ALKOR-Berichte

Electromagnetic resistivity anomalies in Tunnel Valleys: Potential for hidden offshore groundwater? (ENTRAP)

Cruise No. AL611

22.04.2024 – 06.05.2024,

Kiel – North Sea – Kiel (Germany)

ENTRAP

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2024

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1 Cruise Summary

1.1 Summary in English

The role of large subsurface landforms produced during glaciations of the Pleistocene is still poorly understood with respect to groundwater flow. In particular, so-called tunnel valleys (TVs) formed beneath ice sheets acted as drainage systems of glacial meltwater. Due to their mechanism of formation, the fill of buried TVs often consists of highly permeable sands and gravels in their lower part and fine-grained deposits at their top. Such a configuration promotes their role as preferential flow pathways for groundwater sealed from the saltwater above.

To understand the role of TVs for offshore freshened groundwater (OFG) in the southeastern North Sea, the objective of this cruise was to collect marine controlled-source electromagnetic data to answer the following questions: (1) Does the distribution of electrical resistivities indicate the presence of freshened groundwater in the subsurface between Amrum and Heligoland? and (2) Can we delineate different resistivity distributions inside tunnel valleys?

To answer these questions, we acquired 320 km of time-domain controlled-source electromagnetic (TD-CSEM) profiles using the surface-towed SWAN system. These data will be inverted using MARE2DEM to produce a resistivity distribution to assess the salinity distribution in the subsurface.

Additionally, we acquired 888 km of sediment profiling data using the hull-mounted Innomar SES2000 parametric echosounder. On this basis, we identified multiple channels in the subsurface that will be analysed for a paleolandscape reconstruction as part of project TRAPA.

1.2 Zusammenfassung

Die Rolle großer glazialer Strukturen im Untergrund im Zusammenhang mit Grundwasser ist nach wie vor wenig untersucht. Sogenannte Tunneltäler (TT), welche unter Eisschilden des Pleistozäns als Entwässerungssysteme fungierten, nehmen in diesem Zusammenhang eine Sonderrolle ein. Aus ihrer Entstehungsgeschichte lässt sich ableiten, dass die Füllung der TT aus stark durchlässigen Sanden und Kiesen im tiefen Bereich, sowie aus feinkörnigem Material im flachen Bereich besteht. Dieser Aufbau stellt ideale Bedingungen für einen Grundwasserleiter dar, da das frische Pleistozäne Wasser vom Salzwasser abgeschirmt ist.

Um die Rolle von TT in der südöstlichen Nordsee als Grundwasserleiter für offshore frisches bis gering-salzhaltiges Wasser zu verstehen, war das primäre Ziel dieser Ausfahrt die Erhebung mariner elektromagnetischer Daten, um folgende Fragen zu beantworten:

(1) Deutet die Verteilung elektrischer Widerstände im Untergrund zwischen Amrum und Helgoland auf frisches Grundwasser innerhalb der TT hin? und (2) Können wir Bereiche unterschiedlicher Widerstände innerhalb der Tunneltäler unterscheiden?

Um diese Fragen zu beantworten, haben wir auf AL611 320 km aktiv induzierte elektromagnetische Messungen im Zeitbereich (TD-CSEM) mit Hilfe des SWAN Systems durchgeführt. Diese Daten werden mit MARE2DEM invertiert, um aus der resultierenden Widerstandsverteilung Rückschlüsse auf den Salzgehalt des Porenwassers zu ziehen.

Zusätzlich haben wir im nächtlichen Betrieb 888 km Profile mit dem fest verbauten parametrischen Sedimentecholot Innomar SES2000 aufgezeichnet. Auf Basis dieser Daten konnten wir mehrere Kanäle im Untergrund identifizieren, welche detailliert in einer Paläolandschaftsrekonstruktion im Projekt TRAPA untersucht werden.

2 Participants

2.1 Principal Investigators

Name	Institution
Dr. Arne Lohrberg	CAU Kiel

2.2 Scientific Party

Name	Discipline	Institution
Dr. Arne Lohrberg	Marine Geophysics / Chief Scientist	CAU Kiel
Grob, Henrik	Marine Geophysics	CAU Kiel
Carolin Wallmeier	Geophysics	TU Delft
Emma Hadré	Geophysics	CAU Kiel
Dr. Anna Eliana Pastoressa	Geophysics	UM
Friedrich Buck	Student Geophysics	CAU Kiel
Olav Cornelius	Student Geophysics	CAU Kiel
Paula Lea Lürßen	Student Geophysics	CAU Kiel
Isabel Reinicke	-	-
Luisa Rollwage	Student Geophysics	CAU Kiel
Johann Voigtlander	Technician	MBARI

2.3 Participating Institutions

CAU	Christian-Albrechts-Universität zu Kiel
TU Delft	University of Technology Delft
MBARI	Monterey Bay Aquarium Research Institute
UM	L-Università ta' Malta

3 Research Program

3.1 Description of the Work Area

Large subsurface (and now filled) channels with high hydraulic conductivities exist in formerly ice-covered regions that can stretch over more than 100 km in length (Fig. 3.1a; van der Vegt et al., 2012). These glacial landforms are formed by meltwater and direct glacial erosion below ice sheets and are usually termed tunnel valleys (TVs). TVs incised into Quaternary and Neogene strata are up to 400 m deep with widths of 1 to 5 km (Ehlers & Linke, 1989). They are abundant in the subsurface of northern Germany, Scandinavia and the North Sea (Stackebrandt, 2009; van der Vegt et al., 2012) and they cross shorelines in the subsurface.

Our work area is located in the southeastern North Sea between Amrum and Helgoland (Fig. 3.1b). The area has been studied extensively using high-resolution multi-channel 2D seismic reflection data (MCS), which showed the presence of large buried TVs in the subsurface as well as a glaciotectonic complex (Lohrberg et al., 2020; Lohrberg, Krastel, et al., 2022; Lohrberg, Schneider von Deimling, et al., 2022). These buried glacial landforms have been shown to be the result of multiple ice advances in the work area during the Pleistocene, possibly dating as far back as the Cromer glaciation (MIS16). The most prominent TVs, however, are presumed to have formed during the Elsterian glaciation (MIS10-12).

The regional stratigraphy – where not incised or disturbed by glacial landforms – shows a strong influence of salt structures from Zechstein sediments in greater depths. Helgoland is the most prominent example, standing out from the North Sea in the form of a 1.2 km² island as the result of updomed strata due to rising salt beneath. Similar updoming of Cenozoic strata is observed in the work area, with an asymmetry towards the coast. This geometry resulted in the incision of tunnel valleys through different Cenozoic strata with increasing distance from the coast. The detailed knowledge on the distribution of tunnel valleys based on MCS profiles (Fig. 3.1) provides a perfect basis for the investigation of TVs using electromagnetic measurements.

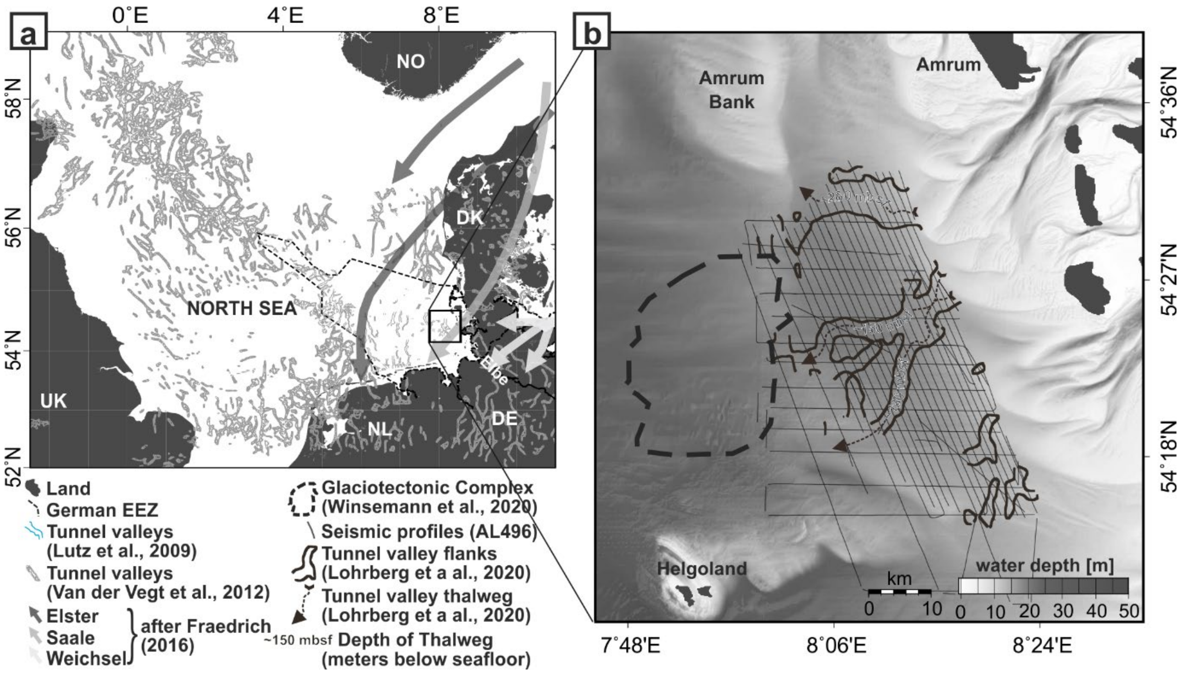

Fig. 3.1 Overview of the work area between Amrum and Helgoland. Buried tunnel valleys are indicated as bold lines with their thalweg indicated as dashed lines. Fine black lines show the location of a part of the available 2D seismic reflection data (AL496).

3.2 Aims of the Cruise

To address the role of subsurface glacial landforms as preferential flow pathways of freshened groundwater in the North Sea, AL611 aimed to

- acquire controlled source electromagnetic data (CSEM) over glacial landforms
- identify and quantify potential offshore freshened groundwater (OFG) in glacial landforms

The CSEM data are needed to understand the significance of buried glacial landforms as flow pathways for offshore groundwater using a combination of acoustic and electromagnetic remote sensing. Such CSEM measurements combined MCS data will result in highly focused electrical resistivities for structures observed and constrained in the MCS data. If TVs between Amrum and Helgoland can be shown to contain OFG using CSEM, these results may stand representative for other areas in the North Sea. Hence, the implications of OFG occurrences in TVs are immense.

3.3 Agenda of the Cruise

The work plan was divided into the primary program of controlled-source electromagnetic (CSEM) profiles and secondary sediment echo sounding (SES) profiles (Fig. 3.2). The CSEM profiles were run perpendicular to known TV structures to investigate variations in electrical resistivity between the subunits of the TVs and the background lithology outside of TVs. Ten CSEM profiles were planned at various distances from the coast to delineate resistivity variations within the TVs associated with increased freshwater-seawater mixing as a function of distance from the coastline. In total, we planned 344 nm of CSEM profiles at a survey speed of 2 knots.

We deployed the CSEM equipment daily at 8:00h, which took between 45 minutes to 1 hour. With the CSEM equipment fully deployed, we planned to sail up to 13 hours along the planned profiles (Fig. 9) and retrieve the equipment latest at 21:00h for scheduled maintenance (i.e. data download and change of batteries). Due to equipment constraints, one deployment of the SWAN system is limited to 40 to 48 hours before batteries need to be checked and data needs to be downloaded, which dictates a cyclic pattern of surveys. Due to visibility constraints, the deployment of the system was limited to daytime operation. For nighttime operation, we planned SES profiles in proximity as part of our secondary program. The next deployment of the CSEM equipment followed in the morning at 8:00h.

