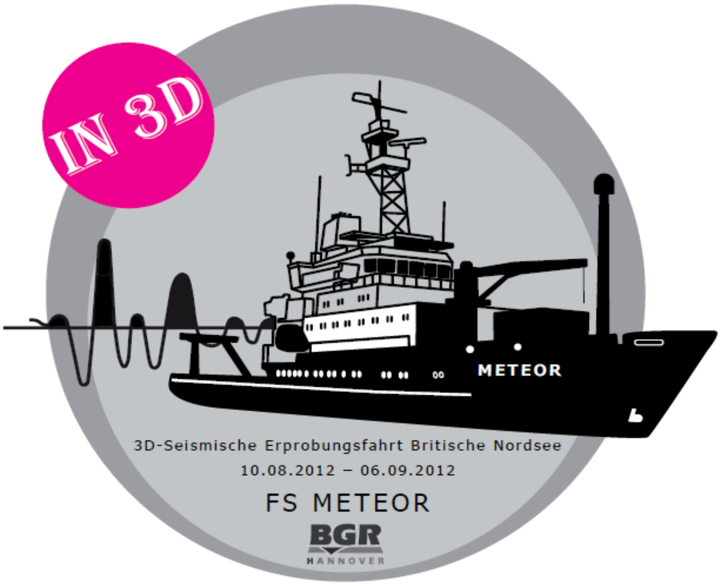
METEOR-Berichte

# *3D-TEST NORTH SEA*

## Cruise No. 88/1

10.08.2012 – 06.09.2012, Bremerhaven – Bremerhaven



**V. Damm,**
**Adam, J., Bargeloh, O., Behrens, T., Block, M., Demir, Ü., Ehrhardt, A., Kallaus, G., Kuhlmann, C., Ladage, St., Lutz, R., Papenberg, C., Schnabel, M., Schrader, U., Schreckenberger, B., Sonnabend, H.**

Editorial Assistance:

Senatskommission für Ozeanographie
MARUM – Zentrum für Marine Umweltwissenschaften der Universität Bremen

2013

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## 1 Summary

During cruise M88/1 RV METEOR was used by the marine seismic group of BGR (Federal Institute for Geosciences and Natural Resources, Hannover).

Main objectives were to initialize and configure all recently purchased components of a mobile 3D marine seismic data acquisition system and subsequently to operate the complete system to acquire a 3D data set in an area of limited extent. The cruise was subdivided into two legs by a call at the port of Aberdeen.

The first two weeks of the allocated 4 weeks time slot were dedicated to acquire methodical know-how in configuring and applying the 3D multichannel seismic equipment onboard a multi-purpose research vessel. After transit to the working area off the Scottish coast all 3D seismic components were individually configured and subsequently comprehensively tested between August 10th and 24th. The tests included deck handling and dragging configuration of the outboard systems as well as testing all hardware and software components for precise navigation, system control and data acquisition according to industry standards. After successfully finishing this leg part of the scientific crew was exchanged.

In the period between August 24th and September 6th a first 3D seismic survey was scheduled for a small sized area. This survey was completed in a 60 km² area W of the Island of Heligoland. The survey area was covered by a regular line grid with 150 m separation of seismic survey lines. Summarizing the total number of 45 3D survey lines data was acquired along 451 km of track lines. During the 3D seismic survey all requirements of precise navigation and standards for maximum folding of 3D seismic data using two 900 m long streamers were aimed.

## Zusammenfassung

Während der Reise M88/1 wurde FS METEOR vom Arbeitsbereich Marine Seismik der BGR (Bundesanstalt für Geowissenschaften und Rohstoffe) Hannover genutzt.

Hauptarbeitsziele waren die Konfiguration und der erstmalige Einsatz aller neu beschafften Komponenten eines mobilen mehrkanaligen 3D-seismischen Mess-Systems. Nach Aufbau und Inbetriebnahme dieser neuen 3D-Seismik war die Erhebung eines ersten 3D-seismischen Datensatzes in einem Testgebiet begrenzter Ausdehnung vorgesehen. Die Fahrt war in zwei Abschnitte unterteilt mit einem Zwischenaufenthalt in Aberdeen.

Während der ersten beiden Wochen der insgesamt 4-wöchigen Reise stand der methodische Know-How-Erwerb beim Umgang mit allen 3D-seismischen Außenbordsystemen an Bord eines Mehrzweck-Forschungsschiffes im Vordergrund. Nach Erreichen des Arbeitsgebietes vor der schottischen Küste wurden alle 3D-seismischen Komponenten konfiguriert und zwischen dem 10. und 24. August in allen Funktionen umfassend getestet. Diese Tests bezogen sich sowohl auf das Ein- und Ausbringen sowie die Schleppkonfiguration der Außenbordsysteme als auch auf die Inbetriebnahme und Tests aller Hard- und Software-Komponenten für die präzise Navigation, Systemkontrolle und Datenerfassung nach Industriestandard. Nach erfolgreichem Abschluß des ersten Fahrtabschnittes wurde ein Teil der wissenschaftlichen Besatzung ausgetauscht.

Für den Zeitraum 24. August bis 6. September war eine erste 3D-seismische Vermessung in einem kleinräumigen Messgebiet geplant. Das 60 km² große Untersuchungsgebiet westlich von Helgoland wurde mit einem Messgitter von insgesamt 45 Linien im Abstand von 150 m abgedeckt. Die Gesamtlänge der Messlinien beträgt 451 km. Die 3D-Datenerhebung mit zwei

Streamern mit jeweils 900 m aktiver Länge wurde entsprechend den Anforderungen und Standards der Explorationsindustrie an Navigation, Überdeckung und Datendichte durchgeführt.

## 2 Participants

| Name | Discipline | Institution | Leg |
|---|---|---|---|
| Damm, Volkmar, Dr. | Geophysicist, Chief Scientist | BGR | A, B |
| Adam, Jürgen | Technician | BGR | A, B |
| Bargeloh, Hans-Otto | Technician | BGR | A, B |
| Behrens, Thomas | Technician | BGR | A, B |
| Block, Martin | Geophysicist | BGR | A, B |
| Breuer, Sonja | Geologist | BGR | A, B |
| Demir, Ümit | Technician | BGR | A, B |
| Deppe, Joachim | Technician | BGR | A |
| Ehrhardt, Axel, Dr. | Geophysicist | BGR | A |
| Fordyce, Ian | Technician | ION | A |
| Kallaus, Günter | Technician | BGR | A, B |
| Karg, Matthias | Public Relation | BGR | A |
| Koopmann, Hannes | Geoscientist | BGR | A, B |
| Kuhlmann, Cornelia | Geoscientist | BGR | A, B |
| Ladage, Stefan, | Geologist | BGR | B |
| Lutz, Rüdiger, Dr. | Geologist | BGR | B |
| Papenberg, Cord, Dr. | Geophysicist | GEOMAR | B |
| Schauer, Michael | Geoscientist | BGR | A |
| Schnabel, Michael, Dr. | Geophysicist | BGR | A |
| Schrader, Uwe | Technician | BGR | A |
| Schreckenberger, Bernd, Dr. | Geophysicist | BGR | A, B |
| Sonnabend, Hartmut | Technician | DWD | A, B |
| Steuer, Stephan | Geologist | BGR | A, B |
| Vinke, Christoph | Administration | BGR | B |
| Wrobel, Susanne | Administration | BGR | B |

A - period from 10.08.-24.08.12 B – period from 24.08.-06.09.12

| | |
|---|---|
| BGR | Bundesanstalt für Geowissenschaften und Rohstoffe |
| DWD | Deutscher Wetterdienst, Geschäftsfeld Seeschiffahrt |
| Geomar | Helmholtz-Zentrum für Ozeanforschung Kiel |
| ION | ION-Concept Systems, Edingburgh, Scotland, UK |

## 3 Research Program

Within the scope of its tasks as the German Geological Survey BGR conducts marine geoscientific research worldwide. Several marine geophysical and geological methods are used for this purpose. Among them multichannel seismic methods have been applied so far for 2D operations by means of a 4,5 km streamer cable using different multipurpose vessels as a platform.

