HEINCKE-Berichte

*"RoboLeaks –*
*Robotic vehicle tests at natural seeps and gas leaks*
*in the North and Baltic Seas"*

Cruise No. HE629

3.10.2023 – 11.10.2023
Stavanger (Norway) – Bremerhaven (Germany)
***RoboLeaks***


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MARUM
2023

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# 2 Cruise Summary

## 2.1 Summary

The expedition aboard the RV Heincke (HE629) focused on evaluating the technical and operational capabilities of a new autonomous underwater vehicle (AUV) called the IMGAM AUV. The evaluation and test scenarios aimed to explore the AUV's potential and limitations, and to identify any shortcomings in its operation for future scientific missions. Although the AUV is designed for seep detection and sampling at depths of up to 2,000 metres, it had only been tested at depths of up to 50 metres prior to this expedition.

Future tasks will involve sonar-based seafloor and water column mapping, high-precision close-proximity opto-acoustic seafloor mapping, autonomous gas flare detection (seep mapping), and adaptive sampling. During this cruise, the vehicle was taken to increasingly greater depths and crucial independent surface and seafloor navigation performance tests were conducted. The R2Sonic 2026 multi-beam sonar system was tested and calibrated by collecting seafloor bathymetry and water column data during short dives of up to one and a half hours. The work area was predominantly around the greater Stavanger Fjord due to favourable test conditions with respect to water depth; adverse weather conditions prevailed outside the fjord. The final work area was in the Skagerrak region, where IMGAM's seep detection capabilities were tested at documented seafloor seep sites. Although the vehicle's performance characteristics, including the multi-beam sonar's interaction with the navigation system, were successfully established, no seeps could be detected using the ship-mounted multibeam or the AUV's sonar system.

The cruise departed from Stavanger on the morning of 3 October 2023, heading for the first work area, and concluded in Bremerhaven in the evening of 9 October. A total of 24 AUV dives were conducted during the eight days at sea, representing an extremely efficient testing regime thanks to the excellent support provided by the crew and vessel, as well as the fjord region providing an excellent testing ground.

## 2.2 Zusammenfassung

Die Expedition an Bord der RV Heincke (HE629) konzentrierte sich auf die Bewertung und Weiterentwicklung der technischen und operativen Fähigkeiten eines neuen autonomen Unterwasserfahrzeugs (AUV) namens IMGAM AUV. Die Bewertungs- und Testszenarien zielten darauf ab, das Potenzial und die Grenzen des AUV zu erkunden und etwaige Mängel in seinem Betrieb für zukünftige wissenschaftliche Missionen zu identifizieren. Obwohl das AUV für die Erkennung und Probenahme von Sickerstellen in Tiefen von bis zu 2.000 Metern konzipiert ist, wurde es vor dieser Expedition nur in Tiefen von bis zu 50 Metern getestet.

Zukünftige Aufgaben umfassen die sonarbasierte Kartierung des Meeresbodens und der Wassersäule, die hochpräzise opto-akustische Kartierung des Meeresbodens aus nächster Nähe, die autonome Erkennung von Gasfackeln (Seep-Kartierung) inklusive autonome Probenahme. Während dieser Fahrt wurde das Fahrzeug in immer größere Tiefen gebracht (max. 300 m) und es wurden wichtige unabhängige Tests zur Leistungsfähigkeit der Navigation an der Oberfläche und am Meeresboden durchgeführt. Das Multibeam-Sonarsystem R2Sonic 2026 wurde getestet und eingestellt, indem während kurzer Tauchgänge von bis zu anderthalb Stunden Daten zur Bathymetrie des Meeresbodens und zur Wassersäule gesammelt wurden. Der Arbeitsbereich befand sich aufgrund der günstigen Testbedingungen hinsichtlich der Wassertiefe überwiegend im Großraum des Stavanger Fjords; außerhalb des Fjords herrschten zudem ungünstige Wetterbedingungen. Der letzte Arbeitsbereich befand sich in der Region Skagerrak, wo die Fähigkeiten des IMGAM zur Erkennung von Gasfackeln an dokumentierten Stellen am Meeresboden getestet werden sollten. Obwohl die technische Leistungsfähigkeit des Fahrzeugs, einschließlich der Integration des Multibeam-Sonars mit dem Navigationssystem, erfolgreich getestet werden konnten, konnten sowohl mit dem schiffsgestützten Multibeam-Sonar als auch dem Sonarsystem des AUV keine Sickerstellen erkannt werden.

Die Fahrt begann am Morgen des 3. Oktober 2023 in Stavanger mit Kurs auf das erste Arbeitsgebiet und endete am Abend des 9. Oktober in Bremerhaven. Während der acht Tage auf See wurden insgesamt 24 AUV-Tauchgänge durchgeführt, was dank der hervorragenden Unterstützung durch die Besatzung und das Schiff sowie die außerordentlich guten Testbedingungen der Fjordregion ein äußerst effizientes Testprogramm darstellte.

# 3 Participants

## 3.1 Principal Investigators

| Name | Institution |
|---|---|
| Bachmayer, Ralf, Prof. | MARUM |

## 3.2 Scientific Party

| Name | Discipline | Institution |
|---|---|---|
| Bachmayer, Ralf | Marine Technology / Chief Scientist | MARUM |
| Spiesecke, Ulli | AUV Technician | MARUM |
| Kienitz, Tim | AUV Technician | MARUM |
| Thorgeirsson, Arni Thor | AUV Technician | MARUM |
| Bazhenova, Evgenia | Hydroacoustics | MARUM |

### 3.3 Participating Institutions

MARUM Center for Marine Environmental Sciences at the University of Bremen

## 4 Research Program

### 4.1 Description of the Work Area

The work area for this cruise was selected based on available save operating depth and surface traffic for the safe deployment, operation and recovery of the IMGAM AUV. Another advantage of the fjord system around Stavanger is that it is always possible to find a sheltered spot where the mountains slow the wind. On the first day, the Karmsundet fjord was chosen for the AUV operation. The ship reached the target area in under three hours and the AUV could be deployed on the first day. For AUV dives, it is mandatory that the ballast is set to the correct value and the vehicle is trimmed properly. The buoyancy needs to be small enough to enable the vehicle to follow a slope while maintaining a constant distance from the seafloor during a constant altitude dive. For safety reasons, it must have enough positive buoyancy, in case of loss of power, so the AUV will float to the surface, where it can be recovered. Since the fjords are influenced by river water with a lower density and North Sea water with a higher salinity, the density difference creates a large range of buoyancy variability that the flotation setup has to work within. The water column is set up in layers with changing density, which we can only estimate before deployment. While diving through these layers, the vehicle's buoyancy will change significantly. Therefore, the AUV's neutral buoyancy was measured in Bremen and recomputed for each specified target area's salinity setup. Since the water surface was calm enough, it was possible to check the vehicles buoyancy in the water with the AUV still connected, which is usually not possible in open seas. This was only possible because the crane does not move according to the sea state, providing a nearly stable vessel.

### 4.2 Aims of the Cruise

The expedition on the RV Heincke (HE629) was focused on technical and operational evaluation of a new autonomous underwater vehicle, the IMGAM AUV with the prime objective of the cruise being the evaluation of the navigational performance of the AUV and bringing the AUV to greater operational depth. This is all conducted with a view of exploring IMGAM’s potential for new and upcoming future scientific research around high precision and close proximity opto-acoustic seafloor mapping, autonomous gas flare detection (seep mapping) and adaptive sampling. The scientific crew, listed in Table 1, reflects the technical focus on this cruise.

## 4.3 Agenda of the Cruise

**3 October 2023 – Ship-based mapping & initial dives**

- Mobilization of AUV IMGAM and onboard systems out of Stavanger..
- Ship based multibeam mapping of target area in Karmsundet Fjord.
- **Dive 31:** AUV shallow functional test (5 m depth).
- **Dive 32:** AUV navigation quality test with turns (20 m depth).

