Wehrtechnische Dienststelle 71

C r u i s e R e p o r t

r/v ELISABETH MANN BORGESE

Cruise- No. EMB 334

This report is based on preliminary data

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1. **Cruise No.:** EMB 334

2. **Dates of the cruise:** from 13.10.2023 to 27.10.2023

3. **Particulars of the research vessel:**
   Name: ELISABETH MANN BORGESE (EMB)
   Nationality: Germany
   Operating Authority: WTD71

4. **Geographical area in which ship has operated:**
   Sognefjord (Norway) and western Baltic sea (Germany)

5. **Dates and names of ports of call**
   Port of Kristiansand, Norway, on Tuesday, 17th, and daily entering and leaving of port of Høyanger, Norway, from Thursday, 19th (first entering), to Sunday, 22nd (last leaving), of October 2023.

6. **Purpose of the cruise**
   The purpose of the research cruise *ARCAS2023* is to improve the scientific methodology of underwater sound propagation experiments in deep water environments and the physical understanding of noise processes in underwater sound transmission. The research is based on results obtained from the preceding sea trial *ARCAS2018* (EMB196), *Sensor2019* (EMB216), and *ARCAS2021* (EMB275) to Sognefjord, Norway.

7. **Crew:**
   Name of master: T. Henning
   Number of crew: 10

8. **Research staff:**
   Chief scientist: Dr. J. Abshagen

   Scientists: 1

   Engineers: 4

   Technicians: 1

9. **Co-operating institutions:** none

10. **Scientific equipment**

- Uniform circular acoustic receiver array with drift buoy
- Vertical array of eight hydrophones with drift buoy
- Towed sound projectors (small and large)
- Single hydropones and sound projectors
- On-board CTD of RV EMB

11 General remarks and preliminary results

11.1 Introduction

The research cruise ARCAS2023 (Advanced Receiver and Channel Analysis) started at WTD 71 in Kiel, Germany, on Friday, 13th of October 2023, with loading measurement equipment to RV ELISABETH MANN BORGESE. Due to a predicted heavy storm in the North Sea the departure from Kiel was postponed by one day from Saturday, 14th, to Sunday, 15th. The research cruise ended on October, 27th, with unloading RV ELISABETH MANN BORGESE at WTD 71 in Kiel.

(a) (b)

Figure 1: RV ELISABETH MANN BORGESE entering Sognefjord on Friday, 19th, and moored in Høyanger harbor, Norway, on Friday, 20th, of October 2023.

Pictures of RV ELISABETH MANN BORGESE entering Songnefjord on October, 19th, and moored in Høyanger harbor on October, 20th, can be seen in Figure 1 (a) and (b), respectively. Persistent bad weather, in particular heavy winds, prevented the conductance of most of the indented research program of ARCAS2023. The intended research is based on results obtained from the preceding sea trial ARCAS2018 (EMB196 [1]), Sensor2019 (EMB216 [2]), and ARCAS2021 (EMB275 [3]) to Sognefjord, Norway.

Due to the bad weather only calibration measurements of hydroacoustic systems with RV ELISABETH MANN BORGESE drifting in a sheltered position near the mouth of the Høyanger fjord were feasible. RV ELISABETH MANN BORGESE left Sognefjord already on October, 22nd, due to pedicted bad weather in the North Sea for sound propagation experiments in the shallow water areas of the western Baltic sea.

11.2 Course of Research Cruise

RV ELISABETH MANN BORGESE was loaded at WTD 71 in Kiel on Friday, 13th, but departed not before Sunday, 15th, on 13:00 p.m. because of a predicted heavy storm on the trip route though the North Sea. Preliminary system tests were performed on Sunday along the route in the Kiel fjord before RV ELISABETH MANN BORGESE started its journey to Sognefjord, Norway, at 17:00 p.m..

