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# RV METEOR Fahrtbericht / Cruise Report M143

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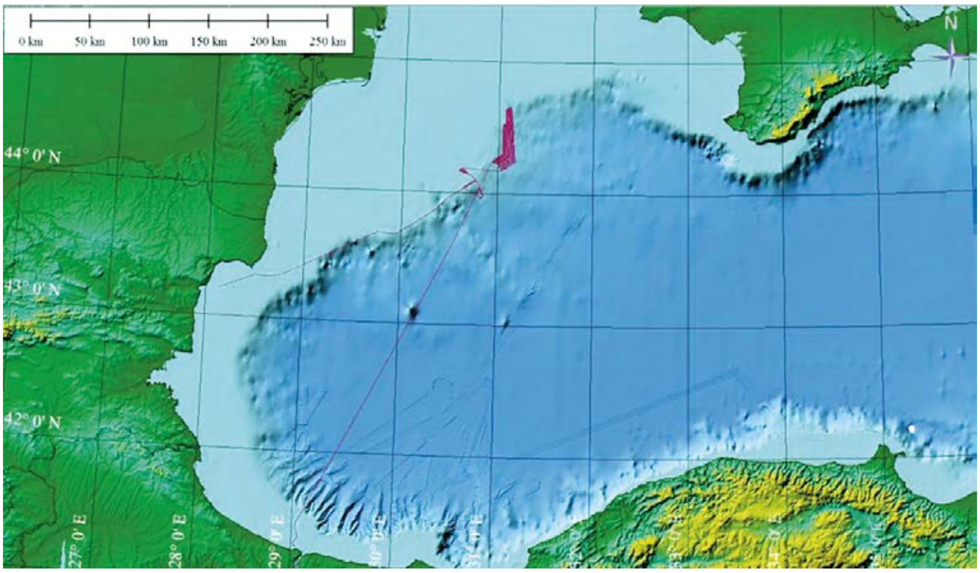
Varna (Bulgaria) – Heraklion (Greece)
12.12.-22.12.2017




Berichte aus dem GEOMAR
Helmholtz-Zentrum für Ozeanforschung Kiel

**Nr. 42 (N. Ser.)**

March 2018

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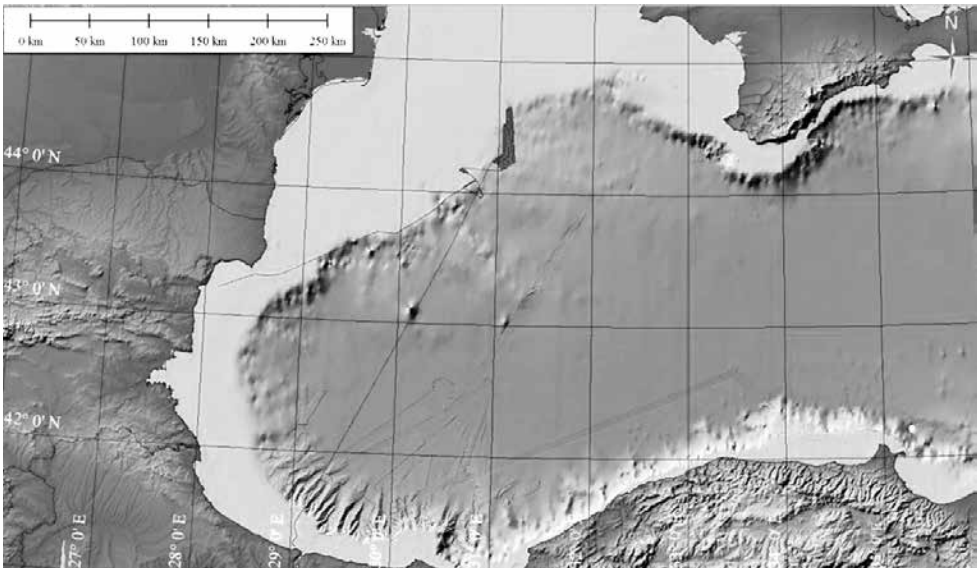


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# 1 Summary

Expedition M143 is a replacement for the originally scheduled expedition to the Marmara Sea to retrieve long term monitoring geodetic equipment. A short proposal to extend bathymetric mapping and imaging of active gas seepage in the Danube Delta region was approved and permission to operate in Romanian waters was successfully secured. Based on the results of mapping completed during the previous expedition M142 and other earlier missions to the same region, a set of survey lines and imaging targets were defined for M143. Objectives for expedition M143 were twofold and include the of use a dedicated 38 kHz single beam echo sounder installed in the moonpool of the research vessel METEOR for gas emission quantification and to complete bathymetric mapping for the detection of sub marine slope failures and mass transport deposits in associated with gas seepage and the occurrence of gas hydrates.

During the active data acquisition phase of expedition M143 (December 12 to December 17, 2017) three sub-regions for gas flare imaging were visited (Lander Site from M142, S2 channel eastern flank, and shallow shelf region). A total of 1,189 line kilometers (642 nautical miles) of data were acquired. Out of these, a total of 238 km were acquired using the 38 kHz EK80 and EM710 (and partially EM122) multibeam data. Also, a full calibration of the 38 kHz echo sounder was accomplished and sound velocity data were recorded at the Lander and shallow shelf region survey sites.

Bathymetric mapping using both EM systems EM122 and EM710 combined with the PARASOUND sub bottom profiler was completed in two main regions filling in data gaps in the existing multibeam coverage prior to M143. The first region was visited during the initial transit to the study region (December 14) around the region of the S2 channel head in water depths ~120 m. Here, a set of six parallel lines were acquired, totaling 70 km line lengths and covering an area of 11.5 square kilometers. The second region was in the eastern part of the Danube delta region, close to the Ukrainian border. In total 805 line kilometers and 472 square kilometers of multibeam data were acquired.

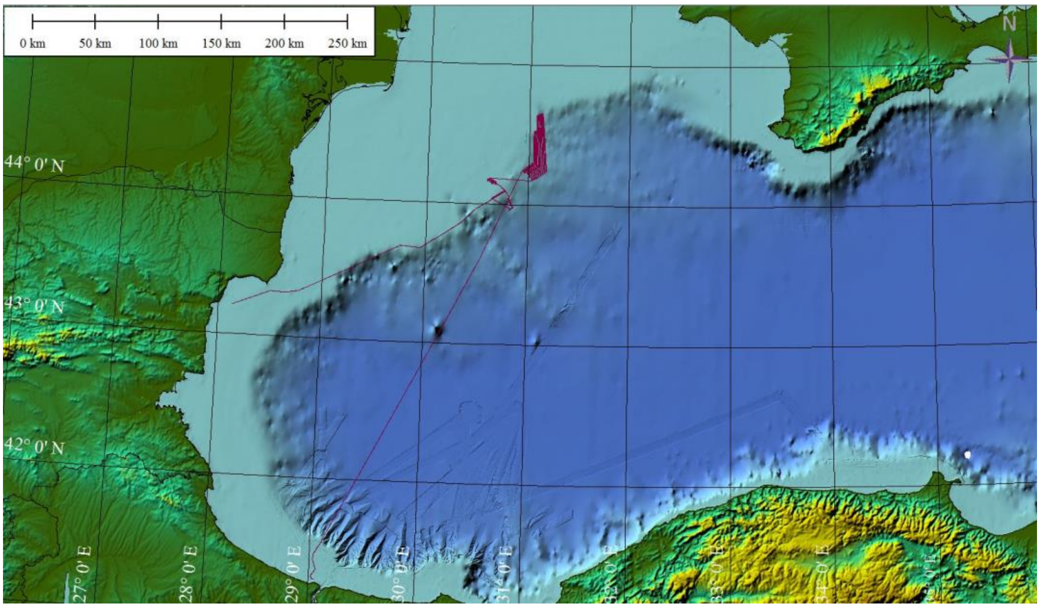


**Figure 1a**: Overview map of survey region for expedition M143 in the Black Sea (Romanian sector only) with track lines completed.

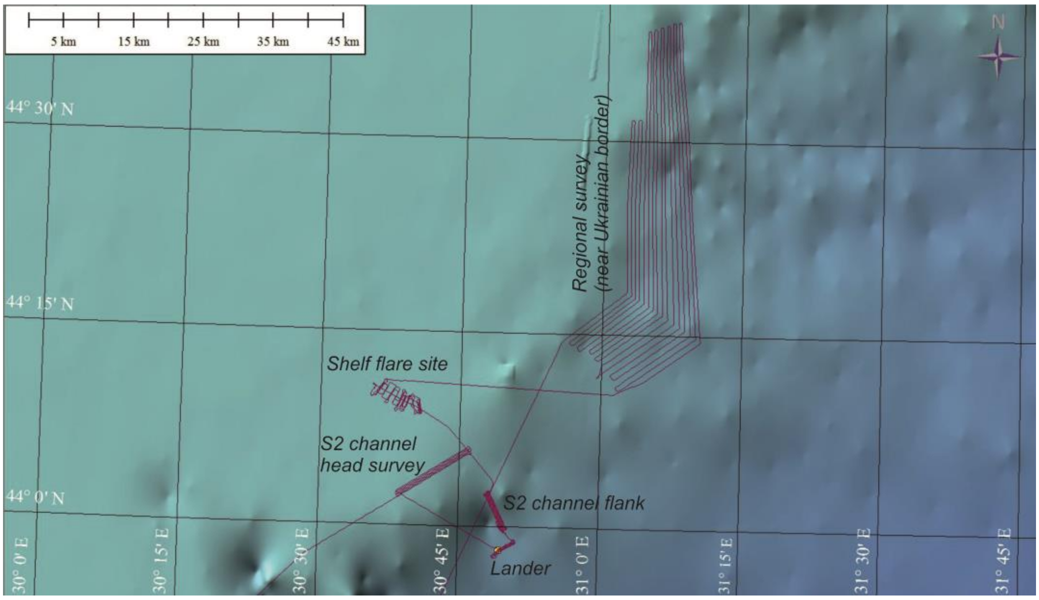


**Figure 1b:** Detailed view of track log of M143 with five sub-survey regions identified.

## 2 Participants

The expedition M143 – SLOGARO is a scientific expedition solely operated by GEOMAR scientists (Figure 2). It is further a collaborative undertaking with scientists from the working group of Prof. Dr. Gerhard Bohrmann (University of Bremen) and scientists from expedition M142. Table 1 shows all participants of the cruise.