Following the cruise, the data will be used for a joint inversion of multi-channel seismic data (MCS) and the acquired CSEM data as part of DFG project 524639242 'More than buried valleys: Do tunnel valleys serve as conduits for preferential freshened groundwater flow within the North Sea?'. The resulting salinity distribution in the subsurface will be used to delineate potential OFG.

Mitigation measures taken include a soft start of the hydroacoustic systems as well as watching for marine mammals before starting hydroacoustic and electromagnetic systems. Acoustic surveys were exclusively planned outside FFH areas.

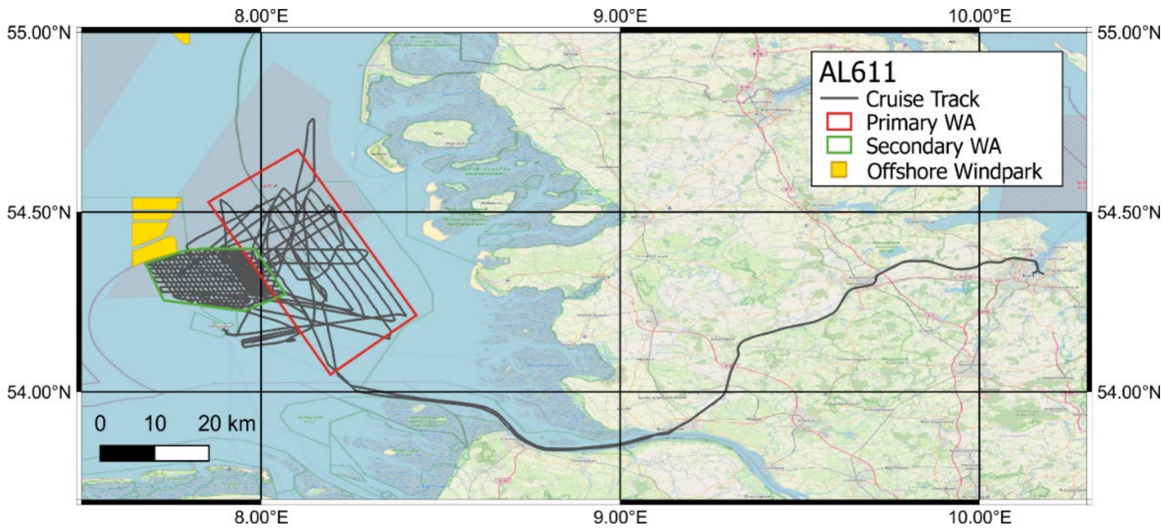

Fig. 3.2 Track chart of R/V ALKOR Cruise AL611. Red and green polygons indicate the primary (CSEM) and secondary (SES) working area.

4 Narrative of the Cruise

The expedition commenced on April 22, 2024, as the team gathered early in the morning to board the ship. After completing customs clearance, we proceeded with the setup of our CSEM equipment. By 13:00 most of the setup was complete and we headed towards the North Sea through Kiel Canal, reaching our research areas between Amrum and Helgoland early the following day. Early into the expedition, we encountered our first significant challenge: the CSEM system proved highly sensitive to waves higher than one meter, which interfered with the reliability of our measurements. Consequently, we headed for shelter at Helgoland port due to deteriorating weather conditions.

Despite this initial setback, the weather improved significantly, enabling us to continue our scientific operations the next day and without further port calls. Our survey routine consisted of the deployment of the CSEM system right after breakfast. CSEM profiling continued until late afternoon to early evening when we retrieved the system and began the soft start protocol for the Innomar SES2000 during daylight. Subbottom profiling using the Innomar SES2000 continued as the night programme until the next morning deployment of the CSEM system. This routine was repeated for the remaining cruise. However, on April 29, after completing our scheduled measurements, our team participated in a sea rescue operation near Helgoland.

After a night and early morning involved in an additional search and rescue operation off Amrum, our scientific activities resumed on April 30. We reached our deployment point for the CSEM profiles right after breakfast and carried out a full day of CSEM profiling. This was again followed by transitioning to nighttime SES profiling, such that we were back in our routine survey pattern. On May 2, an unexpectedly high pull on the system raised safety concerns and prompted us to retrieve the system immediately. This incident slightly adjusted our planned activities for the day and forced us to start the SES profiling early.

The subsequent days, May 3 and 4, allowed us to resume and complete our data collection without further interruptions. A notable event on May 4 was our meet-up with the research vessel Maria S. Merian for a data exchange. This meeting facilitated the exchange of valuable subbottom profiling data, which were the basis for further profile planning on MSM128. After our final CSEM profile in the afternoon, we began preparations for dismantling the equipment, ending our field operations.

As we spent May 5 in Kiel Canal dismantling the CSEM system and cleaning the laboratories, our return to Kiel that evening marked the end of an intense and productive expedition. We docked at the Seefischmarkt pier late in the evening, and the expedition officially ended on the morning of May 6, with the team departing the ship.

5 Preliminary Results

5.1 Electromagnetic Measurements

(A. Lohrberg and Shipboard Scientific Party)

5.1.1 System Overview and Data Processing

Electromagnetic measurements were conducted using the surface-towed SWAN system, which consists of a ~100 m transmitter dipole and up to four 10 m receiver dipoles (Silvion electrodes) connected by ropes and kept near the surface by buoys (Fig. 5.1; (Pastoressa et al., 2023)). The receiver units are equipped with battery-powered 10 kHz data loggers from Magson GmbH. All buoys (Tx1, Tx2, Rx1, Rx2, Tail) were equipped with GPS loggers for information on the geometry of the system during acquisition. Due to nautical constraints and sufficient offset for the depth of investigation, we ran the system with two receiver dipoles instead of four. Table 5.1 provides the survey offsets that were calculated from the ship's GPS and the buoys' GPS, where all offsets are in reference to the ship's position, which in turn is referenced to the aft of the ship (bull's eye marked in Fig. 5.2).

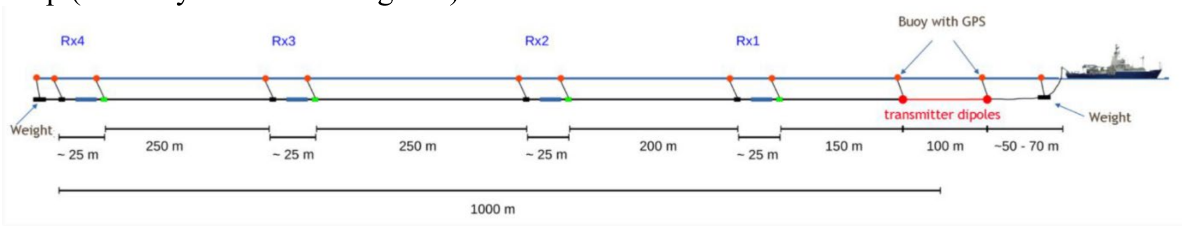

Fig. 5.1 Schematic illustration of the SWAN system as outlined in Pastoressa et al. (2023). The setup on AL611 slightly deviated in rope lengths as the first rope used was 200 m long and the second rope was 250 m long. Precise offsets were measured using the GPS units on the buoys and integrated with the ship's precise DGPS.

Table 5.1 Offsets of the SWAN system in the deployed configuration on AL611 based on GPS measurements on the buoys of each unit of the SWAN system.

Position	Tx1	Tx2	Rx1	Rx2	Tail	TxMid	Rx1TxMid	Rx2TxMid
Offset from Ship GPS [m]	65.4	168.3	385.5	679.4	725.0	116.9	268.7	562.6

TxMid: Middle of Tx1 and Tx2
Rx1TxMid: Distance of TxMid to Rx1
Rx2TxMid: Distance of TxMid to Rx2

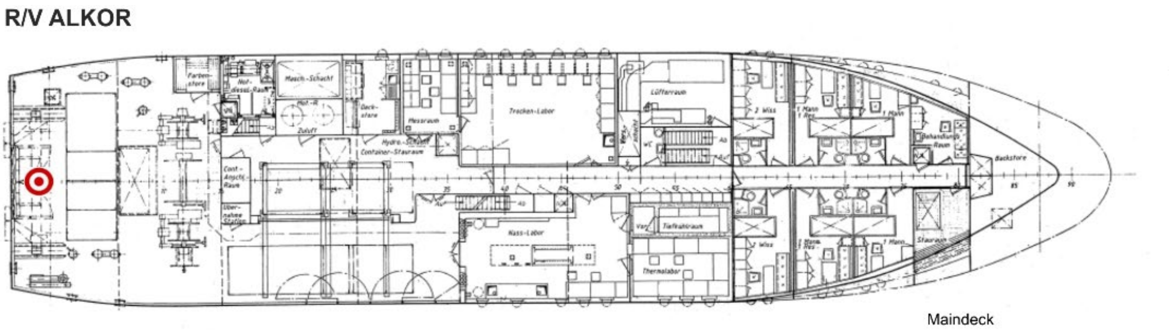

Fig. 5.2 Main deck of R/V ALKOR. The red bull's eye marks the reference point of the ship's GPS (0/0/0 in across, along and down direction), which is also the reference point for distances provided in Table 5.1.

A winch is necessary for the deployment of the system due to the long offsets realized by long rope sections (Fig. 5.1). On AL611 we used the fishery winch of R/V ALKOR, which was modified by blanketing the tread of the winch to protect the ropes and cables from harsh edges. During rig up, we spooled the full string onto the winch – transmitter section first – to speed up deployment in the working area. Unfortunately, the rotation speed of the hydraulic fishery winch is limited and the diameter is small, such that we had to plan about an hour lead-in for the deployment of the whole system, which was later sped up to about 45 minutes. Parts of the deployment sequence and the acquisition setup are shown in Fig. 5.3. Attaching the GPS-equipped buoys to the transmitter units, receiver units and the tail was the last step in the deployment sequence. However, the combination of ship wake and unfavorable wind conditions sometimes made it challenging to have the buoys clear the aft of the ship, in which case the respective unit to be deployed was retrieved and deployment restarted to make sure the buoy cleared the aft of the ship without entangling with the already deployed part of the string. The movement of the buoys, mostly due to wind waves, sometimes led to an interrupted power supply inside the GPS units, which sporadically caused corrupt GPS files. Fortunately, four of five GPS units were always working, such that missing positioning for one buoy could be reconstructed using the other buoys for all profiles.

Fig. 5.3 Snapshots of the deployment sequence of the SWAN system. Full deployment including attaching the transmitter dipoles (top left) and the receiver loggers (top right) took between 45 to 60 minutes due to the slow rotation speed and small diameter of the fishery winch (bottom left). Once the system was deployed, it was routed through an idler pully from the top of the A-frame over the ship's aft door for safe operation on deck.

The lab setup consisted of a Zonge ZTEM-30 transmitter unit connected to a DC power unit and a trigger box, which in turn was connected to a GPS unit for clock synchronization. The system was controlled using GEOMAR's in-house Hydra4 software (kindly provided by GEOMAR at no cost) on a rugged laptop. All lab equipment fit well into the back of the dry lap with a direct connection to the transmitter cable through the cable canal next to the window (Fig. 5.4).