There is an increasing demand for 3D seismic data in the German and international geoscientific community. Currently there are only a few marine 3D seismic systems available worldwide which belong to scientific institutions. The only scientific multichannel 3D seismic systems which meets all standards of the exploration industry is owned by the Lamont Doherty Earth Observatory/University of New York and permanently installed onboard the multipurpose RV Marcus G. Langseth, a former 3D seismic exploration vessel.

In May 2009 the marine seismic group of BGR was entrusted to assemble a mobile 3D seismic system able to be operated from several multipurpose research vessels. This mobile 3D system had to fulfill all requirements of precise 3D survey navigation, shot control and real-time quality control. According to the strategy two configurations of a mobile multi-channel 3D seismic system were planned:

a) a 3D seismic setup with 1500m cable length at maximum and 2 GI guns and
b) a 3D seismic setup with 4000m cable length at maximum and 2 arrays consisting of 8 G-guns each (still in preparation).

The spread between both streamer cables is achieved using paravans, which may be adjusted according to the used seismic setup (Figure 3.1).

Beginning in May 2009 BGR purchased all necessary components to upgrade the already existing 2D multi-channel seismic system to a 3D system.

The cruise M88/1 was aimed at testing a 3D seismic setup with 900 m streamer cables and all system components. A low traffic area in the British sector of the North Sea with water depth deeper than 40 m was selected for these operations (Figure3.2). Subsequently, it was planned to acquire 3D seismic data in a test area of limited extent. The finally selected survey area was located W of Heligoland to make benefit of the acquired data for a currently running mapping project in the German sector of the North Sea. It also represented one of the four targets for survey operations during the subsequent cruise M 88/2 (Figure 3.2).

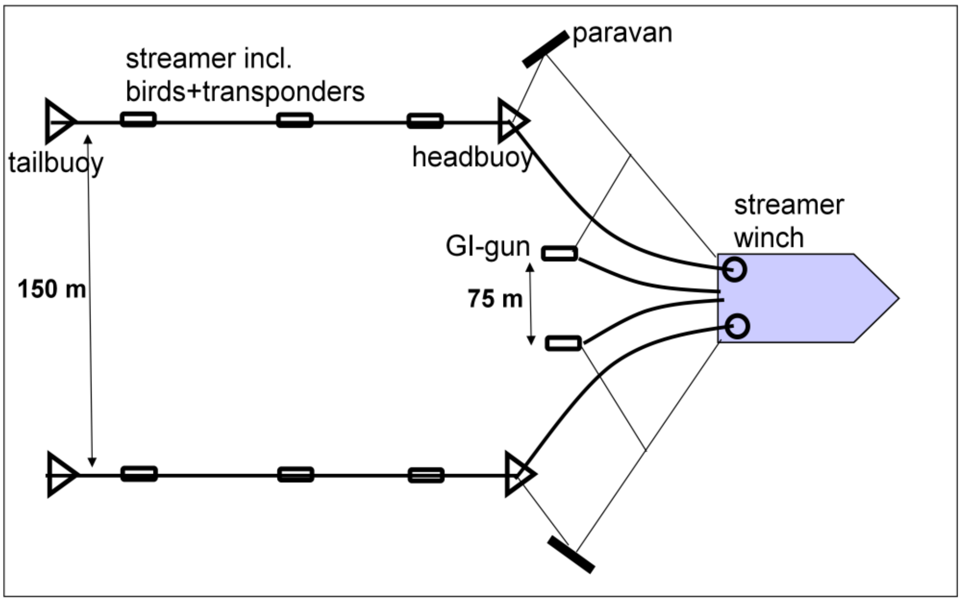

**Fig. 3.1** Pre-planned setup of BGR’s marine multichannel 3D seismic system with 2 streamers

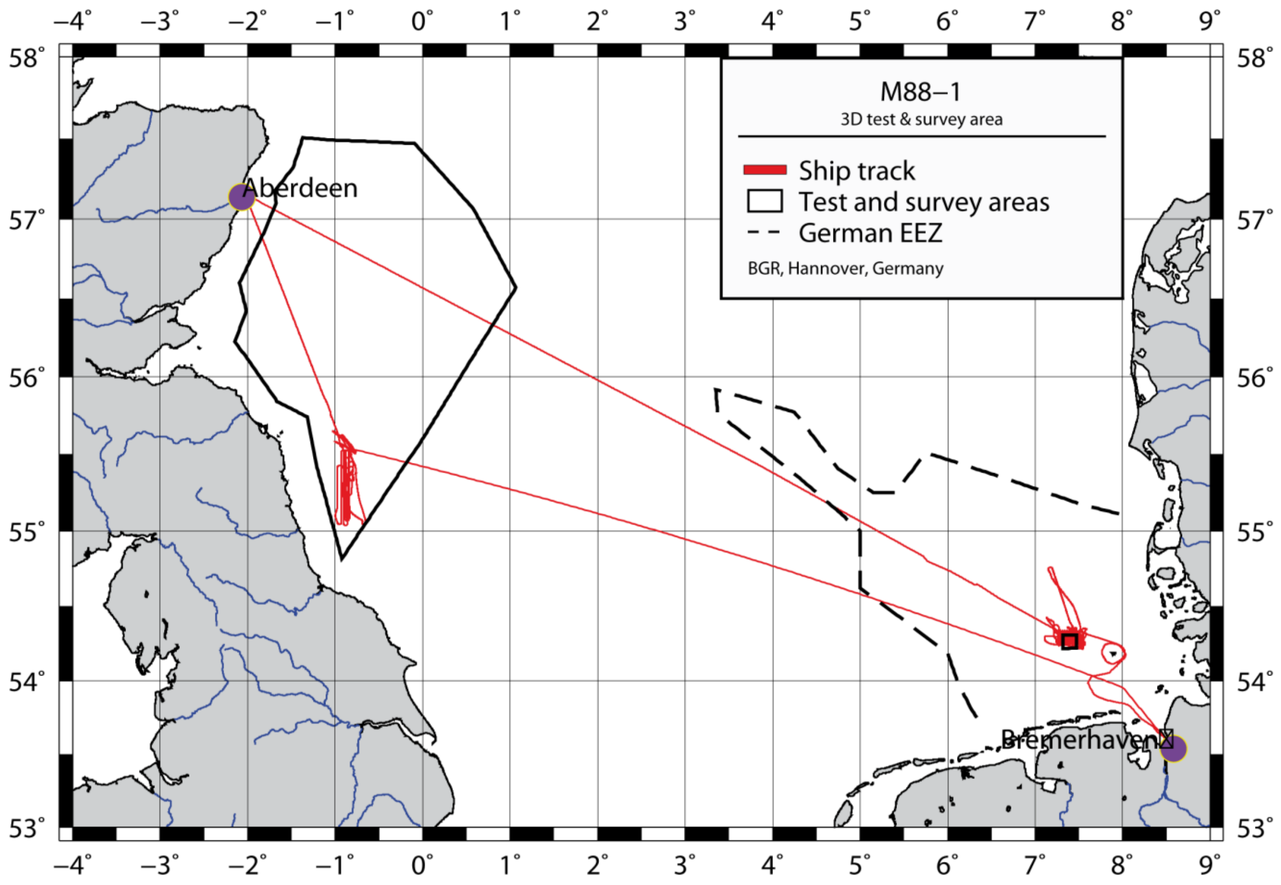

**Fig. 3.2** Track chart of R/V METEOR Cruise M88/1.

## 4 Narrative of the Cruise

### Week 32 (August 10th – August 12th)

RV METEOR was moored on the quay of Lloyds wharf and ready for loading operations and embarkation at Friday morning, August 10th. The scientific crew members arrived 8:00 am and started unloading the containers, which were assigned to stay in Bremerhaven until the return from the journey. Part of the seismic equipment was assembled on quay.

During the last stay in the shipyard the working deck of RV METEOR was partly modified for the special demands of the 3D equipment. Some welding for the foundations of the streamer winches had to be completed immediately before installation of the two winches and all other seismic equipment.

The loading operations were completed by 8:00 pm and RV METEOR cast off at 10:30 pm heading for the first test site in the North Sea off the Scottish coast.

The 30 hours transit time was used for installation of all equipment and instruments necessary for data acquisition and positioning in the laboratories and for safety instructions.

### Week 33 (August 13th – August 19th)

Main objectives during this period were testing of all new outboard components, optimum configuration of the paravans and training for handling the seismic outboard systems, in particular the heavy and stiff trawl doors. We experienced mainly good to fair weather with appropriate sea conditions, but had to interrupt our daylight program due to rough sea for two days. Installation of all navigation equipment was completed and configuration of the in-water sensors was in progress.

