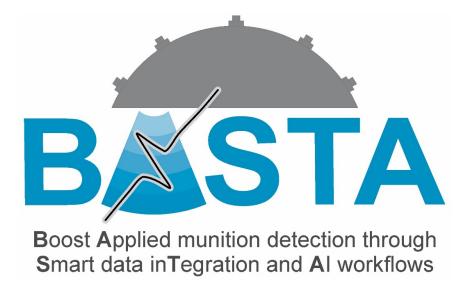
## **ALKOR - Reports**

Mine Monitoring in the German Baltic Sea 2021; Dumped munition monitoring

## **AL567**

17<sup>th</sup> – 31<sup>st</sup> October 2021, Kiel (Germany) – Kiel (Germany) "MineMoni-III 2021"



Editors: Greinert, J.; Kampmeier, M.; Barradas, F.; Beck, A. J.; Diller, N.; Seidel, M.; von See, T

Chief Scientist: Prof. Dr. Jens Greinert

GEOMAR Helmholtz Centre for Ocean Research Kiel

## Table of Contents

1. Cruise Summary	3
1.1 Summary	3
1.2 Zusammenfassung	3
2 Participants	4
2.1 Principal Investigators	4
2.2 Scientific Party	5
2.3 Participating Institutions	5
3 Research Program	5
3.1 Aims of the Cruise	5
3.2 Agenda of the Cruise	5
4 Methods and devices	6
4.1 Acoustic seafloor mapping via ship based multibeam	6
4.2 Optical observations by towed XOFOS	8
4.3 Detailed optical and magnetic mapping with AUV	8
4.4 AUV-based magnetometer measurements	10
4.5 Backseat-driver	11
4.6 Parametric echosounder mapping	11
4.7 MagWing measurements	13
4.8 Water sampling and pre-concentrating of water for munition compound analys	es15
4.9 Sediment and porewater sampling for explosives analysis	18
4.10 SideScan Sonar Data from the German Navy	19
5 Description of the Work Areas	21
6 Narrative of the Cruise	22
7 Preliminary Results	24
7.1 Area 1 – Kolberger Heide	24
7.2 Area 2 – Haffkrug	27
7.3 Area 3 – Pelzerhaken	31
7.4 Area 4 – Trollegrund	34
7.5 Area 5 – Falshöft	37
8 Data and Sample Storage and Availability	
9 Acknowledgements	41
10 References	41
11 Appendix	42
11.1 Static offsets GPS - SBP	42
11.2 AUV Missions Overview	
11.3 Photomosaik processing list	44
11.4 Overall Station List	50

## 1. Cruise Summary

#### 1.1 Summary

ALKOR cruise AL567 took place as part of the EMFF (European Maritime and Fisheries Fund)-funded project BASTA (<u>B</u>oost <u>A</u>pplied munition detection through <u>S</u>mart data 3etection3n and <u>A</u>I workflows; <a href="https://www.basta-munition.eu">https://www.basta-munition.eu</a>) and ExPloTect (<u>Ex</u>-situ, near-real-time 3etection compound 3etection in seawater) (also EMFF-funded). It was the continuation of the munition monitoring started within the BMBF-funded project UDEMM (Environmental Monitoring for the Delaboration of Munition in the Sea; <a href="https://udemm.geomar.de/">https://udemm.geomar.de/</a>).

In previous cruises (POS530 MineMoni I in 2018 and AL548 MineMoni II in 2020) data was gathered for a broad baseline study in the German Baltic Sea. Within UDEMM, expertise was developed to detect, exactly locate and monitor munition (e.g. torpedoes, sea mines, ground mines) on the seafloor using optical and hydroacoustic means. In addition, chemical analyses of dissolved contaminants in the water and sediments was performed. Results indicate a moderate contamination level on regional and coastal scale, but proof higher levels of explosive-type compounds for specific local areas. Data acquired during this cruise are used in BASTA for the development of AUV-based and AI-supported munition detection. On the other hand, the project ExPloTect (Ex-situ, near-real-time exPlosive compound deTection in seawater) (also EMFF-funded) addresses the need for a more effective quasi in-situ sampling approach to detect explosive compounds in seawater on board of a ship. A prototype system was used and successfully tested for the first time during this cruise.

The main focus of the cruise was placed onto the already known dumpsites Kolberger Heide and Lübeck Bight, Falshöft (Schleswig-Holstein) and Trollegrund (Mecklenburg-Vorpommern). In each area high-resolution multibeam mapping was performed and contact lists, indicating potential munition objects, were produced right after acquisition on board. Based on that data, AUV surveys were conducted to ground-truth possible contacts via detailed photograph and magnetometer mapping. This was complemented with towed video profiles, SubBottom Profiler (VLIZ Institute) and towed gradiometer surveys (g-tec SA). The transits to and between those sites were planned along former constraint routes during WWII. These routes were main targets of the British Air Force and mines and bombs can be expected along these ways. During transits water samples were taken with on a CTD- (conductivity, temperature, depth) rosette-mounted Niskin bottles in regular distances, in order to obtain a comprehensive understanding of munition compounds (inter alia trinitrotoluene (TNT)) measurements across the German Baltic Sea.

The cruise was supported by the 3<sup>rd</sup> Minensuchgeschwader vessel 'Bad Rappenau'. During 2 days, work was performed in cooperation between the research vessel ALKOR and the naval unit with their AUV REMUS 100 conducting high resolution sidescan surveys over several pre-defined targets. In addition, navy divers recovered mussel moorings for the toxicological institute of the UKSH. The pre-planned identification of munition objects via navy divers did unfortunately fail due to low visibility conditions.

#### 1.2 Zusammenfassung

Die ALKOR-Fahrt AL567 fand im Rahmen des vom EMFF (Europäischer Meeres- und Fischereifonds) finanzierten Projekts BASTA (<u>B</u>oost <u>A</u>pplied munition detection through <u>S</u>mart data in<u>T</u>egration and <u>A</u>I workflows; <u>https://www.basta-munition.eu</u>) und ExPloTect (<u>Ex</u>-situ, near-real-time ex<u>Plo</u>sive compound de<u>Tect</u>ion in seawater) (ebenfalls vom EMFF finanziert) statt. Sie war die Fortsetzung der Munitionsüberwachung, die im Rahmen des vom BMBF geförderten Projekts UDEMM (Environmental Monitoring for the Delaboration of Munition in the Sea; <a href="https://udemm.geomar.de/">https://udemm.geomar.de/</a>) begonnen wurde.

Auf den vorangegangenen Fahrten (POS530 MineMoni I 2018, und AL548 MineMoni II 2020) wurden Daten für eine breit angelegte Basisstudie in der deutschen Ostsee gesammelt. Im Rahmen von UDEMM wurde Expertise entwickelt, um Munition (z.B. Torpedos, Seeminen, Bodenminen) auf dem Meeresboden mit optischen und hydroakustischen Mitteln aufzuspüren, genau zu lokalisieren und zu überwachen. Darüber hinaus wurden chemische Analysen von gelösten Schadstoffen im Wasser und in den Sedimenten durchgeführt. Die Ergebnisse deuten auf eine mäßige Kontamination auf regionaler und küstennaher Ebene hin, weisen aber für bestimmte lokale Gebiete höhere Werte an explosionsartigen Verbindungen nach. Die auf dieser Fahrt gewonnenen Daten werden im Rahmen von BASTA für die Entwicklung einer AUV-gestützten und KI-gestützten Munitionserkennung verwendet. Andererseits befasst sich das Projekt ExPloTect (Ex-situ, near-real-time exPlosive compound deTection in seawater) (ebenfalls EMFF-finanziert) mit dem Bedarf an einem effektiveren Quasi-In-Situ-Probenahmeverfahren zum Nachweis explosiver Verbindungen im Meerwasser. Während dieser Fahrt wurde erstmals ein Prototypsystem eingesetzt und erfolgreich getestet. Der Schwerpunkt der Fahrt lag auf den bereits bekannten Munitionsversenkungsgebieten Kolberger Heide und Lübecker Bucht, Falshöft (Schleswig-Holstein) und Trollegrund (Mecklenburg-Vorpommern). In jedem Gebiet wurden hochauflösende Fächerecholotkartierungen durchgeführt und direkt nach der Erfassung an Bord Kontaktlisten erstellt, die auf mögliche Munitionsobjekte hinweisen. Auf der Grundlage dieser Daten wurden AUV-Vermessungen durchgeführt, um mögliche Kontakte durch detaillierte Foto- und Magnetometerkartierungen zu überprüfen. Ergänzt wurde dies durch geschleppte Video -Profile, SubBottom Profiler (VLIZ Institut) und geschleppte Gradiometer-Vermessungen (G-tec SA). Die Fahrten zu und zwischen diesen Standorten wurden entlang ehemaliger Zwangsrouten aus dem Zweiten Weltkrieg geplant. Diese Routen waren Hauptziele der britischen Luftwaffe, und entlang dieser Wege ist mit Minen und Bomben zu rechnen. Während der Fahrten wurden in regelmäßigen Abständen Wasserproben mit an einer CTD-Rosette (Leitfähigkeit, Temperatur, Tiefe) befestigten Niskin-Flaschen genommen, um ein umfassendes Verständnis der Messungen von Munitionsverbindungen (u.a. Trinitrotoluol (TNT)) in der deutschen Ostsee zu erhalten. Die Fahrt wurde durch das 3. Minensuchgeschwader und dem Minensuchschiff Bad Rappenau unterstützt. An zwei Tagen wurde in Zusammenarbeit zwischen der Marineeinheit und dem Forschungsschiff ALKOR gearbeitet, und das AUV REMUS der Marine führte hochauflösende Sidescan-Vermessungen über mehrere, vorher festgelegte Ziele durch. Darüber hinaus bargen Marinetaucher Muschelverankerungen für das Toxikologische Institut der CAU Kiel. Die im Vorfeld geplante Identifizierung von Munitionsobjekten durch Marinetaucher scheiterte leider an den schlechten Sichtverhältnissen unter Wasser.

## 2 Participants

#### 2.1 Principal Investigators

Table 1: Principal investigators of AL567.

Name	Institution
Beck, Aaron J., Dr.	GEOMAR
Greinert, Jens, Prof.	GEOMAR
Missiaen, Tine, Prof.	VLIZ

AL567 Cruise Report

#### 2.2 Scientific Party

Table 2: Scientific party of AL567.

Name	Discipline	Institution
Greinert, Jens	Marine Geology / Chief Scientist	GEOMAR
Kampmeier, Mareike	Marine Geology / Senior Scientist	GEOMAR
Seidel, Marc A.	Marine Geophysicist; Magnetic	GEOMAR
von See, Benedikt	Marine Data Science	GEOMAR
Vesely, Nele	Marine Data Science	GEOMAR
Weiß, Tim	Data Management, Technical Support	GEOMAR
Fabrizius, Eduard	Technical Support, OFOS	EGEOS
Beck, Aaron J.	Marine Geochemistry	GEOMAR
Esposito, Mario	Marine Geochemistry	GEOMAR
Diller, Nikolaj	AUV Team	GEOMAR
Reißmann, Sylvia	AUV Team	GEOMAR
Jäckle, Anna	AUV Team	GEOMAR
Scheppukat, Danilo	AUV Team	GEOMAR
Missiaen, Tine	Marine Geophysicist, Subbottom Profiler	VLIZ
Barradas, Felipe J.	Marine Geophysicist, Subbottom Profiler	VLIZ
Frederickx, Ewald	Marine Geophysicist, Towed Magnetic	G-tec

## 2.3 Participating Institutions

GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel Germany

VLIZ Flanders Marine Institute, Ostend, Belgium

G-tec G-tec s.a., Milmort, Belgium

## 3 Research Program

#### 3.1 Aims of the Cruise

- Spatial mapping of dumpsites outside of official borders to identify the extent of contamination
- During the cruise groundtruth data were collected from previously detected contacts including magnetic and underwater photo and video footage. This data will be used to generate a training data set for the AI based algorithm for automated target-picking.
- The goal of the 2021 survey was to deploy the parametric echosounder simultaneously with the MagWing from G-Tec in both areas, which should allow a better characterization of the (buried) objects (their location, depth, size, and type (ferromagnetic or not)).

#### 3.2 Agenda of the Cruise

The cruise was prepared to take place over the course of two weeks for studying four main areas (Kolberger Heide, Falshöft, Lübeck Bight and Mecklenburg Bight) and take water samples on the transits in between. Due to the work program and limited space on board (Covid-19 hygiene concept), the cruise was split into two legs with one crew exchange in Neustadt (i.H.); this took place on October 24<sup>th</sup>, 2022.

Table 3: Cruise agenda and deployed scientific equipment.

Area	Date	Scientific Program
Kolberger Heide	1819.10.2022	CTD, SBP, AUV, MBES, OFOS
		G-MAG, MUC
Transit to Haffkrug	1920.10.2022	CTD
Haffkrug	2021.10.2022	CTD, SBP, AUV, MBES, G-MAG
		MUC
Lübeck Bight	21.10.2022	CTD
Pelzerhaken	2123.10.2022	CTD, AUV, MBES, OFOS, G-MAG
		MUC
Haffkrug	2325-10.2022	CTD, SBP, AUV, MBES, OFOS
		G-MAG, MUC
Lübeck Bight	25.10.2022	CTD
Pelzerhaken	2526.10.2022	CTD, SBP, AUV, MBES, OFOS
Transit to Trollegrund	2627.10.2022	CTD
Trollegrund	27.10.2022	CTD, SBP, AUV, MBES, OFOS
		MUC
Transit to Kolberger Heide	28.10.2022	CTD
Kolberger Heide	28.10.2022	CTD
Transit to Falshöft	2810.2022	CTD
Falshöft	2830.10.2022	CTD, SBP, AUV, MBES, OFOS
		MUC
Transit to Kolberger Heide	30.10.2022	CTD
Kolberger Heide	30.10.2022	CTD, MBES

## 4 Methods and devices

## 4.1 Acoustic seafloor mapping via ship based multibeam

High resolution mapping had been executed in the dumpsites Kolberger Heide, Lübeck Bight, Trollegrund and Falshöft on previous cruises: POS530, L13-20 and AL548. On AL567, existing data was amended with additional mapping to find the borders of contaminated areas, which might not be congruent with their extensions on nautical charts.

Table 4: Measured and calculated offsets of the MBES system.

X Stbd +	Y Fwd +	Z down +	
0.000 m	0.000 m	0.000 m	
1.520 m	4.732 m	6.473 m	
-2.344 m	0.891 m	-9.220 m	
Pitch	Roll	Heading	
1.200°	1.110°	0.500°	
	0.000 m 1.520 m -2.344 m Pitch	0.000 m 1.520 m 4.732 m -2.344 m 0.891 m	0.000 m       0.000 m       0.000 m         1.520 m       4.732 m       6.473 m         -2.344 m       0.891 m       -9.220 m         Pitch       Roll       Heading

Working areas are generally required to be deeper than 10 m, in order to be able to operate RV ALKOR. A RESON T50 multibeam system was rented from MacArtney Germany and installed inside the moon pool. RTK correction for the GPS position was used via GSM NTRIP (AxioNet). Motion compensation was done with a SBG Apogee-U INS system (installed on a fixed installed mounting plate in vicinity to the moon pool). Sound velocity profiles were acquired with a Valeport Swift SVP Profiler. GPS and RTK data were controlled via the Septentrio AsteRx-U Marine Full multi-frequency (GPS, GLONASS, Galileo, Beidou) GNSS receiver. The two Septentrio GNSS antennas were mounted on the monkey deck orthogonally to the vessel length at a distance of 2 m to each other (Figure 1). Since the mounting places are fixed and precisely measured the same offsets as in AL478 are applicable (Table 4).

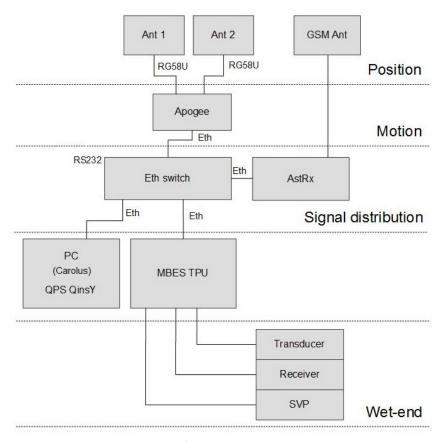


Figure 1: System overview of RESON T50 MBES system used on AL548.