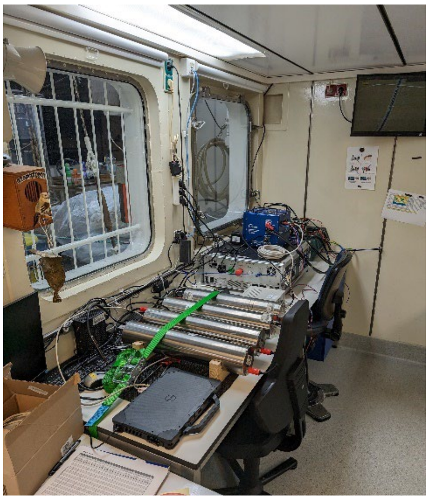

Fig. 5.4 Lap setup of the SWAN system in the dry lab. The four metal tubes are the receiver logger units, which were fitted into a POM housing and connected to the receiver dipoles for acquisition.

We operated the system at 36V voltage and max. 25A current at 50% duty cycle in a 2 second period with a transmission length of 90 seconds and a 30 second break. The transmission break was necessary to let the transmitter cool down in between transmissions, such that a safe peak temperature of the transmitter was reached during hours of operation. The active shift went on deck for visual control and took readings (temperature, current, voltage, error signal lamps) for the protocol every 15 minutes (see Appendix). In the meantime, the system was monitored using the aft camera live feed in the back of the dry lab.

We collected approx. 320 km of TD-CSEM profiles along 10 profiles (Fig. 12). All profiles were acquired along existing high-resolution 2D multi-channel seismic data. Seven profiles were directed NNW to SSE and therefore parallel to the coast, whereas 2 profiles were directed E to W as tie-lines between profiles and 1 profile was acquired along a known tunnel valley.

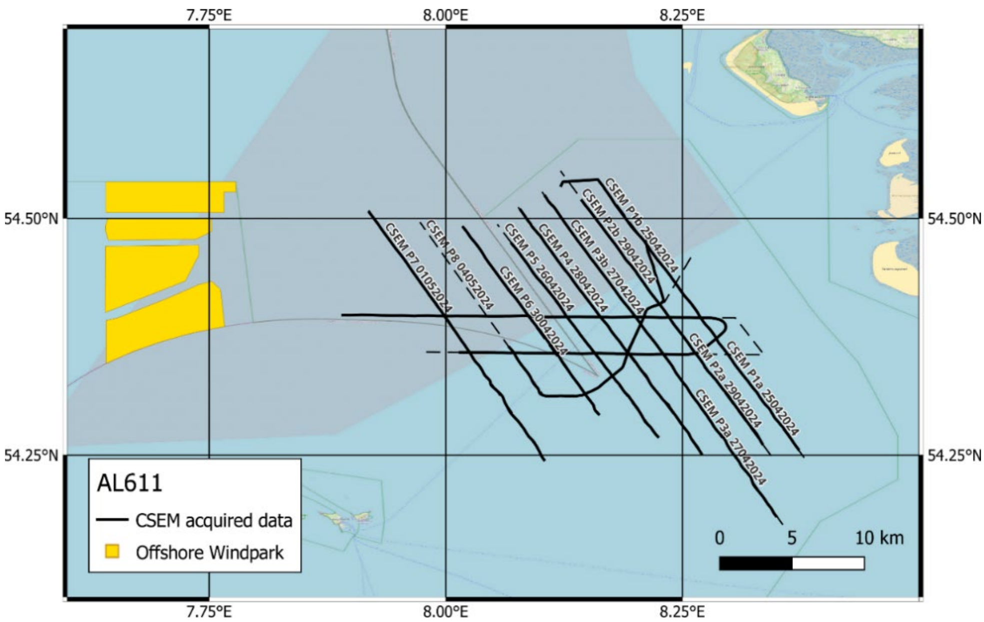

Fig. 5.5 Basemap showing the location of CSEM profiles during AL611. The acquired CSEM data is shown as a bold black line, whereas the dashed line shows the initially planned profiles. The deviation was caused by nautical and time constraints. Profiles were originally split into two parts as planning was initially based on a survey speed of 1 knot. However, the SWAN system operated well at 2 knots, such that we were able to acquire full profiles during a full day.

The SWAN system was running well with most transmissions showing good signal-to-noise ratios in the measurement of the electric field comparable to the one shown in Fig. 5.6, where the shorter offset receiver (Rx1) near perfectly repeats the transmitted square 50% duty cycle signal, whereas the longer offset receiver (Rx2) shows some distortion of the signal. Transmissions were sometimes cut short by the transmission software Hydra4 and the transmitter, which led to some transmissions being shorter (up to only half the set length) than 90 seconds. Unfortunately, the reason for short transmissions could not be resolved and therefore the processing of the data was adapted to handle shorter-than-expected transmission sequences.

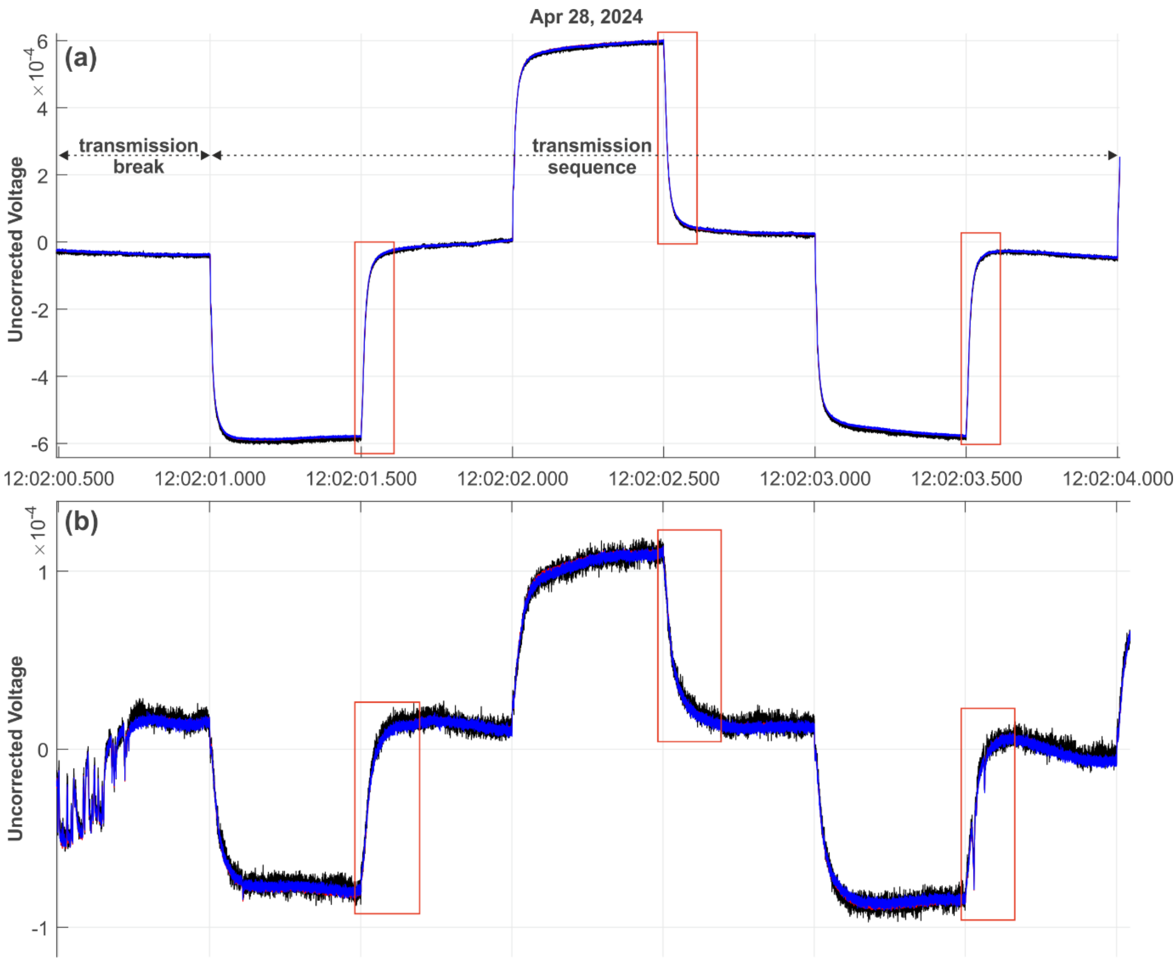

Fig. 5.6 Raw signal recorded at the receivers towed behind the ship during a 90 seconds transmission sequence for all three channels (blue, red, black). The red rectangles mark the step-off signal used to produce transients. (a) shows the signal at the shorter offset receiver Rx1, whereas (b) shows the signal at the farther offset receiver Rx2.

The overall data quality was high during calm sea state and deteriorating with increasing wind speeds and waves. However, most step-off flanks of the data (red rectangles in Fig. 5.6) show sufficient quality. To remove noise from waves and the movement through water, a three-point Hanning window filter was applied for multiples of the period of the transmission sequence (2 seconds). Based on the transmission times and after clock drift and offset correction, the data were cut into full periods and then cut into half periods, of which only the step-off flanks were used. These step-off flanks were then flipped (if negative in polarity) and all flanks were stacked to produce one transient for an (ideally) 90 second transmission sequence for each receiver. Such a transient is shown in Fig. 5.7 for both receivers, with the previous and following transient shown as grey data points. The plot shows that we have very small error bars due to very high signal-to-noise ratios on both receivers after filtering and stacking of the data as the deviation in the amplitudes during one transmission is very small (Fig. 5.6). In general, the processing procedures for the step-off TD-CSEM signals were based and adapted from the workflow and code following Haroon (2016). The full periods and the produced transients were checked after each deployment as routine quality checks to identify potential systematic errors. More transients from the same profile can be found in the Appendix.

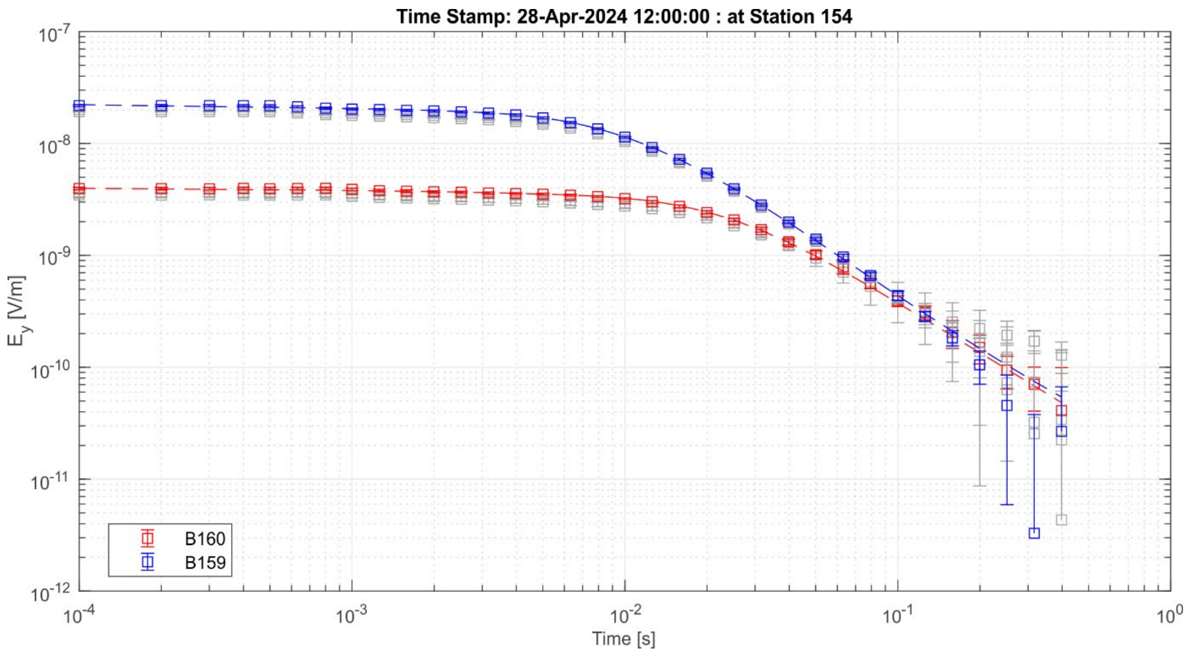

Fig. 5.7 Filtered and stacked step-off signals result in electric field transients for each transmission sequence of which one example is shown here. The plot shows the stack of all step-off flanks during a 90 second transmission for each receiver, where B159 corresponds to shorter offset Rx1 and B160 corresponds to longer offset Rx2. Grey data points and errors show the transients of the previous and following transmission. Note the very small error bars due to very small deviations in the receiver data for early times, whereas the error bars increase for later time points, leading to increased uncertainties in depths below the depth of interest.