**Table 1:** Scientific crew, duties, and affiliation

| | | |
|---|---|---|
| Florian Gausepohl | Multibeam processing, sound velocity profiling | GEOMAR |
| Iason-Zois Gazis | Multibeam processing | GEOMAR |
| Line Hähnel | Multibeam processing | GEOMAR |
| Mareike Kampmeier | Multibeam processing, EK80 | GEOMAR |
| Peter Urban | EK80 | GEOMAR |
| Michael Riedel | Chief Scientist | GEOMAR |
| Robert Scholz | Meteorologist | DWD |

GEOMAR - Helmholtz Centre for Ocean Research Kiel, Wischhofstrasse 1-3, 24146 Kiel, Germany


**Figure 2** Scientists on board the R/V METEOR during the expedition M143. From left to right: Florian Gauspohl, Mareike Kampmeier, Robert Scholz (DWD), Andreas Raeke (DWD), Michael Riedel, Line Hähnel, Iason-Zois Gazis, Peter Urban

**Table 2:** Crew members onboard

| | |
|---|---|
| Hammacher, Rainer | Master |
| Marco Reinstädler | Chiefmate |
| Benjamin Mock | 2nd Officer |
| Lena Werner | First Mate |
| Magnus Keller | 2nd Officer |
| Peter Neumann | Chief Engineer |
| Björn Brandt | 2nd Engineer |
| Jan Erik Wilhelm | 2nd Engineer |
| Wolfgang Starke | Electrical Engineer |
| Gerhard Lange | Fitter |
| Manfred Schroeder | Motorman |
| Frank Krüger | Motorman |
| Sören Worner | Motorman |
| Olaf Willms | Chief Electronic |
| Cathi Hebold | Electronic |
| Stefan Seidel | System Operator |
| Alexander Wolf | Boatswain |
| Hans Behlke | Sailor |
| Michael Zeigert | Sailor |
| Ulrich Hampel | Sailor |
| Henry Schabeck | Sailor |
| Olaf Lison | Sailor |
| Stefan Koch | Sailor |
| Florian Thormählen | Apprentice |
| Klaus Rathnow | Doctor |
| Jan Parlow | Chief Steward |
| Moni Jürgens | 2nd Stewardess |
| Harald Schmandke | 2nd Steward |
| Gou Min Zhang | Laundry Master |
| Mike Fröhlich | Cook |
| Peter Wernitz | Cook |
| Andreas Raeke | Radio-weather technician |

Shipping company: Briese Schiffahrts GmbH & Co KG, Abteilung Forschungsschifffahrt, Hafenstr. 12, 26789, Leer, Germany

## 3 Background and Objectives

In 1974 gas hydrates have been found for the first time in the Black Sea. Since then a significant number of research projects has studied the occurrence and distribution in the abyssal plain and along the continental margins of the Black Sea. Numerous active gas expulsion sites and indicators for gas and hydrate distribution have been found (Starostenko et al. 2010, Vassilev and Dimitrov 2002, Popescu et al. 2007, Naudts et al. 2006). According to current temperature and salinity conditions in the Black Sea gas hydrates are stable in water depth greater than 665 m. Depending on the depth of the seafloor gas hydrates are expected to be stable within 200 m to 300 m below the seafloor (Bialas et al., 2014), defining upper and lower limits of the BSR distribution as shown by Popescu et al., (2006) (Figure 3).

Popescu et al. (2006) also reported on multiple BSRs along the Danube Delta and concluded that they remain from “stable climatic episodes with temperatures between glacial values and the present-day conditions”. Another explanation is given by Baristeas (2006) arguing that deep cutting faults provide migration pathways for microbial gases of Oligocene age. He proposes that superior weighted carbon grades in the gas composition cause hydrate formation at different pressure and temperature levels. The porous and variable sediment structure should support this differentiated BSR formation in the corresponding levee structures. However, Zander et al. (2017a) used high resolution seismic images provided by cruise MSM-34 and temperature models to show that changes in water level during glacial and inter-glacial cycles together with bottom water temperature changes could define paleo BSRs at sediment depth where the multiple BSRs are observed today (Figure 4). Remaining deviations in today’s BSR depth calculations and observed seismic events indicate that gas and gas hydrate distribution in the Black Sea are not yet in equilibrium (Zander et al., 2017b).

Seismic data of cruise MSM-34 indicate an upward bending of the BSR towards the seafloor in about 665 m water depth (Bialas et al. 2014) right underneath the glide plain of a slump event. Active gas expulsion sites circle the headwall of the failed margin segment. With respect to the observed not equilibrated margin setting and the influences of sea level changes during glacial cycles it could be questioned to which extend hydrates may have played a role in destabilization of the slope.

Winguth et al. (2000), Popescu et al. (2006) and others report on seismic indications of multiple slope failure events within the Danube Delta indicated by mass transport deposits (MTD). Analyzing the distribution of MTDs in the Danube Delta shows that mass transfer deposition interferes with channel levee deposits of different ages. The thickness of the MTDs varies significantly and estimates for the largest MTD have an average thickness of 240 m and a volume of 600 km$^3$. Extending the existing maps of the Danube Delta all the way to the shelf will provide a first indication on today's continuity and volume of such slope failures.

Xu et al. (2018) investigated elongated depressions along the Bulgarian slope in the south-western Black Sea partially marked by active gas expulsion (SPUX project). Located in 100 m to 600 m water depth these structures are clearly above the gas hydrate stability zone and gas can move within the sediments. Upward migration of gas causes fracturing within sediment layers, which results in formation of the observed slope-parallel elongated depressions (Figure 5). These depressions and the belonging conduits are believed to further transform into headwalls of slope failure events (Xu et al. 2018).

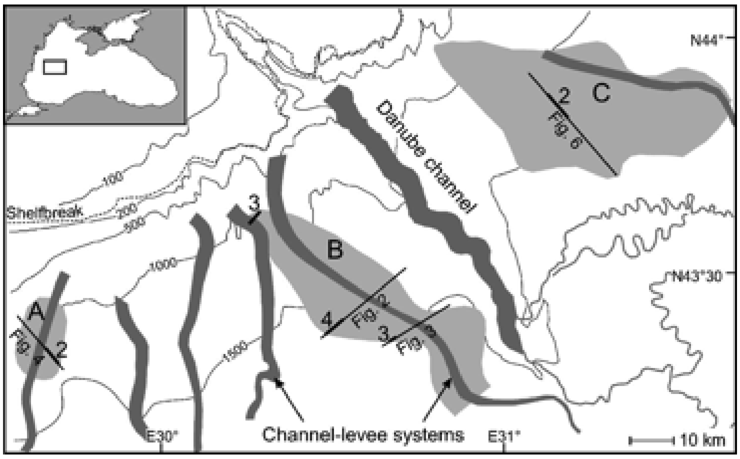


Figure 3: Map of the BSR distribution and major channel systems in the Danube Delta (Popescu et al. 2006). Please note: labels to figures in this map do not correspond to figures shown in this report.

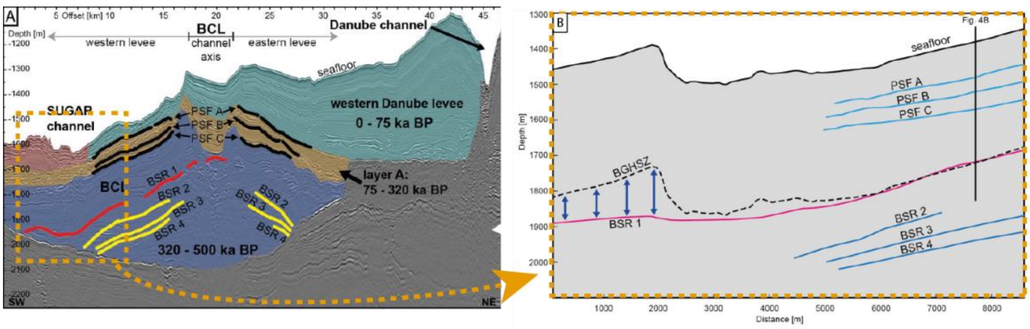


Figure 4: A: Interpreted seismic section from the Danube Delta. Paleo seafloor events (black), multiple BSRs (yellow) and current BSR (red) are lined out.

B: Model results for BSRs related to paleo seafloors (blue) and todays BSR (red). Deviation of today’s BSR underneath thickened levee deposits indicates disequilibrium of the system (after Zander et al., 2017a).

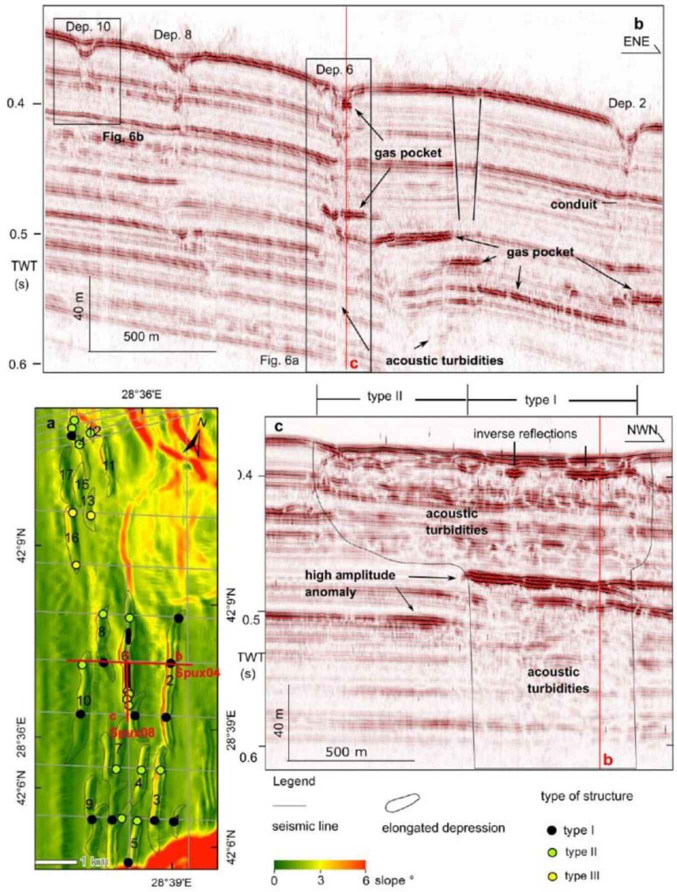


Figure 5: Map and data example of elongated depressions from the SPUX project leading into failed slope events. A: Slope map of elongated depressions (lower half) and headwalls (red; upper half); B & C: Seismic images of elongated depressions indicating vertical gas migration pathways leading towards depressions on the seafloor (after Xu et al., 2018).

Based on the interpretation of seismic data acquired during cruise MSM-34 (Zander et al., 2017a,b) there is evident indication that mass transport deposits do have a major influence on the gas plumbing system along the Bulgarian and Romanian margin. SPUX data (Xu et al. 2018) showed that there is a close relationship between gas migration pathways weakening sediments and the generation of slopes failure along the western Black Sea margin. In addition, the composite bathymetric map compiled by GEOMAR and MARUM scientists shows indications of mass movements caused by slope failures outside the existing SPUX data coverage.

Therefore, the aim of this expedition M143 is to complete the bathymetric map and extend the coverage into shallower waters up to the shelf break and beyond. It is expected to find further failed areas and headwalls originating from various time intervals. In addition, water column imaging with the on board mutlibeam system will provide indications for active gas transport in the vicinity of such failed margin segments. Such active vent locations may then be analysed in detail by simultaneous records of the sediment echosounder PARASOUND, and a portable EK80 system (specifically mounted for the purpose of this expedition inside the echo-sounder shaft) will provide first hints on the shallow gas distribution and tops of migration pathways. The combination of EK80 and multibeam data over known and newly discovered gas vents will allow further developments of techniques for gas-flux quantifications.

Such a data set will provide first hints on the number of slope failure events and the size of such events. In addition first hints on relations between gas migration pathways and headwall settings could be deduced and shed first light if processes as observed along the Bulgarian margin apply in the Danube Delta as well. Unfortunately, the short notice does not allow for mobilisation of seismic equipment as export control processes take too much time. However the acquired data set will be used to develop follow on proposals for deeper penetrating investigations.