By the end of this week the setup of the 3D seismic systems as required was achieved and successfully tested under different conditions.

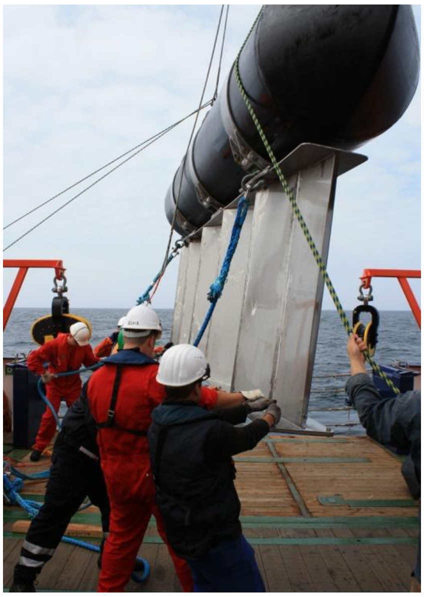

**Fig. 4.1** Deck handling of paravane

**Week 34 (August 20th – August 26th)**

During this week 3D seismic data acquisition along predefined lines was tested for the first time using the newly purchased navigation hard- and software. Navigation training included the permanent communication between responsible person in seismic navigation lab and the nautical navigator at the bridge. Due to optimum weather conditions we were able to complete the first 10 test lines which meet all demands of a 3D survey before the port call at Aberdeen on August, 24th. Based on the achieved progress it was decided to plan for a 3D survey in the German sector of the North Sea during the second leg of the cruise.

**Week 35 (August 27th – September 2nd)**

After arrival in the survey area W of Heligoland all outboard systems were deployed and the 3D seismic data acquisition was started on Monday, August 27th. The previously achieved experiences were of great benefit for the 3D survey operation at high quality standard.

Because of a storm front and bad weather conditions for our survey area forecasted for the end of this week it was decided to interrupt our continuous operations. By then 50% of the planned survey lines were measured. All outboard systems were recovered on Friday morning and due to improved conditions back to water by Saturday evening.

**Fig. 4.2** Recovery of outboard systems

Due to a cracked drag rope we lost a trawling door in the night from Saturday to Sunday. All outboard systems had to be recovered before starting searching operations. On early Sunday morning all seismic equipment was on deck and RV METEOR started a systematic search within a designated area. The paravan was localized later Sunday afternoon in a distance of appr. 9 nm.

**Week 36 (September 3rd – September 6th)**

All systems were deployed again into the water on Monday after minor repair of some components and 3D operations were restarted. Due to the additional off-time we had to slightly modify all planning for the remaining 3 days of survey operations to guarantee a full coverage of 3D seismic data within a finally 60 km² sized area. Data acquisition was terminated Wednesday morning, September 5th, and all equipment was recovered.

The rest of the last day was filled up with demobilization of all seismic equipment and packing. All equipment was ready for unloading before calling the port of Bremerhaven on early Thursday morning, September 6th.

Disembarkation and unloading was completed by Thursday afternoon, September 6th.

# 5 Preliminary Results

## 5.1 Configuration and test of 3D seismic equipment

(Damm, V. and Shipboard Scientific Party)

The planned setup for 3D seismic operations to be used during all testing procedures was compiled of two seismic hydrophone cables and two single GI-guns. Two special trawl doors (paravans also called Barovanes) designed by Baro Mek. Verksted AS - Fosnavåg/Norway were designated to achieve the predetermined separation distance between both streamers. The outboard components were complemented by GPS equipped tail buoys, dilt floats to be used as streamer head buoys, and gun floats able to carry additional navigation equipment. Acoustic network components and streamer peripheral instruments (compass birds) completed the instruments for navigation control (see Figure 3.1). The software license for operation of the Spectra navigation system was leased for the limited period of the cruise.

All newly purchased equipment was not in use before. After a first training of deck handling operations all components had to be tested regarding their floating properties and dragging behavior under various conditions. Main objective was to identify the most appropriate rigging for the trawl doors to guarantee a stable and maximum separation distance between the two streamer cables even in case of varying speed of the vessel.

In a next step all in-water navigation equipment had to be tested. This included the GPS systems mounted at the tail buoys and gun buoys, radio transmission of tail buoy GPS data and functionality of all acoustic network components.

Independent from the outboard system a hardware and a comprehensive software performance check of the Spectra navigation system had to be conducted. Subsequently the 3D version of the Concept Systems Spectra software had to be configured, which is used to determine shot and receiver positions, for navigation, and for distance depending shot control.

### 5.1.1 Outboard systems

(Behrens, Th., Ehrhardt, A., Schrader, U.)

The entire 3D seismic equipment differs significantly in comparison to regular 2D seismic equipment. The specification of the 3D seismic equipment will be split into the outboard (or “in-water”) equipment and the onboard equipment which means all the hard- and software for data acquisition, quality control, survey navigation and data storage.

A schematic overview on the outboard systems is given with Figure 3.1 (p. 5) and the layout of the outboard components shown in Figure 5.1.

Identical streamer and airgun systems were used and towed on starboard and portside, respectively. Separation between the two cables towed by RV METEOR using the two trawling doors can vary up to 200 m. With dual sound sources deployed at half the distance apart as the streamer cables this results in a maximum CDP line spacing of 50 meters. CDP line spacing should be chosen according to the desired frequency content and maximum cross-dips to be imaged.

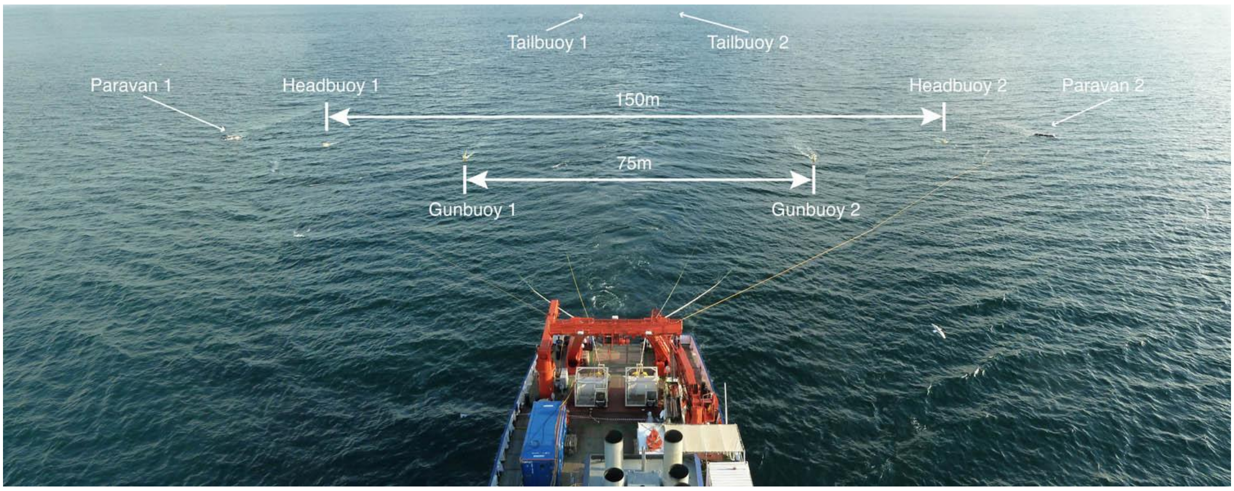

**Fig. 5.1.1:** Bird's eye view of the working deck and the towed equipment. Please compare with Figure 3.1.

We aimed for a streamer separation of 150 m and source separation of 75 m.