The produced transients serve as data input for inversions with MARE2DEM (Key, 2016) with the adaptation to time-domain data (Haroon et al., 2018), which will use these data combined with the acquisition geometry to invert for 2D resistivity models for the subsurface along the profiles. These resistivities will then be compared to the existing seismic data to locate potential resistivity anomalies in the subsurface and inside tunnel valleys.

5.2 Subbottom Profiling

(A. Lohrberg and Shipboard Scientific Party)

5.2.1 System Overview and Preliminary Results

To acquire shallow seismic data, we used the hull-mounted Innomar SES2000 medium sediment echosounder. The Innomar SES2000 medium is a parametric echosounder that takes advantage of harmonics that are generated from the interference of two high primary frequencies. The result is one higher frequency signal from of the addition of both primary frequencies and one lower frequency signal from the subtraction of both primary frequencies. The secondary lower frequency is geometrically constrained by the high frequencies and therefore spatially focused. This focused signal is used to penetrate the seafloor and image subbottom structures directly below the transducer. The system was operated at 6 kHz secondary frequency to image late Pleistocene channels below the seafloor at a vertical resolution of up to ~7 cm. During survey conditions, the system operated at maximum ping rate (depending on the water depth) and the recording window was adjusted to record the seafloor and sufficiently below.

To comply with marine mammal safety protocols, we proceeded with a soft start of the system (20 minutes slow ramp up) after one hour of visual observation for marine mammals. To ensure sufficient visibility, the subbottom profiling operations always starting during the late afternoon or early evening during last daylight. Pinging of the system did not have to be interrupted, as no marine mammals were observed. The Innomar SES2000 operated without significant complications. However, the system was sometimes difficult to start up, as the acquisition software sporadically had to be restarted multiple times before acquiring a connection to the control unit. Once the connection was established, the system ran without interruptions.

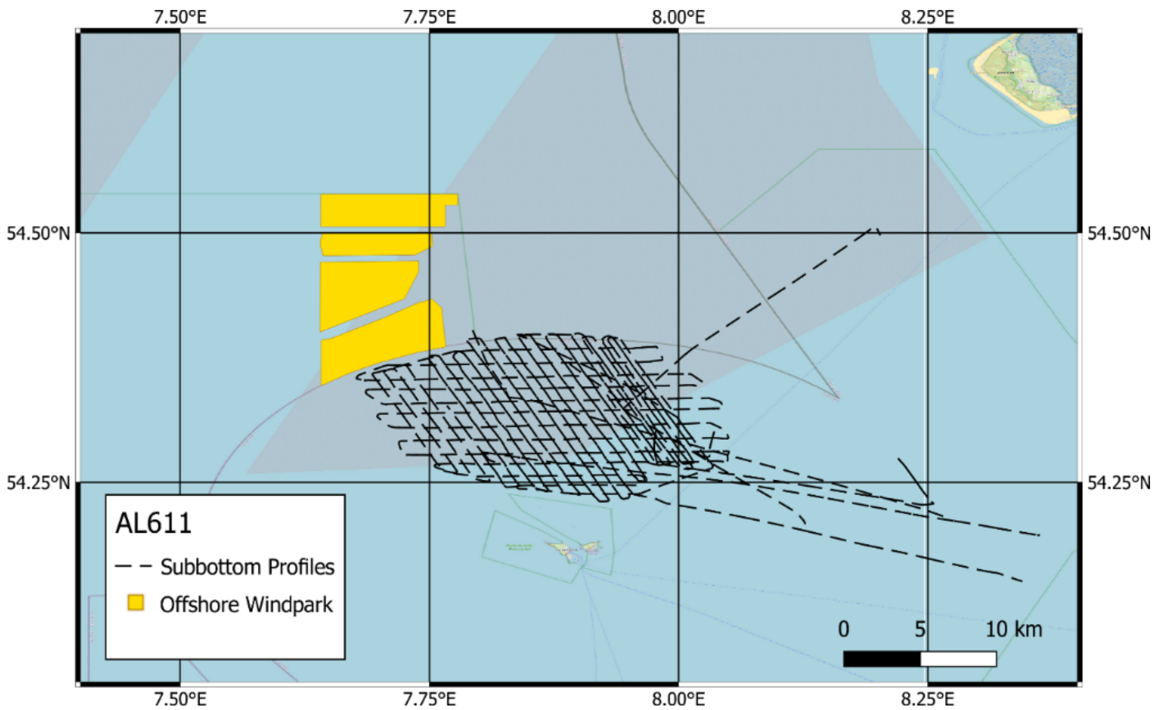

Fig. 5.8 Basemap showing the location of SES/subbottom profiles during AL611. The acquired profiles are shown as a dashed black line.

The hull-mounted Innomar SES2000 parametric sediment echosounder worked very reliably. Following the daily observation for marine mammals and a soft start during afternoon daylight, the system was running at full ping rate and acquired 888 km of profiles along the planned lines (Fig. 5.8).

During the night shifts we crossed multiple paleo channels north of Helgoland that are promising structures for the reconstruction of paleo landscapes as part of project TRAPA. Fig. 5.9 shows a good example of such channels with an apparent width of ca. 250 m and a depth of ca. 10 m, which can be traced over hundreds of meters up to some kilometers – provided a dense enough profile spacing (Fig. 5.10). These data were quality-controlled and only sparsely analysed in seismic interpretation software IHS Kingdom Suite to provide recommendations to MSM128 for on-site profile planning. Further processing and interpretation of these data are part of project TRAPA.

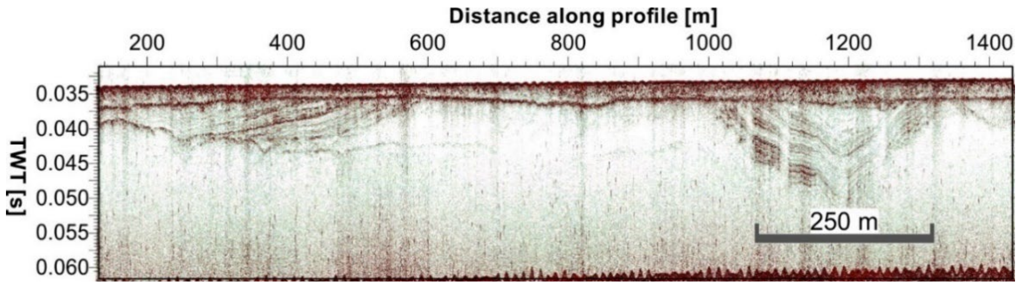

Fig. 5.9 Example of an Innomar SES2000 subbottom profile showing an incised channel on the right and a similar, yet asymmetric feature on the left.

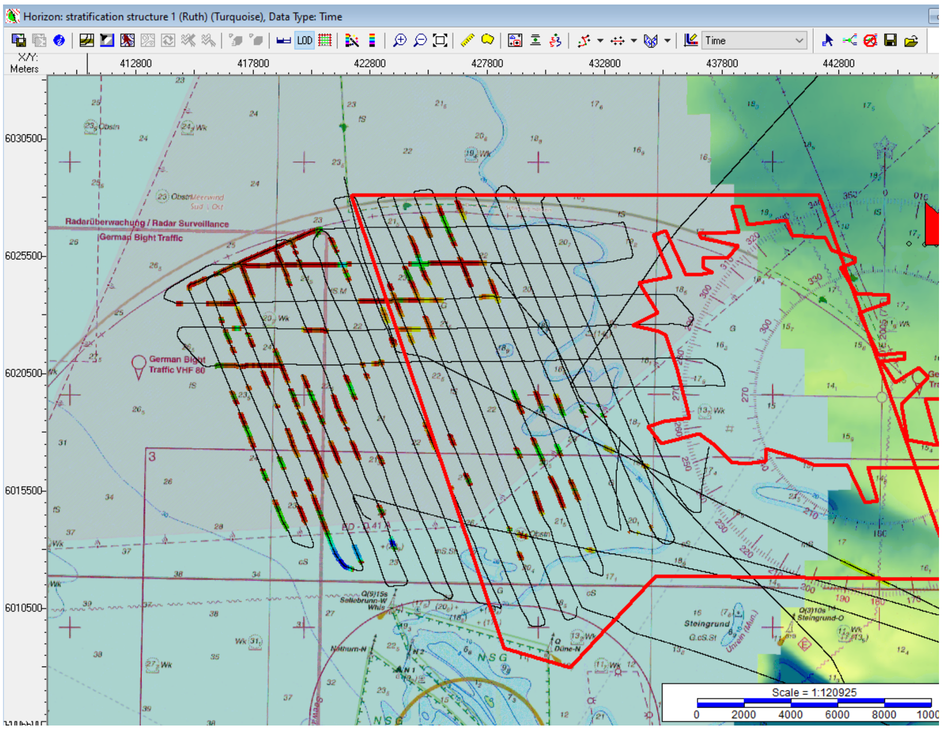

Fig. 5.10 Basemap of the SES data in IHS Kingdom suite (state of May 2nd 2024). Sailed profiles are marked as fine black lines with the nautical chart as the background. Areas along profiles showing potential channels are shown color-coded on top of the sailed profiles. This preliminary interpretation already shows that many channels are present inside the working area.

5.3 Nadir Bathymetry & Water Column Imaging

(A. Lohrberg and Shipboard Scientific Party)

The onboard Simrad EK60/80 system was run simultaneously to all other measurements to log the water depth along transects. As the system records the full water column, water column data was also acquired but did not show any significant anomalies. It did, however, show the fully mixed water column, which is an important information for the inversion of the electromagnetic data.

6 Ship's Meteorological Station

Not available on AL611.