# 4 Cruise Narrative

| | |
|---|---|
| Monday, December 11 | Arrival of all scientists in port of Varna |
| | Installation of equipment |
| Tuesday, December 12 | Departure port of Varna at 10:00 (local time) |
| | Crossing border between Bulgaria and Romania at 18:00 |
| | Start recording bathymetry and PARASOUND data, finishing lines until 07:55 |
| Wednesday, December 13 | 08:00 at Lander location from M142 expedition |
| | Deploy 38 kHz transducer in moonpool and test setup |
| | Collecting lines until 13:00 across Lander site |
| | Deploy sound-velocity profiler (SVP) at position near Lander: |
| | 43° 58.151‘ N; 30° 49.408‘ E; 680 m water depth |
| | Problems with SVP, as recording stopped at 130 m bewlo sea surface; 2nd trial with both SVPs; 2nd deployment successful |
| | In the meantime, the setup for calibrating the 38 kHz sounder is installed using 4 fishing rods to deploy a metallic sphere (38.1 mm in diameter) through the moonpool. |
| | 17:00 Calibration completed |
| | 17:45 Start collecting survey lines with EM710, EM122 and EK80/38 kHz sounder across Lander site. |
| | 18:50 Start collecting survey lines along eastern flank of the S2 Channel with EM710, EM122 and EK80/38 kHz sounder |
| Thursday, December 14 | 10:00 Stop survey lines at S2 channel |
| | 10:20 Transit to shelf site (PARASOUND, EM122, EM710) |
| | 13:40 Sound velocity profile at shallow shelf region |
| | 14:15 Start survey for gas flares with EK80, and EM710 |
| | Completing first a grid of lines for overview of gas flares along seafloor steps; followed by more detailed survey lines |
| Friday, December 15 | 08:00 Stop surveying at shelf flare locations |
| | Recover EK80/38 kHz sounder from moonpool |
| | 08:35 Transit to Ukrainian border at full speed |

| | |
|---|---|
| | 10:05 Start survey along Ukrainian border |
| Saturday, December 16 | All day surveying lines with EM122, EM710 and PARASOUND |
| Sunday, December 17 | 17:20 End of survey lines at Ukrainian border and data collection |
| | 17:30 Start transit to Bosporus |

Monday, December 18 until Thursday, December 21 Transit

| | |
|---|---|
| Thursday, December 21 | 10:00 Arrival in port of Heraklion |

# 5 Hydroacoustic work

## 5.1 Sound velocity profiling

A total of four sound velocity profiles (SVP) were taken during M143 and subsequently used to determine the correct system parameters (“raytracing”) prior to the respective hydroacoustic surveys (EM122 / EM710 / EK80). Two of the profiles (SVP01; SVP03 – Table 1) failed and were not considered for further processing.

**Table 1:** SVP taken during M143

| Station | Date | Time (UTC) | Device | Latitude | Longitude |
|---|---|---|---|---|---|
| M143_4-1 | 13/12/2017 | 11:28 | SVP01 | 43° 58.094' N | 030° 49.351' E |
| M143_5-1 | 13/12/2017 | 12:49 | SVP02 | 43° 58.222' N | 030° 49.348' E |
| M143_5-1 | 13/12/2017 | 12:49 | SVP03 | 43° 58.222' N | 030° 49.348' E |
| M143_8-1 | 14/12/2017 | 11:40 | SVP04 | 44° 10.492' N | 030° 35.728' E |

SVP02 was conducted at the deeper (633 m) survey site – the *lander* area. Results show rapid changes within the first 100 m with decreasing temperature, and as a consequence sound velocity, as well as increasing salinity (see Figure 6a). SVP04 was conducted in the northernmost part of the shallower (102 m) survey site – the *staircase* area – to facilitate the correct configuration of angle and depth (MBES) and single target detection (EK80) since already slight changes in sound speed, as for example with an incorrect SVP severely influence the results of the survey. The temperature of the topmost layer is higher – 11.32 °C compared to 10.85 °C) resulting in a higher sound speed at the transducer (1474.7 m/s compared to 1473 m/s) and a slightly different SVP (see Figure 6b).

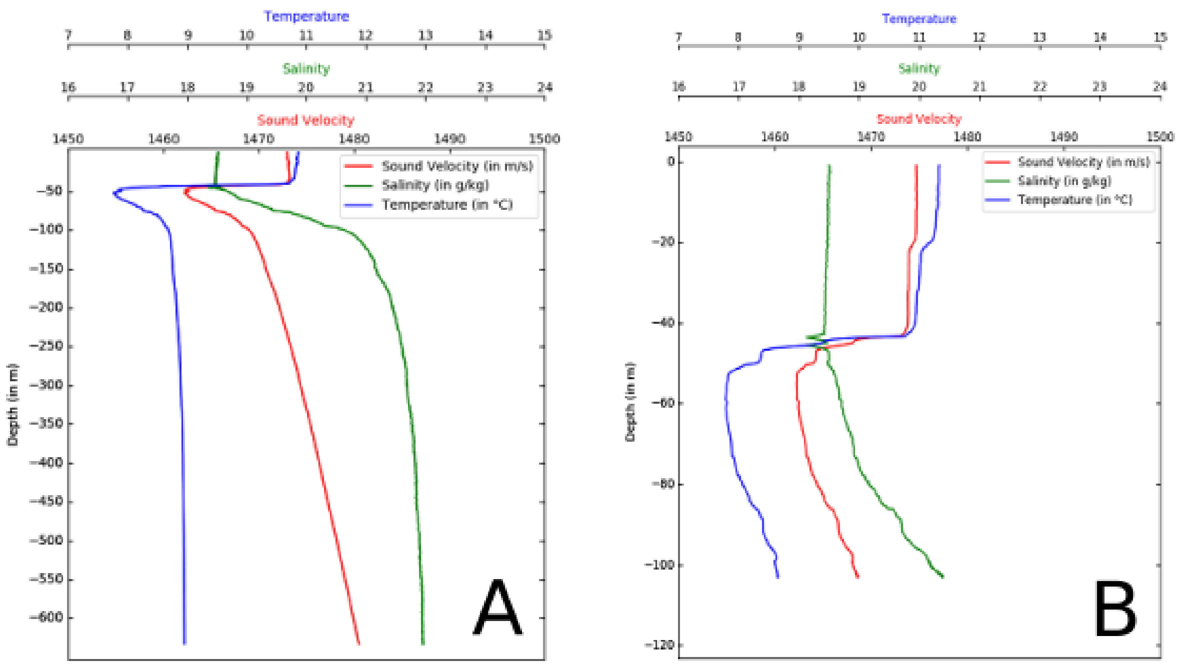


Figure 6: SVP profiles taken during M143 at the lander (A) and at the staircase site (B).

### 5.2 Multibeam echo sounder (EM710, EM122)

During the cruise M143 multibeam data were acquired across the Danube Delta, Black Sea. In total 1,189 km of survey lines were acquired with the multibeam echo sounders on board R/V METEOR: the EM710 and EM122. The EM710 was the primary multibeam echo sounder system (MBES) of this survey. It operated in a frequency range of 70-100 kHz with a footprint 1°/1°. The ping rate (dependent on water depth) was up to 40 Hz, and the maximum number of soundings per ping rate in dual swath mode was set 800. The EM122 is a 12 kHz (11.5-12.25 kHz) MBES that was used supplementary to the EM710, with a footprint of TX 1°/ RX 2° and was used with a ping rate up to 5 Hz (also dependent on water depth). In both systems, the maximum swath angle was set to 130º. The systems were run in HD equidistance mode for spacing the beams across track. Survey speed during transects was varying between 3 knots duinrg EK80 data acquisition 8see below) and 8 knots during multibeam bathymetric mapping surveys and up to 12 knots during transits. Motion data and static offsets were corrected by the ship's internal sensors and directly fed into the MBES. Although two dedicated sound velocity profiles were acquired with the SVP tool during M143, we operated the two MBES with sound velocity information based on casts completed during expedition M142. The multibeam data from M143 will be corrected post-expedition to include the appropriate sound velocity. Data were stored in the Kongsberg *.all format and water-column data were stored as *.wcd format.

During data acquisition, we noticed the existence and persistent presence of seafloor depth artifacts, so called 'Eric's Horn' type artifacts (Figure 7) in both MBES. The presence of these artifacts has been suggested to be correlated with the settings of the penetration filter (Whittaker et al, 2011). Thus different settings were tried (Off, weak, medium, strong). Additionally, the Spike filter was set to Strong mode. However, no significant improvement was observed and thus the artifacts were removed in the post processing phase. Furthermore, we noticed some interference between the EM122 and EK80 as well as EM122 and PARASOUND that resulted in unwanted noise. Consequently the EM122 was switched off during the operation of EK80.

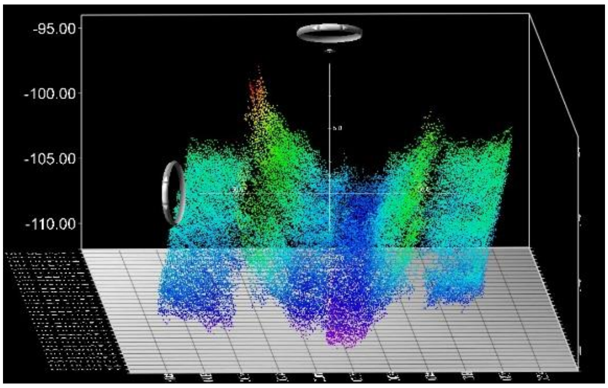


Figure 7: Example of ‘Eric’s Horn’ type artifacts (EM122)

Post-Processing Analysis of Mutltibeam Bathymetric Data (EM710 and EM122)

The acquired data were processed with the Qimera software onboard. The depths were corrected by the use of the local sound velocity profiles that were obtained during the cruise. The filtering and editing of the unwanted soundings were performed in three steps: Firstly, the CUBE algorithm was applied in the entire area and secondly a Spline filter was applied in specific parts of the survey area. Finally, every line was checked and edited manually for optimum results and exported as XYZ files.

Bathymetric Maps

Based on the exported XYZ data, bathymetric grids and derivatives were produced and plotted inside the SAGA GIS software (Figure 8a - e). The produced derivatives are: slope, topographic position index (TPI), and curvature. These derivatives will be used for seafloor classification and further interpretation of the local topographic settings in the spots with recorded gas emissions post expedition.

Backscatter data

The backscatter data were processed with the FMGT software and mosaics in 10 m resolution were created.

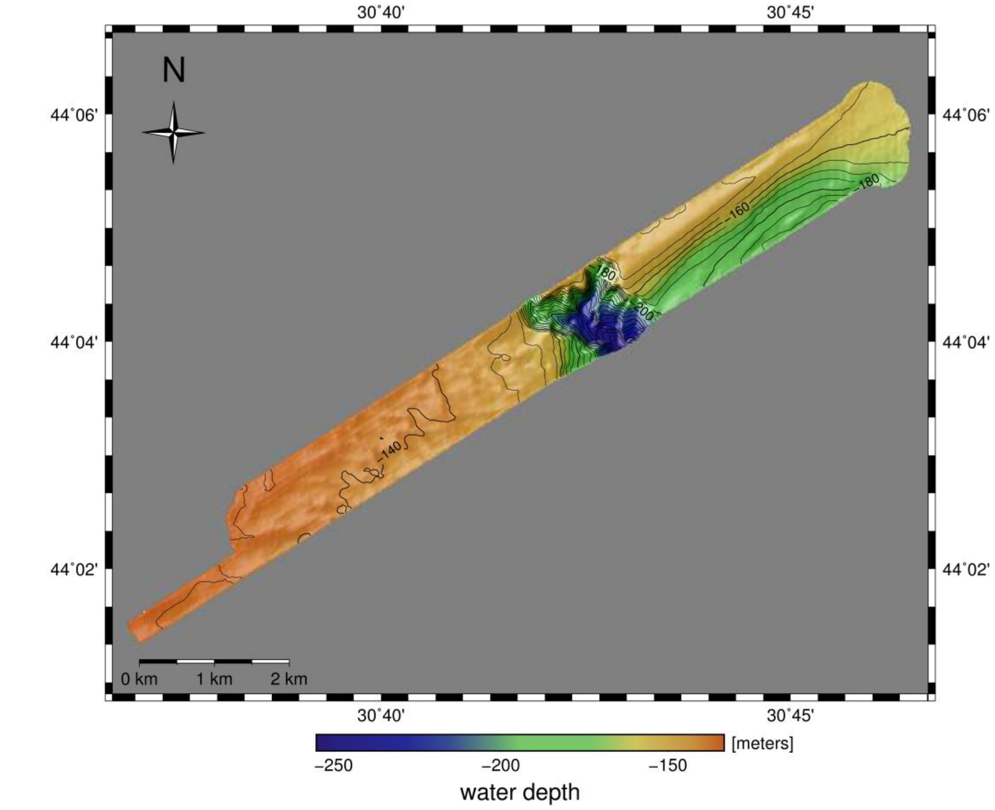


Figure 8a: Bathymetric map of S2 canyon head (EM710)