Data acquisition was done with the software QPS QINSy (in UTM32/33) and processing with QPS Qimera and QPS FMGT to derive multibeam and backscatter information, which was further processed with SAGA and QGIS. The publicly available Baltic Sea bathymetric data set Emodnet was used for survey planning. The time needed to complete each survey was based on a 3.5 kn survey speed. This guarantees dense soundings in the along-track direction. Profile spacing had to be chosen as densely as possible, but also in a way that it could be navigated by the vessel crew. Therefore, the spacing had to be 20 m minimum, which did not always lead to the targeted 50 % overlap (depending on the water depth). Multibeam data were roughly cleaned and gridded to 0.25 cm raster and loaded into the QGIS project for initial contact picking as part of the workflow for munition site investigation (Figure 2).

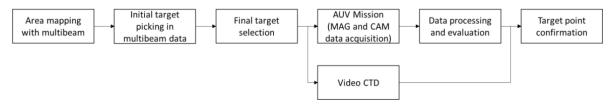


Figure 2: Workflow for munition site investigation.

#### 4.2 Optical observations by towed XOFOS

The XOFOS (eXtended Ocean Floor Observation System) was used to perform video observations of the seafloor with real-time annotation using the OFOP software. Live data is streamed through the mobile fibre optic winch from GEOMAR. The video was recorded online in HD quality for online annotation and control. In addition to the USBL, a downward-facing ADCP in combination with an iXBlue OCTANS IMU enhanced the positioning, which was calculated and recorded via OFOP (Figure 3).

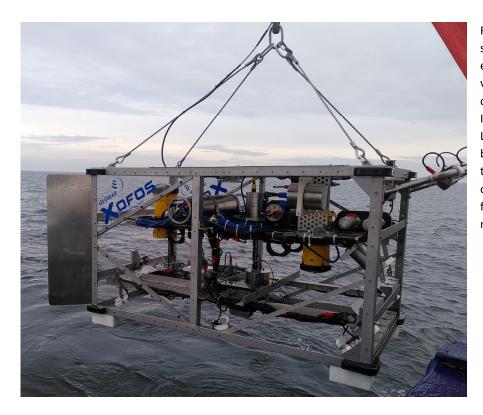


Figure 3: The video sledge XOFOS is equipped with two HD video cameras, one still camera, two ADCPs, an IMU, a CTD, USBL and LED lights. It is towed behind the vessel over the A-frame and data is online recorded over the fibre optical cable of the mobile GEOMAR winch.

## 4.3 Detailed optical and magnetic mapping with AUV

ANTON and LUISE are reconfigurable autonomous underwater vehicles (AUV) of the type Girona 500. They are designed for a maximum operating depth of up to 500m. The vehicles are composed of an aluminium frame, which supports three torpedo-shaped hulls of 0.3m in diameter and 1.5m in length as well as other elements like the thrusters. This design offers a good hydrodynamic performance as long as the space in between is not too occupied with additional payload. Nevertheless, it also offers a large space for housing the equipment while maintaining a compact size, which allows operating the vehicle from small boats.

The overall dimensions of the vehicle are 1m in height, 1m in width, 1.5m in length and a weight of less than 200kg. The two upper hulls, which contain the flotation foam and the electronics housing, are positively buoyant, while the lower one contains the heavier elements such as the batteries and the payload. This particular arrangement of the components makes the separation between the centre of gravity and the

AL567 Cruise Report

centre of buoyancy about 11 cm, which is significantly more than any typical torpedo shape design. This provides the vehicle with passive stability in pitch and roll even at low speeds, making it suitable for imaging surveys. One characteristic of the Girona 500 is its capability to reconfigure for different tasks.

The COLA2 infrastructure on those AUVs is the central control software, developed by IQUA Robotics (Girona, Spain). The communication under and above water is controlled by BELUGA. This marine command and control software is developed by the AUV group of GEOMAR. It also includes the USBL (Ultrashort Baseline) positioning. The belonging transducer/modem is mounted on the ship and is part of the BELUGA ad hoc network.

Besides the navigational sensors like INS (Inertial Navigation System), DVL (Doppler Velocity Log), Pressure Sensor, USBL and GPS it has a CTD (Conductivity, Temperature, Depth) type Seabird FastCAT SBE49 mounted by default. As one optional payload a CoraMo mk II Camera (GEOMAR), is mounted on both vehicles. This down- or forward-looking camera system for photographic surveys can take up to two images per second with a resolution of 12.34MP. CoraMo supports connections for eight high power LEDs.

There are several other payload sensors available like a DeltaT multibeam or a magnetometer. During AL567 AUV LUISE was equipped with Sensys magnetometers as standard configuration (Table 5). Missions can have a duration of up to 9 hours and a total length of about 10 kilometres, depending on settings, payload and environmental conditions like currents. The maximum speed is 1m/s while the minimum speed is not limited, even hovering at one point for an arbitrary amount of time is possible.

Table 5: Overview of the AUV-based sensors for navigation and payload.

System	Device	Description	
		•	
Navigation	INS: iXblue Phins	The internal navigation unit that processes sensor data and	
	Combat C3	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	This device measures the velocity relative to the sea floor and its	
	Explorer 600kHz	altitude.	
	Pressure sensor:	This sensor measures the pressure and converts it to water depth.	
	Valeport ultraP		
	USBL: Evologics	The Evologics S2CR 18/34 modem combines underwater	
	S2CR 18/34	communications and positioning.	
	GPS: Quectel 186	The GPS is used to determine the absolute position at the surface.	
	GNSS module		
Payload	CTD: Sea-Bird SBE	This measurement device acquires the conductivity, temperature	
	49 FastCAT	and the pressure of the surrounding water and calculates the	
		sound velocity. A csv file with the data is produced for each mission	
		and can be found in the missions "exports" directory. Each line	
		contains a timestamp in UTC, the position (latitude and longitude	
		as decimal degrees) and the CTD data itself: pressure [dBar],	
		salinity [psu], temperature [°C], conductivity [S/m] and sound	
		velocity [m/s].	
	Camera: CoraMo	The images and the corresponding metadata can be found in the	
	mk II Camera	missions "pictures" directory. The camera has an number of	
		parameters that can be set for every dive. For each image a csv file	
		containing information about parameter settings of the camera	

	and the CareNa materialia total as well as in the first and
	and the CoraMo system in total as well as navigational and
	environmental information (e.g. position and temperature) from
	the time the image was taken is written. It has the same name as
	the corresponding image. Additionally, one combining file
	containing each single csv files data line is created after a dive
	(images_metadata.csv) and can also be found in the pictures
	directory. Depending on the settings, a second file with metadata
	(metadata_information.csv) is written during the dive. It contains
	some information about camera and system parameters and
	focuses more on the information needed to build mosaics from the
	images like position, rotation and general information about the
	camera equipment.
Magnetometer:	This system consists of up to five single magnetometers connected
Sensys MX3D UW	to one data acquisition unit. In the currently used configuration,
	three magnetometers are mounted in a triangular gradiometer
	configuration about two meters ahead of the AUV. Each
	magnetometer is sampling three dimensions with a rate of 200 Hz.
	The data is saved to the mission bag and can be extracted to a csv
	file, together with the navigation data of the AUV.
Oxygen Optode:	AUV LUISE is able to carry an additional oxygen optode and collect
Aanderaa Optode	its data. The optode used has been borrowed from the ARCHES
4330	Project (Sascha Flögel) for this cruise by the DSM group. The device
	provides dissolved oxygen [μM], relative air saturation [%] and
	ambient temperature [°C], as well as the raw data the final sensor
	values are based on.
 1	

#### 4.4 AUV-based magnetometer measurements

Depending on the degree of decomposition, most munition in Europe's coastal waters contain a significant amount of ferromagnetic material and are therefore detectable by magnetic sensors. In the field of systematic munition detection, the operation of AUVs can generally assist in improving the precision and reliability of the acquired magnetic data. The utilized magnetic sensors are FGM3D/100 UW II 3-axis fluxgate magnetometers from SENSYS GmbH.

GEOMARs scientists and technicians successfully integrated three fluxgate magnetometers into AUV LUISE. The magnetic sensors, three SENSYS 3-axis fluxgate magnetometers of the type "FGM3D UW II", were attached to the AUV via an aluminium arm, which allows for a maximum distance of up to 2 m between the sensors and the nose of the AUV. Since the main thrusters of the AUV, which are considered to be the primary source of electromagnetic noise, are located in the back of the AUV, the distance of the sensors to the main thrusters is up to 3 m. Arranging the sensors in the shape of a vertical triangle perpendicular to the direction of travel allows for the measurements of all three spatial magnetic gradients. In the triangle, the two lower sensors act as a horizontal gradiometer (first gradient) while the third magnetometer is located above, to act as the upper sensor of a vertical gradiometer (second gradient). The third gradient, is obtained by comparing acquired values while moving forward. The magnetometers are sampling at frequencies of up to 200 Hz. Operational flight altitudes of the new system vary between 1 and 2 m. The surveys are usually conducted at velocities around 0.5 m/s. A camera system including illumination is also attached to the AUV for ground-truthing purposes. With the current solution, noise floors as low as 2 to 3 nT can be achieved. The setup can

be used to reliably detect medium sized target objects such as 81 mm mortar shells. Under favourable conditions, even smaller munitions objects like hand grenades may become detectable. Figure 4 shows the latest development of AUV LUISE carrying the magnetometer construction and the camera system. Since the AUV creates different patterns and frequencies of (electro-) magnetic noise, the recorded data was lowpass-filtered above a cut-off frequency of 1 Hz. During AL567, a total of 25 individual magnetic missions were conducted using AUV LUISE above several munition contaminated sites.



Figure 4: Three fluxgate magnetometers deployed to GEOMAR's AUV LUISE.

## 4.5 Backseat-driver

In order to enhance the mapping capabilities of the Girona500 AUVs a backseat-driver was tested. It is a working mode in which arbitrary AUV movements can be implemented that go beyond the classical lawn-mover or spiral patterns. It can be triggered during the pre-planned mission e.g. at certain waypoints but also by environmental data such as magnetic anomalies. If the trigger condition is met the pre-planned mission is paused and the desired AUV behaviour that has to be implemented by the user is performed. Afterwards the pre-planned mission is resumed. This will in the future allow to perform sparse surveys in which dense search patterns are performed only in regions of interest. By this, larger areas can be covered without missing features. Furthermore, this is a step towards a higher degree of autonomy of the vehicles as this working mode allows to react to sensor data in (near) real time.

#### 4.6 Parametric echosounder mapping

During the 2021 campaign, the SES-2000 Quattro multi-transducer parametric echosounder was attached at the portside of RV ALKOR, using the VLIZ over-the-side system with a 4 m pole and a flange (**Figure 5**). The motion sensor (SMC-IMU-108-30) was installed more or less above the transducer's position in the water, so no lever arm corrections had to be applied. The GEOMAR Septentrio GNSS was used for navigation input (including heading) and was installed on top of the container, a Real-Time Kinematic (RTK) AsteRx-U receiver. The RTK signal was stable during the whole survey.



**Figure 5:** VLIZ SES-Quattro SBP on port-side of RV ALKOR. On the right, the transducers are tilted during the transit, with the motion sensor mounted next to the rail.

The GNSS RTK from GEOMAR was used for positioning. It was connected via TCP port to the SBP acquisition unit. No navigation offsets were applied online, the heading from the GNSS antennas has an extra phase of +90 degrees over the recorded data, afterward, a correction of -90 degrees has to be applied in the processing. The offsets from the GNSS to the transducer are shown in Table 2 and were not applied during the survey. The transducer depth below the water level was 1.5 m. The water sound velocity used was depending on the area, and obtained from velocity profiles obtained with a CTD. For more details on the installation see Appendix 11.1 Static offsets. The parametric echosounder works with so-called SIS string IDs that store important information such as positioning, timing, etc. The storage structure is indicated in **Error! Reference source not found.** 

Table 6: SIS strings IDs storage structure.

SIS-	Data	Units/format		Remarks
ID				
1	Latitude (X)	Degrees,	minutes	NMEA GGA position 2
		(DDDMM.MMMM)		
2	Longitude (Y)	Degrees,	minutes	NMEA GGA position 4
		(DDDMM.MMMM)		
3	Time	hhmmss.ss		UTC +00
4	Heading	Degrees		It is roated 90 degrees (-90 correction)
5	Z	m		NMEA GGA position 9 (ref.: msl geoid)
6	<b>GNSS Quality</b>	NA		Fix quality 0 = Invalid; 1 = GNSS fix; 2 = DGPS
				fix; $3 = PPS fix$ ; $4 = RTK$ .
7	Χ	m		WGS 84 UTM zone 32N (EPSG:32632)
8	Υ	m		WGS 84 UTM zone 32N (EPSG:32632)

The SES-Quattro was deployed in single beam mode (SBM) only. In this configuration, the four transducers are combined into one square array and used simultaneously for transmitting and receiving. The combined use of the transducers results in maximum pulse energy but is restricted to one logical survey line per track (sailed line). This mode provides the best penetration and in-line resolution. Both the high frequency (HF, 100 kHz) and low frequency (LF, 10 kHz) signals were recorded.

## 4.7 MagWing measurements

During a cruise the MagWing from G-tec was used for acquiring magnetic data with a standard magnetic system used during commercial UXO surveys. The system consists of two gradiometers in 3m horizontal distance, a pressure sensor and altimeter for depth and altitude information as well as USBL transponder of the AUVs Evelogics USBL system (Figure 6). Data communication was done through a separate winch installed one deck above the main working deck at the aft. The winch could be manipulated through a small control unit that could reach the main dry lab (Figure 8). Data were recorded in a G-tec own software program. Unfortunately, the USBL positioning was not as good as expected so that a simple layback calculation at the end was used as navigation data. Data were preliminary gridded in surfer and exported as geotiff for a first evaluation on the cruise. Due to the 'imprecise' navigation of the MagWing, overlays of bathymetric data with MagWing information often has a slight offset and mismatch.

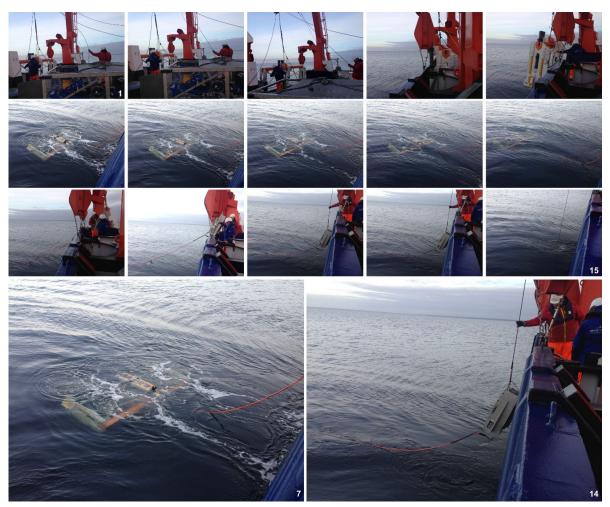


Figure 6: Photo sequence of the MagWing launch during AL567. The system uses a depressor to keep the positively buoyant MagWing at depth.

Figure 7 gives a schematic overview of the used MagWing 3.4 array. The MagWing 3.4 version consists of 4 Geometrics G882/G881 Cesium vapour magnetometer sensors. The sensors are arranged in 2 vertical gradiometry frames at a fixed horizontal distance of 3m. With each survey line, this layout provides 2 vertical gradients with a spacing of 3m. This leads to the online measuring of 8 gradients: 2 transverse, 2 vertical and 4 longitudinal (along track displacement). Both vertical gradiometry frames continuously record the magnetometer data at 10 Hz and are equipped with depth sensors and sonar altimeters. The array is equipped with a motion sensor and an acoustic underwater positioning system which provides accurate positioning of the frame and QA/QC with regards to the distance to the sea bottom and the off-track distance. Since the MagWing is aimed not to fly more than 5m above the seabed, its buoyancy is adjusted as neutral or slightly positive in sea water, and it is towed 12m behind a 120kg ballast. The ballast carries the electronics housing and is towed itself by a strong data cable connected to the winch. Table 7 gives an overview about the technical details of the frame setup.

