Wehrtechnische Dienststelle 71

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

r/v ELISABETH MANN BORGESE

Cruise- No. EMB 275

This report is based on preliminary data

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1. **Cruise No.:** EMB 275

2. **Dates of the cruise:** from 01.09.2021 to 14.09.2021

3. **Particulars of the research vessel:**
   Name: ELISABETH MANN BORGESE (EMB)
   Nationality: Germany
   Operating Authority: WTD 71

4. **Geographical area in which ship has operated:**
   Sognefjord, Norway

5. **Dates and names of ports of call**
   daily entering and leaving of port of Høyanger, Norway, from Sunday, 5th (first entering), to Friday, 10th (last leaving), of September 2021

6. **Purpose of the cruise**
   The research cruise *ARCAS2021* is aimed to gain a deeper scientific understanding of underwater noise processes that interfere the reception of underwater sound. Experiments with different configurations of hydroacoustic transducers and vertical arrays were conducted in Sognefjord. The research is based on results obtained from the preceding sea trial *ARCAS2018* (EMB196).

7. **Crew:**
   Name of master: Dirk Thürsam
   Number of crew:

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

   Scientists: Christian Haak

   Engineers: Jörg Schulz, Ralf Lühder

   Technicians: Klaus Balzer

9. **Co-operating institutions:** n/a

10. **Scientific equipment**

- Ship-suspended systems and drift buoys for sound reception and transmission
- Reception: Vertical array, Reson TC 4014 hydrophones
- Transmission: Spherical transducer, flooded ring transducer
- On-board CTD of RV EMB

11 General remarks and preliminary results

11.1 Introduction

The research cruise ARCAS2021 (Advanced Receiver and Channel Analysis) started at WTD 71 in Kiel, Germany, on September, 1st, and ended there on September, 13th, 2021. The departure of RV ELISABETH MANN BORGESE from Kiel was delayed by one day due to a predicted heavy storm in the North Sea. Improved weather conditions on the following days allowed a smooth passage through the Kattegat and Skagerrak into the North Sea on September, 2nd and 3rd. Pictures of RV ELISABETH MANN BORGESE leaving Kiel Fjord on September, 2nd, can be seen in Fig. 1.

(a) (b)

Figure 1: RV ELISABETH MANN BORGESE in Kiel Fjord on the way to Norway on Thursday, 2nd, of September 2021 (a,b).

The measurement area in Sognefjord, Norway, was reached on September, 5th, in the morning and RV ELISABETH MANN BORGESE sailed back from Sognefjord to Kiel on Friday 10th. After a stoppover for acoustic ranging in Eckernförde Bay (Germany) in the morning of September, 13th, the research cruise EMB275 ended at WTD 71 in Kiel in the afternoon on the same day.

The scientific aim of the research cruise was to deepen the scientific understanding of underwater noise processes that interfere the reception of underwater sound under deep water conditions. The scientific investigations of EMB275 continued those from preceding cruises with RV ELISABETH MANN BORGESE to Sognefjord between 2016 and 2019 [1–3]. During the measurement period from Sunday, 05th, to Friday, 10th, different kinds of underwater experiments on the variability of sound propagation were conducted in central Sognefjord near Høynager. As part of the experiments both transducers [4]) and ships [5] were utilized as sound sources. The hydroacoustic experiments were alinged by CTD measurements of the oceanic stratification. The vertical profiles of temperature, salinity, and sound speed of central Sognefjord are given in section 11.4.

The underwater experiments were performed with vertical arrays combined with a freely drifting buoy system. As a sound projector either a flooded ring transducer suspended from RV ELISABETH MANN BORGESE or a towed spherical transducer was utilized. Furthermore, stationary calibration measurements of hydroacoustic sensor elements were performed with an underwater transducer suspended from the drifting research vessel.

11.2 Course of Research Cruise

RV ELISABETH MANN BORGESE was loaded at WTD 71 in Kiel on Tuesday, 1st, but departed not before Thursday, 2nd, at 01:00 p.m. because of a predicted heavy storm on the trip route though the North Sea. After a journey of two and a half days through the Great Belt, the Kattegat, the Skagerrak, and the North Sea the measurement area in central Sognefjord south of Høyanger, Norway, was reached on Sunday, 5th.

