RV Poseidon POS526 Cruise Report

Bergen (Norway) – Doggerbank (Netherlands) –
Hirtshals (Denmark) – Tisler (Norway) – Kiel (Germany)
July 23rd 2018 – August 11th 2018

POS526 "SeASOM":

Semi-Autonomous Subsurface Optical Monitoring for methane seepage and cold-water coral studies in the North Sea

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1. Cruise Summary

The SeASOM cruise POS 526 from 23 July (Bergen in Norway) to 11th August 2018 (Kiel, Germany) was split in two legs with a stop-over in Hirtshals, Denmark on 1st August. The first part visited the Dogger Bank seep site in the Dutch EEZ. Investigations of gas fluxes of dissolved and free methane (bubbles) were the scientific focus of several different studies. SeASOM was in this respect also applying new technology and was run as part of the Helmholtz infrastructure project MOSES, a new Wave Glider with gas analysing capabilities, the new AUV ANTON as well as a sophisticated gas analysing system from USGS were used to shade light into gas fluxes from the seafloor through the water and into the atmosphere.

The second leg focussed on ecological and technical studies in the Tisler Reef area in Norway. Here the distribution of different fauna and their relation to high resolution bathymetry and bottom current information was the focus of the research. Again technical trails where part of the research, AUV ANTON was used for the first time in difficult terrain and showed its capabilities to dive down to 400m in Oslo Trough. Submersible JAGO was equipped with a stereographic camera system for highly detailed photogrammetric analyses and for the first time it was possible to log and see the locating of JAGO inside the submersible in real time, using underwater navigation and data communication technology of MOSES. In summery the cruise was very successful, ample of good data have been acquired and the cooperation between science and ship crew went smooth and professional.

2. Participants

2.1. Principal Investigators

Prof Dr. Jens Greinert (Chief scientist)
GEOMAR Helmholtz Center for Ocean Research Kiel, Wischhofstr. 1-3, 24148 Kiel, Germany
Dr. Timm Schoening
GEOMAR Helmholtz Center for Ocean Research Kiel, Wischhofstr. 1-3, 24148 Kiel, Germany
Dr. Autun Purser
Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Am Handelshafen 12, 27570 Bremerhaven, Germany

2.2. Scientific Party

Name	Institute	Task	Leg(s)
Jens Greinert	GEOMAR	Hydro-acoustics, CTDs	1&2
Timm Schoening	GEOMAR	Image computing, Data management	1
Björn Fiedler	GEOMAR	Waveglider, CH_4, O_2, CO_2 measurements	1
John Pohlman	USGS	CH_4 & CO_2 measurements	1
Michael Casso	USGS	CH_4 & CO_2 measurements	1
Tim Weiß	GEOMAR	Picarro, GasQuant II, Bubble Box, MfA	1
Malte Jürchott	GEOMAR	CH_4 & CO_2 measurements	1
Kevin Köser	GEOMAR	Image analysis	2
Autun Purser	AWI	Cold-water corals, LOKI	2
Yifan Song	GEOMAR	Image analysis	2
Jochen Mohrmann	GEOMAR	Image analysis	2
Peter Striewski	GEOMAR	Submersible JAGO	1&2
Karen Hissmann	GEOMAR	Submersible JAGO	1&2

Jürgen Schauer	GEOMAR	Submersible JAGO	1&2
Nikolai Diller	GEOMAR	AUV Anton	1&2
Jens Schröder	GEOMAR	AUV Anton	1&2

USGS: United States Geological Survey
AWI: Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research

Figure 1: Group photo of Leg-1, Bergen to Hirtshals.

Figure 2: Group photo of Leg-2, Hirtshals to Kiel.

2.3. Crew

Matthias Günther	Captain
Dirk Thürsam	1st Officer
Oliver Jacobs	2nd Officer
Stefanie Liedtke	Chief Engineer
Michael Rusik	2nd Engineer
Frank Baumann	Electrician
Julian Langhans	Motorman / Sysop
Ralf Dieter Müller Homburg	Cook
Martina Tober	Stewardess
Frank Schrage	Bosun
Roland Heyne	Seaman
Maximilian Schacht	Seaman
Matthias Maas	Seaman
Torge Dembetzki	Seaman
Finn Peterson	Seaman

3. Narrative

Tuesday, July 24th, 16:50 UTC, 56°01N, 004°04E: Poseidon cruise 526 “Semi-Autonomous Subsea Optical Mapping” started on July 19th with the arrival of the international colleagues from the USA in Bergen. On the next day, the first three scientists and technicians from GEOMAR joined them for scientific debates, cruise planning and a first glimpse of Poseidon from afar. By 9am the next morning the group of five arrived at the ship for a warm welcome by the crew and the JAGO team that was already on board during POS525. Eager to get going, the waiting container was opened immediately and the full loading already emptied by 9:45 and all equipment was on its way to the various labs on the ship. In the afternoon the cruise team was completed by the arrival of the AUV technicians and further scientists from GEOMAR. Unpacking and lab setup continued through the next day and by the evening the semi-autonomous gear was readily assembled: the brand new AUV “Anton”, the MOSES WaveGlider, submersible JAGO, the mobile SHiPCC computer cluster and equipment like the BubbleBox, and the GasQuant lander. Many tubes and wires were added to the vessel to pipe gas samples from the bow and the top of the mast to the wet lab, to connect further underwater navigation beacons and hydro-acoustic sensors from the moon-pool and the portside pole to the dry and chemistry lab. With the arrival of the last, delayed equipment by airfreight the cruise personnel and technology was ready to leave port after lunch time with a slight delay of five hours to plan. The ship headed south through the fjords and soon arrived in open water to steam towards the working area. In the morning of the 24th, the vessel stopped for the first equipment test with a successful first buoyancy test of the new AUV and a minor equipment failure during the ADCP pole lowering that could immediately be repaired by the ship’s crew which has been extremely helpful, proactive and professional to achieve the scientific goals of the cruise. Afterwards the course south was resumed, the last sensors connected to the ship’s and additional navigation sensors and the entire range of hydro-acoustic, optical and environmental sensors was waiting for the ETA in the working area at 6 pm to begin the science program.

Friday, July 27th, 16:13 UTC, 55°18N, 004°03E : Three days of extensive testing, sampling and measuring have passed. All labs are in full operation and the data archives are filling up. The

primary working area is the “jumping horse” bubble seep site. We inspected it by two night-long hydro-acoustic surveys using single- and multi-beam echo-sounders combined with a high-accuracy motion sensor and an acoustic Doppler current profiler, all from aboard the vessel. During daytime, these areal measurements were extended by high-resolution bubble measurements with CTDs (sampling the water near the seafloor and throughout the water column) and very successfully by the BubbleBox stereo camera system mounted on JAGO. This system alone acquired more than one Terabyte of image data in the first to days in the working area. Parallel to all stations, the atmospheric methane and CO_2 concentrations are being measured by the Picarro system on board the vessel continuously. By combing all the measurements from all sensors, the methane flux can be measured from the release at the seafloor through the water column and into the atmosphere.
While the scientific work program is proceeding well, currently slightly slowed down by the weather though, the technological program is also fully underway. The BubbleBox has shown its usefulness. The Waveglider first had a hard time moving along due to the near perfectly flat sea surface but is now measuring continuously and has shown its ability to avoid incoming ship traffic (in this case RV Poseidon). The new underwater navigation and communication system that links the AUV, the Waveglider, the vessel and JAGO has created much trouble the first days but now seems to be working well, increasing the navigation accuracy and data exchange capabilities for the upcoming gear deployments. The team is now tweaking the last settings to achieve perfect integration into the existing systems. AUV Anton has had its first dive missions, earned its first bumps and scratches but is still looking forward to produce the first data sets for scientific interpretation. The GasQuant lander has been deployed, inspected and redirected by JAGO and is now acquiring bubble flare data across tidal cycles. As the wind has increased, it is yet unknown for how many tidal cycles it will be recording as recovery with JAGO cannot be conducted the next days.

Monday 6th August 2018, 09:37 local time, 59°00’N, 10°59’E: As anticipated we arrived in Hirtshals ‘bang on time’ at 15:00 in the harbour and our four colleagues from GEOMAR and AWI where already at the pier waiting for us. Kevin., Yifan, Jochen and Autun had started in Kiel at 8:00am make their way to north Denmark, while POSEIDON was still steaming in good weather conditions. In the harbour there was a quick hand over from one group to the others; possibly different to other cruises, the hand over was more about data management, last computer updates, and ‘did you do the camera calibration already’ than taking care of samples, chemical, next sample locations. All this went very fine and the six people leaving he boat could start their 5h journey south shortly before 5pm. As we heard during the evening they arrived safely in Kiel and everybody was dropped off at their final destination.

Ahead of us was a different scientific topic, a different ‘much more rugged’ undersea and oversea landscape, and new technical challenges. Before that everybody stretched their legs in Hirtshals and/or got accustomed with the ship (again two colleagues joined the first time a scientific cruise). We left Hirtshals at 8:00 in the morning of the 2nd August and arrived in the working area of the Tisler Reef at 18:00 to immediately have one CTD for collecting a good sound velocity profile followed by two TV-CTD tows across the reef. These were done to see the state of the corals on top of the reef mountain to see the state of the corals and find a good location for the following ANTON and JAGO dives. With regards to the multibeam, apparently there is only one multibeam data set that is used for many publications from this area. This was recorded during cruise ALKOR 232 in 2003, done by one of the POS526 scientists, a much younger ‘now chief-scientist’. The multibeam on POSEIDON is a modern

Seabeam 3050; the previous one also was a Seabeam but a 1180 system. The new one has more beams, smaller beam width and thus a better resolution as the old one, which became evident when comparing the old, with the new data.

The weather was very good the 3rd August and each one JAGO and AUV dive were successfully undertaken, ANTON tested its multibeam and JAGO aimed at deploying a number of small self-contained camera systems from AWI that have just been finished before the cruise. Unfortunately, the systems didn't work during their first deployment as hoped for, which gave Autun some extra-long hours to fix them. The next day again had good weather for us, two JAGO dives before and after lunch as well as one AUV dive from 12:00 to 14:00 could be performed. The first JAGO dive aimed at performing photogrammetric measurements with a stereographic camera system, this worked out successfully, the second dive was and exploratory dive starting from the deep gully east of the main reef complex. Here Jürgen and Jens experienced some very strong currents that were good for giving first hand insight how plankton might feel from time to time. Despite this they discovered a very healthy and thriving reef system that stretches from the gully upward to the next rugged mount structure in 120 to 105m water depth. This dive finally ended up at the top of the main reef complex in 68m water depth covering the whole length of the living reef. For sure the eastern side is much more alive than the top and we start to think that the top part is much less pristine not due to fishing activity but environmental circumstances. This is because the water structure is strongly stratified with a very strong density change in between 20 and 40m which also gave JAGO some trouble during one dive, it was simply not heavy enough to sink to the bottom and extra weight needed to be put on top to make it finally sink. We think that this strong stratification prevents the deeper parts of the reef to experience warm water episodes keeping these parts under less temperature stress while at the same time being feed by the strong bottom currents through the gully with more than 1 kn speed. After this exciting new finding, the night was spent with ADCP measurements to verify the local current regime at different locations of the reef.

After additional 5 TV-CTD casts crisscrossing the reef during the night, we had delay our plans for further JAGO and AUV dives until the morning of the 6th August due to not so good weather. Time was used to fill in gaps in the multibeam data. At 6:18 UTC on 6th August, AUV ANTON went on a rendezvous with JAGO; both vehicles first met in the water column for taking a first look at each other. ANTON descended quickly and was later on filemed by JAGO how it went up and down one track line very precisely (dives AUV-7 and JAGO-7). The same day both vehicles did a second dive to make a multibeam survey, ANTON, and to go on a exploration and USBL-test survey with JAGO (its 1400 dive with Karen and Jürgen diving together). After filling in multibeam data gaps, the next dive with JAGO finally established the bidirectional data connection. The modem worked as hoped and the exact position of the submersible could be seen inside JAGO in real time for the first time! The same day, two more AUV and JAGO dives were performed before a CTD casts recovered some water to test the LOKI plankton camera system. A series of six CTD cast at different stations across the reef were performed for sampling the water for plankton in different depth, the EK80 SBES and the ADCP were running simultaneously to link acoustic data with CTD and image data for a more conclusive analysis. During the morning of our final working day, JAGO went into the water again to recover a number of PiCAMs that were placed on the top of the 'not so active' reef complex. Before ending the scientific work with three additional TV-CTD tows over the reef, the AUV still needed to show its deep diving capabilities in almost 400m water depth. This dive was somehow stressful for the AUV team and other members of the science team as the vehicle soon after starting its decent went very fast in ENE direction, out of sight of the USBL. For about 30 minutes there were no signs of the AUV anymore, but finally we received messages and positions again that indicated that the AUV is at 395m water depth on N-S transects. After all the station work, the transit back to Kiel started at 8pm. During the transect we experienced a weather spectacle during the night from 30th to 31st with wind gusts of 11 beaufort from southerly directions which slowed the ship down, quite a bit. We nevertheless reached Kiel at 9am on Friday the 31st and started unloading equipment and corals alaike.

4. Aims of the Cruise

The cruise had two general goals separated in technological developments and testing as well as scientific goals in the two working areas. The environmental science goals aimed at continuing monitoring efforts at the Dogger Bank seep site (North Sea) that has been studied for more than 10 years repeatedly (Schroot et al., 2005; Mau et al. 2015; Römer et al., in review) and determine a highly accurate and data supported spatial flux and complete methane budget from the seafloor into the atmosphere. The second science at Tisler cold water coral reef area (Norwegian Skagerrak) was dedicated to continue monitoring of the state of the reef which started very soon after its discovery in 2002 (Lundälv, 2004; Lavaleye, et al., 2009) and to acquire new high resolution data of the distribution of living and dead corals and other associated fauna.

These scientific aims were accompanied by technology testing and integration. GEOMAR's new autonomous underwater vehicle (AUV) “Anton” (Girona500 type) and the manned submersible JAGO were used to link high-resolution / low spatial coverage gas bubble measurements with low-resolution / high spatial coverage hydro-acoustic measurements performed by the vessel. Combined with gas concentration measurements in the water column (CTD water sampling) at the sea surface (equilibrator system) and in the atmosphere (CRDS gas analyzer) from on board the vessel and a waveglider we could cover a larger area in very high detail. This joined data set will provide an ideal calibration data sets for quantifying gas fluxes from the seafloor through the water column into the atmosphere. Contiguous optical mapping of deep water coral reefs by JAGO and towed camera in high-relief terrain provides baseline data for future monitoring campaigns and state-of-the-art data management workflows. These were implemented for image data curation alongside the Digital Earth project to initiate seamless data transfer from sensors to public data repositories. An additional technological task was the standardized underwater navigation and general communication systems between sensors and devices. This was successfully integrated into various diving and surface gear and helped (JAGO, AUV Anton, RV Poseidon, TV-CTD, Waveglider).

Dogger Bank seep area (also a Show Case of Digital Earth)

Quantitatively map the free gas release form the seafloor into the water column and the atmosphere in high spatial resolution, considering external forces (waves, tides) at multiple, differently intense, seep locations in the area:

- Perform repeated hydro-acoustic singlebeam (SBES) and multibeam (MBES) joined surveys for mapping and quantifying free gas flow rates/fluxes from the area and establish links between change detection and external forces on different time scales (hour to several days)

- Use JAGO for deploying the BubbleBox lander and GasQuant-2 based visual and in-situ acoustic observations and measurements to support spatial quantitative bubble flow rate and flux analyses with bubble size distributions, bubble/plume rising speeds and temporal variability
- Perform state-of-the art chemical gas analyses of water and bubble samples
- Link methane distribution patterns in the water column with oceanographic parameters as ship-based ADCP current measurements and tidal information
- Determine the physical properties of the water column using CTD casts
- Perform continuous sea surface water and atmospheric analyses for gas flux analyses using equilibrator technique linked to CRDS (->USGS GAS system) ad direct atmospheric analyses (-> GEOMAR AIS system)

Tisler cold water coral reef area:

Within the Tisler reef area newly collected visual studies aim for a comparison with historical data sets and at the same time perform higher resolving and spatially wider covering visual and acoustic data, various research topics have been addressed:

- Remap the larger Tisler Reef area in higher resolution using the Seabeam 3050 system of RV POSEIDON.
- Perform visual observations in a planned and conclusive approach investigating the entire reef structure as well as outside areas to investigate reef re-establishment and/or decline.
- Study coral and related fauna behavior over a few days to see the influence of changing currents
- Use ship-mounted ADCP to elucidate current speeds and directions at different locations of the reef
- Investigate zooplankton migration in the reef environment to allow the identification of any diel vertical migration into the reef ecosystem

Technological and data science aims

The cruise provided data to that directly address research objectives of national and international projects like MOSES, Digital Earth and ENVRI+ and others:

- Test and deployment of novel shallow water AUVs as platforms for optical imaging.
- Assessment heterogeneous survey terrains with autonomous and manned underwater vehicles in a complimentary way in two very different terrains
- Testing next-generation marine research survey technology in the form of multiple communicating platforms (submersible, AUVs, Waveglider) to provide continuous and accurate underwater navigation as well as rapid feedback of sensor data
- Establish rapid semantic and quantitative assessment of optical imagery using mobile, on-board, high-performance compute infrastructure
- Acquiring optical data for state-of-the-art 3D reconstructions
- Implementing the MOSES and *Digital Earth* data management workflow from data acquisition through processing to storage in public databases and visualization.

5. Agenda of the Cruise

Following the aims of the cruise we performed studies in two different areas, the Dogger Bank Seep Area in the northern tip of the Dutch EEZ (south of the Dogger Bank) and the

Tisler Reef between the Tisler and Herføl islands of the Kosterfjord close to the Swedish border (Figure 3).

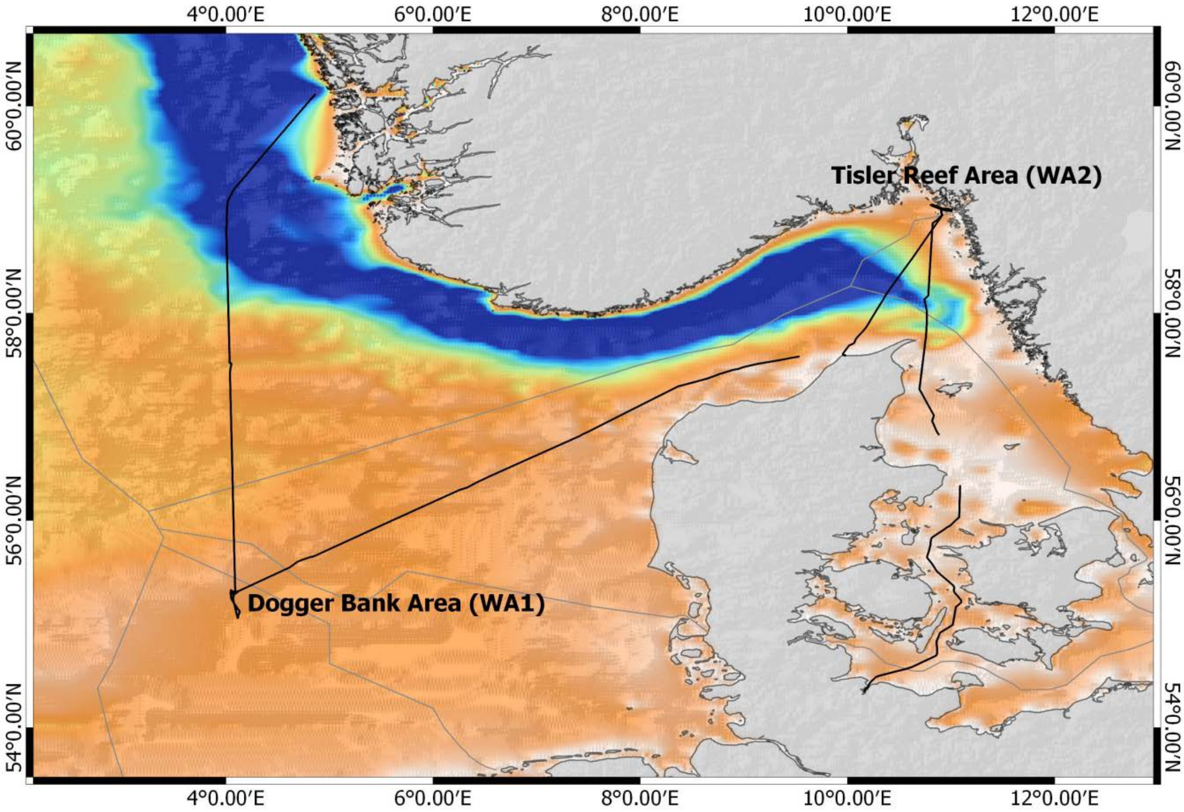


Figure 3: Cruise track of POS526 starting in Bergen, ending in Kiel with a stopover in Hirtshals (Denmark).

5.1. Dogger Bank (Working Area 1)

We started working in WA1 on 24 July at 21:30 UTC, taking a CTD for acquiring a sound velocity profile for all hydroacoustic systems planned to be used: MBES, SBES, ADCP (Appendix 11.1 Station List). Free gas release from the seafloor into the water column was targeted during repeated surveys across Cluster 1 and 5 in ENE-WSW direction (Figure 4) as well as during shorter survey perpendicular lines. Both CRDS Systems were running continuously to measure atmospheric (GEOMAR AIS) and sea surface methane and CO2 concentrations. The Seabeam 3050 was mainly used for recording water column data in WCI format, bathymetric data are not much of use as the seafloor is very flat and only tilts slightly towards the SW. During hydroacoustic surveys the EK80 system with its 38kHz transducer was used as well as the pole mounted 300kHz ADCP with bottom track option.

The Dogger Bank area was selected to test AUV ANTON for the first time because of the flat seafloor and shallow depth. JAGO was planned for detailed seafloor observations, using the BubbleBox gas flow and bubble size distribution measurements as well as for deploying the GasQuant-II lander system. AUV ANTON was planned to perform its maiden-dive and undertook this successfully. Unfortunately due to bad weather we had to stop JAGO and AUV operations and performed an intense CTD water sampling program at Cluster 1 and Cluster 2 instead. Sampling occurred with vertical casts at the same location but different current directions as well as during towed CTD stations where water was collected along transects in about 5m above the bottom. With this strategy we aimed at getting spatial and temporal variability of the tide dependent methane discharge and distribution of the two strong seep Clusters. The station list in the Appendix (11.1) details the different surveys and sample locations.

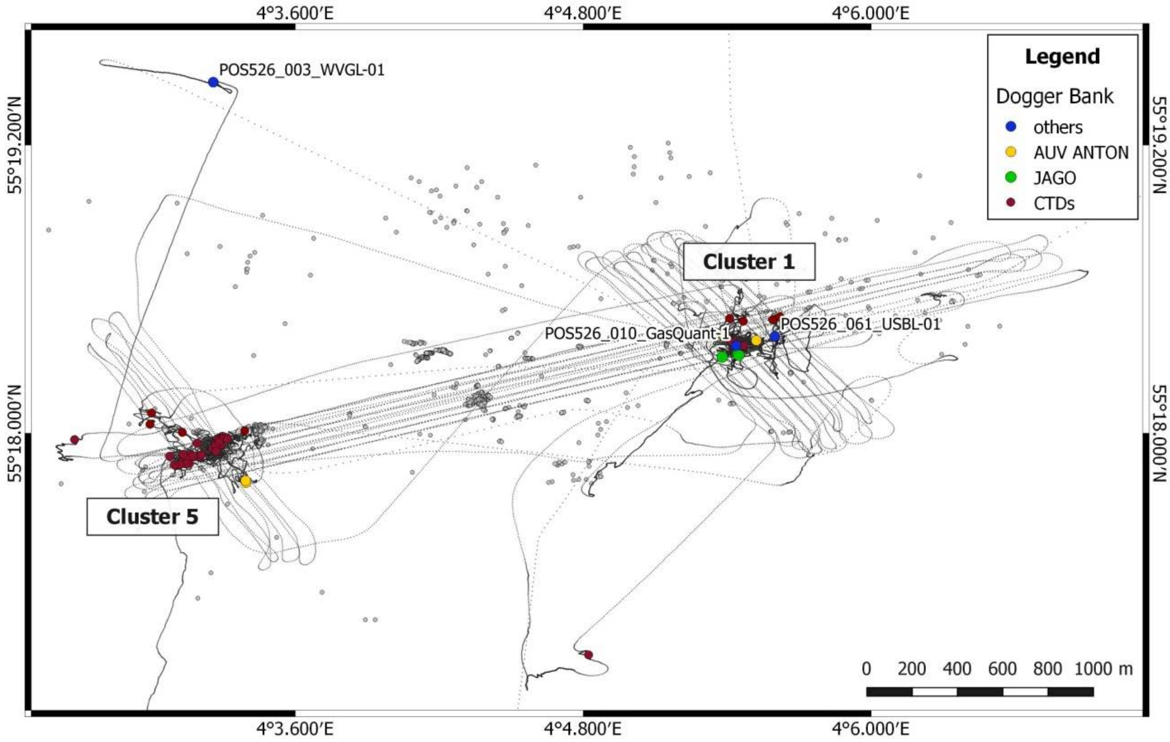


Figure 4: Overview of the cruise track at the Dogger Bank working area and the two main study sites at Cluster 1 and 5 indicated. Grey dots are seep locations from Römer et al. (2017) recorded during RV Heincke cruises.

5.2. Tisler Reef (Working Area 2)

Work in the Tisler Reef working area WA2 (Figure 5) focused on visual and acoustic observations of the seafloor and currents in the water column. As weather was better in the Tisler area, the AUV could be used more often and more JAGO dives could be performed as well. These stations took up most of the work during the day. The nights were spend with MBES mapping and long hours with towed video surveys along and across the reef structure. ADCP stations aimed at studying the different current regime across the reef which is strongly modulated by the morphology and the gully towards the east of the reef. JAGOs duty was to deploy several different camera systems on the seafloor and perform high resolution photogrammetry tracks across selected patches of the reef. Main focus was the top of the reef, although this is not the real active and living reef location as we learned during the cruise. Dives by JAGO and AUV ANTON where complicated due to strong bottom currents of up to 0.5m/s.

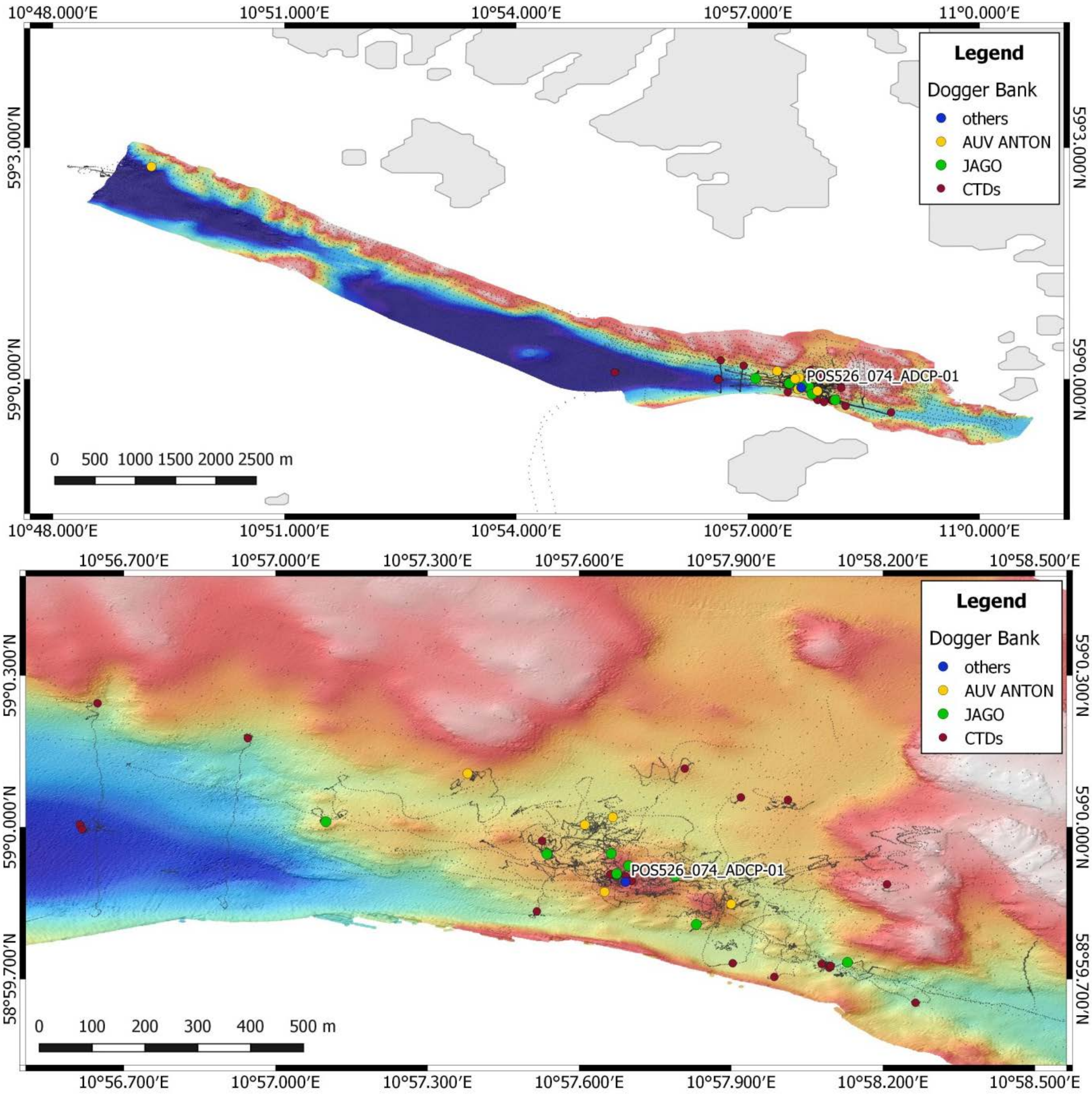


Figure 5: Overview map of the Tisler Reef area WA2 (top) and the Tisler Reef itself (bottom) with small black dots indicating the cruise track every 30sec.

5.3. Technology Tests

Several technological test aimed for integrating sensor system to platforms as well as platform test. In detail the cruise tackled technological challenges related to:

- Deploying and using AUV ANTON
- Testing the EVELOGICS USBL system with AUV ANTON and JAGO
- Test data communication for position update messages into JAGO and live plotting of JAGO positions within the submersible
- Use the WaveGlider to map sea surface methane concentrations and to streaming of data in near-real time
- Use the new EK80 SBES for bubble detection and quantification
- Test the ShipComputerCluster SCC
- Deploy the GasQuant-II lander system
- Deploy the BubbleBox attached to JAGO

- Deploy a stereographic camera rig attached to JAGO

Furthermore the Digital Earth and MOSES data management workflow was to be implemented from data acquisition through processing to storage in public databases and visualization.

6. Settings of the Working Areas

6.1. Dogger Bank seep site (Working Area - WA 1)

The Dogger Bank seep has been first described by Schroot et al. in 2005 and has been revisited after that during three cruises of the Royal Netherlands Institute for Sea Research (NIOZ) in 2011, 2012 and 2013 (cruises 64PE340, 64PE354, 64PE376), as well as during studies with RV Heincke in 2014, 2015, 2016 (cruises HE-413; HE-444, HE-459). During cruise POS526 the investigations focused on Cluster 1 (the "jumping horse"; Urban et al., 2017) and Cluster 5 (Figure 6, image from Römer et al., 2017). More detailed maps can be found in the following sub-sections.

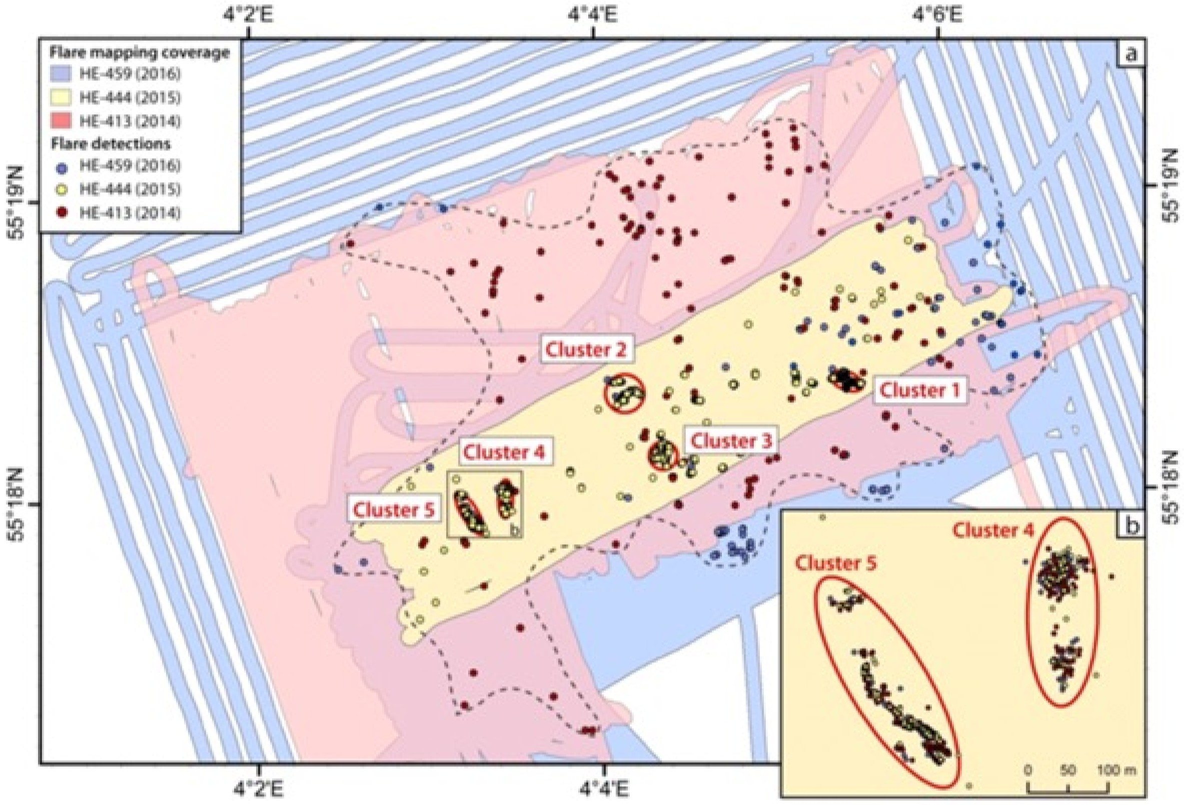


Figure 6: Overview of the Dogger Bank seep area as presented in Römer et al. (2017).

6.2. Tisler Reef site (Working Area - WA 2)

The Tisler Reef comprises an area of approximately 1 km x 250 m, made up of a number of Lophelia pertusa structures some few meters in diameter to interconnected small reefs of 10s of square meters seafloor coverage (see Figure 1Figure 5). The reef crosses a narrow sill in the Norwegian Skagerrak close to the Swedish border and was partially damaged by trawl fishing before fishery closure in 2003. Generally exposed to moderate flow velocity waters, the complexities in physical reef structure may lead to localized pockets of increased nutrient and sediment accumulation particularly during summer months.

At Tisler, Tomas Lundälv established a fixed transect (marked by a weighted bottom line with markers at both ends) through a trawl-damaged part of the reef in 2004. This transect has been documented regularly, first by video transects and still photography of selected targets and later also by video mosaicking between 2005 - 2013. This transect has been monitored repeatedly to study possible recovery after protection was put in place. Some signs of recovery towards the end of the study have been observed, but also continued physical disturbance could be documented despite protection. Some 3Dreconstructions have been performed along the fixed transects and a large number of additional ROV-based video transects through most parts of the reef have also been conducted which provide a baseline for morphometric change detection. Additional video and still image data sets are available for comparison with freshly collected data. A 100 m video transect of a trawl damaged area of the SW region of the reef was recorded in 2007 and formed the basis of an image analysis comparison paper (Purser et al, 2009).

7. Work details and first results

7.1. Description of the Gears

7.1.1. Submersible JAGO

The largest research gear used during POS526 was the GEOMAR-owned manned submersible JAGO that can take two persons, a pilot and a scientific observer, to water depths of maximum 400 m (Figure 7; Hissmann and Schauer, 2017). The submersible has a compact size and a low weight of 3 tons that enables shipment in a single 20' ISO container and deployment from a wide variety of support vessels that have sufficient crane capacity. JAGO is equipped with USBL navigation and positioning system for tracking the submersible under water, fluxgate compass, vertical and horizontal sonar, underwater telephone for voice communication, LED lamps, digital video (HD) and still cameras, CTD sensors and a manipulator arm for collecting and handling various sampling devices and instruments.

Figure 7: Recovery of manned submersible JAGO on board RV POSEIDON during POS526 at the Tisler Reef area.

The submersible operates worldwide and is regularly used from on board the German research vessels including FS POSEIDON. The vessel is very suitable for handling JAGO since it has a low working deck of only 1.5 meters. Periods during which the submersible is lifted and transferred from deck into the water and vice versa are therefore short. The general mobilization of the submersible on board the POSEIDON took place already on June 27-28th in Bergen, Norway, for the foregoing cruise POS525 which ended in Bergen. The submersible and its team stayed on board for POS526. Still in Bergen and during transit to the first working area, all gear and instruments that were going to be used during JAGO dives were prepared for mounting onto JAGO's lower front and for connection to JAGO's power supply. On deck, JAGO was lashed amidships, and lifted and transferred into and out of the water over the ship's side by the main deck crane (SWL 5 tons). The vessel's Rigid Inflatable Boat (RIB, 5.5 m TL, 60 HP Yamaha outboard engine), steered by a crew member, was used to tow the submersible away from the ship's side after deployment and back under crane position for recovery.