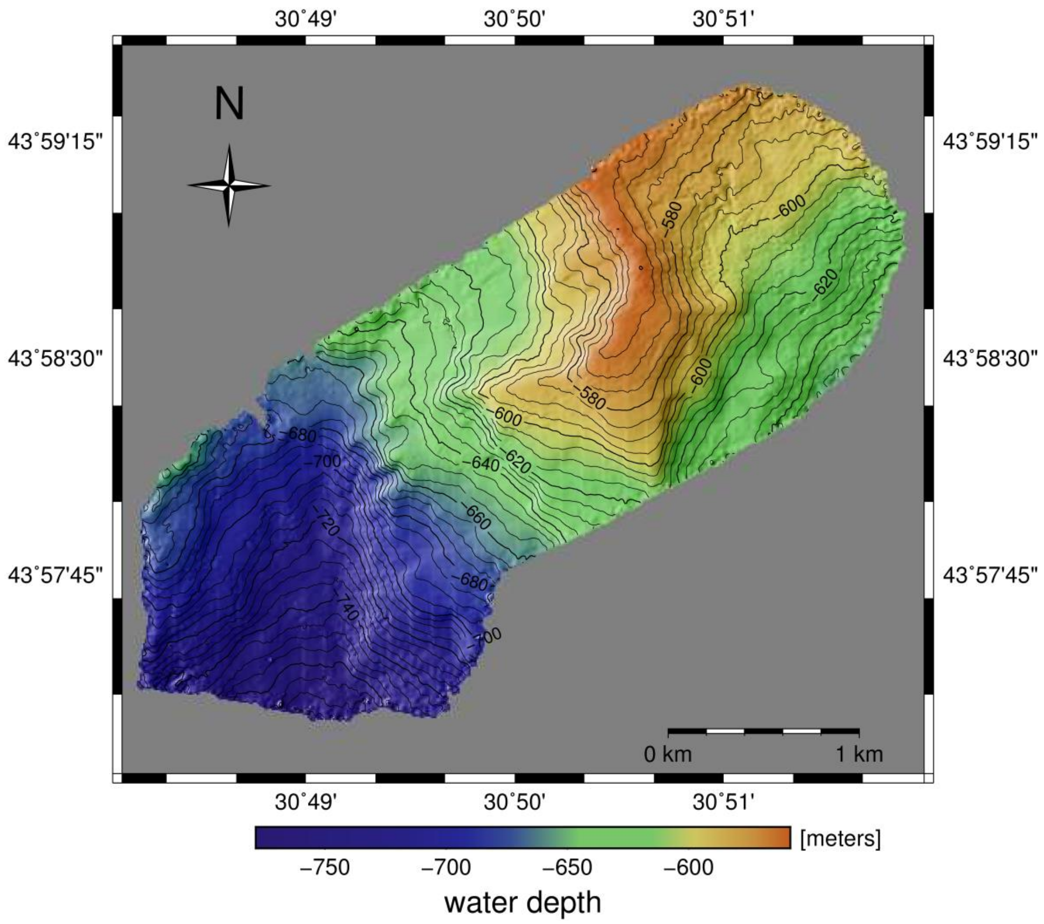


Figure 8b: Lander-Site (EM710)

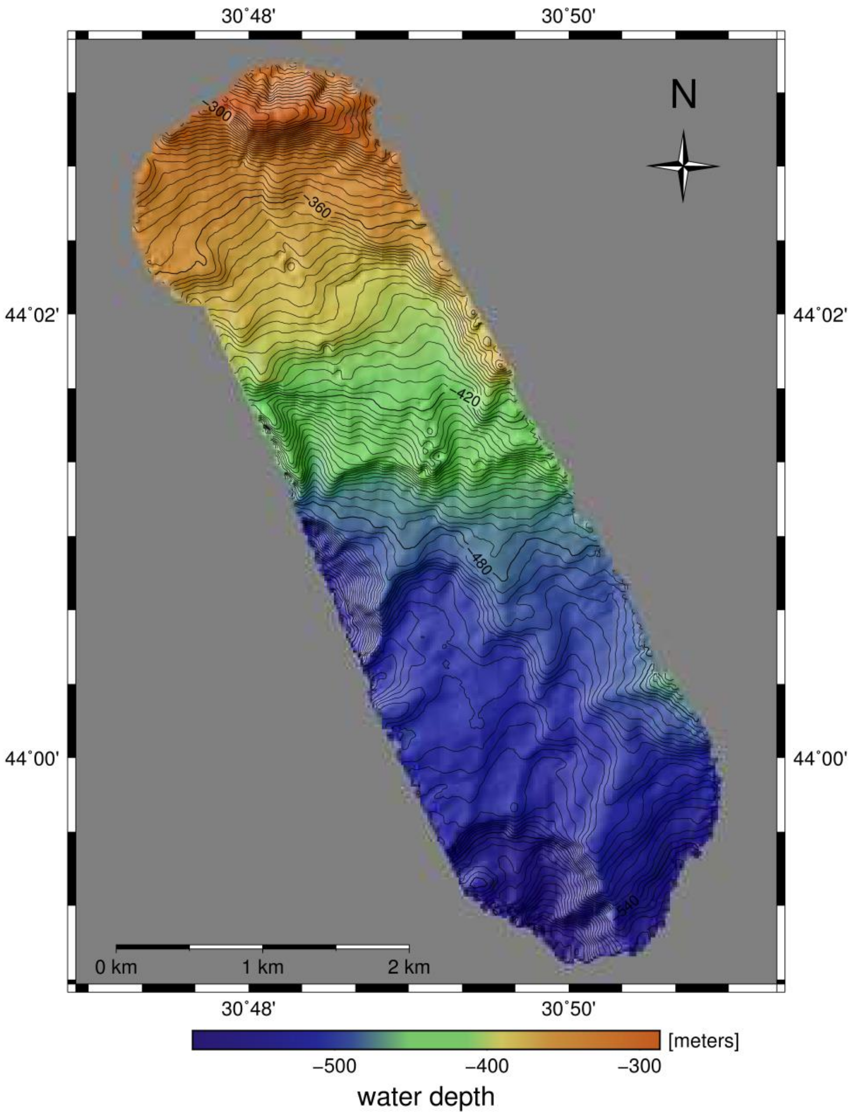


Figure 8c: Bathymetric map of Eastern flank of the S2 channel (EM710)

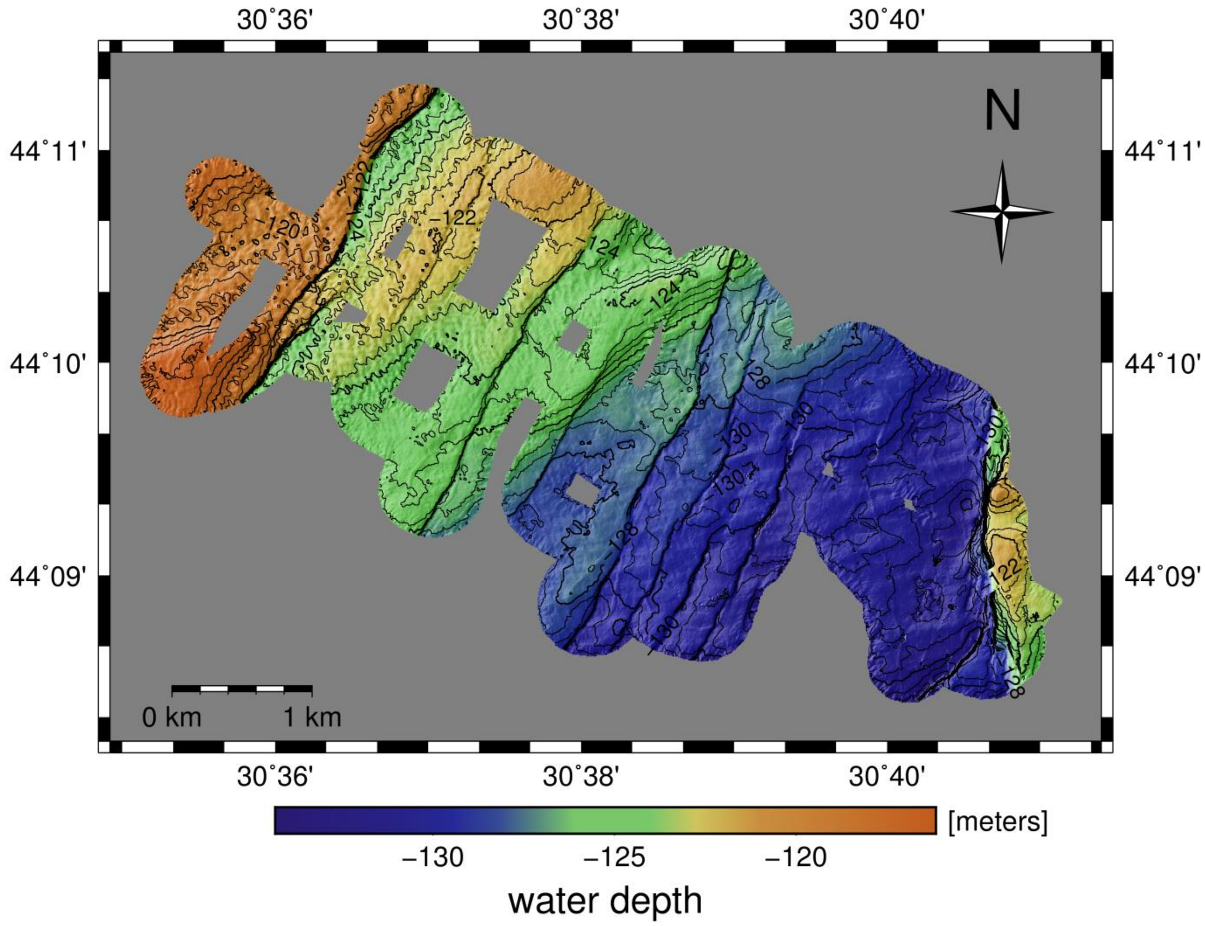


Figure 8d: Bathymetric map of Stair-case sites on Shelf (EM710)