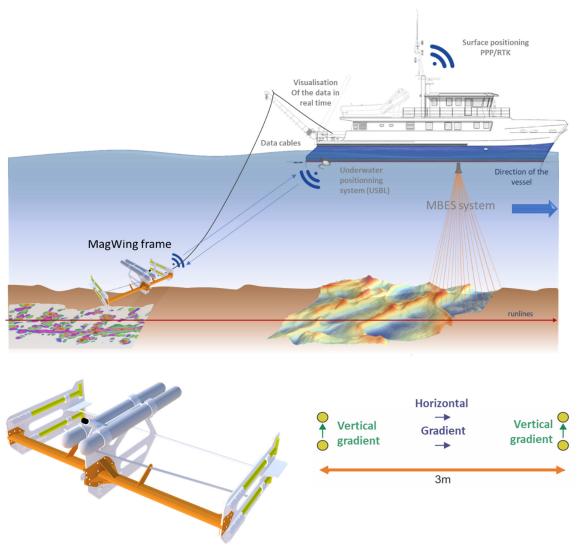


Figure 7: Deployment of the Mag System (MagWing 3.4) along runlines.

Table 7.	Tachnical	dotaile	at tha	frame setup:
Table /.	recillical	uetalis	or the	Haine Setub.

Characteristics	Value	
Overall length	3.0m	
Sensors horizontal separation	3.095m	
Sensors vertical separation	0.36m	
Weight in air	Approx. 150 kg + approx. 120 kg (ballast)	
Underwater positioning	Integrated USBL beacon (onboard powered); responder mode capable (electric	
	triggering through data cable)	
Cable	15mm G-tec In.Mag dedicated cable, containing power + 9 data wire pairs	
	(manufactured by Cortland) – connected to coaxial winch cable	
Winch	Huchez, capable of at least 250m cable. 13 slip rings for power, data collection	
	and beacon TTL triggering; 45m deck cable	
Diving capabilities	All components are designed to resist to 100m immersion, practically 50m	
	(cable length limited)	
Diving	Depressor / ballast situated 12m ahead	
Altitude/depth sensors	2x altimeter + 2x depth sensor on G882 magnetometers	
Additional sensor	Pitch & roll sensor	
	SVP sensor (sound velocity)	

A more in-depth report of the MagWing data processing is given in the Appendix. Figure 8 shows the very crowded but good operational dry lab of ALKOR during the cruise.



Figure 8: View into the main dry lab with many cables and computers for acquiring bathymetric, magnetic and SBP data.

## 4.8 Water sampling and pre-concentrating of water for munition compound analyses Xplotector shipboard dissolved explosive analysis

The project ExPloTect (Ex-situ, near-real-time exPlosive compound deTection in seawater; EMFF Grant Agreement # 863693) aims to develop, optimize, and test a prototype sea-going device for detection of chemicals associated with unexploded ordnance in the marine environment. We envision this system as a supporting munition detection technology for use in combination with existing mature geophysical technologies, such as those employed on AL567. Existing methods for detecting munition compounds (MC)

in seawater have historically been inadequately sensitive, and we have only recently developed techniques to successfully sense these compounds. Our current methods are strictly reliant on labor- and time-intensive sample processing and analysis in land-based laboratories. To address this problem, the ExPloTect project developed a prototype system that is field deployable to achieve cost-effective, sensitive, and real time detection of MC in seawater.

A major objective of this cruise for ExPloTect was to conduct field testing and validation of our prototype system (the "Xplotector"; Figure 9). The system is based upon and automates the discrete water preconcentration method (solid phase extraction, SPE) described below, and couples this with online measurement using a compact electrospray ionization mass spectrometer (ESI-MS; Microsaic MiD 4500) and UV spectrometry. The preconcentration system uses HPLC pumps to extract explosives from seawater onto a special solid phase resin column. With the aid of two switching valves, the concentrated explosives are eluted from the resin with an organic solvent, acetonitrile, and re-concentrated on a second column. This dual column technique improves peak shape and intensity. The explosives are then eluted from the second column and routed by a switching valve to detection by ESI-MS and UV absorption.



Figure 9. Xplotector device in operation during AL567.

During AL567, the system was improved with the addition of a syringe pump to deliver either a mixed explosive standard for external calibration by standard additions, or a stable isotope-labelled TNT spike as internal standard. The labelled TNT ion mass was identified and integrated into the MS analytical suite. Dinitrobenzene (DNB) ionizes poorly, and was removed from the MS analysis in favor of UV detection which is highly sensitive. An improved baseline correction and peak identification algorithm was implemented during the cruise, which helped minimize background interference, especially for the UV detection.

#### XploTaker munition compound preconcentration during "drift transects"

In addition to the Xplotector analytical system, we also tested a new device for in situ collection of MC samples. This underwater device (the so-called "XploTaker"; Figure 10) sequentially preconcentrates MC from seawater over a magazine of 10 cartridges. After deployment and retrieval, the XploTaker is designed to connect directly to the Xplotector, and the 10 preconcentrated samples are measured automatically via software control.

At two locations in Lübecker Bucht and one location in Kolberger Heide, we conducted "CTD drift transects" during which the CTD/Niskin rosette is towed ~2 m above the seafloor while the ship drifts at very low speed over a target on the seafloor. Bottom water samples are collected along the transect with the Niskin bottles, raising and lowering the CTD before closure to capture clean water. During these drift deployments, the XploTaker was mounted on the CTD frame and collected 10 min integrated samples over the drift period (typically 1-2 h).





Figure 10. XploTaker installed on the frame of the TV-CTD and open on the work bench.

#### Discrete water sampling

During AL567, we repeated much of the sample collection strategy and coverage performed during the UDEMM project (2016-2019) and previous MineMoni cruises (POS530, Oct. 2018; AL548, Nov. 2020). Discrete water samples were collected from the Niskin rosette at multiple depths between water surface and seafloor. The deepest sample from all stations was measured on-board with the Xplotector for comparison with the gold-standard laboratory measurement. Discrete samples were pumped through a glass fiber filter membrane ( $1.2 \mu m$ ) before analysis.

Discrete samples for validation of the Xplotector were processed using the technique developed during UDEMM for simplified extraction of munition compounds from seawater. Samples were filled into UV-protected infusion bags, and spiked with stable isotope-labelled TNT and DNB. These spikes are used to quantify extraction efficiency, which can be variable, e.g., due to variation in organic matter, as discussed above. Munition compounds in the samples are then extracted by gravity filtration through the same solid-

phase resin used in the automated system (Figure 11). The resin columns were rinsed, dried, and manually eluted on board. The eluant will be measured by UHPLC-ESI-MS on a Q-Exactive Orbitrap mass spectrometer. In addition to the HPLC separation of target and interfering compounds, this instrument has exact mass capability, and is therefore not sensitive to most mass interferences.



Figure 11: Manual extraction of munition compounds from discrete samples using the infusion bag/gravity method developed during the UDEMM project.

## 4.9 Sediment and porewater sampling for explosives analysis

Sediment cores were collected at 7 stations using a mini-multi corer (MIC, Figure 12). The MIC carries four 10 cm core liners; one of these liners was dismounted to allow space for an underwater camera with shipboard display. At each sampling site, the MIC was lowered slowly to just above the seafloor to check for visible objects at the sediment surface before coring.





Figure 12. Mini-multi corer with two successful sediment samples. The camera mounted in place of a core liner is visible to the left of the cores. Lines with sampling syringes.

One core was immediately sliced at 4 cm intervals, and the bulk sediment frozen for munition compound analysis in the on-shore laboratory. A second core liner had pre-drilled holes at 4 cm intervals. Porewater was extracted from this core using Rhizon filter lances, and the munition compounds immediately preconcentrated with SPE columns placed between the Rhizon and the syringe.

#### 4.10 SideScan Sonar Data from the German Navy

During AL567 we had a joined operation with the 3<sup>rd</sup> Minesweeper Squadron and the mine hunting vessel Bad Rappenau (Figure 13). The Bad Rappenau had eight mine divers on board and two REMUS 100 AUVs with sidescan capability. The initial plan was, that predefined targets at various places in Lübeck Bay are inspected by the divers and that in parallel the AUVs perform detailed surveys of some smaller areas in Pelzerhaken and Haffkrug (Figure 14). Due to bad visibility the divers could not perform detail inspections of munition boxes, but were able to recover two mussel moorings of UKSH that were deployed some month before. Data of the REMUS 100 sidescan were processed at GEOMAR using the SonarWiz Software.

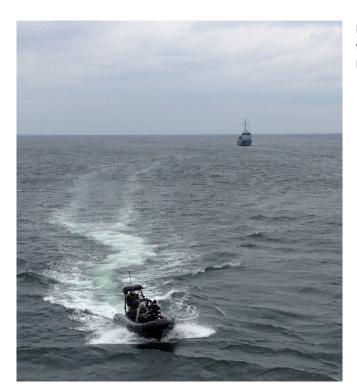


Figure 13: Delivery of Biomonitoring moorings through the Mine-Divers of the Bad Rappenau in Lübeck Bay.



Figure 14: Overview of the acquired REMUS 100 sidescan data through the German Navy. Not all planned areas could be mapped (7, 8 and 9 in the Pelzerhaken area were not mapped).

## **5 Description of the Work Areas**

In total five work areas were investigated and during transits water samples were taken as repetition of previous sampling (Figure 15, Figure 16).

Area 1 – Kolberger Heide (BKB04L): Kolberger Heide is a munition dumpsite where munition was dumped after WWII and munition is stored by the EOD squad of the state of Schleswig-Holstein. All types of munition are found in the area, such as ground mines, torpedoes, torpedo heads, naval mines, depth charges and grenades. The seafloor is characterized by glacial lag sediments, such as fine to medium sands partly mixed with gravel and rocks (Mareike Kampmeier et al., 2020).

Area 2 – Lübeck Bight Haffkrug (BLB02L) – Inner Lübeck Bight, appr. 3.5 nm of Neustadt. This area was used as a munition dumpsite after WWII. All types of German as well as Allied munition were dumped here (cruise report Kampmeier et al., 2019).

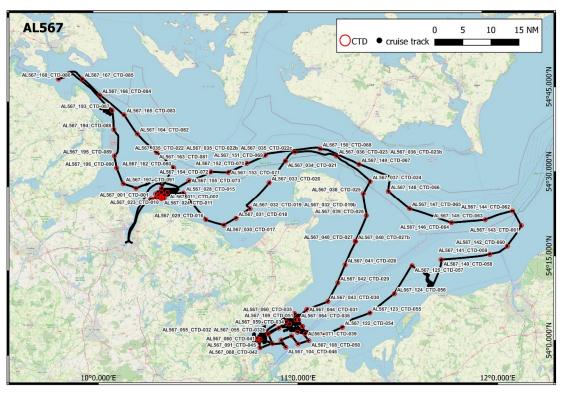


Figure 15: Cruise track of AL567. Red circles indicate water samples taken by CTD along the German Baltic coastline.

Area 3 – Lübeck Bight Pelzerhaken (BLB05L, BLB01L, BLB07L) – Inner Lübeck Bight, appr. 3.4 nm of Pelzerhaken. In the following the areas BLB05L, BLB01L and BLB07L are summarized as area of Pelzerhaken. It was used as munition dumpsite after WWII. All types of German as well as Allied munition were dumped here. In 1971 heavy metal rich blast furnace slag and fly ash was dumped from a metal smelter, possibly covering up some of the munition (Leipe et al., 2017; Leipe et al., 2005).

Area 4 – Trollegrund (BMB11L) – appr. 3 nm west of Kühlungsborn. This area was formerly in use as a shooting range area for military exercise. In addition to training munition, different kinds of dropping ammunition and dumped munition might be present.

Area 5 – Falshöft (BKB01L) – outer Flensburger Förde, appr. 3.5 nm north of Maasholm. Historic reports emphasize the dumping of grenades and cartridges by withdrawing German units. Because submarines were anchoring here during WWII, dumped torpedoes and depth charges can also be expected.

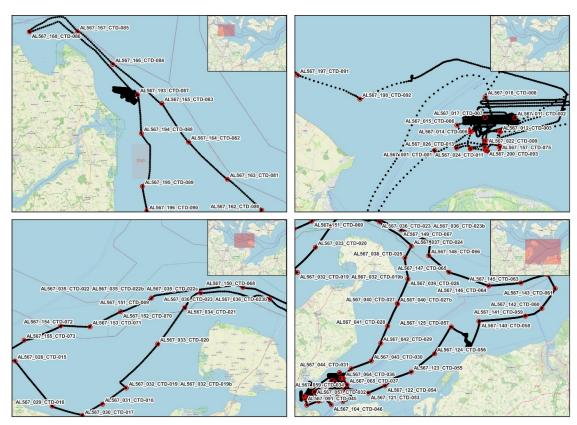


Figure 16: More detailed view of the CTD stations undertaken during AL567.

## **6 Narrative of the Cruise**

Leg I: 17<sup>th</sup> – 24<sup>th</sup> October 2021: The cruise started in the morning of 18<sup>th</sup> October. On board were 12 scientists from Belgium and Germany, from VLIZ, g-Tec and GEOMAR to continue investigations as part of the EUfunded BASTA and EXPLOTECT munition projects. First stop was Kolberger Heide for a functionality test of the equipment, such as the XOFOS and MagWing. All tests went well and a couple of AUV deployments and water sampling were performed, but also several MagWing and SBP profiles to look into the sediment. Tuesday evening, we transited towards Lübeck Bay where we arrived Wednesday morning after taking 23 CTDs on the way. These CTD stations were repetitions of the 2018 and 2020 monitoring campaign. Upon arrival, the Navy vessel BAD RAPPENAU from the 3<sup>rd</sup> Mine Hunting Squadron of the Germany Navy was already on site to deploy their AUVs (REMUS 100) and dive at some of the munition box piles we mapped before. Unfortunately, taking a close look was very challenging as the sight under water was very bad and with less than 50 cm visibility, closer inspection was not possible. Despite this, the Navy did all of the planned

sidescan surveys with the REMUS 100 and also recovered four mussel moorings of our colleagues from the toxicological institute at UKSH. Both crews used the opportunity to visit the other vessel for getting an idea about the equipment, the ship itself, life on board and exchange first news about the findings. On Thursday 13 crew members from ALKOR visited the BAD RAPPENAU, getting a bumpy, wet but safe ride with the Boomranger. The stay on BAD RAPPENAU took longer than expected and we continued working at 18:00 on Thursday. During night, we typically performed joined multibeam, MagWing and SBP surveys and during day time the AUVs and the XOFOS are used. This was not the case for Friday, since wind gusts between 10 and 11 beaufort made it very difficult to keep the ship on track or at station so that for some hours we could not work at all. On 24<sup>th</sup> October we exchanged parts of the scientific crew in Neustadt.

Leg II: 10<sup>th</sup> – 17<sup>th</sup> November 2020: The work continued in Lübeck Bight in the areas off Haffkrug (BLB02L) and Pelzerhaken (BLB05L). On the 26<sup>th</sup> the program was finished and while taking CTDs on the way, we were heading to Trollegrund. After arriving, we directly started multibeam mapping to extend the area from 2020. Since Trollegrund is affected by munitions, but not at such a high concentration as the dumpsites in Lübeck Bight, we could use it as a low-signal reference site for magnetic surveys. Therefore, the AUV Luise was sent to the deepest spot possible (25 m), which was also outside of the contaminated area. There she performed several calibration routines within the water column. From multibeam data we know that there are no large munition objects on the seafloor that could disturb the measurements. Meanwhile, Anton performed the first practice tests with the newly developed 'backseat-driver', which is the next step towards intelligent AUVs. In the 'backseat-driver' operation mode the pre-planned mission is paused and a desired AUV behaviour can be implemented by an external algorithm via setting desired positions, orientations or velocities. On Wednesday evening we left Trollegrund and started a long night of CTD sampling until we reached Kolberger Heide in the morning. This CTD transect revisited 16 stations that were sampled on past Mine-Moni cruises, acting as STV-monitoring sites for the German Western Baltic Sea. In Kolberger Heide, we resampled six previously well-characterized stations to test if the severe storm during the previous week increased the release of chemical contamination from munitions on the seafloor. This is the first cruise with a fully operational Explotector, our system developed in ExPloTect for on-board detection of dissolved explosives. The preliminary results show widespread contamination by e.g., TNT, with highest concentrations detected in Kolberger Heide.

The sampling continued until we reached Falshöft in the early afternoon on Thursday. This site was also object to warfare material dumping and we were able to confirm munition objects on the seafloor. Compared to Lübeck Bight and Kolberger Heide, the targets were much more difficult to find. Falshöft is characterized by a rocky seafloor with large boulders (ca 1 m height), which makes it difficult to distinguish munitions from natural objects in the multibeam data. Therefore, the gradiometer on AUV LUISE plays an essential role. The combination of different sensors greatly improves target detection and are important as training data for the artificial intelligence algorithm. The last night on Saturday, we completed more CTD samples and mapping in Kolberger Heide until the cruise ended in Kiel on Sunday morning. Due to the poor underwater visibility in the first week we could not verify as many targets, as we planned, but we could largely extend mapping around the dumpsite to get an idea of the real extent of the contamination.