The research vessel arrived after a journey of three and a half days through the Great Belt, the Kattegat, the Skagerrak, and the North Sea with a intermediate stay in Kristiansand (due to a medical incident) in the measurement area in central Sognefjord south of Høyanger, Norway, on Thursday, 19th. Due to the bad weather conditions the total delay of the journey to Sognefjord accumulated to two days. A time schedule of the research cruise ARCAS2023 is given below:

Date	Harbor	Leaving	Experiments started	Config.	Experiments finished	Entering
13.10.	Kiel	-	-	loading	-	(0745)
14.10.	Kiel	-	-	tests	-	-
15.10.	Kiel	1300	-	journey	-	-
16.10.	-	-	-	journey	-	-
17.10.	Kristiansand	2130	-	(crew change)	-	1200
18.10.	-	-	-	journey	-	-
19.10.	Høyanger	-	1300	system tests	1600	1700
20.10.	Høyanger	0730	0845	calibration	1350	1500
21.10.	Høyanger	0730	-	-	-	1300
22.10.	Høyanger	0800	0900	calibration	1300	-
23.10.	-	-	-	journey	-	-
24.10.	-	-	-	journey	-	-
25.10.	-	-	0815	shallow water	1725	-
26.10.	Kiel	-	-	-	-	1500
27.10.	Kiel	(1100)	-	unloading	-	-

In contrast to the foretasted (good) weather conditions in the Sognefjord region for the aspired measurement period heavy winds breezed from the east in the measurement area with wind gusts up to 12 BF. Untypically for this area the storm persisted with almost equal intensity over the entire measurement period. Due to a predicted heavy storm on the trip route though the North Sea RV ELISABETH MANN BORGESE started the return journey to Kiel bay already on Sunday, 22nd, on 15:00 p.m., i.e. two days in advance of the scheduled leaving date.

Within the entire measurement period form Thursday, 19th, to Sunday, 22nd, bad weather

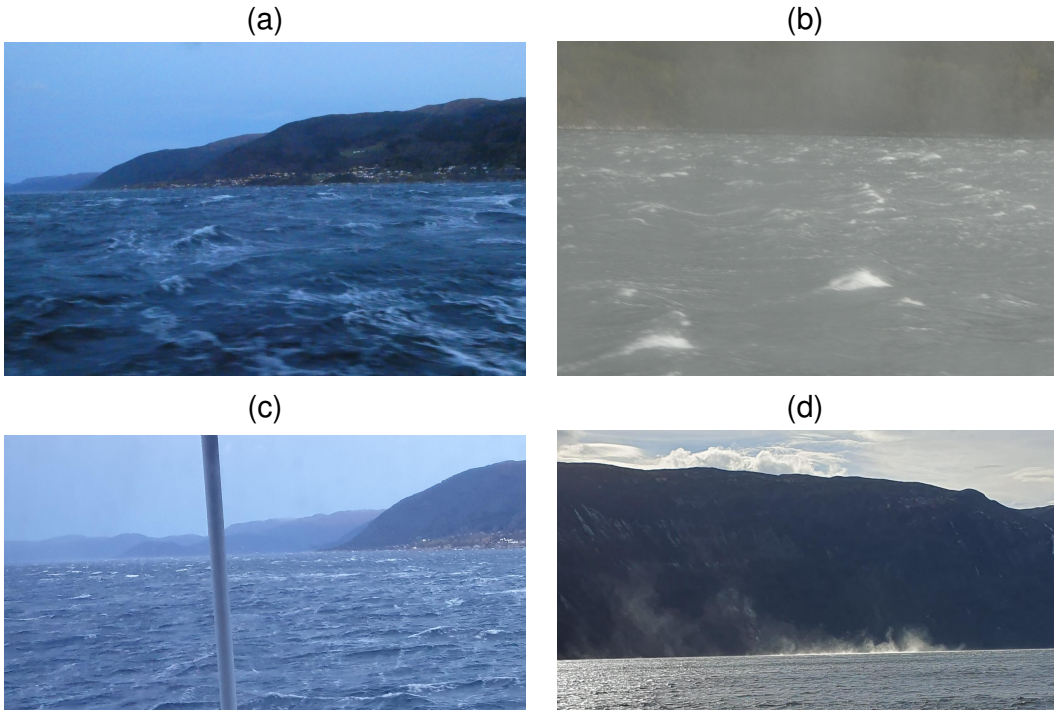

Figure 2: Pictures illustrating the weather conditions in Sognefjord (a-c) and Høyanger fjord (d) within the measurement period