While submerged, JAGO was tracked by means of a new USBL underwater positioning and navigation system (manufactured by EvoLogics, Germany), comprising a S2C R 18/34 Hydroacoustic Modem w/USBL as top-side unit (mounted on a pole at the starboard aft side of the vessel) and a S2C R 18/34 Hydroacoustic Modem attached to JAGO's top railing as down-site unit (for more details see 7.1.20.). Both were recently purchased by GEOMAR for the new Girona500 Hover-AUVs (see 7.1.2.). Alternatively, in particular during the first dives while the new EvoLogics system was not yet running smoothly, the less accurate ORE Trackpoint 3 USBL system was used. The position data were integrated into the navigation software OFOP (http://www.ofop-by-sams.eu/) to display and follow both JAGO and POSEIDON tracks geographically and in real time on a computer screen. Position data were logged in column-based ASCII files. Dive tracks can be combined for annotation with individual dive logs, visual and video observations and CTD records. The recording / logging time for all cameras and sensors was synchronised with the ship's clock and set to UTC. Voice communication between the JAGO crew and the dive supervisor on board the POSEIDON during dives were maintained by acoustic underwater telephone (Subphone 580 by Subsea Import).

The water column and sea floor in front of the submersible's bow window, as well as all activities performed with the manipulator arm were continuously HD video-documented from inside the submersible with a CANON XA25 HD-Camcorder. The camera was mounted forward-looking in the centre of the large acrylic bow window. The camera's 3.67-73.4mm zoom lens allowed wide-angle and detailed close up footage of any object and structure in front of the submersible. The footages were recorded directly from the camera sensor onto an external hard drive (Shogun from Atomos) in ProRes 422 LT format as .mov file. After each dive, the original HD video files were copied onto a NAS-server for storage and further processing. Metadata, like the recording time in UTC, can be made visible if videos are played back and viewed with Quicktime 7 or an image annotation software like OFOP. In addition, a compressed copy of each video file was produced in H.264/MPEG-4 AVC format and overlaid with UTC time stamp for quick and easier geo-referencing and annotation by the science party while still on board the vessel. Video still images can be captured from the original HD footage by frame-grabbing. A dive protocol was written by the dive participants to log observations and activities during the course of the dive.

In addition to the Canon Camcorder for continuous HD video recording, a GoPro Hero4 mini-camera in an underwater pressure housing, rated for 400 m water depth, was used for time laps photographing of the seafloor during some of the survey dives. The camera was mounted vertically downward-looking on a horizontal extension pole at the front of the submersible. It was set to JPG still mode, interval 2 seconds, image size 12 Mpix, maximum

wide angle, 6500 K, spot light exposure measurement. Images were stored on an internal micro-SD card. The camera was power-supplied from inside the submersible.
For quantifying the size of objects observed on the seafloor and captured on video and still images, two green laser points were projected on the seafloor. The distance between the two parallel laser beams was 20 cm.
A CTD (SAIV A/S SD204 Norway), attached to the stern of the submersible, continuously recorded depth, temperature, salinity and density during de- and ascents and while the submersible was at or close to the seafloor. The CTD data are available as ASCII files.
For some dives, two different large-scale devices were temporary mounted to the lower front of the submersible: the Bubble Box (see 7.1.10; Figure 8) during Leg 1 and the BatCam Stereographic Camera System during Leg 2 (see 7.1.13; Figure 9Figure 9). A gas sampler, also attached at the front of the submersible, was used to collect gas at the Dogger Bank. A funnel, attached to the lower end of the flexible collecting tube, was placed with the manipulator arm above a gas outlet (Figure 34). The bubbles then rose through the tube into the collecting bottle.

Figure 8: BubbleBox and gas sampler installed on JAGO.

For both devices, power was supplied by the submersible. Network cables were used to connect the devices to a laptop inside the submersible for monitoring and controlling the operation. The Bubble Box was installed in reach of the manipulator arm that was used to press down a spring valve (Figure 8) to release the gas inside the bubble catcher on top of the device.

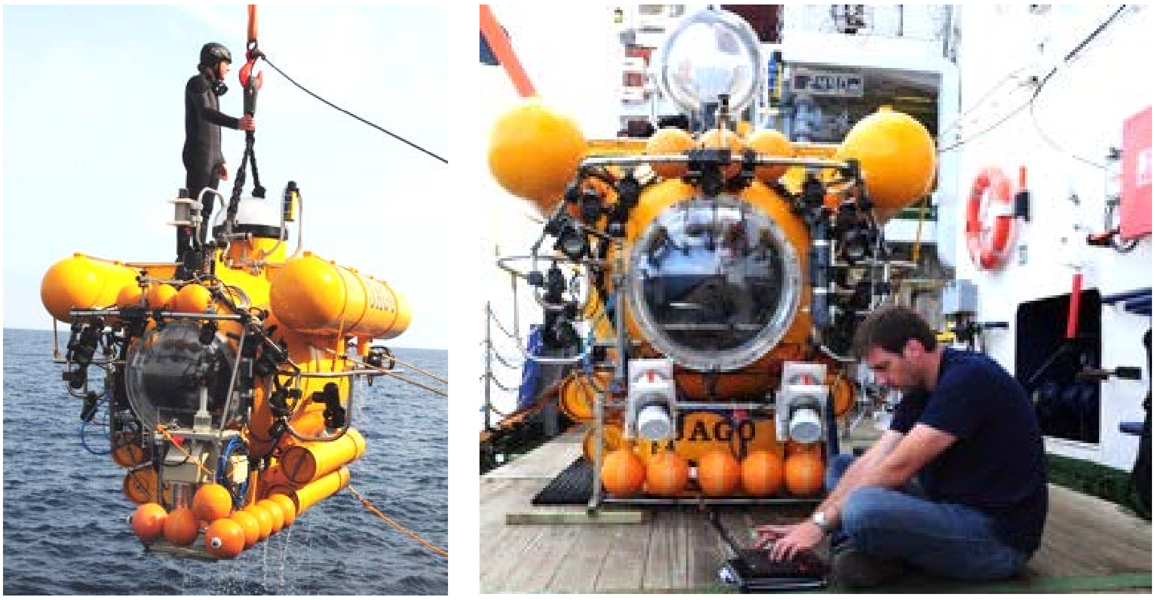


Figure 9: Left: Recovery of submersible JAGO with Bubble Box attached to its lower front after a dive at the Seep Cluster 1 area southeast of the Dogger Bank. Right: Final adjustment of the stereographic camera system on JAGO for a dive at the Tisler Reef complex.

For recovering the Gas Quant II Lander (see 7.1.11.) with JAGO, a snap hook was attached to the end of a rope that was tied to the lamp bar of the submersible. The rope was sufficient long enough to guarantee that the hooked lander would hang below the submersible when lifted off the bottom. The snap hook was hooked to the salvage ring on top of the lander with JAGO's manipulator arm. JAGO was also used to deploy and recover three autonomous cameras (PiCams; see 7.1.14). For transport to and from the sea floor, the cameras were stored in a sampling box mounted on JAGO's instrument porch at the lower front of the submersible (Figure 10).

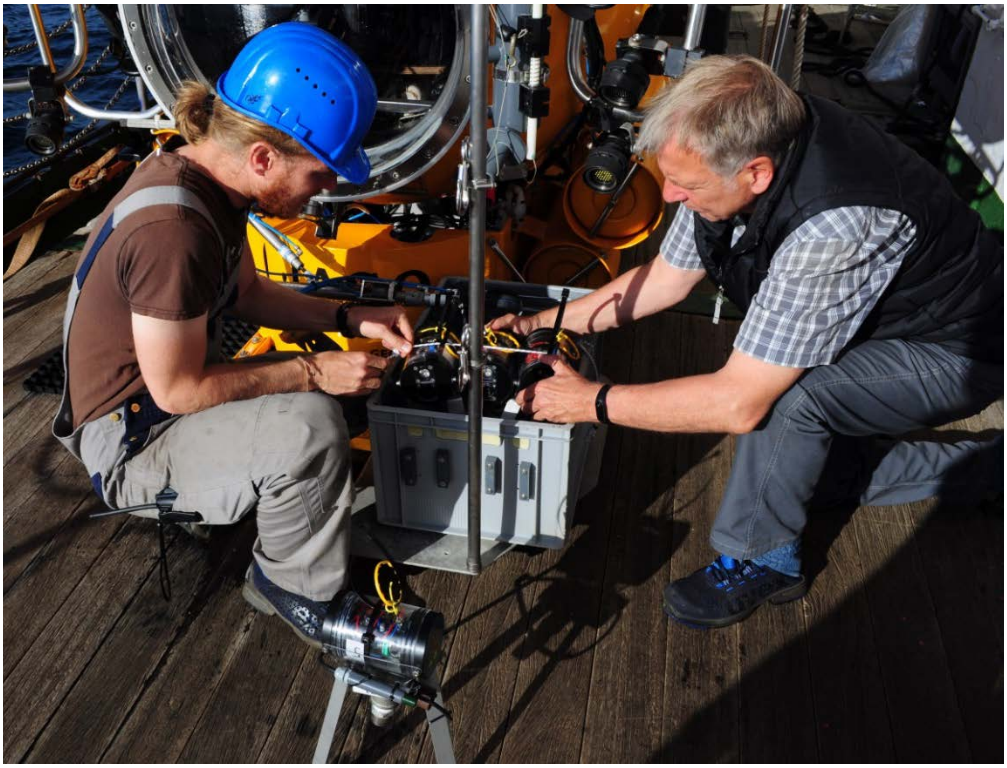


Figure 10: PiCams installed in a box in front of JAGO for deployment.

7.1.2. AUV Anton

The new Autonomous Underwater Vehicle (AUV) Girona500 was recently bought from IQUA Robotics in Spain. It was delivered to the GEOMAR Institute a week before packing begun for the cruise. This is the first test cruise of the vehicle after it was tested for three days in the Mediterranean Sea. The Girona500 is an AUV with a size of 1m x 1m x 1,5m (Figure 11). It consists of three main hulls that are connected with an aluminum structure. The total weight of up to 200 kg are includes all necessary electronics and thrusters to maneuver in five degrees of freedom. It is capable of diving up to 500m deep and has a battery for mission duration of up to 8 hours. The payload area with 35l of volume makes it valuable for scientists, as it can be equipped with additional instruments for specialized tasks. The computer manages all interfaces to the sensors and has additional ports for the payload sensors.

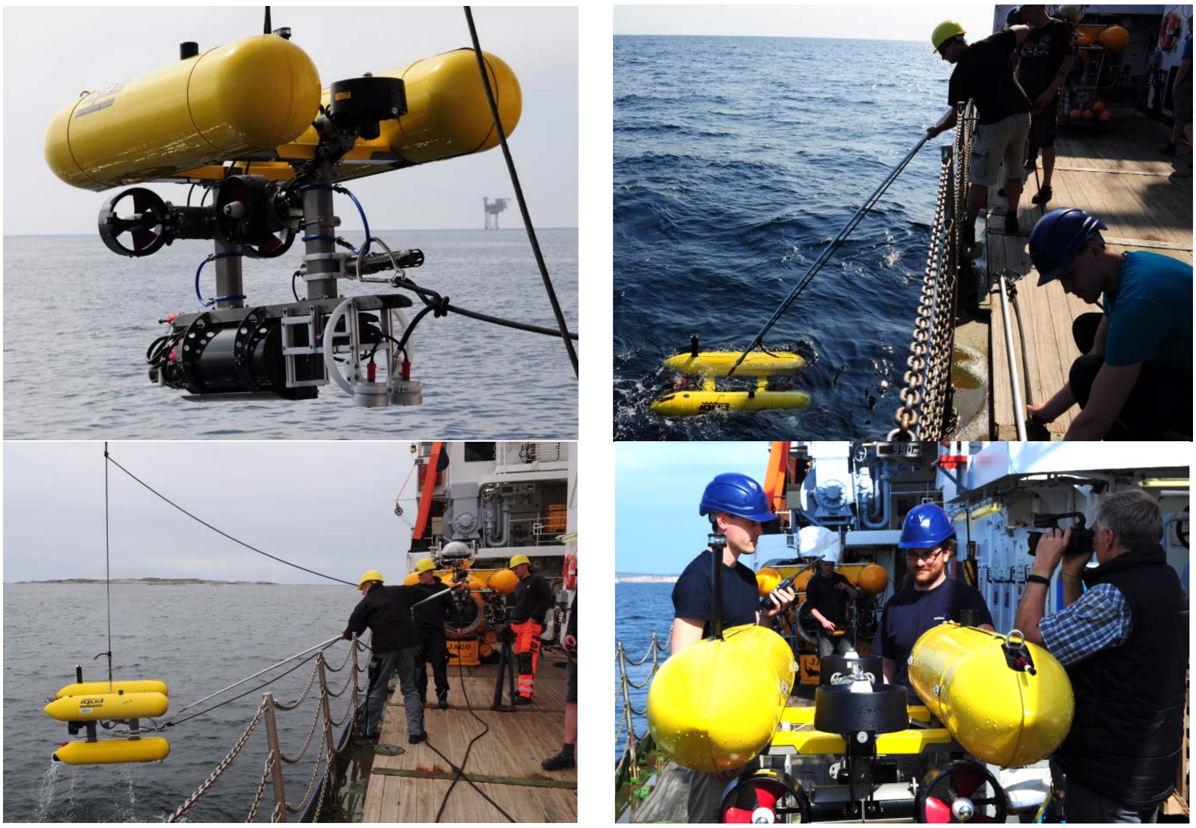


Figure 11: Impressions of AUV ANTON on board RV Poseidon. The top two images are from the Dogger Bank area with production platform B13-03 (Ven-1) at the horizon. The lower images show the Tisler Island in the back.

For calculating its current position, the vehicle is equipped with a high precision inertial measurement system (INS). This sensor also uses additional information about its environment from other sensors and fuses them to a position: A Doppler velocity log (DVL) is giving the altitude and the relative velocity over ground, a pressure sensor contributes the depth of the AUV and on the surface GPS is also taken into account. Via an USBL transceiver on the ship and an USBL transponder on the AUV, it is possible to add absolute positioning measurements when the vehicle is submerged. In this case, the modems are also being used for sending basic information between the AUV and the control station or even simple commands. When on surface, the AUV can be controlled over a WIFI connection. Furthermore, a SeaBird CTD is permanently installed. Table 1 summarizes the basic equipment and scientific payload of the AUV during POS526.

Table 1 Equipment installed on AUV ANTON

Subsystem	Description
Standard equipment	
INS: iXblue Phins Combat C3	The internal navigation unit that processes sensor data and provides position information. The error of this INS is in range of 0,15° for heading and 0,05° for roll and pitch. This leads to a 0,3% DT position accuracy.
DVL: Teledyne RDI Explorer 600kHz (phased array)	This device measures the velocity relative to the sea floor and its altitude. The minimum distance to the seafloor is 60cm
CTD: Sea-Bird SBE 49 FastCAT	It acquires the conductivity, temperature and the pressure of the water and calculates salinity and sound velocity.
Pressure sensor: Valeport ultraP	This sensor measures the pressure and converts it to water depth.
USBL: Evologics S2CR 18/34	The Evologics S2CR 18/34 modem combines underwater acoustics and positioning.
GPS: Quectel l86 GNSS module	The GPS is used to determine the absolute position at the surface.
Scientific equipment	
Light	Two LED lights: The lights are used to illuminate the sea floor. They will be turned on when the camera records images.
Prosilica GC1380 2/3"	The camera records images with a resolution of 1360x1024 pixels in grey scale. It has a fixed focus with a 7mm 2/3” auto iris lens. It can record data with up to 20 images per second.
Imagenex 837B DeltaT 4000	The optionally mounted multibeam sonar is used for mapping purposes

The software is based on the widely used Robot Operating System (ROS) that suits the modular design perfectly. It offers efficient ways to integrate new software nodes into the system because every component works independently. The architecture is focused on defining interfaces that every component in the system can listen and broadcast to.

The AUV is operated with a Graphical User Interface (GUI) that is used for checking the system prior to a mission, mission planning, execution and mission monitoring. Therefore it needs a connection to the USBL modem, the GPS of the ship and the WIFI access point of the vehicle.

The main goal of this cruise for the AUV is to prove its value to the scientific community. This new technology needs to be explored and integrated into the workflows of the scientists as it offers a new approach with its hovering capability as well as its open architecture regarding hard- and software. Getting to know the vehicle, its limits and its possibilities is the main focus. Since the system is quite new, there will be some configuration and errors happening that have to be addressed by the operators. This experience will be gathered and put into a improved version for future cruises using this AUV.

7.1.3. Waveglider

The Wave Glider is an autonomous surface vehicle that creates forward propulsion from wave energy and electricity from solar energy (Figure 12). The glider can be navigated remotely via GSM- or Iridium network and navigational as well as scientific data is being broadcasted back to shore in a decrease temporal resolution. High-resolution data is being stored on the gliders hard disk at a 1-minute interval. The Wave Glider is equipped with a suite of sensors which are assembled in an underway flow-through setup (continuously pumped with a Seabird SBE5T pump). The water intake is located beneath the hull of the floating surface part at a water depth of 0.4 m. The glider is also installed with a hull-mounted CTD sensor as well as a mast-mounted weather station. During the POS526 campaign (Wave Glider mission ID: G4V2) it got additionally equipped with an acoustic modem for underwater positioning of targets equipped a beacon (USBL). Table 2 lists the scientific installed on the Wave Glider.

Figure 12: WaveGlider recovery at the Dogger Bank working area.

Table 2: List of WaveGlider sensors

Sensor	Location	Data
Contros HydroC CO2	Aft payload bay/flow-through	1-min interval
Contros HydroC CH4	Aft payload bay/flow-through	1-min interval
Seabird SBE-63	Aft payload bay/flow-through	1-min interval
WetLabs FLNTURT	Aft payload bay/flow-through	1-min interval
Seabird SBE-5T	Aft payload bay/flow-through	-
Seabird GPCTD	Hull-mounted	1-min interval
Evologics	Aft payload slot/downward-looking	1-sec interval
AIRMAR-200WX	Mast-mounted, 1m high above sea level	20-min interval

7.1.4. Picarro & AIS

Atmospheric CO_2 and CH_4 concentrations were monitored during the cruise using a cavity ring down spectrometer (CRDS, Picarro G2301-f) and GEOMARs 'Atmospheric Intake System' (AIS; Figure 13). The AIS pumps air from different air intakes into integrator volumes via aluminum tubing. Mass-flow controllers regulate precisely how many liters of air are pumped through the different air intakes. A Multipath Valco Valve selects one of the air inlets and routes it towards the CRDS analyzer. Before it reaches the analyser the sampled air is dried through a nafion dryer. Every air intake was sampled for one minute.

Three air intakes were installed on different elevation levels of RV POSEIDON to allow the calculation of concentration gradients for later sea-air gas flux assessments. Other parameters needed for such flux calculations, i.e. wind speed and water temperature were logged via the WERUM DVS data system throughout the cruise.

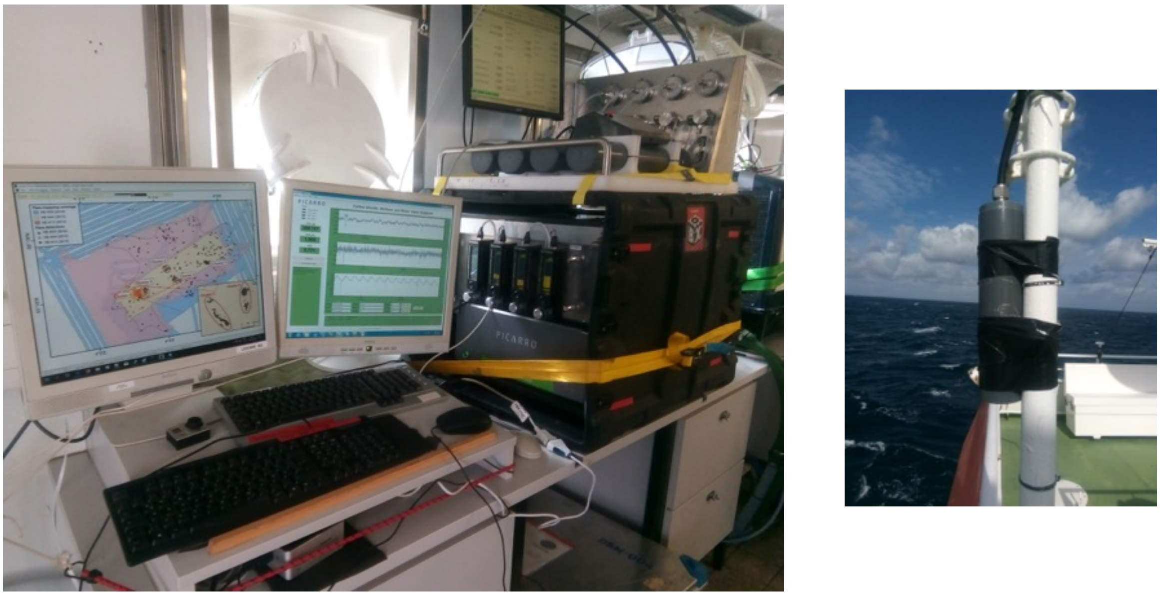


Figure 13: OFOP PC, Picarro and Atmosphere Intake System in the Wet Lab (left); air inlet on the top deck (right)

The long tubing between the AIS in the wet lab and the different air intakes caused time offsets between the air sampling and the actual gas measurement at the Picarro (Table 3: Positions and characteristics of the three air inlets for the Picarro system). Therefore, each flow rate was adjusted according to the delay caused by the tubing. These delays where measured, by timing the arrival of a CO_2 peak generated by the breath of a second person at each air-intake.

The Picarro measured the different air intakes (Figure 14) sequentially one after each other. However, after the initial delay measurement, the flow rates were tuned to adjust the delay of the different air intakes to make sure that the sequentially measured gas samples of the different air intakes originate from the same time point. Each intake was measured for one minute.

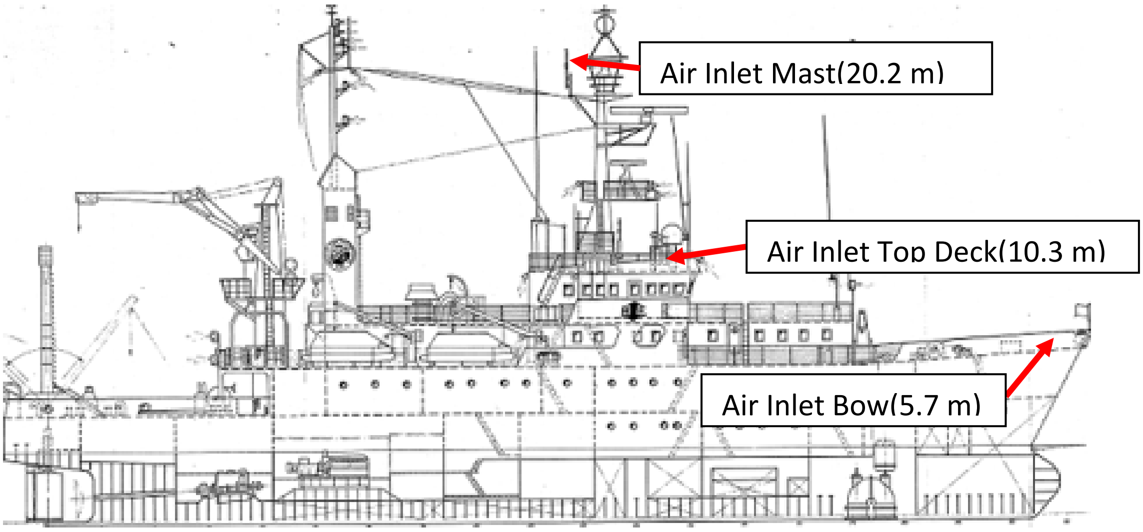


Figure 14: Positions of the three air inlets for the Picarro system mounted on RV Poseidon.

Table 3: Positions and characteristics of the three air inlets for the Picarro system

Air Intake No.	Position	Elevation	Delay	Flow Rate	Volume	Calc. flow rate
1	Bow	5.7 m	107.7 s	1.89 l/min	1.7379 l	2.136 l/min
2	Top Deck	10.3 m	71.09 s	2.048 l/min	2.4205 l	1.338 l/min
3	Mast	20.2 m	55.17 s	1.534 l/min	2.7535 l	0.978 l/min

The Picarro analyzer software was running on the Picarro hardware. The CH_4 and CO_2 concentrations could be monitored in real time, and were logged for post processing. Additionally OFOP (Ocean Floor Observation Protocol) software was running on a second computer. It was used to plot the gas concentrations onto a georeferenced map in real time.

7.1.5. Picarro Discrete Sample Analysis Module (DSAM)

Water samples obtained with Niskin bottles on the CTD rosette were processed using a modification of the standard headspace extraction technique (Magen et al., 2015). First, 900 ml water was collected without headspace in a 1000 ml Hamilton syringe. Second, 100 ml synthetic air (80% N_2, 20% O_2) was added to the syringe. Following a 2 min period of vigorous shaking to achieve chemical equilibrium between the methane and CO_2 in the headspace and sample solution, the headspace was removed and injected into DSAM. Minimally, 80 ml is required to fully load the DSAM analytical loop and avoid diluting the sample when using loop capture injection mode. For high concentration gas samples, for example gas bubbles collected by JAGO from the sea floor or gas bubbles trapped near the sea-air interface from the inflatable boat, smaller volumes are injected into the internal or external sample loops. Figure 15 shows the simple procedure of taking the samples and performing the equilibration immediately after the sampling.

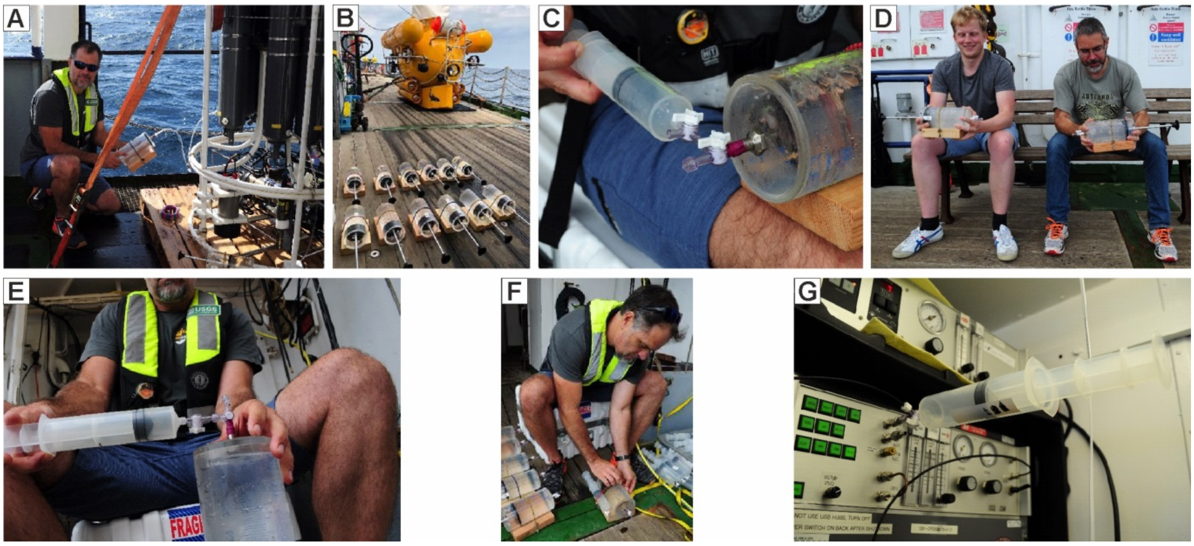


Figure 15: Sampling of water for the DSAM. A: taking water directly from the niskin bottles into 1000ml syringes, B: proud selection of samples, all nicely ladled!; C: injecting 100ml of He to the 900ml of water; D: Shaking 2minutes; E: Extracting headspace; F: having water and gas samples together, water temperature will be analysed in the lab for gas equilibrium corrections; G: Injection into the Picarro.

Concentrations and stable carbon isotopic content of methane and CO_2 were determined by cavity ring-down spectroscopy with the aid of the Discrete Sample Analysis Module (DSAM;

Figure 16). DSAM is a peripheral device developed by the USGS that enables analysis of 1-100 ml gas sample using Picarro trace gas analysers (Pohlman et al., in prep.). For this expedition, we used the model G2201-i CRDS. Gases injected into DSAM are either transferred directly to the CRDS without dilution (loop capture mode) or are quantitatively diluted (sample loop mode) using either a 100 μl internal sample loop or a 1 ml external sample loop. Samples introduced in sample loop mode are circulated within the analytical loop until a homogenous mixture is achieved, which is facilitated with a sample bypass loop. Samples introduced in Loop Capture mode fully fill the analytical loop so mixing is not required.

Figure 16: USGS AGS and DSAM system, the top Picarro unit is the DSAM system with a large syringe for injection of the gas sample.

The injection method selected depends on the concentration of the sample with the goal being to achieve a concentration between 10 and 1000 ppm for methane and 200 to 4000 ppm for CO_2. Within these ranges, the CRDS provides the most consistent stable carbon isotope values. Low concentration samples are typically analysed in loop capture mode, while high concentration samples that require dilution are analysed in the sample loop mode.

Instrument isotopic values (iCO_2 and iCH_4) are converted to $\delta^{13}C$ values using slope and offset factors obtained by analysing at least three gases with known $\delta^{13}C$ values for methane and CO_2. Within the optimal ranges described above, the accuracy and precision of the $\delta^{13}C$ values are less than 1‰. Below 10 ppm methane, the measured isotope values remain consistent, but the precision of the analysis diminishes with decreasing concentration. Figure 17 displays the measurement uncertainty for methane and CO_2 for 252 CTD samples analysed during the expedition. For data analysis, we chose a maximum standard deviation (1 σ) of 3.5 for methane and 1.5 for CO2. 94% of the measured methane values and 96.8% of the measured CO_2 $\delta^{13}C$ values are within these ranges.

After every 5th sample analysed, a reference standard containing 100 ppm CH_4 and 400 ppm CO_2, both of know isotopic composition, were analysed to identify and correct for instrumental drift. The maximum drift correction from was 0.2‰, which means the instrument was stable throughout the expedition. Between 1.2 ppm to 100% methane and 250 ppm to 25,000 ppm CO2, the RSD of replicate concentration measurements is less than 1%. Instrumental values are converted to actual concentrations using a slope-offset calibration procedure similar to the isotopic calibration using at least three gas standards of known methane and CO_2 concentration.

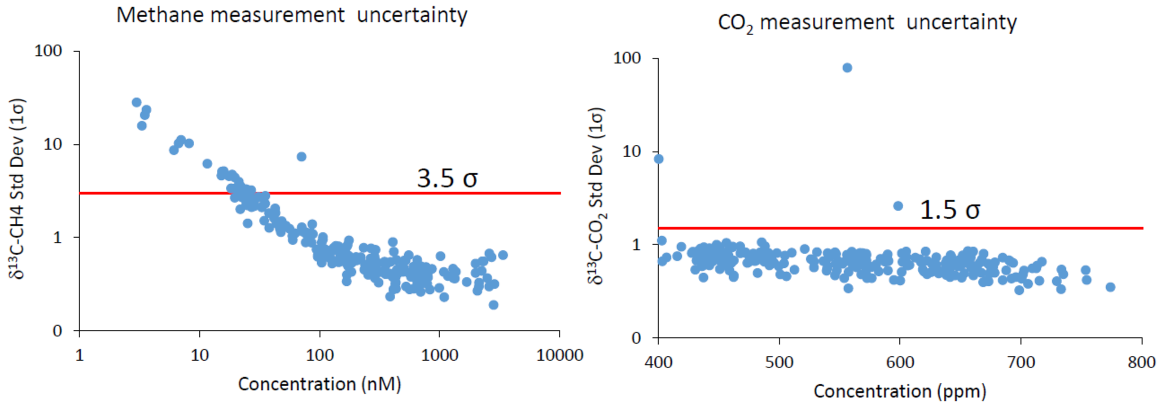


Figure 17: Measurement uncertainties of $\delta^{13}C$ *values for methane and* CO_2 *analysed by DSAM.*

Headspace concentrations are converted to dissolved methane and CO_2 concentrations as described by Pohlman et al. (2017). Bunsen solubility coefficients were calculated using salinity obtained from the CTD record and temperatures measured directly immediately after the headspace extraction. Methane concentrations are reported as nanomolar (nM) and CO_2 concentrations as parts per million by volume (ppmv)in the headspace of syringe. All isotope values are reported in the standard δ-notation which is determined from secondary gas standards referenced to the Vienna Pee Dee Belemnite (VPDB) primary standard.

7.1.6. Picarro Greenhouse Gas Flux System (USGS-GAS)

USGS-GAS fully implemented captures all data required to continuously determine dissolved methane and CO2 fluxes across the sea-air interface and measure concentration gradients of these gases in the marine boundary layer (Pohlman et al., 2017). For expedition POS-526 air gradients were measured with the GEOMAR air intake system (AIS) and wind speed was measured by the ship. Therefore, the components of USGS-GAS employed were the single level air handler interfaced to a Picarro G-2301f, a modified Weiss-type equilibrator and a YSI Exo2 datasonde (Figure 18). The G2301-f measures methane, CO2 and water concentrations at a frequency of ~ 3 seconds. The datasonde measures salinity, temperature, dissolved oxygen, pH, redox, fluorescence, chlorophyll-a, phycocyanin and phycoerythrin.

Figure 18: YSI Exo2 datasonde and Weiss Equilibrator system on board of RV POSEIDON.

Water pumped from the moon pool was delivered through a garden hose to the sink of the wet lab where a distribution manifold split the water flow to the equilibrator (~8.5 liters per minute, LPM) and the flow through chamber of the datasonde (1 LPM). Headspace gas from the equilibrator was circulated through the air handler within a closed loop. Leak tests conducted after installation confirmed the system was leak free, a condition required to achieve accurate surface water methane and CO_2 concentrations. The time constant for the equilibrator was determined at the UGGS Woods Hole Coastal & Marine Science Center prior to the cruise.

Data from the G2301-f and the sonde were recorded with a Labview application developed by the USGS. Data records include time stamps and positional data transmitted by a GPS unit installed above the bridge. Salinity and Temperature from the datasonde are used to calculate surface water methane and CO_2 concentrations collected continuously during the cruise and are combined with the GEOMAR AIS air data and shipboard wind speed to calculate sea-air gas fluxes.

<u>Waveglider methane sensor - USGS-GAS data comparison:</u> To evaluate the performance of the methane sensor deployed on the GEOMAR Waveglider, coincidental data from the methane sensor and USGS-GAS were compared. Two types of comparisons were made: 1) Measurements made when the Waveglider was deployed and both systems were collecting data; and 2) Measurements when the Waveglider sensor system was on board and receiving water from the same source as USGS-GAS. The quality of the deployed Waveglider and USGS-GAS is expected to be influenced by the separation between the ship and the waveglider and the heterogeneity of gas concentrations in the surface water. The expectation is that comparisons would be more direct when the ship and Waveglider were proximal and when the ship was not in the area of active seepage. Comparisons between the

systems sharing the same water source, on the other hand, are only influenced by the differing equilibration times of the systems.

7.1.7. Gas chromatograph

Seawater taken with the CTD was transferred via a plastic tubing into a 60 ml plastic syringe without introducing any air into the syringe. Subsequently, a headspace of 10ml helium was placed in the plastic syringe resulting in 50 ml of sea water and 10 ml of helium head space. The syringe was shaken for two minutes to achieve equilibrium concentrations between the seawater and the headspace. For the actual concentration measurement 100 µl of head space were taken from the helium headspace and injected into the gas chromatograph. In addition, after the gas sampling for the GC, the temperature of the seawater was determined with an electronic thermometer.

The gas chromatograph (Trace GC Ultra) has a molecular sieve column feeding an FID (Flame Ionization Detector) for detecting hydrocarbons from methane up to hexane. The detection limit for methane is 0.1 ppm. The molecular sieve column has an inner diameter of 0.53 mm and a length of 50 m. Helium was used as the carrier gas and the flame in the FID was generated via H_2 from a hydrogen generator and O_2 from synthetic air.

To determine the methane concentration of a sample, 100 µl of gas from the sample was injected via the 170° C injector onto the molecular sieve column and measured isothermally at 50° C for two minutes and a helium flux of 15.3 ml. The subsequently detected methane peak came at a retention time of 1.2 minutes. The evaluation of a measurement was carried out via a previously performed 5-point calibration of 5 ppm to 10.000 ppm, which was measured with a 10 ppm and a 10.000 ppm standard.

7.1.8. Oxygen titration

The sampling was done in 60 mL glass bottles with glass stoppers. After the bottles were carefully rinsed they were filled to the top and first 0.5 mL KI/KOH and then 0.5 mL $MnCl_2$ solution were added separately by using 1 mL syringes. The bottles were closed and then shaken for approximately one minute, stored in the dark and measured within 12 hours after sampling. Oxygen samples were analysed according to a standard Winkler titration protocol.

7.1.9. SHiPCC computer cluster

The *Sea-going high-performace compute cluster* (SHiPCC) is a portable system of 8 GPU accelerated PCs plus one master node that serves as a gateway to the compute nodes, a switch for data transfer and a network attached storage (NAS) to hold data (to be) computed by the nodes. The system with spares and peripherals fits within one large and one small aluminium box. In the current setup it connects to four separate power sockets of the ship. Future version will feature an independent power supply with electrical filtering to connect directly to the ship's main power supply system. The cluster used on board was unit two of three available units. All nodes and the gateway run on Ubuntu Linux 18.04. Connection between the nodes and the NAS is facilitated through Gigabit Ethernet.

