Wehrtechnische Dienststelle 71

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

r/v ELISABETH MANN BORGESE

Cruise- No. EMB 196

This report is based on preliminary data

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1. **Cruise No.:** EMB 196

2. **Dates of the cruise:** from 02.10.2018 to 17.10.2018

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

5. **Dates and names of ports of call**
   daily entering and leaving of port of Høyanger, Norway, from Saturday, 6th (first entering), to Sunday, 14th (last leaving), of october 2018

6. **Purpose of the cruise**
   Purpose of the research cruise *ARCAS2018* was to gain a deeper scientific understanding of underwater noise processes, such as flow- and channel noise, that interfere the reception of underwater sound. Towing and drift experimentes with towed and vertical array as well as a drift buoy were conducted in Sognefjord. The research is based on results obtained from the preceding sea trial NovEMBer2016 (EMB144).

7. **Crew:**
   Name of master: Uwe Scholz
   Number of crew:

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

   Scientists: Dr. Arne Stoltenberg

   Engineers: Jörg Schulz, Jens Benecke

   Technicians: Klaus Balzer

9. **Co-operating institutions:** University of Kiel, Germany

10. Scientific equipment

- Vertical and towed array for hydroacoustic measurements
- Hydroacoustic sensor elements
- Freely drifting buoy with underwater sound transducer
- On-board CTD of RV EMB

11 General remarks and preliminary results

11.1 Introduction

The research cruise ARCAS2018 (Advanced Receiver and Channel Analysis) started on October, 2$^{\text{nd}}$, and and ended in October, 17$^{\text{th}}$, at WTD71 in Kiel, Germany. The departure of RV ELISABETH MANN BORGESE from Kiel was delayed by one day due to a predicted heavy storm hitting the Norwegian coast on the aspired arrival date. During the measurement period from Saturday, 06$^{\text{th}}$, to Sunday, 14$^{\text{th}}$, of October 2018 underwater experiments were conducted in Sognefjord, Norway. The primary scientific aim of the research cruise was to deepen the understanding of underwater noise processes, such a flow and channel noise, that interfere the reception of underwater sound.

(a) (b)

Figure 1: RV ELISABETH MANN BORGESE in Sognefjord, Norway, on Saturday, 6th and in Høyanger habour on Wednesday, 10th, of October 2018.

Pictures of RV ELISABETH MANN BORGESE entering the measurement area south of Høyanger on October, 6th, and moored in Høyanger habour on October,10, th can be seen in Figure 1 (a) and (b), respectively. In the measurement period different kinds of hydroacoustic experiments alinged by CTD measurements of the oceanic stratification were performed. The vertical profiles of temperature, salinity, and sound speed of central Sognefjord are given in section 11.4.

The hydroacoustic experiments were performed with four different receicer and projector configurations. Ambient noise was measured with a vertical array, that was also used together with a freely drifting projector buoy for channel noise analysis. Experiments with a short towed array on flow noise [2, 3] and channel noise in a surface duct [4] were conducted during ARCAS2018 in the same way as in the preceding research cruise NovEMBer2016 [1] in 2016. Furthermore, stationary calibration measurements of hydroacoustic sensor elements were perfomred with an underwater transducer suspended from RV ELISABETH MANN BORGESE.

11.2 Course of Research Cruise

RV ELISABETH MANN BORGESE was loaded at WTD 71 in Kiel on Tuesday, 2nd, but departed not before Wednesday, 3rd, on 10:30 a.m. because of a predicted heavy storm on the trip route though the Norwegian sea. The research vessel arrived after a journey of two and a half days through the Great Belt, the Kattegat, the Skagerrak, and the North Sea in the measurement area in central Sognefjord south of Høyanger, Norway, on Saturday, 6nd. A time schedule of the research cruise ARCAS2018 is given below:

Date	Harbor	Leaving	Experiments started	Config.	Experiments finished	Entering
02.10.	Kiel	-	-	loading	-	(0745)
03.10.	Kiel	1030	-	journey	-	-
04.10.	-	-	-	journey	-	-
05.10.	-	-	-	journey	-	-
06.10.	Høyanger	-	0800	ambient noise	1315	1420
07.10.	Høyanger	0730	0810	calibration	1510	1630
08.10.	Høyanger	0730	0800	calibration	1440	1530
09.10.	Høyanger	0730	0800	calibration	1415	1455
10.10.	Høyanger	0730	0800	channel noise	1600	1650
11.10.	Høyanger	0730	0800	channel noise	1520	1615
12.10.	Høyanger	0730	0800	flow noise	1505	1600
13.10.	Høyanger	0730	0800	channel noise	1335	1425
14.10.	Høyanger	0800	0835	CTD	1040	-
15.10.	-	-	-	journey	-	-
16.10.	-	-	-	journey	-	-
17.10.	Kiel	-	-	unloading	-	0745

