RV LITTORINA L13-20

Cruise Report

04. – 11.07.2020

Chief Scientist:

Mareike Kampmeier
GEOMAR Helmholtz Centre for Ocean Reasearch Kiel

1. Participants

Table 1: Scientific crew

Name	Function	Institution
Mareike Kampmeier	Chief Scientist	GEOMAR Helmholtz Centre for Ocean Research Kiel
José Felipe Barradas	PhD student	VLIZ*
Thomas Mestdagh	Scientist	VLIZ*
** Flanders Marine Institute, Belgium*		

2. Objectives of the Cruise

The objective of the cruise was to locate dumped chemical and conventional munition in dumping grounds around Helgoland in the North Sea.

More specifically the objectives were:

- Mapping dumping grounds with high resolution multibeam (MBES) and identify munition locations on the seafloor
- Evaluating the MBES RESON SeaBat T50 *Extended Range* for enhanced munition detection
- Mapping dumping grounds with sediment echosounder (SES) to learn the sedimentary and geologic background of the areas
- Mapping munition locations with high resolution SES to detect buried munition an create 3D dataset
- Taking water samples for TNT analyses

3. Introduction

More than 1.6 million tons of chemical and conventional munitions are remaining in German territorial waters. These are either unexploded ordnances (UXO) from direct war actions or dumped munitions after the war had ended. Even though locations of dumpsites are known, knowledge about their real extent underwater, exact positions and numbers of munitions is rather incomplete. Munitions in the sea are not only a risk for offshore industries, but also for fishery, coastal tourism, and marine food consumers. Whereby the risk of explosion is rated as rather low (apart from offshore construction sites), carcinogenic TNT is leaking out and is taken up by the marine environment (Beck et al., 2018; Strehse et al., 2017). The effect of TNT and its metabolites inside the food chain is subject of ongoing research. Within the UDEMM project (2016-2019) methods for monitoring dumpsites have been developed and evaluated.

The 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) project started in December 2019 and is funded by the European Maritime and Fisheries Fund (EMFF) of the European Union in the "Blue Labs" program. It aims for increasing the accuracy and cost-efficiency of munition detection methods on local and larger scale. Therefore, advanced data-acquisition such as ultra-high-resolution 3D sub-bottom profiling (SBP), intelligent autonomous underwater vehicle (AUV) based magnetic mapping will be combined with high-resolution multibeam mapping. A multi-sensor database enables sustainable use of survey data and automated data analysis.

During cruise L13-20, two dumpsites around Helgoland were targeted to be mapped with SBP, MBES and magnetics. Due to Corona regulations, and resulting restrictions on staff on board, the towed magnetic could not be performed. Since the GIRONA 500 AUVs from GEOMAR are not capable to work against tidal currents, no AUV for magnetic and optical data acquisition was taken on board.

