to the reagent volume and power constraints, rather than measuring each reference material after each sample, the State Machine (“TA RAPID Ready”) was set up as follows:

- Wait for scheduler
- 4 samples
- 2 Reference material 1
- Wait for scheduler
- 4 samples
- 2 Reference material 2
- Wait for scheduler
- 4 samples

- 2 Reference material 3

Table 29: Reference materials used on the TA sensors. [1] characterized by Metrohm TiTouch 916 on Scripps CRM-calibrated titrant

Name	Material	TA (μmol/kg)	Salinity (psu)	Sensor port label
Reference material 1	Scripps CRM batch 198	2200.67	33.504	CRM
Reference material 2	pAqSW281021	[1]2477.16	32.1	cal1
Reference material 3	pAqSW250122	[1]1640.91	32.4	cal2

The day before each relevant mooring was deployed, the frames were erected in the hangar so the sensors could be checked, flushed, and tested with a Reference Material. During the testing, the sensors were powered by the batteries on the frame. The clips on the reagent bags were opened, and the tightness of all the connections were checked.

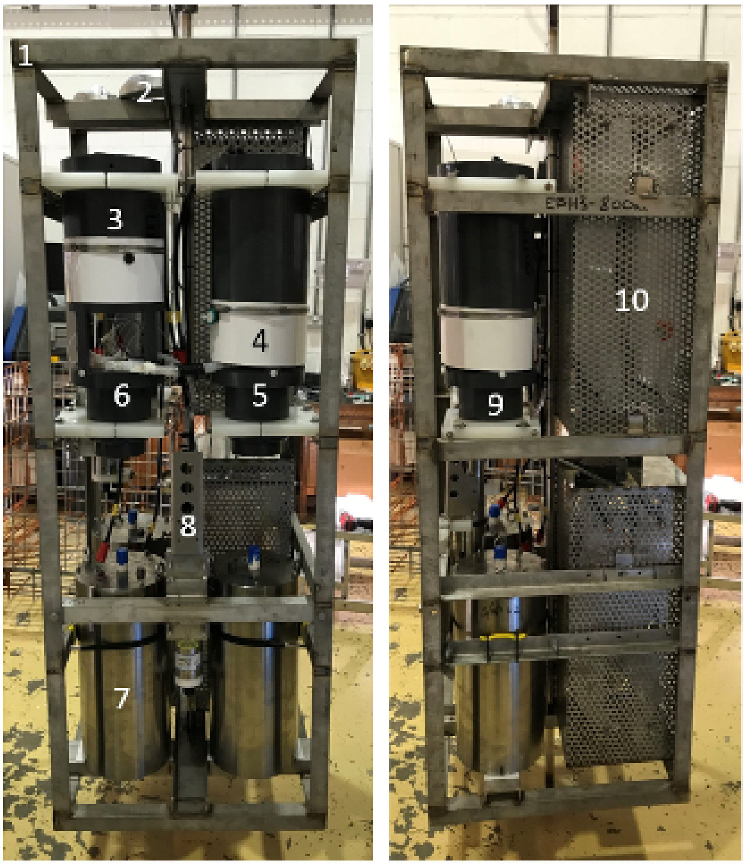


Figure 39: EBH3 800m frame. 1) Stainless steel frame. 2) Anode. 3) Reagent housing. 4) Protective sleeve. 5) pH sensor. 6) TA sensor. 7) Titanium battery housing. 8) MicroCAT. 9) Nitrate sensor. 10) Waste housing containing 10L waste bags.

It was observed that the optics on some of the sensors were no longer in alignment (i.e., the voltage of LED1 and LED2 weren't the same as each other anymore). This is uncommon when the sensors are not being used, so this may be a result of all the movement during mobilisation or sitting for a long time on deck during rough weather. Where required, the optics were adjusted, and a new configuration log was saved for reference.

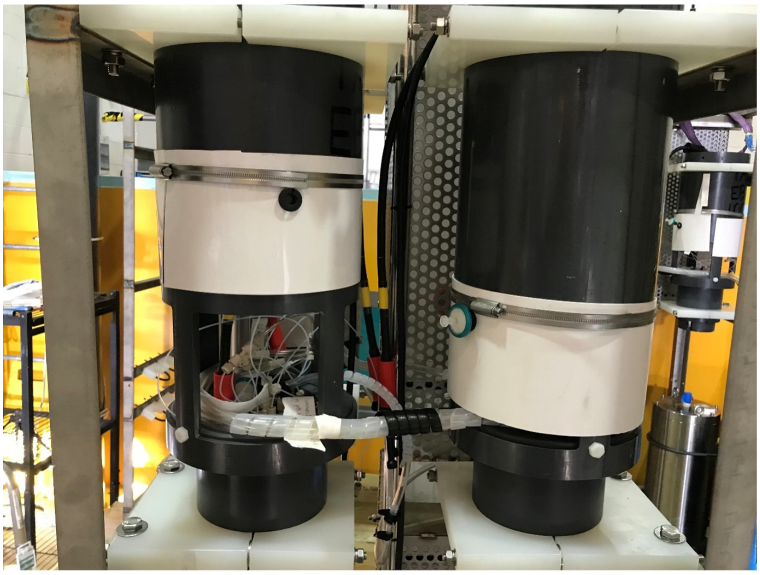


Figure 40: TA sensor (left) and pH sensor (right) on one of the frames. Grey plastic is the reagent housing which is attached onto the grey sensor housing using nylon bolts. The white plastic is the protective sleeve held on by the jubilee band.

Shortly before the moorings were deployed, the OTE sensors were connected to the batteries whilst also being connected to a laptop via USB. This allowed final checks of the Real Time Clock, Autostart, Start Time, End Time, Sampling Frequency and valve open wait time. Most importantly, it allowed confirmation that the sensor woke up and began operating automatically once connected to the power!

On 26/02/22 it was observed that the NaOH had precipitated out into the Tygon tubing in TA18 and TA19. It is likely that TA20 had the same issue, but this wasn't spotted before the deployment because the sensor performed well during the testing, and the NaOH lines were well wrapped so it was not obvious that there was precipitate in the tubing. All of the Flexboy bags, plus all the spare NaOH brought onto the cruise were checked, and no precipitate was observed anywhere other than the Tygon tubing. This suggests that there is an interaction between the tubing and the NaOH, or more likely gas exchange and a reaction between NaOH and CO2 to form Na2CO3 (sodium carbonate). To resolve this, new tubing was made from 0.5mm PEEK tubing (on TA18) and 0.5mm PTFE tubing on TA19.

Unfortunately, it was not possible to deploy EBH4, so it was decided that all the sensors scheduled to be deployed on EBH4 would be moved onto EBH3, which required modifications to the frames. A new plastic spacer was fabricated to fit between the Contros battery housing and the 50m frame to hold the battery in place securely. The plastic spacer was made using a mill, where the sides of a block were machined and a boring head was used to make the curve to allow it to sit up against the battery securely.

21.5 Deployment summary

Table 30: OTE deployment summary

Station	**Depth**	**Sensor**	**Start time (UTC)**	**Interval**	**Stop date**	**Valve open time**	**Standards**
EBH1	3000m	pH SN50	23:57:00	6 hours	30/11/2023	7,200s	NA
EBH1	3000m	TA SN20	23:54:00	6 hours	30/11/2023	7,200s	NA
EBH3	50m	Nitrate SN130	23:55:00	4 hours	08/10/2022	21,600s	10µM
EBH3	400m	Nitrate SN128	23:55:00	4 hours	08/10/2022	21,600s	25 µM
EBH3	400m	Phosphate SN64	23:55:00	4 hours	08/10/2022	21,600s	1.5 and 3 µM
EBH3	800m	pH SN47	23:57:00	6 hours	10/12/2023	21,600s	NA
EBH3	800m	TA SN17	23:54:00	6 hours	10/12/2023	21,600s	NA
EBH3	800m	Nitrate SN129	23:55:00	4 hours	08/10/2022	21,600s	25 µM
EBH3	1000m	pH SN48	23:57:00	6 hours	10/12/2023	21,600s	NA
EBH3	1000m	TA SN18	23:54:00	6 hours	10/12/2023	21,600s	NA

22 Heriot-Watt Surface Micro Layer sampling

Alba Navarro-Rodriguez, Sevda Norouzi, Ryan Pereira

22.1 Sample collection

Samples of the surface micro layer SML, defined to be at the uppermost 1000 μm of the ocean and sub surface water SSW around 1 m depth were collected for this study. SML was collected using a Garret Screen (GS) of 50 x 50 cm attached on a metal frame and lowered via rope on the starboard side for every location. The GS was washed with deionized water and a brush and washed several times in ocean water prior sample collection. The water collected was transferred to 60 mL high density polyethylene (HDPE) bottles previously acid washed with HCL (10 %) for 24 h further rinsed with analytical grade water for 24 h, 18.2 MΩ cm, Milli-Q Millipore system. A note was also made accounting for how many GS were necessary to fill a sample bottle. In addition, a metal bucket was used to collect the SSW fraction using the same procedure as described for SML and to fill a 10 L carboy for further filtering of particulate organic carbon (POC) and Chlorophyl.

All HDPE bottles were rinsed 3 times with sea water and collected in triplicate for in situ analysis of surfactant activity (SA) and dissolved organic carbon (DOC). Another set of sea water samples was collected following the same rinsing protocol in triplicates and packed at -20 °C degrees for further analysis in the Lyell lab, Heriot-Watt University.

Further sea water samples of CTD stations from Niskin bottles of the 6 nearest depths from surface were collected following the same rinsing procedure in HDPE bottles and stored at -20 °C for further analysis in the Lyell lab. Approximately 2 L of water was taken from the 2 Niskin bottles of nearest depths to surface for chlorophyl filtration (0.2 mum nylon filters). Filters were folded and enclosed in pre-combusted aluminium sachets in a ziplock bag and stored at -20 °C for later analysis.

Approximately 4 L of sea water was filtered for POC using pre-combusted at 450 °C for 4 h and pre-weighted GF/F filters. Filters were folded and enclosed in pre-combusted aluminium sachets in a ziplock bag and stored at -20 °C after filtration.

22.1.1 Sampling stations

Table 31: Summary of locations and information for all stations collected from the event logger and CTD files. Time (ship's time). Date of analysis refers to SA and DOC analysis in the ship's lab. Salinity and Temperature values were taken from the CTD files. CTD column indicates when samples from Niskin bottles were collected for further analysis in the Lyell lab. CTD stops for gas tank, makes a reference where samples were measured for Sevda's project. Location 13 was used to calibrate our U-50 Horiba multi-probe using the salinometer in the ship's lab.

Station name	**Longitude**	**Latitude**	**Date and time of collection**	**Date of analysis**	**Salinity**	**Water Temperature**	**CTD**	**CTD stops gas tank**
Location 1	38.05	-14.62	13/02/2022 09:00	14/02/2022	36.19	16.48	-	-
Location 2	37.56	-14.97	13/02/2022 14:00	15/02/2022	36.21	16.59	-	-
Location 3	27.19	-21.99	16/02/2022 13:30	16/02/2022	37.05	21.04	Y	-
Location 4	24.74	-23.55	17/02/2022 09:00	17/02/2022	36.75	21.81	Y	-
Location 5	23.77	-24.16	18/02/2022 21:00	19/02/2022	36.92	21.85	Y	-
Location 6	24.04	-23.46	19/02/2022 20:01	21/02/2022	36.92	21.53	Y	Y
Location 7	24.94	-21.27	21/02/2022 16:00	22/02/2022	36.99	21.29	Y	Y
Location 8	27.22	-15.40	23/02/2022 19:00	24/02/2022	36.88	19.96	Y	-
Location 9	27.62	-14.20	24/02/2022 19:00	25/02/2022	36.67	18.86	Y	Y
Location 10	27.80	-13.76	25/02/2022 03:00	-	-	-	Y	-
Location 11	27.83	-13.75	25/02/2022 18:00	26/02/2022	36.58	18.57	Y	Y
Location 12	27.83	-13.75	27/02/2022 19:00	-	36.46	17.90	Y	-
Location 13	27.87	-13.55	28/02/2022 14:00	-	36.51	17.89	-	-
Location 14	34.73	-12.67	03/03/2022 14:00	-	36.42	17.43	Y	Y

Table 32: Summary of location of CTD casts and selection of depths at which Niskin bottles were fired for sample collection. Collection included the 6 nearest to surface depths for each CTD cast which varies amongst locations. Depth expressed in meters.

Station name	**CTD number**	**Longitude**	**Latitude**	**CTD**	**Depth 1**	**Depth 2**	**Depth 3**	**Depth 4**	**Depth 5**	**Depth 6**
Location 1	-	38.05	-14.62	-	-	-	-	-	-	-
Location 2	-	37.56	-14.97	-	-	-	-	-	-	-
Location 3	1	27.19	-21.99	Y	2025	1008	504	100	50	10
Location 4	2	24.74	-23.55	Y	1414	1006	804	504	100	10
Location 5	3	23.77	-24.16	Y	1819	1411	803	508	83	14
Location 6	4	24.04	-23.46	Y	1829	1416	806	503	58	13
Location 7	5	24.94	-21.27	Y	1818	1414	806	506	98	13
Location 8	6	27.22	-15.40	Y	1109	757	405	152	88	13
Location 9	7	27.62	-14.20	Y	706	506	380	177	62	12
Location 10	8	27.80	-13.76	Y	405	380	76	50	25	12
Location 11	9	27.83	-13.75	Y	-	-	2031	809	41	21
Location 12	21	27.83	-13.75	Y	407	379	78	52	27	12
Location 13	23	27.87	-13.55	-	-	-	-	-	-	-
Location 14	24	34.73	-12.67	Y	1100	750	400	150	50	10

22.2 Surfactant Activity analysis

22.2.1 Analytical protocol

SA analyses were conducted using a Metrohm 663 VA Stand with a potentiostat/galvanostat and an Autolab motor controller unit operating with automated Hg drop production. This system consists of three-electrodes, a reference electrode Ag/AgCl in 3M KCl, a platinum coil as an auxiliary electrode and a hanging mercury drop electrode HMDE as a working electrode. Drop size was automated and regulated by keeping the nitrogen connection constant at $\sim$1 bar throughout the whole analysis to keep a constant Hg surface. Sweep potential was set from -0.6 V to -1.8 V, measurements being taken at -0.6 V. SA quantification is based on surfactants adsorption to the Hg drop which will cause a change in the capacity current ΔIc at an applied potential (E) of -0.6 V following Ćosović and Vojvodić (1998) method.

The measurement cell was furnaced prior analysis and rinsed with 10 % HCl and analytical grade water in between samples. Five readings at selected 15 s, 30 s and 60 s deposition times each were completed per sample.

Figure 41: Image of the polarograph set up in the ship's general laboratory mounted on a gimble table.

22.2.2 Salinity measurements

Salinity measurements from each location were taken with the multiprobe Horiba U-50 and salinities from the CTD casts were also recorded. Two samples from location 13 were taken and analysed in the ship's salinometer and this data used to calculate a correction factor for our Horiba multiprobe.

22.2.3 SA calibration

An external calibration was chosen in this exercise ranging from 0.05 mg mL^{-1} to 2 mg mL^{-1} using T-X-100 as a standard in 38.8 PSU salinity matrix and a blank of the same ionic strength. Quantification of SA was therefore expressed as mg L^{-1} T-X-100 eq. The capacity current Ic was calculated relative to that of the blank. The corrected capacity was therefore calculated as follows: ΔIc = Icblank- Ic sample. All samples were then adjusted to the same ionic strength (38.8 psu) through the whole exercise.

22.3 DOC analysis

22.3.1 Analytical protocol

DOC analyses were conducted in situ using a high performance liquid chromatography (HPLC) Agilent 1200 system with size exclusion chromatography (SEC) column Toyopearl HW-50-S and a variable wavelength detector (VWD) set at 254 nm. This exercise was an explorative opportunity to assess this chromatographic analytical technique when applied to marine samples and its experimental nature and

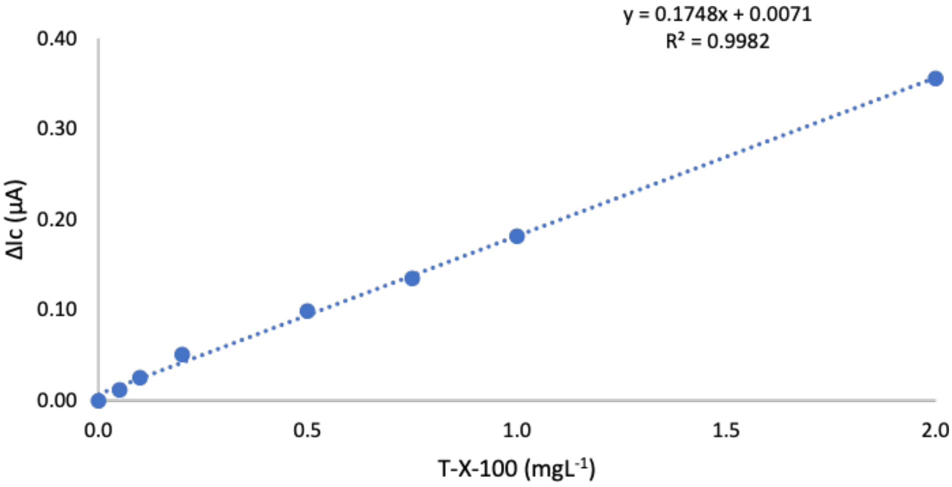


Figure 42: Example of external calibration using a serial dilution of T-X-100 used as standard 0.05-2 mgL^{-1} . Calibration was prepared in a matrix of 38.8 PSU NaCl and a blank was used to correct for salinity matrix effects. Five readings at 15 s deposition time were collected and the capacity current measured at -0.6 V (ΔIc in μA).

results will need further verification. The chromatographic system consisted of a degasser, a binary pump, an autosampler with a 1.4 mL sample loop. Open Lab was the operative software. Phosphate buffer was the mobile phase and was prepared using 10.0 g KH2PO4 and 6.0 g Na2HPO4 x 2 H2O to 5 L of lab water (22.5 mM). Mobile phase flow was set up at 2 mLmin^{-1} and 1 mL sample injection for this exercise. DOC is defined as the organic fraction capable of passing through a 0.45 μm filter, therefore every sample was filtered prior analysis. DOC is described as a complex mixture of organic carbon bounded compounds with an important contribution of aromaticity. The principle of this techniques is to fractionate the complex DOC pool into groups according to molecular size using size exclusion chromatography and measure the UV absorbance at 254 nm. Previous analysis of DOC in freshwater samples have shown a fractionation into five groups [Huber et al., 2011]. It is also known that high ionic strength of that of marine waters alters the capacity and resolution of this technique. Calibration of the VWD detector was carried out using Potassium Hydrogenphthalate PHP at a range of concentrations in fresh water. Standards from the International Humic Substances Society IHSS were used in this exercise to stablish retention times. Two standards from the Suwannee River 3S101H, Humic and 3S101F Fulvic were run in lab water and 35 PSU matrix to emulate similar matrix conditions and observe any shifts in retention times and interactions within the column.