7 Station List AL611

7.1 Overall Station List

Station No.	Gear	Date & Time [UTC]	Action	Latitude	Longitude	Depth (m)
Underway-1	TSG	22.04.2024 10:20	profile start	54° 19,718' N	010° 10,722' E	0
AL611_01-1	CSEM	23.04.2024 06:36	in the water	54° 15,592' N	008° 10,875' E	16
AL611_01-1	CSEM	23.04.2024 07:42	deployed	54° 17,502' N	008° 10,003' E	15
AL611_01-1	CSEM	23.04.2024 13:01	at surface	54° 27,583' N	008° 02,194' E	18
AL611_01-1	CSEM	23.04.2024 13:58	on deck	54° 26,926' N	008° 01,039' E	17
AL611_02-1	CSEM	25.04.2024 06:18	in the water	54° 12,931' N	008° 24,032' E	8
AL611_02-1	CSEM	25.04.2024 07:14	deployed	54° 15,393' N	008° 22,333' E	11
AL611_02-1	CSEM	25.04.2024 16:36	at surface	54° 32,483' N	008° 09,625' E	13
AL611_02-1	CSEM	25.04.2024 17:32	on deck	54° 33,701' N	008° 08,410' E	12
AL611_03-1	SES	25.04.2024 20:26	profile start	54° 17,183' N	008° 00,727' E	19
AL611_03-1	SES	26.04.2024 04:47	profile end	54° 16,129' N	007° 59,042' E	21
AL611_04-1	CSEM	26.04.2024 06:01	in the water	54° 13,879' N	008° 15,164' E	14
AL611_04-1	CSEM	26.04.2024 06:52	deployed	54° 16,151' N	008° 13,466' E	12
AL611_04-1	CSEM	26.04.2024 13:51	at surface	54° 29,587' N	008° 03,320' E	19
AL611_04-1	CSEM	26.04.2024 14:48	on deck	54° 31,047' N	008° 02,032' E	15
AL611_05-1	SES	26.04.2024 17:24	profile start	54° 16,193' N	007° 58,176' E	21
AL611_05-1	SES	27.04.2024 03:16	profile end	54° 14,354' N	007° 57,193' E	19
AL611_06-1	CSEM	27.04.2024 04:49	in the water	54° 08,961' N	008° 21,432' E	13
AL611_06-1	CSEM	27.04.2024 05:36	deployed	54° 11,063' N	008° 21,005' E	14
AL611_06-1	CSEM	27.04.2024 15:51	at surface	54° 31,835' N	008° 05,939' E	16
AL611_06-1	CSEM	27.04.2024 16:43	on deck	54° 33,840' N	008° 03,956' E	16
AL611_07-1	SES	27.04.2024 18:52	profile start	54° 14,056' N	007° 56,545' E	17
AL611_07-1	SES	28.04.2024 03:50	profile end	54° 20,205' N	007° 49,697' E	23
AL611_08-1	CSEM	28.04.2024 06:06	in the water	54° 12,692' N	008° 17,175' E	14
AL611_08-1	CSEM	28.04.2024 06:53	deployed	54° 15,101' N	008° 16,198' E	11
AL611_08-1	CSEM	28.04.2024 14:09	at surface	54° 30,692' N	008° 04,620' E	18
AL611_08-1	CSEM	28.04.2024 15:00	on deck	54° 32,563' N	008° 03,235' E	17
AL611_09-1	SES	28.04.2024 17:39	profile start	54° 20,100' N	007° 49,765' E	23

AL611_09-1	SES	29.04.2024 05:11	profile end	54° 16,639' N	007° 48,242' E	563
AL611_10-1	CSEM	29.04.2024 07:45	in the water	54° 12,174' N	008° 22,263' E	13
AL611_10-1	CSEM	29.04.2024 08:39	deployed	54° 14,783' N	008° 20,760' E	12
AL611_10-1	CSEM	29.04.2024 16:42	at surface	54° 31,131' N	008° 08,623' E	16
AL611_10-1	CSEM	29.04.2024 17:22	on deck	54° 32,487' N	008° 07,544' E	15
AL611_11-1	SES	30.04.2024 00:00	profile start	54° 16,384' N	007° 48,542' E	24
AL611_11-1	SES	30.04.2024 00:53	profile end	54° 19,583' N	007° 46,068' E	23
AL611_12-1	CSEM	30.04.2024 07:31	in the water	54° 15,296' N	008° 10,939' E	16
AL611_12-1	CSEM	30.04.2024 08:19	deployed	54° 17,623' N	008° 09,667' E	14
AL611_12-1	CSEM	30.04.2024 14:15	at surface	54° 29,498' N	008° 01,056' E	17
AL611_12-1	CSEM	30.04.2024 15:07	on deck	54° 31,140' N	007° 59,433' E	17
AL611_13-1	SES	30.04.2024 17:10	profile start	54° 19,462' N	007° 46,124' E	23
AL611_13-1	SES	01.05.2024 04:29	profile end	54° 22,161' N	007° 53,679' E	22
AL611_14-1	CSEM	01.05.2024 06:05	in the water	54° 12,603' N	008° 07,725' E	16
AL611_14-1	CSEM	01.05.2024 06:49	deployed	54° 14,662' N	008° 06,266' E	15
AL611_14-1	CSEM	01.05.2024 14:22	at surface	54° 30,450' N	007° 55,105' E	20
AL611_14-1	CSEM	01.05.2024 15:12	on deck	54° 31,861' N	007° 53,545' E	20
AL611_15-1	SES	01.05.2024 16:18	profile start	54° 22,171' N	007° 53,935' E	22
AL611_15-1	SES	02.05.2024 04:19	profile end	54° 19,341' N	007° 56,960' E	23
AL611_16-1	CSEM	02.05.2024 06:00	in the water	54° 30,353' N	008° 11,824' E	14
AL611_16-1	CSEM	02.05.2024 06:20	at surface	54° 29,490' N	008° 12,268' E	14
AL611_16-1	CSEM	02.05.2024 06:49	on deck	54° 28,545' N	008° 12,399' E	15
AL611_17-1	SES	02.05.2024 08:00	profile start	54° 19,392' N	007° 57,595' E	21
AL611_17-1	SES	03.05.2024 02:56	profile end	54° 18,835' N	007° 59,963' E	20
AL611_18-1	CSEM	03.05.2024 03:57	in the water	54° 23,876' N	007° 50,457' E	22
AL611_18-1	CSEM	03.05.2024 04:41	deployed	54° 23,866' N	007° 53,474' E	21
AL611_18-1	CSEM	03.05.2024 16:33	at surface	54° 21,507' N	008° 00,796' E	20
AL611_18-1	CSEM	03.05.2024 17:22	on deck	54° 22,151' N	007° 59,166' E	21
AL611_19-1	SES	03.05.2024 18:01	profile start	54° 18,864' N	008° 00,046' E	21
AL611_19-1	SES	04.05.2024 03:41	profile end	54° 23,614' N	007° 53,259' E	20
AL611_20-1	CSEM	04.05.2024 06:30	in the water	54° 30,638' N	008° 12,004' E	14
AL611_20-1	CSEM	04.05.2024 07:17	deployed	54° 28,518' N	008° 12,670' E	15
AL611_20-1	CSEM	04.05.2024 14:14	at surface	54° 21,901' N	008° 03,964' E	16
AL611_20-1	CSEM	04.05.2024 14:58	on deck	54° 23,314' N	008° 02,853' E	17
Underway-2	TSG	05.05.2024 12:40	profile end	54° 21,994' N	010° 08,076' E	13

8 Data and Sample Storage and Availability

The associated scientific data out of moratorium will be submitted to World Data Centers (WDC) such as PANGAEA before the completion of the associated DFG project 524639242 or upon publication. Bathymetric and hydroacoustic data will also be delivered to the BSH data center. Electromagnetic data (several Giga-bytes) will be made available in binary format or as processed ASCII files. SES data will be stored in the vendor format and converted to standard SEG-Y files for further use and sharing. The data will additionally be supplied to state authorities as part of the Geologiedatengesetz. Arne Lohrberg (AL) and Amir Haroon (AH) will be responsible to handle the long-term data accessibility by providing the data to the aforementioned data repositories. All data is also archived on managed backup servers at Kiel University. The data will be extensively analysed as part of DFG project 524639242.

Table 8.1: Overview of data availability

Type	Database	Available	Free Access	Contact
Electromagnetic raw data (ASCII)	PANGAEA	Nov 24	Jan 26	arne.lohrberg@ifg.uni-kiel.de
Electromagnetic processed data (SEGY)	PANGAEA	Feb 25	Jan 26	arne.lohrberg@ifg.uni-kiel.de
Sediment profiling data (RAW+SEGY)	PANGAEA	Nov 24	Jan 26	arne.lohrberg@ifg.uni-kiel.de
Bathymetry and WCI (RAW)	PANGAEA	Nov 24	Jan 26	arne.lohrberg@ifg.uni-kiel.de

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11 Abbreviations

TV	Tunnel Valley
MCS	Multi-channel Reflection Seismic Data
TD-CSEM	Time-Domain Controlled-Source Electromagnetics
Tx	Transmitter
Rx	Receiver
SES	Sediment Echosounding
TSG	Thermosalinograph
E_y	Inline electric field

12 Appendices

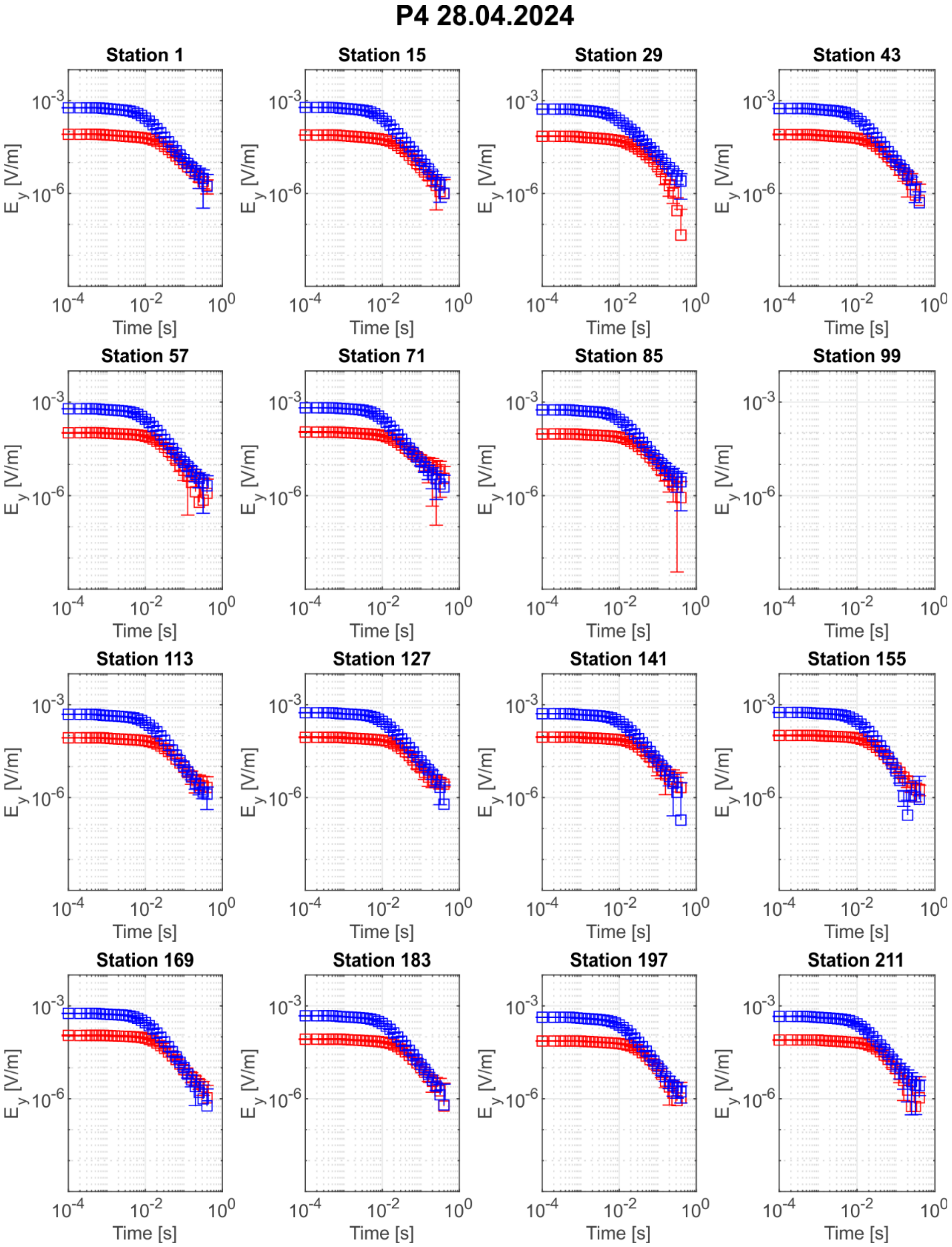

Fig. 12.1: Transients from 16 stations along profile P4 acquired on April 28th 2024. Note that station 99 is blank as this station does not contain valid data. This might be due to a short transmission or due to unreliable data on that station.