Immediately after arrival in Sognefjord, ambient noise measurement were performed with a vertical array. From Sunday, 7th, to Tuesday ,9th calibration measurements were conducted by suspending both receiver and projector from the drifting research vessel. Those measurements were followed by experiments on flow- and channel-noise on the next four days. Channel noise was measured with a vertical array (October, 10th and 11th) and a towed array (October, 13th) in combination with a freely drifting projector buoy. Flow noise generation was studied with towed array on October, 12th. Before RV ELISABETH MANN

BORGESE started the return journey to Kiel at 10:40 a.m., two CTD measurements at different positions in Sognefjord located about 10 nm apart were performed. The harbor of WTD 71 in Kiel was entered on Wednesday, 17th, at 7:45 a.m., where RV ELISABETH MANN BORGESE was unloaded on the same day.

11.3 Hydroacoustic experiments

Hydroacoustic experiments with a vertical arrays allow a separation between ship and channel noise by wavenumber-frequency analysis.

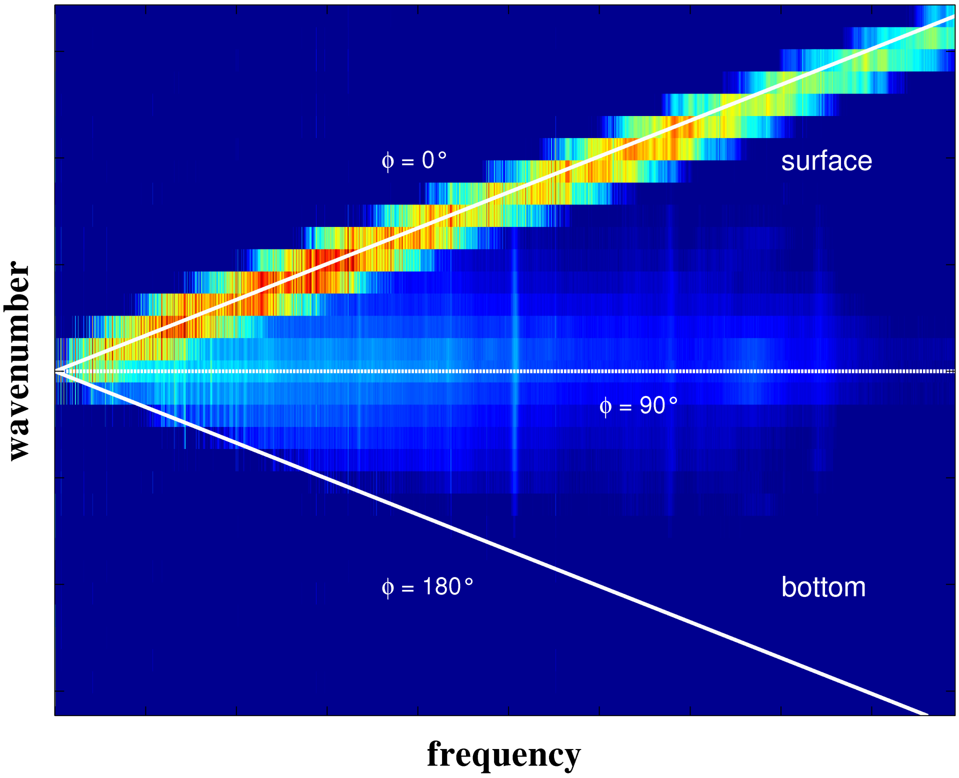

Figure 2: Wavenumber-frequency spectrum of ambient noise in central Sognefjord measured with a vertical array at about 100 m depth on Saturday, 6th .

In Fig. 2 a wavenumber-frequency spectrum measured with a vertical array at about 100 m depth is depicted. The dominant noise source, the stationary research vessel, is clearly visible in the surface beam (Φ = 0^o) and can be separated from the ambient noise is the deep sound channel. Due to the vertical position of the array ambient noise mainly contributes to sound that arrive from the horizontal direction (Φ = 90^o) or under small angles with respect to this direction. As expected, no significant spectral level originates from the sea bottom. It can be seen from Fig. 2 that array processing allow the analysis of channel noise in Sognefjord.