7.1.10. Bubble Box

For the assessment of bubble size distribution and bubble rise velocity, a bubble imaging box (Bubble Box) was designed and constructed at GEOMAR in the project SUGAR II, received post processing routines (Jordt et al. 2015) in the project QUABBLE and significant technical improvement by the DeepSea Monitoring group. The Bubble Box consists of a metal frame, which holds the camera systems, the backlit LED flash and an optional closing lid (Figure 19). Two cameras take images at high frame rates (80-100 frames/second). The closing lid allows either undisturbed vertical flow-through, or precise flux measurements into predefined capture volumes. The gas in the capture volumes can be released using a physical ROV pull-switch to reset the measurement.

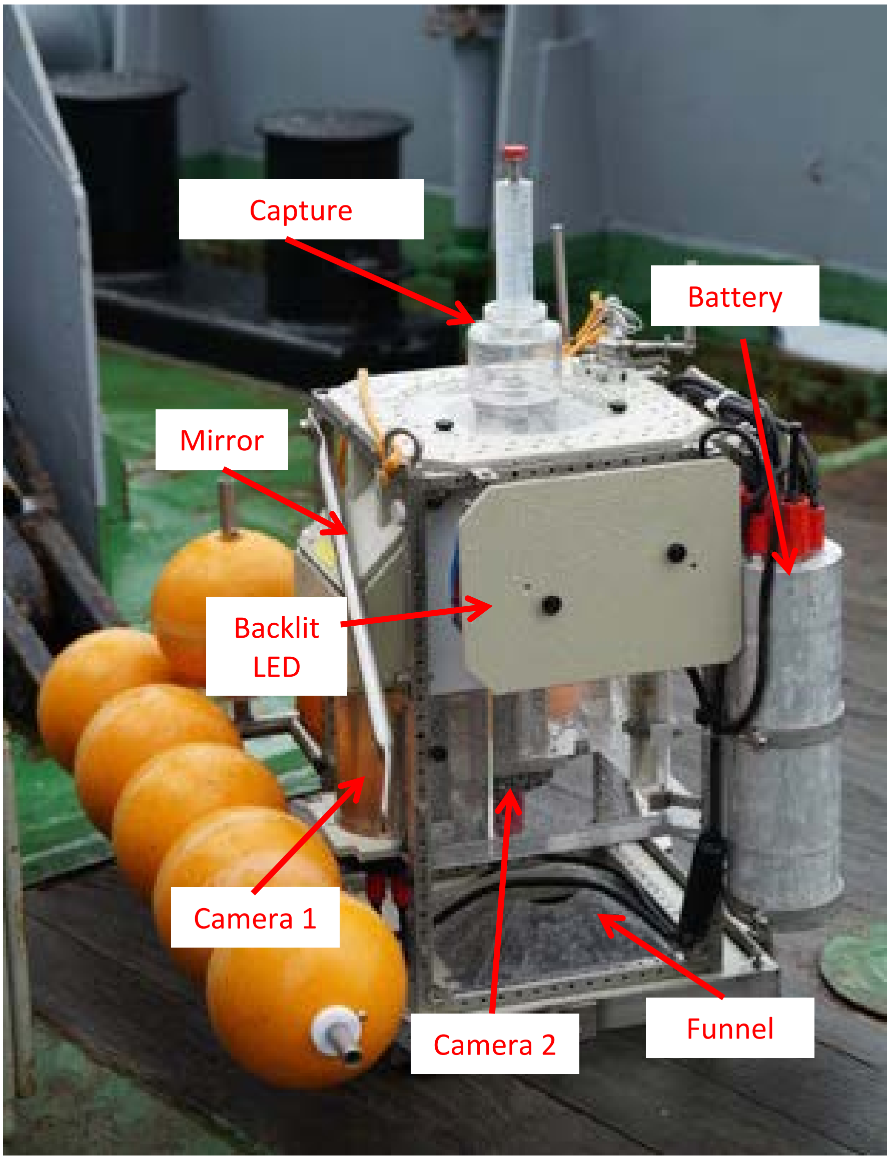


Figure 19: Components of the bubble box. The orange floatation spheres were attached to make the box neutrally buoyant.

The lower front and sidewalls are made of transparent acrylic glass for video observation, while the back wall is made of a white acryl glass acting as a light diffuser for backlit illumination of the gas bubbles. The green LED flash and the cameras are synchronized by a programmable trigger signal which controls the frame rate and the exposure time.

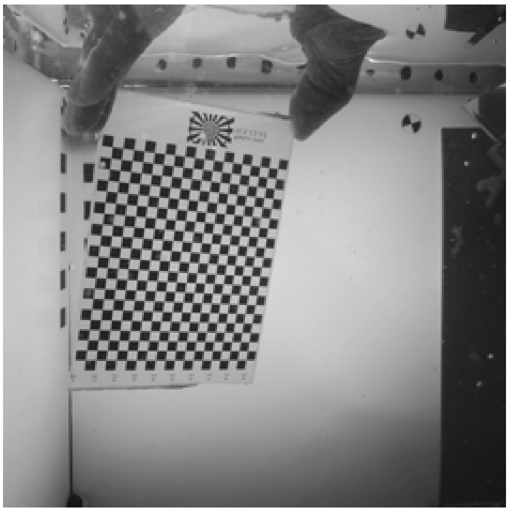


Figure 20: Checkerboard calibration of the bubble box cameras in water before the cruise

The time synchronization between the cameras is achieved via a black (not illuminated) frame, which happens every 5000 frames. The camera housings use a dome port to minimize diffraction at the air-glass-water interface. The cameras were individually calibrated using checkerboards in a test tank at GEOMAR (Figure 20). This allows the determination of the exact position of the cameras towards each other.

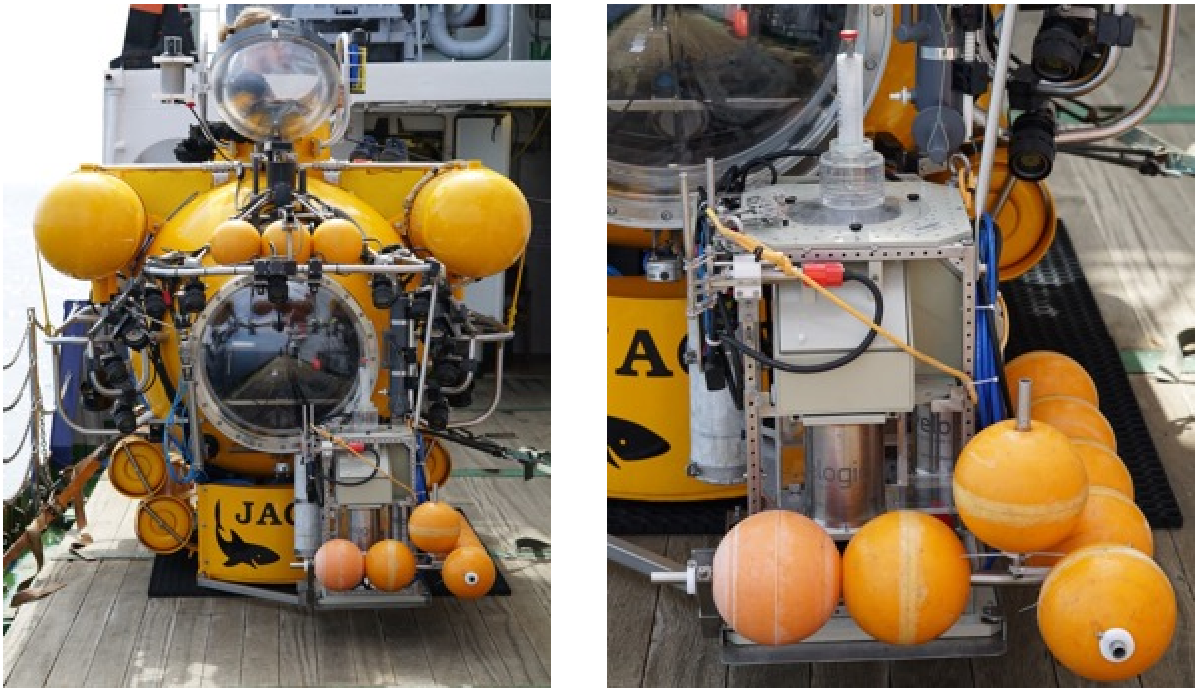


Figure 21: Bubble box as attached to the front of JAGO.

The system was attached on the submersible JAGO (Figure 21). The orange floats cause a neutral buoyancy to maintain the good maneuverability of JAGO. Power is provided by the submersible. The system itself works autonomous after start up. However, it is also possible to observe and control the cameras via a network cable from each camera into the submersible. In the submersible a laptop with a remote desktop application allows to monitor the operation and to make sure the rising bubbles are displayed in the images.

Additionally, the system status can also be observed from the inside of the submersible using the LED backlit flash:

- 2 second flash: system power on (no bubble computer booted yet)
- 0.5 second flash: the master computer „bubble 2" booted
- 80 fps: both computer „bubble 2" and „bubble 1" booted and the system is recording data

The powerful LED flash allows exposure times of 1 ms to record detailed slow-motion videos of bubbles without significant motion blur.

7.1.11. Gas Quant II lander

GasQuant II is a hydroacoustic system analysing seep activity and intensity using a horizontally looking multibeam system (Figure 22). It is designed to quantify marine gas release using an Imagenex 87B Delta T multibeam. The multibeam is installed on top of a small tripod and the beams are aligned horizontally to the ocean floor in range of gas seepages to detect and monitor activity and strength of rising gas bubbles. The system was built as the successor of the Gas Quant I system (Greinert et al., 2008), which has been successfully used for tempo-spatial variability of gas releases in the past.

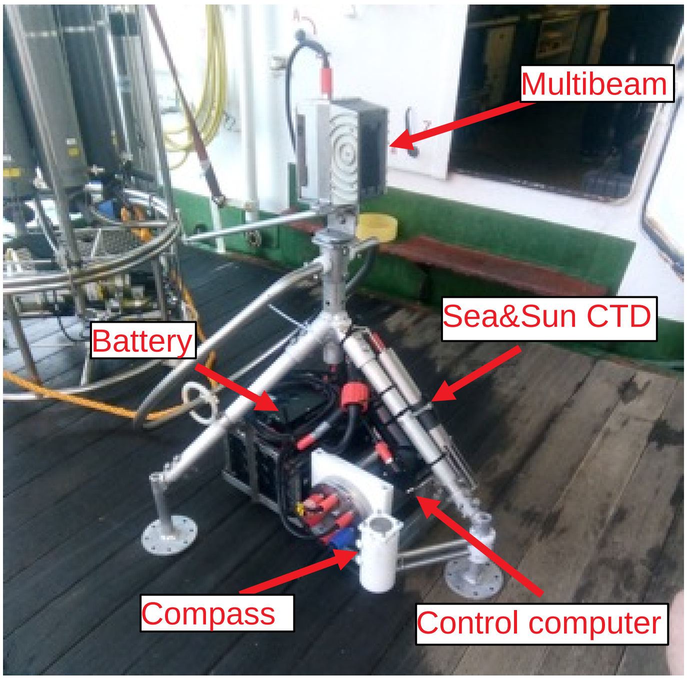


Figure 22: Gas Quant 2 lander on deck with its components highlighted.

The new system is lighter (ca. 60 kg), more energy efficient and designed for ROV deployments. Hence the positioning of the system with respect to the bubble seepage could be improved. Besides of the multibeam the system consists of an underwater housing containing a power distribution board and a small computer to control the sensors and record data. A OS5000 compass and a small Sea & Sun CTD are attached to record orientation and environmental parameters. Power is provided by a 2kWh underwater battery of Enitech (now Kraken Power).

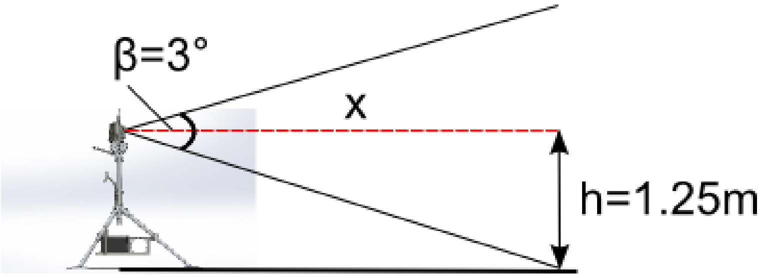


Figure 23: View angle of the Gas Quant 2 lander

The optimal distance to a seep site results from the vertical opening angle of the multibeam (3°) and the height of the installation (1.25m; Figure 23).

$$x = \frac{1.25m}{tan\left(\frac{3°}{2}\right)} = 47.73m$$

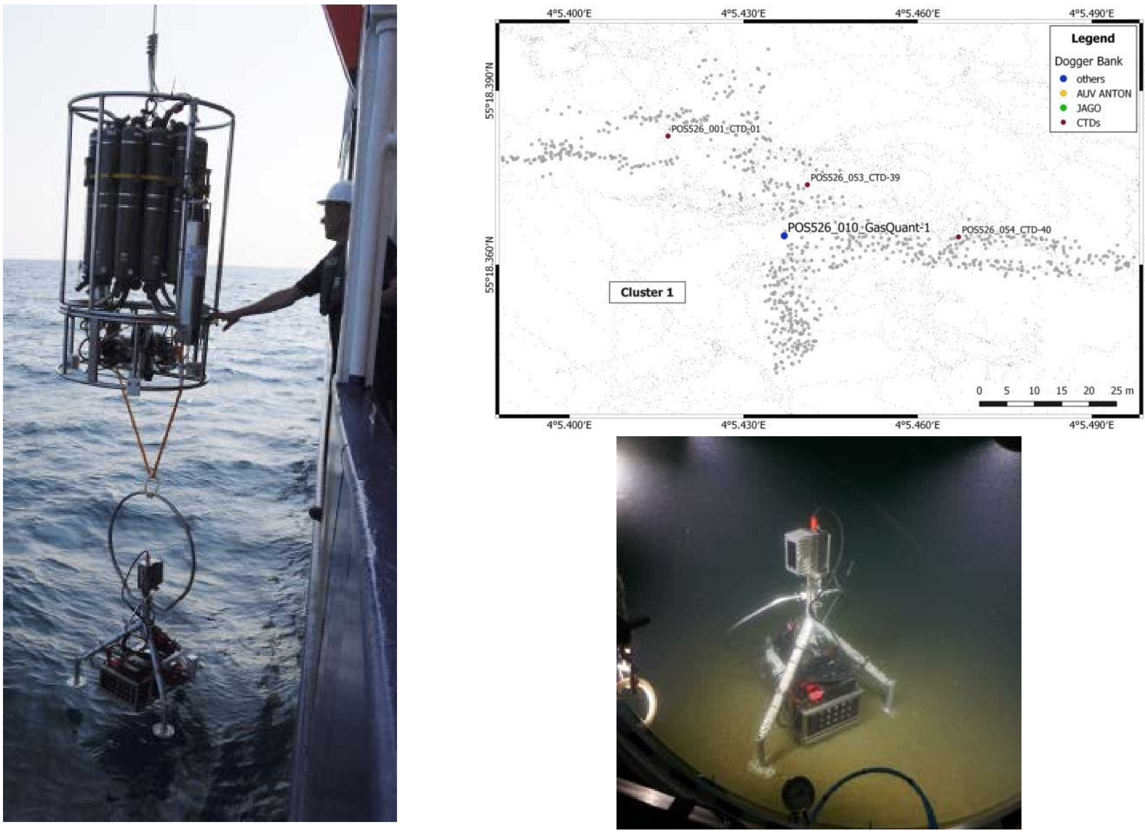


Figure 24: Left: GasQuant deployed below the CTD with an acoustic release. Top-right, final position of GasQuant Cluster 1. The view direction was changed during a following JAGO dive towards 120° pointing straight towards strong bubble release.

To avoid any reflections from the bottom a range setting of 40m was selected and the multibeam was installed tilting slightly upward. During the POS526 cruise the GasQuant was deployed using an acoustic releaser connected to Poseidons CTD system. During the 2nd JAGO dive the direction of the multibeam was positioned towards the main bubble release of Cluster 1. The head of the system was turned using JAGOs manipulator to 120° degrees during JAGO dive 1394/02, the final position is shown in Figure 24.

7.1.12. TV CTD

During POS526 we used a Sea& Sun Technology telemetry system to run a SeaBird 911 CTD with 12 water sampling bottles (each 10l) and a HD camera system simultaneously.

Figure 25: Images of the CTD video system.

The system uses the coaxial cable in winch 2 for data transmission. A detailed description of the system is given by Linke et al. (2015). The camera records HD video (locally, at the bottom unit) and transmits a lower quality video to the top unit as a live preview. Three lamps were used during the cruise as far as possible opposite of the camera (Figure 25); the length of rope for the metal ring weight was 1.4m. For the Video CTD tows (-> OFOS) the CTD was also equipped with the Evologics USBL beacon (Figure 26).

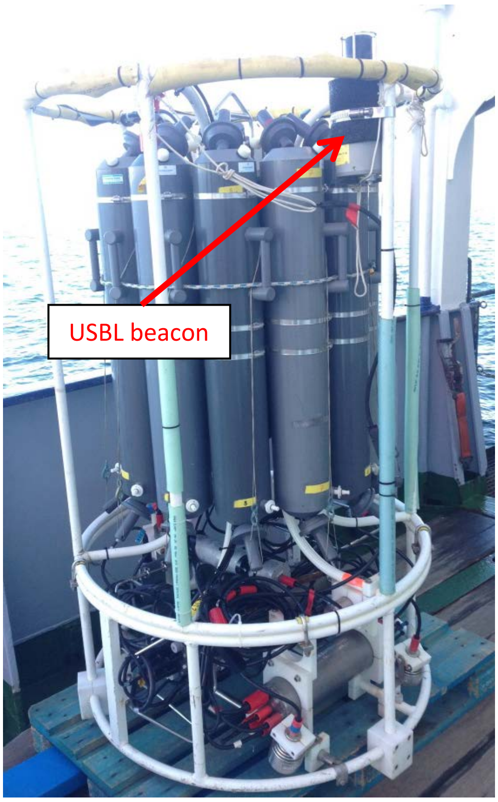


Figure 26: CTD with USBL beacon attached to it.

Data recording occurred with the standard SeaBird CTD software, a streamlined processing workflow generated smoothed and averaged data. Bin averaged data were loaded into ODV and the ODV compatible ASCII files are ready for upload into PANGAEA. Depth bin averaging for vertical casts was set to 0.5m, averaging over time for towed CTDs in the Tisler area occurred with a 1 second interval. These one second data sets were merged with the edited, smoothed and interpolated OFOP observations files to a complete data set with preliminary observation information.

7.1.13. BatCam Stereo camera

The BatCam stereo camera is comprised of two Teledyne Dalsa Genie TS machine vision cameras in pressure housings with flat sapphire port. The cameras are triggered by a programmable microcontroller. Optionally, the system can be extended by the Imagenex deltaT multibeam echo sounder (BatCam), but during this cruise the multibeam was not attached to the system (Figure 27). Each of the two pressure housings also contains a computer with 1TB solid state drive for recording the images and an external network port for remote login into the computer (for image preview, settings). The network cable was connected into JAGO, such that the camera computers were accessible through a laptop of the JAGO scientist. The system has been designed for usage with bright flashes, but during POS526 the cameras have been used with the standard lights of JAGO.

Figure 27: The two pressure housings with flat optical port mounted to JAGO. Left: JAGO also carries a chessboard for underwater camera calibration.

The cameras record color images at a resolution of 4096x3072 pixels and are triggered at a frame rate of 2 Hz. They were mounted in a way such that the optical centers are 62cm apart from one another, the cameras looking 45° downward and with slightly convergent views (each camera facing 6° inward to improve the overlap area). The full set of calibration and orientation parameters can be obtained from the chessboard images that have been recorded underwater. The cameras have internal SSDs of 1TB to store the images files, usually in jpg format to save space (raw is possible).

7.1.14. PiCam miniature camera landers

PiCam concept: The last five years has seen a huge increase in the interest in using small, extremely cheap computer systems to carry out a range of tasks, both recreationally and in various fields of research. Keen 'maker' communities can be found globally and online, focusing on different topics such as ROV development, i.e. the 'OpenROV' project. Code snippets can be readily exchanged via platforms such as Github.

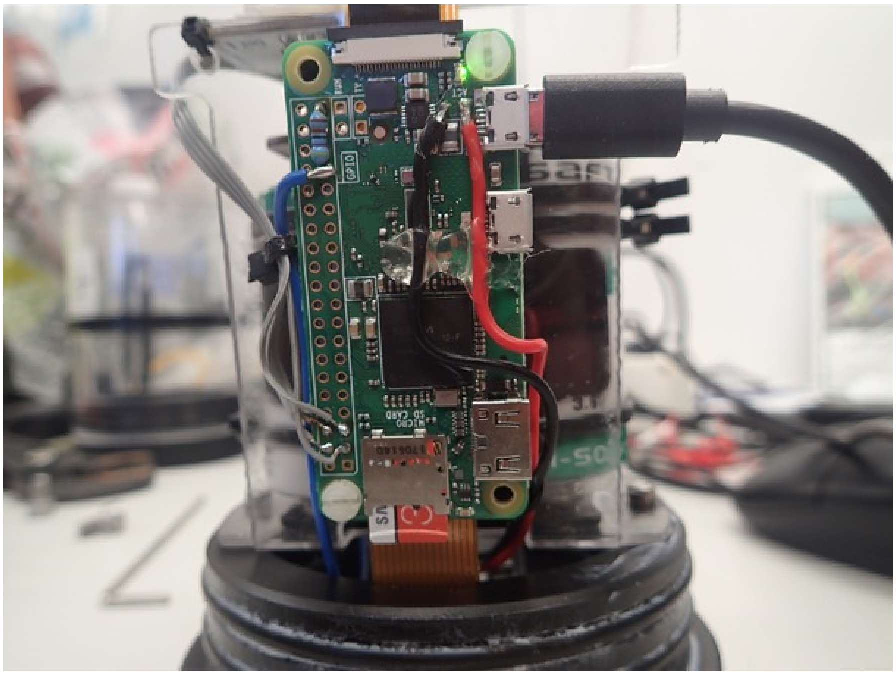


*Figure 28**:** Raspberry Pi circuit board mounted within a PiCam. Several wires are soldered to the GPIO board which connect to an integrated RTC chip which maintains a UTC timecode for all images.*

The Raspberry Pi family of microcomputers comprise various credit card-sized or smaller computers, integrated with a camera port and a set of GPIO ports which can be used to control accessories such as camera flashes or sensor systems. The 'Rasperry Pi Zero W' computer is the smallest of the family currently available, and though it is only measuring 3 x 8 x 0.5 cm, it supports a 512 Mb processor, camera port, wi-fi antennae, Bluetooth antennae, micro USB power port, micro USB accessory port and microHDMI port. The operating system and RAM is supplied by a standard small SD card of up to 32 Gb standard.

The PiCam concept has been developed during the last 6 months at AWI (Figure 28), where it is the intention to use these small computers to control basic cameras that can be used to monitor the activities of deep sea instruments, such as oxygen optode penetrators, and the track of deep sea tracked vehicles. For these applications high resolution images are not required so standard Raspberry Pi cameras (<10 Euro cost) are perfectly acceptable. Within the group at AWI various pressure housing solutions are being developed for these cameras, with plexiglass tubes of 11 cm diameter being appropriate for <250 m deployments.

To allow longterm operation of the devices, a pair of disposable 3.6V AAA lithium batteries are used to supply power. A pair of power regulators ensure the circuit board and the integrated flash unit are delivered the correct supply of power required. For scientific application, the device is augmented with a D1307 RTC to maintain UTC and ensure accurate dating of all collected images.

PiCams and the Tisler Reef: The main scientific aim of deploying PiCam cameras at the Tisler Reef was to address a range of long-standing questions on reef functioning over time. With this in mind, 10 PiCams were brought on POS526, each with an integrated tripod and programmable flash unit. Battery life was estimated to allow each camera to take an image every two minutes for the duration of a week. The cameras were programmed with deployment specific variants of the 'PiCam_dev.py3' Python 3 script developed by technicians at AWI and cruise participant Autun Purser.

Figure 29: 5 PiCams mounted on deployment tripods, with additional 1 kg weight added.

The small PiCams each had a weight with tripod of just 1.6 kg, to which an additional 1 kg of waste metal was added for further ballast (Figure 29). 5 of these cameras could be deployed by JAGO at a time. Unfortunately the first JAGO deployment was aborted as it was discovered the battery boxes within the PiCams did not operate well in waves, so a rapid fixing of these battery boxes was carried out and three cameras were successfully deployed for a period of 48 hrs, to monitor three flanks of an upper reef, imaging the reef once a minute throughout the survey period (Figure 30).

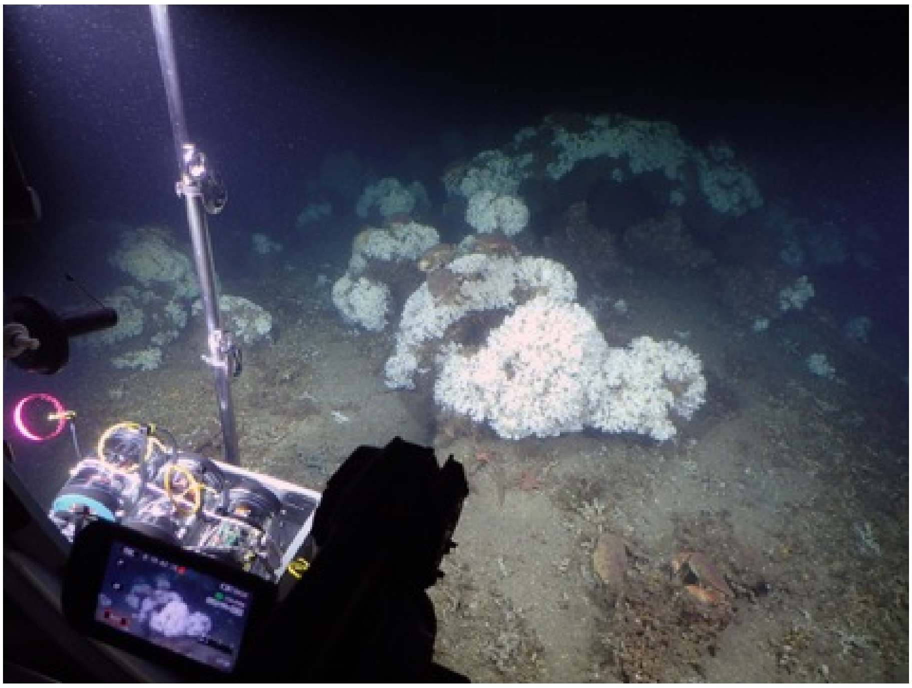


Figure 30. 5 PiCam cameras in JAGO sample box, awaiting deployment at a Tisler Reef coral thicket.

In addition to time series deployments, the cameras were also mounted on both JAGO and the TV-CTD, with various combinations of ISO setting, flash state or filters tested (Figure 31). Table 7 gives an overview of these deployments.

Figure 31: Array of 3 PiCams mounted on the TV-CTD, adjacent to the main camera.

7.1.15. LOKI

The LOKI (Lightframe On-sight Key species Investigation) system has been under development by AWI and ISITEC for a number of years (Figure 32). For POS526 a new, lightweight version of the system, designed for depths of up to 300 m and for mounting on the AWI ROV 'Beast', was brought for possible deployment by JAGO.

Figure 32: The LOKI ROV camera, configured for desktop use during POS526.

The LOKI system in summary is a 24 fps camera focused on a small volume of water which is passed through the device by a funnel. In the configuration brought on POS526 the LOKI device captures images with the 'LOKI plankton recorder V2.3.1.5), then automatically extracts from the images items of interest, such as zooplankton, detritus, or bubbles.
During POS526 the attempt was made to use the device for imaging water samples collected via CTD from contrasting regions of the Tisler reef. During the three stations POS526_094_CTD-57 to POS526_096_CTD-59 each time 20 – 30 l of water was collected from the seafloor, mid-depth and 5 m below surface. All this water was passed through the LOKI device and images extracted.

7.1.16. Seaguard RCM

The majority of actions carried out within POS526 at the Tisler Reef took place at depths of shallower than 150 - 200 m, and therefore the flow conditions could be determined using the ship-borne ADCP system.

During the evening of 7th August – early 8th August three locations were visited twice by RV Poseidon (Stations POS526_95_TV-CTD_57 to POS526_99_TV-CTD_61), with CTDs being collected from each, on each visit. Simultaneous collection of ship-borne ADCP data was augmented with flow data collected concurrently with a 262b Seaguard RCM (Figure 33), mounted directly onto the CTD frame. This was carried out the CTD dives at two of the locations was conducted in waters of >200m.

The device was configured to fire 500 pings every minute, to best minimize noise in the output signal. An AANDERAA oxygen optode (4330) (calibrated at factory 6 weeks prior to the cruise) was mounted as an additional sensor to augment the integrated pressure and temperature sensors.

Figure 33: AANDERAA Seaguard RCM deployed at station POS526_95_TV-CTD_57 to POS526_99_TV-CTD_61.

7.1.17. Multi-beam echo-sounder

The ship installed SeaBeam 3050 multibeam was used for seafloor and water column mapping. The 3050 system uses 50kHz with 1.5° transmit and 2° receive beam opening angle. Swath values were generally set between 100° and 130°, power and pulse length was typically set to automatic. Most of the time we run the system with 120° swath angle and equidistance spacing mode. The settings of the equidistance value and the swath width finally determine the beam spacing/number of beams. With 120° swath angle and a equidistance value of 1. 70% the system transmits 204 beams. Data were recorded in XSE format for bathymetric and WCI format for water column data. WCI data have only been recorded in the Dogger Bank area for comparison with the single-beam data of the EK80. Data processing for map generation on board of the XSE data occurred with MB-Systems, no new/additional sound velocity correction was undertaken (Figure 34) and xyz data only were exported using MB-Systems.

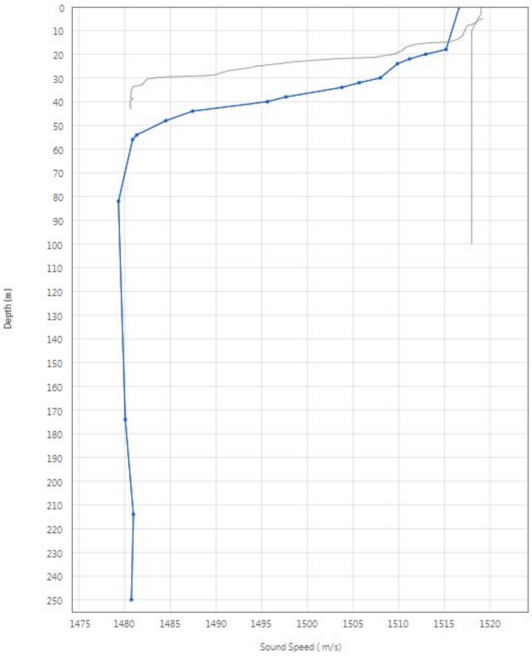


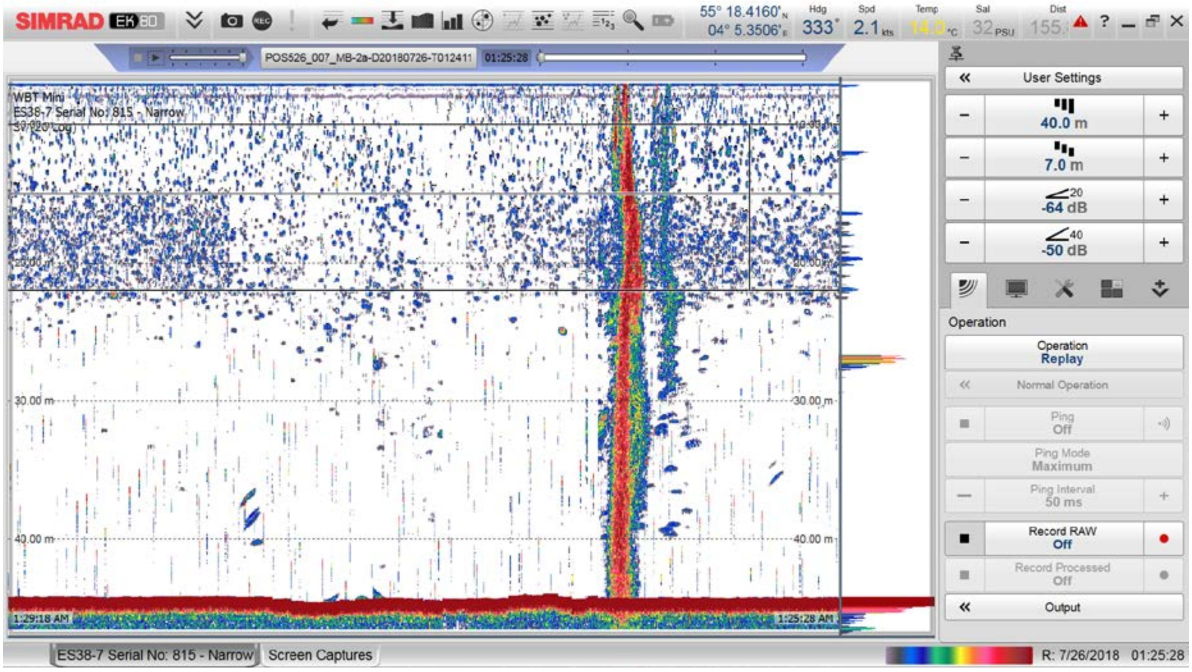
Figure 34: SVP from the Tisler Reef area.

Later processing including more detailed editing with Qimera version 1.7.0. This version is able to read the respective XSE format and apply SVP corrections. Exported xyz data were gridded using SAGA GIS (IDW algorithm with different cell sizes and search radii; 1m cell size, 5m search radius) and subsequent Gaussian filtering for reducing high frequency noise from these grids (radius 2 to 5 cells). Hill-shade files and contour lines were also created in SAGA GIS and exported as geotiff or shape file. Q-GIS was used for plotting resulting data.

7.1.18. Single-beam echo-sounder

To detect and quantify gas bubble in the water column a mobile EK80 scientific echo-sounder was installed in the moon pool of RV POSEIDON. A 38kHz scientific split beam echo sounder with 7° beam angle was used (ES38-7; sn 201) connected to a WBT Mini electronics (sn 261197), both from Kongsberg. Data acquisition used the Kongsberg own recording software SIMRAD EK80 (Figure 35). Navigational data were imported into the software from the ships data distribution system via a serial port. The FURUNO GPS data stream was used. Motion information was supplied from an OCTANS 3000 motion sensor installed together with the ES transducer in the moon-pool. The TSS1 data format was used for motion data. Data files were stored according to the station number and name most of the time. All data were recorded in .raw format.

During the survey we generally selected continuous wave pulses (CW) as standard with low energy and short pules length signals. Figure 35 shows a screenshot of the recording software in action. Preliminary post-processing and manual flare position picking was done with FM-Midwater version 7.8.0, this version can read CW pulse EK80 data, but cannot read data with FM pulses. Flare locations were manually picked in FM-Midwater.



Operation Replay

Normal Operation

Ping Off

Ping Mode Maximum

Ping Interval 50 ms

Record RAW Off

Record Processed Off

Figure 35: Screenshot of the recording software (here in reply mode)

7.1.19. Acoustic Doppler Current Profiler

For measuring water currents during slow steaming or on station we used an RDI Teledyne 300kHz ADCP with bottom track mode. The system was installed on the starboard side pole of the vessel, similar as the USBL system (Figure 36). A GPS antenna was placed one deck above the working deck close to the pole position. This GPS signal was fed into the VMDAS software for running the ADCP and acquiring data. Different settings were used during surveys (see chapter 7.2.14; Table 5). At the beginning of the cruise some files were recorded with the wrong orientation of the transducer towards the ships axis; this can be corrected in the post processing. The installation worked very well and the performance of the ADCP was good, reaching almost 130m in the Tisler reef area (Figure 37). The ship sailed with 3 to 4 knots while the pole was in the water. Measurements where not disturbed by vibrations which were very low in general.

Figure 36: ADCP installed on the starboard side pole of RV POSEIDON.