**4 October 2023 – AUV preparation & system repair**

- Detection and repair of drop-weight power malfunction.
- Transit to Nedstrandsfjord
- Ship based multibeam mapping of target area in Nedstrandsfjord for dive planning.

**5 October 2023 – Sonar setup & surface trials**

- **Dive 33:** Surface mapping line with live R2Sonic setup.
- **Dive 34–35:** Repeated lines for sonar calibration (surface).
- **Dive 36–37:** Deeper dives (40 m) for stable sonar testing.

**6 October 2023 – Deep fjord calibration attempts**

- **Dive 38:** Sonar calibration mission at 60 m; drop-weight malfunction discovered.
- Attempted dive aborted due to buoyancy imbalance.
- Transit to Sandsfjorden because adverse weather conditions
- Additional ship-based multibeam mapping of new area.

**7 October 2023 – Mapping missions & controller tests**

- **Dive 39:** Mission aborted due to planning tool error.
- **Dive 40:** First full mapping mission with altitude control (40–80 m).
- **Dive 41:** Descent ratio tests to 110 m; navigation failure triggered recovery.
- **Dive 42:** Stable 700 m mapping line at 50 m depth.

**8 October 2023 – Calibration series & cross-line mapping**

- **Dive 43–46:** Repeated parallel and crossing mapping lines at 50 m for multibeam calibration.
- **Dive 47:** Continuation of cross-line mapping pattern.
- **Dive 48–50:** Improved navigation setup; cross-line and altitude vs. depth mapping tests.

- Transit to Skagerrak for seep mapping and deep open water trials.

**9 October 2023 – Open-sea trial**

- **Dive 51:** First deep-water open-sea mission (220–300 m); successful mapping despite DVL misalignment issue.
- Return to Bremerhaven

**10 October 2023 – Demobilisation**

- Demobilisation

**Throughout Cruise**

- Launch and recovery procedure development under variable fjord and offshore conditions.
- Continuous vehicle maintenance, hardware modifications, and on-board data processing.

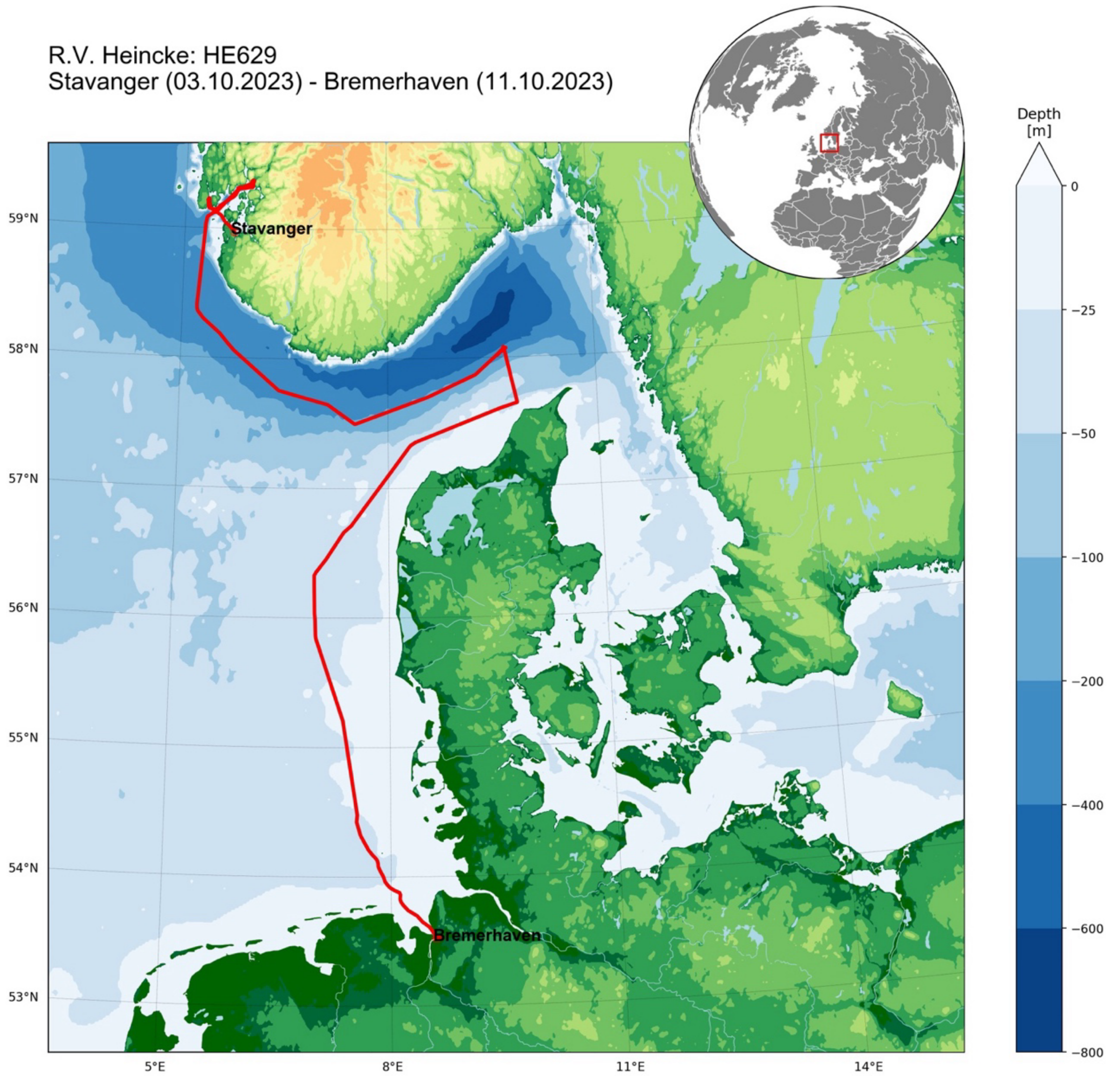


**Fig. 4.1:** Track chart of R/V HEINCKE Cruise HE529. Two main working areas (Stavanger Fjords and Skagerrak).

# 5 Narrative of the Research Cruise HE629 (RV Heincke, Oct. 2023)

The research cruise HE629, conducted aboard RV *Heincke* in October 2023, focused on advancing the development and testing of the AUV IMGAM, a 1.2-ton prototype vehicle designed to autonomously detect and sample gas emissions using multibeam sonar and associated sensors. The primary objective was to evaluate and improve the AUV's navigation, dive stability, and mapping capabilities in preparation for future scientific missions.

Operations were carried out in the sheltered fjords near Stavanger, Norway, where variable salinity and density layers provided a challenging but controlled testing environment. Initial efforts involved detailed ship-based multibeam mapping to prepare high-resolution bathymetric grids for comparison with AUV-based surveys. Over the course of the cruise, more than 24 dives were attempted, ranging from shallow functional checks to the first deep-water trial reaching 300 m depth.

The dives progressively addressed vehicle control, buoyancy, navigation stability, and sonar calibration. Early trials focused on mission execution, surface "live mapping" tests, and tuning of the R2Sonic sonar. Subsequent dives in Nedstrandsfjord and other fjord sites targeted systematic mapping lines, cross-line calibrations, and controller improvements. Despite technical setbacks—including repeated failures of the drop-weight electronics, navigation drift linked to DVL misalignment, and occasional software faults—the AUV successfully performed multiple stable mapping missions, collecting over 1.4 TB of data.

Launch and recovery of the 4-meter AUV posed consistent challenges under variable weather and fjord wind conditions. Several recoveries required the use of the fast rescue boat, highlighting both the risks and the learning opportunities for handling procedures. Between dives, significant time was devoted to maintenance, hardware modifications, and data analysis to ensure mission safety and continuity.