with heavy winds and currents prevented most of the planned hydroacoustic experiments. In particular the use of drift buoys but also drift experiments with suspended equipment (including CTD measurements with the onboard system of RV ELISABETH MANN BORGESE) were not feasible in Sognefjord. The bad measurement conditions in Sognefjord and Høyanger fjord during the measurement period are illustrated in Fig. 2. Attempts to change the location toward a more inland area within the authorized measurement area were not successful. Therefore only calibrations measurement were performed in a sheltered position near the mouth of the Høyanger fjord. But even in this area the available measurement time was substantially limited due the influence of the bad weather.

After a return journey of two and a half days through the North Sea, the Skagerrak, and the Kattegat RV ELISABETH MANN BORGESE arrived in Kiel bay located in the western Baltic Sea, Germany, on Wednesday, 25th. Hydroacoustic experiments on sound propagation were conducted on that day, but further experiments scheduled for Thursday, 26th, had to be canceled due upcoming bad weather also in the Kiel bay. RV ELISABETH MANN BORGESE entered the harbor of WTD 71 in Kiel in the afternoon of Thursday, 26th, and was unloaded on Friday, 27th of October.

11.3 Hydroacoustic Systems

In Fig. 3 pictures of the hydroacoustic systems intended to use for sound transmission experiments during the research cruise ARCAS2023 can be seen.