## 7 Preliminary Results

## 7.1 Area 1 - Kolberger Heide

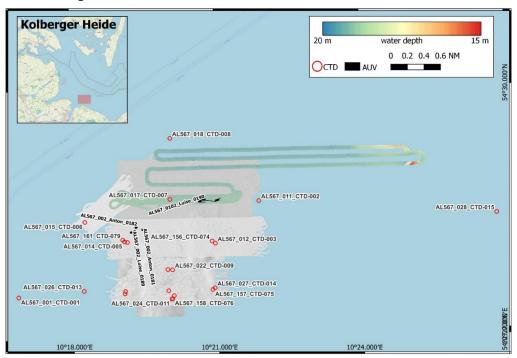


Figure 17: Mapped area in Kolberger Heide during AL567 with CTD and AUV stations. The coloured multibeam data was acquired on AL583, the grey-shaded data was recorded on previous surveys.

The cruise started with re-mapping an area in Kolberger Heide, where SBP data were acquired on a previous cruise. To verify potential buried object, the same area was mapped again with the towed MagWing. In addition to that, an old dataset containing magnetic contacts was ground-truthed via multibeam and SBP.

#### **MBES**

Some of the magnetic contacts could be found inside the multibeam data as objects on the seafloor. Since the coverage of magnetic surveys on the seafloor are typically very narrow, objects next to the survey line were obviously missed out, which are clearly present inside the multibeam track. Even though the data is partly inside the munition-suspected area, trawl marks on the seafloor indicate fishing activities that could have relocated munition (Figure 18).

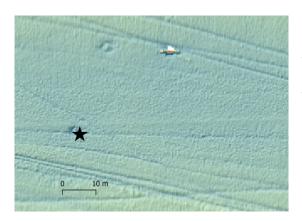


Figure 18: Multibeam data from AL567. The star marks a magnetic contact from the Sensys data set, which is also visible as an object on the seafloor. Appr. 40 m towards northeast lies a torpedo-shaped object. Trawl marks from fishing gear cross the seafloor and also the objects.

#### MagWing

In Kolberger Heide several lines with the MagWing were run in the north of the restricted area where indications of buried munition were found during previous investigations. The lines in Kolberger Heide were also used to test the equipment and get used to running the survey. Simultaneously during the survey MBES and SBP data were acquired. An example of the MagWing data is given in Figure 19.

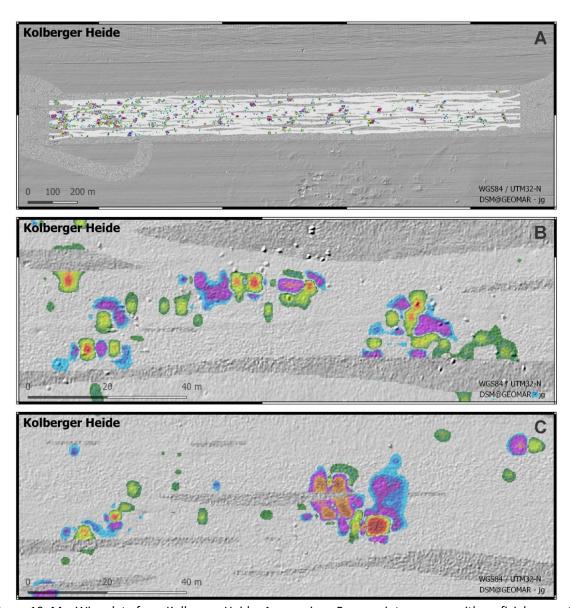


Figure 19: MagWing data from Kolberger Heide; A: overview; B: zoom into an area with surficial magnetic objects; C: zoom into an area with buried magnetic objects.

## **SBP**

In the northern Kolberger Heide dumpsite, acoustic imaging of the area is characterized by buried objects, partially buried, and objects exposed on the seafloor (Figure 20). A part of those targets shows sinking evidence, most likely because of the soft sediments, as indicated by the low amplitude layering in the subbottom profiles.

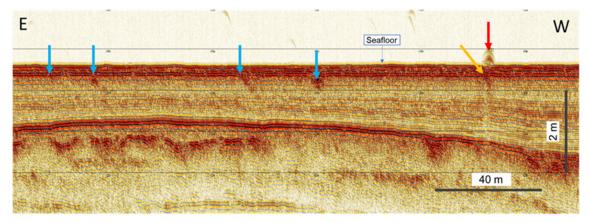


Figure 20: Subbottom profile from the northern part of Kolberger Heide showing buried objects (blue arrows). A target at the seafloor is easy to recognize (red arrow), and seems to be associated with a second object that is buried with some sagging evidence (yellow arrow).

#### Magnetic AUV

On Oct. 18th and 19th, AUV Luise conducted four individual magnetic missions in the northern parts of Kolberger Heide in order to extend our databases of possible magnetic UXOs in this area. Figure 21 shows the underlying bathymetry/hillshade data, the AUV tracks, the vertical magnetic gradient and the analytic signal of a 70 x 30 m² mission area. The values of the vertical magnetic gradient range between -10 and +30 nT/m. The AUV flight altitude was 1.4 m and the vehicle velocity was 0.5 m/s. The linespacing of the AUV tracks was 2 m. The magnetic signatures can be referred to medium-sized, yet unclassified, munition objects lying prominently on the seafloor.

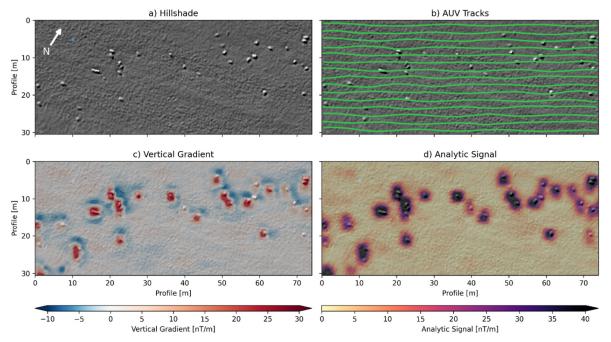


Figure 21: Vertical magnetic gradient and analytic magnetic signal together with MBES/hillshade data and the tracks of AUV Luise in the northern regions of Kolberger Heide (mission Luise 190A).

#### **Optical AUV**

No photo mosaic could be created, due to very low visibility and resulting bad photo quality. See AUV table in the appendix.

#### Water sampling & chemical analyses

Results from the water analyses were not ready at the time the report was finished.

## 7.2 Area 2 – Haffkrug

In order to map the real extent of the munition dumpsite, mapping was continued to the west and the east of the official area (Figure 22). Thereby two new potential munition piles were detected around 900 m outside of the official area. Unfortunately, the visibility was too low for AUV-based camera groundtruth. Nevertheless, this once more shows the imprecise confinement of those dumpsites.

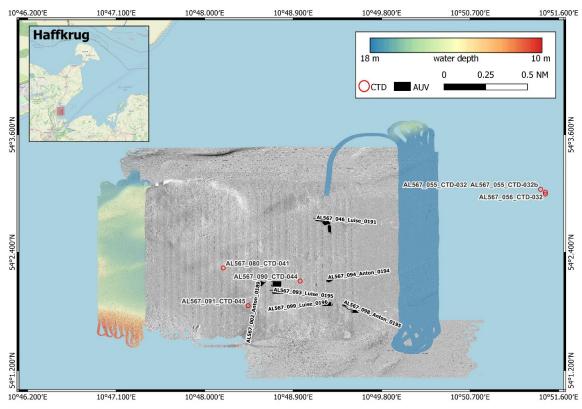


Figure 22: Mapped area in Haffkrug in Lübeck Bay during AL567 with CTD and AUV stations. The coloured multibeam data was acquired on AL583, the grey-shaded data was recorded on previous surveys.,

## **MBES**

The previously mapped area was extended towards the west and the east. Shallow ridges are covered with rocks and form a contrast to the predominant flat and homogenous seafloor. A few anchoring marks witness from bottom fishing. Two suspicious piles lay ca 900 m outside of the official dump site. Both are around 20 m in diameter and are composed of single objects on a rather flat seafloor. Scours around the piles have been formed by currents and cause depressions in the surrounding seafloor (Figure 23). In the western part there is one feature, which might be caused by on-route-dumping (Figure 24). Objects of ca 1 m size form a 600 m long track. If this is man-made or a geological feature has not been ground-truthed yet.

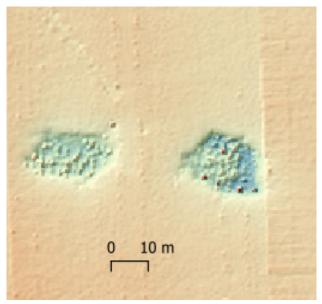


Figure 23: Two munition piles in multibeam data on the seafloor in Haffkrug.

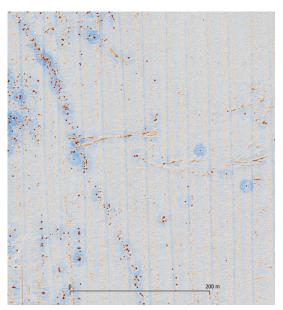


Figure 24: Possible on-route dumping in Haffkrug. Derivatives (here: TPI of the Real Surface Area) enhance morphological features on the seafloor. While minor elevations and the waterdepth are neglected, object patterns become clearly more visible.

#### MagWing

In Haffkrug three MagWing survey patterns were run parallel to SBP and partly multibeam investigations. The surveys were undertaken to verify if an area of scattered objects is magnetic and to acquire a designated area for later MIC sampling is free of metallic objects. Figure 25 gives an overview of the mapped area and two detailed inserts.

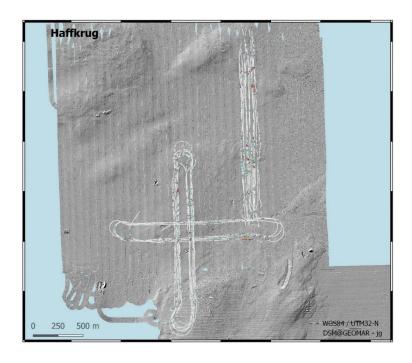


Figure 25: The figure shows the three MagWing survey lines in Haffkrug area. The southern cross was run to acquire data to enable sediment sampling in2022.

#### **SBP**

In general, in the Lubeck Bay areas, geology plays a crucial factor in discrimination between munition-related targets and geological features. For instance, some of the objects may be related to boulders from the glacial till, and others may be related to munition objects. As shown in Figure 26, the geology shows a hard-outcropping layer, with numerous exposed targets and where no buried targets were observed. On the other hand, where the hard layer is not outcropping, there are some buried features in the soft sediments overlying the hard layer. This seems to confirm the theory that most likely the exposed targets are boulders linked to a glacial till layer.

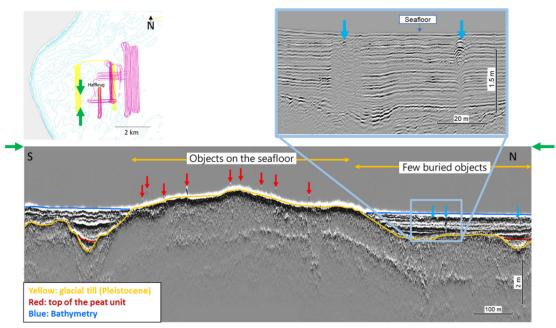


Figure 26:2D SBP section from Haffkrug (Lubeck Bay). Multiple objects can be seen on the seafloor (red arrows) where a hard glacial till layer is outcropping, showing up as a strong acoustic horizon. The blue arrows mark targets that are buried into the soft sediments overlying the hard glacial till. At the top-right a zoom-in of the section showing the same buried targets represented as hyperbolas.

## **AUV Magnetic**

During the first week of the AL567 cruise, AUV Luise conducted a total of 6 magnetic missions in the area of Haffkrug. Figure 27 shows the 2D interpolated magnetic results (vertical gradient) of the AUV-based magnetic measurements during mission "Luise\_196" near Haffkrug covering an area of approximately 100 x 60 m² with 2 m linespacing. The map shows numerous magnetic signatures with significant amplitudes (ranging from -800 to +600 nT/m) that can hardly be referenced to any objects the MBES/hillshade data. The objects that infer the displayed signatures must therefore assumed to be relatively small or, more probable, mostly buried. Interpolation has been conducted using the Radial Basis Function (RBF) interpolation scheme from SciPy.

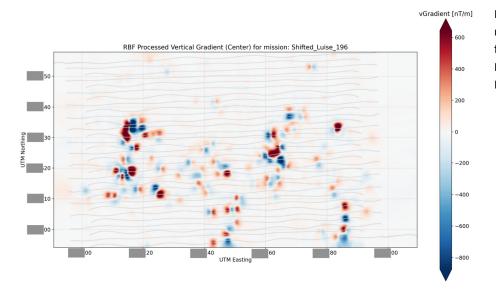


Figure 27: Vertical magnetic gradient for AUV mission Luise\_196 near Haffkrug.

Figure 28 shows the analytic magnetic signal of an 80 x 80 m<sup>2</sup> area during AUV mission Luise\_194. Four east-west oriented very long anomalies can clearly be observed. The origins of these anomalies are unknown but they can probably be explained by anchor chains or cables. Since the quality of camera images was poor due to the water turbidity, no image-based ground-truthing was possible. The linespacing was 2 m.

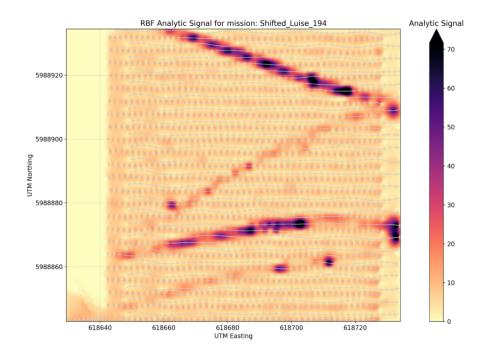


Figure 28: Analytic magnetic signal for AUV mission
Luise\_194 near
Haffkrug showing four elongated magnetic signatures.

## **Optical AUV**

The visibility was very low, which alters the AUV photos significantly. Resulting photo mosaics have decreased resolution and clear identification of features was not always possible. At least one pile of boxes could be reconstructed in a photo mosaic (Figure 29 and Figure 30).



Figure 29: Photomosaic (AL567\_098\_ANTON-0195a\_ortho\_correctedimages) of pile of munition boxes in Haffkrug.

Figure 30: Close up of munition boxes in Haffkrug.

#### 7.3 Area 3 - Pelzerhaken

In Pelzerhaken, more mapping was done towards the north and south (Figure 31Error! Reference source not found.).

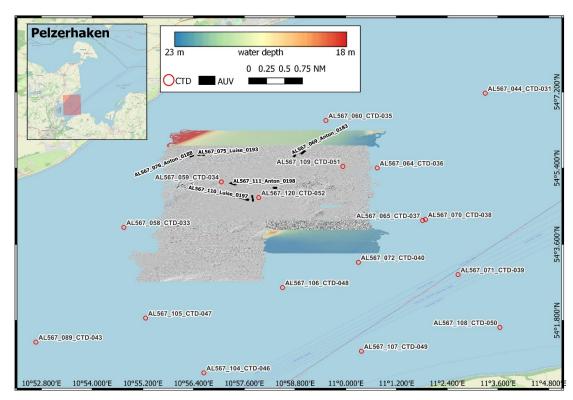


Figure 31: Mapped area in Pelzerhaken in Lübeck Bay during AL567 with CTD and AUV stations. The colored multibeam data was acquired on AL583, the grey-shaded data was recorded on previous surveys

#### **MBES**

By creating derivatives (here: TPI of the surface area), objects become easily visible and in the northern part 2-3 potential munition piles and one on-route dumping track were spotted (Figure 32). The south-eastern part, is characterized by rocky seafloor on one hand, and flat and highly disturbed by trawl marks seafloor on the other hand. There were no clear munition findings.

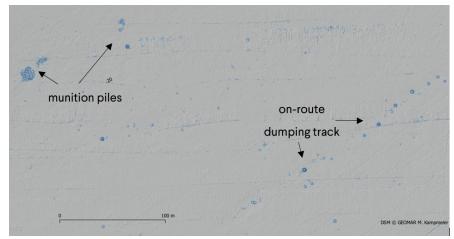


Figure 32: Derivatives (here: TPI of the Real Surface Area) enhance morphological features on the seafloor. While minor elevations and the waterdepth are neglected, object patterns become clearly more visible.