CSEM Protocol

23.04.2024							
Date	Time UTC	Longitude	Latitude	Duty Cycle	Current [A]	Temperature [°C]	Comments
23.04.2024	07:37	08°10.12	54°17.43	50%	25.2		full string in water
23.04.2024	07:41	08°10.03	54°14.47	50%	25,2		start transmit, P6
23.04.2024	07:44						trigger interrupted
23.04.2024	08:00	08°09.48	54°17.93	50%	25	36.2	
23.04.2024	08:15	08°09.127	54°18.416	50%	25	38.6	
23.04.2024	08:30	08°08.772	54°18.923	50%	25	39.8	
23.04.2024	08:45	08°08.402	54°19.330	50%	25	40.7	
23.04.2024	09:00	08°07.977	54°19.891	50%	25.1	40.9	
23.04.2024	09:15	08°07.730	54°20.380	50%	25.1	41.6	
23.04.2024	09:30	08°07.390	54°20.860	50%	25.01	41.3	
23.04.2024	09:45	08°07.029	54°21.315	50%	25.01	41.8	
23.04.2024	10:00	08°06.700	54°21.776	50%	25.01	42.5	
23.04.2024	10:15	08°06.275	54°22.280	50%	25.00	42.5	
23.04.2024	10:30	08°05.940	54°22.793	50%	25.00	42.7	
23.04.2024	10:45	08°05.559	54°23.265	50%	25.00	42.8	
23.04.2024	11:00	08°05.288	54°23.779	50%	25,01	43.2	
23.04.2024	11:15	08°04.974	54°24.280	50%	25.00	43.4	
23.04.2024	11:30	08°04.658	54°24.661	50%	25.00	43.4	
23.04.2024	11:45	08°04.256	54°25.127	50%	25.01	43.50	
23.04.2024	12:00	08°03.875	54°25.603	50%	25.01	43.6	
23.04.2024	12:15	08°03.540	54°26.106	50%	25.00	43.5	
23.04.2024	12:30	08°03.160	54°26.688	50%	25.00	43.6	
23.04.2024	12:45	08°02.820	54°27.212	50%	25.01	43.4	
23.04.2024	12:50						EOL, stop transmit
23.04.2024	12:52	08°02.626	54°27.459				Trigger stopped

25.04.2024							
25.04.2024	04:34			50%			ping into resistor with B159 at 04:34:00 UTC, gains on 1
25.04.2024	04:37			50%			ping into resistor with B160 at 04:34:00 UTC, gains on 1
25.04.2024	04:39			50%			gains back to 1, 2, 4
25.04.2024	04:40			50%			B159, resync time
25.04.2024	04:43			50%			B159 dropped 7 secs
25.04.2024	06:17	008°24.047	54°12.922	50%			START deploying the system
25.04.2024	07:10	08°22.41	54°15.294	50%			system in water
25.04.2024	07:14	08°22.351	54°15.373	50%		29.90	start trigger and sending
25.04.2024	07:28	08°22.037	54°15.809	50%	25.01	35.30	restart trigger to get back to full minute
25.04.2024	07:45	008°21.708	54°16.299	50%	25.00	37.90	
25.04.2024	08:00	008°21.423	54°16.700	50%	25.00	39.40	
25.04.2024	08:15	008°21.024	54°17.180	50%	25.00	40.10	
25.04.2024	08:30	008°20.701	54°17.632	50%	25.01	41.00	
25.04.2024	08:45	008°20.423	54°18.043	50%	25.01	40.9	
25.04.2024	09:00	008°20.053	54°18.475	50%	25	41.8	
25.04.2024	09:15	008°19.768	54°18.909	50%	25	42.1	
25.04.2024	09:30	008°19.391	54°19.369	50%	25.01	42.3	
25.04.2024	09:45	008°19.069	54°19.795	50%	25.01	42.4	
25.04.2024	10:00	008°18.655	54°20.333	50%	25	42.4	Shift start Emma, Olav, Luisa
25.04.2024	10:15	008°18.243	54°20.868	50%	25	42.3	
25.04.2024	10:30	008°17.900	54°21.370	50%	25.01	42.1	
25.04.2024	10:45	008°17.427	54°21.970	50%	25.01	42.1	
25.04.2024	11:00	008°17.180	54°22.346	50%	25	41.4	
25.04.2024	11:15	008°16.879	54°22.807	50%	25	41.4	
25.04.2024	11:30	008°16.437	54°23.313	50%	25.1	41.5	
25.04.2024	11:45	008°16.095	54°23.803	50%	25.1	41.8	

25.04.2024	12:00	008°15.771	54°24.320	50%	25	42.3	
25.04.2024	12:15	008°15.439	54°24.753	50%	25.01	42.9	trigger time restartet at 12:13:53
25.04.2024	12:30	008°15.039	54°25.227	50%	25.01	43	
25.04.2024	12:45	008°14.722	54°25.684	50%	25.01	42.5	
25.04.2024	13:00	008°14.378	54°26.141	50%	25.01	42.3	
25.04.2024	13:15	008°14.052	54°26.602	50%	25	41.8	
25.04.2024	13:30	008°13.704	54°27.032	50%	25	41.8	
25.04.2024	13:45	008°13.324	54°27.497	50%	25.01	41.8	trigger time restarted at 13:47:45
25.04.2024	14:00						Shift start Caro, Isabel, Friedrich
25.04.2024	14:01	008°12.960	54°28.009	50%	25.00	41.6	
25.04.2024	14:15	008°12.675	54°28.432	50%	25.00	41.3	trigger time restarted at 14:13:21
25.04.2024	14:30	008°12.321	54°28.854	50%	25.00	40.3	
25.04.2024	14:46	008°11.886	54°29.346	50%	25.00	41.1	
25.04.2024	15:00	008°11.557	54°29.778	50%	25.00	41.3	
25.04.2024	15:15	008°11.280	54°30.151	50%	25.00	41.4	
25.04.2024	15:30	008°10.942	54°30.615	50%	25.00	41.1	
25.04.2024	15:45	008°10.613	54°31.081	50%	25.01	40.8	
25.04.2024	16:00	008°10.364	54°31.468	50%	25.01	40.5	
25.04.2024	16:15	008°10.062	54°31.896	50%	25.00	40.3	
25.04.2024	16:30	008°09.755	54°30.320	50%	25.00	40.3	
25.04.2024	16:36	008°09.618	54°38.494	50%			trigger stopped, profile end
25.04.2024							
25.04.2024	17:51						trigger to logger 159 into shunt
25.04.2024	17:53						trigger to logger 160 into shunt

26.04.2024 ONLY B160 (Rx2) ACTIVE							
26.04.2024	04:53						ping into resistor with B159 at 04:34:00 UTC, gains on 1
26.04.2024	04:50						ping into resistor with B160 at 04:34:00 UTC, gains on 1
26.04.2024	05:51						ping into resistor with B162 at 04:34:00 UTC, gains on 1
26.04.2024	06:49	08°13.56	54°16.04				system in the water
26.04.2024	06:53	008°13.398	54°16.231	50%	25	30.7	start trigger
26.04.2024	06:55						trigger shift break from 06:55-06:56
26.04.2024	07:00	008°13,243	54°16,410		25.01	32.7	
26.04.2024	07:15	008°12,896	54°16,859	50%	25	36.5	
26.04.2024	07:30	008°12,472	54°17,427		25	39.1	
26.04.2024	07:45	008°12,177	54°17,914		25.01	40.8	
26.04.2024	08:00	008°11.877	54°18.337	50%	25	41.7	
26.04.2024	08:15	008°11.592	54°18.737	50%	25.01	42.3	
26.04.2024	08:30	008°11.228	54°19.148	50%	25	42.4	
26.04.2024	08:45	008°10.844	54°19.660	50%	25	42.9	
26.04.2024	09:00	008°10.512	54°20.078	50%	25.01	43	
26.04.2024	09:15	008°10.170	54°20.510	50%	25	42.9	
26.04.2024	09:30	008°09.830	54°20.977	50%	25	42.9	
26.04.2024	09:45	008°09.459	54°21.396	50%	25	43.1	
26.04.2024	10:00	008°09.080	54°21.928	50%	25.01	41.8	
26.04.2024	10:15	008°08.695	54°22.425	50%	25.01	41.9	
26.04.2024	10:30	008°08.307	54°22.939	50%	25.01	42.5	
26.04.2024	10:45	008°07.919	54°23.458	50%	25.01	42.4	
26.04.2024	11:00	008°07.555	54°23.940	50%	25.01	42.8	
26.04.2024	11:15	008°07.224	54°24.464	50%	25.01	42.5	
26.04.2024	11:30	008°06.829	54°25.000	50%	25.01	43	
26.04.2024	11:45	008°06.471	54°25.445	50%	25.01	42.6	
26.04.2024	12:00	008°06.080	54°25.917	50%	25.01	43.2	

26.04.2024	12:15	008°05.631	54°26.438	50%	25.01	42.8	
26.04.2024	12:30	008°05.277	54°26.968	50%	25.01	42.3	
26.04.2024	12:45	008°04.912	54°27.463	50%	25.01	43.1	
26.04.2024	13:00	008°04.557	54°27.939	50%	25.01	42.8	
26.04.2024	13:15	008°04.024	54°28.595	50%	25.01	42.2	
26.04.2024	13:30	008°03.795	54°28.917	50%	25.01	41.7	
26.04.2024	13:45	008°03.489	54°29.357	50%	25	41.5	
26.04.2024	13:51	008°03.310	54°29.601			41.8	trigger stopped, profile end
26.04.2024	13:56						start retrieving streamer
26.04.2024	14:28						first Rx on board
26.04.2024	14:43						second Rx on board
26.04.2024	14:48						recovery completed
	14:55						triggered into shunt both loggers