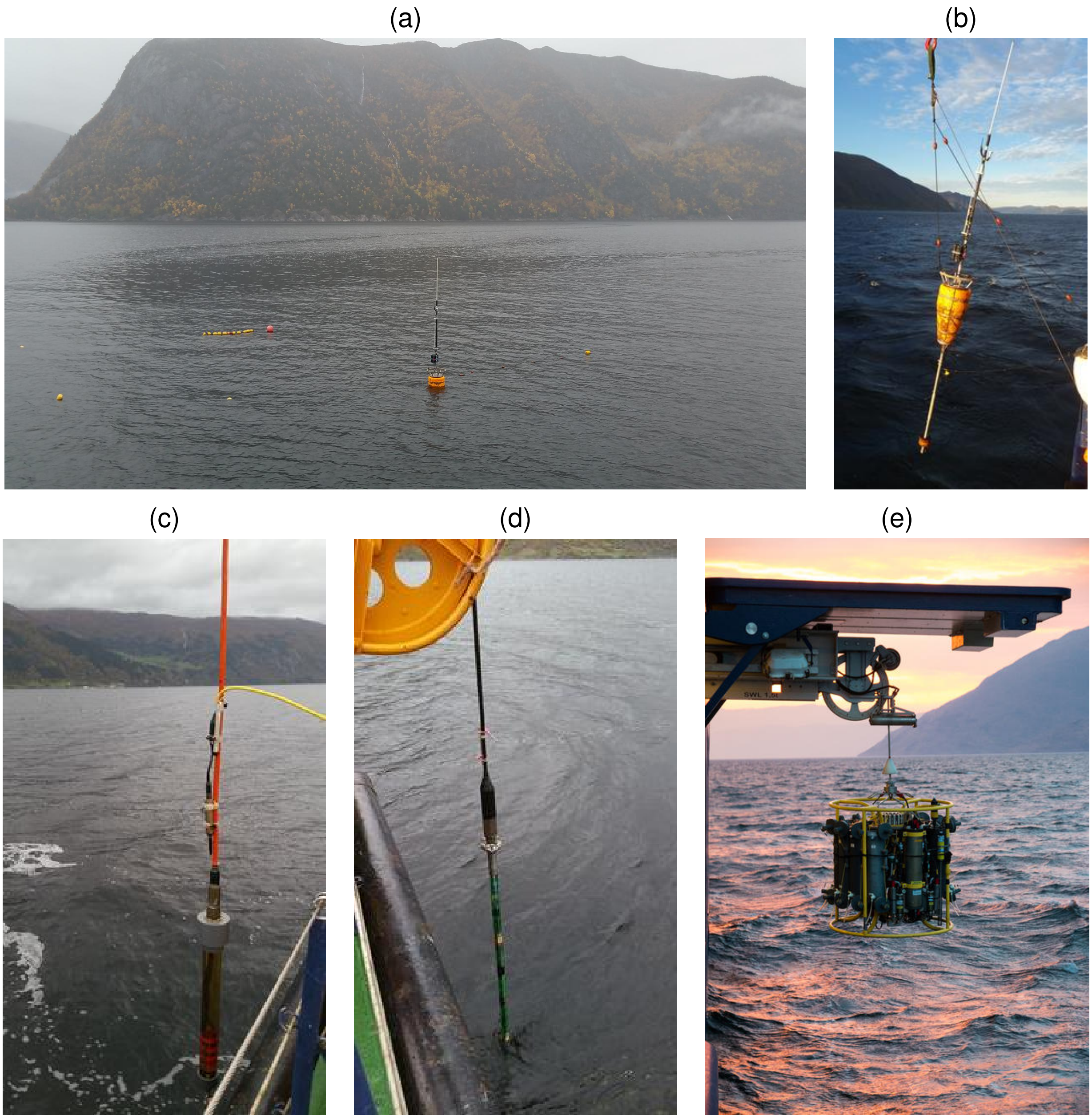

Figure 3: Pictures of measurement equipment used during ARCAS2018: freely drifting projector buoy directly before recovering in Sognefjord (a), communication unit of drift buoy (b), hydroacoustic receicer (c), vertical hydroacoustic array(d), and CTD probe installed on-board of RV ELISABETH MANN BORGESE (e).