22.4 Gas transfer velocity estimates

To estimate the gas exchange suppression of DOM we used a paired approach of a laboratory-based gas exchange tank (Figure 44) and a portable in-situ gas exchange sensor platform (Figure 45) designed for field deployment. Combining a laboratory tank with an in-situ gas exchange sensor platform merges the power of controlled experiments with fixed water-side turbulence (a baffle) to produce a gas transfer rate suppression factor compared to surfactant-free water (Milli-Q) with a portable field platform designed to estimate gas flux because of surfactants present at a given time in differing environmental turbulence regimes. Prototypes of two instruments for the direct flux measurements of CO_2 were tested in the DY146 cruise; In-situ gas transfer velocity measurement instrument (Insi-k) and a under bench gas exchange tank for CO_2 (GETCO$_2$) gas transfer velocity estimation. The locations of sweater samples collected for gas exchange tank are location 6, 7, 9, 11 and 14 shown in Table 31.

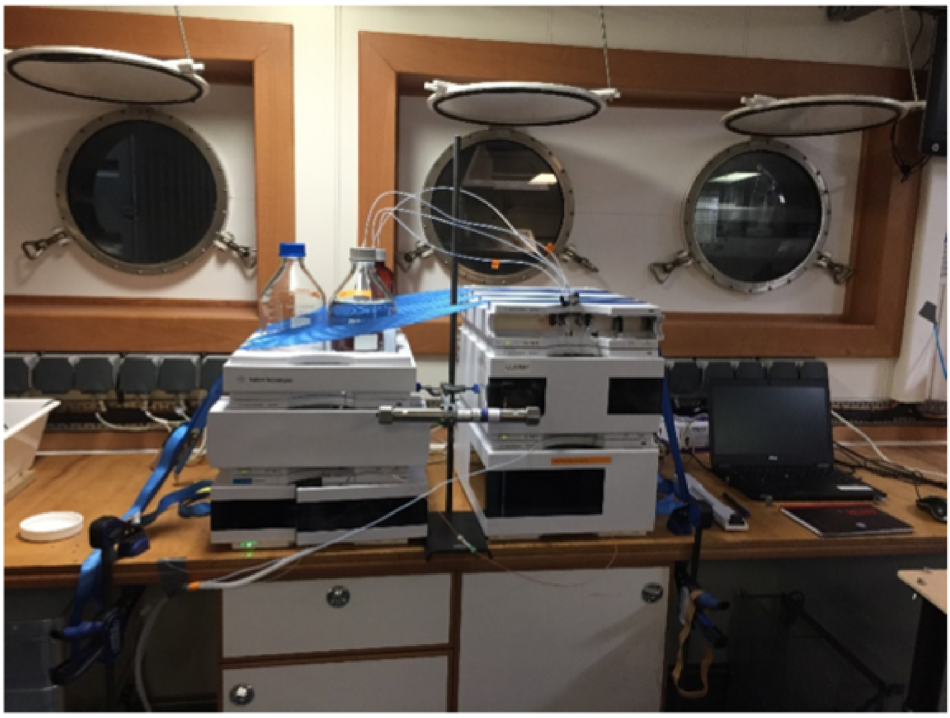


Figure 43: Image of the HPLC set up in the general lab.

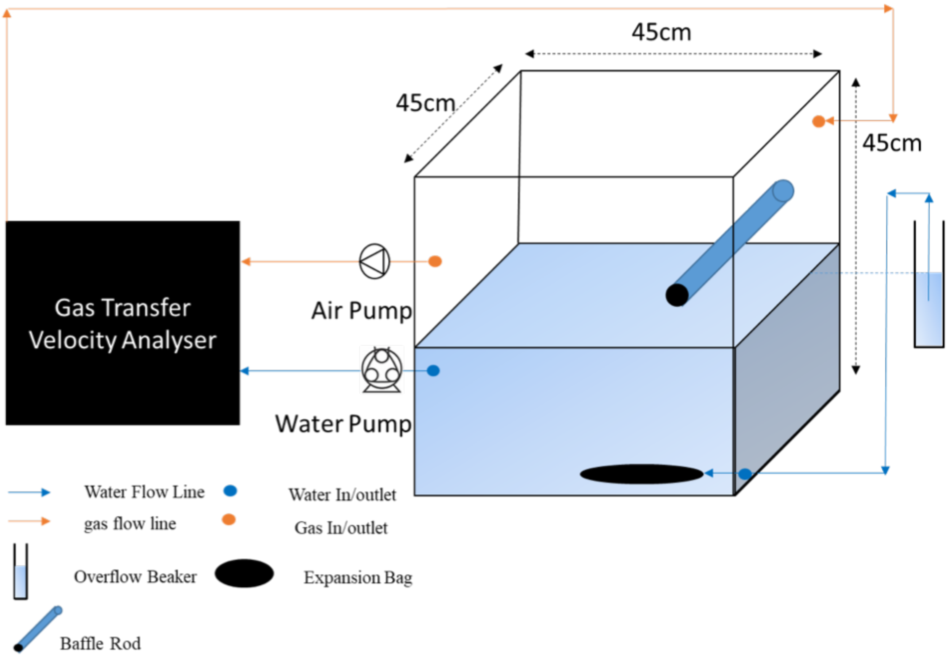


Figure 44: Gas exchange tank schematic

22.4.1 In-situ gas transfer velocity Analyser (Insi-k)

This instrument uses CO_2 Engine K30 FR fast response (10,000 ppm) CO_2 sensor for air CO_2 measurement. The same sensor is used to measure water CO_2 concentration with the help of an automated equilibrator, which accelerates the equilibration between water and air phase with different CO_2 concentrations. This goal is achieved by using a closed cycle of bubbling the water with the air phase inside the equilibrator.

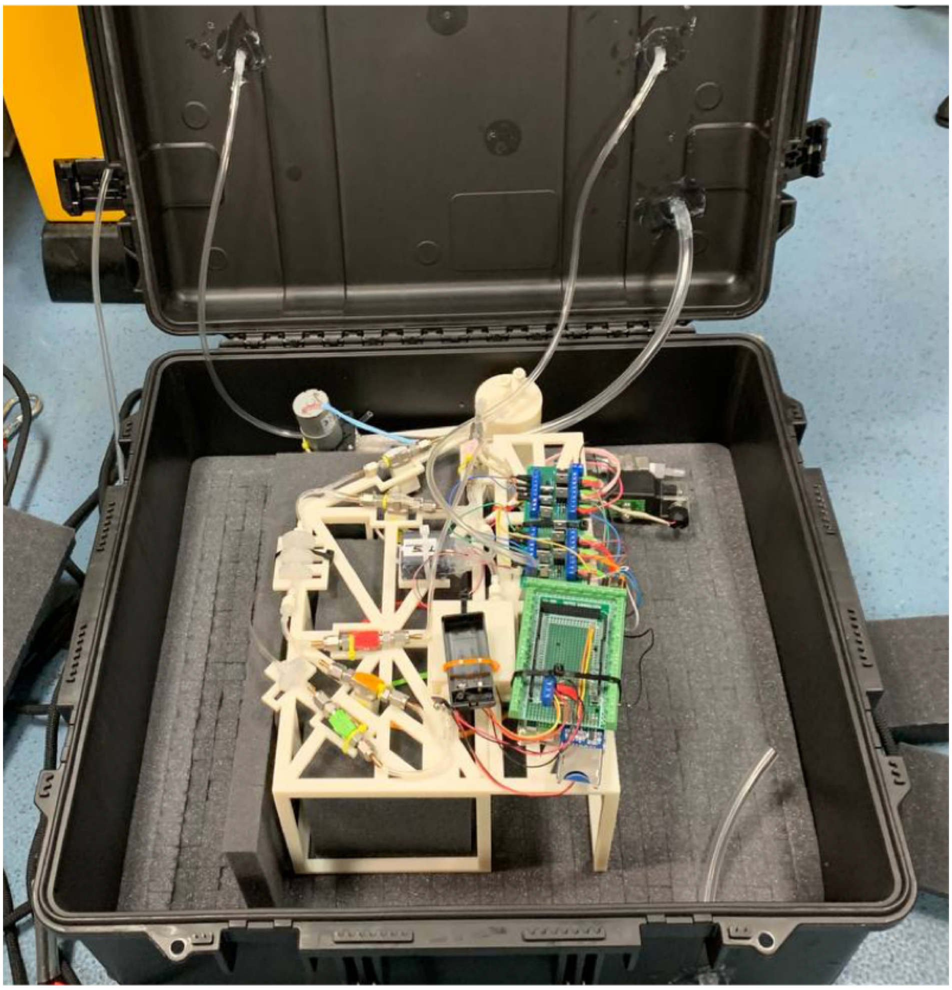


Figure 45: In-situ gas transfer velocity Analyser (Insi-k).

Insi-k was calibrated using 2 different gases (Pure N_2: 0 ppm CO2 and 865.8 ppm CO_2) for 3 measurements for bubbling and air line on 15th February. Insi-k was tested on the 13/02 at 14:30, 16/02 at 14:20, 19/02 at 21:00 and 21/02 at 17:45. The initial the observations from these deployments are as follows:

- The instrument performed well with the sea water and humid air but further development is required for making it suitable for deployment in a sea.
- As the sea state increases error in the volume of the water sample in the system for CO2 measurement increases.
- To overcome design inefficiencies and test Insi-k further, the instrument was tested on the deck of RSS Discovery rather than on the water surface. This method does not collect the air CO2 concentration data and the water samples had to be taken closer to the ship.
- Despite issues with increasing turbulence, Insi-k can be used in calmer marine waters.

22.4.2 The gas exchange tank

The gas exchange tank measures the gas transfer between water and air in a gas tight tank. Water and air samples were taken from the tank every 10 minutes for CO_2 measurement. The same sensor and procedure is utilised as the Insi-k with a different program for air and water CO_2 measurement. Before each test, the tank was properly cleaned and rinsed with Milli-Q. For each seawater sample test a blank test was run afterwards to account for the ship movement. The air CO_2 measurement line, ambient air CO_2 measurement line and water bubbling cycle of the instrument was calibrated using two gases (pure N2: 0 ppm CO_2 and ambient air collected in a gas bag with known concentration of 444.2 ppm) for three measurements on 15th February. k660 was estimated for blank (Milli-Q) water and seawater samples collected for selected locations (Table 31). Table 3 includes the summary of the locations in which the gas exchange tank experiments were done. Further work is ongoing to interrogate the early results of these experiments and validate the experimental setup for future work.

Table 33: Summary of the locations where gas exchange tank experiments were done for water samples collected at location 6, 7, 9, 11 and 14 and Milli-Q water. Information taken from CTD files and event logger on the ship.

Date and time	**Water Sample**	**Latitude**	**Longitude**	**Ground Speed (knot)**	**Relative Wind Speed (m/s)**	**Relative Wind Direction (degree)**
19/02/2022 14:56	Milli-Q	23.77918	-24.12065	1.7	4.21	177
21/02/2022 10:48	Milli-Q	24.93676	-21.27056	0.7	7.54	12
21/02/2022 13:24	Milli-Q	24.93674	-21.27052	0.1	8.39	353
22/02/2022 15:43	Location 6	24.03743	-23.46027	10.5	4.7	1
23/02/2022 09:45	Milli-Q	27.21702	-15.42002	3.8	4.99	252
25/02/2022 09:43	Location 11	27.82553	-13.74893	0.9	7.71	355
25/02/2022 20:34	Milli-Q	27.35912	-15.00038	0.2	11.91	3
28/02/2022 10:41	Location 9	27.62398	-14.19543	7	18.48	359
28/02/2022 13:55	Milli-Q	27.88088	-13.50928	0.8	14.33	352
03/03/2022 12:35	Location 7	24.93673	-21.27052	9.4	15.56	358
03/03/2022 17:48	Milli-Q	34.80673	-12.69584	9.2	14.72	17
05/03/2022 13:48	Location 14	34.72793	-12.67347	9.5	12.65	344

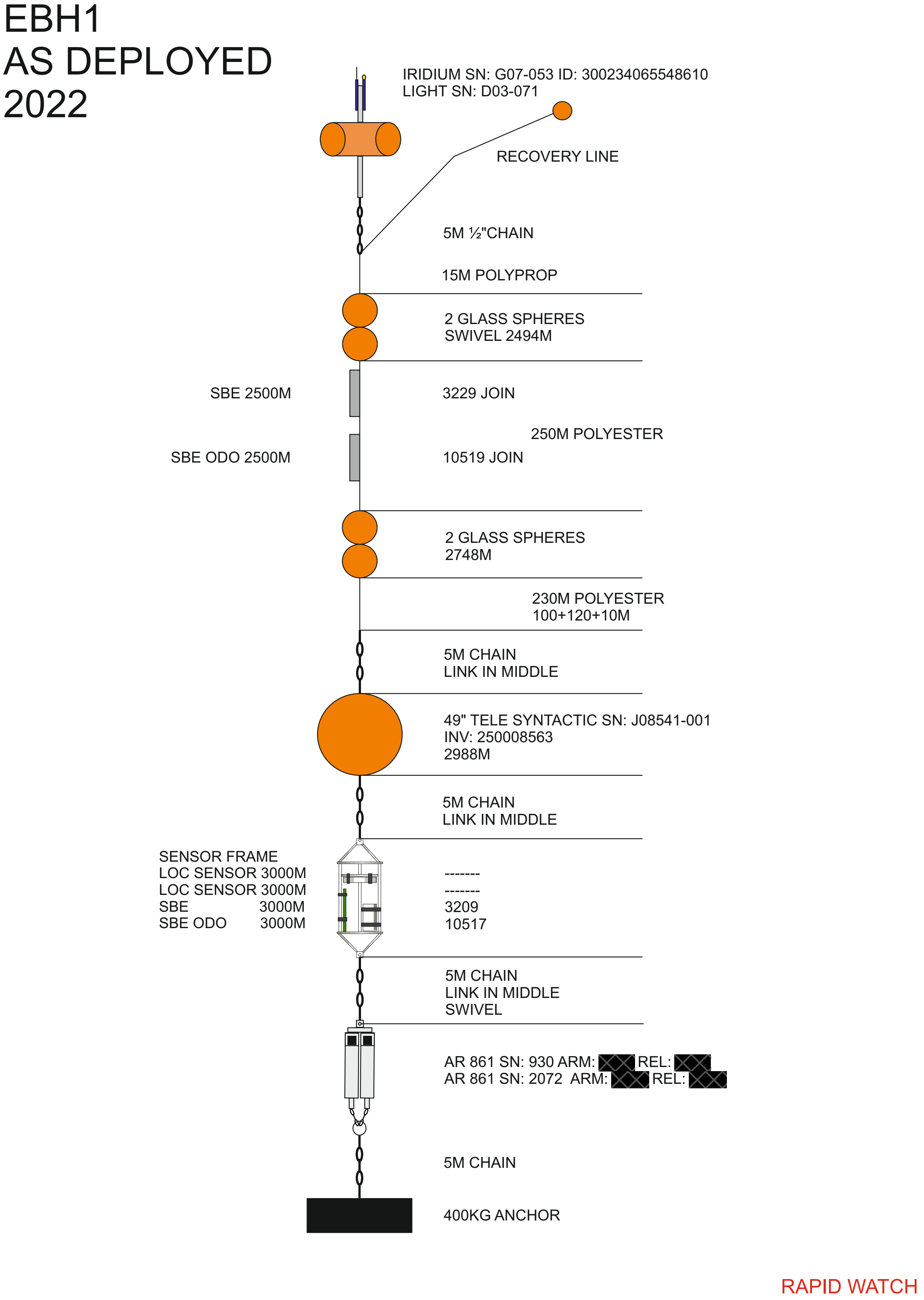
References

C. H. Culberson and S. Huang. Automated amperometric oxygen titration. *Deep Sea Research Part A. Oceanographic Research Papers*, 34:875–880, 1987. ISSN 0198-0149. doi: https://doi.org/10.1016/0198-0149(87)90042-2. URL `https://www.sciencedirect.com/science/article/pii/0198014987900422`.

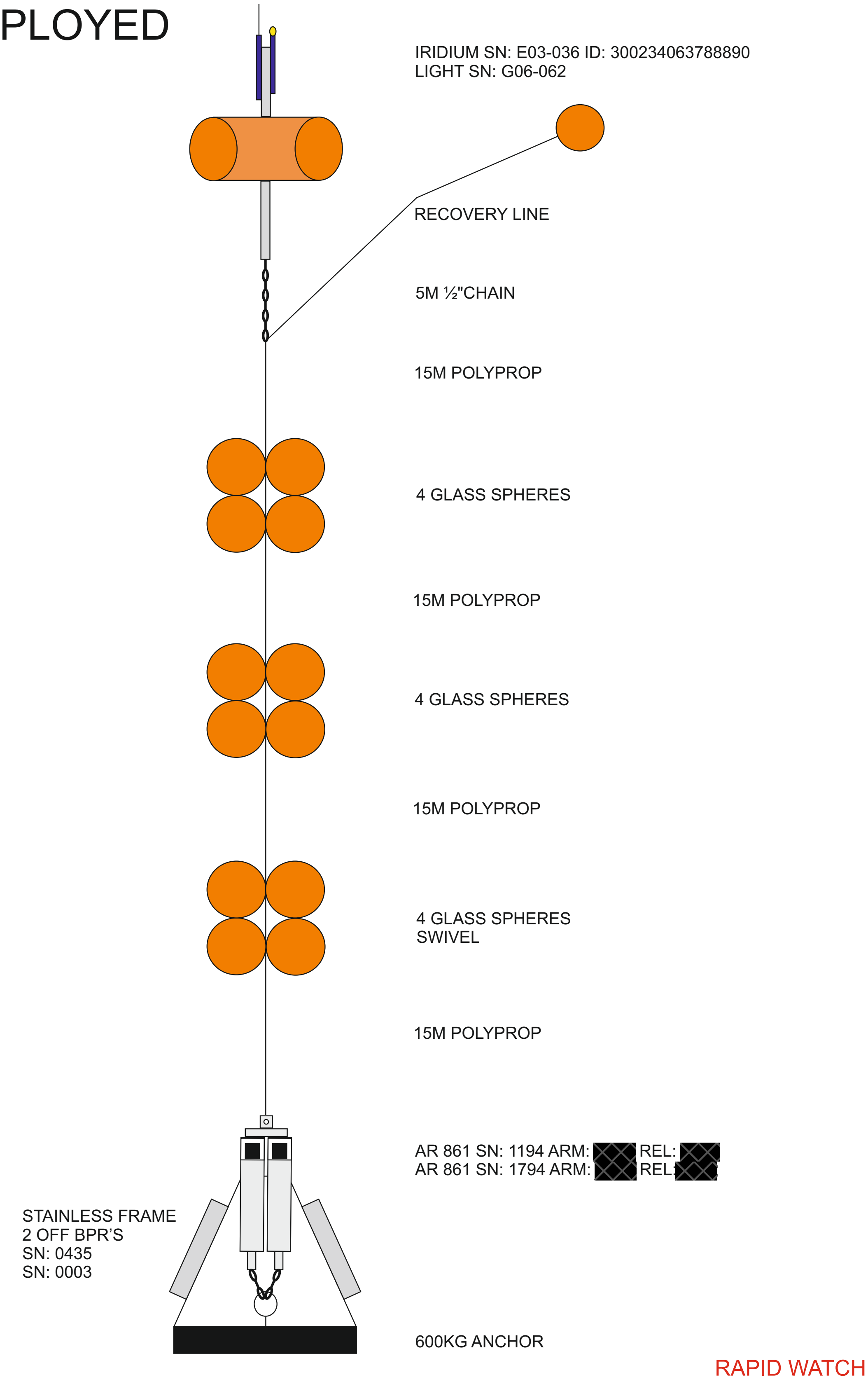
S. A. Huber, A. Balz, M. Abert, and W. Pronk. Characterisation of aquatic humic and non-humic matter with size-exclusion chromatography – organic carbon detection – organic nitrogen detection (lc-ocd-ond). *Water Research*, 45:879–885, 2011. ISSN 0043-1354. doi: https://doi.org/10.1016/j.watres.2010.09.023. URL `https://www.sciencedirect.com/science/article/pii/S0043135410006779`.