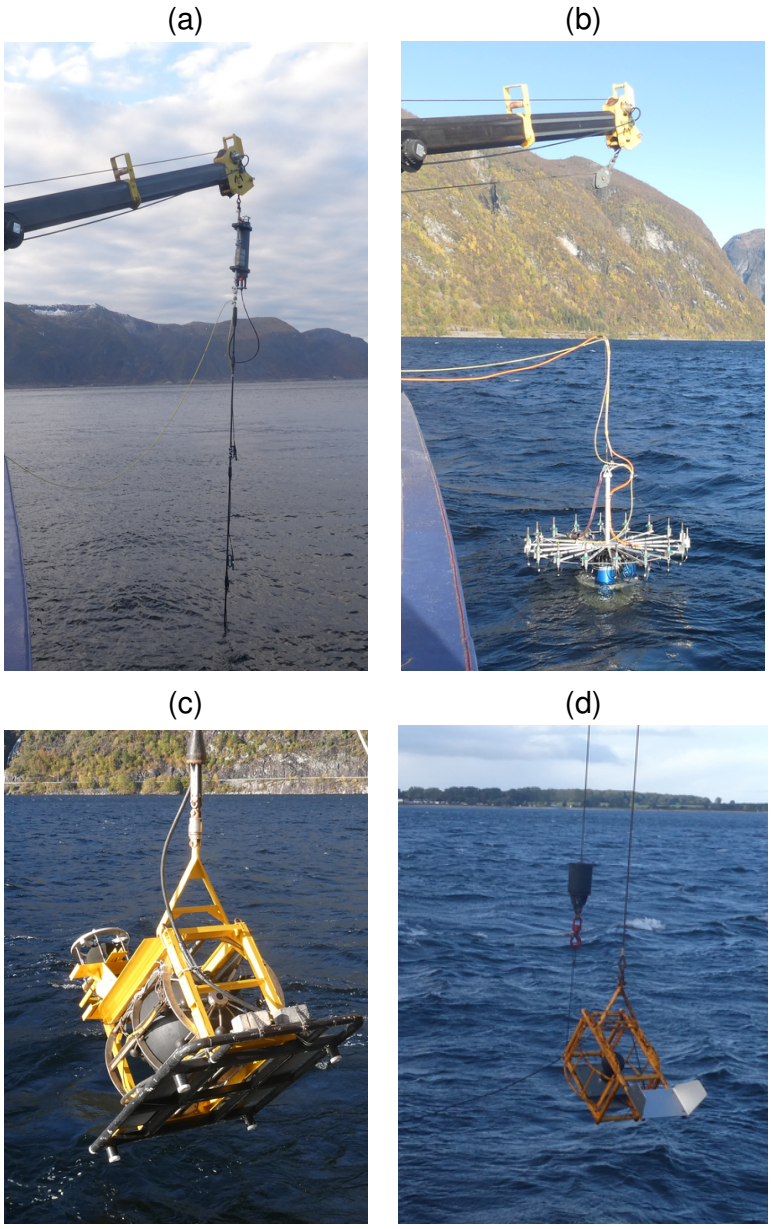

Figure 3: Pictures of a vertical array (a) and a uniform circular array (b) released from RV ELISABETH MANN BORGESE for calibration measurements during ARCAS2023. Pictures of a large towed sound transducer during system tests in Høyanger fjord (a) and of a small towed sound transducer in the Kiel bay (b).

In the upper row of Fig. 3 the two array systems, a vertical AMAR (Autonomous Multi-channel Acoustic Receiver, JASCO Ltd.) array system with eight hydrophones (a) and a universal circular array (b), are shown. The lower row of Fig. 3 displays two different towed sources, a low-frequency source with additional high frequency component (c) and a small high frequency sound source (d). For the calibration measurements the systems were suspended from RV ELISABETH MANN BOGESE, which was drifting in a sheltered position. Neither towing experiments with towed sources, nor experiments with drift buoy have been performed during ARCAS2023.

11.4 CTD measurements

The speed of sound in sea water depends strongly on temperature, salinity, and pressure and can vary significantly with depth and time in Sognefjord. Sound speed profiles are essential for hydroacoustic calibration measurement. Dates, time, position, and depth of each CTD station of the research cruise ARCAS2023 are given below:

Date	Station	Time (UTC+2)	Position (Lat, Lon)	Depth (m)	c_{min} (m/s)	c_{max} (m/s)
19.10.	0001	11:25:39	61 10.58 N, 6 00.70 E	101.00	1471.80	1502.19
20.10.	0002	06:58:49	61 10.49 N, 6 00.79 E	101.66	1479.93	1502.29
22.10.	0003	07:01:34	61 10.64 N, 6 00.70 E	101.60	1483.84	1501.22

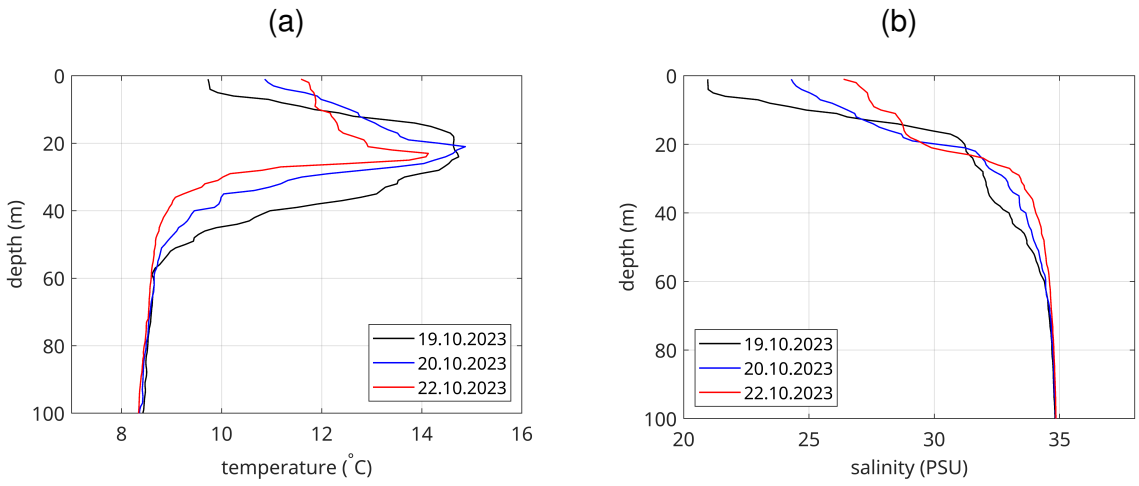

Figure 4: Vertical profiles of temperature (a) and salinity (b) near the mouth of Høyanger fjord during ARCAS2023.