27.04.2024							
27.04.2024	03:51						triggering into shunt with B160
	03:54						triggering into shunt with B159
	03:56						triggering into shunt with B162
27.04.2024	04:48						start deployment of system into water
27.04.2024	05:35	008°20.944	54°11.137				system in water
27.04.2024	05:39	008°20.944	54°11.37	50%	25	30.8	start trigger
27.04.2024	05:45	008°20.780	54°11,363	50%	25	34.5	
27.04.2024	06:00	008°20,490	54°11,820		25	37.8	
27.04.2024	06:15	008°20,171	54°12,276		25	39.6	
27.04.2024	06:29	008°19,762	54°12,795		25	41.5	
27.04.2024	06:45	008°19.432	54°13.333	50%	25	42.3	
27.04.2024	07:00	008°19.140	54°13.851	50%	25.01	42.5	
27.04.2024	07:15	008°18,723	54°14,365		25	42.2	
27.04.2024	07:30	008°18.383	54°14.876	50%	25	41.7	transmit and break one time only 60 seconds
27.04.2024	07:45	008°17.963	54°15.462	50%	25	42.1	
27.04.2024	07:50						Transmit for 120 seconds and then waited for the next minute
27.04.2024	08:00	008°17.751	54°15.887	50%	25	40.6	restart trigger
27.04.2024	08:05						one trigger stamp possibly wrong
27.04.2024	08:15	008°17.313	54°16.418	50%	25	41.2	
27.04.2024	08:30	008°16.953	54°16.887	50%	25	40.8	
27.04.2024	08:45	008°16.593	54°17.443	50%	25	41.3	
27.04.2024	09:00	008°16.277	54°17.874	50%	25	41.1	
27.04.2024	09:15	008°15.925	54°18.381	50%	25	41.2	
27.04.2024	09:19						stop for 37 sec
27.04.2024	09:30	008°15.656	54°18.738	50%	25	40.6	
27.04.2024	09:46	008°15.303	54°19,273		25.01	41.4	
27.04.2024	10:05	008°14.847	54°19,869	50%	25	41.3	

27.04.2024	10:15	008°14.607	54°20.194	50%	25	41.4	
27.04.2024	10:30	008°14.357	54°20.636	50%	25	41.6	
27.04.2024	10:45	008°13.968	54°21.166	50%	25	41.4	
27.04.2024	11:00	008°13.632	54°21.618	50%	25	41.8	
27.04.2024	11:15	008°13.045	54°22.043	50%	25	41.7	
27.04.2024	11:30	008°12.874	54°22.611	50%	25.1	41.8	
27.04.2024	11:44	008°12.563	54°23.019	50%	25	41.7	
27.04.2024	12:00	008°12.175	54°23.570	50%	25	41.4	
27.04.2024	12:15	008°11.850	54°24.000	50%	25	41.4	
27.04.2024	12:30	008°11.380	54°24.580	50%	25	40.8	
27.04.2024	12:45	008°10.971	54°25.107	50%	25.01	40.3	
27.04.2024	13:00	008°10.600	54°25.626	50%	25.1	40.8	
27.04.2024	13:16	008°10.213	54°26.133	50%	25.1	40.8	
27.04.2024	13:30	008°09.851	54°26.617	50%	25.01	41.1	
27.04.2024	13:45	008°09.510	54°27.072	50%	25.01	40.5	
27.04.2024	14:00	008°09.140	54°27.544	50%	25.01	40.6	Begin shift: Carolin, Friedrich, Isabel
27.04.2024	14:15	008°08.772	54°28.064	50%	25.01	40.8	
27.04.2024	14:30	008°08..385	54°28.563	50%	25.01	40.8	
27.04.2024	14:43						90s pause!!
27.04.2024	14:45	008°08.010	54°29.083	50%	25	39.3	
27.04.2024	15:00	008°07.617	54°29.630	50%	25	40.5	
27.04.2024	15:15	008°07.185	54°30.258	50%	25	40.6	
27.04.2024	15:30	008°06.630	54^°30.947	50%	25	40.8	70/50 instead of 90/30 at 15:24
	15:50	08°06.017	54°31.750	50%	25		Stop trigger, EOL
	16:51						trigger into shunt with B159

28.04.2024							
28.04.2024	04:45			50%			trigger into shunt with B160
28.04.2024	04:47			50%			trigger into shunt with B159
28.04.2024	04:49			50%			trigger into shunt with B162
28.04.2024	06:05	008°17.177	54°12.666	50%			start deployment of system to water
28.04.2024	06:46	008°16.371	54°14.835	50%			deployment finished
28.04.2024	06:53	008°16.198	54°16.107	50%			trigger started
28.04.2024	07:00	008°15.938	54°15.515	50%	25	35.2	transmit only for 76 s
28.04.2024	07:13	008° 15.658	54°15.869	50%			restart trigger
28.04.2024	07:30	008°15.292	54°16.526	50%	25	39.8	
28.04.2024	07:34	008°15.198	54°16.653	50%			posix time incomplete
28.04.2024	07:45	008°14.926	54°16.999	50%	25	40.9	
28.04.2024	08:00	008°14.405	54°17.730	50%	25.01	41.9	
28.04.2024	08:30	008°13,653	54°18,667	50%	25	42.8	
28.04.2024	08:38			50%			trigger transmitted only for 24 s
28.04.2024	09:00	008°12.811	54°19.831	50%	25	42.7	
28.04.2024	09:08						trigger transmitted only 6 s
28.04.2024	09:12						trigger transmitted only 12 s
28.04.2024	09:15	008°12.397	54°20.378	50%	25	41.2	
28.04.2024	09:26	008°12.149	54°20.735	50%		42.2	sending current just for 80s
28.04.2024	09:30	008°12.096	54°20.800	50%	25	42.3	
28.04.2024	09:34	008°11.969	54°20.971	50%		42.8	stopping just for 23 seconds
28.04.2024	09:46						transmit for 47 s
28.04.2024	10:00	008°11.392	54°21.678	50%	25	42.9	
28.04.2024	10:15	008°10.930	54°22.308	50%	25	41.8	
28.04.2024	10:19						restart triggerbox because of too many short transmissions
28.04.2024	10:30	008°10.623	54°22.689	50%	25	42.5	
28.04.2024	10:42						Trigger for only 8 seconds, then stop for 82+30s
28.04.2024	10:49	008°10.125	54°23.381	50%	25	41.8	

28.04.2024	10:55						Trigger for 56 s, then stop for 64s
28.04.2024	10:59						stop logging (restart triggerbox/ stromlos)
28.04.2024	11:00	008°09.786	54°23.776	50%	25	42	
28.04.2024	11:02						start logging
28.04.2024	11:15	008°09.422	54°24.269	50%	25	43.2	
28.04.2024	11:30	008°09.023	54°24.799	50%	25	43.7	
28.04.2024	11:45	008°08.590	54°25.361	50%	25	44.2	
28.04.2024	12:00	008°08.164	54°25.921	50%	25	44.5	
28.04.2024	12:15	008°07.838	54°26.386	50%	25.01	44.6	
28.04.2024	12:30	008°07.418	54°26.903	50%	25	44.8	
28.04.2024	12:45	008°06.985	54°27.489	50%	25	44.8	
28.04.2024	13:00	008°06.553	54°28.119	50%	25	44.9	
28.04.2024	13:10						first hickup since restart: 72sec on, 48 off
28.04.2024	13:15	008°06.181	54°28.608	50%	25	44.7	
28.04.2024	13:30	008°05.813	54°29.094	50%	25	44.9	
28.04.2024	13:45	008°05.364	54°29.682	50%	25	44.5	
28.04.2024	14:00	008°4.942	54°30.247	50%	25	44.4	
28.04.2024	14:07	008°4.675	54°30.620				trigger stopped
	14:09	008°04.617	54°30.701	50%			EOL
	14:59						trigger into shunt with B159
	15:10						trigger into shunt with B160
	16:06						trigger into shunt with B162

29.04.2024							
29.04.2024	07:01						trigger into shunt with B159
	07:03						trigger into shunt with B160
29.04.2024	08:43	008°20,892	54°14,606		25	29	start trigger
29.04.2024	08:45	008°20.614	54°15.005	50%	25	33.9	
29.04.2024	09:00	008°20.247	54°15.471	50%	25	36.7	
29.04.2024	09:06						transmitting only 8 s
29.04.2024	09:07						restart trigger
29.04.2024	09:15	008°19.918	54°15.985	50%	25	38.2	
29.04.2024	09:30	008°19.646	54°16.438	50%	25	40.2	
29.04.2024	09:47	008°19,209	54°16,978		25.01	41.4	
29.04.2024	10:00	008°18.820	54°17.529	50%	25	41.8	
29.04.2024	10:15	008°18.564	54°17.855	50%	25	42.3	
29.04.2024	10:30	008°18.228	54°18.304	50%	25	42	
29.04.2024	10:45	008°17.875	54°18.825	50%	25	42.4	
29.04.2024	11:00	008°17.466	54°19.329	50%	25	42.5	
29.04.2024	11:15	008°17.079	54°19.821	50%	25	42.3	
29.04.2024	11:30	008°16.647	54°20.293	50%	25.01	42.4	
29.04.2024	11:46	008°16.274	54°20.851	50%	25	42.7	
29.04.2024	12:00	008°15.963	54°21.278	50%	25.01	42.8	
29.04.2024	12:15	008°15.614	54°21.730	50%	25	43.1	
29.04.2024	12:30	008°15.213	54°22.313	50%	25.01	43.2	
29.04.2024	12:45	008°14.920	54°22.703	50%	25.01	43.5	
29.04.2024	13:00	008°14.418	54°23.338	50%	25.01	43.6	
29.04.2024	13:15	008°14.006	54°23.950	50%	25.01	43.6	
29.04.2024	13:30	008°13.700	54°24.380	50%	25.01	43.8	
29.04.2024	13:45	008°13.319	54°24.864	50%	25.01	44.2	
29.04.2024	14:00	008°12.821	54°25.516	50%	25.01	44.1	
29.04.2024	14:15	008°12.465	54°26.030	50%	25	44	
29.04.2024	14:30	008°12.131	54°26.530	50%	25	44	
29.04.2024	14:45	008°11.700	54°27.075	50%	25	43.8	

29.04.2024	15:00	008°11.272	54°27.588	50%	25	44	
29.04.2024	15:15	008°10.974	54°28.032	50%	25	44.2	
29.04.2024	15:30	008°10.473	54°28.708	50%	25	43.3	
29.04.2024	15:45	008°10.145	54°29.277	50%	25	44.1	
29.04.2024	16:00	008°09.707	54°29.718	50%	25	44.2	
29.04.2024	16:15	008°09.357	54°30.183	50%	25	44.5	
29.04.2024	16:30	008°08.939	54°30.722	50%	25.01	44.7	
29.04.2024	16:43	008°08.577	54°31.195				trigger stop
	17:38						trigger into shunt with B159
	17:43						trigger into shunt with B160

30.04.2024 RECEIVERS SWITCHED (Rx1=B160, Rx=B159)							
30.04.2024	06:30			50%			trigger into shunt with B160
30.04.2024	06:32			50%			trigger into shunt with B159
30.04.2024	06:57			50%			trigger into shunt with B162
30.04.2024	08:19	08° 09.685	54° 17.609	50%			start triggering
30.04.2024	08:30	08°09.436	54°17.924	50%	25	34.8	
30.04.2024	09:00	008°08.776	54°18.960	50%	25.1	39	
30.04.2024	09:14	008°08.459	54°19.424	50%	25	40.5	transmitting only 44 s
30.04.2024	09:25						transmitting only 20 s
30.04.2024	09:30	008°07.700	54°19.931		25	41.1	
30.04.2024	09:34						transmitting only 52 s
30.04.2024	09:45	008°07.733	54°20.421		25	41.7	
30.04.2024	10:00	008°07.424	54°20.868	50%	25	42.3	
30.04.2024	10:15	008°07.116	54°21.354	50%	25.01	43	
30.04.2024	10:23						stop-start only 19s
30.04.2024	10:35	008°06.583	54°22.063	50%	25.1	43.5	
30.04.2024	10:46	008°06.331	54°22.410	50%	25.1	43.2	
30.04.2024	11:00	008°06.966	54°22.889	50%	25.01	43.6	
30.04.2024	11:12						transmitting 55s, stop-start 65s
30.04.2024	11:14	008°05.587	54°23.365	50%	25.01	43	trigger restart
30.04.2024	11:30	008°05.222	54°23.850	50%	25.01	43.7	
30.04.2024	11:45	008°04.851	54°24.369	50%	25.01	43.8	
30.04.2024	12:00	008°04.500	54°24.846	50%	25	43.9	
30.04.2024	12:15	008°04.060	54°25.385	50%	25	44	
30.04.2024	12:30	008°03.661	54°25.915	50%	25	43.4	
30.04.2024	12:33						restart trigger
30.04.2024	12:45	008°03.314	54°26.389	50%	25	43.5	
30.04.2024	13:00	008°02.921	54°26.926	50%	25	43.7	
30.04.2024	13:15	008°02.568	54°27.416	50%	25	44	
30.04.2024	13:30	008°02.252	54°27.926	50%	25	44.1	
30.04.2024	13:45	008°01.829	54°28.495	50%	25	44.8	