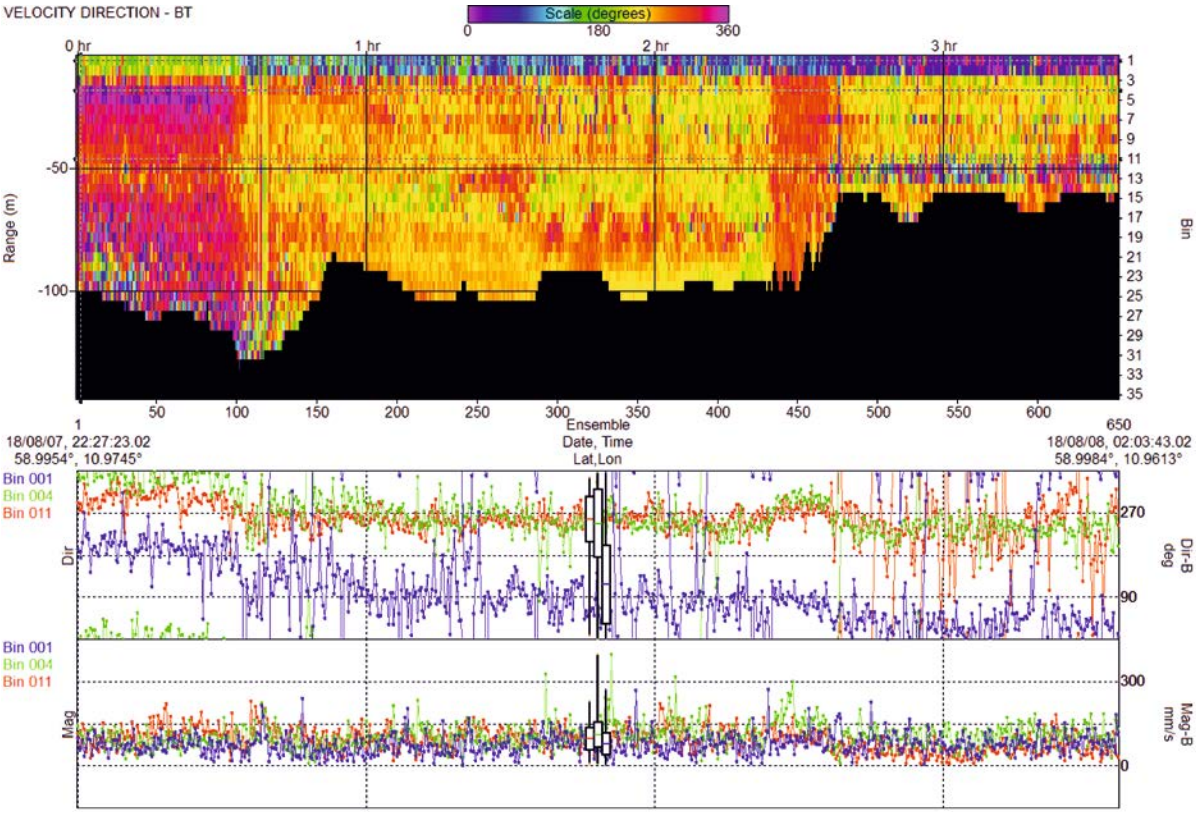


Figure 37: Data from the Tisler Reef area, showing the good performance of the ADCP down to 130m.

7.1.20. USBL Navigation and Communication

During POS526 a new Evelogics USBL and Modem system was used. The system is part of the AUV ANTON underwater navigation and data exchange system. For using this capability a second transponder was used to be mounted either on JAGO or the TV-CTD for accurate underwater navigation. For this purpose the SINAPS software by Evelogics was used. Input data into the software are GPS position as well as well as heading information provided via intranet from the ship. Data were output from the SINAPS software into the ships network as UDP broadcast; the Kongsberg SSB data string in radians was send and could be received by OFOP computers in the network. In this way several logging computers can see ships and SUB positions simultaneously.

The mechanical installation was straight forward, but the interfacing with different input signals, understanding how static offsets between the common reference point, the GPS antenna and the USBL position are handled was difficult and remains nebulous. Also sending position data of the transponder on JAGO back to the transponder for online display in OFOP inside JAGO took a longer while before it could be accomplished during JAGO dive 1400.

7.2. First Results

7.2.1. Submersible JAGO

During POS526, JAGO was used for (1) visual *in situ* observation, (2) high-resolution video and still documentation, (3) deployment and recovery of autonomous cameras, landers and optical bar-cod markers, (4) testing of a new USBL navigation and communication system, (5) selective collection of natural gas (), (6) collection of CTD data close to the sea floor, (7) first documentation of the Girona500 AUV flying above the seafloor and (8) as platform to carry and operate large instruments like the Bubble Box and the stereo camera.

In total, eleven JAGO dives were performed during POS526; three dives took place in the first working area Dogger Bank, and eight dives in the second working area Tisler Reef (Table 4). Total dive time was 28 hours and 8 minutes, during which 16 hours and 49 minutes of HD video footage (1.300 GB) were recorded and 15.430 stills (96 GB) taken. Dives were performed during daytime hours between 08:00 and 17:00 (local time) at maximum bottom depths between 43 (Dogger Bank) and 117 m (Tisler Reef). Nine members of the scientific team participated in a dive.

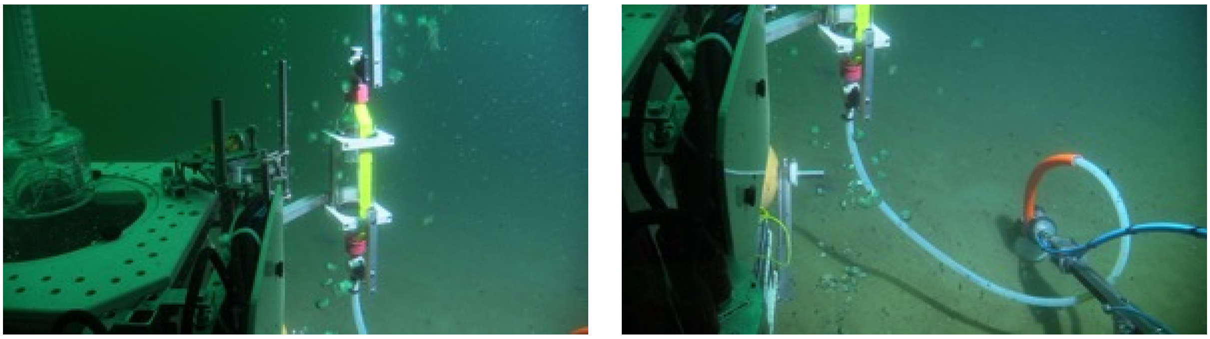


Figure 38: In situ gas sampling with JAGO at a seep site southeast of the Dogger Bank

The wind and sea conditions in the North Sea allowed the deployment of the submersible on 3 out of 7 days, and in the Skagerrak at the Tisler Reef on 5 out of 6 days on station. At both sites, a very distinctive thermocline was present. It was one of the factors that caused difficulties for the acoustic USBL communication and tracking of the submersible. Bottom currents were often strong (up to 2 kn) in the Tisler Reef area, in particular at the southwest facing slopes of the explored mounds, which were exposed to the dominate current direction from SE to NW, and at the deeper mounds at the SE side of the area closer to the channel. During some of the dives, the current caused difficulties for keeping the submersible on track and close to the bottom when flying close the reef top.

Figure 39. Left: Tim Weiß inside JAGO controlling the operation of the Bubble Box. Right: Gas Quant II Lander at the sea flow close to a seep cluster shortly before recovery with JAGO

Despite of these difficulties, most of the missions involving the submersible could be accomplished. The Bubble Box was successfully used on JAGO during two dives at the Dogger Bank (Figure 38, Figure 39). Active gas seeps could be detected with JAGO's horizontal single beam echo sounder from a distance of 50 metres (Garmin FishFinder 320C). The Gas Quant II lander – acoustically marked with a small pinger – was quickly located at the sea floor and its multibeam sensor turned in direction of the seep cluster. The lander was then recovered with JAGO five days after its deployment. During one of the dives at the Dogger Bank, natural gas was collected from an active seep.

Figure 40. Cold water coral reef at the Tisler Reef complex. White Lophelia pertusa corals with short branches and massive dead coral framework below, Mycale lingua sponges growing in between coral colonies, redfish Sebastes viviparous, and Cancer pagurus edible crabs

In the second WA, the Tisler Reef, the first JAGO dive was used to explore the summit of the central reef mound for a good site to deploy the autonomous PiCam cameras. In another dive, three of those cameras were placed with JAGO around a *Lophelia* deep water coral colony. The cameras were recovered again two days late. During two dives at the Tisler Reef, the stereographic camera system was attached to the lower front of JAGO. One of those dives targeted the coral colonies at the summit of the central reef mound. Synchronously to stereo filming, video footages were taken through the front window with a Sony Alpha 7s camera, equipped with wide-angle lens, and time-laps stills with JAGO's downward-looking GoPro Hero4 camera system. A second dive with the same set-up took place in a less structured area at the base of the central mound where the seafloor was mainly covered with soft sediment, cobbles, pebbles and boulders. During this dive, about twelve 40 metres long parallel transects with an overlapping field of view for photogrammetric measurements were performed in north-south direction. Another dive targeted the gully east of the main reef complex. Here a very much living and diverse reef was discovered (Figure 40).

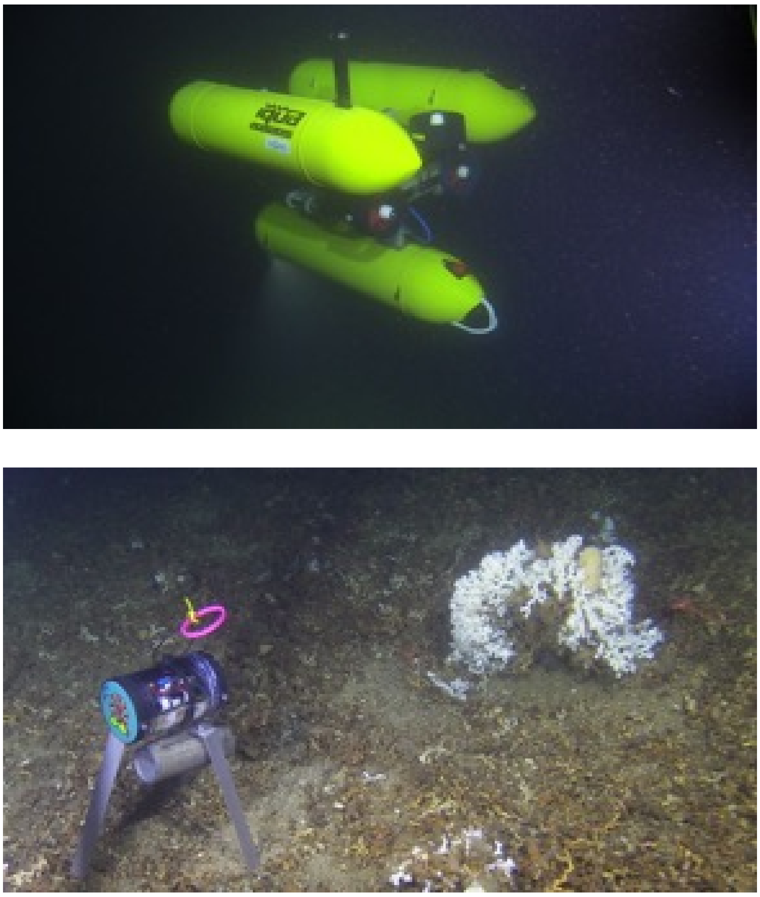


Figure 41. Top: Hover-AUV ‚Anton' passing submersible JAGO during their first mutul dive. Bottom: PiCam autonomous time-lapse still camera placed with JAGO in front of a coral colony at the Tisler Reef.

During JAGO dive 1399(07), St84, the submersible and the Hover-AUV met first in the water column at 20 m depth and then again at the sea floor at 111m (Figure 41). JAGO followed the AUV on its 50 m long parallel transects two metres above the sea floor and video documented its underwater performance for the first time under *in situ* conditions. The video footages will be used for a short video film about the first scientific test mission of the AUV.

In the second half of leg 2 most of the initial difficulties with the new EvoLogics USBL positioning and digital communication system were solved (see 7.2.18.). This finally allowed the JAGO underwater position to be sent from the top-site USBL modem below the ship to the down-site modem on top of JAGO and to be displayed on a tablet PC inside the submersible within the OFOP software (Figure 42). This improvement was one of the technical priority aims for the JAGO-Team during POS526. It enables now accurate positioning in real-time available both inside JAGO and on the support vessel.

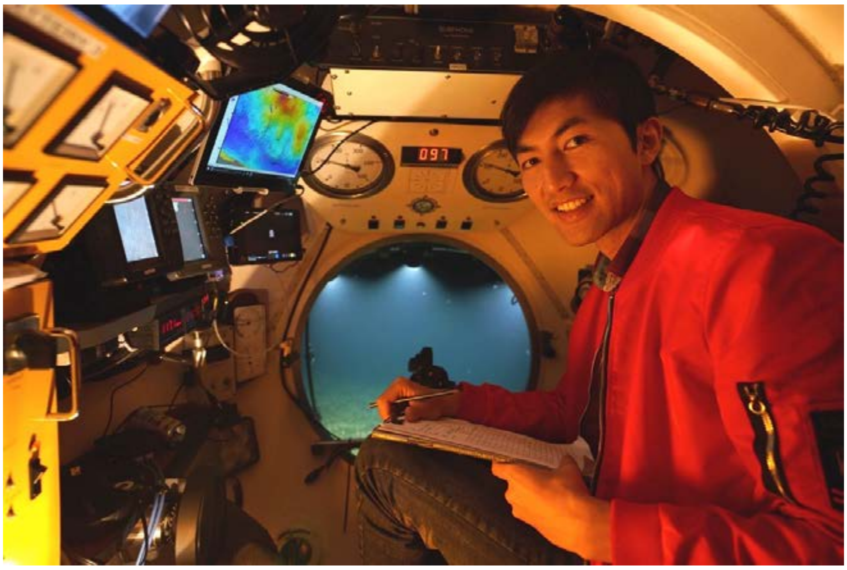


Figure 42: Inside JAGO – PhD student Yifan Song during a dive at the Tisler Reef. Upper left monitor with display of multibeam map, produced during POS526, and USBL underwater position of JAGO.

The handling of the submersible from on board the POSEIDON went very safe and smooth. The teamwork between the captain and officers on the bridge, the bosun and his deck hands, the work boat team and the JAGO-Team during launch and recovery was as excellent and professional as during previous JAGO-POSEIDON cruises. Deployment and recovery of the submersible took usually only few minutes. The POSEIDON once again proved to be a very suitable support vessel for JAGO operations.

Table 4. Metadata of submersible JAGO dives conducted during RV POSEIDON cruise POS526 (time is related to submerging and surfacing, position is related to dive start and end at seabed). Max D: maximum water depth during the surveys.

Dive #	Station #		Date [ddmm]	Time [UTC]	Longitude [N]	Latitude [E]	Max D [m]	Remarks
				Dogger Bank				
1393/01	2	Start	25.07.	11:09	55°18.41’	04°05.37’	43	Survey for gas seeps, use of BubbleBox at 4 different seeps (Schauer/Weiß)
		End	25.07.	14:52	55°18.32’	04°05.37’		
1394/02	11	Start	26.07.	11:13	55°18.40’	04°05.38’	43	GasQuant inspected + multibeam sensor turned in direction of seeps, use BubbleBox at 3 different seeps, collect gas (Striewski/Schauer)
		End	26.07.	15:00	55°18.35’	04°05.44’		
1395/03	60	Start	31.07.	06:56	55°18.35’	04°05.47’	43	Recovering GasQuant; final GasQuant position determined by good USBL navigation (Schauer/Pohlman)
		End	31.07.	08:12	55°18.37’	04°05.44’		
				Tisler Reef				
1396/04	66	Start	03.08.	06:41	58°59.87’	10°57.71’	83	Exploring central Tisler reef complex, stand-alone cameras (PiCams) not deployed because of internal power failure (Schauer/Purser)
		End	03.08.	09:03	58°59.88’	10°57.75’		

1397/05	71	Start	04.08.	06:26	58°59.89’	10°57.69’	79	Stereographic camera (BatCam), GoPro-stills, Sony-Alpha survey at summit of Tisler reef (Schauer/Köser)
		End	04.08.	09:15	58°59.90’	10°57.69’		
1398/06	73	Start	04.08.	12:41	58°59.74’	10°58.08’	122	Exploration survey from the eastern gully towards the central Tisler reef summit (Schauer/Greinert)
		End	04.08.	15:09	58°59.90’	10°57.66’		
1399/07	84	Start	06.08.	06:36	58°59.99’	10°57.55’	111	UW-meeting with AUV, following AUV on its transect, deployment of 3 PiCam cameras close to summit of central Tisler reef (Schauer/Purser)
		End	06.08.	09:04	58°59.90’	10°57.69’		
1400/08	86	Start	06.08.	12:27	58°59.83’	10°57.76’	106	Exploration survey from lower eastern reef mounds up to central Tisler mound, strong current, transmisson of USBL navigation data to JAGO worked well (Schauer/Hissmann)
		End	06.08.	14:36	58°59.91’	10°57.75’		
1401/09	89	Start	07.08.	07:08	58°59.99’	10°57.14’	117	Exploration of smaller mounds west of central Tisler reef mound, solid rock + coral rubble mound, USBL nav. inside JAGO (Schauer/Striewski)
		End	07.08.	09:04	58°59.99’	10°57.30’		
1402/10	91	Start	07.08.	12:16	58°59.94’	10°57.54’	103	Stereographic camera (BatCam), GoPro-stills, Sony-Alpha images along parallel transects in boulder/cobble area west of central Tisler reef mound (Schauer/Köser)
		End	07.08.	15:01	58°59.92’	10°57.55’		
1403/11	100	Start	08.08.	06:41	58°59.94’	10°57.68’	117	Collecting 3 PiCam cameras at reef top, exploration of slope with coral reef towards south of central Tisler reef summit (Schauer/Song)
		End	08.08.	09:06	58°59.87’	10°57.49’		

7.2.2. AUV Anton

As this was the first cruise for the new AUV, the first deployment of the AUV dedicated to test its buoyancy in the environment of the working area. This was done to verify the trim of the vehicle and that it is not pointing upward/downward but lies flat and almost neutral in the water. This test was important because the AUV was to be deployed in a different sea with a different water density than before. The preparations were carried out as if it would have been a normal mission dive. Everything was set, so that the AUV could be lowered into the North Sea for the first time. The AUV was floating in the water and waves were passing slightly over the AUV. The waves did not seem to create too much lift. The calculated remaining buoyancy was 5,1kg.

Overview of Missions: Figure 43, Figure 44, and Figure 45 show the missions that were planned during the cruise. The Tracks are illustrated, but the depth is not shown in the figures. The missions are described in more detail in the following section. All data are recorded in a Rosbag-files. This is a standard format in that ROS records data. Each Rosbag-file consists of binary data and holds sequences of records. The specific format can be found at http://wiki.ros.org/Bags/Format.

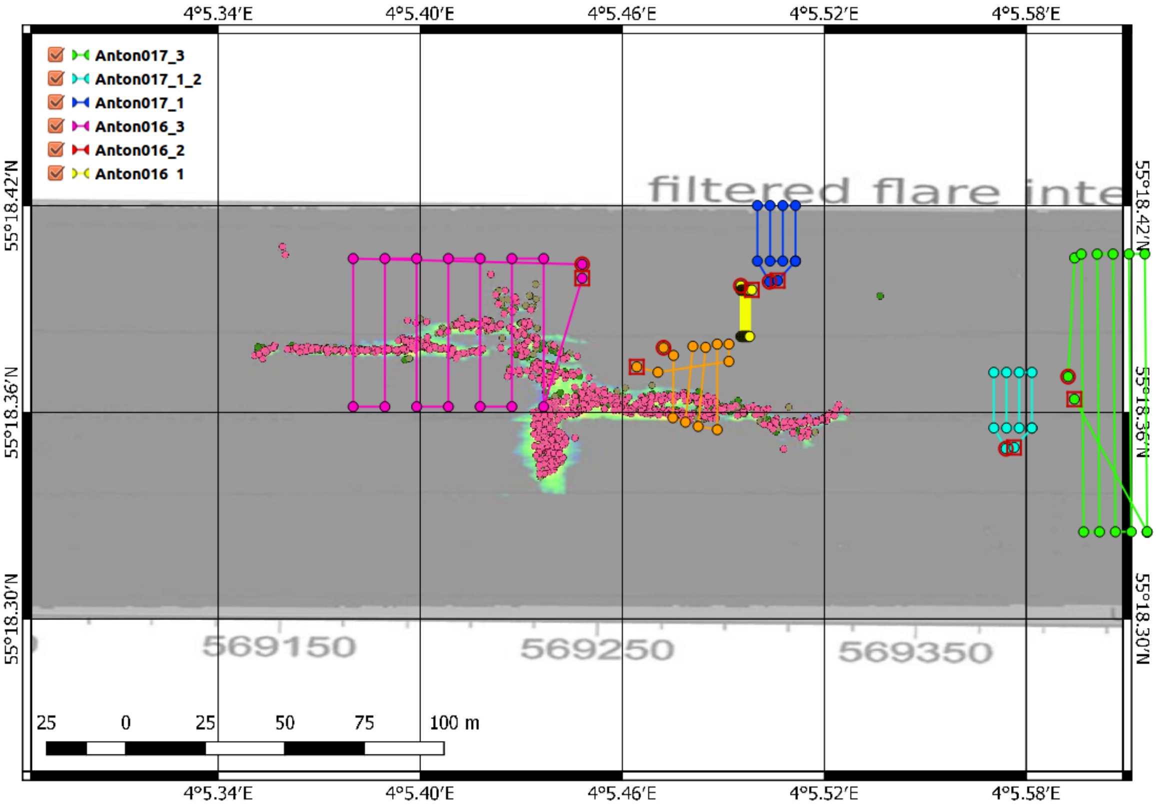


Figure 43: Planning of missions Anton016 - Anton017

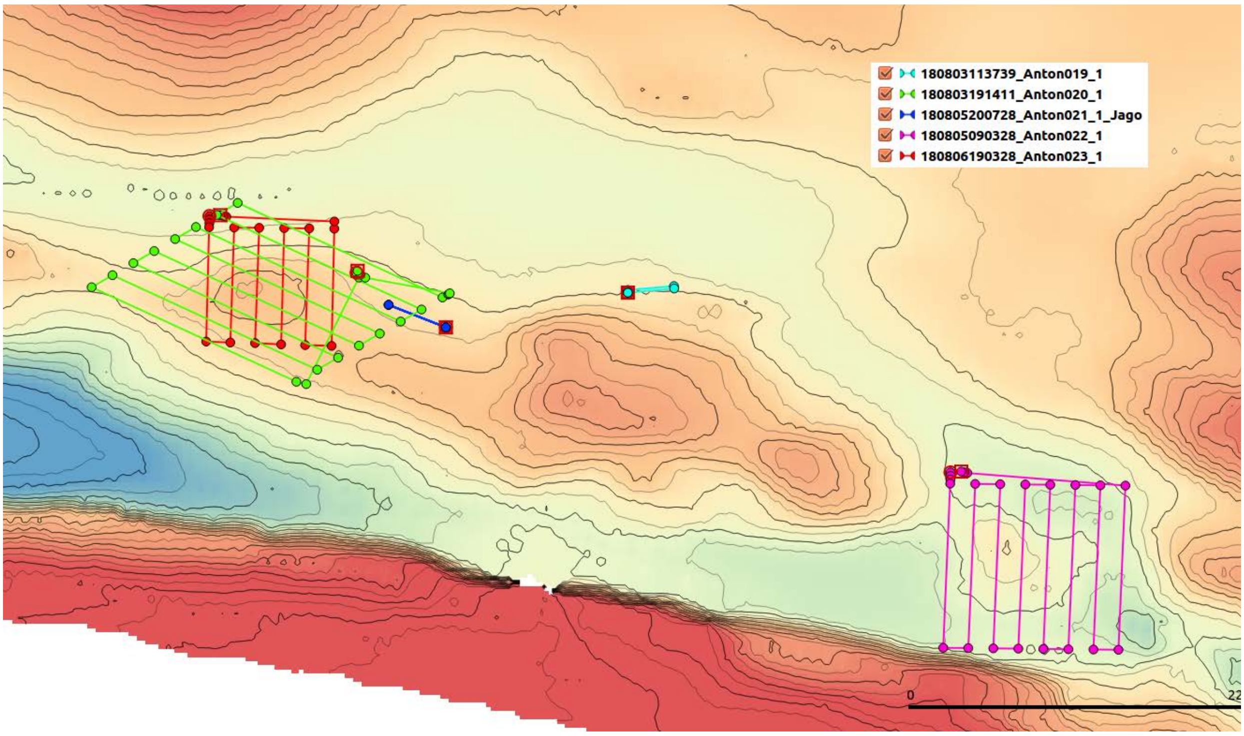


Figure 44: Planning of missions Anton019 - Anton023

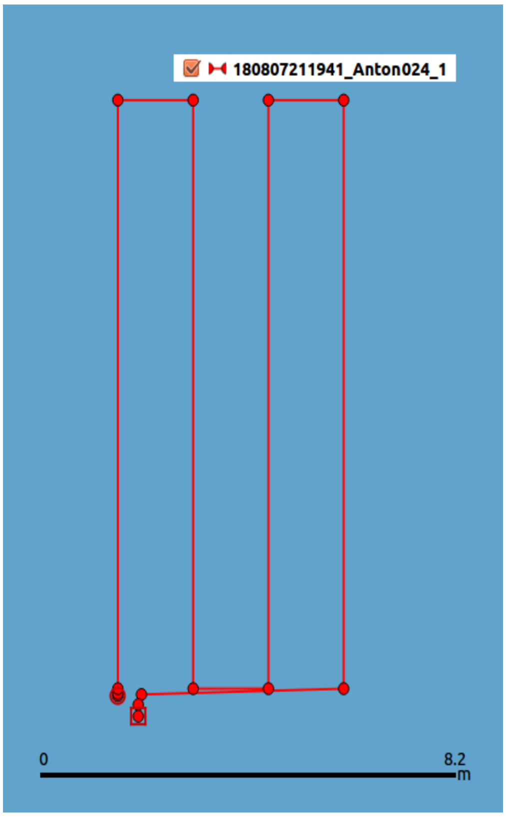


Figure 45: Planning of mission Anton024

Station 04/04 / Dive Anton016 / Area Dogger Bank

Date:	25th July 2018		
Launch:	06:55 UTC	Survey Time:	0:32 hours
Recovery:	08:52 UTC	Distance Traveled:	680 m

The first deployment for a mission took place on the 25th of July. The primary goal was to get the USBL communication to work properly. Therefore the AUV was programmed to stay at a certain depth. There were no pings received from the AUV. A first try was to rotate the ship, so that the USBL pole was closer to the AUV. But this did not yield any pings either. Also shutting down all sensors of the ship was not changing anything.

A second mission was designed within a very close radius of the ship for better USBL reception. This short mission showed some anomaly when starting the mission. The AUV started to dive down and drifted back to the surface. This was repeated for several times. Because of the workload this problem was not addressed at this time. This behaviour occurred again but was observed infrequently.

This third dive of the day showed for the first time true USBL pings from the AUV. The mission was a simple survey of the seafloor. The camera data was not good, but with the SiNAPS program pings were received and correctly mapped.

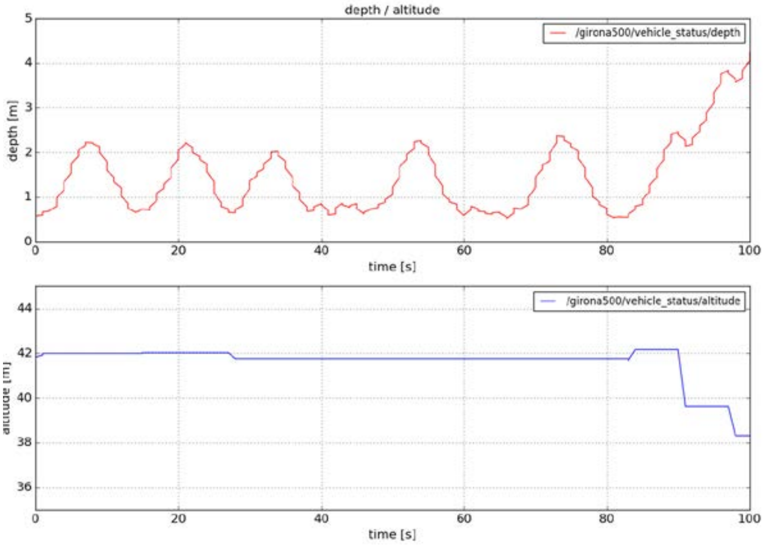


Figure 46 : Anton016 - Plot of depth and altitude at the start of the mission with drifting back to surface

Station 09/09 / Dive Anton017 / Area Dogger Bank

Date:	26th July 2018		
Launch:	05:39 UTC	Survey Time:	0:54 hours
Recovery:	08:10 UTC	Distance Traveled:	1,2 km

The first mission of this station was designed to experiment with the camera settings for taking good images. Unfortunately it was designed with an old configuration file, so that no data was saved and it had to be executed a second time.

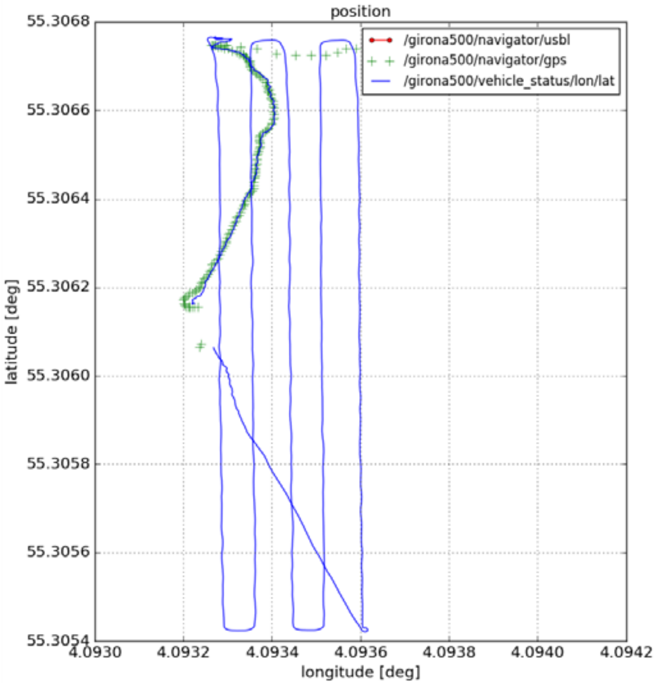


Figure 47: Anton017 - Plot of the position of the AUV

The third mission was a camera test mission in 3 m altitude. The plots show the different parts of the dive and some of the data that was recorded. The recorded images were not useful. All images are completely black because of the bad underwater visibility of this location. The data from the CTD sensor seems to be quite good but is only stored in the raw rosbag file and thus needs to be extracted in a post processing step. A very odd behaviour was observed in the beginning, when the AUV was trying to dive down, but kept coming up again a few times until it finally submerged. The cause of this is unclear and has to be evaluated.

Station 18/19 / Dive Anton018 / Area Dogger Bank

Date:	27th July 2018		
Launch:	13:20 UTC	Survey Time:	0 hours
Recovery:	14:30 UTC	Distance Travelled:	- m

Waves were starting to form because of up to 20 kts of wind. The AUV was not yet used in such conditions, so a deployment and recovery test was performed. The AUV was constantly secured with an attached rope. The first two times showed, that the AUV struggles with the waves. The AUV was in the water with repeatedly no connection for more than 15 seconds. Having no connection is problematic, because the vehicle ignores all commands from the remote controller.

During the third deployment the waves caused a loss of the Wi-Fi connection for over 70 seconds. The AUV drifted to the rear of the ship and the connection was not getting better, so that the AUV had to be pulled back with the security rope. Because the AUV was towed from the ship, it was damaged by the ships hull, when waves pushed ship and AUV together. The AUV was on deck shortly after the incident and the damage was minimal. In summary some scratches on the hull. Two nylon screws had to be replaced to fix the position of the antenna.

Due to the bad weather conditions in the following days, this was the last test of the AUV in the first working area.

Station 67/67 / Dive Anton019 / Area Tisler Reef

Date:	3rd August 2018		
Launch:	10:18 UTC	Survey Time:	0:32 hours
Recovery:	13:30 UTC	Distance Travelled:	680 m

This dive was the first dive in the second working area. The plan was to check how the AUV behaves in this new environment and subsequently launching planned missions.

The depth of the working area for this day was about 100m. This means, that the DVL has no bottom lock for about the first 60 meters. The AUV was behaving unexpectedly during the first hour of this station. Missions were not executed or aborted immediately. The AUV started a mission and was back at the surface before the bottom was reached. This was caused by a timeout of the software architecture. This error was not found on this day since the focus was set on the USBL communication.

This was the first dive after the USBL connection error was examined closely. Several tests were made, where the AUV was held at a certain depth to have a USBL signal. After some further error fixing, the USBL was working with the current configuration. Two short test missions were executed to see the AUV in operation and verify that pings are received by the USBL topside. As seen in Figure 48, the positions are not accurate. Accurate positions were obtained using the SiNAPS software though.

The final dives of the day were simple missions to test the camera. The focus was readjusted beforehand to a distance of 2 m. Measuring from the centre of the AUV, a short dive in 3 m altitude was designed. Images were captured with lights enabled, but the settings did not yield good pictures. Only a few images showed jellyfish contours while the rest were black. Even with better visibility than in the first working area, the AUV has to get closer to the objects in order to acquire good data.

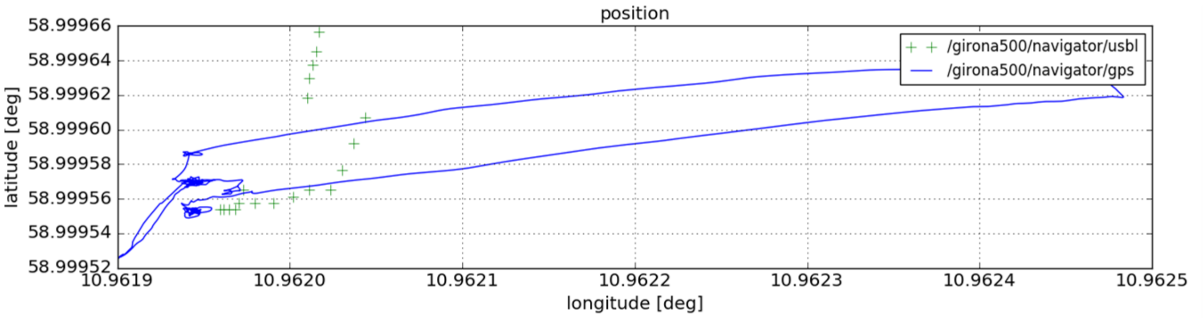


Figure 48: Anton019 - Last dive, plot of the position of the AUV

Also the multibeam was successfully enabled for a short time during the dive, resulting in the first small dataset of this cruise.

Profile point filter: Bottom Following	Averaging: 9	Number of beams: 480
Automatic sound speed: true	Beam width: 2	Sector size: 120°
Record formats: 837, 83P	Gain: 4	Range: 5m

Station 72/72 / Dive Anton020 / Area Tisler Reef

Date:	4th August 2018		
Launch:	10:00 UTC	Survey Time:	1 hour
Recovery:	13:43 UTC	Distance Travelled:	2 km

Mission 20 was supposed to further test the USBL connection, as well as the multibeam and the camera in a longer mission. For that, a multibeam survey in 25m altitude with a speed of 0.75 m/s was planned including a short dive to 2 m altitude for the camera at the end.
The vehicle aborted the mission in the descend phase due to a timeout event first recognized in this mission at 40 m depth. One of the DVL timeouts was set to 20 seconds and led to a “abort and surface” recovery action when the DVL was not giving trustworthy data for more than 20 seconds. The AUV was sent to a position close to the Poseidon, and after a short trouble shooting, a higher timeout value was set over WIFI.
After that, the mission was started again and ended as planned with many USBL pings visible in the GUI (horizontally distance between ship and AUV up to 200 m).

Profile point filter: Bottom Following	Averaging: 9	Number of beams: 480
Automatic sound speed: true	Beam width: 2	Sector size: 120°
Record formats: 837, 83P	Gain: 4	Range: 50m

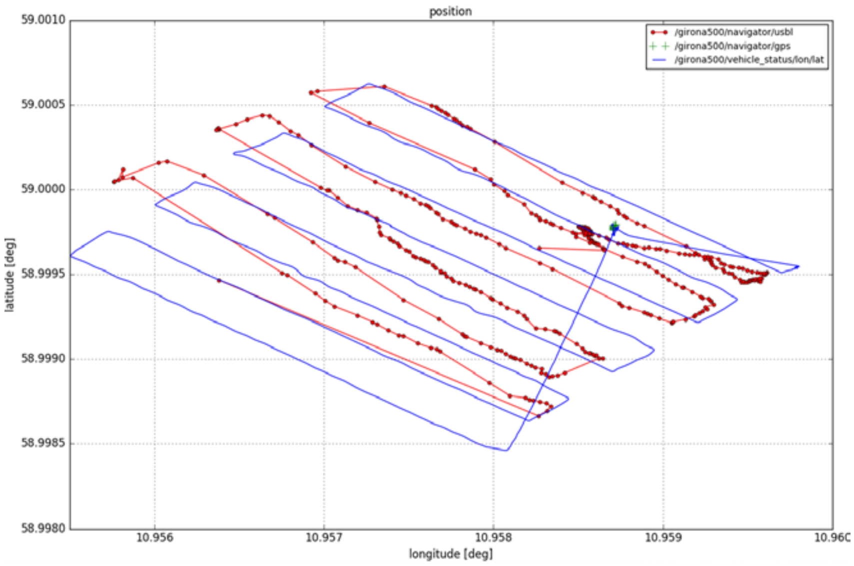


Figure 49: Anton020 - Plot of the position of the AUV with USBL positions

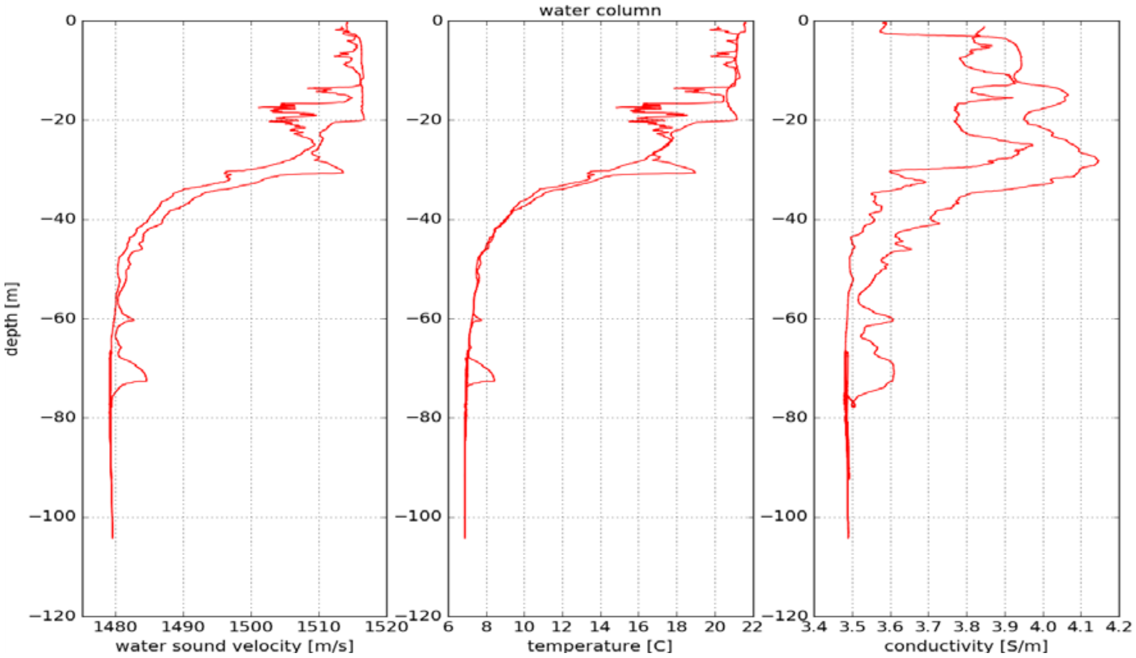


Figure 50: Anton020 - Plot of the CTD data (sound speed, temperature, conductivity)

Station 83/83 / Dive Anton021 / Area Tisler Reef

Date:	6th August 2018		
Launch:	06:18 UTC	Survey Time:	1:20 hours
Recovery:	08:05 UTC	Distance Travelled:	460 m

The goal of mission 21 was to have a dive together with JAGO, so the behaviour of the AUV could be analysed while moving underwater. For that, the following mission was programmed: Go to a depth of 20 m, wait for JAGO for 5 minutes, go to 2 m altitude, wait 20 minutes for JAGO again, then follow a 50 m track back and forth 6 times with 0.15 m/s and finally go back to the surface. In the time of the line following, the camera was enabled to experiment with longer exposure time and slower moving speeds. In the diving phase, the AUV and JAGO experienced a lot of drift visible in SiNAPS and were separated in the water column, but after JAGO found the AUV at the bottom, lots of good video material showing the AUV could be obtained.