C. Langdon. Determination of dissolved oxygen in seawater by winkler titration using the amperometric technique, 2010.

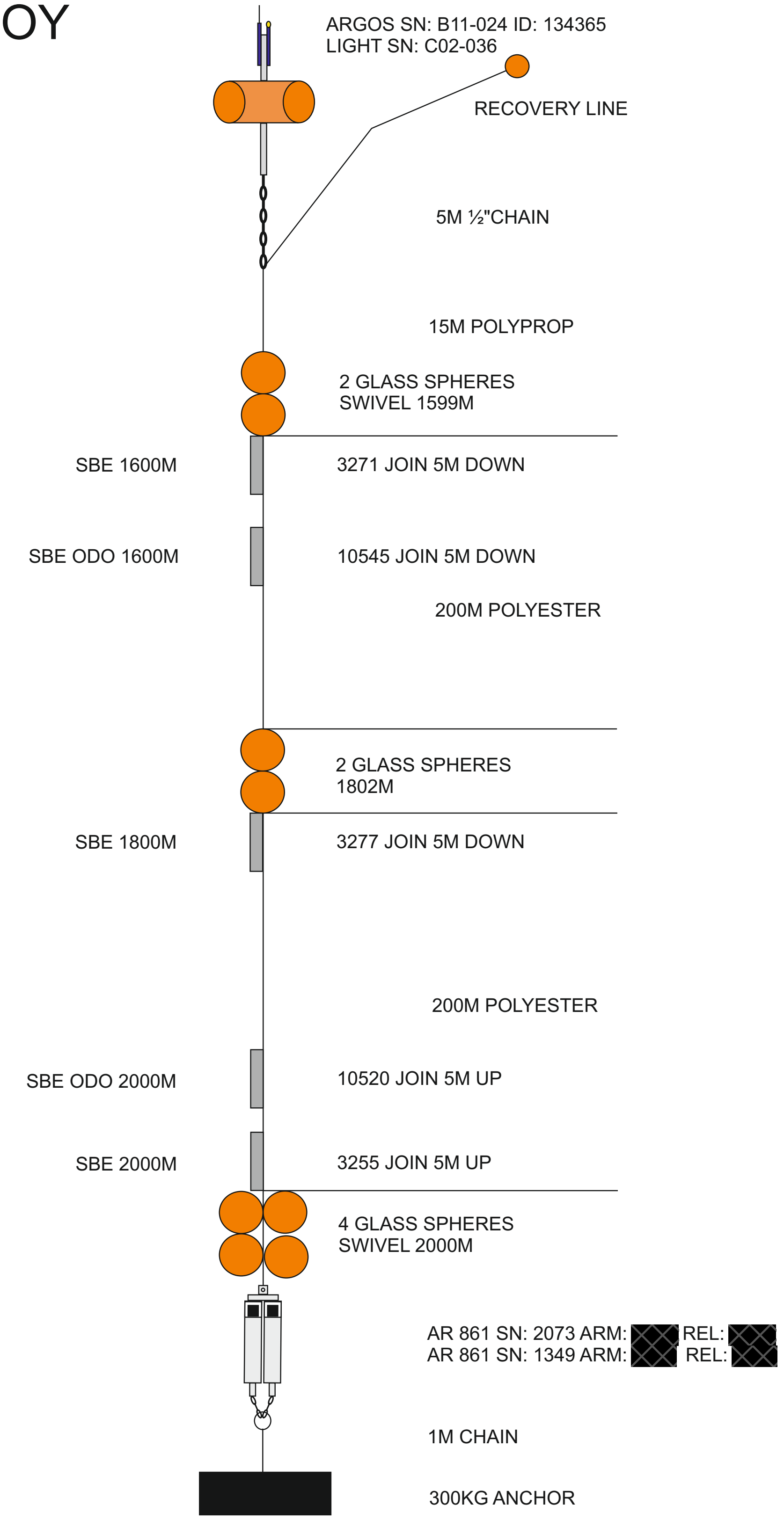
A Diagrams of deployed moorings



EBH1L15
AS DEPLOYED
2022

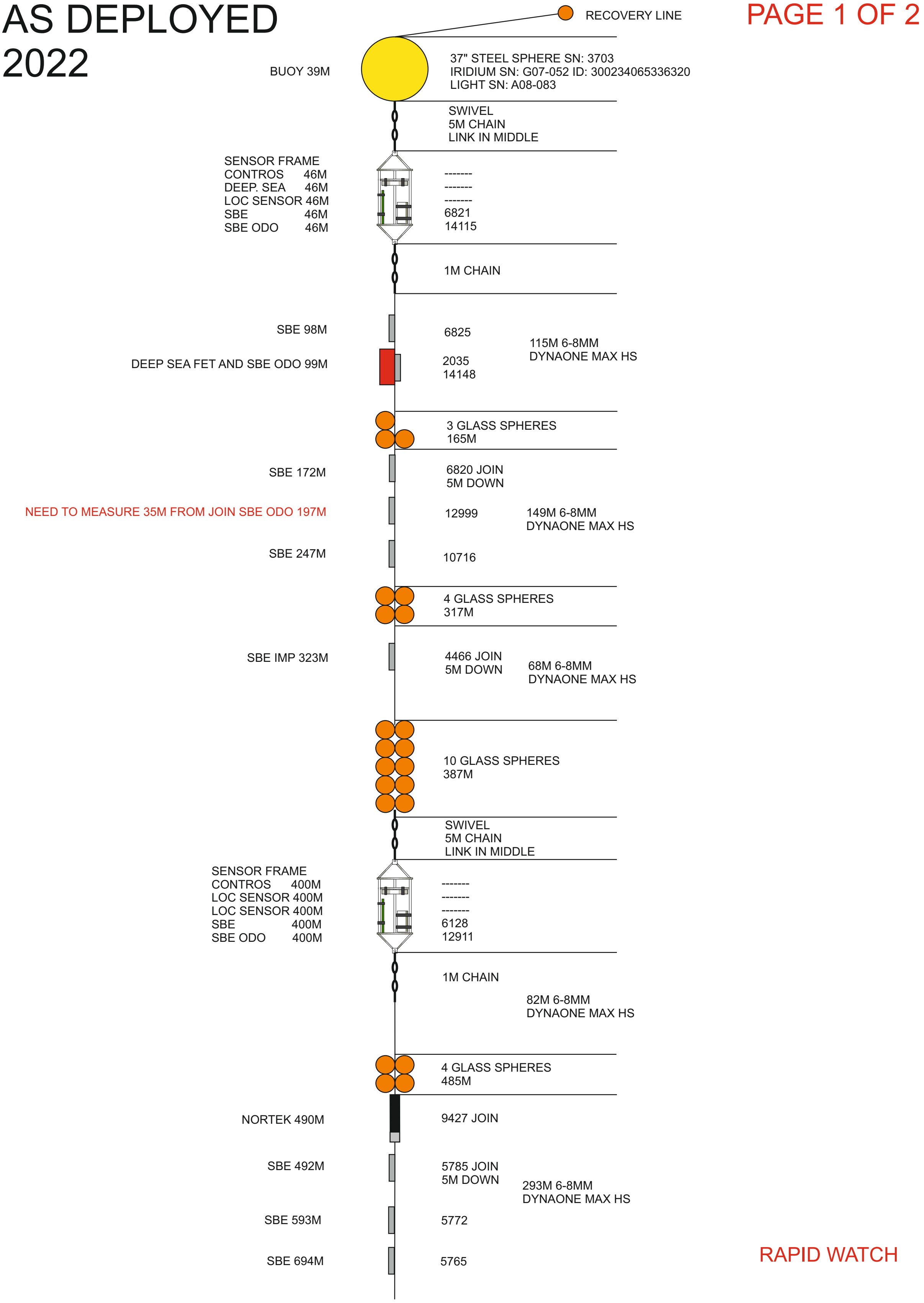


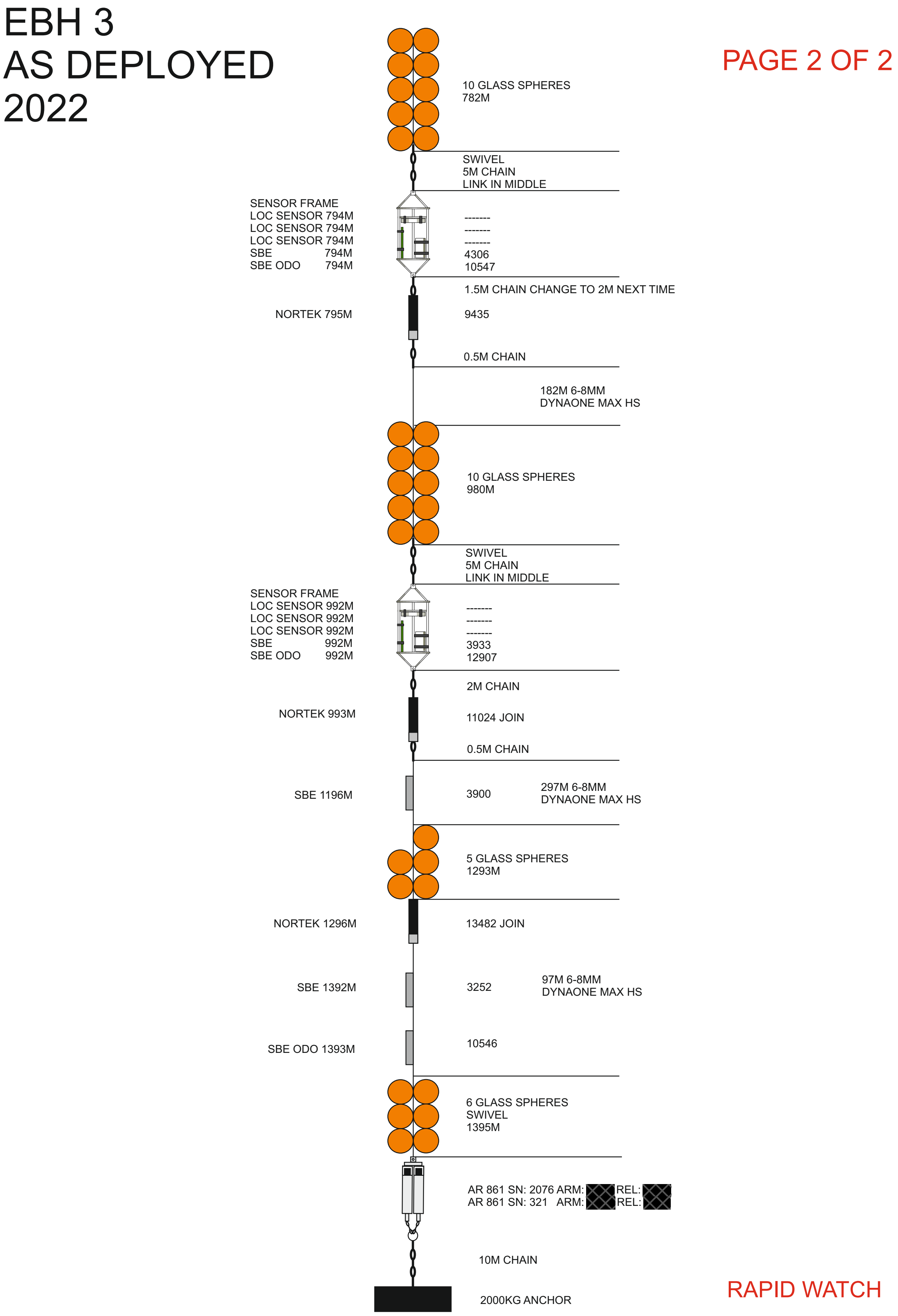
EBH2
TO DEPLOY
2022



RAPID WATCH

EBH3
AS DEPLOYED
2022

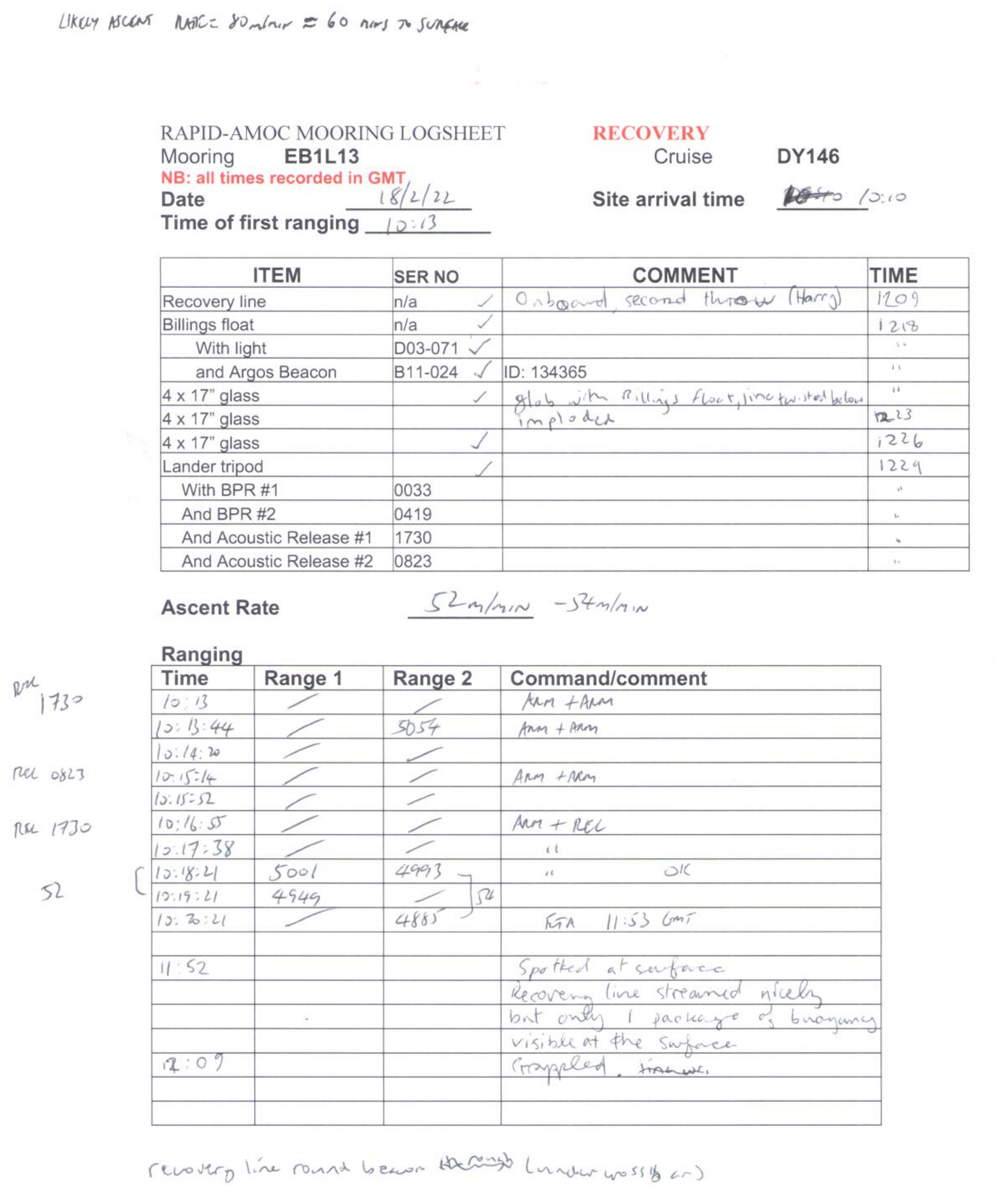



EBH 3
AS DEPLOYED
2022
PAGE 2 OF 2
10 GLASS SPHERES
782M
SWIVEL
5M CHAIN
LINK IN MIDDLE
SENSOR FRAME
LOC SENSOR 794M
LOC SENSOR 794M
LOC SENSOR 794M
SBE 794M
SBE ODO 794M

4306
10547
1.5M CHAIN CHANGE TO 2M NEXT TIME
NORTEK 795M
9435
0.5M CHAIN
182M 6-8MM
DYNAONE MAX HS
10 GLASS SPHERES
980M
SWIVEL
5M CHAIN
LINK IN MIDDLE
SENSOR FRAME
LOC SENSOR 992M
LOC SENSOR 992M
LOC SENSOR 992M
SBE 992M
SBE ODO 992M

3933
12907
2M CHAIN
NORTEK 993M
11024 JOIN
0.5M CHAIN
SBE 1196M
3900
297M 6-8MM
DYNAONE MAX HS
5 GLASS SPHERES
1293M
NORTEK 1296M
13482 JOIN
SBE 1392M
3252
97M 6-8MM
DYNAONE MAX HS
SBE ODO 1393M
10546
6 GLASS SPHERES
SWIVEL
1395M
AR 861 SN: 2076 ARM: [redacted] REL: [redacted]
AR 861 SN: 321 ARM: REL:
10M CHAIN
2000KG ANCHOR
RAPID WATCH