The final dive of the cruise demonstrated the AUV's capability for open-sea deployment, achieving stable operations at depth while identifying remaining navigation issues to be resolved in future calibrations. Overall, HE629 successfully advanced IMGAM from prototype stage toward operational readiness, delivering critical insights into its performance, limitations, and required improvements for future scientific use.

# 6 Preliminary Results

## 6.1 Technical description of IMGAM AUV

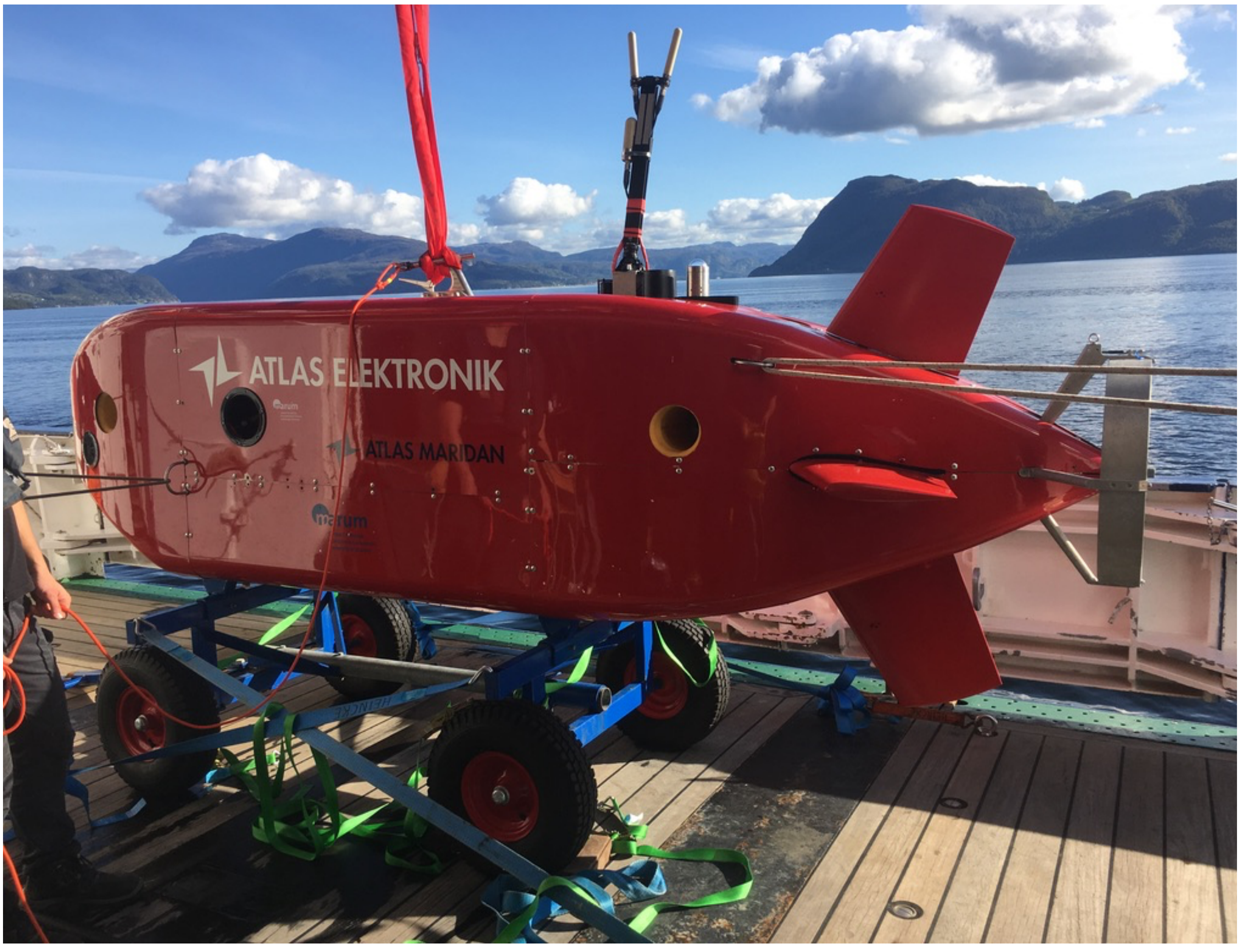


**Fig. 6.1:** IMGAM AUV on its deployment cart on board RV Heincke.

The vehicle was built by Atlas Electronic - Maridan in cooperation with the University of Bremen. It was designed for autonomous operation up to a maximum water depth of 2000 m. The vehicle's dry weight is about 1.2t with an overall length of 4 m. It has plane controlled forward diving abilities as well as thruster supported hovering functionality. The initial purpose of the vehicle was to be able to find and locate seafloor gas seeps using a MBES in water column mode. The vehicle can be equipped with a purpose designed modular gas-sampler. The concept of operations for gas sampling is after detection and localization to switch into a hovering mode and guide the vehicle above the seepage using optical and acoustic methods for accurate positioning. After conclusion of the sampling, the vehicle should switch back into its mapping mode again. As payload the vehicle is equipped a MBES, a single beam echosounder, CTD, cameras, lights and a gas sampler. The vehicle onboard navigation suite is comprised of an Inertial Navigation System combined with a Doppler Velocity Log and pressure sensor. An acoustic modem and acoustic beacon for USBL localization provides ship based tracking and intervention capabilities. A GPS unit, Satellite and WiFi surface communications provide connectivity while at the surface.

## 6.2 AUV trials and operations

(Ulli Spieseke/Sophia Schillai)

**Fig. 6.2:** Left image shows IMGAM AUV approaching RV Heincke for recovery. Right image shows the AUV getting hooked for the recovery.

The dives were planned to collect data for analysis and evaluation of the vehicle's behaviour and capabilities, and to enable us to improve dive stability. The goal is to transition the AUV from prototype to scientific usage. The focus is on proving the mapping ability and dive stability, and on identifying issues that need to be addressed before the AUV can be used for scientific purposes. To achieve this, we collected navigation, controller and AUV status data.

Independent navigation data was recorded by tracking the vehicle from the ship's side using an Ultra Short Baseline navigation system (USBL). To calibrate and improve mapping capabilities, multibeam mapping data was collected from the same area using the ship's Kongsberg EM712 MBES sonar and the AUV's R2Sonic 2026 MBES. More than 1400 GB of data was collected on HE629 and will be analysed.

