JC180 Cruise report- Strategies for the Environmental Monitoring of Marine Carbon Capture and Storage, STEMM-CCS

Lead: Doug Connelly

National Oceanography Centre

April 25th 2019 – May 30th 2019
Southampton - Aberdeen - Southampton

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1 Crew list

1.1 Leg one Southampton to Aberdeen

Name	Institute	Role/Team
Doug Connelly	NOC	PSO
Chris Pearce	NOC	Geochem (Co-Chief)
Kevin Saw	NOC	Drill
Rob Brown	NOC	Drill
Veerle Huvenne	NOC	Mapping
Estelle Dumont	SAMS	Gavia
Rudolph Hanz	NOC	Sensors
Brett Hosking	NOC	Mapping
James Strong	NOC	Mapping
Mark Wells	Cellular Robotics	Drill
Dirk Koopmans	MPI	BBL
Michael Faggetter	Southampton	Acoustics
Jianghui Li	Southampton	Acoustics
Jon Bull	Southampton	Acoustics
Ben Roche	Southampton	Acoustics
Sam Monk	NOC	Sensors
Nicholas Harker	NMF	Scientific Ships Systems
Emre Mutlu	NMF	ROV
Mike Smart	NMF	Gavia
Jared Mazlan	NMF	Gavia
Kate Peel	NOC	Geochem
Anita Flohr	Southampton	Geochem
Allison Schaap	NOC	Sensors
Hannah Wright	NOC	Drill
Russell Locke	NMF	ROV
David Turner	NMF	ROV (Senior Tech)
Andy Webb	NMF	ROV
Josue Viera Rivero	NMF	ROV
Juan Ward	NMF	Scientific Ships Systems
Richard Austin-Berry	NMF	ROV
Will Handley	Contractor	ROV

1.2 Leg two Aberdeen to Southampton

Name	Institute	Role/Team
Doug Connelly	NOC	PSO
Chris Pearce	NOC	Geochem (Co-Chief)
Kevin Saw	NOC	Drill
Rob Brown	NOC	Drill
Veerle Huvenne	NOC	Mapping
Isabelle Mekelnburg	GEOMAR	Benthic Chamber
Rudolph Hanz	NOC	Sensors
Brett Hosking	NOC	Mapping
James Strong	NOC	Mapping
Jonas Gros	GEOMAR	Benthic Chamber
Dirk Koopmans	MPI	BBL
Moritz Holtappels	AWI	BBL
Dirk de Beer	MPI	BBL
Paul White	Southampton	Acoustics
Ben Roche	Southampton	Acoustics
Sam Monk	NOC	Sensors
Nicholas Harker	NMF	Scientific Ships Systems
Emre Mutlu	NMF	ROV
Mike Smart	NMF	Gavia
Jared Mazlan	NMF	Gavia
Kate Peel	NOC	Geochem
Anita Flohr	Southampton	Geochem
Allison Schaap	NOC	Sensors
Hannah Wright	NOC	Drill
Russell Locke	NMF	ROV
David Turner	NMF	ROV (Senior Tech)
Andy Webb	NMF	ROV
Josue Viera Rivero	NMF	ROV
Juan Ward	NMF	Scientific Ships Systems
Richard Austin-Berry	NMF	ROV
Will Handley	Contractor	ROV

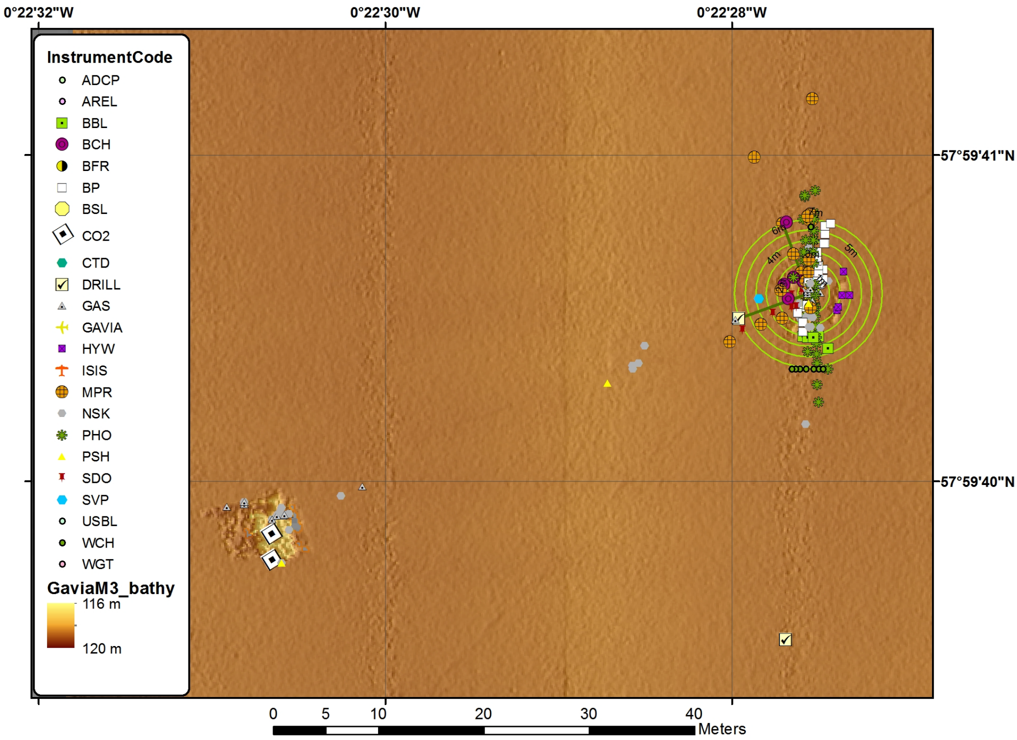
2 Aims and abstract

JC180 is the main experimental cruise component of the EC funded €16m project Strategies for the environmental monitoring of marine carbon capture and storage STEMM-CCS. The overall goals of the STEMM-CCS project are to develop techniques and methods to constrain potential leakage pathways for CO_2 should it be stored in reservoirs and to develop techniques to detect and quantify CO_2 release from the seabed should it leak from storage reservoirs in the future if they are developed on a commercial scale in the North Sea. This cruise, and the whole project aims to increase the confidence the science community and the public have as we move towards using old hydrocarbon reservoirs for CO_2 storage to mitigate climate change. If we use these storage sites we need to ensure that should they leak we will be able to detect any leakage and quantify it.

This cruise is technologically ambitious and will place a CO_2 tank on the seabed in the North Sea and use a pipe to release the CO_2 under the surface sediments. The pipe drill rig and the CO_2 storage tanks for deployment are bespoke and the drill rig is the first of a kind, designed for the experiment by Cellula Robotics of Canada. The aim is to release CO_2 below the seabed to create a rising plume of dissolved CO_2 and then emit a stream of CO_2 bubbles into the seawater. This release will be monitored using AUV, ROV, landers and moorings with an aim to test all of the currently available, and developing technologies, to detect leakage from the seabed of the placed CO_2.

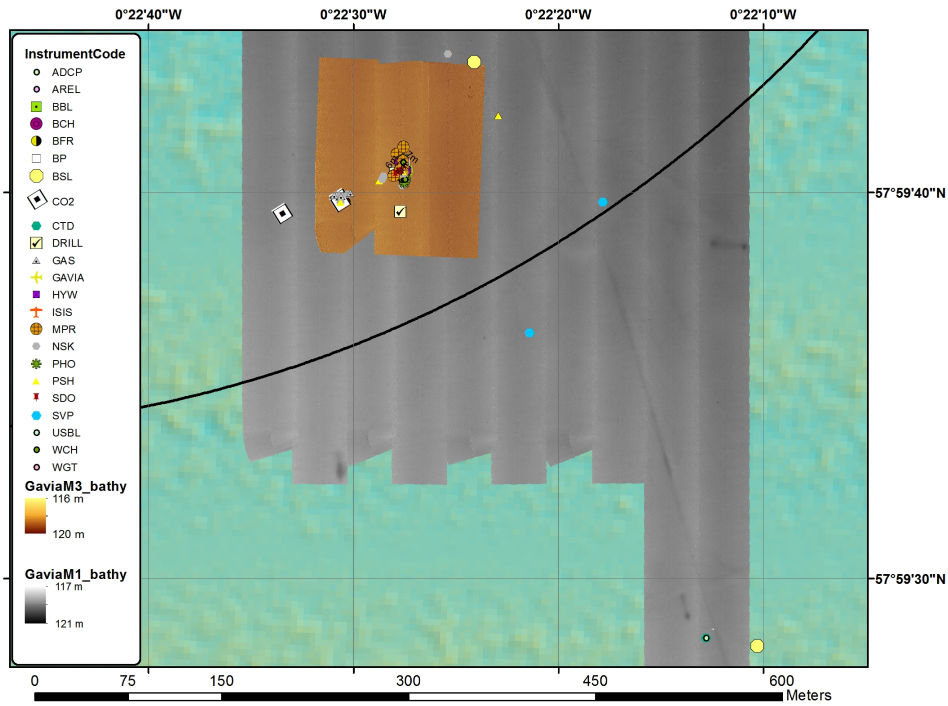
The project has had a number of associated cruises and has a linked UK funded project called Chimney, with its own dedicated cruise. The CHIMNEY project and a component of the STEMM-CCS project is directed towards the study of seismic chimneys in the seabed, these features, common in basin areas are thought to be release paths of methane that occurred in the past and may be active now. They are of interest because of their occurrence in areas that may in the future be used for storage reservoirs, and questions remain how they are formed, what they are composed of an will they act as a conduit in the future if CO_2 is stored below them. There have been two cruises to study these features and we have drilled on of these pipes using the BGS rock drill. In addition to these geophysical cruises we have performed two background cruises aboard German research vessels to gather background data and baseline data for the cruise. We have also placed a baseline lander on the seabed above the Goldeneye reservoir, equipped with geophysical, hydrographical and chemical sensors. This lander was put in place in October 2017, unfortunately we have had no contact with it since and a scheduled service cruise in early 2018 was unable to contact the lander and release it to the surface. On JC180 we will find the lander and recover it to collect the vital baseline data it has.

The plan was to deploy the gas supply to the seabed and then link the supply to pre-laced pipes under the seabed using the Cellula Robotics drill system, this all went according to plan. The gas flow was started and very quickly we had gas flowing through the pipes and then being released as a steady stream of bubbles into the seabed. We designated this as the centre of our study area and the relationship of this to the location of the gas supply can be seen in Map A. The study area was a 7m diameter circle centred on the release point.



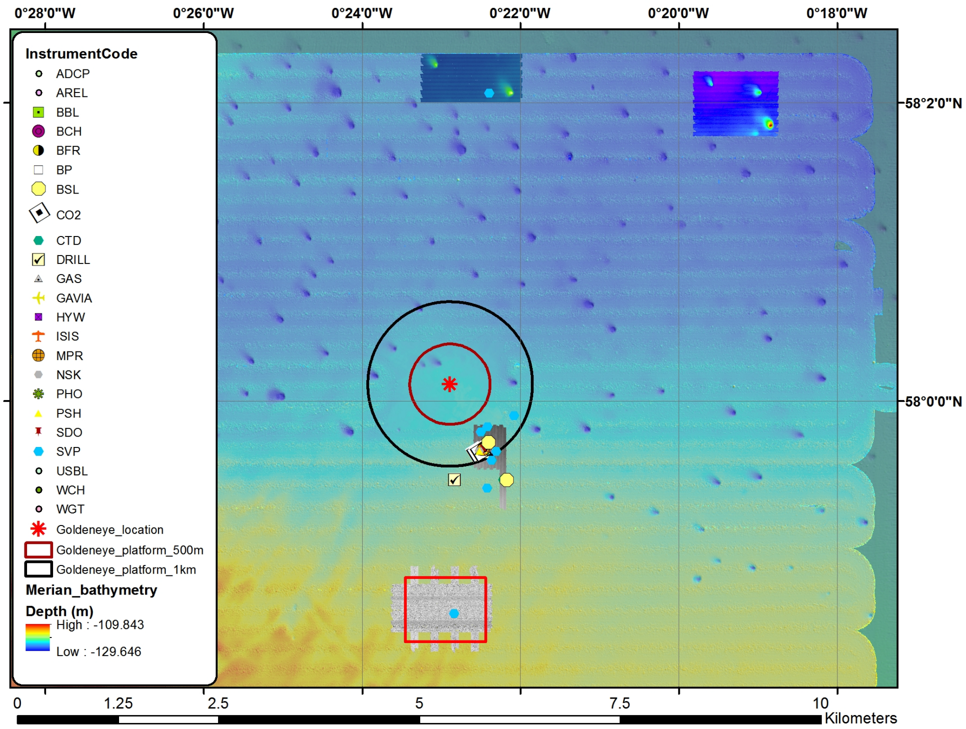
Map A. Location of the gas supply in relation to our 7 m test area

Map B shows the locations of the wider area, with the 1000m exclusion zone from the rig marked, along with the baseline lander (BSL)



Map B. wider area view of the test release site.

To complete the work proposed in the original project proposal we had a series of offsite surveys, looking at scour marks, background environmental status and surveys for trawl marks. These additional surveys can be seen in Map C, in relation to the test area and the location of the Goldeneye platform.

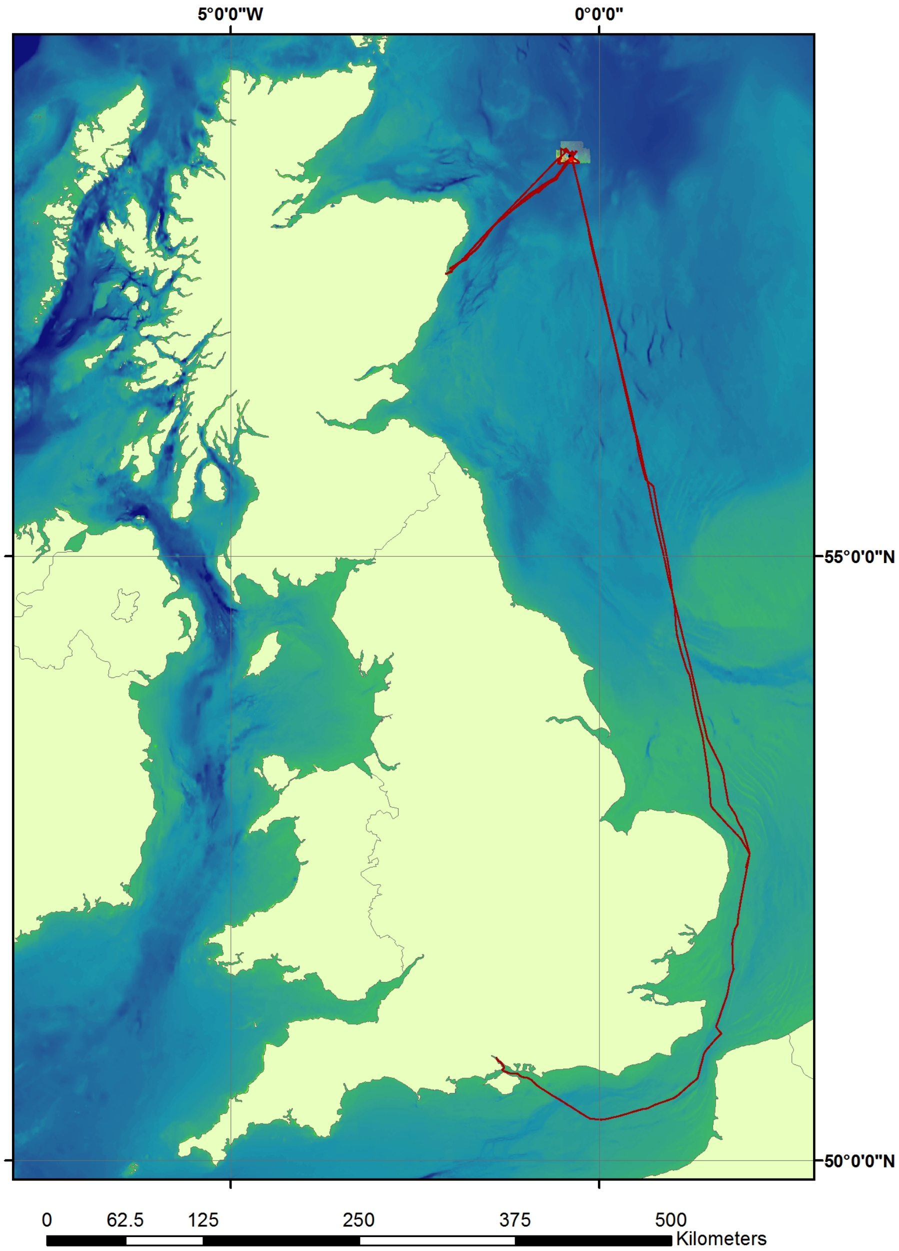


Map C. Location of the offsite survey areas in relation to the Goldeneye platform and our study area.

The cruise was incredibly successful with all expectations being met. We increased the flow of the gas at a number of points during the experiment

2l per minute	11/5/19 15:19
5 l per minute	14/5/19 15:27
10 l per minute	15/5/19 06:48
30 l per minute	17/5/19 16:54
50 l per minute	19/5/19 15:50
Stopped gas	22/5/19

We managed three full deployments of all equipment on the seabed, we recovered the lost lander and did all of the AUV missions planned plus an extra offsite survey. The final cruise track for JC180 can be seen in Map D.



Map D. Cruise Track for JC180

3 Daily Operations

Thursday 25th April 2019
We left our home port of Southampton to head to the Goldeneye platform in the Central North Sea

Friday 26th April 2019
In transit

Saturday 27th April 2019
Arrived at the Goldeneye site and started work with a test of the USBL beacon, a mini CTD system and an acoustic release. We then deployed the ROV as a shake down dip and to hunt for the baseline lander that was deployed in October 2017. This was successful, the lander was found in perfect condition, no sign of trawling damage and 4 of the original 6 data pods still in place. The ROV did a series of practice sampling using the push cores, Niskin water samples and the gas samplers for Anita Flohr. All work went well and the ROV was safely recovered to the deck at 8pm GMT.

Sunday 28th April 2019
The seas were good so we started a deployment of the Gavia AUV to survey our study area which is outside of the 500m exclusion zone for the platform but within the 1km no fishing area. The Gavia was equipped with a Sea-pHox pH system, and ran camera surveys as well as a SBP. We did a Sound velocity profile for deploying the ROV, we then spent some time filling gaps in the multibeam data.

Monday 29th April 2019
We deployed the gas release rig off the rear A frame and settled it onto the seabed, followed by the float release system, all of this went very well and it represents one of the heaviest deployments off the JC. We deployed the ROV Isis to inspect the positioning of the gas rig and also to straighten out the deployment rope. The ROV then started the test program for the gas release system on the gas rig. Unfortunately, the system did not work sufficiently well and so the ROV was recovered and then we recovered the gas rig using the float recovery line.

Tuesday 30th April 2019
We did a test dip of the Cellula robotics drilling rig, all went well. We the proceeded immediately to drill the first of two pipes for our deployment of the CO_2 below the sediments. This operation went very well. We then deployed the ROV for Isis dive 349 with the sub bottom profiler on to determine where the pipes were on the seabed and to estimate where the end of the pipe was to determine the release point. This dive was successful.

Wednesday 1st May 2019
Since work was continuing on the gas rig we brought forward one of the Gavia off site surveys, looking at the impact of fishing activities on the seabed and going over a number of natural seabed features such as pockmarks. This dive was successful and we collected a large number of good quality seabed images. We then transited to the container deployment site. Unfortunately, on deployment of the rig the winch stripped the outer layer from our

deployment line. The rig was placed back on the deck as it would have been unsafe to continue, this ended the operations for the day.

Thursday 2nd May 2019
The day started with OK weather but the forecast was for strong winds and high seas later in the day. There were a number of options discussed to continue with the deployment of the rig, however all of the safe options involved work alongside in Aberdeen on the scheduled port stop for crew change on Saturday. There was the possibility of a RIV deployment but the weather worsened and we switched to an EK60 survey over the plugged and abandoned wells to the NW of the Goldeneye platform to see if any of them were leaking. There was no evidence found that there were any wells leaking and we finished the survey. We then proceeded to Aberdeen due to deteriorating conditions and to get the winch system modified to prevent any further damage to the deployment and recovery lines for the gas rig.

Friday 3rd May 2019
We arrived at anchorage off Aberdeen and waited for an available berth. There was no berth so we stayed at the anchorage all day.

Saturday 4th May 2019
Alongside waiting for parts and also doing a science crew changeover, see list above for leg 2.

Sunday 5th May 2019
In Aberdeen

Monday 6th May 2019
In Aberdeen.

Tuesday 7th May 2019
We arrived back at the Goldeneye site and deployed the SVP to collect the data for the subsequent ROV dives. At 0800 we deployed the ROV for dive 349, the start of he dive was over the end of pipe two to reset the doppler we then deployed the 4 sediment optodes, 1, 2, 4 and 7 m from the center of our 7m study area. The Niskin bottles on the ROV were then fired to collect water samples, followed by the collection of 6 push cores just outside of our designated study area. The ROV was recovered and turned around for dive 350, the ROV placed the hydrophone wall on the seabed to the NE of the study area at a distance of 4 m from the epicentre. The ROV was recovered and the ROV loaded with the Benthic boundary layer sampler from MPI. The lander was deployed 4 m from the centre of our study area to the SSW. The Niskin bottles were fired again to collect further water samples for the GEOMAR chamber group.

Wednesday 8th May 2019
Weather very good so started the day with an ROV dive (352) to deploy the microprofiler in a transect from the centre point of our survey area, we did a total of 5 deployments, each on means the profiler sits in place for 65 minutes. These all appeared to go well but on recovery it was found that the three pH sensors on the instrument were broken. After a successful recovery the ROV was turned around and redeployed (353) for the placement of the GEOMAR

benthic chamber. On recovery of the ROV we steamed to Aberdeen for the pick of the parts needed for the gas system.

Thursday 9th May 2019

Received parts needed for the gas rig repair at about 0700 GMT, left the anchorage to return to Goldeneye. Once back on site we did a ROV dive (ISIS 354) to replace the Benthic boundary layer lander with the second lander. A second dive (ISIS 355) was then done to place the second hydrophone wall into position. One of the walls will be there for the entire duration of the experiment the other will be recovered and redeployed at set periods of time. We continued to work on the repair of the gas tank and mixing system, his continued overnight. The Poseidon is in the area now.

Friday 10th/Saturday 11th May 2019

We moved the ship 500 m so that the Poseidon could deploy their lander. The gas system was tested overnight with somewhat mixed results. The tracer system seems to have an intermittent fault but the feeling is the CO_2 side is working well enough to deploy. An SVP was done first thing to gather data for the days CTD dives as the storm may have affected the depth of the thermocline. The gas tanks were then deployed off the aft of the ship. The CO_2 rig was then deployed without incident, it is expected to be 49m from the end of the pipes. The ROV (ISIS 356) was deployed to get the lay of the land, it went down over the recovery float for the gas tanks. Once located the ROV followed the recovery rope to the gas tanks to see how much needed to be straightened. This operation went without a hitch. Following the rope realignment the ROV recovered the benthic chamber and returned to the surface. The second deployment of the ROV (ISIS 357) was started at around 7pm and ran into Saturday until recovery on Saturday at 18:28. The main aim of the dive was to connect the hoses to the pipes in the seabed. Initially pipe one was connected then pipe two, pipe on is purely a back-up, we have all of the equipment for the science deployed around pipe 2. The gas delivery system was tested and worked well, gas flow was started to pipe 1. We could see intermittent flares on the EK60, indicating that we had gas flow, constant to and for inspection of the predicted release site showed no obvious gas release, this may be because we are creating micro-bubbles due to low flow. We switched the flow to pipe 2 and within 10-15 minutes it was clear we had flow, inspection of the predicted release area showed clear signs of bubble flow through the sediments. We collected water samples over the site and gas samples from the gas containers for checking the tracer levels.

Saturday 11th May 2019

After recovery and checking the ROV we deployed the ROV again (ISIS 358). This dive was to do a transect survey with the sediment microprofiler and to collect water, gas and core samples from around the gas release area. This was an overnight ROV.

Sunday 12th May 2019

The start of the day was the end of ROV dive 358. The ROV was turned around and deployed for dive 359. This dive deployed the Boundary layer lander and replace it with the other one. The ROV was recovered at 18:47 and then redeployed for dive 360 to deploy the bubble frame lander. This was an overnight dive.

Monday 13th May 2019

The ROV was back on deck at around 10:20 and the gear was removed from the sledge. Unfortunately it was clear that the bubble frame lander had not worked due to flooding of the camera housings, these were bought pieces of equipment so it was very disappointing, contingency plans have gone into place to ensure the next deployment is successful. Another dive (ISIS 361) was started at 12:15 with the plan to deploy the benthic chamber for a 48-hour experiment. Samples of gas were also collected in the bubble stream and at the gas rig. A new bubble stream had appeared and one of the older ones had disappeared. We downloaded the flow data from the gas rig. The ROV was recovered at around 16:15 and we left the site to allow the Poseidon site access for a video guided CTD study. We then allowed 4 hours of quiet time over the site before we returned.

Tuesday 14th May 2019

We returned to the site around 7 am and at 0906 deployed an SVP along with the modified camera housing from the bubble frame, to allow testing of pressure tolerance. We then deployed the Gavia for a nested mission, 7m high sub bottom profiler survey followed by a 3m video image survey. Unfortunately the Gavia malfunctioned after the first survey and after trying numerous attempts to start the second survey we switched to an earlier ROV deployment. We did an ROV dive (ISIS 362) deployed around 13:30 for changing the flow on the gas tanks up to 5 l per minute and change the benthic boundary lander for the replacement of like with like. The ROV was recovered in the afternoon and the redeployed in the early evening for an overnight dive (ISIS 363) for a microprofiler survey using the MPI system. The gas was more vigorous as expected and there were larger pockmarks being formed. At 0648 on the 15th we increased the flow rate to 10 litres per minute.

Wednesday 15th May 2019

The ROV was recovered at just after 10 am and then turned around for the next dive (ISIS 364). This dive was to recover the hydrophone wall that had been in the seabed for a few days. The ROV was recovered at around 1300. The ROV was rapidly turned around and redeployed (ISIS 365). This dive was to swap around the GEOMAR benthic chamber, collect some gas samples and water samples. The ROV was recovered at around 16:30. On this dive (ISIS 366) the bubble frame developed by the University of Southampton was deployed for 3 hours over and actively venting seep. A whole series of pH optode measurements, using the TU Graz system, were made at increasing heights above the venting bubbles. Niskin and gas samples were collected and the ROV was recovered on Thursday 16th.

Thursday 16th May 2019

The ROV was recovered and redeployed (ISIS 367) for swapping out the hydrophone walls. The ROV was recovered, turned around and ISIS 368 started, the benthic boundary layer lander was swapped out. The dive was then stopped due to a medical issue on board that meant we had to steam towards Aberdeen for a helicopter evacuation. This went successfully and we steamed back to the area of study, we stayed 3 km off site to provide some quiet time for acoustic measuring.

Friday 17th May 2019

At around 0700 the Gavia was deployed for its 7 and 3m surveys over the study area. Following the Gavia we did an ROV deployment (ISIS 369) to deploy the GEOMAR benthic chamber, recover the old one and collect gas samples and Niskin bottles in the bubble stream and also over the gas tanks. We increased the gas flow to 30 l per minute. The recovered benthic chamber had malfunctioned again. At 20:36 we deployed the ROV (ISIS 370) This was an overnight microprofiler dive with additional survey for bubble dissolution using the modified light wall. We took gas samples and Niskin samples at the bubble site and at the gas container. We collected a series of push cores along the top of the main actively venting bubble pock marks. We recovered the ROV in the morning.

Saturday 18th May 2019
We recovered ISIS 30 dive in what was rough weather so we delayed deploying the next ROV until the afternoon. The ROV was deployed at 16:26 and was used to swap out the benthic boundary layer samplers. The ROV was back on deck at 18:30. We then deployed the ROV (ISIS 372) for night operations. Hydrophone wall deployed, gas and Niskin samples taken, pH optode survey taken.

Sunday 19th May 2019
Isis dive 372 recovered at 10:20. The ROV (Isis 373) was deployed at 12:37. We deployed the benthic chamber and took gas and Niskin samples. The flow rate on the gas container was increased to 50l per minute. ROV was recovered at 16:56. The ROV was deployed (Isis374) at 18:35 to deploy the hydrophone wall, this was a quick turn around and was back on deck at 19:42. We left the site to allow the Poseidon to collect CTD samples.

Monday 20th May 2019
We returned to the site at around 06:30 and deployed the Gavia for a mission, this mission finished and the AUV was recovered at 12:50. During the mission we also did an SVP to update the information for the upcoming ROV dives. The ROV was deployed at 13:43 (Isis 375) this was to deploy the benthic boundary layer sampler and recover the old one. Gas and Niskin samples were collected. The ROV was deployed at 20:15 (Isis 376) for its usual night program. We did a microprofiler survey, a bubble survey using the light board, took Niskin samples, gas samples and 6 push cores close to the actively venting bubbles.

Tuesday 21st May 2019
On recovery of the ROV the system lost power, the ROV was recovered OK, but all subsequent operations with the ROV were halted while trouble shooting occurred. The baseline lander was recovered at 12:26 without incident. The ROV was reterminated later in the day as the fault was on the termination. The potting and curing took place over night. No operations took place till morning of the 22nd.

Wednesday 22nd May 2019
ROV back in operation, deployed 10:30 and then went to gas cage, stowed hose reels. Turned off gas flow at hoses at 11:17, still venting out excess through the sample point on the gas cage. Hose one disconnected at 11:38. Hose 2 at 13:10. We then did a series of ROV dives in quick succession to recover the equipment on the seabed. The weather closed in and we recovered the ROV.

Thursday 23rd May 2019
The weather was bad so we were hove too.

Friday 24th May 2019
Bad weather so still hove too.

Saturday 25th May 2019
Weather finally abated a little so we did a Gavia deployment, for an offsite survey. After an aborted dive the Gavia descended and started the survey. We did an SVP. We then recovered the Gavia and recovered the gas tanks from the seabed, following this we deployed the release mechanism for the old baseline lander.

Sunday 26th May 2019
We started the day with a Gavia survey in an offsite area. The Poseidon is on the main site doing a series of gravity cores (9 in total) and multicores. We then deployed the release float and weights for the recovery of the lost lander. The Gavia was recovered and we deployed the ROV. The deployment was successful and the ROV worked on putting the release package on the lost lander. The ROV then did a video survey over both the main experiment area and the pipe one area. The ROV then took two Niskin bottles over the former gas tank site and 4 over the main gas release site. The area was covered in collapsed pock marks, presumably due to the cutting off of the gas. There was evidence that the Poseidon cores were taken to the NW of the main experiment area, 3-5 m away, the multi corer was 5 m to NW and another set of gravity cores were on the 7m mark to the NW. We then collected 6 push cores, three for Dirk de Beer and 3 for us, all except on in the centre of the main release impacted area. The ROV was then recovered.

Monday 27th May 2019
At 0700 we recovered the release float that is now attached to the old lost lander. The lander was then successfully recovered and returned to the deck, complete with a large cod inside it, this was returned to the sea. At 0900 we did an SVP then deployed the Gavia for an offsite survey, this was finished and the Gavia recovered at 15:14, marking the last science operation of the JC180 cruise.

Tuesday 28th May 2019
On Transit

Wednesday 29th May 2019
On Transit

Thursday 30th May 2019
Arrive for pilot at 0700, alongside Southampton XXX

4 Scientific Operations

4.1 Logistics and Engineering: Kevin Saw, Hannah Wright and Robin Brown (NOC)

4.1.1 Drill Rig

Photo: Ben Roche

The ‘Drill Rig’ is a bespoke piece of equipment designed to push a pre-curved 9 m long pipe into the seabed. The pipe is carbon steel, 38.1 mm OD x 12.7 mm bore. Once positioned in the seabed, it’s leading (outlet) end finishes approximately 3 m below the seabed surface and with an upward pointing attitude. Its trailing (inlet) end protrudes vertically approximately 0.75 m above the seabed surface and carries a push-fit coupling for later connection to the CO_2 supply hose. The outlet end is fitted with a 3 mm thick grade 316 stainless steel sintered tubular diffuser with a pore size of 9 µm (Amespore). This discharges through an arrangement of twenty-eight 12.7 mm diameter holes through the pipe wall.

The Rig was manufactured by Cellula Robotics in Vancouver, Canada. A Cellula Robotics technician, Mark Wells, was on board to oversee operation of the Rig.

A test deployment (with no pipe loaded) was carried out first, followed by insertion of two pipes. The test deployment commenced at 0823h on 30 April at position 57° 59.473’ N, 00° 22.828’ W. The deployment was successful with all rig functions working as expected. A magnetic compass was fitted to indicate the direction of the inserted pipe. The compass was lit using a modified diver’s torch and was found to be over-illuminated and unreadable; the torch was not used for subsequent deployments and the general rig lighting was found to provide sufficient illumination.

The first pipe (Pipe 1) was inserted at position 57° 59.659’ N, 00° 22.462’ W. The insertion process commenced at 1136h on 30 April and was complete at 1158h. It was intended to insert the pipe in a NE direction; this was achieved by rotating the ship once the Rig was close to the seabed and reading direction from the compass. Penetration into the sediment was very smooth although some increased resistance occurred around the 8 m mark; push force was increased accordingly and the pipe was fully inserted without further issue. On recovery, a high wire load in excess of 7 tonnes was experienced. The load was released momentarily which caused the rig to side-swipe the pipe end. It was feared the coupling may have been damaged but this later proved not to be the case.

The second pipe (Pipe 2) was successfully inserted at position 57° 59.675’ N, 00° 22.466’ W. The insertion process commenced at 1409h on 30 April and was complete at 1433h. Due to the high pull-out load experienced previously, the two concrete ballast blocks were removed for this deployment reducing the total weight by 2 tonnes. The pipe was inserted in an ENE direction.

The extendable legs (provided to help lock the rig to the seabed) were not used for either deployment.

During both deployments, loss of communication with the seabed package was lost on several occasions. The reason for this wasn’t established conclusively but seemed to occur most often when the umbilical was being physically handled. The excessively long Ethernet cables could also have played a part in this.

4.1.2 CO_2 Gas Rig

The CO_2 Gas Rig was designed and built in-house by OTEG. The rig carries ~3 tonnes of liquid CO_2 and 200 litres of gaseous tracer mix comprising 0.3% C3F8, 3.8% SF6, 25.1% CO_2 and 70.8% Kr, by mass. The Rig is self-contained and gas flow is controlled by a pair of mass flow controllers (Bronkhorst) which together maintain a CO_2 to tracer mix ratio of 10,000:1. Outlet flow rate is selectable in the range 2 to 80 ‘normal’ litres per minute (‘normal’ defined as 0°C, 1.01325 bar). Power is provided by two banks of two 12 V 160 Ah dryfit lead acid batteries configured to provide 24 V. Outlet pressure is controlled by a pressure regulator that references to seawater pressure (for a given regulator setting, outlet pressure remains constant despite changing water pressure due to tidal height) and can be adjusted by the ROV. Max outlet pressure is 6.8 bar above ambient.

The mass flow controllers are controlled remotely via acoustic (from the ship) or optical (via the ROV) modems. In practice, acoustic communication was not successful. The reasons are not fully understood but are expected to be related to the acoustic beacon on the Rig being shadowed by the spare recovery rope box. Conversely, the optical modem proved to be very successful and was used exclusively to change flow rates and download logged data on a (near) daily basis.

Deployment of the Rig was to be achieved by lowering the Rig to the seabed on a 200 m length of 47 tonne breaking strain Dyneema rope (28 mm Marlow Superline HS with polyester outer jacket, non-floating). The rope was then paid out to the seafloor, keeping it as taut as possible, by moving the ship away from the deployment position. A flotation lander was attached to the free end and, using the starboard pedestal crane, released to the seabed.

The Rig was first deployed at 0715h on 29 April at position 57° 59.670' N, 00° 22.552' W. Testing was conducted via the sampling point at increasing flow rates. At 40 LPM, pressure gauge G2 became unstable and at 60 LPM G2 lost all pressure. This followed previous issues with both the first and second stage pressure regulators that were thought to have been fixed. The Rig was recovered for investigation. Although abortive, this deployment was useful in proving that the deployment and recovery procedures were sound.

The pressure regulators were stripped down and re-worked and deck tests suggested that all was well, albeit up to a maximum flow rate of 50 LPM. A second deployment was attempted at 1200h on 1 May at position 57° 59.690' N, 00° 22.510' W. On entering the water the spare recovery rope box lid was forced off allowing the spare rope to begin flaking out of the box. The rig was immediately recovered back to the deck but in doing so the deployment rope dragged across part of the winch scrolling gear which resulted in a section of the outer cover being peeled off. The deployment rope was swapped with the spare rope which was wound onto the deck winch under tension using a hired reeling winch during our Aberdeen port call. This also gave us an opportunity to purchase two new regulators to replace the suspect ones. The new regulators were fitted and tested OK although the first stage regulator appeared to have leaked CO_2 into its housing (this was later confirmed by the first stage pressure gauge, G1, reading full tank pressure throughout the deployment). The Rig was successfully re-deployed at 0915h on 10 May at position 57° 59.690' N, 00° 22.512' W. Flow tests via sample point were successfully carried out up to 50 LPM. Hose Reel 1 (white) was connected to Pipe 2 and Hose Reel 2 (black) was connected to Pipe 1 without incident.

Flow to Pipe 1 (test site) was started at 2 LPM. No flow was indicated by the mass flow controller initially with outlet pressure of 0.55 bar. Outlet pressure was gradually increased over a 1.5 hour period to 1.3 bar but sustained flow could not be established.

Attention was switched to Pipe 2 (science site) and flow was started at 2 LPM at 1454h on 11 May. Sustained flow at 2 LPM was soon achieved at 1519h with an outlet pressure of 1.15 bar. Inspection of the hose/pipe connection revealed no leaks (although a slight leak was present during the experiment at higher flow rates) and bubbles were observed rising from the sediment in the vicinity of the buried pipe end at 1552h.

A flow of 2 LPM was maintained until 1528h on 14 May when it was increased to 5 LPM and then 10 LPM at 0648h on 15 May, 30 LPM at 1654h on 17 May and finally 50 LPM at 1550h on 19 May. Flow at all rates for both the tracer mix and bulk CO_2 was steady throughout. Flow was eventually stopped at 1117h on 22 May and both hoses were disconnected from their respective pipes leaving the Rig in a state to be recovered. Sea state at this time was considered too high for a safe recovery so the Rig was left in place pending better weather. The Rig was eventually recovered at 15:15h on 25 May without incident. The flotation lander was released acoustically, carrying the original deployment rope with it, and recovered to the ship. Once the recovery rope was rigged and attached to the winch, the ship moved to a position directly over the Rig and it was hauled to the surface and onto the deck. At this point the two gas hoses which had been disconnected from the buried pipes but left lying on the seabed, remained hanging over the stern; these were easily hauled by hand onto deck.

4.1.3 'New' Baseline Lander

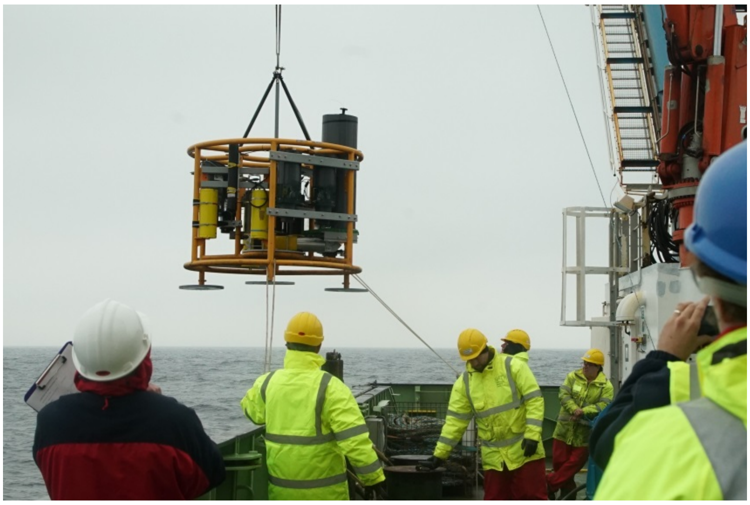


Photo: Ben Roche

Due to the failure of the original Develogic baseline lander that was deployed in October 2017, a replacement lander was built at short notice by OTEG engineers for deployment 'off-site' for the duration of the release experiment. The lander carried the following sensors:

- NOC wet chemical nitrate
- NOC wet chemical pH
- NOC wet chemical DIC
- NOC wet chemical phosphate
- NOC wet chemical total alkalinity
- Seabird SeapHOx
- Wildlife Acoustics bioacoustic recorder
- Nortek Aquadopp current meter

The Lander was deployed at 1226h on 27 April at position 57° 59.471’ N, 00° 22.171’ W in 122 m of water. It was subsequently checked by the ROV and found to have landed in good condition.

The recovery rope was released acoustically at 1107h on 21 May and the Lander was safely recovered onto the deck at 1129h. Refer to relevant sections of this cruise report for details of how each of the sensors performed.

4.1.3.1 ‘Lost’ Develogic Baseline Lander

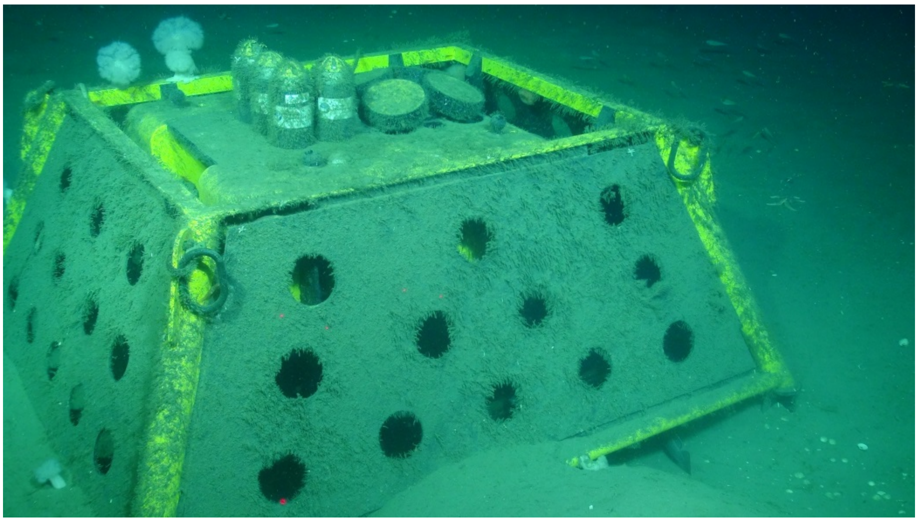


Photo: ROV ISIS

The Develogic Baseline Lander was originally deployed from the Poseidon (POS518) at 0500h on 16.10.17 at position 57° 59.74’N, 00° 22.38’W. Recovery was planned for August 2018 (POS527) but attempts to find it and release it acoustically were not successful.

Of the three pop-up beacons that were scheduled to release, the first didn’t transmitted anything but was found by fishermen off northern Norway on 4 August 2018 and, following delivery to Geomar, was found to have no data on it. The second one indicated position 58° 31.164’N, 03° 07.858’ W (on a beach north of Wick in Scotland) on 17 March 2018 but was never found. The third pop-up was never released.

The lander was found on 27 April 2019 during ROV dive 346 (see photo). The lander was found to be upright and, apart from some biofouling and some damage to the top cover of pop-up beacon #4 (presumably occurred on deployment), in generally good condition – indicating that it had not been trawled or otherwise interfered with as had been feared. Pop-up beacon #4 was found to have a small amount (eggcup full?) of water inside.

Following recovery of the Gas Rig a 130 kg weight was lowered to a position 10 m south of the lost lander by re-using the Gas Rig deployment rope. A four-legged lifting bridle was constructed from 2 m webbing slings, a master link and shackles and the ROV carried this down and attached it to the four master links on the lander frame top corners. The rope was paid out to the seabed in an easterly direction and, similar to the Gas Rig deployment method, the flotation lander was attached and released to the seafloor. The lander was successfully recovered at 0735h on 27 May.

Battery voltages were measured at ~29V. All four remaining pop-up beacons were found to have no data. Data was copied from all of the SD cards found in the two main housings and data was found for all sensors up until late April 2018 except for the hydrophones which only had data for 16, 17 and 18 October 2017.

5 Sub-bottom profiling: Jonathan Bull, Michael Faggetter, Ben Roche, Paul White, Jianghui Li (University of Southampton)

During JC180, sub-bottom profiling using chirp sources was completed using a Teledyne system mounted on the Gavia AUV, and an Edgetech system fixed onto the ISIS ROV.

5.1 Gavia sub-bottom profiling – Pre-Release

The sub-bottom profiler on the Gavia AUV can produce a chirp pulse with source frequencies between 14 and 21 kHz. Source sweep lengths are selectable with options of 1, 3, 5 milliseconds (ms) length, and with additional control on source power. During the first Gavia survey a grid of data was collected at 7.5 m and 2 m elevation above the seabed. For the survey at 7.5 m elevation, the Gavia used a 5 ms length sweep at maximum power. For the survey lines at 2 m elevation (when camera data was also collected), a shorter sweep length of 1 ms was used, and with reduced power (setting of "2"). The ping rate for the Gavia was 15 pings per second throughout the survey which equated to an average ping spacing of c. 7 cm.

The on-site grid of lines covered an area of 500 m x 400 m, with a line spacing of 40 m in a north-south direction to ensure complete sidescan coverage. Some of the north-south profiles were longer, c. 1 km in length to give some regional perspective, and some additional east-west lines were collected to provide tie lines.

The sub-bottom data collected by the Gavia was of good quality. The 7.5 m elevation Gavia data appears saturated in the near-surface, perhaps because of the hard seabed and high power, whereas the 2 m elevation data was less saturated and gave better imaging at depth. Gavia data was recorded in both correlated bi-polar and uncorrelated raw SEGY data format. The source sweep for the Gavia was not available at the time of JC180, and therefore the bi-polar correlated data was used for further processing.

The correlated Gavia data was processed using the following flow: band-passed filter (13.5-14.0-21-22 kHz), top mute, time varying gain, static correction using the mean Gavia elevation, trace mixing (3-point moving average), migration (Stolt with 1483 ms^{-1}) and automatic gain control (1.3 ms length), and finally enveloped to improve interpretability. The Gavia data navigation was corrected using the ships USBL system.

The complete grid of processed unmigrated profiles was read into Petrel for seismic interpretation (both 2 m and 7. 5 m elevation data). The data imaged the top 10 ms two-way time (TWT) of the sub-surface (top 7 – 8 m of the sub-surface), and gave complete imaging of the Witch Ground formation and the top of the Coal Pit Formation. Within Petrel the seabed and a strong laterally continuous reflector within the Witch Ground Formation at c. 6 ms TWT average arrival time was picked on all lines. An isopach map of the interval between these reflectors ("Upper Witch Ground") was produced and used to select the optimal location for the CO_2 container and lateral coring.

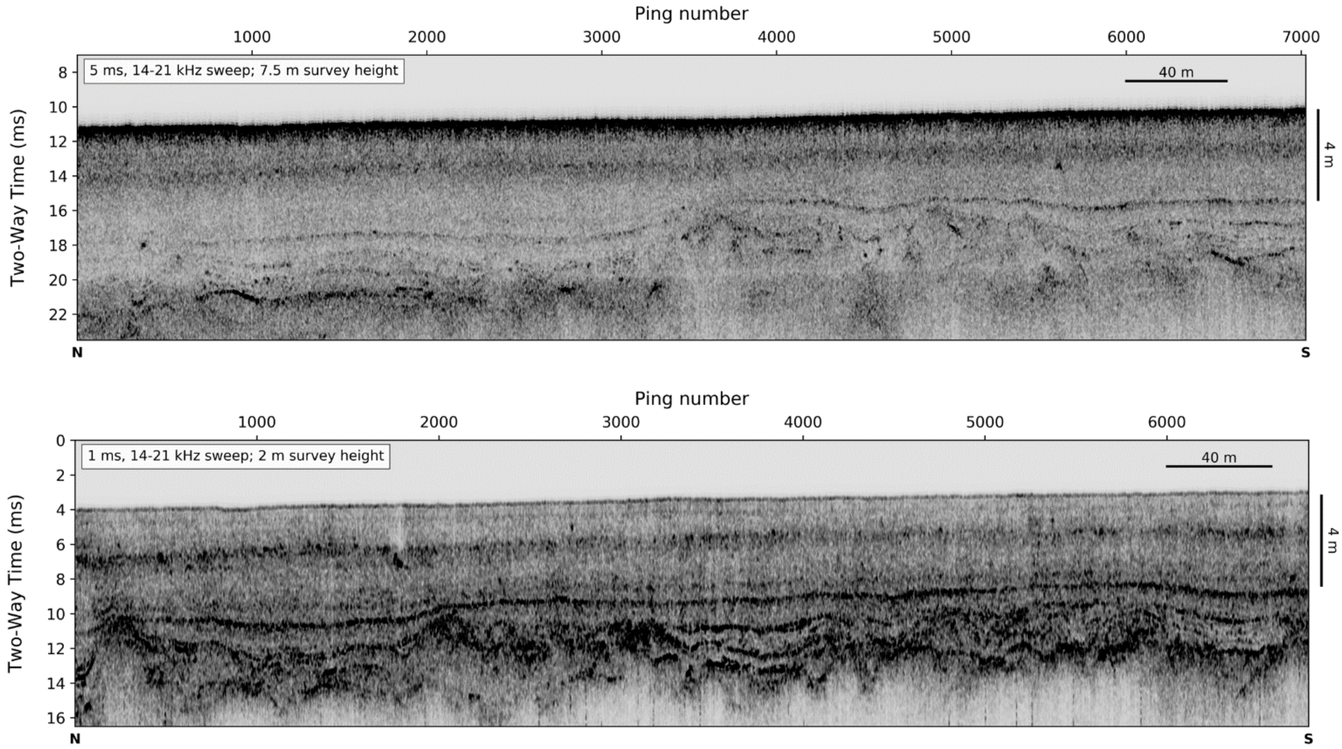


Figure 5.1. North to south GAVIA AUV profiles (mission 1) across detailed survey area SE of Goldeneye platform at 7.5 m (top) and 2 m (bottom) elevations. 7.5 m seismic section is third profile from western edge of survey; 2 m, second profile from western edge.

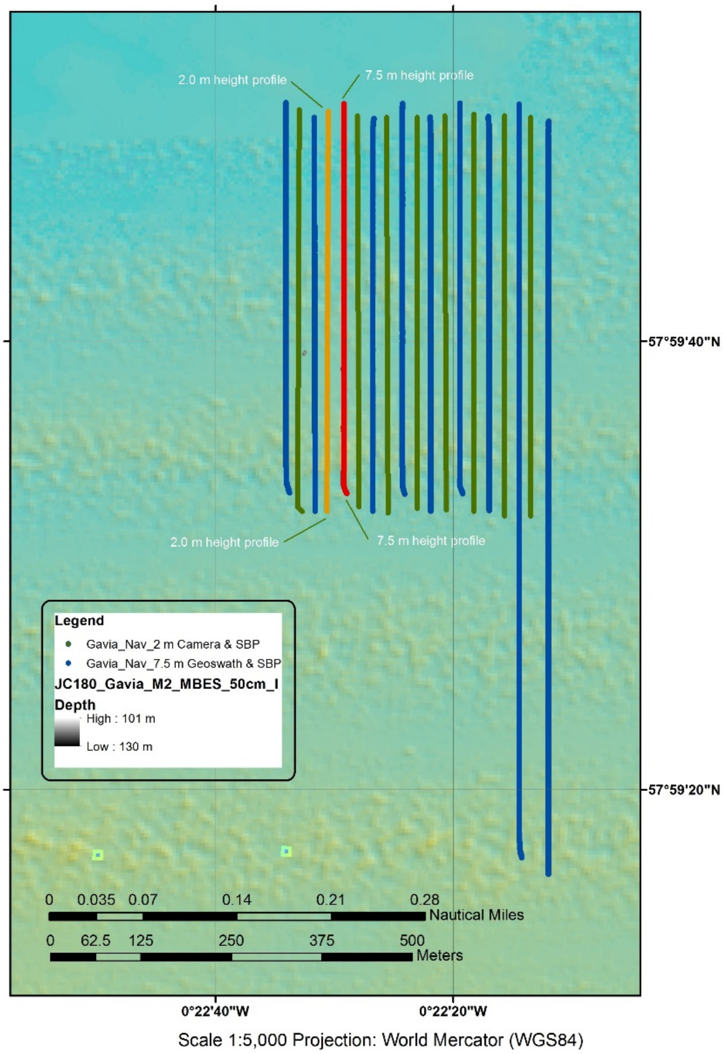


Figure 5.2. Position of the Gavia sub-bottom profiles SE of the Goldeneye platform shown in Figure 4.1

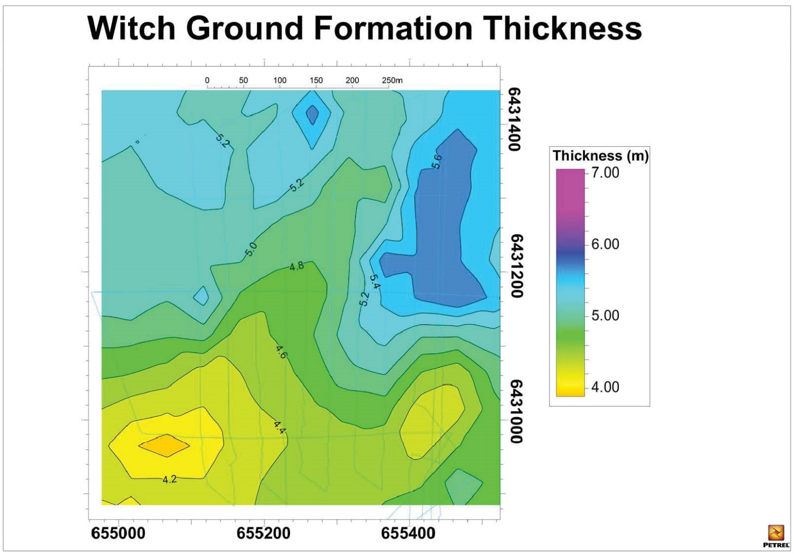


Figure 5.3. Isopach map of Upper Witch Ground for the detailed survey area SE of Goldeneye platform

The second Gavia survey (Figure 5.4) comprised an off-site survey of an area affected by pockmarks. The survey lines were orientated west to east and were 1 km in length, with lines being collected at both 2 m and 7.5 m elevation with source sweep specifications as before. The data images the pockmarks, with Figure 3 showing two profiles, one at 7.5 m and one at 2 m elevation in the south-east of the off-site survey area with profiles around 30 m apart. One of the profiles (Fig. 5, top) is through the centre of a pockmark; the other (Fig. 5.5, bottom) is towards its lateral edge.

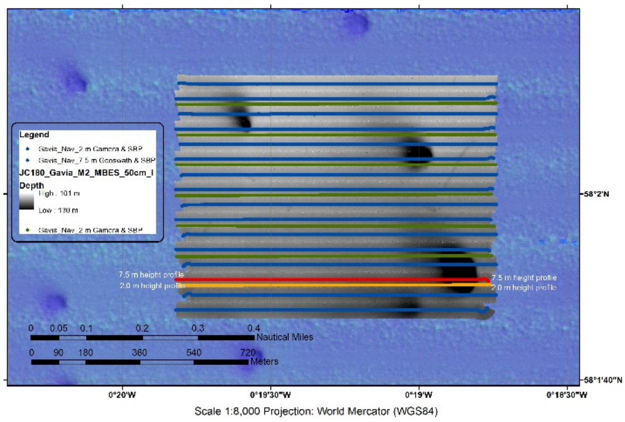


Figure 5.4. Position of the Gavia sub-bottom profiles NE of the Goldeneye platform shown in Figure 5

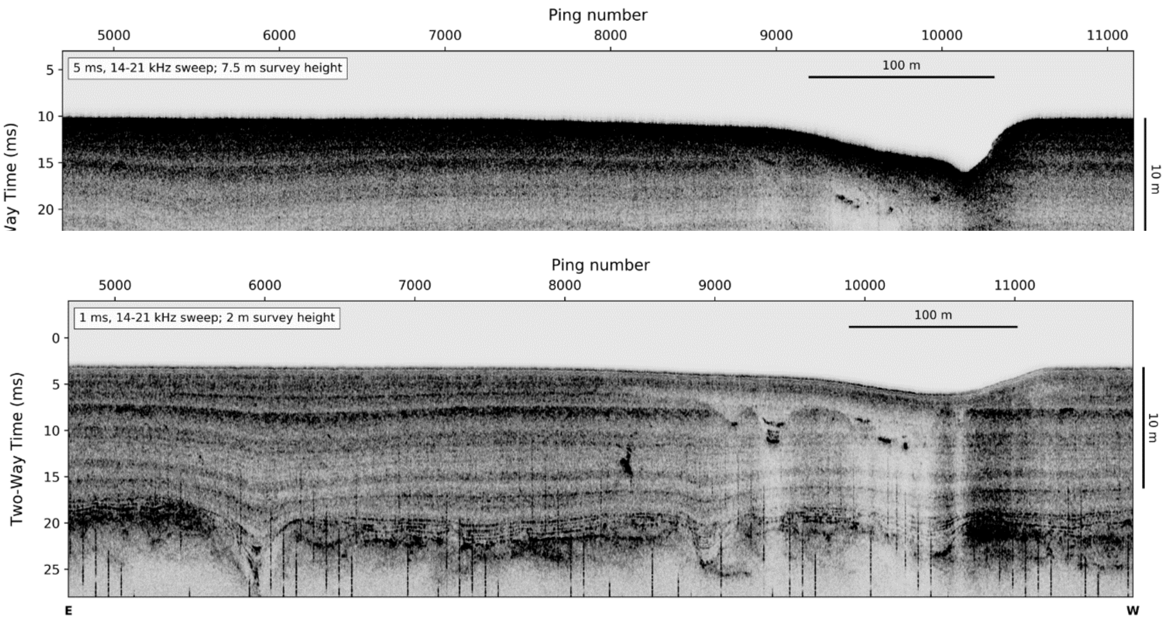


Figure 5.5 East to west GAVIA AUV profiles (mission 2) across the off-site survey area NE of Goldeneye platform at 7.5 m (top) and 2 m (bottom) elevations. The profiles are around 30 m apart with the same pockmark being images on the western end of both profiles, with the top profile cutting across the centre of the pockmark.

5.2 Gavia sub-bottom profiling – Syn-Release

Three Gavia sub-bottom surveys were conducted once the gas flow was initiated to give an understanding of gas pathways through the sediment and potential pooling. These were collected on the 14th, 17th and 20th of May.

As with the pre-release surveys, grids of data were collected at 7.5 m and 2 m elevation above the seabed. For the survey at 7.5 m elevation, the Gavia used a 5 ms length sweep at maximum power. For the survey lines at 2 m elevation (when camera data was also collected), a shorter sweep length of 1 ms was used, and with reduced power (setting of "2"). The ping rate for the Gavia was 15 pings per second throughout the survey which equated to an average ping spacing of c. 7 cm. As before the sub-bottom data collected by the Gavia was of good quality. The 7.5 m elevation Gavia data appears saturated in the near-surface, while the 2 m elevation data was less saturated and gave better imaging at depth.

Gavia data was recorded in both correlated bi-polar and uncorrelated raw SEGY data format. The source sweep for the Gavia was not available at the time of JC180, and therefore the bi-polar correlated data was used for further processing. The correlated Gavia data was processed identically to the pre-release survey, to ensure easy comparison, using the following flow: band-passed filter (13.5-14.0-21-22 kHz), top mute, time varying gain, static correction using the mean Gavia elevation, trace mixing (3-point moving average), migration (Stolt with 1483 ms^{-1}) and automatic gain control (1.3 ms length), and finally enveloped to improve interpretability. The Gavia data navigation was corrected using the ships USBL system.

Due to time restrictions it was not possible to read the unmigrated profiles into Petrel for seismic interpretation. Instead preliminary assessments were made using observations in Seismic Unix and examples of near identically-positioned lines are presented.

5.2.1 On Site Gavia Sub-bottom 14/05/19

The third Gavia survey (Figure 5.6.) was conducted when the gas was being injected at 2L/min. The survey was composed of a dense grid of lines collected at 7.5m height in a NNW SSE orientation ~160m in length with 5m spacing, and 4 perpendicular lines collected at 40m spacing. This gave detailed coverage across the survey area allowing us to observe the build-up of gas beneath the sediment and infer the approximate depth of the top of the pipe. A profile at 7.5m height (Figure 5.7.) shows the gas pooling and the resulting seismic shadow underneath.

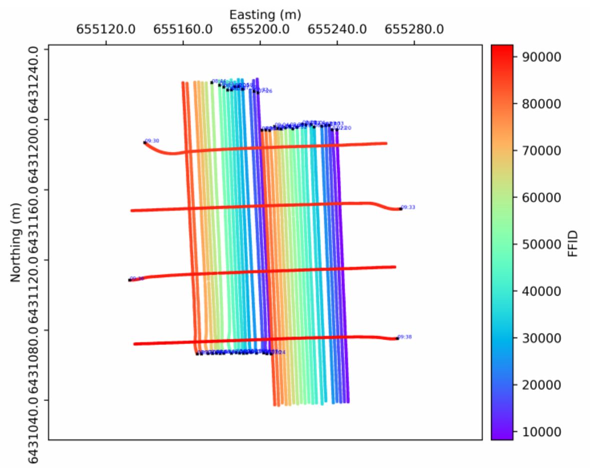


Figure 5.6. Gavia survey 3 conducted on the 14/05/19 across the release site

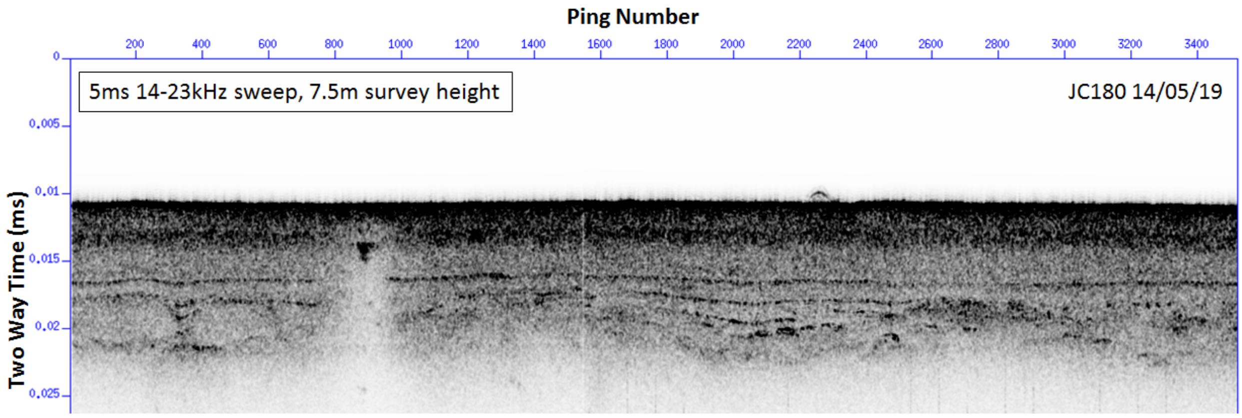


Figure 5.7. North to South (left side) GAVIA AUV profiles (mission 3) across the release site at 7.5m height. Visible on the left is gas pooling beneath the sediment, potential along an internal layer within the Witch Ground Formation as visible by the strong internal reflector.

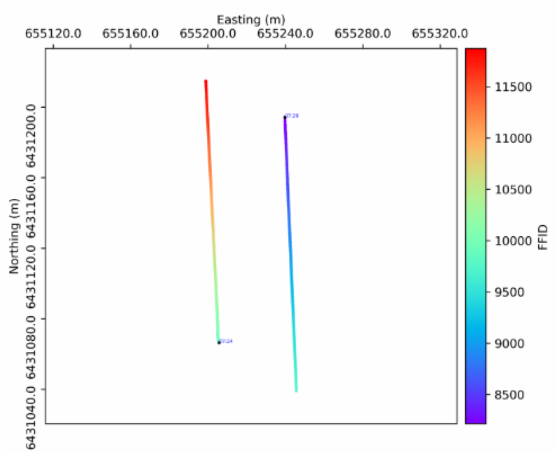


Figure 5.8. The position and orientation of Figure 7.

5.2.2 On Site Gavia Sub-bottom 17/05/19

The fourth Gavia survey (Figure 5.9.) was conducted when the gas was being injected at 10L/min. The survey at 7.5m height was composed of a dense grid of lines in a North South orientation ~200m in length with 2m line spacing. This was immediately followed by a survey at 2m with 12 line profiles orientated at 45° increments at 5m line spacing. Despite detailed coverage across the survey area we were unable observe the build-up of gas beneath the sediment though shadowing is apparent, suggesting gas is passing through the area but not pooling. A profile at 7.5m height (Figure 5.7.) shows seismic shadow underneath.

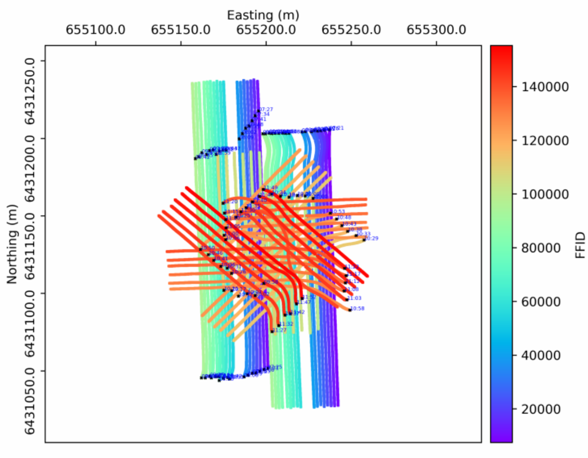


Figure 5.9. Gavia survey 4 conducted on the 17/05/19 across the release site

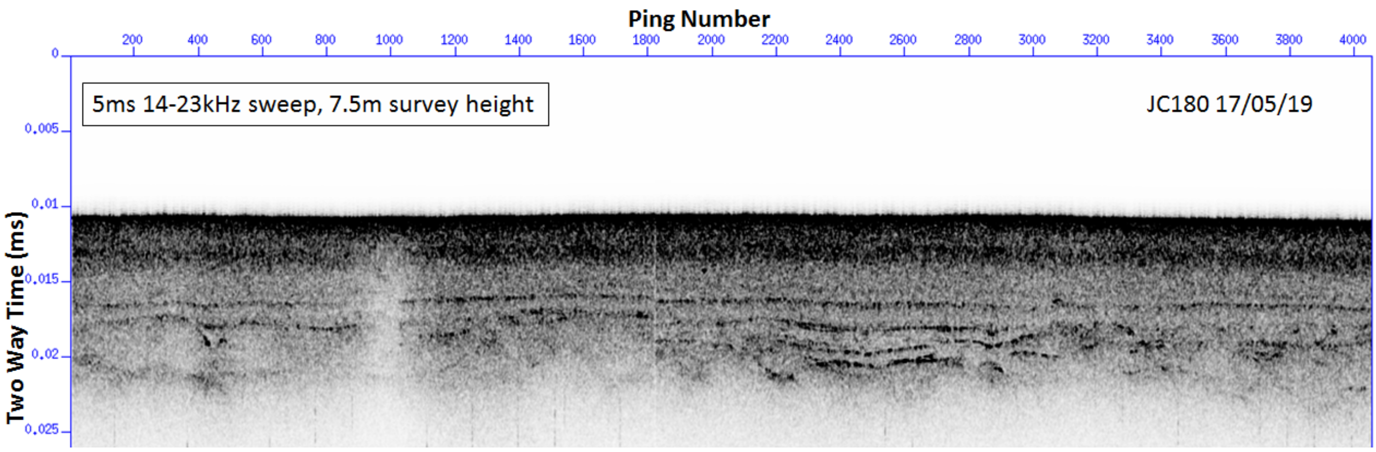


Figure 5.10. North to South (left side) GAVIA AUV profiles (mission 4) across the release site at 7.5m height. Visible on the left is the presumed seep site with no obvious gas pooling but some shadowing

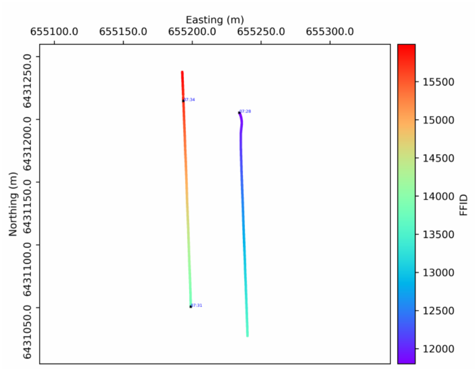


Figure 5.11. The position and orientation of Figure 5.10

5.2.3 On site Gavia Sub-bottom 20/05/19

The fifth Gavia survey (Figure 5.12.) was conducted when the gas was being injected at 50L/min. The survey at 7.5m height was composed of a dense grid of lines in a North South orientation ~180m in length at 2m spacing's and 4 EW lines at 50m spacing. This was immediately followed by a survey at 2m with 12 line profiles orientated at 45° increments at 5m spacing's. This time a strong reflector was seen indicating a gas pocket however this was much smaller than that observed on the 14th suggesting less pooling. A profile at 7.5m height (Figure 7.) shows the small gas pool.