4. Research Area

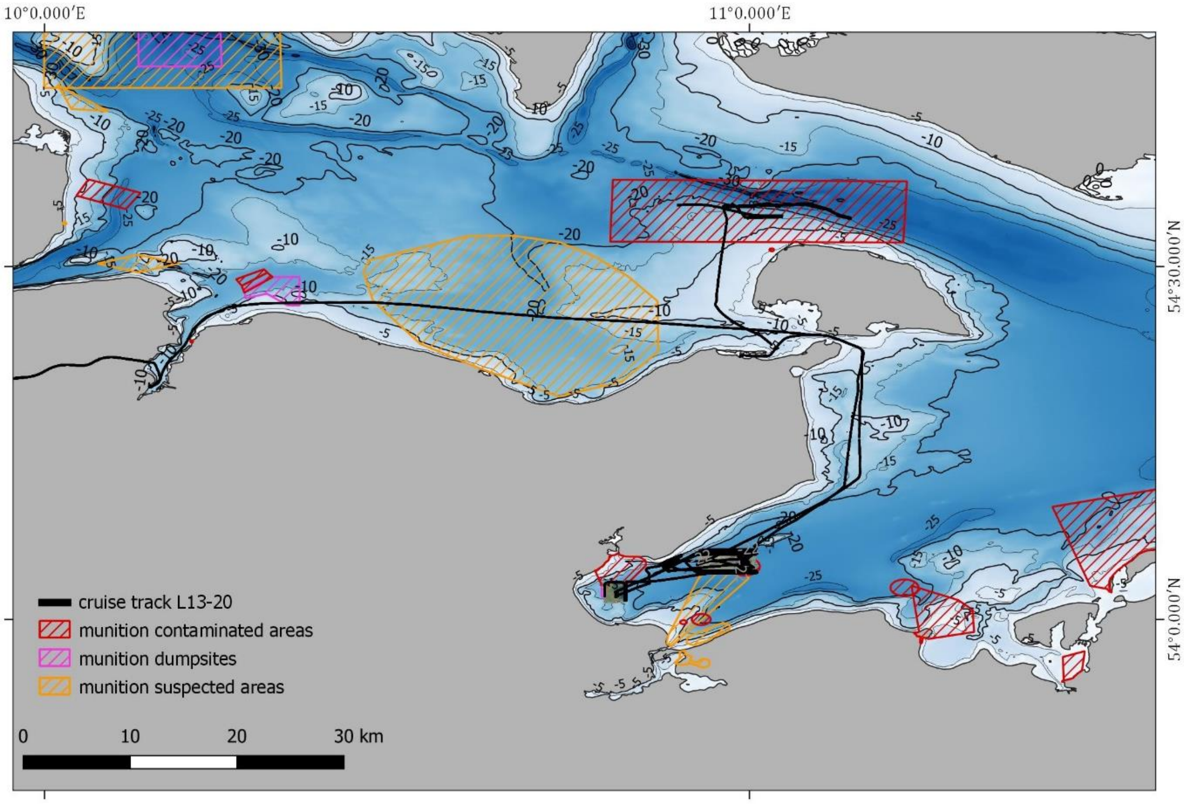

Figure 1: Overview map of the working area of cruise L13-20. The black line shows the cruise track.

Due to very bad weather conditions in the North Sea (< 1.5 m waves, NW winds) the research program had to be changed. The same objectives were then reached inside Lübeck Bay in the Baltic Sea. This area has been previously mapped during POS530 (2018). Within L13-20, gaps could be filled, additional sub seafloor data could be gained, and the increased MBES performance could be evaluated based on known targets. Additionally, areas of interest could be mapped for the MELUND north-west of Fehmarn.

Lübeck Bay in general

A later German document from Civil-EOD descript the area and shows a complete number of dumped Ammunition with 60 000 tons, 50 000 tons in dumpsite BLB50L and 10 000 tons in Haffkrug-area. In time 1950-1960, a civil company recovered nearly 15 000 tons of different kinds Ammunition (mostly bombs and heavy artillery shells). But 45 000 tons ore more, are still at sea (Böttcher et al., 2011).

Beginning from 1rst December 1945, the ammunitions were transported by trains to Lübeck Schlutup, loaded from trains to Hubber-barges and were sent in the dumping areas.

Lübeck Bay – Pelzerhaken

Within the area of Pelzerhaken, sea mines and phosphor grenades are suspected. This area is very shallow (12-5 m) and has not been mapped with high-resolution MBES so far.

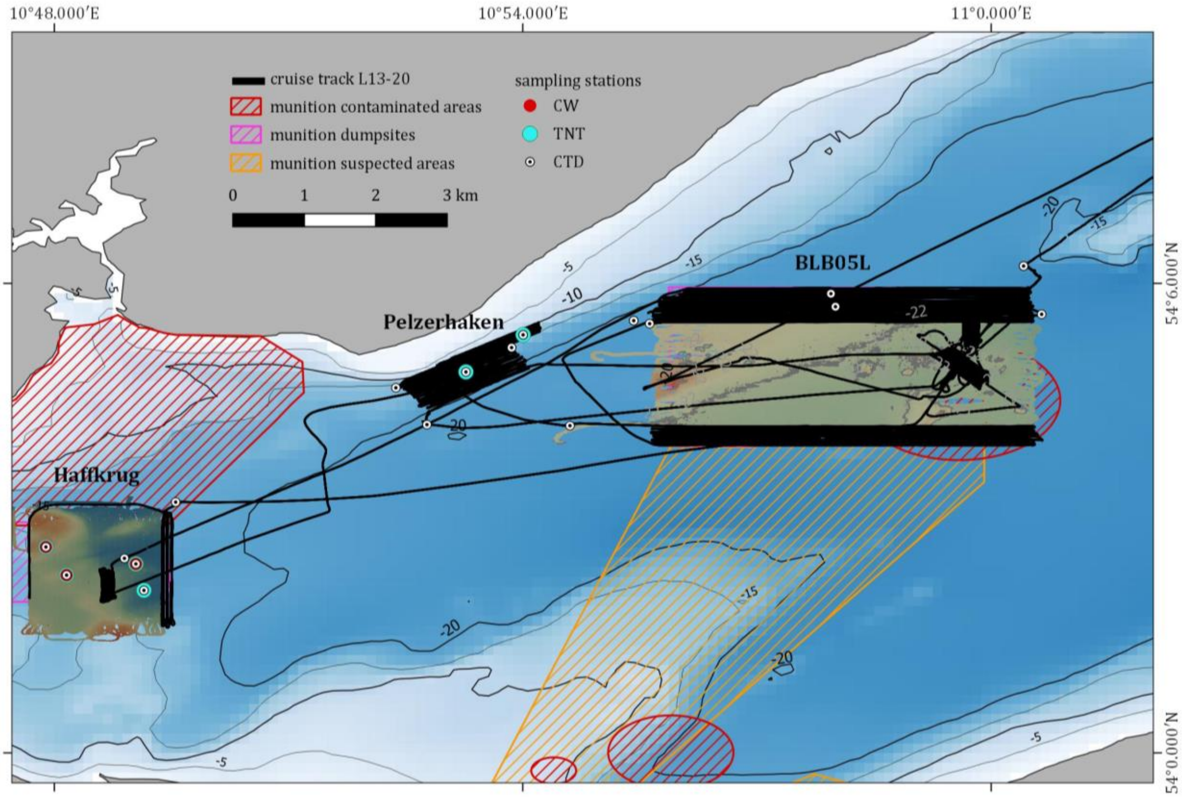

Figure 2: Map of working area in Lübeck Bay. The black cruise track indicates mapped areas during L13-20. MBES maps of Haffkrug and BLB05L were conducted on POS530 in 2018. Sampling stations for CTD, TNT and CW (chemical warfare agents) are color-coded as shown in the legend.