A time schedule of the research cruise ARCAS2018 is given below:

Date	Harbor	Leaving	Experiments started	Config.	Experiments finished	Entering
01.10.	Kiel	-	-	loading	-	(0745)
02.09.	Kiel	1300	-	journey	-	-
03.09.	-	-	-	journey	-	-
04.09.	-	-	-	journey	-	-
05.09.	Høyanger	-	0730	ship noise	1325	1440
06.09.	Høyanger	0730	0800	ship noise	1509	1615
07.09.	Høyanger	0730	0800	calibration	1619	1730
08.09.	Høyanger	0730	0800	sound channel	1603	1710
09.09.	Høyanger	0730	0800	sound channel	1505	1600
10.09.	Høyanger	0730	0800	ship noise	1512	-
11.09.	-	-	-	journey	-	-
12.09.	-	-	-	journey	-	-
13.09.	Eckernförde and Kiel	0830	0900	ship noise unloading	1425	1645

When arriving in the central Sognefjord south of Høyanger on Sunday, 5th, ship noise measurements were started immediately and were continued on the following day. On Tuesday, 7th, calibration measurements were performed by suspending both projectors and receivers from the drifting research vessel. On the following two days (8th/9th), experiments related to the variability in sound channel propagation were conducted using a freely drifting vertical array mounted to a drift buoy as well as different projectors suspended from the research vessel. On the final day of the measurement period (September, 10th) additional experiments on ship noise were performed with a freely drifting vertical array. After the return

journey to Germany RV ELIASBETH MANN BORGESE was acustically ranged in Eckernförde Bay on Monday, Sep. 13th, before entering the harbour of WTD 71 in Kiel at 4:45 p.m, where it was unloaded.

11.3 Hydroacoustic experiments

Ship noise measurements were performed using a freely drifting vertical array, which was connected to a buoy.

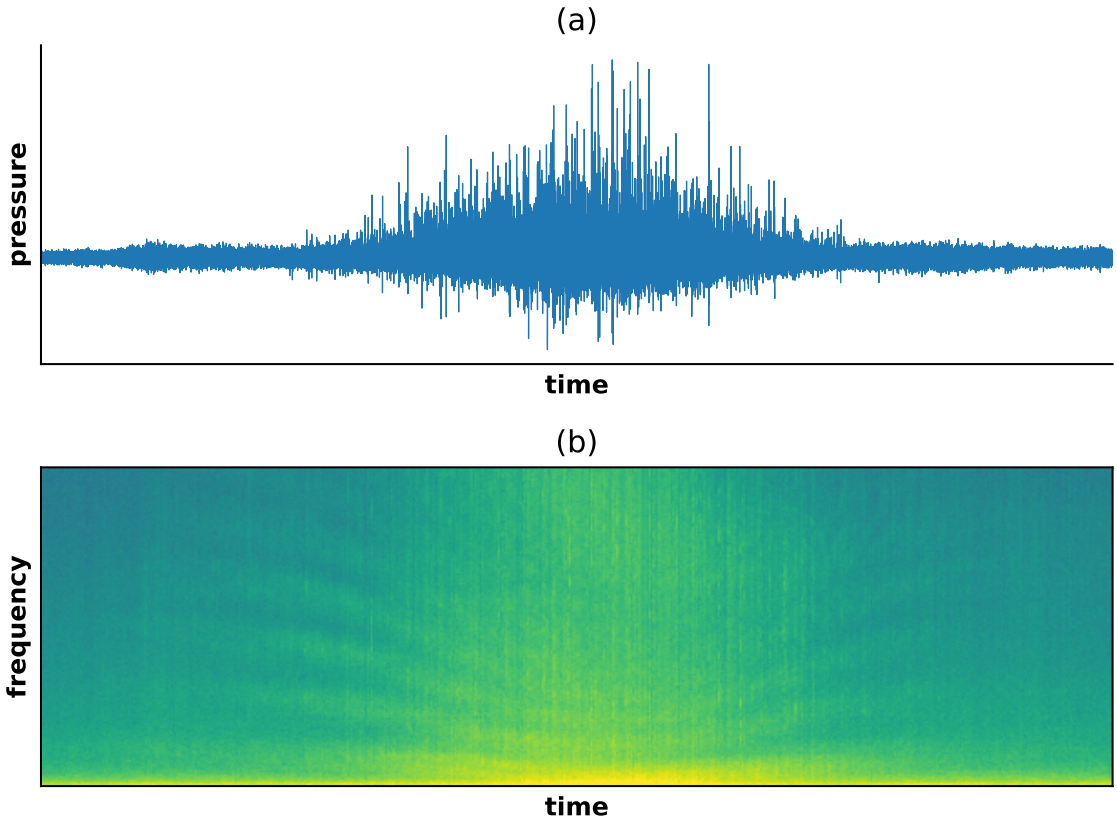

Figure 2: Measured signal (a) and resulting spectrogram (b) of a passing cargo vessel, with the closest point of approach (cpa) being approximately at the middle of the time axis.