In detail the outboard systems consisted of (see Figures 5.1.2, 4.1, 4.2, and Appendix D)

- 2 x Barovane (or paravans) with ~12m² (each 2150 kg),
- 2 x Streamer winches (7 tons each)
- 2 x 900 m Sercel ALS streamer (oil filled)
- 2 x Partnerplast tail buoys for the streamer
- 2 x Partnerplast head buoys for the streamers (260 l each)
- 2 x Sodera-GI-guns, reduced 45/45 = 90cu.in.= 1,4748l
- 2 x Partnerplast buoys for GI-guns (260 l each)
- 2 x BGR umbilicals for GI-guns (each 140 m)
- 2 x Evotec Fairlead blocks (each 200 kg)
- 2 x Trelleborg bend protectors to prevent unwanted bending of the streamer lead-in
- 2 x 500m dynema ropes attached to the paravans, winded on mooring winches

A recovery system (Concord SRD-500S) with a self triggering mechanism at a depth of 50 m was mounted. We operated the cable at a depth of 6 m in the test area off the Scottish coast and at a depth of 4 m during our 3D seismic survey in the area west of Helgoland.

Compressed air was supplied by the AWI-owned Compressor Container equipped with a Sauer&Sohn electric driven compressor with 8m³/min at 200bar at maximum.

To allow for proper accommodation and operation of the outboard systems several installations and modifications had to be conducted prior the cruise. These preparations included construction of foundations for the two streamer winches, two support frames for mounting the two fairlead blocks at the A-frame of the vessel for streamer deflection and two auxiliary arm assemblies at the stern bulwark for the umbilicals (Figure 5.1.3). The deflection of the dynema rope through the roll-hawse was not practicable as the hawse caused abrasion to the dynema rope because of swell movement of the vessel. In order to prevent this abrasion a boss for a roll-block was welded to the outer storage of the A-Frame. The block was attached by a shackle and perfectly compensated swell movements. (see Figure 5.1.3).

Umbilicals of 80 m length were prepared, which were mounted to dragging wire during deployment of the GI-guns using the two auxiliary arm assemblies at the stern bulwark.

**Fig. 5.1.2** Streamer end buoy with GPS (left), bend protector with connecting rope to the paravan; also visible Fairlead block and multi wheel block for streamer deployment (middle), GI gun float with GPS (right)

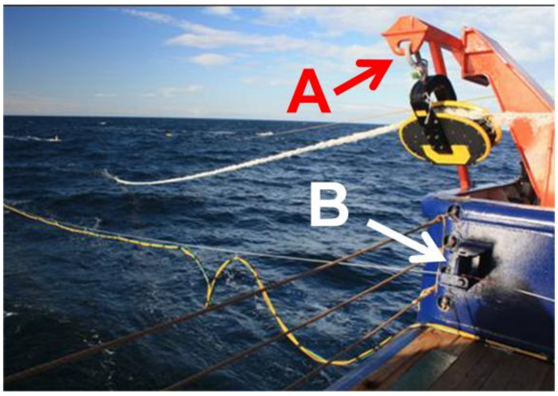

**Fig. 5.1.3** Special constructions for proper operation the 3D seismic onboard components. Foundation for streamer winches (installation of winch) – (upper left), support frame for Fairlead block (A) and auxiliary arm assembly for umbilical (B) – (upper right), welded boss (A) for mounting a block for the trawling door rope; also visible block (B) with rope for GI gun deflection

Because of the limited crane capacity and working deck clearance an explicit sequence was elaborated and necessary for unproblematic deployment (for detail see Appendix D).

1. Deployment of both paravans with the main crane at low speed. The paravans had to kept close to the vessel. Portside door must be deployed first.
2. Deployment of first streamer including tail-buoy, all acoustics, birds and head buoy. Heave down paravan and deflecting streamer to final position.
3. Deployment of second streamer, respectively.
4. Deployment of first GI-gun with float. Attachment of GI-gun using a free rolling block onto the dynema rope. Heave down the GI-Gun and deflecting to the final position.
5. Deploy second GI-gun, respectively.
6. Recovery is in the opposite sequence.

Spectra navigation software allows for full control of separation distance of all components which is shown on the screen. (see Figure 5.1.3.2 on page 15).

## 5.1.2 Seismic streamer and equipment for shooting, recording, and positioning control

(Adam, J., Block, M., Demir, Ü., Kallaus, G.)

### 5.1.2.1 Seismic shooting

The two GI-guns used as seismic sources were fired by a new shot controller (BigShot Seismic Source Controller (BSSC), manufactured by Real Time Systems, Fredericksburg/USA).

Shot triggering was conducted distance dependent. For this all shot points had to be predefined by the Spectra navigation system and a trigger signal from the Power Real Time Navigation Unit (PRTNU2) of Spectra is sent to the BSSC shot controller which fires the guns once the sources reach a line perpendicular to the survey line at the position of the shot point location.

Moreover, the BSSC employs several control and data acquisition functions:

- receives trigger from navigation
- fires solenoid power supply units (PSU)
- gathers data from solenoid power supply units
- processes data from guns and updates PSU for next shot
- displays graphical data to user for current shot
- sends serial header to recording system
- receives manifold pressure data for display (not used)

For more detail of BSSC configuration please refer to Appendix B.

### 5.1.2.2 Seismic streamers

For our 3D seismic setup we used two streamers manufactured by SERCEL. The streamer cable itself is oil-filled and consists of 150-meter sections. Each section has 12 hydrophone groups, which are 12.5 meters long. We used 6 sections to allow for 900 m active streamer length equivalent to 72 channels. Each streamer was equipped with a dilt float as head buoy and a tail buoy with flash light, radar reflector and GPS navigation with radio communication. To each streamer 7 birds (Model 5011 DigiBIRD Compass – ION Concept Systems), 6 transponders (DigiRange - ION) (see Figure 5.1.2.2.1) and 4 streamer recovery devices (SRD 500/ 500S – Geospace Technologies) were mounted. The birds provide adjustable depth control of the streamer, depth measurement, ballast information, and compass heading data. The DigiRange acoustic system is used for streamer positioning control. All bird and transponder data were transmitted via streamer to the vessel. Configuration of the starboard and portside streamer is shown in Figure 5.1.2.2.2. The bird and acoustic control unit, DigiCOURSE System 3, was connected to the Spectra navigation system

**Fig 5.1.2.2.1:**

DigiBIRD units for depth control and compass navigation (red), DigiRANGE transponders (yellow), and recovery system (green)

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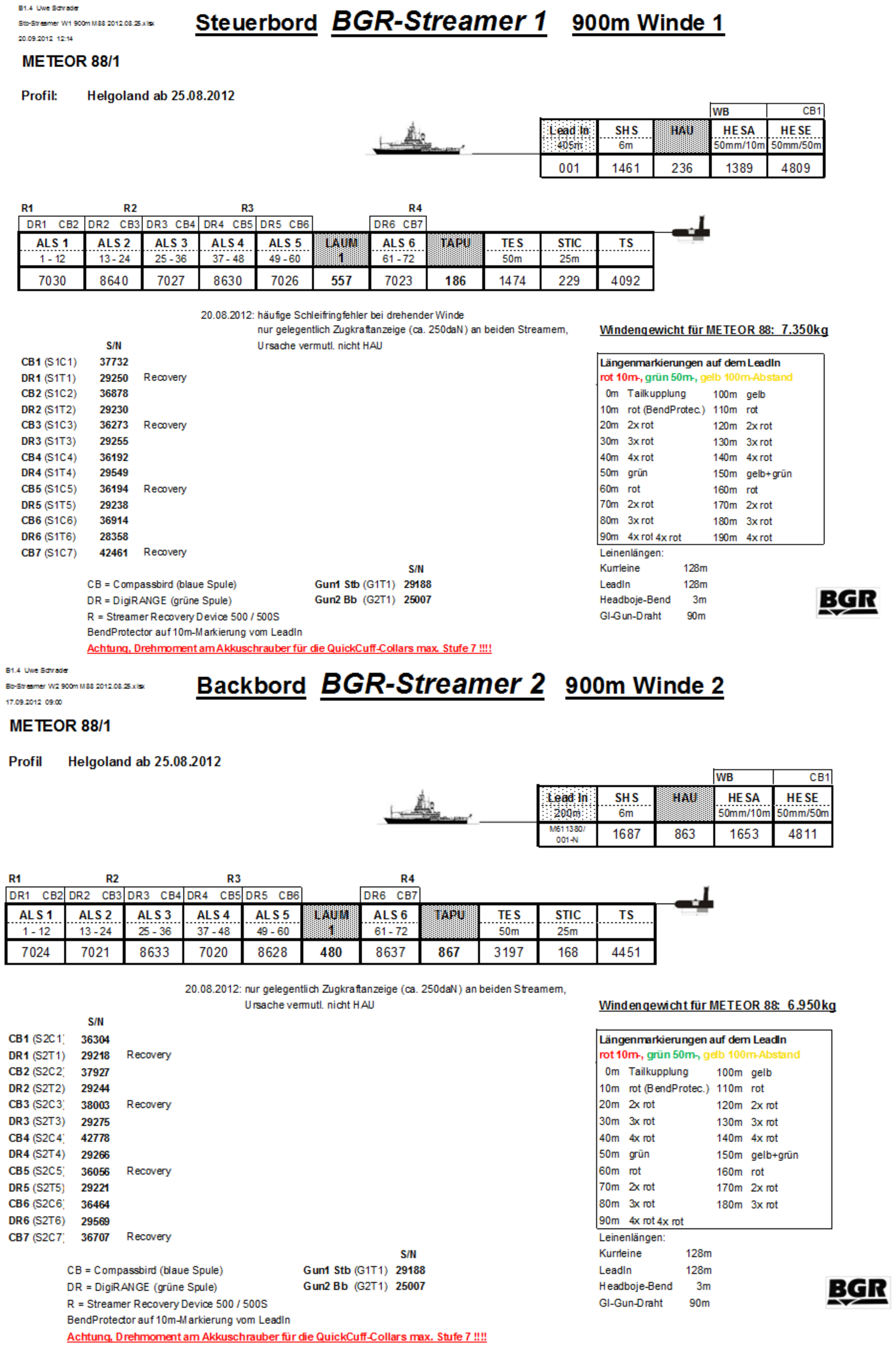