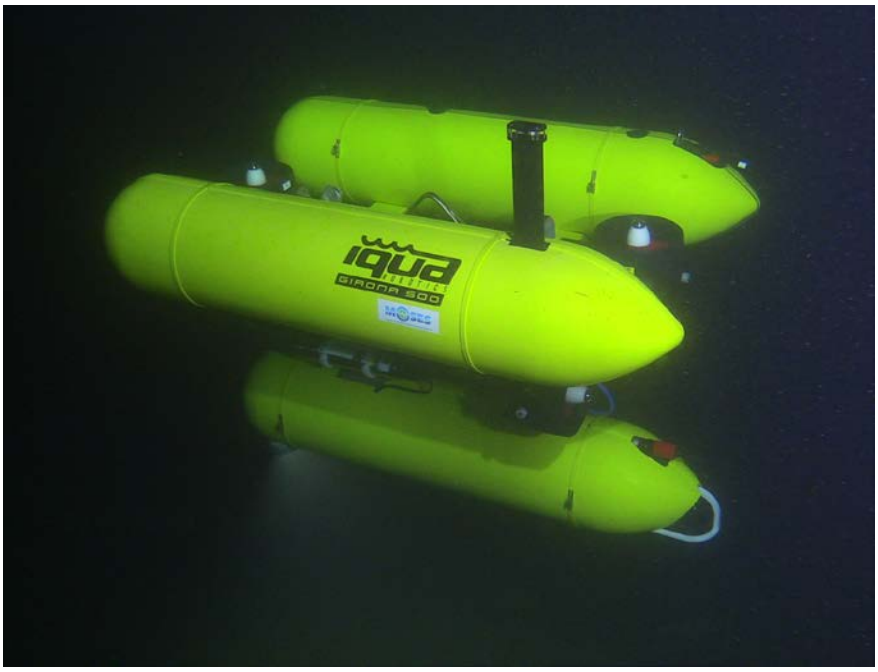


Figure 51: Anton021 - Picture of the AUV on a mission.

Station 85/85 / Dive Anton022 / Area Tisler Reef

Date:	6th August 2018		
Launch:	10:22 UTC	Survey Time:	1:20 hours
Recovery:	12:02 UTC	Distance Travelled:	2,2 km

Mission 22 was supposed to gather more multibeam data. To test whether a lower speed can reduce a fluctuation in the pitch-axis observed in mission 19, the mission speed was set to 0.5 m/s. On the way to the bottom, USBL position updates for the navigation were activated. When the vehicle was arriving on the seafloor, the GUI showed many good USBL fixes. After some minutes though, the direction of the AUV shown in the GUI diverted considerably from the programmed path. However, when switching to SiNAPS, the USBL pings indicated a normal behaviour of the AUV, so the mission was continued until it finished as expected.

Profile point filter: Bottom Following	Averaging: 9	Number of beams: 480
Automatic sound speed: true	Beam width: 2	Sector size: 120°
Record formats: 837, 83P	Gain: 4	Range: 50m

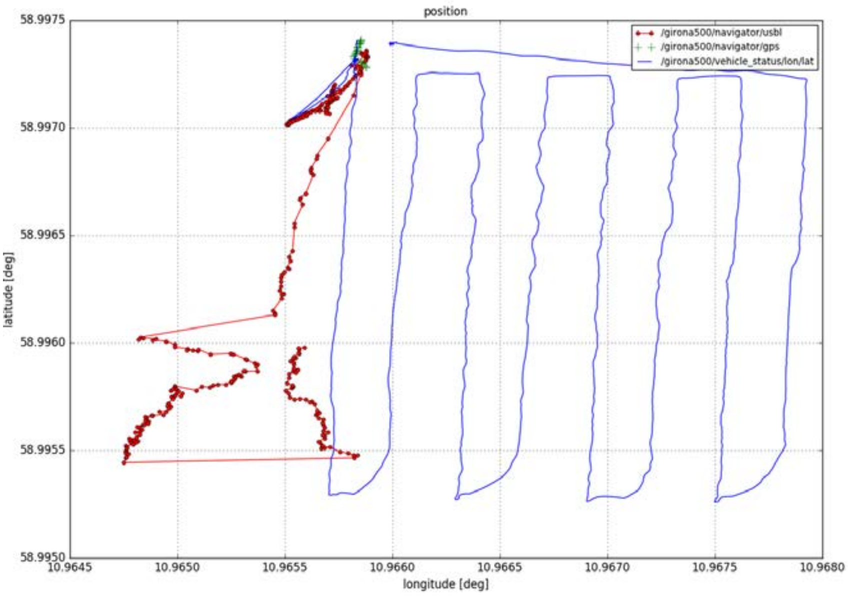


Figure 52: Anton022 - Plot of the position of the AUV

Station 90/90/ Dive Anton023 / Area Tisler Reef

Date:	7th August 2018		
Launch:	10:26 UTC	Survey Time:	1 hour
Recovery:	11:20 UTC	Distance Travelled:	2 km

Mission 23 was supposed to further test the multibeam. This time the AUV was used in depth mode of 80 m instead of altitude mode to test the impact on the stability in the pitch axis of the vehicle. Due to inaccurate USBL positions in the GUI, SiNAPS was used for visualizing the position of the AUV. Because of that, no USBL position updates could be sent to the Girona500, and thus there was a drift in the diving phase. Besides of this offset, the mission was carried out as expected.

Profile point filter: Bottom Following	Averaging: 9	Number of beams: 480
Automatic sound speed: true	Beam width: 2	Sector size: 120°
Record formats: 837, 83P	Gain: 4	Range: 60m

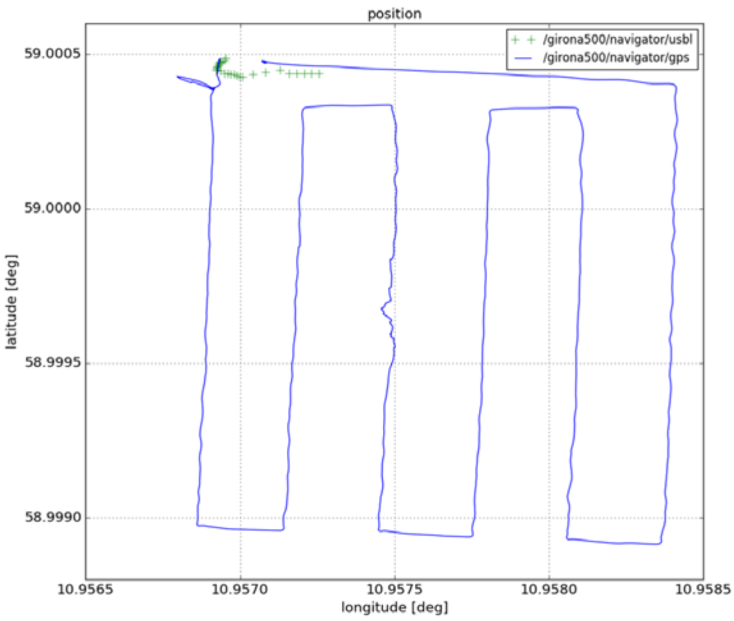


Figure 53: Anton023 - Plot of the position of the AUV.

Station 102/102/ Dive Anton024 / Area Tisler Reef

Date:	8th August 2018		
Launch:	11:18 UTC	Survey Time:	0:43 hours
Recovery:	13:04 UTC	Distance Travelled:	1,3 km

Mission 24 was the last dive of the cruise and was supposed to test the AUV in a depth of 400 m. For that, a short camera mission with 4 legs of 20 m length was designed and started. With the beginning of the dive, the AUV was drifting away quickly from the ship until the USBL connection was lost for about 20 minutes.

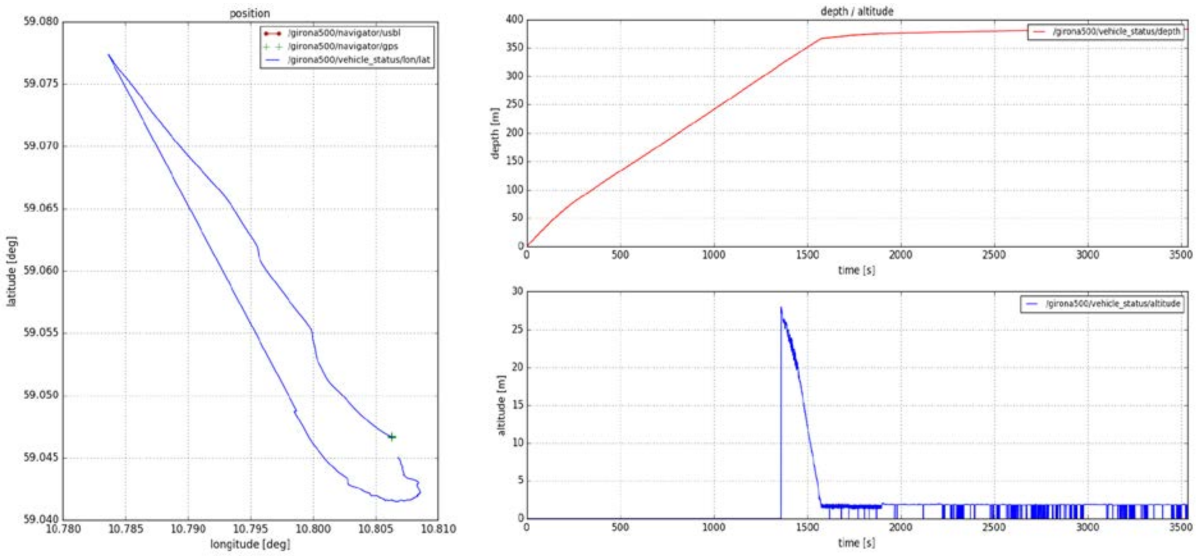


Figure 54: Anton024 - Plot of the position of the AUV with drift; altitude and depth reached, maximum of 380m.

After the Poseidon followed the AUV in the direction of the drift, USBL fixes showed up again in SiNAPS, indicating, the vehicle made its way to the ground, executing the mission as planned. After a while though, it was clear from the visible USBL path, that it was not following the mission, but slowly going back in the direction of the deployment instead. It was decided to wait for about 15 minutes, until the timeouts of the architecture would bring the AUV back to the surface. Five minutes before that, it stopped moving horizontally and began to rise slowly. After 25 minutes it surfaced about 70 meters away from the ship. Because the robot was switched off completely, it could not be controlled and the Poseidon had to approach the AUV for the recovery.

7.2.3. Waveglider

At the beginning the Wave Glider first had a hard time moving along due to the near perfectly flat sea surface but luckily was later on cruising with more than 2 kn in the much rougher weather with gusts of up to 50 knots. The Wave Glider complemented ship-borne CH_4 sensors by following a grid across the working area at the methane seeps sites. While the ship was concentrating on certain seeps sites, the Wave Glider was observing the far field by moving in and out of the seeps area several times. Several crossing between the ship and the Wave Glider were performed in order to compare data from the CRDS and the Wave Glider for methodological studies. Additionally, the glider was tested with an USBL beacon which was lowered from the ship. While the glider was approaching the ship (within 200 m) it successfully located the beacon several times and reported its position via satellite to shore (Figure 55).

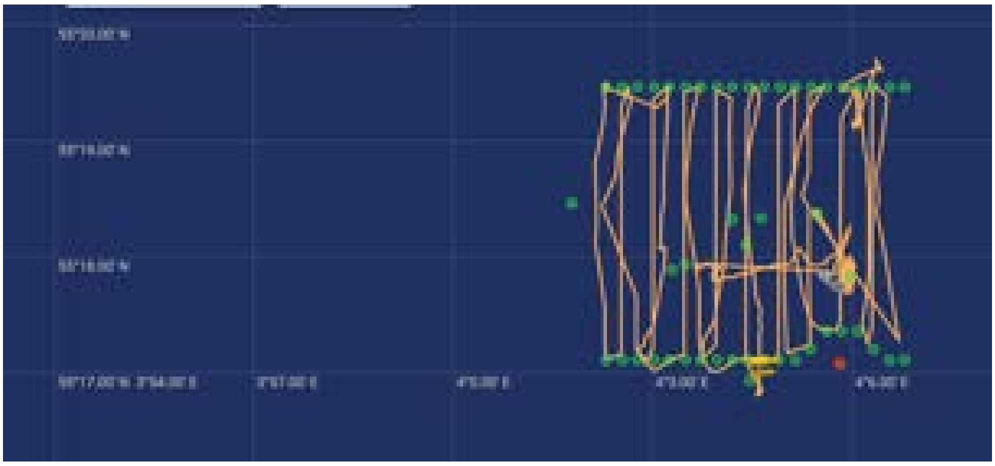


Figure 55: Cruise track of GEOMAR-4 Wave Glider during the G4V2 mission

Unfortunately, a malfunction occurred during high sea states which led to critical limitations in navigating the glider safely anymore. Thus, the glider was recovered after being 3.5 days on mission in order to avoid more severe damages during the high sea state. On deck the Wave Glider was connected to the underway seawater supply system (water intake in the moonpool) and the sensor payload was running in parallel for a direct comparison of the sensor mounted in the Wave Glider with the benchtop CRDS (CO_2 & CH_4) system.

Preliminary data from the 3.5 day mission show very promising results when comparing with the more sophisticated and matured benchtop CRDS system. The Wave Glider data shows clear patterns of elevated CH_4 values near the seeps sites and concentrations are levelling out when the glider was moving away outside of the seep area (Figure 56).

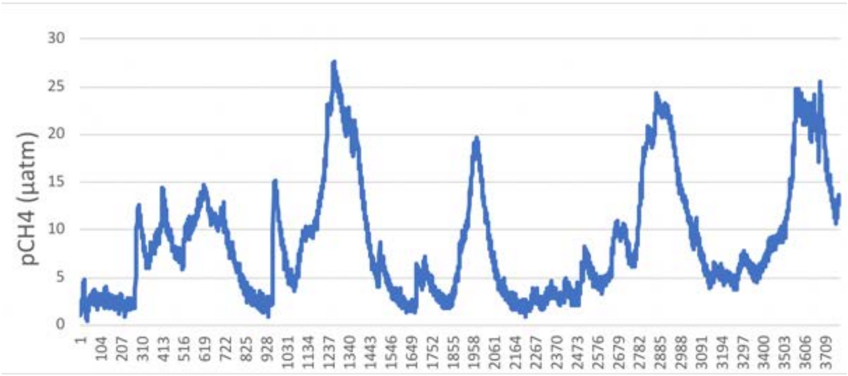


Figure 56: Methane partial pressure obtained during the Wave Glider mission

7.2.4. Picarro & AIS

The focus of atmospheric gas measurements was during the first part of the cruise on the Dogger Bank. Especially interesting were the time slots when the ship conducted acoustic surveys and the different seep clusters were systematically tracked using a lawn mown pattern. Figure 57 shows maps of the different air inlets and the CH_4 Dry concentrations. The grey triangles show locations of gas releases on the ocean floor (jumping horse site). The black vectors display the wind direction at the time of measuring. All measurements were done between 26.07. 19:00 UTC and 27.07. 04:00 UTC. The goal is to measure gradients between the different air inlets. These gradients can be observed at several locations on the map (e.g. west of jumping horse site). The measured CH_4 concentrations are higher on the lower air inlets and decline on the higher air inlets.

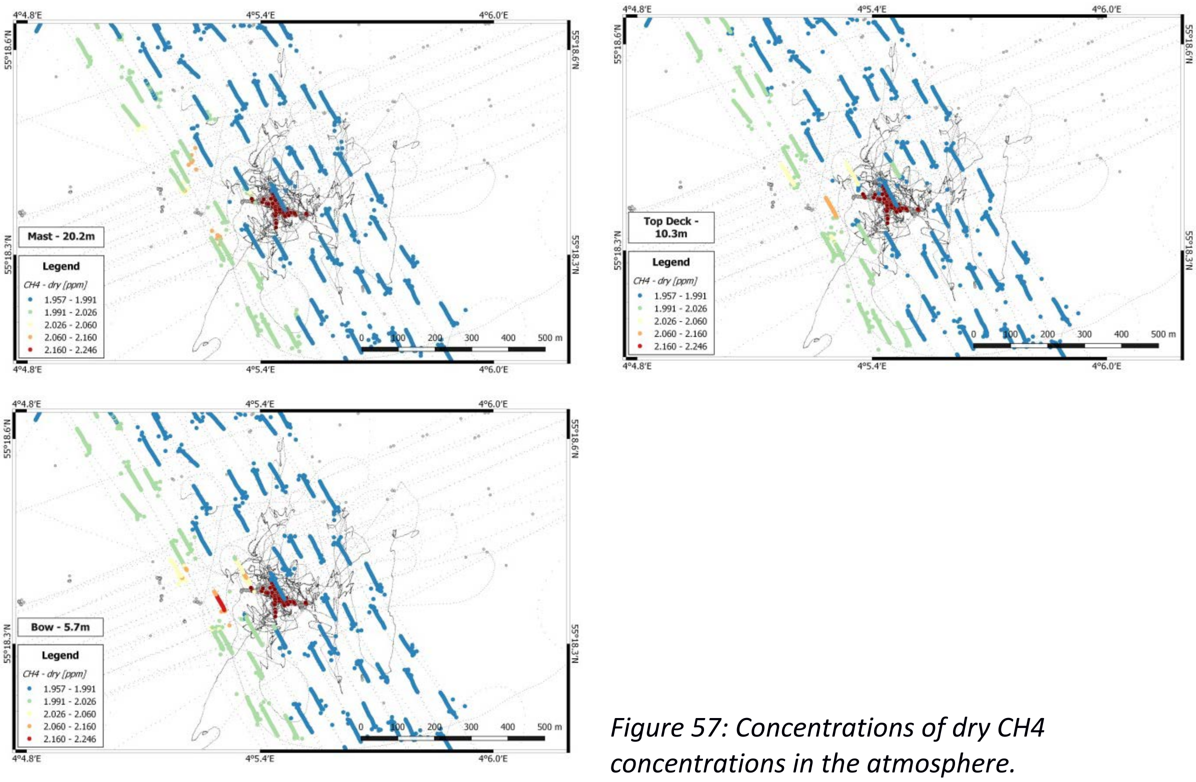


Figure 57: Concentrations of dry CH4 concentrations in the atmosphere.

7.2.5. CTD water sampling and physical oceanography

Water sampling occurred in the Dogger Bank area to investigate the distribution patterns of dissolved methane also in conjunction with tidal changes. For this vertical CTD casts were performed within the centers of Cluster 1 and 5 to define ‘the strongest’ methane concentration in the water. At Cluster 1 three vertical CTDs casts were performed (Figure 58, Figure 59).

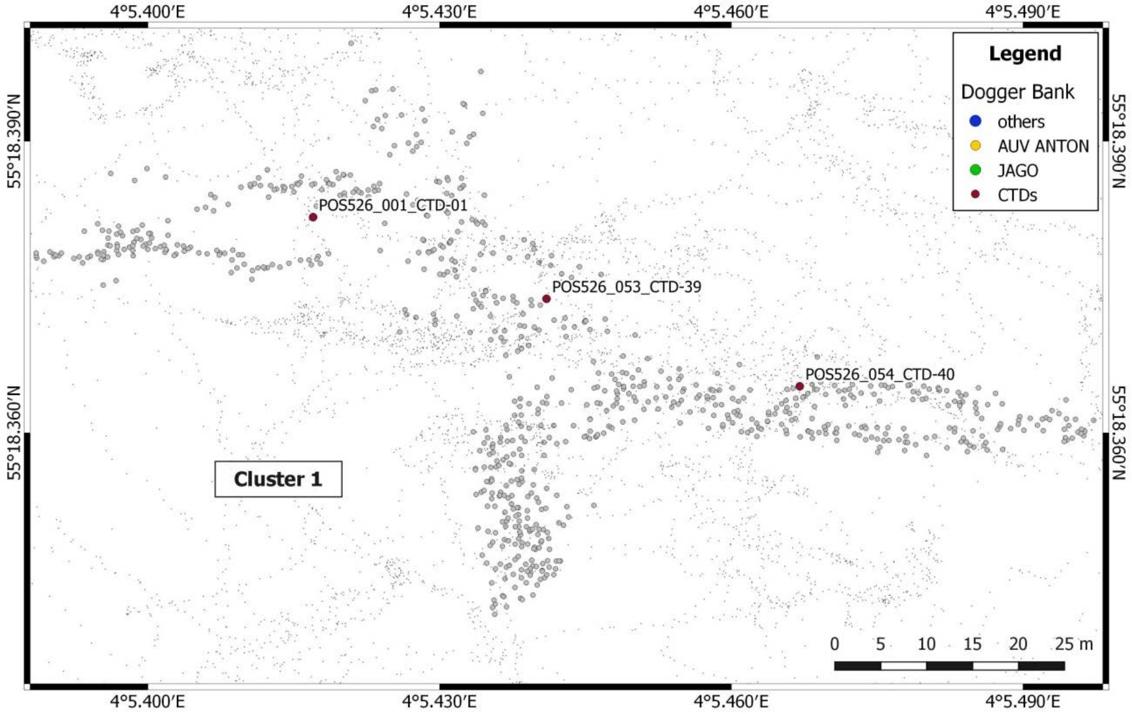


Figure 58: Vertical CTD stations in Cluster 1, Dogger Bank.

Six additional horizontal tows were undertaken at Cluster 1 to see concentration changes across the main seep field (POS_006-CTD-02). Several N-S tow tracks were performed 300 and 150 downstream of Cluster 1 as well as through the cluster (Figure 59). All bottles were closed below the pycnocline within the well mixed bottom layer in about 37m water depth.

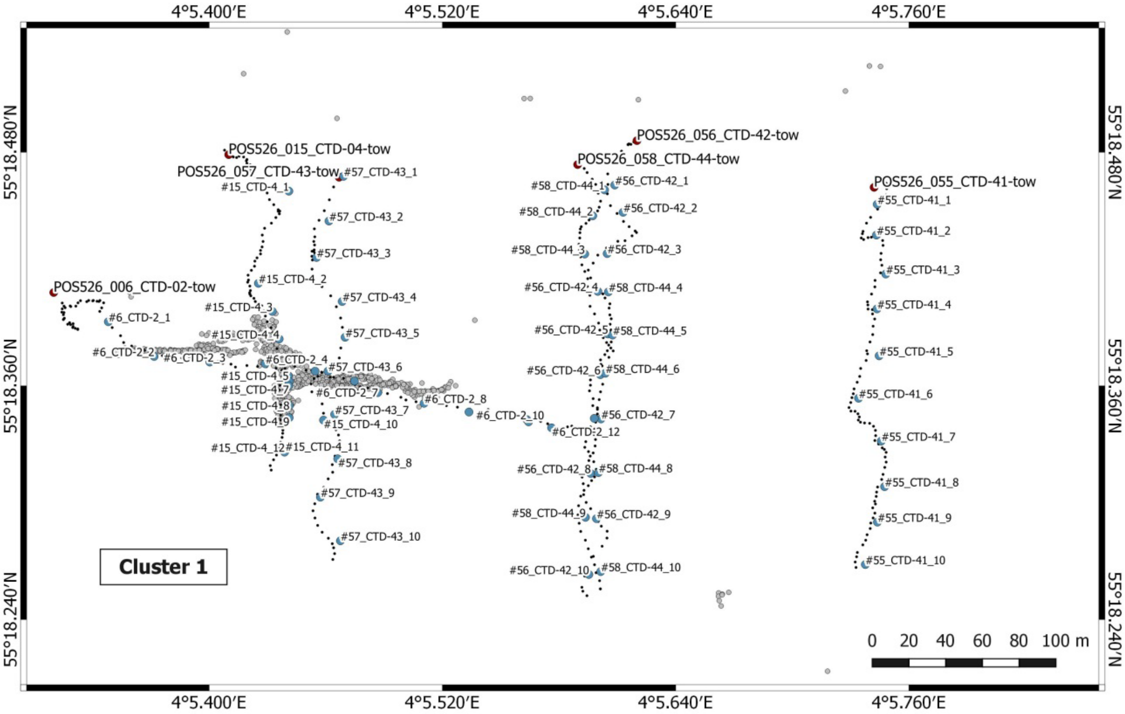


Figure 59: Horizontal CTD stations and sampling locations in Cluster 1, Dogger Bank.

Similarly we performed horizontal water sampling at Cluster 5 (Figure 60).

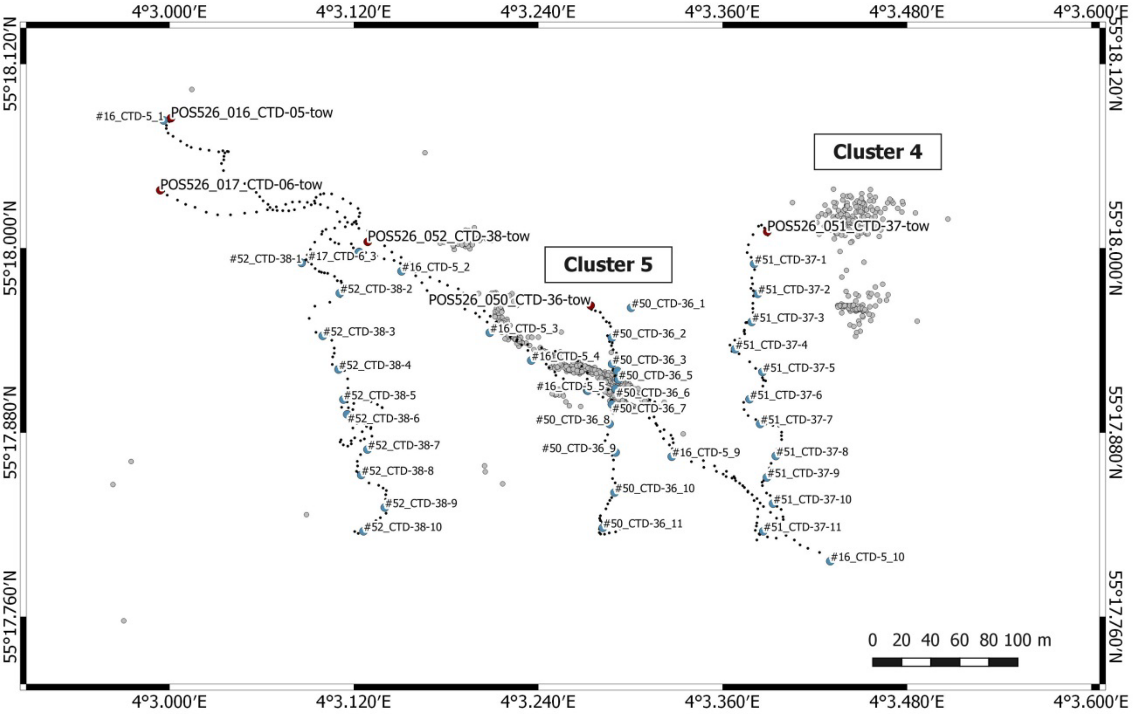


Figure 60: Horizontal CTDs and sampling locations at Cluster 5.

In addition this very intense cluster was select for a 24h time series sampling during different current direction states (Figure 61). Simple ODV plots of the physical property changes during these 24h are given in Figure 62.

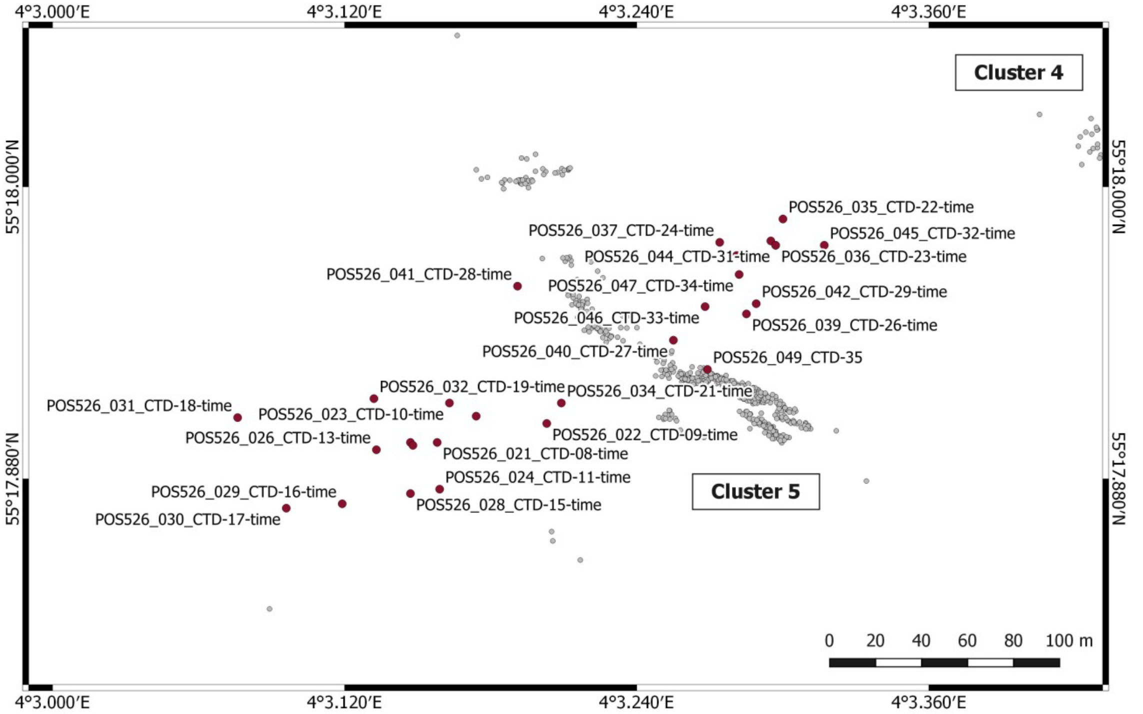


Figure 61: Time series CTDs at Cluster 5.

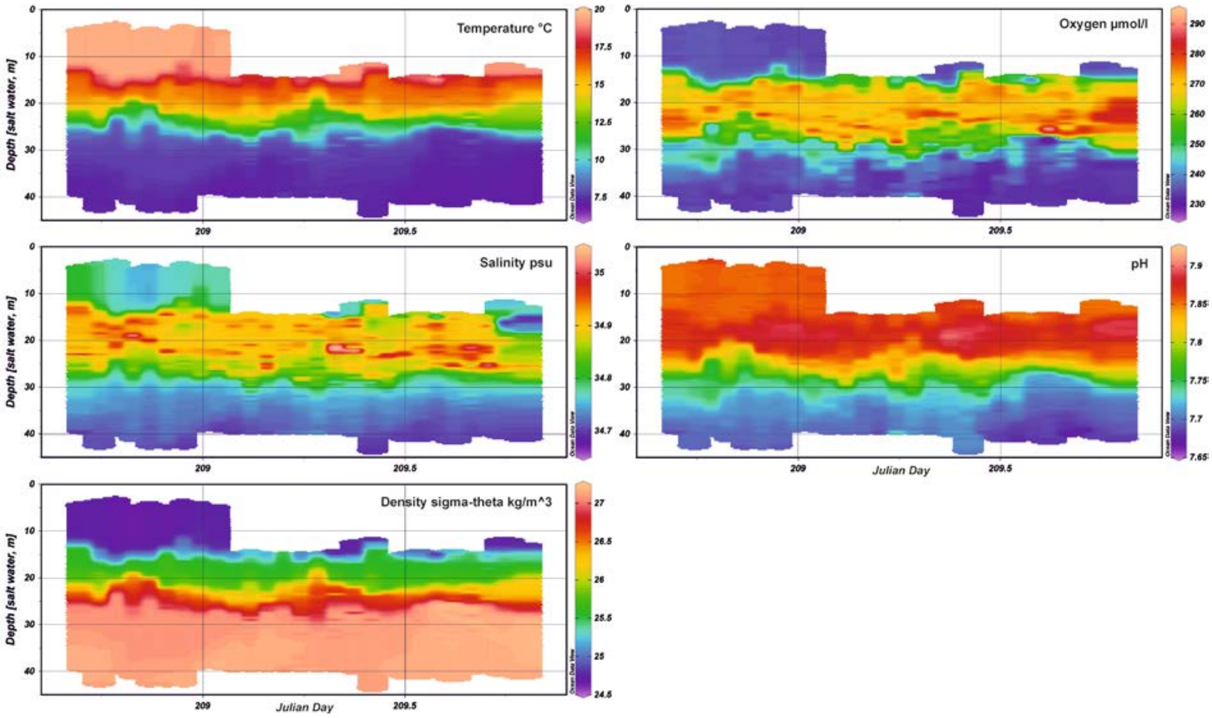


Figure 62: CTD data during the time of the 24h CTD-water sampling.

7.2.6. Picarro & Discrete Sample Analysis Module (DSAM)

A simple compilation of all discrete water samples analysed by the DSAM is shown in Figure 63. Methane concentrations can reach very high values below the pycnocline of about 3500nM. Isotopic data indicate methane oxidation below the pyconocline with increasing distance to the methane source / decreasing concentrations. The source isotopic composition is clearly at -82‰ δ^{13}C PDB. Additional processing needs to be done to merge the chemical data with the physical data and analyses the data in their spatial context.

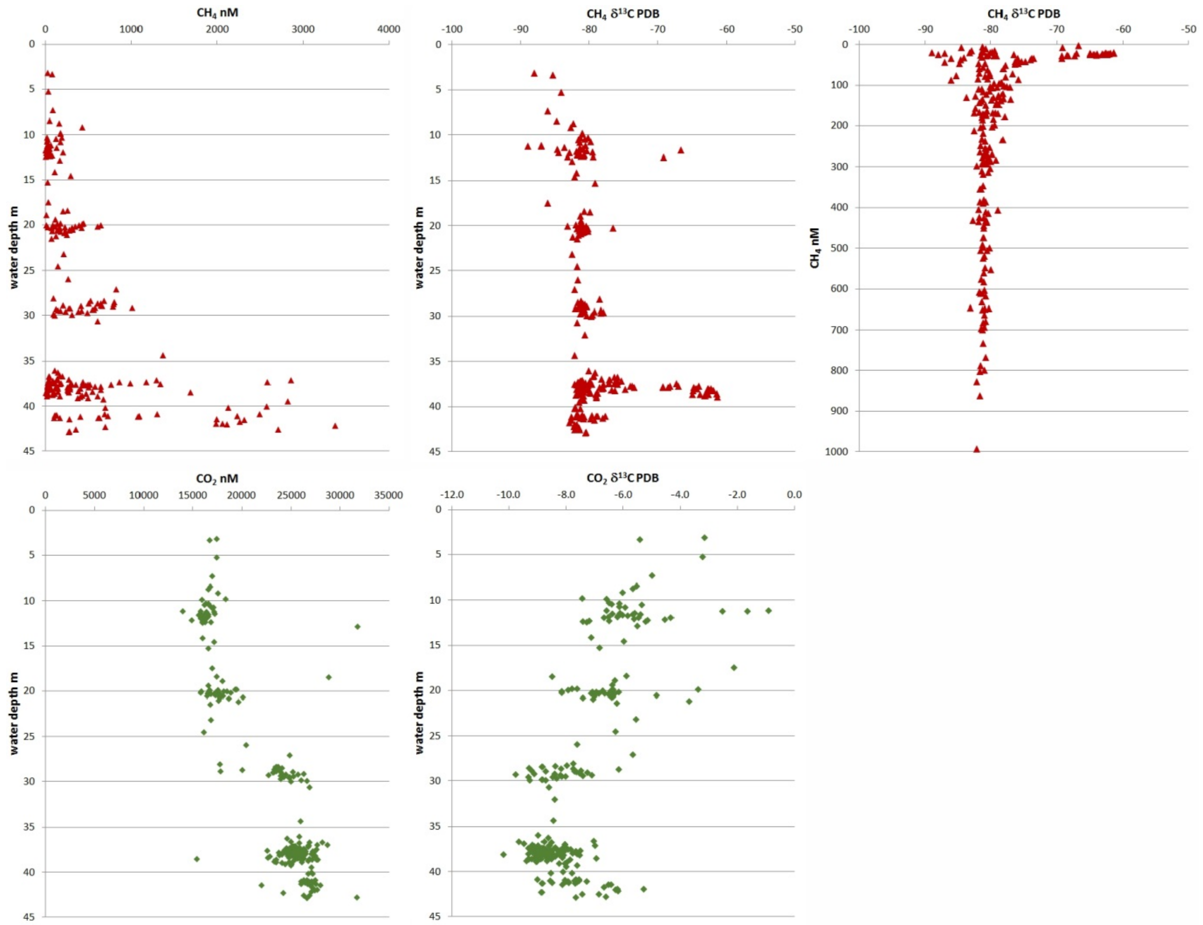


Figure 63: Preliminary methane and CO2 data of the DSAM analyses.