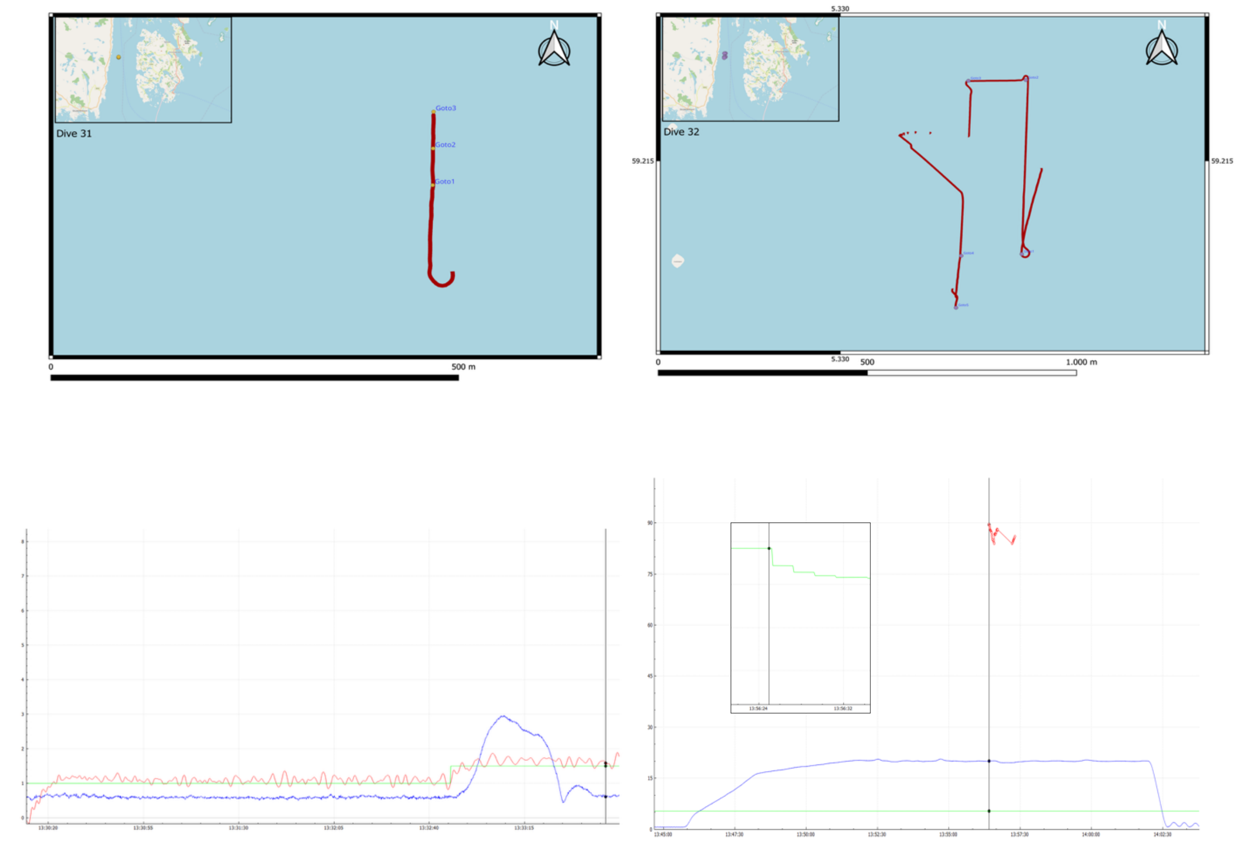


**Fig. 6.3:** Dive 31 (left) and Dive 32 (right) in Karmsundet Fjord. Dive 31 log graph shown on the lower left with depth [m] (blue); vehicle velocity [m/s] (red) and desired velocity in green. The lower right panel shows an excerpt of Dive 32 flight data, with depth [m] (blue), altitude [m] (red) and degree longitude [°] (green). Note the jump in longitude as the altimeter gets the bottom range also seen in the zoomed inline view.

During the 8 days of the cruise a total of 24 dives were conducted evaluating various subsystems, in particular with respect to navigation issues and vehicle dynamics. Overall the vehicle performed well, however some issues with respect to the vehicle dynamics and controller tuning as well as some navigation issues were discovered, see the jump in longitude during Dive 32 shown in Fig. 5.3 (right panels). During previous tests in the North and Baltic Sea these issues were not visible due to the shallow water conditions and continuous bottom log of the DVL.

Exemplary to the conducted dive tests Dive 40 is shown to illustrate the overall good performance of the system while some of the above mentioned needed improvements are vident in the data.

### Dive 40, 7.10.2023

The mission was restarted on the 7.10.2023 at 12:48 UTC. The AUV performed the first standard mapping mission, flying a parallel dive pattern programmed to keep a constant distance to sea bottom. Three sections aiming for mapping at 40, 50, 60 and 80 m altitude were planned and executed. The vehicle was able to fly with fixed altitude. However, there are sections where the vehicle starts to oscillate, pitching up and down, suggesting improvements to altitude controller to reduce pitching motion and improve mapping quality.

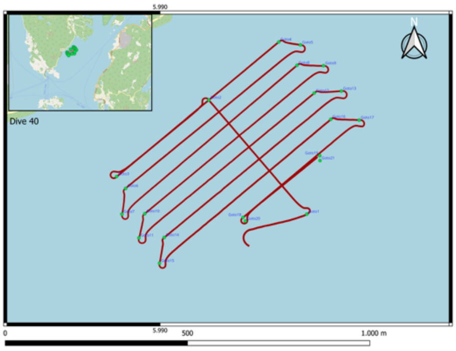


**Fig. 6.4:** IMGAM AUV Dive 40 trackline.

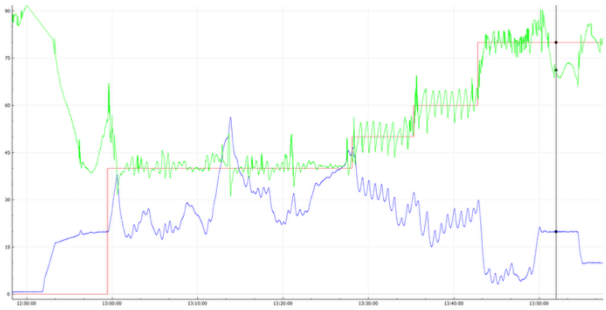

**Fig. 6.5:** IMGAM AUV Dive 40 log data showing blue: depth [m] (blue); altitude set point [m] (red) and reported altitude [m] (green).

### Launch and recovery

The AUV is equipped with an Atlas Maridan penguin hook for launch and recovery of the AUV. It has an opening at the front, which can be used for regular launch and to slip lifting equipment into the hook, see Fig. 5.6 and 5.7. Depending on the sea state and the behavior of the ship the attachment of the crane hook can be difficult. A successful slinging of the hook is shown in Fig. 5.5. Launch and recovery of the 1,2t robot under offshore conditions is a difficult task with a wide variety of hazards for the device and the crew involved. During HE629 different setups were used to deploy and recover the AUV to gain the best and safest experience with the is AUV.

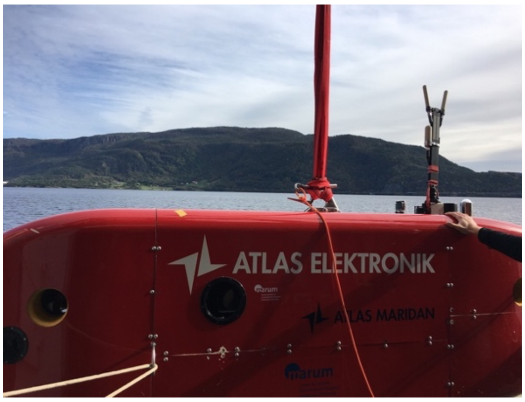


**Fig. 6.6:** IMGAM AUV Penguin hook rigged for slip lifting.

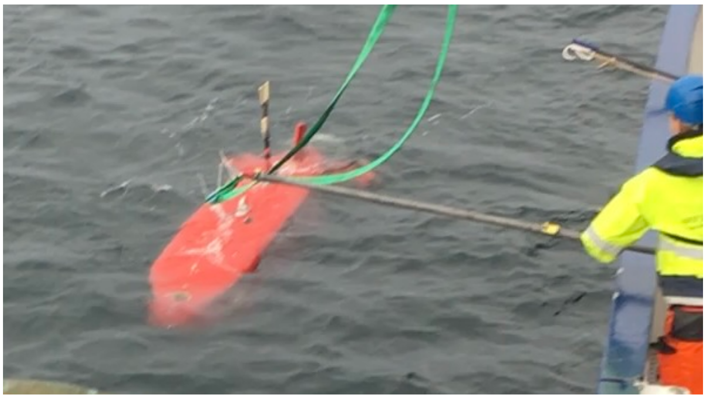

**Fig. 6.7:** Slinging the IMGAM AUV Penguin hook for recovery.

## 6.3 Multi-beam bathymetric mapping during the HE629 cruise Underway Hydroacoustics

(E. Bazhenova)

### EM712 data acquisition and processing

In order to provide bathymetric maps for the AUV mission planning, reconnaissance surveys were performed using the hull-mounted Kongsberg EM712 multi-beam echosounder integrated with the motion and positioning systems installed on the RV Heincke.
The hull-mounted sound velocity sensor Valeport miniSVS was used to provide real-time sound velocity measurements at the MBES transducer head. Vertical sound velocity profiles (SVP) were collected using the Valeport MIDAS SVP probe in the chosen target areas, to correct the acoustic ray tracing for the water column stratification during the MBES data acquisition, as well as during the operation of the shipboard GAPS positioning system.