## **MagWing**

As for Haffkrug and in preparation of sampling on up-coming cruises an area was mapped in high detail with the MagWing in a long-loop pattern. Two of these loops cross each other with a 90° angle, the crossing lines mark the corridor of the planned sediment sampling (Figure 33).

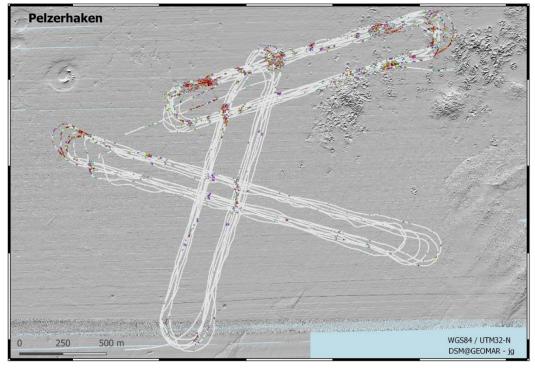


Figure 33: MagWing lines in the Pelzerhaken area.

#### **SBP**

The magnetic data is congruent with surficial features, seen inside the multibeam data. In few cases, no they show more targets, which might indicate buried objects. On the other hand, furnace slag, which was dumped in Pelzerhaken, also shows a magnetic signature, which will make it difficult to distinguish between munition and slag (Figure 34). Even the visibility became slightly better it was not possible to create good photo mosaics for ground truthing targets.

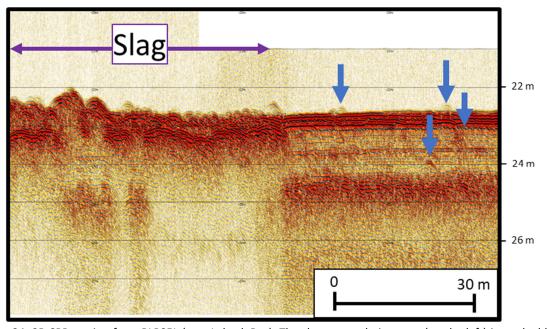


Figure 34: 2D SBP section from BLB05L (east Lubeck Bay). The slag accumulation area (on the left) is marked by a cluster of high amplitude hyperbolas, that prevent the acoustic energy propagation. On the right some features are indicated with blue arrows. It is possible that some of the buried features could be related to gas escapes.

#### **Magnetic AUV**

Near Pelzerhaken, we conducted six individual magnetic missions with AUV Luise, three missions on Oct. 23<sup>rd</sup> and three missions on Oct. 26<sup>th</sup>. Figure 35 shows the magnetic analytic signal of AUV mission Luise\_197B covering an area of approximately 80 x 70 m². No prominent objects can be observed in the MBES/hillshade background data. However, the system detected are at least four magnetic anomalies, two of them with huge gradients of > 1000 nT/m at a sensor altitude of 1.4 m above the seafloor. The objects causing these anomalies are most probably buried.

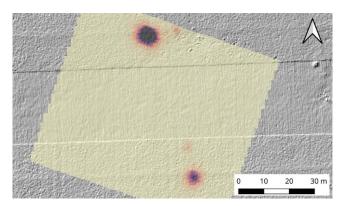


Figure 35: Analytic magnetic signal of two huge anomalies during AUV mission Luise\_197B near Pelzerhaken.

#### **Optical AUV**

It was not possible to generate any usable photomosaic in Pelzerhaken, due to low visibility and resulting poor image qualities.

#### **AUV Tests**

In Pelzerhaken basic tests with the backseat driver were conducted such as the activation and deactivation of the working mode. Furthermore, the navigation in the backseat driver mode was tested by basic predefined missions such as driving along a set of waypoints in different depths as well as driving along a sine wave in the horizontal and vertical direction.

#### 7.4 Area 4 - Trollegrund

In Trollegrund, similar to the Haffkrug area, buried features were observed (Figure 36). However, it is not clear if they are related to munition since the hard layer (just below the objects) does not outcrop in the area, and there is no magnetic mapping to distinguish ferromagnetic objects. However, since the bottom reflection has a high amplitude suggesting a hard seafloor (which would prevent objects sinking down), it seems likely that the buried features are related to boulders from a till layer. Trollegrund was also used as a testing site for the magnetometers (see Magnetometer report section)

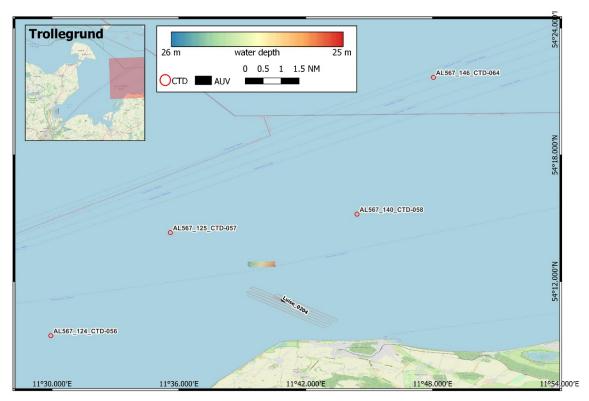


Figure 36: Mapped area during AL567 with multibeam, MUC and AUVs stations.

#### **MBES**

The seafloor bathymetry in Trollegrund is characterized by a gentle, from east to west dipping slope. The only features are trawl marks criss-crossing the area. The water depth ranges from 25 to 26 m. No suspicious objects are visible on the seafloor.

# **SBP**Several lines were run with the SBP in the Trollegrund area. An example is given in Figure 37.

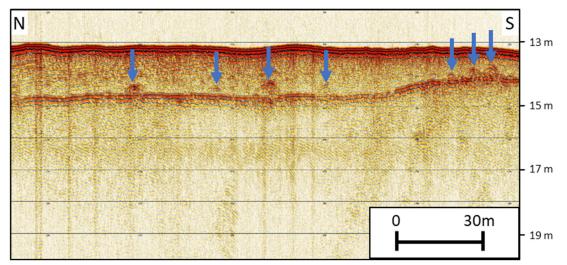


Figure 37: SBP section from Trollegrund, the blue arrow indicated buried features that are likely related to a till.

#### **Magnetic AUV**

The area near Trollegrund has been visited the year before during AL548 to conduct numerous testing and calibration maneuvers. By chance, we detected several magnetic objects at that time which turned out to be 12.3 cm FLAK grenades from WW2. During the present cruise, we revisited the area for two purposes: First, to investigate medium-sized munition objects that have been found the year before and to compare the acquired magnetic data with data recorded by the new magnetic sensors and, second, to conduct calibration and test missions in the middle of the water column since water depths at the area of Trollegrund reach 25 m and more. Moreover, this relatively deep testing area was expected to be free of UXOs and adequately far away from shipping routes. The test missions contained different AUV flights of straight lines and circles, both, in different water depths and with different velocities. Additional noise tests have been conducted during hovering periods of fixed AUV location. During the circular test missions, the AUV team successfully handed over the AUV internal mission control to an external "backseat driver" algorithm. Unfortunately, huge waves disturbed the noise measurements on that day. The effects of the waves on the AUV (i.e. the measured data) could be seen to water depths of approximately up to 10 m. Data quality below 10 m was satisfying. Figure 38 shows results for all three sensors of a noise measurement during a 50 s parking manoeuvre at 12 m water depth, i.e. in the middle of the water column. The noise level anomaly of the raw total field values is on average between -1 and +1 nT. The lowpass filtered data (coloured lines) yield much better results indicating noise possible noise levels < 1 nT when decent conditions.

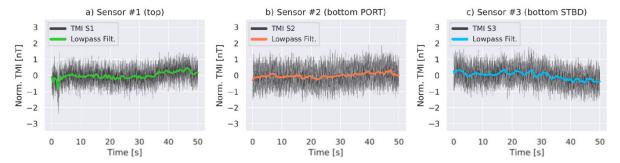


Figure 38: Raw and filtered total magnetic intensities of all three magnetometers during a 50s parking manoeuvre near Trollegrund.

When revisiting the same area near Trollegrund from last year, we again discovered many new UXO objects (FLAK grenades) and one larger, unknown object which was approximately 1 m long. Figure 39 and Figure 40 show the Total Magnetic Intensity (TMI) values of all three sensors and an image of the large UXO taken by the onboard camera.

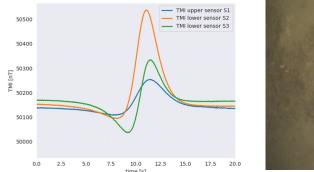




Figure 39: Magnetic TMI values of a large UXO Figure 40. Camera footage of the large Trollegrund UXO from Trollegrund.

## **Optical AUV**

Photomosaic qualities are rather poor. Tile matching was often not possible, which unfortunately caused significant gaps inside the mosaics. Manual point picking and matching is needed here.

#### **AUV Tests**

At Trollegrund, we conducted the first tests of the so-called Backseat-Driver (BSD) with magnetometers deployed to the AUV. The BSD was wrapped up inside a simple three-waypoint mission commanding the AUV controller to switch command to the BSD after reaching the center waypoint. The BSD mission patterns consisted of predefined circular or straight missions at different water depths and with different AUV velocities. After a successful termination of the BSD algorithm, waypoint three of the initializing mission was targeted and eventually reached by AUV Luise. A dependence of the BSD mission setup on the measured magnetic TMI values was not yet implemented and tested.

#### 7.5 Area 5 – Falshöft

Approximately half of the area of Falshöft has been mapped by now (Figure 41). The seafloor changes from homogenous sand to stony reefs. On the sand it is rather simple to identify munition objects, but it becomes difficult in between stones. Visual groundtruth via OFOS mapping did not work, since the level of biofouling prohibited clear identification.

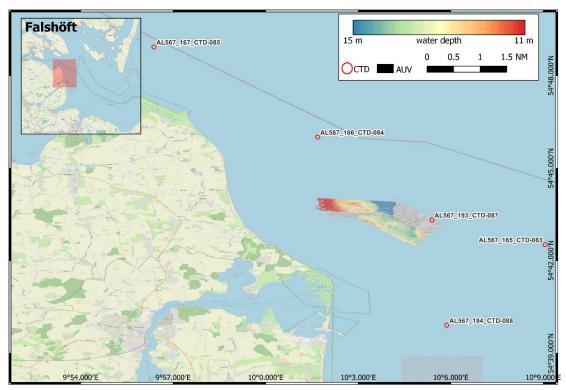


Figure 41: Mapped area in Falshöft during AL567 with CTD and AUV stations. The colored multibeam data was acquired on AL583, the grey-shaded data was recorded on previous surveys

#### **MBES**

Water depths range from 11 to 15 m and the seafloor sediments change from large sand dunes to shallow, rock-covered areas. Except a few suspicion points, no distinct munition objects were found inside the new data. However, the presence of rocks decreases the detection possibility.

#### **SBP**

The Falshöft area has a hard layer outcropping which is marked by numerous exposed targets, no buried targets were observed (Figure 42). This seems to indicate that most likely the exposed target are boulders linked to a glacial till layer. In general, this area is geologically more complex compared with the other surveyed areas during the 2021 campaign.

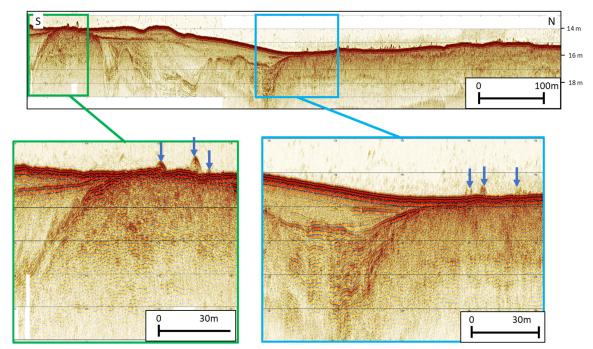


Figure 42: 2D SBP section from Falshöft, showing a hard layer outcropping with numerous exposed targets (blue arrows). No buried targets were observed here.

## **Magnetic AUV**

During the final phase of the cruise, AUV Luise conducted an additional 10 magnetic missions near Falshöft where the density of UXOs is much less compared to Kolberger Heide or Lübeck Bay. The most astonishing finding of the AUV survey near Falshöft was the detection of several completely non-magnetic objects that looked like torpedo heads (Figure 43) and are made of unknown materials. The size of these objects was about 1.2 m in length 0.5 m in diameter. According to Uwe Wichert, the origin of these torpedo heads may be related to a torpedo manufacturing facility from WW2 near Eckernförde, where different materials and compounds for torpedo heads were tested during the war.



Figure 43: Non-magnetic UXO near Falshöft, probably a torpedo head from WW2.

#### **Optical AUV**

The visibility in Falshöft was much better compared to the other sites and allows for good quality photomosaics. One shows a torpedo head, which has a characteristic blue shell (Figure 43). Similar torpedo heads have been found in Falshöft before and magnetic surveys revealed, that they are most likely amagnetic. Additionally, grenades, cartridges and metal scrap were found (Figure 44). The seafloor seems to be highly bioturbated with low algae coverage.

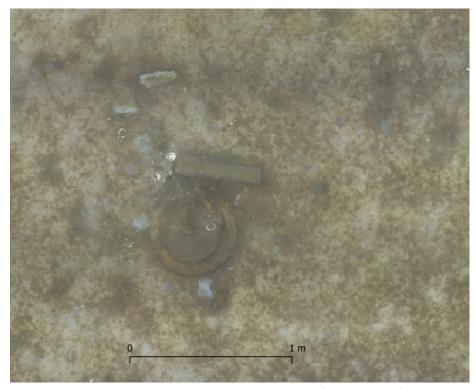


Figure 44: A cartridge and metal scrap on the seafloor in Falshoeft.

#### **AUV Tests**

For the calculation of the photo mosaics or navigation correction via methods such as SLAM (simultaneously localisation and mapping) it can be beneficial to regularly drive to the same position during an AUV mission. Therefore, a classical lawnmower patter was planned and at the middle of each second line the pre-planned mission was stopped and the backseat-driver mode was used to drive the AUV to the centre of the lawnmover grid where the AUV turned, drove back and resumed the pre-planned mission. This does not create much overhead during the AUV mission but helps to improve the quality of the photo mosaics as the centre can serve as a tie point. In this test the tolerance for reaching this position was chosen as 1 m. This led to only a small overlap between the lines coming from the left half and the ones from the right half of the lawnmower pattern. Reducing the tolerance is not feasible as it reduces the robustness of the AUV navigation and can lead to larger mission times if the AUV is not able to reach the point e.g. due to currents. Therefore, the next time the position that the AUV drives to should be chosen slightly to the right of the centre and slightly to the left for the left and right half of the lawnmower patter, respectively.

The second test at Falshöft aimed at improving the photo coverage for structure from motion techniques. Software as e.g. Agisoft Metashape (Agisoft LLC, 2022) or COLMAP (Schoenberger, 2022) can calculate a 3-D model of an object from 2-D photos. For good quality models a large number of photos from several directions is needed. Therefore, we let the AUV drive two star-patterns, the first in the global mission mode

and the second one slightly rotated in the backseat-driver mode to investigate if there is a difference between the two modes. There are some very small differences in the AUV paths, e.g. that the AUV does in the backseat driver mode not overshoot waypoints as much as in the mission mode but overall these differences are not significant. The star pattern was planned with the centre on a distinct object based on a multibeam map but due to the GPS uncertainty of the AUV the target was missed. This highlights the importance of being able to react to sensor data in real time by updating the pre-planned navigation. By this such search patterns could be triggered by e.g. magnetic anomalies.

Lastly, we tested the boundary layer detection and tracking described in von See, et al (2022). To acquire ground truth data for the evaluation we let the AUV first drive two complete depth-profiles. Afterwards we started the boundary layer tracking algorithm to detect the halocline. The AUV was commanded to drive a small lawnmower grid and simultaneously detect and track the boundary layer in z-direction. The AUV path as well as the depth and salinity over time are shown in Figure 45. It can be seen in the middle and bottom subplot that there is a district but very large boundary from approximately 3 to 8 m depth. In principle the algorithm worked as is should but we expected a smaller boundary layer so that the excitation amplitude of the boundary layer tracking was chosen too small to cover the complete boundary.