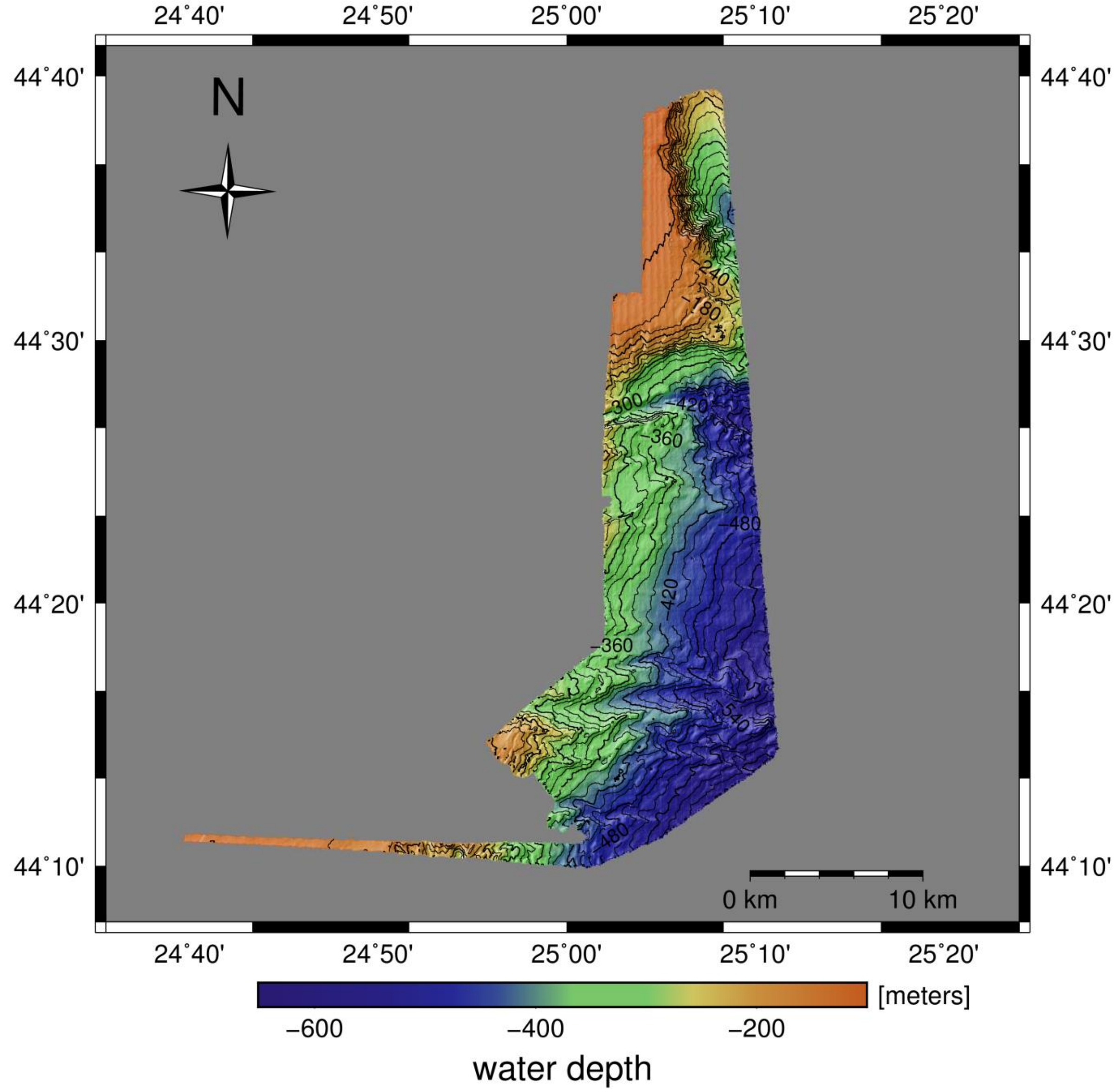


Figure 8e: Bathymetric map of Ukrainian border region (M710)

### 5.3 Sub-Bottom Profiler PARASOUND

The PARASOUND echosounder installed on board the R/V METEOR utilizes the parametric effect based on the nonlinear relation of pressure and density during sonar propagation. Two high intensity acoustic waves with frequencies of 18-20 kHz (called primary high frequency, PHF) and 22-24 kHz were used to create a secondary high (40-42 kHz) and a secondary low (~4 kHz) frequency (referred to as SLF). While the SLF is used for the sub bottom profiling, the PHF can be used to image gas bubbles, plankton or fish in the water column. However, for the purpose of expedition M143, we focus on the SLF for profiling, as the 38 kHz single beam echo sounder provided imaging of the water column and the EM710 and EM122 multibeam systems are used for gas flare location detection.

The opening angle of the transducer is 4 by 5°, which corresponds to a footprint size of about 7 % of the water depth. The program ATLAS PARASTORE is used for storing and displaying echograms. The settings applied in PARASTORE for PHF and SLF displaying are variable and dependent on the actual performance influenced by, e.g., water depth, water and weather conditions. Several file formats are recorded during PARASOUND operations: Original *.asd files, which were replayed in PARASOUND for further processing, contain data of the entire water column as well as the sub seafloor. PARASTORE also produces *.ps3 files recorded along with the auxiliary data. The depth range of the *.ps3 files was always adjusted to record the full sub bottom data range. The original *.asd files were replayed with PARASTORE post-acquisition and an oversampling ratio (varying between 3.5 and 4.7, depending on the length of the recorded data window) to create *.ps3 files. These were then converted to *.sgy data using the conversion tool ps32sgy. This conversion allows to store the acquisition coordinates into the SGY header words (73: X-coordinate and 77: Y-coordinate) in UTM system (Zone 36 for M143). After conversion, the *.sgy data were loaded into the Kingdom Suite project set up for Expedition M143 for display and interpretation.

The sub bottom profiler data show penetration depths varying from only 20 m across the shelf region to > 100 m in deeper water settings. Abundant evidence for seafloor pockmarks, elongated depressions and slope failures were found (Figure 9), indicating that processes described by Xu et al. (2018) based on the SPUX data also occur along the eastern margin of the Danube delta region off Romania.

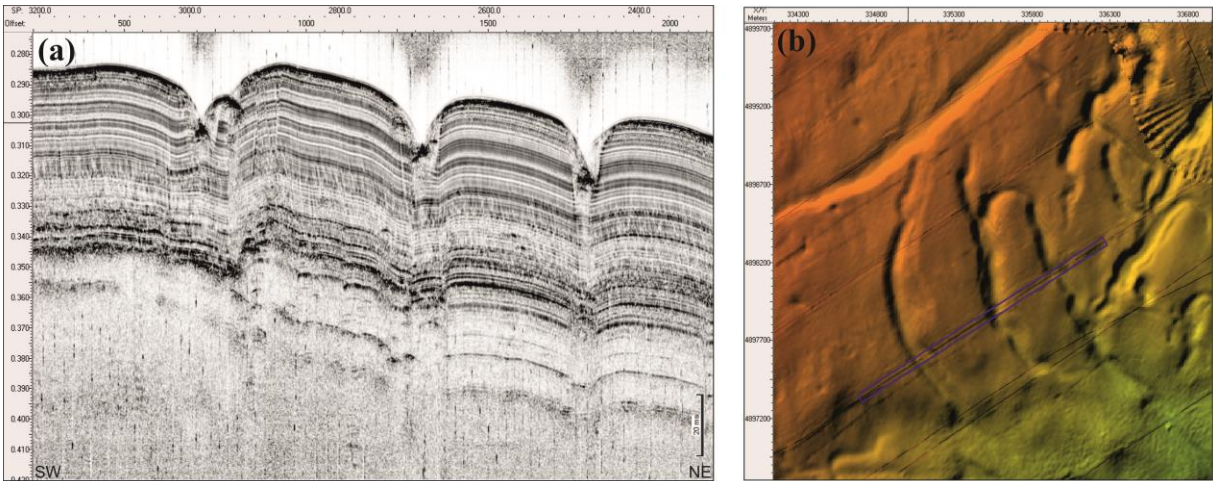


**Figure 9:** **(a)** Example of a PARASOUND profile (shown is envelope and processing included an automatic gain control with a window length of 0.05s) across an area shown in (b) with prominent elongated seafloor depressions, similar in shape and nature described in Xu et al., (2018), demonstrating that the processes described in the region off the southern Bulgarian margin are also acting on the slope off the Danube Delta region.

## 5.4 Single beam Simrad EK80

### *5.4.1 Objectives*

During the expedition M143 we used a Simrad EK80 with a 38 kHz Simrad ES38-7 transducer in combination with EM710 Multibeam to assess a new methodology for quantitative estimates of benthic gas bubble streams. Unlike the EM710, the EK80 can be calibrated with a calibration-sphere to receive absolute target strength values. It is therefore suitable to obtain quantitative estimates of gas bubble flow using acoustic inversion (Veloso et al. 2015). However there are two disadvantages towards the EM710: it has a very limited coverage due to the beam opening angle of only 7°, and the quantification approach is only valid when the bubble streams are entirely covered by the beam, which is difficult to validate using Ek80 echograms only.

Our aim is to generate a high quality data set that can be used for reaching effective and valid quantitative estimates from a combination of the EK80 data with the EM710 water column images (WCI). For this purpose:

- The EK80 was properly installed and calibrated
- Interferences between the acoustic systems in the water column was minimized as much as possible

- 4 Surveys with focus on high quality water column images in the EK80 and the EM710 where planned for the assessment

### *5.4.2 Methodology – Installation and calibration of the EK80*

The 38 kHz transducer was installed in the moonpool of the R/V METEOR. We used 50 cm long spacers to place the transducer below the ship hull to avoid negative influences of bubbles at the transducer (Figure 10). The transducer was driven by a Simrad WBT-Mini wide-band transceiver which can drive the transducer with up to 1000 W per ping. The WBT-Mini was controlled via a laptop computer running the EK80 software.

The laptop received GPS (C-NAV 3050 / Meteor C-NAV 2) and Motion (Seapath 350 GPS) information from the Meteor via Ethernet. The environment parameters of the system (surface sound speed, average sound speed, water salinity and water temperature) where updated manually. (Surface sound speed from the ships sound velocity probe, the other parameters once with every SVP-cast).

The reference point for both, the GPS and Motion data, is the ships MRU. The static offsets of the Transducer are as follows[1]

From MRU to ES38-7 Transducer:

- X (positive forward): -19.649 m
- Y (positive starboard): -0.287 m
- Z (positive downwards): 6.615 m + 0.385[2] m

[1] Taken from the „Positionen und Offsets neu2011.pdf" provided by the R/V METEOR
[2] 38.5 cm offset of the ES87-7 transducer head below the ship's hull.

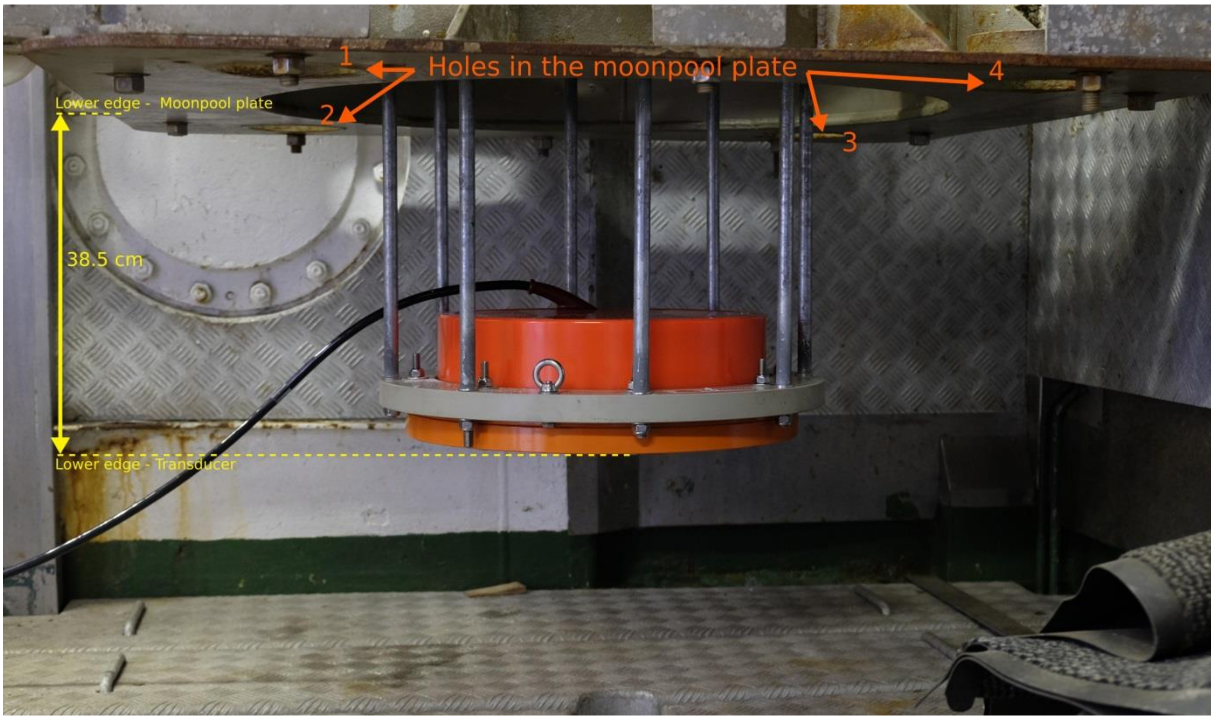


**Figure 10:** ES38-7(orange) attached to the moonpool plate with 50 cm long spacer elements. (Foto credit Peter Urban)

The EK80 can be calibrated to produce absolute target strength (TS) values. For this procedure, a special sphere (Tungsten, diameter 38.1 mm / ca. 0.5 kg) with known target strength had to be placed at least 6 meters below the transducer (Demer et al., 2015). The sphere was attached to four fishing lines which were attached to a simple calibration rack that allowed a precise lifting and lowering of the sphere (Figure 11). Each of the fishing lines was passed through one of four holes in the moonpool plate which were located ca. 53 cm away from the transducer center (Figure 1). This allows controlling the position of the sphere by hoisting or veering the individual fishing lines.