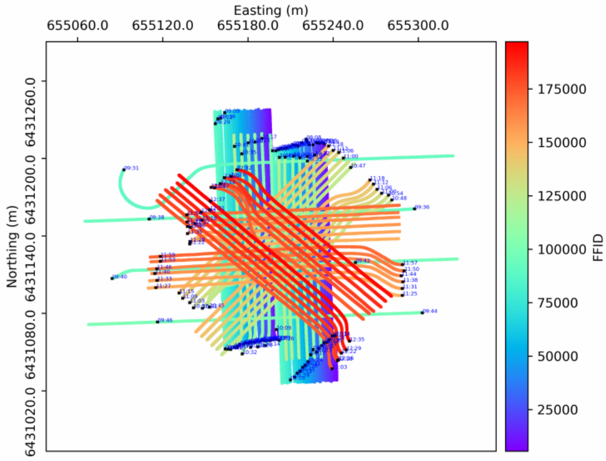


Figure 5.12. Gavia survey 5 conducted on the 20/05/19 across the release site

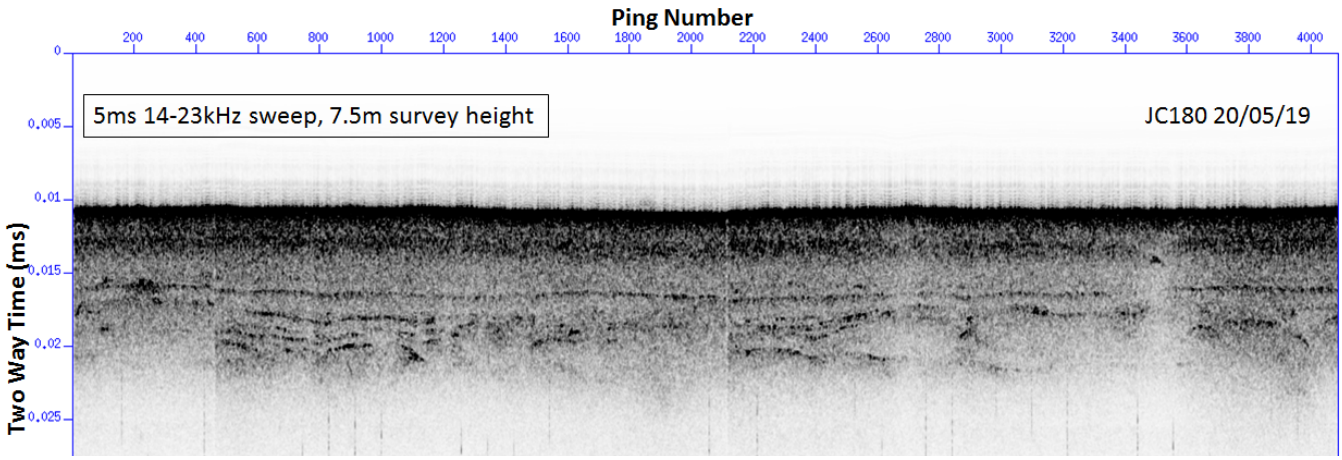


Figure 5.13. North to South (right side) GAVIA AUV profiles (mission 5) across the release site at 7.5m height. Visible on the right is the presumed seep site with a small strong reflector (a gas pocket).

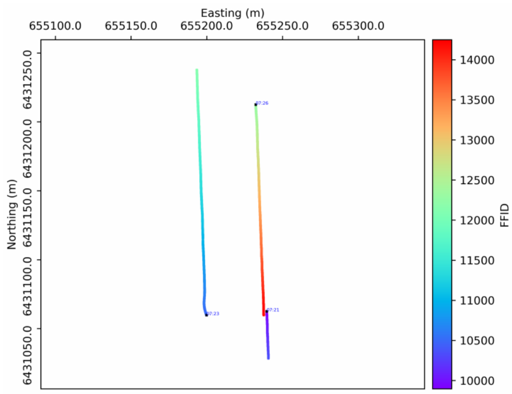


Figure 5.14. The position and orientation of Figure 13

5.3 Gavia sub-bottom profiling – Post-Release

Three Gavia sub-bottom surveys were conducted once the gas flow was turned off on the 22nd, one on site to observe how the remaining gas acts within the sediment when no longer under pressure and two offsite. These were collected on the 25th, 26th and 27th of May.
As with the pre and mid-release the onsite survey grids were collected at 7.5 m and 2 m elevation above the seabed while the offsite surveys were collected at 7.5 m. For the survey at 7.5 m elevation, the Gavia used a 5 ms length sweep at maximum power. For the survey lines at 2 m elevation (when camera data was also collected), a shorter sweep length of 1 ms was used, and with reduced power (setting of "2"). The ping rate for the Gavia was 15 pings per second throughout the survey which equated to an average ping spacing of c. 7 cm. As before the sub-bottom data collected by the Gavia was of good quality. The 7.5 m elevation Gavia data appears saturated in the near-surface, while the 2 m elevation data was less saturated and gave better imaging at depth.

Gavia data was recorded in both correlated bi-polar and uncorrelated raw SEGY data format. The source sweep for the Gavia was not available at the time of JC180, and therefore the bi-polar correlated data was used for further processing. The correlated Gavia data was processed identically to the pre-release survey, to ensure easy comparison, using the following flow: band-passed filter (13.5-14.0-21-22 kHz), top mute, time varying gain, static correction using the mean Gavia elevation, trace mixing (3-point moving average), migration (Stolt with 1483 ms^{-1}) and automatic gain control (1.3 ms length), and finally enveloped to improve interpretability. The Gavia data navigation was corrected using the ships USBL system.

Due to time restrictions it was not possible to read the unmigrated profiles into Petrel for seismic interpretation. Instead preliminary assessments were made using observations in Seismic Unix and examples of near identical lines to those in presented in the mid release report are shown below.

5.3.1 Off Site Gavia Sub-bottom 25/05/19

The sixth Gavia survey (Figure 5.15.) comprised an off-site survey of an area affected by pockmarks. The survey consisted of 12 lines orientated east to west ~1 km in length, 4 lines 1km long lines orientated North South, both collected at 7.5m elevation and 2 East to West 1km long lines collected at 2m elevation. The data once again imaged pockmarks in the area, with Figure 16 showing one such feature from a profile at 7.5 m.

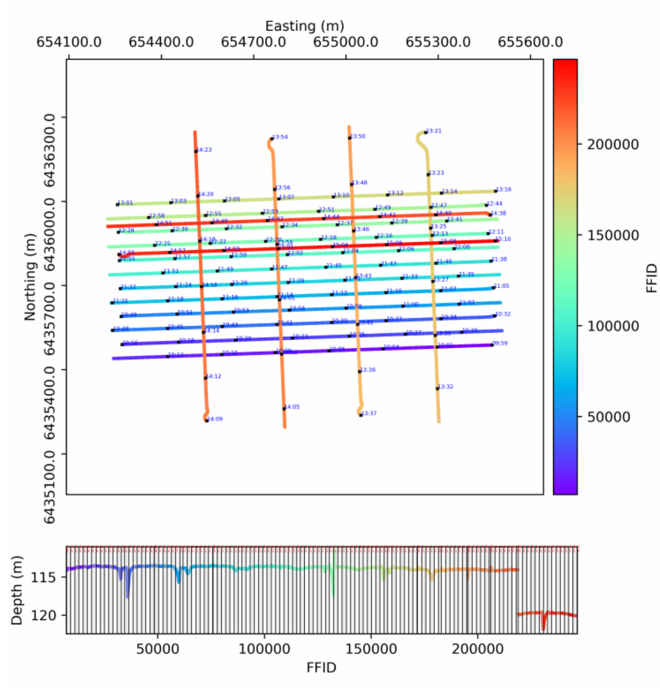


Figure 5.15. Gavia survey 6 conducted on the 25/05/19 offsite over a number of pockmarks

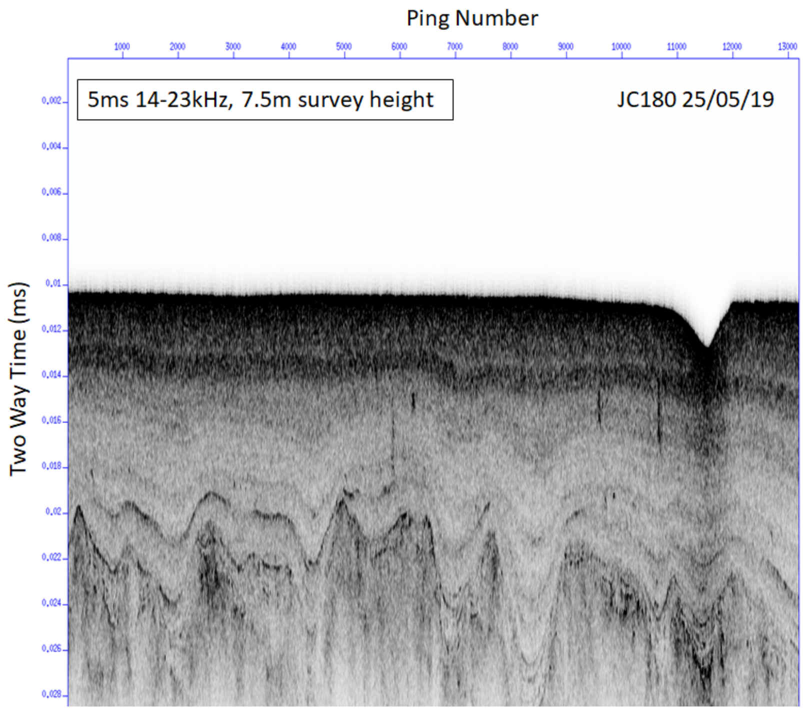


Figure 5.16. West to East GAVIA AUV profiles (mission 6) across offsite pockmarks.

5.3.2 Off Site Gavia Sub-bottom 26/05/19

The seventh Gavia survey (Figure 5.17.) comprised an off-site survey of an area affected by pockmarks. The survey consisted of 12 lines orientated east to west ~1 km in length, 4 lines 1km long lines orientated North South, both collected at 7.5m elevation and 2 East to West 1km long lines collected at 2m elevation. The data successfully imaged the underlying area, with Figure 5.18 showing an example profile at 7.5 m.

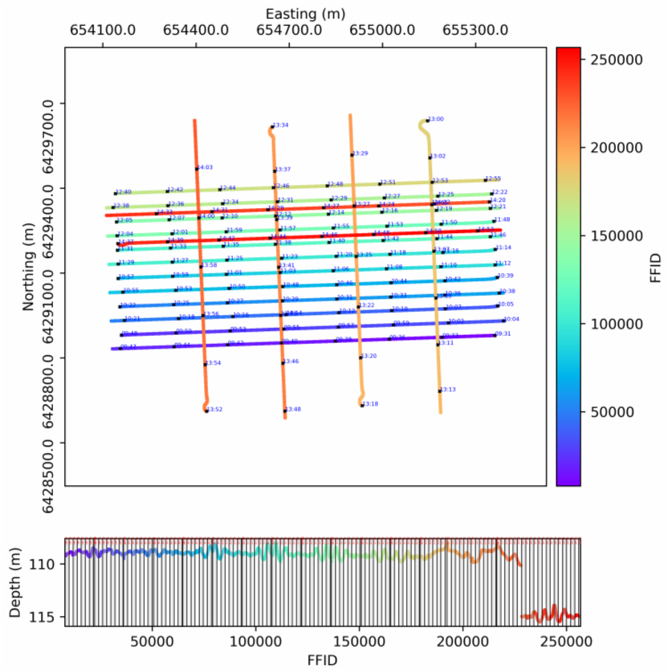


Figure 5.17. Gavia survey 7 conducted on the 26/05/19 offsite

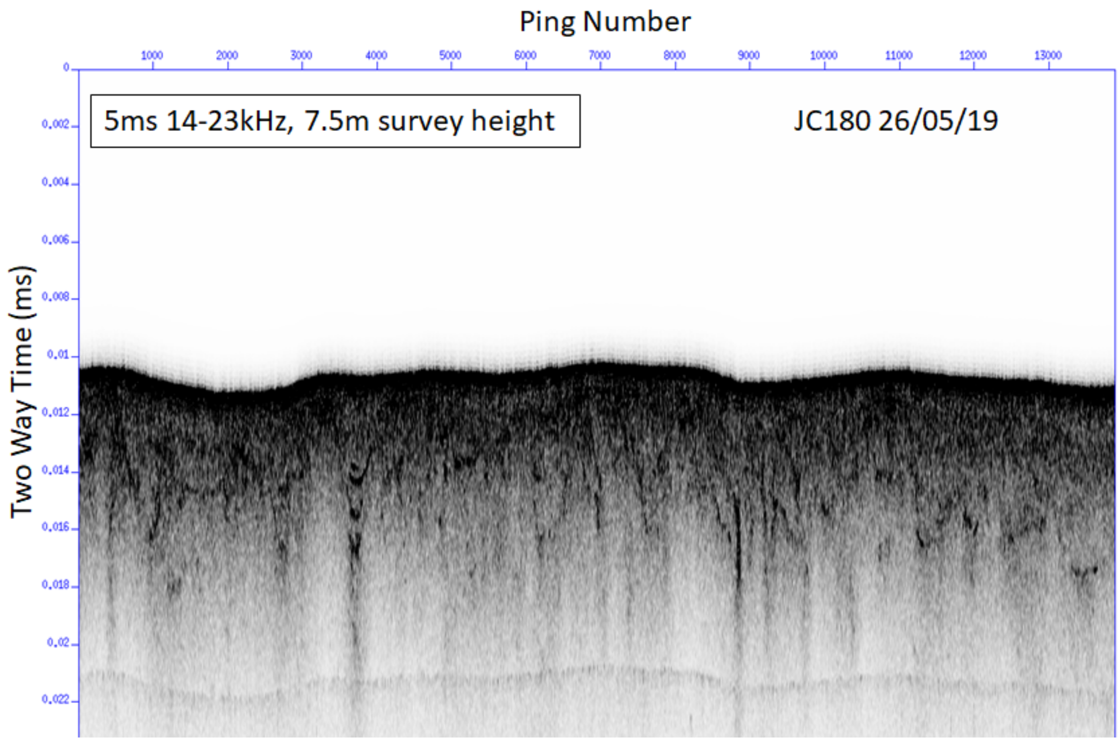


Figure 5.18. West to East GAVIA AUV profiles (mission 7) offsite.

5.3.3 On Site Gavia Sub-bottom 27/05/19

The eighth Gavia survey (Figure 5.19.) was conducted over the release site after injection was stopped. The survey at 7.5m height was composed of a dense grid of lines in a N S orientation ~180m in length at 2m spacing's and 4 EW lines at 50 m spacing. This was immediately followed by a survey at 2m with 12 line profiles orientated at 45° increments at 5m spacing. Figure 20 is a profile along the same line as the mid-release examples presented above, collected at 7.5m with a strong reflector located near where the pipe previously was.

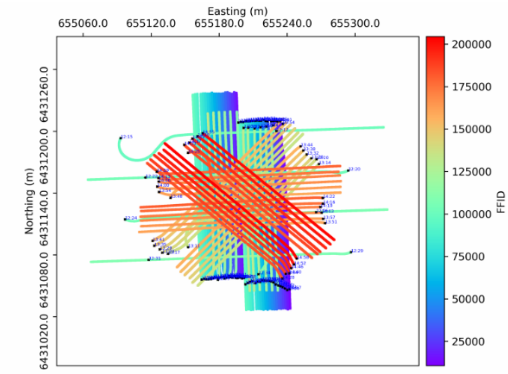


Figure 5.19. Gavia survey 8 conducted on 27//08/19 onsite

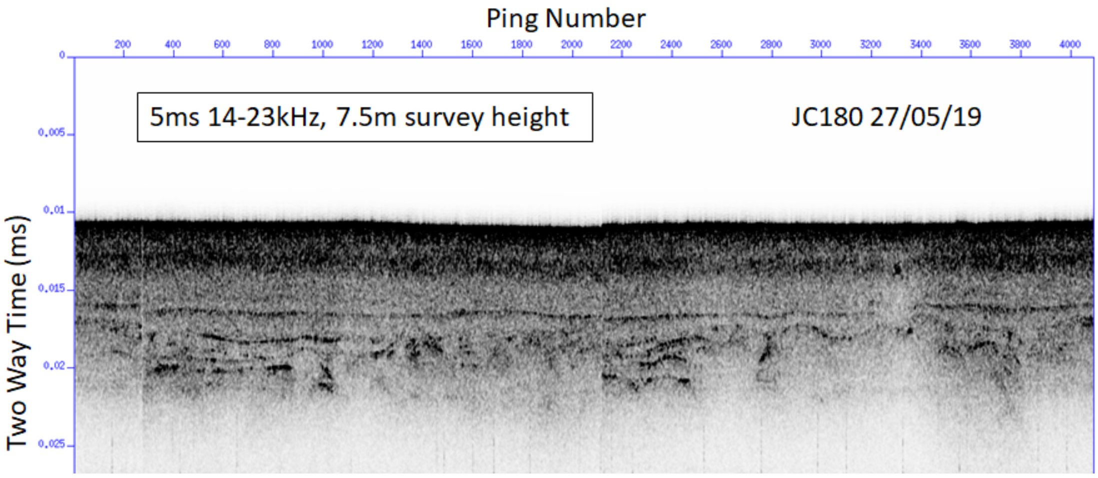


Figure 5.20. North to South (right side) GAVIA AUV profiles (mission 8) across the release site at 7.5m height. Visible on the right is the presumed seep site with a small strong reflector (a gas pocket).

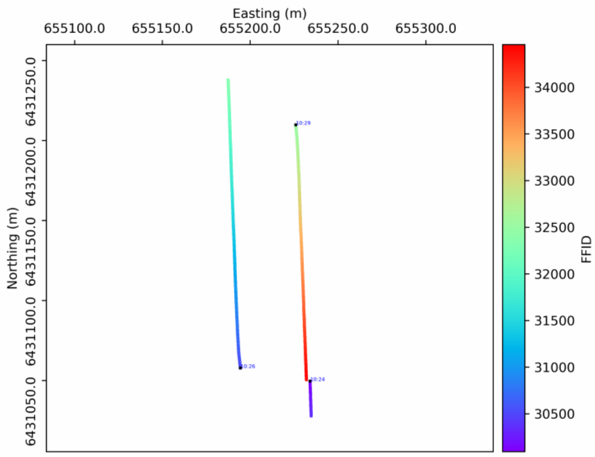


Figure 5.21. The position and orientation of Figure 20

5.4 Edgetech sub-bottom profiler on ISIS ROV.

The Edgetech profiler (transducer, and two separate parallel hydrophones), was connected to the base of the ROV at in a rear starboard position. The mid-point of the profiler was situated 2000.5 mm aft and 479.3 mm starboard of the ISIS navigation point (or c. 2.0 and 0.48 m respectively). The correlated data was recorded on the bottle on the ROV in JSF format, and topside in real time in both SEGY and JSF format. It was not obvious in the version of the sonar.ini file that was accessible from the ROV, what settings needed to be changed to record uncorrelated and correlated data, and **therefore only correlated, enveloped data were recorded.**

During the ROV dive (348), the correlated enveloped data could be seen in real-time in the Edgetech Discover software. The ROV data was as expected quite noisy especially when the vehicle was turning. The Discover software allowed alterations to the ping rate, but this caused a change in the sweep length. During the survey either a 1-9 kHz sweep of 40 ms duration at 4 Hz ping rate was used or a 1- 9 kHz sweep of 20 ms duration at 6Hz ping rate.
The ROV completed a survey on 1/5/19 over the positions of the two pipes inserted by the Cellula Robotics rig with Edgetech sub-bottom data collected between c. 17:44 and 20:10. The survey did 1 to 2 m spaced lines of 30 – 50 m in length perpendicular to each pipe, at least one profile along the approximate position of the pipe. For each pipe location the ROV also did a complete circumnavigation at c. 4 m distance, although this circuit data was particularly noisy.

The ROV supplied Doppler navigation (x,y), while the depth information was determined from a pressure sensor within the Edgetech system. All these values were successfully read into the SEGY headers for subsequent processing, taking into account the offset between the ROV navigation reference point and the mid-point of the Edgetech system. The data had minimal further processing which included trace mixing and an automatic gain control.

Penetration of the sub-bottom data was c. 12 ms TWT, but data was noisy. The data imaged the whole of the Witch Ground formation, and the top of the Coal Pit, but could not image the 4 cm diameter steel pipes in the sub-surface. See Figure 6 for a typical Edgetech image collected perpendicular to the position of the northern pipe.

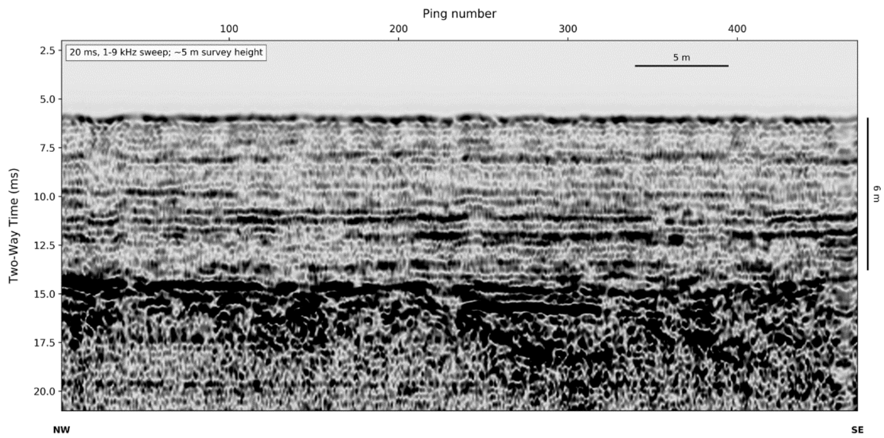


Figure 5.22. NW to SE **Edgetech sub-bottom profiler image collected at 5 m elevation with the system mounted on the bottom (aft, rear) of the ISIS ROV. This profile is taken perpendicular to the starting position of the northern pipe drilled by the Cellula Robotics rig. The pipe was seen visually entering the surface at around ping number 220 but cannot be imaged at depth.**

6 Optical Measurements: Ben Roche, Paul White (University of Southampton)

During JC180, video footage of bubbles escaping the vent site were filmed both at the seabed and up to 6m into water column in order to determine their size and dissolution rate.

6.1 Optical Lander

The optical lander (or bubble frame) was custom built for this cruise for the purposes of accurately measuring bubble sizes at the point of release. It has a light open design (Figure 6.1.) allowing it to be easily manoeuvred by the ISIS ROV and placed directly over the seep. On one side of the frame sits two camera housings externally designed and built to each hold a Sony FDR-X3000 Action Cam and external battery pack. Perpendicular to the cameras on the rear of the frame is a lighting panel which provides a clear backdrop so that the bubbles are more prominent and easier to identify with later detection algorithms. The batteries for the panel only last ~4 hours and must be activated on deck, meaning deployment of the optical lander must be the first priority of an ROV dive.

The top of the lander is comprised of an inverted funnel. The funnel is capable of catching 200ml of gas before buoyancy forces cause it to upturn, releasing the gas and reverting to its original position. Thus allowing a physical measurement of gas flux to be made by observing the frequency of tilts.

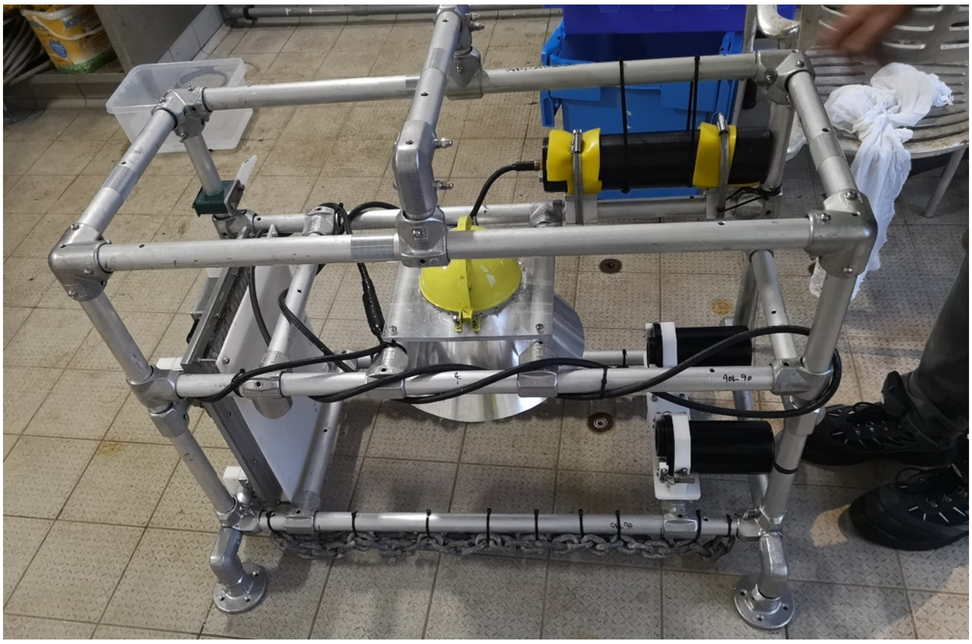


Figure 6.1. The Optical Lander; to the left is the lighting panel, in the centre the inverted funnel, in the upper right is the battery pack used to power the lighting panel and in the lower right are the two camera housings.

6.1.1 Optical Lander Deployment 1

The first deployment of the optical lander (Figure 6.2) on 12/05/19 was largely a failure. Despite the lighting panel working and the inverted funnel giving a flux rate of 0.008L/min consistent with other estimates from gas sampling, the camera housings proved not to be watertight. This was apparent when the lander was back on deck and water started pouring out of the them. This damaged the cameras and external batteries irreparably with the video files corrupted and unusable.

The cause of this failure was identified to be a small manufacturing fault in the camera housing. A screw designed to attach the lens cover to the main body of the housing pierced the housing creating an ingress point (figure 3). Whether this was a fundamental design flaw or a manufacturing error is yet to be determined.

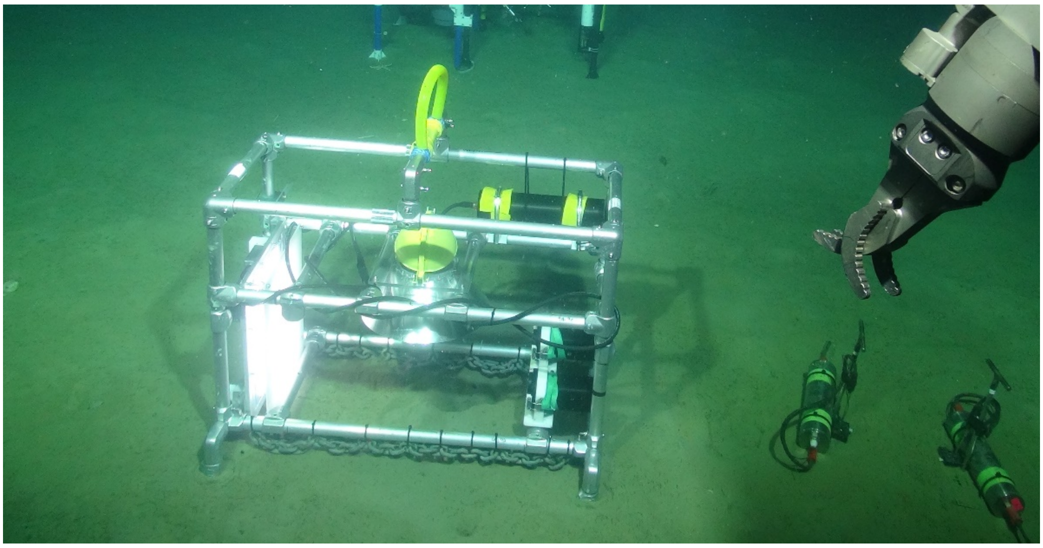


Figure 6.2. The Optical Lander on the Sea Bed over a seep during its initial deployment.

Figure 6.3. An internal view of the camera housing revealing the fatal screw that allowed water to enter. This was initially hidden from view as the Sony Action cameras sat directly over it.

6.1.2 Optical Lander Deployment 2

Repairs were successfully made to the camera housings by the engineering team and tested by lowering the housing to 110m depth over the side of the ship. The spare Sony action cam was then placed inside and attached to the frame alongside a GoPro Hero4 camera in an off the shelf housing rated to 500m. As before both were mounted facing perpendicular to the lighting panel. Additionally, the inverted funnel was slightly modified to ensure it would revert back to its starting position more reliably.

The 2nd deployment of the Optical Lander on the 15/05/19 was a success. Position over the largest pockmark in the release site we were able to record footage from two seep simultaneously, though only the gas from one was captured by the funnel. The GoPro recorded 26.5 minutes of footage from the seabed at 1080p and 90fps while the Sony Action Cam collected 90 minutes of footage from the seabed at 1080p and 30fps. Unfortunately, due to the relative position of the camera to the seep and the direction of the current the Sony footage is not often suitable for later bubble analysis.

Preliminary analysis suggests bubble diameters ranging from 0.5cm to 3cm

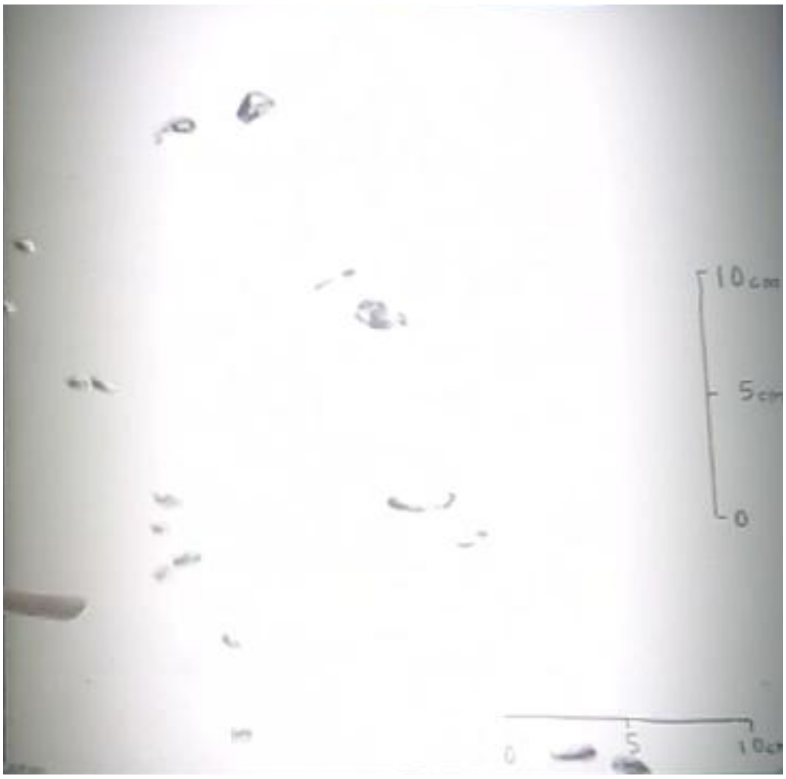


Figure 6.4. Example still from the GoPro on the 2nd deployment of the optical lander, recorded at 1080p 90fps.

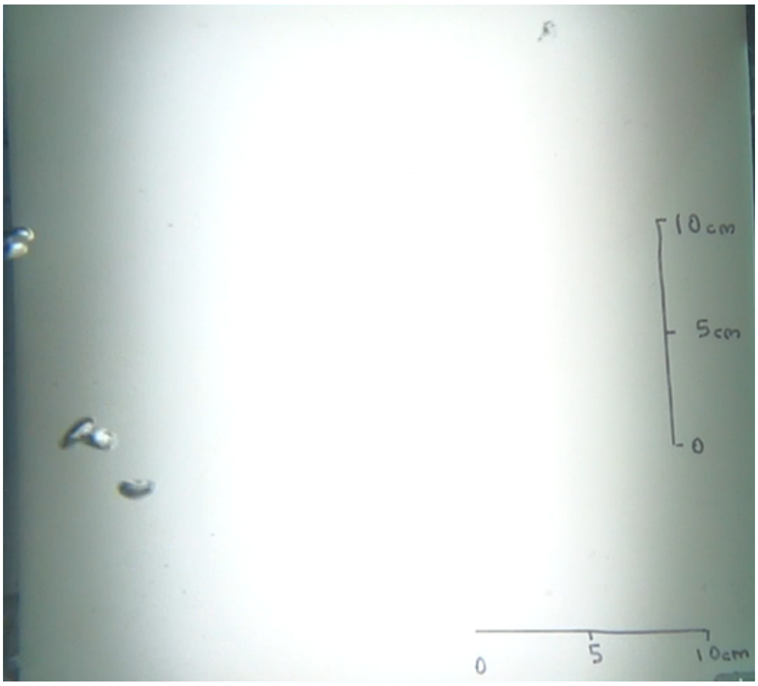


Figure 6.5. Example still from the Sony Action Cam on the 2nd deployment of the optical lander, recorded at 1080p 30fps.Bubble Screen

6.2 Bubble Screen

Following the successful deployment of the Optical Lander a new experiment was designed with the aim of measure bubble sizes at different heights in the water column to observe dissolutions rates. The lighting panel from the Optical Lander was removed and attached to a metal pole which acted as a handle for the ROV. The panel was held perpendicular to the ROV on board cameras and was positioned so that bubbles from a seep passed just in front of it. The ROV starting, at 2m off the seabed, would then rise in 0.5m increments, adjusting its position to keep the bubble chain visible.

The first deployment of the bubble screen on the 17/05/19 was partially successful, recording footage of bubbles at multiple heights in the water column though the currents made following a seep higher than 4m impossible. Waiting till slack tide solved this problem allowing us to follow plumes up to 6m up but meant the reduced power of the batteries supplying the lighting panel produced dim lighting making observations difficult. It was also noted that the ROV lights often produced a bubble shadow that would likely be problematic during later automated detection processes.

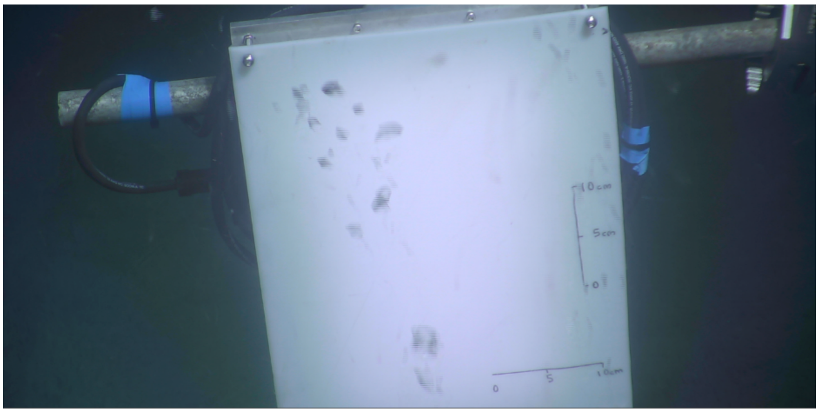


Figure 6.6. the bubble panel on the first deployment as seen by the Scorpio camera at 2m height

The second deployment of the bubble screen on 20/05/19 was more successful, recording bubble footage at up to 6m height. Here deployed was aligned with a slack tide making the plumes easier to follow whilst the lighting panel was still bright. Preliminary observations of the data suggest the largest bubbles seen at the sea bed 2-3cm in diameter were able to rise between 6 and 6.5m in the water column. The experiment was terminated because the ROV had other higher priority operations to perform.

Figure 6.7. The bubble panel on the 2nd deployment as seen by the Scorpio camera at 2m height

7 Passive Acoustic methods: Paul White and Ben Roche. University of Southampton

7.1 Aims

The goals of this component of the project is to demonstrate that passive acoustics can be used to detect, quantify and localise the sounds of bubbles as they are released into the water column.

7.2 Background

A bubble is formed as gas is released from the sediment into the water column. During this formation process, surface tension causes the bubble to attach to the sediment, and the buoyancy forces then distort the bubble's shape. When the bubble reaches a sufficient size, the buoyancy force overcomes surface tension and the bubble detaches and freely rises in the water. The breaking of the attachment leads to a release of energy, which causes the bubble to oscillate in volume and leads to the radiation of sound. It is this sound which we will detect. The frequency of the sound is defined by the natural frequency of the bubble's oscillations which follow a well-established theory, developed from the work of Minnaert, the amplitude of the oscillation (which controls the loudness the sound) is only known empirically, currently, with large uncertainty. We seek to show these sounds are detectable in the field, at depth and that the quantity of gas leaking can be estimated and further that the location of the leak can be determined.

Using Minnaert's work we anticipate that the sounds from the bubbles at 120 m water depth are likely to fall within the 1 kHz – 10 kHz frequency band (assuming the bubbles are of radii 1 – 10 mm (larger bubbles giving rise to lower frequency sounds).

7.3 Equipment

The majority of the acoustic data collection during the STEMM-CCS cruise was conducted using a pair of hydrophone walls, referred to as Hydrophone Wall 1 (HW1) and Hydrophone Wall 2 (HW2). The acoustic recording system which is at the heart of both walls is the RS ORCA (RS Aqua). The Orcas allow autonomous acoustic recording on 5 hydrophones simultaneously. For the cruise Geospectrum M36 hydrophones were selected with nominal sensitivities of -165 dB re 1 V/µPa. HW1 is the primary system and, as such, has an additional battery pack attached to allow the ORCA to record data for the full period of the cruise. HW2 lacks the additional battery pack, relying on an internal battery, which limits its deployments to shorter durations, 2-5 days. The role of HW2 is to allow data to be analysed during the cruise to understand the acoustic environment and to then modify protocols as necessary.
Each hydrophone wall comprised an aluminium frame on which the hydrophones were attached along with the body of the recorder which was sited at the bottom of the wall. Figure 1 shows a photograph of HW1, shortly before it was deployed by the ROV, and Table 1 shows the locations of the hydrophones for both walls, using a co-ordinate system with its origin at the base of the frame directly under hydrophones 1 and 4.

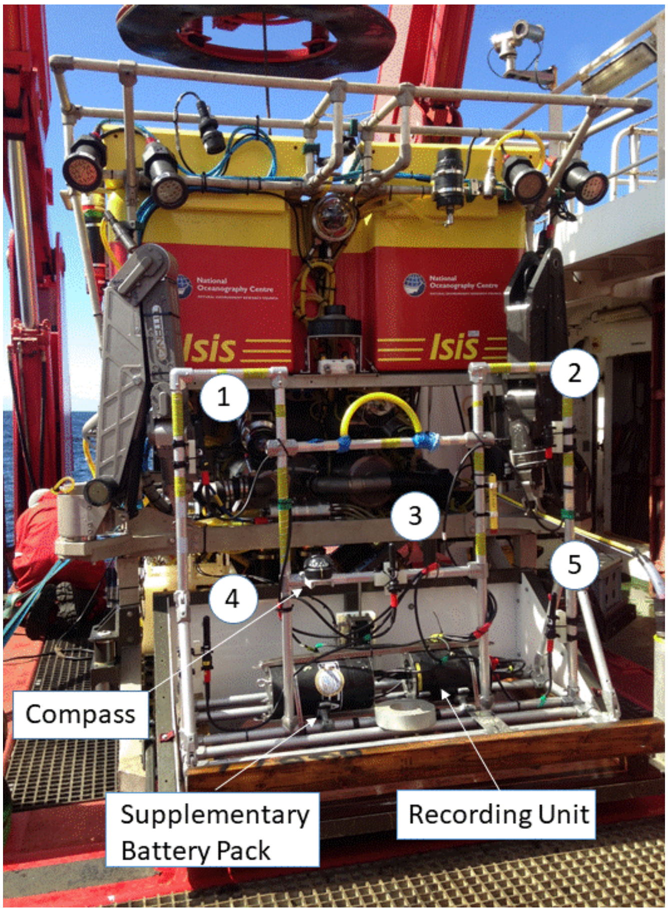


Figure 7.1: Hydrophone Wall 1 (HW1) Loaded on the ROV (ISIS) prior to deployment. Hydrophones are numbered and the elements of the system labelled.

Hydrophone	Location for HW1 (x,z) [m]	Location for HW2 (x,z) [m]
1	(0,1.06)	(0,1.10)
2	(1.23,1.06)	(1.3,1.10)
3	(0.62,0.61)	(0.61, 0.61)
4	(0.0.41)	(0,0.41)
5	(1.23,0.38)	(1.23,0.4)

Table 7.1: Hydrophone Locations on the two Hydrophone walls. Origin of co-ordinate system is below hydrophones 1 and 4 on the sea floor. x is the co-ordinate along the length of the wall, whilst z is the height above the bottom of the frame (y is defined perpendicular to the plane of the hydrophones, hence for all of the hydrophones locations y=0).

Recordings were made using these systems primarily at a sample rate of 96 kHz, with some HW2 data being collected at 48 kHz, all data was sampled with 16 bits of resolution. The recordings were made using a duty cycle of 5 mins recording and then waiting 5 mins before starting the next recording. Resulting in 50% temporal coverage of the acoustic environment and the collection of a total of 641 Gb of data contained in 2,800 files, each of 5 min duration and stored in wav format.

The ORCA allows one to select different gains for the preamplifiers in each channel of recorder. The gains for each wall were the same: with gains of 15 dB were used for hydrophones 1,2,4 and 5 and a gain of 30 dB selected for hydrophone 3 (the centrally located hydrophone).

In addition to the hydrophone walls, there was a recorder capturing data from a single hydrophone on the baseline lander, shown in Figure 6.2. The recorder was an SM4M recorder (Unit number S4A05592, Wildlife Acoustics ltd), using the hydrophone (serial #681945) with a nominal sensitivity of -155 dB re 1 V/µPa. This data was collected using a duty cycle of 5 mins recording, 25 mins off, so collected 2 five minute records every hour, at a sample rate of 32 kHz (16 kHz bandwidth) and 16 bits of resolution. This was deployed during the period from 11:00 on 27/4/19 until 19:00 on 24/5/19.

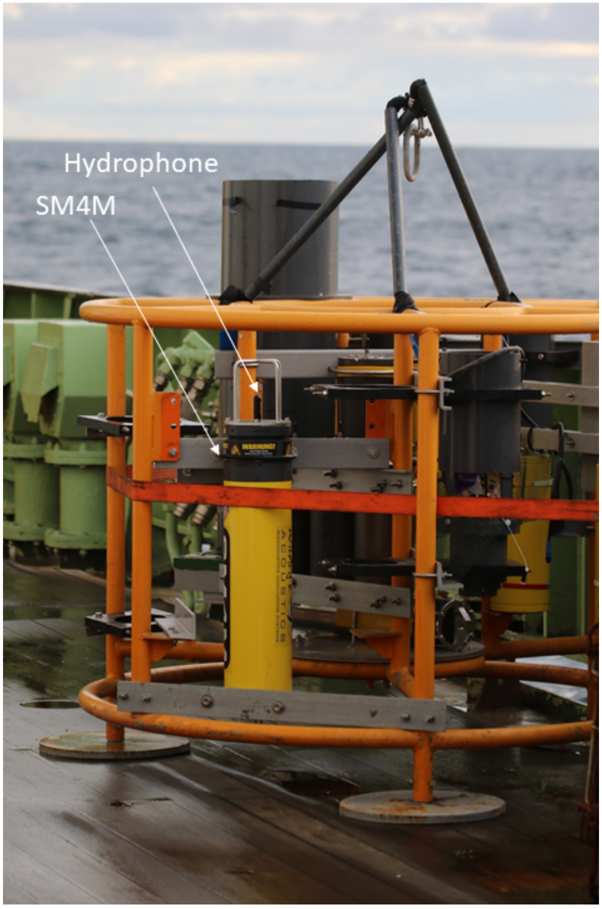


Figure 7.2: SM2M Acoustic Recorder on the Frame of the Baseline Lander

Upon recovery of the original Develogic lander, it was found that only 2 days' worth of acoustic background data was recorded. It is not clear what the cause of this failure was.

7.4 Deployment Details

There was at least one wall recording throughout the period from 7/5/19 to 22/5/19. Table 7.2 details the times at which the different hydrophone walls were in place and the sample rates used during those deployments.

Hydrophone Wall	Deployed Dive No.	Deployed Date and time	Recovered Dive No.	Recovered Date and time	Sample Rate
1	350	7/5/19, 13:49	367	16/5/19, 13:06	96 kHz
2	355	9/5/19, 18:06	364	15/5/19, 13:05	96 kHz
2	367	16/5/19, 13:01	372	19/5/19, 09:51	48 kHz
1	372	18/5/19, 21:25	381	22/5/19, 18:08	96 kHz
2	374	19/5/19, 19:24	380	22/5/19, 17:15	48 kHz

Table 7.2: Details of Deployments of Hydrophone Walls. The times shown are the times at which the walls reach, or depart from, the seafloor.

On retrieval of HW2 on 15/5 the data set was found to be shorter than expected. So at that point HW2 was recharged and redeployed, with a reduced sample rate (48 kHz, as opposed to 96 kHz) and HW1 returned to the ship to ensure it was functioning as expected. On inspection HW1 was operating correctly and it was recharged and redeployed at the next available opportunity (18/5/19).

Figure 7.3 illustrates the times at which the recorders were functioning. HW2 was sometimes deployed with a delayed start to the recording cycle, so whilst it may be deployed it is not always recording. There are two periods when HW2 was deployed but had reached the end of its battery life, so was no longer recording data. Note that during this time HW1 was fully functioning and so acoustic data was being collected.

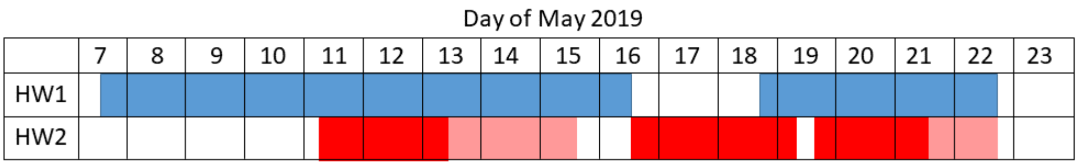


Figure 7.3: Recording times for HW1 and HW2. The light red shading represents the period for which HW2 was deployed but had ceased recording.

The sounds of the bubbles were quiet, especially when the gas flux was low, i.e. at the start of the experiment. Further, the activity around the site meant that there were comparatively high levels of background noise. This had been anticipated and the cruise's experimental program was designed to include periods when both James Cook and Poseiden were off-site, so that background noise is reduced to near ambient levels and to maximise the possibility of the acoustic system detecting the bubbles. In addition to these scheduled quiet periods several other periods were opportunistically created. These quiet times are detailed in Table 7.3.

Date	Start and End Time (Approx.)	Flow Rate (L/min std)	HW	Comments
8/5/19	20:00-14:00 (9/5)	0	1	Trip back to Aberdeen for regulator
12/5/19	13:00-14:00	2	1&2	Long ROV turn round, moved to 500 m
14/5/19	4:30-6:30	2	1	Scheduled quiet time
16/5/19	17:00-21:00	10	2	Medical emergency. JC leaves site, but Poseiden did move in, not clear if there is a quiet period here.
17/5/19	05:00-06:00	10	2	Scheduled quiet time
19/5/19	20:20-21:10	50	1&2	Interval between JC leaving and Poseiden coming on site. Loud impulses, stopping somewhere between 21:05 and 21:10.
20/5/19	04:00-06:20	50	1&2	Scheduled quiet time, delay in JC leaving site, meant Poseiden was also late and it is not clear there was any quiet time in the change-over between vessels. Some useable data.
20/5/19	17:40-19:30	50	1&2	During ROV turn around moved to 1 km, to create a quiet time.
21/5/19	15:00-07:30 (22/5)	50	1	ROV breakdown, ca 11:00, so move to site for Garvia survey, 2.5 km North of site. Poseiden not in the vicinity.

Table 7.3: Lists the quiet times, i.e. periods of reduced activity (lower noise). The table also shows the CO_2 injection rate on each occasion and lists the hydrophone walls (HW) which were deployed at the time.

7.5 Background Noise

In order to detect the sounds from bubble formation one needs to be able to measure these sounds against those of the marine environment. In this experiment, for a great deal of time, that noise will be dominated by the sounds associated with the research vessels and the ROV. So, as discussed the preceding section, quiet periods are intended to give times when these noises are greatly reduced. It is worth understanding the character of the noise environment when there is activity on the site. Figure 7.4 shows a typical power spectrum of the acoustic signal measured when the ROV is deployed (and, hence, the James Cook is in the vicinity). We can observe in the spectrum some discrete lines associated with the sonars on the James Cook that were activated at this time. These sonars are the EK60 (which emits 18 kHz, 38 kHz, 70 kHz, 120 kHz and 200 kHz) and the EA640 depth sounder (10 kHz). Whilst these signals fall outside the band of primary interest, the individual pulses are loud and can cause the measurements to saturate, resulting in loss of information.

The aft and bow thruster emit energy predominantly at the frequencies: 2440 Hz, 2560 Hz and 3760 Hz. There exist, along with these components a rich set of harmonics and broadband components.

Figure 7.4 shows two spectra, the blue one representing the noise measured when the ROV was deployed and the red one the noise with it on deck. From both curves one can see spectral peaks at frequencies associated with the EK60 and EA640, specifically at 10, 18 and 38 kHz. Comparing the spectrum of data with the ROV in the water with a period when the ROV is on deck, allows us to understand the contribution of the ROV to the underwater noise. Figure 4 suggests that the ROV primarily generates noise in the 20-35 kHz range, significantly higher than that we wish to use to study the bubbles. In Figure 7.4 there is a line corresponding to the 3760 Hz component which appears to be from the thrusters on the James Cook.

Other potential source of noise are the other instrumentation on the sea bed (benthic boundary lander (BBL) and the benthic chamber (BCH) both have electric motors on them (the BBL does have a Doppler velocity device, but that operates a 60 MHz). In the quiet data sets there are times when noise believed to be from these experiments is evident, but outside the band of interest, i.e. above 10 kHz.

To reduce the background noise levels the EK60 was turned off on the James Cook on 15/5/19.

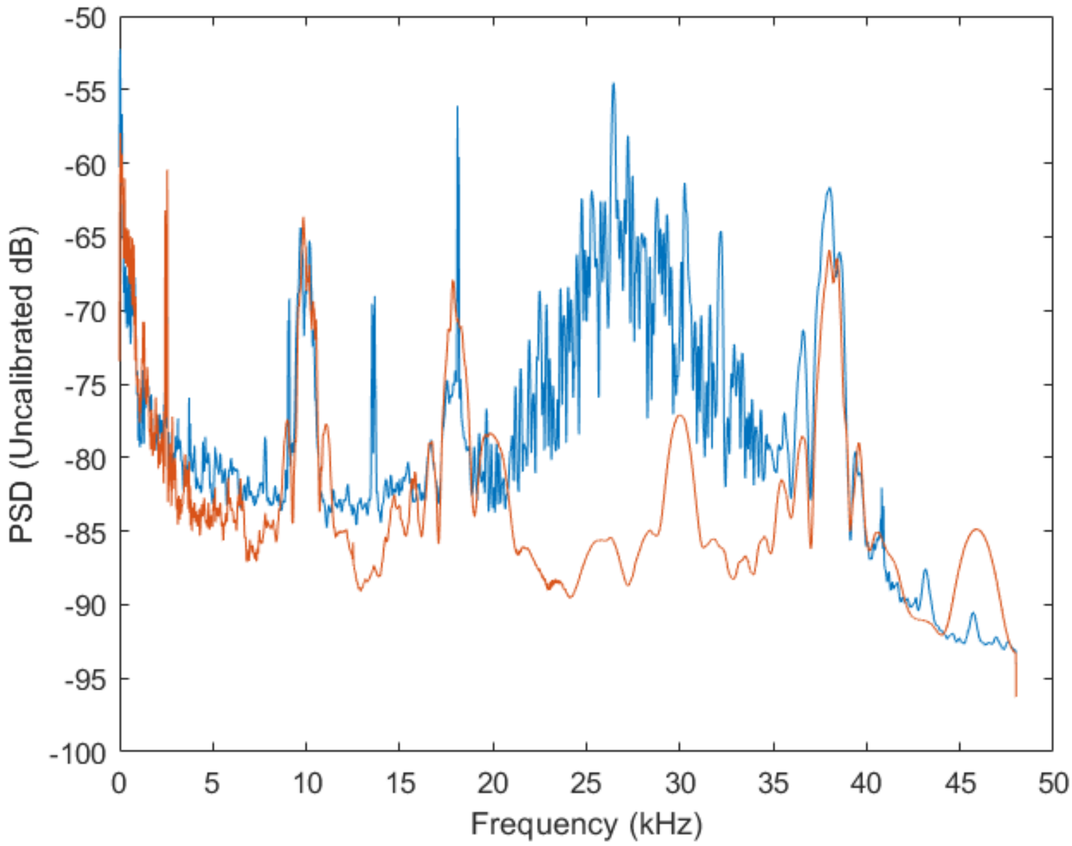


Figure 7.4: Spectrum of two 5 min Sections. Computed with a resolution of 3 Hz. The blue curve shows data collect when the ROV was deployed with the red curve showing data between ROV deployments, so the ROV noise is absent.

It should also be noted that the noise increases significantly at low frequencies. This is a common trend in underwater noise measurements, but in this instance the noise is generated from a distant, high energy, anthropogenic source. In these data the low frequency data is contaminated by high energy pulses, which occur roughly every 7 s.
Figure 5 shows the kurtosis computed for the band 20 Hz – 200 Hz for the baseline lander. The kurtosis is a measure of impulsiveness and filtering to the 20 Hz -200 Hz means that this measures predominantly the sound of these distant impulses. There is a hiatus in the appearance of these impulses between the morning of 2/5/19 and early on 7/5/19. The cessation of activity is most likely the consequence of the bad weather during that time, the fact that neither research vessel was present during this period means that ambient noise returns to a near Gaussian state with a kurtosis close to 3 (or log kurtosis of 0.477, shown a horizontal dashed line in Figure 7.5).

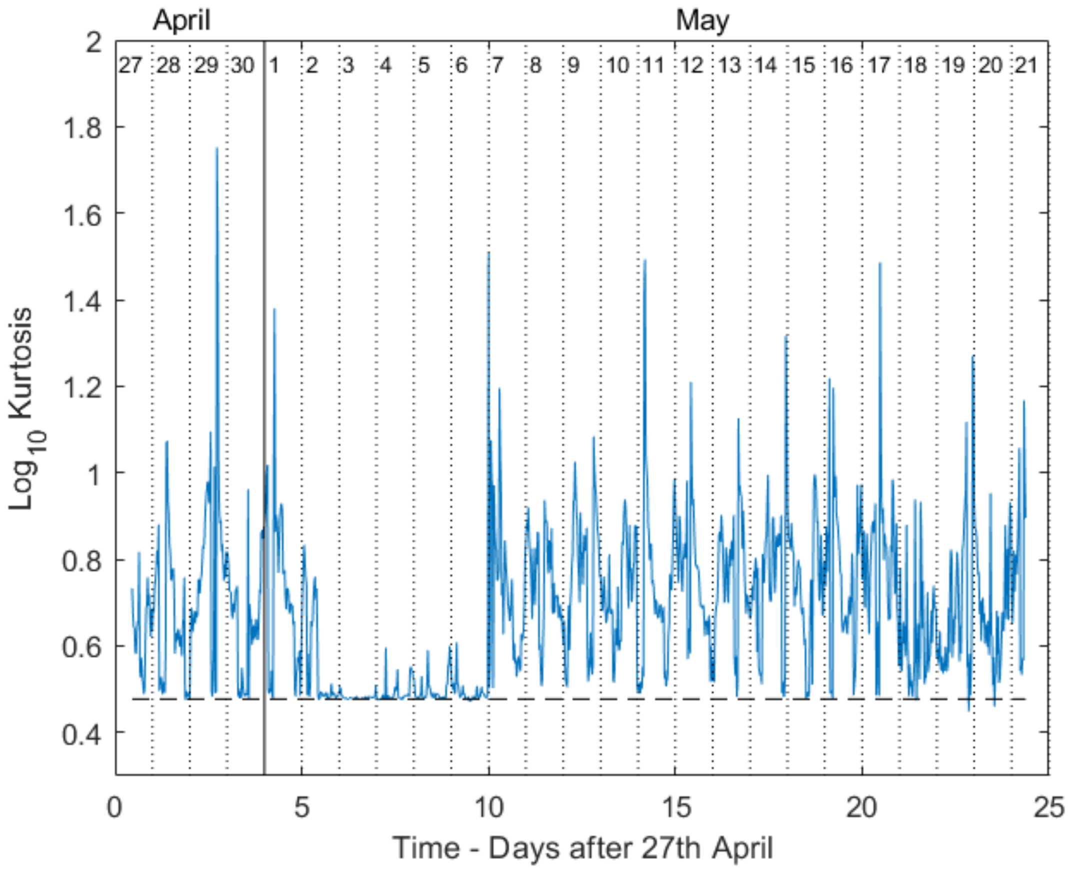


Figure 7.5: Kurtosis of the Low Frequency Component of the Acoustic Data on the Baseline Lander. This measure largely reflects the degree of low frequency impulsive noise on the site. The horizontal dashed line represents the value of 0.477 which is the value associated with Gaussian noise.

Each pulse shows the characteristic dispersion relations associated with modal propagation in shallow water. Figure 7.6 (a) shows the spectrogram of a single pulse. The 3 high energy bands below 100 Hz represent the first 3 propagating modes. Assuming a constant water depth of 120 m and a sound speed of 1480 m/s one can fit theoretical curves to these measurements and in so doing, estimate the range to the source, this fit is shown in Figure 7.6 (b). In this case resulting in an estimated range to the source of 120 km.

This noise is likely to be the consequence of either a seismic survey or construction (pile driving). Given that is it observed throughout these measurements, it seems most reasonable to assume it is a seismic survey, piling tends to have down-times as one pile is completed and the next prepared.

Whilst the majority of the energy in these pulses is less than 100 Hz its energy does extent upwards and contaminates the lower end of the band we are interested in.
The impulsive sound shown in Figure 6 is the one which is present for most of the time, but there are periods when sound from a second similar impulsive source is also present and this second source is louder and closer than the one illustrated here.

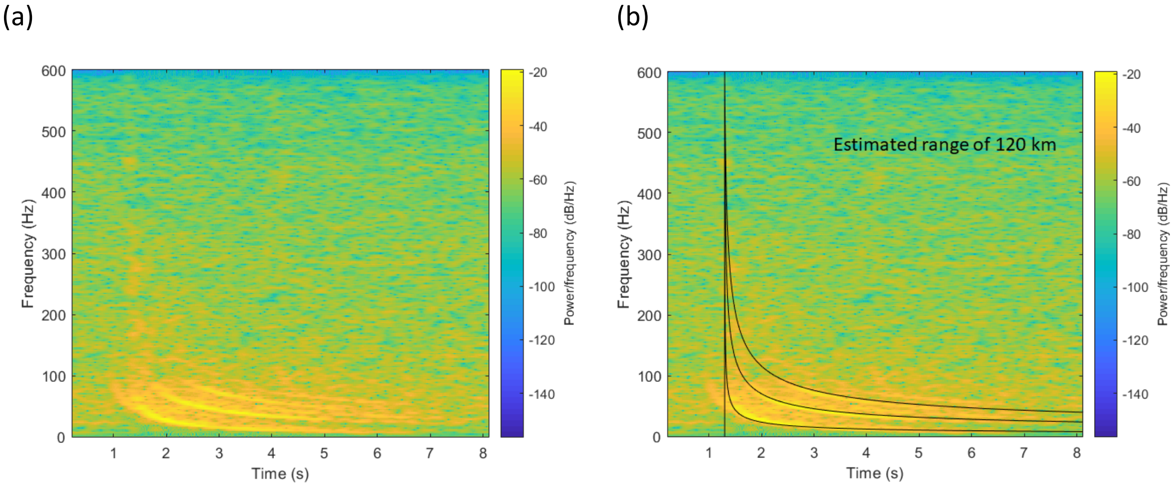


Figure 7.6: Spectrogram of single low frequency pulse. (a) Shows the raw spectrogram, (b) Shows that same spectrogram with solid lines representing the predicted arrival times of the first 3 modes, assuming c=1480 m/s, constant water depth of 120 m and a source range of 120 km.

7.6 Overview of the Acoustic Dataset

To understand the evolution of the sound field over a period of time one can compute a long-term spectrogram (LTS). For these datasets an LTS is computed by estimating one spectrum of for each of 5 min recordings. The spectra are then stacked vertically to produce a time vs frequency plot (akin to a spectrogram) but with each line representing 5 mins of data and there being 6 lines an hour (recall the recording duty cycle of 5 mins on 5 mins off). The LTS is a way of providing an overview of a large quantity of data.

Figure 7.7 shows an LTS of the data collected over the 2 deployments of HW1. Note the absence of data on the 17th May, and short datasets on 16th and 18th, all due to the retrieval and redeployment, as described in Table 7.2.

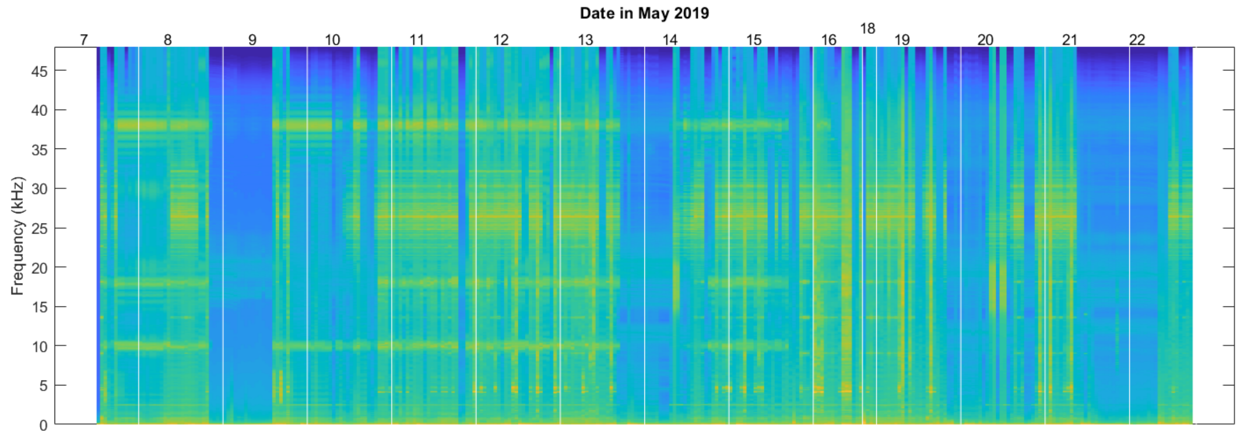


Figure 7.7: Long-Term Spectrogram for the HW1 dataset, showing the full deployment from 7/5/19 to 22/5/19.

Examining the data in Figure 7.7 one can see the quiet periods detailed in Table 7.3, the termination of the spectral lines at 18 kHz and 38 kHz on 15/7/19 corresponds to the point when the EK60 was turned off. The deployments on the ROV appear when the energy in the 25-30 kHz region is large. The periods when the thrusters of the James Cook are being used heavily generates bands at 4 kHz which can also be seen in this figure.

7.7 Bubble Sounds

During the quiet periods the sounds of bubbles can be heard on the data from the hydrophone walls, with varying degrees of clarity (depending on the flow rate and the levels of the competing noise sources). The clearest bubble sounds are heard during the period 21/5/19 to 22/5/19. Figure 7.8 shows an averaged spectrogram, i.e. the result of averaging the spectrograms across the 5 acoustic channels, for the data from HW1 at midnight between 21st and 22nd May. The near vertical features, some of which have been circled, represent the sounds made by the bubbles.

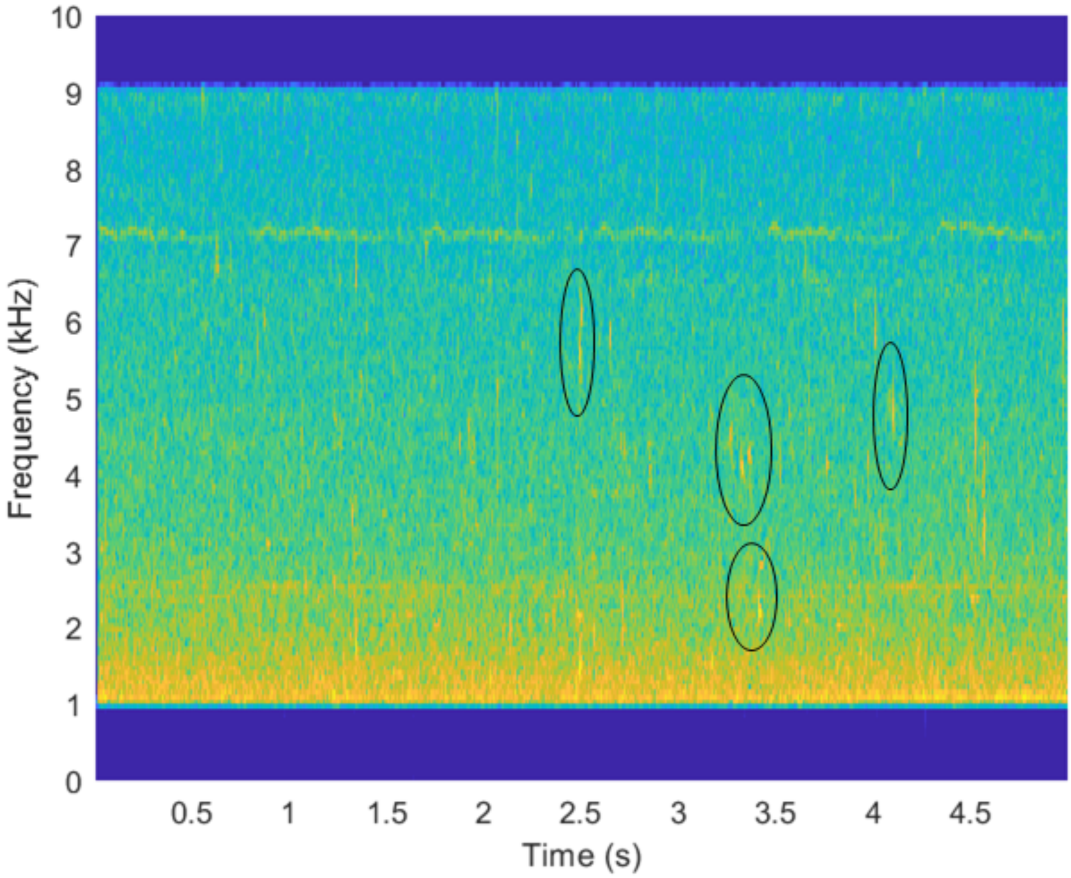


Figure 7.8: Averaged Spectrogram of Data at 00:00 on 22/5/19. Circled areas show a few examples bubble signatures visible in this plot

Forthcoming work will take these acoustic data, will apply calibrations to them, along with implementing a beamformer to reduce the noise. This will then allow the estimation of the gas flux.

8 Sediment Core Geochemistry: Kate Peel, Douglas Connelly, Chris Pearce (NOC) and Anita Flohr (University of Southampton)

8.1.1 Background and aims

The aim of the sediment sampling and analyses during this cruise was to search for chemical indicators of CO_2 movement through the sediment profile, including the displacement of pre-existing porewaters and changes driven by the dissolution or reaction of CO_2 within the sediments, and to monitor how these changes progressed over the course of the experiment. Push cores were taken from specific locations using the ROV at regular intervals throughout the experiment, including pre-release background samples, under each gas flow rate, and post-CO_2 release. Sample sites were chosen to assess the spatial impact of CO_2 migration through the sediment and its relation to the visible points of CO_2 release on the sediment surface. The push cores provide targeted high resolution samples at the sediment-water interface to complement the deeper 3m gravity cores collected after the experiment by the RV Poseidon.

Alkalinity and sediment pH analyses were conducted onboard the James Cook to give a preliminary indication of the changes occurring within the sediment over the course of the experiment and to help guide sampling strategies, while sediment and porewater samples were separated and preserved for post-cruise geochemical analysis.

8.1.2 Sampling

Up to six 30cm long x 8cm diameter push cores were taken with the ROV on selected dives at each stage of the release experiment. The location of the coring was selected whilst watching the live camera to be as close as possible to visible bubbling vents, within the constraints of ROV manoeuvrability and other equipment present on the sea floor. Background cores were taken in advance ~50 m from the active site. Details of sample locations and relative positions are given in Table 8.1 and 8.2

Gas flow l/min	start date	start time GMT	core set no.	coring date	coring time (start) GMT	ROV no.	Depl no.	Lat. N	Long. W	water depth m
0			1	07/05/2019	10:12	349	20	57' 59.672	00' 22.479	118.0
2	11/05/2019	15:19	2	12/05/2019	10:56	358	31	57' 59.680	00' 22.447	118.7
5	14/05/2019	15:27	3	15/05/2019	09:12	363	38	57' 59.670	00' 22.486	119.4
10	15/05/2019	06:48				370	47	57' 59.676	00' 22.459	119.4
30	17/05/2019	16:54	4	18/05/2019	10:34	376	55	57' 59.680	00' 22.434	117.9
50	19/05/2019	15:50	5	20/05/2019	07:26					
0	22/05/2019	11:17	6	26/05/2019		381	65			

Table 8.1 Coring events during stages of release experiment.

Core set	ROV no.	ROV core no.	location description	Core label Geochem	sampling type
1	349	B3	background	A	solid phase
		R1	background	D	PW sliced on bench
		R3	background	B	PW standing in glove box
		B2	background	C	PW standing in glove box
2	358	B3	close to regular bubble stream pos. 1. 2cm away	A	solid phase
		B2	other side of vent, 4cm away	B	PW sliced in glove box
		B1	25cm from vent	C	PW sliced in glove box
		R3	50cm from vent	D	PW sliced in glove box
		R2	75cm from vent	E	PW sliced in glove box
		R1	100cm from vent	F	PW sliced in glove box
3	363	R1	close to vent hole	A	solid phase
		R2	close to vent hole	B	PW sliced in glove box
		R3	25cm from vent	C	PW sliced in glove box
		B1	50cm from vent	D	PW sliced in glove box
		B2	75cm from vent, taken to East to replace first dropped core	E	PW sliced in glove box
		B3	100cm from vent	F	PW sliced in glove box
4	370	Y1	near far left sporadic vent	B	PW sliced in glove box
		Y2	8cm to south-west of Y1	C	PW sliced in glove box
		Y3	6cm south of Y2	A	solid phase
		B1	west from Y3, visible gas flow when pulled out tube	D	PW sliced in glove box
		B2	south of big vent, next to small vent	E	PW sliced in glove box
		B3	west of B2, near big hole	F	PW sliced in glove box
5	376	B3	centre of site, between active and large extinct pockmark	A	solid phase
		B2	centre, east of active pockmark	C	PW sliced in glove box
		B1	centre, 5cm north of B3	B	PW sliced in glove box
		Y3	centre, 5cm north of B2	F	PW sliced in glove box
		Y2	centre of site	E	PW sliced in glove box
		Y1	centre of site	D	PW sliced in glove box
6	381			A	
				B	
				C	
				D	

Table 8.2 Push core positions and handling information.

The push cores were taken towards the end of the dive to minimise the time between coring and core processing, and transferred upright to a Controlled Temperature (CT) Lab at 7°C as soon as possible after recovery on deck.

8.1.3 Core handling and sub-sampling

Of the six cores taken each dive, one was used for solid phase sediment sampling, and 5 for porewater extraction.