B Logsheets - Recovery



LIKELY ASCENT RATE = 80m/min ≃ 60 mins TO SURFACE

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EB1L13** Cruise **DY146**

NB: all times recorded in GMT

Date 18/2/22

Site arrival time ~~1010~~ 10:10

Time of first ranging 10:13

ITEM	SER NO		COMMENT	TIME
Recovery line	n/a	✓	Onboard, second throw (Harry)	1209
Billings float	n/a	✓		1218
With light	D03-071	✓		"
and Argos Beacon	B11-024	✓	ID: 134365	"
4 x 17" glass		✓	glob with Billings float, line twisted below	"
4 x 17" glass			imploded	~~12~~ 1223
4 x 17" glass		✓		1226
Lander tripod		✓		1229
With BPR #1	0033			"
And BPR #2	0419			"
And Acoustic Release #1	1730			"
And Acoustic Release #2	0823			"

Ascent Rate 52m/min -54m/min

Ranging

	Time	Range 1	Range 2		Command/comment
Rel 1730	10:13	/	/		Arm + Arm
	10:13:44	/	5054		Arm + Arm
	10:14:20	/	/		
Rel 0823	10:15:14	/	/		Arm + Arm
	10:15:52	/	/		
Rel 1730	10:16:55	/	/		Arm + Rel
	10:17:38	/	/		"
52	10:18:21	5001	4993	54	" OK
	10:19:21	4949	/		
	10:20:21	/	4885		ETA 11:53 GMT
	11:52				Spotted at surface
					Recovery line streamed nicely
					but only 1 package of buoyancy
					visible at the surface
	12:09				Grappled. ~~[illegible]~~

recovery line round beacon [illegible] (under crossbar)

RAPID-AMOC MOORING LOGSHEET **RECOVERY**
Mooring **EB1** Cruise DY146
NB: all times recorded in GMT
Date 19/2/22 **Site arrival time** OVERNIGHT
Time of first ranging 08:50

SPOTTED ON SURFACE 09:00

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a ✓	grapple ~1024 mod. foul block	1033
Billings float	n/a ✓		1034
With light	A08-083 ✓	Algae	
And Iridium beacon	E03-036 ✓	ID 300234063788890	
MicroCAT	5241 ✓	mod foul barnacles	1035
MicroCAT-ODO	14117 ✓	"	1037
MicroCAT	4714 ✓	crinoid line clean below	1041
37" steel sphere	3703		1045
with light	D01-049 ✓		
and Iridium Beacon	G07-054 ✓	ID: 300234065334270	
MicroCAT	5984 ✓	clean	1050
MicroCAT	3206 ✓	label coming off	1054
MicroCAT	4466 ✓		1056
MicroCAT	6839 ✓		1059
MicroCAT - ODO	14145 ✓		"
4 x 17" glass (493m)	n/a	all fine	1102
MicroCAT	3212 3312	It is instrument 3212, label is wrong	1108
4 x 17" glass (792m)	n/a	all fine	1114
MicroCAT	6811 ✓	Top open, no batteries. End cap separate	1116
MicroCAT-ODO	14146 ✓		"
MicroCAT	3890 ✓		1124
4 x 17" glass (1129m)	n/a	All fine.	1128
MicroCAT	3229 ✓		1136
MicroCAT-ODO	14149 ✓		1145
4 x 17" glass (1532m)	n/a	All fine	1146
MicroCAT	4722 ✓		1151
MicroCAT-ODO	14150 ✓		1204
MicroCAT	6813 ✓	On first	1204
5 x 17" glass (2285m)	n/a	all fine	1213
MicroCAT	3222 ✓		1234
MicroCAT	3224 ✓		1249
5 x 17" glass (3292m)	n/a	all fine	1257
MicroCAT	10716 ✓		1308
MicroCAT-ODO	14151 ✓		1309
4 x 17" glass (3898m)	n/a	All fine	1320
MicroCAT	5985 ✓		1328
4 x 17" glass (4492m)	n/a	~~4~~ all gone (imploded)	1342
MicroCAT	5979 ✓		1345
MicroCAT	3932 ✓		1400
8 x 17" glass (5049m)	n/a	all imploded	1402
Acoustic Release #1	354 ✓		1408
Acoustic Release #2	2222 ✓	released	"

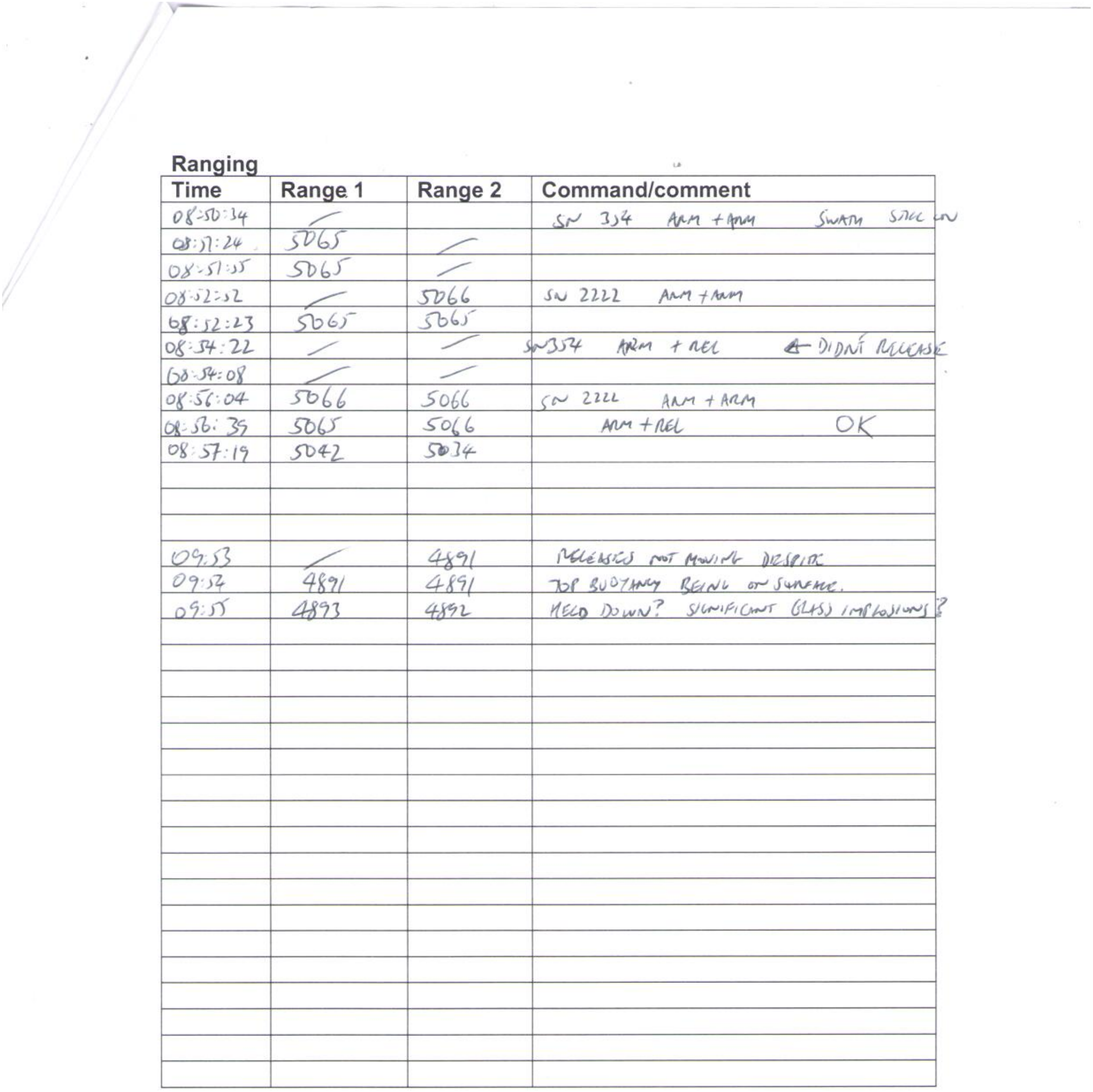
under control

in hanger

eyes on

spooling mis-aligned and hang change spool → 1226

bird



Ranging

Time	Range 1	Range 2	Command/comment
08:50:34	/		SN 354 ARM + ARM SWATM STILL ON
08:51:24	5065	/	
08:51:55	5065	/	
08:52:52	/	5066	SN 2222 ARM + ARM
08:52:23	5065	5065	
08:54:22	/	/	SN354 ARM + REL ← DIDN'T RELEASE
08:54:08	/	/	
08:56:04	5066	5066	SN 2222 ARM + ARM
08:56:39	5065	5066	ARM + REL OK
08:57:19	5042	5034	
09:53	/	4891	RELEASES NOT MOVING DESPITE
09:54	4891	4891	TOP BUOYANCY BEING ON SURFACE.
09:55	4893	4892	HELD DOWN? SIGNIFICANT GLASS IMPLOSIONS?

LIKELY ASCENT RATE = 36 m/min ≃ 2HR20 to SURFACE

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EB1L14** Cruise **DY146**

NB: all times recorded in GMT

Date 18/2/22 **Site arrival time** OVERNIGHT

Time of first ranging ____________

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a	grappel 0939	0944
Syntactic lander			0946
With Iridium beacon	G07-053 ✓		"
With light	G06-062 ✓		"
With BPR #1	0029 ✓		"
And BPR #2	0389 ✓		"
And Acoustic Release #1	2069		"
And Acoustic Release #2	917		"

with hi-vis vest ✓ "

Ascent Rate ____________

Ranging

REL 2069

37 m/min [07:08:17 – 07:09:17]

38.5 m/min [07:09:17 – 07:11:17]

Time	Range 1	Range 2	Command/comment
07:03	~~5040~~	5040	ARM + ARM
07:04:15			~~ARM + REL~~ WRONG CODE.
07:05:17	5039	5040	ARM + REL OK
07:05:55	5040	5040	OK
07:06:38	5036	5030	OK
07:07:17	5011	5006	OK
07:08:17	4974	4969	OK
07:09:17	4937	4931	
07:11:17	4860	4856	
			ETA ~ 09:15 – 09:20
09:22			spotted ~100m, NE

RAPID-AMOC MOORING LOGSHEET
Mooring **EB1P**
NB: all times recorded in GMT
Date 18/2/22
Time of first ranging [illegible] 1432

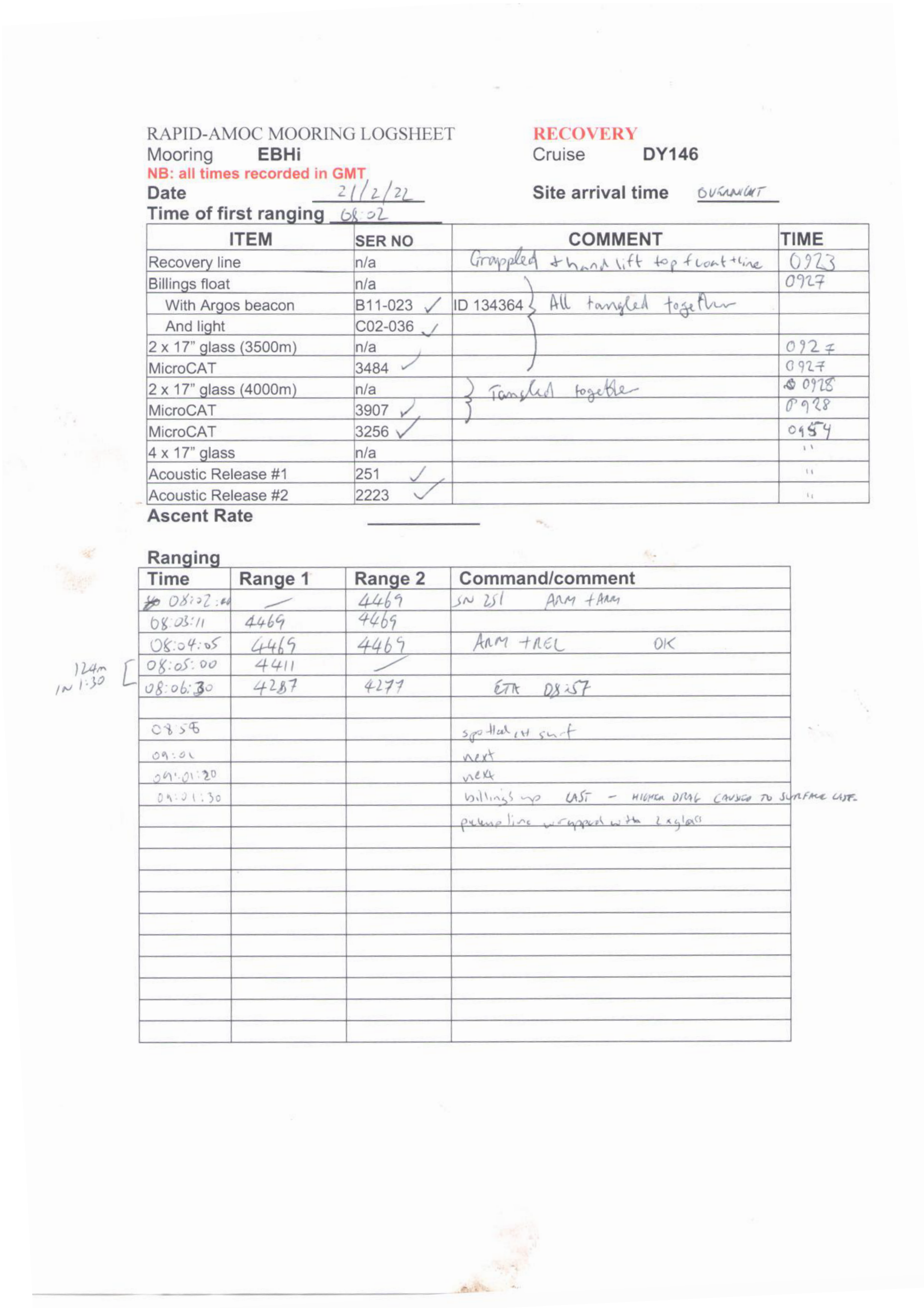
RECOVERY
Cruise **DY146**
Site arrival time 1431

ITEM	**SER NO**	**COMMENT**	**TIME**
Recovery line		Gone	
PIES in frame + controller			1656

Ranging

Time	**Range 1**	**Command/comment**
[illegible] 1432		Clear has been heard out of telemetry
1433		" " " " " "
1433		Transpond mode sent
1433		Transpond mode received.
1434:14	5052	Ranging
1434:27	5051	Ranging
14 34 :46		Clear sent
14:35:00		Clear received
14:35:08		Clear Sent
14 :35:26		Not received
14:35:34		Clear sent
14:35:49		Clear received
14:36:17		Release sent
14:36:45		Six pings received
14:37:11		Pulse every 4 secs, release underway.
		1452 earliest release, 1603 earliest time at surface
1640		Sighted at surface

Recovery instructions on reverse



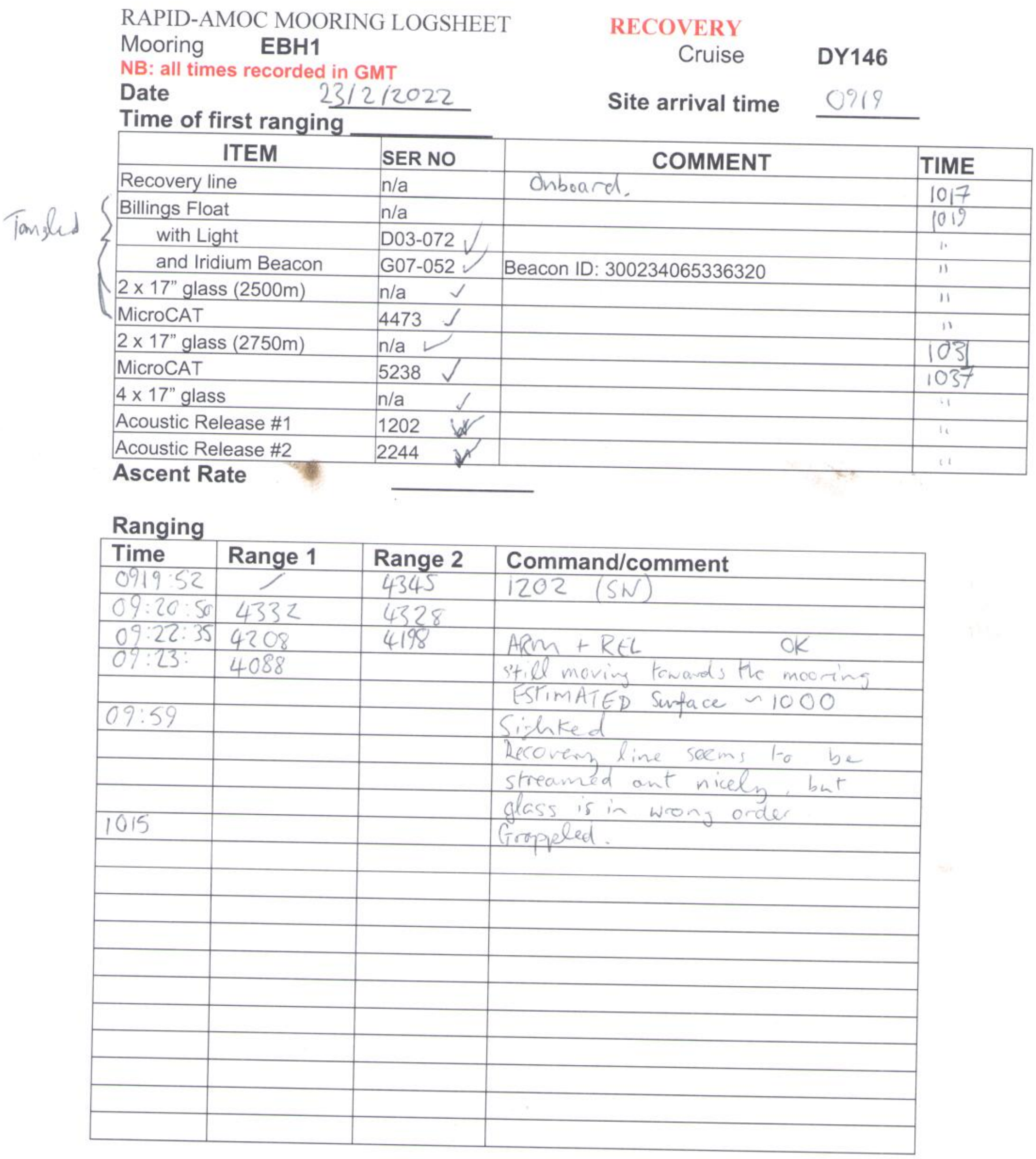
RAPID-AMOC MOORING LOGSHEET **RECOVERY**
Mooring **EBHi**
Cruise **DY146**
NB: all times recorded in GMT
Date 21/2/22
Site arrival time OVERNIGHT
Time of first ranging 08:02