**Figure 11:** Calibration racks with fishing lines attached to the calibration sphere which is already below the moonpool. (Foto credit Line Hähnle; in picture: Mareike Kampmeier)

The calibration was carried out on Wednesday, December 13, 2017, 13:00-17:00 (local ship time). During this time period there were little wind and waves, and the ship was drifting with the existing currents. Prior to the calibration, a SVP cast was used to obtain the latest environment parameters for the EK80 (water temperature, salinity, and sound speed). Then, the sphere was lowered ca. 9 meters below the transducer. During this procedure the EK80 software was used to observe the depth the sphere (Figure 12).

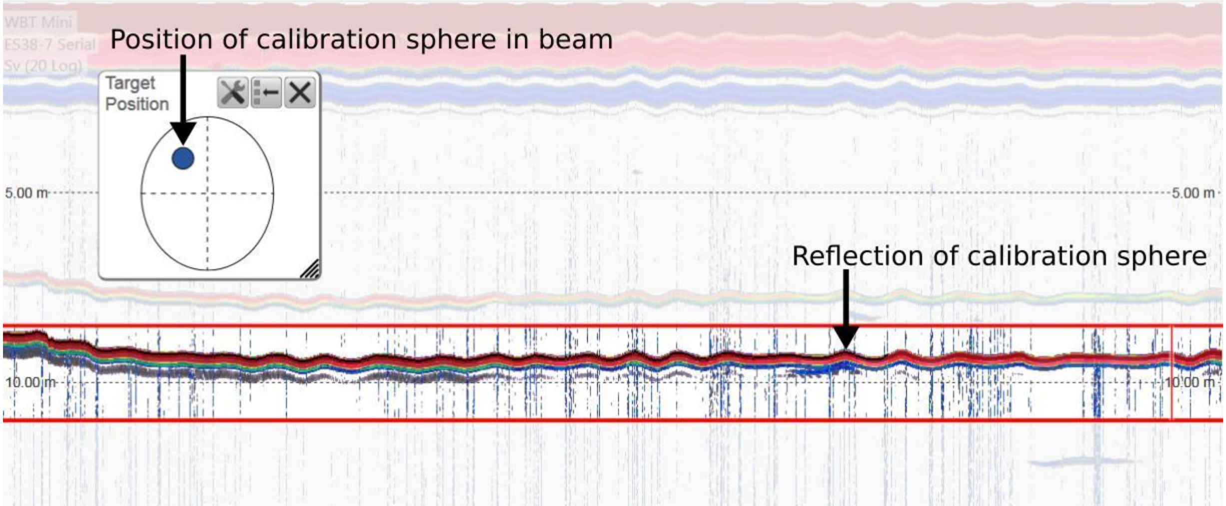


**Figure 12:** EK80 Echogram with the calibration sphere visible as a long red line. In the upper left part of the image, the position of the sphere in the beam is visible because of the single target detection capability of the EK80.

The position of the sphere inside the beam could be observed using the single target detection capabilities of the ES38-7 split-beam transducer. Once the sphere was at the correct depth and inside the beam, the calibration program of the EK80 software was started. Inside this software a rough depth range around the sphere was defined to avoid interference of false targets. During calibration, the sphere must be placed in all sectors of the beam with a minimal coverage of at least 50% for each sector while the software automatically records the target strength and position of the sphere. The number of soundings per calibration is limited to 5000. The freedom of positioning the sphere was limited by the distance of four holes towards the transducer center (ca. 53 cm). Still, we could cover each individual sector sufficiently and reached an overall coverage of 88% which is a good result (Figure 13).

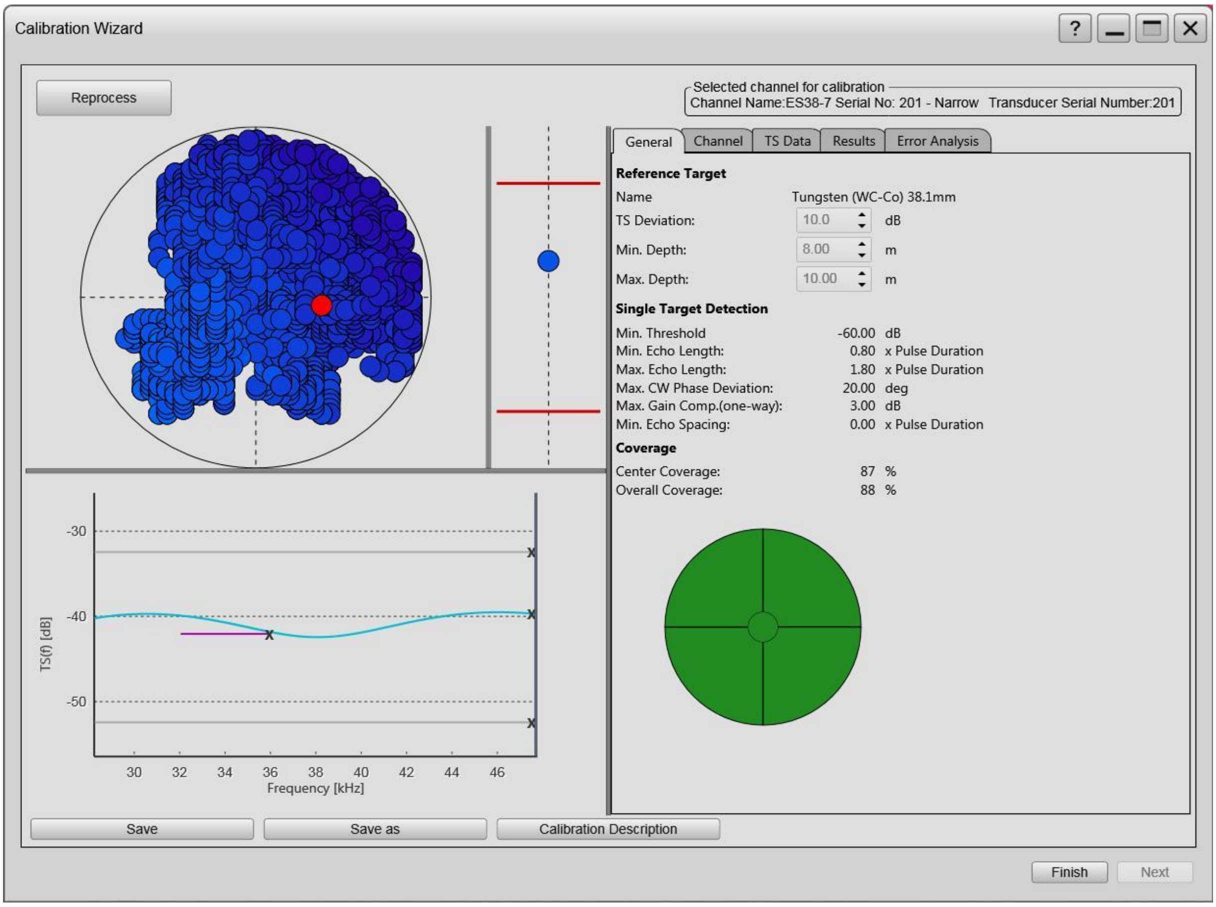


**Figure 13:** Calibration results from the EK80 software. Position of the soundings from the sphere can be seen blue in the upper left part of image. The green color for each sector (down right) indicates a sufficient coverage for each sector of the beam.

### *5.4.3 Methodology – Survey planning and minimizing interferences*

For the assessment of the method, we ran three surveys which were planned using the initial flare positions determined by the previous cruise M142. The setup and line spacing were optimized for water column imaging. Water column images are much more sensitive to interferences by other systems than bathymetric data. Therefore some of the systems where turned off to reduce interference artifacts. To be able to process complete acoustic flare maps (Urban et al., 2015), the line spacing must be much higher than what would be required for standard bathymetric surveys. However, to generate high quality assessment datasets and to maximize the chance of collecting high quality data from bubble streams with the EK80, we reduced the line spacing even further and the survey speed was reduced to 3 knots (5 knots during transit with the EK80 in the moonpool).

The first survey (13.12.2017 7:47 – 18:14 ship time; Figure 14) was planned over the location where the lander mounted with an EK80 from Kongsberg was placed during M142. Therefor we will be able to compare these datasets in the future. During the survey only the EK80, EM122 and the EM710 were turned on, while the PARASOUND was turned off. To optimize the EM122 and the EM710 for Water Column Imaging, we deactivated the Dual-Swath mode, FM-Pulses and the YAW-Stabilization in both systems. We also experimented with the ping-mode (shallow/medium), where the shallow ping mode produced higher resolution but we eventually decided that the medium ping mode seems to have a better signal to noise ratio. The EK80 was setup with maximum Power (1000W), CW-Pulse form with fast ramping at the maximum Pulse-Length of 2048ms. During this survey, some problems with the EM710 led to short interruptions in the recording. However due to the high line spacing, the area is still well and completely covered.

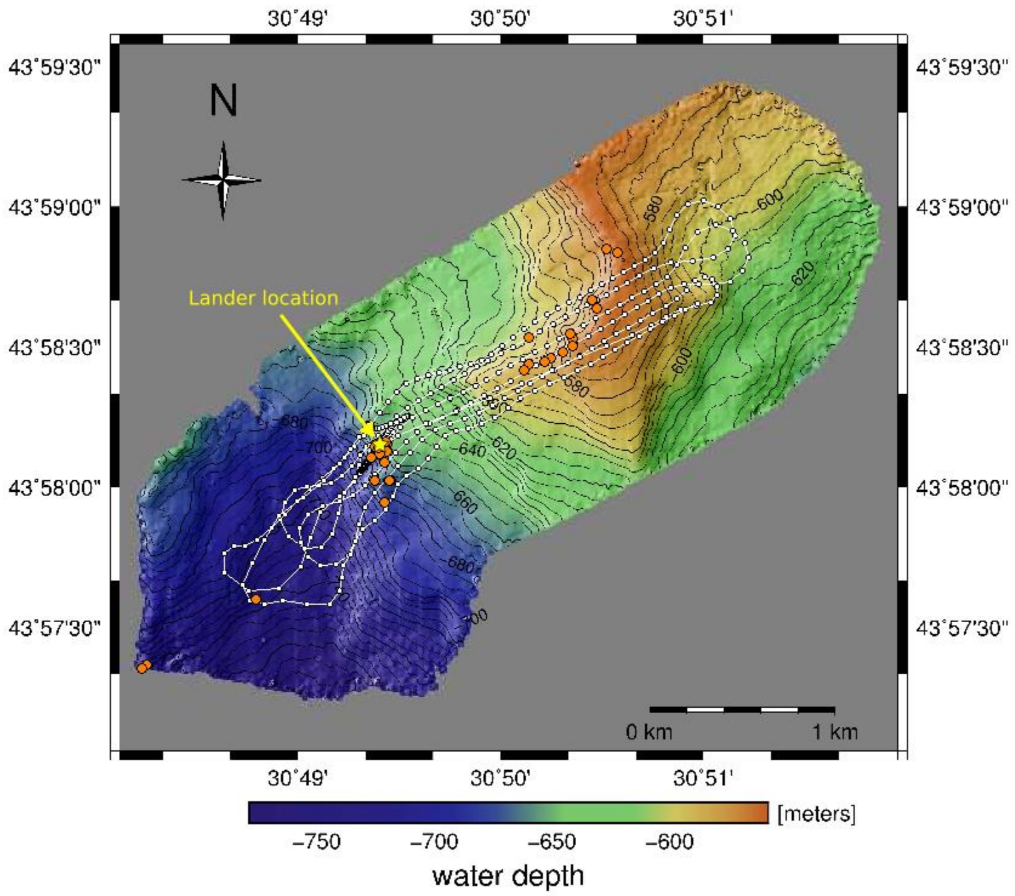


**Figure 14:** Track and bathymetry of the first water column survey at the M142 lander site. The shiptrack is in white lines with dots. The line spacing was ca. 20m. Flares detected during M142 plotted as orange points. The lander location is marked as a star.