7.2.7. Picarro & Greenhouse Gas Flux System

Data still need to be processed.

7.2.8. Gas chromatograph

The measured methane concentrations range from 1.8ppm up to 321ppm. The increased methane concentrations occur only in direct proximity to the gas leaks on the seabed. The closer a water sample was taken to a gas bubble stream, the higher the methane concentrations were measured on the gas chromatograph.

7.2.9. Oxygen titration and salinity measurements

Table 5: Oxygen measurements from CTD water samples in the Dutch North Sea

Station	Cast No.	Nisk. Bot.	Depth (m)	Bottle Volume (ml)	Bottle factor	Factor Thiosulphate	Thios. (ml)	O2 (µmol/L)	Delta-O2
2	2	1	42	60.631	83.8490	0.9862	2.98	246.4201519	0.8993963
2	2	1	42	60.8129	83.5940	0.9862	3	247.3195483	
2	2	5	3.5	61.1	83.1947	0.9862	3.3	270.7519026	2.2743311
2	2	5	3.5	60.6908	83.7650	0.9862	3.25	268.4775715	
12	3	2	8	60.631	83.8490	0.9970	3.16	264.1703439	
12	3	4	7	60.8129	83.5940	0.9970	3.07	255.8660044	
12	3	6	6	60.714	83.7325	0.9970	3.02	252.1156763	

12	3	8	5	61.1	83.1947	0.9970	3.04	252.1553476	
12	3	10	3	60.6908	83.7650	0.9970	2.99	249.7082322	
12	3	12	4	60.893	83.4822	0.9970	3.01	250.5298623	
16	5	11	19	60.631	83.8490	0.9901	2.94	244.0753206	0.0853938
16	5	11	19	60.8129	83.5940	0.9901	2.95	244.1607144	
16	5	12	9	61.186	83.0758	0.9901	3.14	258.2752543	
22	9	2	38	61.1	83.1947	0.9901	3.06	252.0551556	
22	9	6	20	60.714	83.7325	0.9901	3.38	280.2135725	
24	11	6	20	60.6908	83.7650	0.9901	3.39	281.1518394	
24	11	9	12	60.893	83.4822	0.9901	3.26	269.4574301	
26	13	2	38	61.341	82.8624	0.9901	3.03	248.5871961	0.658341
26	13	2	38	60.983	83.3570	0.9901	3.02	249.2455371	
35	2	2	38	60.631	83.8490	0.9954	3.02	252.0477713	
35	2	6	20	60.8129	83.5940	0.9954	3.28	272.9147419	
38	25	6	20	61.186	83.0758	0.9954	3.4	281.1457011	
38	25	9	11	61.1	83.1947	0.9954	3.26	269.9548529	
42	29	6	20	60.6908	83.7650	0.9954	3.41	284.3118692	0.702046
42	29	6	20	60.893	83.4822	0.9954	3.43	285.0139152	
42	29	7	11	60.714	83.7325	0.9954	3.02	251.6974353	
52	38	2		61.186	83.0758	0.9954	2.98	246.4159381	
54	40	7	20	60.631	83.8490	0.9954	3.42	285.4315821	
54	20	10	10	60.8129	83.5940	0.9954	3.07	255.4415419	

Overall 29 samples were collected from Niskin bottles during 11 hydrocast with the Video CTD (Table 5). From the underway water supply (moonpool intake) 4 samples were taken. Using duplicate samples the precision was estimated to be 0.7 µmol L^{-1}. Obtained dissolved oxygen concentration values will be used to calibrate Clark-type oxygen sensors (SBE43) at the Video CTD rosette system and to validate sensor-based underway oxygen measurements both at the CRDS system and at the Wave Glider (Table 6).

Table 6: Oxygen measurements from the underway water system connected to the Picarro system; the water inlet was at 4m depth

Station	Date (UTC)	Time (UTC)	Bottle Volume (ml)	Bottle factor	Factor Thiosulphate	Thios. (ml)	O2 (µmol/L)	Delta-O2
underway	7/29/2018	12:27:00 PM	60.631	83.84900	0.99536	3	250.379	0.9027
underway	7/29/2018	12:29:00 PM	60.8129	83.59401	0.99536	3.02	251.281	
underway	7/30/2018	11:41:00 AM	61.186	83.07580	0.99536	3	248.070	
underway	7/30/2018	9:42:00 PM	61.1	83.19468	0.99536	3.02	250.081	

To absolutely calibrate salinity values of the CTD data, additional water samples in brown beer bottles were taken and later on analysed at GEOMAR using a salinometer. Results are shown in Table 7.

Table 7: Salinometer results of selected samples from the North Sea dataset.

Station	Cast	Niskin bottle	Sample #	Comment	Salinity
12	3	2	948		34.8434
12	3	12	1154		34.7743

16	5	3	724		34.7197
16	5	3	1328	duplicate	34.7201
16	5	12	432		34.8796
22	9	2	444		34.7195
22	9	6	1389		34.8468
24	11	6	689	niskin dripped	34.8362
24	11	9	1280		34.857
26	13	2	630		34.7392
26	13	2	1146	duplicate	34.7331
38	25	6	636		34.858
38	25	9	645		34.8174
54	40	2	708		34.6889
54	20	10	1073		34.8357

7.2.10. SHiPCC computer cluster

Cruise POS526 was the first deployment of the SHiPCC 2 at sea. The NAS storage device was used to store large optical image data sets (from the BubbleBox, JAGO handheld camera, AUV still images, etc.). Those data sets were duplicated to a separate NAS for backup. Image data from the AUV was processed by one node to compute a bubble distribution map at cluster 1 (Figure 64). All BubbleBox data (ca. 900 GBs) was processed by all eight nodes for bubble size distribution and rising speed estimates within. In the process, 8.6 million bubbles were assessed (bubbles were repeatedly imaged), see Figure 60 for results.

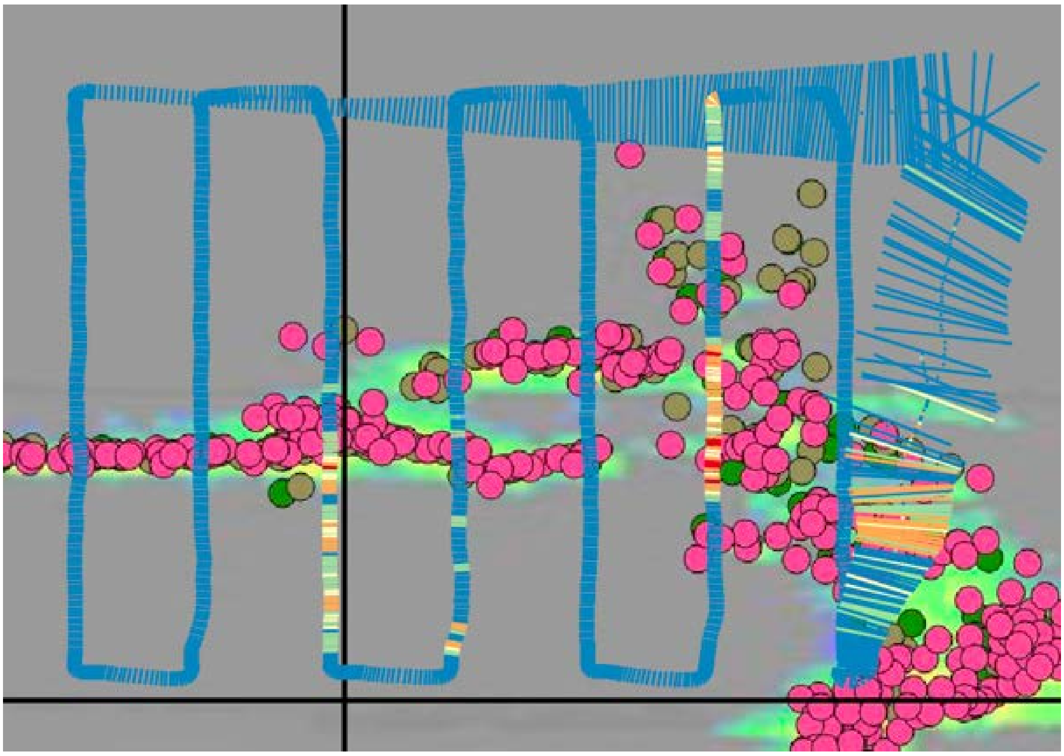


*Figure 64**:** Bubble detection results from AUV dive POS526_004_AUV-01. The background map shows bubble activity from multiple previous multi-beam hydro-acoustic surveys. The colored tracks on top mark the AUV dive trajectory and are color coded by bubble intensity extracted from imagery (blue: none, yellow: medium, red: high). The width of the bars encodes altitude above ground. The relative offsets in bubble activity from the different sensors indicate a deviation of the AUV from the dive plan.*

7.2.11. Bubble Box

The Bubble Box was attached during two dives of JAGO. Both dives were conducted at the “flying horse” seep cluster (55° 18.364’N, 004° 5.429’E). Before the bubble box cameras were started the area was surveyed to find representative bubble streams. Once a stream was selected for sampling the JAGO pilot positioned the bubble box over the stream of bubbles. It was then powered up. Images were taken for 3-15 minutes at each location. The capture volume was filled and flushed for several times. The capture volume times were noted and also recorded using the JAGO video camera. Overall more than 900,000 images were taken in two dives. During the first dive one of the cameras (bubble 1) recorded a significantly lower number of images than the other. The reason could not be fully resolved yet.

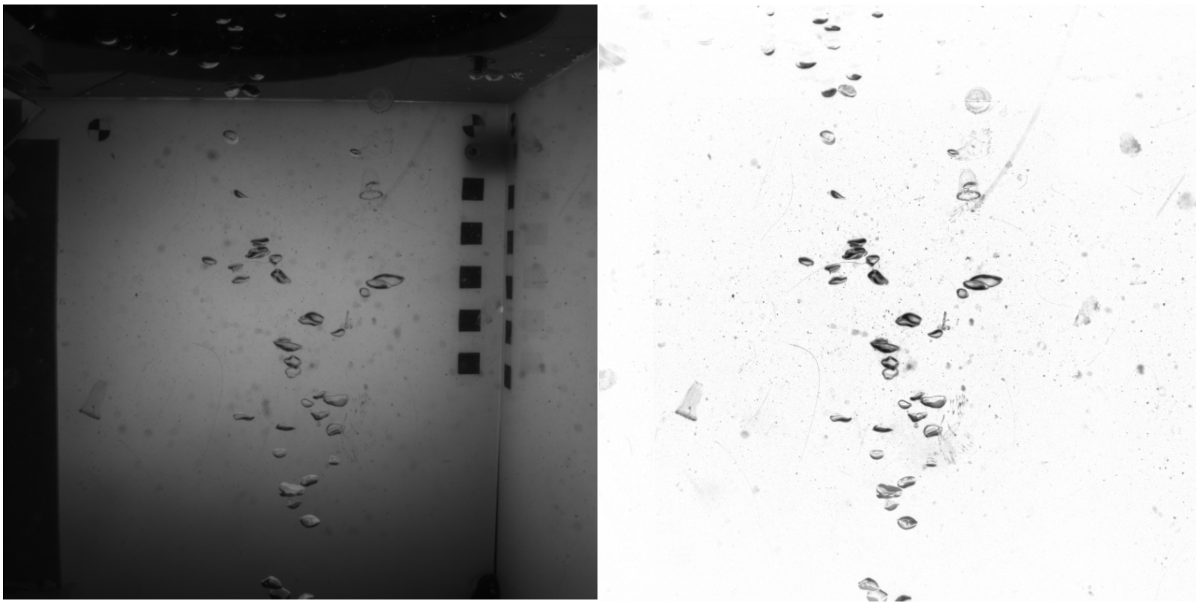


Figure 65: The left image is a sample image of the bubble box from JAGO dive 2 (station 11), showing rising bubbles. The ShipCC cluster has been used onbaord to automatically compute the static components. Once the static parts are removed the bubbles are much easier to identify, but it can also be seen that there are not only bubbles in the water.

7.2.12. Gas Quant II lander

Due to bad weather conditions only one deployment was possible for the GasQuant lander. JAGO was needed to recover the lander during station the 3rd JAGO dive of the cruise on 31st July. This extended time at the sea floor caused that the batteries were completely empty, but the data storage was full with 98GB of data that now need to be processed.

7.2.13. Single-beam echo-sounder

Preliminary analyses included the manual picking of flare positions in the Dogger Bank area (Figure 66; Figure 67).

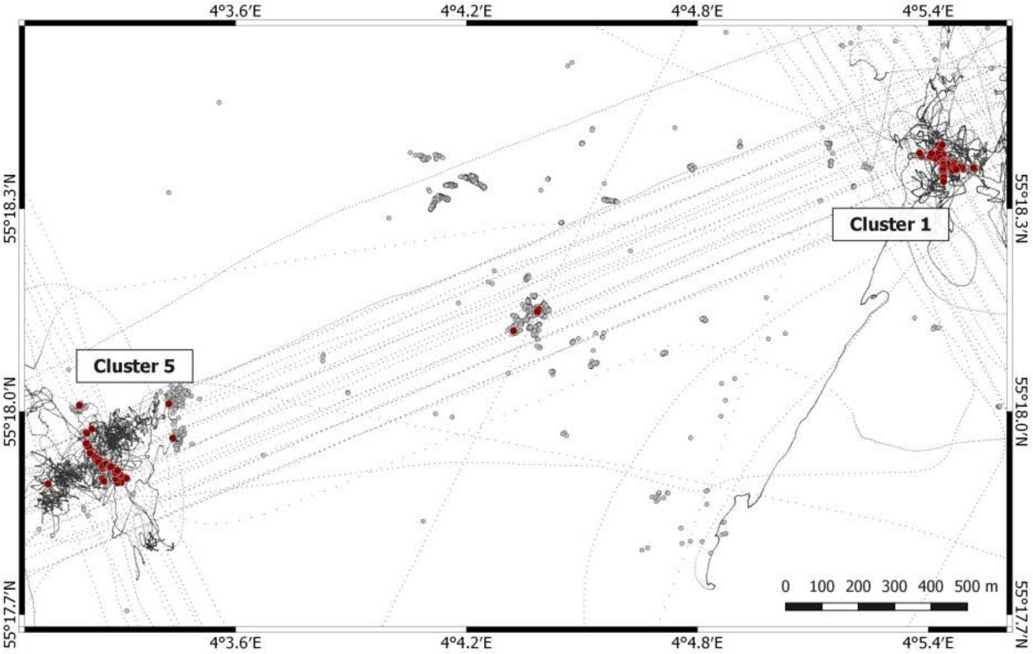


Figure 66: Flare locations (red dots) detected with the EK80.

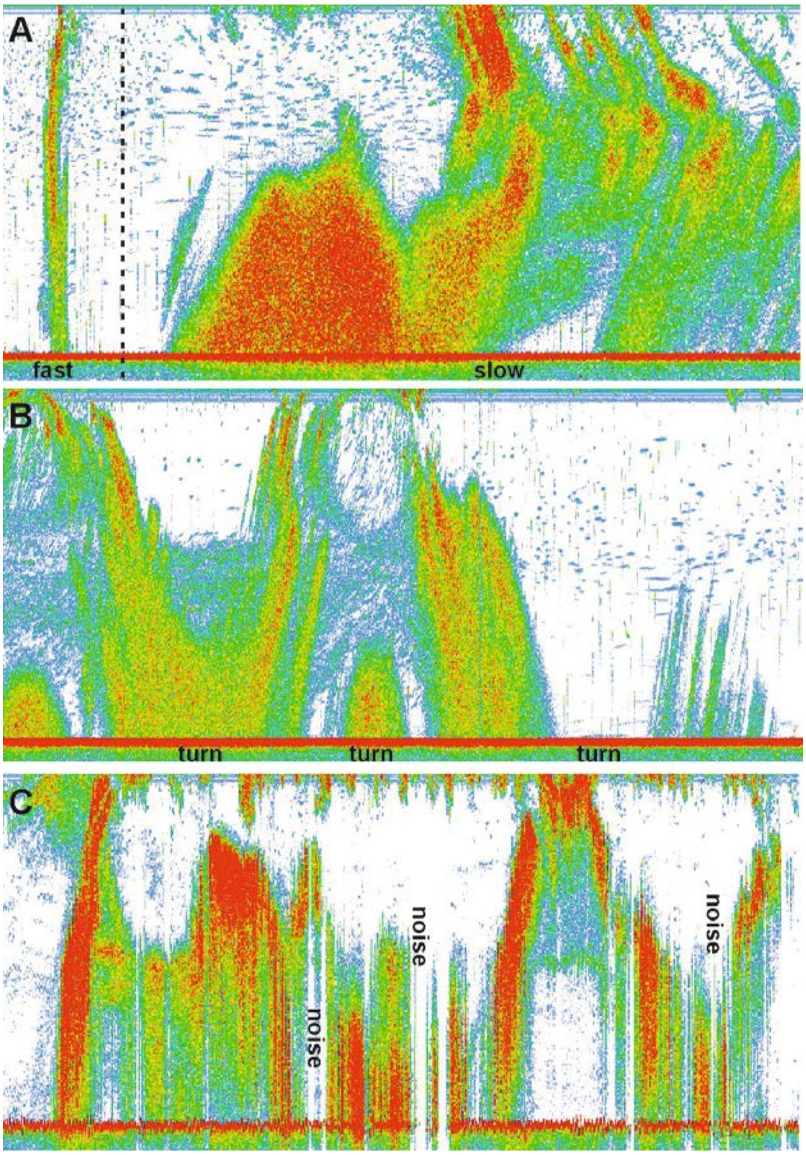


Figure 67: Echograms with flares from the Dogger Bank seep area.

Figure 68 also shows single target measurements of a 10m thick layer just above the bottom and higher in the water column. These measurements can be used to analyze bubble dissolution through the water column and link these analyses with data from bubble dissolution models and gas analyses of bubbles at the seafloor and sea surface. More detailed work will include flow rate calculations using the volume backscattering strength of certain depth cells.

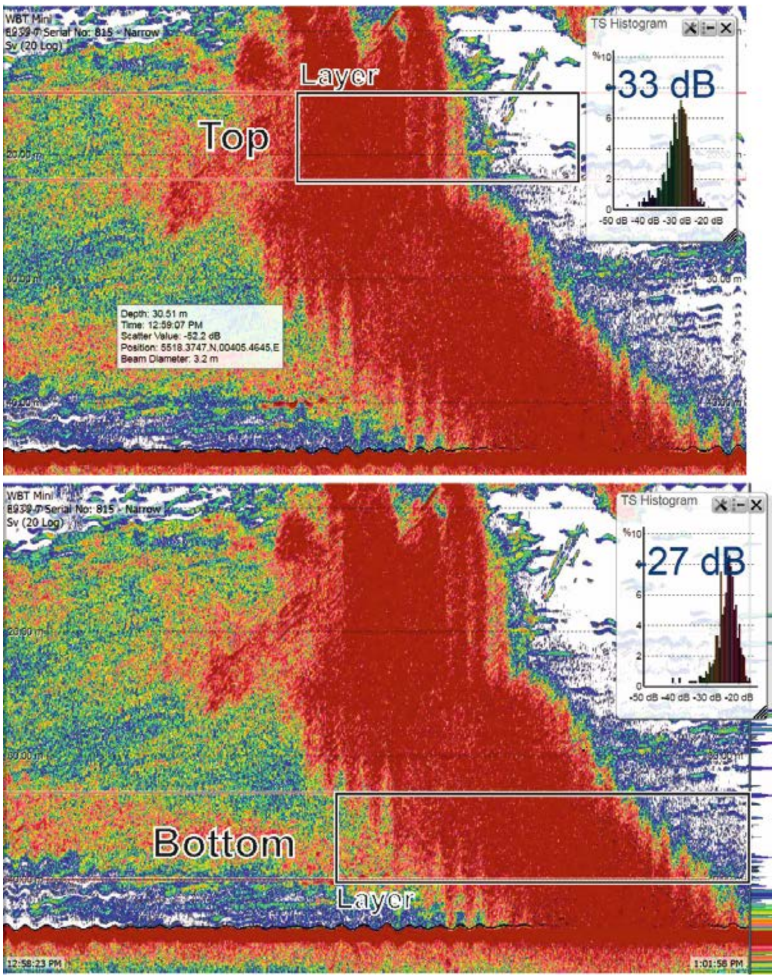


Figure 68: Single target histograms of a bubbles in the top and lower part of a flare. The higher dB value at the bottom clearly shows that bubble shrink and thus become less strong backscatterers. The wavy pattern of the flare is caused by stronger roll of the vessel.

7.2.14. Acoustic Doppler Current Profiler

ADCP measurements were performed in the North Sea to know about the water currents in general and during CTD sampling (time series station POS526_#021 to POS526_#047) in particular. The system was used at the same time as sea surface methane concentrations, WCI multibeam mapping and EK80 data collection happened (Table 8). In the Tisler Reef area during a dedicated ADCP survey to learn about the special change of currents around the reef complex (POS526_#074).

Table 8: Overview of recorded ADCP files, with time and settings.

Station	LTA files	Settings
POS526_MB-1 To POS526_MB-3	several	1st Bin -4.14 m, Bin Size 2.00 m No. Bins 18, Pings/Ens 33, Time/Ping 00:00.00 First Ensemble 00000001 18/07/26 20:41:50.04 Last Ensemble 00001841 18/07/27 06:55:10.08 Average Ensemble Interval 00:00:20.00; ***wrong ADCP orientation! Reprocessing needed!***
POS526_#021_CTD-008	POS526_#21_CTD-time-	1st Bin -5.17 m, Bin Size 3.00 m

to POS526_#047_CTD_037 **Time Series CTDs at Cluster 5**	series_20180727T190204_019_000000.LTA	No. Bins 12, Pings/Ens 34, Time/Ping 00:00.00 First Ensemble 00000001 18/07/27 19:02:09.03 Last Ensemble 00002444 18/07/28 08:36:29.04 Average Ensemble Interval 00:00:20.00
	POS526_#35_CTD-time-series_20180728T083847_019_000000.LTA	1st Bin -5.17 m, Bin Size 3.00 m No. Bins 12, Pings/Ens 34, Time/Ping 00:00.00 First Ensemble 00000001 18/07/28 08:38:52.06 Last Ensemble 00002250 18/07/28 21:08:32.06 Average Ensemble Interval 00:00:20.00
N-S over Cluster 5 with ADCP and SBES	POS526_#48-MB-6_Cluster-5_20180728T225926_002_000000.LTA	1st Bin -4.14 m, Bin Size 2.00 m No. Bins 20, Pings/Ens 34, Time/Ping 00:00.00 First Ensemble 00000001 18/07/28 22:59:31.04 Last Ensemble 00003065 18/07/29 16:00:51.05 Average Ensemble Interval 00:00:20.00
POS526_054_CTD-40 To POS526_058_CTD-44 **CTD tows in Cluster 1**	POS526_#55-CTDs_Cluster-1_20180730T093055_002_000000.LTA	1st Bin -4.14 m, Bin Size 2.00 m No. Bins 20, Pings/Ens 33, Time/Ping 00:00.00 First Ensemble 00000001 18/07/30 09:31:00.01 Last Ensemble 00000826 18/07/30 14:23:20.03 Average Ensemble Interval 00:00:21.26
	POS526_#55-CTDs_Cluster-1_20180730T143032_003_000000.LTA	1st Bin -4.14 m, Bin Size 2.00 m No. Bins 20, Pings/Ens 33, Time/Ping 00:00.00 First Ensemble 00000001 18/07/30 14:30:37.04 Last Ensemble 00000550 18/07/30 17:33:37.09 Average Ensemble Interval 00:00:20.00
POS526_059_MB-07 **Repeating MB-1 from Cluster 1 to Cluster 5**	POS526_#59-MB-7_20180730T173410_003_000000.LTA	1st Bin -4.14 m, Bin Size 2.00 m No. Bins 20, Pings/Ens 33, Time/Ping 00:00.00 First Ensemble 00000001 18/07/30 17:34:15.04 Last Ensemble 00002328 18/07/31 06:29:55.05 Average Ensemble Interval 00:00:20.00
POS526_#74_ADCP-1 **Measuring different locations at Tisler Reef**	POS526_#74_ADCP-Tisler-spot-1_20180804T190337_009_000000.LTA	1st Bin -7.21 m, **Bin Size 5.00 m** No. Bins 20, Pings/Ens 26, Time/Ping 00:00.00 First Ensemble 00000001 18/08/04 19:03:42.02 Last Ensemble 00000074 18/08/04 19:28:02.08 Average Ensemble Interval 00:00:20.00
	POS526_#74_ADCP-Tisler-spot-1_20180804T192835_010_000000.LTA	1st Bin -6.18 m, **Bin Size 4.00 m** No. Bins 35, Pings/Ens 19, Time/Ping 00:00.00 First Ensemble 00000001 18/08/04 19:28:40.03 Last Ensemble 00000767 18/08/04 23:44:00.07 Average Ensemble Interval 00:00:20.00
	POS526_#94_ADCP-with_CTD-sampling_20180807T222717_010_000000.LTA	1st Bin -6.18 m, Bin Size 4.00 m No. Bins 35, Pings/Ens 19, Time/Ping 00:00.00 First Ensemble 00000001 18/08/07 22:27:23.02 Last Ensemble 00001483 18/08/08 06:41:23.03 Average Ensemble Interval 00:00:20.00

At the Dogger Bank site, typical tidal effects can be seen that change current direction and velocity, southward directions swap to northward directions and back (Figure 69, Figure 70). Rose plots of about 6 hours each during the time of POS526_#021 and POS526_#047 (CTDs 008 to 037) indicate stronger surface currents changing between 120° and 330° and currents of more than 300mm/s in 17m above the pycnocline and more N-S currents and slower velocities at 32m water depth.

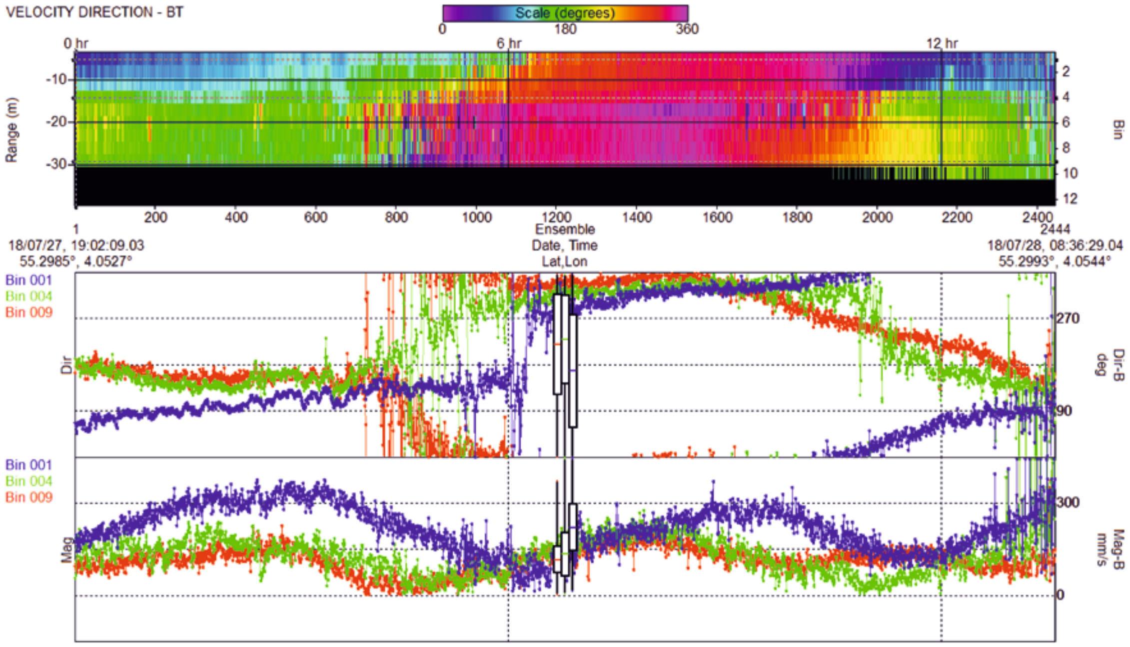


Figure 69: Tide influenced current direction during the time series CTD stations at Cluster 5.

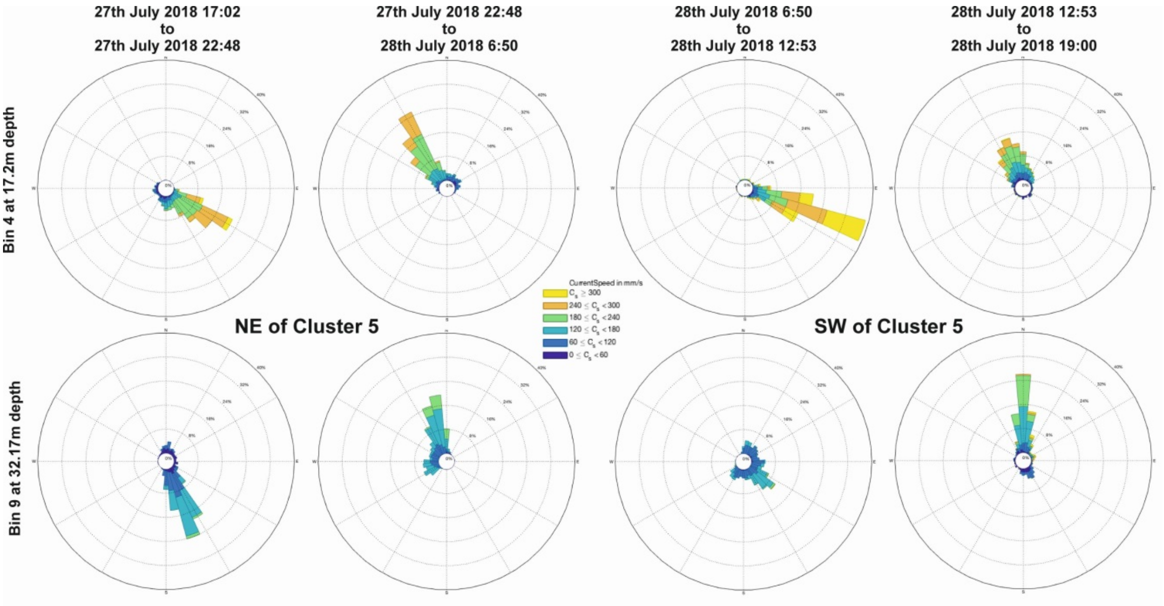


Figure 70: Rose plots during time series CTD stations.

Upward vertical velocities are faster when the ship is moving over rising gas bubbles. The backscatter intensity in the water column clearly detects free gas, the example in Figure 71 shows stronger signals higher up in the water column which might point towards more bubbles that are insonified close to their resonance frequency at this depth.

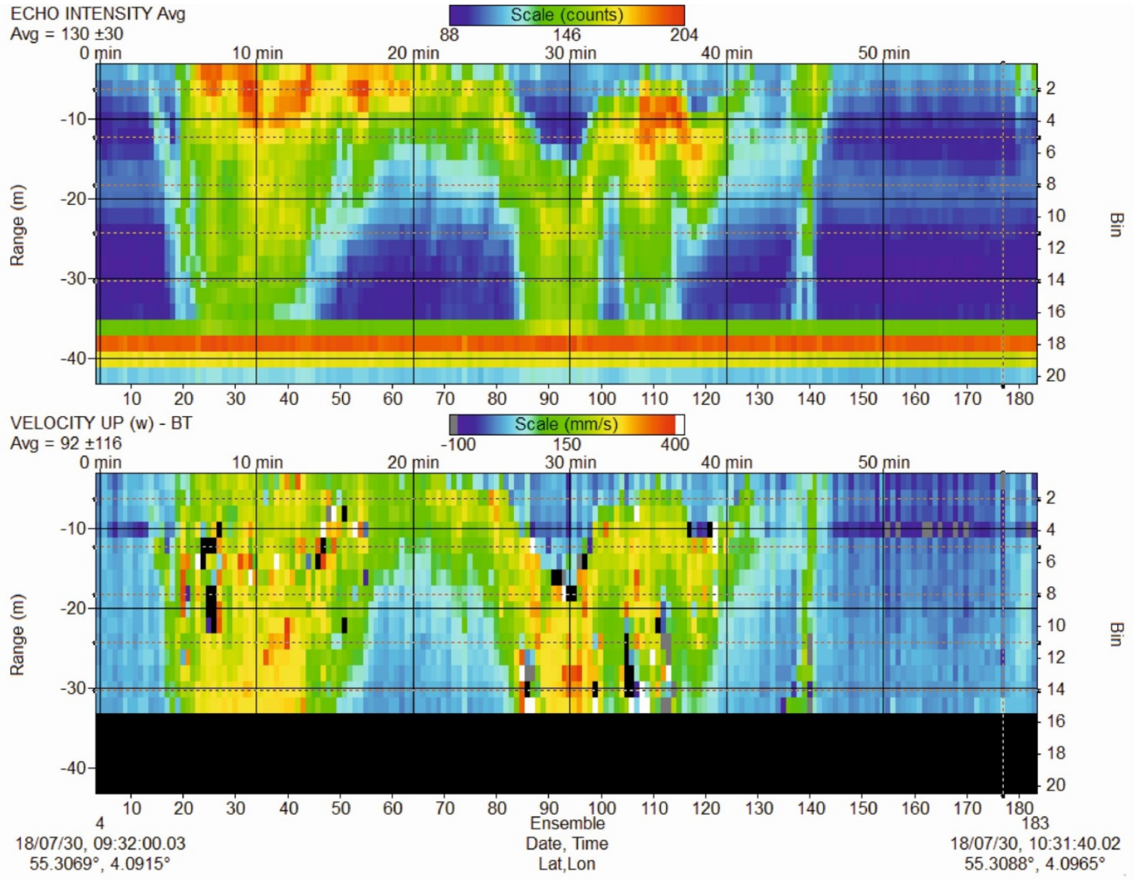


Figure 71: ADCP data from a transit through Cluster 1, showing the upward velocity of gas bubbles.

In the Tisler area, one dedicated ADCP station was performed to see the changing current regime around the reef. At position 3 and 4 (Figure 72; Figure 73) strong westward currents can be observed which are caused by the funneling effect of generally westward directed currents through the pronounced morphological gully.

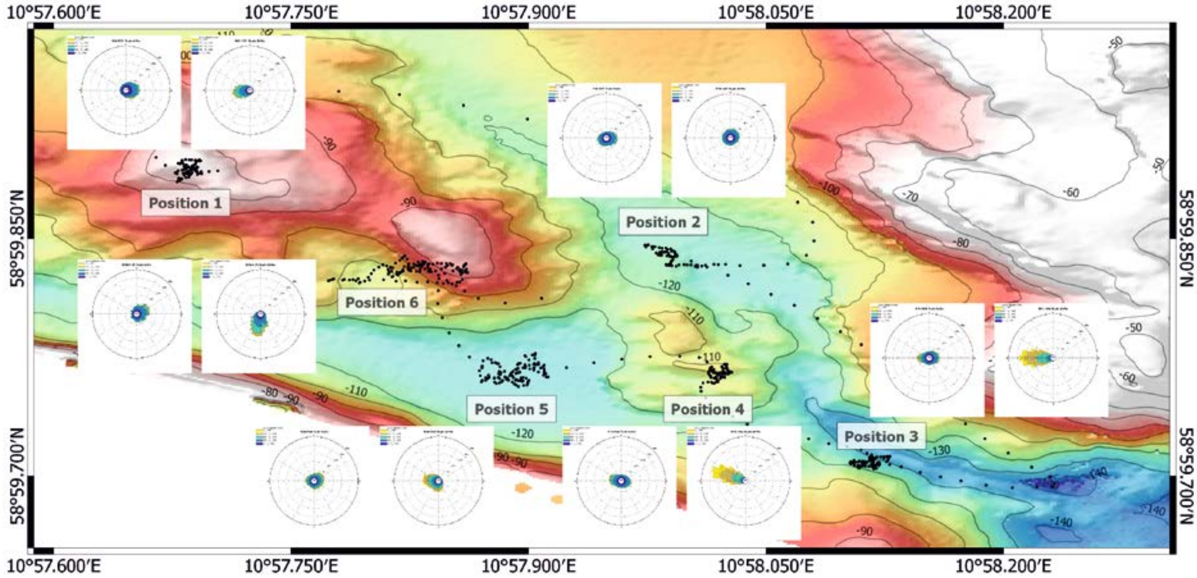


Figure 72: Current rose diagrams at the six ADCP measurement sites in around the Tisler Reef.