ITEM	**SER NO**	**COMMENT**	**TIME**
Recovery line	n/a	Grappled + hand lift top float + line	0923
Billings float	n/a	}	0927
With Argos beacon	B11-023 ✓	ID 134364 } All tangled together	
And light	C02-036 ✓	}	
2 x 17" glass (3500m)	n/a	}	0927
MicroCAT	3484 ✓	}	0927
2 x 17" glass (4000m)	n/a	} Tangled together	0928
MicroCAT	3907 ✓	}	0928
MicroCAT	3256 ✓		0954
4 x 17" glass	n/a		"
Acoustic Release #1	251 ✓		"
Acoustic Release #2	2223 ✓		"

Ascent Rate ____________

Ranging

Time	**Range 1**	**Range 2**	**Command/comment**
~~10~~ 08:02:[illegible]	—	4469	SN 251 ARM + ARM
08:03:11	4469	4469	
08:04:05	4469	4469	ARM + REL OK
124m IN 1:30 [08:05:00	4411	—	
08:06:30	4287	4277	ETA 08:57
08:58			spotted at surf
09:01			next
09:01:20			next
09:01:30			billings up LAST – HIGHER DRAG CAUSED TO SURFACE LAST.
			pickup line wrapped with 2 x glass



RAPID-AMOC MOORING LOGSHEET

RECOVERY

Mooring **EBH1**

Cruise **DY146**

NB: all times recorded in GMT

Date 23/2/2022

Site arrival time 0919

Time of first ranging ________

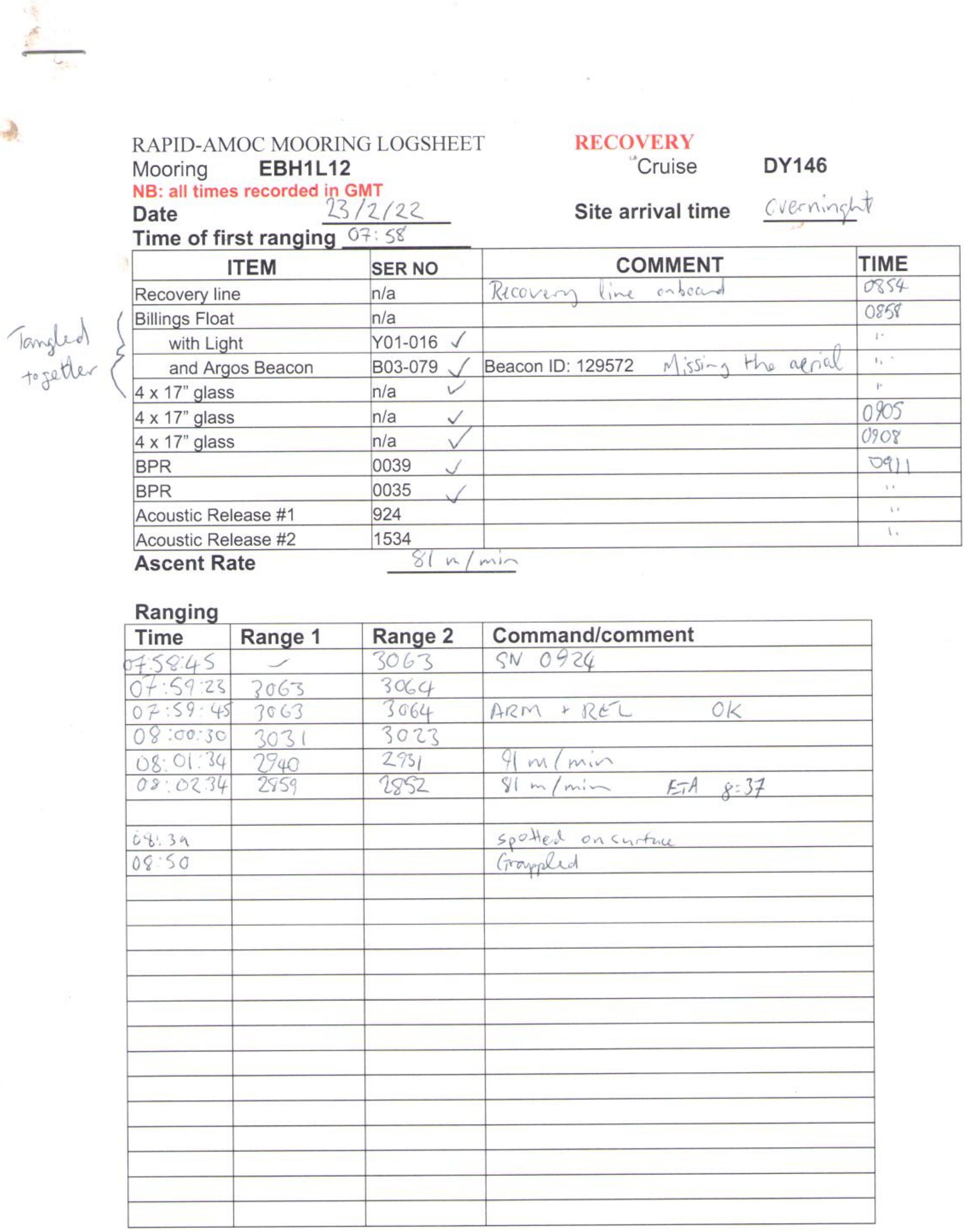
Tangled

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a	Onboard.	1017
Billings Float	n/a		1019
with Light	D03-072 ✓		"
and Iridium Beacon	G07-052 ✓	Beacon ID: 300234065336320	"
2 x 17" glass (2500m)	n/a ✓		"
MicroCAT	4473 ✓		"
2 x 17" glass (2750m)	n/a ✓		1031
MicroCAT	5238 ✓		1037
4 x 17" glass	n/a ✓		"
Acoustic Release #1	1202 ✓		"
Acoustic Release #2	2244 ✓		"

Ascent Rate ________

Ranging

Time	Range 1	Range 2	Command/comment
0919:52	/	4345	1202 (SN)
09:20:50	4332	4328	
09:22:35	4208	4198	ARM + REL OK
09:23:	4088		still moving towards the mooring
			ESTIMATED Surface ~1000
09:59			Sighted
			Recovery line seems to be
			streamed out nicely, but
			glass is in wrong order
1015			Grappled.



RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EBH1L12** Cruise **DY146**

NB: all times recorded in GMT

Date 23/2/22 **Site arrival time** Overnight

Time of first ranging 07:58

Tangled together

ITEM	**SER NO**	**COMMENT**	**TIME**
Recovery line	n/a	Recovery line onboard	0854
Billings Float	n/a		0858
with Light	Y01-016 ✓		''
and Argos Beacon	B03-079 ✓	Beacon ID: 129572 Missing the aerial	''
4 x 17" glass	n/a ✓		''
4 x 17" glass	n/a ✓		0905
4 x 17" glass	n/a ✓		0908
BPR	0039 ✓		0911
BPR	0035 ✓		''
Acoustic Release #1	924		''
Acoustic Release #2	1534		''

Ascent Rate 81 m/min

Ranging

Time	**Range 1**	**Range 2**	**Command/comment**
07:58:45	✓	3063	SN 0924
07:59:23	3063	3064	
07:59:45	3063	3064	ARM + REL OK
08:00:30	3031	3023	
08:01:34	2940	2931	91 m/min
08:02:34	2859	2852	81 m/min ETA 8:37
08:39			spotted on surface
08:50			Grappled

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EBH2** Cruise **DY146**

NB: all times recorded in GMT

Date 24/2/2022 **Site arrival time** 07:45

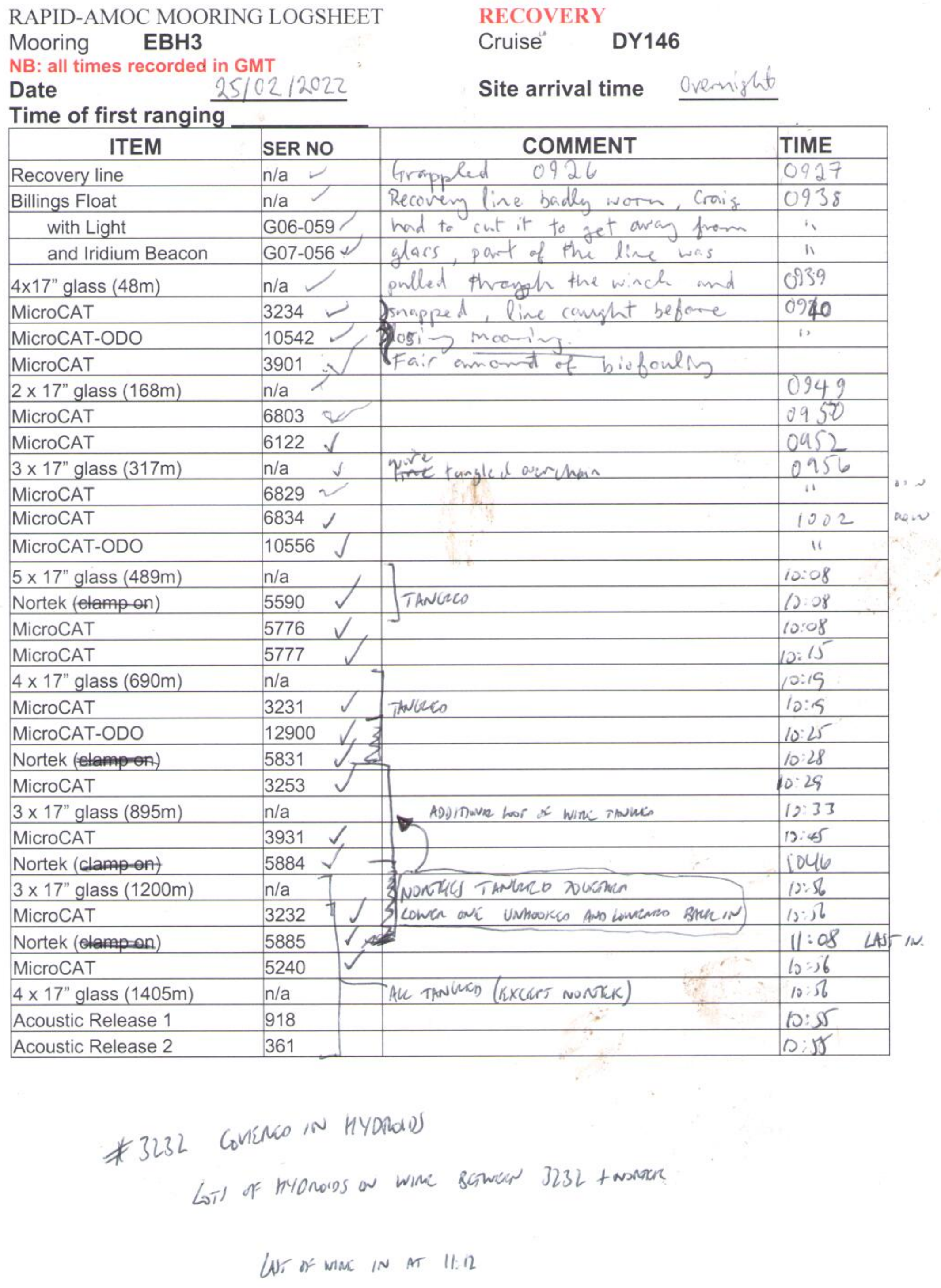
Time of first ranging ____________

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a	Grappled 0932	0935
Billings Float	n/a		0937
with Light	G06-063 ✓		〃
and Argos Beacon	B11-022 ✓	Beacon ID: 134363	〃
2 x 17" glass	n/a		0940
MicroCAT	4184 ✓	dragged on with T	0940
2 x 17" glass	n/a	↕	0947
MicroCAT	6125 ✓	moreline	〃
MicroCAT	6113 ✓		0954
4 x 17" glass	n/a		〃
Acoustic Release #1	~~1345~~ 1346		0958
Acoustic Release #2	2071 ✓		〃

Ascent Rate 70 m/min

Ranging

Time	Range 1	Range 2	Command/comment
08:55:30		2073	SN 1346
08:55:49	2074	2074	
08:56:53	2074	2074	ARM REL OK
08:57:53	2004	1995	
08:58:53	1918	1909	Estimated surface time 0925
09:20			Sighted at surface



RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EBH3** Cruise **DY146**

NB: all times recorded in GMT

Date 25/02/2022 **Site arrival time** Overnight

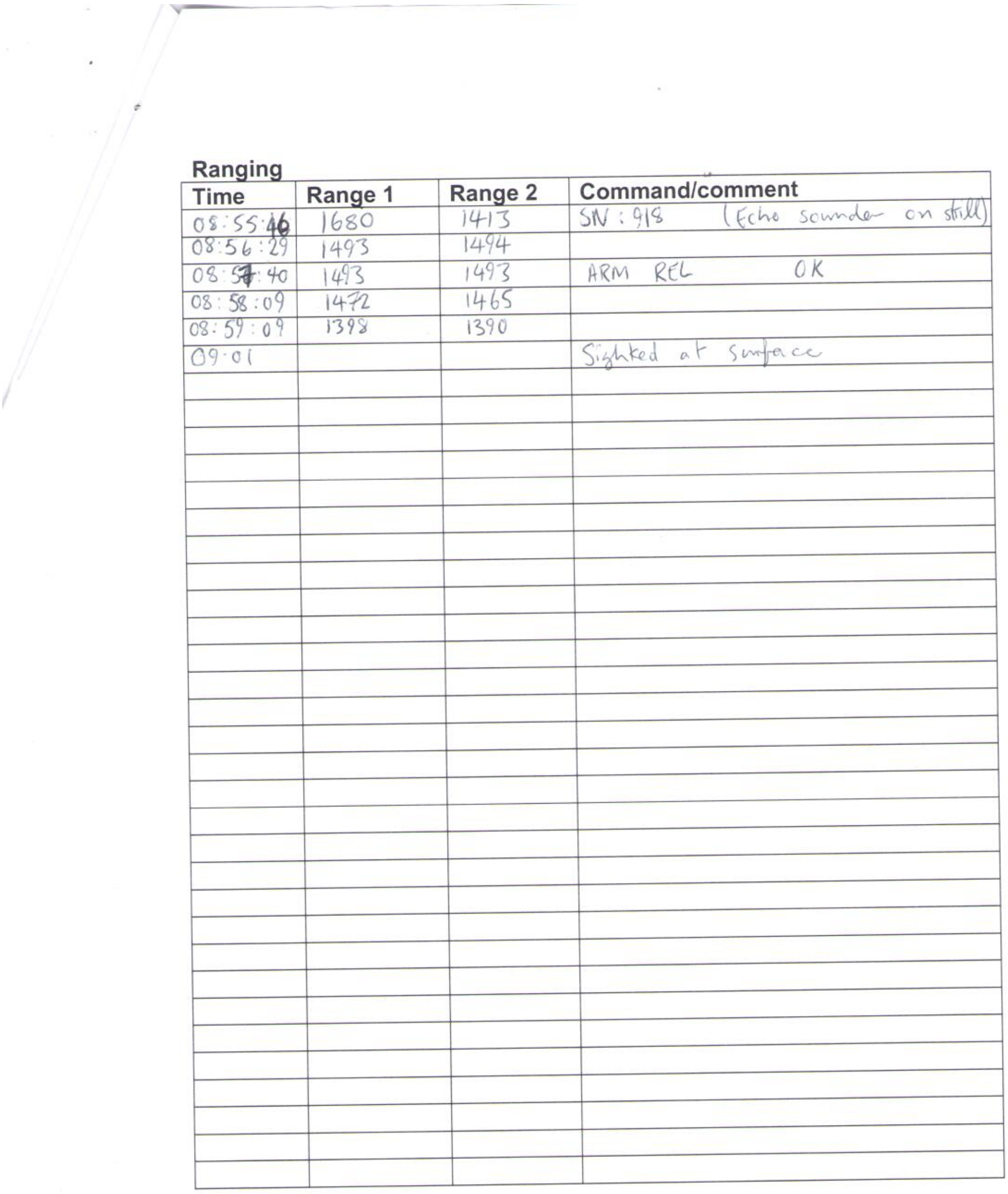
Time of first ranging ____________

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a ✓	Grappled 0926	0927
Billings Float	n/a ✓	Recovering line badly worn, Craig	0938
with Light	G06-059 ✓	had to cut it to get away from	"
and Iridium Beacon	G07-056 ✓	glass, part of the line was	"
4x17" glass (48m)	n/a ✓	pulled through the winch and	0939
MicroCAT	3234 ✓	snapped, line caught before	0940
MicroCAT-ODO	10542 ✓	losing mooring.	"
MicroCAT	3901 ✓	Fair amount of biofouling	
2 x 17" glass (168m)	n/a ✓		0949
MicroCAT	6803 ✓		0950
MicroCAT	6122 ✓		0952
3 x 17" glass (317m)	n/a ✓	wire ~~line~~ tangled over chain	0956
MicroCAT	6829 ✓		"
MicroCAT	6834 ✓		1002
MicroCAT-ODO	10556 ✓		"
5 x 17" glass (489m)	n/a ✓		10:08
Nortek (~~clamp on~~)	5590 ✓	TANGLED	10:08
MicroCAT	5776 ✓		10:08
MicroCAT	5777 ✓		10:15
4 x 17" glass (690m)	n/a		10:19
MicroCAT	3231 ✓	TANGLED	10:19
MicroCAT-ODO	12900 ✓		10:25
Nortek (~~clamp on~~)	5831 ✓		10:28
MicroCAT	3253 ✓		10:29
3 x 17" glass (895m)	n/a	ADDITIONAL LOOP OF WIRE TANGLED	10:33
MicroCAT	3931 ✓		10:45
Nortek (~~clamp on~~)	5884 ✓		1046
3 x 17" glass (1200m)	n/a	NORTEKS TANGLED TOGETHER	10:56
MicroCAT	3232 ✓	LOWER ONE UNHOOKED AND LOWERED BACK IN	10:56
Nortek (~~clamp on~~)	5885 ✓		11:08 LAST IN.
MicroCAT	5240 ✓		10:56
4 x 17" glass (1405m)	n/a	ALL TANGLED (EXCEPT NORTEK)	10:56
Acoustic Release 1	918		10:55
Acoustic Release 2	361		10:55