The outer casing of the coring assembly was removed first, leaving the base with bung attached in the bottom of the core tube, the top bung (with ROV T handle) was then removed, and the core examined and photographed. An example is shown in Figure 8.1. A 10ml sample of the water at the sediment interface was taken with syringe and treated as for porewater (details below), any remaining water was removed.

Figure 8.1 Left: push core tube assembly, right: example sediment core

The whole core was then immediately transferred to a nitrogen filled glove-box to minimise contact with atmospheric oxygen (Figure 8.2 a) The bung was removed from the base of the core and it was moved onto a core extruder, the core tube could then be lowered gradually exposing the sediment at the top (figure 8.2 b) Successive layers were sliced and removed with a plastic plate in 1cm depth intervals for the top 10 cm, then 2cm intervals until the bottom was reached. The slices of sediment were put into 50 ml centrifuge tubes with holes pre-drilled in the lids. Water was extracted with Rhizon Soil Moisture samplers (Rhizon CSS: length 5 cm, pore diameter 0.2 µm; Rhizosphere Research Products, Wageningen, Netherlands). These samplers consist of a small microporous polymer tube that is supported by a stabilizing glass fibre wire and connected to a PVC tube[1]. The porewater was extracted by attaching a syringe held open to maintain a negative pressure (Figure 8.2 c and d) The negative pressure was reapplied several times over several hours to extract the maximum amount of porewater from the sediments. Between 2 and 10 ml of porewater was extracted from each section in this way.

a) b) c) d)

Figure 8.2 a) nitrogen filled glove box in CT lab; b) extruding and slicing a core inside the glove box; c) and d) porewater extraction from sediment slices with rhizon and syringe.

Following extraction porewater was sub-sampled into different vials (Figure 8.3) for subsequent analysis as follows:

i) 2.2ml into a glass vials for DIC/$\delta^{13}C$ with no headspace;
ii) 2.2ml into a glass vials for $\delta^{18}O/\delta D$ with no headspace;
iii) 1ml into a plastic pot for Total Alkalinity (TA);
iv) 2ml in an acid cleaned Nalgene bottle for cations;
v) 1ml into an Eppendorf tube for anions;
vi) 1ml into a plastic pot for nutrients.

When limited water was extracted, analytes were prioritised in the order above.

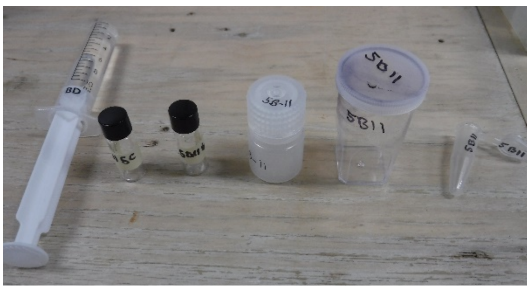


Figure 8.3 vials used for sub-sampling; from left: water extracted with syringe; glass vials for DIC/$\delta^{13}C$ and $\delta^{18}O/\delta D$; acid-washed Nalgene bottle for cations; plastic pot for TA and nutrients; Eppendorf tube for anions.

Samples for cation analysis were preserved by addition of 10µl sub-boiled nitric acid, and samples for DIC/$\delta^{13}C$ and $\delta^{18}O/\delta D$ were poisoned with 5 µl of saturated mercuric chloride solution. Samples for anion analysis were kept refrigerated and nutrient samples were frozen at -20°C.

For solid phase sediment sampling one core was sliced in the same way as for porewaters. For each sediment slice, 3cm^3 of sediment was measured using a cut down cylinder of a syringe, put into a pre-weighed pot and kept refrigerated for subsequent porosity measurement. The remaining sediment was bagged and frozen at -20°C for elemental content, stable isotope ratios and grain size analysis.

8.1.4 Analytical methods

Total Alkalinity measurements were conducted on board within 1-2 days of sample extraction by titration using a Metrohm 775 Dosimat (Figure 8.4 a). Sample volumes of 0.5 – 1 ml were titrated against 0.0004M HCl (for low TA samples) or 0.002M HCl (high TA samples), using a mixture of methyl red and methylene blue as an indicator, which turns from green to pink at the end-point (Figures 8.4 b-d). Nitrogen gas was bubbled through the solution throughout the procedure to mix the acid and remove the CO_2 produced. Analyses were calibrated against IAPSO seawater standard measured in triplicate at the beginning of each analytical session. Accuracy and precision were monitored by regular measurements of the IAPSO standard interspersed with the samples.

a) b) c) d)

Figure 8.4 a) Metrohm 775 Dosimat Titrator; b) to d) colour change from green to pink during titration.

Sediment pH was measured on solid phase samples in small bags prior to freezing. The probe was inserted into the sediment and the reading allowed to stabilise for ~30 mins.

At NOC Southampton, porewater cations will be analysed by ICP-OES/ICP-MS; anions (chloride, fluoride, sulphate, bromide) will be measured by ion chromatography; and nutrients (ammonium, silica, phosphate) will be measured by nutrient auto-analyser. DIC concentration will be analysed by Apollo Infra-Red and $\delta^{13}C_{DIC}$ by Gasbench – IRMS. Analysis of $\delta^{18}O$ and δD will be carried out by a third party (University of Oxford).

In the solid phase, porosity will be measured by weight loss on drying, total carbon and nitrogen content and $\delta^{13}C_{TC}$ by EA-IRMS; total organic carbon and $\delta^{13}C_{OC}$ by EA-IRMS following acidification; and total inorganic carbon and $\delta^{13}C_{IC}$ by difference. Particle size of the sediment will be measured by Malvern Mastersizer.

8.1.5 Preliminary results

All sediments consisted of a uniform fine sandy clay; which was progressively drier down core. pH measurements were fairly consistent around 7-8 with no obvious trends.
TA ranged from 2.3 mmol/l, typical for seawater, in background cores and those further from bubble vents, up to 44 mmol/l at active sites on the highest flow rate of 50 l/min. Examples of downcore TA profiles are shown in Figure 8.5.

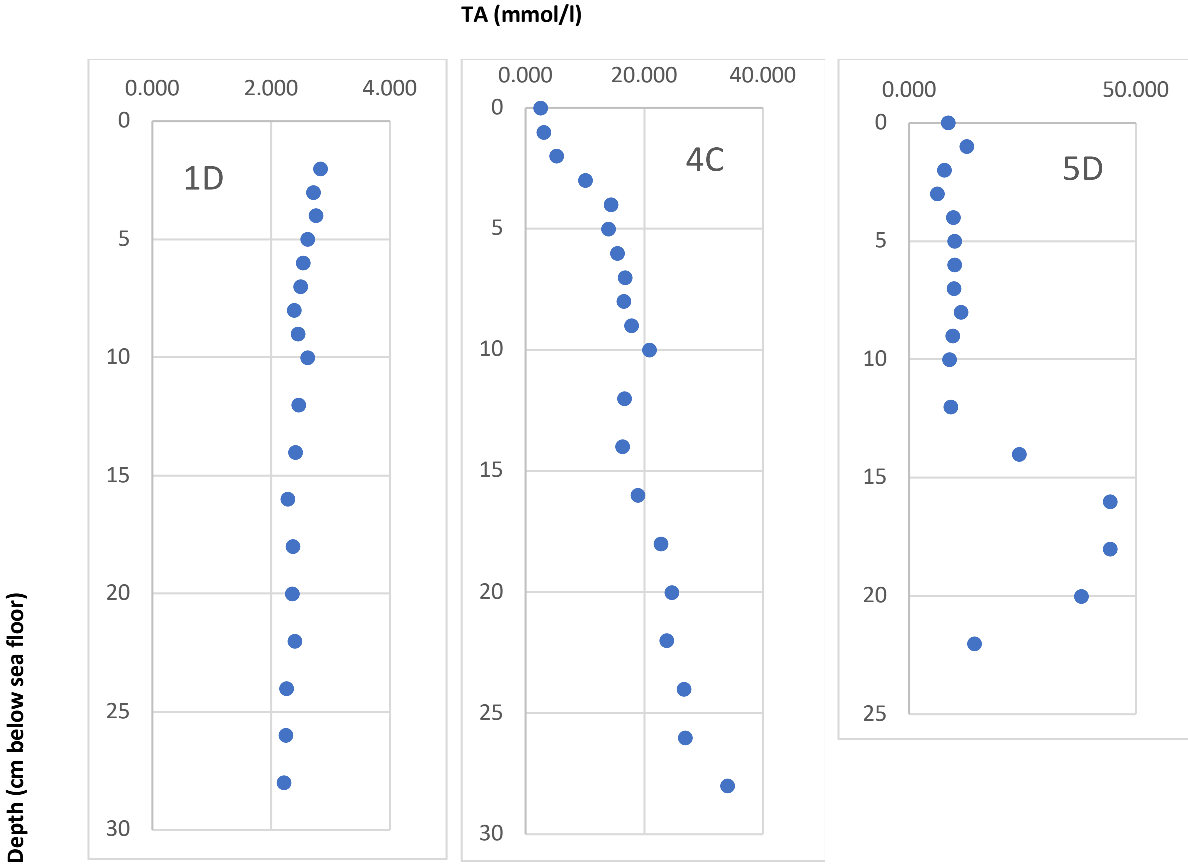


Figure 8.5 Total Alkalinity measured on porewaters: 1D) backgound site; 4C) close to bubble vent at 30 l/min flow; 5D) centre of several bubble vents at 50 l/min.

8.1.6 References

[1] Seeberg-Elverfeldt, J., Schlüter, M., Feseker, T., & Kölling, M. (2005). Rhizon sampling of pore waters near the sediment/water interface of aquatic systems. Limnology and oceanography: Methods, 3(8), 361-37.

9 Artificial and natural tracers: Anita Flohr (University of Southampton), Jonas Gros and Isabelle Mekelnburg (GEOMAR), Kate Peel, Doug Connelly and Chris Pearce (NOC)

9.1 Objective

One of the objectives of STEMM-CCS WP4 is to investigate the utility of tracers for CO_2 leakage detection, attribution and quantification. During JC180 we used a combined approach of natural, inherent tracers ($\delta^{13}C$, $\delta^{18}O$) and a set of non-toxic, artifical tracer gases (octafluoropropane (C_3F_8), sulfur hexafluoride (SF_6) and krypton (Kr)) to derive estimates on the fraction of CO_2 dissolving in the pore water of the sediment and in the water column as a function of injection flow rates.

9.2 Methods

9.2.1 Tracer injection

The gases used as artificial tracers during the release experiment were octafluoropropane (C_3F_8), sulfur hexafluoride (SF_6) and krypton (Kr). These gases are non-toxic, chemically stable and show very low background concentrations. A concentrated mix of these trace gases (0.11% C_3F_8, 1.77 % SF_6, 58.7 % Kr, 39.5 % CO_2; BOC UK) was filled into 2 x 50 L accumulators (30 bar filling pressure) positioned on the gas rig. During the release experiment the tracer mix was injected into the CO_2 at a constant ratio of CO_2:tracers = 10.000:1 to yield a final concentration of tracers in the injection CO_2 of approximately 0.1 ppmv C_3F_8, 1.8 ppmv SF_6 and 60 ppmv Kr. This ratio was kept constant for all injection flow rates throughout the release experiment. Tests prior to the gas rig deployment showed that the CO_2 in the gas tanks contained CH_4 (~58 ppmv) which was used as an additional tracer.

9.2.2 Gas sampling

Gas was sampled using gas bubble samplers (GBS) (Corsyde, Germany) (Fig. 9.1) with an internal volume of 500 mL. Prior to sampling, the samplers were flushed with N_2 for several minutes and then evacuated to ~$2x10^{-5}$ bar. The samplers were attached to the lid of a box on the ROV's sliding arm (Fig. 9.1). Gas was collected once or twice a day depending on the ROV schedule. Gas was sampled at (i) the gas rig sample point, (ii) the seep directly above the sediment and (iii) from 0.5-2m above the seafloor. The time needed to fill the funnel with gas was noted to derive an approximate estimate of the gas flow rate.

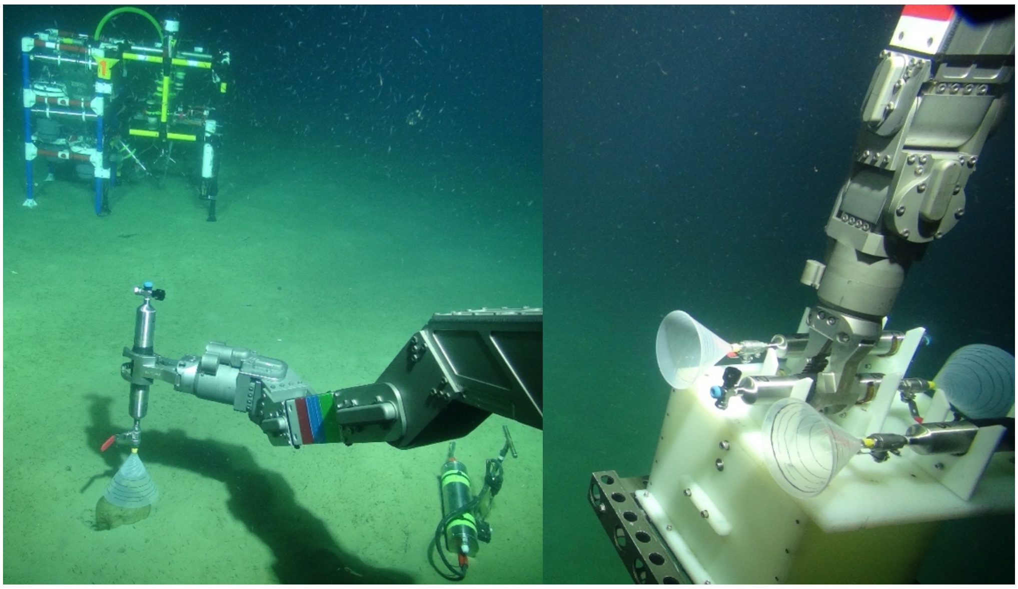


Figure 9.1 Gas bubble sampling (photos courtesy of NOC).

9.2.3 Gas measurements

A flow-through Fourier-Transmission Infra-Red (FTIR) analyser (*atmos*FIR, Protea Ltd UK) (Fig. 9.2) was used to measure the gas composition with respect to CO_2, CH_4, SF_6 and C_3F_8. **Prior** to sampling the GBS was warmed up by flushing with hot water to increase internal pressure and thus measurement time. The GBS was connected to a regulator to reduce the outlet pressure to 10 psi (~0.7 bar) above atmospheric pressure. The gas then passed a water trap ($Mg(ClO_4)_2$), a temperature logger (Lascar Electronics) and the sampling port before entering the analyser (at 0.2 mL/min). The sampling port allowed for retrieving discrete samples for later analysis of $\delta^{13}C_{CO2}$, $\delta^{18}O_{CO2}$ signature and Kr composition of the gas.

Prior to every measurement of gas samples, the gas line was flushed with nitrogen (N_2) to determine the background followed by flushing with a secondary calibration gas containing 30 ppmv of C_4F_{10} (both at a pressure of 10 psi and a flow of ~0.2 mL/min). The sample line was then flushed with the gas sample. A drop of C_4F_{10} to background values indicated that the gas line was fully flushed with the sample gas.

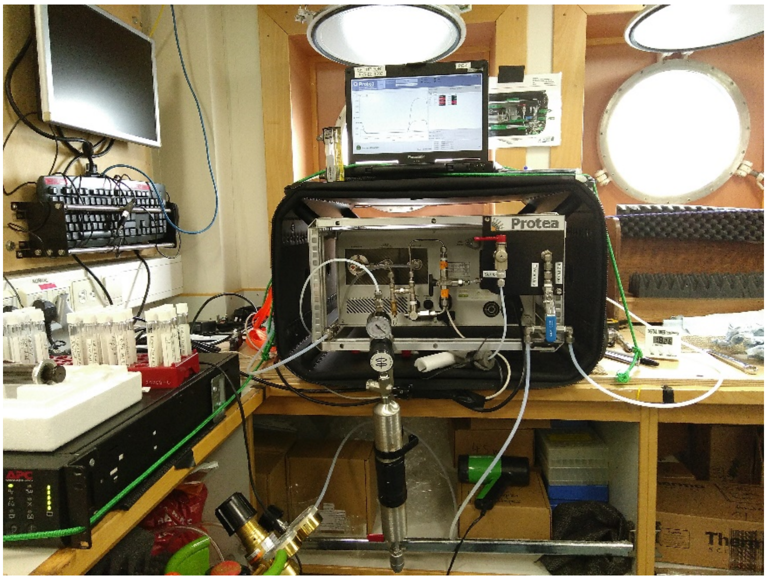


Figure 9.2 FTIR used for on board analysis of gas composition (photo A. Flohr)

Discrete gas samples were retrieved using gas tight syringes (Hamilton; needle diameter 0.3 or 0.4 mm) and injected into pre-evacuated 12 mL Exetainers (Labco) with double wadded septa (Glatzel and Well, 2008). The syringes were flushed before each sampling using a 150 mL gas sampling tube (Lenz) that was constantly flushed with N_2. Discrete samples were retrieved from (i) pure N_2 (background measurements) and from (ii) the secondary standard to check for tightness of the Exetainers, and from (iii) the gas samples for later analysis of $\delta^{13}C_{CO2}$, $\delta^{18}O_{CO2}$ and Kr composition at the University of Oxford. The Exetainers were overcharged to avoid suction of atmospheric air after the injection process. For storage, silicone sealant (Dow Coring 734, multi-purpose one component silicone sealant) was applied on top of the septum to seal the puncture. The gas samples were stored at room temperature.

Table 9.1 Summary of gas samples retrieved during the release experiment. Successful (x), failed (-), GBS (gas bubble sampler), seep wc = seep water column.

Day of exp.	Date	ROV dive #	Injection flow rate [L/min STP]	Location	GBS #	FTIR analysis	Discrete gas sub-samples
1	11/05/2019	357	2	rig	1	x	-
1	11/05/2019	357	2	rig	2	x	-
1	11/05/2019	357	2	rig	3	x	-
1	11/05/2019	358	2	rig	7	x	x
2	12/05/2019	358	2	rig	4	x	x
2	12/05/2019	358	2	seep	8	-	-
3	13/05/2019	359	10	rig	5	-	-
3	13/05/2019	359	10	rig	6	x	x
3	13/05/2019	359	10	seep	3	x	x
3	13/05/2019	360	10	rig	8	-	-
3	13/05/2019	360	10	rig	5	x	x
3	13/05/2019	360	10	seep	2	x	x
3	13/05/2019	361	10	rig	3	x	x
3	13/05/2019	361	10	rig	4	x	x
3	13/05/2019	361	10	seep	1	x	x
5	15/05/2019	363	10	rig	6	x	x
5	15/05/2019	363	10	rig	1	x	x
5	15/05/2019	363	10	seep	8	x	x

6	16/05/2019	366	10	rig	4	x	x
6	16/05/2019	366	10	seep	7	-	-
6	16/05/2019	366	10	seep wc	2	-	-
7	17/05/2019	369	10	seep	1	x	x
7	17/05/2019	369	10	seep	6	-	-
7	17/05/2019	369	10	seep	8	-	-
8	18/05/2019	370	30	seep	7	x	x
8	18/05/2019	370	30	seep	3	x	x
8	18/05/2019	370	30	rig	5	x	x
9	19/05/2019	372	30	seep	1	x	x
9	19/05/2019	372	30	seep wc	4	x	x
9	19/05/2019	372	30	rig	6	x	x
9	19/05/2019	373	30	seep	8	x	x
9	19/05/2019	373	30	seep wc	7	x	x
9	19/05/2019	373	30	rig	5	x	x
10	20/05/2019	375	50	seep	3	x	x
10	20/05/2019	375	50	seep wc	7	x	x
10	20/05/2019	375	50	rig	6	x	x
11	21/05/2019	376	50	seep	4	x	x
11	21/05/2019	376	50	seep wc	1	x	x
11	21/05/2019	376	50	rig	5	x	x

9.2.4 Dissolved tracers

Water was sampled by 6 Niskin bottles (1.7 L each) mounted at the back of the ROV. Usually 4 Niskin bottles were fired above the bubble stream between 1.5-2.5 m above seafloor, 2 Niskin bottles were fired close to the gas rig – both towards the end of the dive. For water sampling, the sampling tube was placed to the bottom of the vial to assure filling the vial from bottom to top allowing an overflow volume of 2-3. Water samples for total alkalinity (TA), dissolved inorganic carbon (DIC), carbon and oxygen isotopes ($\delta^{13}C_{DIC}$, $\delta^{18}O_{H2O}$) and deuterium (^{2}H) were filled into 12 mL Exetainer borosilicate glass vials (Labco) and 40 mL borosilicate glass vials (Thermo) with no headspace, poisoned with $HgCl_2$ and stored upside down at room temperature. The samples will be analysed at the NOC, Southampton and University of Oxford. Water samples for dissolved SF_6, C_3F_8 and Kr where filled into 20 mL glass vials with no headspace, capped with blue 20 mm butyl-rubber septa (Belco Glass), crimp-sealed, sealed with silicone sealant (Dow Coring 734, multi-purpose one component silicone sealant) and stored in a box filled with water (MilliQ) at room temperature. The samples will be analysed at GEOMAR, Kiel and NOC, Southampton. Nutrient samples were filtered (Nylon, 0.45 µm), filled into 15 mL HDPE vials and frozen and will be analysed by a Skalar autoanalyser at the NOC, Southampton.

Table 9.2 Summary of Niskin bottle sampling

Day of exp.	Date	ROV dive #	Injection flow rate [L/min STP]	Location	Diss. SF_6, C_3F_8, Kr	TA, DIC	$\delta^{13}C_{CO2}$, $\delta^{18}O_{H2O}$, ^{2}H	Nutrients
-4	07/05/2019	349	-	exp. site	x	x	x	x
-4	07/05/2019	351	-	exp. site	x	x	x	x
-3	08/05/2019	353	-	exp. site	x	x	x	x
-3	08/05/2019	353	-	exp. site	x	x	x	x
-2	09/05/2019	354	-	exp. site	x	x	x	x
1	11/05/2019	357	2	rig	x	x	x	x
1	11/05/2019	357	2	seep	x	x	x	x
2	11/05/2019	358	2	rig	x	x	x	x

2	12/05/2019	358	2	seep	x	x	x	x
3	13/05/2019	359	10	rig	x	x	x	x
3	13/05/2019	359	10	seep	x	x	x	x
3	13/05/2019	360	10	rig	x	x	x	x
3	13/05/2019	360	10	seep	x	x	x	x
3	13/05/2019	361	10	rig	x	x	x	x
3	13/05/2019	361	10	seep	x	x	x	x
5	15/05/2019	363	10	rig	x	x	x	x
5	15/05/2019	363	10	seep	x	x	x	x
6	16/05/2019	366	10	rig	x	x	x	x
6	16/05/2019	366	10	seep	x	x	x	x
7	17/05/2019	369	10	rig	x	x	x	x
7	17/05/2019	369	10	seep	x	x	x	x
8	18/05/2019	370	30	rig	x	x	x	x
8	18/05/2019	370	30	seep	x	x	x	x
9	19/05/2019	372	30	rig	x	x	x	x
9	19/05/2019	372	30	seep	x	x	x	x
9	19/05/2019	373	30	rig	x	x	x	x
9	19/05/2019	373	30	seep	x	x	x	x
10	20/05/2019	375	50	rig	x	x	x	x
10	20/05/2019	375	50	seep	x	x	x	x
11	21/05/2019	376	50	rig	x	x	x	x
11	21/05/2019	376	50	seep	x	x	x	x

9.3 Preliminary results

Figure 9.3 shows preliminary results of quantifications of CO_2 loss for 30 L/min STP (#372) and 50 L/min STP (#376) injection flow rate. The raw data suggests that at an injection flow rate of 30 L/min STP between 52-70 % of the initial CO_2 dissolved in the pore water of the sediment and additional 13-19% dissolved within ~0.9 m above the seafloor. The flow rate of the CO_2 seep just above the sediment was ~55 mL/min and dropped to ~35 mL/min at 0.9 m above seafloor. At an injection flow rate of 50 L/min STP between 42-58 % of the initial CO_2 dissolved in the pore water and additional 37-47 % dissolved within ~2 m above the seafloor. The flow rate of bubbles collected close to the seafloor was ~250 mL/min and dropped to ~20 ml/min at ~2 m above seafloor. However, higher in the water column the bubbles disperse and are more difficult to catch. Thus, the flow rates of bubbles caught in the water column are rather underestimated.

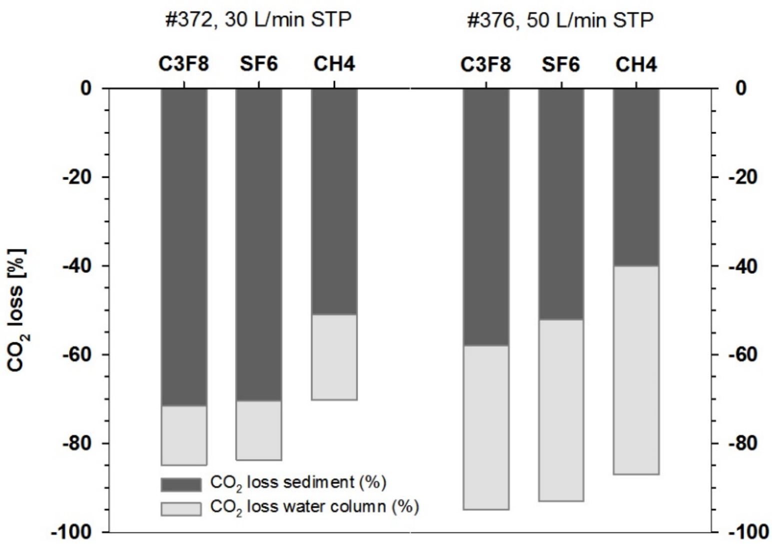


Figure 9.3 Preliminary results of CO_2 loss (%) from the initial injection CO_2 due to dissolution in the sediment (dark grey) and dissolution in the water column (light grey) at ~0.9 m (#372) and ~2 m (#376) above the seafloor.

9.4 Acknowledgements

Special thanks to Hannah Wright, Robin Brown and Kevin Saw for all the help along the way.

9.5 References

Glatzel, S., and Well, R.: Evaluation of septum-capped vials for storage of gas samples during air transport, Environ Monit Assess, 136, 307-311, 2008.

10 Lab-on-chip chemical sensors: Allison Schaap, Sam Monk, Rudolf Hanz (NOC)

10.1 Equipment description

The lab-on-chip (LOC) chemical sensors are autonomous instruments capable of each measuring a single chemical parameter in situ. Reagents and standards are attached to the devices, which perform modified versions of standard laboratory assays. The sensors each have a pump and several valves which control the intake of seawater and reagents/standards; the sample and reagents are drawn into a syringe pump and pushed into microfluidic channels where they mix and/or react. The assay outcome is then measured with optical or conductometric transducers.

All of the LOC sensors use flexible bags to store the reagents and standards necessary to perform measurements and calibrations. Seawater is pumped into the sensors through a 0.45 µm pore size PES syringe filter. All waste produced by the sensors is collected in bags which were emptied into storage containers by the sensor team as necessary.

Thirty three lab-on-chip autonomous chemical sensors were brought along on JC180 (Table 10.1)

Table 10.1 Overview of LOC sensors on JC180

Parameter	Quantity	Serial numbers	Sensor version
Nitrate + nitrite (N)	6	114, 116, 119, 121, 122, 123	3.3c (all)
Phosphate (P)	7	56, 57, 58, 59, 60, 61, 62	3.3e (all)
pH	7	34, 35, 38, 40, 41, 42, 43	3.3b (34, 35, 38); 3.3c (40-43)
Total alkalinity (TA)	6	5, 8, 9, 10, 11, 12	3.3c (all)
Dissolved inorganic carbon (DIC)	7	1, 2, 3, 4, 5, 6, 7	3.3a (1-4, 7); 3.3b (5, 6)

The LOC sensors deployed on this cruise were all developed and manufactured by the Ocean Technology & Engineering Group at the NOC Southampton. The nitrate, phosphate, and pH sensors have been previously deployed on other projects, although modifications to the methods and capabilities were developed specifically for STEMM-CCS. The sensors for dissolved inorganic carbon and total alkalinity were developed specifically for this project and this cruise is the second time that they have been deployed outside of Southampton.
The sensors were deployed on the baseline lander, the ISIS, the benthic boundary layer landers from MPI, and the ship's underway system. Each deployment platform is described separately below.

10.2 Overview of specific LOC sensor methodologies

The following is a description of the generic setup of each of the LOC sensor types brought along on JC180; platform-specific changes or modifications are noted within the sections below.

10.2.1 Nitrate+nitrite

The nitrate sensor uses a colourimetric assay based on the standard Griess assay [1], [2]. The sample is mixed with Imidazole buffer made up to pH 7.8 and the mixture pushed through a cadmium column where the nitrate is reduced to nitrite. The addition of the reagent forms a colour the intensity of which is read in three optical cells of lengths approx. 10, 1, and 0.1 cm long. The sensor carries a preserved, salinity-matched blank and standard which are sampled regularly and used to calibrate on the fly. All of the nitrate sensors on the cruise used a 15 µM standard and a blank, both preserved with chloroform. Subsamples of the standards and blanks were collected regularly on the ship for later analysis to ensure that no change in standard concentration had taken place.

Figure 10.1. (Left) Interior of a lab-on-chip nitrate+nitrite sensor; (middle) sensor in a housing; (right) sealed sensor with a reagent housing on top

10.2.2 Phosphate

The phosphate sensor uses a modified version of the molybdate blue assay [3], [4]. A molybdic acid solution mixes with the sample to produce phosophomolybdic acid, which is reduced with the addition of a second reagent containing ascorbic acid. As with the nitrate sensor, the intensity of the resulting colour is read in three optical cells of lengths approximately 10, 1, and 0.1 cm long. All of the phosphate sensors deployed on JC180 have a blank and 1.0 µM standard and some have an additional 0.5 µM standard. The blanks/standards are acidified and salinity-matched to 35 PSU and are measured regularly by the sensor to recalibrate. Subsamples of the standards and blanks were collected regularly on the ship for later analysis to ensure that no change in standard concentration had taken place.

10.2.3 pH

The pH sensor injects a small plug of the pH indicator bromocrescol purple into a seawater sample entering a long microchannel [5]. While traveling through the channel the plug undergoes Taylor-Aris dispersion, effectively creating a titration curve of dye and seawater. The optical absorbance of the dye-seawater mixture is read at two wavelengths and the ratio of their absorbance is used to calculate the pH. The pH sensor requires the external temperature and salinity for corrections; some preliminary data in this report may contain data which has not yet been accurately corrected for these factors.

10.2.4 Total alkalinity (TA)

The TA sensor uses a single-point open-cell titration of seawater and a titrant containing acid and the pH indicator bromophenol blue. The titrant and seawater are mixed and the CO_2 resulting from the seawater acidification is removed by passing it through a tube-in-a-tube degassing system with NaOH on the other side of a gas permeable membrane. The degassed solution returns to the microfluidic chip for an optical measurement of the pH of the solution at two wavelengths (592 nm and 437 nm), from which the TA of the original solution can be calculated. The TA sensors regularly measure two certified reference materials (CRMs) purchased from the Dickson lab to provide an ongoing recalibration. With the current version of the sensor, the recalibration data from the CRMs is applied by the user after deployment rather than performed automatically on the sensor.

10.2.5 Dissolved inorganic carbon (DIC)

The DIC sensor operates in a similar manor to the TA system, however instead of an optical detector a conductometric detector is used. For each measurement a sample of seawater is acidified and the dissolved inorganic carbon is converted to CO_2 which crosses a gas permeable membrane and reacts with a sodium hydroxide solution. This alters the conductivity of the sodium hydroxide which is measured. The sensor can also carry either one or two on board CRMs (purchased from the Dickson Lab) to enable it to carry out *in situ* calibrations.

10.3 LOC sensors on baseline lander

10.3.1 Setup & methods

One LOC sensor of each parameter was deployed on the baseline lander (Table 10.2). The lander was deployed roughly 475 m southeast of the main bubble release site with the goal of doing background measurements throughout the experiment in an unaffected region of the local environment.

The sensors were powered by batteries (Saft LSH-20) in 4S6P configuration, which provided an estimated 54 Ah at 14.4 V at 7ºC. The sensors were plugged in to the batteries shortly before deployment; they were programmed to sleep for 3 hours and then to subsequently begin measuring at the next scheduled hourly (or two-hourly) point. The start times of each measurement were chosen to have the sensors withdraw their seawater sample as close as possible to the hour.

The intake filters for the N, P, TA, and pH sensors were all at 80±1 cm above the bottom of the lander feet; the DIC intake filter was at 55 cm height.

Table 10.2 LOC sensors deployed on the baseline lander

Sensor	Serial number	Sampling frequency	Calibration frequency
pH	43	Hourly on the hour	n/a
Nitrate	121	Every two hours	With every sample
Phosphate	59	Every two hours	With every sample
TA	11	Every two hours	4x per day
DIC	2	Every two hours	6x per day

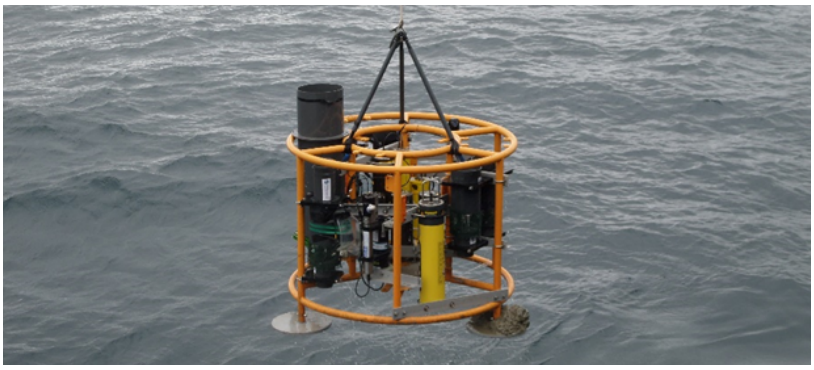


Figure 10.2. Baseline lander being recovered.

10.3.2 Deployment

The lander was deployed on 27/04/2019 and was released from the winch at 12:45 that afternoon while the ship was at location 57º, 59.47 N and 0º22.17 W. The lander was recovered on 21/05/2019 at 11:00.

10.3.3 Preliminary data

Preliminary (uncorrected, unchecked) data from the baseline lander showed values within the expected range of the measured parameters: 4.5-6.5 µM nitrate+nitrite, 0.4-0.8 µM phosphate, 2320-2350 µmol/kg alkalinity, and pH between 8.02 and 8.06.

10.4 LOC sensors on ISIS ROV

10.4.1 Setup & methods

One LOC sensor of each parameter was deployed on the ROV Table 10.4.

The starboard rear corner of the ROV contained the five sensors on an aluminium mounting sled. The mounting sled also provided attachment points for the reagent and waste bags. The reagents were at ambient temperature (7 – 10 °C) throughout the experiment. A seabird SBE submersible pump transported water from the front of the ROV to a manifold for distribution to the sensors (see schematic, Figure 10.3). The speed of the pump ensured the water sample was transported to the manifold at near real time. The pump inlet was 20 cm above and 32 cm behind the ROV's central reference point. This equated to a point 104.5 cm above the bottom and 92 cm from the front of the ROV.

Table 10.4 LOC sensors deployed on ROV

Sensor	Serial number	Sampling frequency (typical)	Calibration frequency
pH	38	10 minutes	n/a
Nitrate	122	6 minutes	Every 10 samples
Phosphate	61	10 minutes	Every 10 samples
TA	8	7 minutes	Every 10 samples
DIC	5, 6	16 minutes	Every 10 samples

Figure 10.3 Schematic of sampling system for LOC sensors on ROV

The LOC sensors are programmed to each calculate a concentration of the parameter of interest after each sample. On the ROV, whenever a new value was calculated it was sent via serial RS232 communications through the ROV to a desktop running in the laboratory where the received data could be viewed. This provided an initial (but not quality-controlled) estimate of the concentration of each chemical parameter. When the ROV was on deck, the raw data files were copied off the sensors for later in-depth processing.

10.4.2 Complementary commercial sensors

For two of the long overnight dives a SBE Deep SeaFET was also mounted on the ROV to collect higher temporal resolution pH data (1 Hz). The SeaFET was approximately 5 cm lower, 43 cm further back, and 80 cm to the starboard side of the ROV than the Seabird pump intake point. From dive 366 onwards a Seabird MicroCAT (SBE37SM) was mounted on the ROV to measure temperature and salinity. The MicroCAT was mounted approximately 20 cm from the Seabird pump intake point.

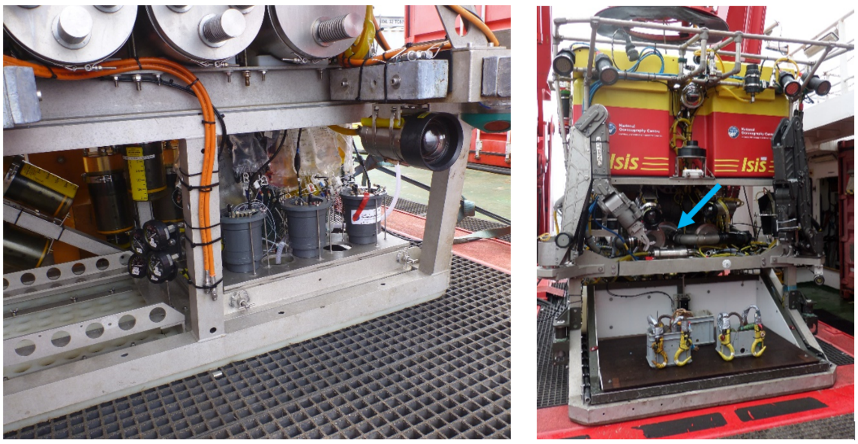


Figure 10.4. (Left) View of the ISIS from the back, showing the LOC sensors mounted on the rear starboard bottom corner on their aluminium sled. (Right) Front view of the ISIS with the position of the intake pump marked with a blue arrow.

10.4.3 Deployments

The sled and sensors were in place for the main scientific dives of the cruise. All sensors ran during most of these 30 dives (Table 10.4). Occasional maintenance or power failures resulted in between zero and seven dives being missed from any one sensor.

During the descent phase of the ROV the pump and sensors were turned on, typically at around 20 m depth. The nitrate, phosphate and DIC sensors calibrated first and then made ten measurements at which point recalibration started. Depending on the sensor chemistry, calibration took from 10 to 30 minutes. TA operated in the reverse configuration, taking 10 measurements and then calibrating. The pH sensor does not require calibration and ran continuously. Just prior to or at the beginning of ascent all sensors were stopped using the serial GUI and then powered off by the ROV technicians.

During a standard dive, the sensors would be recording data while the ROV was operating at the seafloor. This included the release site, CO_2 gas tank and areas in-between and around these locations. A typical altitude of the ROV during dives was 1-3 meters however it also spent time landed on the seabed or at higher altitudes.

Survey dives with the ROV took placed during the nights of the 13th, 15th, 18th and 20th of May. The ROV had one or two tasks to complete and during downtime, this survey and the pH optode survey took place. These dives measured the north-south and vertical extent of the plume. Vertical altitudes were either 1.5, 2.5 or 3.5 meters above the seafloor. The last dive measured the east-west lateral extent of the plume at approximately 6 m from the bubble emission site. The pH optodes were not present on this dive but the LOC sensors and SeaFET were sampling continuously.

10.4.4 Example results: dive 366

During dive 366 gas was flowing to the pipe at a rate of 10 litres per minute. A vertical transect at 1.5, 2.5 and 3.5 meters above the bubbles was followed by a transect northwards to 10 meters at 1.5 and 3.5 meters. Measurements were also taken at approximately 6 meters up current from the bubble site. The vertical transect was taken over a one and a half hour period while the horizontal component was split into two 2.5 hr transects. During the horizontal transect the current was approximately running from the south to the north at varying speeds.

From the uncorrected pH data, it was possible to see some evidence of a plume down current from the bubble stream at both 1.5 and 3.5 m altitude. A decrease in pH was also visible while doing the vertical transect at 1.5, 2.5 and 3.5 meters altitude above the bubble site.

Table 10.4. Summary of which sensors ran on each dive. Dives highlighted in grey included a site survey.

ROV Dive	Date	Nitrate	Phosphate	pH	TA	DIC	SeaFET	MicroCAT
349	07/05/2019	X	X	X	X	X		
350	07/05/2019	X		X		X		
351	07/05/2019	X		X		X		
352	08/05/2019		X	X	X	X		
353	08/05/2019		X	X	X	X		
354	09/05/2019		X	X		X		
355	09/05/2019		X	X		X		
356	10/05/2019		X	X	X	X		
357	10/05/2019		X	X	X	X		
358	11/05/2019	X	X	X	X	X		
359	12/05/2019	X	X	X	X	X		
360	12/05/2019	X	X	X	X			
361	13/05/2019	X	X	X	X	X		
362	14/05/2019	X	X	X	X	X		
363	15/05/2019	X	X	X	X	X		
364	15/05/2019	X	X	X	X			
365	15/05/2019	X	X	X	X	X		
366	15/05/2019	X	X	X	X	X		X
367	16/05/2019	X	X	X	X			X
368	16/05/2019	X	X	X	X			X
369	17/05/2019	X	X	X	X	X		X

370	17/05/2019	X	X	X	X	X		X
371	18/05/2019	X		X	X	X		X
372	18/05/2019	X		X	X	X	X	X
373	19/05/2019	X		X		X		X
374	19/05/2019	X		X	X	X		X
375	20/05/2019	X	X	X	X			X
376	20/05/2019	X	X	X	X		X	X
377	22/05/2019	X	X	X	X	X		X
381	26/05/2019	TBD	TBD	TBD	TBD	TBD		

10.5 LOC sensors on benthic boundary layer landers

10.5.1 Setup & methods

Two benthic boundary layer (BBL) landers were built for the cruise by the Max Planck Institute for Marine Microbiology. One half of each contained an eddy covariance system (belonging to and being run by MPI) and a second half containing five lab-on-chip sensors. Each LOC had two separate sample inlets, which the sensors would alternate between while running. The goal of this approach was to both measure the chemistry of the plume and to quantify any vertical gradients present in the measurands.

The landers were designed to be swapped every 48 hours; longer deployments were not possible as the weight restrictions of the ROV sled prevented the addition of more batteries. Each LOC sensor was powered by 4 Saft LSH-20 lithium batteries in a 4S configuration, housed in deep sea-rated titanium battery housings. These batteries were able to power the N, P, and TA sensors for an entire 48 hour deployment, the pH sensors for 44 hours, and the DIC sensor for 25 hours.

Each sensor had enough reagents or standards for at least 2 deployments attached to it, wrapped in thick plastic mesh which was attached to the frame at the top and bottom of bags to prevent strain on the tubing connecting the bags to the sensors.

The intake filters for the sensors were attached facing east near the top and bottom of the frame in the southeast corner of the frame in the deployment orientation. The bottom intake filters were at an average height of 16.9 cm above the seabed and the top intake filters an average height of 87.2 cm.

The sensors were programmed to perform 20 measurements (10 from each intake filter) between calibrations / reference measurements. The one exception to this is the pH sensor which does not carry reference materials on board; it ran continuously alternating between the inlets.

Figure 10.5. .MPI BBL lander with the LOC sensors mounted on the blue and red portion of the frame. The photo on the left shows the (as-deployed) east side of the frame with the sensor intake filters at the top and bottom of the left-hand side of the lander. The right photo shows the north face of the lander.

10.5.2 Deployments

The MPI BBL landers were deployed a total of 7 times; the landers were carried to the seafloor and put in place by ISIS and the previous lander was retrieved during the same dive. Not every sensor successfully ran throughout every deployment (Table 10.5). The frames were typically deployed 2-3 m directly south of the bubble release points, although the position of the BBL in deployment 4 was an estimated 2 m further south than intended.

Table 10.5 Deployment records of the LOC sensors on the MPI BBL landers; the serial numbers which have an asterisk next to them indicate that the sensor failed at some point during this deployment.

				Serial numbers				
Deployment #	Lander #	Date deployed	Date retrieved	N	P	pH	TA	DIC
1	1	07/05/2019	09/05/2019	119	60	40	5*	3
2	2	09/05/2019	12/05/2019	114*	56	42	9	1
3	1	12/05/2019	14/05/2019	119	60	40	5	3
4	2	14/05/2019	16/05/2019	123*	56	42	9	1
5	1	16/05/2019	18/05/2019	119	60	40*	5	3*
6	2	18/05/2019	20/05/2019	114*	56	42	10	1*
7	1	20/05/2019	22/05/2019	119	60	41	5	3*

10.5.3 Example results

Figure 10.6 shows preliminary results from the LOC pH sensor during the highest CO_2 flow rate.

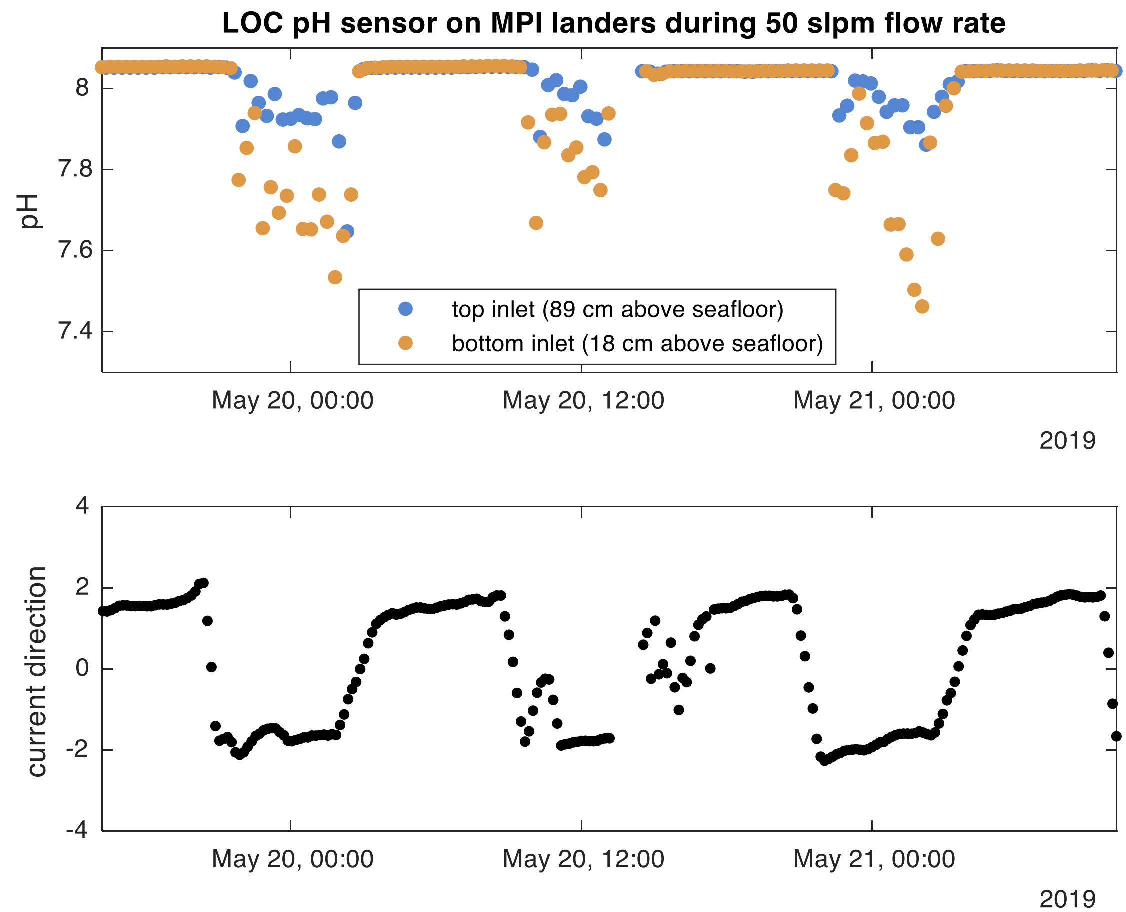


Figure 10.6. Preliminary data from the LOC pH sensor on the MPI BBL lander during the highest gas flow rate (50 standard lpm). The current direction in the bottom plot is given in radians from east; positive is to the north and negative is to the south. The lander was positioned due south of the plume. Current data is from the Nortek Vector instrument on the MPI lander, courtesy of Dirk Koopmans.

10.6 LOC sensors on ship's underway system

10.6.1 Setup & methods

A full complement of the LOC sensors were plumbed into the ships underway system, in order to capture both the spatial variation while transiting and also temporal variation on site of the surface waters (see Table 10.6). The underway system pumps water from 5.5m below the sea surface through a suite of ship systems sensors (SBE45 Thermosalinograph, Wetlabs Flurometer and Transmissiometer). This was also compared to meteorological data collected by the ship systems (Photosynthetically Active Radiation (PAR), air temperature, wind speed and direction).

The plumbing consisted of tygon tubing and was arranged with two inverted Y bends which acted to remove bubbles in the line. As shown in Figure , underway water was flowing into a plastic bottle from tubing which terminated at the bottom of the bottle. Three outlet tubing ports on the side of the bottle allowed the water to drain into the sink. The intake filter of all 5 LOC sensors were in the middle of the bottle. The bottle took an estimated 1 minute to fill from empty.

In order to validate the LOC measurements bottle samples were taken hourly during the transits, and at intervals while on the experiment site. These samples will be run when back on land and will be analysed for Nitrate, Phosphate, DIC and TA (allowing pH to be derived).

Table 10.6 LOC sensors deployed on the underway system

Sensor	Serial number	Sampling frequency	Calibration frequency
pH	35	Every 30 minutes	n/a
Nitrate	116	Every hours	With every sample
Phosphate	45	Every hours	With every sample
TA	12	Every hours	4x per day
DIC	7	Every 30 minutes	6x per day

Figure 10.7. 5 LOC sensors sampling from the ship's underway system.

10.6.2 Deployments

The ship systems sensors ran almost continuously while the ship was underway. During the transits the LOC sampling frequencies were increased in order to capture a finer spatial resolution. This has resulted in ~ 35 days of continuous measurements. During this time there were occasions when the system had to be shut down (when in port and during "quiet time" for the hydrophone walls).

10.6.3 Example results

Figure shows the underway TSG data and the LOC pH as we departed Aberdeen on the 6th of May and returned to the Goldeneye Site. The LOC data is uncorrected for temperature and salinity effects.

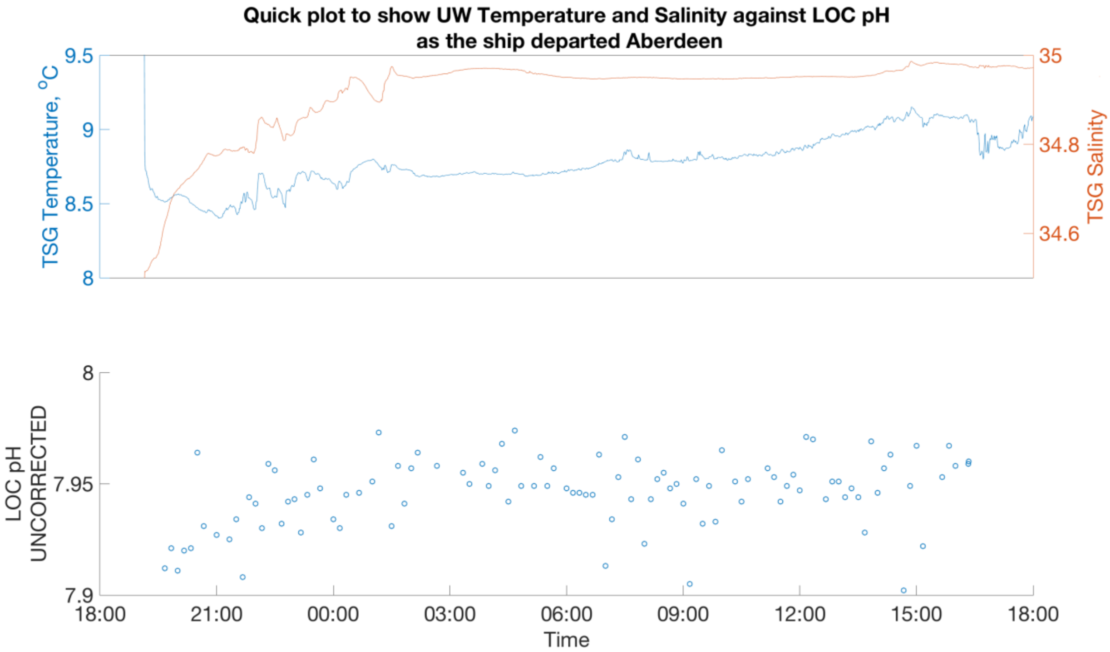


Figure 10.8. Underway system temperature and salinity, with LOC pH data, during the transit from Aberdeen back to the Goldeneye site.

10.7 Summary & acknowledgements

Overall we regard the deployment of the LOC sensors on JC180 as quite successful. While there will still be a substantial effort required to quality-check, process, and assimilate all the data, the preliminary results shown here suggest that the approach of using in situ chemical analyzers to characterize a plume of CO_2 is a viable option to pursue in the future.

From a project and planning point of view, we also consider this deployment to be a success. This was by far the largest single deployment of the Ocean Technology & Engineering Group's lab-on-chip sensors: the number of LOC sensors on this cruise represents nearly an entire year's manufacturing output. The deployment would not have been possible without the hard work of the entire group over the past few years.

10.8 References

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11 Benthic chambers: Jonas Gros & Isabelle Mekelnburg (GEOMAR), and Anita Flohr (University of Southampton)

11.1 Introduction and objectives

During cruise JC180, two benthic chambers were deployed with the ROV Isis at the experimental site near the Goldeneye platform. The objective was to monitor the fluxes of dissolved chemical species across the sediment-water interface. Additionally, it is intended to use chemical indicators to identify and quantify the inflow of extraneous CO_2 originating from the gas released during the experiment to validate quantification and attribution methods, which could be used for the monitoring and assessment of existing and future CO_2 storage sites. Finally, the data will be used to evaluate the effect of the CO_2 release on the benthic fluxes.

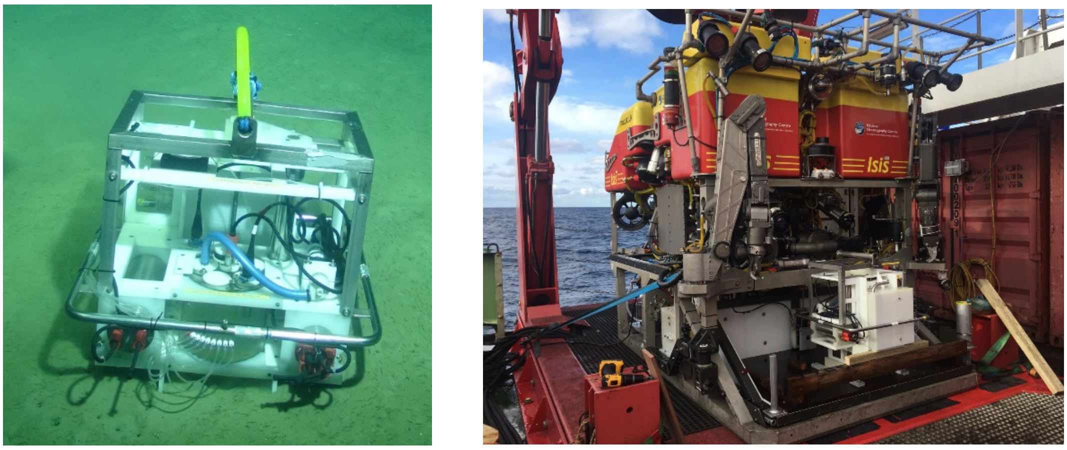

Figure 11.1. (Left) Benthic chamber 1 after its first deployment on the sea floor (May 8th, 2019 17:50). (Right) Benthic chamber 1 on the porch of the ROV Isis (May 8th, 2019).

11.2 Methods

11.2.1 The instrument

The two identic benthic chambers used in this experiment have been described previously (Radtke et al. 2019; McGinnis et al. 2014). The benthic chambers consist of a support frame that carries two cylindrical pressure tubes, a Plexiglas incubation chamber and a syringe sampler. The syringe sampler contains eight 50 ml syringes collecting water samples of usually ~46 ml at chosen time points. One titanium cylinder houses all electronics, including the control unit and data acquisition computer, the other one carries batteries. The measurement principle relies on in situ incubation of a volume of sediment along with a known volume of well-mixed bottom seawater during a measurement period (here 27–38 hours, depending on deployment). The measured evolutions of concentrations of dissolved species allow calculation of fluxes across the sediment-water interface based on the recorded ratio of water volume to sediment surface area within the chamber. Concentrations are monitored either by in-situ sensors or by ex-situ analysis of the eight water samples collected by the syringes. The centrally stirred chamber has an inner diameter of 19 cm and hence encloses an area of 284 cm^2 together with a 20–25 cm height of bottom seawater depending on sediment penetration depth (i.e. 6–8 l).

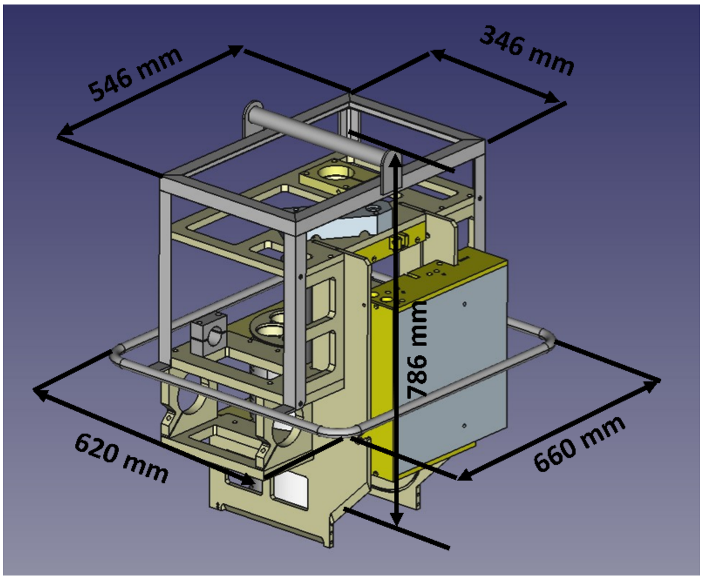

Figure 11.2. Diagram of the benthic chambers.

11.2.2 Instrument preparation

Before deployment, a two-point calibration of the oxygen optodes was conducted. Bottom seawater collected with Niskin bottles and stored in the cold room at approximately 11°C (renewed once during the cruise) was used for calibration. After bubbling with air (approximately 100% air saturation), 4–7 readings of the oxygen optode were recorded together with seawater temperature as sensed with the oxygen optode temperature sensor. Then, the seawater was bubbled with argon until optode readings stabilized at a low level (approximately 0% air saturation), and at that point 5–6 readings were recorded. After calibration, optodes were mounted on the chamber.

Battery packs used twenty 1.5-V alkali batteries mounted in two parallel series of ten batteries, resulting in an initial voltage of 16 V at deployment. For BC1-D3, a customized battery pack was used, consisting of a set of twelve 3.6-V Lithium batteries mounted in three parallel series of four batteries, resulting in an initial voltage of 14.5 V at deployment (designed and constructed on-board by Hannah Wright and Robin Brown). New batteries were used for each deployment, and voltage was verified for each battery (individually (with and without resistance), as well as the total voltage after mounting them on the battery pack). The eight syringes were prepared as follows. They were filled with MilliQ water at temperature close to deep-sea temperature (in the cold room, air temperature ~11°C) and were devoid of gas bubbles. This MilliQ water was then used to flush Vigon tubes, closed under water using a Vigon lid. This procedure ensured that the 6 ml water in the Vigon tubes connected to the syringes were devoid of gas bubbles, and that the syringes were empty when mounted on the chamber. At deployment, syringes were connected to the benthic chamber. Consequently, 6 ml of MilliQ water was mixed with the collected samples (total volume of ~52 ml). Samples of MilliQ water were taken to enable quantification and potential correction for this artifact.

11.2.3 Sampling

Oxygen. The changing concentration of oxygen was monitored by two oxygen optodes (Aanderaa Instruments, Norway) positioned inside and outside the chamber, and the data was recorded at a 5-min interval. Data from the oxygen optode situated within the chamber was used to determine oxygen fluxes at the sediment-water interface.

Figure 11.3. The eight syringes filled with seawater in the syringe sampler (benthic chamber 2, deployment 1, May 15, 2019 at 7 pm). On this photo, syringes are numbered according to sampling order (sampling interval: 3 h 23 min).

Other parameters will be determined by on-shore analysis of collected subsamples of the syringe water samples. The samples of the eight 50 ml syringes were divided into four subsamples:

1. Subsample for pCO_2, Kr, and SF_6 analysis (20 ml)
2. Subsample for dissolved inorganic carbon (DIC) analysis (4.5 ml)
3. Subsample for $\delta^{13}C$ of DIC and $\delta^{18}O$ of H_2O analysis (4.5 ml)
4. Subsample for total alkalinity (TA) analysis (4.5 ml)
5. Subsample for nutrients analysis (≥2.5 ml)

11.2.3.1 1. Subsamples for pCO_2, Kr, and SF_6 analysis

These subsamples were transferred into gas-tight 20 ml glass vials, closed with blue 20 mm butyl-rubber septa (Belco Glass), crimped, poisoned with a small amount of saturated $HgCl_2$ solution (aimed: ~35 µl), covered with silicon (Dow Corning 734, multi-purpose one-component silicone sealant) and stored in MilliQ water at room temperature (~22°C). Analysis will be conducted by means of a Membrane-introduction mass spectrometer (MIMS) at GEOMAR, Kiel (Germany).

11.2.3.2 2. Subsamples for DIC analysis

These subsamples were transferred into 4.5 ml gas-tight Exetainer vials (without air bubbles), and were poisoned with a small amount of $HgCl_2$. They will be analyzed at the National Oceanographic Centre (NOC) in Southampton (England).

11.2.3.3 3. Subsamples for $\delta^{13}C$ of DIC and $\delta^{18}O$ of H_2O analysis

These subsamples were transferred into 4.5 ml gas-tight Exetainer vials (without air bubbles), and were poisoned with a small amount of $HgCl_2$. They will be analyzed at the National Oceanographic Centre (NOC) in Southampton (England).

11.2.3.4 4. Subsamples for TA analysis

These subsamples were transferred into 4.5 ml gas-tight Exetainer vials (without air bubbles), and were poisoned with a small amount of $HgCl_2$. They will be analyzed at the National Oceanographic Centre (NOC) in Southampton (England).

11.2.3.5 5. Subsamples for nutrient analysis

Depending on the residual amount of water, between 2.5 and 5 ml subsample were filtered with a 0.45-µm syringe filter and transferred into 15-ml high-density polyethylene (HDPE) vials, and frozen at -18°C until analysis that will be performed at the National Oceanographic Centre (NOC) in Southampton (England).

11.2.4 List of collected subsamples

Table 11.1 Summary of collected subsamples and analysis parameters.

Deployment name	20 ml glass vials for pCO_2, Kr, and SF_6 analysis	4.5 ml Exetainer vials for DIC analysis	4.5 ml Exetainer vials for $\delta^{13}C$ of DIC and $\delta^{18}O$ of H_2O analyses	4.5 ml Exetainer vials for TA analysis	15-ml HDPE vials for nutrients analysis
BC1-1	2	3	3	3	3
BC2-1	7	8	8	7*	8
BC1-2	/	/	/	/	/
BC2-2	6	8	8	7*	8
BC1-3	8	8	8	8	8

* for one syringe, the volume was insufficient to fill three 4.5 ml Exetainer vials. This happened for the first syringe, which was mostly filled with gas, which seems to indicate that the first syringe may have been released in air during deployment possibly due to ROV movement. This process did not affect subsequent syringes.

Table 11.2. Summary of conducted deployments.

Deployment name	Date started	Date ended	Total incubation time (h)	Distance to closest CO_2 seep (m)	CO_2 flow rate during incubation (L_{STP}* min^{-1})	Comments
BC1-1	8.5.2019	10.5.2019	36	~7m from pipe end (before CO_2 release)	0	complete oxygen data collected; only three syringes collected, the first one mostly filled with gas
BC2-1	13.5.2019	16.5.2019	27	<1m	2 (5 for the last (8th) syringe)	~10h of oxygen data; eight syringes collected, the first mostly filled with gas
BC1-2	15.5.2019	17.5.2019	30	~1m	10	complete oxygen data collected; only the first syringe collected, mostly filled with gas
BC2-2	17.5.2019	19.5.2019	30	<1m	30	complete oxygen data collected; eight syringes collected, the first one mostly filled with gas
BC1-3	19.5.2019	21.05.2019	30	<1m	50	complete oxygen data collected; eight syringes collected, the first one mostly filled with gas

* CO_2 flow rates are expressed at standard temperature and pressure (STP, 273.15 K and 101325 Pa). The density of CO_2 at STP is 1.98 g L^{-1}, and 26.9 g L^{-1} at 1.3 MPa and 7.7°C (seafloor conditions), as calculated with the Peng-Robinson equation of state (Socolofsky 2017; Gros et al. 2016).

				Flow rate					
				0	2	5	10	30	50
DEPLOYMENT	DEPLOYMENT CODE	START DATE	START TIME						
1	**BC1-1**		-						
1.1	START OF DEPLOYMENT	Wed 5/08/19	17:48:02						
1.2	DEPLOYMENT STARTED	Wed 5/08/19	20:48:00						
1.3	START FLUSH PUMP	Wed 5/08/19	20:48:00						
1.4	FLUSH PUMP STOPPED;FLUSH TIME(min) 30	Wed 5/08/19	21:18:03						
1.5	SYRINGE No.1 RELEASED	Thu 5/09/19	21:18:03						
1.6	SYRINGE No.2 RELEASED	Thu 5/09/19	06:19:21						
1.7	SYRINGE No.3 RELEASED	Thu 5/09/19	10:50:27						
1.8	SYRINGE No.4 RELEASED	Thu 5/09/19	15:21:27						
1.9	SYRINGE No.5 RELEASED	Thu 5/09/19	19:52:27						
1.10	SYRINGE No.6 RELEASED	Fri 5/10/19	00:23:27						
1.11	SYRINGE No.7 RELEASED	Fri 5/10/19	04:54:27						
1.12	SYRINGE No.8 RELEASED	Fri 5/10/19	09:25:27						
2	**BC2-1**		-						
2.1	START OF DEPLOYMENT	Mon 5/13/19	10:40:03						
2.2	DEPLOYMENT STARTED	Mon 5/13/19	14:20:00						
2.3	START FLUSH PUMP	Mon 5/13/19	14:20:00						
2.4	FLUSH PUMP STOPPED;FLUSH TIME(min) 30	Mon 5/13/19	14:50:09						
2.5	SYRINGE No.1 RELEASED	Mon 5/13/19	18:12:21						
2.6	SYRINGE No.2 RELEASED	Mon 5/13/19	21:35:22						
2.7	SYRINGE No.3 RELEASED	Tue 5/14/19	00:58:22						
2.8	SYRINGE No.4 RELEASED	Tue 5/14/19	04:21:22						
2.9	SYRINGE No.5 RELEASED	Tue 5/14/19	07:44:22						
2.10	SYRINGE No.6 RELEASED	Tue 5/14/19	11:07:26						
2.11	SYRINGE No.7 RELEASED	Tue 5/14/19	14:30:27						
2.12	SYRINGE No.8 RELEASED	Tue 5/14/19	17:53:27						
3	**BC1-2**		-						
3.1	START OF DEPLOYMENT	Wed 5/15/19	13:47:08						
3.2	DEPLOYMENT STARTED	Wed 5/15/19	17:44:00						
3.3	START FLUSH PUMP	Wed 5/15/19	17:44:00						
3.4	FLUSH PUMP STOPPED;FLUSH TIME(min) 30	Wed 5/15/19	18:14:00						
3.5	SYRINGE No.1 RELEASED	Wed 5/15/19	21:59:26						
3.6	SYRINGE No.2 RELEASED	Thu 5/16/19	01:45:26						
3.7	SYRINGE No.3 RELEASED	Thu 5/16/19	05:31:27						
3.8	SYRINGE No.4 RELEASED	Thu 5/16/19	09:17:27						
3.9	SYRINGE No.5 RELEASED	Thu 5/16/19	13:0326						
3.10	SYRINGE No.6 RELEASED	Thu 5/16/19	16:49:27						
3.11	SYRINGE No.7 RELEASED	Thu 5/16/19	20:35:27						
3.12	SYRINGE No.8 RELEASED	Fri 5/17/19	00:21:27						
4	**BC2-2**		-						
4.1	START OF DEPLOYMENT	Fri 5/17/19	12:37:21						
4.2	DEPLOYMENT STARTED	Fri 5/17/19	16:37:00						
4.3	START FLUSH PUMP	Fri 5/17/19	16:37:00						
4.4	FLUSH PUMP STOPPED;FLUSH TIME(min) 30	Fri 5/17/19	17:07:11						
4.5	SYRINGE No.1 RELEASED	Fri 5/17/19	20:52:21						
4.6	SYRINGE No.2 RELEASED	Sat 5/18/19	00:38:22						
4.7	SYRINGE No.3 RELEASED	Sat 5/18/19	04:24:21						
4.8	SYRINGE No.4 RELEASED	Sat 5/18/19	08:10:21						
4.9	SYRINGE No.5 RELEASED	Sat 5/18/19	11:56:22						
4.10	SYRINGE No.6 RELEASED	Sat 5/18/19	15:42:27						
4.11	SYRINGE No.7 RELEASED	Sat 5/18/19	19:28:27						
4.12	SYRINGE No.8 RELEASED	Sat 5/18/19	23:14:26						
4.13	SLIDE CLOSE DELAY TIME	Sat 5/18/19	23:14:27						
4.14	BEGIN SLIDE CLOSE	Sat 5/18/19	23:24:00						
5	**BC1-3**		-						
5.1	START OF DEPLOYMENT	Sun 5/19/19	12:26:16						
5.2	DEPLOYMENT STARTED	Sun 5/19/19	15:41:00						
5.3	START FLUSH PUMP	Sun 5/19/19	15:41:00						
5.4	FLUSH PUMP STOPPED;FLUSH TIME(min) 30	Sun 5/19/19	16:11:03						
5.5	SYRINGE No.1 RELEASED	Sun 5/19/19	19:56:24						
5.6	SYRINGE No.2 RELEASED	Sun 5/19/19	23:42:21						
5.7	SYRINGE No.3 RELEASED	Mon 5/20/19	03:28:22						
5.8	SYRINGE No.4 RELEASED	Mon 5/20/19	07:14:21						
5.9	SYRINGE No.5 RELEASED	Mon 5/20/19	11:00:21						
5.10	SYRINGE No.6 RELEASED	Mon 5/20/19	14:46:21						
5.11	SYRINGE No.7 RELEASED	Mon 5/20/19	18:32:21						
5.12	SYRINGE No.8 RELEASED	Mon 5/20/19	22:18:22						

Figure 11.5 Gantt chart of the five benthic chamber deployments. Incubation starts after the flush pump is stopped.