Lübeck Bay – BLB50L

The dumpsite BLB05L in Lübeck Bight is a mainly flat area of 18-22 m water depth. During POS530 the area was already almost fully mapped (figure 2). In the east of the area occurs a sediment-dumping ground where toxic blast furnace slag was dumped. It extends around 3.5 m above the seafloor with terraces of 1 m height. Additionally, a number of ca 100 suspicious objects was detected in 2018 and at least one pile of mines and grenades was validated inside underwater video footage (Kampmeier et al., 2018).

During L13-20 the area could be mapped further to the north and south in order to cover the whole extent as indicated on navigation charts.

Lübeck Bay– Haffkrug

The second area in Lübeck Bight is dominated by silt to fine sand on top of mud. Towards the east the sediment becomes coarser and sandier. One grab sample also had stones inside, mixed with mud. In the MBES data nine mounds of not definable composition could be detected. Diver and AUV footage show that at least two of these mounds are composed of hundreds of munition boxes, filled with grenades (Kampmeier, et al., 2018). As during POS530 only the central area was mapped, the eastern and western boundaries could be extended during L13-20 (figure 2).

Fehmarn Belt

Groundmines were blasted during the NATO manoeuvre “Northern Coast” in 2019. The blasting locations should now be mapped to evaluate the state of the seafloor and in order to detect munition remnants, if still present (figure 3).

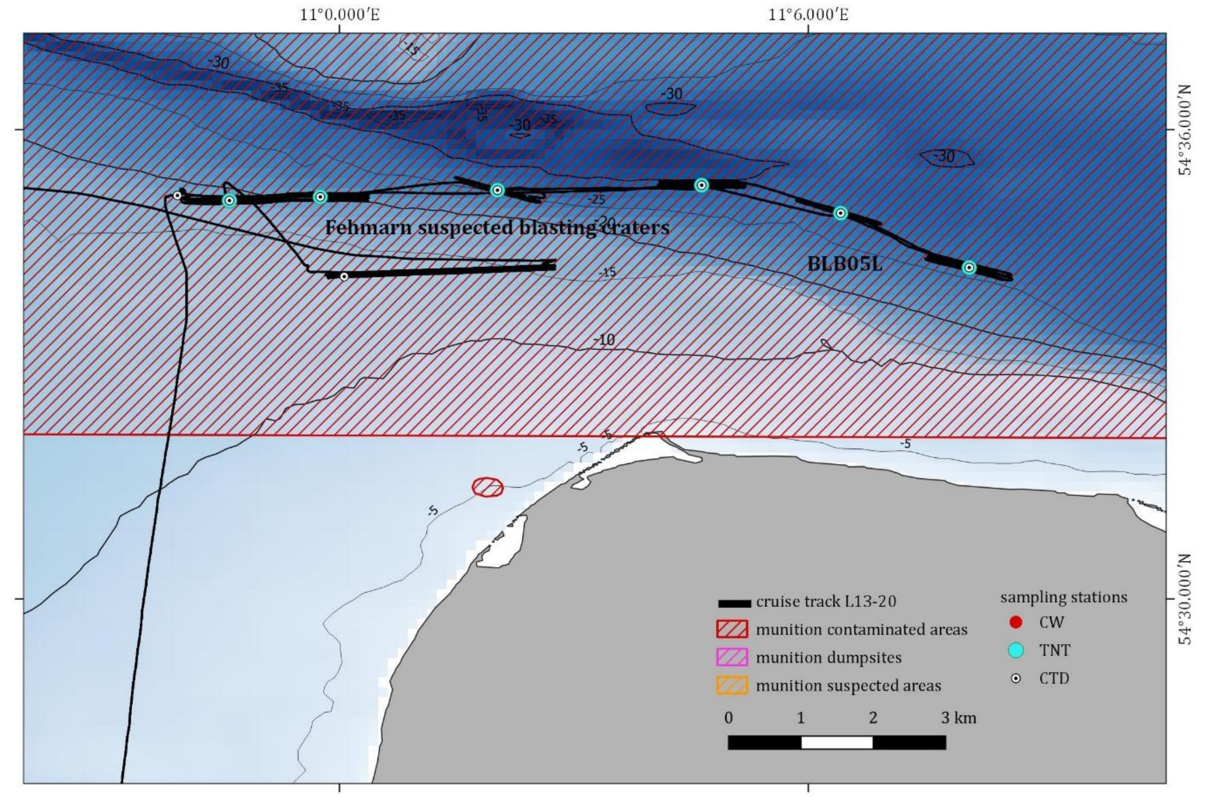

Figure 3: Map of working area in Lübeck Bay. The black cruise track indicates mapped areas during L13-20. stations for CTD, and TNT are color-coded as shown in the legend.