In Fig. 3 pictures of the measurement system used during the research cruise ARCAS2018 can be seen. In (a) and (b) the freely drifting projector buoy, used already in preceding research cruises (see e.g. [1]), is displayed. The hydroacoustic projector is mounted to a submerged electronic unit (located below yellow buoy in (a)) and operated at about 90 m depth, i.e. within the deep sound channel of Sognefjord. The electronic unit is connected to a communication buoy by a cable of about 50 m length. This buoy can be seen in Fig. 3 (a) and during launching in detail in (b). A hydroacoustic receiver and the vertcal array can be seen during launching on different measurement days in Fig. 3 (c) and (d). The on-bord CTD measurement system of RV ELISABTH MANN BNORGESE is shown during operation in (d). Directly before launching of measurement equipment the sound velocity profile was determined on each measurement day with this on-board CTD probe.

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. Since sound speed profiles are essential for hydroacoustic experiments, in particular for studies on channel noise, such profiles were determined every day during the measurement period. Dates, time, position, and depth of each CTD station of the research cruise ARCAS2018 are given below:

Date	CTD Station	Time (UTC+2)	Position	Depth (m)	$\bar{c}$ (m/s)
06.10.	0001	05:57:34	61 08.6003N, 5 48.9777E	609.50	1487.53
06.10.	0002	07:30:24	61 08.6821N, 5 59.7739E	810.00	1488.71
07.10.	0003	06:07:37	61 08.6785N, 5 59.8068E	405.50	1486.87
08.10.	0004	06:05:37	61 08.6590N, 5 59.4850E	404.75	1486.99
09.10.	0005	06:07:16	61 08.7581N, 5 59.7658E	607.75	1487.74
10.10.	0006	06:04:48	61 08.6486N, 5 59.8304E	607.00	1487.79
11.10.	0007	06:07:50	61 08.6851N, 5 59.7699E	607.75	1487.82
12.10.	0008	06:13:42	61 08.7005N, 5 59.7490E	608.00	1487.73
13.10.	0009	06:02:24	61 08.7506N, 5 59.6688E	608.00	1487.85
14.10.	0010	06:37:23	61 08.7340N, 5 59.6900E	607.00	1487.78
14.10.	0011	07:55:37	61 08.6061N, 5 48.9313E	607.25	1487.67

CTD profiles were measured with the on-board CTD probe of RV ELISABETH MANN BORGESE down to a depth of 800 m. Since variations that are significant to the hydroacoustic experiments could not be detected below about 500 m, a measurement depth of 600 m was chosen to be sufficient. From the measured quantities the speed of sound was calulated with the on-board system of IOW (Institute of Baltic Sea Research, Warnemünde, Germany).