11.3 Preliminary results

Evident differences between the concentration patterns recorded by the two optodes (inside and outside the chamber, Figure) confirmed that the chamber had been correctly deployed by ROV Isis and that the chamber effectively isolated the enclosed bottom seawater volume from neighbouring seawater for all of the five deployments performed during the cruise. Preliminary results indicate little change in oxygen fluxes across the sediment-water interface between the CO_2-unaffected background measurement collected prior to the on-set of CO_2 release and the subsequent deployments at varying CO_2 release flow rates. Measured sediment total oxygen uptake (TOU) fluxes average 7.0 mmol m^{-2} d^{-1} showing variability that seem independent of CO_2 injection rate. These values are on average 13% larger than the average 6.2±0.6 mmol m^{-2} d^{-1} (mean ± standard deviation) observed on 16–20 October 2017 during cruise Poseidon 518 at the Goldeneye site (Linke, P., Haeckel, M. (eds.) 2018). The apparent lack of effect of the CO_2 injection rate on the TOU agrees with findings of other measurements performed during this cruise and seems to possibly indicate a minor effect of CO_2 injection on the sediment microbiology. Further insight will be gained after the syringe samples are analyzed for the other key parameters of the system, enabling a more thorough understanding of the processes in play.

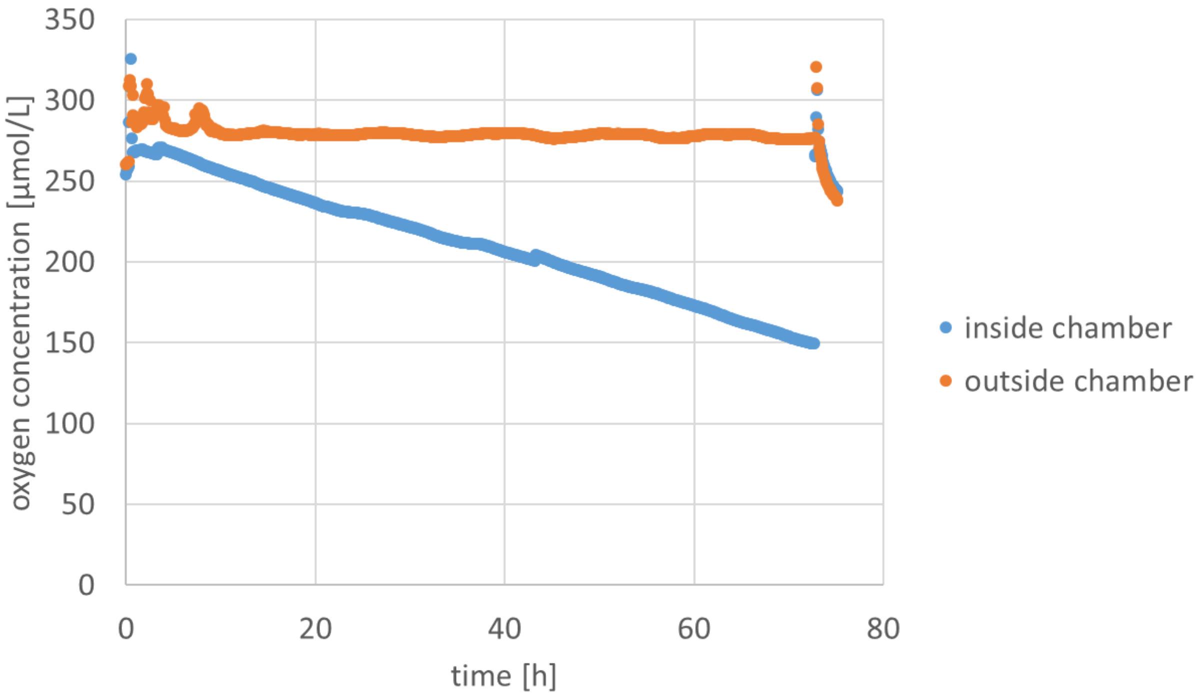

Figure 11.4. Preliminary oxygen concentration recorded during deployment 3 of benthic chamber 1 (May 19–20, 2019; flow rate of 50 standard liter of CO_2 per minute). These data indicate a total oxygen uptake (TOU) of -8.8 mmol O_2 m^{-2}.

Table 11.3. Total oxygen uptake (TOU) of the sediments based on oxygen optode measurements (preliminary results).

Deployment name	TOU (mmol m^{-2} d^{-1})	CO_2 flow rate during incubation (L_{STP}* min^{-1})
BC1-1	-7.9	0
BC2-1	-3.9**	2 (5 for the last (8th) syringe)
BC1-2	-9.3	10
BC2-2	-4.9	30
BC1-3	-8.8	50
average	7.0	
standard deviation	2.4	

* CO_2 flow rates are expressed at STP (273.15 K and 101325 Pa). The density of CO_2 at STP is 1.98 g L^{-1}, and 26.9 g L^{-1} at 1.3 MPa and 7.7°C (seafloor conditions), as calculated with the Peng-Robinson equation of state (Socolofsky 2017; Gros et al. 2016).
** based on 15 hours of data, afterwards the optode stopped working; the failing optode (inside the chamber for BC2-1) was swapped for the non-failing optode (outside the chamber) for the second deployment (BC2-2).

11.4 References

Gros, J., C. M. Reddy, R. K. Nelson, S. A. Socolofsky, and J. S. Arey. 2016. "Simulating Gas–liquid–water Partitioning and Fluid Properties of Petroleum under Pressure: Implications for Deep-Sea Blowouts." *Environmental Science & Technology* 50 (14): 7397–7408. https://doi.org/10.1021/acs.est.5b04617.

Linke, P., Haeckel, M. (eds.). 2018. "RV POSEIDON Fahrtbericht/Cruise Report POS518, Baseline Study for the Environmental Monitoring of Subseafloor CO_2 Storage Operations." 40. Kiel: GEOMAR.

McGinnis, Daniel F., Stefan Sommer, Andreas Lorke, Ronnie N. Glud, and Peter Linke. 2014. "Quantifying Tidally Driven Benthic Oxygen Exchange across Permeable Sediments: An Aquatic Eddy Correlation Study." *Journal of Geophysical Research: Oceans* 119 (10): 6918–32. https://doi.org/10.1002/2014JC010303.

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Socolofsky, S. A. 2017. *TAMOC* (version 1.1.1). College Station. https://github.com/socolofs/tamoc.

12 Benthic Boundary Layer Landers: Dirk Koopmans (Max Planck Institute for Marine Microbiology)

12.1 Overview

Our goal was to quantify the dissolved inorganic carbon (DIC) produced during the CO_2 release experiment. To accomplish this, we determined benthic fluxes of dissolved oxygen and hydrogen ions using the aquatic eddy covariance technique. As carbon dioxide is introduced to seawater, the pH of seawater decreases. Thus, a flux of hydrogen ions can be used to quantify a source of DIC. Where the supply of DIC exceeds oxygen consumption, the source is abiotic.

12.2 Methods

Water velocities were measured at 16 Hz with an acoustic Doppler velocimeter at a height of 16 cm above the seafloor. Eddy covariance pH was determined with an ion sensitive field-effect transistor (ISFET). Dissolved oxygen was determined with an optode minisensor (PyroScience, GmbH). The instrument was preprogrammed and had a runtime of 60 hours. Lab on chip sensors were included in collaboration with the National Oceanography Centre to quantify carbonate system dynamics (Figure 12.1). The frames were positioned 3- to 5-m south of the point of CO_2 release by a remotely operated vehicle. Two identical landers (BBL 1 and 2) were used so that when one lander was retrieved from the site, an alternate lander could be positioned in its place to continue the measurements.

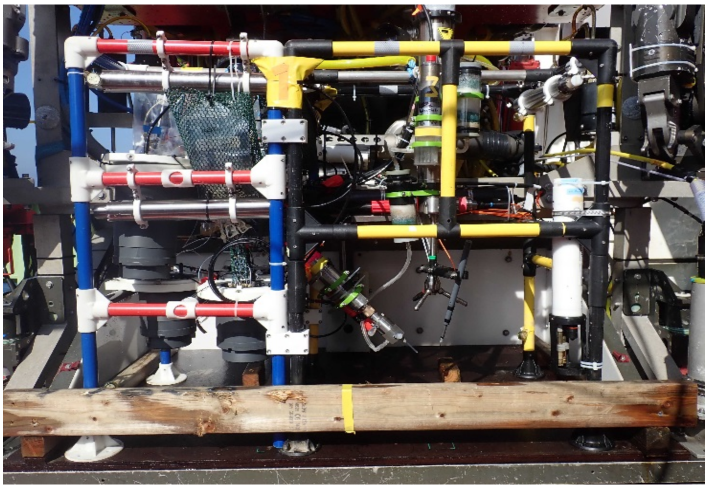


Figure 12.1. A benthic boundary layer lander on the tool sled of the ROV immediately before deployment. Eddy covariance instruments are mounted on the right. Lab on chip sensors are mounted on the left.

Table 12.1. Benthic Boundary Layer lander deployments during the release experiment.

Lander	ROV Dive	Date and time	Latitude	Longitude	Duration (hours)
BBL 1	351	07.05.2019 16:57	57° 59.6735 N	-0° 22.46 E	46
BBL 2	354	09.05.2019 15:08	57° 59.6736 N	-0° 22.4595	48
BBL 1	359	12.05.2019 15:31	57° 59.6730 N	-0° 22.4575	47
BBL 2	362	14.05.2019 15:01	57° 59.6733 N	-0° 22.4590	48
BBL 1	368	16.05.2019 16:38	57° 59.6703 N	-0° 22.4600	48
BBL 2	371	18.05.2019 17:28	57° 59.6725 N	-0° 22.4602	45
BBL 1	375	20.05.2019 14:58	57° 59.6734 N	-0° 22.4587	47

12.3 Results

The pH and oxygen eddy covariance system was successful. Hydrogen ion fluxes were determined during six of the seven deployments. These measurements constitute the longest record of eddy covariance hydrogen ion fluxes in an aquatic ecosystem. The lander was positioned so that southward flow would carry dissolved constituents from the bubble plume past the eddy covariance sensors. Indeed, with southward flow we recorded peaks in dissolved inorganic carbon flux of 50 to 500 times the background rate (Figure 12.2). Lab on chip sensors confirmed the pH dynamics. Dissolved oxygen flux was between 4 and 8 mmol m^{-2} d^{-1}. The oxygen fluxes were orders of magnitude smaller than peak DIC fluxes, hence the peak DIC fluxes were abiotic.

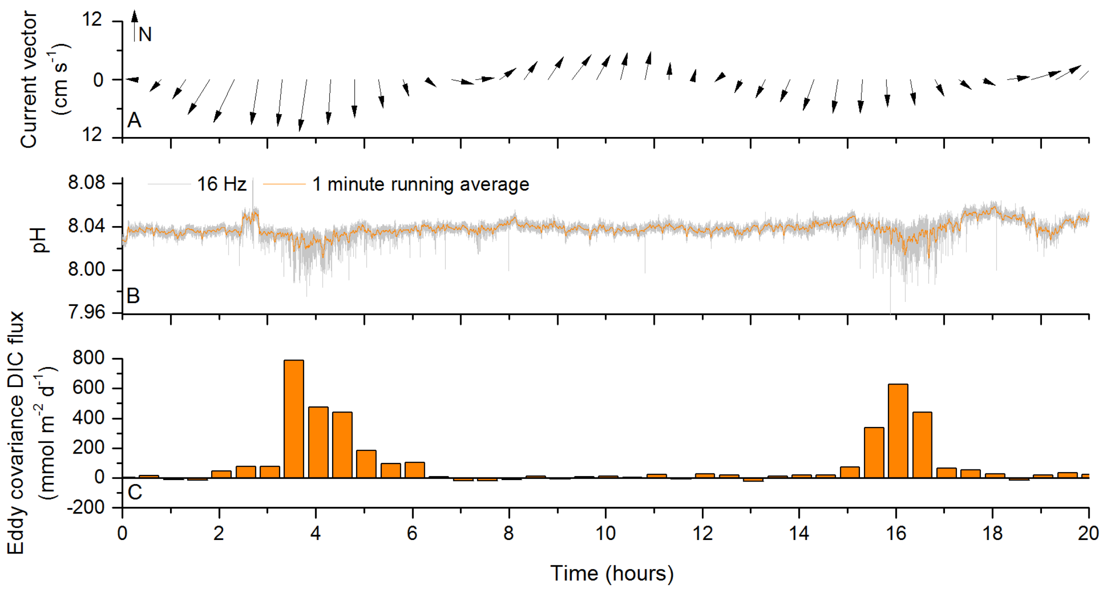


Figure 12.2. Example of measurements of the elevated dissolved inorganic carbon flux due to CO_2 dissolution in the bubble plume. A) Current vector, B) eddy covariance pH measurements, C) the flux of DIC calculated from the flux of hydrogen ions.

13 In situ pH optodes: Hannah Wright (NOC)

13.1 Approach

Five Optodes from Sergey Borisov at the Technical University of Graz were compiled into a bundle with handle for deployment by the ROV. There were a total of three deployments with the optode bundle.mTwo set of calibration buffer tablets were provided

13.1.1 Deployment 1

Date: 12/05/2019 **Gas flow rate:** 2 LPM **ROV Dive:** 360

Model Current Estimations: Going N to S 21:30 18/05/19 to 02:50 19/05/19
Going S to N 3:00 19/05/19 to 08:00 19/05/19

Optode Configuration:

Prototype	Sensor config	Type of cap	Calibration type
2	pH	Metal	Old
3	O2	Plastic	NA
4	pH	Plastic	Old
5	O2	Plastic	NA
6	pH	metal	Old

Deployment Events:

Event	Location	Altitude	ROV heading	Time and Duration
1	4m North of bubbles (downstream)	~1.5m	S	00:08 – 00:23
2	4m South of bubbles (upstream)	~1.5m	E	00:38 – 00:53
3	Held directly over bubble stream	~1m	E	01:22 – 01:54
4	Held 4m North of bubbles (upstream as current has changed)	2m	E/W	02:55 – 03:15
5	Held 4m South of bubbles (downstream)	2m	E/W	03:26 – 03:46
6a	Held above transect bubble stream	~2m		03:56 – 04:16
6b	Held above transect bubble stream	~1m		04:17 – 04:45
6c	Held above transect bubble stream	~3m		04:46 – 05:03
7	Held 4m North of bubbles	1.5m	E/W	07:57 -
8a	Held above bubbles	~2m		08:22
8b	Held above bubbles	~1m		08:43
8c	Held above bubbles	~3m		09:03

Deployment Notes:

Due to the current change and placement of other instrumentation in the experiment site it was not possible to complete a full transect.

13.1.2 Deployment 2

Date: 15/05/2019 **Gas flow rate:** 10 LPM **ROV Dive:** 366

Model Current Estimations: Going N to S 21:30 18/05/19 to 02:50 19/05/19
Going S to N 3:00 19/05/19 to 08:00 19/05/19

Optode Configuration:

Prototype	Sensor config	Type of cap	Calibration type
2	pH	Metal	Old
3	O2	Plastic	NA
4	pH	Plastic	Old

5	O2	Plastic	NA
6	pH	metal	New

Deployment Events:

Event	Location	Altitude	ROV heading	Time and Duration
1	Directly above bubble stream	1.5m	SW	23:45 – 00:14
2	Directly above bubble stream	2.5m	SW	00:15 – 00:45
3	Directly above bubble stream	3.5m	SW	00:46 – 01:14
4	1m North bubbles	1.5m	SW	01:18 – 01:35
5	2m North bubbles	1.5m	W	01:39 – 01:56
6	4m North bubbles	1.5m	W	01:57 – 02:07
7	5m North bubbles	1.5m	W	02:08 – 02:27
8	6m North bubbles	1.5m	W	02:28 – 02:38
9	8m North bubbles	1.5m	W	02:40 – 02:50
10	10m North bubbles	1.5m	W	02:51 – 03:01
11	6m South bubbles	1.5m	W	03:23 – 03:40
12	6m South bubbles	3.5m	W	03:41 – 04:07
13	1m North bubbles	3.5m	W	04:33 – 04:51
14	2m North bubbles	3.5m	W	04:57 – 05:12
15	4m North bubbles	3.5m	W	05:15 – 05:25
16	5m North bubbles	3.5m	W	05:26 – 05:43
17	6m North bubbles	3.5m	W	05:44 – 05:55
18	8m North bubbles	3.5m	W	05:56 – 06:07
19	10m North bubbles	3.5m	W	06:08 – 06:18

Deployment Notes:

13.1.3 Deployment 3

Date: 18/05/2019 **Gas flow rate:** 30 LPM **ROV Dive:** 372

Model Current Estimations: Going N to S 21:30 18/05/19 to 02:50 19/05/19
Going S to N 3:00 19/05/19 to 08:00 19/05/19

Optode Configuration:

Prototype	Sensor config	Type of cap	Calibration type
2	pH	Metal	Old
~~3~~	~~pH~~	~~Plastic~~	~~New~~
4	pH	Plastic	Old
5	O2	Plastic	NA
6	pH	metal	New

Prototype 3 was not reconfigured properly to pH optode and so no valid data available.

Deployment Events:

Event	Location	Heading	Altitude (m)	Time (min)	Actual Time	Current
1	Close	178	1.5	30	21:46 – 22:17	Heading S
2	Close	178	2.5	30	22:19 – 22:49	Heading S
3	Close	178	3.5	30	22:50 – 23:20	Heading S
4	1 m S of bubbles	90	3.5	17	23:25 – 23:42	Heading S
5	2 m S of bubbles	90	3.5	17	23:43 – 00:01	Heading S
6	3 m S of bubbles	90	3.5	17	00:02 – 00:21	Heading S

7	4 m S of bubbles	90	3.5	17	00:22 – 00:40	Heading S
8	5 m S of bubbles	90	3.5	17	00:40 – 01:00	Heading S
9	6 m S of bubbles	90	3.5	10	01:01 – 01:11	Heading S
10	8 m S of bubbles	90	3.5	10	01:12 – 01:12	Heading S
11	10 m S of bubbles	90	3.5	10	01:23 - 01:33	Heading S

Event 12: Optode bundle was dropped on seafloor around 02:51. Given a good shake to get out sediment

Northward Current Transect

Start Time: 03:00 Duration: 2hrs 20 minutes Finish By: 6:00

Event	Location	Heading	Altitude (m)	Time (min)	Actual Time	Current
13	1m N of Bubbles	180	1.5	10	03:02 – 03:12	Heading N
14	2m N of Bubbles	180	1.5	10	03:12 – 03:22	Heading N
15	4m N of Bubbles	90	1.5	10	03:25 – 03:36	Heading N
16	5m N of Bubbles	90	1.5	10	03:37 – 03:47	Heading N
17	6m N of Bubbles	90	1.5	10	03:47 – 03:57	Heading N
18	8m N of Bubbles	90	1.5	10	03:58 – 04:10	Heading N
19	10m N of Bubbles	90	1.5	10	04:11 – 04:21	Heading N
20	1m N of Bubbles	180	2.5	10	04:28 – 04:39	Heading N
21	2m N of Bubbles	180	2.5	10	04:39 – 04:50	Heading N
22	4m N of Bubbles	90	2.5	10	04:55 – 05:07	Heading N
23	5m N of Bubbles	90	2.5	10	05:08 – 05:18	Heading N
24	6m N of Bubbles	90	2.5	10	05:19 – 05:29	Heading N
25	8m N of Bubbles	90	2.5	10	05:31 – 05:42	Heading N
26	10m N of Bubbles	90	2.5	10	05:43 – 05:56	Heading N

Extra vertical bubble profile

Event	Location	Heading	Altitude (m)	Time (min)	Actual Time	Current
27	Over bubbles	180	1.5	10	09:08 – 09:19	Heading N
28	Over bubbles	180	2.5	10	09:20 – 09:30	Heading N
29	Over bubbles	180	3.5	10	09:31 – 09:41	Heading N

14 In situ porewater profiles: Dirk de Beer, MPI-MM, Bremen

14.1 Overview

We aimed to find the spatial heterogeneity of seepage, by measuring the effect of venting on the porewater profiles. Part of the CO_2 will dissolve and form DIC (dissolved inorganic carbon, sum of CO_2, HCO_3^- and H_2CO_3). We also aim to estimate how much of the CO_2 escapes as DIC. A microsensor profiler was used to measure transects of the profiles of O_2, pH, T, H_2S and ORP. The O_2 profiles will provide information on the microbial activities. pH, T and ORP are well documented sensitive indicators for seepage, where the pH and ORP decrease, and T increases due to upward porewater flow. Venting, the excape of gas bubbles, drives seepage, the movement of porewater. Porewater is generally lower in pH and enhanced in reduced substances. ORP is measured by a bare Pt sensor, that reacts primarily with H_2, H_2S and Fe^{2+} (ORP down), and weakly with O_2 (ORP up). We expected the T in the sediments to be lower than the bottom water.

The combination of pH and alkalinity profiles will further allow calculating the DIC profiles, and from profiles we can calculate the DIC fluxes.

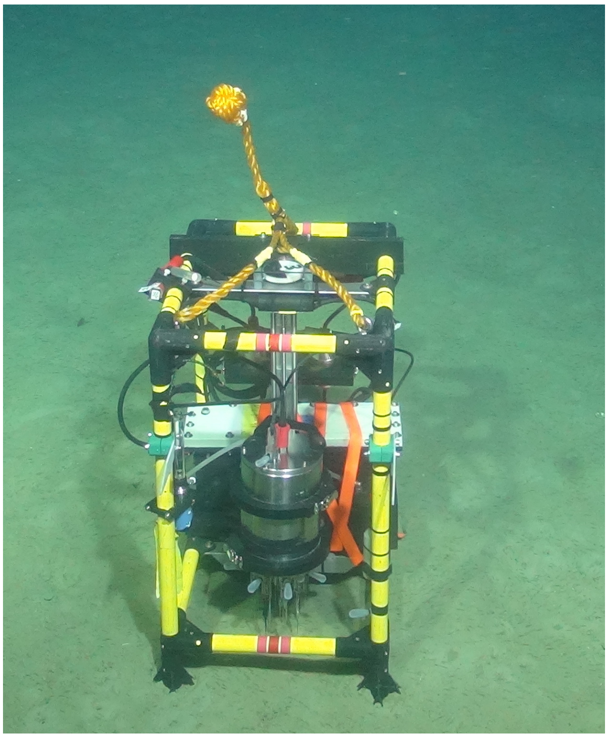


Figure 14.1. Benthic lander in position on the release site

14.2 Preliminary results

The profiles were mostly measured along N-S transects, and once along a E-W transect. The profiler was positioned by the ROV, and started. Each measurement took an hour after which the profiler could be repositioned and restarted for a new measurement. Measurements were done before venting, and during venting of 2, 5, 30 and 50 L CO_2/min. Altogether 37 profiler measurements were done.

date	Distance from vent	Venting rate L/min	remarks
8/5/2019	1, 2, 4, 7, 14	0	

11/5/2019	0, 0, 0, 1, 2, 4, 8	2	Heterogeneity around vent
14/5/2019	0, 0, 0, 0, 1, 2, 3, 4	5	Heterogeneity around vent, incl pockmark and new vent
17/5/2019	0, 1, 2, 3, 4, 4, 8, 8	30	The 2nd 4 m and 8 m positions were after current turned N
20/5/2019	0, 1, 4, 8, 20 0, 3, 5, 8	50	The second series was measured E-W direction.

Also we deployed 4 pH optode and T loggers at 1, 2, 4 and 8 m from the expected vent to document the pH and T dynamics upon CO_2 venting. These data are being processed by Moritz Holtappels and Sergey Borisov.

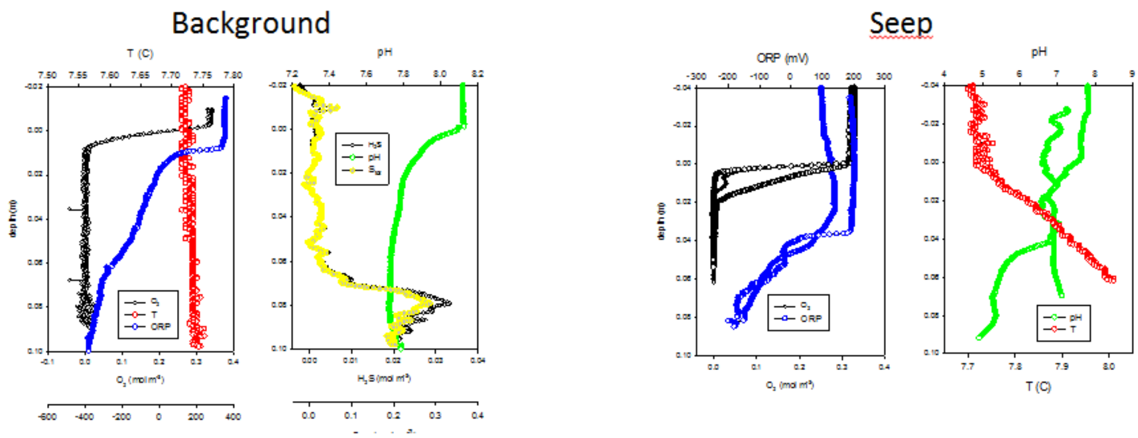


Figure 14.2. Example profiles show effects of venting:

At the vent profiles often became a bit chaotic, the pH decreased near vents and the temperature increased. Sulfide was measured occasionally, but at the lower end of the detection window, and was not further analysed.

No consistent effect was observed on the ORP profiles, except for some occasional disturbance by gas venting. This means that the dissolved Fe^{2+} is not washed out. Effects of pH and T were observed along the transects at similar distances.

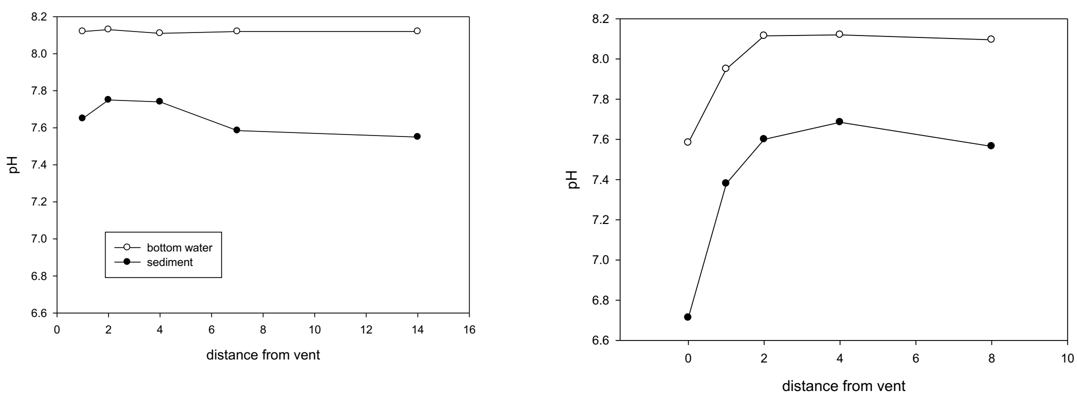


Figure 14.3 Examples of distribution of the pH effects of seepage. Background (left) and 2 L/min (right). Plotted are the bottom water pH, that is also influenced by the current direction and the pH at 5 cm depth. The pH effects are very local, 2-4 m from the venting.

Venting can influence the temperature and porewater chemistry up to 4 m distance from the seeps. Thus an area of about 50 m^2 is impacted. First analysis indicates that higher CO_2 debits than 5 L min^{-1} does not further enhance effects. No effects of CO_2 venting on the O_2 uptake rates could be found, which means that the benthic respiration is not influenced by the decrease in pH or the increase in CO_2 levels.

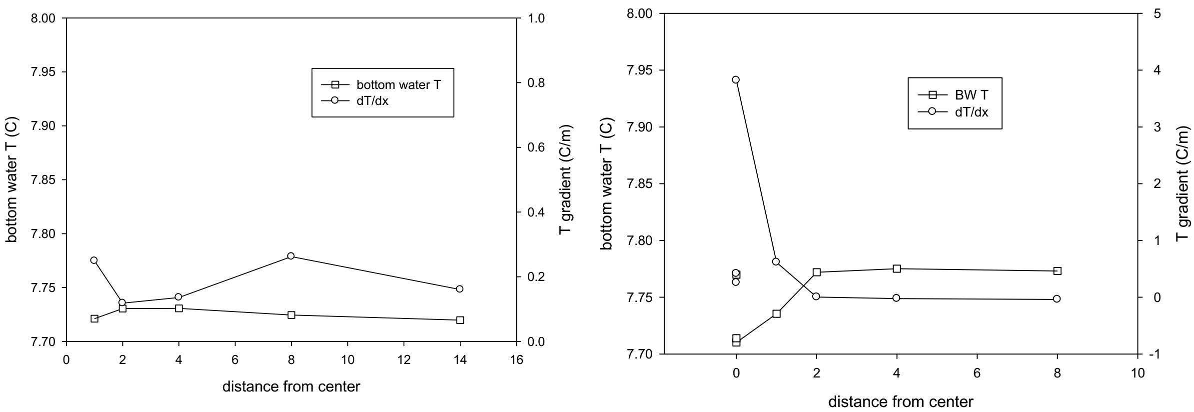


Figure 14.4 Distribution of the temperature due to seepage. Plotted are the bottom water T and the T gradients inside the sediment. Also the T effects are very local.

After the cruise the DIC profiles will be calculated from the pH profiles and alkalinity profiles from Dr Pearce, and the resulting DIC fluxes using a 1-D diffusion model.

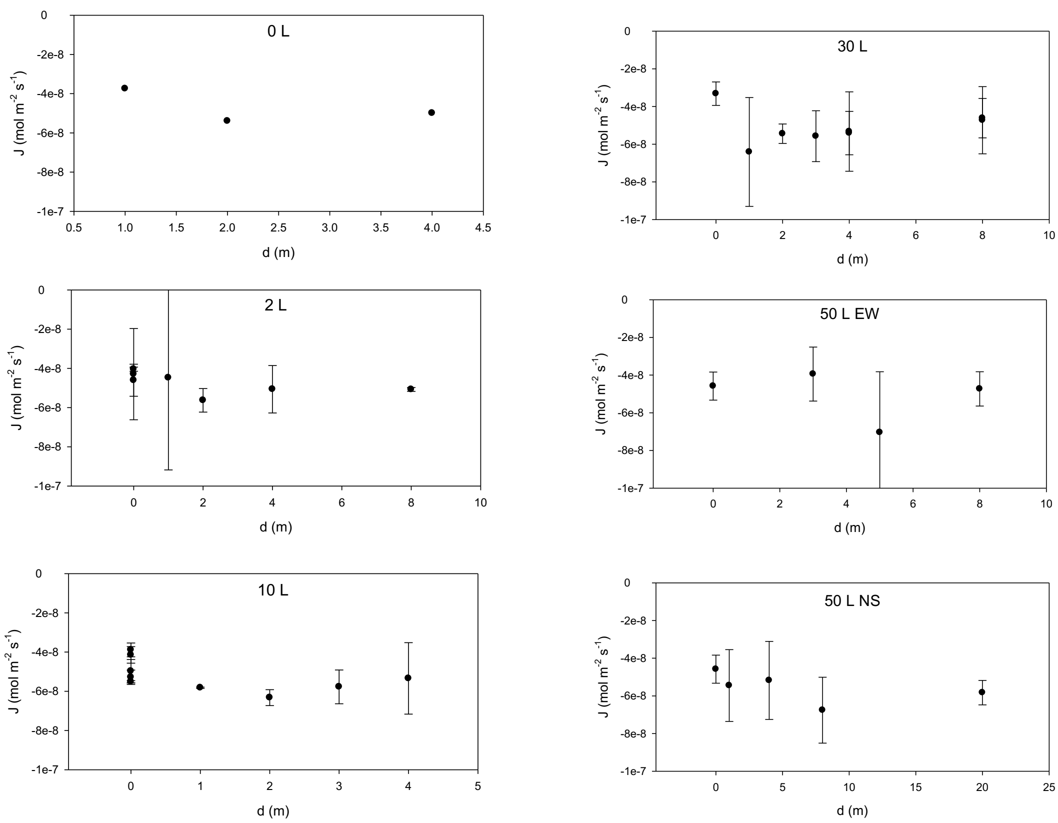


Figure 14.5. Summary of oxygen fluxes

The diffusive fluxes are calculated from the profiles. The total fluxes are the sum of diffusive and advective fluxes, which means the sum of the fluxes by bioventilation and current-driven exchange. The values given below may thus underestimate the total flux. The total flux, measured by benthic chambers, is often double the diffusive flux.

The O_2 influx is variable (Figure 14.5), per location averages from 4-6x10^{-8} mol m^{-2} s^{-2}. Near the venting the rates are slightly reduced, but statistically this is weak.

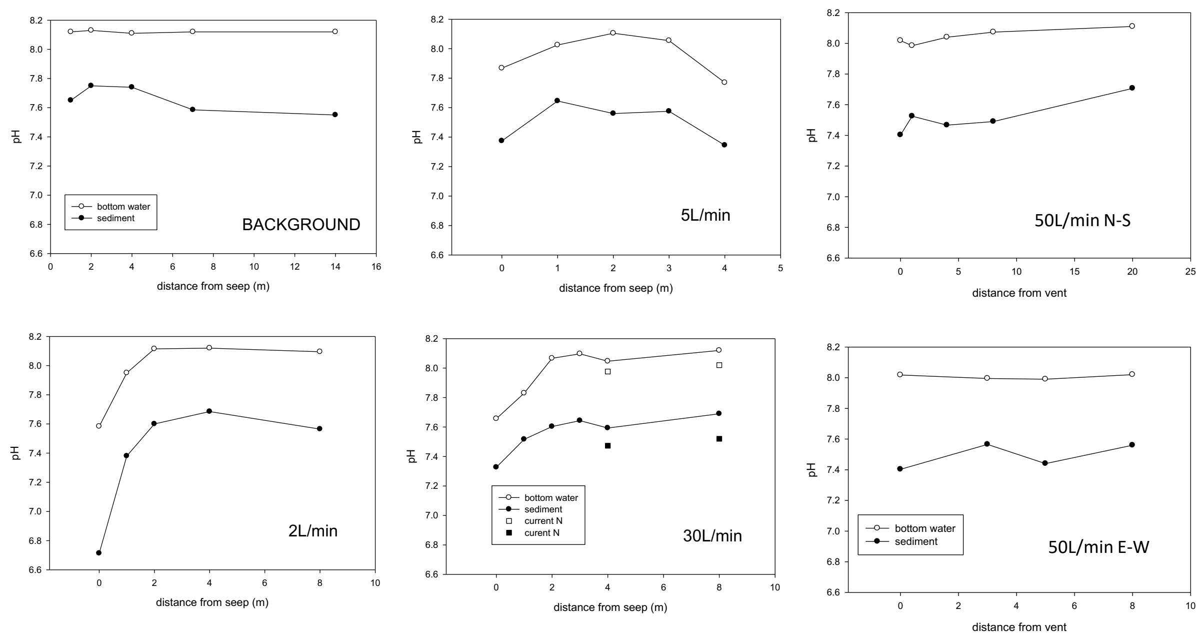


Figure 14.6 The summary of all pH profiles

The pH is reduced by venting, as expected (Figure 14.6), both inside the sediment and in the boundary layer above it. Inside the sediments extreme values were occasionally as low as 5.8, probably when the sensor tip entered a gas channel. Mostly the pH inside sediments was between 7.3 and 7.6 near vents, while the background values were 7.8. The effects are very local 2- 4 m from the venting sites. The pH decrease was not enhanced by higher CO_2 venting.

Surprisingly the temperature increased in the sediment during CO_2 venting, Figure 14.7. This was unexpected as the deeper sediments were thought to be colder than the bottomwater. Either there is a heat 'pool' residing due to the higher temperatures from last summer, or CO_2 venting generates heat by friction or by chemical reactions between sediment and CO_2. The temperature effects were clearly detectable up to 4 m from the vents, although even at 8 m distance occasionally elevated T-gradients were found. The second transect of 50L/min was done in E-W direction.

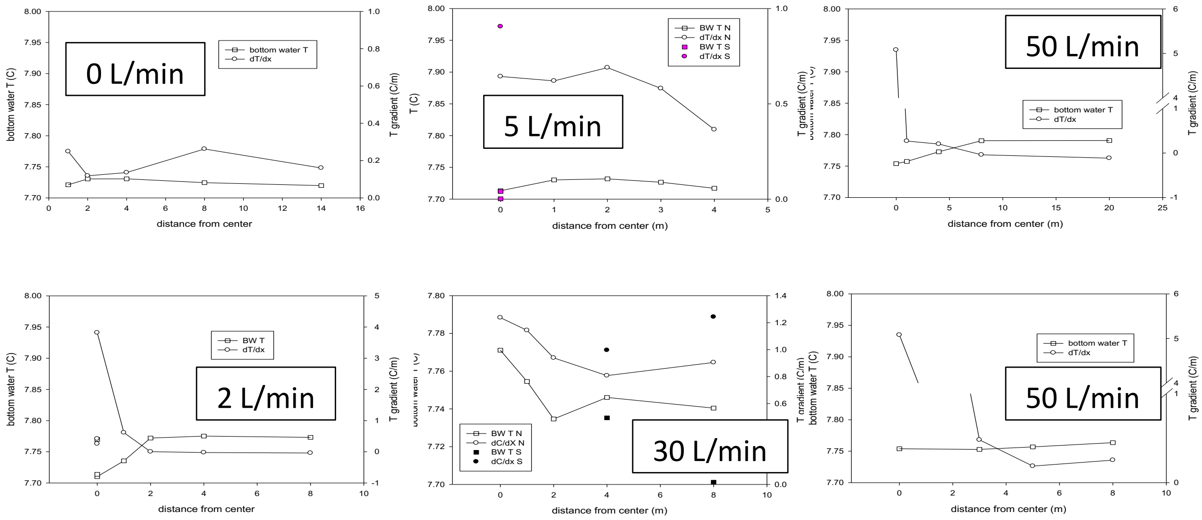


Figure 14.7 Summary of the temperature data

15 Seafloor mapping: James Strong, Brett Hosking & Veerle Huvenne

15.1 Shipboard mapping: EM710 surveys

15.1.1 Collection of additional bathymetry data

As part of the STEMM-CCS project, seafloor bathymetry data had already been collected in the Goldeneye area in 2017 (RV Merian cruise) and 2018 (RV Poseidon cruise). However, particularly the Poseidon survey had been carried out in adverse weather conditions, and the bathymetric dataset contained a number of gaps. Those were filled during JC180, using a short survey as listed in Table $$$. The data were processed in CARIS, exported at 5m pixel resolution, and integrated into the STEMM GIS.

15.1.2 Investigation of abandoned wells

In addition to the dedicated EM710 bathymetry surveys, bathymetric data were also collected during an investigation of two abandoned wells in the wider Goldeneye area (at the same time as EK60 data), with the aim of identifying any seabed structures and/or bubble plumes formed by potential leaks. Surveys and settings are listed in Table 15.1.

15.1.3 Stationary multibeam data collection

Throughout most of leg1, EM710 bathymetry data were collected while the ship was stationary over the instrument site. Intermittently, the water column data were also stored, in order to record potential bubble streams (either as a natural, background phenomenon to be registered before the experiment, or as a result of the experiment). No further data processing was carried out on board with these datasets. The EM710 was switched off during leg2 to limit the amount of noise in the water column and provide a quit(er) environment for the hydrophone walls.

15.1.4 Underway multibeam data collection

EM710 data were also collected during some transits to and from the research area, as a general data collection opportunity for the UK research community. Settings were kept general (65/65 deg swath cover), using the lastvalid sound velocity profile (SVP) at the time (Fig. 15.1).

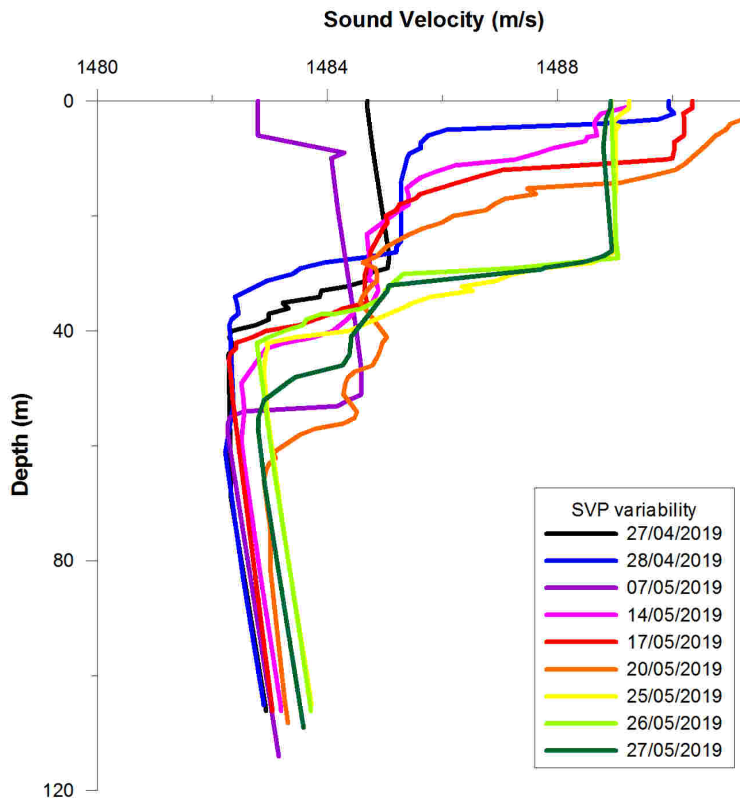


Fig. 15.1 JC180 Sound velocity profiles used for bathymetry processing

Table 15.1. Shipboard EM710 multibeam bathymetry surveys

EM710 survey	Date	Start time	End time	Swath cover (deg)	Speed (kn)	SVP used	Comments
Filling bathy gaps	28/04	16:37	21:42	65/65	6	28042019_edited_ sorted_thinned.asvp	Reduced ping rate as result of synchronisation by ADCP
Abandoned wells	02/05	13:49	16:10	45/45	4.0 – 5.5	28042019_edited_ sorted_thinned.asvp	Survey carried out under worsening weather which made ship handling challenging

15.2 Gavia missions

15.2.1 Survey types

The Gavia AUV was used for four different types of seafloor survey, each with their own design, optimising the data collection to answer different questions. System settings for all surveys are listed in Table 15.2

i. Pre-site survey

Before the STEMM-CCS experiment was installed on the seafloor, the site was surveyed to establish the character of the seafloor, and to evaluate the safety for deployment of the CO_2 and drill rigs. The survey combined seafloor mapping (Geoswath sidescan and multibeam data collection) with sub-bottom profiling to establish the thickness of the Witch Ground Formation (see Section 5) and the collection of seafloor images. A lawn-mower pattern with line spacing of 40 m was chosen, oriented N-S (parallel to the main tidal current direction), complemented by a number of crossing lines to provide tie-lines for the SBP survey (Fig. 15.2). In addition, seafloor photographs were collected at ~2m above the seafloor.

ii. Off-site surveys

Three off-site Gavia missions were carried out as part of the environmental baseline survey for the Goldeneye site. Their emphasis was more on mapping of seafloor characteristics, in particular different seafloor habitats and traces of anthropogenic impacts (e.g. trawl scars), rather than on imaging the sub-seafloor, hence line spacing was increased to 50 m and length to 1000 m in order to obtain maximum coverage. Also here, photographs were taken, and the sub-bottom profiler recorded data.

iii. On-site surveys

Three on-site Gavia missions were carried out, between the different phases of the release experiment. The primary objective was to obtain sub-bottom profiler data, however, GeoSwath data were collected for a number of survey lines (both N-S and E-W oriented). Survey lines were close together (20 - 40m) and short (~200m). They offered a chance to map out the larger pieces of equipment at the experimental site (CO_2 rig, large instrument frames), and even the Baseline Lander that was deployed in 2017. During the last on-site survey, GeoSwath data were also collected along SW-NE and NW-SE oriented survey lines. These lines were part of the SeaFET survey (see Section 17.11) carried out at 4.5m altitude. The survey was used as an opportunity to test various settings on the GeoSwath.

iv. Post-experiment survey

The last activity of the cruise was another Gavia survey over the experiment site, following the same survey pattern as the on-site surveys, but with the SeaFET part of it carried out at 2m altitude, to allow simultaneous photography.

Table 15.2 Gavia AUV seafloor mapping surveys

					Geoswath survey					Camera Survey		
Gavia Mission	Deployment	Date	Time	Total Duration (h)	Altitude (m)	Range (m)	Line spacing (m)	Line Length (m)	Nr of lines	Altitude (m)	Length (m)	Nr Lines
M1/pre-site	JC180-009-AUV02	28/04	08:00	5h02	7.5	50	40	500 - 1000	8	2	500	8
M2/off-site	JC180-017-AUV03	01/05	10:53	6h53	7.5	50	50	1000	16	2	1000	8
M3/on-site	JC180-035-AUV04	14/05	06:59	5h35	7.5	30	40	200	2x4	NA	NA	NA
M4/on-site	JC180-044-AUV05	17/05	07:01	5h14	7.5	30	40 and less	200	6	2	xx	xx
M5/on-site	JC180-052-AUV06	20/05	06:55	5h55	7.5 4.5	30 20	40 and less	200, 175	36	2	xx	xx
M6/off-site	JC180-060-AUV07	25/05	09:12	6h19	7.5	50	50	1000	12+4	2	1000	2

M7/off-site	JC180-063-AUV08	26/05	09:08	6h07	7.5	50	50	1000	12+4	2	1000	2
M8/post-exp	JC180-067-AUV09	27/05	09:22	5h54	7.5	30	40	200	8+4	2	200	

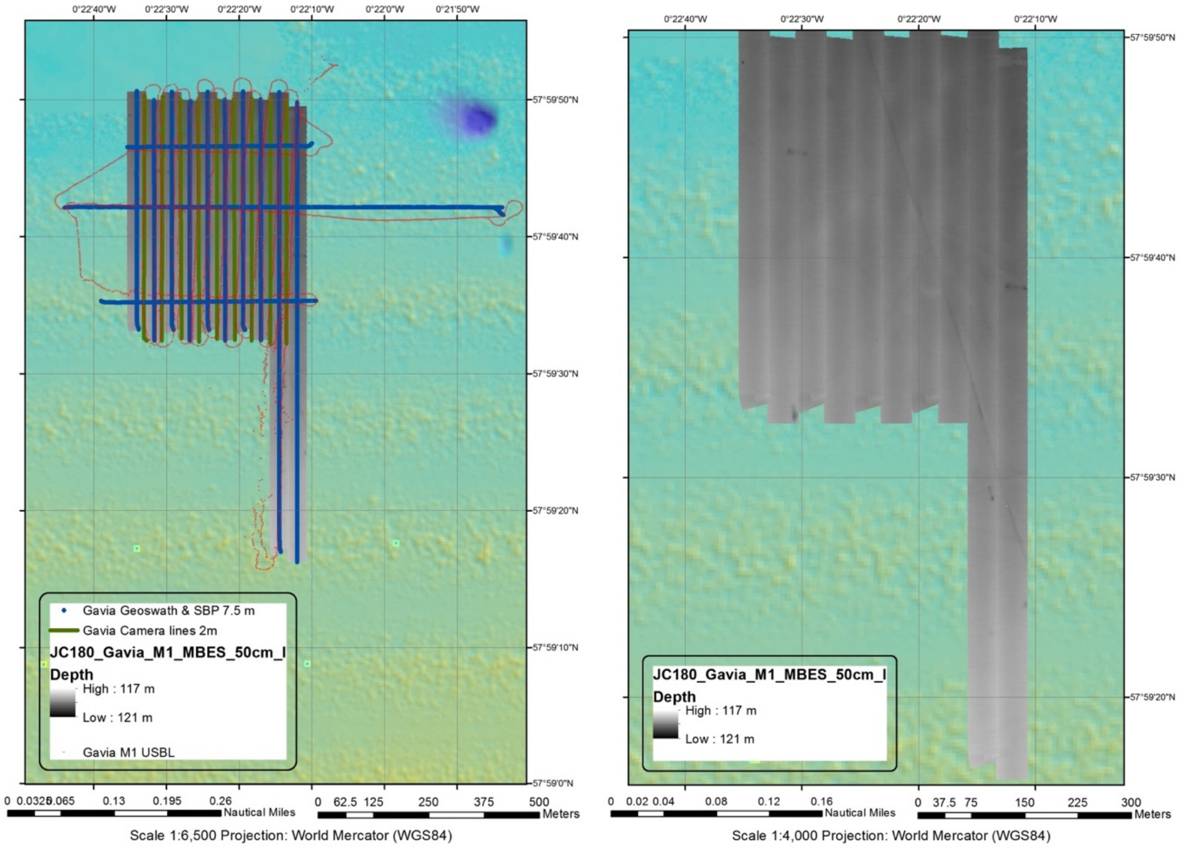


Figure 15.2 Gavia Doppler/ inertial navigation unit track (blue) and USBL positioning (red) for the pre-site survey (left) and processed bathymetry (r

15.2.2 Gavia bathymetry data

The Gavia GeoSwath data were recorded in .rdf format, and initially processed with the GS4 software. This software package allows the user to set a number of basic filters (e.g. based on depth limits). Due to the nature of the GeoSwath system, the raw data are inherently noisy (Fig. 13.3).

The GS4 filters provide the tools to remove the majority of the noise. The data were exported from GS4 as 'flagged' .rdf files, and imported into CARIS Hips & Sips for further processing (corrections for tide, sound velocity) and data cleaning. Despite the initial filtering in GS4, severe further data cleaning was needed as it appeared that the GS4 flags were not correctly imported in CARIS. Significant levels of noise persisted around the nadirs, and at the outer ranges (>25m).

Sound velocity corrections were based on sound velocity profiles collected regularly from the ship (Fig. 15.1), in addition to sound velocity measurements at the hull of the Gavia. Despite these corrections, slight across-track distortions were still visible in some of the data, particularly at the outer ranges. The very low grazing angles of the GeoSwath may induce ray path refraction effects.

Tide corrections were based on tide ranges modelled with the NOC Liverpool POLPRED model.

The final bathymetry surfaces were gridded with the CUBE algorithm at 15 or 25cm pixel resolution and exported as GeoTiff to the cruise GIS (Fig. 15.4).

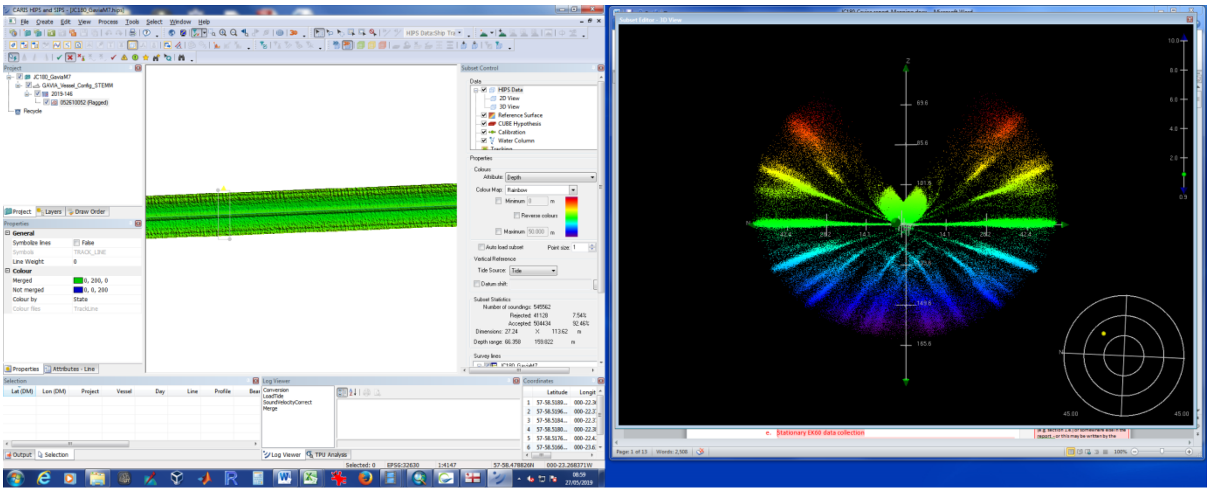


Fig. 15.3 Noise patterns around Gavia GeoSwath bathymetry data

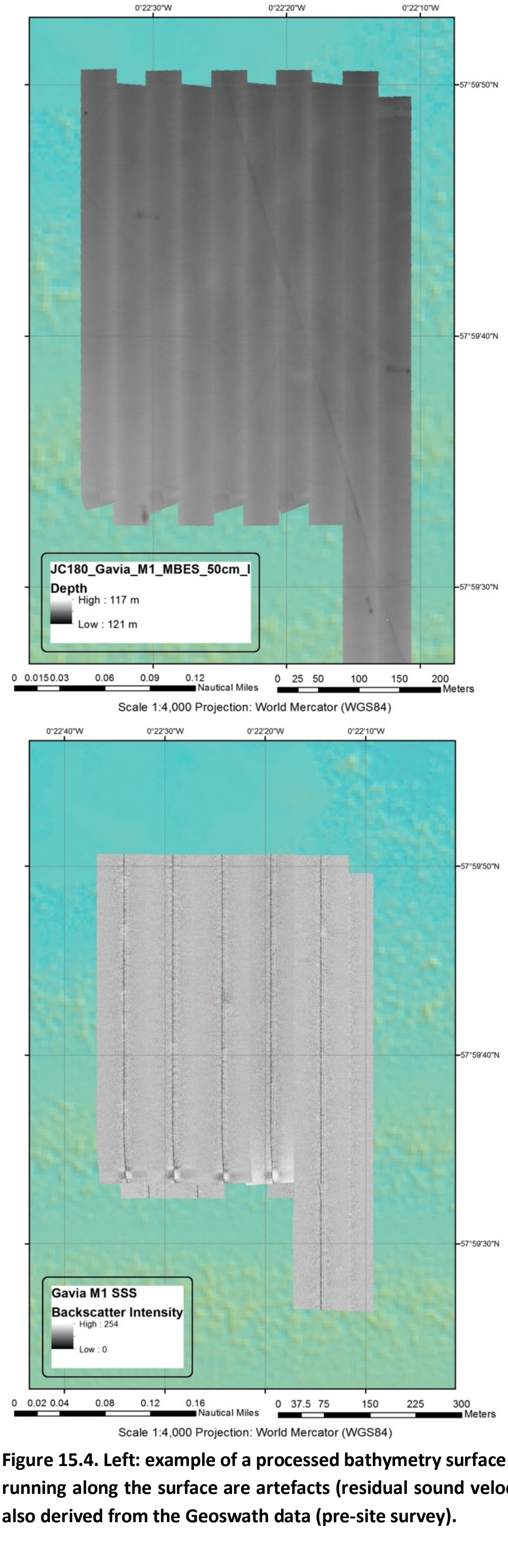


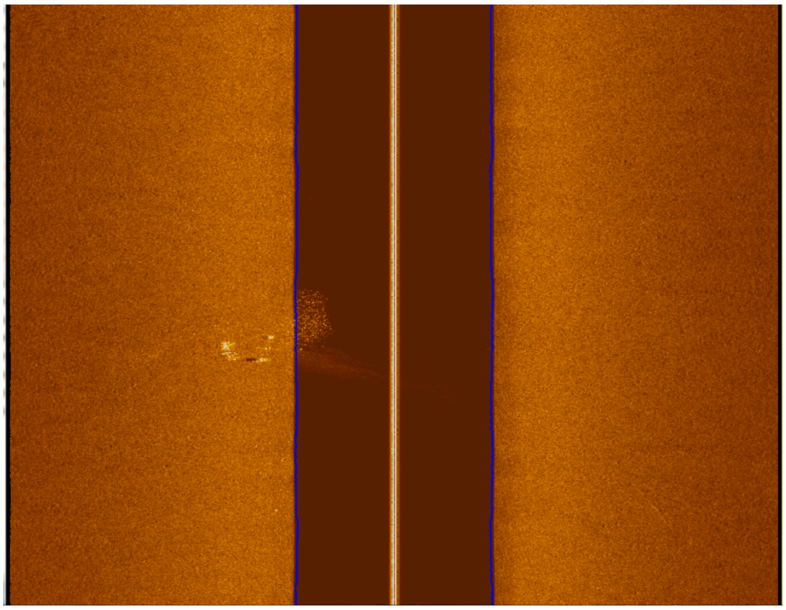
Figure 15.4. Left: example of a processed bathymetry surface derived from GeoSwath data (pre-site survey). Vertical stripes running along the surface are artefacts (residual sound velocity errors/noise). Right: example of side-scan sonar imagery also derived from the Geoswath data (pre-site survey).

15.2.3 Gavia sidescan sonar

Sidescan sonar data were processed in the SonarWiz software. Input data consisted of the same .rdf files as used for the bathymetry processing. Processing steps differed slightly between surveys, depending on maximum range and on data characteristics. Typically, they consisted of a quick check of the bottom tracking (which was generally OK), followed by application of a TVG (scalar = 20 on both port and starboard side), a nadir filter (filter angle 20) and in some cases an AGC. The levels of these filters differed between surveys, and even between lines. It appears that the GeoSwath system on board of the Gavia applies some automated gain control, although no settings for this were found in the mission design software. Where necessary, the range displayed was limited to just over half the line spacing to create the final mosaic and the display colour scale was adapted manually to optimally visualise the mapped features.

The output files were gridded as 5cm resolution GeoTiff files and exported to the ArcGIS project.

A useful by-product of the sidescan sonar surveys was the fact that the sonar recorded in its 'watercolumn' section a series of fish schools that had gathered around our equipment, but most importantly also the bubble plumes created at the higher flow rates (30-50l/min – Fig. 15.5)



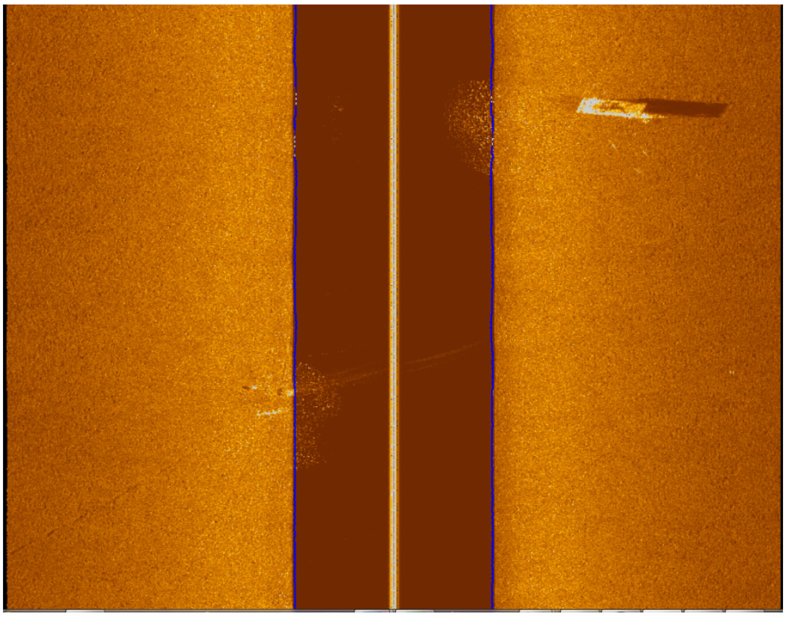


Fig. 15.5 Illustrations of bubble plume and potential schools of fish as picked up by the Gavia AUV on the Geoswath data. Images from Gavia M5

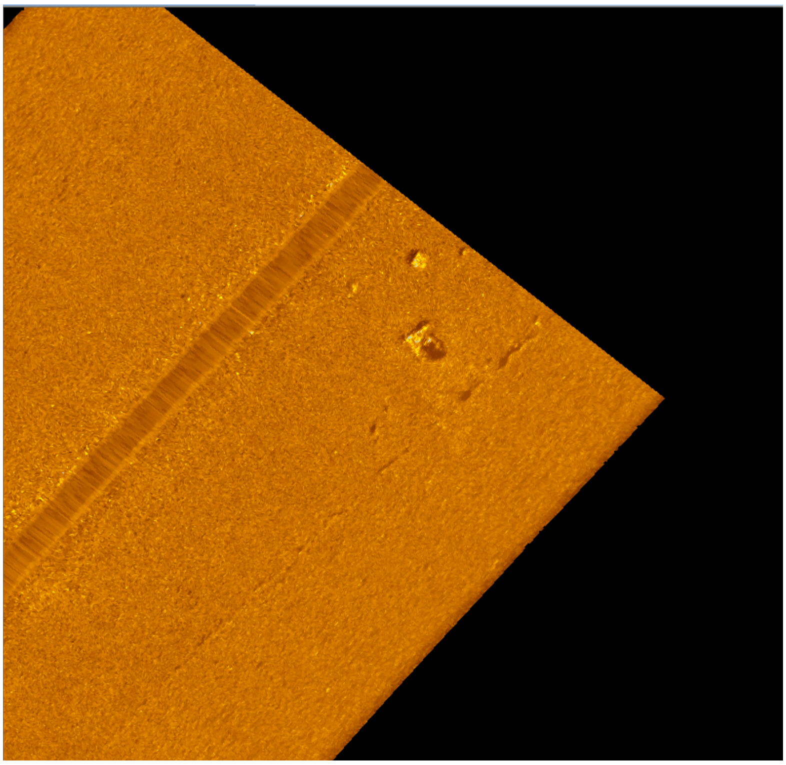


Fig. 15.6 Raw sidescan sonar image of the lost baseline lander with surrounding depressions and potential trawl scar.

As part of the third on-site Gavia survey, a number of range and gain settings were tried out while the AUV was carrying out the SeaFET survey at 4.5m altitude. This allowed us to evaluate system performance. The settings used are summarised in Table 15.3. No marked differences in performance were observed, probably because the internal AGC may have adjusted the final gains used. Changes in range mainly affected the swath width and hence coverage, but also the pixel resolution (both across- & along-track, the latter as a result of higher ping rate).

Table 15.3 GeoSwath settings for test lines during Gavia M5

File number	Orientation	Range	Gain Setting
052010453	SW-NE	30	5
052010483	SW-NE	30	5
052010514	SW-NE	30	3
052010543	SW-NE	30	3
052010574	SW-NE	30	4
052011003	SW-NE	30	4
052011034	SW-NE	20	4
052011064	SW-NE	20	4
052011094	SW-NE	20	5
052011124	SW-NE	20	5
052011154	SW-NE	20	3
052011184	SW-NE	20	3
052012010	NW-SE	30	5
052012034	NW-SE	30	5
052012072	NW-SE	30	3
052012100	NW-SE	30	3
052012134	NW-SE	30	4
052012162	NW-SE	30	4
052012200	NW-SE	20	4
052012224	NW-SE	20	4
052012262	NW-SE	20	5
052012290	NW-SE	20	5
052012324	NW-SE	20	3
052012352	NW-SE	20	3

15.2.4 Gavia photography

As the Gavia camera had not had much usage prior to this cruise, other than for capturing monochrome jpeg imagery, there was some degree of experimentation and trial and error during the initial deployments to produce desirable image quality. This also meant that the amount of storage required for imagery prior to this cruise was relatively small and it wasn't until after the first Gavia mission (and during M2) that it was realised that the memory card within the camera only had a 16 GB capacity. Using the minimum temporal sampling frequency of 1.875 fps, the maximum spatial frequency of 1280x960 pixels, the 'RAW' setting, and including the camera system files, it is possible to capture roughly 32 minutes of continuous imagery. For this reason, from M3 onwards, camera surveys were programmed to be much shorter so not to waste time that could be used for collecting other forms of data using the Gavia at different altitudes.

The first mission produced images that were predominantly green and it was initially unclear why this was the case (Fig. 15.7). Tests performed on deck, with the same settings, produced a much more desirable colour balance. It was therefore expected that the colour temperature of the flash was the cause, as the images on deck were captured under natural light. The Gavia manual also states that the flash is designed to be used for monochrome images. Post processing produced better results but lack of information in the blue and red channel meant that it was hard to produce a realistic colour balance with sufficient detail. An error also caused the camera logs to be dated 14th June 2014. This error was calculated to be -153719717.155357794 seconds.

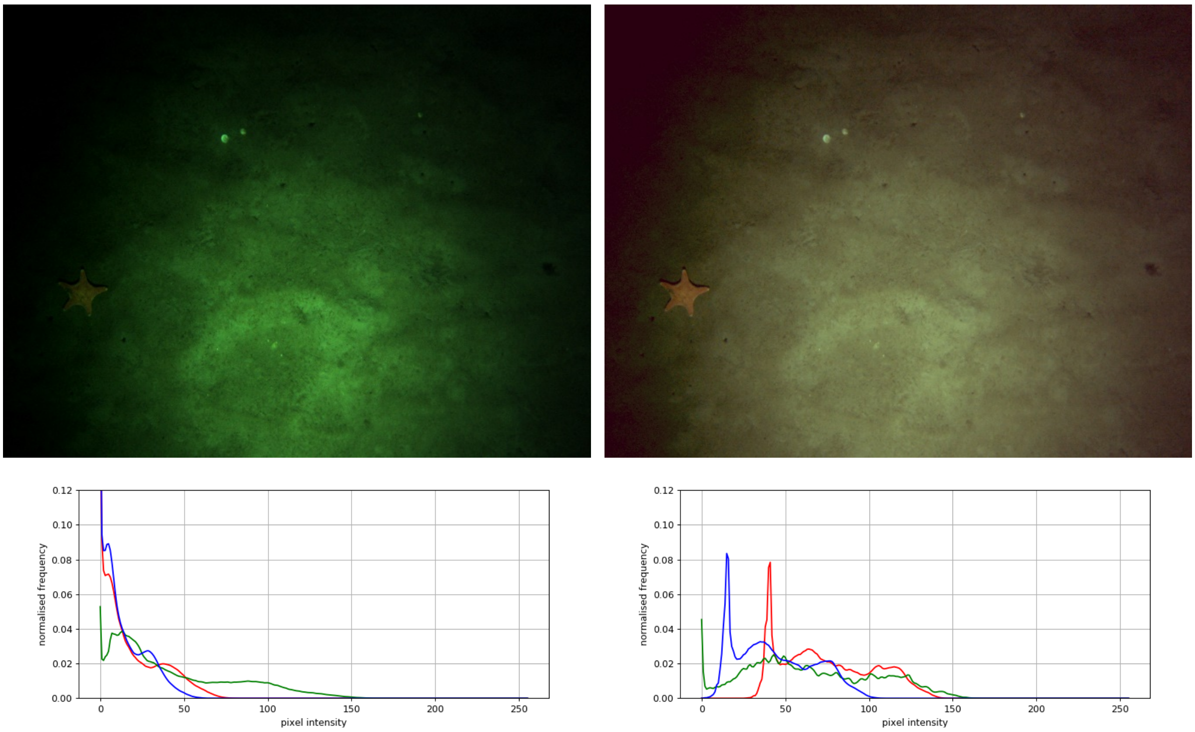


Fig. 15.7 Example from the first Gavia Mission – Original (Top Left) and Processed (Top Right) image. Minor post processing was applied to produce a better colour balance and reduce contrast (Red+30, Green-10, Blue+5, contrast-40). Original image histogram (Bottom Left), Processed image histogram (Bottom Right)

Different colour gain combinations were tested during the beginning on M2 and slight adjustments were made for the main camera survey in an attempt to counteract the problem. The images captured for this mission were still predominantly green but the results gave us a better idea of what adjustments should be made for future missions. Due to difficulties during M3, no camera data were collected. Part of M4 was used to run a short camera survey (just off from the experimental site) to test more camera settings. From these we were able to learn a good combination of parameters that we intended to use for the remainder of the camera surveys. M5 produced images with a much more realistic colour balance (Fig. 15.8). M6, however, produced images similar to M2 as parameters were input into the Gavia Control Centre software incorrectly. This was rectified before M7, which produce images similar in colour to those of M5. The final mission over the experimental site, M8, also produce images similar in colour to those of M5.

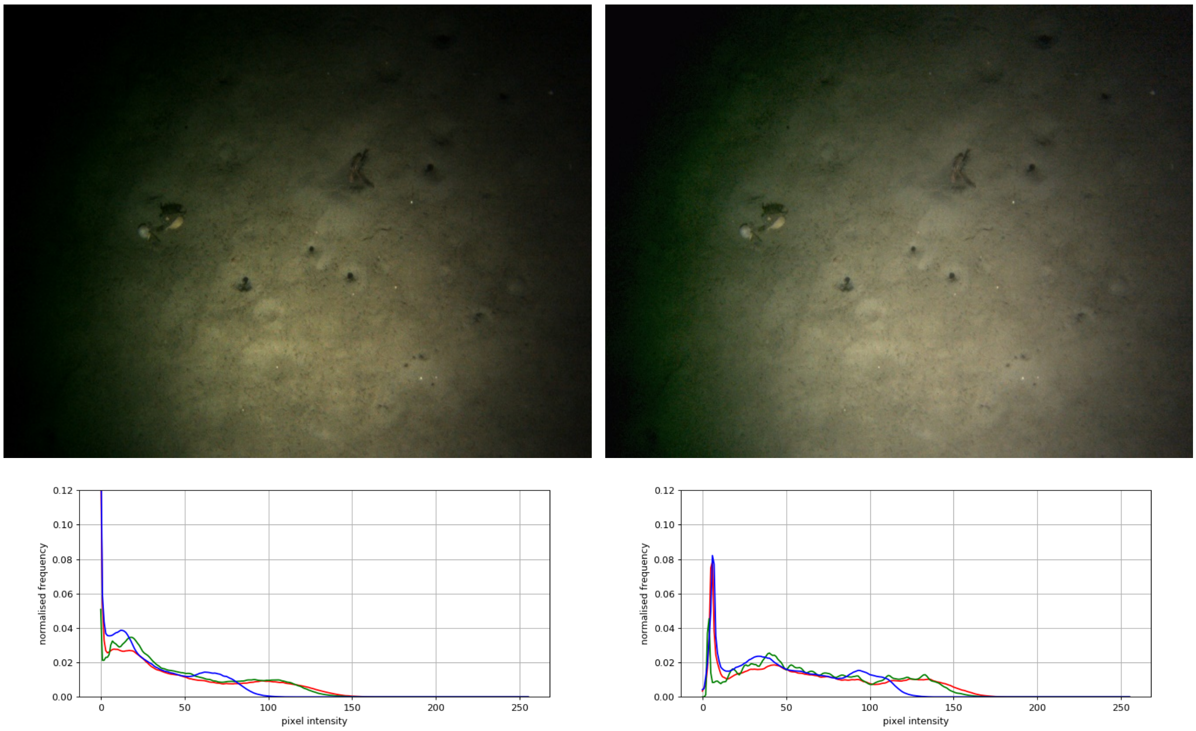


Fig. 15.8 Example from the fifth Gavia Mission – Original (Top Left) and Processed (Top Right) image. Minor post processing was applied to produce a better colour balance and reduce contrast (Red+2, Green+0, Blue+2, contrast-14). Original image histogram (Bottom Left), Processed image histogram (Bottom Right)

It is recommended that a greater capacity memory card is fitted to allow for longer camera surveys. However, it should be noted that the download time from the Gavia takes roughly 30 minutes with a 16 GB memory card and therefore longer download times should be expected with greater capacity memory cards. To reduce vignetting the Gavia could be flown at a lower altitude, however, this increases the risk of colliding into the seafloor.