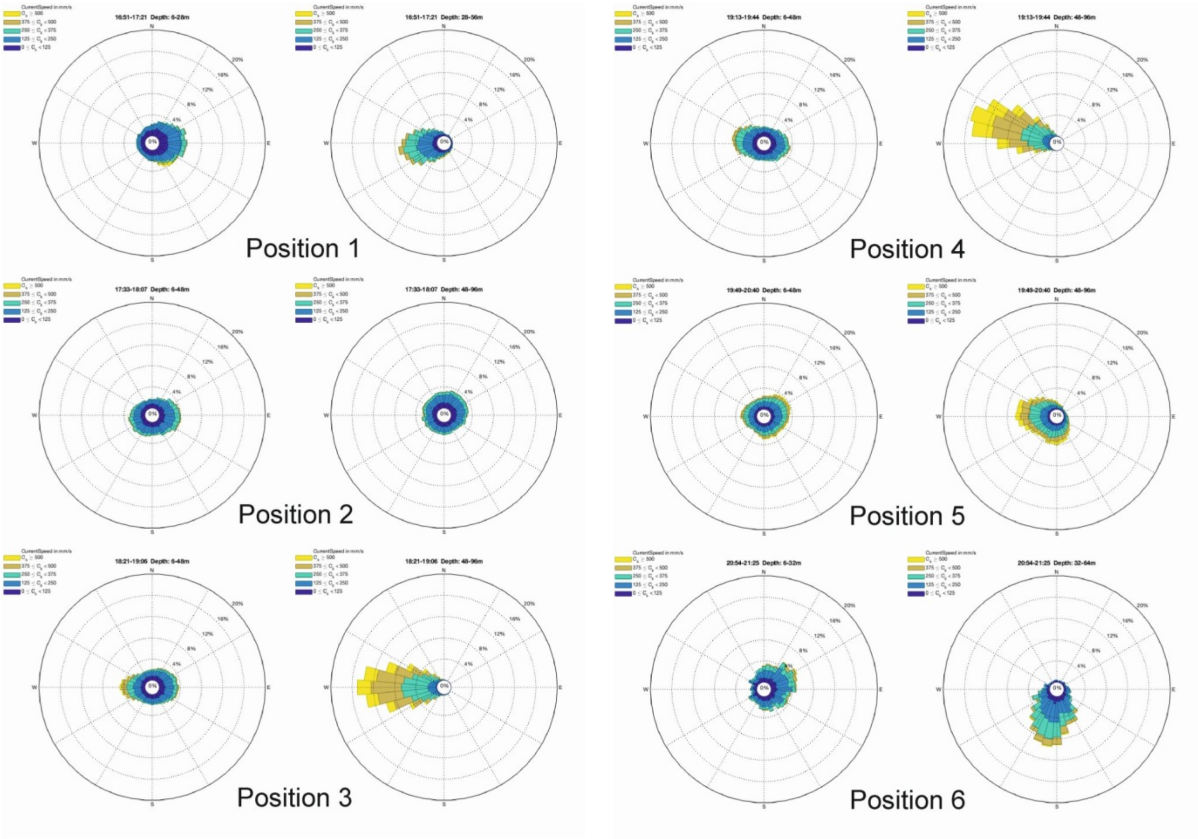


Figure 73: ADCP rose plots of current direction and velocity at Tisler Reef.

7.2.15. Multi-beam echo-sounder; Tisler Reef

Multibeam data for bathymetric mapping were only acquired in the Tisler Reef working area. The North Sea Dogger Bank area does not show any resolvable features worth presenting. In Tisler, the entire reef was mapped as well as the NW running trough. Different to the previous data acquired during ALKOR 232 the newer Seabeam 3050 has smaller beam angles (1.5° x 2°) and more beams, which results in a general higher resolution. Figure 74, Figure 75, Figure 76 give an impression of the Tisler Reef working area, presentations are either in UTM32 coordinates and projection, or Mercator projection as indicated.

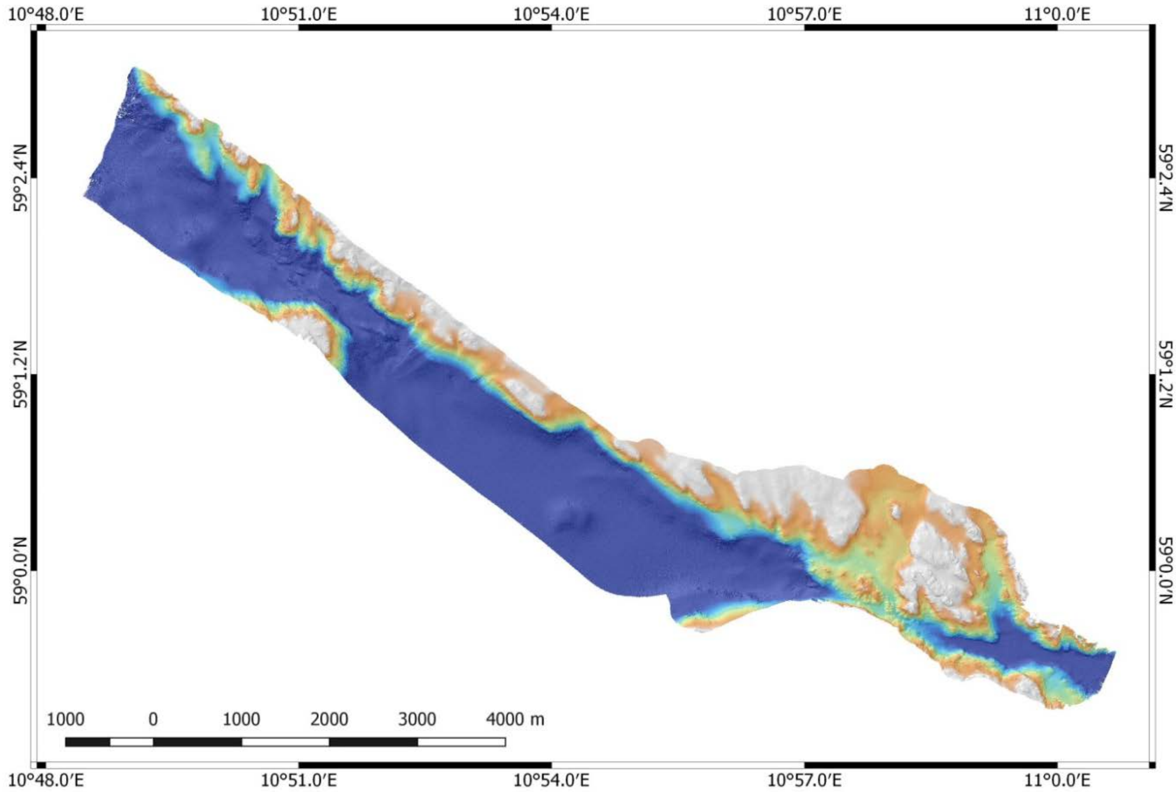


Figure 74: Overview map of the Tisler Reef area in Mercator projection. Illumination generally comes from the NW. Three different illumination directions and slope information was used for the hill shading effect. The final '400m' deep AUV deployment occurred in the northwestern most region of the map.

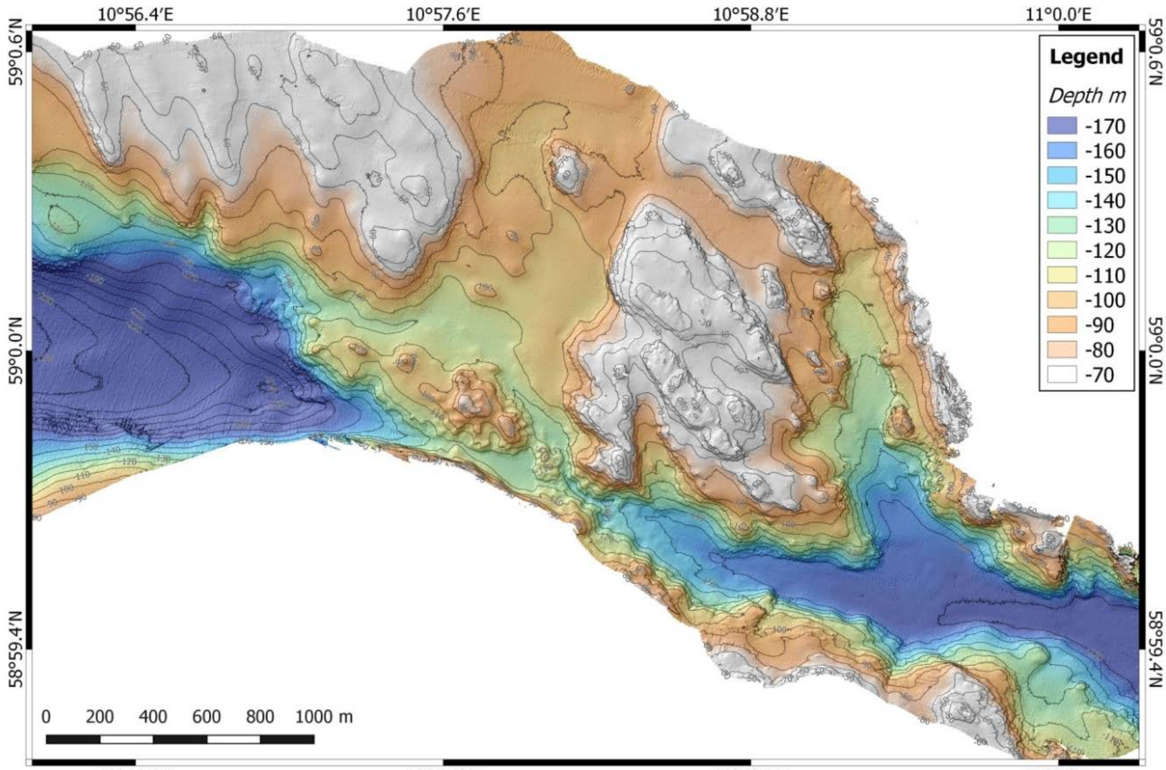


Figure 75: Tisler Reef bathymetry, well visible is the narrow gully toward the east of the main reef complex. Visual investigations show that the currently most active reef complex is within this gully and the small mound immediately towards the east. Map is in UTM32 coordinates.

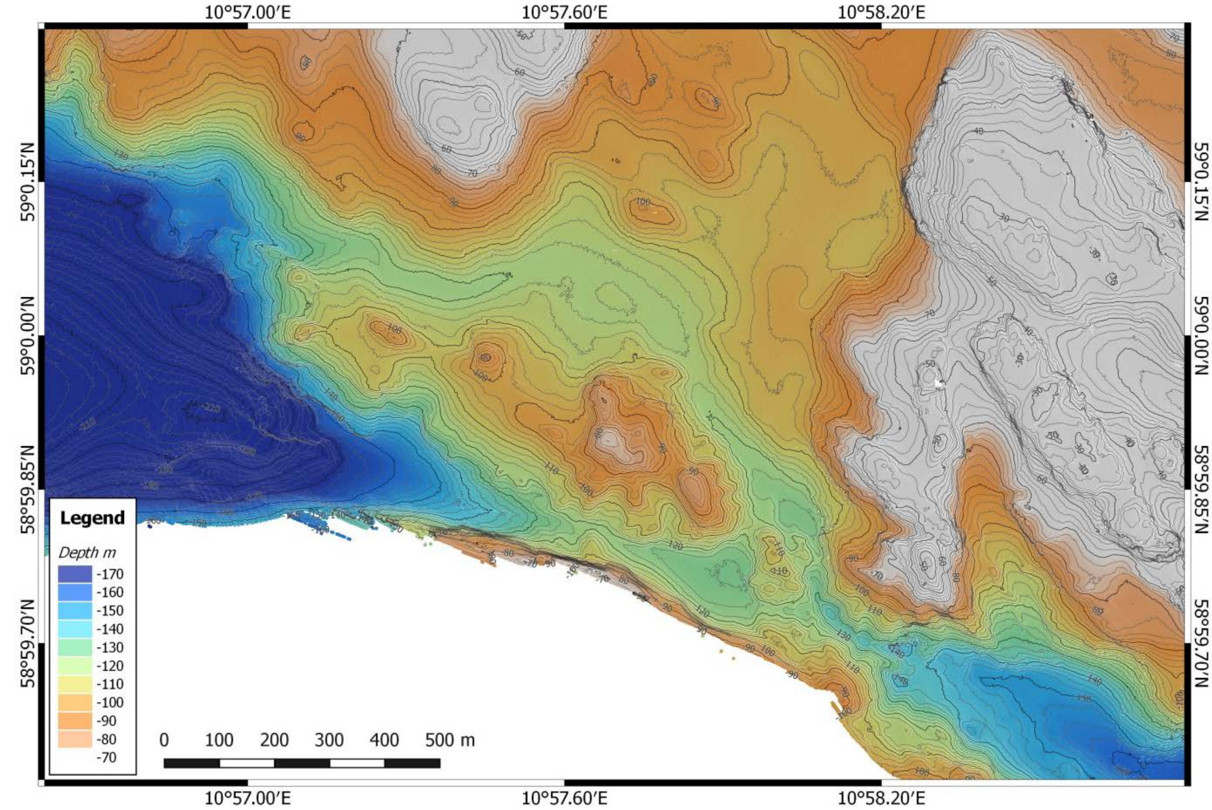


Figure 76: Zoom of the entire Tisler Reef with 10m and 2m contours

7.2.16. TV CTD

The main observations with the video CTD occurred in the Tisler reef area. In total 13 TV-CTDs tows were undertaken crisscrossing the reef (Figure 77). Preliminary results clearly show that the highest part of the reef complex in 74m is not the area where the most active reef is living, this is clearly towards the west in the gully area and the southern slopes of the complex.

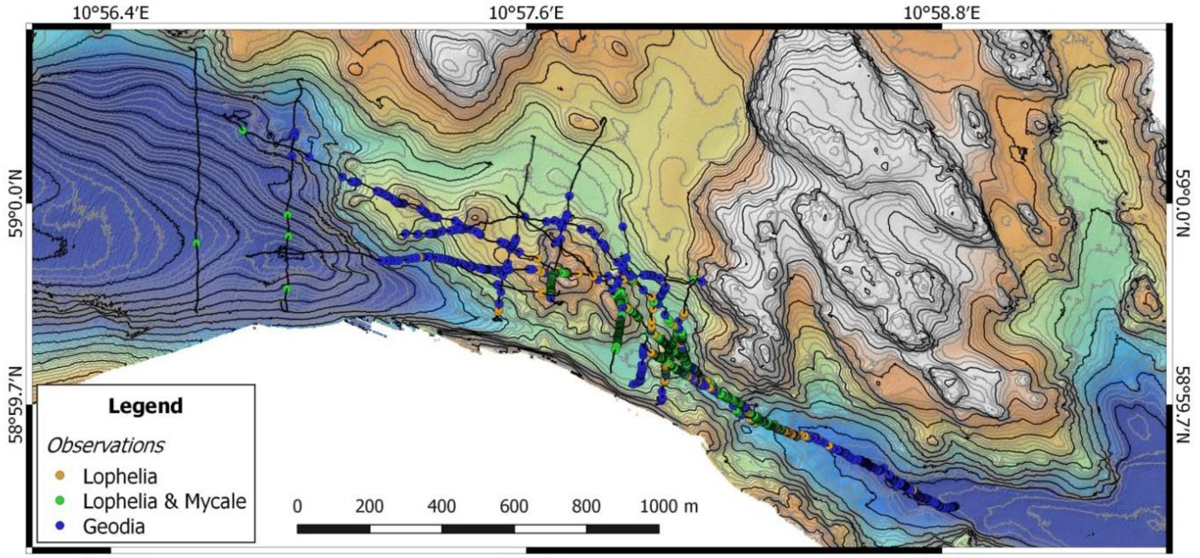


Figure 77: Overview of video observations in the Tisler Reef area. Thin black lines indicate the two track.

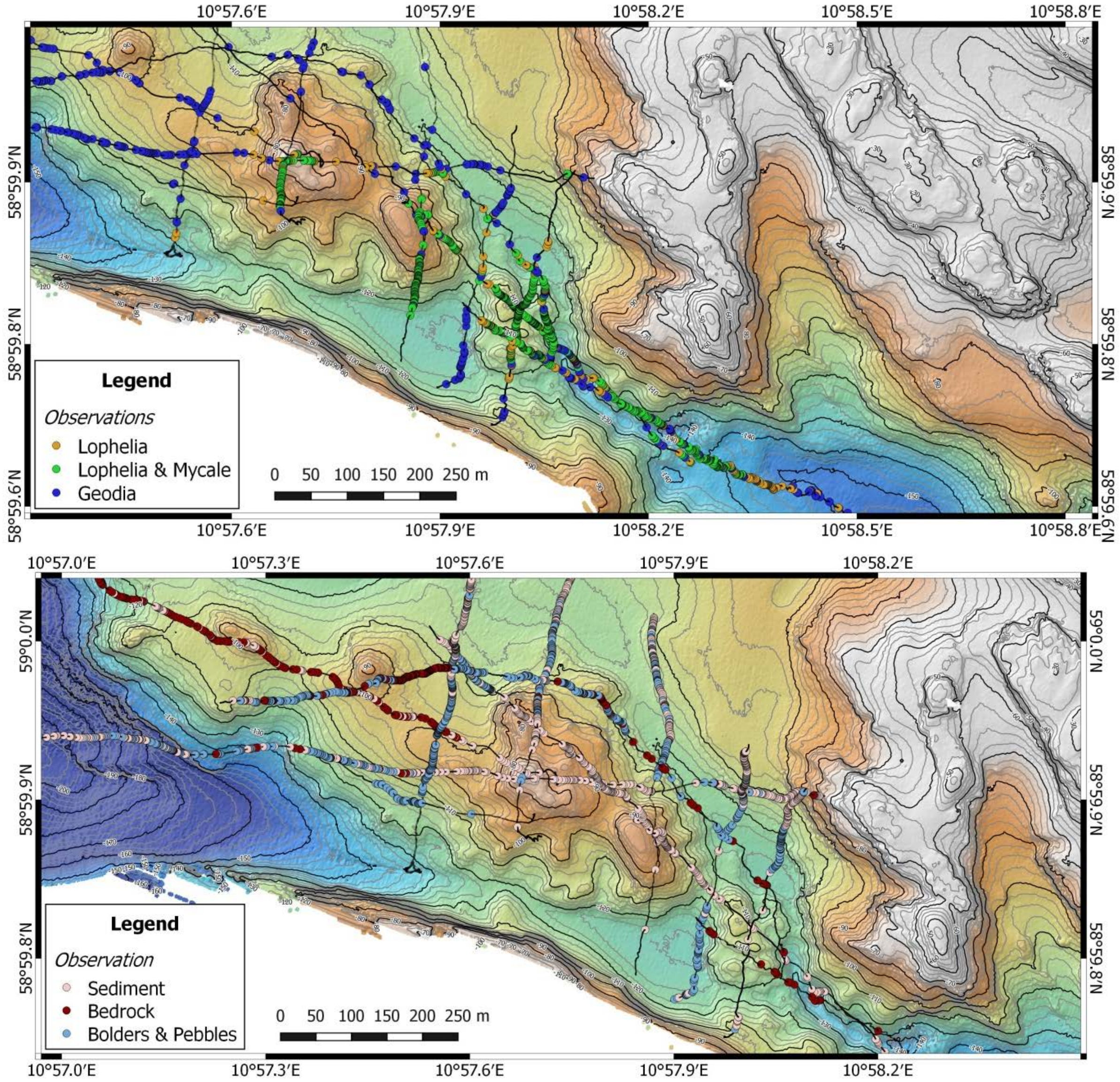


Figure 78: Top - details of the faunal distribution of corals and sponges. Bottom - detail of the sediment and rock distribution at Tisler Reef.

More detailed analyses of the exact faunal distribution and its correlation with terrain derivatives and water currents will be done in the future. The preliminary ‘on the fly’ annotation comprised observations as indicated in Table 9.

Table 9: OFOP Button file used during POS526.

# Observation names	Entry ID of OFOP
Lophelia	1
Loph. + Mycale	2
Geodia	3
Dead Coral	4
Coral Rubble	5
Lost Fishing	6
Sediment	7
Bedrock	8
Soft Sed.	9
? Interesting	10
Rubbish	801
Bolders	803

Pebbles	804
Anemone	815
Crustacions	810

7.2.17. BatCam Stereo camera

The stereo camera has been deployed two times during the cruise, to capture synchronized stereo image data with 2Hz at the top of the hill with the coral reef (JAGO dive 5) and in an area with several smaller and larger rocks that is flat on a coarse scale but has significant relief (JAGO dive 10). Besides obtaining 3D maps of the area the goal of these stations was to further collect practical experience with the stereo camera system on JAGO and to get a better understanding of the advantages and limitations for detailed optical mapping with JAGO. While the advantage of the machine vision cameras inside the BatCam is that they can be triggered precisely, their disadvantage is that there is little to no intelligence built into the cameras to auto-adapt the exposure. This means that exposure time and ISO level have to be set manually and they are not adapted within the dive, leading to blurred images (when the camera moved too fast) or badly exposed images (too much or too little light). This should be improved in the future through analyzing the images while capturing.

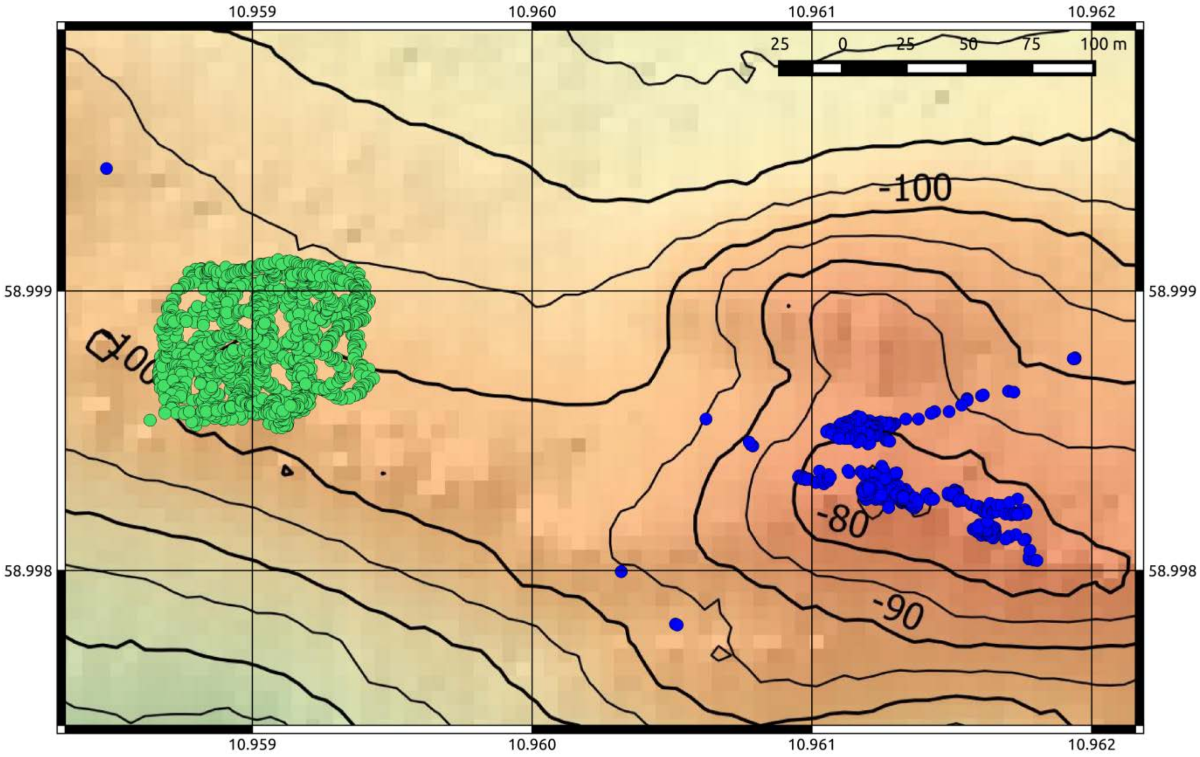


Figure 79: USBL position data of JAGO dives 5 (blue) and 10 (green). The blue positions document the dive to map the corals at the top of the hill, but both navigation and localization were very challenging. The green positions show the measured positions from a lawnmower-pattern to survey a deeper, largely flat area.

The dive at the tip of the hill turned out to be very challenging for JAGO, as the goal was to systematically photograph the entire area of the tip. Good pictures could only be taken at reasonably slow speeds, i.e. when flying against the strong current. But the currents were not constant and navigation as well as keeping a constant distance with respect to the ground was very challenging. Although USBL information was displayed inside JAGO, the

USBL positions contained sudden jumps and there were gaps in USBL transmission, so that it was decided that a systematic “lawnmowing” pattern of the area is not feasible. Instead JAGO passed the tip several times, following a probabilistic/opportunistic strategy to map as much as possible. A sample picture can be seen below (left).

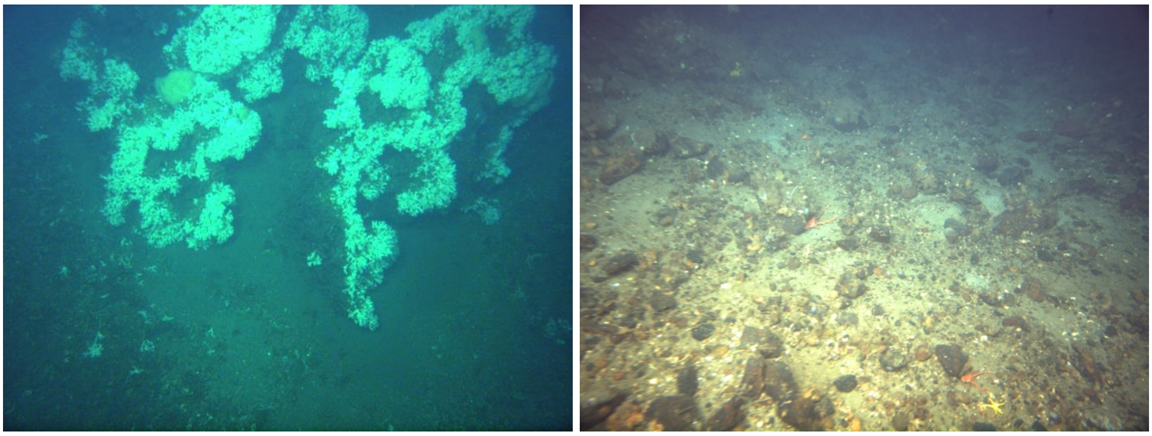


Figure 80: The left image is from JAGO dive 5 and shows cold water corals at the tip of the hill. The right image is from

During this dive we have also photographed a chessboard in order to calibrate the stereo camera system on site. Because of the challenging situation during JAGO dive 5, JAGO dive 10 was then planned for an area with less (and less dynamic) currents at approximately 100m water depth (see right sample image in Figure 80). Also in this dive, navigation was quite challenging because of the currents, but it was possible to follow 5 north-south lines (and 5 south-north lines) during 2:15h at the bottom at a target altitude of 2m. The cameras only see a few meters of seafloor, and therefore a quite narrow line spacing is required to avoid gaps in the visual maps (target line spacing was 3m). From inside JAGO, this was very hard to judge. The USBL localization was of great help, but the delay of about ten seconds and the need for maneuvering in the currents made the systematic seafloor capture very challenging. We still have to evaluate the seafloor coverage in the image data.

A preliminary result is that optical mapping with its strong requirements for following predefined tracks is very challenging with JAGO when there are strong currents. The clear advantage (as compared to AUV-based mapping) is however the possibility to adapt the plan during the mapping and to inspect interesting structures in detail or to extend to previously unplanned neighboring targets. For a few images from the JAGO dive to the tip of the reef, a coarse digital 3D model has been reconstructed. A computer generated image of this model (rendered) can be seen in Figure 81.

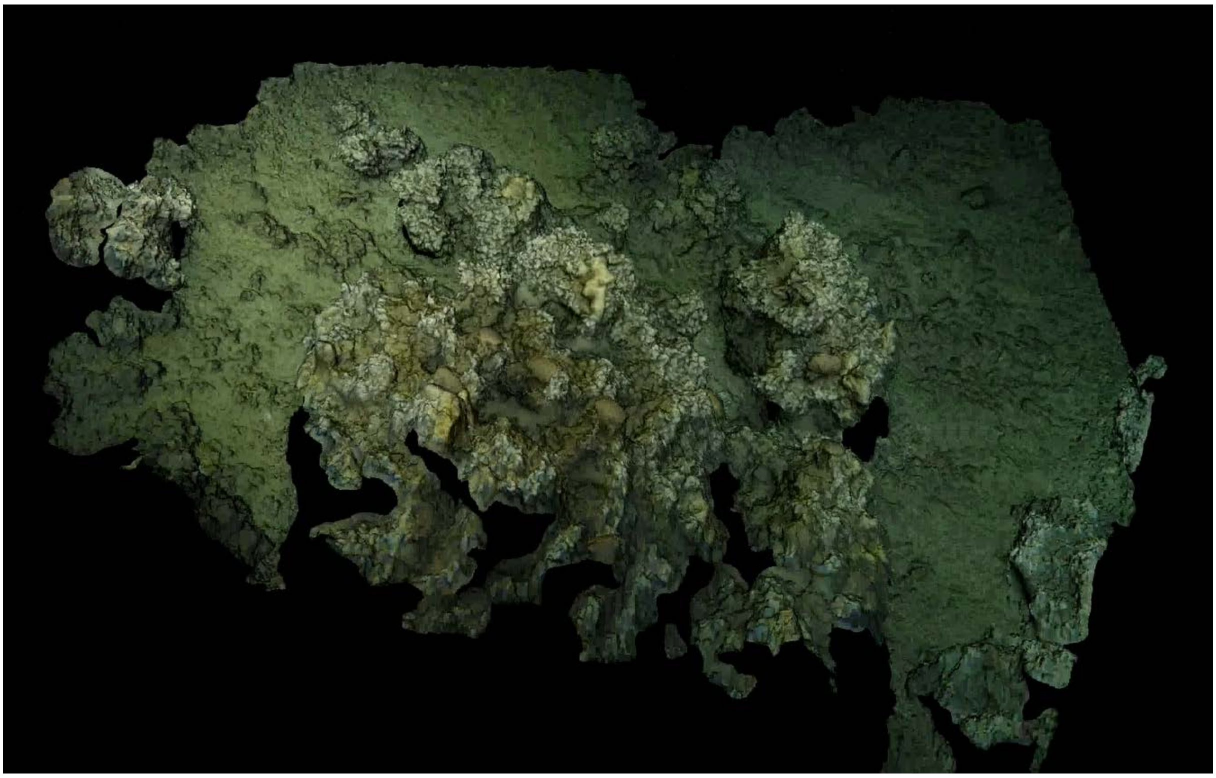


Figure 81: Rendered image of the seafloor on top of the Tisler reef.

7.2.18. PiCam miniature camera landers

For the duration of all TV-CTDs the PiCams operated perfectly and to programmed specifications, collecting in total almost 20,000 seafloor images. These varied in quality as a function of vessel speed, distance from seafloor and programmed parameters. To summarise the technical findings, a high ISO setting, coupled with a mounting distance from an external flash unit gave the optimum imaging results.

Table 10: Details of all PiCam deployments made during POS526.

Station Number	PiCams used	Rationale	Settings used	Number of scientific images
POS526_068_TV-CTD_48	PiCam3	Gauge suitability of standard PiCam for towed camera work	ISO 200 Flash 1 img / 10 s	784
POS526_075_TV-CTD_50	PiCam3 PiCam5 PiCam8	Test camera parameters on CTD	ISO 200 Flash on/off Night filter 5 &10s / img	~1,800
POS526_076_TV-CTD_51	PiCam3 PiCam5 PiCam8	Test camera parameters on CTD	As above	~1,600
POS526_077_TV-CTD_52	PiCam3 PiCam5 PiCam8	Test camera parameters on CTD	As above	~1,200
POS526_078_TV-CTD_53	PiCam3 PiCam5 PiCam8	Test camera parameters on CTD	As above	~1,600
POS526_079_TV-CTD_54	PiCam3 PiCam5 PiCam8	Test camera parameters on CTD	As above	~2,000
POS526_082_TV-CTD_55 A	PiCam2 PiCam4 PiCam8	Test importance of ISO and flash combinations	ISO 600, 1000 Flash on/off	~10,000

POS526_082_TV-CTD_55 B	PiCam2 PiCam4 PiCam8	Test importance of ISO and flash combinations	As above	~600
POS526_084_JAGO-7	PiCam3 PiCam4 PiCam6	48 hrs of monitoring coral reef activity on 3 flanks of coral outcrop	ISO 50 Flash 1 min per image	~10000
POS526_100_JAGO-11	PiCam5	Investigate the suitability of PiCams to be mounted as secondary monitoring devices on JAGO	ISO 200 No Flash	3,020

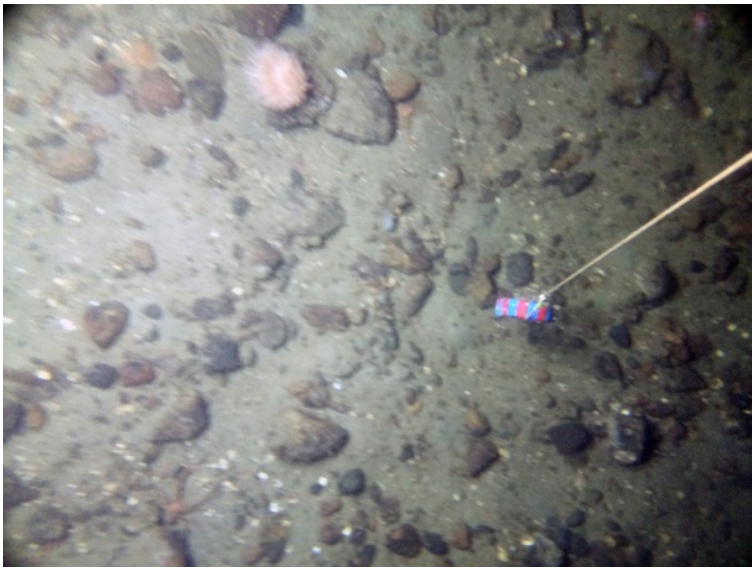


Figure 82: Pebble strewn seafloor imaged during POS526_082_TV-CTD_55 A by PiCam2.

The time series deployments at the reef also collected good data, though the batteries failed during the 48 hrs in one of the devices. These photos will be analysed for fauna distribution change over time, and ideally polyp activity assessed in context with the ADCP measurements taken concurrently with the deployment.

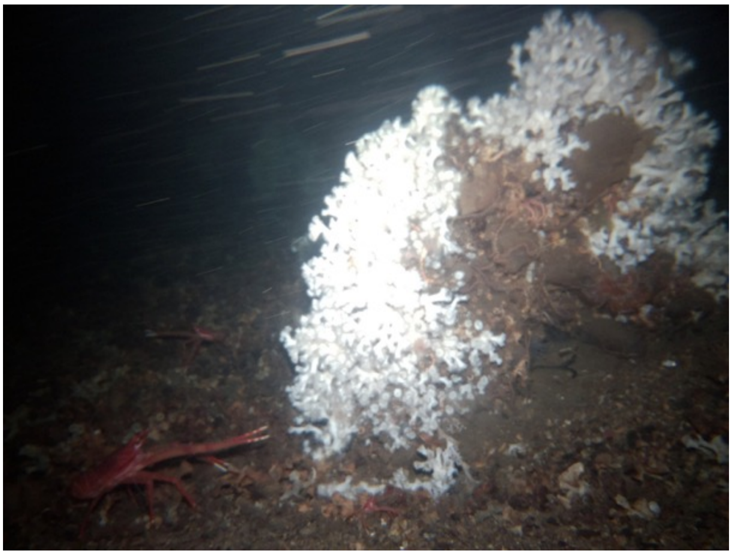


Figure 83: Squat lobsters investigate coral mound during period of high flow. Taken by PiCam 3 during POS526_084_JAGO-7.

Throughout all deployments the proximity of the PiCam flash to the camera caused some problems – over illuminating the central region of an image, whilst simultaneously causing backscatter from particles in the water. More successful were deployments when the images were collected with PiCams concurrently with the deployment of other light sources (e.g. TV-CTD lamps, JAGO lighting rig).

7.2.19. LOKI

The LOKI camera captured many 1000s of potential objects of interest from each water sample. The performance of the device was variable, with the camera frequently achieving a capture rate of less than 24 fps. The collected data will be analyzed by two zooplankton experts in AWI for potential usefulness.