### Vertical datum

No tidal corrections were applied during the data acquisition or post-processing.

### Data post-processing

Raw bathymetry data (.kmall) were recorded using the Kongsberg SIS v.5.11.1 software package and consequently imported into the QPS Qimera software v.2.5.3. Achieved sounding density at different depths allowed for gridding data at 2-4 m horizontal resolution. Initial quality control included 1) verification that the SVP data were applied correctly based on the time and location; 2) filtering of the outliers using the weak spline, 3) manual point cloud cleaning if required. Obtained bathymetric grids were exported as georeferenced .tiff files (see Fig. 5.8 and Appendix**Error! Reference source not found.**).

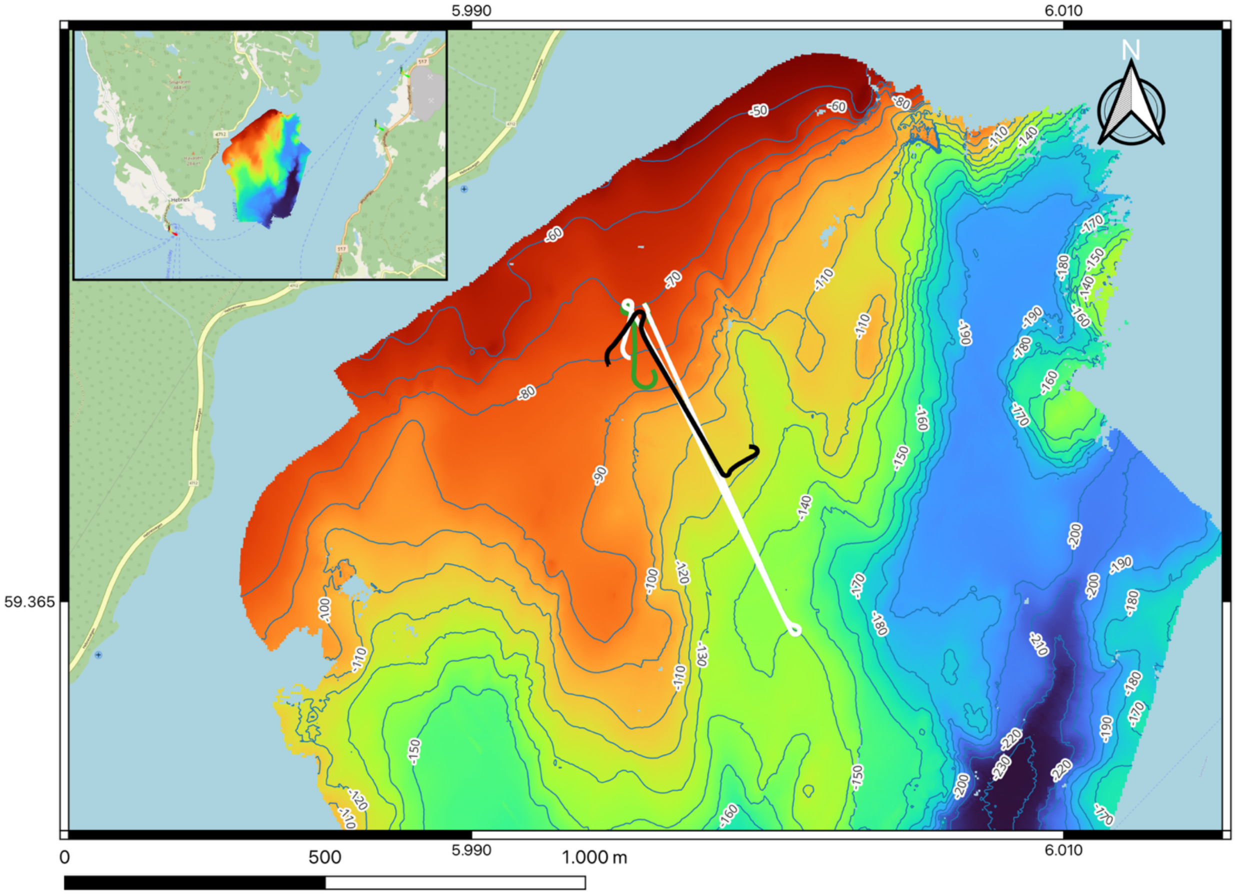


**Fig. 6.8:** Bathymetric map of Target Area 3 obtained using the shipboard EM712 MBES.

## 6.4 IMGAM AUV: R2Sonic data acquisition and processing

The IMGAM AUV is equipped with a R2Sonic 2026 MBES integrated with an iXBlue INS, depth and a Seabird CTD for sound-velocity measurements, as well as GPS system for surface position acquisitions.

The raw bathymetry data (.bath) were collected using the R2Sonic proprietary data acquisition software, where linear and angular mounting offsets for the R2Sonic MBES were set to zero. The raw file extension was manually changed from *.bath to *.r2sc before importing the files into the QPS Qimera v.2.5.3 post-processing software.

Linear offsets for the transmitting and receiving antennas of the R2Sonic MBES were measured onboard RV Heincke using the measuring tape and applied within the Qimera software as shown in Figure 5.2.

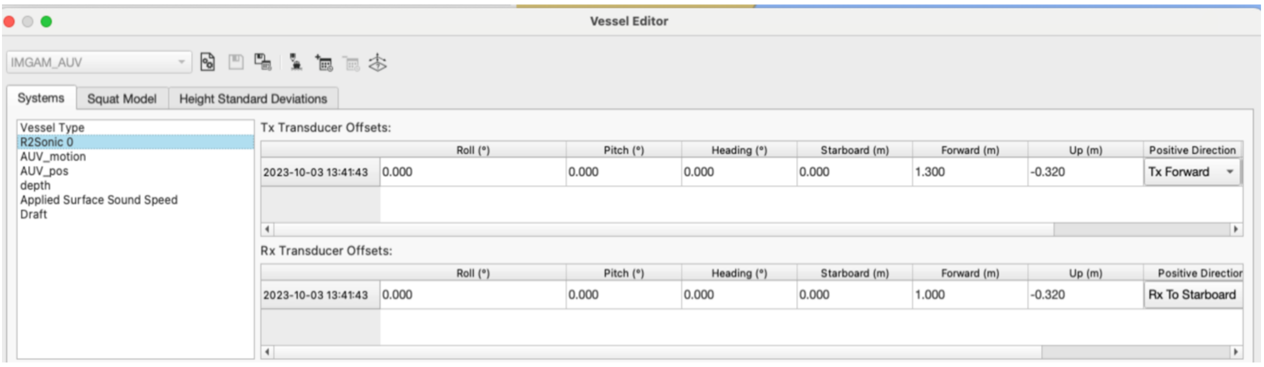


**Fig. 5.2**: Qimera processing software panel with R2Sonic Multibeam Echosounders translational offset registration.

The IMGAM AUV reference frame is centred at the INS reference frame position. Navigation and motion data were recorded by the iXBlue INS software in different formats. For post-processing of bathymetry data, high-frequency data (100 Hz) stored as .ph files were converted into .ascii format using a Python script.

Angular mounting offsets (roll, pitch, heading) should be determined during a standard routine procedure designed for calibration of multi-beam echosounders (patch test) and entered into the angular offset panel as shown in Figure 5.3.