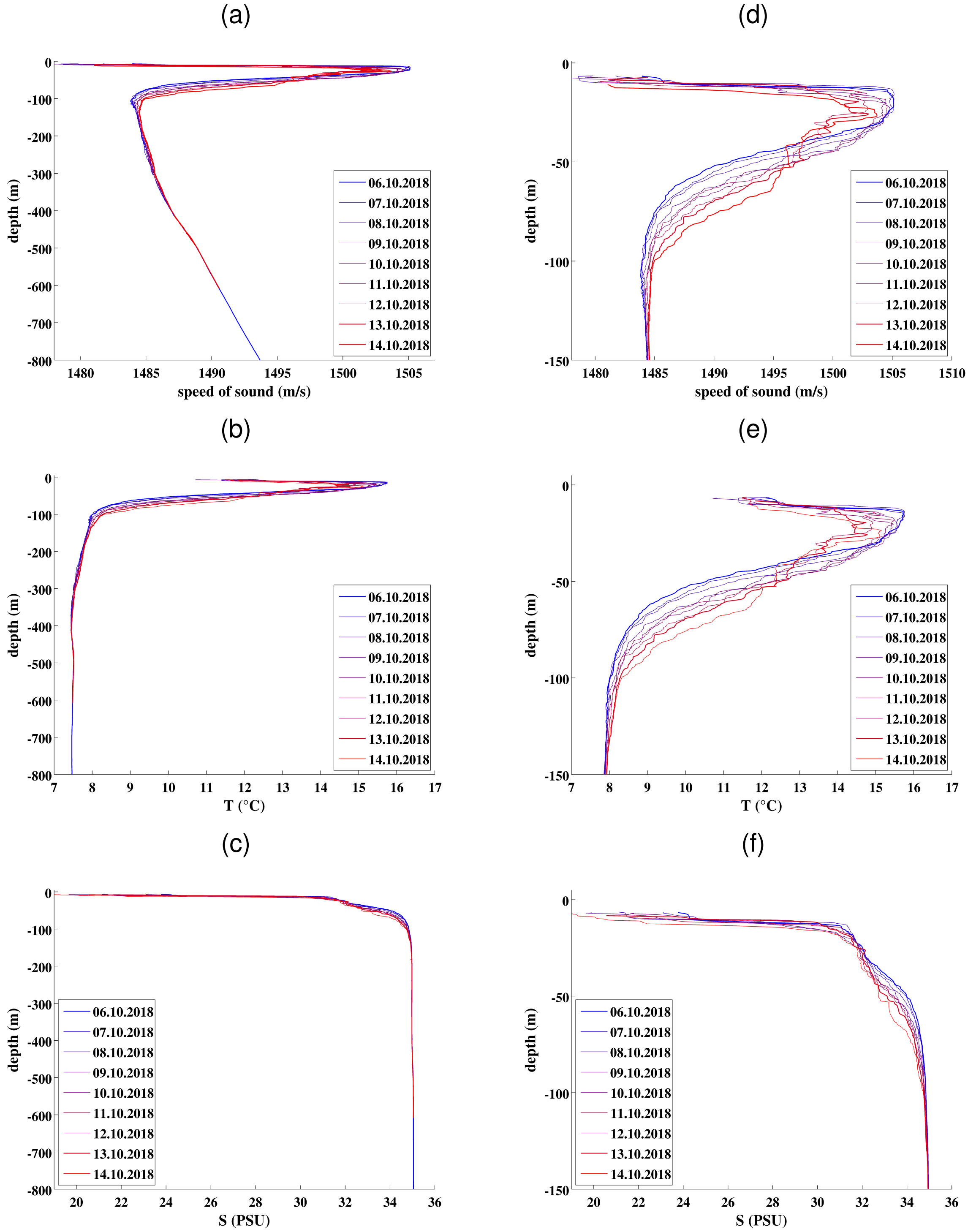

Figure 4: Vertical profiles of sound speed (a,b), temperature (c,d), and salinity (e,f) in central Sognefjord south of Høyanger. In the figures on the right (b,d,f) the upper 150 m of the respective deep profiles (a,c,e) are depicted.