In Fig. 2 the measured sound pressure (a) and the resulting spectrogram (b) of a passing cargo vessel is shown. In the time series (a), an increase and decrease of the signal strength can be observed, depending on whether the vessel is approaching or distancing. Additionally, relatively high peaks are clearly visible while the vessel is close to the array.

The peaks are caused by cavitation at the propellor and strongly exceed the remaining signal. In the corresponding spectrogram (b) several lines can be detected, which over time slowly de- and increase to lower or higher frequencies, respectively, depending on whether the ship is approaching or distancing. This U-shaped pattern is caused by the Lloyd-Mirror-effect, the interference of sound travelling the direct and the reflected surface path. Since the peaks caused by cavitation are relatively short in time (a), they are respresented by an relatively broad band of frequencies and can be observed as vertical lines in the spectrogram (b).

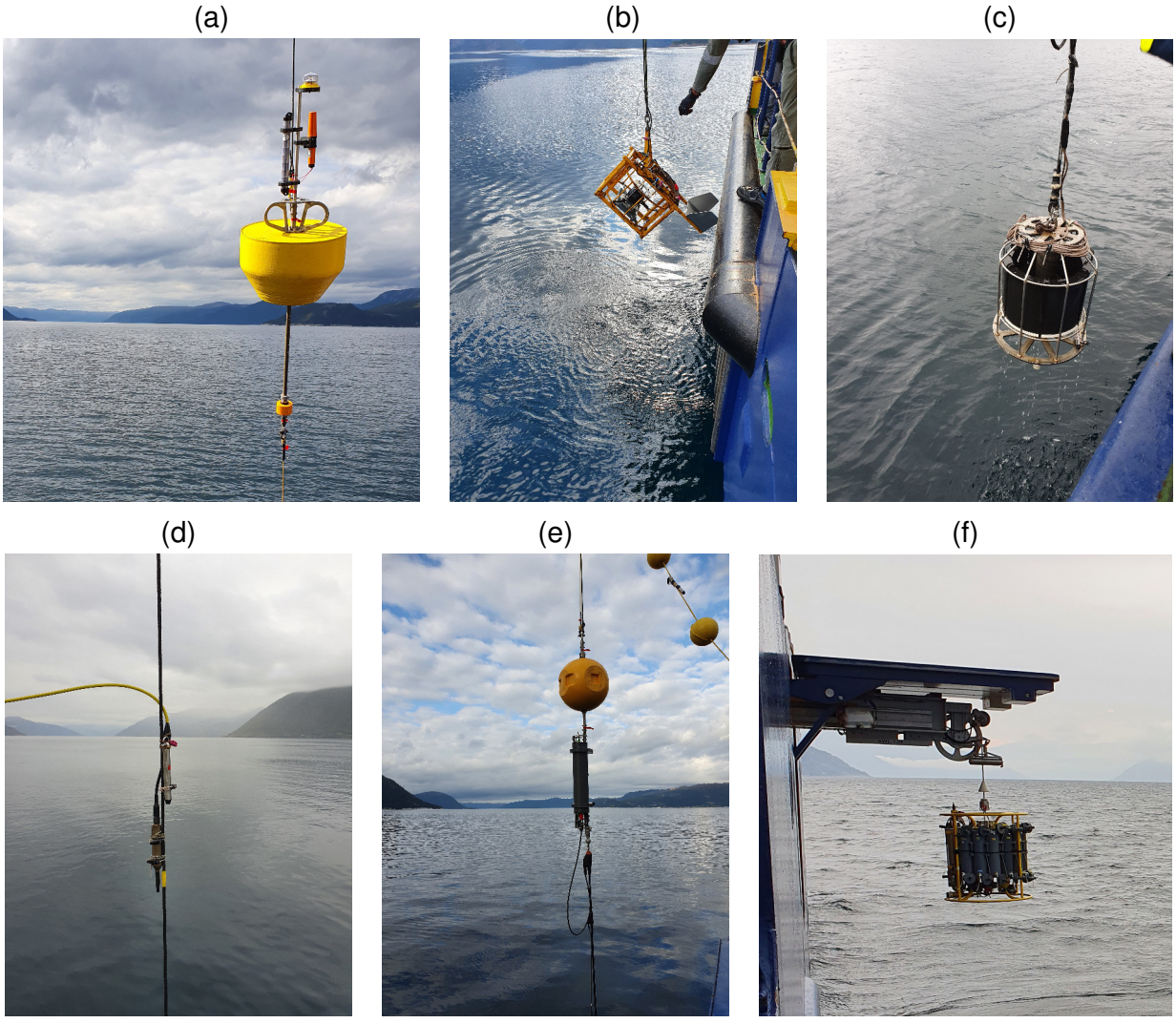

Figure 3: Pictures of measurement equipment used during ARCAS2021: communication unit of drift buoy (a), spherical transducer (b), flooded ring transducer (c), hydroacoustic receicer (d), hydroacoustic array (e), and CTD probe installed on-board of RV ELISABETH MANN BORGESE (f).

Pictures of the measurement system used during the research cruise ARCAS2021 can be seen in Fig. 3. In (a) the communication unit of the drift buoy is shown. When used freely drifting, the hydroacoustic array (e) could be connected to it via a decoupling line. In this case, the array could be trimmed by weights to operate at a desired depth. In (b) the transducer to be towed is displayed, respectively the flooded transducer to be suspended from the research vessel in (c). The pictures in (d) and (e) represent the operated hydroacoustic receiver and array. In (f) the on-board CTD measurement system of RV ELISABETH MANN BORGESE is ready to be lowered for operation.