B1.4 Uwe Schrader
Stb-Streamer W1 900m M88 2012.08.25.xlsx
20.09.2012 12:14

**Steuerbord** ***BGR-Streamer 1*** **900m Winde 1**

**METEOR 88/1**

**Profil:** **Helgoland ab 25.08.2012**

| | | | WB | CB1 |
|---|---|---|---|---|
| Lead In 405m | SHS 6m | HAU | HESA 50mm/10m | HESE 50mm/50m |
| 001 | 1461 | 236 | 1389 | 4809 |

| R1 | R2 | | R3 | | | R4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| DR1 CB2 | DR2 CB3 | DR3 CB4 | DR4 CB5 | DR5 CB6 | | DR6 CB7 | | | | |
| ALS 1 1 - 12 | ALS 2 13 - 24 | ALS 3 25 - 36 | ALS 4 37 - 48 | ALS 5 49 - 60 | LAUM 1 | ALS 6 61 - 72 | TAPU | TES 50m | STIC 25m | TS |
| 7030 | 8640 | 7027 | 8630 | 7026 | **557** | 7023 | **186** | 1474 | 229 | 4092 |

20.08.2012: häufige Schleifringfehler bei drehender Winde
nur gelegentlich Zugkraftanzeige (ca. 250daN) an beiden Streamern,
Ursache vermutl. nicht HAU

**Windengewicht für METEOR 88: 7.350kg**

| | S/N | |
|---|---|---|
| **CB1** (S1C1) | **37732** | |
| **DR1** (S1T1) | **29250** | Recovery |
| **CB2** (S1C2) | **36878** | |
| **DR2** (S1T2) | **29230** | |
| **CB3** (S1C3) | **36273** | Recovery |
| **DR3** (S1T3) | **29255** | |
| **CB4** (S1C4) | **36192** | |
| **DR4** (S1T4) | **29549** | |
| **CB5** (S1C5) | **36194** | Recovery |
| **DR5** (S1T5) | **29238** | |
| **CB6** (S1C6) | **36914** | |
| **DR6** (S1T6) | **28358** | |
| **CB7** (S1C7) | **42461** | Recovery |

Längenmarkierungen auf dem LeadIn
rot 10m-, grün 50m-, gelb 100m-Abstand

| | | | |
|---|---|---|---|
| 0m | Tailkupplung | 100m | gelb |
| 10m | rot (BendProtec.) | 110m | rot |
| 20m | 2x rot | 120m | 2x rot |
| 30m | 3x rot | 130m | 3x rot |
| 40m | 4x rot | 140m | 4x rot |
| 50m | grün | 150m | gelb+grün |
| 60m | rot | 160m | rot |
| 70m | 2x rot | 170m | 2x rot |
| 80m | 3x rot | 180m | 3x rot |
| 90m | 4x rot 4x rot | 190m | 4x rot |

| | S/N |
|---|---|
| **Gun1 Stb** (G1T1) | **29188** |
| **Gun2 Bb** (G2T1) | **25007** |

Leinenlängen:

| | |
|---|---|
| Kurrleine | 128m |
| LeadIn | 128m |
| Headboje-Bend | 3m |
| GI-Gun-Draht | 90m |

CB = Compassbird (blaue Spule)
DR = DigiRANGE (grüne Spule)
R = Streamer Recovery Device 500 / 500S
BendProtector auf 10m-Markierung vom LeadIn
Achtung, Drehmoment am Akkuschrauber für die QuickCuff-Collars max. Stufe 7 !!!!

B1.4 Uwe Schrader
Bb-Streamer W2 900m M88 2012.08.25.xlsx
17.09.2012 09:00

**Backbord** ***BGR-Streamer 2*** **900m Winde 2**

**METEOR 88/1**

**Profil** **Helgoland ab 25.08.2012**

| | | | WB | CB1 |
|---|---|---|---|---|
| Lead In 200m | SHS 6m | HAU | HESA 50mm/10m | HESE 50mm/50m |
| M611380/ 001-N | 1687 | 863 | 1653 | 4811 |

| R1 | R2 | | R3 | | | R4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| DR1 CB2 | DR2 CB3 | DR3 CB4 | DR4 CB5 | DR5 CB6 | | DR6 CB7 | | | | |
| ALS 1 1 - 12 | ALS 2 13 - 24 | ALS 3 25 - 36 | ALS 4 37 - 48 | ALS 5 49 - 60 | LAUM 1 | ALS 6 61 - 72 | TAPU | TES 50m | STIC 25m | TS |
| 7024 | 7021 | 8633 | 7020 | 8628 | **480** | 8637 | **867** | 3197 | 168 | 4451 |

20.08.2012: nur gelegentlich Zugkraftanzeige (ca. 250daN) an beiden Streamern,
Ursache vermutl. nicht HAU

**Windengewicht für METEOR 88: 6.950kg**

| | S/N | |
|---|---|---|
| **CB1** (S2C1) | **36304** | |
| **DR1** (S2T1) | **29218** | Recovery |
| **CB2** (S2C2) | **37927** | |
| **DR2** (S2T2) | **29244** | |
| **CB3** (S2C3) | **38003** | Recovery |
| **DR3** (S2T3) | **29275** | |
| **CB4** (S2C4) | **42778** | |
| **DR4** (S2T4) | **29266** | |
| **CB5** (S2C5) | **36056** | Recovery |
| **DR5** (S2T5) | **29221** | |
| **CB6** (S2C6) | **36464** | |
| **DR6** (S2T6) | **29569** | |
| **CB7** (S2C7) | **36707** | Recovery |

Längenmarkierungen auf dem LeadIn
rot 10m-, grün 50m-, gelb 100m-Abstand

| | | | |
|---|---|---|---|
| 0m | Tailkupplung | 100m | gelb |
| 10m | rot (BendProtec.) | 110m | rot |
| 20m | 2x rot | 120m | 2x rot |
| 30m | 3x rot | 130m | 3x rot |
| 40m | 4x rot | 140m | 4x rot |
| 50m | grün | 150m | gelb+grün |
| 60m | rot | 160m | rot |
| 70m | 2x rot | 170m | 2x rot |
| 80m | 3x rot | 180m | 3x rot |
| 90m | 4x rot 4x rot | | |

| | S/N |
|---|---|
| **Gun1 Stb** (G1T1) | **29188** |
| **Gun2 Bb** (G2T1) | **25007** |

Leinenlängen:

| | |
|---|---|
| Kurrleine | 128m |
| LeadIn | 128m |
| Headboje-Bend | 3m |
| GI-Gun-Draht | 90m |

CB = Compassbird (blaue Spule)
DR = DigiRANGE (grüne Spule)
R = Streamer Recovery Device 500 / 500S
BendProtector auf 10m-Markierung vom LeadIn
Achtung, Drehmoment am Akkuschrauber für die QuickCuff-Collars max. Stufe 7 !!!!