With the second survey (13.12.2017 18:50 - 14.12.2017 09:58; Figure 15) we mapped a larger area at the eastern flank of the large canyon were we could cover many bubble streams in different depth (300m – 600m) with a very small line spacing of only 60m. After initial problems with the EM710, we restarted both, the EM710 and the survey. From this moment on, there were no further problems with the EM710.

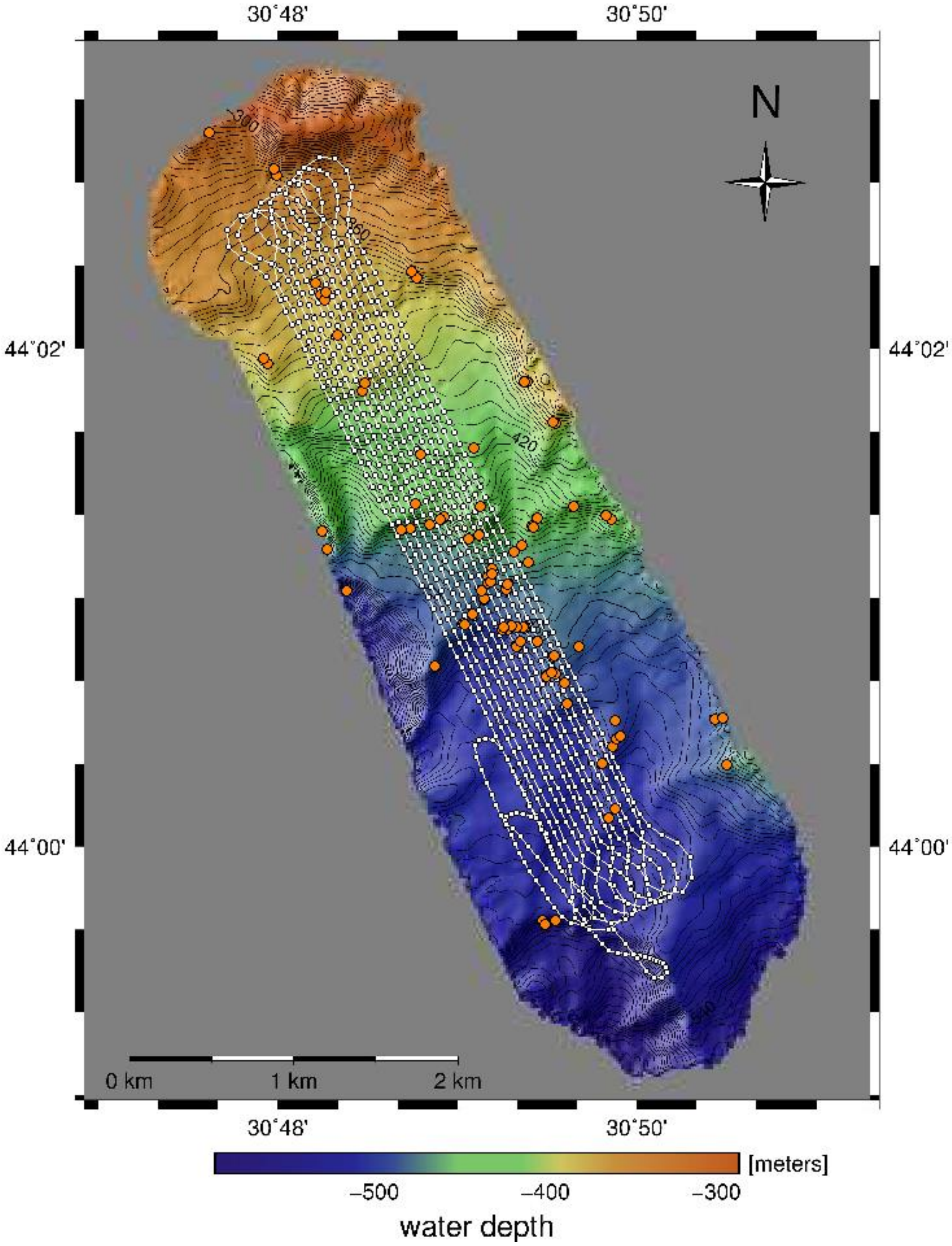


**Figure 15:** Track and bathymetry of the second water column survey at the eastern flank of the canyon. The shiptrack is in white lines with dots. The line spacing was ca. 60m. Flares detected during M142 plotted as orange points.

With the third survey (2017.12.14 11:27 - 2017.12.15 06:38; Figure 16) we covered a shelf area (115m -135m) with some known bubble stream locations along bathymetric depressions. During this survey the interferences in EM710 and EK80 data could be reduced significantly compared to the previous surveys by turning of the EM122 and setting the EK80 ping-shape to “slow ramping”. The EM710 was set to shallow mode to reach higher resolution. The survey can be divided into three sub-surveys. First an overview survey, that covers locations along the bathymetric ‘stairs’. Second a circular survey along two of the stairs with an ultra-dense line-spacing of only 10 m. This allows for repetitive comparison of all flare locations in the EM710 and ensures that most of these bubble streams were covered very well in the EK80. The third survey covered some bubble streams that were detected in the EM710 during the first sub-survey but were not yet mapped well enough for complete flare mapping. (See “visible water column” in Urban et al. 2015)

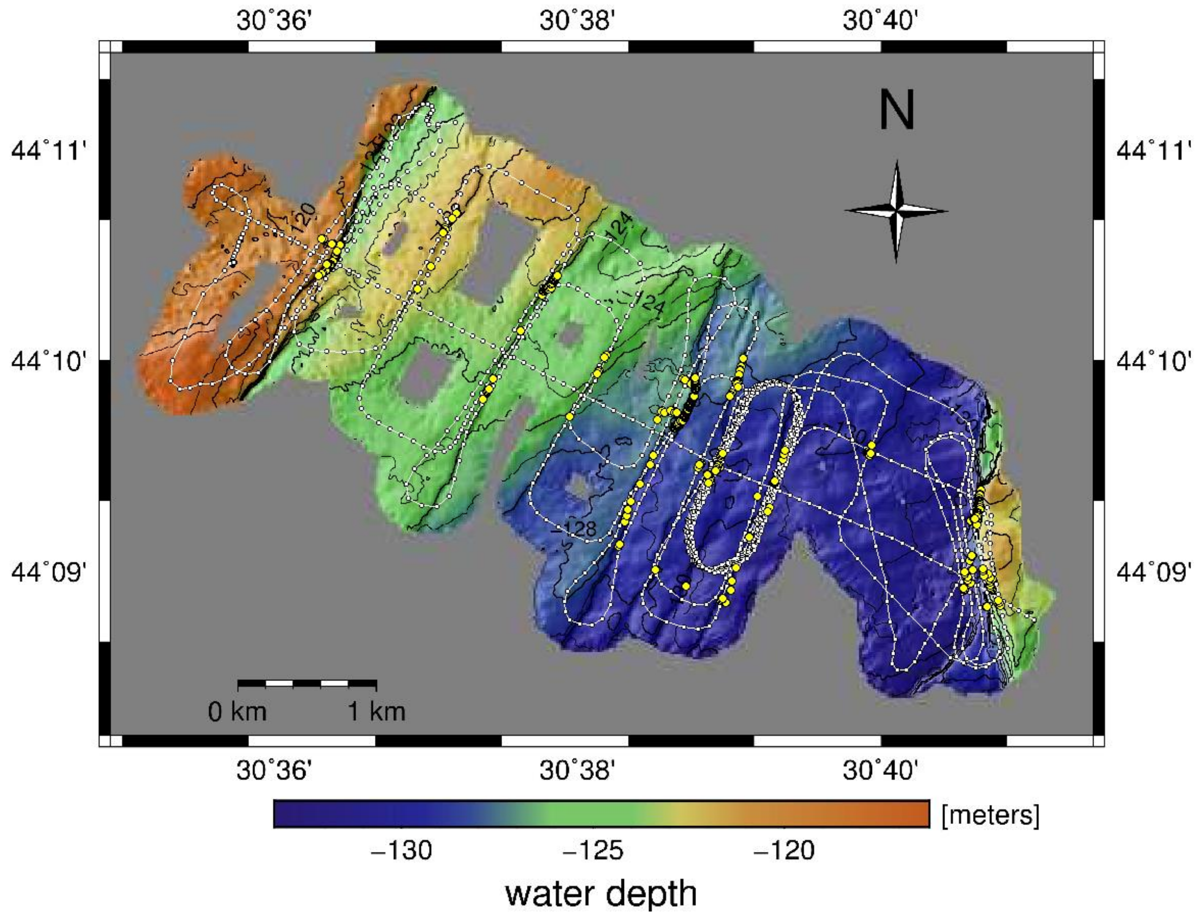


**Figure 16:** Track and bathymetry of the third water column survey at the shelf area. The shiptrack is in white lines with dots. The most dense line spacing was ca. 10m. Flares that where coarsly picked from the overview sub survey during M143 are marked in yellow.

### 5.4.4 Preliminary Results

A first look through the dataset revealed that the overall quality of the WCI is generally good throughout all surveys. In total we acquired 128,4 nautical miles (237.8 km) of continuous profiles of EK80 data (at a nominal speed of 3 knots) and an additional 8,7 nautical miles (16.1 km) of transit (with a nominal speed of 5 knots). In the first two surveys one can observe that the noise level close to the seafloor starts getting stronger. This is because of the depth of above 400 m. However, bubble streams are still well visible in both the EM710 and the EK80 (Figure 17).

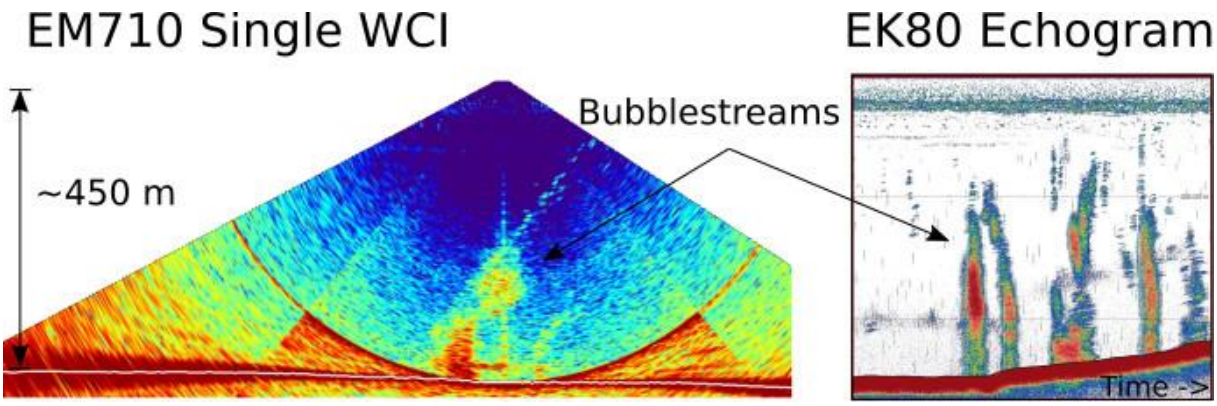


**Figure 17:** Example for a bubble stream (acoustic flare) in a EM710 WCI and the EK80 Echogram in ca. 450m depth.

The EM122, which was only turned on during the first two surveys, generally produced good results with flares being well visible (Figure 18). However, compared to the EM710 the resolution is very low and specifically when the water depth decreased interferences of the EM122 where visible in the EM710 and the EK80.