11.4 CTD measurements

The speed of sound is essential for hydroacoustic experiments. Temperature, salinity, and pressure have an great influence on the sound velocity. Hence it can vary significantly with depth and time in Sognefjord. Therefore, such profiles where determined on each measurement day with the on-board CTD-probe of RV ELISABETH MANN BORGESE.

Date	CTD Station	Time (UTC+2)	Position	Depth (m)	$\bar{c}$ (m/s)
05.09.	0001	05:44:25	61 08.7248N, 5 52.2311E	607.75	1487.12
06.09.	0002	06:26:23	61 08.7821N, 5 54.9557E	203.25	1484.81
07.09.	0003	06:28:48	61 08.7844N, 5 54.9829E	203.50	1485.09
08.09.	0004	06:25:22	61 08.7904N, 5 55.2220E	203.50	1485.24
09.09.	0005	06:23:16	61 08.7161N, 5 55.1312E	304.75	1485.63
10.09.	0006	06:27:58	61 08.8083N, 5 54.9964E	607.50	1487.19

Since the profiles in the Sognefjord were known from previous research cruises (e.g. ARCAS2018 [2]) not to vary significantly in lower depths, the profiles were measured with the on-board CTD probe down to a depth of 600 m on the first and last day to prove it. Thus a measurement depth of 200 m was chosen to be sufficient for the remaining measurement days. From the measured quantities the speed of sound was calulated with the on-board system of IOW (Institute of Baltic Sea Research, Warnemünde, Germany).

The vertical profiles of sound speed, temperature, and salinity that were measured within the period from September, 5th, to September, 10th, in central Sognefjord are depicted in Fig. 4 (a), (b), and (c), respectively. On this scale, no strong variations could be observed in lower depths. A zoom of the same profiles down to a depth of 150 m is shown Fig. 4 (d), (e), and (f). In these enlargements some variation in the thermocline can be observed, as it seems to continuously to lower.