**Fig. 5.1.2.2.2:** Streamer configurations for starboard and portside streamer

### 5.1.2.3 Seismic recording

We used BGR's SEAL seismic recording system (408xl, SERCEL) for data acquisition, which is capable to handle up to 2000 channels per streamer. The sampling rate during seismic data acquisition was 1 ms. Data was recorded on two SDLT 320 tape drives and, simultaneously, one NAS system was used. Data format is 4byte - SEG-D revision 2, demultiplexed 32 bit IEEE, Code 8058. The record length was set to 5000 ms.

The seismic recording system was triggered by Spectra, from where it received the data for the external header. This included all information from the bird and acoustic control unit, the ships navigation system, and the remote GPS navigation systems at the tail and gun buoys.

Continuous online quality control of seismic data was performed using a SeaProQC (Sea Processing Quality Control) ‘SunBlade 2500’ to display:

- the attributes of the data from the previous shots and summarize errors and source attributes for the successive shots processed by the SeaProQC,
- the last shot record. The traces are displayed in the time/distance range with the noise of each trace on top of the display,
- the data of one selected channel from the streamer with the new acquired trace added to the window.

### 5.1.2.4 Positioning control

In addition to the DigiBIRD compass and DigiRANGE acoustic data (Chapter 5.1.2.2) GPS receivers on the tail buoys, gun buoys and the vessel were designated for logging of source and receiver positions. Each tail buoy was equipped with a Seatrack 220 system and each gun float with a Seatrack 320 system (Kongsberg Seatex AS) in addition to a DigiRANGE transponder. Seatrack 220 and Seatrack 320 units have the same electronics but Seatrack 320 has a special enclosure and mechanics to withstand the shocks on a gun float. Both units receive GPS signals and transmit them by UHF radio to the host vessel. Seatrack 220/320 units track in real time the position of the tail buoys and the gun floats relative to that of the vessel and/or each other. The control unit Seatrack VCU 230 was installed on the vessel.

BGR's Kongsberg system setup consisted of the following main parts: (Figure 5.2.4.1).

- Tail buoy units Seatrack 220
- Gun float units Seatrack 320
- VCU 230 (Vessel Control Unit) (RNAV)
- Seadiff (data collection software)
- HHT (hand held terminal to configure Seatrack 220/320 and VCU)
- Vessel UHF antenna
- Vessel main GPS receiver

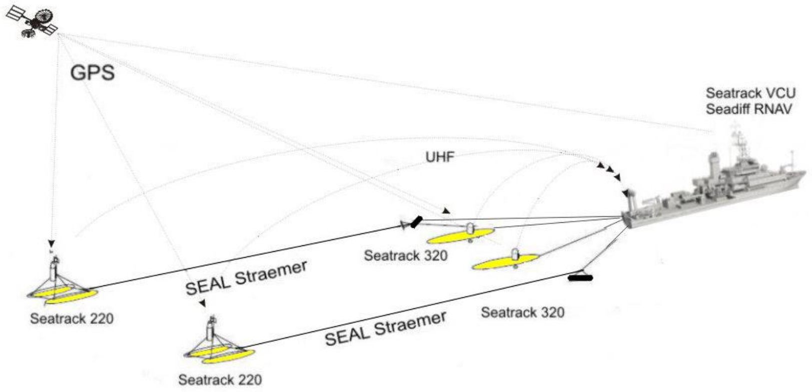


**Fig. 5.2.4.1:**

Kongsberg Seatrack Tracking System

### 5.1.3 Seismic survey navigation using Spectra

(Bargeloh, O., Kallaus, G., Schnabel, M., Schreckenberger, B.)

To meet the demand of precise navigation during 3D seismic operations we used the software package Spectra (ION Concept Systems) which is (together with the later version Orca) the standard navigation software in the exploration industry. This software has four main tasks:

- collection of all kind of sensor positioning data with accurate timing as well trigger signals,
- calculating network solutions (positions of the ship and all sensors).
- real-time binning and visualization of coverage with seismic reflection points.
- generation of P1/90 and P2/94 files according to UKOOA standards.

The design of Spectra employs a central Data Server process which acts as the information bank and data broker for the system. Data produced (i.e. configuration data, raw data or positional solution data) are stored by the data server and made available on demand. Further parts of Spectra are the following components (so-called Nodes):

- Line Management Node (LMN): defines survey lines and to control shooting when online.
- Real Time Configuration Node (RTCN): configures interfaces and triggers the real time unit.
- Spectra Configuration Node (SCN): configures the nominal positions of all nodes and sensors, and observations between nodes.
- Network Calculation Node (NCN): calculates the positions of all sensors on the vessel (the NCC network) every second and the positions of all other sensors (the main network) at the time of the shot. Further on, the NCN delivers the estimated time of the next shot.
- Data Logging Node (DLN): writes both P1/90 and P2/94 files to disk.
- Navigation Logging Node (NLN): logs summary navigation data in the form of a shot log.
- Display Node (DN): provides user configurable numerical and graphical displays of network solution, real time binning data and raw data.

We used Spectra version 14.12.1, patch level 630. The software was installed on a Dell Precision R5400 with Red Hat Linux 5. A second Dell R5400 was installed in the lab to allow the installation of 2 additional screens and to log the navigation data to a second hard disk. Further on, one machine was installed on the bridge to provide the nautical officers with information from the Display Node.

As real time unit we used a PowerRTNU II manufactured by ION Concept Systems. This unit receives all positioning information via a RS232 interfaces and sends and receives trigger signals. It is connected to the Spectra machine via Ethernet. Most of the serial interfaces were connected via a Data Distributor to the RTNU. This provides full electrical and optical isolation between the sensor and the RTNU as well as additionally LED indication of RX & TX data activity for each channel. The RTNU has an own GPS antenna to obtain a correct time signal.

Data from the navigation sensors of RV METEOR (see Appendix A for location and distances to the reference point) was provided by the scientific technical service (WTD) via Ethernet on four different ports. We used a Moxa NPort Server to feed this information to 4 serial interfaces at the RTNU. The following Spectra interfaces to decode information from these strings were used: DG_NMEA_GGA delivering mainly latitude and longitude information from the DGPS; PH_NMEA delivering pitch, roll and heading; GY_NMEA_GYRO delivering heading; EC_NMEA_DPT delivering depth information. Examples for these four data strings are given in Appendix A.

Additionally, we interfaced BGR's seismic equipment (see chapter 5.1.2) to the RTNU. For the Kongsberg RGPS system we used the interface RG_SEATRACK to obtain range and bearing for the gun floats and the tail buoys. To receive gun data from the gun controller we applied the interface GN_SYNTRON_V2. With this interface, a GCS90 control string (containing the line name, the array to be selected for the next shot and the shot number) was sent to the gun controller. The SEAL header was sent to the seismic recording system. The Positioning Control System (PCS) was connected to the Spectra machine via Ethernet. Data from the birds and the acoustic transponders were decoded by the virtual interface vid – a process running on the Spectra machine.

The RTNU also creates and receives triggers. All times are referenced to the next shot (a data item which is called @SHOTPREDICT@). At -120 ms the recording system obtains a trigger to start the system (TTL active high, 100 ms duration). At -50 ms a trigger is sent to the gun controller (TTL active high, 100 ms duration). The RTNU receives an input trigger (the timebreak) from the gun controller (TTL, active low). At -1000 ms the PCS receives a Contact Closure trigger from the RTNU. With a certain delay, the PCS submits the bird data to the Spectra system and the ranging between the acoustics is estimated subsequently.

**Fig. 5.1.3.1:** Spectra navigation system with the screens for QC of sensor data (left), navigation window (2nd left), binning control (2nd right), and QC of streamer positions (right)

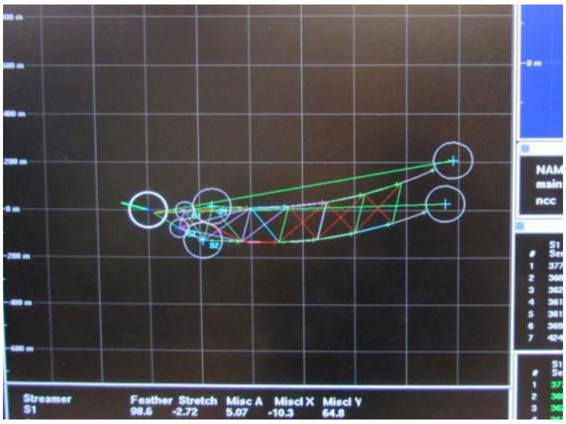


**Fig. 5.1.3.2:** Display of Spectra navigation system for controlling the position and separation distances of seismic sources and streamers (radius of big circles is 75m, radius of small once is 37,5m) – turn over starboard

The connection scheme of all hardware components of BGR's 3D seismic system including all sensors for the navigation system is shown in Figure 5.1.3.3.