#3232 COVERED IN HYDROIDS

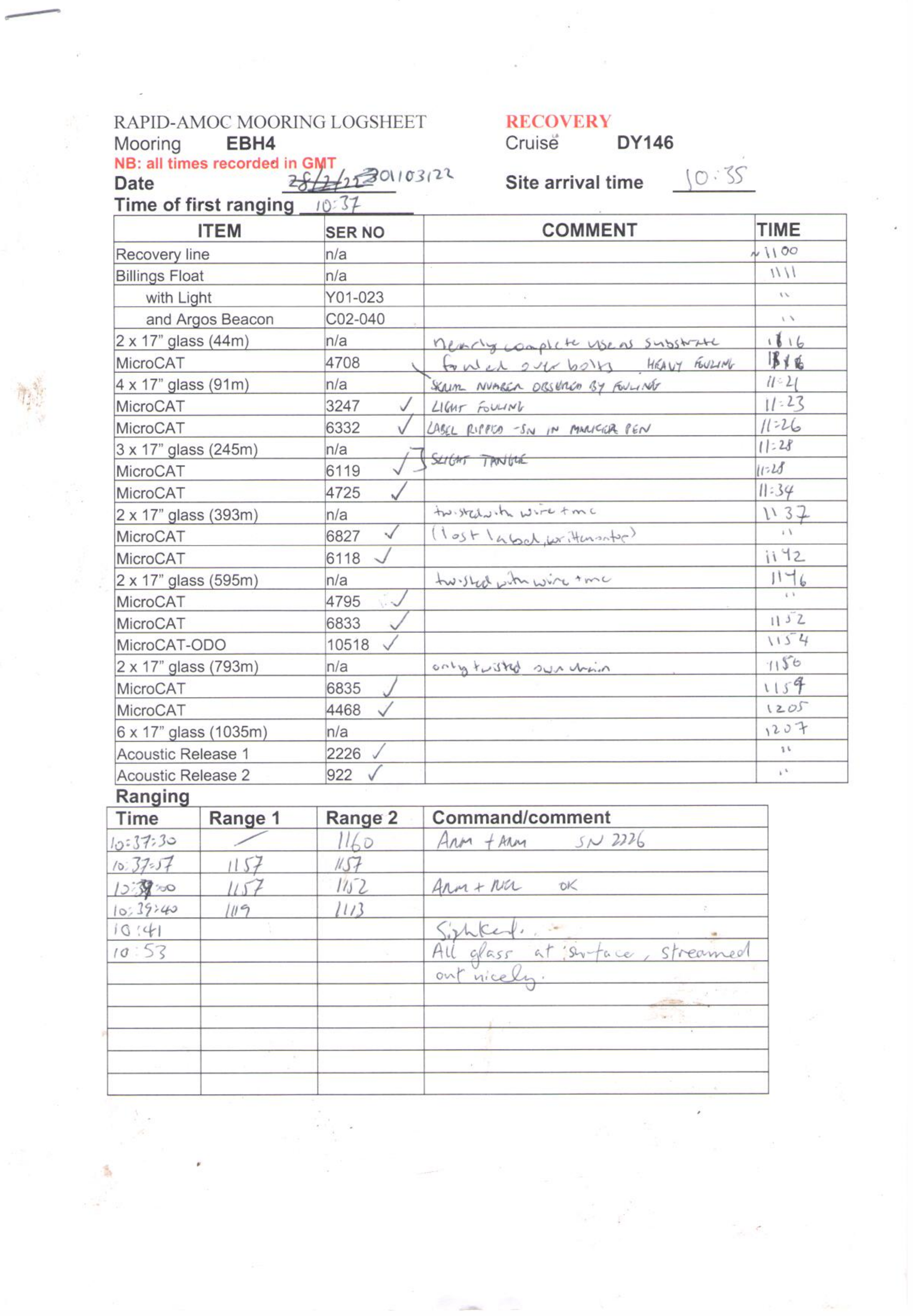
LOTS OF HYDROIDS ON WIRE BETWEEN 3232 + NORTEK

LAST OF WIRE IN AT 11:12



Ranging

Time	Range 1	Range 2	Command/comment
08:55:46	1680	1413	SN : 918 (Echo sounder on still)
08:56:29	1493	1494	
08:57:40	1493	1493	ARM REL OK
08:58:09	1472	1465	
08:59:09	1398	1390	
09·01			Sighted at surface



RAPID-AMOC MOORING LOGSHEET

RECOVERY

Mooring **EBH4**

Cruise **DY146**

NB: all times recorded in GMT

Date ~~28/2/22~~ 30/03/22

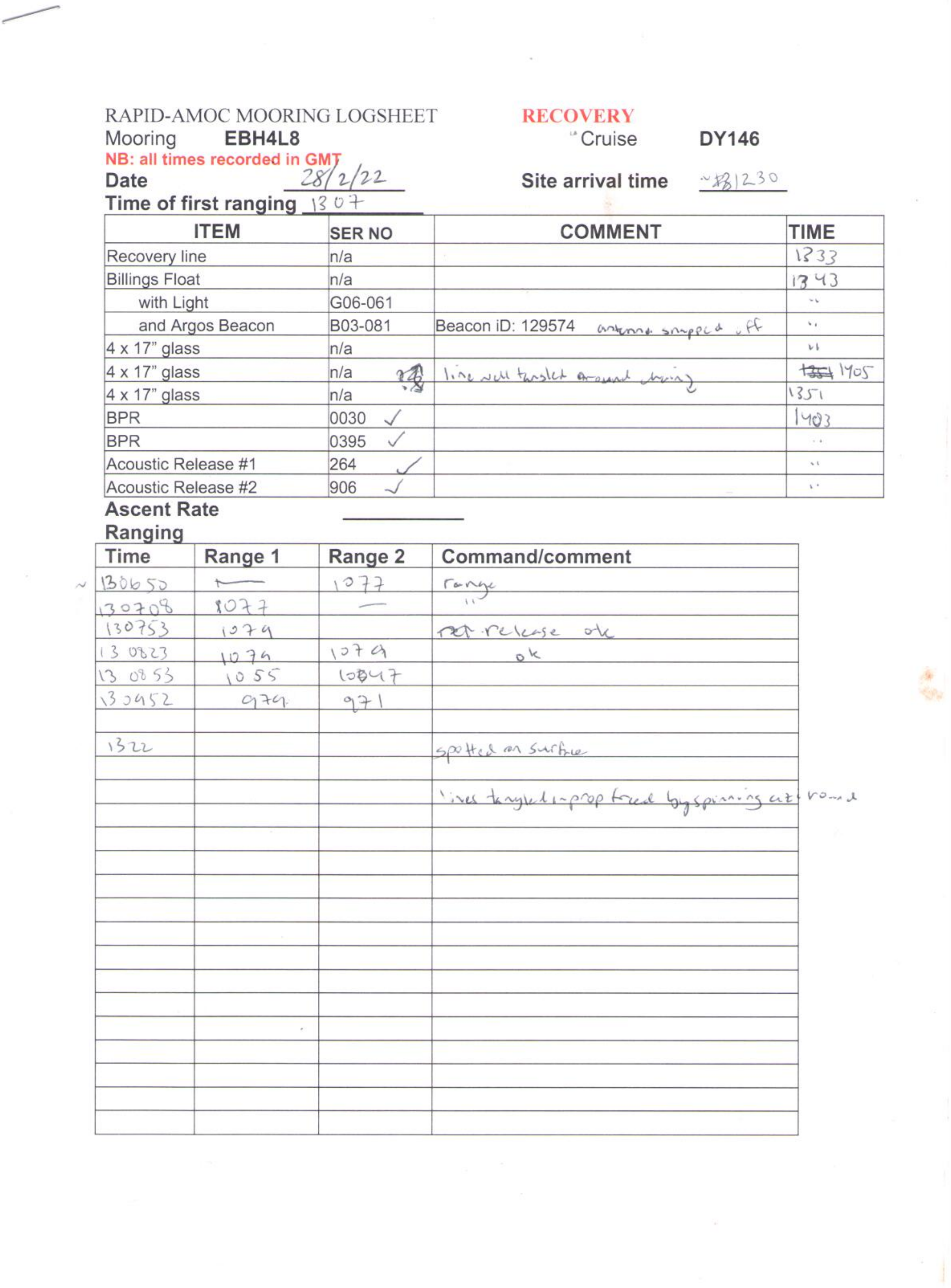
Site arrival time 10:35

Time of first ranging 10:37

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		~1100
Billings Float	n/a		1111
with Light	Y01-023		''
and Argos Beacon	C02-040		''
2 x 17" glass (44m)	n/a	nearly complete use as substrate	1116
MicroCAT	4708	fouled over bolts. HEAVY FOULING	1118
4 x 17" glass (91m)	n/a	SERIAL NUMBER OBSCURED BY FOULING	11:21
MicroCAT	3247 ✓	LIGHT FOULING	11:23
MicroCAT	6332 ✓	LABEL RIPPED - SN IN MARKER PEN	11:26
3 x 17" glass (245m)	n/a	~~SLIGHT TANGLE~~	11:28
MicroCAT	6119 ✓		11:28
MicroCAT	4725 ✓		11:34
2 x 17" glass (393m)	n/a	twisted with wire + mc	1137
MicroCAT	6827 ✓	(lost label, written on tag)	''
MicroCAT	6118 ✓		1142
2 x 17" glass (595m)	n/a	twisted with wire + mc	1146
MicroCAT	4795 ✓		''
MicroCAT	6833 ✓		1152
MicroCAT-ODO	10518 ✓		1154
2 x 17" glass (793m)	n/a	only twisted over chain	1156
MicroCAT	6835 ✓		1159
MicroCAT	4468 ✓		1205
6 x 17" glass (1035m)	n/a		1207
Acoustic Release 1	2226 ✓		''
Acoustic Release 2	922 ✓		''

Ranging

Time	Range 1	Range 2	Command/comment
10:37:30	/	1160	Arm + Arm SN 2226
10:37:57	1157	1157	
10:39:00	1157	1152	Arm + Rel OK
10:39:40	1119	1113	
10:41			Sighted.
10:53			All glass at surface, streamed
			out nicely.



RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EBH4L8** Cruise **DY146**

NB: all times recorded in GMT

Date 28/2/22 **Site arrival time** ~~~13~~1230

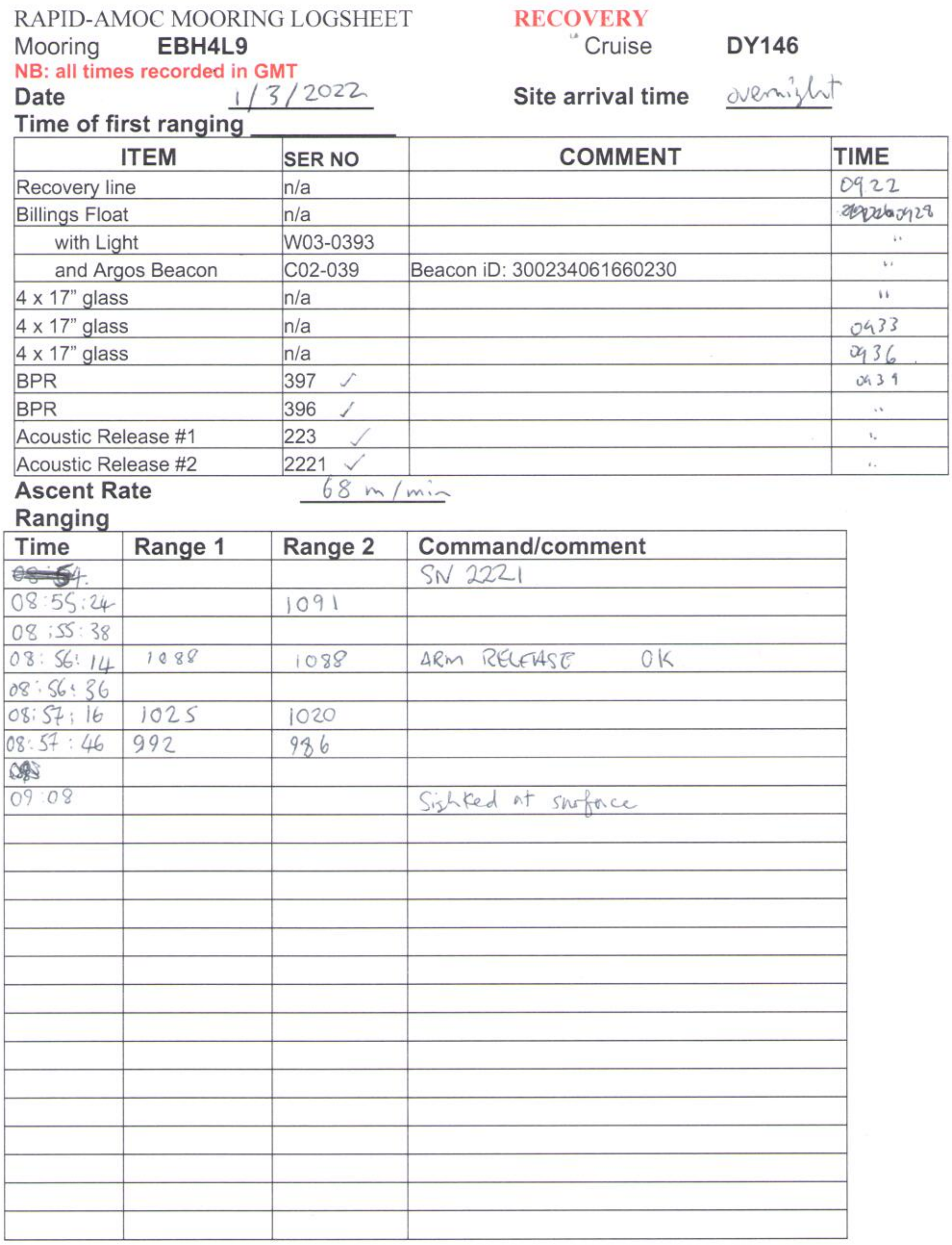
Time of first ranging 1307

ITEM	**SER NO**	**COMMENT**	**TIME**
Recovery line	n/a		1333
Billings Float	n/a		1343
with Light	G06-061		"
and Argos Beacon	B03-081	Beacon iD: 129574 antenna snapped off	"
4 x 17" glass	n/a		"
4 x 17" glass	n/a	line well tangled around chain	~~1351~~ 1405
4 x 17" glass	n/a		1351
BPR	0030 ✓		1403
BPR	0395 ✓		"
Acoustic Release #1	264 ✓		"
Acoustic Release #2	906 ✓		"

Ascent Rate __________

Ranging

Time	**Range 1**	**Range 2**	**Command/comment**
~130650	—	1077	range
130708	1077	—	"
130753	1079		~~rel~~ release ok
130823	1079	1079	ok
130853	1055	1047	
130952	979	971	
1322			spotted on surface
			lines tangled in prop freed by spinning azi round



RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EBH4L9** Cruise **DY146**

NB: all times recorded in GMT

Date 1/3/2022 **Site arrival time** overnight

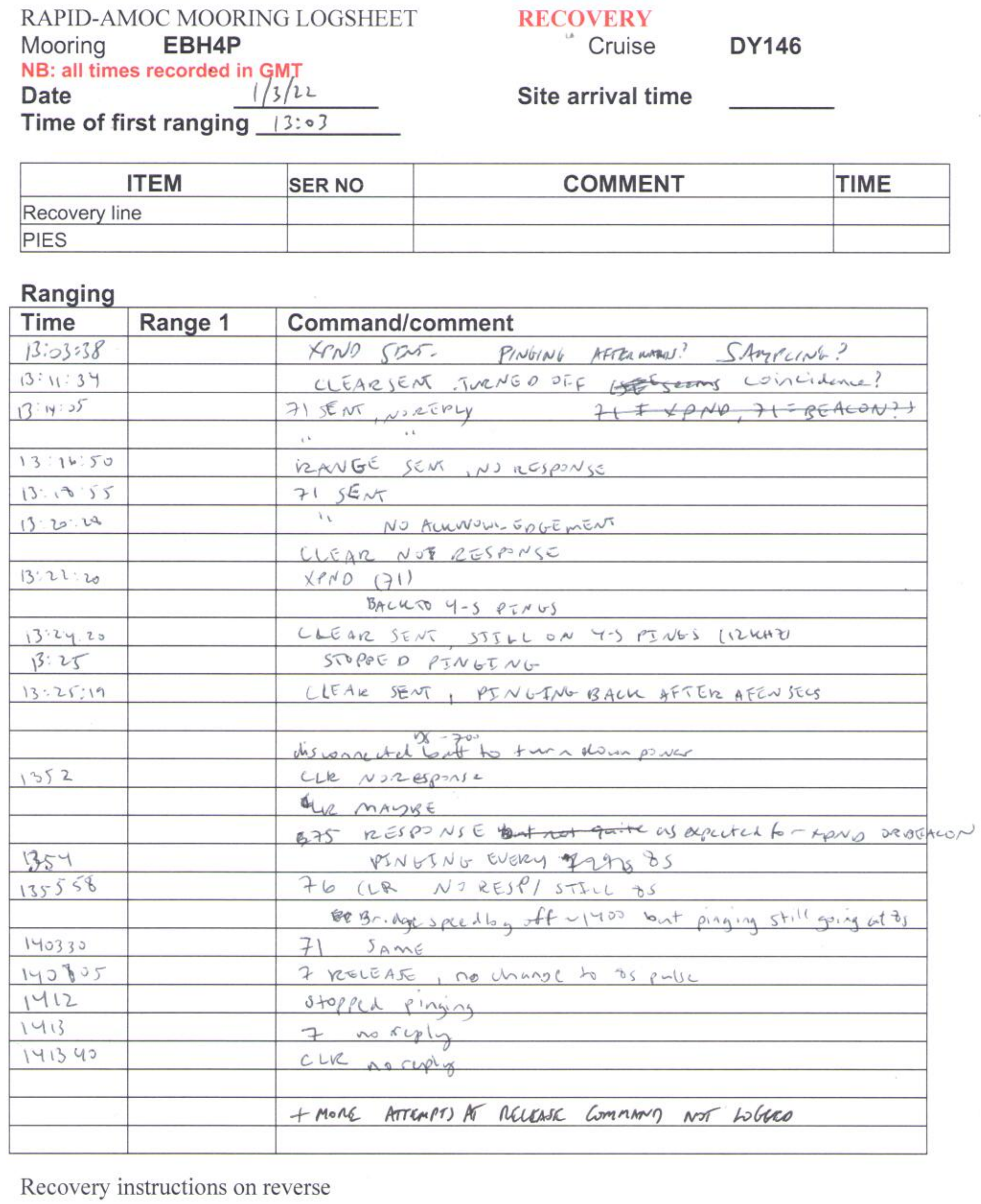
Time of first ranging ____________

ITEM	**SER NO**	**COMMENT**	**TIME**
Recovery line	n/a		0922
Billings Float	n/a		0928
with Light	W03-0393		"
and Argos Beacon	C02-039	Beacon iD: 300234061660230	"
4 x 17" glass	n/a		"
4 x 17" glass	n/a		0933
4 x 17" glass	n/a		0936
BPR	397 ✓		0939
BPR	396 ✓		"
Acoustic Release #1	223 ✓		"
Acoustic Release #2	2221 ✓		"