The Gavia Control Centre (*master_build-213_2018-11-26_dbdcb34d-181126-1330*) was used for programming the Gavia missions. The Gavia camera logs were processed using a purpose-built Python package *Gavia (*github.com/brett-hosking/gavia [version 0.0.1]), which was developed onboard, see *examples* section on GitHub for usage examples. Image histograms were calculated using Python and image processing was applied using IrfanView. All plots were generated using Python and Matplotlib. Examples of specimens were located manually using the processed imagery. The full version of the camera report can be found at github.com/brett-hosking/gavia/docs/reports/.

Mission	**Survey Images**	**Average Survey Altitude (m)**	**Survey Duration (mins)**	**Test Images**
1	3704	2.3531	37.57	0
2	3445	2.3652	34.51	255
3	0	-	-	0
4	0	-	-	593
5	1315	2.3427	14.7640	0
6	3495	2.3400	32.6926	0
7	3594	2.3646	33.7414	0
8	3671	2.3679	82.0243*	0

*There was a break in the middle of the camera survey

Fig. 15.9 Examples of specimens found throughout JC180

15.3 ROV-based mapping

15.3.1 Release site photogrammetry

The exact spatial arrangement of seabed instruments in relation to the gas vents was of particular interest to all of the researchers. Photogrammetry techniques provide a convenient method for constructing three-dimensional renditions of the experimental site using still imagery derived from videos. The ISIS ROV was used to collect slow, orbiting video transects round the experimental site. Still imagery was extracted from the videos using VLC, at a rate of 1/50 frames). The images were subsequently imported into the Agisoft Photoscan software and processed (photo alignment, building dense point cloud & mesh, creating textured DEM – see example Fig. 15.10).

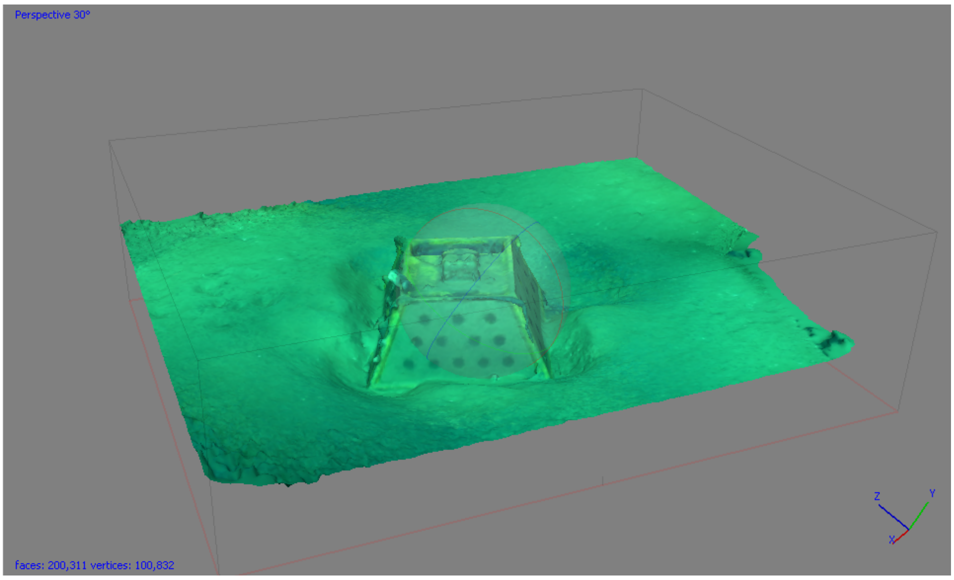


Figure 15.10 Example of 3D photogrammetry reconstruction of lost baseline lander

15.3.2 Release and test-release site video surveys

A series of specific seabed video transects were carried out with the aim to: (i) assess the detailed distribution of seabed disturbance from seeping gas, instrumental observations and gravity core sampling (Poseidon) ; (ii) characterise the assemblage of emergent megafaunal and epifaunal species e.g. polychaete tubeworms (probably *Galathowenia oculata*), seapens (typically *Pennatula phosphorea*), burrowing megafauna (*Nephrops norvegicus* and other burrowing species) and abundant seastars (*Asterias rubens)*, at both sites; and (iii) whether experimental conditions (either disturbed ground or CO_2/CO_2 derivatives) were attracting mobile epifaunal species to the site - ISIS-based transects were collected at both the experimental site ('pipe 2') and the test–release site ('pipe 1') with the latter being taken as a control site for the former.

Two video transect patterns were designed to provide either a 'rapid' or a 'detailed' survey (Fig. 15.11). The 'rapid' transects consisted of three parallel transects separated by 3 m. Each transect was: (i) 14 m in length; (ii) flown at an altitude of 2.5 m; (iii) orientated along the direction of the pipe; and (iv) flown at a speed of 0.05 knots. The ROV pilot camera was set to a broad field of view to capture the mobile epifaunal species (e.g. *Asteria* sp.). The science camera was panned down for a near-vertical view to capture and identify burrowing megafaunal species from burrows entrances and spoil mounds. The scorpio camera was zoomed fully in to capture the laser scaling and the polychaete tubes. The rapid assessment was flow at both sites before, during and after experimental observations. The 'detailed' survey had 14 parallel transects separated by 1 m. Individual transects were: (i) 15 m in length; (ii) flown at an altitude of 1.0 m; (iii) orientated along the direction of the pipe; and (iv) flown at a speed of 0.05 knots. The configuration of cameras was the same as the rapid survey. The 'detailed' survey was only conducted once at the experimental site after the gas flow was stopped and all seabed instruments removed. Image processing after the expedition will be used to generate full-coverage photo mosaics and 3D photogrammetry models for specific features. These products will be used to derive the faunal densities.

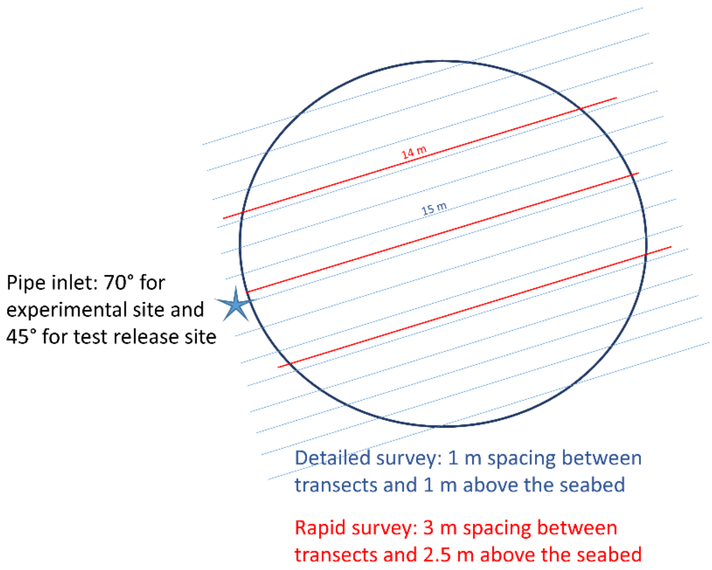


Figure 15.11. Configuration of the detailed and rapid video transect surveys.

15.3.3 A note on equipment navigation and positioning

Throughout the expedition, the Ultra Short Base Line underwater navigation system (USBL) was used to position the ROV and AUV, and some other key pieces of equipment (e.g. drill rig, CO_2 rig) during their operations. However, following the first AUV mission and the first two ROV dives, it was noted that the USBL system was affected by considerable errors, particularly when the equipment was not operating directly under the ship. Horizontal positioning errors >20m were observed (Fig. 15.12). Both the ship's Port and Starboard USBL poles caused similar errors. The sound velocity profiles used in the Ranger software to correct for acoustic ray path refraction were frequently updated with the latest measurements, but even then the errors persisted. Hence any future user of the JC180 dataset should be cautious when relying equipment positions (e.g. positions recorded in the OFOP software etc.).

For the AUV missions, the internal inertial navigation of the Gavia was preferred over the USBL registered navigation. The bathymetry and sidescan sonar images of consecutive survey lines were largely internally coherent, with only small positional offsets in the order of 1-3m caused by natural drift of the inertial navigation. Particularly during the on-site surveys, those offsets became apparent as a result of the clear objects we had present on the seafloor (CO_2 rig, various landers). However, larger offsets would build up during the diving phase of the AUV missions, when the vehicle was moving from GPS-based positioning at the surface to internal, Doppler-based navigation at the seafloor. This drift caused offsets in the order of 5-8m.

For the ROV dives, the working solution was also to use the vehicle's Doppler navigation. At the start of every dive, and after every time the ROV had to land on the seafloor (landing would cause the Doppler navigation to 'drift' away) the ROV would be positioned at a known location, and the Doppler navigation system would be 'reset' to that known coordinate. The main reference point used was the visible end of the drilled pipe at the experimental site, where the ROV would line up with a heading of 70°. The coordinates of this point were determined with confidence from the location where the drill rig was deployed, right next to the ship, when it drilled the pipe. This reference point enabled the ROV to work with satisfactory spatial accuracy within the 7m radius experimental site. A secondary reference point was chosen at the CO_2 rig, being the panel that contained the valves and gauges. The ROV would square up to the rig before the Doppler would be reset.

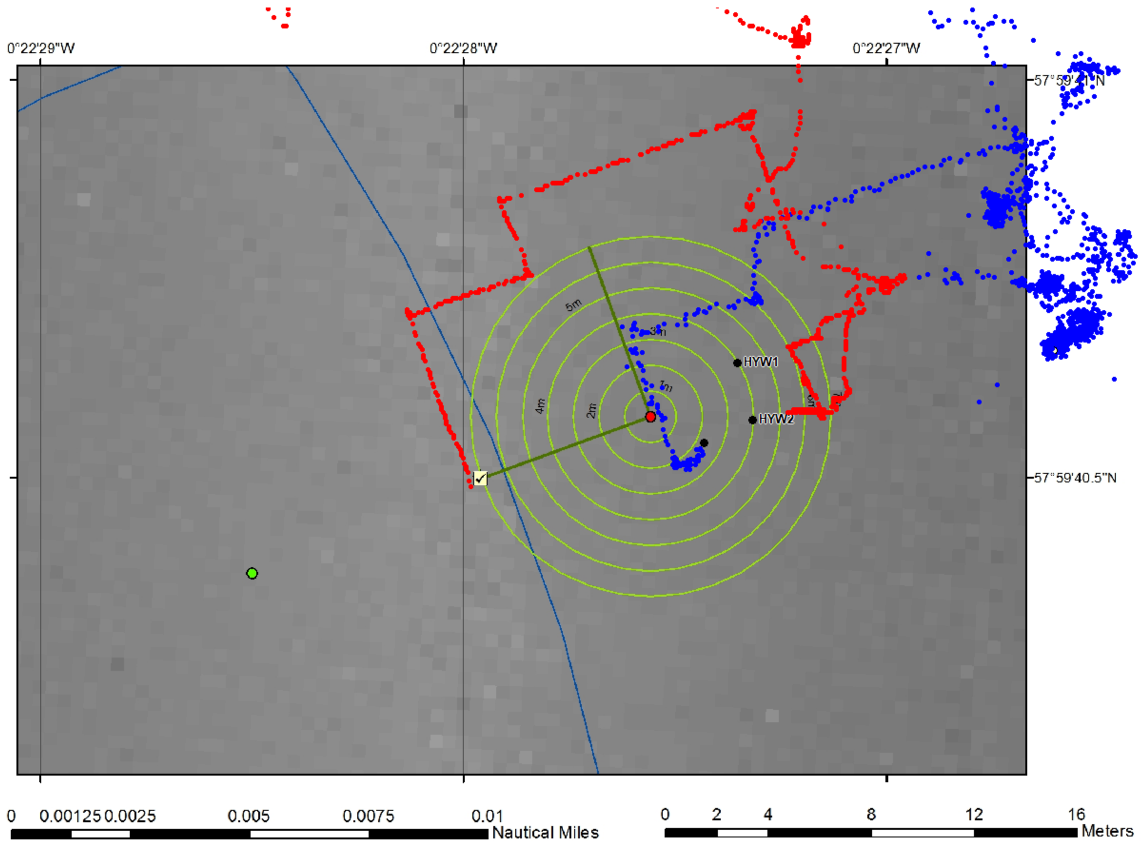


Fig. 15.12 Dive355 navigation plot illustrating USBL errors. Red positions are taken from the Doppler navigation, which was georeferenced on the known location of the pipe (tick box), blue positions were obtained from the USBL. Note the 7m offset between the two.

The Doppler navigation (and also the USBL) of the ROV represents the position of the central reference point on the ROV frame, which is located at the front of the vehicle, just below the cameras. However, given the very small working area, it was necessary to register the positions of the deployed pieces of equipment themselves, rather than the positions of the ROV at the moment of deployment. This was achieved by estimating the deployment positions within the OFOP real-time tracking software, taking into account the position and heading of ISIS, and the estimated distance in front of the vehicle where the instruments would be deployed (typically ca. 1-1.5m). A marker was placed on the OFOP map for each piece of equipment deployed, and those coordinates can be found in the equipment deployment list. Note that the coordinates recorded on the ROV Event logs and in the Deployment table refer to the positions of ISIS, rather than of the instruments.

16 Project Outreach: James Strong and Ben Roche

16.1 Aerial imagery (drone) James Strong

A DJI Phantom 4 drone was used to collect aerial imagery during the cruise. Imagery was gathered for each type of significant over-the-side deployment. The purpose of the imagery was to support outreach and public awareness activities supporting the STEMM-CCS project. Deployment and recovery imagery was collected for:

- CO_2 container deployment and recovery
- GAVIA deployment and recovery (small boat collection)
- Baseline lander deployment (new lander) and recovery (old lander)
- ISIS ROV deployment and recovery
- Drill rig deployment
- RRV James Cook, Poseidon and Goldeneye sequence
- SVP deployment
- Various other material of RRV James Cook (example figure below)

Figure 16.1. RRV James Cook above the experimental site with Goldeneye in the background.

16.2 Schools Outreach Program: Ben Roche (University of Southampton)

During JC180, a number of liaison sessions were held between the James Cook and school children in the UK, discussing the cruise and life as a marine scientist.

16.2.1 Pre-Cruise Sessions

In the year building up to the cruise PhD student Ben Roche visited 2 primary schools and 4 high schools located in Cardiff or Southampton. He gave a brief talk on CCS and his life as a scientist before introducing the Controlled Release Experiment. The students then participated in an activity creating and measuring the size of bubbles in small fish tanks using cell phone cameras. This exercise was in essence a small scale replication of the Optical Lander used during this cruise, teaching them how to process optical data. Approximately ~500 students were involved with the pre-cruise sessions with plans to re-engage with the higher ability high school students and all of the primary school students.

16.2.2 Cruise Session

During the cruise Ben Roche hosted a series of 30-45min long live sessions with the schools previously visited. They were run using either Skype or Zoom conferencing, signal was good throughout though notably clearer with Zoom.
Sessions involved quickly summarising CCS, the objectives of the cruise and events at sea up to that moment. After this was a lengthy Q&A with students asking any questions they had about the experiment or life as a scientist at sea. To end the sessions, the students were given recently collected bubble footage and were tasked with using what they had previously learned to measure the bubbles and relay their results to the crew. The objective here being to give greater purpose to classroom activities and reinforce the idea that they are all capable of becoming scientists. It is hoped the schools will eventually be cited as co-authors on a paper written using the Optical Lander data.

Date	School	Year Group	Number of Students
20/05/19	Whitchurch High	8 (13-14 years old)	7
21/05/19	Oasis Academy Mayfield	10 (15-16 years old)	10
22/05/19	Birchgrove Primary	5 (9-10 years old)	60
22/05/19	Cantell High	10 (15-16 years old)	30
24/05/19	Valentine Primary	5 (9-10 years old)	90

Figure 16.2. Cruise Skype session with Birchgrove Primary Schoo

17 Gavia operations: Estelle Dumont (SAMS), Michael Smart and Jared Mazlan (NOC)

17.1 Deployment 1

Conditions: Calm, overcast, very little swell
Date 27th April 2019
Deployment: Ballasting check (Deployment 1)
Operators: Estelle Dumont, Michael Smart, Jared Mazlan
Overview: Ballasting check in operation area with Seafet and USBL installed on the Gavia.
Mission Planning: No mission for ballast check.

Pre-Deployment
We got the crew together and showed them the videos we had from trials in Portland harbour and the deployment and recovery procedures. This included showing everyone the equipment we use so that they were all clear as to how the set up looks.

Launch
For the ballast check we had the Gavia connected with 6m strops directly onto the crane so it couldn't be accidently released from the crane, we had guide lines attached forward and aft and the crane operator was instructed to try and keep the strops out of the water as much as possible.

Deployment
The deployment was brief as there are only a few seconds to look at how the Gavia is sitting before lines start to weigh her down in the water. We decided that the Gavia looked ok in the water and were happy that it floated and could be released safely for the mission the next day.

Recovery
Recovery was simple as the Gavia was still attached to the lines - we simply lifted her back up using the guide lines to keep parallel with the James Cook before resting back in the cradle. We had put red tape on the back of the cradle to ensure we also sat the Gavia down safely as some modules needed breaks in the rails for instruments to sit freely. We then strapped the Gavia down and carried back into the hanger with 6 people.

Safety
All safe, everyone on deck wearing correct PPE for lifting equipment.

Issues
None.

Improvements
Potential to look into if there is strop/line available which doesn't affect the weight of the Gavia when hanging from the hook so we can get a better understanding of how it's sitting in the water.

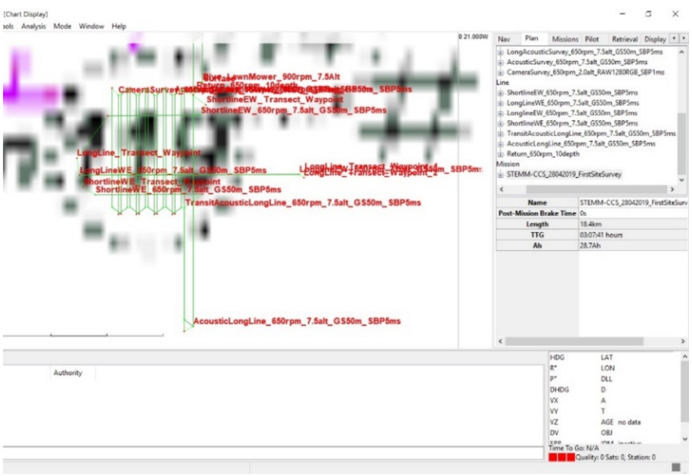
Summary
Gavia is ready for deployment in the area, we will launch the small MOB boat for the first deployment just to be available if there is any ballasting issues with the addition of the USBL externally mounted since we had the trials in Portland harbour.

17.2 Deployment 2

Conditions: Calm, sunny, very little swell
Location: North Sea (Goldeneye platform)
Date: 28th April 2019
Deployment: Initial Site Survey (Deployment 2)
Operators: Estelle Dumont, Michael Smart, Jared Mazlan

Overview
Once we arrived on site we were asked to carry out a first survey of the site before any other equipment went down so we have a base level of what the site initially looks like.This consisted of running two lawnmower patters over the site, the first at 7.5m from the sea floor running Geo-swath, SBP, oxy optode and CTD.The second lawnmower running at 2m from the sea floor and using the SBP, oxy optode, CTD and camera. The externally mounted Seafet will be powered on during the entire mission.

Mission Planning
We planned a mission to include both survey runs with a long 1000m leg on the start of the 7.5m alt survey for the SBP. The Line spacing between the lawnmowers was 40m with a 15m offset between the two so the camera wasn't running over non covered area of the geo-swath. These lawnmower patters ran north to south so we included some runs going from west to east and back again one short line and one line for each to help with the sensor alignment.



Pre-Deployment

During the pre-deployment checks we had an issue with the INS not aligning on the deck once the Gavia had been brought out of the hanger, we made the decision to shut down and restart the Gavia and the alignment went a lot better the second time.

Once happy with the checks Mike and Jared prepared the equipment needed for the boat and got ready to launch to be in the water encase needed.

No other issues with the pre-deployment checks.

Launch

The Gavia was launched from the James Cook at 08:35 on the starboard aft quarter with two 6m strops one each through the Gavia lift points then back up to a sea catch held by the crane. There was also two tag lines around the strops to keep control of everything.

The sea catch released the strops and was pulled though the lifting handles and the Gavia was free, we then waited for it to drift down behind the James Cook and into clear water.

It was noted that the crane should take up the slack on the strops rather than use the tag lines as this bought the Gavia closer in towards the James Cook.

During this period the small boat crew where deployed in the water and close by to assist if needed.

Deployment

Once clear from the James Cook the boat crew took a look at how the Gavia was sitting in the water and it was decided that no further ballasting adjustment was needed as the pitch and height in the water looked good. A cable tie was fitted to the bungee cord near the DVL to keep it from sitting across the sensor.

At 08:45 the Gavia was sent an execute command for the mission and dived it returned to the surface 08:49 with the abort reading “abort due to not reaching depth”.

The mission was attempted to be executed again but the Gavia wouldn’t accept the mission. After a brief discussion it was decided to shut down the Gavia in the water via the small boat team and restart to allow the Gavia to accept new missions this was done at 09:18.

Once restarted we had to wait to allow the INS to get down to the correct alignment, this time was used to look at the mission on control centre and a new Dive waypoint was added before the dive lawnmower to help get down to the correct depth.

When ready to be deployed again the execute command was sent and the Gavia dived successfully 10:41 we kept the small boat in the water until we had got some hits through the accoms pinger to make sure the Gavia wasn’t going to come back to the surface. It was discovered during this time that the accoms was using the old cable and not working properly so the new one was swapped in and we then had some returns from the Gavia so could recover the small boat which was back on board by 11:30.

The USBL was set up by the ship support team and was being displayed in the main lab so we could track the position of the Gavia two ways, although it was noted that the USBL depths where inaccurate.

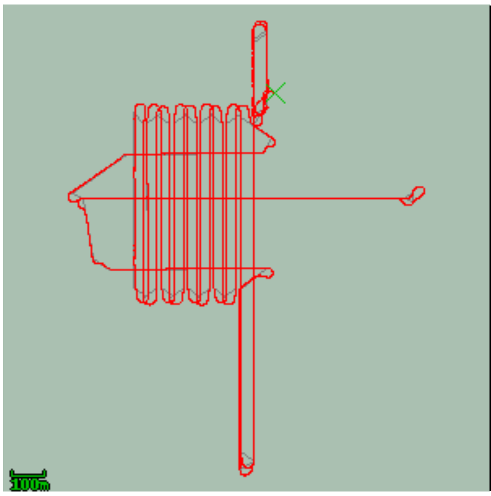
We estimated the finish of the survey to be around 14:30 so at 14:00 we gave the waypoint of the surface position to the bridge and brought the accoms pinger on board and moved to a closer position to spot the Gavia once it surfaced, we could still track the Gavia using the USBL so had a good idea where it was in relation to the ship.

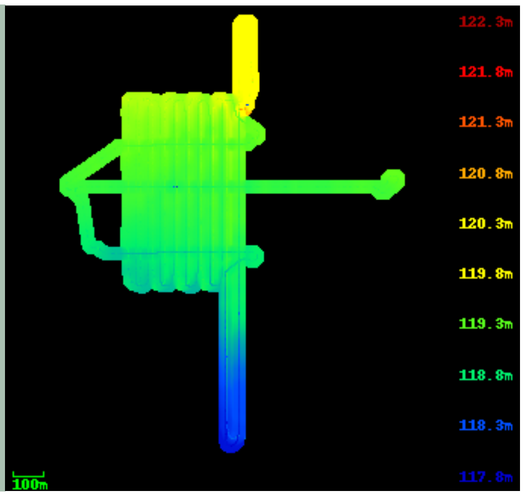
Gavia reached the end of the survey just after 14:30 and started to float up to the surface.

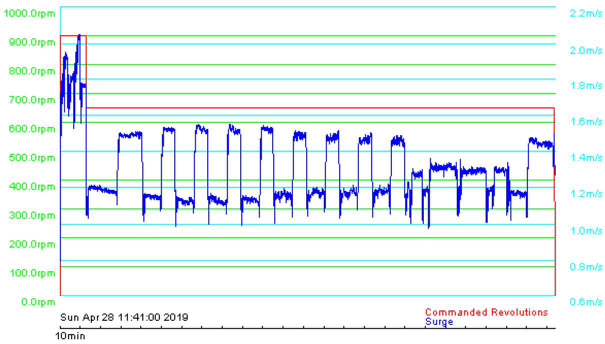
At 14:51 the Gavia was spotted on the surface and the small boat was launched to bring it back on board.

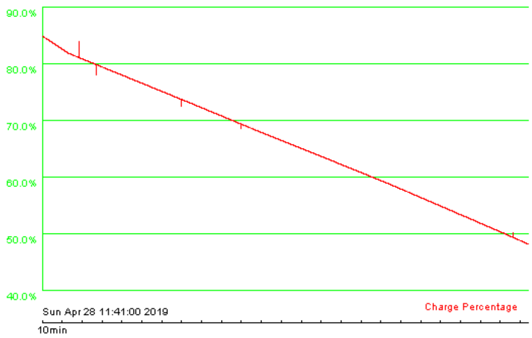
Recovery
14:55 the Gavia is picked up by the small boat a brought around to the rear of the James Cook to make an approach for the starboard rear quarter crane with the recovery gear already attached and hanging down to be attached by the boat crew.
The Gavia was hooked up to the James Cook crane at 15:05 and brought back onto the ship once we the boat was clear and the crane started to lift out the water it was noticed that the rear strop had been attached incorrectly through the rope handle rather than the metal handle on the battery module as the Gavia was already out the water it was decided to just bring it aboard at this point and was placed back on to the cradle. The small boat was then recovered back onto the James Cook by 15:15 and data was then recovered and Gavia and equipment then washed down with fresh water and carried back in to the hanger.

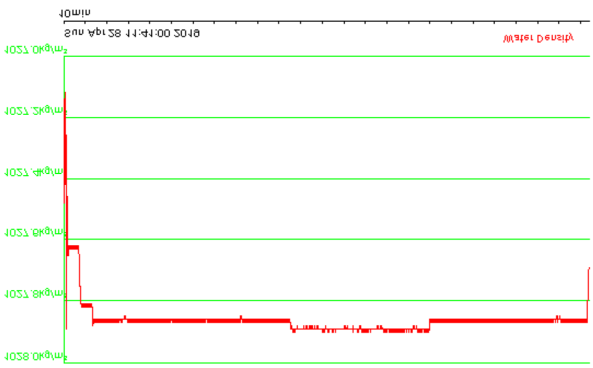

Gavia mission data











Safety

Make sure correct lifting point is used to avoid risk of injury from non-regulation lifting equipment.

Issues

INS alignment appears to be struggling to get down on start-up of the Gavia. Gavia had an issue with performing the deep dive procedure correctly. Recovery non lift point used on rear of the Gavia.

Improvements

Take a look at ways to help improve the time needed to align the INS. Use Estelle new method of adding a dive waypoint before running the lawnmower down to depth (this seemed to fix the issue with Gavia not diving correctly). Make sure the boat crew in the small boat are aware of the correct way to rig the strops on recovery, go through the correct way before picking up the Gavia and point out the correct lifting handles when the Gavia is first grabbed by the small boat.

Summary

After an initial issue with the Gavia getting down to depth correctly the survey was successful and some good data collected of the seafloor operational area, camera survey showed to have issues with capacity and colour of the pictures.

17.3 Deployment 3

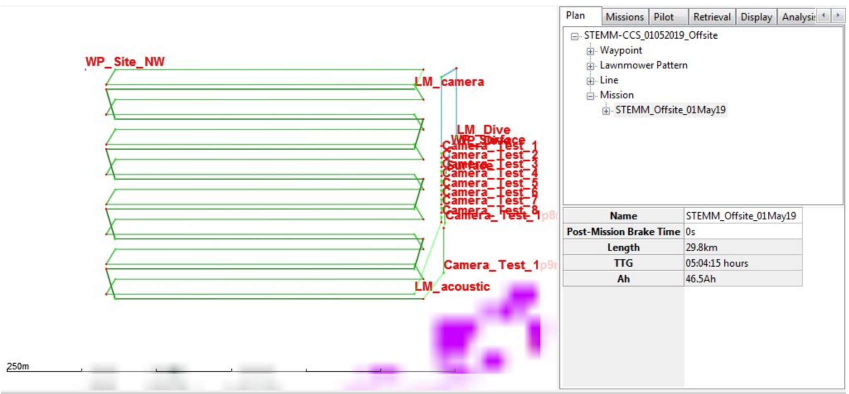
Conditions: Calm, overcast, small swell during recovery
Location: North Sea (Goldeneye platform)
Date: 1st May 2019
Deployment: Offsite survey (deployment 3)
Operators: Estelle Dumont, Michael Smart, Jared Mazlan

Overview

After a decision was taken at 07:00 that drill rig was not going to be deployed it was seen as a chance to run a survey of an offsite area to compare levels around the main survey site against another location.

Mission Planning

With the late call to run the offsite survey we had to plan the mission quite quickly to be ready for 11:00 so gathered all the people together to discuss the best plan for the survey.
It was agreed to run a short camera test to see if we could improve the colour issues we had seen on the previous deployment. Then we will run two lawnmowers one at 7.5m altitude from the seafloor with the acoustic survey equipment then a second at 2m altitude for a main camera run with the SBP also running.



Pre-Deployment

We ran the usual pre deployment checks and again had issues with the INS not aligning on the first start up so had to restart the Gavia again, like the last deployment the INS aligned ok on the second start up. All other aspects of the pre-deployment check list went fine.

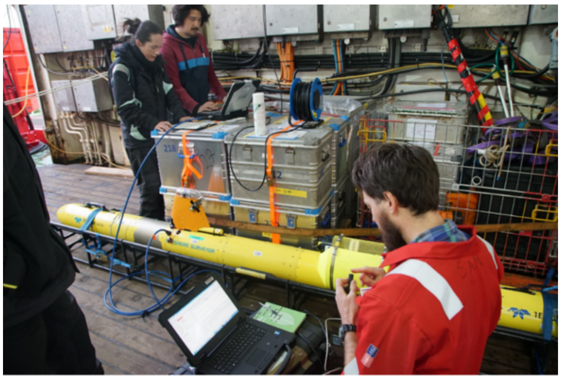
Launch
We were ready to launch for the 11:00 and felt confident to deploy without the small boat as previous issues had been resolved. The deployment was good and the lines came through the handles smoothly.

Deployment
After waiting for the Gavia to drift out behind the James Cook and safely clear we sent the start command at 11:14 and the mission started successfully. The accoms pinger was put over the side to establish the mission was being followed by the Gavia, once happy it was pulled back up and the James Cook moved to a northern waypoint above the survey area to get maximum range for the accoms pinger and then was deployed over the side again, we also had the USBL reporting to the ship and being displayed on the screen in the main lab.

It was predicted that the Gavia would surface at 17:30 so just after 16:20 we started heading back to the recovery area with the ship we arrived at the area 16:50 so put the accoms back in the water to track the Gavia before it came to the surface and the small boat crew went to sort out the boat for deployment once the Gavia was spotted.

Recovery
At 17:32 the Gavia was spotted on the surface so the small boat was launched to go and bring back to the James Cook. We had a little choppier weather than we had previously seen, this made the approach in the small boat trickier as we had to approach coming with the swell to get the Gavia in the correct orientation. This took two attempts but once we had her under control we had a short travel back to the James Cook.

Once lined up with the ship to approach the starboard rear quarter and get hold of the lifting gear we hooked up to the crane safely and the Gavia was brought back on board before the small boat was then brought back on board on the port side to its usual position.

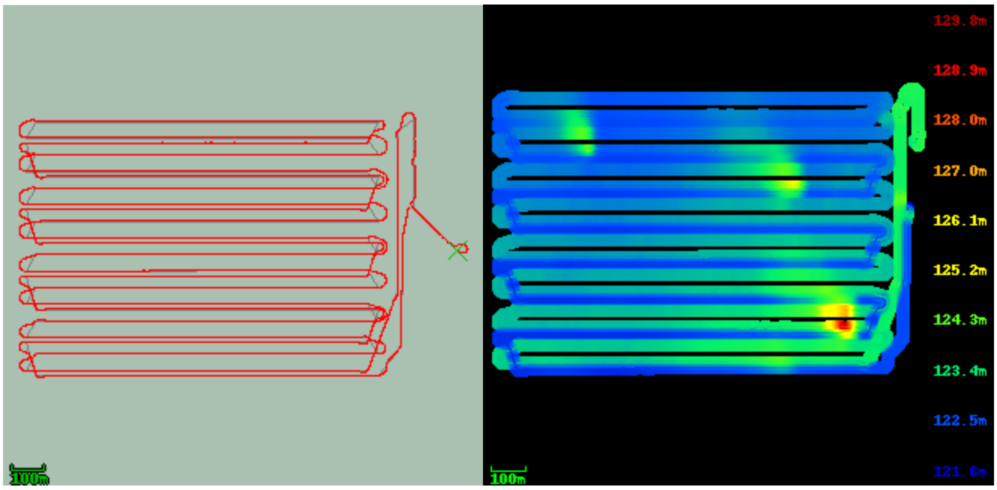


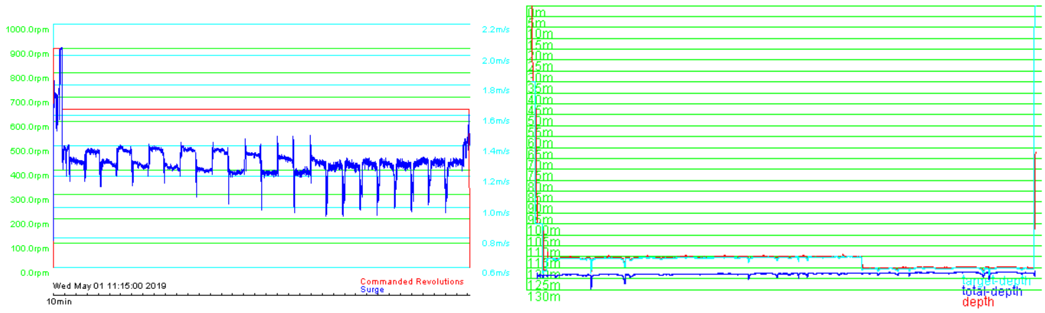
Safety
No safety issues

Issues
INS still not coming into alignment on first start up.

Improvements
Control centre will be left closed on the laptop until the strobe sequence has come on the Gavia to see if this helps

Gavia Mission Data





Summary
Good operation, with successful deployment and recovery and a smooth mission with good data collected. Camera still having issues with colour so will look at more options as to how to improve this. Will run some tests with Bret on the ship to try and get a better understanding of how the camera interprets colour changes.

17.4 Deployment 4

Conditions: Calm, sunny
Location: North Sea (Goldeneye platform)
Date: 14th March 2019
Deployment: Onsite acoustic survey and Seafet survey
Operators: Michael Smart, Jared Mazlan

Overview
This will be the first survey over the operational site since we have the gas bubbles on and all the sensor equipment on the sea floor, we want to run a close lawnmower pattern with 2m line spacing and star pattern survey to capture runs over the bubble leak at 4m alt.

Mission Planning

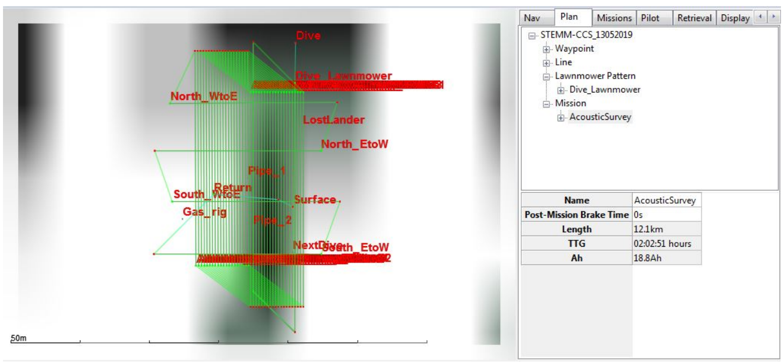
The first part of this deployment was to run a Lawnmower acoustic survey over the work site of 75m x 125m at 7.5m altitude and 2m line spacing between the lines.

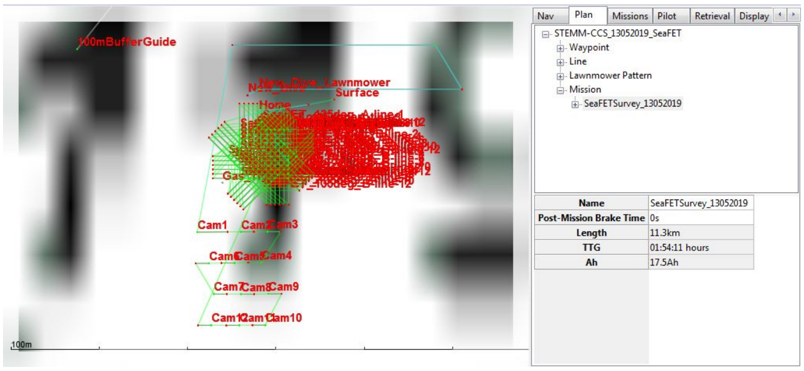
When attempting to make a lawnmower pattern we came across a few issues attempting to get 2m line spacing with the length of the Gavia giving us a turning circle of around 30/35m. After a few failed attempts to make the pattern without lots of extra lines and wasted time we finally managed to make a pattern with two lawnmowers with 1m spacing and double the amount of line required. These were put side by side then exploded into lines and this then allowed us to delete the lines running north to south on one and south to north on the other, we could then link the lines in the mission so that they ran long loops that then had a 2m offset between each until we had covered the required area of 75m then lines where 150m in length to allow the Gavia to get onto the line nicely before going over the gas site. Also included in this survey are 4 cross lines to help with the calibration of the data after for the sci team.

The second half of the mission was to run the Seafet survey was to run a star like pattern that would centralise over the gas release point, with the Gavia diving down to around 108m we were not sure if we would be able to accurately hit a central waypoint as after leaving the surface we would not get bottom lock until the Gavia could see the sea floor (around 40m from the sea floor) this would mean the vehicle could drift during the dive stage and may not be over the site so we took the decision that we would run a star pattern with a small lawnmower pattern to hopefully cover and drift that we may see.

This was a challenging thing to try and design on the control centre planning especially with is being overlapped by the acoustic lawnmower that was running in the same spot so we thought the easiest way to be able to design this would be on its own mission. So we would have the gavia return to the surface in-between the two mission and be sent the next mission and over Wi-Fi and execute the Seafet mission.

Once we were happy with two mission we still had some available time left in the deployment window we had been given so added a camera test survey south of the work onto the end of the Seafet survey so Bret could try some settings to see if we can get the camera producing some better images.





Pre-Deployment

At around 06:10 the Gavia was taken outside and powered up, we made sure that the control centre on the laptop was shut down before inserting the power key and waited until the light sequence had started up before starting control centre as it was believed this may solve the issue we had been seeing with the INS and pilot controls not working properly first time around.

All the checks went successfully through first time around so we will keep this point in for future deployments, after Sam had turned on the Seafet and placed the water intake on it we were ready to deploy by 06:50.

Launch

Once the ships crew had rigged the seacatch the Gavia was deployed at 07:00 from the starboard aft quarter crane and we slowly had the James Cook go ahead to allow the Gavia to drift down aft and clear from the ship. The Gavia ended up sitting facing towards the ship so we had to use the piloting controls to make sure we had a safe deployment and no risk of the gavia turning underneath the James Cook.

Deployment

The mission was started at 07:14 and the Gavia dived successfully with an estimated end of 09:46 allowing for the Seafet drag we had seen previously.

The accoms pinger was put over the side of the ship to check the mission was going ok and the USBL positions where displayed up in the main lab so we could monitor the Gavia once happy with the way the mission had started we brought the accoms back on the James Cook and moved the ship to the east side of the work area so we were in a good position for the mission and when the gavia returned to the surface before being sent on the second half of the mission.

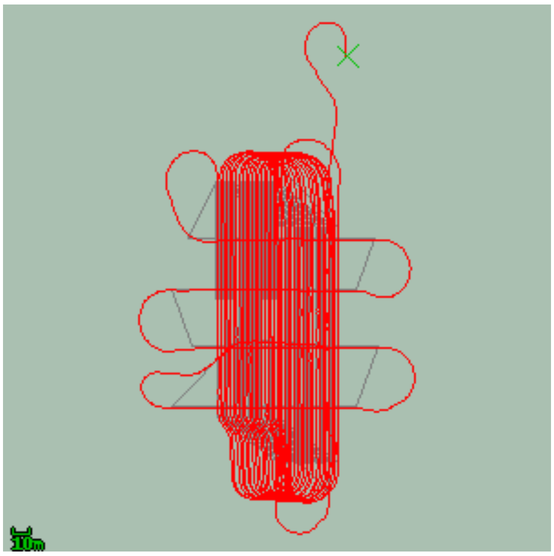
The accoms where put back into the water over the side of the ship and the mission was monitored from on-board. At 09:47 the Gavia came back to the surface after completing the acoustic survey we then reconnected over the Wi-Fi and sent the next Seafet mission at 10:02 and the Gavia dived again before returning to the surface after a few minutes with an error message reading “error depth not reached” we quickly looked over the dive and compared it against the earlier dive everything appeared to be the same so we tried reuploading the mission to the gavia and sending it again, but again after a few minutes the gavia was back on the surface with the same error. We then moved the dive waypoint and dive lawnmower to allow a little more time between them to see if that fixed the depth issue but again after sending the mission the gavia quickly came back to the surface.

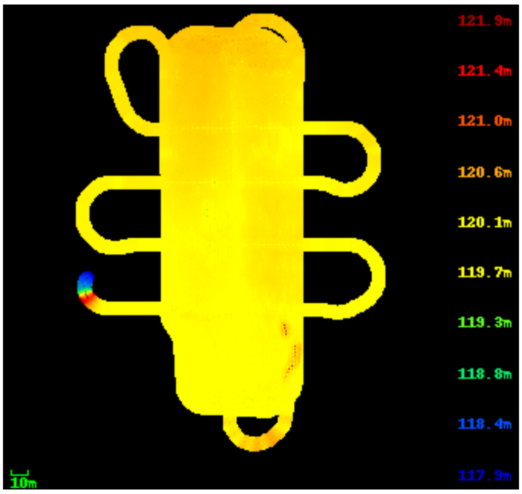
It was then decided to launch the small boat with the intention to shut down the Gavia and remove the power key before restarting the gavia and hopefully this would mean the new mission would work successfully. We kept Jared on the James Cook so he could operate the laptop safely so we asked Sam from the science team to help in the boat so we had the correct amount of people in the boat if we had to recover the Gavia. The boat was launched just before 11:00 and after getting to the auv and making sure everyone in the small boat where happy with the job they had to do we shut down the gavia and removed the power key for 2minutes before replacing it and restarting the auv. The INS was going to take time to be ready to deploy the gavia so we allowed it to drift on the surface to avoid the risk of it coming into contact with the boat. Once ready to deploy we brought the gavia back to a safe position near the James Cook and sent the mission to it and then gavia then dived again at 12:42 before coming back to the surface still with the same error message. The dive elements where again tweaked to see if this fixed the issue but after two more unsuccessful attempts it was decided that we would recover the auv and bring it back on-board the ship at 13:15.

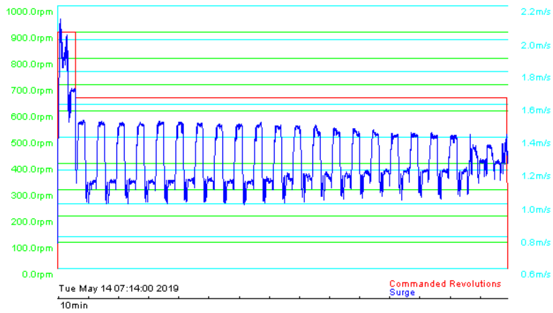
Recovery

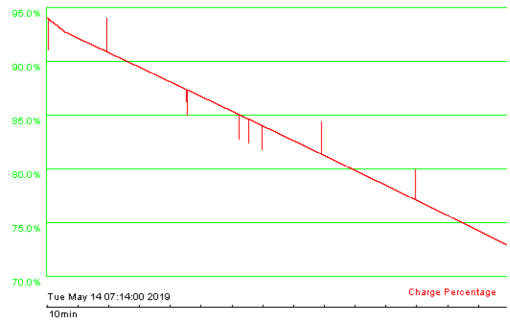
The ships crew got the recovery equipment ready on the starboard aft quarter crane whilst the boat crew got the gavia alongside the small boat and came under the crane once secured to the crane the auv was lifted back on to the James Cook by 13:30 and the small boat then was recovered on the port side at 13:40 after being secured down on the frame and washed down the auv was then carried back into the hanger and data downloaded.

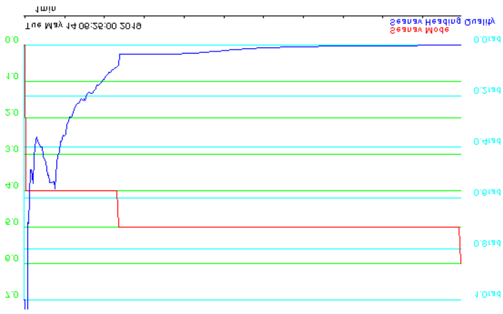
Gavia Mission Data











Safety
No safety issues to report.

Issues
Failed to carry out the second half of the deployment.

Improvements
After looking into the issues with resending a second dive we looked back at past missions to see what had been different to avoid repeating this again.

We had previously used a 100m constant depth lawnmower rather than trying to get an altitude of the seafloor which we used on the dives today. We had a successful dive on the first mission and looks like it had travelled faster than we had previously seen so think we got lucky with the first dive this morning and that is why we couldn't recreate the same dive on the second mission.

Going forward we will make sure we use a dive waypoint to a constant dive of 35m before a 100m constant depth lawnmower to get down to a depth where the gavia can use bottom lock to the run the surveys.

Summary
50% successful dive and we managed to get some good data on the acoustic survey, luckily we will have the opportunity to run the mission again so we will attempt to try and put the two mission into one to avoid the risk with the gavia returning to the surface and needing to accept a new mission to go underway again.

17.5 Deployment 5

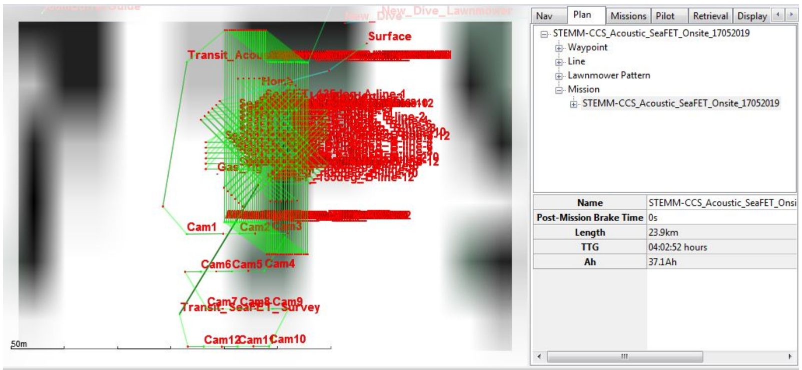
Conditions: Small swell, sunny, clear
Location: North Sea (Goldeneye platform)
Date: 17th March 2019
Deployment: Second onsite acoustic survey and Seafet survey
Operators: Michael Smart, Jared Mazlan

Overview
Second survey of the deployment site again running an acoustic survey and Seafet survey, this time they will be ran on the same dive to limit the risk of having issues on multiple dives again. We will also run a small camera test as this didn't get done with the Seafet survey last time.

Mission Planning
We have taken the time to look at previous deep dives we have used in earlier missions and believe we have identified the issues we saw in the second half of the last mission. For the next dive the Gavia will dive down to depths of 35m on the waypoint and 100m on the lawnmower dive before then changing to using the altitude off the seafloor. On the acoustic survey will run the geoswath on lines on the outside of the deployment area and towards the centre of the area allowing for the angle for its shaded area as the last survey ran directly over the sight and missed some features. The cross lines will also run the geoswath to help calibration. The survey will be ran the same way as last time with the 2m offset loop being used at 7m altitude and lines of 125m.

We will then run down to the south and run the camera test with the new settings Bret has given us to try, this will be ran in short 15m lines and leaving 15m between lines so we can easily see the different settings after in timestamps.

The Seafet survey will be ran after the camera test and will be the same star pattern lawnmower at 4.5m altitude, the whole mission is expected to take about 5hours allowing for the drag of the Seafet and will be 23.9km in length.



Pre-Deployment

We ran though the checks the night before as we were deploying at 07:00 the next morning and had a ROV dive planned for the afternoon so wanted to make sure everything was in working order while we had time to fix any issues. Again we started up the Gavia with the control centre closed on the laptop and this seemed to solve the issues we have seen with certain elements not updating, we were happy that the gavia was working without issue so shutdown for the night and put all the equipment back on charge overnight. Sam had removed the Seafet to allow it to run overnight in seawater as he had noticed that is has a long up period so wanted to make sure it was ready to operate when we deployed in the morning.

At 06:15 the next morning we brought the Gavia outside and switched on the same way as the night before and by 06:45 we had the Gavia ready to be deployed and Sam mounted the Seafet back on to the vehicle along with the USBL and we were ready to launch just before 07:00.

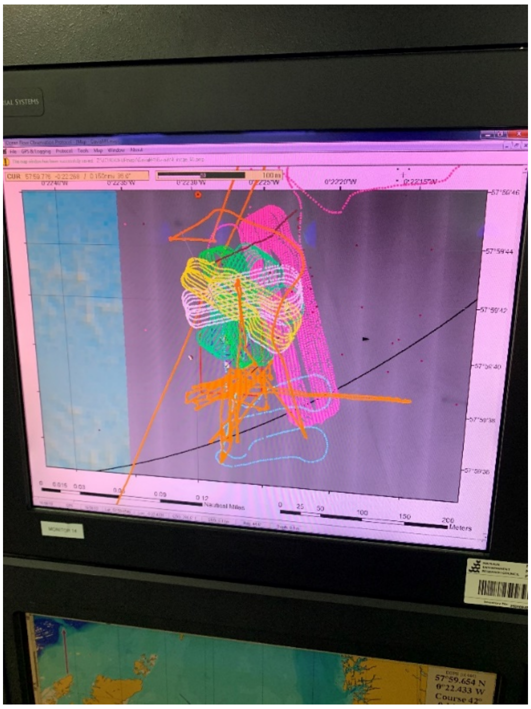
Launch

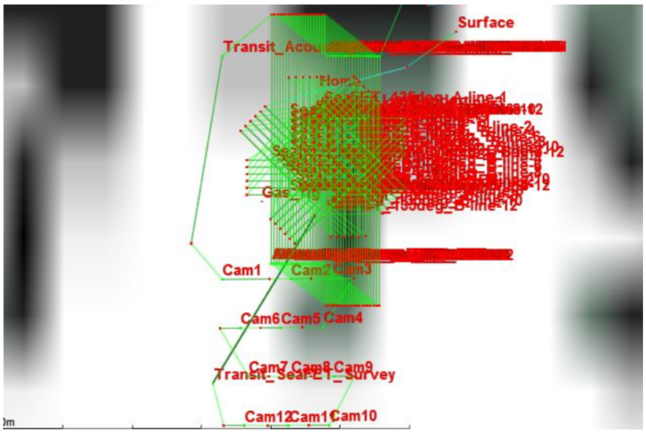
We released into the water at 07:04 and like normal had the ship then move slowly forward as the gavia drifted down to the aft of the James Cook once we were happy with the orientation of the gavia we sent the go command at 07:13 and the gavia dived without issue and as normal we put the accoms pinger over the side to get some early contact with the auv to make sure it was happy. We used the USBL to check on the depth of the gavia which was reporting what we expected to see.

Deployment

Once started on its mission we noted that it appeared to be starting the mission in the wrong position according to the USBL updates and saw that it was running the lawnmower loop acoustic pattern around 80m to the east of the bubble site. We checked the ships position and noted that we were sat around 300m off of the Gavia so believe we were seeing inaccuracy with the USBL positions as previously the ROV had seen that the position drifted due to the shallow water depth in the north sea. It was decided that we will carry on with the mission with the assumption that we were actually over the correct position and later as the ship moved closer after they had finished other operations we found the USBL realigned to give something closer to where we expected to be when running the star pattern for the Seafet.

The USBL position are shown below against and followed by the planned mission track.



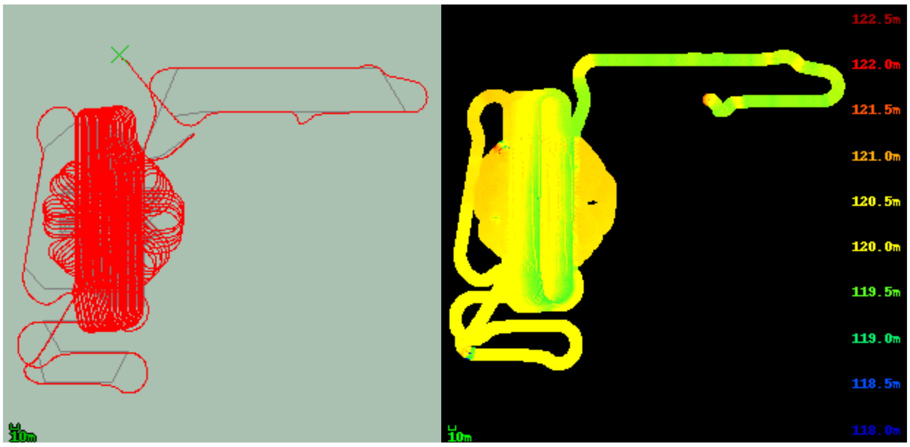


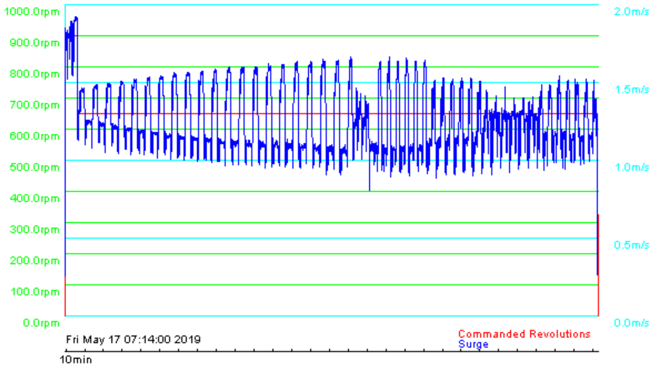
Recovery
Again during recovery Sam helped out in the boat to mean that Mike could stay on the James Cook just to make sure someone was available with the laptop if we had to take control of the Gavia for any issue.

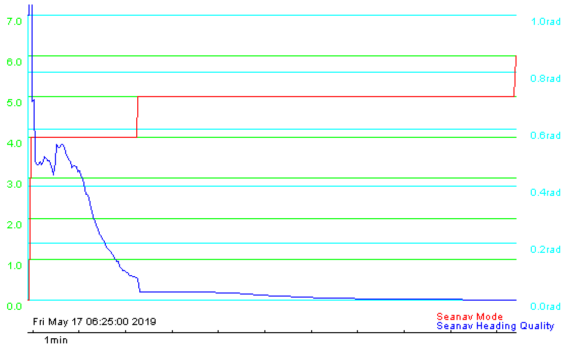
The gavia was back on the surface at 11:59 which was slightly earlier than we had predicated and from looking at the mission it appears the Seafet survey ran 15mins quicker than expected.

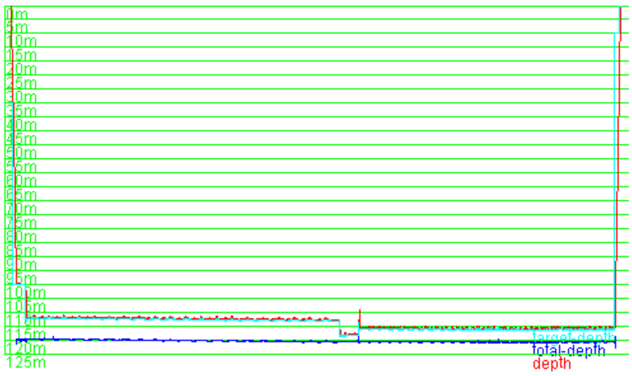
The small boat was launched and got to the gavia by 12:06, there was a bit more swell a chop on the water today and once the guys got hold of the gavia and towed it alongside to the James Cook it was noted by the skipper on the small boat that any longer distance we should use the tow line until we get within the last 20/30m as in rougher weather and with everyone over one side the boat is harder to control.

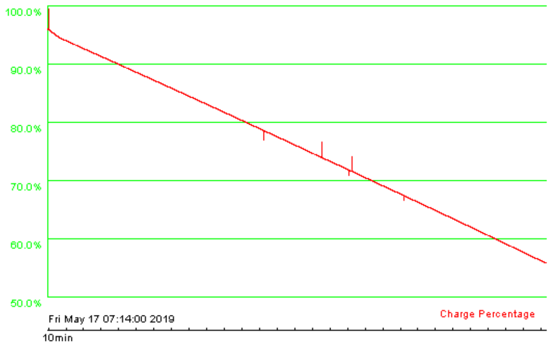
Gavia Mission Data











Safety
No safety issues.

Issues
Once we gave the sensor data across to the sci teams we realised that the crosslines had been missed of in the mission planning, this was noted as a potential issue with the survey being ran as one continues mission and a lot of lines on the screen it made it tricky to see what was happening on the screen.

Small boat in rough weather may need to use the tow line to keep the boat stable and easier to manoeuvre.

Improvements
We will try and be more aware of what aspects of the mission are being ran whilst double checking complicated missions and may prepare a tick rough tick sheet to just make sure we have captured everything.

Small boat will use the tow line when bringing the gavia into the James Cook in rougher weather and the last 20/30m can be done with the gavia alongside the small boat.

Summary

Again a mostly successful mission, with only issues coming from human error with reading the mission plan of the screen and missing the crosslines from the acoustic survey. As we learn more about what is achievable in the small boat we have adapting the ops to have the smoothest recovery as possible.

17.6 Deployment 6

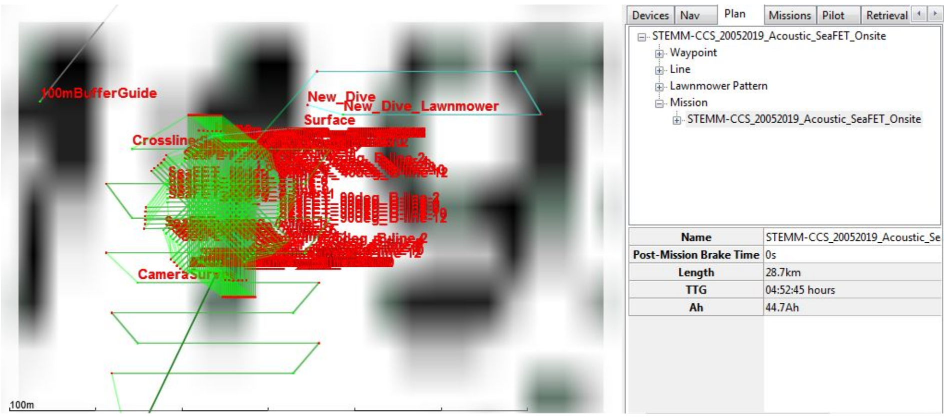
Conditions: Foggy, Calm
Location: Goldeneye
Date: 20/05/2019
Deployment: STEMM_CCS_20052019_Acoustic_Seafet_Onsite
Operators: Jared Mazlan, Mike Smart

Overview
Third run over the deployment site of the experiment, running the same mission as previous dive. This time the bubble rate has been increased to 50 l per minute.

Mission Planning
The previous mission was duplicated and adjusted this time to include the crosslines in the acoustic survey which got missed on the last run just with the amount of lines running over the same area it was undetected until after the survey.

We also added in some geoswath lines in the Seafet survey to try and help with the accuracy of the SBP. The idea is if we can use the geoswath to show known positions of surface we can then more accurately map the SBP data.

Brett has a camera setting that he is now to run so we be including that in this run and setting up a lawnmower to get him a bigger data set for him to look over.



Pre-Deployment
Gavia switched on at 06:20 and pre-launch procedures carried out like normal without issues ready for Sam to fit the Seafet at 06:45 and all lifting gear attached and ready for deployment Once the ship was happy and in position.

Launch
We arrived on location just before 07:00 and the James Cook then moved to a position facing towards the south as we had a stronger northern current than we had seen in previous deployments, this meant that would let the current take the glider north and away from the ship into a safe position to deploy.

We launched at 07:00 into the water and the Gavia was deployed safely and drifted out to the north like anticipated we then quickly pointed the gavia to the east and sent the execute command and the auv was underway at 07:02.

Deployment
Once we were happy that Gavia had dived successfully we put the accoms in the water and got the USBL reporting back positions again we saw that the USBL was showing that the position was off but with previous knowledge we knew this to not be correct so were happy to carry on the mission.

We spoke with the bridge about the plan for the operation and the estimated end time for the Gavia, this was an assumed time as we have to calculate the extra drag that we get from the Seafet sensor as this is accounted for in the estimated mission end time we get in the control centre. After adding the additional time we gave the surface waypoint and estimated finish time of 13:20.

At 11:00 the ship's captain wanted to change the ships position around the waypoint, again with the knowledge that we were operating in stronger currents than we had previously seen before. The James Cook was positioned south east of the waypoint to allow the gavia to drift away from the ships starboard side, this should also help with using the small boat on recovery.

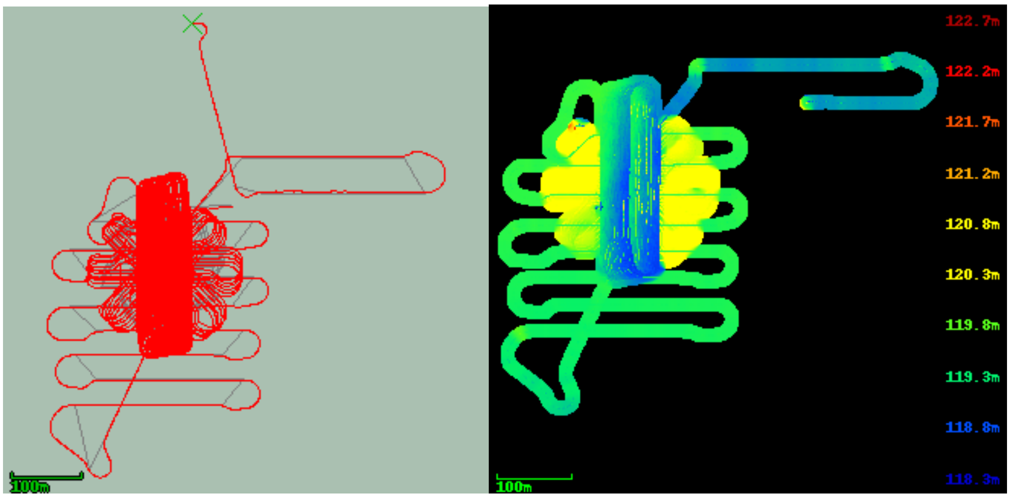
From checking the gavias tracks and position we noticed that it was running the Seafet survey faster than we had planned so around 11:45 we contacted the bridge and small boat crew that we think the gavia will complete the mission between 12:45 and 13:00, the crew and ship got ready accordingly for the recovery.

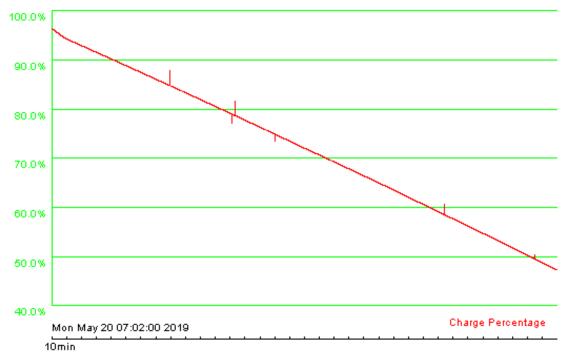
Recovery

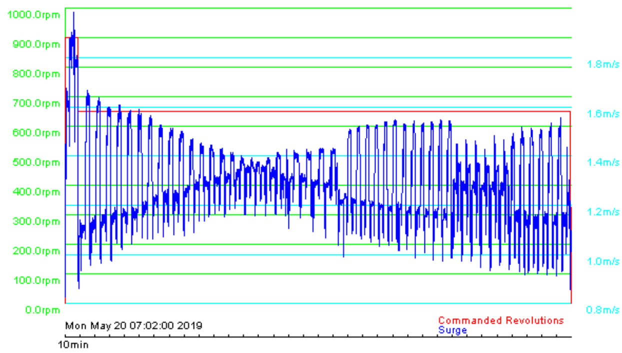
The small boat crew where ready and positioned at the boat ready to launch at 12:35. The Gavia completed its mission and came to the surface, we then deployed the boat with Mike and Sam and two of the ship's crew to collect the gavia which had surfaced quite close to the James Cook, once we had hold of the AUV we kept it alongside the small boat as we only had a short distance to travel back to the James Cook.

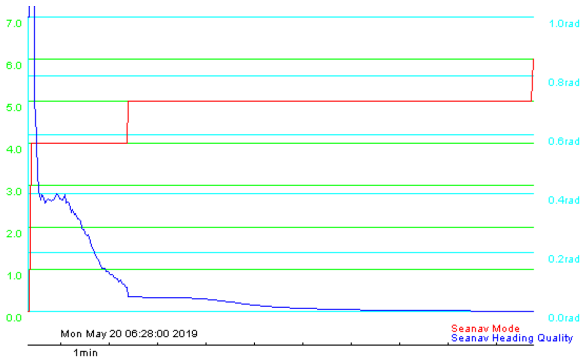
Once underneath the starboard aft crane we connected the gavia in the usual manner with a short line going through each lift handle and connecting to a metal snap hook that was end of a long strop with the other end of the strop already in it.

Gavia Mission Data







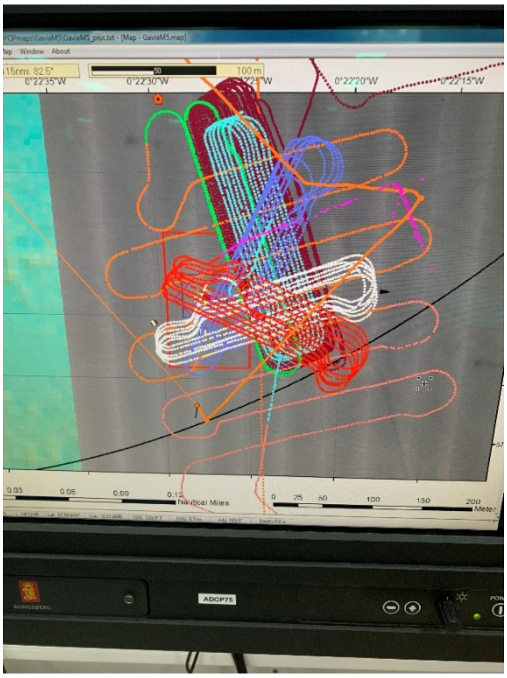


Safety

No safety issues.

Issues

James Cook USBL receiver still reporting incorrect position.



Improvements
The ships USBL is designed for deeper water so it is struggling with range and depth the Gavia is operating at, Juan has looked into options that could improve this in the future.

Summary
Good mission with good coverage of the area and all data downloaded successfully. Both launch and recovery went smoothly.

17.7 Deployment 7

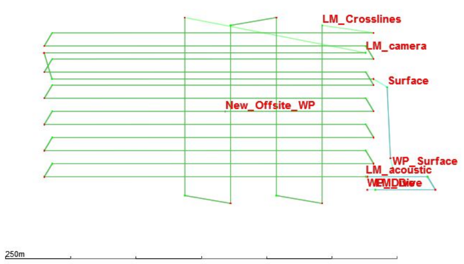
Conditions: Overcast, small swell
Location: Goldeneye, North Sea (offsite)
Date: 21/05/2019
Deployment
Operators: Mike Smart, Jared Mazlan

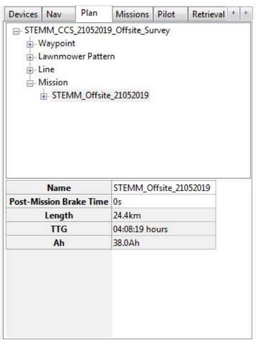
Overview
The ROV had power issues when completing its first dive this morning so was recovered and they started to look into the issue they had. The Gavia team were asked if we could have an offsite mission ready for potential deployment in a few hours at 11:00.

The call was made at 13:00 that Gavia will be going instead of the ROV.

Mission Planning
Once we were asked we started sorting that mission in the control centre, after speaking with the sci team and getting a deployment position. We had to make a number of changes in order to have the Gavia mission end time fit into the ships daylight work hours as we can't have the small boat in the water after 19:30.

Once both the sci team and the Gavia operators were happy we set about preparing the gavia ready for the deployment.





Pre-Deployment
To start the pre deployment checks we wanted to check the battery level as we had deployed the day before and wanted to make sure we had enough battery to be able carry out the mission.