5. Methods and Devices

MBES

For high-resolution seafloor mapping, a RESON Seabat T50 Extended Range had been used on the ELAC pole on starboard side. This MBES was rented from the company MacArtney Germany and financed by the MELUND SH. It allows high-resolution data also in water depths more than 20 m, which is necessary to detect munition objects. The navigation done by two Septentrio DGPS antennas and supporting RTK via NTRIP. Motion correction was applied using the SBG Apogee motion sensor. Acquisition software was QinsY from QPS. The data are referenced to the geoid model GCG2005 and recorded as UTM32N.

Table 2: Specification RESON T50 Extended Range.

Frequency	400 kHz
Across-track beam width	0.5°
Along-track beam width	0.5°
Number of beams	10-1024
Swath angle	10-165°

SBP

The Innomar SES-2000 quattro multi-transducer SBP is owned by VLIZ and was mounted portside of FK LITTORINA. It is composed of four transducers in across-track direction, which can be used in different modes, such as single beam mode and quad beam mode.

Table 3: Specification INNOMAR SES-200.

Single beam mode	
PF source level / acoustic power	>245 dB / µPa re 1m / ~4 kW
Transmit beam width (-3 dB)	ca ±1.5° for all frequencies

Water depth range	1 – 500 m
Sediment penetration	up to 50 m*
Ping rate	up to 60 pings/s
Quad beam mode	
PF source level / acoustic power	>235 dB / μPa re 1m / ~2 kW
Transmit beam width (-3 dB)	ca ±2.5° for all frequencies
Water depth range	0.5 – 30 m
Sediment penetration	up to 20 m*
Ping rate	up to 15 pings/s per transducer

** Depending on sediment type and noise level*

TNT water sampling

At each station two water samples in two different heights were taken (surface and 2 m above seafloor). For each sample 1 l of seawater was filled into a urine bag and was spiked with 20 ml TNT solution. The sample was then hanged up and let drip through a resin filter. Once the water sampled was completely dripped through, the filter was wrapped in aluminium foil and stored inside a fridge (ca 6 °C).

CTD

Parallel to every water sample, a CTD profile was taken via a Sea and Sun Technologies CTD. It records pressure, temperature, conductivity and calculates resulting sound velocities. SRD files have been transformed to ASCII *.TOB files.

6. Cruise Narrative

Date	Time	Area	Action	Remark
2020-07-04	10:30	NOK	Transit	transit to Cuxhaven
	20:30	Cuxhaven	Port	arrival Cuxhaven
2020-07-05	10:00	NOK	Transit	transit to Kiel
	21:00	Kiel	Port	arrival Kiel
2020-07-06	4:00	Kiel-Lübeck Bay	Transit	transit to Lübeck Bay
	11:00	BLB50L	Calibration	MBES calibration profiles
	12:40	Pelzerhaken	Mapping	MBES + SBP
	22:15	BLB05L	Mapping	MBES + SBP
2020-07-07	4:15	BLB05L	Mapping	MBES + SBP
	9:05	BLB05L to Haffkrug	Transit	MBES + SBP
2020-07-08	2:05	Haffkrug	Mapping	MBES + SBP
	10:00	Haffkrug	Water sampling	TNT
	12:30	Pelzerhaken	Mapping	MBES + 3D SBP
	16:30	Pelzerhaken	Water sampling	TNT
	18:05	BLB05L	Mapping	MBES + SBP
2020-07-09	5:10	Haffkrug	Mapping	MBES + SBP
	8:05	Transit	Mapping	transit
	10:10	BLB05L	Mapping	MBES + SBP
	14:00	BLB05L	Water sampling	TNT
	15:10	BLB05L to Heiligenhafen	Transit	transit to Heiligenhafen
	18:30	Heiligenhafen	Port	arrival Heiligenhafen
2020-07-10	5:30	Transit	Tranist	transit to Fehmarn
	8:06	Fehmarn	Mapping	MBES + SBP
	14:24	Fehmarn	Water sampling	TNT

	17:35	Fehmarn	Mapping	MBES + SBP
	20:30	Fehmarn-Kiel	Transit	waves > 1.3 m
2020-07-11	00:30	Kiel	Port	arrival Kiel

7. Preliminary Results

During the cruise L13-20 more than 250 nmi of mapping profiles were conducted. Three research areas in Lübeck Bay (Pelzerhaken, BLB50L and Haffkrug) were mapped, respectively existing mapping could be extended (Figure 2). Unfortunately, it was not possible to fully map the area of Pelzerhaken, due to extensive ground net fishing.

Nevertheless, the dumpsites of BLB50L and Haffkrug were completed and the lateral and vertical extent of the furnace slag dumping ground was achieved by dense SBP profiles.

The increased performance of the MBES RESON T50 *Extended Range* could be compared on known targets from POS530 (mapped with RESON T50-P). Therefore, two sites were repeatedly mapped with different settings. First results clearly show improved resolution of targets on the seafloor, but it turned out quickly, that full coverage mapping with ultra-high-resolution settings significantly increase file sizes (500 m profile, 120° swath, 1024 beams, ca 2 GB). It is rather recommended to map wide areas in lower resolution (120° swath, 600 beams) and do detailed mapping (with 1024 beams) on suspicious targets only. These detailed surveys then provide more exact information about shape and number of objects (e.g. munition boxes in Haffkrug area).