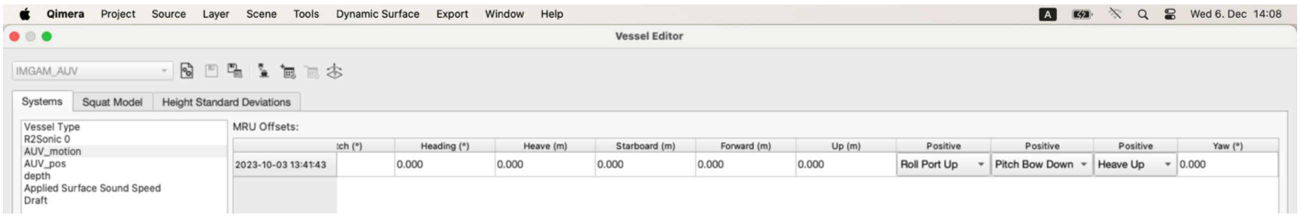


**Fig. 5.3:** Qimera processing software panel with R2Sonic Multibeam Echosounders rotational offset registration.

During the HE629 cruise, several attempts were undertaken to collect the required bathymetry data. However, two parallel overlapping swaths are required to calibrate roll and heading of the MBES.

Dives 049 and 050 were performed at 3 kts. Dive 049 was set to run in the constant AUV depth mode (ca. 50 m bsl) and seems to provide the best AUV bathymetry data collected during the HE629 cruise, shown in Appendix 11.1. Figure 11.1 and 11.3. However, at the used AUV speed the sounding density appears to be low for the deeper areas.

Dive 051 was planned to collect the required calibration data over a well-defined target (ship wreck of ca. 100 m length mapped by the EM712 MBES), however, navigation issues did not allow for a successful mapping mission.

# 7 Station and AUV Dive List for HE629

## 7.1 Overall Station List

| Station No. | | Date | Gear | Time | Latitude | Longitude | Remarks/Recovery |
|---|---|---|---|---|---|---|---|
| Heincke | MARUM | 2023 | | [UTC] | [°N] | [°W] | |
| HE629_1-1,2,3,4 | IMGAM#31, #32 | 3.10. | MBES, SVP, AUV | 13:30 | 59°13,3′ | 5°20,6′ | AUV dive tests, trim and ballast Karmsundet (Fjord Stavanger) |
| HE629_2-1,2,3,4 | - | 4.10. | MBES, SVP, AUV | 9:30 | 59°20,3′ | 5°59,7′ | Relocating, Mapping Nedstrandsfjoren |
| HE629_3-1 | IMGAM#33, 34, 35, 36, 37 | 5.10. | AUV | 11:30 | 59°19,8′ | 5°58,9′ | AUV mission execution and mapping mission Nedstrandsfjoren |
| HE629_4-1 | IMGAM#38 | 6.10. | AUV | 9:30 | 59°19,3′ | 5°58,7′ | AUV mapping missions, MBES roll calibration Nedstrandsfjoren |
| HE629_5-1,2,3 | IMGAM#39, 40, 41,42, | 7.10 | MBES, SVP, AUV | 9:30 | 59°22,8′ | 6°00,1′ | AUV mapping constant depth and constant altitude mission Sandsfjorden |
| HE629_6-1 | IMGAM#43, 44, 45, 46, 47, 48, 49, 50 | 8.10 | AUV | 9:30 | 59°22,1′ | 5°59,6′ | AUV Sonar calibration runs in various navigation modes (INS,DVL) Sandsfjorden |
| HE629_7-1,2,3 | IMGAM#51 | 9.10 | MBES, SVP, AUV | 13:30 | 58°03,7′ | 9°39,8′ | AUV descent test to 300m, mapping mission, Navigation solution jumps caused mission to abort Skagerrak |

## 7.2 IMGAM AUV Dive List

| HE629 | IMGAM | Date | Start Time of Mission | Mission duration | Location | Purpose |
|---|---|---|---|---|---|---|
| Station list | Dive Nr. | DD/MM/YY | UTC | HH:MM:SS | | |
| HE629_1-3 | 31 | 03.10.23 | 13:30:00 | 00:03:00 | Karmsundet (Fjord Stavanger) | First Dive test, one short line to 5m |
| HE629_1-4 | 32 | 03.10.23 | 13:41:00 | 00:23:00 | Karmsundet (Fjord Stavanger) | two parallel lines at 20m depth, test for R2Sonic mapping and depth mode dive |

| | | | | | | |
|---|---|---|---|---|---|---|
| HE629_3-1 | 33 | 05.10.23 | 11:57:00 | 00:05:00 | Nedstrandsfjoren | Short line on Surface |
| HE629_3-2 | 34 | 05.10.23 | 14:11:00 | 00:47:00 | Nedstrandsfjoren | Lines at surface with right angle turns at the end |
| HE629_3-3 | 35 | 05.10.23 | 15:04:00 | 00:17:00 | Nedstrandsfjoren | hold position to prepare next dive |
| HE629_3-4 | 36 | 05.10.23 | 15:26:00 | 00:19:00 | Nedstrandsfjoren | 40m depth mapping check roll calibration |
| HE629_3-5 | 37 | 05.10.23 | 15:49:00 | 00:19:00 | Nedstrandsfjoren | 40m depth mapping roll calibration, (unwanted) repeated by using the go to point function on neptus |
| HE629_4-1 | 38 | 06.10.23 | 12:12:00 | 01:03:00 | Nedstrandsfjoren | 60m depth mapping for roll calibration on anti-parallel lines |
| HE629_4-1 | noDive | 06.10.23 | 13:31:00 | 00:22:00 | Nedstrandsfjoren | at surface |
| HE629_4-1 | noDive | 06.10.23 | 13:56:00 | 00:11:00 | Nedstrandsfjoren | at surface |
| HE629_4-1 | noDive | 06.10.23 | 14:08:00 | 00:09:00 | Nedstrandsfjoren | same as previouis mission |
| HE629_5-1 | 39 | 07.10.23 | 12:00:00 | 00:09:00 | Sandsfjorden | 40m altitude mapping |
| HE629_5-1 | 40 | 07.10.23 | 12:48:00 | 01:09:00 | Sandsfjorden | 40m altitude mapping |
| HE629_5-1 | 41 | 07.10.23 | 14:11:00 | 00:23:00 | Sandsfjorden | deeper dive in star pattern descent to 110m depth with 10 and 20m depth steps |
| HE629_5-1 | 42 | 07.10.23 | 15:21:00 | 00:36:00 | Sandsfjorden | 50m depth first of three calibration lines for sonar |
| HE629_6-1 | 43 | 08.10.23 | 07:00:00 | 00:21:00 | Sandsfjorden | 50m depth first of three calibration lines for sonar |
| HE629_6-1 | 44 | 08.10.23 | 07:24:00 | 00:03:00 | Sandsfjorden | 50m depth second of three calibration lines for sonar. |
| HE629_6-1 | 45 | 08.10.23 | 07:36:00 | 00:19:00 | Sandsfjorden | 50m depth second of three calibration lines for sonar |
| HE629_6-1 | 46 | 08.10.23 | 08:06:00 | 00:22:00 | Sandsfjorden | 50m depth third of three calibration lines for sonar, parallel line |

| | | | | | | |
|---|---|---|---|---|---|---|
| HE629_6-1 | 47 | 08.10.23 | 08:36:00 | 00:17:00 | Sandsfjorden | dive to altitude 40m and 60m for testing changed Phins parameter, Altitude Mode : Depth sensor instead of Stabilization |
| HE629_6-1 | 48 | 08.10.23 | 09:35:00 | 00:07:00 | Sandsfjorden | short dive to 10m for testing changed Phins parameter, Altitude Mode : Depth sensor instead of Stabilization |
| HE629_6-1 | 49 | 08.10.23 | 09:51:00 | 00:18:00 | Sandsfjorden | dive to 50m for testing changed Phins parameter, Altitude Mode : Depth sensor instead of Stabilization |
| HE629_6-1 | 50 | 08.10.23 | 10:16:00 | 00:19:00 | Sandsfjorden | dive to altitude 40 and 60 for testing changed Phins parameter, Altitude Mode : Depth sensor instead of Stabilization |
| HE629_7-1 | 51 | 09.10.23 | 12:55:00 | 00:45:00 | Skagerrak | dive two layers with holding depth to map a registered wreck for sonar calibration; no seeps detected from shipboard MBES |

# 8 Data and Sample Storage and Availability

The collected bathymetric data at the different test locations are stored on the PANGEA open access library as a dataset.