Unfortunately at this point we found that the extension reel that had been running to the power supply for the gavia had a power cut at some point over night and means that the Gavia only charged up to 60% so was unable to complete this mission, after speaking with the science team it was decided to cancel the deployment.

Issues
Extension lead power trip

Improvements
Whilst Gavia is on charge check at regular intervals to make sure everything is ok with the power supply to the Gavia.

Summary
No dive due to extension lead problems not charging the Gavia overnight, more care will be taken to try and make sure the Gavia is checked regularly.

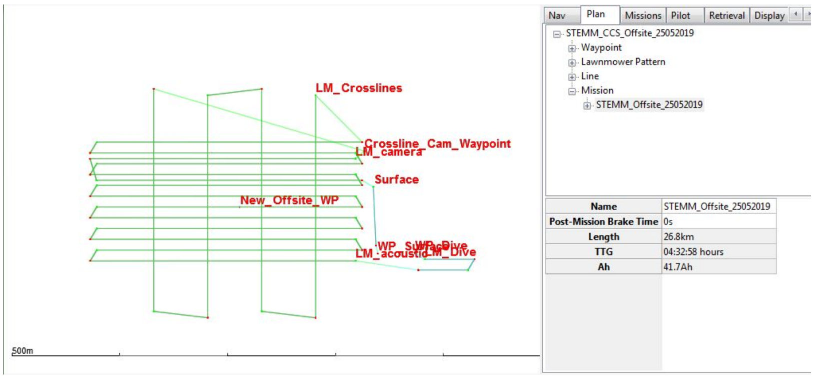
17.8 Deployment 8

Conditions: Windy, overcast, swell
Location: Offsite position 2
Date: 25/05/2019
Deployment
Operators: Jared Mazlan, Mike Smart

Overview
Second attempt to run a second offsite mission to gain some background data for the science team. With more time available with the dive we added more parts to the survey.

Mission Planning
Call was made in the morning that Gavia would be deployed for the offsite mission at 09:00.

We quickly sat with the science team to get an idea of what changes to make to the failed offsite mission we made the other day as we had more time to run the mission time around, we added in an extra cross line lawnmower pair. Once happy with the mission and double checked we began to set up for the deployment.



Pre-Deployment

We ran the standard pre deployment checks without issue, and had the Gavia ready to deploy for 09:00 but the ship was still making its way to the launch area. Once at the launch area we asked to be positioned south west of the launch area but this was miss understood to the bridge and ended up sitting south east, so after we had the ship move to the west we were ready to launch.

Launch

09:14 Gavia picked up on the starboard aft quarter crane and lowered into the sea using a seacatch to release, all went smoothly and gavia moved away from the ship staying on the starboard side of the ship, we had to wait for the Gavia to turn away from the ship before sending the mission launch.

Deployment

When happy with the position of the auv the launch command was sent at 09:24, the gavia dived from the surface without issue and we went to view it on the USBL, we noticed that it had got down to around 85m before it started to return to the surface and was back up by 09:35 with the error message “couldn’t track depth”

We took some time to look into why we think this may have happened as we couldn’t see anything wrong in the mission. We noticed that during the time on the surface the gavia had drifted over to the south east side of the waypoint so when it dived it would have to double back on itself to reach the start of the dive waypoint and we believe this is where the error came from. As the Gavia is turning we have seen that it won’t dive deeper so think it would of reached the start of the waypoint and then aborted as it had not made the required depth.

We moved the dive waypoint and lawnmower to be in further to the east of the Gavia and then resent the go command at 09:45, and this time the Gavia ran through the dive sequence and started on the acoustic lawnmower without issue.

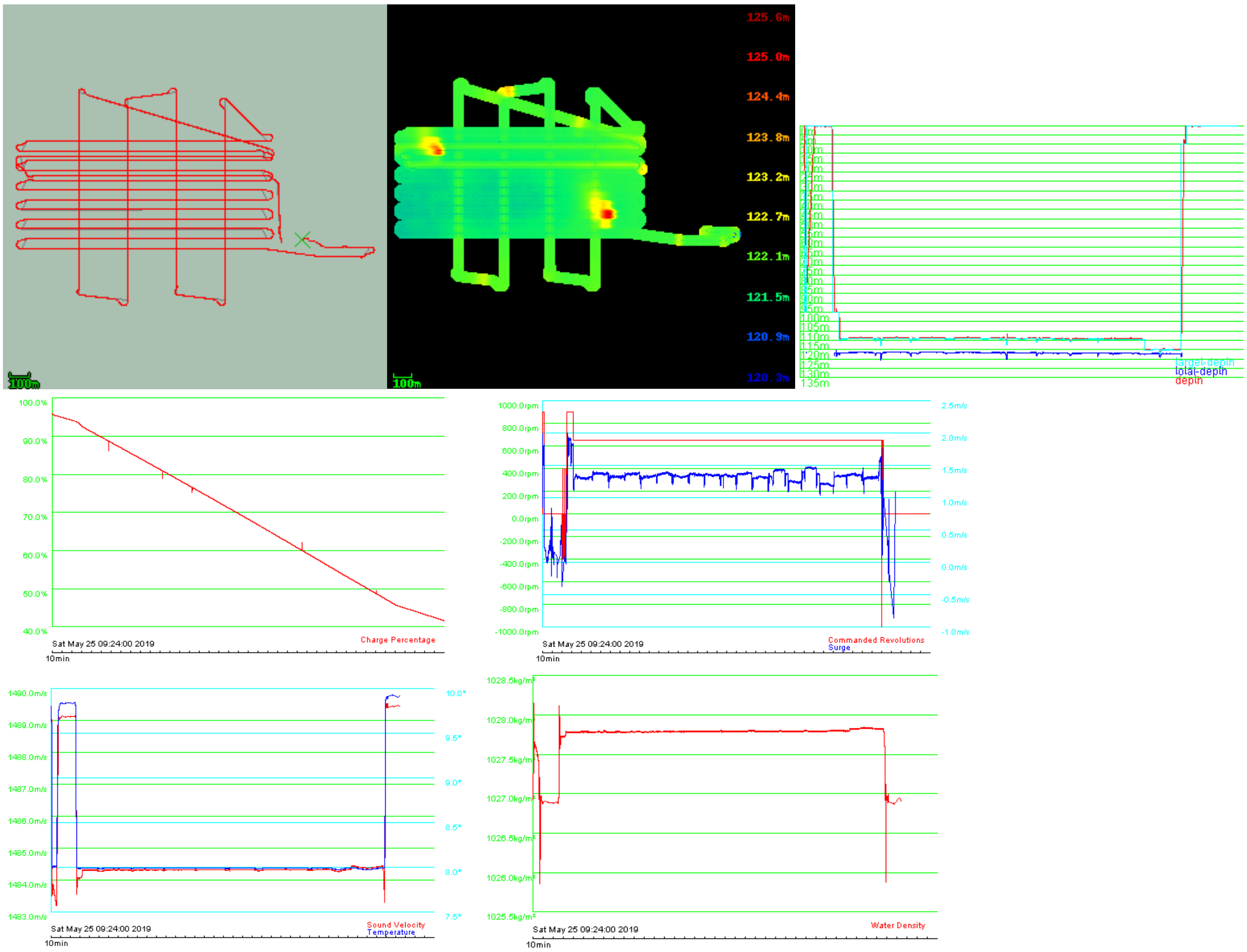
As the acoustic survey lines were 1200m in length the Gavia would run out of range for the USBL, the first time this happened we suddenly saw the depth come up just before it lost range so believed it may have aborted again and then wasn’t seen on the USBL as it was floating on the surface. This turned out not to be the case and as we moved the ship closer to the area to take a look realised that as the auv started calling back in again. We then left the ship towards the middle of the survey area as this gave us the best range for getting replies from the USBL.
The rest of the mission ran without issue although slower than predicted with the first prediction of 14:45 being about 30mins early of the actual surface time.

Recovery

The gavia came back up to the surface at 15:16 about 150m to the starboard aft of the James Cook. We then launched the small boat to recover the auv and bring it under the starboard aft quarter crane which had the recovery lines already attached to hook up the Gavia.

The conditions proved to give some issues with keeping control of the small boat under the crane and ended up with the front being connected to the crane and the rear having to be left lose as the boat was re positioned to allow the aft to be connected and brought up onto the ship. Once connected the Gavia was brought aboard at 15:29, and then the small boat was recovered onto the port side position.

Gavia Mission Data



Safety

Risk with the small boat under the crane hook in swell but managed responsibly by the ships crew and the boat operator.

Issues

Gavia aborted on deep dive.
USBL misreading info.

Improvements

Talk with the ship to get an understanding of how the current will affect the gavia and adjust the launch position to allow for this, also make sure the operators are happy with the launch area before putting in the water.

Talk with Juan about any potential for improvement of the USBL in shallow ocean. Look into gavia own USBL shipside receiver if going to be used long term.

Summary

After resolving the issues with the dive and early USBL issues the rest of the mission was smooth. On recovery with the added swell and conditions the boat crew managed any issues and made a safe recovery possible, I think the weather on that day was the top of what's acceptable to recovery the Gavia in currently. (1.6m wave height)

17.9 Deployment 9

Conditions: Overcast/light rain, swell, wind
Location: Offsite location 3 (Goldeneye)
Date: 26/05/2019
Deployment: STEMM_CCS_Offsite_26052109
Operators: Jared Mazlan, Mike Smart

Overview

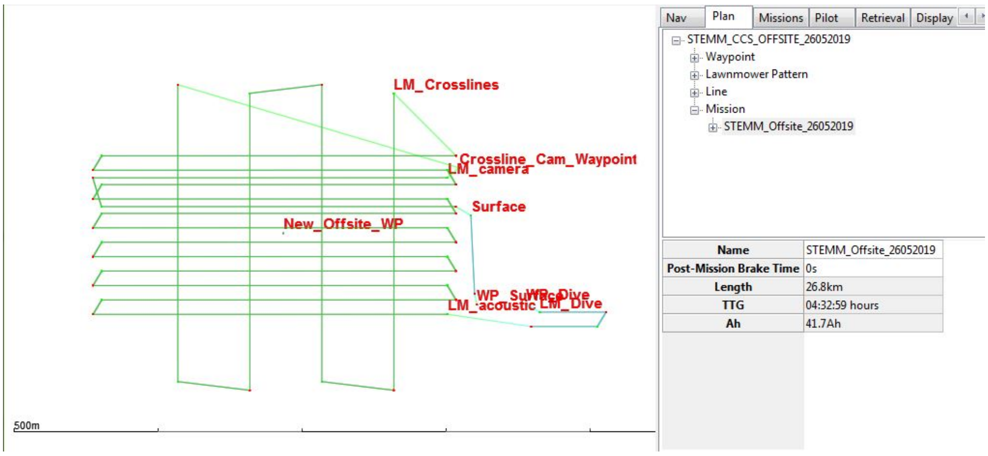
Survey of a new offsite location to the south of the main work area, final offsite mission and using the same template as the previous one carried out, with acoustic survey followed by crosslines and finally a camera survey.

Mission Planning

The previous mission file could be duplicated and offset to the new central waypoint give to us from the science team, this meant we could quickly move the mission the morning of deployment as we hadn't been given a waypoint the previous night.

Pre-Deployment

Pre-deployment again went smoothly, all checks carried out without issue. Sam fitted the Seafet and we were ready to deploy before the requested launch time of 09:00, but had to wait for the ship to be at the correct launch waypoint before launching the Gavia.



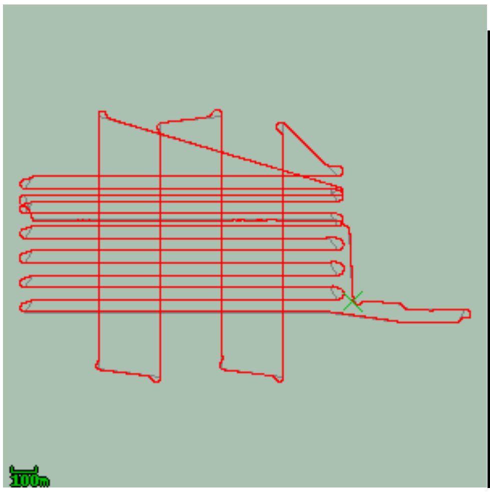
Launch
Once ready the launch went without issue at 09:08 and once we turned the Gavia to be facing away from the starboard side of the James Cook we sent the mission at 09:20 and Gavia dived successfully, we monitored the early stages of the dive to make sure all was ok via the USBL.

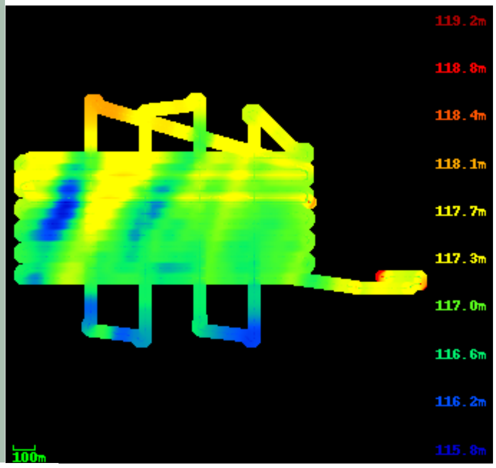
Deployment
Deployment again went without issue as we had a good dive and started the acoustic survey once at the end of the first lawnmower line were positioned the James Cook to be in the centre of the work area to give best coverage of the work site and managed to get good range this time around.

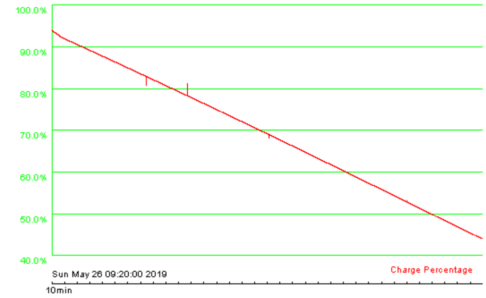
The accoms pinger was deployed over the side of the James Cook and we had sporadic hits when the Gavia passed within close proximity of the ship, but the main way of keeping tracks of this mission was via the USBL.

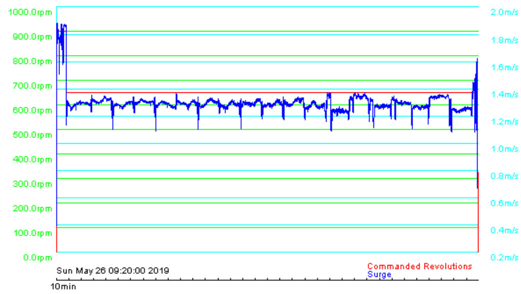
Recovery
The Gavia returned to the surface at 15:30 and the small boat launched, once we got to the Gavia it was decided to use the long line attached to the front of the gavia and tow it back into towards the James Cook and then brought alongside the small boat to then follow the standard recovery procedure. The transition being towing the Gavia and getting alongside was a little tricky with the swell and waves, but once alongside the rest of the recovery was smooth and quick. The Gavia was brought back on-board at 15:35 via the starboard aft quarter crane and the small boat then recovered on the port side.

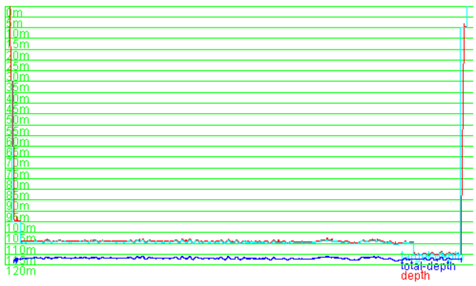
Gavia Mission Data

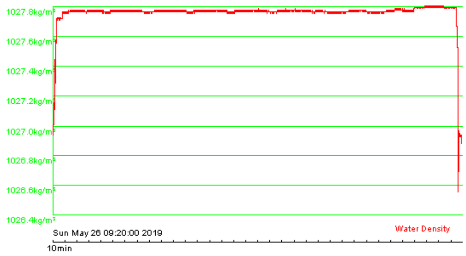












Safety
No safety issues.

Issues
Accoms struggling to get replies from gavia on long missions.

Improvements
Look into ways to optimise the range we can get from the Accoms.

Summary
Good mission over new survey site, in tricky conditions all operations were handled smoothly and under control as all people involved get more experienced with working with the Gavia in more testing conditions.

17.10 Deployment 10

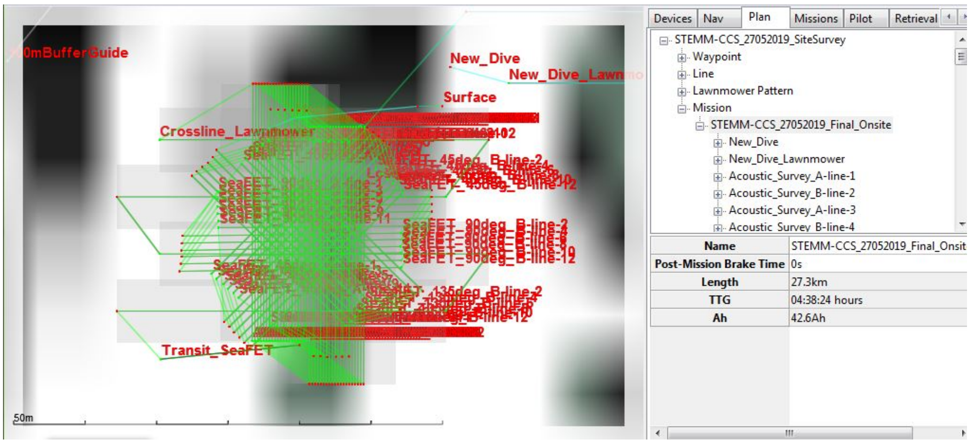
Conditions: Clear, small swell.
Location: Goldeneye worksite
Date: 27/05/19
Deployment: STEMM_CCS_270519_Final_Onsite
Operators: Jared Mazlan, Mike Smart

Overview

Final survey of the worksite area now that all the equipment has been brought up and back onto the James Cook. Running the same acoustic lawnmower and star pattern from previous onsite deployment with small changes now there isn't equipment to be warry of.

Mission Planning

An old version of the onsite survey was duplicated and the star pattern was changed to 2m alt so that the camera can be used to get images of the work site, because of this the original camera survey was removed. We also removed the geoswath from the star pattern as it was not needed for this survey.



Pre-Deployment

The pre-deployment checks were started at 08:30 and went without issue, a launch position was given to the bridge and we were on site and ready to launch the Gavia at 09:23.

Launch

We had no issues during the launch and the Gavia turned to face away from the ship so we could be in a position ready to deploy quickly as we saw we had a bit of surface drift happening today.

Deployment

We sent the go command at 09:26 and the Gavia dived without issue from the surface, we then went to check the USBL to make sure that everything was running smoothly. Whilst watching the screen we noticed the Gavia was heading off the planned route which suggested that it had not reached depth during the dive as was returning to the surface, we radioed the bridge so they could be ready and the gavia came back to the surface at 09:32.

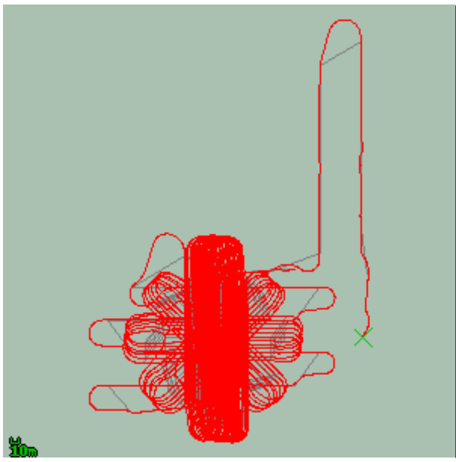
After taking a look at the gavia surface positions from the first dive it was noted that we had drifted south on the surface and given the Gavia more of an angle than we would like to turn from the dive waypoint to lawnmower. As we were drifting south we decided to put the dive point south of the lawnmower so that it could run straight onto it and we should eliminate the issue.

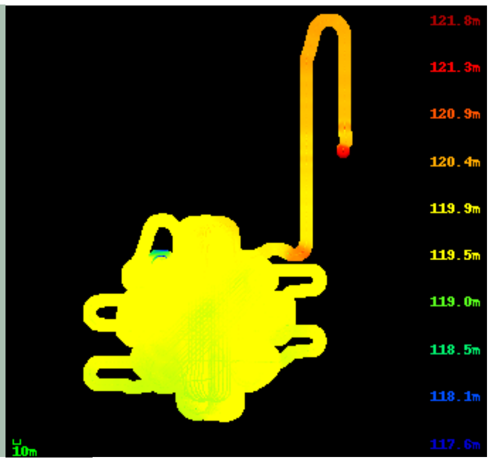
Once we had the new dive and the rest of the mission loaded onto the auv we sent it off again and this time it dived without issue and continued onto the acoustic lawnmower.

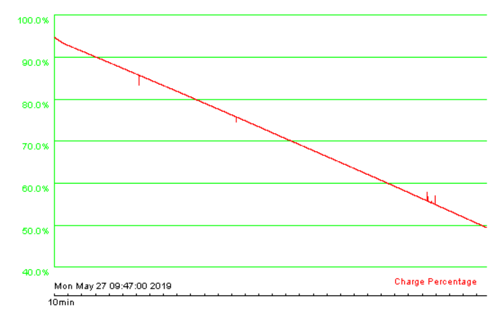
Recovery

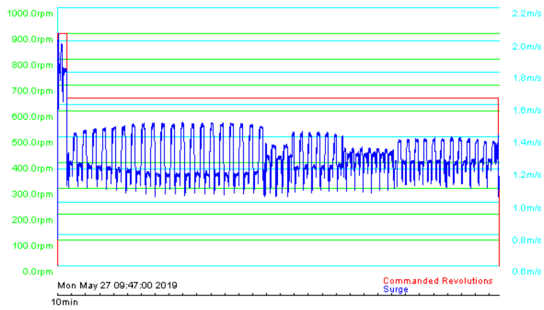
The method of towing the Gavia behind the small boat was again used to get the auv close to the James Cook. It was then brought along the port side of the small boat and brought under the crane on the starboard side of the James Cook and connected up without issues and brought back onto the ship and placed into its carrying frame.

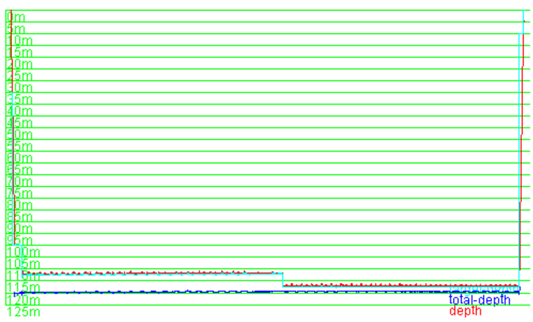
Gavia Mission Data

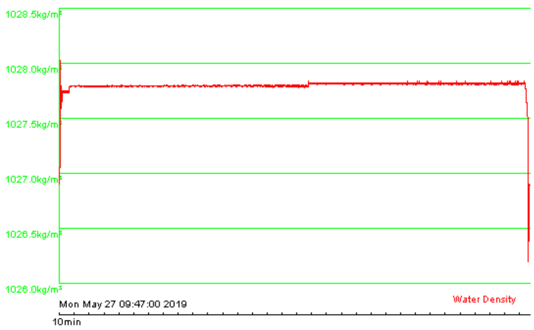












Safety

No issues.

Issues
Surface drift on the launch meant we had to sharp a turn to be able dive down properly on the first dive.

Improvements
Get the ship to update on sea conditions to make sure we are set up for the best possible launch.

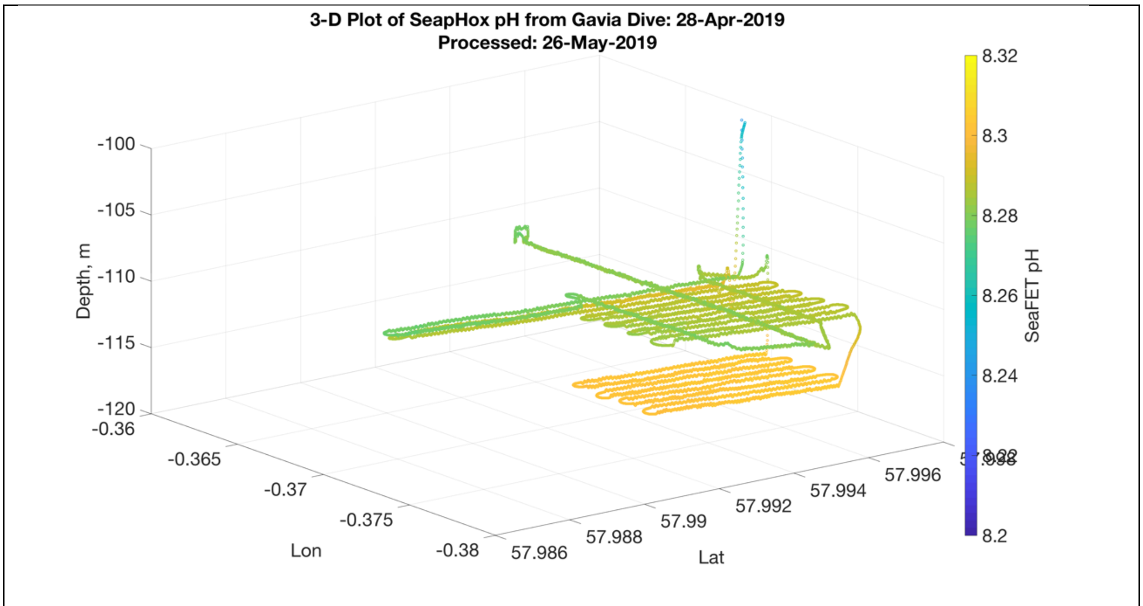
Summary
Successful mission after a first dive abort, but the issue was quickly picked up and sorted out and all other part of the

17.11 Gavia deployed sensors

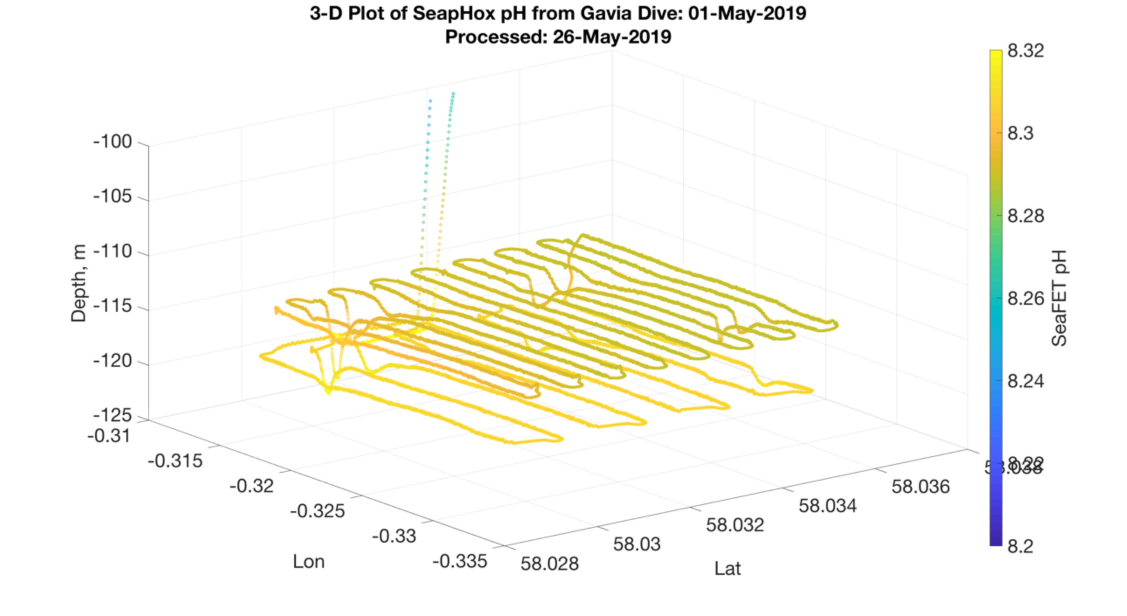
In order to study the spatial variability of pH during the course of the STEMM-CCS experiment a Sea Bird Electronics SeaFET pH sensor was mounted on the AUV GAVIA, in a custom made Syntactic foam bracket. The SeaFET is an early model of the Deep SeaFET, rated to 2000m. The SeaFET records data at 1 Hz and with a manufacture reported precision of 0.001 pH units (when averaging is applied).

Over the cruise the SeaFET was deployed on 8 dives. During the dive on the 20th of May 2019 (Dive 6) the SeaFET stopped recording data 340 seconds after it started recording. This fault occurred while the sensor had plenty of battery remaining (fresh batteries two dives before, and enough power for the deployment confirmed prior to starting the dive). The fault could not be recreated during post dive testing; it was possibly the result of an intermittent short in the sensor, potentially caused during the mounting of the sensor however this is a working hypothesis. The sensor was not recording during the initial dive 1, as this was a ballasting test conducted with the GAVIA tethered to the ship.

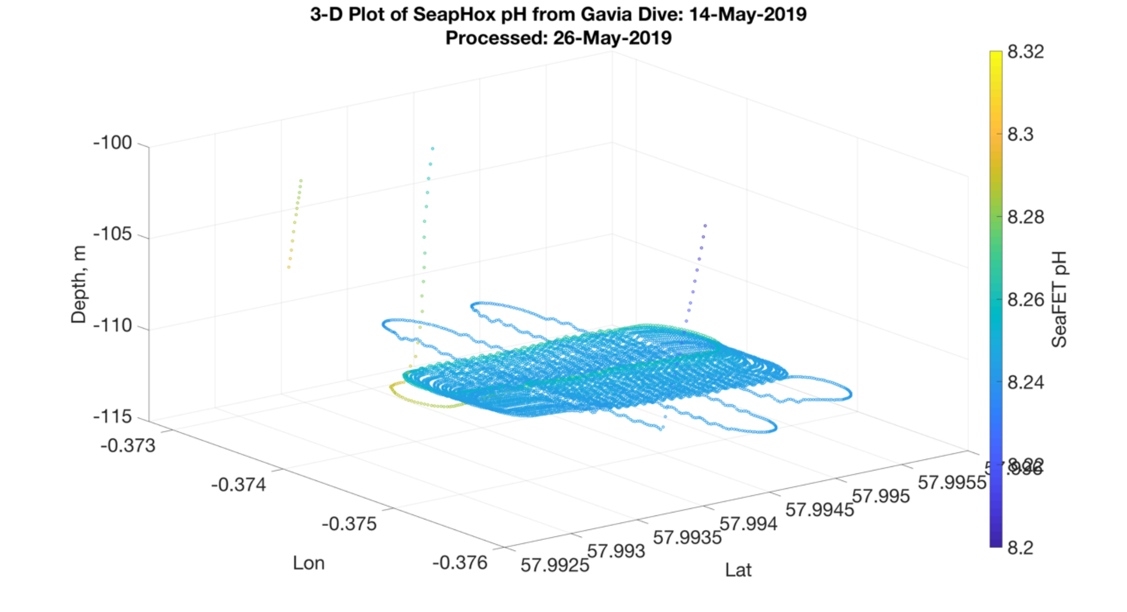
The sensor appeared to have a pressure effect, which hasn't been completely accounted for using the standard pressure calibration, so these values should be treated as uncorrected, post processing should improve these data.



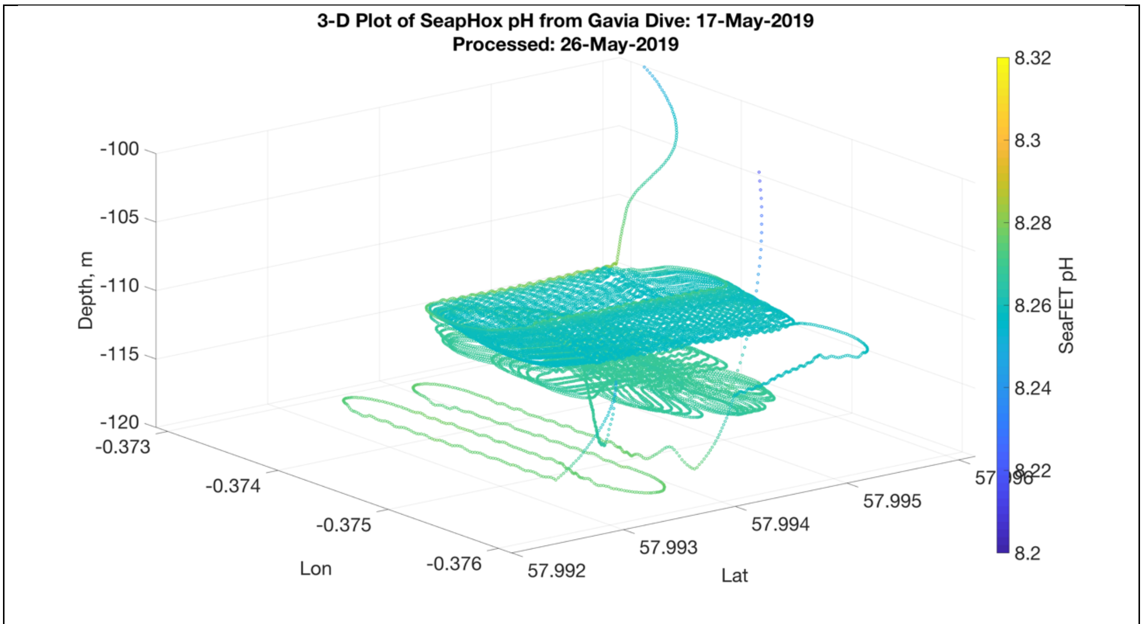
Dive 2


3-D Plot of SeaPHox pH from Gavia Dive: 01-May-2019
Processed: 26-May-2019
Depth, m
-100
-105
-110
-115
-120
-125
-0.31
-0.315
-0.32
-0.325
-0.33
-0.335
Lon
58.028
58.03
58.032
58.034
58.036
Lat
SeaFET pH
8.32
8.3
8.28
8.26
8.24
8.2

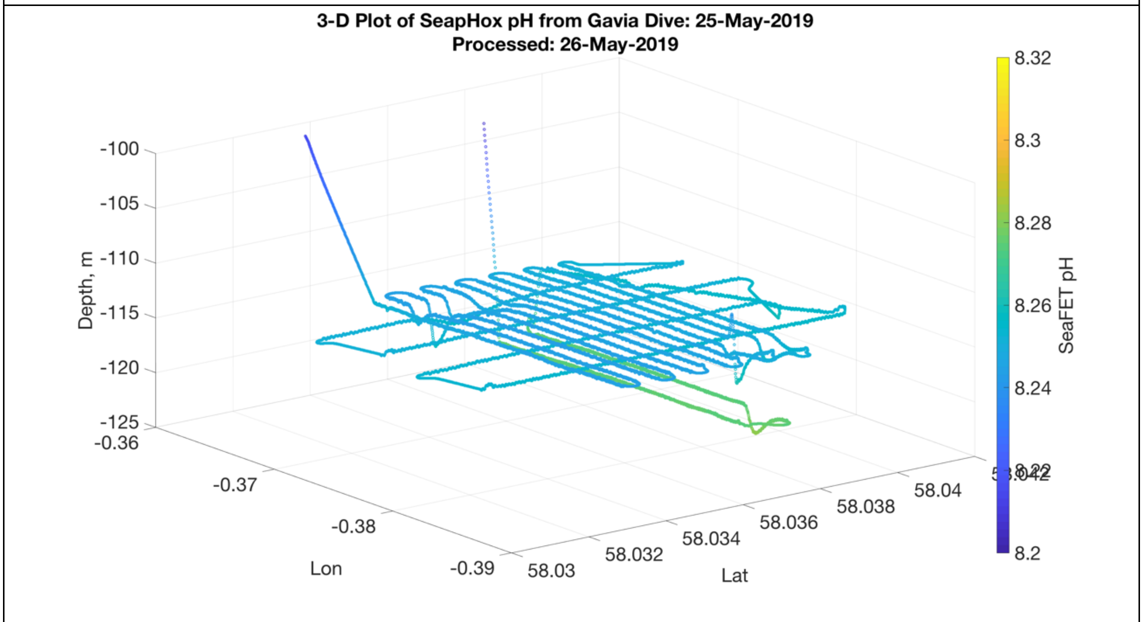
Dive 3


3-D Plot of SeaPHox pH from Gavia Dive: 14-May-2019
Processed: 26-May-2019
Depth, m
-100
-105
-110
-115
-0.373
-0.374
-0.375
-0.376
Lon
57.9925
57.993
57.9935
57.994
57.9945
57.995
57.9955
Lat
SeaFET pH
8.32
8.3
8.28
8.26
8.24
8.2

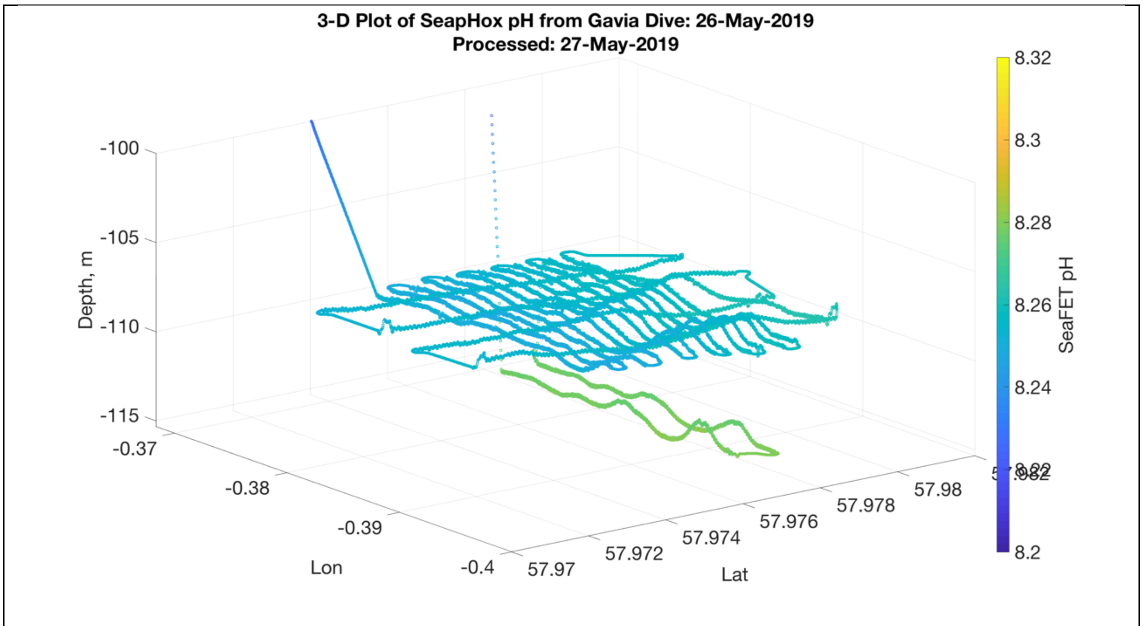
Dive 4


3-D Plot of SeapHox pH from Gavia Dive: 17-May-2019
Processed: 26-May-2019
Depth, m
-100
-105
-110
-115
-120
-0.373
-0.374
-0.375
-0.376
Lon
57.992
57.993
57.994
57.995
Lat
8.32
8.3
8.28
8.26
8.24
8.22
8.2
SeaFET pH

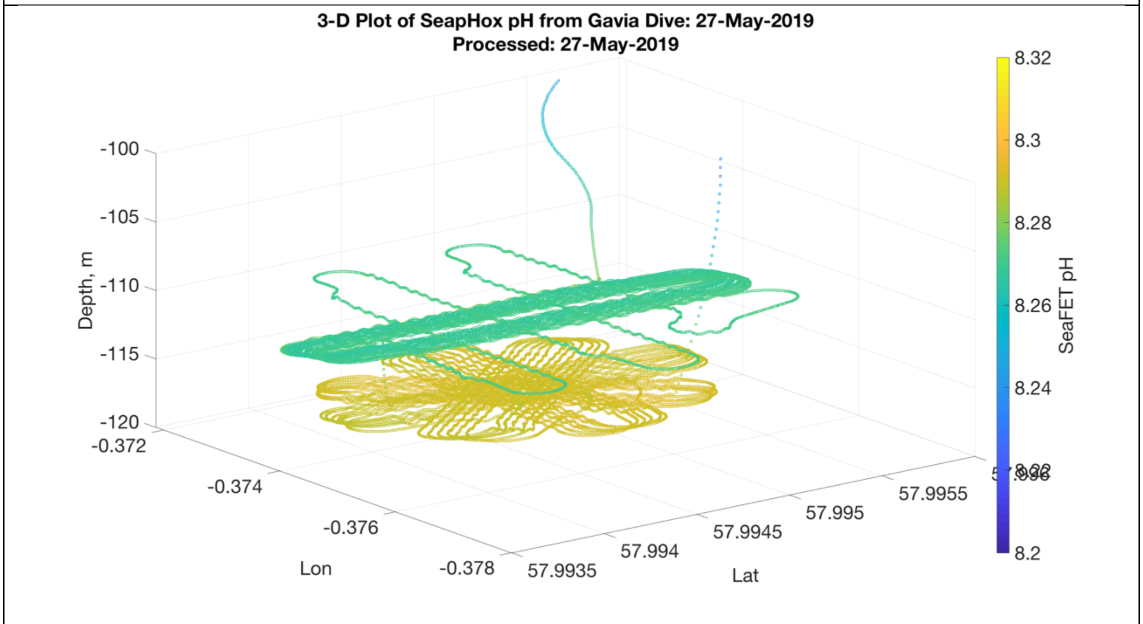
Dive 5


3-D Plot of SeapHox pH from Gavia Dive: 25-May-2019
Processed: 26-May-2019
Depth, m
-100
-105
-110
-115
-120
-125
-0.36
-0.37
-0.38
-0.39
Lon
58.03
58.032
58.034
58.036
58.038
58.04
Lat
8.32
8.3
8.28
8.26
8.24
8.22
8.2
SeaFET pH

Dive 7


3-D Plot of SeapHox pH from Gavia Dive: 26-May-2019
Processed: 27-May-2019
Depth, m
-100
-105
-110
-115
-0.37
-0.38
-0.39
-0.4
Lon
57.97
57.972
57.974
57.976
57.978
57.98
Lat
8.32
8.3
8.28
8.26
8.24
8.2
SeaFET pH

Dive 8


3-D Plot of SeapHox pH from Gavia Dive: 27-May-2019
Processed: 27-May-2019
Depth, m
-100
-105
-110
-115
-120
-0.372
-0.374
-0.376
-0.378
Lon
57.9935
57.994
57.9945
57.995
57.9955
Lat
8.32
8.3
8.28
8.26
8.24
8.2
SeaFET pH

Dive 9

18 ROV ISIS report: Dave Turner, Andy Webb, Russel Locke, Josue Viera, Emre Mutlu, Richard A. Berry (NOC), William Handley (Contractor)

18.1 ROV Dive Stats

No. of dives JC180	36 (Dive nos. 346 to Dive no. 381)
Total run time for (JC180) thrusters:	208.52 hrs
Total time at seabed or survey depth:	189.44 hrs
Isis ROV *total* run time:	5001.33 hrs
Max Depth and Dive Duration:	119m and 22.95hrs (Dive 357) (24.04hrs in water)
Max Dive Duration and Depth:	22.95hrs at 119m (Dive 357) (24.04hrs in water)
Shallowest Depth and Duration	118m for 2.07hrs (Dive 349) (2.65 hrs in water).

Recorded Data:

Video (34TB)	DVLNAV (23.83GB)
Techsas (7.46 GB)	CTD (273 MB)
OFOP Event Logger (922 MB)	Sonardyne (6.52 GB)
Scorpio Digital Still (20,113 files, 70.1GB)	Reson Seabat (0GB)
EdgeTech SBP (3.14GB)	

Master #1 Lacie Raid unit SER# (MRVL0001B6E0C3481B0E) will be installed in the NOC media room for BODC to archive and provide access for scientists post cruise.
Backup #1 Lacie Raid unit SER# (MRVL0001B6FCC83B1F02) will be retained by the ROV team until BODC have archived the Master unit.

18.1.1 Mobilisation

Southampton (NOC): 18th April to 24th April 2019 (Easter Weekend)
The Isis ROV system was mobilised in Southampton. This was a straight forward installation with a 9000kg installation load test carried out. All containers and electrical installation were checked by the Chief Engineer and ETO. The ship sailed at approximately 09-00hrs on Thurs 25th April as scheduled.

18.1.2 De-Mobilisation

The ship arrived along-side at NOC on 30th May 2019 at approx. 0800 hrs

18.2 Operations

Unfortunately at a late stage in the mobilisation it became apparent that Steve, one of the ROV techs, would not be able to support the cruise. Fortunately with the late addition of the new recruit, Emre, it was decided that no additional support was required and that the level of operational support would be sufficient to support the expedition. This did mean that the watches would need to be configured slightly different.
For the best part of the first week most of the work was carried out on day work between 08-00hrs and 20-00hrs, enabling a fair bit of training and familiarity with systems.

Following this the two teams went onto the following watch patterns:

04-00hrs to 16-00hrs	16-00hrs to 04-00hrs
Russell Locke	Josue Viera
Will Handley	Andy Webb
Emre Mutlu (training)	Richard A Berry (training)

10-00hrs to 22-00hrs
Dave Turner

All launch and recoveries were carried out between 10-00hrs and 22-00hrs, this working typically with the ROV being recovered at 10-00hrs and then being turned around and dived again either once or twice during the day, before being re-configured and deployed at around 21-00hrs for a 12 to 14 hrs night deployment.

For each deployment/recovery Emre and Richard covered the engineer role to support the pilot. With the vehicle deployed each watch had minimum of two fully trained staff at any one time with three available for 6hrs on each watch. This technical cover was adequate cover to carry out the required tasks of piloting the vehicle and doing the scientific operations with the manipulator arms, and giving some level of rest bight during the 12hr shift.

With the amount of dives covered on this expedition, due to the shallow water depth and tasks required, it proved to be a perfect platform for the trainee operators to get familiar with the various operations. Due to the complexity of some of the manipulator tasks, this area may have been more restricted, however a suitable level of using the equipment was achieved.

Due to the shallow water depths (120m) there were a few consideration to be taken into account.

- Umbilical temp, due to approx. 7000m of umbilical remaining on the drum during operations.
- Manoeuvrability from the vessel
- De-coupling of the tether from the ROV, delta length, and the amount of floatation required?
- Range of operation
- Rotation of the vessel

From previous operations we have not experienced excessive cable temps, even in tropical locations, and from the limited shallow dives we have carried out work, again no real issues have presented themselves. During the expedition the cable temp was monitored on an hourly basis during operation and cooled with the non-toxic water supply. This coupled with the relatively cool air temps did not seem to present any problems.

As a precautionary, a 50m/45°cone was added to the vessel drawing that gets imported into the Sonardyne system. This helped the ROV pilot with the positioning of the ROV relative to the ship, limiting the potential wire angles from the docking head. This worked well also in enabling the ships officers to make any heading changes to the vessel, in such that they could manoeuvre the vessel whilst changing the heading keeping the ROV in the same position. In addition to this only five football floats were used at approx. 8m spacing, with the first two floats attached close together approx. 10-12m from the ROV. A delta of approx. 30m was maintained for most dives, which proved to work well.
For the first deployment the usual umbilical WMT beacon was attached a few metres up from the last football float. This proved not to be very beneficial for the shallow water operation setup up of the umbilical, and was not used for the rest of the deployments.

- The floatation on the wire was reduced to five floats at approx. 8m apart.
- The umbilical beacon was not attached.
- A delta of approx. 30m was maintained.
- An approx. distance of 40 to 50m was maintained from the port side of the vessel. (Sonardyne 50m /45° cone)

18.3 ROV Handling Systems

18.3.1 Hydraulic Power Unit (HPU)

During Dive 354 a small leak was noted coming from the FL-12 Indicator. Upon further inspection of the leaking unit, revealed a damaged 'o'ring. A replacement 'o'ring of a similar size was found in an 'o'ring kit. This replacement worked well with no further problems. No spare FL-12 indicators or filter housing could be located in the spares.

Other than that the HPU worked well for the duration of the cruise, with no problems reported.

Future modification/requirements:

- Standard post cruise checks and maintenance
- Check spares, and update
- Order FL-12 indicators (Fault 150)
- Look at servicing all filter housings

18.3.2 Storage Drum/Traction Winch

Worked well for the duration of the cruise, with no problems reported. Chain found to be tight and was adjusted during mobilisation. It was noted that some of the links may have seized.
QD on the signal line to traction winch was damaged due to being dragged on deck.

Future modification/requirements:

- Check brake assembly.
- Put together a planned maintenance schedule.
- Replace or overhaul filter housings.
- Inspect chain and sprockets for wear. Replace chain if links have seized.
- Replace damaged traction winch hose (marked with blue tape) (Fault 149)
- Consider changing the leaking QDs to Holmbury flat face type. If the males are put on the fixed ends and females put on the hose ends, then burrs are not developed when they are dragged on the deck
- Tighten back nuts that hold terminals for 3 x phases in Winch HV JB. (Fault 160)
- Possibly move F/O ST/FC on bracket to one side to make more space (Fault 160)
- Slipring to be removed and the F/O part to be switched back from the unit taken out of the TMS.
    - The whole unit is to then be returned to manufactures for complete overhaul.

18.3.3 Storage Drum/Traction Winch Base Plate

The storage drum located nicely onto the base plate. The repaired tombstone hole unfortunately did not line up exactly with the thread insert on the storage drum.

Future modification/requirements:

- Tombstone hole to be opened up

18.3.4 Launch and Recovery System (LARS)

The complete system was load tested to 9000kg using the spectra test rope, traction head, storage drum, and a water bag supplied by water-weights. At each 1000kg interval the winch was hauled/veered until 7000kg was achieved. (dynamic test)   Ref test cert No. LARS-005 JC180

Slight leak identified at the control consul, possible hose or fitting replacement. Tugger wheel mounting screws checked half way through trip and were re-tightened after being found to be loose.

Future modification/requirements:

- Inspect sheave drive sprocket/chain.
- Check tugger wheel assembly. Consider using seizing wire to prevent mounting screws from coming loose.
- Add drive chain sprocket/chain to inspection and testing procedure.
- Standard post cruise checks and maintenance.
- Put together a planned maintenance schedule.
- Investigate control consul oil leak.

18.3.5 Umbilical

Prior to the termination approximately 25m of umbilical was removed and disposed of.
Total umbilical remaining 7557m
Ref Isis Umbilical Log 03
The umbilical was mechanically and electrically terminated and load tested after the mobilisation. A load of 7000kg was applied and held for 5 minutes. (SWL of 5600kg)
Ref test cert No. UMB-03-010
Due to the shallow water depth no wire stream was carried out and the umbilical termination was pinned to stop the potted part of the termination rotating with the inside of the docking bullet.
The attenuations for each of the new fibre connections were recorded from the vehicle end to the control container patch panel.

The attenuation for each fibre was recorded as:

Black	1310:	12.92dB (-20.08dBm)	1550:	11.03dB (-18.33dBm)
Red	1310:	8.05dB (-15.3dBm)	1550:	7.77dB (-14.98dBm)
Grey	1310:	14.0dB (-21.15dBm)	1550:	13.18dB (-20.42dBm)

Red fibre - For vehicle telemetry
Black fibre - For CWDM (cameras)
Grey fibre – Spare

It was noted that when the fibres were connected to the vehicle the ST/ST couplers in the junction box were giving high attenuation results. Following the replacement of these, the losses were significantly reduced. (See above). Both the Red and Grey fibre ST couplers were then not secured into the bulkhead as this seemed to increase the attenuation.

Now that the steelite fibres in the umbilical are terminated using the fusion splicer, the jumpers are no longer needed to electrically isolate the steelite fibres. If the fusion spliced end is taken into the upper FO termination box, the jumpers and a set of ST-ST couplers can be removed from the signal path.

It is suggested that the steelite fibre from the FO junction box to the telemetry tube is moved to the top dorn and the CWDM fibre that is in the top dorn moved to the side dorn. If this is done then the it will be possible to bleed air back into the JB during filling, rather than having to take all tywraps off the fibre and disconnect it to bleed it

During the recovery of Dive 377, and at a point when the vehicle had just returned to the surface, a significant Ground Fault (GF) occurred tripping the Ground Fault Monitor (GFM) and shutting power to the ROV.
An HV isolation carried out, proving the system dead and putting the necessary safety checks/locks in place.

The deck cable from jetway power source to the rest of the umbilical was isolated at the Junction Box (JB) on the storage drum. The GFM was then energised, showing that no fault was on this part of the system.

Each conductor of the umbilical was then resistance tested at the JB on the winch using a 1000v megga. On the blue conductor (L3) a low resistance was recorded (13kOhms) between the conductor and the shielding (grnd) compared to the 1GOhms recorded from the other conductors.

At this stage it was difficult to identify where this fault would be in the 7km of umbilical on the drum. However, it did seem likely that the fault was more likely to lie in the outer end of the umbilical where it had been handled and tugged for the last 30 dives. Therefore 200m of umbilical was removed from the wet end of the umbilical, cutting the termination off from the ROV. Further tests were then carried out showing that the 13k Ohms low resistance had now gone.

A full 5000v test was carried out as per pre-cruise electrical testing, to compare readings and satisfy that all was in order.

L1 (R) to L2 (Y) 2.32G Ohms
L1 (R) to L3 (B) 2.31G Ohms
L2 (Y) to L3 9B) 2.86G Ohms
L1 to earth 650M Ohms
L2 to earth 633M Ohms
L3 to earth 563 Ohms

The umbilical was mechanically, electrically, optically terminated and then load tested. A load of 7000kg was applied and held for 5 minutes. (SWL of 5600kg)

Ref test cert No. UMB-03-011

The attenuation for each fibre was recorded as:

Black	1310:	13dB (dBm)	1550:	11.8dB (dBm)
Red	1310:	5.7dB (dBm)	1550:	5.5dB (dBm)
Grey	1310:	15dB (dBm)	1550:	14.6dB (dBm)

Red fibre - For vehicle telemetry
Black fibre - For CWDM (cameras)
Grey fibre – Spare

Future modification/requirements:

- Look at replacement umbilical.
- Look at introducing the mk2 turns counter to the bullet assembly.
- Look at the bulkhead ST couplers to see if an alternative fixing method could be achieved.
- Steve to run tests on 150m length of failed umbilical (Fault 161)
- Steve to write procedure for using ETDR, with example plots and failures (Fault 161)
- Replace for each cruise the 35-40 cm F.O. colour tails joining the HV JB with the FO JB.
- Check St-ST couplers to ensure that they are not multimode.
- Look at removing interconnect fibres between HV and Fibre JB’s (see text)
- Look at swapping the Steelite Fibre with the CWDM fibre in the F/O JB. This will prevent the need to bleed the CWDM tail.

18.4 CCTV & Lighting

A new HD system consisting of two fixed , one varifocal zoom looking at the A-Frame and one PTZ dome camera for deployments was trialled on this expedition, in a move to replace the old, heavy, PAL camera system. This worked extremely well and is a vast improvement.

Some of the Deck 110V lights were tripping the RCD in the workshop. Additionally two units developed an earth fault on one side of its panel. This side of the light was isolated so that the remainder of the LED's could be used. The 110v RCDs were checked using the 17th edition tester and all tripped around 8mA

Future modification/requirements:

- Write off and dispose the old CCTV system
- Procure another two varifocal zoom cameras
- Procure a spare HDMI PIP Matrix
- Investigate an Analog HD dome camera + outdoor display on top of A-Frame for winch driver
- Repair/procure Deck lights. [Fault 142]
- Buy spare deck light

18.5 Containers

18.5.1 Control 1

The Control 1 was fitted with a new hardwired fire alarm system to comply with the Ship's requirements of having an alarm system on powered containers.
During the mobilisation, the systems were checked by the Chief and the ETO, but the Control 1 installation was triggering the alarm on the ship. The issue was promptly resolved finding a loose wire connection on the break glass.

The Public Address (P.A.) speaker on the control van and the workshop did not work during the general test done by the ship on the second week of the cruise.

From a safety inspection held on 23/05/19 a couple of recommendations were made.

1. Recommend to remove the 240V warning sign from the inner container door and fit a large yellow 'Warning High Voltage' sign with the electrocution symbol. I've looked onboard, I don't have a spare.
2. Replace the rags stuffed in cable entries with intumescent pillows. A google search for 'intumescent pillows' shows various products of differing size. Use of this product will expand and seal the entry when heated by fire

Future modification/requirements:

- Remove 240V sign and fit HV sign (as per 1. Above)
- Replace rags used to stuff cable entries (as per 2. Above)
- Revise wiring and do schematic
- Check fire alarm installation (P.A. not working on James Cook) [Fault 140]
- Check RRS Discovery wiring details on mob DY103 and update ROV installation if required.

18.5.2 Control 2

Door seal needed repairing at one point. This worked well, and hopefully need no further attention.
From a safety inspection held on 23/05/19 a couple of recommendations were made.

1. The ventilation isolation to the van is poor. There is a fixed exhaust vent on the aft bulkhead. This should be modified to a hinged flap with a rubber seal. It should be possible to seal this vent without hand tools.

2. Post an evacuation plan inside the Van in a prominent position. Plan to include exit route and actions upon exit. Preferred exit is to the open deck through the aft door. Actions to take would be hit the fire break glass, close the doors and trip ventilation. Sealing the space and stopping the ventilation will help the ship fight a fire and reduce risk. It may be convenient to wire the break glass into the ventilation stop.

Future modification/requirements:

- Touch up paint defect for next cruise.
- Investigate replacement containers.
- Change red light to LED's with a diffuser.
- Modify exhaust fan (as per 1. above)
- Evacuation plan (as per 2. Above)

18.5.3 Workshop

The workshop was fitted with a new hardwired fire alarm system to comply with the Ship's requirements of having an alarm system on powered containers.
A slight leak around A/C unit noted when raining. This was investigated and was found to be a blocked drain hose.
The External deck lights keep tripping the RCD in the container switch box. The lights would come on, but only after cycling the RCD a couple of times.

Future modification/requirements:

- Revise wiring and do schematic
- Check fire alarm installation (P.A. not working on James Cook) [Fault 140]
- Check RRS Discovery wiring details on mob DY103 and update ROV installation if required
- Replace the electrical installation with updated 240V RCDs. [Fault 143]
- Add a small 415v/240v to 110V transformer

18.5.4 Spares

Worked well for the duration of the cruise
Future modification/requirements:

- Once LUVU container fitted out with shelving move equipment used during mobilisation into LUVU to give space for spares.

Future modification/requirements:

- Replace the heater and lights with 240V units.
- Replace 110V orange power lead

18.5.5 LUVU

No problems reported. Better storage and method for securing the oil drums would be advantageous.

Future modification/requirements:

- Fit some shelves and racking.
- Following welding work have container blasted and painted.
- Replace / repair window in door
- Fit Rechargeable battery PIR lights

18.6 ROV External and Sampling Equipment

18.6.1 Sonardyne Beacons

18.6.2 Compatt 5 Midi Beacon

The Compatt 5 beacon address 110 was attached to the ROV for the duration of the cruise. This beacon was only on the vehicle for back up and was not tracked during the dives.

The STEMM-CCS Gas Rig was fitted with a spare C5 unit, borrowed from the AUV.

Future modification/requirements:

- Batteries to be disconnected and stored in LI battery store at NOC.
- New battery to be purchased once a cruise code has been released for next ISIS cruise.

18.6.3 G6 WMT Beacons

Beacon 2702 was used to track the ROV and 2709 was used to track the umbilical on the first dive. Following this only beacon 2702 was used on the ROV, as is proved not necessary to track the umbilical in these shallow waters. (119m)

Beacon 2702, is trickle charged from the ROV and remained on the vehicle for the duration of the cruise.

A new SVP was loaded into the Ranger topside unit, as and when they were carried out by the Ships System team.

Future modifications/recommendations/maintenance

- Connect to terminal and switch off both beacons.
- Raise question of USBL accuracy and priority with PM’s and Ships System Group.
    - When was last Casius calibration carried out?

18.6.4 Football Floats

5x 6000m floats were used for the duration of the cruise.

Future modifications/recommendations/maintenance:

- Check and re-tighten float latches where necessary.
- Check quantities and order replacements if necessary.

18.6.5 Suction Sampler

Not requested for this expedition.

Future modifications/recommendations/maintenance:

- Investigate a solid pipe arrangement for the rear of the drawer to further improve suction pipe path.
- A solution to filling all the chambers without having to rotate the mechanism would be useful.

18.6.6 Push Cores

The port bio box was modified prior to the expedition to accommodate 6 x tubes (1 box). This modification was made so that science could take push cores on most dives without taking space on the tool sled, which would be required. This worked very well.

Future modifications/recommendations/maintenance:

- Service units and make ready for next cruise.
- Look at an easier way to secure the boxes to the tool sled.

18.6.7 Magnetic Tubes
Not used for this expedition.

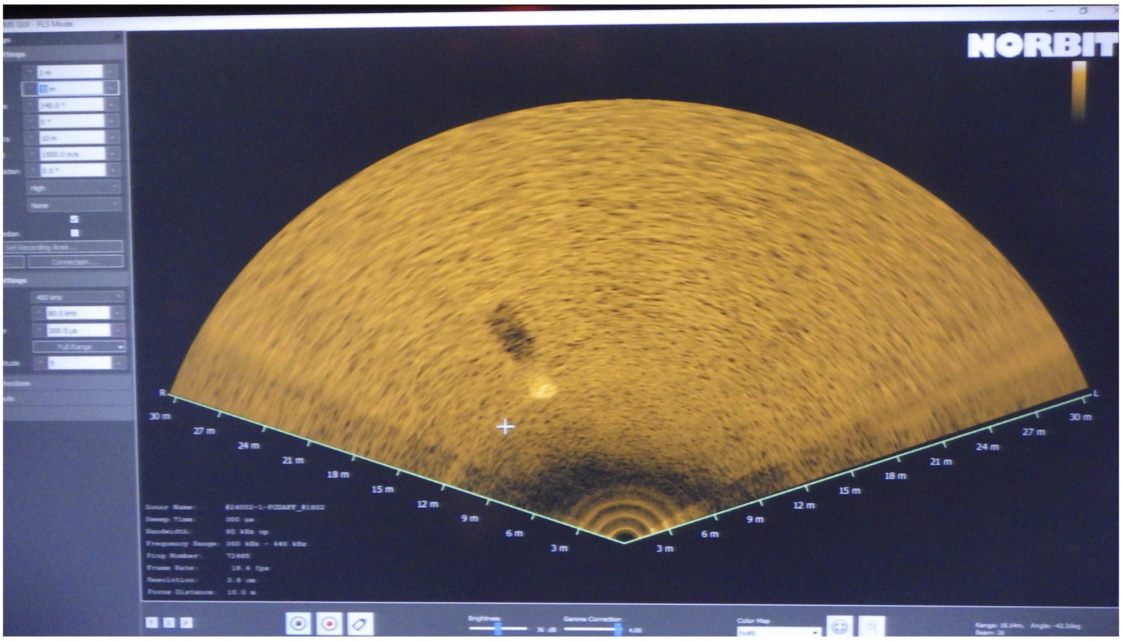
18.6.8 Niskin Carousel
Used on most dives to take samples at the bubble stream and the gas rig.
No issues reported.

Future modifications/recommendations/maintenance:
- Service indexing mechanism. Inspect and replace rubber tubing if necessary.

18.6.9 Reson Installation
The Reson was prepared and configured for the STEMM-CCS cruise. This system was not used.

18.6.10 Norbit FLS Installation
A Norbit XXX was borrowed from the AUV Development group. The unit was brand new and never had been used. This action provided the chance to run the unit on the ROV, as well as testing the unit for the AUV Dev group.

The system was integrated onto the ROV prior to the expedition, using the Reson port on the CWDM, and a modified connector on the science bus to provide the correct power (24V) through the CWDM.
The unit was only used during the first dives since it did not provide enough resolution for ROV navigation and manipulator work. A slight GF was seen on the system possibly due to potting on the modified connector.



Future modification/requirements:
- Return Norbit FLS to AUV Dev group.

18.6.11 Edgetech 2205
The Edgetech 2205 from the Autosub Operations group was used on the ROV. The purpose was using the SBP as the tool to detect the end of the pipe buried 3 meters deep.

The system was integrated onto the ROV prior to the expedition using the Reson port on the CWDM and standard 48V. The installation was challenging since the AUV documentation had several errors, while the real-time software had never been used before.

The unit worked correctly on the Dive 348 with only the Sound Bottom Profiler being used (not the Side Scan subsystem). Science were pleased with the real-time visualization, even though the post-processed data was not great since this platform is not meant to be used on an ROV (noise). The size and depth of the gas pipe did not help since it was too small and quite deep.
Future modification/requirements:

- Return the two Edgetech 2205 units to AUV Operations group.

18.6.12 OTE Optical Modem

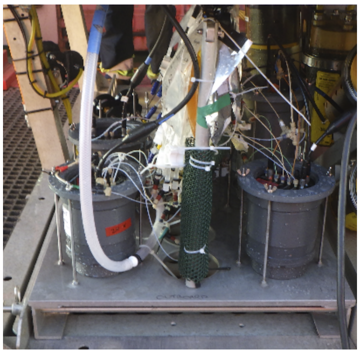
An AQUAmodem-OP2 optical modem was integrated onto the ROV prior to the expedition. The modem was connected to the spare Sci Bus 11 internally in the oil filled Low Power JB. The unit was fitted to the ROV to communicate optically with the gas rig.

This proved essential on this cruise, since it was necessary on the initial setup of the gas flows of the gas rig (the acoustic link was not reliable) and was used almost on every dive to download the data from the Gas Rig.

Future modification/requirements:

- Return the optical modem to OTE.
- Disconnect the optical modem tail from the Low Power JB.

18.6.13 Lab On Chip



The five Lab On Chip sensors worked successfully using five channels of the Science Bus of the ROV.

A Seabird pump borrowed from the Sensors & Moorings group was integrated onto the ROV during the cruise, as this was a late request from science, to give extra flow to the Lab On Chip sensors.

Future modification/requirements:

- Purchase on cruise code an 8-pin Subconn tail used to join the SBE Pump tail.

18.6.14 Bubble Chamber

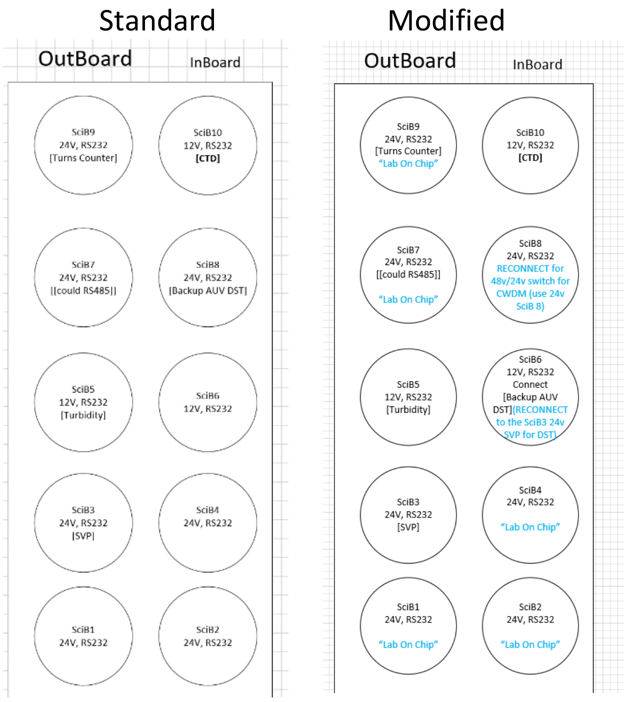
The unit consisted of a frame with a moving lid, along with an LED panel which illuminated the bubble. This was recorded by two Sony cameras powered by battery powerbanks fitted on pressure housings.
On recovery both cameras housings had suffered water ingress. It was later noted that the batteries inside were getting hot and at the Master's approval, were thrown overboard (Near Miss report xxxx).
Future modification/requirements:

- Future science equipment to be installed on the ROV should be Pressure tested (Certificate required to be provided prior to the cruise).
- Any equipment containing batteries should be noted on the Pre-Cruise Meeting, as well as have a Risk Assessment, required to be provided prior to the cruise. Pick up with cruise PM'

18.7 Isis ROV

18.7.1 Low Power Junction Box

The new upgraded Science Bus connectors fitted on a tight timeframe before this cruise proved essential. The six channel Impulse Science Bus connectors were upgraded to a ten channel Subconn 8 pin connectors. The new connectors can provide 24V and up to four Amps, including two channels for 12V devices. One of the channels is pre-allocated for the ROV CTD Sensor, but the rest (nine) are available to science (final quantity depends if they require other ROV sensors). As a backup, the AUV Tritech unit can be plugged in to the Science Bus 6 which is already configured in the ROV Tritech Software.
The standard configuration is:
Seven channels for Science, SciB_5 for Turbidity, SciB_8 for AUV Tritech Backup unit, SciB_10 for CTD.



This configuration had to be modified to be able to support the extra equipment integrated on the ROV for this cruise. One connector was used as a power selection plug to switch between the Edgetech 48V and the Norbit 24V connected on the CWDM bottle. Science used channels 1,2,4,7 and 9 for the Lab On Chips. The Optical Modem was wired directly inside the Low Power JB to SciB_11.

Future modification/requirements:

- Change back to standard configuration.
- Rewire connector SciB8 to 24V.

18.7.2 Thrusters

On Dive 346 the Aft Lateral suffered several motor faults during the recovery, with the vehicle on the surface. The Subconn connector was serviced and this cleared the fault.

On Dive 348, the Forward Lateral showed an erratic behaviour several times during the dive. Currents were moderate, but the ROV was not able to lateral to the left. The Motor controller status showed that it was suffering "Phase overcurrent". On the post-dive of 348, the motor controller was checked using the diagnosing driveblok software. The software allows to run the thruster and increase the speed using a slider. A backup of the parameters was done before the test. We then tried to "Start" the thruster on 200 rpm, but the driveblok came with a motor fault error of "Efficiency below 50%".
Since we had suspicion that it could be a parameter setup error, the original WHOI parameters file was uploaded to the driveblok and this allowed to run successfully the thruster with the software.
Upon some investigation, it was found that the parameters uploaded by Antonio on 2016 were not the correct ones.

The original WHOI parameters ("WorkingDrive4B_170412") have the Acceleration and De-acceleration rates set to 5000 (rpm/sec), while the F0C W12_SWITCH (switch point to Acc. rate 2) is set to 1900 (rpm). Since we only operate up to 1750 rpm, this means that the switch point will never be reached.
The other major difference is that the WHOI has the C01 DRIVE_MODE set to "64767". This has bit 8 and 9 values as 0/cleared, so the driveblok operates on enhanced mode and more important, on BDLM Brushless DC thruster mode.