30.04.2024	14:00	008°01.450	54°28.980	50%	25.01	44.1	
30.04.2024	14:14	008°01.070	54°29.490				trigger stopped
30.04.2024	14:59						Found upon retrieval: B160 in front
30.04.2024	15:00						Trigger into shunt with B160
30.04.2024	15:14						Trigger into shunt with B159

01.05.2024							
	05:09						trigger into shunt with B159
	05:11						trigger into shunt with B160
01.05.2024	06:49	008°14.623	54°14.633	50%	25	29.5	trigger start
01.05.2024	06:51						trigger restart
01.05.2024	07:00	008°06.036	54°15.000	50%	25	33.8	
01.05.2024	07:15	00°05.702	54°15.655	50%	25	37.5	
01.05.2024	07:30	008°05.313	54°16.131	50%	25	38.9	
01.05.2024	07:45	008°04.936	54°16.697	50%	25	40.4	
01.05.2024	08:00	008°04.540	54°17.204	50%	25	41.2	
01.05.2024	08:11						transmitting stopped only for 11 s
01.05.2024	08:15	008°04.100	54°17.690	50%	25	41.5	
01.05.2024	08:30	008°03.811	54°18.221	50%	25	41.8	
01.05.2024	08:45	008°03.484	54°18.853	50%	25	42.3	
01.05.2024	09:00	008°02.983	54°19.319	50%	25	42	
01.05.2024	09:15	008°02.681	54°19.852	50%	25	42.2	
01.05.2024	09:30	008°02.301	54°20.396	50%	25	42.2	
01.05.2024	09:34						
01.05.2024	09:45	008°01.888	54°20,920		25	42.2	
01.05.2024	10:00	008°01.531	54°21.484	50%	25	42.3	
01.05.2024	10:16	008°01.173	54°22.013	50%	25	42.1	
01.05.2024	10:31	008°00.783	54°22.575	50%	25	42.4	
01.05.2024	10:44	008°00.458	54°23.034	50%	25	42.5	
01.05.2024	11:00	008°00.064	54°23.634	50%	25.01	42.3	
01.05.2024	11:05						transmitting only 79s, stopped 41s
01.05.2024	11:14	007°59.706	54°24.135	50%	25.01	42.5	stopped only 22s
01.05.2024	11:30	007°59.322	54°24.662	50%	25.01	42.2	
01.05.2024	11:45	007°58.941	54°25.155	50%	25.01	42.5	
01.05.2024	11:54						transmitting only 23s, stopped 97s
01.05.2024	12:01	007°58.545	54°25.725		25.01	41.5	transmitting only 55s, stopped 65s

01.05.2024	12:16	007°58.182	54°26.220	50%	25.01	41.9	
01.05.2024	12:30	007°57.878	54°25.659	50%	25.01	42.1	
01.05.2024	12:45	007°57.510	54°27.202	50%	25.01	42.3	
01.05.2024	13:00	007°57.151	54°27.684	50%	25.01	42.6	
01.05.2024	13:15	007°56.748	54°28.194	50%	25.01	43.2	
01.05.2024	13:30	007°56.378	54°28.701	50%	25.01	42.8	
01.05.2024	13:45	007°56.000	54°29.215	50%	25.01	42.7	
01.05.2024	14:00	007°55.666	54°29.700	50%	25.01	42.7	
01.05.2024	14:15	007°55.300	54°30.181	50%	25	43.1	
01.05.2024	14:21	007°55.114	54°30.32				trigger stopped
01.05.2024	15:06						trigger into shunt with B159
01.05.2024	15:17						trigger into shunt with B160

03.05.2024							
03.05.2024	03:35						trigger into shunt with B159
03.05.2024	03:37						trigger into shunt with B160
03.05.2024	04:37	007°53.305	54°23.866				system in water
03.05.2024	04:41	007°53.479	54°23.866	50%	25	30.2	trigger started
03.05.2024	05:00	007°54.628	54°23.882	50%	25	37.8	
03.05.2024	05:15	007°55.390	54°23.868	50%	25	38.7	
03.05.2024	05:17						only 44s sending and 76s pause
03.05.2024	05:30	007°56.290	54°23.845	50%	25	40.6	
03.05.2024	05:45	007°57.232	54°23.844	50%	25	41.9	
03.05.2024	06:00	007°57.901	54°23.818	50%	25	42.1	
03.05.2024	06:15	007°58.949	54°23,834	50%	25.01	42.8	
03.05.2024	06:30	007°59.865	54°23.813	50%	25	42.8	
03.05.2024	06:45	008°00.805	54°23.814	50%	25	43.2	
03.05.2024	07:00	008°01.631	54°23.810	50%	25	43.2	
03.05.2024	07:15	008°02.706	54°23.798	50%	25.01	43.2	
03.05.2024	07:30	008°03.517	54°2.800	50%	25.01	43.2	
03.05.2024	07:46	008°04.381	54°23.813	50%	25	43.2	
03.05.2024	08:00	008°05.311	54°23.845	50%	25	37.8	
03.05.2024	08:15	008°06.523	54°23.753	50%	25	39	
03.05.2024	08:30	008°07.430	54°23.757	50%	25	40.7	
03.05.2024	08:45	008°08.352	54°23.763	50%	25.01	40.8	
03.05.2024	09:00	008°09.309	54°23.756	50%	25	41.8	
03.05.2024	09:15	008°10.292	54°23.733	50%	25	41.7	transmit only 15 s
03.05.2024	09:30	008°11.393	54°23.747	50%	25.01	42.6	
03.05.2024	10:04	008°13,368	54°23,723	50%	25	43	
03.05.2024	10:16	008°14.097	54°23.725	50%	25	43.4	
03.05.2024	10:30	008°14.907	54°23.719	50%	25	43.3	
03.05.2024	10:45	008°15.785	54°23.710	50%	25	43.7	
03.05.2024	11:00	008°16.655	54°23.696	50%	25	44	
03.05.2024	11:00						Start of slow turning

03.05.2024	11:15	008°17.515	54°23.504	50%	25	44.1	
03.05.2024	11:34	008°17.640	54°22.832	50%	25	43.8	
03.05.2024	11:45	008°17.281	54°22.501	50%	25	44.2	
03.05.2024	12:00	008°16.764	54°22.065	50%	25	44.1	
03.05.2024	12:15	008°16.255	54°21.627	50%	25	44.4	
03.05.2024	12:16						Start of next turn
03.05.2024	12:30	008°15.447	54°21.388	50%	25	43.7	
03.05.2024	12:34						on course
03.05.2024	12:45	008°14.578	54°21.377	50%	25.01	43.8	
03.05.2024	13:00	008°13.587	54°21.391	50%	25.01	44.5	
03.05.2024	13:15	008°12.593	54°21.381	50%	25.01	44.4	
03.05.2024	13:30	008°11.759	54°21.395	50%	25.01	44.6	
03.05.2024	13:45	008°10.764	54°21.425	50%	25.01	44.8	
03.05.2024	14:00	008°09.881	54°21.445	50%	25.01	44.7	
03.05.2024	14:16	008°09.052	54°21.435	50%	25.0	44.3	
03.05.2024	14:30	008°08.345	54°21.432	50%	25	44.3	
03.05.2024	14:45	008°07.258	54°21.456	50%	25	43.8	
03.05.2024	15:00	008°06.551	54°21.451	50%	25	43.8	
03.05.2024	15:15	008°05.546	54°21.460	50%		44.2	
03.05.2024	15:30	008°04.822	54°21.474	50%	25	43.7	
03.05.2024	15:45	008°03.821	54°21.481	50%	25	43.5	
03.05.2024	16:00	008°02.966	54°21.492	50%	25.01	43.8	
03.05.2024	16:15	008°01.926	54°21.495	50%	25.01	42.6	
03.05.2024	16:30						
	17:17						trigger into shunt with B159
	17:30						trigger into shunt with B160

04.05.2024							
	04:46						trigger into shunt with B160
	04:48						trigger into shunt with B159
04.05.2024	07:17	008°12.657	54°28.554				start of triggering
04.05.2024	07:30	008°12.773	54°28.108	50%	25	34	
04.05.2024	07:45	008°12.937	54°27.556	50%	25	36.8	
04.05.2024	08:00	008°13.108	54°27.107	50%	25	38.4	
04.05.2024	08:15	008°13.237	54°26.616	50%	25	39.5	
04.05.2024	08:30	008°13.385	54°26.141	50%	25	40.1	
04.05.2024	08:45	008°13.592	54°25.542		25.01	40.4	
04.05.2024	09:00	008°13.754	54°25.001	50%	25	40.5	
04.05.2024	09:03	008°13.801	54°25.853	50%	25	40.5	start of turn
04.05.2024	09:15	008°13.376	54°24.490	50%	25	40.08	
04.05.2024	09:30	008°12.704	54°24.134	50%	25	41.3	
04.05.2024	09:47	008°12.448	54°23.484	50%	25	41.4	
04.05.2024	10:06	008°12.138	54°22.817	50%	25	41.6	
04.05.2024	10:15	008°11.978	54°22.469	50%	25	41.7	
04.05.2024	10:35	008°11.631	54°21.734	50%	25	41.8	
04.05.2024	10:45	008°11.506	54°21.394	50%	25	42.1	
04.05.2024	11:00	008°11.323	54°20.833	50%	25	42.1	
04.05.2024	11:15	008°10.969	54°20.341	50%	25	42.1	
04.05.2024	11:30	008°10.384	54°19.866	50%	25	42.2	
04.05.2024	11:46	008°09.808	54°19.383	50%	25.01	42.4	Begin SAR Training OPS (Helicopter arrives!)
04.05.2024	12:00	008°09.132	54°19.004	50%	25.01	42.7	
04.05.2024	12:19	008°07.614	54°18.749	50%	25	42.8	End of SAR Helicopter training
04.05.2024	12:28						helicopter passing over Alkor repeatedly again
04.05.2024	12:30	008°07.056	54°18.744	50%	25.01	42.3	
04.05.2024	12:35	008°06.664	54°18.732	50%	25	41.8	Begin of 90° turn
04.05.2024	12:50	008°05.908	54°19.062	50%	25	42.2	

04.05.2024	13:00	008°05.722	54°19.357	50%	25	42.3	End of 90° turn, on profile again
04.05.2024	13:16	008°05.394	54°19.893	50%	25.01	42.2	
04.05.2024	13:31	008°05.021	54°20.426	50%	25.01	42.5	
04.05.2024	13:45	008°04.690	54°20.870	50%	25.01	42.1	
04.05.2024	14:00						group picture :-)
04.05.2024	14:14						Trigger stop. Time to say Goodbye :'(
	15:04						trigger into shunt with B159
	15:06						trigger into shunt with B160