Access is granted through https://www.pangaea.de/ or is accessible through the following reference:

Bazhenova, Evgenia A; Bachmayer, Ralf (2025): Multibeam bathymetry raw data (Kongsberg EM712 entire dataset) of RV HEINCKE during cruise HE629 [dataset]. PANGAEA, https://doi.org/10.1594/PANGAEA.982661

**Table 8.1** Overview of data availability

| **Type** | **Database** | **Available** | **Free Access** | **Contact** |
|---|---|---|---|---|
| Bathymetry | | Date | Date | E-Mail |
| raw bathymetry data | PANGAEA | June 20, 2025 | 12, 2025 | ebazhenova@marum.de |

# 9 Acknowledgements

All participants of Expedition HE629 thank the Norwegian and Danish authorities for the permission of research in their Exclusive Economic Zone. We would like to express our gratitude to the chief and crew of the RV Heincke and the involved AWI team to make the expedition possible. The captain and crew of R/V HEINCKE are thanked for their support, which immensely contributed to the success of the expedition. The Master and crew of the RV Heincke have developed substantial expertise on the handling of the IMGAM AUV during launch and recovery. (Note: The IMGAM AUV has now been deployed during three expeditions from the RV Heincke: HE275, HE590 and HE629). Particular gratitude goes also to the German Science Foundation, German Ministry for Research and Education (BMBF), the German Research Fleet Coordination Centre and the shipping company Briese Research for their support. The cruise was funded by the DFG Excellence Cluster "The Ocean Floor" (EXC2077) coordinated at MARUM.

# 10 References

Bazhenova, Evgenia A; Bachmayer, Ralf (2025): Multibeam bathymetry raw data (Kongsberg EM712 entire dataset) of RV HEINCKE during cruise HE629 [dataset]. PANGAEA, https://doi.org/10.1594/PANGAEA.982661

# 11 Abbreviations

**AUV** Autonomous Underwater Vehicle

**MBES** Multi Beam Echo Sounder

**DVL** Doppler Velocity Log

**SVP** Sound Velocity Probe

**USBL** Ultra Short Baseline System

# 12 Appendices

## 12.1 Selected overlays of Multibeam data with AUV trajectory

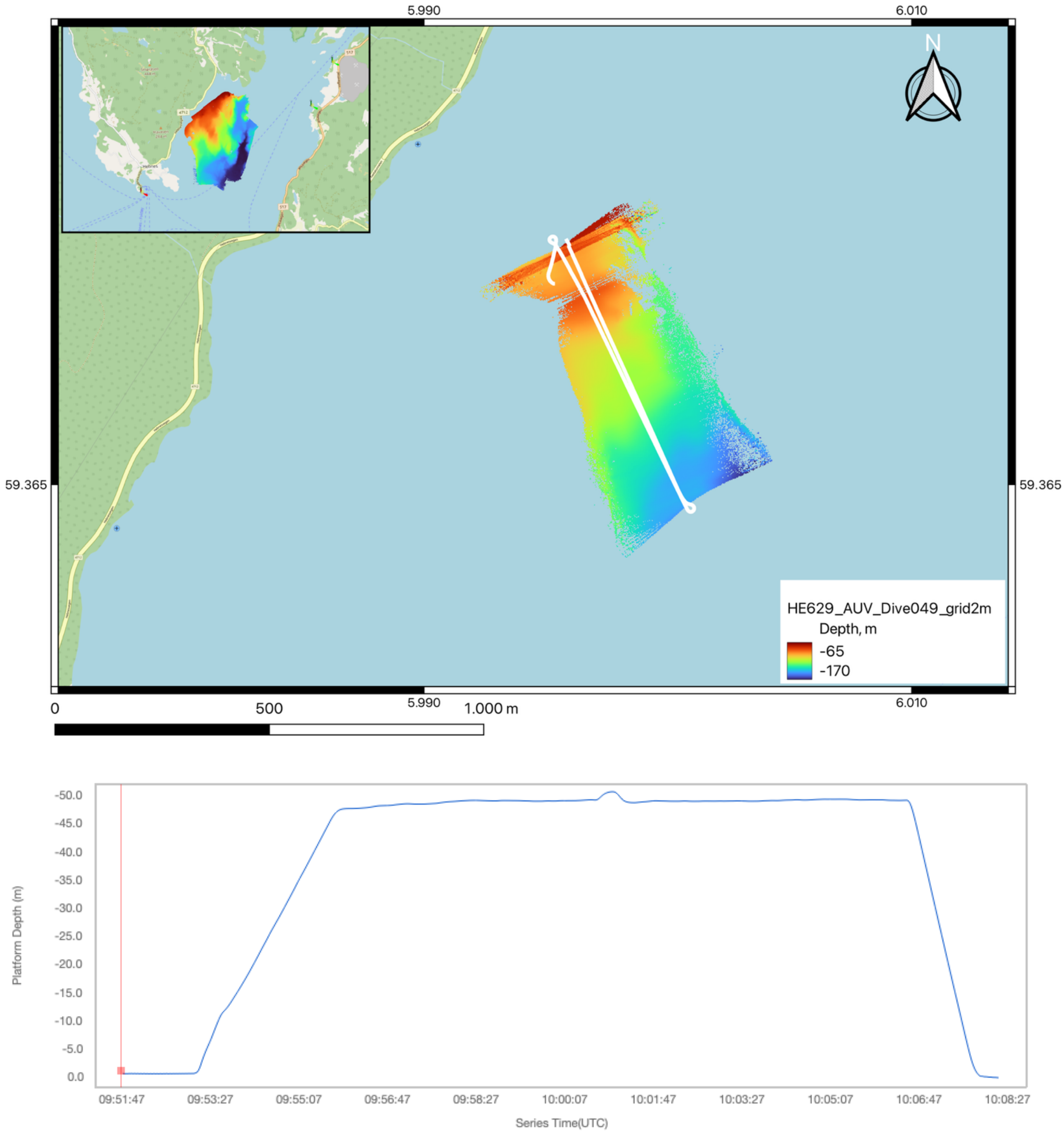


**Fig. 11.1**: Dive 049 was performed using the constant depth mode. Upper image shows MBES overlay with IMGAM AUV trajectory. Image inlay in the upper left corner shows ship based MBES map for reference with good agreement. Lower panel shows the depth profile of the AUV using the constant depth mapping mode.