Antonio had reduced the Acceleration/Deacc rates to 2400, which makes sense to try to reduce the instantaneous current consumption and still deliver enough instantaneous thrust (thrusters will reach 1750 rpm in less than a second). He did switch also the F0C W12_SWITCH value to 1100, which does not make sense. The other value as stated before that Antonio had changed was the C01 DRIVE_MODE set to 65535, which means the driveblok operates on standard mode and is operating on erroneous AC thruster mode.
It is not clear how this thruster was running when connected to topside. Possibly topside overrides the efficiency error and forces the driveblok to keep running unless a major fault such as phase overcurrent or motor fault happens.

Therefore, on the post-dive of 348, the Forward Lateral parameters were changed to and will be tested on Dive 349:

Acc/Deacc rate of 2400
F0C W12_SWITCH 1100 (This should be set in the future to 1900)
C01 DRIVE_MODE set to "64767".

On the thruster laptop, there was also a folder from 2016 test that probably are backups of all the ROV vehicle's drivebloks made by Antonio before he left. Quickly checking the files, seemed that the Fwd Lat, Stbd Horizontal and Stbd Vertical have potentially the wrong operating mode set.

During post-dive 348, both Horizontals thrusters were tested running on air and it was noted that the current consumption was slightly higher on the Stbd Horizontal. This will be checked in more detail during the Dive349.

Post Dive 352. The Forward lateral still showed signs of power cuts after the above changes. It was decided to swap around the leads from the "Starboard Vertical" with the FwdLat leads. This will allow to test the FwdLat thruster with the original "StbdVert" driveblok. This test will allow checking two things: The power leads to the FwdLat have an issue, or if the driveblok is faulty the power cuts will now happen on the "StbdVert". The DGO comms lines were not swapped around on the pod since they are too short. Therefore, the change was done on the topside Prizm ports 50 and 31.

Dive 353. The problem still existed during this dive on the FwdLat. This proves that the "FwdLat" driveblok is not faulty, since it was powering correctly the StbdVertical thruster.

For dive 354, the previous change was undone (swapped the thrusters and the serials comms back to the original standard setup). Then the following change was done relating to the power input to the driveblоks: The FwdLat power lead from the High power JB connects to the StbdVertical Thruster, while the StbdVertical power lead from the High power JB connects to the FwdLat Thruster.
This will test two conditions:

a) If the FwdLat power lead is faulty, the StbdVertical thruster will cut with phase overcurrent. This will potentially happen when using the vertical thruster flat out, showing the error on the FwdLat icon on the GUI.

b) If the FwdLat thruster is faulty, thrusting laterally the error will show on the StbdVertical icon on the GUI since it is being powered by the StbdVertical power lead.

During the consequent dives, only during the deployment and recovery of the ROV, the StbdVertical showed the fault “phase overcurrent”, and occasionally during the descent/ascent if the verticals were fully commanded flat out. Therefore, this proves that the “Forward Lateral” power lead from the High power JB now powering the “Starboard Vertical” has an issue, either with the connector pins or the soldering of the wires to the back of the connector.

Dive 357. During a long period of having the ROV landed on the seabed and thrusting 80% downwards, the AC GF on the vehicle started to show a fault, decreasing from the standard 40000KOhm down to 9000KOhm. Both thrusters showed a motor fault message. The thruster’s power were isolated and this cleared the GF fault. They were re-enabled individually and they worked correctly for the rest of the dive. The connectors of both Port and Starboard thrusters were serviced on the post-dive.

As a precaution, for long periods of landing on the consecutives dives, the Verticals were only being used to a 50% of their max power. This worked since no more AC GF faults appeared on the Vertical thrusters.

These faults can also be related to operating the ROV on shallow water (100m), since there is not a big underwater pressure being exerted on the external body of the connectors, which can cause them to be slightly “loose” and not do a full tight connection between the plug and the bulkhead of the motor pods.

Following each dive all the thruster units had their compensation oil flushed through, and were checked for bearing noise and leaking seals.

Future modification/requirements:

- Contact WHOI about the Acc/Deacc rates and the operating mode. [Fault 145]
- Change and test all the thrusters to the correct Acc/Deacc rates to 2400 rpm/sec, W12_Switch 1900 rpm and Drive mode “FCFF”.
- Check topside.ini file matches the new parameters.
- Check topside code (mts_thread.cpp and .h) for parameters 2400 and 1100/1900.
- Change if required, the power leads in the motor pod. [Fault 148]
- Check the FwdLat power lead and connector from the High Power JB.
- All motors to be stripped with bearings and seals replaced.
-

18.7.3 Hydraulic System

On pre-dive 346, the Sys comp gauges were not showing a correct value, probably had some air inside. They were serviced and later replaced with spares.

From pre-dive of 361 the Hyd comp reservoir indicator was intermittently failing. It usually indicated correctly values 120 and 123. This is probably a failing potentiometer track, where the magnetic reel switches are reading between those values.

Following each dive an oil sample was taken from the reservoir and inspected for water ingress. All samples appeared free of water.

Future modifications/recommendations/maintenance:

- Flush oil system and change all filters.
- Procure spare pressure gauges [Fault 141]
- Replace damaged small bore hydraulic hoses.
- Service all hydraulic motors and actuators.
- Purchase new comp pressure sensor (vertical resistor/magnetic switch oil level sensor) [Fault 152]

18.7.4 Manipulators

18.7.4.1 Kraft Predator

This unit was calibrated during mobilisation, and worked well for the duration of the cruise. On occasion a GF of 0.1 showed, mainly during the stowing of the arm.

Future modifications/recommendations/maintenance:

- Service Jaws
- Flush compensation oil
- Service connectors in back of arm. (review necessity of connectors being sealed in rubber sleeve filled with grease)
- Clean and inspect for corrosion/oil leaks
- Think about a planned maintenance procedure.

18.7.4.2 Schilling T4

This unit was calibrated during mobilisation and worked well for the duration of the cruise
The master jaw grip was removed and serviced, as it was sometimes not reading the user input. IPA and some very fine scotch bright was used for this cleaning process.

Future modifications/improvements/maintenance:

- Perform visual inspection of Schilling T4.
- Flush compensating oil.
- Remove camera and lights in preparation for ≥4000m dives (check next cruise requirements)

18.7.5 Tool sled

Worked well for the duration of the cruise.
A selection of ply sheets were cut and used to screw various fixings onto, so that the scientific experiments could be easily attached and secured for their deployments.

Future modifications/improvements/maintenance:

- None.

18.7.6 Vehicle Compensation System

The vehicle main compensation system worked well for the duration of the cruise. Following each dive oil samples were taken from each junction box, to check for water ingress.

Future modifications/improvements/maintenance:

- Check all comps for cracks and general wear.
- Inspect compensator hoses for splits and UV damage and replace if necessary.
- Install tee & bleed point on HV junction Box.

18.7.7 Thruster Compensators

The thruster compensators worked well with no faults.
Future modifications/improvements/maintenance:

- Perform visual inspection of compensators for leaks/damage.
- Inspect compensator hoses for splits and UV damage and replace if necessary.

18.7.8 Manipulator Compensators

The manipulator compensators worked well with no faults. Neither Schilling nor Kraft compensators lost any significant amount of oil during dives.

Future modifications/improvements/maintenance:

- Perform visual inspection of compensators for leaks/damage.
- Inspect compensator hoses for splits and UV damage and replace if necessary.

18.7.9 Pan & Tilt Units

The Kongsberg unit was installed into the pilot camera position, with the Mini Zeus camera mounted on it. This configuration worked well for the duration of the cruise with no problems reported.
Future modification/requirements:

- Development project to produce a new camera controller that communicates with the P&T units.

18.7.10 Cameras

18.7.10.1 Mini Zeus HD (pilot)

Worked well for the duration of the cruise.
Following the buoyancy check on each dive, with the ROV just off the seabed, the camera was white balanced using the Kraft arm and white sheet mounted on the wrist arm.

Future modification/requirements:

- Wash and stow units in draw.

18.7.10.2 HD P&T Dome Unit

On a couple of occasions Dive 362, 367, this camera had a slight glitch (black out) when panning at high speed. This seemed to recover each time and carry on without any further issues
Small piece of debris spotted on inside of dome.

Future modification/requirements:

- Contact Imenco Look at different lens option [Fault 155]
- Check protocol to enable White Balance (see below on DevCon)
- Ask Imenco if GUI can be modified to give access to White Balance function.

18.7.10.3 Scorpio

During almost all the cruise, unit SC103 was used. Occasionally the unit lost its settings and had to be reconfigured on power up. On pre-dive 376 the camera would not power up. The GUI was showing that the Vicor was only outputting 6V. The camera was disconnected and Isis was power cycled. With the Subconn disconnected, the Vicor gave again 24V. The unit SC103 was reconnected but the voltage went down again to 6V. At this point, the spare Scorpio SC102 was mounted and run correctly for the rest of the cruise.

The unit SC103 was powered up on the bench and it was fine. Both cameras struggle sometimes on power up due to the rechargeable battery being completely flat and probably “expired”. It can also be related to the Vicor DC-DC / PCB.

Future modification/requirements:

- Replace the 24V Vicor in the telemetry tube and check the PCB (Wecon 43). [Fault 159]
- Send Scorpio SC102 to Insite Pacific for battery replacement.
- After receiving SC102 and tested, send SC103.
- Investigate reusing old camera housing with a Sony 4K module + HDMI to SDI + serial comms

18.7.10.4 Tooling Cameras

All tooling cameras worked well with no issues reported.
These are positioned in the following locations:

Draw down looking	bullet upward
gauges/suction sampler	Niskins

On Dive 362 and 363 both of the draw cameras were replaced by two of the new MPUS Aurora + cameras for testing purposes and to see the difference. A vast improvement was noted.
The position of the cameras was also adjusted to improve the view of the draw and the experiments.

On dive 369 the Niskin and gauges cameras were replaced with the other two new Auroras + for testing.
It would appear the new cameras are a wider view and less zoomed, as the gauges were harder to read.

Future modification/requirements:

- Look at upgrading the Sony module on the old Auroras
- Return Auroras cameras to MPUS

18.7.11 Lights

18.7.11.1 DSPL Multi Sealite (LED)

All the units functioned well with no faults recorded.

These are positioned in the following locations:

Aux – side of draw	bullet up looking
Draw down looking	gauges/Suction Sampler
2 x aft facing	

Future modification/requirements:

- Acquire more LED spares.
- Acquire more Y-Slice leads.
- Test new MPUS DSP Lumos lights when the new tails arrive

18.7.11.2 Aphos 16 LED

Unit xxx failed during the final checks at NOC and was left behind.
Unit xxx failed at the beginning of the cruise and was replaced with a spare.
Dive 362 4 x Russ diffusers were tested. Further testing is required, preferably when the visibility is nice and clear, so it is easier to see if there is an improvement or not.

The remaining units continued to work well for the duration of the cruise.
On a couple of occasions the inner two lamps were adjusted to put the light further forward, and then re-adjust closer in where it seemed to be more preferable.

Future modification/requirements:

- Look at serial port connection for dimming option
- Inspect wiring harnesses and replace were required.
- Check all lights used on desk and return failed/faulty units to Cathx
- Over the winter months trial light unit angles in a dark hangar to establish some optimal positions.

18.7.12 Lasers

18.7.12.1 NOC Lasers

One pair of the NOC lasers were mounted onto the Scorpio stills science camera, and pair was mounted central to the vehicle below the science dome camera.
No faults occurred during the duration of the cruise.

Future modifications/improvements/maintenance:

- Perform visual inspection of lasers. Check and re-grease o-rings as required.

18.7.13 CWDM F/O Multiplexor

Worked well for the duration of the cruise.

Future modifications/improvements/maintenance:

- Check spare stock of F.O. Rattlers.
- Acquire a spare long F.O. patch lead.

18.7.14 Sonars

18.7.14.1 Doppler

On post Dive 348 the Doppler was swapped from the 300 KHz to the 1200 KHz. This reduces the minimum altitude required for obtaining a bottom lock. The higher frequency unit allowed to land without losing lock, which proved essential to do the high precision navigation required in the 7m radius experimental area. Isis was able to move sideways centimetres to position the experiments.

The Doppler 1200KHz was used for the rest of the cruise. It proved as an essential working tool to be able to keep bottom lock during all the operations of positioning the landers and sensors at 1m height. The ROV was even able to land and keep still bottom lock. The drawback is it only starts seeing the bottom at approx. 30m altitude.
Future modification/requirements:

- Consider a training course for some of the team members.
- Install 300KHz back on Isis
-

18.7.14.2 Altimeter

This unit worked well for the duration of the cruise

18.7.14.3 Tritech Imaging

This unit worked well for the duration of the cruise, and was the preferred unit for finding targets as opposed to the Norbit solid state unit that was on loan from team AUV development.

A new tail was made to facilitate using the AUV Tritech unit in the event that the ROV unit failed. Fortunately this was not required.

Future modification/requirements:

- Check oil levels in sonar head.
- Return spare unit to AUV

18.7.14.4 Digiquartz Pressure Sensor
The unit worked well for the duration of the cruise.

Future modification/requirements:
- Do Depth sensor calibration on cruise code

18.7.15 CTD
Worked well for the duration of the cruise.

Future modification/requirements:
- Do CTD calibration on cruise code.

18.8 ROV Topside Systems
18.8.1 Jetway
Worked well for the duration of the cruise.

Future modification/requirements:
- Ongoing investigation of replacement Jetway.

18.8.2 Monitors
No issues with monitors.

Future modification/requirements:
- Investigate 4K Screens that will fit in CV cameras are upgraded in the future.

18.8.3 Promise Pegasus R6
Now only used for backups.

Future modification/requirements:
- Buy spare hard drives.

18.8.4 Clearcomm
Continued issues from the previous cruise were still present at the beginning of the cruise with lots of background noise being present when both outside headsets were in transmit mode (mike down)

However after some playing with various settings, it was discovered that using the linked mode on the ROV desk master unit significantly reduced the background noise between headsets. Additionally, adding a headset for the pilot to wear further improved the communications between all roles. (Deck 1, Deck 2, Pilot, Engineer and the Bridge)

Future modification/requirements:
- Review headsets and order any necessary spares.
- Consider purchasing spare wireless headset for pilot.

18.8.5 New HP Prodesk 400 mini PCs
Several units were fitted to replace the old HP G5 that have been working for the last 8 years on the Control Van. They have performed well, with no issues related to software problems, as well as reducing the noise and heat dissipation.

Future modification/requirements:

- Buy spare HP unit.
- Buy spare hard drives for backups
- Do backup of all computers (including HP G5 and G6).

18.8.6 HP G5/G6 Computers

Only Techsas and Topside are running on the EOL G5 Computers. Both HP G6 that had Ranger 2 and Database have been replaced with new computers.
Some machines have been serviced and fitted as spares on the sound rack in the Control Container #2.
They act as potential spares for the Topside, Techsas. Just in case, a spare G6 unit is also available as a spare for the old Database or the Ranger 2.

18.8.7 Topside PC

Performed correctly. Still using old HP G5 machines.

Future modification/requirements:

- Software tech needs to develop new topside code that uses MOXAs instead of old legacy/EOL Digiboxes.
- Move Topside software to new computer.
- Check the code differences between the running operating version rov_66.70-isis April 2016 and the development version started by Antonio. Check also the the S Drive version _rov_67.055-isis.

18.8.8 Database PC

The new installed computer functioned correctly. The NTP serviced had to be configured since it was not syncing to the ROV NTP server.
Future modification/requirements:

- Fix issue with boot resolution.
- Modify the existing logbook to convert to lowercase the cruise and DB name. [Fault 139]
- Fix bug on logbook: overlay thread needs to be restarted twice to display correctly.
    - Check overlay socket is being closed when clicking on the X/Exit button of the logbook
- Rewrite the logbook+overlay GUI to use realtime data instead of a postgres DB.
- Investigate the SSS Datalogger and EventLogger.

18.8.9 Overlay Data Display

This unit was used with the Science camera. Overlay code was modified to remove the rolling compass.
Future modification/requirements:

- Investigate issue of unit requiring a powercycle on every dive. Probably related to logbook.
- Procure and replace video BNC cable to overlay [Fault 147]

18.8.10 OFOP Science PC

OFOP started to show incorrect longitude coordinates on the Doppler and storing the science waypoints. These issues are related to operating on the lat/long near to 0 degrees. The first issue was solved modifying the conversion script of the Doppler conversion. The second issue is intrinsic to the software, so when science tried to save the dive waypoints, the negative sign was not saved on the text files.
Future modification/requirements:

- Contact OFOP to see if fix related to waypoint zero negative sign. Ask them also to add a change cameras now popup when timer expires (now only 10 and 5 minutes reminders) [Fault 154]
- Procure spare license USB dongle.

18.8.11 CLAM PC

The new version of CLAM developed by Josue was used again this cruise.
No issues reported, so the old XP CLAM has been archived.

18.8.12 Device Controller PC

The new gamepad controller to replace the EOL science joystick worked well. This included the Labview modifications to add the new Eyeball camera as well as smoother operation of the electric P&T.

Future modification/requirements:

- Add the option to switch Auto/Manual Focus on the game controller.
- Modify labview code to detect and map always the game controller to Eyeball camera.
- Test if two game controllers can be used on the same computer (to replace EOL joystick) and procure extra controller if required.
- Test the top Edgeport since it is labelled as possibly dodgy.
- Move the two P&T serials from the Edgeport USB to a Moxa. This will free up the Edgeport unit and act as a spare.

18.8.13 Sonardyne PC

The new Steatite rack computer to replace the old HP G6 was used on this cruise.
On Dive 348 when looking for the drilled pipes, it was observed that there was a big discrepancy between the USBL positions of the drill rig when the pipes were drilled and the USBL position of the ROV. This was possibly due to the fact that on the ROV usually uses the big head (Starboard), while ships operations uses the standard head (Port).

The ship USBL head was then swapped to the Port on the ROV dive, but there was still around a 12m difference. Further investigation by the Ship Scientific System Techs highlighted that the heads were last calibrated on 2017, and these are also not suitable for 100m depth operations. The range on the Environmental settings in Ranger 2 was changed from the standard 6000m to 500m.

Future modification/requirements:

- Prior to cruise, change Ranger2 Translation and Rotational offsets to appropriate head.
- Change Ranger2 Environmental range back to 6000m
- Read documentation/contact Sonardyne to remove the “S xxx” on the display from the beacon info.
- Contact Sonardyne to check if old NSH of Fusion can be upgraded from serial to Ethernet.

18.8.14 Techsas

This software still runs on an old HP G5 machine. The version being used is an old one (V 2.0), while the ship systems have an improved later version running on the ships. Ship is using a Dell rackserver with VMWare ESXi OS for the virtual machine of CentOS Techsas v5.

Future modification/requirements:

- Install a bare-metal virtualization (VMWare ESXi, Xen, etc) on the CV PCs to test the Ship’s Techsas.
- Upgrade Techsas to v5 and add the ROV sensors.

18.8.15 QNAP

The QNAP has proven to be a good upgraded of the old EOL X-Serve. This provides direct access to all the ROV data as well as a webpage developed for Science to access guides, templates and datasheets related to Isis.

Future modification/requirements:

- Buy spare 3TB hard drive

18.8.16 Ki Pro Recorders

Worked correctly. The AJA Ki Pro rack units only support 1080 interpolated resolution, while our cameras are able to output 1080 progressive resolution.

Future modification/requirements:

- Investigate PAL REC cables/feed since PAL recorder stopped working.
- Check if there is a spare Blackmagic PAL to SDI converter.
- Trial direct recording using the SDI splitter to compare KiPro vs Ultrastudio. Check storage increase when recording on 1080p.
- Investigate Blackmagic Ultrastudio ProRes codec and H265 requirements (storage and recording software).
- Investigate and contact science party implications of changing to H265 (quality, workflow, Final Cut Pro support of H265, etc)
- Procure new F.O. (FC to ST) xx meters cord for main lab.

18.8.17 Workshop PC

Worked well.

18.8.18 iMacs

Science used the iMac with the Final Cut Pro software to access the video and data stored on the Lacie units. A hard drive was made available for science to copy data from the iMac to their computers.

Future modification/requirements:

- Buy a small 2.5” hard drive for data transfer.

18.8.19 Prizm

On dive 359, the surface Prizm board started to show a fault (orange LED) on the +5V power supply. [Fault 158]

Future modification/requirements:

- Need to replace the whole system on the topside and subsea as no spare boards are available.
- Check spares for new system and procure if necessary.
- Investigate possibility of relocating the Prizm unit so that connections are more accessible.

18.8.20 Joybox

Worked correctly and no further power off issues have happened after the earthing of the case performed some cruises ago.

Future modification/requirements:

- Try to backup Hard drive inside unit.
- Replace Z thruster on Joybox unit #3.
- Acquire two Z thruster joysticks.
- Fix XY rotation joystick on unit #4. [Fault 156]
- Acquire 1 x XY and rotation joystick
- Start a development project to produce a joybox that communicates with topside.

18.8.21 Network Time Protocol (NTP) Server

This unit performed correctly. No more loosing lock issues have aroused after the firmware upgrade done after talking with the manufacturer prior to this cruise.

18.8.22 Colour bar generator

The PAL colour bar generator used by the matrix stopped working. Related probably to the PSU or the unit.

Future modification/requirements:

- Procure new PSU and/or new colour bar generator. [Fault 153]

18.8.23 Raspberry Pi TV Changer

A Raspberry Pi was installed in the Control Van. It was fitted with a pushbutton that allowed the Engineer to quickly change the TV from PC mode to HDMI. This allows to get a better display of the Pilot HD camera.

18.8.24 4K HDMI Splitter

A 4K 4port HDMI splitter was installed to be able to duplicate the Pilot HD video feed to the Control Van's TVs and to the H264 HDMI encoder.
This unit caused some issues with the TVs, since on power up the display went green. The issue was resolved by power cycling the TV (or changing the input source on the remote).

Future modification/requirements:

- Procure a different HDMI splitter and test it. [Fault 157]

18.9 ROV video streaming test

This cruise had an optional objective of trialling a video streaming back to NOC of the ROV cameras. This is now possible due the new higher upload speed on the ship.

On the previous cruise (Trials JC166), two options were used. The first using the old PAL Axis video server along with a Linux machine running a script prepared by SSS. The second was using the Ultrastudio Blackmagic box with the Mac Mini that is used by science to do their video copying. Both options are not ideal; the first one is low quality while the second is an expensive setup only to do HD streaming.

A dedicated HDMI encoder box was procured, configured and tested with the SSS Youtube account. The video stream was used only for NOC internal purpose (the link was not made public).

The first test carried out were using the fixed Scorpio camera, with a baud rate of 500kpbs and a resolution of 960x560px. The feed was later changed with some wiring modifications in the Control Van to the Pilot P&T camera, which proved to be more adequate since it is always pointing at where the events and action is happening. The resolution was slightly increased since the encoder box did not quite like the previous one. The baud rate was still 500 kbps, which is in theory a third of the available upload bandwidth of the ship.

Overall, the tests were successful, provided that the upload bandwidth was "free" and the Untangle QoS prioritized the Video streaming over other protocols to prevent the video from cutting.

The test was done using a H264 HDMI encoder box. This could be upgraded to the new H265 units which allow better quality and reducing at the same time the required bandwidth by around a 50%.

On another point, streaming the ROV video footage raises data protection and science conflict issues, which will need to be discussed and approved by the different parties involved.

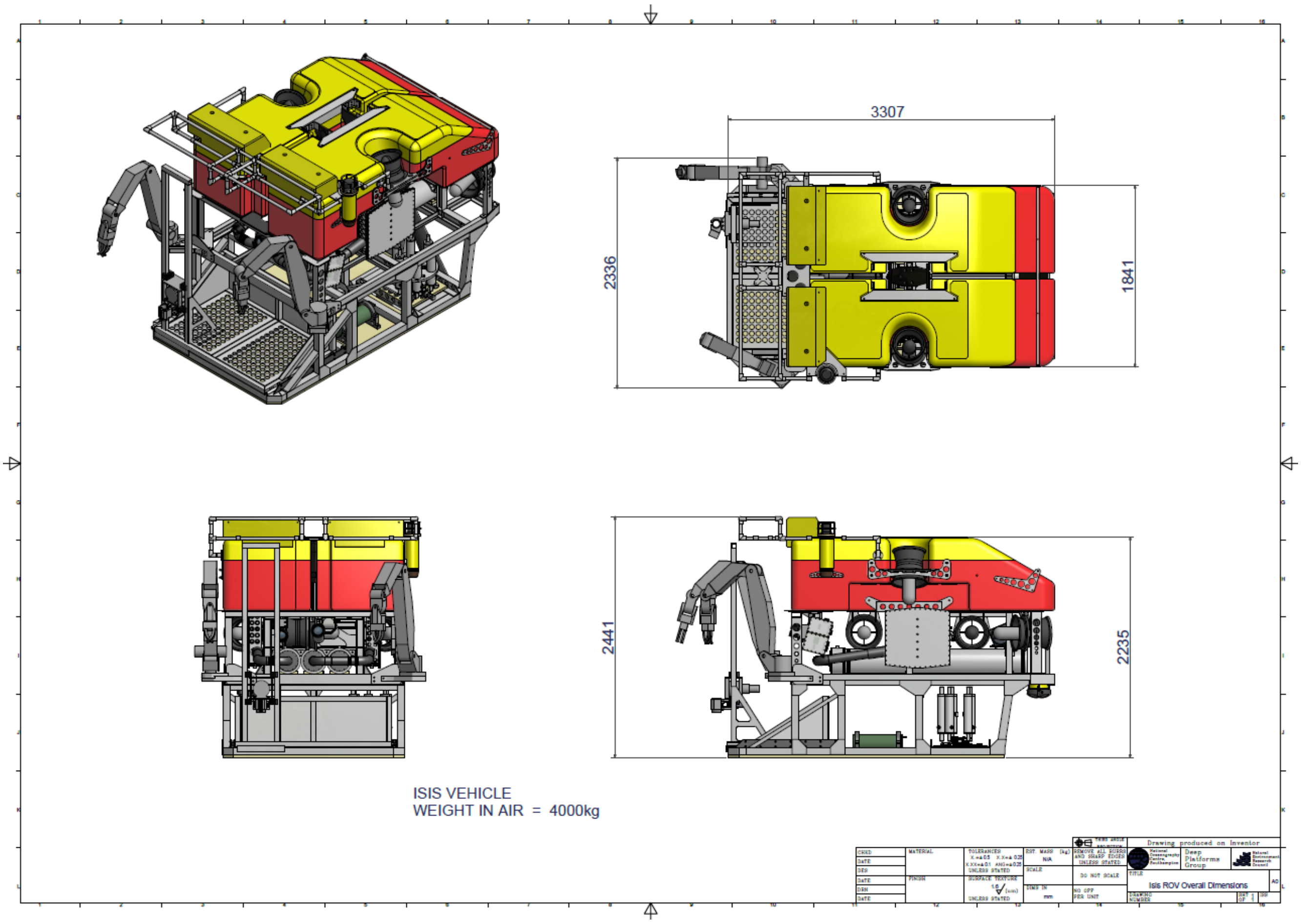
Future modification/requirements:

- Discuss with Maaten requirements of the streaming in accordance to NOC strategy and objectives, and budget allocation for equipment (H265 units, HDMI splitters).
- Could replace the Axis video server with the H264/H265 encoders. This will allow easier and better quality stream on the Ship's internal network to science.

18.10 Isis ROV Dive Hr Summary

Cruise No.	Dive No.	Dive Hrs Decimal	Dive Hrs:Mins:Sec	Cruise Total Hrs Decimal	System Total Hrs decimal	Max Depth (m)	Bottom Time Hrs:Mins:Sec	Bottom Time (Hrs Decimal)
JC180								
1	346	5.094	05:05:00			119	04:30:00	4.50
2	347	8.047	08:02:00			119	07:29:00	7.49
3	348	4.717	04:43:00			116	04:08:00	4.13
4	349	2.650	02:39:00			118	02:04:00	2.07
5	350	1.417	01:25:00			118	00:54:00	0.90
6	351	1.783	01:47:00			119	01:20:00	1.33
7	352	7.750	07:45:00			119	07:14:00	7.23
8	353	1.433	01:26:00			119	00:51:00	0.85
9	354	1.217	01:13:00			118	00:40:00	0.67
10	355	1.667	01:40:00			118	01:11:00	1.18
11	356	4.100	04:06:00			119	03:24:00	3.40
12	357	24.050	00:03:00			119	22:57:00	22.95
13	358	14.867	14:52:00			119	14:02:00	14.03
14	359	4.633	4:38;00			119	04:06:00	4.10
15	360	13.217	13:13:00			119	12:46:00	12.77
16	361	3.917	03:55:00			119	03:25:00	3.42
17	362	3.233	03:14:00			119	02:49:00	2.82
18	363	14.750	14:45:00			119	14:10:00	14.17
19	364	1.017	01:00:00			119	00:29:00	0.48
20	365	1.800	01:48:00			119	01:24:00	1.40
21	366	15.283	15:17:00			119	14:51:00	14.85
22	367	1.283	01:17:00			119	00:47:00	0.78
23	368	1.650	01:39:00			119	01:05:00	1.08
24	369	4.800	04:48:00			119	04:02:00	4.03
25	370	14.667	14:40:00			119	14:17:00	14.28
26	371	2.167	02:10:00			119	01:54:00	1.90
27	372	13.700	13:42:00			119	13:14:00	13.23
28	373	4.167	04:10:00			119	03:36:00	3.60
29	374	0.983	00:59:00			119	00:34:00	0.57
30	375	3.417	03:25:00			119	02:52:00	2.90
31	376	12.383	12:23:00			119	11:54:00	11.90
32	377	3.250	03:15:00			119	02:41:00	2.68
33	378	2.550	02:33:00			119	02:05:00	2.08
34	379	0.733	00:44:00			119	00:23:00	0.38
35	380	0.867	00:52:00			119	00:28:00	0.47
36	381	5.267	05:16:00			119	04:48:00	4.80
JC166 Totals	36	208.525	203:51:00	208.52	5001.33	119	189:24:00	189.439

18.11 Appendix ROV Vehicle Specification.



Maximum Operating Depth	6500m
Size	3.3m (L) x 2.3m (W) x 2.4m (H)
Weight	In air: ~3750kg
	In water: neutrally buoyant
Payload	up to 90kg (in water weight)
Propulsion	6 x 5HP Brushless DC Electric Thrusters (113 kg force/motor)
Umbilical	Rochester 0.68" (17.4mm dia 3 core triple armoured 3 fibre single mode (Part No.A302351)
Electrical Power	Pmax: ~18kW at 6500m (2800V@ 400Hz)
Hydraulic Power	1 x 3.7Kw (5HP) HPU
	Max pressure 3000psi (207bar)
	Max Flow 21L/min @ <1700psi
	Max Flow 12.5L/min @ > 1700psi
	8 Function Manifold
Max Vehicle Speed	Fwd: 1.5 knot, Lateral: 0.5 knot, Vertical: 0.7knot
Max on Bottom Transit Speed	0.5 knot
Descent/Ascent Rate	40m/min
Auto Functions	Depth (+/-1m), Altitude (+/-1m), Heading (<=+/-1°)
Manipulators	1 x Schilling Titan 4 (7 function)
	1 x Kraft Predator (7 function with force feedback)

19 NMF Ship systems: Nick Harker and Juan Ward

19.1 Cruise overview

Cruise	Departure	Arrival	Technicians
JC180	25/04/2019 GBSOU	30/05/2018 GBSOU	Nick Harker (nihark@noc.ac.uk) Juan Ward (juaward@noc.ac.uk)

Scientific Ship Systems (SSS) is responsible for managing the Ship's network infrastructure, data acquisition, compilation and delivery, the email system and a range of ship-fitted instruments and sensors.

All times in this report are UTC

19.2 Scientific Computer Systems

19.2.1 Acquisition

Network drives were setup on the on-board file server; firstly a read-only drive of the ships instruments data and a second scratch drive for the scientific party. Both were combined at the end of the cruise and copied to a disk for BODC.
The Ship-fitted instruments that were logged are listed in the below file (includes BODC/Level-C notes):

'JC180_Ship_fitted_information_sheet.docx'
Cruise Disk Location: ***'JC180/CRUISE_REPORTS/'***

Data was logged by the Techsas 5.11 data acquisition system, this also includes tracking data recorded while the USBL was being used. The system creates NetCDF and ASCII output data files. The format of the data files is given per instrument in the "Data Description" directory:

Cruise Disk Location: ***'JC180/Ship_Systems/TECHSAS/Data_Description/'***

The raw NMEA strings from the instruments were also time stamped and logged. These are included on the data disk in the directory:

Cruise Disk Location: ***'JC180/Ship_Systems/Raw_NMEA'***

19.2.2 Main Acquisition Events/Data Losses

See surfmet section 3.3.1 for underway events.
Data gaps in the raw NMEA (and therefore Techsas asci & netcdf) are noted in appendix 1.

The main echo sounders (EA640, EK60, ADCPs, &EM170 & SBP) were only run consistently for the passage leg of the cruise and for leg 1. After this, they were only run on request due to the need for reduced noise in the water. More detail for each instrument is listed in section 3.4.

19.2.3 Internet provision

Satellite Communications were provided with both the Vsat and Fleet Broadband (FBB) systems. The Vsat had a guaranteed speed of 1.5 Mbps, bursts greater than this when there is space on the satellite, and unlimited data. The FBB had a maximum un-guaranteed speed of 256 kbps with a fair use policy that equates to 15 GB of data a month. Solid service throughout, there were very few interruptions (likely due to mast blockages when on a northerly heading). Outreach activities (using Skype) and ROV video streaming testing (youtube) all were performed successfully and without the need of adding any further restrictions.

19.2.4 Email provision

Email communications were primarily provided by whitelisting institutional pages and encouraging their use through Outlook and Apple Mail desktop clients.

19.3 Instrumentation

19.3.1 Coordinate reference

19.3.1.1 Datum

The common coordinate reference was defined by the Blom Maritime survey (2006) as:

1. The reference plane is parallel with the main deck abeam (transversely) and with the baseline (keel) fore- and aft-ways (longitudinally).
2. Datum (X = 0, Y = 0, Z = 0) is centre topside of the Applanix motion reference unit (MRU) chassis.

19.3.1.2 Multibeam

The Kongsberg axes reference conventions are (see Figure 18.1) as follows:

1. X positive forward,
2. Y positive starboard,
3. Z positive downward.

The roll reference is set to follow the convention of Applanix PosMV.

19.3.1.3 Applanix PosMV Primary scientific position and attitude system

The translations and rotations provided by this system have the following convention:

1. Roll positive port up,
2. Pitch positive bow up,
3. Heading true,
4. Heave positive up.

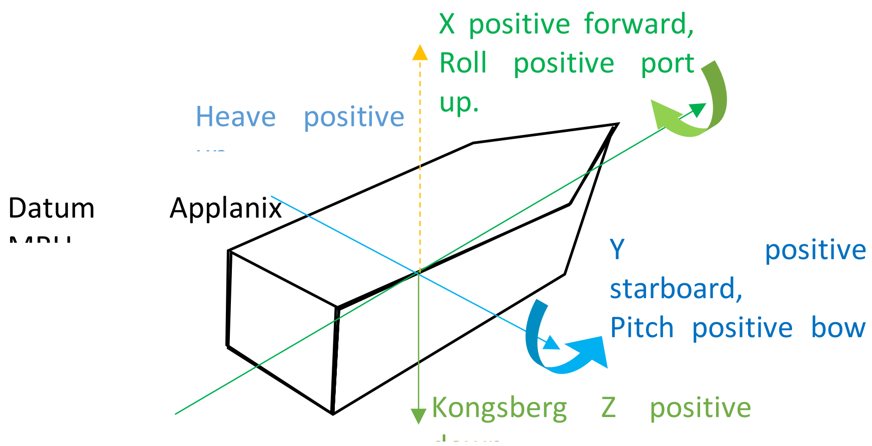


Figure 18.1 Conventions used for position and attitude.

19.3.1.4 Position and attitude

GPS and attitude measurement systems were run throughout the cruise.

The ***Applanix POSMV*** system is the vessel's primary GPS system, outputting the position of the ship's common reference point in the gravity meter room. The POSMV is available to be sent to all systems and is repeated around the vessel. The position fixes attitude and gyro data are logged to the RVDAS and Techsas system. True Heave is logged by the Kongsberg EM710 systems when surveying.

The ***Kongsberg Seapath 330+*** system is the vessel's secondary GPS system. This was the position and attitude source that was used by the EM710 due to its superior real-time heave data. Position fixes and attitude data are logged to the RVDAS system.

The ***CNav 3050*** GPS system is the vessel's differential correction service. It provides the Applanix POSMV and Seapath330+ system with RTCM DGPS corrections (greater than 1m accuracy). The position fixes data are logged to the Techsas and RVDAS system.

19.3.1.5 POS/ATT Instrument Events

Occasional drop outs on the Seapath.

19.3.1.6 Meteorology and sea surface monitoring package

The NMF Surfmet system was run throughout the cruise, excepting times for cleaning, entering and leaving port and whilst alongside. Please see the separate information sheet for details of the sensors used and whether calibrations values have been applied:

> *'JC180_Surfmet_sensor_information_sheet.docx'*
> Cruise Disk Location: ***'JC180/CRUISE_REPORTS/'***

The Surfmet system is comprised of:

- Hull water inlet temperature probe (SBE38).
- Sampling board conductivity, temperature salinity sensor (SBE45).
- Sampling board transmissometer (CST).
- Sampling board fluorometer (WS3S)

- Met platform temperature and humidity probe (HMP45).
- Met platform port and starboard ambient light sensors (PAR, TIR).
- Met platform atmospheric pressure sensor (PTB110).
- Met platform anemometer (Windsonic).

Instrument calibration sheets are included in the directory:

Cruise Disk Location: ***'JC180/Ship_Systems/Met/SURFMET/calibrations/'***

Table of surfmet data outages:

Date	Stop	Start	Event
25/04/2019		07:02	SURFMET logging
27/04/2019	13:44	13:53	Data gap
04/05/2019	11:00		Data gap
05/05/2019		09:30	
20/05/2019	13:50	15:20	Data gap

19.3.1.7 Underway Water Events

Date	Start Time	Stop Time	Cleaned
Underway Water started after departing GBSOU			
25/04/2019	13:07	--	No
Underway cleaned			
01/05/19	18.22	19.14	Yes
Underway turned off due to Aberdeen port call			
03/05/2019	07:00		
Underway Water restarted after port call in Aberdeen			
Underway Water stopped on arrival to GBSOU			

19.3.1.8 TSG Sampling Log

Cruise Disk Location: ***'JC180/Ship_Systems/Met/SURFMET/TSG_Salinities/'***

19.3.1.9 Drop Keel Sound Velocity Sensor

The surface Sound Velocity (SV) sensor (AML SmartSV) mounted on the drop keel was used throughout providing SV data to the EM710 & EM122. The both drop keels remained flush with the hull for the duration of the cruise.

19.3.1.10 Wamos Wave Radar

The Wamos wave radar was run for the first half of the cruise for calibration and testing purposes.

19.3.2 Hydro Acoustic Systems

The hydro acoustic systems were mostly run during passage and for leg 1 of the cruise. Otherwise, they were only run on request, or for testing purposes.

19.3.2.1 Kongsberg EA640 10/12 kHz Single-beam

The EA640 single-beam echo-sounder was run throughout the cruise apart from specific during operations (e.g. acoustic modem operations, releases. Port calls etc). Both the 10 kHz and 12 kHz were run in active mode triggered by K-Sync. Pulse parameters were consistent through out the cruise due to the shallow depth (30W). Data runs:
07/05 16:50 -14/05 17:30
28/05 15:07 - 03/05 07:32
27/05 15:50 – end of cruise
It was used with a constant sound velocity of 1500 ms^{-1} throughout the water column to allow it to be corrected for sound velocity in post processing. Kongsberg Raw files and XYZ files are logged and depths were logged to Techsas, Level-C and RVDAS (so exact data gaps can be seen in appendix 1, RVDAS log).

Cruise Disk Location: ***'JC180/Ship_Systems/Acoustics/EA-640'***

19.3.2.2 Kongsberg EM122 & 710 multi-beam echo sounders.

The EM122 multibeam echo sounder was not run due to the water depth and so was left off apart from for occasional testing purposes.

The EM710 was run during leg 1 of the cruise and then only on request:
27/04/32018 10:20 – 02/05/ 21:05
27/05 15:50 - end of cruise
And for periods on 15/05 & 17/05 for testing. Water column logging was only recorded on request (02/05).

The position and attitude data was supplied from the Seapath 330+ due to its superior real-time heave. Applanix PosMV position and attitude data is also logged to the .all files as the secondary source and True Heave *.ath file are logged to allow for inclusion during reprocessing.

Sound velocity profiles were recorded using a Valeport SV profiler and applied to the EM multibeam data.

The following figures show the system installation configuration. The values are from the ships Parker survey report, which is included on the data disk. The attitude angular corrections for use with the Seapath 330+ system were derived from a post refit trial calibration on JC108 Sept 2014. The attitude angular corrections for use with the Applanix Posmv system are from calibration during JC103 May 2014.

Location offset (m)

	Forward (X)	Starboard (Y)	Downward (Z)
Pos, COM1/MCAST1:	0.00	0.00	0.00
Pos, COM3/MCAST2:	0.00	0.00	0.00
Pos, COM4/UDP2/MCAST3:	0.00	0.00	0.00
TX Transducer:	5.415	-0.015	6.96
RX Transducer:	4.988	0.013	6.96
Attitude 1, COM2/UDP5:	0.00	0.00	0.00
Attitude 2, COM3/UDP6:	-0.350	0.056	-0.373
Waterline:			1.376
Depth Sensor:	0.00	0.00	0.00

Figure 18.2 – EM710 transducer locations

Offset angles (deg.)

	Roll	Pitch	Heading
TX Transducer:	-0.418	0.228	0.000
RX Transducer:	0.130	-0.000	0.000
Attitude 1, COM2/UDP5:	-0.45	0.68	-0.38
Attitude 2, COM3/UDP6:	-0.46	0.39	-1.01
Stand-alone Heading:			0.00

Figure 18 3 – EM170 transducer offsets

19.3.2.3 Sound velocity profiles

Sound velocity profiles were recorded with a Valeport SV profiler. These were input to the EM and Ranger systems when required.

Cruise Disk Location: ***'JC180/Ship_Systems/Acoustics/*****Sound_Velocity_Profiles/'**

*.000 files are the original data from the SV probe, *.asvp files were made for EM multibeam systems (EM710) and *.pro files for the Sonardyne Ranger software used with the USBLs.

Date	Time	Probe
27/04/2019	09:46	22355

28/04/2019	15:37	22355
07/05/2019	07:00	22355
10/05/2019	07:09	22241
14/05/2019	09:00	22355
14/05/2019	09:00	22241
17/05/2019	09:31	22355
20/05/19	09:09	22355
25/05/2019	13:19	22355
26/05/2019	11:36	22355
27/05/19	09:00	22355

19.3.2.4 ADCP's

Both the 75 and 150 kHz were run during the initial passage leg of cruise, then on site, only when requested for immediate current information or for testing purposes. Triggering was K-sync and bottom track was enabled so heading calibration can be performed.
Set up: 75kHz NarrowBand, 48 bins each 16m with 8m blanking.
Run:
27/04 11:18 – 28/04
27/05 15:50 - end of cruise
150kHz Narrowband, 96 bins each 4m with 4m blanking.
28/04 01:16 02/05 12:29
27/05 15:50 - end of cruise

Cruise Disk Location: ***'JC180/Ship_Systems/Acoustics/*****OS75kHz/'**
'JC180/Ship_Systems/Acoustics/**OS150kHz/'**

19.3.2.5 EK-60

The EK-60 was run from the cruise start until 17/05 when it was requested to be switched off to reduce noise in the water column for the hydrophone wall measurements. The 70 kHz was run passively when the EM710 was running to prevent interference.
27/04 10:34 - 02/05 21:04
07/05 11:10 – 15/05 16:40
27/05 15:50 - end of cruise

Cruise Disk Location: ***'JC180/Ship_Systems/Acoustics/*****EK-60/'**

02/05/2019 13:00: EK60 survey was started and Water Column Logging data was requested from the 710.

19.3.2.6 Sub bottom Profiler (SBP)

The SBP was run from the
28/04 19:04 – 02/05 21:04
06/05 20:34 - 09/05 19:39
27/05 15:50 - end of cruise

Cruise Disk Location: ***'JC180/Ship_Systems/Acoustics/*****SBP-120/'**

19.3.2.7 USBL

Tracking data from the Sonardyne Ranger software was only recorded during USBL deployment. This can be found in the Raw_NMEA & TECHSAS folders.

19.3.3 Geophysical Systems

19.3.3.1 Gravity Meters

The AT1M-U12 meter was run throughout the cruise, though only for testing purposes. Tie-ins were performed at the beginning and end of the cruise at the base location within NOC Southampton.

19.3.4 Other Systems

19.3.4.1 EM Speed logs

The single axis bridge Skipper Log and the dual axis Chernikeef science log were logged throughout the cruise. The Chernikeef log was calibrated in December 2017 offshore of Tenerife with an additional adjustment on 21/03/2018 as below.

RPM	True Speed	True Speed (21/03/18)	Measured Speed
R0030	S0301	0274	A0079
R0050	S0500	0455	A0126
R0080	S0767	0698	A0192
R0110	S1015	0924	A0257
R0001	N/A	S0001	A0001
R0140	N/A	S1617	A0450

19.3.5 Appendix

19.3.5.1 RAW NMEA data gaps

19/04/2019 12:20:05.196 SBE45_TSG data gap from Fri, 19 Apr 2019 11:58:19 GMT to Fri, 19 Apr 2019 12:20:04 GMT.
23/04/2019 15:35:46.917 NMF_SURFMET data gap from Tue, 23 Apr 2019 11:37:46 GMT to Tue, 23 Apr 2019 15:35:46 GMT.
23/04/2019 15:52:47.060 NMF_SURFMET data gap from Tue, 23 Apr 2019 15:40:50 GMT to Tue, 23 Apr 2019 15:52:46 GMT.
25/04/2019 18:26:47.907 NMF_SURFMET data gap from Thu, 25 Apr 2019 13:32:18 GMT to Thu, 25 Apr 2019 18:26:47 GMT.
28/04/2019 08:41:49.153 RANGER2_USBL data gap from Sat, 27 Apr 2019 09:58:45 GMT to Sun, 28 Apr 2019 08:41:48 GMT.
28/04/2019 08:51:49.157 RANGER2_USBL data gap from Sun, 28 Apr 2019 08:47:47 GMT to Sun, 28 Apr 2019 08:51:47 GMT.
28/04/2019 21:18:49.571 EM120_DEPTH data gap from Sun, 28 Apr 2019 19:45:28 GMT to Sun, 28 Apr 2019 21:18:15 GMT.

□ 28/04/2019 21:50:49.590 EM120_DEPTH data gap from Sun, 28 Apr 2019 21:18:15 GMT to Sun, 28 Apr 2019 21:50:48 GMT.
□ 29/04/2019 09:02:49.797 EM600_DEPTH data gap from Mon, 29 Apr 2019 07:24:26 GMT to Mon, 29 Apr 2019 09:02:34 GMT.
□ 29/04/2019 18:26:50.083 EM120_DEPTH data gap from Sun, 28 Apr 2019 21:51:42 GMT to Mon, 29 Apr 2019 18:26:49 GMT.
□ 29/04/2019 18:45:50.090 EM600_DEPTH data gap from Mon, 29 Apr 2019 17:33:13 GMT to Mon, 29 Apr 2019 18:45:42 GMT.
□ 30/04/2019 11:15:50.554 RANGER2_USBL data gap from Sun, 28 Apr 2019 16:41:41 GMT to Tue, 30 Apr 2019 11:15:46 GMT.
□ 30/04/2019 12:24:50.582 EM120_DEPTH data gap from Mon, 29 Apr 2019 19:58:38 GMT to Tue, 30 Apr 2019 12:24:44 GMT.
□ 30/04/2019 12:32:50.590 EM120_DEPTH data gap from Tue, 30 Apr 2019 12:30:19 GMT to Tue, 30 Apr 2019 12:32:44 GMT.
□ 30/04/2019 13:43:50.623 RANGER2_USBL data gap from Tue, 30 Apr 2019 12:17:32 GMT to Tue, 30 Apr 2019 13:43:50 GMT.
□ 30/04/2019 20:34:50.760 EM600_DEPTH data gap from Tue, 30 Apr 2019 15:02:35 GMT to Tue, 30 Apr 2019 20:34:44 GMT.
□ 01/05/2019 11:18:51.036 RANGER2_USBL data gap from Tue, 30 Apr 2019 14:44:53 GMT to Wed, 01 May 2019 11:18:51 GMT.
□ 01/05/2019 18:52:51.181 SBE45_TSG data gap from Wed, 01 May 2019 18:25:48 GMT to Wed, 01 May 2019 18:52:51 GMT.
□ 05/05/2019 08:38:57.148 ENV_TEMP data gap from Sat, 04 May 2019 17:23:17 GMT to Sun, 05 May 2019 08:38:56 GMT.
□ 05/05/2019 09:18:57.170 NMF_SURFMET data gap from Sat, 04 May 2019 11:01:05 GMT to Sun, 05 May 2019 09:18:56 GMT.
□ 05/05/2019 13:21:57.235 ENV_TEMP data gap from Sun, 05 May 2019 12:30:16 GMT to Sun, 05 May 2019 13:21:56 GMT.
□ 06/05/2019 18:54:57.743 EM600_DEPTH data gap from Fri, 03 May 2019 06:12:17 GMT to Mon, 06 May 2019 18:54:57 GMT.
□ 06/05/2019 18:58:57.745 ENV_TEMP data gap from Mon, 06 May 2019 17:50:51 GMT to Mon, 06 May 2019 18:58:13 GMT.
□ 07/05/2019 09:09:58.086 ENV_TEMP data gap from Mon, 06 May 2019 18:58:13 GMT to Tue, 07 May 2019 09:09:57 GMT.
□ 14/05/2019 07:23:01.515 RANGER2_USBL data gap from Wed, 01 May 2019 18:16:29 GMT to Tue, 14 May 2019 07:23:00 GMT.
□ 17/05/2019 07:02:03.412 RANGER2_USBL data gap from Tue, 14 May 2019 14:02:25 GMT to Fri, 17 May 2019 07:02:02 GMT.

17/05/2019 12:21:03.504 EM600_DEPTH data gap from Wed, 15 May 2019 16:32:51 GMT to Fri, 17 May 2019 12:21:02 GMT.
17/05/2019 13:17:03.538 EM600_DEPTH data gap from Fri, 17 May 2019 13:14:07 GMT to Fri, 17 May 2019 13:16:42 GMT.
17/05/2019 13:24:03.542 EM600_DEPTH data gap from Fri, 17 May 2019 13:20:50 GMT to Fri, 17 May 2019 13:23:46 GMT.
17/05/2019 13:31:03.543 EM600_DEPTH data gap from Fri, 17 May 2019 13:24:55 GMT to Fri, 17 May 2019 13:31:03 GMT.
17/05/2019 13:39:03.543 EM600_DEPTH data gap from Fri, 17 May 2019 13:32:26 GMT to Fri, 17 May 2019 13:39:02 GMT.
20/05/2019 07:04:04.726 RANGER2_USBL data gap from Fri, 17 May 2019 12:22:28 GMT to Mon, 20 May 2019 07:04:04 GMT.
20/05/2019 15:20:04.896 NMF_SURFMET data gap from Mon, 20 May 2019 13:51:14 GMT to Mon, 20 May 2019 15:20:04 GMT.
23/05/2019 11:25:06.314 EM600_DEPTH data gap from Fri, 17 May 2019 14:33:17 GMT to Thu, 23 May 2019 11:25:04 GMT.
25/05/2019 09:25:07.173 RANGER2_USBL data gap from Mon, 20 May 2019 13:32:32 GMT to Sat, 25 May 2019 09:25:07 GMT.
26/05/2019 09:24:07.611 RANGER2_USBL data gap from Sat, 25 May 2019 16:14:44 GMT to Sun, 26 May 2019 09:24:05 GMT.
27/05/2019 09:28:08.254 RANGER2_USBL data gap from Sun, 26 May 2019 16:32:54 GMT to Mon, 27 May 2019 09:28:08 GMT.

20 . Station list JC180

For full details see the recorded information at BODC

Cruise	Site	DeployNo	GearCode	GearNo	EventNo	InstrumentCode	InstrDeployNo	InstrumentID	SampleNo	StartDate	StartTimeGMT	Comments
JC180	Lander site	001	Other	OTHER01	1	WGT	WGT01		JC180-001-OTHER01/WGT01	27/04/2019	**09:22:00**	Test to measure length of line on way up, tags every 2 m for 10 m
JC180	Lander site	002	SVP	SVP01	1	SVP	SVP01		JC180-002-SVP01/SVP01	27/04/2019	**09:51:00**	
JC180	Lander site	002	SVP	SVP01	2	USBL	USBL01	Nano	JC180-002-SVP01/USBL01	27/04/2019	**09:51:00**	test of Nano USBL beacon from Gavia
JC180	Lander site	002	SVP	SVP01	3	USBL	USBL02	WSM	JC180-002-SVP01/USBL02	27/04/2019	**09:51:00**	test of WSM USBL beacon for drill rig
JC180	Lander site	003	Other	OTHER02	1	CTD	CTD01	Castaway	JC180-003-OTHER02/CTD01	27/04/2019	**10:09:00**	test of Castaway CTD for Gavia team
JC180	Lander site	003	Other	OTHER02	2	CTD	CTD02	Gas Lander CTD	JC180-003-OTHER02/CTD02	27/04/2019	**10:09:00**	Test of CTD system to be bolted on BSL
JC180	Lander site	003	Other	OTHER02	3	ADCP	ADCP01	Acquadop	JC180-003-OTHER02/ADCP01	27/04/2019	**10:09:00**	test of ADCP to be bolted on BSL
JC180	Lander site	004	Other	OTHER03	1	USBL	USBL03		JC180-004-OTHER03/USBL03	27/04/2019	**12:06:00**	USBL before acoustic release
JC180	Lander site	005	Other	OTHER04	1	AREL	AREL01		JC180-005-OTHER04/AREL01	27/04/2019	**12:19:00**	Acoustic Release
JC180	Lander site	006	BSL	BSL01	1	BSL	BSL01	New BSL	JC180-006-BSL01/BSL01	27/04/2019	**12:26:00**	heading 109.5
JC180	Lander site	007	AUV	AUV01	1	GAVIA	GAVIA00		JC180-007-AUV01/GAVIA00	27/04/2019	**12:56:00**	ballasting was hard to tell due to swell - need to do another check tomorrow with small boat
JC180	Lander Site	008	ROV	ROV346	0	ISIS	ISIS346		JC180-008-ROV346/ISIS346	27/04/2019	**14:15:00**	Aim of dive was to practice deployment and recovery + doppler + train ROV team - Found missing BaseLine Lander

JC180	Lander Site	008	ROV	ROV346	1	NSK	NSK01		JC180-008-ROV346/NSK01	27/04/2019	**16:14:18**	
JC180	Lander Site	008	ROV	ROV346	2	NSK	NSK02		JC180-008-ROV346/NSK02	27/04/2019	**16:14:54**	Samples not kept
JC180	Lander Site	008	ROV	ROV346	3	NSK	NSK03		JC180-008-ROV346/NSK03	27/04/2019	**16:15:18**	Samples not kept
JC180	Lander Site	008	ROV	ROV346	4	NSK	NSK04		JC180-008-ROV346/NSK04	27/04/2019	**16:15:39**	Samples not kept
JC180	Lander Site	008	ROV	ROV346	5	NSK	NSK05		JC180-008-ROV346/NSK05	27/04/2019	**16:15:52**	Samples not kept
JC180	Lander Site	008	ROV	ROV346	6	NSK	NSK06		JC180-008-ROV346/NSK06	27/04/2019	**16:16:01**	Samples not kept
JC180	Lander Site	008	ROV	ROV346	7	BSL	BSL02	Old BSL	JC180-008-ROV346/BSL02	27/04/2019	**17:24:26**	On Seabed at lander site
JC180	Lander Site	008	ROV	ROV346	8	GAS	GAS01		JC180-008-ROV346/GAS01	27/04/2019	**17:42:00**	
JC180	Lander Site	008	ROV	ROV346	9	GAS	GAS02		JC180-008-ROV346/GAS02	27/04/2019	**17:50:00**	
JC180	Lander Site	008	ROV	ROV346	10	GAS	GAS03		JC180-008-ROV346/GAS03	27/04/2019	**17:50:00**	
JC180	Lander Site	008	ROV	ROV346	11	PSH	PSH01		JC180-008-ROV346/PSH01	27/04/2019	**18:10:00**	Samples not kept
JC180	Lander Site	008	ROV	ROV346	12	BSL	BSL02	u	JC180-008-ROV346/BSL02	27/04/2019	**19:00:00**	Old Lander location
JC180	Survey Site	009	AUV	AUV02	1	GAVIA	GAVIA01		JC180-009-AUV02/GAVIA01	28/04/2019	**08:00:00**	Gavia aborted mission twice due to not obtaining bottom lock - set a mid water waypoint to get around the problem
JC180	Survey Site	010	SVP	SVP02	1	SVP	SVP01		JC180-010-SVP02/SVP01	28/04/2019	**15:22:00**	
JC180	Survey_Site	011	CO2	CO201	1	CO2	CO201		JC180-011-CO201/CO201	29/04/2019	**07:13:00**	Once the container was on the bottom, the rest of the rope was released from the winch and attached to the recovery float. Note: start position is USBL position of CO2 rig deployment

JC180	Survey_Site	012	ROV	ROV347	0	ISIS	ISIS347		JC180-012-ROV347/ISIS347	29/04/2019	**09:20:00**	ROV dive lasted a lot longer than expected due to issues with the regulator on the CO2 container. No Samples collected.
JC180	Survery Site	013	DRILL	DRILL00	1	DRILL	DRILL00		JC180-013-DRILL00/DRILL00	30/04/2019	**08:23:00**	Test Dip
JC180	Survey Site	014	DRILL	DRILL01	1	DRILL	DRILL01		JC180-014-DRILL01/DRILL01	30/04/2019	**11:10:00**	Deployed facing East.Rotated to face South on the way down. final NE
JC180	Survey Site	015	DRILL	DRILL02	1	DRILL	DRILL02		JC180-015-DRILL02/DRILL02	30/04/2019	**13:39:00**	Stopped 5m above the seafloor, reset comms, checked alignment: NE. Lost comms a few times.
JC180	Survery Site	016	ROV	ROV348	0	ISIS	ISIS348		JC180-016-ROV348/ISIS348	30/04/2019	**15:45:00**	No samples taken
JC180	Offsite Survey1	017	AUV	AUV03	1	GAVIA	GAVIA02		JC180-017-AUV03/GAVIA02	01/05/2019	**10:53:00**	Took a while to get a satelite fix
JC180	Survery Site	018	CO2	CO202	1	CO2	CO201		JC180-018-CO202/CO201	01/05/2019	**20:01:00**	Centre of A-frame set to 57degrees 59.6640N, 0degrees 22.5110W. Ship heading due North. Had to abort due to frayed rope
JC180	Survey Site	019	SVP	SVP03	1	SVP	SVP01		JC180-019-SVP03/SVP01	07/05/2019	**07:05:00**	Profile downloaded.
JC180	Survey Site	020	ROV	ROV349	0	ISIS	ISIS349		JC180-020-ROV349/ISIS349	07/05/2019	**08:08:00**	Position during recovery wasn't recorded in log - extracted from OFOP
JC180	Survey Site	020	ROV	ROV349	1	SDO	SDO01	SDO4	JC180-020-ROV349/SDO01	07/05/2019	**09:42:00**	optode 4: 1m range
JC180	Survey Site	020	ROV	ROV349	2	SDO	SDO02	SDO3	JC180-020-ROV349/SDO02	07/05/2019	**09:46:00**	optode3: 2m range
JC180	Survey Site	020	ROV	ROV349	3	SDO	SDO03	SDO1	JC180-020-ROV349/SDO03	07/05/2019	**09:52:00**	optode1: 4m range
JC180	Survey Site	020	ROV	ROV349	4	SDO	SDO04	SDO2	JC180-020-ROV349/SDO04	07/05/2019	**10:06:00**	optode2: 7m range - took two attempts
JC180	Survey Site	020	ROV	ROV349	5	NSK	NSK01		JC180-020-ROV349/NSK01	07/05/2019	**10:10:00**	bottles fired in rapid sucesion
JC180	Survey Site	020	ROV	ROV349	6	NSK	NSK02		JC180-020-ROV349/NSK02	07/05/2019	**10:10:00**	bottles fired in rapid sucesion

JC180	Survey Site	020	ROV	ROV349	7	NSK	NSK03		JC180-020-ROV349/NSK03	07/05/2019	**10:10:00**	bottles fired in rapid sucesion
JC180	Survey Site	020	ROV	ROV349	8	NSK	NSK04		JC180-020-ROV349/NSK04	07/05/2019	**10:10:00**	bottles fired in rapid sucesion
JC180	Survey Site	020	ROV	ROV349	9	NSK	NSK05		JC180-020-ROV349/NSK05	07/05/2019	**10:10:00**	bottles fired in rapid sucesion
JC180	Survey Site	020	ROV	ROV349	10	NSK	NSK06		JC180-020-ROV349/NSK06	07/05/2019	**10:10:00**	bottles fired in rapid sucesion
JC180	Survey Site	020	ROV	ROV349	11	PSH	PSH01	2R	JC180-020-ROV349/PSH01	07/05/2019	**10:12:00**	2R
JC180	Survey Site	020	ROV	ROV349	12	PSH	PSH02	3B	JC180-020-ROV349/PSH02	07/05/2019	**10:16:00**	3B
JC180	Survey Site	020	ROV	ROV349	13	PSH	PSH03	2B	JC180-020-ROV349/PSH03	07/05/2019	**10:18:00**	2B
JC180	Survey Site	020	ROV	ROV349	14	PSH	PSH04	1R	JC180-020-ROV349/PSH04	07/05/2019	**10:20:00**	1R
JC180	Survey Site	020	ROV	ROV349	15	PSH	PSH05	3R	JC180-020-ROV349/PSH05	07/05/2019	**10:21:00**	3R
JC180	Survey Site	020	ROV	ROV349	16	PSH	PSH06	2B	JC180-020-ROV349/PSH06	07/05/2019	**10:24:00**	2B
JC180	Survery Site	021	ROV	ROV350	0	ISIS	ISIS350		JC180-021-ROV350/ISIS350	07/05/2019	**12:37:00**	
JC180	Survery Site	021	ROV	ROV350	1	HYW	HYW01	HYW1	JC180-021-ROV350/HYW01	07/05/2019	**13:49:00**	1st Hydophone Wall placed on seafloor
JC180	Survery Site	022	ROV	ROV351	0	ISIS	ISIS351		JC180-022-ROV351/ISIS351	07/05/2019	**15:35:00**	Benthic Boundary Lander deployment
JC180	Survey Site	022	ROV	ROV351	1	BBL	BBL01	BBL1	JC180-022-ROV351/BBL01	07/05/2019	**16:57:00**	
JC180	Survey Site	022	ROV	ROV351	2	NSK	NSK01	NSK 5	JC180-022-ROV351/NSK01	07/05/2019	**17:08:00**	Niskin Bottle 4 failed
JC180	Survey Site	022	ROV	ROV351	3	NSK	NSK02	NSK 6	JC180-022-ROV351/NSK02	07/05/2019	**17:09:00**	
JC180	Survey Site	022	ROV	ROV351	4	NSK	NSK03	NSK 1	JC180-022-ROV351/NSK03	07/05/2019	**17:09:35**	
JC180	Survey Site	022	ROV	ROV351	5	NSK	NSK04	NSK 2	JC180-022-ROV351/NSK04	07/05/2019	**17:09:56**	

JC180	Survey Site	022	ROV	ROV351	6	NSK	NSK05	NSK 3	JC180-022-ROV351/NSK05	07/05/2019	**17:10:05**	
JC180	Survey Site	023	ROV	ROV352	0	ISIS	ISIS352		JC180-023-ROV352/ISIS352	08/05/2019	**08:19:00**	
JC180	Survey Site	023	ROV	ROV352	1	MPR	MPR01		JC180-023-ROV352/MPR01	08/05/2019	**09:17:00**	profile 1m from centre
JC180	Survey Site	023	ROV	ROV352	2	MPR	MPR02		JC180-023-ROV352/MPR02	08/05/2019	**10:33:00**	profile 2m from centre
JC180	Survey Site	023	ROV	ROV352	3	MPR	MPR03		JC180-023-ROV352/MPR03	08/05/2019	**11:55:00**	profile 4m from centre
JC180	Survey Site	023	ROV	ROV352	4	MPR	MPR04		JC180-023-ROV352/MPR04	08/05/2019	**13:17:00**	profile 7m from centre
JC180	Survey Site	023	ROV	ROV352	5	MPR	MPR05		JC180-023-ROV352/MPR05	08/05/2019	**14:36:00**	profile 14m from centre
JC180	Survey Site	024	ROV	ROV353	0	ISIS	ISIS353		JC180-024-ROV353/ISIS353	08/05/2019	**18:08:00**	
JC180	Survey Site	024	ROV	ROV353	1	BCH	BCH01	BCH1	JC180-024-ROV353/BCH01	08/05/2019	**19:05:55**	Deploy BCH1 at 7m. Touch sediment at 19:05. Toppled over a little. Straighten, then push down front edge. Quite hard when floating. Next time put ROV on the floor for more force
JC180	Survey Site	024	ROV	ROV353	2	NSK	NSK01	NSK4	JC180-024-ROV353/NSK01	08/05/2019	**19:25:50**	Fired OK. Taken at pushcore site
JC180	Survey Site	024	ROV	ROV353	3	NSK	NSK02	NSK5	JC180-024-ROV353/NSK02	08/05/2019	**19:26:04**	Fired OK. Taken at pushcore site
JC180	Survey Site	024	ROV	ROV353	4	NSK	NSK03	NSK6	JC180-024-ROV353/NSK03	08/05/2019	**19:26:20**	Fired OK. Taken at pushcore site
JC180	Survey Site	024	ROV	ROV353	5	NSK	NSK04	NSK1	JC180-024-ROV353/NSK04	08/05/2019	**19:26:30**	Fired OK. Taken at pushcore site
JC180	Survey Site	024	ROV	ROV353	6	NSK	NSK05	NSK2	JC180-024-ROV353/NSK05	08/05/2019	**19:26:43**	Fired OK. Taken at pushcore site
JC180	Survey Site	024	ROV	ROV353	7	NSK	NSK06	NSK3	JC180-024-ROV353/NSK06	08/05/2019	**19:26:50**	Fired OK. Taken at pushcore site
JC180	Survey Site	025	ROV	ROV354	0	ISIS	ISIS354		JC180-025-ROV354/ISIS354	09/05/2019	**14:19:00**	Replace BBL1 with BBL2. BBL2 placed to the right of BBL1 when facing North

JC180	Survey Site	025	ROV	ROV354	1	BBL	BBL02	BBL2	JC180-025-ROV354/BBL02	09/05/2019	**15:04:00**	
JC180	Survey Site	025	ROV	ROV354	2	BBL	BBL01	BBL1	JC180-025-ROV354/BBL01	09/05/2019	**15:08:00**	picked up BBL1
JC180	Survey Site	025	ROV	ROV354	3	NSK	NSK01	NSK4	JC180-025-ROV354/NSK01	09/05/2019	**15:15:00**	
JC180	Survey Site	025	ROV	ROV354	4	NSK	NSK02	NSK5	JC180-025-ROV354/NSK02	09/05/2019	**15:15:00**	
JC180	Survey Site	025	ROV	ROV354	5	NSK	NSK03	NSK6	JC180-025-ROV354/NSK03	09/05/2019	**15:15:00**	
JC180	Survey Site	025	ROV	ROV354	6	NSK	NSK04	NSK1	JC180-025-ROV354/NSK04	09/05/2019	**15:15:00**	
JC180	Survey Site	025	ROV	ROV354	7	NSK	NSK05	NSK2	JC180-025-ROV354/NSK05	09/05/2019	**15:15:00**	
JC180	Survey Site	025	ROV	ROV354	8	NSK	NSK06	NSK3	JC180-025-ROV354/NSK06	09/05/2019	**15:15:00**	
JC180	Survey Site	026	ROV	ROV355	0	ISIS	ISIS355		JC180-026-ROV355/ISIS355	09/05/2019	**16:52:00**	Hydrophone wall 2 deployment
JC180	Survey Site	026	ROV	ROV355	1	HYW	HYW02	HYW2	JC180-026-ROV355/HYW02	09/05/2019	**18:05:00**	Hydrophone wall heading due west
JC180	Survey Site	027	SVP	SVP04	1	SVP	SVP01		JC180-027-SVP04/SVP01	10/05/2019	**07:10:00**	2 SVP intruments deployed at the same time
JC180	Survey Site	028	CO2	CO203	1	CO2	CO201		JC180-028-CO203/CO201	10/05/2019	**09:14:00**	
JC180	Survey Site	029	ROV	ROV356	0	ISIS	ISIS356		JC180-029-ROV356/ISIS356	10/05/2019	**10:50:00**	Check rope to C02 rig and pick up the Benthic Chamber
JC180	Survey Site	029	ROV	ROV356	1	BCH	BCH01	BCH1	JC180-029-ROV356/BCH01	10/05/2019	**14:34:00**	pick up
JC180	Survey Site	030	ROV	ROV357	0	ISIS	ISIS357		JC180-030-ROV357/ISIS357	10/05/2019	**18:27:00**	
JC180	Survey Site	030	ROV	ROV357	1	GAS	GAS01	GAS1	JC180-030-ROV357/GAS01	11/05/2019	**17:00:00**	Taken at Gas Rig
JC180	Survey Site	030	ROV	ROV357	2	GAS	GAS02	GAS2	JC180-030-ROV357/GAS02	11/05/2019	**17:10:00**	Taken at Gas Rig
JC180	Survey Site	030	ROV	ROV357	3	GAS	GAS03	GAS3	JC180-030-ROV357/GAS03	11/05/2019	**17:17:00**	Taken at Gas Rig

JC181	Survey Site	030	ROV	ROV357	4	NSK	NSK01	NSK4	JC181-030-ROV357/NSK01	11/05/2019	**17:30:00**	Taken at Gas Rig
JC182	Survey Site	030	ROV	ROV357	5	NSK	NSK02	NSK5	JC182-030-ROV357/NSK02	11/05/2019	**17:30:00**	Taken at Gas Rig
JC183	Survey Site	030	ROV	ROV357	6	NSK	NSK03	NSK6	JC183-030-ROV357/NSK03	11/05/2019	**17:30:00**	Taken at Gas Rig
JC184	Survey Site	030	ROV	ROV357	7	NSK	NSK04	NSK1	JC184-030-ROV357/NSK04	11/05/2019	**17:30:00**	Taken at Gas Rig
JC185	Survey Site	030	ROV	ROV357	8	NSK	NSK05	NSK2	JC185-030-ROV357/NSK05	11/05/2019	**17:30:00**	Taken at Gas Rig
JC186	Survey Site	030	ROV	ROV357	9	NSK	NSK06	NSK3	JC186-030-ROV357/NSK06	11/05/2019	**17:30:00**	Taken at Gas Rig
JC180	Survey Site	031	ROV	ROV358	0	ISIS	ISIS358		JC180-031-ROV358/ISIS358	11/05/2019	**21:16:00**	
JC180	Survey Site	031	ROV	ROV358	1	SDO	SDO02	SDO3	JC180-031-ROV358/SDO02	11/05/2019	**22:47:00**	repositioning optode 3 (2nd nearest to bubbles)
JC180	Survey Site	031	ROV	ROV358	2	SDO	SDO01	SDO4	JC180-031-ROV358/SDO01	11/05/2019	**23:00:00**	repositioning of optode 4 (moved it from closest to bubbles to 2nd closest)
JC180	Survey Site	031	ROV	ROV358	3	MPR	MPR01		JC180-031-ROV358/MPR01	11/05/2019	**23:20:00**	MPR at bubble stream
JC180	Survey Site	031	ROV	ROV358	4	GAS	GAS01	GAS7	JC180-031-ROV358/GAS01	11/05/2019	**23:57:00**	sampling gas sampler #7
JC180	Survey Site	031	ROV	ROV358	5	MPR	MPR02		JC180-031-ROV358/MPR02	12/05/2019	**01:10:00**	MPR at most distant point 8 m north of seep
JC180	Survey Site	031	ROV	ROV358	6	HYW	HYW01	HYW1	JC180-031-ROV358/HYW01	12/05/2019	**01:37:00**	HYW1 repositioning, moving clockwise to other side of HYW2
JC180	Survey Site	031	ROV	ROV358	7	MPR	MPR03		JC180-031-ROV358/MPR03	12/05/2019	**02:24:00**	moved 4 m south
JC180	Survey Site	031	ROV	ROV358	8	MPR	MPR04		JC180-031-ROV358/MPR04	12/05/2019	**03:45:00**	moved 2m south
JC180	Survey Site	031	ROV	ROV358	9	MPR	MPR05		JC180-031-ROV358/MPR05	12/05/2019	**05:10:00**	moved 0.8 m south close to bubbles. Started at 05:15
JC180	Survey Site	031	ROV	ROV358	10	MPR	MPR06		JC180-031-ROV358/MPR06	12/05/2019	**06:30:00**	moved to centre of bubbles
JC180	Survey Site	031	ROV	ROV358	11	MPR	MPR07		JC180-031-ROV358/MPR07	12/05/2019	**07:42:00**	directly over bubbles. Note this is not a deployment but the pick-up moment of MPR06

JC180	Survey Site	031	ROV	ROV358	12				JC180-031-ROV358/	#REF!		entry in event log was made for optical modem - is not an event
JC180	Survey Site	031	ROV	ROV358	13	GAS	GAS02	GAS4	JC180-031-ROV358/GAS02	12/05/2019	**08:32:00**	sampling gas sampler #4, end 08:41
JC180	Survey Site	031	ROV	ROV358	14				JC180-031-ROV358/	#REF!		entry in event log was made for optical modem - is not an event
JC180	Survey Site	031	ROV	ROV358	15	GAS	GAS03	GAS8	JC180-031-ROV358/GAS03	12/05/2019	**09:26:00**	sampling gas sampler #8, start 09:26:48, end 09:52:00
JC180	Survey Site	031	ROV	ROV358	16	NSK	NSK01	NSK4	JC180-031-ROV358/NSK01	12/05/2019	**10:32:00**	NSK samples over vent holes. We could see bubbles
JC180	Survey Site	031	ROV	ROV358	17	NSK	NSK02	NSK5	JC180-031-ROV358/NSK02	12/05/2019	**10:32:00**	NSK samples over vent holes. We could see bubbles
JC180	Survey Site	031	ROV	ROV358	18	NSK	NSK03	NSK6	JC180-031-ROV358/NSK03	12/05/2019	**10:33:00**	NSK samples over vent holes. We could see bubbles
JC180	Survey Site	031	ROV	ROV358	19	NSK	NSK04	NSK1	JC180-031-ROV358/NSK04	12/05/2019	**10:33:00**	NSK samples over vent holes. We could see bubbles
JC180	Survey Site	031	ROV	ROV358	20	NSK	NSK05	NSK2	JC180-031-ROV358/NSK05	12/05/2019	**10:33:00**	NSK samples over vent holes. We could see bubbles
JC180	Survey Site	031	ROV	ROV358	21	NSK	NSK06	NSK3	JC180-031-ROV358/NSK06	12/05/2019	**10:33:00**	NSK samples over vent holes. We could see bubbles
JC180	Survey Site	031	ROV	ROV358	22	PSH	PSH01	3Blue	JC180-031-ROV358/PSH01	12/05/2019	**10:57:00**	Close to the regular bubble stream positoin1 2 cm away
JC180	Survey Site	031	ROV	ROV358	23	PSH	PSH02	2Blue	JC180-031-ROV358/PSH02	12/05/2019	**10:57:00**	Other side of hole 4 cm away
JC180	Survey Site	031	ROV	ROV358	24	PSH	PSH03	1Blue	JC180-031-ROV358/PSH03	12/05/2019	**11:01:00**	25cm from vent
JC180	Survey Site	031	ROV	ROV358	25	PSH	PSH04	3Red	JC180-031-ROV358/PSH04	12/05/2019	**11:03:00**	50cm from vent
JC180	Survey Site	031	ROV	ROV358	26	PSH	PSH05	2Red	JC180-031-ROV358/PSH05	12/05/2019	**11:05:00**	75cm from centre just *** pH optode
JC180	Survey Site	031	ROV	ROV358	27	PSH	PSH06	1Red	JC180-031-ROV358/PSH06	12/05/2019	**11:08:00**	100cm from centre below pH optode
JC180	Survey Site	032	ROV	ROV359	0	ISIS	ISIS359		JC180-032-ROV359/ISIS359	12/05/2019	**14:08:00**	end position given as 'off bottom' as ship position on deck wasn't recorded
JC180	Survey Site	032	ROV	ROV359	1	BBL	BBL03	BBL1	JC180-032-ROV359/BBL03	12/05/2019	**15:31:00**	Deployed BBL01.