CTD profiles were measured with the on-board CTD probe of RV ELISABETH MANN BORGESE down to a depth of 100 m. From the measured quantities the speed of sound was calculated with the on-board system of IOW (Institute of Baltic Sea Research, Warnemünde, Germany).

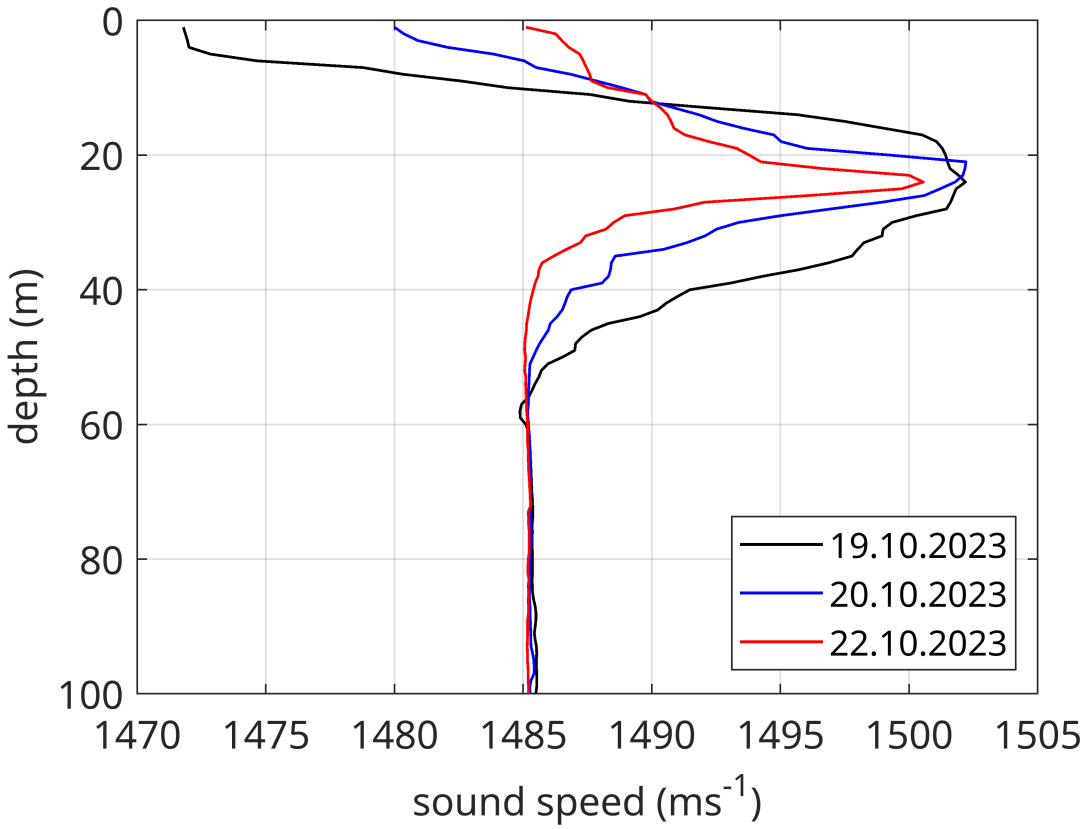

Figure 5: Vertical profiles of sound speed near the mouth of in Høyanger fjord during ARCAS2023.

The vertical profiles of temperature and salinity that were measured within the period between October, 19th, to October, 22nd, near the mouth of the Høynager fjord are depicted in Fig. 4 (a) and (b), respectively. Fig. 5 displays the corresponding vertical profiles of sound speed. Strong variations between the profiles can be found near the surface and within the thermocline region that in located at the measurement positions within the water layer down to about 60 m depth.

The measurements of sound speed illustrate the temporal variability in the upper layer caused by heavy winds during the measurement period. The knowledge of sound speed is important for the calibration measurements in order to calculate the transmission loss between sound source and receiver.

11.5 Western Baltic Sea

In the remaining measurement time of the reseach cruise ARCAS2023 sound propagation experiments were performed in the shallow water areas of Kiel bay in the western Baltic sea. Due to heavy easterly winds on October, 26th, the shallow water experiments were limited to the 25th of October.