Ascent Rate 68 m/min

Ranging

Time	**Range 1**	**Range 2**	**Command/comment**
~~08:54~~			SN 2221
08:55:24		1091	
08:55:38			
08:56:14	1088	1088	ARM RELEASE OK
08:56:36			
08:57:16	1025	1020	
08:57:46	992	986	
09:08			Sighted at surface



RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EBH4P** Cruise **DY146**

NB: all times recorded in GMT

Date 1/3/22 **Site arrival time** ________

Time of first ranging 13:03

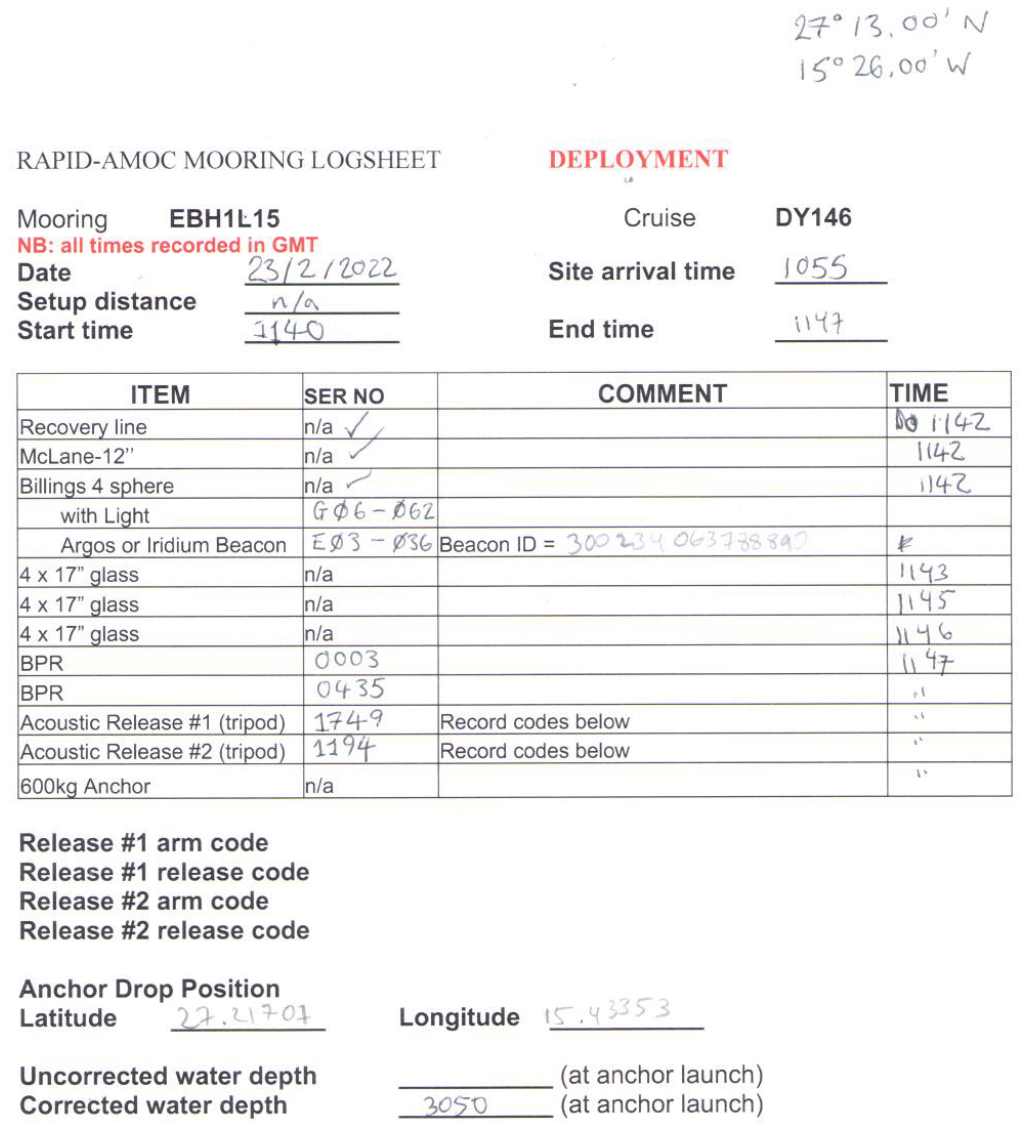
ITEM	SER NO	COMMENT	TIME
Recovery line			
PIES			

Ranging

Time	Range 1	Command/comment
13:03:38		XPND SENT. PINGING AFTERWARDS? SAMPLING?
13:11:34		CLEAR SENT. TURNED OFF ~~[illegible]~~ seems coincidence?
13:14:05		71 SENT, NO REPLY ~~71 = XPND, 71 = BEACON??~~
		" "
13:16:50		RANGE SENT, NO RESPONSE
13:19:55		71 SENT
13:20:24		" NO ACKNOWLEDGEMENT
		CLEAR NOT RESPONSE
13:22:20		XPND (71)
		BACK TO 4-S PINGS
13:24.20		CLEAR SENT, STILL ON 4-S PINGS (12KHZ)
13:25		STOPPED PINGING
13:25:19		CLEAR SENT, PINGING BACK AFTER A FEW SECS
		disconnected 8X-700 batt to turn down power
1352		CLR NO RESPONSE
		CLR MAYBE
		875 RESPONSE ~~but not quite~~ as expected for ~ XPND OR BEACON
1354		PINGING EVERY ~~[illegible]~~ 8S
135558		76 CLR NO RESP / STILL 8S
		Bridge speedboat off ~1400 but pinging still going at 8s
140330		71 SAME
140805		7 RELEASE, no change to 8s pulse
1412		stopped pinging
1413		7 no reply
141340		CLR no reply
		+ MORE ATTEMPTS AT RELEASE COMMAND NOT LOGGED

Recovery instructions on reverse

C Logsheets - Deployment



27° 13.00' N
15° 26.00' W

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

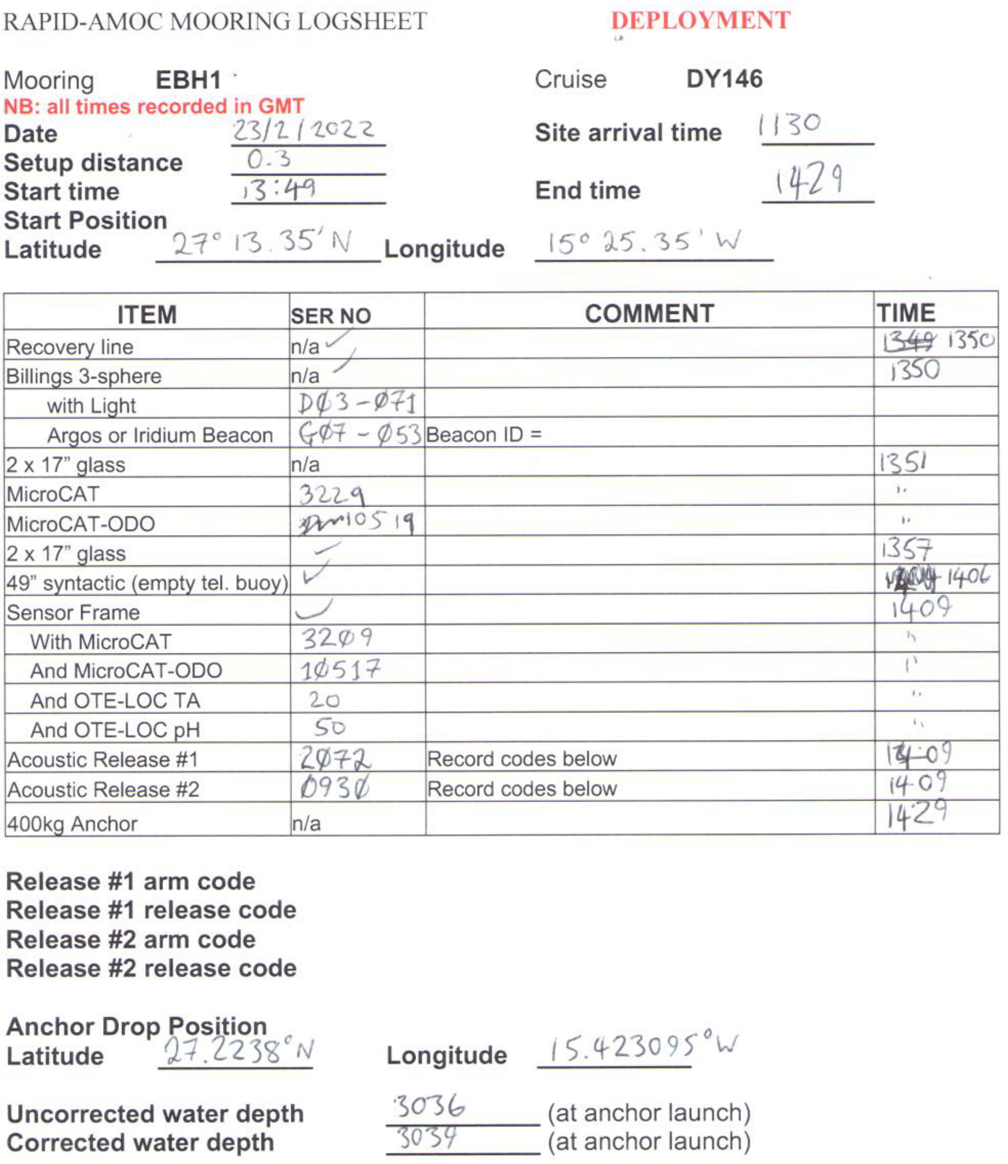
Mooring	**EBH1L15**	Cruise	**DY146**
NB: all times recorded in GMT			
Date	23/2/2022	**Site arrival time**	1055
Setup distance	n/a		
Start time	1140	**End time**	1147

ITEM	**SER NO**	**COMMENT**	**TIME**
Recovery line	n/a ✓		1142
McLane-12"	n/a ✓		1142
Billings 4 sphere	n/a ✓		1142
with Light	G06-062		
Argos or Iridium Beacon	E03-036	Beacon ID = 300234063788890	"
4 x 17" glass	n/a		1143
4 x 17" glass	n/a		1145
4 x 17" glass	n/a		1146
BPR	0003		1147
BPR	0435		"
Acoustic Release #1 (tripod)	1749	Record codes below	"
Acoustic Release #2 (tripod)	1194	Record codes below	"
600kg Anchor	n/a		"

Release #1 arm code
Release #1 release code
Release #2 arm code
Release #2 release code

Anchor Drop Position
Latitude 27.21707 **Longitude** 15.43353

Uncorrected water depth ____________ (at anchor launch)
Corrected water depth 3050 (at anchor launch)



RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **EBH1** Cruise **DY146**

NB: all times recorded in GMT

Date 23/2/2022 **Site arrival time** 1130

Setup distance 0.3

Start time 13:49 **End time** 1429

Start Position

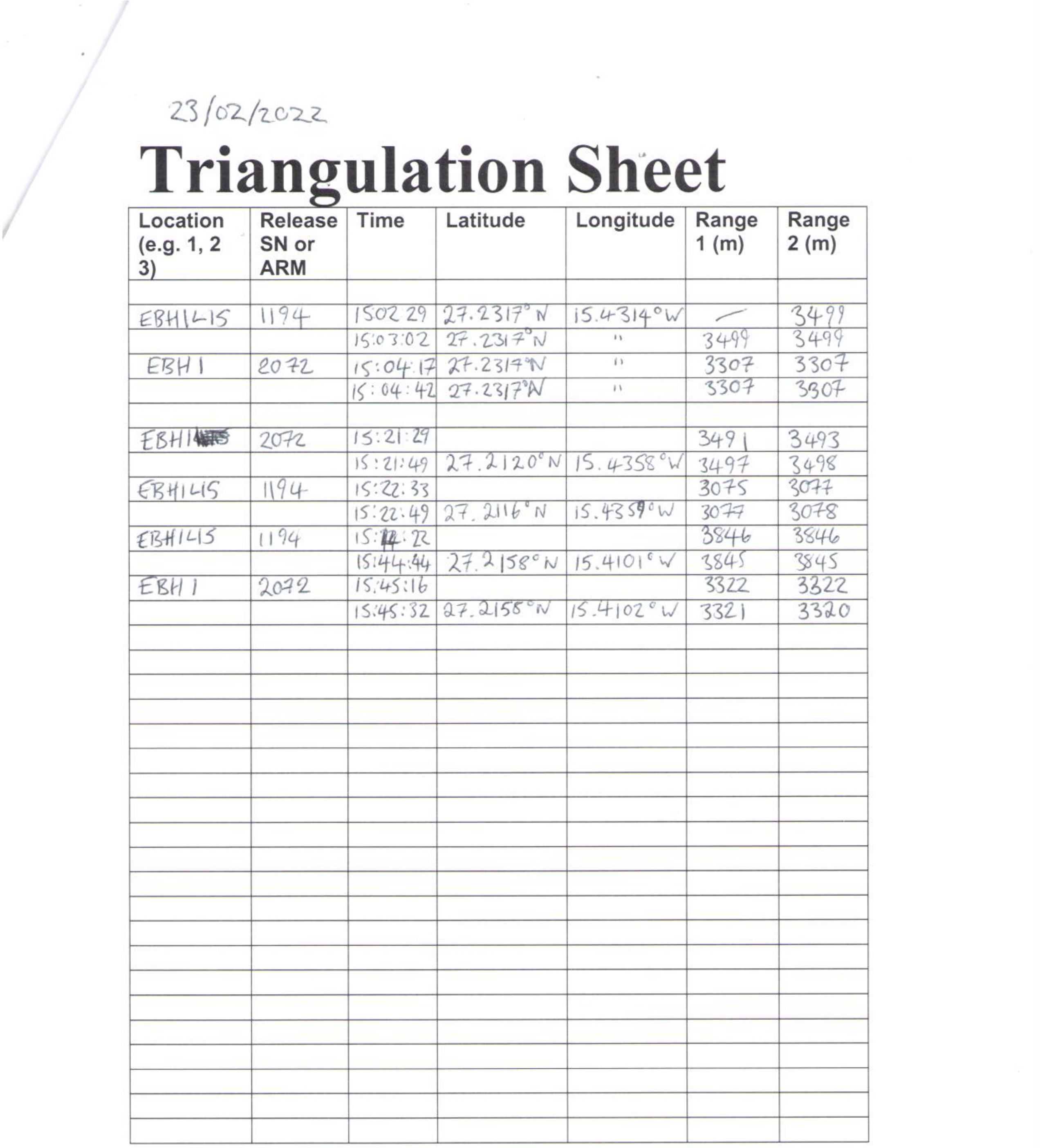
Latitude 27° 13.35' N **Longitude** 15° 25.35' W

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a ✓		~~1349~~ 1350
Billings 3-sphere	n/a ✓		1350
with Light	D03-071		
Argos or Iridium Beacon	G07-053	Beacon ID =	
2 x 17" glass	n/a		1351
MicroCAT	3229		"
MicroCAT-ODO	10519		"
2 x 17" glass	✓		1357
49" syntactic (empty tel. buoy)	✓		1406
Sensor Frame	✓		1409
With MicroCAT	3209		"
And MicroCAT-ODO	10517		"
And OTE-LOC TA	20		"
And OTE-LOC pH	50		"
Acoustic Release #1	2072	Record codes below	1409
Acoustic Release #2	0930	Record codes below	1409
400kg Anchor	n/a		1429

Release #1 arm code
Release #1 release code
Release #2 arm code
Release #2 release code

Anchor Drop Position
Latitude 27.2238°N **Longitude** 15.423095°W

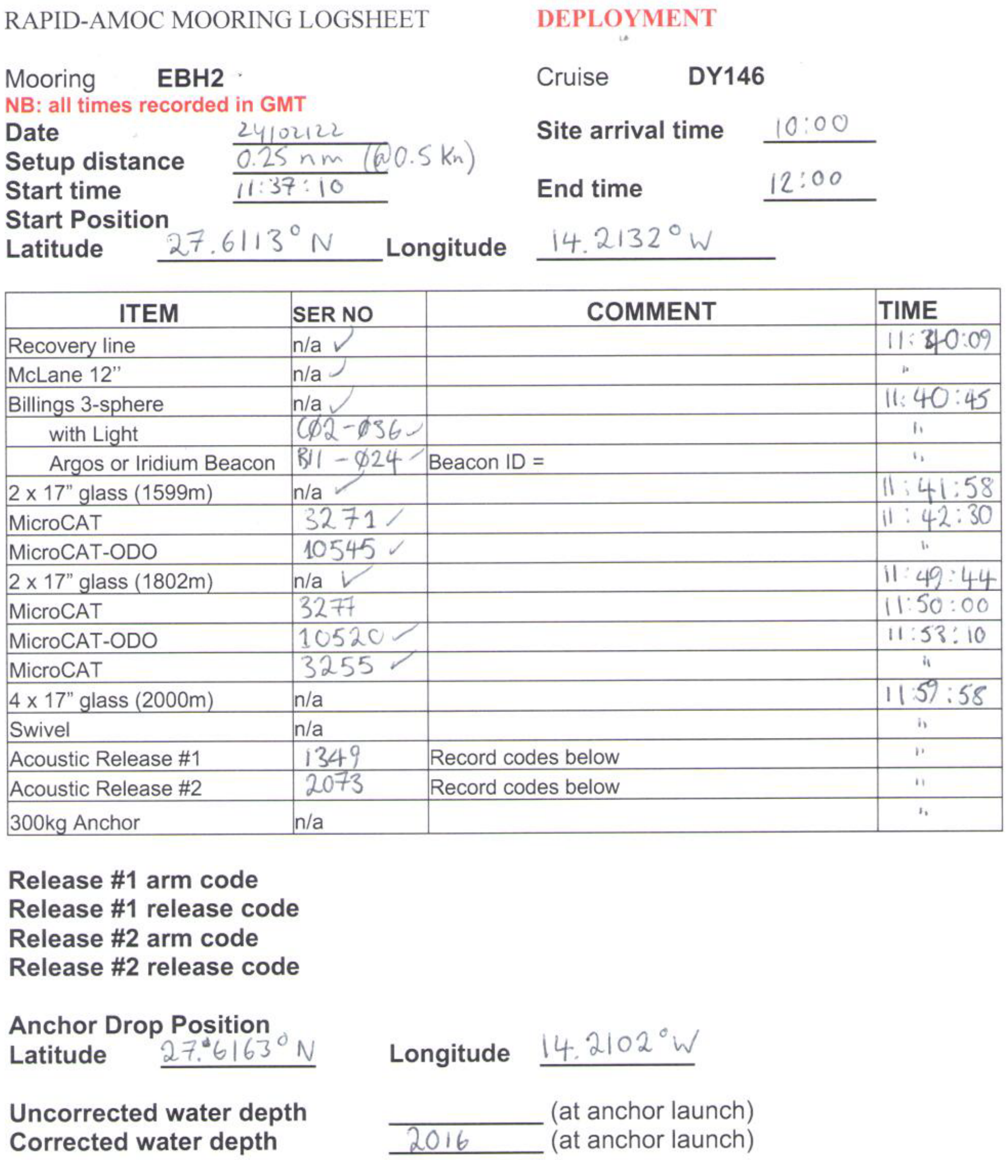
Uncorrected water depth 3036 (at anchor launch)
Corrected water depth 3039 (at anchor launch)