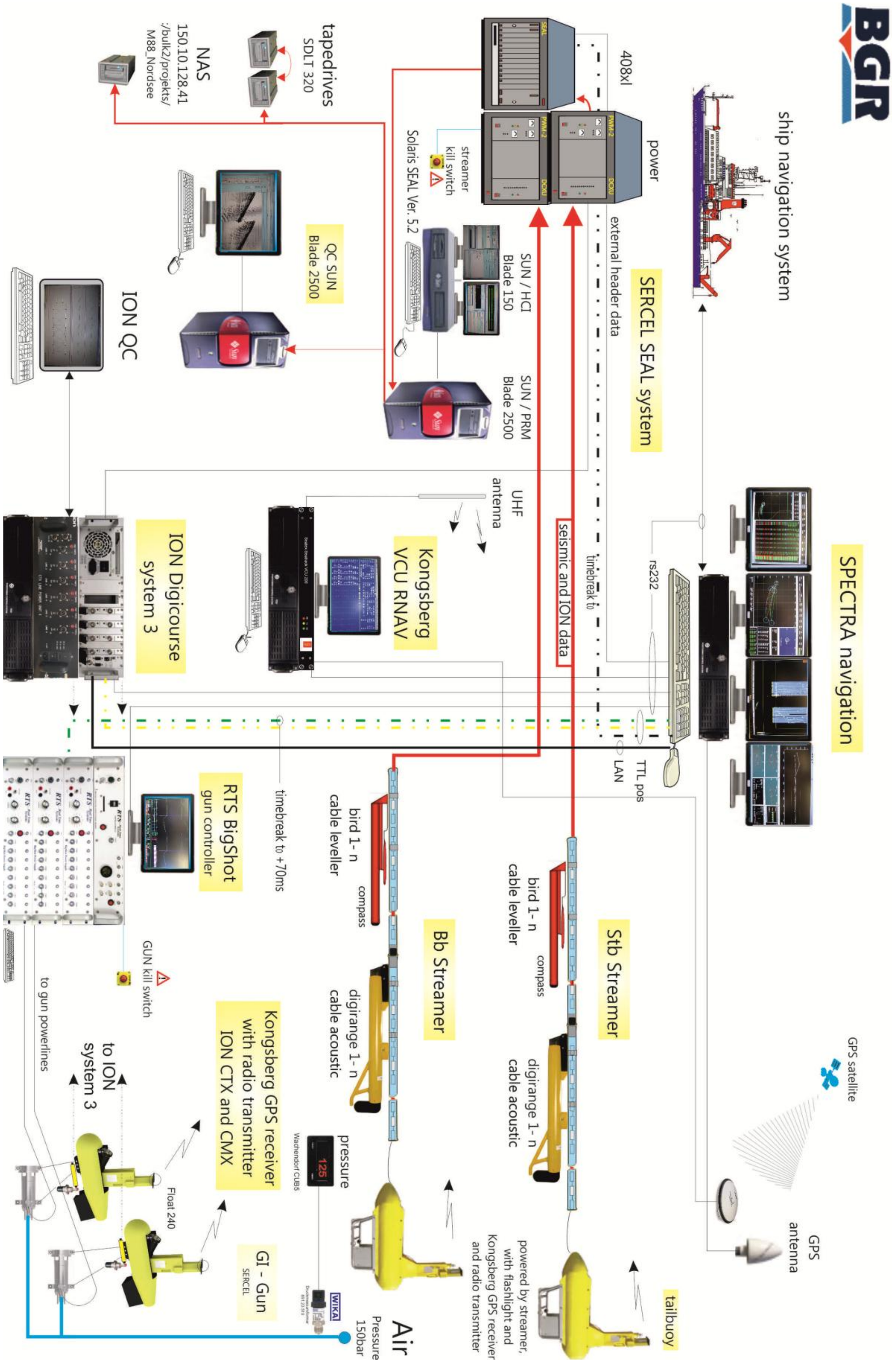


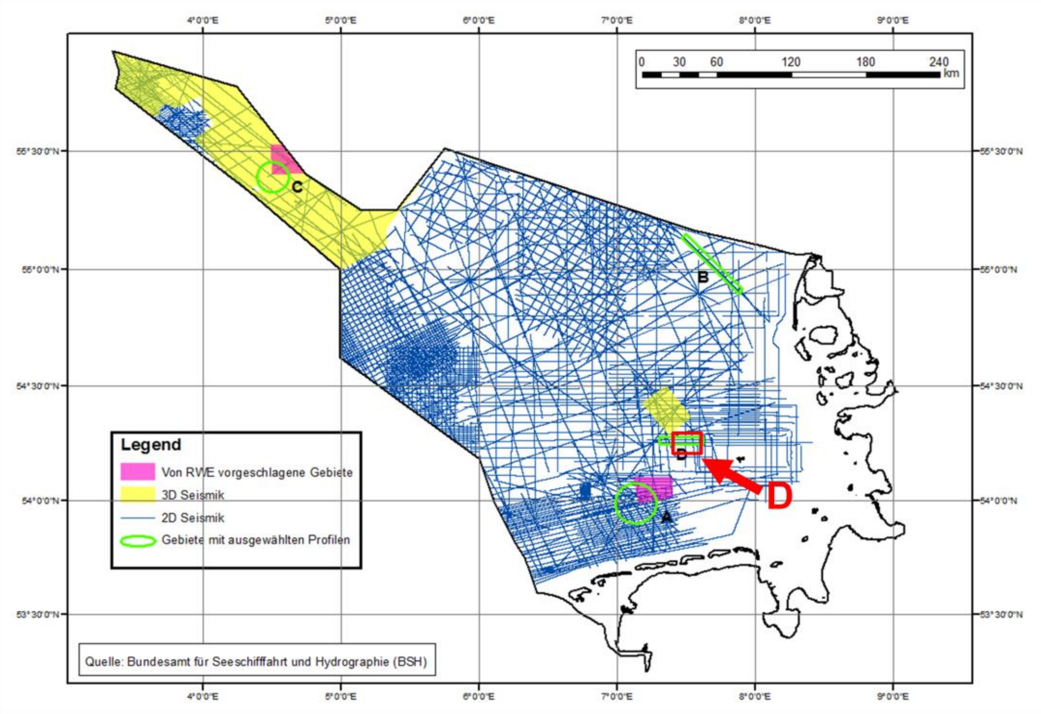
**Fig. 5.1.3.3:** Connection scheme of all hardware components of BGR’s 3D seismic system

## 5.2 3D seismic survey W of Heligoland/German Bight

(Damm, V. and Shipboard Scientific Party)

For a first test survey an area in the German sector of the North Sea was selected. This offered the option to use the acquired data for the running mapping project aiming to extend the German geodatabase of the North Sea in case of a successful completion of the 3D test survey. The German sector is widely covered by 2D and 3D seismic surveys mainly conducted by the exploration industry. We chose an area which was selected as a target for electromagnetic investigations during the subsequent cruise M88/2 of RV METEOR.

The test site is located 12 nm west of Heligoland and overlaps northward to a small extent with an existing 3D seismic dataset. To the South the survey area is bordered by the traffic separation zone of the German Bight (Figure 5.2.1).



Quelle: Bundesamt für Seeschifffahrt und Hydrographie (BSH)

**Fig. 5.2.1:** Location of 3D seismic survey in the German North Sea (target D of subsequent cruise M88/2)

### 5.2.1 Survey parameters, arrangement of towed 3D seismic equipment, survey design

(Damm, V.)

The short time period which was available for the 3D test survey only allowed for a small sized survey area (black square in Fig. 5.2.1.1). For the survey operation we planned to use the setup and spread for streamers and GI-guns as figured out during the calibration tests.