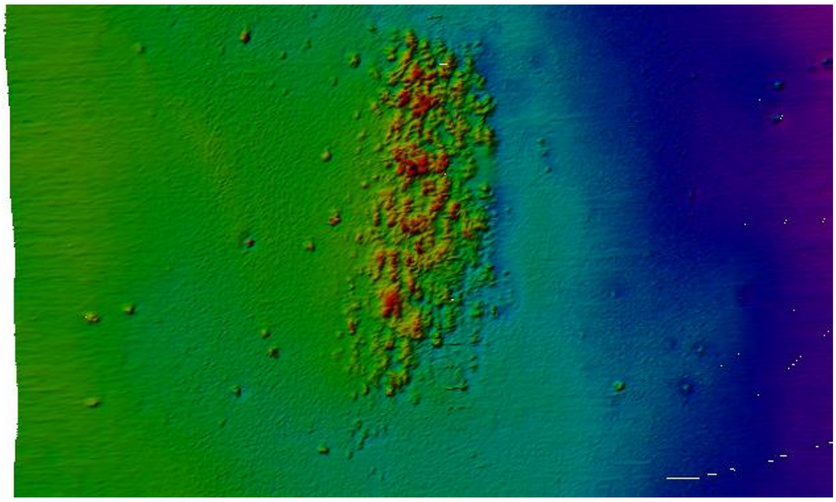

Figure 4: Pile of munition boxes, recorded with 120° swath and 1024 beams. Pixel resolution: 10 cm; footprint: 48 m

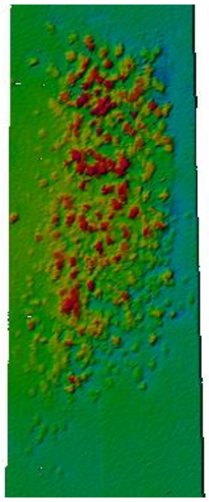

Figure 5: Pile of munition boxes, recorded with 120° swath and 1024 beams. Pixel resolution: 7 cm; footprint: 7.6 m

Comparing the resulting data reveals that there is no great enhancement whether 120° swath + 1024 beams or 30° swath + 1024 beams are used. The along-track resolution does not increase within the same extent (figure 5).

Table 4: MBES resolution depending on swath opening angle.

Swath	Across-track resolution	Along-track resolution	Footprint
120°	0.048 m	0.092	48 m
30°	0.008 m	0.06	7.6 m

In fact, the increase of grid cell resolution about 2 cm (in 16.90 m water depth) by using 30° swath, does not compensate for the limited footprint on the seafloor (Table 4). Therefore 120° swath and 1024 beams seem to be good settings for detailed surveys.

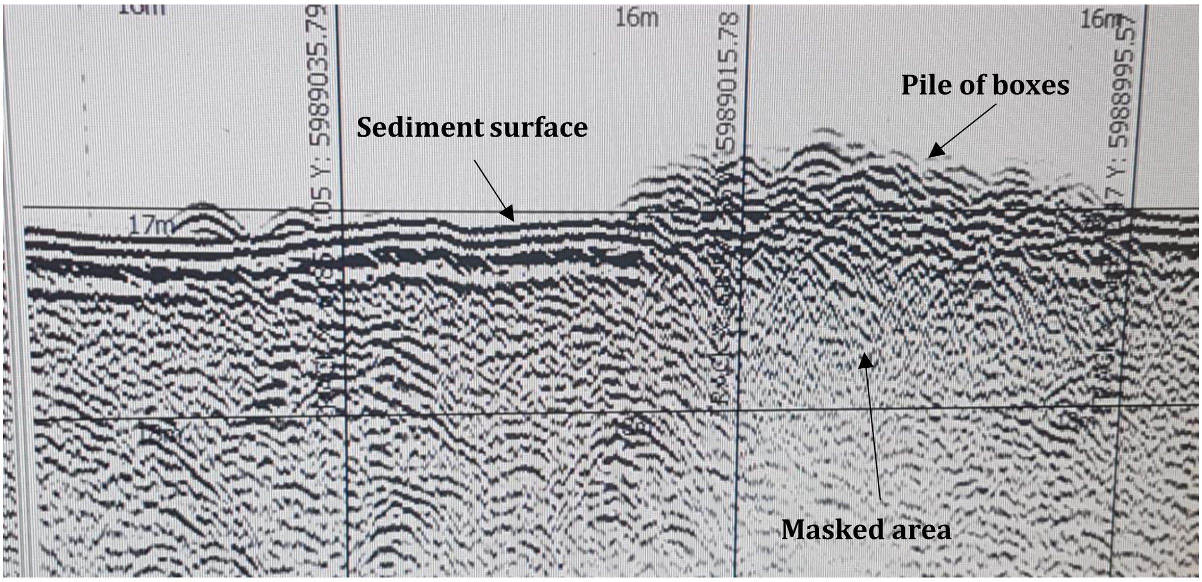

Figure 6: SBP image of the pile of munition boxes. It seems that the boxes are mainly resting on the sediment and not within. Sediment below the boxes is masked.

In BLB50L at least one more pile of scattered objects was found. Last proof must be given by groundtruth methods, e.g. AUV photo surveys.