23/02/2022

Triangulation Sheet

Location (e.g. 1, 2 3)	Release SN or ARM	Time	Latitude	Longitude	Range 1 (m)	Range 2 (m)
EBHILIS	1194	1502 29	27.2317° N	15.4314°W	—	3499
		15:03:02	27.2317°N	"	3499	3499
EBH1	2072	15:04:17	27.2317°N	"	3307	3307
		15:04:42	27.2317°N	"	3307	3307
EBH1	2072	15:21:29			3491	3493
		15:21:49	27.2120°N	15.4358°W	3497	3498
EBHILIS	1194	15:22:33			3075	3077
		15:22:49	27.2116°N	15.4359°W	3077	3078
EBHILIS	1194	15:44:22			3846	3846
		15:44:44	27.2158°N	15.4101°W	3845	3845
EBH1	2072	15:45:16			3322	3322
		15:45:32	27.2158°N	15.4102°W	3321	3320



RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **EBH2**

NB: all times recorded in GMT

Date 24/02/22

Setup distance 0.25 nm (@0.5 Kn)

Start time 11:37:10

Start Position

Latitude 27.6113° N **Longitude** 14.2132° W

Cruise **DY146**

Site arrival time 10:00

End time 12:00

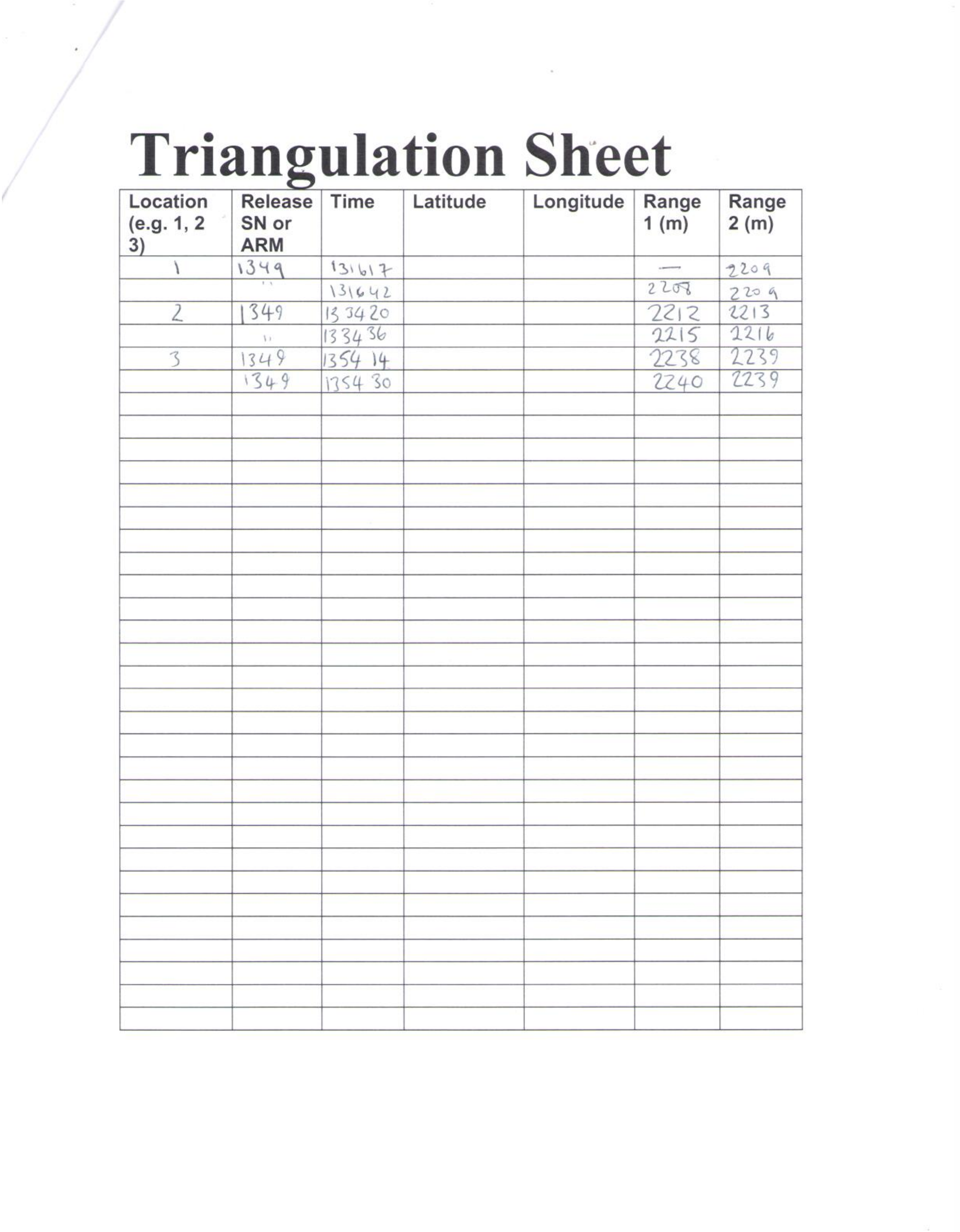
ITEM	SER NO	COMMENT	TIME
Recovery line	n/a ✓		11:~~3~~40:09
McLane 12”	n/a ✓		"
Billings 3-sphere	n/a ✓		11:40:45
with Light	C02-036 ✓		"
Argos or Iridium Beacon	B11-024 ✓	Beacon ID =	"
2 x 17” glass (1599m)	n/a ✓		11:41:58
MicroCAT	3271 ✓		11:42:30
MicroCAT-ODO	10545 ✓		"
2 x 17” glass (1802m)	n/a ✓		11:49:44
MicroCAT	3277		11:50:00
MicroCAT-ODO	10520 ✓		11:53:10
MicroCAT	3255 ✓		"
4 x 17” glass (2000m)	n/a		11:57:58
Swivel	n/a		"
Acoustic Release #1	1349	Record codes below	"
Acoustic Release #2	2073	Record codes below	"
300kg Anchor	n/a		"

Release #1 arm code
Release #1 release code
Release #2 arm code
Release #2 release code

Anchor Drop Position

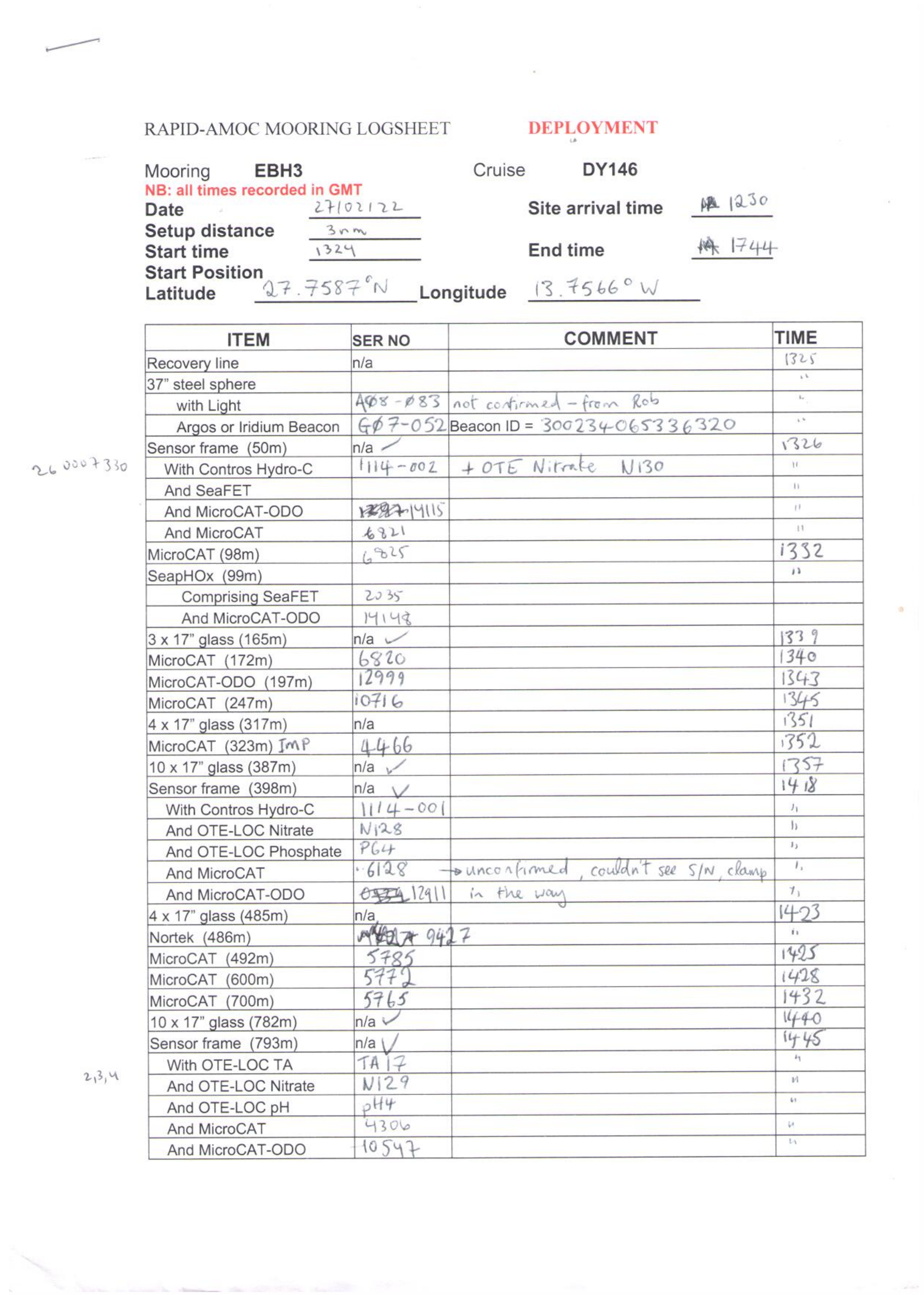
Latitude 27.6163° N **Longitude** 14.2102° W

Uncorrected water depth ________ (at anchor launch)
Corrected water depth 2016 (at anchor launch)



Triangulation Sheet

Location (e.g. 1, 2 3)	Release SN or ARM	Time	Latitude	Longitude	Range 1 (m)	Range 2 (m)
1	1349	131617			—	2209
	"	131642			2208	2209
2	1349	133420			2212	2213
	"	133436			2215	2216
3	1349	135414			2238	2239
	1349	135430			2240	2239



RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **EBH3** Cruise **DY146**

NB: all times recorded in GMT

Date 27/02/22

Setup distance 3nm

Start time 1324

Site arrival time ~~[illegible]~~ 1230

End time ~~[illegible]~~ 1744

Start Position

Latitude 27.7587°N **Longitude** 13.7566° W

26 0007330

2,3,4

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		1325
37" steel sphere			"
with Light	A08-083	not confirmed - from Rob	"
Argos or Iridium Beacon	G07-052	Beacon ID = 300234065336320	"
Sensor frame (50m)	n/a ✓		1326
With Contros Hydro-C	1114-002	+ OTE Nitrate N130	"
And SeaFET			"
And MicroCAT-ODO	~~[illegible]~~ 14115		"
And MicroCAT	6821		"
MicroCAT (98m)	6825		1332
SeapHOx (99m)			"
Comprising SeaFET	2035		
And MicroCAT-ODO	14148		
3 x 17" glass (165m)	n/a ✓		1339
MicroCAT (172m)	6820		1340
MicroCAT-ODO (197m)	12999		1343
MicroCAT (247m)	10716		1345
4 x 17" glass (317m)	n/a		1351
MicroCAT (323m) IMP	4466		1352
10 x 17" glass (387m)	n/a ✓		1357
Sensor frame (398m)	n/a ✓		1418
With Contros Hydro-C	1114-001		"
And OTE-LOC Nitrate	N128		"
And OTE-LOC Phosphate	P64		"
And MicroCAT	6128	→ unconfirmed, couldn't see S/N, clamp	"
And MicroCAT-ODO	~~[illegible]~~ 12911	in the way	"
4 x 17" glass (485m)	n/a		1423
Nortek (486m)	~~[illegible]~~ 9427		"
MicroCAT (492m)	5785		1425
MicroCAT (600m)	5772		1428
MicroCAT (700m)	5765		1432
10 x 17" glass (782m)	n/a ✓		1440
Sensor frame (793m)	n/a ✓		1445
With OTE-LOC TA	TA17		"
And OTE-LOC Nitrate	N129		"
And OTE-LOC pH	pH4		"
And MicroCAT	4306		"
And MicroCAT-ODO	10547		"

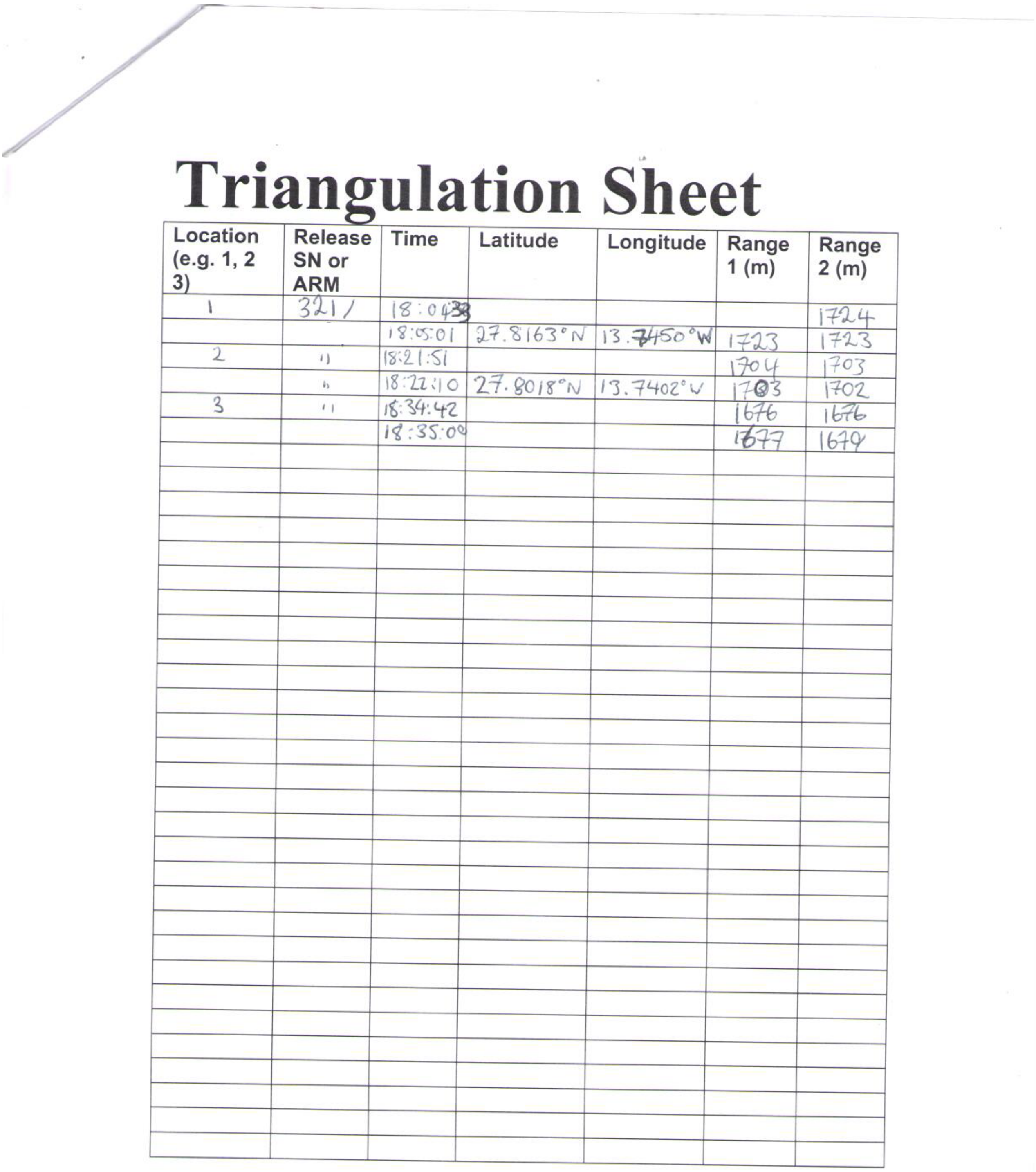
7,11

Nortek (795m)	9435	1 m of chain added between	1449
10 x 17" glass (980m)	n/a ✓	frame and Nortek	1458
Sensor frame (990m)	n/a		1502
With OTE-LOC TA	TA18		"
And OTE-LOC pH	PH48		"
And MicroCAT	3933		"
And MicroCAT-ODO	12907		"
Nortek (993m)	11024	1.5m of chain added between	1505
MicroCAT (1196m)	3900	frame and Nortek.	1513
5 x 17" glass (1293m)	n/a ✓		1518
Nortek (1296m)	13482		~~[illegible]~~ "
MicroCAT (1392m)	~~8~~3252		1525
MicroCAT-ODO (1393m)	10546		"
6 x 17" glass (1395m)	n/a ✓		1527
Acoustic Release #1	321	Record codes below	"
Acoustic Release #2	2076	Record codes below	"
1700kg Anchor	n/a		1744:11

Release #1 arm code
Release #1 release code
Release #2 arm code
Release #2 release code

Anchor Drop Position
Latitude 27.8106°N **Longitude** 13.7463°W

Uncorrected water depth ________ (at anchor launch)
Corrected water depth 1421 (at anchor launch)



Triangulation Sheet

Location (e.g. 1, 2 3)	Release SN or ARM	Time	Latitude	Longitude	Range 1 (m)	Range 2 (m)
1	321/	18:0433				1724
		18:05:01	27.8163°N	13.7450°W	1723	1723
2	"	18:21:51			1704	1703
	"	18:22:10	27.8018°N	13.7402°W	1703	1702
3	"	18:34:42			1676	1676
		18:35:09			1677	1679