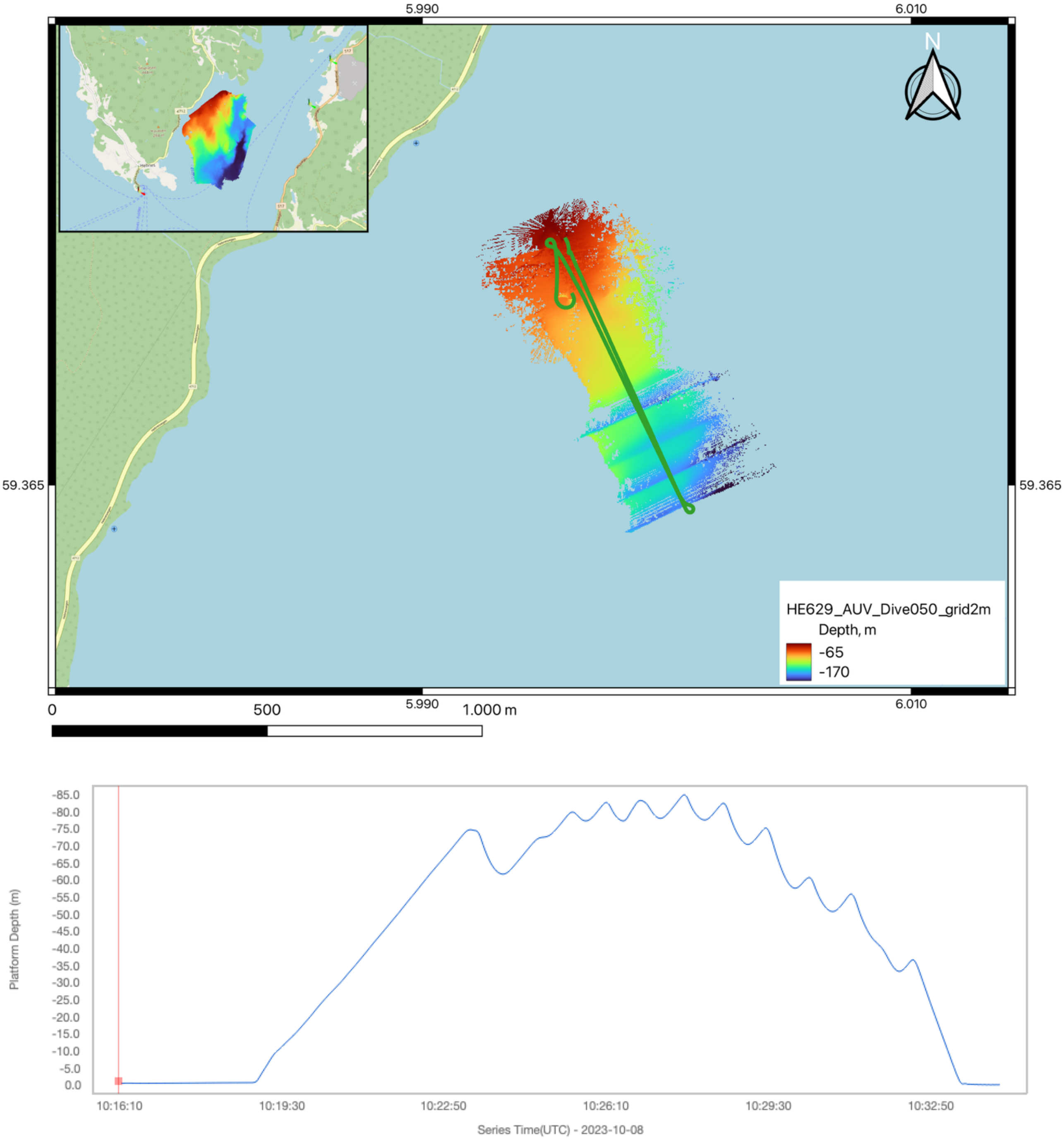


**Fig. 11.2:** Dive 050 was performed using the constant altitude mode. Upper image shows MBES overlay with IMGAM AUV trajectory. Image inlay in the upper left corner shows ship based MBES map for reference. Lower panel shows the depth profile of the AUV in constant altitude mapping mode, showing MBES data artifacts from vehicle oscillations.

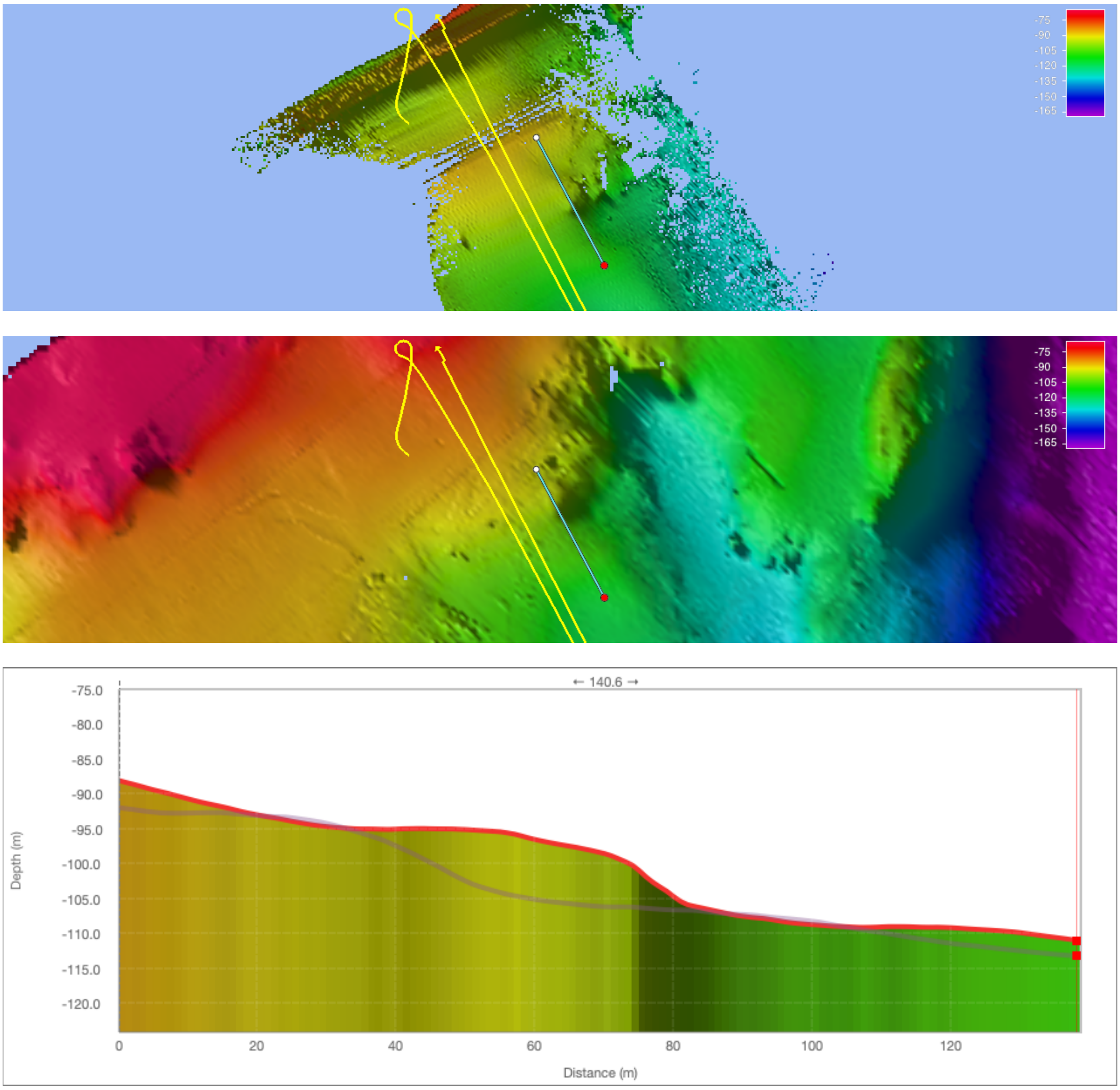


**Fig. 11.3:** Dive 049 ship AUV based mapping comparison. The upper panel shows R2Sonic MBES bathymetry with the yellow line showing the AUV track. The middle panel shows the ship's MBES EM712 generated bathymetry for the same area. For comparison a vertical profile at the same location, the SE-NW blue line shown in both maps, was extracted from the maps. The profiles are shown in the lower panel with the red profile showing AUV data. The crossed topographic feature is located at ca. 30 m horizontal offset along the AUV track.