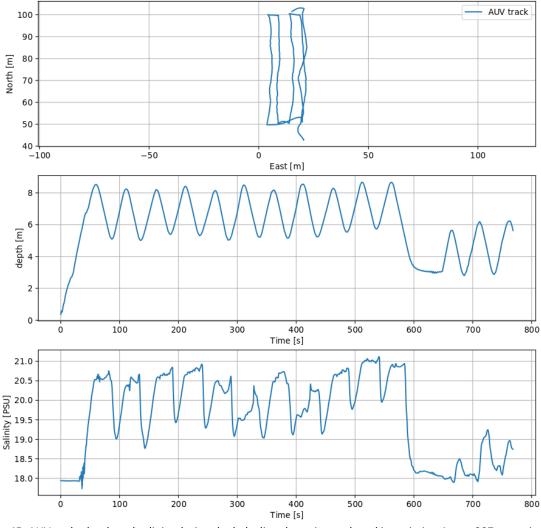


Figure 45: AUV path, depth and salinity during the halocline detection and tracking mission Anton 207 at station 192 in Falshöft.

## 8 Data and Sample Storage and Availability

Mapping data (multibeam, photographs, magnetic and GIS projects) are stored on GEOMAR servers with access control and are only available to project internal staff. Munition findings will be reported to corresponding authorities (EOD squads and the Navy underwater data centre in Rostock). Data will be provided to project members if required. Data including navigation data from munition findings will not be made publicly available. Position data from munition locations will not be uploaded onto the GEOMAR data management server OSIS. Access to such sensitive data is restricted.

## 9 Acknowledgements

We thank the master and crew of RV ALKOR for their excellent support during the scientific campaign of AL567 and MacArtney Germany GmbH for the reliable installation and set-up of the multibeam system. This cruise was performed within the framework of the EU-funded project BASTA (EMFF-Blue Economy 2018 program, project nr. 863702; www.basta-munition.eu).

## 10 References

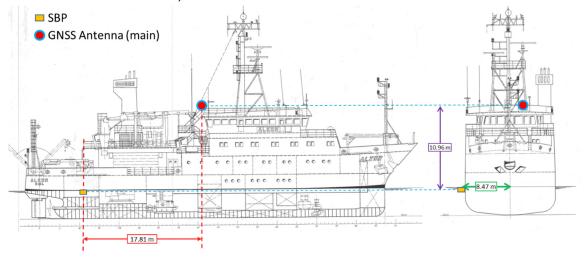
Agisoft LLC. (2022). https://www.agisoft.com/.

- Kampmeier, M, Greinert, J., Strehse, J., Beck, A. J., Wichert, U., Diller, N., Kurbjuhn, T., Wenzlaff, E., & Schröder, J. (2019). RV Poseidon POS526 Cruise Report (Issue September). https://doi.org/http://oceanrep.geomar.de/id/eprint/47567
- Kampmeier, Mareike, van der Lee, E. M., Wichert, U., & Greinert, J. (2020). Exploration of the munition dumpsite Kolberger Heide in Kiel Bay, Germany: Example for a standardised hydroacoustic and optic monitoring approach. Continental Shelf Research, 198, 1–39. https://doi.org/https://doi.org/10.1016/j.csr.2020.104108
- Kampmeier, M. (2020). *RV LITTORINA L13-20 Cruise Report 04.–11.07.2020 BASTA*. GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany, 15 pp.
- Leipe, T., Naumann, M., Tauber, F., Radtke, H., Friedland, R., Hiller, A., & Arz, H. W. (2017). Regional distribution patterns of chemical parameters in surface sediments of the south-western Baltic Sea and their possible causes. Geo-Marine Letters, 37(6), 593–606. https://doi.org/10.1007/s00367-017-0514-6
- Leipe, Thomas, Kersten, M., Heise, S., Pohl, C., Witt, G., Liehr, G., Zettler, M., & Tauber, F. (2005). Ecotoxicity assessment of natural attenuation effects at a historical dumping site in the western Baltic Sea. Marine Pollution Bulletin, 50(4), 446–459. https://doi.org/10.1016/j.marpolbul.2004.11.049
- Schoenberger, J. L. (2022). https://colmap.github.io/.
- von See, T. B., Meurer, T., & Greinert, J. (2021, September). Marine boundary layer tracking using an AUV with UKF based extremum seeking. *IFAC-PapersOnLine 54*, pp. 320–326.

# 11 Appendix

## 11.1 Static offsets GPS - SBP

Drawing of the RV ALKOR with the real offsets. from the main antenna and the SBP transducers. The offsets are shown in real-scale, after the re-scale.



## 11.2 AUV Missions Overview

## **AUV** data missions

# of missions	Total mission duration	Total length	# of pictures
29	71.25h	93km	233024

#### AUV data and test missions

# of missions	Total mission duration	Total length	# of pictures
46	72.35h	~94km	233024

The following table includes all AUV missions that took place during this cruise. In addition to the payload listed in the table (camera, magnetometers and optode), CTD data has been collected during all missions. Table 8 gives an overview of the AUV missions.

Table 8: Overview of all AUV missions during the cruise.

- ·			10			I all Aov	11113310113	during the cruise.		1	Ī
Date (2021)	AUV	Dive	Station	Start (UTC)	End (UTC)	Duration	Ü	Center Position	Pics	Mag.	Optode
18.10.	Anton	181	2	11:08	12:30	~1.3 h	1400 m	54.4718, 10.3243	4123		
18.10.	Luise	189	2	12:02	13:27	~1.5 h	1400 m	54.4714, 10.3203	4168	X	
18.10.	Anton	182	2	12:44	15:57	~1.3 h	1500 m	54.4723, 10.3219	4141		
19.10.	Luise	190	10	08:42	13:29	~5.3 h	6500 m	54.4774, 10.3471	16449	X	
20.10.	Luise	191	46	07:45	11:30	~4 h	5862 m	54.0450, 10.8206	12258	X	X
23.10.	Luise	192	68	06:43	09:33	~3.3 h	4600 m	54.0962, 10.9831	9850	X	X
23.10.	Anton	183	68	07:05	09:08	~2 h	100 m	-	7593		
23.10.	Anton	184	68	09:20	09:51	~	1000 m	54.0950, 10.9797	1732		
23.10.	Luise	193	75	10:44	13:10	~2.3 h	1920 m	54.0953, 10.9430	7750	X	X
23.10.	Anton	185	75	10:52	10:53		-	-			
23.10.	Anton	186	75	10:55	11:00		-	-			
23.10.	Anton	187	75	11:01	11:06		-	-			
23.10.	Anton	188	75	11:15	13:23	~	3513 m	54.0947, 10.9391	7599		
24.10.	Luise	194	83	12:09	14:45	~2.5h	4294 m			X	X
24.10.	Anton	189	84	12:23	12:20	~2h	2728m	54.0347, 10.8095	5852		
25.10.	Luise	195	93	06:30	08:15	~1.75h	3240m	54.0333, 10.8123	6866	X	X
25.10.	Anton	190	94	06:58	07:03	5 min	-	54.0354, 10.8221			
25.10.	Anton	191	94	07:04	07:10	6 min	-	54.0354, 10.8221			
25.10.	Anton	192	94	07:11	07:15	4 min	-	54.03534, 10.8221			
25.10.	Anton	193	94	07:18	07:21	3 min	-	54.03534, 10.8221			
25.10.	Anton	194	94	07:45	10:00	~2 h	2885m	54.03543, 10.8214	6044		
25.10.	Anton	195	98	11:20	14:45	~ 2.5 h	4150m	54.0306, 10.8246	8904		
25.10.	Luise	196	99	11:32	14:20	~ 2 h	3243m	54.0312, 10.8206	7087	X	X
26.10.	Luise	197	110	06:30	~ 10:30	~ 4.5 h	6370m	54.0782, 10.9583	14212	X	X
26.10.	Anton	196	111	06:50	~ 07:00	10 min	-	-			
26.10.	Anton	197	111	07:35	~ 10:19	~3 h	4474m	54.0781, 10.9633	9477		
26.10.	Anton	198	111	10:35	~ 14:30	~ 4 h	5918m	54.0839, 10.9554	12423		
26.10.	Luise	198	115	11:17	~ 14:15	~ 2 h	3033m	54.0823, 10.9722	6598	X	X
27.10.	Luise	199	128	06:14	~07:08	~ 1 h	-	-		X	
27.10.	Luise	200	128	07:18	~07:30		-	-		X	
27.10.	Luise	201	131	08:36	~08:54		-	-		X	
27.10.	Luise	202	131	08:59	09:17	~ 15 min	-	-		X	
27.10.	Luise	203	131	09:21	09:30	~ 10 min	-	-		X	
27.10.	Luise	204	134	10:30	~ 14:15		4757m	54.1848, 11.6821	10857	X	
28.10.	Anton	199	169	12:30	14:26	~ 2 h	3669m	54.7222, 10.0847	6935		
28.10.	Luise	205	170	12:40	14:28	~ 2 h	2552m	54.7212, 10.0853	6202	X	
29.10.	Luise	206	176	06:00	11:03	~ 5 h	7876m	54.7207, 10.0884	17817	X	
	Anton	200	177	06:20	06:26	~ 5 min	-	-			
	Anton	201	177	06:27		~ 20 min	-	-			
29.10.	Anton	202	178	07:10	12:00	~ 4 h	5418m	54.7226, 10.0882	12123		
29.10.	Anton	203	183	14:23	~ 14:40	~ 20 min	-	54.7210, 10.0660	1160		
29.10.	Anton	204	183	~ 14:50		~ 20 min	-	54.7214, 10.0658	1451		
30.10.	Luise	207	186	06:35	~ 08:45		3335m	54.7197, 10.0709	7488	X	
30.10.	Anton	205	187	06:41		~ 2.3 h	3336m	54.7205, 10.0674	6938		
30.10.	Anton	206	192			~ 10 min	-	-			
30.10.	Anton	207	192			~ 10 min	-	-			
		,						1			l .

# 11.3 Photomosaik processing list

Mission	Area	Photoquality	objects	interesting image	Metashape processed	Metashape results	Comments
AL567_002_ANTON-0181	Kolberger Heide	low			no		not done because of low quality
AL567_002_ANTON-0182	Kolberger Heide	low			no		not done because of low quality
AL567_002_LUISE-0189	Kolberger Heide	low			no		not done because of low quality
AL567_010_LUISE-0190a	Kolberger Heide	low			no		not done because of low quality
AL567_010_LUISE-0190b	Kolberger Heide	low			no		not done because of low quality
AL567_010_LUISE-0190c	Kolberger Heide	low			no		not done because of low quality
AL567_046_LUISE-0191a	Haffkrug	low			no		not done because of low quality
AL567_046_LUISE-0191b	Haffkrug	medium	UXO		yes	low	all photos greenish, should be edited before mosaic
AL567_046_LUISE-0191b_ Processed pictures	Haffkrug	medium	UXO		yes	medium- low	mosaic of edited images, very bright, slightly better than not edited
AL567_046_LUISE-0191c	Haffkrug	low			no		not done because of low quality
AL567_068_LUISE-0192	Pelzerhaken	low			no		not done because of low quality
AL567_069_ANTON-0183	Pelzerhaken	low			no		not done because of low quality
AL567_069_ANTON-0184	Pelzerhaken	medium	UXO		yes	low	very bad quality
AL567_075_LUISE-0193a	Pelzerhaken	medium	UXO	013250-013255	no		not done because of low quality
AL567_075_LUISE-0193b	Pelzerhaken	low			no		not done because of low quality
AL567_076_ANTON-0185	Pelzerhaken	no photos			no	NONE	
AL567_076_ANTON-0186	Haffkrug	no photos			no	NONE	
AL567_076_ANTON-0187	Haffkrug	no photos			no	NONE	

Mission	Area	Photoquality	objects	interesting image	Metashape processed	Metashape results	Comments
AL567_076_ANTON-0188	Pelzerhaken	medium	UXO	12510	yes	low	very bad quality
AL567_083_LUISE-0194	Haffkrug	low			no		not done because of low quality
AL567_084_ANTON-0189	Haffkrug	low	UXO	002956-002965	yes	low	mosaic of edited images directly, still did not work at all
AL567_093_LUISE-0195	D93_LUISE-0195 Haffkrug medium rocks 3491 ye		yes	medium	first good quality brownish, but towards the end more greenish color, some features look like rocks but could be munition parts as well		
AL567_094_ANTON-0190	Haffkrug	no photos			no	NONE	
AL567_094_ANTON-0191	Haffkrug	no photos			no	NONE	
AL567_094_ANTON-0192	Haffkrug	no photos			no	NONE	
AL567_094_ANTON-0193	Haffkrug	no photos			no	NONE	
AL567_094_ANTON-0194	Haffkrug	low			no		not done because of low quality
AL567_098_ANTON-0195a	Haffkrug	good	Boxes	6485, 7509, 7723-7744, 7856-7884, 8039- 8083, 8180-8226, 8377-8425, 8514-8562, 8713-8761, 8850-8898, 9049-9089,9202-9227	yes	good	
AL567_098_ANTON-0195b	Haffkrug	good	UXO?	10789, 11059	yes	very good	
AL567_098_ANTON-0195c	Haffkrug	good	UXO Box, rocks	11441, 11664, 11671, 12022, 12029, 12180, 12281-12308, 12406-12436, 12553-12591, 12671-12710, 12828-12863, 12942-12978,1300-13131, 13209-13248, 13370-13408, 13484-13511, 13642-13664	yes	very good	
AL567_099_LUISE-0196	Haffkrug	medium, but corrected good			yes	good but further away	
AL567_110_LUISE-0197a	Pelzerhaken	very blurry, might have objects			yes	very low	
AL567_110_LUISE-0197b	Pelzerhaken	only last few pics show floor			yes	medium	artefacts on the sides and no munition
Mission	Area	Photoquality	objects	interesting image	Metashape processed	Metashape results	Comments

AL567_110_LUISE-0197c	Pelzerhaken	low, greenish color			yes	low	
AL567_111_ANTON-0196		no photos			no	NONE	
AL567_111_ANTON- 0197_part1	Pelzerhaken	very low, soup			yes	low	only 70 of nearly 5000 photos aligned
AL567_111_ANTON- 0197_part2	Pelzerhaken	very low, soup			yes	low	only 70 of nearly 5000 photos aligned
AL567_111_ANTON-0197_all	Pelzerhaken	very low, soup			yes	low	
AL567_111_ANTON-0198	Pelzerhaken	low			yes	low	12k photos!
AL567_111_ANTON_0198_ editedphotos	Pelzerhaken				yes	low	might have munition, but very bad ortho, split in two parts
AL567_111_ANTON_0198_ editedphotos_part1	Pelzerhaken				yes	low	still bad
AL567_111_ANTON_0198_ editedphotos_part2	Pelzerhaken				yes	low	also not very good ortho
AL567_115_LUISE-0198	Pelzerhaken				yes	low, only small part	only lower right corner fotos aligned
AL567_128_LUISE-0199		no photos			no	NONE	
AL567_128_LUISE-0200		no photos			no	NONE	
AL567_131_LUISE-0201		no photos			no	NONE	
AL567_131_LUISE-0202		no photos			no	NONE	
AL567_131_LUISE-0203		no photos			no	NONE	
AL567_134_LUISE-0204a	Trollegrund	good			yes	low	
AL567_134_LUISE-0204b	Trollegrund	good			yes	medium	
AL567_134_LUISE-0204c	Trollegrund	good			yes	medium	
AL567_134_LUISE-0204d	Trollegrund				yes	low	
AL567_169_ANTON-0199a	Falshöft	no photos			no	NONE	only 3 photos from deck
AL567_169_ANTON-0199b	Falshöft	very good			yes	good	
AL567_169_ANTON-0199c	Falshöft	very good			yes	very good	transit
Mission	Area	Photoquality	objects	interesting image	Metashape processed	Metashape results	Comments