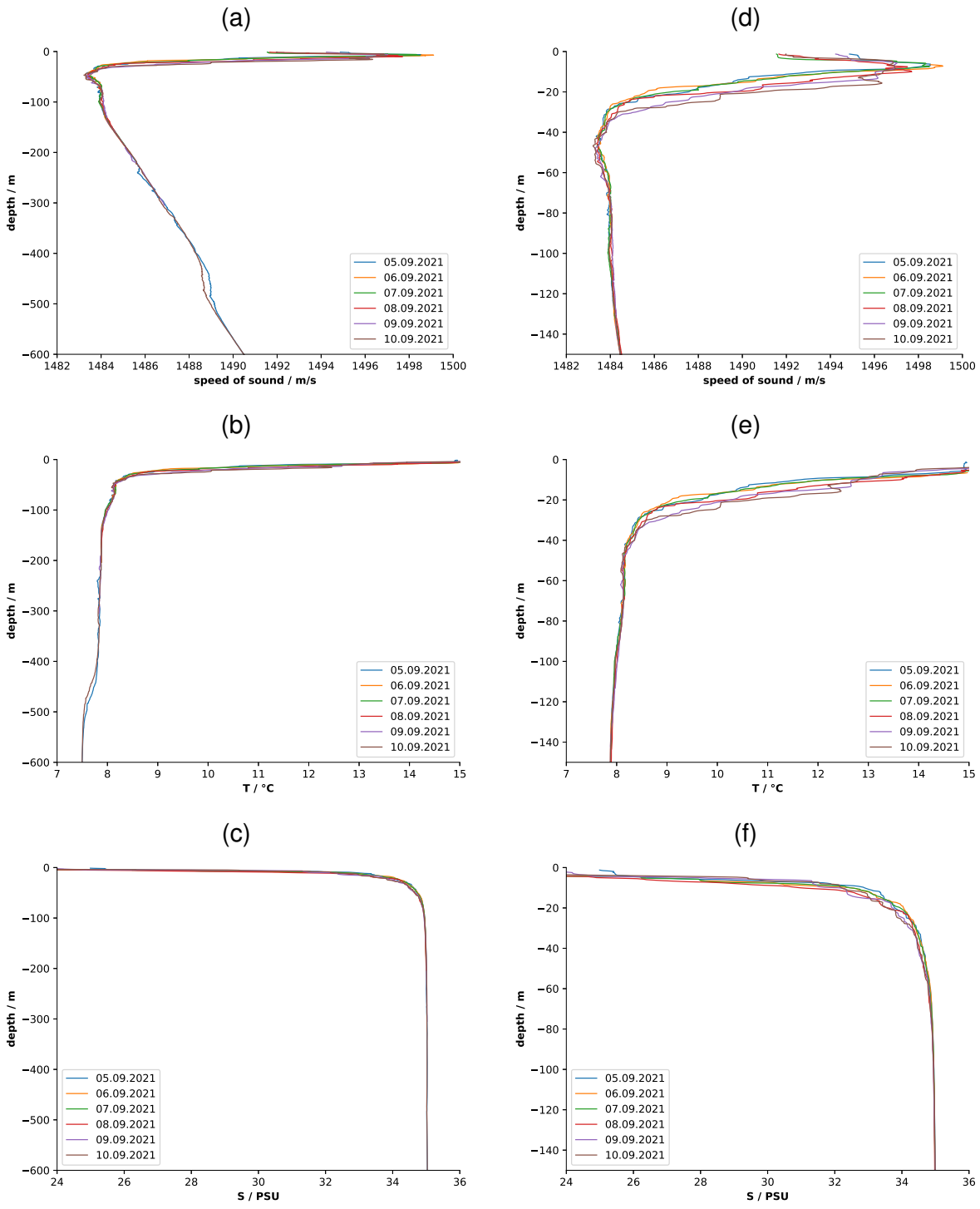

Figure 4: Vertical profiles of sound speed (a,d), temperature (b,e), and salinity (c,f) in central Sognefjord south of Høyanger. In the figures on the right (d,e,f) the upper 150 m of the respective deep profiles (a,b,c) are depicted.