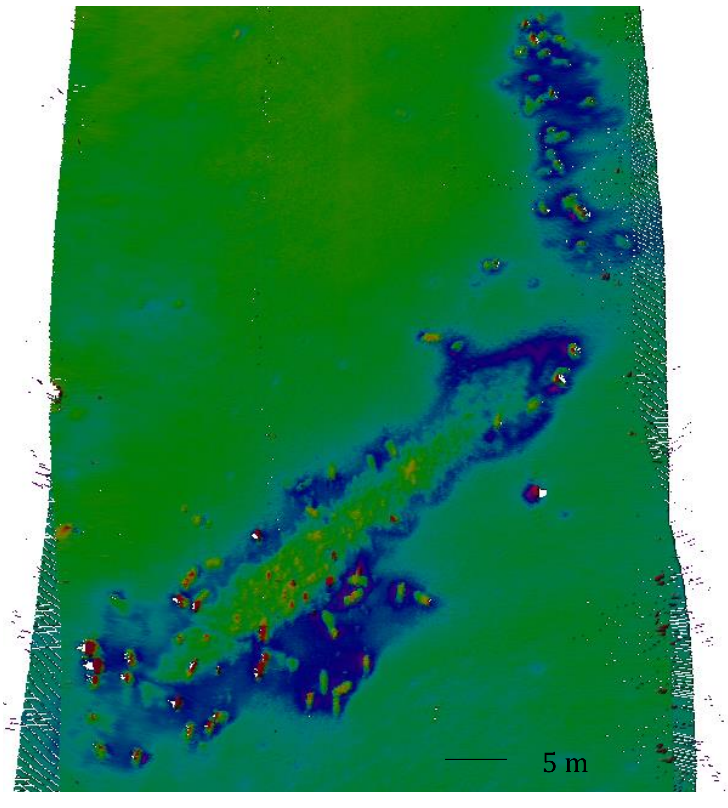

Figure 7: Pile of dumped munition, with scattered objects of ca 3 m length.

The blasting locations in Fehmarn Belt were mapped with dense profile spacing (figure 3). First results do not clearly show detonation craters. Because the area is characterized by high sedimentary mobility due to increase currents and resulting mega ripples (figure 8), it is likely that craters are not long lasting within this regime.

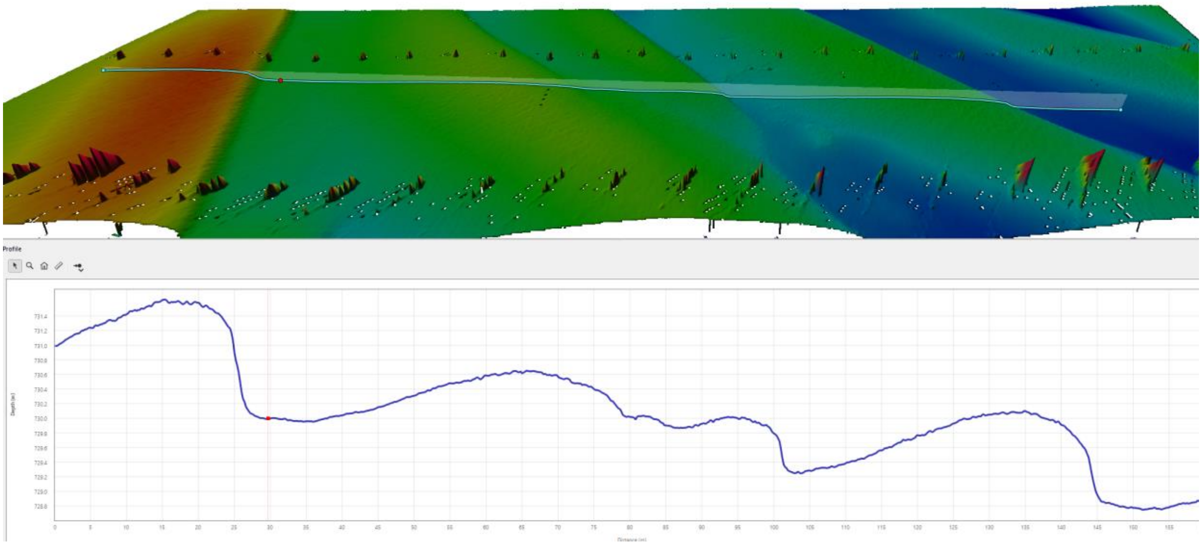

Figure 8: Mega ripples in the Fehmarn Belt. Ripple heights of up to 1.6 m can occur. Unprocessed data, artefacts due to SBP interferences still present.

8. Acknowledgements

Thanks goes to the crew and master of FK LITTORINA for the excellent cruise. We would also like to thank BRIESE RESEARCH for making research cruises possible, also in 'Corona-times'. The MBES rent was financed by the MELUND SH and installation and support were reliably done by MacArtney Germany. The cruise was performed as part of the European funded project BASTA ([863702] — [BASTA] — EMFF-2018-1.2.1.7).