Mission	Area	Photoquality	objects	interesting image	Metashape processed	Metashape results	Comments
AL567_176_LUISE-0206g	Falshöft	no useful photos			no	NONE	only water column pictures
AL567_176_LUISE-0206f	Falshöft	good			yes	very good	transit, no munition visible
AL567_176_LUISE-0206e	Falshöft	good		009633 ff. (interesting), 010183 (munition)	yes	very good	might be munition in the center of the ortho
AL567_176_LUISE-0206d	Falshöft	good			yes	low	transit
AL567_176_LUISE-0206c	Falshöft	good			yes	very good	rocks, no munition visible
AL567_176_LUISE-0206b	Falshöft	good			yes	low	transit
AL567_176_LUISE-0206a	Falshöft				yes	very good	
AL567_170_LUISE-0205f	Falshöft				yes	good	no munition visible
AL567_170_LUISE-0205e	Falshöft			005235 ff. (munition)	yes	good	transit
AL567_170_LUISE-0205d	Falshöft				yes	good	no munition visible
AL567_170_LUISE-0205c	Falshöft				yes	good	transit
AL567_170_LUISE-0205b	Falshöft			000552 ff., 000956 ff., 000968 (interesting), 001040 ff., 001715 ff., 001768 ff., 002580 ff.	yes	very good	munition visible
AL567_170_LUISE-0205a	Falshöft	no photos			no	NONE	only 3 water column photos
AL567_169_ANTON-0199m	Falshöft	no photos			no	NONE	
AL567_169_ANTON-0199I	Falshöft	no photos			no	NONE	
AL567_169_ANTON-0199k	Falshöft	no photos			no	NONE	
AL567_169_ANTON-0199j	Falshöft	no photos			no	NONE	
AL567_169_ANTON-0199i	Falshöft	no photos			no	NONE	
AL567_169_ANTON-0199h	Falshöft	no photos			no	NONE	
AL567_169_ANTON-0199g	Falshöft	very good		5060 interesting	yes	good	
AL567 169 ANTON-0199f	Falshöft	very good			yes	good	transit
AL567_169_ANTON-0199e	Falshöft	very good		3727 ff.	yes	good	some munition, one very
AL567_169_ANTON-0199d	Falshöft	very good		2526 ff. (munition), 2988 ff. (interesting)	yes	good	

Mission	Area	Photoquality	objects	interesting image	Metashape processed	Metashape results	Comments
AL567_178-ANTON-0202q	Falshöft				yes	very good	munition on the lower right
AL567_178-ANTON-0202p	Falshöft			no	yes	very good	transit
AL567_178-ANTON-02020	Falshöft				yes	good	munition in the center
AL567_178-ANTON-0202n	Falshöft			no	yes	very good	transit
AL567_178-ANTON-0202m	Falshöft				yes	good	munition in the center
AL567_178-ANTON-0202I	Falshöft			no	yes	good	transit
AL567_178-ANTON-0202k	Falshöft				yes	good	something is in the center
AL567_178-ANTON-0202j	Falshöft				yes	good	transit
AL567_178-ANTON-0202i	Falshöft				yes	good	something is in the center
AL567_178-ANTON-0202h	Falshöft			no	yes	very good	transit
AL567_178-ANTON-0202g	Falshöft				yes	good	probably rocks
AL567_178-ANTON-0202f	Falshöft				yes	very good	transit
AL567_178-ANTON-0202e	Falshöft				yes	good	something anthropogenic in the center
AL567_178-ANTON-0202d	Falshöft			prominent rocks in center	yes	very good	transit
AL567_178-ANTON-0202c	Falshöft			munition in the center	yes	very good	munition
AL567_178-ANTON-0202b	Falshöft			algae or rocks on the left side?	yes	very good	transit
AL567_178-ANTON-0202a	Falshöft				yes	good	might be only rocks
AL567_177_ANTON-0201	Falshöft	no photos			no	NONE	
AL567_177_ANTON-0200	Falshöft	no photos			no	NONE	
AL567_176_LUISE-0206k	Falshöft	very good		017090 ff. (munition)	yes	very good	munition on the upper part
AL567_176_LUISE-0206j	Falshöft	good			yes	good	transit, one rock
AL567_176_LUISE-0206i	Falshöft	good		015038 ff. (probably munition), 015301 ff. (munition), 015461 ff. (munition), 015510 ff. (munition), 015554 ff., 015609 ff., 015761 ff.	yes	very good	lots of munition, mostly in upper part of ortho
AL567_176_LUISE-0206h	Falshöft	ok			yes	very good	transit

	1						
AL567_178-ANTON-0202r	Falshöft				yes	low	DEM might be okay, ortho does not look nice
AL567_178-ANTON-0202s	Falshöft				yes	good	might have some munition, not clearly distinguishable
AL567_178-ANTON-0202t	Falshöft				yes	very good	transit, but no munition
AL567_178-ANTON-0202u	Falshöft				yes	good	probably just rocks visible, but not sure
AL567_183-ANTON-0203	Falshöft				yes	very good	munition in the center
AL567_183-ANTON-0204	Falshöft				yes	very good	probably just rocks visible, but not sure
AL567_186-LUISE-0207a	Falshöft			munition	yes	good	
AL567_186-LUISE-0207b	Falshöft			no	yes	very good	transit
AL567_186-LUISE-0207c	Falshöft				yes	good	munition visible on two spots
AL567_186-LUISE-0207d	Falshöft			munition	yes	very good	transit, few photos but took long to process, munition!
AL567_186-LUISE-0207e	Falshöft				yes	low	lot of disturbance within the ortho, still munition at one site (lower left) pretty clear
AL567_186-LUISE-0207_01	Falshöft			munition upper left corner	yes	good	first dive canceled
AL567_186-LUISE-0207_02	Falshöft	no photos			no	NONE	first dive canceled, only 1 photo
AL567_187-ANTON-0205a	Falshöft	very good	munition		yes	very good	munition visible
AL567_187-ANTON-0205b	Falshöft	very good			yes	good	transit, nothing special observed
AL567_187-ANTON-0205c	Falshöft	very good		-	yes	good	no munition visible
AL567_192-ANTON-0206	Falshöft	no photos			no	NONE	no photos in raw folder
AL567_192-ANTON-0207	Falshöft	no photos			no	NONE	no photos in raw folder

# 11.4 Overall Station List

(Reduced navigation precision due to confidential position data.)

Area	Date & Time	Station	Latitude (deg)	Longitude (deg)	Depth (m)	Action	Comment
	10/18/2021 8:54	AL567_1-1_CTD	54.459	10.281	16	in the water	
	10/18/2021 9:55	AL567_2-1_MB	54.473	10.327	19	in the water	
	10/18/2021 10:19	AL567_2-3_SBP	54.472	10.326	18	in the water	
	10/18/2021 11:00	AL567_2-2_AUV A	54.473	10.327	19	in the water	Anton 181 & 182
	10/18/2021 11:55	AL567_2-4_AUV L	54.471	10.328	18	in the water	Luise 189
	10/18/2021 12:10	AL567_3-1_MB	54.469	10.334	15	profile start	
	10/18/2021 13:06	AL567_3-1_MB	54.472	10.328	19 18	profile end	
	10/18/2021 13:42 10/18/2021 14:13	AL567_4-1_AUV L AL567_5-1_AUV A	54.470 54.472	10.323 10.326	19	on deck on deck	
	10/18/2021 14:13	AL567_6-1_OFOS	54.472	10.341	16	in the water	
	10/18/2021 14:23	AL567 6-1 OFOS	54.467	10.327	13	on deck	
	10/18/2021 17:15	AL567_7-1_G-MAG	54.476	10.328	19	profile start	
-	10/19/2021 7:10	AL567_7-1_G-MAG	54.487	10.415	18	profile end	
	10/19/2021 8:08	AL567_8-1_MIC	54.472	10.363	19	in the water	
	10/19/2021 8:20	AL567_9-1_MIC	54.472	10.363	19	in the water	
	10/19/2021 8:38	AL567_10-1_AUV L	54.478	10.353	19	in the water	Luise 190a, b, c
ide	10/19/2021 9:13	AL567_11-1_CTD	54.477	10.365	19	in the water	
Kolberger Heide	10/19/2021 9:45	AL567_12-1_CTD	54.469	10.349	15	in the water	
rgel	10/19/2021 10:09	AL567_13-1_CTD	54.469	10.333	15	in the water	
le le	10/19/2021 10:52	AL567_13-2_CTD	54.469	10.334	15	in the water	CTD problems
8	10/19/2021 11:01	AL567_13-4_CTD	54.469	10.334	15	in the water	CTD problems
	10/19/2021 11:28	AL567_13-4_CTD	54.469	10.319	17	in the water	CTD problems
	10/19/2021 11:17	AL567_14-2_CTD	54.470	10.317	17	in the water	CTD problems
	10/19/2021 11:23	AL567_14-4_CTD	54.469	10.318	17	in the water	CTD problems
	10/19/2021 11:40	AL567_15-2_CTD	54.474	10.304	19	in the water	CTD problems
	10/19/2021 12:04	AL567_17-2_CTD	54.478	10.334	19 20	in the water	
	10/19/2021 12:34 10/19/2021 12:47	AL567_18-2_CTD AL567_19-2_MIC	54.490 54.490	10.334 10.334	20	in the water in the water	
	10/19/2021 12:47	AL567_19-2_IVIIC AL567_20-1_AUV L	54.477	10.345	19	on deck	
	10/19/2021 14:12	AL567_21-1_OFOS	54.478	10.358	19	in the water	
	10/19/2021 16:02	AL567_21-1_OFOS	54.478	10.337	19	on deck	
	10/19/2021 16:27	AL567_22-1_CTD	54.464	10.334	13	in the water	
	10/19/2021 16:48	AL567_23-1_CTD	54.460	10.333	12	in the water	
	10/19/2021 17:01	AL567_24-1_CTD	54.458	10.334	11	in the water	
	10/19/2021 17:19	AL567_25-1_CTD	54.459	10.318	8	in the water	
	10/19/2021 17:41	AL567_26-1_CTD	54.460	10.304	11	in the water	
	10/19/2021 18:11	AL567_27-1_CTD	54.460	10.349	11	in the water	
	10/19/2021 18:54	AL567_28-1_CTD	54.474	10.446	15	in the water	
	10/19/2021 19:44	AL567_29-1_CTD	54.393	10.557	14	in the water	
	10/19/2021 20:18	AL567_30-1_CTD	54.375	10.648	12	in the water	
	10/19/2021 20:47	AL567_31-1_CTD	54.394	10.710	18	in the water	
	10/19/2021 21:19	AL567_32-1_CTD	54.422	10.783	12 12	in the water	
	10/19/2021 22:16	AL567_33-1_CTD AL567_34-1_CTD	54.498	10.882 10.968	13	in the water	
	10/19/2021 23:00 10/19/2021 23:35	AL567_35-1_CTD	54.562 54.587	11.018	23	in the water in the water	
ransit	10/20/2021 0:38	AL567_36-1_CTD	54.572	11.229	29	in the water	
ran	10/20/2021 1:37	AL567_37-1_CTD	54.493	11.396	28	in the water	
F	10/20/2021 2:05	AL567_38-1_CTD	54.458	11.359	19	in the water	
	10/20/2021 2:39	AL567_39-1_CTD	54.392	11.371	22	in the water	
	10/20/2021 3:24	AL567_40-1_CTD	54.317	11.310	20	in the water	
	10/20/2021 3:34	AL567_40-1_CTD	54.316	11.312	21	in the water	
	10/20/2021 4:16	AL567_41-1_CTD	54.248	11.255	21	in the water	
	10/20/2021 4:50	AL567_42-1_CTD	54.196	11.216	20	in the water	
	10/20/2021 5:27	AL567_43-1_CTD	54.141	11.163	22	in the water	
	10/20/2021 6:06	AL567_44-1_CTD	54.120	11.055	15	in the water	
	10/20/2024 7 44	AL567_45 ?	E 4 0 4 5	10.022	10	in the	Luico 101 - L
	10/20/2021 7:41	AL567_46-1_AUV L	54.045	10.823	19	in the water	Luise 191a, b, c
1	10/20/2021 0:51	AL567_47 ?	54 042	10 820	19	profile start	
1	10/20/2021 9:51 10/20/2021 10:51	AL567_48-1_SBP AL567 48-1 SBP	54.043 54.045	10.828 10.835	19 19	profile start profile end	
	10/20/2021 10:31	AL567_49-1_3BP AL567_49-1_AUV L	54.043	10.824	19	on deck	
	10/20/2021 11:32	AL567_49-1_AUV L AL567_50-1_MIC	54.043	10.824	19	in the water	
56	10/20/2021 13:40	AL567_51-1_SBP	54.043	10.814	19	profile start	
- ķ	10/20/2021 15:14	AL567_51-1_SBP	54.047	10.829	19	profile end	
Haffkrug	10/20/2021 15:37	AL567_52-1_G-MAG	54.048	10.821	18	profile start	
] -	10/20/2021 21:53	AL567_52-1_G-MAG	54.047	10.821	18	profile end	
	10/20/2021 22:11	AL567_53-1_MB	54.057	10.833	19	profile start	
_	10/21/2021 5:21	AL567_53-1_MB	54.057	10.839	19	profile end	
	10/21/2021 7:54	AL567_54-1_MIC	54.053	10.835	19	in the water	
	10/21/2021 8:18	AL567_55-1_CTD	54.051	10.857	20	in the water	
	10/21/2021 8:27	AL567_56-1_CTD	54.050	10.858	21	in the water	
	10/21/2021 9:31	AL567_57-1_CTD	54.050	10.858	21	in the water	