JC180	Survey Site	032	ROV	ROV359	2	GAS	GAS01	GAS3	JC180-032-ROV359/GAS01	12/05/2019	**16:38:00**	
JC180	Survey Site	032	ROV	ROV359	3	NSK	NSK01	NSK4	JC180-032-ROV359/NSK01	12/05/2019	**17:15:00**	
JC180	Survey Site	032	ROV	ROV359	4	NSK	NSK02	NSK3	JC180-032-ROV359/NSK02	12/05/2019	**17:15:00**	
JC180	Survey Site	032	ROV	ROV359	5	NSK	NSK03	NSK6	JC180-032-ROV359/NSK03	12/05/2019	**17:16:00**	
JC180	Survey Site	032	ROV	ROV359	6	NSK	NSK04	NSK1	JC180-032-ROV359/NSK04	12/05/2019	**17:16:00**	
JC180	Survey Site	032	ROV	ROV359	7							Optical Modem - Not an event
JC180	Survey Site	032	ROV	ROV359	8							Check Gauges - Not an event
JC180	Survey Site	032	ROV	ROV359	9	GAS	GAS02	GAS6	JC180-032-ROV359/GAS02	12/05/2019	**17:58:00**	
JC180	Survey Site	032	ROV	ROV359	10	NSK	NSK05	NSK2	JC180-032-ROV359/NSK05	12/05/2019	**18:15:00**	
JC180	Survey Site	032	ROV	ROV359	11	NSK	NSK06	NSK3	JC180-032-ROV359/NSK06	12/05/2019	**18:16:00**	
JC180	Survey Site	033	ROV	ROV360	0	ISIS	ISIS360		JC180-033-ROV360/ISIS360	12/05/2019	**20:59:00**	
JC180	Survey Site	033	ROV	ROV360	1	BFR	BFR01		JC180-033-ROV360/BFR01	12/05/2019	**21:58:00**	BFR deployed
JC180	Survey Site	033	ROV	ROV360	2	BFR	BFR01		JC180-033-ROV360/BFR01	12/05/2019	**22:46:00**	BFR moved 20cm
JC180	Survey Site	033	ROV	ROV360	3	GAS	GAS01	GAS8	JC180-033-ROV360/GAS01	12/05/2019	**23:25:00**	gas sampler didn't fill very much
JC180	Survey Site	033	ROV	ROV360	4	PHO	PHO01		JC180-033-ROV360/PHO01	13/05/2019	**00:08:00**	4m downstream (N) of bubble stream. Held in stream for 15mins until 00:23, ROV heading 180
JC180	Survey Site	033	ROV	ROV360	5	PHO	PHO02		JC180-033-ROV360/PHO02	13/05/2019	**00:38:00**	4m upstream (S) of bubble stream. Held for 15mins until 00:53 ROV heading 86
JC180	Survey Site	033	ROV	ROV360	6	PHO	PHO03		JC180-033-ROV360/PHO03	13/05/2019	**01:20:00**	logger above bubble stream, stopped 1:55

JC180	Survey Site	033	ROV	ROV360	7	PHO	PHO04		JC180-033-ROV360/PHO04	13/05/2019	**02:55:00**	4m north of bubble stream at 2m altitude for 20mins
JC180	Survey Site	033	ROV	ROV360	8	PHO	PHO05		JC180-033-ROV360/PHO05	13/05/2019	**03:26:00**	4m south of bubble stream, 2m altitude for 20mins
JC180	Survey Site	033	ROV	ROV360	9	PHO	PHO06		JC180-033-ROV360/PHO06	13/05/2019	**03:56:00**	above bubble stream 2m altitude
JC180	Survey Site	033	ROV	ROV360	10	PHO	PHO07		JC180-033-ROV360/PHO07	13/05/2019	**04:17:00**	above bubble stream 1m altitude. Questions over actual altitude
JC180	Survey Site	033	ROV	ROV360	11	PHO	PHO08		JC180-033-ROV360/PHO08	13/05/2019	**04:41:00**	move 2m up for sample 3m over bubble
JC180	Survey Site	033	ROV	ROV360	12	PHO	PHO09		JC180-033-ROV360/PHO09	13/05/2019	**05:03:00**	marks end of pHO sampling - not a new sample
JC180	Survey Site	033	ROV	ROV360	13	GAS	GAS02	GAS2	JC180-033-ROV360/GAS02	13/05/2019	**05:15:00**	
JC180	Survey Site	033	ROV	ROV360	14	NSK	NSK01	NSK4	JC180-033-ROV360/NSK01	13/05/2019	**06:30:00**	Lat doesn't look correct
JC180	Survey Site	033	ROV	ROV360	15	NSK	NSK02	NSK5	JC180-033-ROV360/NSK02	13/05/2019	**06:30:00**	
JC180	Survey Site	033	ROV	ROV360	16	NSK	NSK03	NSK6	JC180-033-ROV360/NSK03	13/05/2019	**06:30:00**	
JC180	Survey Site	033	ROV	ROV360	17	NSK	NSK04	NSK1	JC180-033-ROV360/NSK04	13/05/2019	**06:31:00**	
JC180	Survey Site	033	ROV	ROV360	18				JC180-033-ROV360/			Checking Gauges - Not an event
JC180	Survey Site	033	ROV	ROV360	19	GAS	GAS03	GAS5	JC180-033-ROV360/GAS03	13/05/2019	**06:58:00**	500ml collected at 07:04
JC180	Survey Site	033	ROV	ROV360	20	GAS	GAS04	GAS5	JC180-033-ROV360/GAS04	13/05/2019	**07:11:00**	same gas sampler, failed
JC180	Survey Site	033	ROV	ROV360	21	NSK	NSK05	NSK2	JC180-033-ROV360/NSK05	13/05/2019	**07:23:00**	
JC180	Survey Site	033	ROV	ROV360	22	NSK	NSK06	NSK3	JC180-033-ROV360/NSK06	13/05/2019	**07:23:00**	
JC180	Survey Site	033	ROV	ROV360	23	PHO	PHO10		JC180-033-ROV360/PHO10	13/05/2019	**07:57:00**	2m above and 4m No of a new seep point
JC180	Survey Site	033	ROV	ROV360	24	PHO	PHO11		JC180-033-ROV360/PHO11	13/05/2019	**08:22:00**	2m directly above older vent centre point

JC180	Survey Site	033	ROV	ROV360	25	PHO	PHO12		JC180-033-ROV360/PHO12	13/05/2019	**08:43:00**	1m directly above older vent centre point
JC180	Survey Site	033	ROV	ROV360	26	PHO	PHO13		JC180-033-ROV360/PHO13	13/05/2019	**09:03:00**	3m directly above older vent centre point
JC180	Survey Site	034	ROV	ROV361	0	ISIS	ISIS361		JC180-034-ROV361/ISIS361	13/05/2019	**12:15:00**	deployed benthic chamber at experiment site
JC180	Survey Site	034	ROV	ROV361	1	NSK	NSK01	NSK4	JC180-034-ROV361/NSK01	13/05/2019	**13:08:00**	
JC180	Survey Site	034	ROV	ROV361	2	NSK	NSK02	NSK5	JC180-034-ROV361/NSK02	13/05/2019	**13:08:00**	
JC180	Survey Site	034	ROV	ROV361	3	NSK	NSK03	NSK6	JC180-034-ROV361/NSK03	13/05/2019	**13:08:00**	
JC180	Survey Site	034	ROV	ROV361	4	NSK	NSK04	NSK1	JC180-034-ROV361/NSK04	13/05/2019	**13:08:00**	
JC180	Survey Site	034	ROV	ROV361	5	BCH	BCH02	BCH2	JC180-034-ROV361/BCH02	13/05/2019	**13:29:00**	
JC180	Survey Site	034	ROV	ROV361	6	GAS	GAS01	GAS1	JC180-034-ROV361/GAS01	13/05/2019	**13:49:00**	seep site, finished 14:34
JC180	Survey Site	034	ROV	ROV361	7	NSK	NSK05	NSK2	JC180-034-ROV361/NSK05	13/05/2019	**15:01:00**	at gas rig
JC180	Survey Site	034	ROV	ROV361	8	NSK	NSK06	NSK3	JC180-034-ROV361/NSK06	13/05/2019	**15:01:00**	at gas rig
JC180	Survey Site	034	ROV	ROV361	9	GAS	GAS02	GAS4	JC180-034-ROV361/GAS02	13/05/2019	**15:06:00**	at gas rig
JC180	Survey Site	034	ROV	ROV361	10	GAS	GAS03	GAS3	JC180-034-ROV361/GAS03	13/05/2019	**15:25:00**	at gas rig
JC180	Survey Site	035	AUV	AUV04	1	GAVIA	GAVIA03		JC180-035-AUV04/GAVIA03	14/05/2019	**06:59:00**	completed first 7m altitude acoustic survey, failed to complete 3 m altitude seafet survey.
JC180	Survey Site	036	SVP	SVP05	1	SVP	SVP01		JC180-036-SVP05/SVP01	14/05/2019	**09:08:00**	SVP + Camera housing pressue test. 2z SVP units, camera housing for optical (zombie) lander
JC180	Survey Site	037	ROV	ROV362	0	ISIS	ISIS362		JC180-037-ROV362/ISIS362	14/05/2019	**13:39:00**	
JC180	Survey Site	037	ROV	ROV362	1	BBL	BBL04	BBL2	JC180-037-ROV362/BBL04	14/05/2019	**15:01:00**	

JC180	Survey Site	037	ROV	ROV362	2				JC180-037-ROV362/			Gas Flow - Not an event
JC180	Survey Site	038	ROV	ROV363	0	ISIS	ISIS363		JC180-038-ROV363/ISIS363	14/05/2019	**19:24:00**	
JC180	Survey Site	038	ROV	ROV363	1	MPR	MPR01		JC180-038-ROV363/MPR01	14/05/2019	**21:00:00**	on central bubble stream
JC180	Survey Site	038	ROV	ROV363	2	MPR	MPR02		JC180-038-ROV363/MPR02	14/05/2019	**22:09:00**	4m north of bubble stream
JC180	Survey Site	038	ROV	ROV363	3	MPR	MPR03		JC180-038-ROV363/MPR03	14/05/2019	**23:21:00**	3m north of bubble stream
JC180	Survey Site	038	ROV	ROV363	4	MPR	MPR04		JC180-038-ROV363/MPR04	15/05/2019	**00:29:00**	2m north of bubble stream
JC180	Survey Site	038	ROV	ROV363	5	MPR	MPR05		JC180-038-ROV363/MPR05	15/05/2019	**01:43:00**	<1m north of bubble stream
JC180	Survey Site	038	ROV	ROV363	6	MPR	MPR06		JC180-038-ROV363/MPR06	15/05/2019	**02:48:00**	placed on smaller stream next to large one
JC180	Survey Site	038	ROV	ROV363	7	MPR	MPR07		JC180-038-ROV363/MPR07	15/05/2019	**04:05:00**	placed over main crater
JC180	Survey Site	038	ROV	ROV363	8	MPR	MPR08		JC180-038-ROV363/MPR08	15/05/2019	**05:17:00**	placed at 0.5m site
JC180	Survey Site	038	ROV	ROV363	9	MPR	MPR09		JC180-038-ROV363/MPR09	15/05/2019	**06:30:00**	placed on secondary bubble stream - end of measurement
JC180	Survey Site	038	ROV	ROV363	10				JC180-038-ROV363/	15/05/2019		Optical Modem - Not an event
JC180	Survey Site	038	ROV	ROV363	11	NSK	NSK01	NSK4	JC180-038-ROV363/NSK01	15/05/2019	**07:07:00**	
JC180	Survey Site	038	ROV	ROV363	12	NSK	NSK02	NSK5	JC180-038-ROV363/NSK02	15/05/2019	**07:08:00**	
JC180	Survey Site	038	ROV	ROV363	13	GAS	GAS01	GAS6	JC180-038-ROV363/GAS01	15/05/2019	**07:11:00**	v4 opened at 7:11, closed at 7:27
JC180	Survey Site	038	ROV	ROV363	14	GAS	GAS02	GAS1	JC180-038-ROV363/GAS02	15/05/2019	**07:33:00**	v4 closed at 7:43
JC180	Survey Site	038	ROV	ROV363	15	NSK	NSK03	NSK6	JC180-038-ROV363/NSK03	15/05/2019	**08:25:00**	
JC180	Survey Site	038	ROV	ROV363	16	NSK	NSK04	NSK1	JC180-038-ROV363/NSK04	15/05/2019	**08:25:00**	

JC180	Survey Site	038	ROV	ROV363	17	NSK	NSK05	NSK2	JC180-038-ROV363/NSK05	15/05/2019	**08:25:00**	
JC180	Survey Site	038	ROV	ROV363	18	NSK	NSK06	NSK3	JC180-038-ROV363/NSK06	15/05/2019	**08:25:00**	
JC180	Survey Site	038	ROV	ROV363	19	GAS	GAS03	GAS8	JC180-038-ROV363/GAS03	15/05/2019	**08:35:00**	at seep
JC180	Survey Site	038	ROV	ROV363	20	PSH	PSH01	1Red	JC180-038-ROV363/PSH01	15/05/2019	**09:12:00**	close to venting hole
JC180	Survey Site	038	ROV	ROV363	21	PSH	PSH02	2Red	JC180-038-ROV363/PSH02	15/05/2019	**09:14:00**	close to venting hole
JC180	Survey Site	038	ROV	ROV363	22	PSH	PSH03	3Red	JC180-038-ROV363/PSH03	15/05/2019	**09:17:00**	25cm from hole
JC180	Survey Site	038	ROV	ROV363	23	PSH	PSH04	1Blue	JC180-038-ROV363/PSH04	15/05/2019	**09:20:00**	50cm from vent
JC180	Survey Site	038	ROV	ROV363	24	PSH	PSH05	2Blue	JC180-038-ROV363/PSH05	15/05/2019	**09:26:00**	75cm from vent
JC180	Survey Site	038	ROV	ROV363	25	PSH	PSH06	3Blue	JC180-038-ROV363/PSH06	15/05/2019	**09:28:00**	100cm from vent
JC180	Survey Site	039	ROV	ROV364	0	ISIS	ISIS364		JC180-039-ROV364/ISIS364	15/05/2019	**11:55:00**	
JC180	Survey Site	039	ROV	ROV364	1	HYW	HYW02	HYW2	JC180-039-ROV364/HYW02	15/05/2019	**12:44:00**	picked up HYW2
JC180	Survey Site	040	ROV	ROV365	0	ISIS	ISIS365		JC180-040-ROV365/ISIS365	15/05/2019	**14:40:00**	
JC180	Survey Site	040	ROV	ROV365	1	BCH	BCH03	BCH1	JC180-040-ROV365/BCH03	15/05/2019	**15:27:00**	deployed BCH1, doppler was drifting
JC180	Survey Site	041	ROV	ROV366	0	ISIS	ISIS366		JC180-041-ROV366/ISIS366	15/05/2019	**19:17:00**	
JC180	Survey Site	041	ROV	ROV366	1	BFR	BFR01		JC180-041-ROV366/BFR01	15/05/2019	**19:53:00**	deployment of bubble frame over largest hole
JC180	Survey Site	041	ROV	ROV366	2				JC180-041-ROV366/	15/05/2019		was end of BFR deployment so listed with Ev1
JC180	Survey Site	041	ROV	ROV366	3	PHO	PHO01		JC180-041-ROV366/PHO01	15/05/2019	**23:45:00**	1.5m above bubble stream 30mins
JC180	Survey Site	041	ROV	ROV366	4	PHO	PHO02		JC180-041-ROV366/PHO02	16/05/2019	**00:15:00**	2.5m above bubble stream 30mins

JC180	Survey Site	041	ROV	ROV366	5	PHO	PHO03		JC180-041-ROV366/PHO03	16/05/2019	**00:46:00**	3.5m above bubble stream 30 mins no visual of bubbles at this height
JC180	Survey Site	041	ROV	ROV366	6	PHO	PHO04		JC180-041-ROV366/PHO04	16/05/2019	**01:19:00**	1.5m above seafloor, 1m north of bubble stream. 17 mins
JC180	Survey Site	041	ROV	ROV366	7	PHO	PHO05		JC180-041-ROV366/PHO05	16/05/2019	**01:38:00**	1.5m above seafloor, 90 deg turned, now facing west. 2m north of bubbles
JC180	Survey Site	041	ROV	ROV366	8	PHO	PHO06		JC180-041-ROV366/PHO06	16/05/2019	**01:57:00**	1.5m above seafloor, 4m north of bubbles, face west
JC180	Survey Site	041	ROV	ROV366	9	PHO	PHO07		JC180-041-ROV366/PHO07	16/05/2019	**02:10:00**	1.5m altitude, 5m north of bubbles, face west
JC180	Survey Site	041	ROV	ROV366	10	PHO	PHO08		JC180-041-ROV366/PHO08	16/05/2019	**02:28:00**	1,5m altitude, 6m north of bubbles, face west
JC180	Survey Site	041	ROV	ROV366	11	PHO	PHO09		JC180-041-ROV366/PHO09	16/05/2019	**02:39:00**	1.5m altitude, 8m north of bubbles, face west
JC180	Survey Site	041	ROV	ROV366	12	PHO	PHO10		JC180-041-ROV366/PHO10	16/05/2019	**02:50:00**	1.5m altitude, 10m north of bubbles, face west
JC180	Survey Site	041	ROV	ROV366	13	PHO	PHO11		JC180-041-ROV366/PHO11	16/05/2019	**03:23:00**	6m south of bubbles at 1,5m altituce, face east
JC180	Survey Site	041	ROV	ROV366	14	PHO	PHO12		JC180-041-ROV366/PHO12	16/05/2019	**03:41:00**	6m south of bubbles at 3.5m altitude, face east
JC180	Survey Site	041	ROV	ROV366	15	PHO	PHO13		JC180-041-ROV366/PHO13	16/05/2019	**04:33:00**	1m north of bubble stream at 3.5m, heading 200deg
JC180	Survey Site	041	ROV	ROV366	16	PHO	PHO14		JC180-041-ROV366/PHO14	16/05/2019	**04:57:00**	2m north of bubble stream at 3.5 m, heading 270
JC180	Survey Site	041	ROV	ROV366	17	PHO	PHO15		JC180-041-ROV366/PHO15	16/05/2019	**05:15:00**	4m north of bubble stream at 3.5m, heading 270
JC180	Survey Site	041	ROV	ROV366	18	PHO	PHO16		JC180-041-ROV366/PHO16	16/05/2019	**05:26:00**	5m north of bubble stream at 3.5m altitude, heading 270
JC180	Survey Site	041	ROV	ROV366	19	PHO	PHO17		JC180-041-ROV366/PHO17	16/05/2019	**05:44:00**	6m north of bubble stream at 3.5m altitude, heading 270
JC180	Survey Site	041	ROV	ROV366	20	PHO	PHO18		JC180-041-ROV366/PHO18	16/05/2019	**05:56:00**	8 m north of bubble stream at 3.5m altitude, heading 270
JC180	Survey Site	041	ROV	ROV366	21	PHO	PHO19		JC180-041-ROV366/PHO19	16/05/2019	**06:08:00**	10m north of bubble stream at 3.5m altitude, heading 270
JC180	Survey Site	041	ROV	ROV366	22	NSK	NSK01	NSK4/5	JC180-041-ROV366/NSK01	16/05/2019	**06:38:00**	NSK4 and NSK5 both at 06:38 at rig

JC180	Survey Site	041	ROV	ROV366	23	GAS	GAS01	GAS4	JC180-041-ROV366/GAS01	16/05/2019	**06:49:00**	V4 open at 06:49, closed at 07:06
JC180	Survey Site	041	ROV	ROV366	24	NSK	NSK02	NSK6	JC180-041-ROV366/NSK02	16/05/2019	**07:39:00**	Niskin over gas plume
JC180	Survey Site	041	ROV	ROV366	25	NSK	NSK03	NSK1	JC180-041-ROV366/NSK03	16/05/2019	**07:39:44**	Niskin over gas plume
JC180	Survey Site	041	ROV	ROV366	26	NSK	NSK04	NSK2	JC180-041-ROV366/NSK04	16/05/2019	**07:39:54**	Niskin over gas plume
JC180	Survey Site	041	ROV	ROV366	27	NSK	NSK05	NSK3	JC180-041-ROV366/NSK05	16/05/2019	**07:40:03**	Niskin over gas plume
JC180	Survey Site	041	ROV	ROV366	28	GAS	GAS02	GAS7	JC180-041-ROV366/GAS02	16/05/2019	**07:53:00**	above seep close to seafloor
JC180	Survey Site	041	ROV	ROV366	29	GAS	GAS03	GAS2	JC180-041-ROV366/GAS03	16/05/2019	**08:19:00**	above seep approx 1.3 m , reduced height above ground at 08:57, sample failed
JC180	Survey Site	042	ROV	ROV367	0	ISIS	ISIS367		JC180-042-ROV367/ISIS367	16/05/2019	**12:21:00**	
JC180	Survey Site	042	ROV	ROV367	1	HYW	HYW03	HYW2	JC180-042-ROV367/HYW03	16/05/2019	**13:01:00**	HYW2 placed at temporary position
JC180	Survey Site	042	ROV	ROV367	2	HYW	HYW01	HYW1	JC180-042-ROV367/HYW01	16/05/2019	**13:06:00**	HYW1 picked up
JC180	Survey Site	042	ROV	ROV367	3	HYW	HYW01	HYW1	JC180-042-ROV367/HYW01	16/05/2019	**13:10:00**	HYW1 placed at temporary position
JC180	Survey Site	042	ROV	ROV367	4	HYW	HYW03	HYW2	JC180-042-ROV367/HYW03	16/05/2019	**13:12:00**	HYW2 picked up
JC180	Survey Site	042	ROV	ROV367	5	HYW	HYW03	HYW2	JC180-042-ROV367/HYW03	16/05/2019	**13:15:00**	HYW deployed at new position (1m closer to seep site than HYW1 previously)
JC180	Survey Site	042	ROV	ROV367	6	HYW	HYW01	HYW1	JC180-042-ROV367/HYW01	16/05/2019	**13:22:00**	HYW1 picked up an placed on tool sled
JC180	Survey Site	043	ROV	ROV368	0	ISIS	ISIS368		JC180-043-ROV368/ISIS368	16/05/2019	**15:09:00**	Dive aborted because of an emergency
JC180	Survey Site	043	ROV	ROV368	1	BBL	BBL05	BBL1	JC180-043-ROV368/BBL05	16/05/2019	**16:38:00**	BBL1 deployed, retrieved BBL2
JC180	Survey Site	044	AUV	AUV05	1	GAVIA	GAVIA04		JC180-044-AUV05/GAVIA04	17/05/2019	**07:01:00**	
JC180	Survey Site	045	SVP	SVP06	1	SVP	SVP01		JC180-045-SVP06/SVP01	17/05/2019	**09:32:00**	deployed at the gavia deployment area

JC180	Survey Site	046	ROV	ROV369	0	ISIS	ISIS369		JC180-046-ROV369/ISIS369	17/05/2019	**13:25:00**	
JC180	Survey Site	046	ROV	ROV369	1	BCH	BCH04	BCH2	JC180-046-ROV369/BCH04	17/05/2019	**14:43:00**	Deployed Benthic Chamber 2
JC180	Survey Site	046	ROV	ROV369	2	GAS	GAS01	GAS08	JC180-046-ROV369/GAS01	17/05/2019	**14:59:00**	Used funnel from Gas Sampler #8 to measure leakage from pipe 2 - lost funnel
JC180	Survey Site	046	ROV	ROV369	3	GAS	GAS02	GAS06	JC180-046-ROV369/GAS02	17/05/2019	**15:19:00**	Funnel lost
JC180	Survey Site	046	ROV	ROV369	4	GAS	GAS03	GAS01	JC180-046-ROV369/GAS03	17/05/2019	**15:26:00**	
JC180	Survey Site	046	ROV	ROV369	5	NSK	NSK01	NSK4	JC180-046-ROV369/NSK01	17/05/2019	**16:15:00**	
JC180	Survey Site	046	ROV	ROV369	6	NSK	NSK02	NSK5	JC180-046-ROV369/NSK02	17/05/2019	**16:15:00**	
JC180	Survey Site	046	ROV	ROV369	7	NSK	NSK03	NSK6	JC180-046-ROV369/NSK03	17/05/2019	**16:15:00**	
JC180	Survey Site	046	ROV	ROV369	8	NSK	NSK04	NSK1	JC180-046-ROV369/NSK04	17/05/2019	**16:15:00**	
JC180	Survey Site	046	ROV	ROV369	9	NSK	NSK05	NSK2	JC180-046-ROV369/NSK05	17/05/2019	**16:31:00**	
JC180	Survey Site	046	ROV	ROV369	10	NSK	NSK06	NSK3	JC180-046-ROV369/NSK06	17/05/2019	**16:31:00**	
JC180	Survey Site	047	ROV	ROV370	0	ISIS	ISIS370		JC180-047-ROV370/ISIS370	17/05/2019	**20:36:00**	MPR+Bubble Panel
JC180	Survey Site	047	ROV	ROV370	1	MPR	MPR01		JC180-047-ROV370/MPR01	17/05/2019	**21:23:00**	
JC180	Survey Site	047	ROV	ROV370	2	BP	BP01		JC180-047-ROV370/BP01	17/05/2019	**21:48:00**	1.5m altitude
JC180	Survey Site	047	ROV	ROV370	3	BP	BP02		JC180-047-ROV370/BP02	17/05/2019	**21:57:00**	2m altitude
JC180	Survey Site	047	ROV	ROV370	4	BP	BP03		JC180-047-ROV370/BP03	17/05/2019	**22:09:00**	2.5m altitud
JC180	Survey Site	047	ROV	ROV370	5	BP	BP04		JC180-047-ROV370/BP04	17/05/2019	**22:11:00**	3m altitude
JC180	Survey Site	047	ROV	ROV370	6	MPR	MPR02		JC180-047-ROV370/MPR02	17/05/2019	**22:41:00**	

JC180	Survey Site	047	ROV	ROV370	7	MPR	MPR03	JC180-047-ROV370/MPR03	17/05/2019	**23:48:00**	
JC180	Survey Site	047	ROV	ROV370	8	MPR	MPR04	JC180-047-ROV370/MPR04	18/05/2019	**00:59:00**	
JC180	Survey Site	047	ROV	ROV370	9	MPR	MPR05	JC180-047-ROV370/MPR05	18/05/2019	**02:13:00**	
JC180	Survey Site	047	ROV	ROV370	10	BP	BP05	JC180-047-ROV370/BP05	18/05/2019	**02:27:00**	1.5m altitude
JC180	Survey Site	047	ROV	ROV370	11	BP	BP06	JC180-047-ROV370/BP06	18/05/2019	**02:33:00**	2m altitude
JC180	Survey Site	047	ROV	ROV370	12	BP	BP07	JC180-047-ROV370/BP07	18/05/2019	**02:37:00**	2.5m altitud
JC180	Survey Site	047	ROV	ROV370	13	BP	BP08	JC180-047-ROV370/BP08	18/05/2019	**02:42:00**	3m altitude
JC180	Survey Site	047	ROV	ROV370	14	BP	BP09	JC180-047-ROV370/BP09	18/05/2019	**02:46:00**	3.5m altitude
JC180	Survey Site	047	ROV	ROV370	15	BP	BP10	JC180-047-ROV370/BP10	18/05/2019	**02:57:00**	4m altitude
JC180	Survey Site	047	ROV	ROV370	16	BP	BP11	JC180-047-ROV370/BP11	18/05/2019	**03:04:00**	4.5m altitude
JC180	Survey Site	047	ROV	ROV370	17	MPR	MPR06	JC180-047-ROV370/MPR06	18/05/2019	**03:25:00**	
JC180	Survey Site	047	ROV	ROV370	18	BP	BP12	JC180-047-ROV370/BP12	18/05/2019	**03:47:00**	4.8m altitude
JC180	Survey Site	047	ROV	ROV370	19	BP	BP13	JC180-047-ROV370/BP13	18/05/2019	**03:50:00**	5m altitude
JC180	Survey Site	047	ROV	ROV370	20	BP	BP14	JC180-047-ROV370/BP14	18/05/2019	**03:56:00**	5.5m altitude
JC180	Survey Site	047	ROV	ROV370	21	BP	BP15	JC180-047-ROV370/BP15	18/05/2019	**04:06:00**	6m altitude
JC180	Survey Site	047	ROV	ROV370	22	BP	BP16	JC180-047-ROV370/BP16	18/05/2019	**04:15:00**	6.6m altitude
JC180	Survey Site	047	ROV	ROV370	23	MPR	MPR07	JC180-047-ROV370/MPR07	18/05/2019	**04:42:00**	1m from bubbles
JC180	Survey Site	047	ROV	ROV370	24	BP	BP17	JC180-047-ROV370/BP17	18/05/2019	**04:57:00**	2m altitude

JC180	Survey Site	047	ROV	ROV370	25	BP	BP18		JC180-047-ROV370/BP18	18/05/2019	**05:02:00**	2.5m altitud
JC180	Survey Site	047	ROV	ROV370	26	BP	BP19		JC180-047-ROV370/BP19	18/05/2019	**05:08:00**	3m altitude
JC180	Survey Site	047	ROV	ROV370	27	BP	BP20		JC180-047-ROV370/BP20	18/05/2019	**05:14:00**	3.5m altitude
JC180	Survey Site	047	ROV	ROV370	28	BP	BP21		JC180-047-ROV370/BP21	18/05/2019	**05:24:00**	4m altitude
JC180	Survey Site	047	ROV	ROV370	29	BP	BP22		JC180-047-ROV370/BP22	18/05/2019	**05:30:00**	4.5m altitude
JC180	Survey Site	047	ROV	ROV370	30	BP	BP23		JC180-047-ROV370/BP23	18/05/2019	**05:40:00**	5m altitude
JC180	Survey Site	047	ROV	ROV370	31	BP	BP24		JC180-047-ROV370/BP24	18/05/2019	**05:45:00**	stowing panel
JC180	Survey Site	047	ROV	ROV370	32	MPR	MPR08		JC180-047-ROV370/MPR08	18/05/2019	**06:30:00**	0m on bubble plume. Issue turning on, magnet missing so had to use spare
JC180	Survey Site	047	ROV	ROV370	33	MPR	MPR09		JC180-047-ROV370/MPR09	18/05/2019	**06:39:00**	MPR turned on
JC180	Survey Site	047	ROV	ROV370	34	BP	BP25		JC180-047-ROV370/BP25	18/05/2019	**06:56:00**	3m altitude
JC180	Survey Site	047	ROV	ROV370	35	BP	BP26		JC180-047-ROV370/BP26	18/05/2019	**07:03:00**	3.5m altitude
JC180	Survey Site	047	ROV	ROV370	36	BP	BP27		JC180-047-ROV370/BP27	18/05/2019	**07:09:00**	4m altitude
JC180	Survey Site	047	ROV	ROV370	37	BP	BP28		JC180-047-ROV370/BP28	18/05/2019	**07:11:00**	4.5m altitude
JC180	Survey Site	047	ROV	ROV370	38	BP	BP29		JC180-047-ROV370/BP29	18/05/2019	**07:19:00**	5m altitude
JC180	Survey Site	047	ROV	ROV370	39	BP	BP30		JC180-047-ROV370/BP30	18/05/2019	**07:25:00**	5.5m altitude
JC180	Survey Site	047	ROV	ROV370	40	BP	BP31		JC180-047-ROV370/BP31	18/05/2019	**07:29:00**	6m altitude
JC180	Survey Site	047	ROV	ROV370	41	BP	BP32		JC180-047-ROV370/BP32	18/05/2019	**07:30:00**	stowing bubble panel
JC180	Survey Site	047	ROV	ROV370	42	GAS	GAS01	GAS7	JC180-047-ROV370/GAS01	18/05/2019	**08:01:00**	Sample from bottle 7. 2nd bubble hole from left. Filled funnel by 08:05

JC180	Survey Site	047	ROV	ROV370	43	GAS	GAS02	GAS3	JC180-047-ROV370/GAS02	18/05/2019	**08:15:00**	Location as previous sample, full 08:18, closed 08:20
JC180	Survey Site	047	ROV	ROV370	44	GAS	GAS03	GAS7	JC180-047-ROV370/GAS03	18/05/2019	**08:28:00**	Re-opened bottle and after collecting ~400ml gas, no further suction
JC180	Survey Site	047	ROV	ROV370	45	NSK	NSK01	NSK4	JC180-047-ROV370/NSK01	18/05/2019	**09:09:00**	~2.5m above bubble stream
JC180	Survey Site	047	ROV	ROV370	46	NSK	NSK02	NSK5	JC180-047-ROV370/NSK02	18/05/2019	**09:09:00**	
JC180	Survey Site	047	ROV	ROV370	47	NSK	NSK03	NSK6	JC180-047-ROV370/NSK03	18/05/2019	**09:09:00**	
JC180	Survey Site	047	ROV	ROV370	48	NSK	NSK04	NSK1	JC180-047-ROV370/NSK04	18/05/2019	**09:10:00**	
JC180	Survey Site	047	ROV	ROV370	49	NSK	NSK05	NSK2	JC180-047-ROV370/NSK05	18/05/2019	**09:23:00**	at 117.5 m above ground
JC180	Survey Site	047	ROV	ROV370	50	NSK	NSK06	NSK3	JC180-047-ROV370/NSK06	18/05/2019	**09:23:00**	
JC180	Survey Site	047	ROV	ROV370	51	GAS	GAS04	GAS5	JC180-047-ROV370/GAS04	18/05/2019	**09:38:00**	~450ml, valve 4 open from 09:36 - 9:49
JC180	Survey Site	047	ROV	ROV370	52	PSH	PSH01	1Y	JC180-047-ROV370/PSH01	18/05/2019	**10:34:00**	far left vent
JC180	Survey Site	047	ROV	ROV370	53	PSH	PSH02	2Y	JC180-047-ROV370/PSH02	18/05/2019	**10:37:00**	8cm to west ish from previous
JC180	Survey Site	047	ROV	ROV370	54	PSH	PSH03	3Y	JC180-047-ROV370/PSH03	18/05/2019	**10:39:00**	6cm south from previous
JC180	Survey Site	047	ROV	ROV370	55	PSH	PSH04	1B	JC180-047-ROV370/PSH04	18/05/2019	**10:42:00**	west from 3Y
JC180	Survey Site	047	ROV	ROV370	56	PSH	PSH05	2B	JC180-047-ROV370/PSH05	18/05/2019	**10:44:00**	south of big vent
JC180	Survey Site	047	ROV	ROV370	57	PSH	PSH06	3B	JC180-047-ROV370/PSH06	18/05/2019	**10:47:00**	west of 2B
JC180	Survey Site	048	ROV	ROV371	0	ISIS	ISIS371		JC180-048-ROV371/ISIS371	18/05/2019	**16:17:00**	
JC180	Survey Site	048	ROV	ROV371	1	BBL	BBL05	BBL1	JC180-048-ROV371/BBL05	18/05/2019	**17:13:00**	BBL2 deployed temporarily
JC180	Survey Site	048	ROV	ROV371	2	BBL	BBL06	BBL2	JC180-048-ROV371/BBL06	18/05/2019	**17:28:00**	BBL1 deployed, retrieved BBL2 - latitude not recorded

JC180	Survey Site	049	ROV	ROV372	0	ISIS	ISIS372		JC180-049-ROV372/ISIS372	18/05/2019	**20:28:00**	
JC180	Survey Site	049	ROV	ROV372	1	HYW	HYW04	HYW1	JC180-049-ROV372/HYW04	18/05/2019	**21:25:00**	deployed HYW1 (a little north of HYW2)
JC180	Survey Site	049	ROV	ROV372	2	PHO	PHO01		JC180-049-ROV372/PHO01	18/05/2019	**21:46:00**	first pHO measurement location over stream. 30mins
JC180	Survey Site	049	ROV	ROV372	3	PHO	PHO02		JC180-049-ROV372/PHO02	18/05/2019	**22:18:00**	2nd pHO location 1m above previous, 30min
JC180	Survey Site	049	ROV	ROV372	4	PHO	PHO03		JC180-049-ROV372/PHO03	18/05/2019	**22:50:00**	3rd pHO location, 3.5m above bubble stream, 30min
JC180	Survey Site	049	ROV	ROV372	5	PHO	PHO04		JC180-049-ROV372/PHO04	18/05/2019	**23:25:00**	1m south of bubbles, 3.5 m altitude, 17mins
JC180	Survey Site	049	ROV	ROV372	6	PHO	PHO05		JC180-049-ROV372/PHO05	18/05/2019	**23:43:00**	2m south of bubbles, 3.5 m altitude, 17 mins
JC180	Survey Site	049	ROV	ROV372	7	PHO	PHO06		JC180-049-ROV372/PHO06	19/05/2019	**00:02:00**	3m south of bubbles, 3.5m altitude, 17 mins
JC180	Survey Site	049	ROV	ROV372	8	PHO	PHO07		JC180-049-ROV372/PHO07	19/05/2019	**00:22:00**	4m south of bubbles, 3.5m altitude, 17mins
JC180	Survey Site	049	ROV	ROV372	9	PHO	PHO08		JC180-049-ROV372/PHO08	19/05/2019	**00:40:00**	5m south of bubbles, 3.5m altitude, 17 mins
JC180	Survey Site	049	ROV	ROV372	10	PHO	PHO09		JC180-049-ROV372/PHO09	19/05/2019	**01:00:00**	6m south of bubbles, 3.5m altitude, 10mins
JC180	Survey Site	049	ROV	ROV372	11	PHO	PHO10		JC180-049-ROV372/PHO10	19/05/2019	**01:12:00**	8 m south of bubbles, 3.5m altitude, 10 mins
JC180	Survey Site	049	ROV	ROV372	12	PHO	PHO11		JC180-049-ROV372/PHO11	19/05/2019	**01:23:00**	10 m south of bubbles, 3.5m altitude, 10mins
JC180	Survey Site	049	ROV	ROV372	13	PHO	PHO12		JC180-049-ROV372/PHO12	19/05/2019	**03:02:00**	1m north of bubbles, 1.5m altitude, 10mins
JC180	Survey Site	049	ROV	ROV372	14	PHO	PHO13		JC180-049-ROV372/PHO13	19/05/2019	**03:13:00**	pHO13, 2m north of bubbles, 1.5m altitude, 10mins
JC180	Survey Site	049	ROV	ROV372	15	PHO	PHO14		JC180-049-ROV372/PHO14	19/05/2019	**03:24:00**	pHO 14, 4m north of bubbles, 1.5m altitude, 10 mins
JC180	Survey Site	049	ROV	ROV372	16	PHO	PHO15		JC180-049-ROV372/PHO15	19/05/2019	**03:31:00**	pHO15, 5m north of bubbles, 1.5m altitude, 10mins
JC180	Survey Site	049	ROV	ROV372	17	PHO	PHO16		JC180-049-ROV372/PHO16	19/05/2019	**03:47:00**	pHO16, 6m north of bubbles, 1.5m altitude, 10 min

JC180	Survey Site	049	ROV	ROV372	18	PHO	PHO17		JC180-049-ROV372/PHO17	19/05/2019	**03:58:00**	pHO17, 8m north of bubbles, 1.5m altitude, 10min
JC180	Survey Site	049	ROV	ROV372	19	PHO	PHO18		JC180-049-ROV372/PHO18	19/05/2019	**04:11:00**	pHO18, 10m north of bubbles, 1.5m altitude, 10 mins
JC180	Survey Site	049	ROV	ROV372	20	PHO	PHO19		JC180-049-ROV372/PHO19	19/05/2019	**04:28:00**	pHO19, 1 m north of bubbles, 2.5m altitude, 10min
JC180	Survey Site	049	ROV	ROV372	21	PHO	PHO20		JC180-049-ROV372/PHO20	19/05/2019	**04:39:00**	pHO20, 2m north of bubbles, 2.5m altitude, 10mins
JC180	Survey Site	049	ROV	ROV372	22	PHO	PHO21		JC180-049-ROV372/PHO21	19/05/2019	**04:57:00**	pHO21, 4m north of bubbles, 2.5m altitude, 10 mins
JC180	Survey Site	049	ROV	ROV372	23	PHO	PHO22		JC180-049-ROV372/PHO22	19/05/2019	**05:08:00**	pHO22, 5m north of bubbles, 2.5m altitude, 10mins
JC180	Survey Site	049	ROV	ROV372	24	PHO	PHO23		JC180-049-ROV372/PHO23	19/05/2019	**05:19:00**	pHO23, 6m north of bubbles, 2.5m altitude, 10mins
JC180	Survey Site	049	ROV	ROV372	25	PHO	PHO24		JC180-049-ROV372/PHO24	19/05/2019	**05:31:00**	pHO24, 8m north of bubbles, 2.5m altitude, 10mins
JC180	Survey Site	049	ROV	ROV372	26	PHO	PHO25		JC180-049-ROV372/PHO25	19/05/2019	**05:43:00**	pHO25, 10m north of bubbles, 2.5m altitude, 10mins
JC180	Survey Site	049	ROV	ROV372	27	GAS	GAS01	GAS1	JC180-049-ROV372/GAS01	19/05/2019	**06:10:00**	at seep, SW of benthic chamber ~450ml
JC180	Survey Site	049	ROV	ROV372	28	GAS	GAS02	GAS4	JC180-049-ROV372/GAS02	19/05/2019	**06:30:00**	at seep, 1m off seabed, altitude doppler = 1.3m
JC180	Survey Site	049	ROV	ROV372	29	NSK	NSK01	NSK4	JC180-049-ROV372/NSK01	19/05/2019	**07:04:00**	altitude 1.3m
JC180	Survey Site	049	ROV	ROV372	30	NSK	NSK02	NSK5	JC180-049-ROV372/NSK02	19/05/2019	**07:04:00**	
JC180	Survey Site	049	ROV	ROV372	31	NSK	NSK03	NSK6	JC180-049-ROV372/NSK03	19/05/2019	**07:04:00**	
JC180	Survey Site	049	ROV	ROV372	32	NSK	NSK04	NSK1	JC180-049-ROV372/NSK04	19/05/2019	**07:05:00**	
JC180	Survey Site	049	ROV	ROV372	33	NSK	NSK05	NSK2/3	JC180-049-ROV372/NSK05	19/05/2019	**07:20:00**	
JC180	Survey Site	049	ROV	ROV372	34	GAS	GAS03	GAS6	JC180-049-ROV372/GAS03	19/05/2019	**07:25:00**	valve 4 on: 07:25, closed 07:35, ~450ml suction
JC180	Survey Site	049	ROV	ROV372	35	PHO	PHO26		JC180-049-ROV372/PHO26	19/05/2019	**09:08:00**	over bubble at 1.5m altitude, heading 180, 10mins

JC180	Survey Site	049	ROV	ROV372	36	PHO	PHO27		JC180-049-ROV372/PHO27	19/05/2019	**09:20:00**	over bubble at 2.5m altitude, heading 180, 10 mins
JC180	Survey Site	049	ROV	ROV372	37	PHO	PHO28		JC180-049-ROV372/PHO28	19/05/2019	**09:31:00**	over bubble at 3.5m altitude, heading 180, 10 mins
JC180	Survey Site	049	ROV	ROV372	38	HYW	HYW03	HYW2	JC180-049-ROV372/HYW03	19/05/2019	**09:55:00**	HYW placed on sled
JC180	Survey Site	050	ROV	ROV373	0	ISIS	ISIS373		JC180-050-ROV373/ISIS373	19/05/2019	**12:37:00**	
JC180	Survey Site	050	ROV	ROV373	1	BCH	BCH05	BCH1	JC180-050-ROV373/BCH05	19/05/2019	**14:10:00**	deployed BCH
JC180	Survey Site	050	ROV	ROV373	2	GAS	GAS01	GAS8	JC180-050-ROV373/GAS01	19/05/2019	**14:33:00**	~450ml suction. Funnel fell of after sample taken
JC180	Survey Site	050	ROV	ROV373	3	GAS	GAS02	GAS7	JC180-050-ROV373/GAS02	19/05/2019	**14:51:00**	altitude 1.5m
JC180	Survey Site	050	ROV	ROV373	4	NSK	NSK01	NSK4	JC180-050-ROV373/NSK01	19/05/2019	**15:15:00**	altitude 1.3m above bubble streams
JC180	Survey Site	050	ROV	ROV373	5	NSK	NSK02	NSK5	JC180-050-ROV373/NSK02	19/05/2019	**15:15:00**	altitude 1.3m above bubble streams
JC180	Survey Site	050	ROV	ROV373	6	NSK	NSK03	NSK6	JC180-050-ROV373/NSK03	19/05/2019	**15:15:00**	altitude 1.3m above bubble streams
JC180	Survey Site	050	ROV	ROV373	7	NSK	NSK04	NSK1	JC180-050-ROV373/NSK04	19/05/2019	**15:15:00**	altitude 1.3m above bubble streams
JC180	Survey Site	050	ROV	ROV373	8	NSK	NSK05	NSK2	JC180-050-ROV373/NSK05	19/05/2019	**15:28:00**	altitude 1.7m at CO2 container
JC180	Survey Site	050	ROV	ROV373	9	NSK	NSK06	NSK3	JC180-050-ROV373/NSK06	19/05/2019	**15:28:00**	altitude 1.7m at CO2 container
JC180	Survey Site	050	ROV	ROV373	10	GAS	GAS03	GAS5	JC180-050-ROV373/GAS03	19/05/2019	**15:35:00**	valve 4 open 15:32 - 15:41
JC180	Survey Site	051	ROV	ROV374	0	ISIS	ISIS374		JC180-051-ROV374/ISIS374	19/05/2019	**18:35:00**	
JC180	Survey Site	051	ROV	ROV374	1	HYW	HYW05	HYW2	JC180-051-ROV374/HYW05	19/05/2019	**19:25:00**	deployment of HYW2
JC180	Survey Site	052	AUV	AUV06	1	GAVIA	GAVIA05		JC180-052-AUV06/GAVIA05	20/05/2019	**06:55:00**	
JC180	Survey Site	053	SVP	SVP07	1	SVP	SVP01		JC180-053-SVP07/SVP01	20/05/2019	**09:10:00**	

JC180	Survey Site	054	ROV	ROV375	0	ISIS	ISIS375		JC180-054-ROV375/ISIS375	20/05/2019	**13:43:00**	
JC180	Survey Site	054	ROV	ROV375	1	BBL	BBL06	BBL2	JC180-054-ROV375/BBL06	20/05/2019	**14:43:00**	BBL2 picked up
JC180	Survey Site	054	ROV	ROV375	2	BBL	BBL07	BBL1	JC180-054-ROV375/BBL07	20/05/2019	**14:58:00**	BBL1 deployed
JC180	Survey Site	054	ROV	ROV375	3	GAS	GAS01	GAS03	JC180-054-ROV375/GAS01	20/05/2019	**15:29:00**	
JC180	Survey Site	054	ROV	ROV375	4	GAS	GAS02	GAS07	JC180-054-ROV375/GAS02	20/05/2019	**15:38:00**	
JC180	Survey Site	054	ROV	ROV375	5	NSK	NSK01	NSK4	JC180-054-ROV375/NSK01	20/05/2019	**15:57:00**	altitude 1.4m
JC180	Survey Site	054	ROV	ROV375	6	NSK	NSK02	NSK5	JC180-054-ROV375/NSK02	20/05/2019	**15:57:00**	niskins above bubble stream at seep site
JC180	Survey Site	054	ROV	ROV375	7	NSK	NSK03	NSK6	JC180-054-ROV375/NSK03	20/05/2019	**15:57:00**	
JC180	Survey Site	054	ROV	ROV375	8	NSK	NSK04	NSK1	JC180-054-ROV375/NSK04	20/05/2019	**15:58:00**	
JC180	Survey Site	054	ROV	ROV375	9	NSK	NSK05	NSK2	JC180-054-ROV375/NSK05	20/05/2019	**16:18:00**	niskins at 2m altitude at gas rig
JC180	Survey Site	054	ROV	ROV375	10	NSK	NSK06	NSK3	JC180-054-ROV375/NSK06	20/05/2019	**16:19:00**	
JC180	Survey Site	054	ROV	ROV375	11	GAS	GAS03	GAS06	JC180-054-ROV375/GAS03	20/05/2019	**16:24:00**	Written as Niskin in the Event Log but it was a Gas Sample
JC180	Survey Site	055	ROV	ROV376	0	ISIS	ISIS376		JC180-055-ROV376/ISIS376	20/05/2019	**20:15:00**	
JC180	Survey Site	055	ROV	ROV376	1	MPR	MPR01		JC180-055-ROV376/MPR01	20/05/2019	**21:11:00**	First MPR deployment at 20m
JC180	Survey Site	055	ROV	ROV376	2	BP	BP01		JC180-055-ROV376/BP01	20/05/2019	**21:47:00**	Bubble panel at 1.9m above seabed
JC180	Survey Site	055	ROV	ROV376	3	BP	BP02		JC180-055-ROV376/BP02	20/05/2019	**21:51:00**	bubble panel at 2.4m above seabed
JC180	Survey Site	055	ROV	ROV376	4	BP	BP03		JC180-055-ROV376/BP03	20/05/2019	**21:55:00**	bubble panel at 3.4 m altitude
JC180	Survey Site	055	ROV	ROV376	5	BP	BP04		JC180-055-ROV376/BP04	20/05/2019	**21:57:00**	bubble panel at 4.0 m altitude

JC180	Survey Site	055	ROV	ROV376	6	BP	BP05	JC180-055-ROV376/BP05	20/05/2019	**22:03:00**	bubble panel at 4.5m altitude
JC180	Survey Site	055	ROV	ROV376	7	BP	BP06	JC180-055-ROV376/BP06	20/05/2019	**22:07:00**	second deployment 8m north of bubble seep
JC180	Survey Site	055	ROV	ROV376	8	MPR	MPR02	JC180-055-ROV376/MPR02	20/05/2019	**22:26:00**	bubble panel at 3.9m altitude
JC180	Survey Site	055	ROV	ROV376	9	BP	BP07	JC180-055-ROV376/BP07	20/05/2019	**22:53:00**	bubble panel at 4.5m altitude
JC180	Survey Site	055	ROV	ROV376	10	BP	BP08	JC180-055-ROV376/BP08	20/05/2019	**22:57:00**	bubble panel at 5.1m altitude
JC180	Survey Site	055	ROV	ROV376	11	BP	BP09	JC180-055-ROV376/BP09	20/05/2019	**23:09:00**	bubble panel at 5.4 m altitude
JC180	Survey Site	055	ROV	ROV376	12	BP	BP10	JC180-055-ROV376/BP10	20/05/2019	**23:16:00**	third deployment
JC180	Survey Site	055	ROV	ROV376	13	MPR	MPR03	JC180-055-ROV376/MPR03	20/05/2019	**23:49:00**	at -50cm from reference point
JC180	Survey Site	055	ROV	ROV376	14	WCH	WCH01	JC180-055-ROV376/WCH01	21/05/2019	**00:02:00**	at reference point
JC180	Survey Site	055	ROV	ROV376	15	WCH	WCH02	JC180-055-ROV376/WCH02	21/05/2019	**00:09:00**	at 50 cm from reference point
JC180	Survey Site	055	ROV	ROV376	16	WCH	WCH03	JC180-055-ROV376/WCH03	21/05/2019	**00:19:00**	at 100cm from reference point
JC180	Survey Site	055	ROV	ROV376	17	WCH	WCH04	JC180-055-ROV376/WCH04	21/05/2019	**00:29:00**	at -50cm from reference point
JC180	Survey Site	055	ROV	ROV376	18	WCH	WCH05	JC180-055-ROV376/WCH05	21/05/2019	**00:39:00**	at -100cm from reference point
JC180	Survey Site	055	ROV	ROV376	19	MPR	MPR04	JC180-055-ROV376/MPR04	21/05/2019	**01:03:00**	fourth deployment on bubble stream
JC180	Survey Site	055	ROV	ROV376	20	WCH	WCH06	JC180-055-ROV376/WCH06	21/05/2019	**01:17:00**	at reference point
JC180	Survey Site	055	ROV	ROV376	21	WCH	WCH07	JC180-055-ROV376/WCH07	21/05/2019	**01:29:00**	at -50 cm from reference point
JC180	Survey Site	055	ROV	ROV376	22	WCH	WCH08	JC180-055-ROV376/WCH08	21/05/2019	**01:39:00**	at -100cm from reference point
JC180	Survey Site	055	ROV	ROV376	23	WCH	WCH09	JC180-055-ROV376/WCH09	21/05/2019	**01:49:00**	at -150cm from reference point

JC180	Survey Site	055	ROV	ROV376	24	MPR	MPR05		JC180-055-ROV376/MPR05	21/05/2019	**02:24:00**	3m west of seep
JC180	Survey Site	055	ROV	ROV376	25	WCH	WCH10		JC180-055-ROV376/WCH10	21/05/2019	**02:37:00**	at reference point
JC180	Survey Site	055	ROV	ROV376	26	WCH	WCH11		JC180-055-ROV376/WCH11	21/05/2019	**02:58:00**	at 100cm from reference point
JC180	Survey Site	055	ROV	ROV376	27	MPR	MPR06		JC180-055-ROV376/MPR06	21/05/2019	**03:35:00**	5m west of seep
JC180	Survey Site	055	ROV	ROV376	28	MPR	MPR07		JC180-055-ROV376/MPR07	21/05/2019	**04:51:00**	1m north of seep
JC180	Survey Site	055	ROV	ROV376	29	NSK	NSK01	NSK4	JC180-055-ROV376/NSK01	21/05/2019	**05:01:00**	2.2m altitude
JC180	Survey Site	055	ROV	ROV376	30	NSK	NSK02	NSK5	JC180-055-ROV376/NSK02	21/05/2019	**05:01:00**	2.2m altitude
JC180	Survey Site	055	ROV	ROV376	31	GAS	GAS01	GAS5	JC180-055-ROV376/GAS01	21/05/2019	**05:11:00**	at tank
JC180	Survey Site	055	ROV	ROV376	32	MPR	MPR08		JC180-055-ROV376/MPR08	21/05/2019	**06:11:00**	mpr station 8: close to pipe and outermost sediment probe (picking up MPR?)
JC180	Survey Site	055	ROV	ROV376	33	NSK	NSK03	NSK6	JC180-055-ROV376/NSK03	21/05/2019	**06:21:00**	2m altitude
JC180	Survey Site	055	ROV	ROV376	34	NSK	NSK04	NSK1	JC180-055-ROV376/NSK04	21/05/2019	**06:21:00**	2m altitude
JC180	Survey Site	055	ROV	ROV376	35	NSK	NSK05	NSK2	JC180-055-ROV376/NSK05	21/05/2019	**06:22:00**	2m altitude
JC180	Survey Site	055	ROV	ROV376	36	NSK	NSK06	NSK3	JC180-055-ROV376/NSK06	21/05/2019	**06:22:00**	2m altitude
JC180	Survey Site	055	ROV	ROV376	37	GAS	GAS02	GAS4	JC180-055-ROV376/GAS02	21/05/2019	**06:30:00**	at bubble site and ground level
JC180	Survey Site	055	ROV	ROV376	38	GAS	GAS03	GAS3	JC180-055-ROV376/GAS03	21/05/2019	**07:16:00**	at 2 m altitude
JC180	Survey Site	055	ROV	ROV376	39	PSH	PSH01	3B	JC180-055-ROV376/PSH01	21/05/2019	**07:26:00**	centre of site, between active and large extinct pockmark
JC180	Survey Site	055	ROV	ROV376	40	PSH	PSH02	2B	JC180-055-ROV376/PSH02	21/05/2019	**07:28:00**	centre, east of active pockmark
JC180	Survey Site	055	ROV	ROV376	41	PSH	PSH03	1B	JC180-055-ROV376/PSH03	21/05/2019	**07:31:00**	centre, 5cm north of first pushcore

JC180	Survey Site	055	ROV	ROV376	42	PSH	PSH04	3Y	JC180-055-ROV376/PSH04	21/05/2019	**07:33:00**	centre, 5cm north of second pushcore
JC180	Survey Site	055	ROV	ROV376	43	PSH	PSH05	2Y	JC180-055-ROV376/PSH05	21/05/2019	**07:36:00**	centre
JC180	Survey Site	055	ROV	ROV376	44	PSH	PSH06	1Y	JC180-055-ROV376/PSH06	21/05/2019	**07:39:00**	centre of site
JC180	Survey Site	055	ROV	ROV376	45	WCH	WCH12		JC180-055-ROV376/WCH12	21/05/2019	**08:01:00**	6m north of seep 50cm west
JC180	Survey Site	056	ROV	ROV377	0	ISIS	ISIS377		JC180-056-ROV377/ISIS377	22/05/2019	**09:51:00**	
JC180	Survey Site	056	ROV	ROV377	1	BCH	BCH05	BCH1	JC180-056-ROV377/BCH05	22/05/2019	**13:02:00**	picking up
JC180	Survey Site	057	ROV	ROV378	0	ISIS	ISIS378		JC180-057-ROV378/ISIS378	22/05/2019	**13:52:00**	
JC180	Survey Site	057	ROV	ROV378	1	HYW	HYW05	HYW2	JC180-057-ROV378/HYW05	22/05/2019	**14:56:00**	HYW moved to storage location
JC180	Survey Site	057	ROV	ROV378	2	HYW	HYW04	HYW1	JC180-057-ROV378/HYW04	22/05/2019	**15:41:00**	HYW moved to storage location
JC180	Survey Site	057	ROV	ROV378	3	SDO	SDO04	SDO2	JC180-057-ROV378/SDO04	22/05/2019	**15:52:00**	flipped SDO recovered
JC180	Survey Site	057	ROV	ROV378	4	SDO	SDO03	SDO1	JC180-057-ROV378/SDO03	22/05/2019	**15:57:00**	flipped SDO recovered
JC180	Survey Site	057	ROV	ROV378	5	SDO	SDO01	SDO4	JC180-057-ROV378/SDO01	22/05/2019	**16:01:00**	flipped SDO recovered
JC180	Survey Site	057	ROV	ROV378	6	SDO	SDO02	SDO3	JC180-057-ROV378/SDO02	22/05/2019	**16:05:00**	flipped SDO recovered
JC180	Survey Site	057	ROV	ROV378	7	BBL	BBL07	BBL1	JC180-057-ROV378/BBL07	22/05/2019	**16:09:00**	BBL collected
JC180	Survey Site	058	ROV	ROV379	0	ISIS	ISIS379		JC180-058-ROV379/ISIS379	22/05/2019	**16:39:00**	
JC180	Survey Site	058	ROV	ROV379	1	HYW	HYW04	HYW2	JC180-058-ROV379/HYW04	22/05/2019	**17:15:00**	HYW picked up and put onto tool sled
JC180	Survey Site	059	ROV	ROV380	0	ISIS	ISIS380		JC180-059-ROV380/ISIS380	22/05/2019	**17:38:00**	
JC180	Survey Site	059	ROV	ROV380	1	HYW	HYW05	HYW1	JC180-059-ROV380/HYW05	22/05/2019	**18:08:00**	HYW picked up and put onto tool sled

JC180	Offsite Survey2	060	AUV	AUV07	1	GAVIA	GAVIA06		JC180-060-AUV07/GAVIA06	25/05/2019	**09:12:00**	
JC180	Offsite Survey2	061	SVP	SVP08	1	SVP	SVP01		JC180-061-SVP08/SVP01	25/05/2019	**13:02:00**	
JC180	Old BSL site	062	BSL	BSL02	1	BSL	BSL01	Old BSL	JC180-062-BSL02/BSL01	25/05/2019	**18:35:00**	weight deployed and lander recovered
JC180	Offsite Survey3	063	AUV	AUV08	1	GAVIA	GAVIA07		JC180-063-AUV08/GAVIA07	26/05/2019	**09:08:00**	
JC180	Survey Site	064	SVP	SVP09	1	SVP	SVP01		JC180-064-SVP09/SVP01	26/05/2019	**11:21:00**	
JC180	Survey Site	065	ROV	ROV381	0	ISIS	ISIS381		JC180-065-ROV381/ISIS381	26/05/2019	**16:06:00**	
JC180	Survey Site	065	ROV	ROV381	1	BSL	BSL02	Old BSL	JC180-065-ROV381/BSL02	26/05/2019	**18:33:00**	strops attached and recovery line in place
JC180	Survey Site	065	ROV	ROV381	2	VT	VT01	Video Transect	JC180-065-ROV381/VT01	26/05/2019	**19:05:00**	start of pipe 2 video transect
JC180	Survey Site	065	ROV	ROV381	3	VT	VT02	Video Transect	JC180-065-ROV381/VT02	26/05/2019	**20:01:00**	start of pipe 1 video transect
JC180	Survey Site	065	ROV	ROV381	4	VT	VT03	Video Transect	JC180-065-ROV381/VT03	26/05/2019	**20:24:00**	footprint of co2 container
JC180	Survey Site	065	ROV	ROV381	5	NSK	NSK01	NSK4	JC180-065-ROV381/NSK01	26/05/2019	**20:30:00**	Estimated time as not recorded in log, at CO2 container
JC180	Survey Site	065	ROV	ROV381	6	NSK	NSK02	NSK5	JC180-065-ROV381/NSK02	26/05/2019	**20:30:00**	Estimated time as not recorded in log, at CO2 container
JC180	Survey Site	065	ROV	ROV381	7	NSK	NSK03	NSK6	JC180-065-ROV381/NSK03	26/05/2019	**20:40:00**	Niskin over centre release point
JC180	Survey Site	065	ROV	ROV381	8	NSK	NSK04	NSK1	JC180-065-ROV381/NSK04	26/05/2019	**20:40:00**	Niskin over centre release point
JC180	Survey Site	065	ROV	ROV381	9	NSK	NSK05	NSK2	JC180-065-ROV381/NSK05	26/05/2019	**20:40:00**	Niskin over centre release point
JC180	Survey Site	065	ROV	ROV381	10	NSK	NSK06	NSK3	JC180-065-ROV381/NSK06	26/05/2019	**20:40:00**	Niskin over centre release point
JC180	Survey Site	065	ROV	ROV381	11	PSH	PSH01	1Red	JC180-065-ROV381/PSH01	26/05/2019	**20:46:00**	Doppler drift, no possition given. Taken at crater
JC180	Survey Site	065	ROV	ROV381	12	PSH	PSH02	2Red	JC180-065-ROV381/PSH02	26/05/2019	**20:49:00**	Doppler drift, no possition given. Taken at crater

JC180	Survey Site	065	ROV	ROV381	13	PSH	PSH03	3Red	JC180-065-ROV381/PSH03	26/05/2019	**20:52:00**	Doppler drift, no possition given. Taken at crater
JC180	Survey Site	065	ROV	ROV381	14	PSH	PSH04	1Blue	JC180-065-ROV381/PSH04	26/05/2019	**20:54:00**	Doppler drift, no possition given. Taken at crater
JC180	Survey Site	065	ROV	ROV381	15	PSH	PSH05	2Blue	JC180-065-ROV381/PSH05	26/05/2019	**20:57:00**	Doppler drift, no possition given. Taken at crater
JC180	Survey Site	065	ROV	ROV381	16	PSH	PSH06	3Blue	JC180-065-ROV381/PSH06	26/05/2019	**21:07:00**	Doppler drift, no possition given. Taken at crater
JC180	Survey Site	066	SVP	SVP10	1	SVP	SVP01		JC180-066-SVP10/SVP01	27/05/2019	**09:04:00**	On bottom time used
JC180	Survey Site	067	AUV	AUV09	1	GAVIA	GAVIA08		JC180-067-AUV09/GAVIA08	27/05/2019	**05:16:48**	
JC180	Survey Site								JC180-000-/			

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