9. References

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10. Appendix

I. Stationlist

Date	Time	Area	Action	Name	Remark	Long	Lat
2020-07-04	10:30	NOK	Transit		transit to Cuxhaven		
2020-07-04	20:30	Cuxhaven	Port		bad weather on North Sea, no improvement forecasted for the week (2.5m waves at Wangerooge, westerly wind)		
2020-07-05	10:00	NOK	Transit		transit to Kiel		
2020-07-05	21:00	Kiel	Transit		arrival Kiel		
2020-07-06	4:00	Transit	Transit		transit to Lübeck Bay		
2020-07-06	10:00	BLB50L	Transit		arrival Lübeck Bay		
2020-07-06	10:12	BLB50L	CTD	L13-20_CTD01	Valeport and SST	11.0069383	54.1037100
2020-07-06	11:00	BLB50L	Calibration		MBES calibration profiles		
2020-07-06	12:30	BLB50L	CTD	L13-20_CTD02	Valeport and SST	10.8795550	54.0699200
2020-07-06	12:40	Pelzerhaken	Mapping		MBES and SBP; ground fishing nets in centre of planned area		
2020-07-06	17:00	Pelzerhaken	CTD	L13-20_CTD03	Valeport and SST	10.8976267	54.0863283
2020-07-06	17:10	Pelzerhaken	Mapping		continue Pelzerhaken profiles S		
2020-07-06	19:30	Pelzerhaken	CTD	L13-20_CTD04	Valeport and SST	10.8729183	54.0777717

2020-07-06	19:35	Pelzerhaken	Mapping		continue Pelzerhaken profiles S		
2020-07-06	22:08	Pelzerhaken	CTD	L13-20_CTD05	Valeport and SST	10.9100917	54.0696967
2020-07-06	22:15	BLB05L	Mapping		MBES and SBP; interference got worse		
2020-07-07	4:13	BLB05L	CTD	L13-20_CTD06	Valeport and SST	54.0665633	11.0105300
2020-07-07	4:15	BLB05L	Mapping		change frequency to **360 kHz** and **pulse length to 1000**: less inteference		
2020-07-07	4:52	BLB05L	Mapping		**L13-20_20200707_0048_0001.db** first profile with **new database**. Geoid has been changed to GCG05 and roll offset to -0.53°, other profiles need to be replayed with new database		
2020-07-07	8:07	Transit	Transit		check out nets in Pelzerhaken area; still present, not worth it to go there		
2020-07-07	9:00	BLB05L	CTD	L13-20_CTD07	Valeport and SST	10.9271033	54.0914217
2020-07-07	9:05	BLB05L	Mapping		MBES and SBP		
2020-07-07	16:21	BLB05L	CTD	L13-20_CTD08	Valeport and SST	11.0107917	54.0934267

2020-07-07	16:30	BLB05L	Mapping		closeup of dumpsite; MBES and SBP; 800 beams, 100°swath		
2020-07-08	2:01	BLB05L	CTD	L13-20_CTD09	Valeport and SST	10.8259033	54.0534200
2020-07-08	2:05	Haffkrug	Mapping		MBES and SBP		
2020-07-08	5:00	Haffkrug	Mapping		MBES and SBP; 130°swath		
2020-07-08	9:41	Haffkrug	CTD	L13-20_CTD10	Valeport and SST	11.0069383	54.1037100
2020-07-08	10:00	Haffkrug	TNT	L13-20_TNT01	A and B sample	10.7981983	54.0438617
2020-07-08	10:00	Haffkrug	CTD	L13-20_CTD11	SST	10.7981983	54.0438617
2020-07-08	10:15	Haffkrug	CW	L13-20_CW01		10.7981983	54.0438617
2020-07-08	10:15	Haffkrug	CTD	L13-20_CTD12	SST	10.7981983	54.0438617
2020-07-08	10:30	Haffkrug	TNT	L13-20_TNT02	A and B sample	10.8026150	54.0378717
2020-07-08	10:30	Haffkrug	CTD	L13-20_CTD13	SST	10.8026150	54.0378717
2020-07-08	10:40	Haffkrug	CW	L13-20_CW02		10.8026150	54.0378717
2020-07-08	10:40	Haffkrug	CTD	L13-20_CTD14	SST	10.8026150	54.0378717
2020-07-08	11:00	Haffkrug	TNT	L13-20_TNT03	A and B sample	10.8174100	54.0402533
2020-07-08	11:00	Haffkrug	CTD	L13-20_CTD15	SST	10.8174100	54.0402533
2020-07-08	11:05	Haffkrug	CW	L13-20_CW03		10.8174100	54.0402533
2020-07-08	11:05	Haffkrug	CTD	L13-20_CTD16	SST	10.8174100	54.0402533
2020-07-08	11:30	Haffkrug	TNT	L13-20_TNT04	A and B sample	10.8191300	54.0346233
2020-07-08	11:25	Haffkrug	CTD	L13-20_CTD17	SST	10.8191300	54.0346233
2020-07-08	11:30	Haffkrug	CTD	L13-20_CTD18	SST	10.8191300	54.0346233
2020-07-08	12:30	Pelzerhaken	Mapping		3D SBP profiles (5m spacing) Pelzerhaken; SBP and MBES (60°, 800 beams)		