Area	Date & Time	Station	Latitude (deg)	Longitude (deg)	Depth (m)	Action	Comment
Aicu	10/21/2021 10:01	AL567_58-1_CTD	54.067	10.913	22	in the water	comment
	10/21/2021 10:22	AL567_59-1_CTD	54.085	10.951	22	in the water	
	10/21/2021 10:45	AL567_60-1_CTD	54.109	10.992	22	in the water	
	10/21/2021 11:24	AL567_61-1_MIC	54.097	10.980	22	in the water	
	10/21/2021 11:47	AL567 62-1 OFOS	54.083	11.010	23	in the water	no on deck station
	10/21/2021 19:05	AL567 63-1 MB	54.100	10.975	21	profile start	
_	10/22/2021 7:42	AL567_63-1_MB	54.103	11.011	22	profile end	
	10/22/2021 7:57	AL567_64-1_CTD	54.090	11.012	22	in the water	
	10/22/2021 8:18	AL567_65-1_CTD	54.069	11.030	23	in the water	
	10/22/2021 8:24	AL567_65-2_CTD	54.069	11.031	22	in the water	
	10/22/2021 9:29	AL567_66-1_MB	54.065	11.007	22	profile start	
_	10/22/2021 14:07	AL567_66-1_MB	54.062	10.971	23	profile end	
Pelzerhaken	10/22/2021 14:51	AL567_67-1_G-MAG	54.083	10.978	22	profile start	
, r	10/23/2021 6:06	AL567_67-1_G-MAG	54.090	10.959	22	profile end	
elze	10/23/2021 6:40	AL567_68-1_AUV L	54.095	10.982	22	in the water	Luise 192
<u>~</u>	10/23/2021 6:55	AL567_69-1_AUV A	54.094	10.980	22	in the water	Anton 183 & 184
	10/23/2021 7:35	AL567_70-1_CTD	54.070	11.031	23	in the water	
	10/23/2021 8:03	AL567_71-1_CTD	54.048	11.044	24	in the water	
	10/23/2021 8:26	AL567_72-1_CTD	54.053	11.005	23	in the water	
	10/23/2021 9:43	AL567_73-1_AUV L	54.093	10.980	22	on deck	
	10/23/2021 9:59	AL567_74-1_AUV A	54.093	10.980	22	on deck	
	10/23/2021 10:42	AL567_75-1_AUV L	54.094	10.941	22	in the water	Luise 193a, b
	10/23/2021 10:49	AL567_76-1_AUV A	54.093	10.940	22	in the water	Anton 185, 186, 187,
	10/23/2021 11:43	AL567_77-1_OFOS	54.101	10.946	22	profile start	
	10/23/2021 12:43	AL567_77-1_OFOS	54.104	10.954	22	profile end	
	10/23/2021 13:16	AL567_78-1_AUV L	54.093	10.943	22	on deck	
	10/23/2021 13:37	AL567_79-1_AUV A	54.094	10.938	22	on deck	
	10/23/2021 14:48	AL567_80-1_CTD	54.037	10.803	17	in the water	
	10/23/2021 15:30	AL567_81-1_G-MAG	54.036	10.810	17	profile start	
	10/23/2021 21:35	AL567_81-1_G-MAG	54.031	10.821	19	profile end	
_	10/23/2021 22:16	AL567_82-1_MB	54.028	10.840	20	profile start	
	10/24/2021 6:07	AL567_82-1_MB	54.059	10.843	20	profile end	
	10/24/2021 12:04	AL567_83-1_AUV L	54.035	10.813	17	in the water	Luise 194
	10/24/2021 12:16	AL567_84-1_AUV A	54.034	10.814	18	in the water	Anton 189
	10/24/2021 12:49	AL567_85-1_OFOS	54.027	10.817	15	profile start	
	10/24/2021 13:02	AL567_85-1_OFOS	54.026	10.816	14	profile end	
	10/24/2021 13:15	AL567_85-1_OFOS	54.027	10.817	14	profile start	
	10/24/2021 14:00	AL567_85-1_OFOS	54.023	10.813	13 17	profile end	
	10/24/2021 14:31	AL567_86-1_AUV A	54.034	10.809	17	on deck	
	10/24/2021 14:56 10/24/2021 15:42	AL567_87-1_AUV L AL567_88-1_CTD	54.035 54.010	10.812 10.815	14	on deck in the water	
	10/24/2021 15:42	AL567_89-1_CTD	54.022	10.813	20	in the water	
	10/24/2021 10.30	AL307_83-1_CTD	34.022	10.878	20	in the water /	
<u>p0</u>	10/24/2021 17:15	AL567_90-1_CTD	54.035	10.816	19	towed	
Haffkrug						in the water /	
₽	10/24/2021 19:25	AL567_91-1_CTD	54.031	10.807	16	towed	
_	10/24/2021 21:04	AL567_92-1_MB	54.028	10.790	12	profile start	
-	10/25/2021 5:51	AL567_92-1_MB	54.031	10.805	17	profile end	
	10/25/2021 6:28	AL567_93-1_AUV L	54.031	10.813	17	in the water	Luise 195
	10/25/2021 6:55	AL567_94-1_AUV A	54.035	10.813	19	in the water	Anton 190, 191, 192,
	10/25/2021 8:25	AL567_95-1_OFOS	54.034	10.830	19	profile start	230, 131, 132,
	10/25/2021 9:24	AL567_95-1_OFOS	54.033	10.822	19	profile end	
	10/25/2021 9:53	AL567_96-1_AUV A	54.032	10.822	19	on deck	
	10/25/2021 10:11	AL567 97-1 AUV L	54.032	10.816	19	on deck	
	10/25/2021 11:14	AL567_98-1_AUV A	54.031	10.823	19	in the water	Anotin 195a, b, c
	10/25/2021 11:30	AL567_99-1_AUV L	54.032	10.825	19	in the water	Luise 196
	10/25/2021 13:31	AL567_100-1_OFOS	54.035	10.838	20	profile start	
	10/25/2021 14:06	AL567_100-1_OFOS	54.036	10.833	19	profile end	
	10/25/2021 14:30	AL567_101-1_AUV L	54.031	10.822	19	on deck	
	10/25/2021 14:42	AL567_102-1_AUV A	54.031	10.826	19	on deck	
	10/25/2021 15:04	AL567_103-1_SBP	54.043	10.827	20	profile start	
	10/25/2021 21:22	AL567_103-1_SBP	54.094	10.975	22	profile end	
>	10/25/2021 16:28	AL567_104-1_CTD	54.009	10.944	21	in the water	
Lübeck Bay	10/25/2021 17:35	AL567_105-1_CTD	54.031	10.921	13	in the water	
Š	10/25/2021 18:22	AL567_106-1_CTD	54.043	10.975	23	in the water	
ği	10/25/2021 19:02	AL567_107-1_CTD	54.018	11.006	23	in the water	
	10/25/2021 19:54	AL567_108-1_CTD	54.027	11.061	17	in the water	
	10/25/2021 22:06	AL567_109-1_MB	54.062	10.973	23	profile start	
_	10/26/2021 5:20	AL567_109-1_MB	54.057	10.972	24	profile end	<del></del>
	10/26/2021 6:29	AL567_110-1_AUV L	54.077	10.964	23	in the water	Luise 197a, b, c
	10/26/2021 6:46	AL567_111-1_AUV A	54.077	10.964	23	in the water	Anton 196, 197, 198
	10/26/2021 8:21	AL567_112-1_OFOS	54.087	10.944	22	profile start	

Area	Date & Time	Station	Latitude (deg)	Longitude (deg)	Depth (m)	Action	Comment
	10/26/2021 10:07	AL567_112-1_OFOS	54.080	10.962	22	profile end	
u <sub>0</sub>	10/26/2021 10:59	AL567_113-1_AUV L	54.078	10.958	22	on deck	
ake	10/26/2021 11:31	AL567_114-1_OFOS	54.082	10.973	21	in the water	
ë	10/26/2021 12:11	AL567_114-1_OFOS	54.082	10.972	22	on deck	
Pelzerhaken	10/26/2021 12:14	AL567_115-1_AUV L	54.081	10.972	22	in the water	Luise 198
_	10/26/2021 13:00	AL567_116-1_OFOS	54.083	10.964	22	profile start	
	10/26/2021 14:03	AL567_116-1_OFOS	54.081	10.955	22	profile end	
	10/26/2021 14:34	AL567_117-1_AUV L	54.082	10.972	22	on deck	
	10/26/2021 15:00	AL567_118-1_AUV A	54.084	10.956	22	on deck	
	10/26/2021 16:25	AL567_119-1_CTD	54.091	10.999	23	in the water / towed	
	10/26/2021 18:32	AL567_120-1_CTD	54.078	10.966	22	in the water	
	10/26/2021 21:25	AL567_121-1_CTD	54.042	11.141	25	in the water	
	10/26/2021 22:09	AL567_122-1_CTD	54.063	11.231	20	in the water	
Transit	10/26/2021 22:56	AL567_123-1_CTD	54.103	11.372	16	in the water	
<u> </u>	10/26/2021 23:38	AL567_124-1_CTD	54.157	11.499	21	in the water	
	10/27/2021 0:25	AL567_125-1_CTD	54.239	11.592	25	in the water	
	10/27/2021 0:31	AL567_125-2_CTD	54.239	11.593	25	in the water	
	10/27/2021 1:08	AL567_126-1_MB	54.215	11.652	27	in the water	
	10/27/2021 1:23	AL567_126-1_MB	54.215	11.658	26	profile start	
	10/27/2021 3:44	AL567_126-1_MB	54.212	11.671	26	profile end	
	10/27/2021 4:18	AL567_127-1_MB	54.187	11.673	20	profile start	
	10/27/2021 5:26	AL567_127-1_MB	54.186	11.673	19	profile end	
	10/27/2021 6:04	AL567_128-1_AUV L	54.214	11.664	26	in the water / iBox	Luise 199, 200
	10/27/2021 7:11	ALS67 120 1 OFOS	54 214	11 665	26	Navigation Test	
	10/27/2021 7:11 10/27/2021 7:48	AL567_129-1_OFOS AL567_129-1_OFOS	54.214 54.214	11.665 11.665	26 26	in the water on deck	
	10/27/2021 7:48	AL567_130-1_AUV L	54.214	11.661	26	on deck	
2	10/2//2021 7.59	AL307_130-1_A0V L	34.214	11.001	20	in the water / iBox	
Trollegrund	10/27/2021 8:20	AL567_131-1_AUV L	54.213	11.663	26	Navigation Test	Luise 201, 202, 203
€	10/27/2021 8:46	AL567_132-1_OFOS	54.213	11.663	26	in the water	
F	10/27/2021 9:25	AL567_132-1_OFOS	54.213	11.664	26	on deck	
	10/27/2021 9:51	AL567_133-1_AUV L	54.213	11.664	26	on deck	
	10/27/2021 10:26	AL567_134-1_AUV L	54.185	11.683	21	in the water	Luise 204a, b, c, d
	10/27/2021 10:48	AL567_135-1_OFOS	54.184	11.685	20	in the water	
	10/27/2021 11:57	AL567_135-1_OFOS	54.178	11.676	17	on deck	
	10/27/2021 13:50	AL567_136-1_AUV L	54.185	11.682	20	on deck	
	10/27/2021 14:09	AL567_137-1_MIC	54.176	11.673	13	in the water	
	10/27/2021 14:12	AL567_137-2_MIC	54.176	11.673	13	in the water	
	10/27/2021 14:26	AL567_138-1_SBP	54.178	11.670	13	profile start	
	10/27/2021 15:01	AL567_138-1_SBP	54.174	11.679	14	profile end	
	10/27/2021 15:50	AL567_139-1_MIC	54.253	11.741	25	in the water	
	10/27/2021 16:15	AL567_140-1_CTD	54.253	11.740	25	in the water	
	10/27/2021 17:21	AL567_141-1_CTD	54.263	11.988	17	in the water	
	10/27/2021 18:03	AL567_142-1_CTD	54.285	12.078	18	in the water	
	10/27/2021 18:51	AL567_143-1_CTD	54.344	12.153	18	in the water	
	10/27/2021 19:23	AL567_144-1_CTD	54.388	12.112	21	in the water	
	10/27/2021 20:07	AL567_145-1_CTD	54.366	11.972	17	in the water	
ısit	10/27/2021 20:56	AL567_146-1_CTD	54.361	11.801	23	in the water	
Transit	10/27/2021 21:57	AL567_147-1_CTD	54.408	11.591	25 26	in the water	
	10/27/2021 22:41	AL567_148-1_CTD	54.462 54.545	11.486	26 29	in the water	
_	10/27/2021 23:50 10/28/2021 0:48	AL567_149-1_CTD	54.545 54.594	11.342 11.147	29 28	in the water	
	10/28/2021 0:48	AL567_150-1_CTD AL567 151-1 CTD	54.594 54.580	10.867	28 20	in the water	
	10/28/2021 2:36	AL567_151-1_CTD AL567_152-1_CTD	54.550 54.557	10.772	23	in the water	
	10/28/2021 2:36	AL567_152-1_CTD AL567_153-1_CTD	54.537 54.532	10.772	23	in the water	
	10/28/2021 3:41	AL567_154-1_CTD	54.535	10.587	16	in the water	
	10/28/2021 4:18	AL567_155-1_CTD	54.511	10.475	16	in the water	
o o	10/28/2021 4:18	AL567_156-1_CTD	54.469	10.348	15	in the water	
eid	10/28/2021 5:12	AL567_157-1_CTD	54.460	10.348	12	in the water	
F.	10/28/2021 5:26	AL567_158-1_CTD	54.458	10.334	11	in the water	
rge	10/28/2021 5:43	AL567_159-1_CTD	54.464	10.333	12	in the water	
Kolberger Heide	10/28/2021 6:05	AL567_160-1_CTD	54.460	10.318	9	in the water	
8	10/28/2021 6:21	AL567_161-1_CTD	54.470	10.317	18	in the water	
	10/28/2021 7:06	AL567_162-1_CTD	54.550	10.399	18	in the water	
	10/28/2021 7:38	AL567_163-1_CTD	54.596	10.314	16	in the water	
±	10/28/2021 8:18	AL567_164-1_CTD	54.651	10.217	20	in the water	
Transit	10/28/2021 8:52	AL567_165-1_CTD	54.709	10.151	25	in the water	
	10/28/2021 9:33	AL567_166-1_CTD	54.767	10.028	28	in the water	
-	10/20/2021 9.33	AL307_100-1_CTD	34.707			tile water	
-	10/28/2021 10:07	AL567_167-1_CTD	54.815	9.940	26	in the water	

10/28/2021 12:21						
10, 20, 2021 12:21	AL567_169-1_AUV A	54.723	10.087	18	in the water	Anton 199a, b, c, d, e, f,
						g, h, i, j, k, l, m
10/28/2021 12:31	AL567_170-1_AUV L	54.723	10.086	18	in the water	Luise 205a, b, c, d, e, f
10/28/2021 13:03	AL567_171-1_OFOS	54.722	10.090	17	profile start	
					•	
			10.087			
			10.086			
10/28/2021 15:44	AL567_174-1_MB	54.714	10.086			
	AL567_174-1_MB				•	
10/29/2021 4:50	AL567_175-1_MIC	54.721	10.089	16	in the water	
10/29/2021 4:57	AL567_175-2_MIC	54.721	10.089	16	in the water	
10/29/2021 5:02	AL567_175-3_MIC	54.721	10.089	16	in the water	
10/29/2021 5:06	AL567_175-4_MIC	54.721	10.089	16	in the water	
10/20/2021 5:55	ALEGT 176 1 ALIVI	E / 721	10.000	16	in the water	Luise 206a, b, c, d, e, f,
10/29/2021 5.55	AL307_170-1_AUV L	34.721	10.069	10	iii tile watei	g, h, i, j, k
10/29/2021 6:11	AL567_177-1_AUV A	54.721	10.089	16	in the water	Anton 200, 201
10/29/2021 6:58	AL567_177-1_AUV A	54.721	10.089	16	on deck	
						Anton 202a, b, c, d, e, f,
10/29/2021 7:07	AL567_178-1_AUV A	54.722	10.089	16	in the water	g, h, i, j , k, l, m , n, o, p,
						q, r, s, t, u
10/29/2021 8:19	AL567_179-1_OFOS	54.731	10.066	19	profile start	
10/29/2021 8:43	AL567_179-1_OFOS	54.729	10.066	17	profile end	
10/29/2021 9:16	AL567_179-1_OFOS	54.729	10.066	17	profile start	
10/29/2021 11:09	AL567_179-1_OFOS	54.718	10.067	14	profile end	
10/29/2021 11:50	AL567_180-1_AUV L	54.721	10.085	17	on deck	
10/29/2021 12:02	AL567_181-1_AUV A	54.723	10.085	18	on deck	
10/29/2021 13:09	AL567_182-1_MB	54.723	10.051	13	profile start	
10/29/2021 13:57	AL567_182-1_MB	54.723	10.051	13	profile end	
10/29/2021 14:20	AL567_183-1_AUV A	54.721	10.067	14	in the water	Anton 203
10/29/2021 15:23	AL567_184-1_AUV A	54.721	10.067	14	on deck	
10/29/2021 16:40	AL567_185-1_MB	54.726	10.049	13	profile start	
10/30/2021 5:27	AL567_185-1_MB	54.731	10.069	20	profile end	
10/30/2021 6:10	AL567_186-1_AUV L	54.721	10.070	14	in the water	Luise207a, b, c, d, e; 207 01, 02
10/30/2021 6:37	AL567 187-1 AUV A	54.721	10.070	14	in the water	Anton 205a, b, c
		54.719	10.068	14	profile start	
		54.714	10.062	12	•	
				15	on deck	
			10.067	15	on deck	
			10.085	18	profile start	
				17	profile end	
				17	in the water	Anton 206, 207
						,
					•	
					•	
10/30/2021 20:08	AL567_200-1_CTD	54.459	10.335	12	•	
10/30/2021 22:34	AI 567 201-1 MR	54 474	10 362	19		
10/30/2021 22:34	AL567_201-1_MB	54.479	10.315	19	profile start	
	10/29/2021 4:30 10/29/2021 4:50 10/29/2021 4:57 10/29/2021 5:02 10/29/2021 5:06 10/29/2021 5:55 10/29/2021 6:58 10/29/2021 6:58 10/29/2021 8:43 10/29/2021 8:43 10/29/2021 9:16 10/29/2021 11:50 10/29/2021 12:02 10/29/2021 13:57 10/29/2021 13:57 10/29/2021 13:57 10/29/2021 16:40 10/30/2021 5:27 10/30/2021 6:10 10/30/2021 6:37 10/30/2021 6:37 10/30/2021 10:00 10/30/2021 10:00 10/30/2021 12:21 10/30/2021 12:21 10/30/2021 13:37 10/30/2021 15:56 10/30/2021 10:00 10/30/2021 12:21 10/30/2021 13:17 10/30/2021 13:58 10/30/2021 15:58 10/30/2021 15:58 10/30/2021 15:58 10/30/2021 17:11 10/30/2021 19:28	10/28/2021 14:58 10/28/2021 15:01 10/28/2021 15:01 10/28/2021 15:04 10/28/2021 15:04 10/29/2021 4:50 10/29/2021 4:50 10/29/2021 5:02 10/29/2021 5:06 10/29/2021 5:05 10/29/2021 5:55 10/29/2021 6:58 10/29/2021 6:58 10/29/2021 6:58 10/29/2021 7:07 10/29/2021 8:43 10/29/2021 8:43 10/29/2021 8:43 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/29/2021 1:09 10/30/2021 1:09 10/30/2021 1:09 10/30/2021 1:09 10/30/2021 1:09 10/30/2021 1:09 10/30/2021 1:09 10/30/2021 1:09 10/30/2021 1:09 10/30/2021 1:09 10/30/2021 1:09 10/30/2021 1:09 10/30/2021 1:09 10/30/2021 1:09 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00 10/30/2021 1:00	10/28/2021 14:58	10/28/2021 14:58	10/28/2021 14:58	10/28/2021 14:58