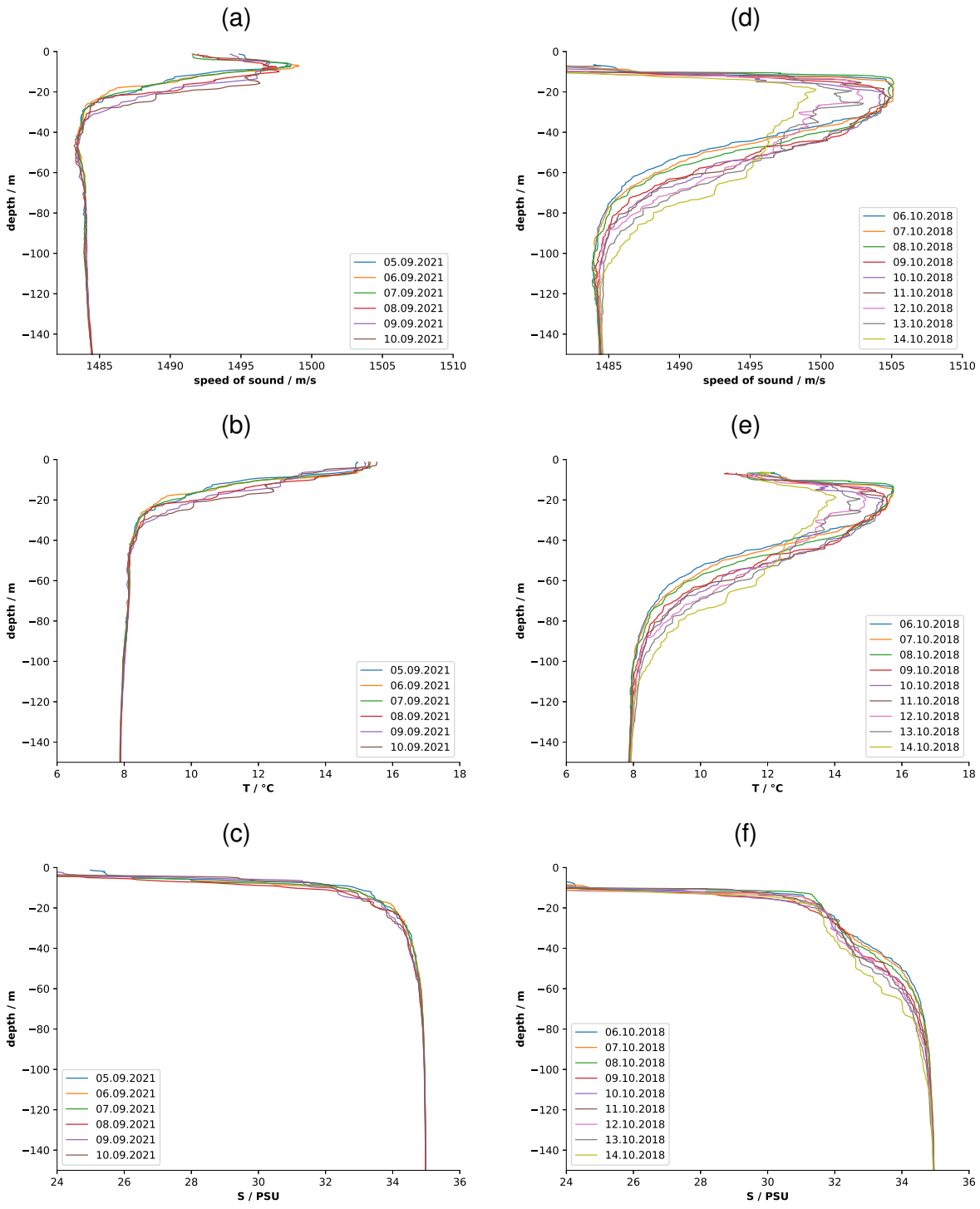

Figure 5: Comparison of the profiles of sound speed (a,d), temperature (b,e), and salinity (c,f) in central Sognefjord south of Høyanger. The figures on the left (a,b,c) correspond to the research cruise ARCAS2021, the figures on the right (d,e,f) to the previous research cruise ARCAS2018 [2].

In Fig. 5 the measured profiles of ARCAS2021 and the previous research cruise, ARCAS2018 [2], are displayed. Compared to the CTD measurements carried out in ARCAS2018, the varations are not very strong and the profiles can be considered as relatively stable down from a depth of about 80 m. While the deep sound channel of Sognefjord was located at a depth of about 100 m during ARCAS2018, it raised up to a depth of about 50 m during ARCAS2021. The research cruise ARCAS2018 was carried out in October, while ARCAS2021 was conducted earlier in the year in September.

Acknowledgements

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. EMB144_Abshagen (2016)

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

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

[4] J. Abshagen and V. Nejedl: Sound Propagation Experiments in a Norwegian Fjord, Proceedings of the 23th International Congress on Acoustics (ICA2019), Aachen, Germany (2019).

[5] A. Galka, J. Abshagen, A. Stoltenberg, V. Nejedl: Optimal Frequency Bands for Modelling the Coupling of Structure-borne to Underwater Sound of a Surface Vessel, IEEE Journal of Ocean Engineering, Vol. 42 (2), pp. 410 - 423 (2017)