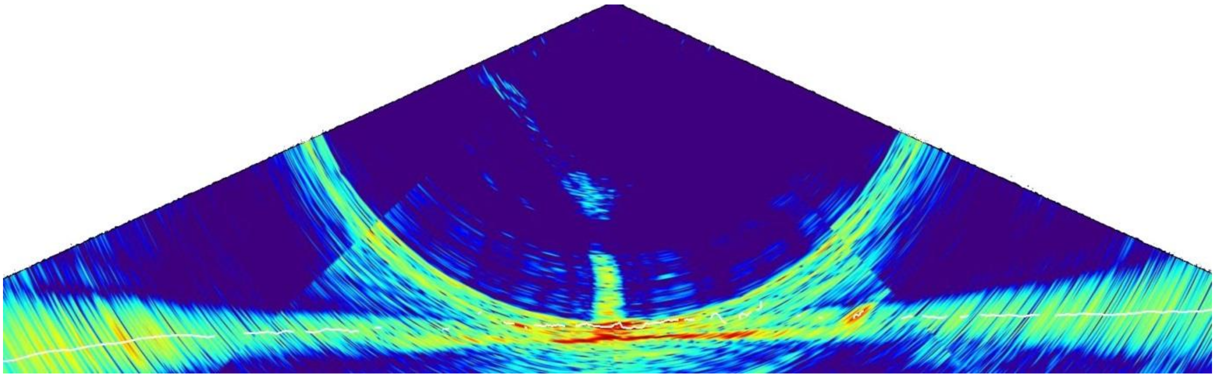

**Figure 18:** Example for a bubble stream in a EM122 WCI at ca. 450 m water depth. It can be observed tat there is significantly less background noise. Hover the resolution of the system is much lower and less detailed than the EM710 data.

During the last survey on the shelf the background noise of the EM710 became unnoticeable and the quality water column images increased even further because we could set the system in shallow mode (Figure 19). Because the EM122 was turned off and the EK80 pulse-shape was set to slow ramping, the visible interferences in the EM710 could be reduced significantly, such that specifically the inner sector of the EM710, which looks downwards, is nearly free of interferences.

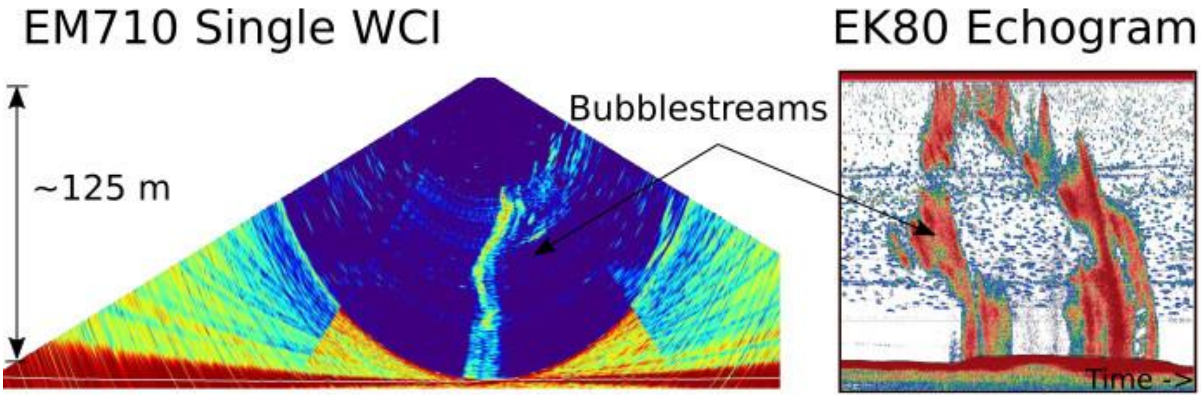


Figure 19: Example for a bubble stream (acoustic flare) in an EM710 WCI and the EK80 Echogram in ca. 125m depth.

### *5.4.5 Additional comments for processing the data*

- The offsets of the EK80 system are NOT includet in the .raw files.
- During the first survey the EK80 system was not yet calibrated for TS-values. Thus the data need to be replayed and reprocessed with the correct calibration file.
- The svp files included in the EM710 and the EM122 where not always updated. Therefore the svp profiles which are included in the files must be replaced with the correct sound velocity profiles taken by the svp casts.

## 5.5 Scientific Data Management

The raw data recorded by the ship's acquisition computers were copied to ship's server. For processing (Qimera / ArcGIS / SAGA GIS / GMT), the data were copied to local work stations. The processed data were then collected on the ship's server again and ultimately copied to several external hard drives together with the raw data and all other acquired data during M143.

# 6 Acknowledgements

We would like to thank Captain Rainer Hammacher and his entire crew for the great support during expedition M143, especially during installation of the 38 kHz sounder, which was never done before on board the R/V METEOR. Additional thanks go to the German Research Fleet Coordination Centre at the University Hamburg for granting ship time, as well as our staff at GEOMAR (especially Anne Völsch) in helping to coordinate travel, shipping, and overall logistics.

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# 8 Appendix

## 8.1 Weather report


Deutscher Wetterdienst
Wetter und Klima aus einer Hand

The expedition started in Varna on 12th December 2017 at 10:00 local time. The RV Meteor was heading into the northwestern parts of the Black Sea. A low pressure system was centered over northern Italy and a storm over the Baltic Sea; on the other hand there was an extensive high pressure area over Russia and the Caucasus. On the first days a southerly flow dominated, at the start with 5 Bft, going down to 3 Bft the following day. The swell from southwest of 1,5 meters was decreasing slowly. Except from that weather and was fine for the profiling and mapping experiments.

On the next day the swell was decreasing below 0.5 meters and with weak winds the weather conditions were excellent for the calibration of the single beam EK 80 echo sounder.

High clouds start to cover the sky and on Wednesday 14th December a weak cold front crosses the Black Sea. The weak winds were temporally veering to west while the sky was overcast without any precipitation. After that the wind was backing to south. The comparison experiments between the single and multibeam sonars were successful completed. After that the RV Meteor continued with bathymetric measurements on the Danube valley.

An area of low pressure from northeastern Europe down the northern Italy was slowly moving eastwards. On Saturday 16th December a strong low was moving from Romania to Russia. Across the Caucasus high pressure prevailed, so strong winds from the south were expected for that day. The measurements on board the FV Meteor recorded wind speeds up to gale force (7 Bft) and wave height up to 3 meters, but fair weather conditions. On the following night the wind decreased to 5 Bft.

On the last the day of the measurements, Sunday 17th December, another low was approaching the area from the Balkan Peninsula heading directly for the expedition area. At 18:00 all sonar soundings were finished and the RV Meteor was heading south to the Bosporus, just before the cold front arrived at the northwestern Black Sea with strong northerly veering winds.

## 8.2 List of survey regions, stations with sound-velocity measurements, and transit profiles

| Station/Profile ID | | Date / Time (UTC) | Device | Action | Latitude | Longitude | Depth (m) | Speed of vessel (kn) | Course (°) |
|---|---|---|---|---|---|---|---|---|---|
| M143_1-1 | Transit to research region | 12/12/2017 16:03 | Multibeam and Parasound Profile | profile start | 43° 41,197' N | 029° 45,197' E | 82.2 | 7 | 95.6 |
| M143_1-1 | | 12/12/2017 23:07 | Multibeam and Parasound Profile | profile end | 44° 05,498' N | 030° 45,813' E | 172.3 | 7 | 61.5 |
| M143_2-1 | Survey region “S2 channel head” | 12/12/2017 23:14 | Multibeam and Parasound Profile | profile start | 44° 05,683' N | 030° 46,008' E | 165.9 | 5 | 231.4 |
| M143_2-1 | | 12/13/2017 4:15 | Multibeam and Parasound Profile | profile end | 44° 02,683' N | 030° 38,511' E | 136.7 | 7 | 239.2 |
| M143_3-1 | Survey region “Lander Position” | 12/13/2017 7:32 | Multibeam and Parasound Profile | profile start | 43° 57,977' N | 030° 49,039' E | 662.9 | 4 | 47.3 |
| M143_3-1 | | 12/13/2017 10:52 | Multibeam and Parasound Profile | profile end | 43° 58,592' N | 030° 50,781' E | 576.4 | 4 | 240.4 |
| M143_3-1 | | 12/13/2017 15:48 | Multibeam and Parasound Profile | profile start | 43° 57,957' N | 030° 49,469' E | 679.2 | 3 | 21.7 |
| M143_3-1 | | 12/13/2017 16:13 | Multibeam and Parasound Profile | profile end | 43° 58,636' N | 030° 50,920' E | 592 | 3 | 62.8 |
| M143_4-1 | | 12/13/2017 11:28 | Sound Velocity Profiler | in the water | 43° 58,094' N | 030° 49,351' E | 687.2 | 0 | 126.4 |
| M143_5-1 | | 12/13/2017 12:49 | Sound Velocity Profiler | in the water | 43° 58,222' N | 030° 49,348' E | 687.2 | 0 | 43.8 |
| M143_6-1 | Survey region “S2 channel flank” | 12/13/2017 18:18 | Multibeam and Parasound Profile | profile start | 43° 59,924' N | 030° 49,571' E | 521.8 | 3 | 333.1 |
| M143_6-1 | | 12/14/2017 7:59 | Multibeam and Parasound Profile | profile end | 44° 02,530' N | 030° 48,372' E | 360.8 | 3 | 330.3 |
| M143_7-1 | Transit to shelf survey region | 12/14/2017 8:17 | Multibeam and Parasound Profile | profile start | 44° 03,654' N | 030° 48,488' E | 310.3 | 5 | 320.3 |
| M143_7-1 | | 12/14/2017 11:20 | Multibeam and Parasound Profile | profile end | 44° 10,681' N | 030° 35,834' E | 119.8 | 3 | 298.6 |
| M143_8-1 | | 12/14/2017 11:40 | Sound Velocity Profiler | in the water | 44° 10,492' N | 030° 35,728' E | 120 | 1 | 205.4 |
| M143_9-1 | Survey region 1 on shelf | 12/14/2017 12:14 | Multibeam and Parasound Profile | profile start | 44° 10,048' N | 030° 35,919' E | 119.3 | 4 | 43.5 |
| M143_9-1 | | 12/14/2017 15:38 | Multibeam and Parasound Profile | profile end | 44° 08,673' N | 030° 40,289' E | 131.8 | 3 | 211.2 |
| M143_10-1 | Survey region 2 on shelf | 12/14/2017 16:07 | Multibeam and Parasound Profile | profile start | 44° 09,778' N | 030° 39,027' E | 129.4 | 3 | 194.7 |
| M143_10-1 | | 12/14/2017 22:07 | Multibeam and Parasound Profile | profile end | 44° 09,772' N | 030° 39,510' E | 129.7 | 3 | 22.5 |
| M143_11-1 | Survey region 3 shelf | 12/14/2017 22:25 | Multibeam and Parasound Profile | profile start | 44° 09,467' N | 030° 40,597' E | 130.9 | 4 | 180.9 |
| M143_11-1 | | 12/15/2017 5:58 | Multibeam and Parasound Profile | profile end | 44° 10,966' N | 030° 36,717' E | 125 | 3 | 33.8 |
| M143_12-1 | Survey region Eastern slope | 12/15/2017 8:07 | Multibeam and Parasound Profile | profile start | 44° 10,640' N | 031° 02,090' E | 492.4 | 7 | 68.1 |
| M143_12-1 | | 12/17/2017 15:19 | Multibeam and Parasound Profile | profile end | 44° 14,531' N | 030° 55,954' E | 182 | 8 | 230.9 |

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