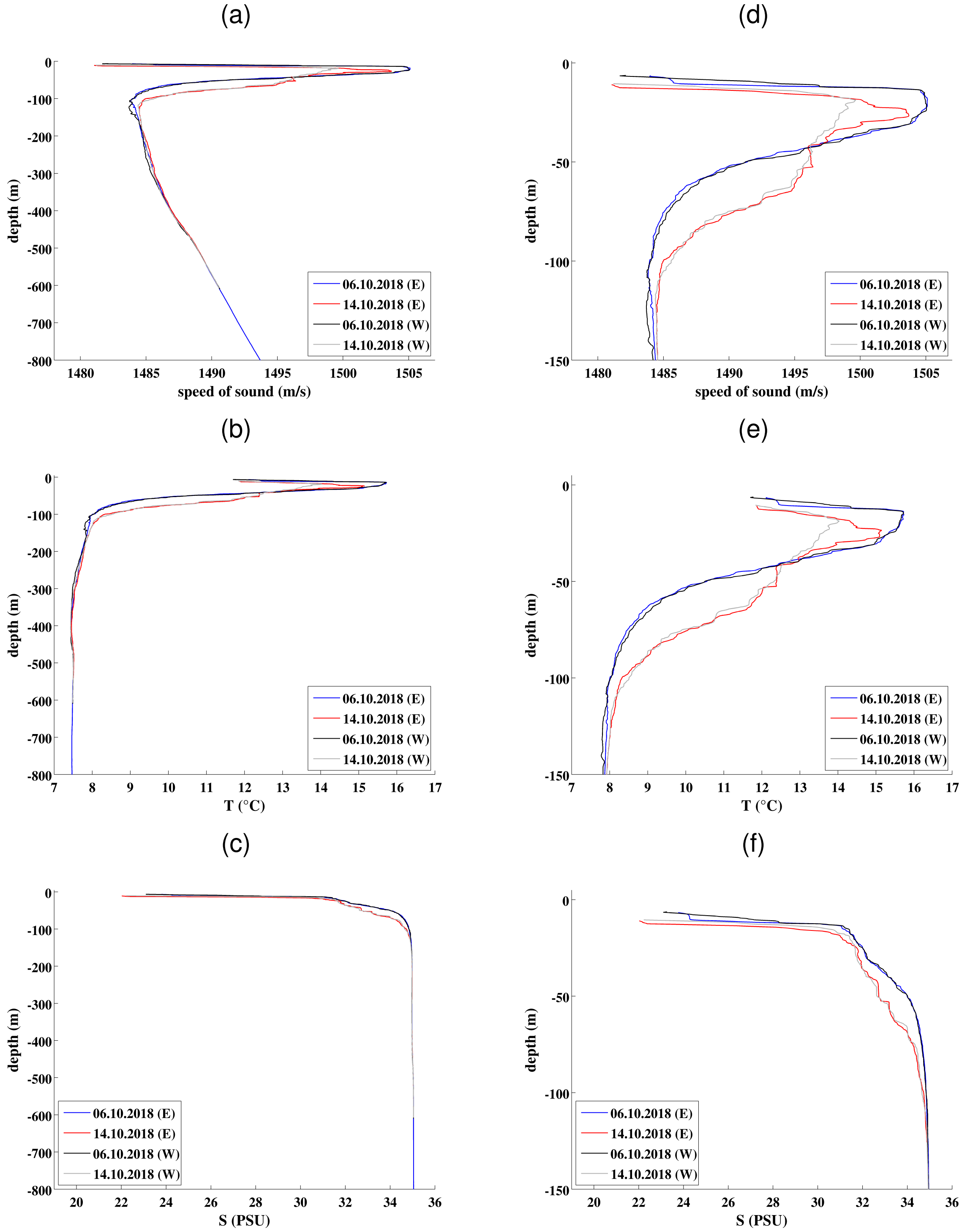

Figure 5: Comparison of sound speed (a,b), temparature (c,d) and salinity (e,f) profiles measured at the beginning (06.10.) and the end (14.10.) of the measurement period at two different positions in Sognefjord. The CTD station 2 and 10 were located in the east (E) and the stations 1 and 11 in the west (W) of the measurement area. The distance between the two positions was about 10 nm.

The vertical profiles of sound speed, temperature, and salinity that were measured within the period from October, 6^{th}, to October, 14^{th}, in central Sognefjord are depicted in Fig. 4 (a), (b), and (c), respectively. It can be seen that below about 500 m the profiles of all three quantities are indistinguishable on this scale.

Stronger variations of the profiles during the measurement period can be found in the thermocline that in located in within the water layer down to about 150 m depth. Enlargements of the profiles shown in (a), (b), and (d) displaying the three quantities within this water layer are depicted in Fig. 4 (d), (e), and (f). It can be seen that during the measurement period the thermocline continuously lowered. There was a pronounced freshwater inflow into the upper layer that originates from rain but also from melting water draining from the mountains. The cold termperatures at the beginning of the measurement, that were only slightly above the freezing point, rose substantially with peak values up to more than 20^{o}C towards the end of the period due to a break-in of warm air from the south-east. The strong winds accompanyied with this change in weather resulted in an enhanced mixing activity in the upper water layer of Sognefjord.

On the first and the last day of the measurements period additional CTD measurements were perfomred also near the western boundary of the measurement region in Sognefjord. The postions of these additional two station were close together and located about 10 nm western to the other nine postions (which were also almost identical). These measurements illustrate not only the temporal but also the spatial variability of sound speed in central Sognefjord during the measurement period, which is rather weak except of the upper layer. The results for these CTD measurmenents are given in Fig. 5. The quantities are represented in the same order as in Fig. 4.

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 and V. Nejedl : *Turbulentes Strömungsgeräusch in einer hydroakustische Antenne mit Querschnittserweiterung* (in german), Proceedings of DAGA2017, Kiel, Germany (2017)

[3] J. Abshagen and V. Nejedl: *Noise induced in a cylindrical towed model from separated/reattached turbulent flows*, Proceedings of NOVEM2018 (Noise and vibrations - emerging methods), Ibiza, Spain (2018).

[4] J. Abshagen, D. Stiller, and V. Nejedl: *Schallausbreitung in einem Oberflächenkanal im norwegischen Sognefjord* (in german), Proceedings of DAGA2018, München, Germany (2018)