(a) (b)

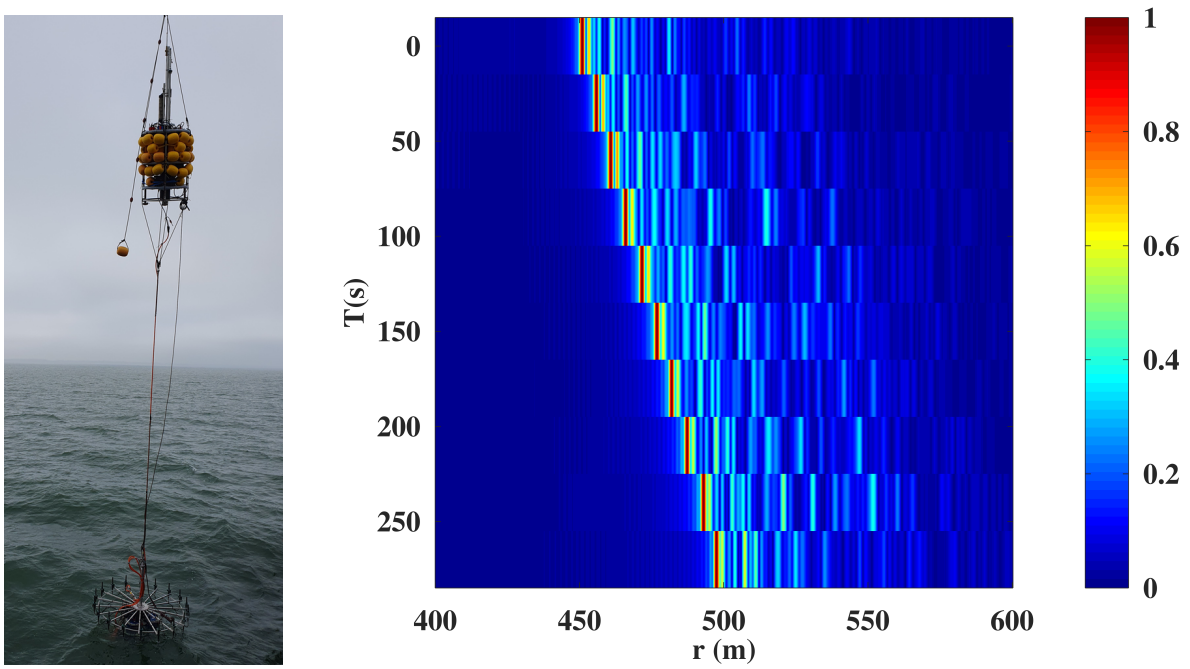

Figure 6: Picture of UCA with drift buoy during deployment in Kiel bay (a). Output of (normalized) matched filter (b) from drift experiment with distances of about 500 m between ship with sound source and drifting receiver buoy.

The universal circular array was deployed as a buoy system at a depth of 10 m, i.e. about half water depth in the measurement area. A picture of the universal circular array with drift buoy be seen in Fig. 6 (a).

Fig. 6 (b) displays the (normalized) output of the matched filter in a sound propagation experiment, where the distance between sound source suspended from drifting RV ELISABETH MANN BORGESE and the drift receiver buoy was about 500 m. Low-frequency LFM-sweeps with a length of 500 ms and a repetition rate of 30 s were utilized. The influence of drift and multipath propagation can be seen in Fig. 6 (b).

Acknowledgments

The support from the Captain and all members of the crew of RV ELISABETH MANN BORGESE was excellent and is gratefully acknowledged.

References

[1] J. Abshagen, Cruise Report, r/v ELISABETH MANN BORGESE, Cruise-No. EMB196_Abshagen (2018)

[2] J. Abshagen and A. Schulz, Cruise Report, r/v ELISABETH MANN BORGESE, Cruise-No. EMB216_Abshagen (2019)

[3] J. Abshagen, Cruise Report, r/v ELISABETH MANN BORGESE, Cruise-No. EMB275_Abshagen (2021)