Certainly, the bottom water collected during POS526_96_CTD-59 was the most abundant in larger fauna, which could be clearly seen in suspension prior to funneling into the LOKI device. A large shrimp of 3 cm length was also captured by the TV-CTD within a Niskin bottle from that depth (Figure 84)

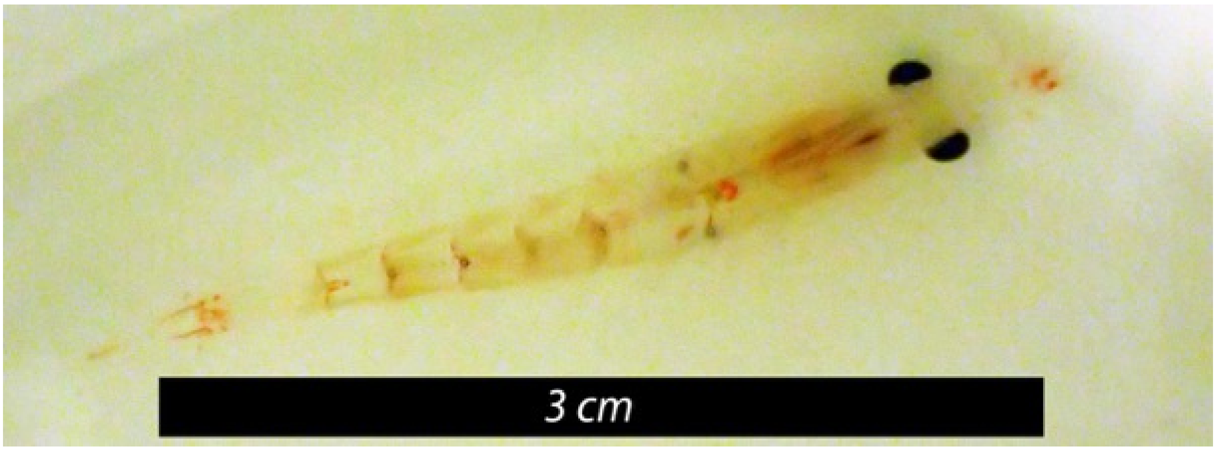


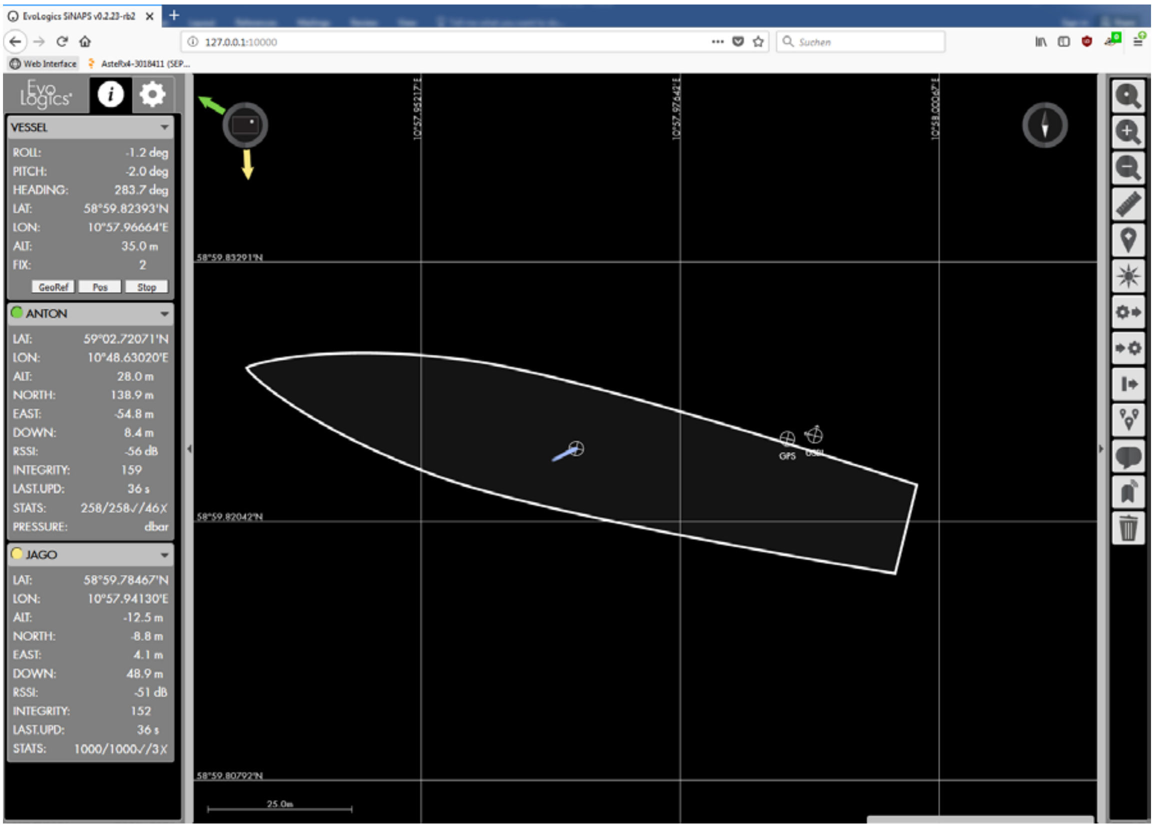
Figure 84: Shrimp captured within Niskin bottle when acquiring water samples for LOKI from bottom waters during station POS526_96_CTD-59

7.2.20. Seaguard RCM

Data appears to have been collected correctly during deployments but has to be processed with the appropriate software back on shore.

7.2.21. USBL Navigation and Communication

With great hopes we installed the Evelogics USBL-Data Modem on RV Poseidon but had to realize that finding the correct settings, linking the right input data on the right ports and defining the correct offset settings between the pole the USBL transponder was mounted on, the GPS antenna position and the common reference point was not that easy (Figure 85, Figure 86, Figure 87). The manual was only very moderately of help. After many trials we finally fund the right settings which are illustrated in the screenshots below. It is strongly advised to familiarise oneself with the system and potential settings well in advance of its use. The SiNAPS software is not self-explaining and e.g. ports to external sensors do not have simple text field in which received data are shown. Further the heading of the vessel is only updated with the actual value if a valid USBL fix is received; this means the heading direction does not change when the ship is only steaming. We will seek the exchange with Evelogics to advance their software in the future.

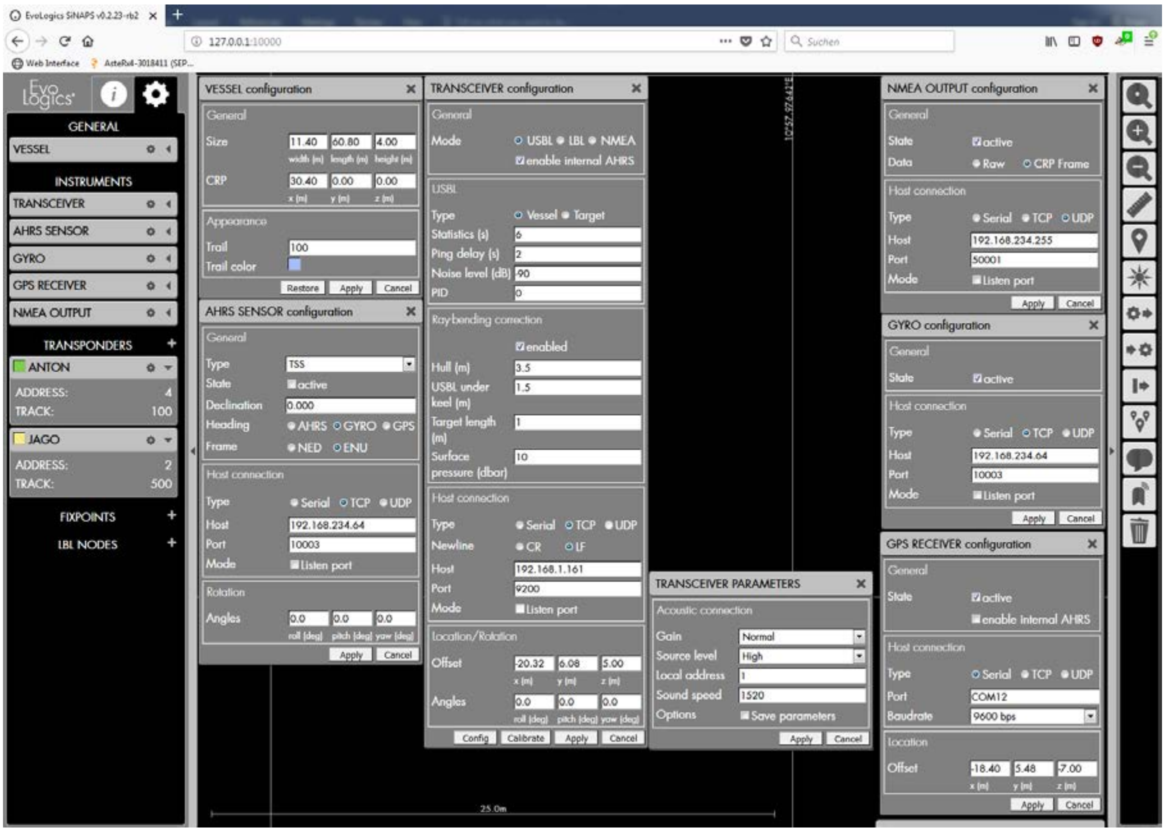


VESSEL
ROLL: -1.2 deg
PITCH: -2.0 deg
HEADING: 283.7 deg
LAT: 58°59.82393'N
LON: 10°57.96664'E
ALT: 35.0 m
FIX: 2

ANTON
LAT: 59°02.72071'N
LON: 10°48.63020'E
ALT: 28.0 m
NORTH: 138.9 m
EAST: -54.8 m
DOWN: 8.4 m
RSSI: -56 dB
INTEGRITY: 159
LAST.UPD: 36 s
STATS: 258/258✓/46✗
PRESSURE: dbar

JAGO
LAT: 58°59.78467'N
LON: 10°57.94130'E
ALT: -12.5 m
NORTH: -8.8 m
EAST: 4.1 m
DOWN: 48.9 m
RSSI: -51 dB
INTEGRITY: 152
LAST.UPD: 36 s
STATS: 1000/1000✓/3✗

Figure 85: Screenshot of the SiNAPS software showing the ship to scale the GPS as well USBL position. The circle with the short blue line is the common reference point, its position is measured from the central stern of the ship forward (we assume ti should be set in the centre of gravity).



GENERAL
VESSEL

INSTRUMENTS
TRANSCEIVER
AHRS SENSOR
GYRO
GPS RECEIVER
NMEA OUTPUT

TRANSPONDERS
ANTON
ADDRESS: 4
TRACK: 100
JAGO
ADDRESS: 2
TRACK: 500

FIXPOINTS
LBL NODES

VESSEL configuration

General
Size: 11.40 width (m), 60.80 length (m), 4.00 height (m)
CRP: 30.40 x (m), 0.00 y (m), 0.00 z (m)

Appearance
Trail: 100
Trail color

AHRS SENSOR configuration

General
Type: TSS
State: ☐ active
Declination: 0.000
Heading: ○ AHRS ● GYRO ○ GPS
Frame: ○ NED ● ENU

Host connection
Type: ○ Serial ● TCP ○ UDP
Host: 192.168.234.64
Port: 10003
Mode: ☐ Listen port

Rotation
Angles: 0.0 roll (deg), 0.0 pitch (deg), 0.0 yaw (deg)

TRANSCEIVER configuration

General
Mode: ● USBL ○ LBL ○ NMEA
☑ enable internal AHRS

USBL
Type: ● Vessel ○ Target
Statistics (s): 6
Ping delay (s): 2
Noise level (dB): -90
PID: 0

Ray bending correction
☑ enabled
Hull (m): 3.5
USBL under keel (m): 1.5
Target length (m): 1
Surface pressure (dbar): 10

Host connection
Type: ○ Serial ● TCP ○ UDP
Newline: ○ CR ● LF
Host: 192.168.1.161
Port: 9200
Mode: ☐ Listen port

Location/Rotation
Offset: -20.32 x (m), 6.08 y (m), 5.00 z (m)
Angles: 0.0 roll (deg), 0.0 pitch (deg), 0.0 yaw (deg)

TRANSCEIVER PARAMETERS

Acoustic connection
Gain: Normal
Source level: High
Local address: 1
Sound speed: 1520
Options: ☐ Save parameters

NMEA OUTPUT configuration

General
State: ☑ active
Data: ○ Raw ● CRP Frame

Host connection
Type: ○ Serial ○ TCP ● UDP
Host: 192.168.234.255
Port: 50001
Mode: ☐ Listen port

GYRO configuration

General
State: ☑ active

Host connection
Type: ○ Serial ● TCP ○ UDP
Host: 192.168.234.64
Port: 10003
Mode: ☐ Listen port

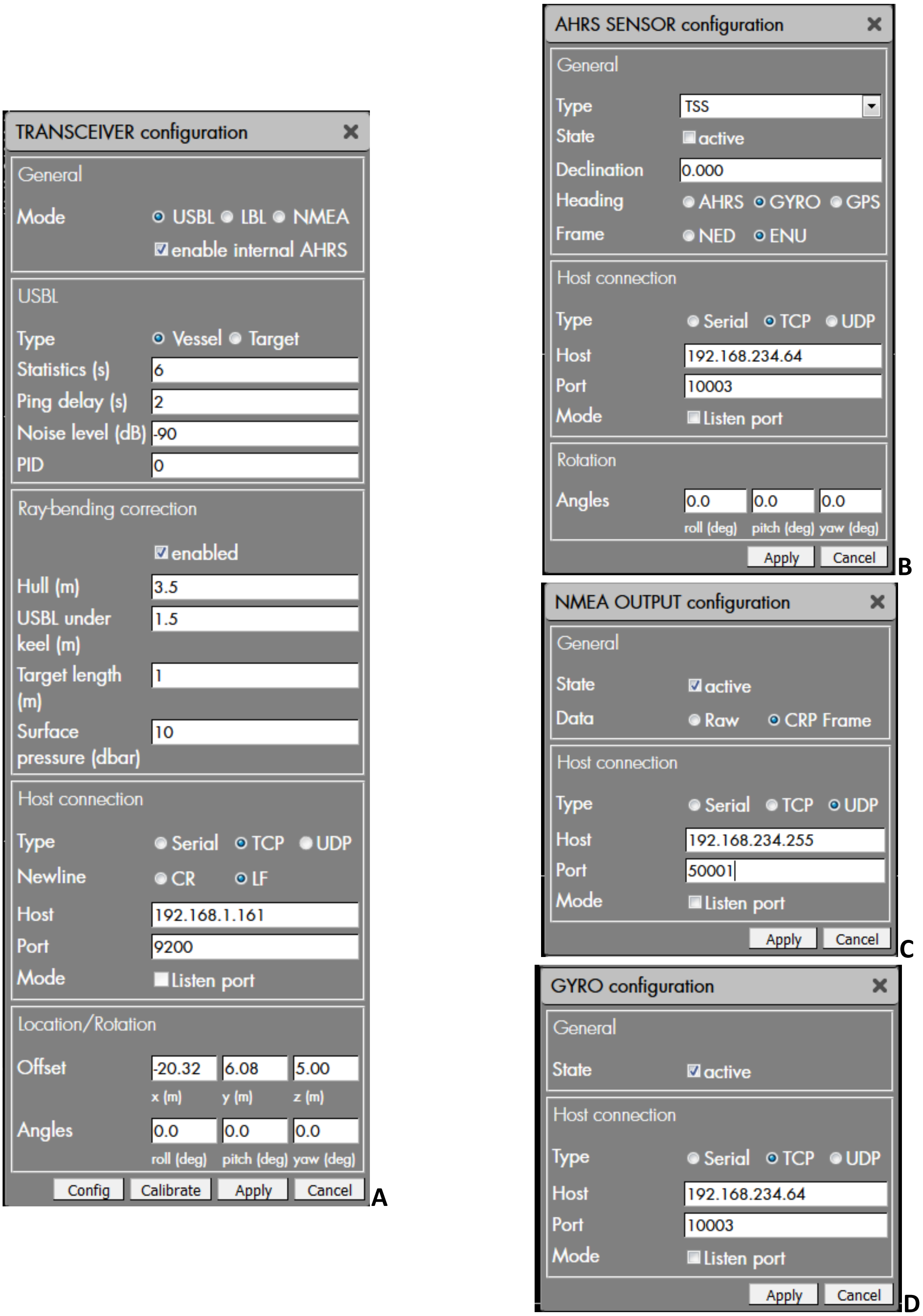
GPS RECEIVER configuration

General
State: ☑ active
☐ enable internal AHRS

Host connection
Type: ● Serial ○ TCP ○ UDP
Port: COM12
Baudrate: 9600 bps

Location
Offset: -18.40 x (m), 5.48 y (m), -7.00 z (m)

Figure 86: Screenshots of all settings windows of the software, they are detailed below.



TRANSCEIVER configuration

General

Mode ◉ USBL ○ LBL ○ NMEA

☑ enable internal AHRS

USBL

Type ◉ Vessel ○ Target

Statistics (s) 6

Ping delay (s) 2

Noise level (dB) -90

PID 0

Ray-bending correction

☑ enabled

Hull (m) 3.5

USBL under keel (m) 1.5

Target length (m) 1

Surface pressure (dbar) 10

Host connection

Type ○ Serial ◉ TCP ○ UDP

Newline ○ CR ◉ LF

Host 192.168.1.161

Port 9200

Mode ☐ Listen port

Location/Rotation

Offset -20.32 x (m) 6.08 y (m) 5.00 z (m)

Angles 0.0 roll (deg) 0.0 pitch (deg) 0.0 yaw (deg)

AHRS SENSOR configuration

General

Type TSS

State ☐ active

Declination 0.000

Heading ○ AHRS ◉ GYRO ○ GPS

Frame ○ NED ◉ ENU

Host connection

Type ○ Serial ◉ TCP ○ UDP

Host 192.168.234.64

Port 10003

Mode ☐ Listen port

Rotation

Angles 0.0 roll (deg) 0.0 pitch (deg) 0.0 yaw (deg)

NMEA OUTPUT configuration

General

State ☑ active

Data ○ Raw ◉ CRP Frame

Host connection

Type ○ Serial ○ TCP ◉ UDP

Host 192.168.234.255

Port 50001

Mode ☐ Listen port

GYRO configuration

General

State ☑ active

Host connection

Type ○ Serial ◉ TCP ○ UDP

Host 192.168.234.64

Port 10003

Mode ☐ Listen port

Figure 87: A: Transceiver configuration sets the main parameters of the system. Mode enables the internal AHRS; the Host connections links the SiNAPS software to the modem; the USBL settings gives the frequency of the pinging between the USBL system and the beacon on the AUV/JAGO (here 2 seconds). B: AHRS here means external motion sensor input. This was not used (State is not checked) and thus the internal motion sensor was used (see image A). C: Output was given to OFOP and others via a UDP port. Using the IP address of xxx.xxx.xxx.255 means that all PCs in the respective subnetwork (234) can receive the massages (here PTSAG data) when listening on port 50001. D: Heading of the ship was used as input (State = active), in this case it came via a TCP connection on port 10003, alternatively it could come from separate sensor (Octans, or similar) but could also come from the AHRS of the Evelogics system.

8. Acknowledgements

We thank the captain and crew of RV Poseidon for their excellent support during the scientific campaign of POS526, the governments of the Netherlands, Norway and Denmark for allowing to conduct research in their national water and the GEOMAR data management team for their proactive spirit in conducting and developing the data management plan.

9. References

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10. Abbreviations

AWI	Alfred Wegener Institute Helmholtz Center for Polar and Marine Research
AUV	Autonomous Underwater Vehicle
CTD	Conductivity Temperature Depth
GEOMAR	GEOMAR Helmholtz Center for Ocean Research Kiel
LOKI	Light frame on-sight key species investigation
RV	Research Vessel
WA	Working Area
MBES	Multibeam Echosounder
SBES	Singelbeam Echosounder
ADCP	Acoustic Doppler Current Profiler
USBL	Ultrat Short Base Line
CRDS	Cavity Ringdown Spectrometer
USGS GAS	Equilibrator based sea surface gas measurement system (CH4, CO2, H2O) with CRDS sensor
GEOMAR AIS	Air Intake System for atmospheric measurements based on CRDS

11. Appendix

11.1. Station List

Station	Date UTC	Time UTC	Latitude N dd:mm.mmm	Longitude E dd:mm.mmm	Longitude E dd.dddddd	Latitude N dd.dddddd	Sub Area	Comment
Dogger Bank Area								
POS526_001_CTD-01	24.07.18	21:26	55:18.382	004:5.417	4.090283	55.30637	Cluster 1	SVP for hydroacoustic
POS526_002_MB-01	24.07.18	21:57	55:18.387	004:5.673	4.09455	55.30645	Cluster 1 to 5	MBES, ADCP, EK80
POS526_003_WVGL-01	25.07.18	04:43	55:19.462	004:3.258	4.0543	55.32437	Surveying W to E	surveying Dogger Bank area in a N-S grid
POS526_004_AUV-01	25.07.18	06:43	55:18.387	004:5.521	4.092017	55.30645	Cluster 1	First dive, Camera and USBL-tests (missions 016_1 to 016_3)
POS526_005_JAGO-01	25.07.18	10:59	55:18.329	004:5.443	4.090717	55.30548	Cluster 1	survey for gas seeps, use of BubbleBox at 4 different seeps (Schauer/Weiß)
POS526_006_CTD-02	25.07.18	16:14	55:18.408	004:5.320	4.088667	55.3068	Cluster 1	tow over Cluster 1
POS526_007_MB-02	25.07.18	17:30	55:18.392	004:5.707	4.095117	55.30653	Cluster 1 to 5	MBES, ADCP, EK80
POS526_008_MB-03	25.07.18	23:45	55:18.096	004:5.478	4.0913	55.3016	Cluster 1	MBES, ADCP, EK80
POS526_009_AUV-02	26.07.18	04:59	55:18.409	004:5.386	4.089767	55.30682	Cluster 1	Testing different depths for camera (missions 017_1 to 017_3)
POS526_010_Lander-01	26.07.18	09:30	55:18.361	004:5.437	4.090617	55.30602	Cluster 1	GasQuant in Cluster 1, Positioned at: 55:18.365 004:05.437; looking at 120°
POS526_011_JAGO-02	26.07.18	11:09	55:18.325	004:5.448	4.0908	55.30542	Cluster 1	GasQuant inspected, turned multibeam sensor in direction of seeps 130°, use BubbleBox at 3 different seeps, collect gas (Striewski/Schauer)
POS526_012_CTD-03	26.07.18	18:26	55:17.078	004:4.822	4.080367	55.28463		WaveGlider comparison
POS526_013_MB-04	26.07.18	19:09	55:18.023	004:5.543	4.092383	55.30038	Cluster 1	
POS526_014_MB-05	27.07.18	00:26	55:17.542	004:3.378	4.0563	55.29237	Cluster 4 and 5	only Cluster 5 done
POS526_015_CTD-04	27.07.18	07:13	55:18.479	004:5.410	4.090167	55.30798	Cluster 1	tow over Cluster 1
POS526_016_CTD-05	27.07.18	09:09	55:18.084	004:3.001	4.050015	55.30141167	Cluster 5	tow from NW-SE over Cluster 5
POS526_017_CTD-06	27.07.18	11:45	55:18.038	004:2.994	4.0499	55.30063	Cluster 5	tow from NW-SE over Cluster 6
POS526_018_AUV-03	27.07.18	13:26	55:17.795	004:3.394	4.056567	55.29658	Cluster 5	swim tests in 1.5m waves (no mission)
POS526_019_AUV-04	27.07.18	13:39	55:17.803	004:3.393	4.05655	55.29672	Cluster 5	swim tests in 1.5m waves (no mission)
POS526_020_CTD-07	27.07.18	14:29	55:17.974	004:2.680	4.044667	55.29957	Cluster 5	USBL beacon test
POS526_021_CTD-08	27.07.18	16:56	55:17.895	004:3.158	4.052633	55.29825	SW of Cluster 5	time series over 12h
POS526_022_CTD-09	27.07.18	17:51	55:17.903	004:3.203	4.053383	55.29838	SW of Cluster 5	time series over 12h
POS526_023_CTD-10	27.07.18	18:51	55:17.911	004:3.163	4.052717	55.29852	SW of Cluster 5	time series over 12h

POS526_024_CTD-11	27.07.18	19:50	55:17.876	004:3.159	4.05265	55.29793	SW of Cluster 5	time series over 12h
POS526_025_CTD-12	27.07.18	20:50	55:17.895	004:3.147	4.05245	55.29825	SW of Cluster 5	time series over 12h
POS526_026_CTD-13	27.07.18	21:52	55:17.892	004:3.133	4.052217	55.2982	SW of Cluster 5	time series over 12h
POS526_027_CTD-14	27.07.18	22:48	55:17.894	004:3.148	4.052467	55.29823	SW of Cluster 5	time series over 12h
POS526_028_CTD-15	27.07.18	23:52	55:17.874	004:3.147	4.05245	55.2979	SW of Cluster 5	time series over 12h
POS526_029_CTD-16	28.07.18	00:50	55:17.870	004:3.119	4.051983	55.29783	SW of Cluster 5	time series over 12h
POS526_030_CTD-17	28.07.18	01:50	55:17.868	004:3.096	4.0516	55.2978	SW of Cluster 5	time series over 12h
POS526_031_CTD-18	28.07.18	02:51	55:17.905	004:3.076	4.051267	55.29842	SW of Cluster 5	time series over 12h
POS526_032_CTD-19	28.07.18	03:49	55:17.913	004:3.132	4.0522	55.29855	SW of Cluster 5	time series over 12h
POS526_033_CTD-20	28.07.18	04:48	55:17.906	004:3.174	4.0529	55.29843	SW of Cluster 5	time series over 12h
POS526_034_CTD-21	28.07.18	05:50	55:17.911	004:3.209	4.053483	55.29852	SW of Cluster 5	time series over 12h
POS526_035_CTD-22	28.07.18	06:50	55:17.987	004:3.300	4.055	55.29978	NE of Cluster 5	time series over 12h
POS526_036_CTD-23	28.07.18	07:50	55:17.976	004:3.297	4.05495	55.2996	NE of Cluster 5	time series over 12h
POS526_037_CTD-24	28.07.18	09:02	55:17.977	004:3.274	4.054567	55.29962	NE of Cluster 5	time series over 12h
POS526_038_CTD-25	28.07.18	10:05	55:17.972	004:3.281	4.054683	55.29953	NE of Cluster 5	time series over 12h
POS526_039_CTD-26	28.07.18	10:56	55:17.948	004:3.285	4.05475	55.29913	NE of Cluster 5	time series over 12h
POS526_040_CTD-27	28.07.18	11:58	55:17.937	004:3.255	4.05425	55.29895	NE of Cluster 5	time series over 12h
POS526_041_CTD-28	28.07.18	12:53	55:17.959	004:3.191	4.053183	55.29932	NE of Cluster 5	time series over 12h
POS526_042_CTD-29	28.07.18	13:57	55:17.952	004:3.289	4.054817	55.2992	NE of Cluster 5	time series over 12h
POS526_043_CTD-30	28.07.18	14:50	55:17.978	004:3.295	4.054917	55.29963	NE of Cluster 5	time series over 12h
POS526_044_CTD-31	28.07.18	15:59	55:17.976	004:3.297	4.05495	55.2996	NE of Cluster 5	time series over 12h
POS526_045_CTD-32	28.07.18	16:55	55:17.976	004:3.317	4.055283	55.2996	NE of Cluster 5	time series over 12h
POS526_046_CTD-33	28.07.18	17:55	55:17.951	004:3.268	4.054467	55.29918	NE of Cluster 5	time series over 12h
POS526_047_CTD-34	28.07.18	18:55	55:17.964	004:3.282	4.0547	55.2994	NE of Cluster 5	time series over 12h
POS526_048_MB-06	28.07.18	20:57	55:17.899	004:3.324	4.0554	55.29832	Cluster 5	going N-S over cluster 5 with SBES and ADCP
POS526_049_CTD-35	29.07.18	06:21	55:17.925	004:3.269	4.054483	55.29875	Cluster 5 central	vertical cast centre of Cluster 5
POS526_050_CTD-36	29.07.18	07:55	55:17.963	004:3.274	4.054567	55.29938	Cluster 5	horizontal tow N-S, through Cluster 5
POS526_051_CTD-37	29.07.18	10:24	55:18.011	004:3.389	4.056483	55.30018	Cluster 5 east	horizontal tow N-S, east of Cluster 5 (currents towards the east)
POS526_052_CTD-38	29.07.18	12:41	55:18.004	004:3.129	4.05215	55.30007	Cluster 5 west	horizontal tow N-S, west of Cluster 5 (currents towards the east)
POS526_053_CTD-39	30.07.18	06:49	55:18.374	004:5.441	4.090683	55.30623	Cluster 1	no samples taken, bottles missfired
POS526_054_CTD-40	30.07.18	07:16	55:18.365	004:5.467	4.091117	55.30608	Cluster 1	vertical cast in Cluster 1
POS526_055_CTD-41	30.07.18	09:01	55:18.462	004:5.742	4.0957	55.3077	Cluster 1	horizontal tow N-S, 300m east of Cluster 1 (currents towards the east)
POS526_056_CTD-42	30.07.18	11:02	55:18.486	004:5.620	4.093667	55.3081	Cluster 1	horizontal tow N-S, 150m east of Cluster 1 (currents towards the east)
POS526_057_CTD-43	30.07.18	12:40	55:18.467	004:05.467	4.09111333	55.30778667	Cluster 1	horizontal tow N-S, 150m west of Cluster 1 (currents towards the north

POS526_058_CTD-44	30.07.18	14:30	55:18.474	004:05.589	4.09315833	55.307895	Cluster 1	horizontal tow N-S, 150m east of Cluster 1 (currents towards the north
POS526_059_MB-07	30.07.18	16:13	55:18.582	004:6.490	4.108167	55.3097	Cluster 1 - 5	repeating MB-1 from Cluster 1 to Cluster 5 EK80; ADCP
POS526_060_JAGO-03	31.07.18	06:52	55:18.318	004:5.379	4.08965	55.3053	Cluster 1	recovering GasQuant; final GasQuant position determined by good USBL navigation (Schauer/Pohlman)
POS526_061_USBL-01	31.07.18	09:11	55:18.404	004:5.598	4.0933	55.30673	Cluster 1	testing USBL setting and offstes with the CTD. NO CTD data exist!
Tisler Reef								
POS526_062_CTD-45	02.08.18	16:11	59:00.09	10:55.275	10.92125	59.0015		SVP collection
POS526_063_CTD-46	02.08.18	17:24	58:59.894	10:57.703	10.96172	58.99823		Camera tow across Tisler. Pressure test for Picam cameras.
POS526_064_CTD-47	02.08.18	19:44	58:59.887	10:58.208	10.97013	58.99812		Camera tow across Tisler
POS526_065_MB-08	02.08.18	22:28	59:00.222	10:55.271	10.92118	59.0037		mapping larger area; MBES
POS526_066_JAGO-04	03.08.18	06:40	58:59.908	10:57.674	10.96123	58.99847		exploring central Tisler reef complex, stand-alone cameras (Picams) not deployed because of internal power failure (Schauer/Purser)
POS526_067_AUV-05	03.08.18	10:12	59:00.02	10:57.666	10.9611	59.00033		First tests in Tisler, testing system in new environment (mission 019_1_1, 019_1_2)
POS526_068_CTD-48	03.08.18	14:31	58:59.653	10:58.264	10.97107	58.99422		video tow across Tisler. 1 Picam also attached to CTD
POS526_069_CTD-49	03.08.18	16:59	59:0:054	10:58.012	10.96687	59.0009		Camera problems, no deplyoment
POS526_070_MB-09	03.08.18	19:15	59:0.049	10:58.059	10.96765	59.00082		reduced swath to 90° similar to MB-8; MBES
POS526_071_JAGO-05	04.08.18	06:19	58:59.904	10:57.789	10.96315	58.9984		stereographic camera, GoPro-stills, Sony-∂ survey on top of Tisler reef (Schauer/Köser)
POS526_072_AUV-06	04.08.18	10:04	59:00.005	10:57.611	10.96018	59.00008		Tests with Multibeam and camera, solving dvl problems (mission 020_1_1, 020_1_2)
POS526_073_JAGO-06	04.08.18	12:49	58:59.733	10:58.130	10.96883	58.99555		exploration survey from the eastern gully and up towards the central Tisler reef top (Schauer/Greinert)
POS526_074_ADCP-01	04.08.18	16:38	58:59.892	10:57.691	10.96152	58.9982		measuring currents at 6 different locations at the eastern side of the reef area
POS526_075_CTD-50	04.08.18	23:59	59:00.116	10:57.808	10.96347	59.00193		video tow; 3 Picams attached to CTD frame
POS526_076_CTD-51	05.08.18	01:30	59:00.059	10:57.919	10.96532	59.00098		video tow; 3 Picams attached to CTD frame
POS526_077_CTD-52	05.08.18	02:28	58:59.731	10:57.903	10.96505	58.99552		video tow; 3 Picams attached to CTD frame
POS526_078_CTD-53	05.08.18	03:29	58:59.704	10:57.985	10.96642	58.99507		video tow; 3 Picams attached to CTD frame
POS526_079_CTD-54	05.08.18	04:39	58:59.834	10:57.516	10.9586	58.99723		video tow; 3 Picams attached to CTD frame
POS526_080_MB-10	05.08.18	07:39	59:0.038	10:54.613	10.91022	59.00063	Tisler-Djupekrak	not so good weather
POS526_081_MB-11	05.08.18	11:19	59:0.228	10:55:062	10.9177	59.0038	Tisler-Djupekrak	not so good weather

POS526_082_CTD-55	05.08.18	19:19	58:59.730	10:58.079	10.96798	58.9955		
POS526_083_AUV-07	06.08.18	06:18	58:59.872	10:57.650	10.96083	58.99787		Being filmed by JAGO, dive to 20m, wait 5min, dive to seafloor wait 20min, execute patrolling for 45min, wait 5min and back to surface (mission 021_1)
POS526_084_JAGO-07	06.08.18	06:23	58:59.948	10:57.663	10.96105	58.99913		Under water meeting with AUV 'ANTON', following AUV on its transect, deployment of 3 Picam cameras close to top of central Tisler reef (Schauer/Purser)
POS526_085_AUV-08	06.08.18	10:18	58.59.848	10:57.900	10.965	58.99747		multibeam survey, constant altitude (mission 022_1)
POS526_086_JAGO-08	06.08.18	12:13	58:59.808	10:57.831	10.96385	58.9968		exploration survey from lower eastern reef mounds up to central Tisler mound, strong current, transmisson of USBL navigation data to JAGO worked well (Schauer/Hissmann)
POS526_087_MB-12	06.08.18	15:19	58:59.981	10:57.002	10.95003	58.99968		filling in gaps
POS526_088_MB-13	06.08.18	18:55	59:00:101	10:59:168	11.0300	59.00168		filling in gaps
POS526_089_JAGO-09	07.08.18	06:59	59:00.011	10:57.099	10.95165	59.00018		exploration of smaller mounds west of central Tisler reef mound, solid rock + coral rubble mound, USBL nav. inside JAGO (Schauer/Striewski)
POS526_090_AUV-09	07.08.18	10:57	59:00.106	10:57:379	10.95632	59.00177		multibeam survey, constant depth (mission 023_1)
POS526_091_JAGO-10	07.08.18	11:58	58:59.947	10:57.536	10.95893	58.99912		stereographic camera, GoPro-stills, Sony-∂ along parallel transects in boulder/cobble area west of central Tisler reef mound (Schauer/Köser)
POS526_092_CTD-56	07.08.18	12:45	58:59.973	10:57.526	10.95877	58.99955		sampling water for testing LOKI system
POS526_093_MB-14	07.08.18	16:13	59:00.003	10:58.245	10.97075	59.00005		filling gaps
POS526_094_CTD-57	07.08.18	22:06	58:59.722	10:58.094	10.96823	58.99537		sampling water for LOKI (3 depths). SeaGard RCM, color absorption measurements; ADCP and EK80 running. 3 Picams mounted on CTD
POS526_095_CTD-58	07.08.18	23:49	58:59.907	10:57.661	10.96102	58.99845		sampling water for LOKI (3 depths); ADCP and EK80 running. 3 Picams mounted on CTD
POS526_096_CTD-59	08.08.18	00:53	59:0.005	10:56.613	10.94355	59.00008		sampling water for LOKI (3 depths). Seaguard RCM; ADCP and EK80 running. 3 Picams mounted on CTD
POS526_097_CTD-60	08.08.18	02:10	58:59.726	10:58.097	10.96828	58.99543		Seaguard RCM; ADCP and EK80 running. 3 Picams mounted on CTD
POS526_098_CTD-61	08.08.18	02:49	58:59.903	10:57.691	10.96152	58.99838		Seaguard RCM; ADCP and EK80 running. 3 Picams mounted on CTD
POS526_099_CTD-62	08.08.18	03:27	58:59.996	10:56.617	10.94362	58.99993		Seaguard RCM; ADCP and EK80 running. 3 Picams mounted on CTD
POS526_100_JAGO-11	08.08.18	06:38	58:59.924	10:57.697	10.96162	58.99873		collecting 3 Picam cameras at reef top, exploration of slope with coral reef towards south of central Tisler reef summit (Schauer/Song). 1 Picam attached to JAGO for dive

POS526_101_MB-15	08.08.18	09:52	58:59.960	10:57.429	10.95715	58.99933		filling gaps on the way to 400 AUV dive
POS526_102_AUV-10	08.08.18	11:14	59:02.755	10:49.274	10.82123	59.04592	Oslo Trough	400m AUV dive, abort with shutdown (mission 024_1)
POS526_103_CTD-63	08.08.18	14:47	59:00.245	10:56.648	10.94413	59.00408		video transect west of Tisler reef
POS526_104_CTD-64	08.08.18	16:18	59:00.176	10:56.945	10.94908	59.00293		video transect west of Tisler reef
POS526_105_CTD-65	08.08.18	17:55	58:59.570	10:58.854	10.9809	58.99283		video transect E - W through gully

11.2. Summary of Deployments

Gear	**No. of deployments Dogger Bank**	**No. of deployments Tisler Reef**	**Total Mission Time**	**Total Data volume**
JAGO	3	8	44:25	
AUV Anton	4	6	25:23	
Waveglider	1		2:00	
GasQuant 2	1		2:00	
BubbleBox	2			
BatCAM		2		
TV-CTD observations		11	30:49	
TV-CTD water sampling	41		66:42	
SeaBeam 3050 bathymetry		8	53:51	
SeaBeam 3050 WCI	7		54:22	
ADCP	7	1	49:39	
EK80	7	8	53:30	

Table above maybe not completely correct.