2020-07-08	16:30	Pelzerhaken	TNT	L13-20_TNT05	A and B sample	10.9000900	54.0890500
2020-07-08	16:50	Pelzerhaken	CTD	L13-20_CTD19	SST	10.9000900	54.0890500
2020-07-08	16:55	Pelzerhaken	CTD	L13-20_CTD20	SST	10.9000900	54.0890500
2020-07-08	17:00	Pelzerhaken	TNT	L13-20_TNT06	A and B sample	10.8878767	54.0811450
2020-07-08	17:15	Pelzerhaken	CTD	L13-20_CTD21	SST	10.8878767	54.0811450
2020-07-08	17:20	Pelzerhaken	CTD	L13-20_CTD22	SST	10.96677446	54.09504365
2020-07-08	18:00	Pelzerhaken	CTD	L13-20_CTD23	Valeport and SST	10.9236967	54.0920667
2020-07-08	18:05	BLB05L	Mapping		MBES and SBP		
2020-07-08	22:18	BLB05L	CTD	L13-20_CTD24	Valeport and SST	10.965805	54.097814
2020-07-09	5:00	Haffkrug	CTD	L13-20_CTD25	Valeport and SST	10.8149650	54.0414400
2020-07-09	5:10	Haffkrug	Mapping		closeup; MBES and SBP (60°, 1000 beams)		
2020-07-09	7:30	Haffkrug	Mapping	_172	30°, 1024 beams		
2020-07-09	7:50	Haffkrug	Mapping	_174	120°, 1024 beams		
2020-07-09	8:05	Transit	Mapping		120°, 600 beams		
2020-07-09	10:01	BLB05L	CTD	L13-20_CTD26	Valeport and SST	10.9236967	54.0920667
2020-07-09	10:10	BLB05L	Mapping	_177	closeup; ab _177: 60°, 1024 beams		
2020-07-09	13:00	BLB05L	Mapping	_199	closeup; 30°, 1024 beams		
2020-07-09	13:23	BLB05L	Mapping	_202	closeup; 120°, 1024 beams		
2020-07-09	14:00	BLB05L	TNT	L13-20_TNT07	A and B sample	11.08686600	54.15742100
2020-07-09	14:00	BLB05L	CTD	L13-20_CTD27	SST	11.08686600	54.15742100
2020-07-09	14:05	BLB05L	CTD	L13-20_CTD28	SST	11.08686600	54.15742100
2020-07-09	14:20	BLB05L	TNT	L13-20_TNT08	A and B sample	11.13617300	54.20137800
2020-07-09	14:20	BLB05L	CTD	L13-20_CTD29	SST	11.13617300	54.20137800

2020-07-09	14:25	BLB05L	CTD	L13-20_CTD30	SST	11.13617300	54.20137800
2020-07-09	14:40	BLB05L	TNT	L13-20_TNT09	A and B sample	11.14312000	54.25925300
2020-07-09	14:40	BLB05L	CTD	L13-20_CTD31	SST	11.14312000	54.25925300
2020-07-09	14:45	BLB05L	CTD	L13-20_CTD32	SST	11.14312000	54.25925300
2020-07-09	15:10	Transit	Transit		transit to Heiligenhafen		
2020-07-10	5:30	Transit	Tranist		transit to Fehmarn		
2020-07-10	7:20	Fehmarn	CTD	L13-20_CTD33	Valeport and SST	10.9654550	54.5860117
2020-07-10	8:06	Fehmarn	Mapping		suspected craters; MBES and SBP; _206: no RTK, **change geoid to GCG2016**, old database used, **old roll offset**		
2020-07-10	8:26	Fehmarn	Mapping	_207	suspected craters; RTK back		
2020-07-10	14:24	Fehmarn	TNT	L13-20_TNT10	A and B sample	11.13435	54.5706377
2020-07-10	14:24	Fehmarn	CTD	L13-20_CTD34	SST	11.13435	54.5706377
2020-07-10	14:45	Fehmarn	TNT	L13-20_TNT11	only bottom sample	11.1069141	54.5822456
2020-07-10	14:45	Fehmarn	CTD	L13-20_CTD35	SST	11.1069141	54.5822456
2020-07-10	15:08	Fehmarn	TNT	L13-20_TNT12	only bottom sample	11.0772718	54.5881921
2020-07-10	15:08	Fehmarn	CTD	L13-20_CTD36	SST	11.0772718	54.5881921
2020-07-10	15:30	Fehmarn	TNT	L13-20_TNT13	only bottom sample	11.0337198	54.5871371
2020-07-10	15:30	Fehmarn	CTD	L13-20_CTD37	SST	11.0337198	54.5871371

2020-07-10	15:40	Fehmarn	Mapping		map reference station (L13-20_TNT13)		
2020-07-10	16:39	Fehmarn	TNT	L13-20_TNT14	only bottom sample	10.9959236	54.5856985
2020-07-10	16:39	Fehmarn	CTD	L13-20_CTD38	SST	10.9959236	54.5856985
2020-07-10	17:00	Fehmarn	TNT	L13-20_TNT15	only bottom sample	10.9765458	54.5849312
2020-07-10	17:00	Fehmarn	CTD	L13-20_CTD39	SST	10.9765458	54.5849312
2020-07-10	17:25	Fehmarn	CTD	L13-20_CTD40	SST	11.001034	54.568721
2020-07-10	17:35	Fehmarn	Mapping	_236	profiles southern Fehmarn Belt; still with **GCG2016**		
2020-07-10	20:30	transit	Transit		transit to Kiel		
2020-07-10	0:30	Kiel	Arrival				