Based on the remaining time slot of 12 days including transit to/from the designated survey area we calculated for an maximum area to be covered with a predefined spacing of 150 m between track lines which arises from the setup for the seismic equipment as described in Chapter 5.1.1. With alternate dual sound sources 150 m streamer separation and 75 m source separation 4 CDP lines can be acquired along each track line. The shot point spacing was 50 m, and the guns were shot in flip-flop operation mode. The resulting CDP line spacing is 37.5 meters as shown in Figure 5.2.1.2.

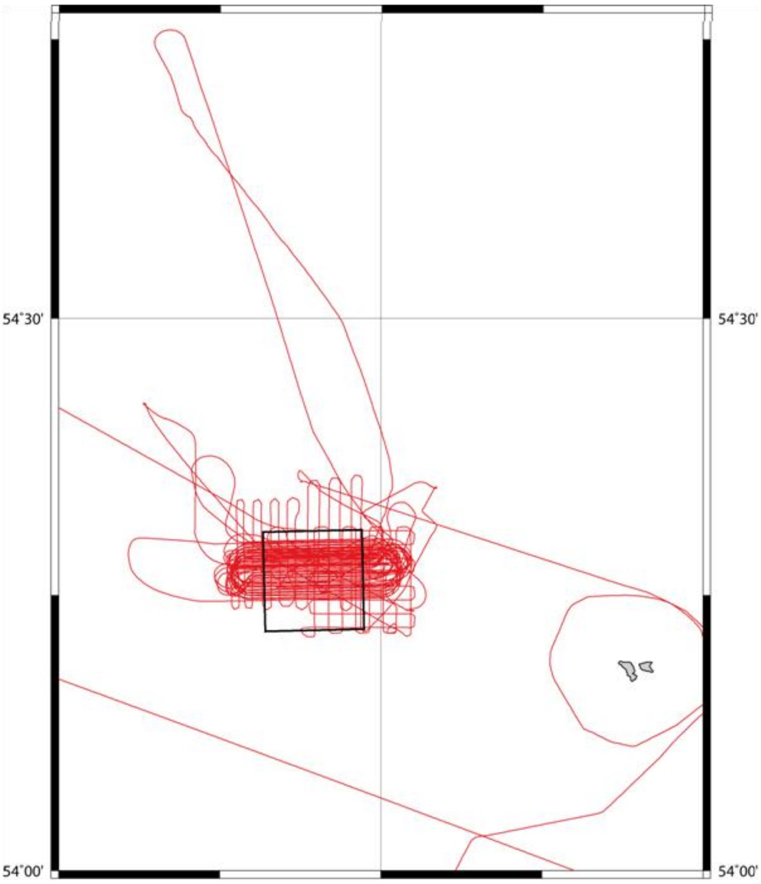


**Fig. 5.2.1.1:**

Planned area (black square) for the 3D test survey and tracklines of seismic and bathymetric data acquisition during the survey

All calculations were done based on the following input parameters for the survey:

Sources:

| | | | |
|---|---|---|---|
| Number of sources: | 2 | Shot interval/flip-flop (m): | 25 |
| Source separation (m) | 75 | Source towing depth (m): | 4 |

Streamers:

| | | | |
|---|---|---|---|
| Number of streamers: | 2 | Length active section (m): | 900 |
| Channel interval (m): | 12.5 | Near offset (m): | 200 |
| Streamer separation (m): | 150 | Streamer towing depth (m): | 4 |

Other parameters:

| | | | |
|---|---|---|---|
| Line length (m) | 10000 | width of survey area (m) | 8000 |
| Ship speed (kn) | 4 | | |
| Sample interval (ms) | 1 | record length (s) | 4 |

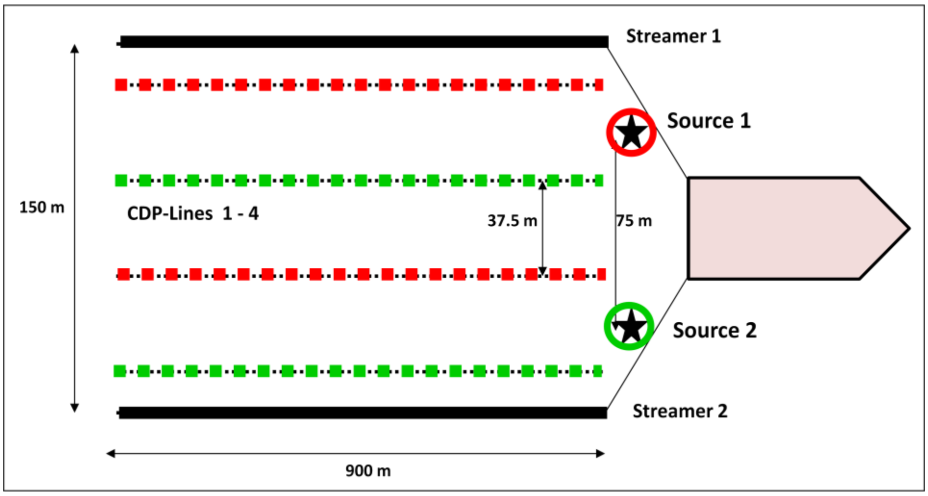


**Fig. 5.2.1.2:**

Setup of seismic streamers and sources during 3D data acquisition. GI-guns operated in flip-flop-mode (green shots produce green CDP lines, red shots produce red CDP line)

The geometry of the CDP lines and requested time for the seismic survey is dictated by the above parameters. We calculated for a survey area of 80 km² covered by individual sail lines of 10 km length the following data, resulting in a total survey time of 7.5 days at 30% infill time.

Geometry:

| | | | |
|---|---|---|---|
| CDP inline spacing (m) | 6.25 | CDP crossline spacing (m) | 37.5 |
| track line spacing (m) | 150 | CDP fold | 9 |

Survey Area

| | | | |
|---|---|---|---|
| shots per line | 400 | approx shot intervall (s) | 12,14 |
| line duration (hrss) | 1:20 | time for line change (hrs): | 1,3 |
| number of inlines | 54 | total time required (prime): | 5 days 19:46 hrs |
| infill: | 30% | total time + infill: | 7 days 13:42 hrs |
| | | Size of survey area (km²) | 80 |

### 5.2.2 Operation of the 3D-seismic equipment and navigation

(Schreckenberger, B., Damm, V.)

3D seismic operations require that the survey area is subdivided into bin grid cells that are defined by the streamer and airgun geometry as estimated in Chapter 5.2.1. The Common Mid Point (CMP) location for every shot-receiver combination is sorted into the bins based on the high precision navigation and positioning of airgun arrays and streamers.

<u>Bin grid calculation</u>

The bin grid geometry for the Spectra navigation was set up using the Reflex program (ION Concept Systems) designed for that purpose. For input the preset or calculated parameters described in Chapter 5.2.1 were used. Furthermore, the streamer was subdivided into three receiver group zones with near (100-400m), middle (400-700m) and far (700-1000m) shot-receiver offset.

The maximum area to be surveyed was set for this purpose 10 by 10 km. We use the Reflex convention and denote the cross line axis as the I-Axis and the inline direction as the J-Axis. The 10x10 km survey area, that was potentially intended to be surveyed with complete fold coverage, is represented by bins 1001 to 2601 in the J-axis direction and 101 to 368 in the I-axis direction. An additional border of 2000 m on either side of the survey area in the J-direction for approach and run-out and of 750 m in the I-direction to account for possible strong feathering was added to the bin grid. The final grid therefore consists of bins 81 to 388 in the I- and 681 to 2921 in the J-direction.

Line numbering starts with 102, the number of the bin on the left of the line, and is incremented by 4 as four CMP lines are covered by one survey line. Shot points in the inline direction are mapped on the bin numbers as shown in Figure 5.2.2.1. The shot point distance of 25 m results in an increment of four bins per shot. The first shot point number is equal to the first bin number on the regular line and is incremented for every shot by one to reach SP 1401 at the end of the line. Approach and run-out were chosen to be 20 shot points long. This assures that on approach the position of the vessel can be fine-tuned due to requirements resulting from coverage data displayed by the binning node of Spectra for previous lines and from actual feathering data. The run-out of approx. half of the streamer length ensures that full coverage is obtained for the inner survey area at the end of each line.

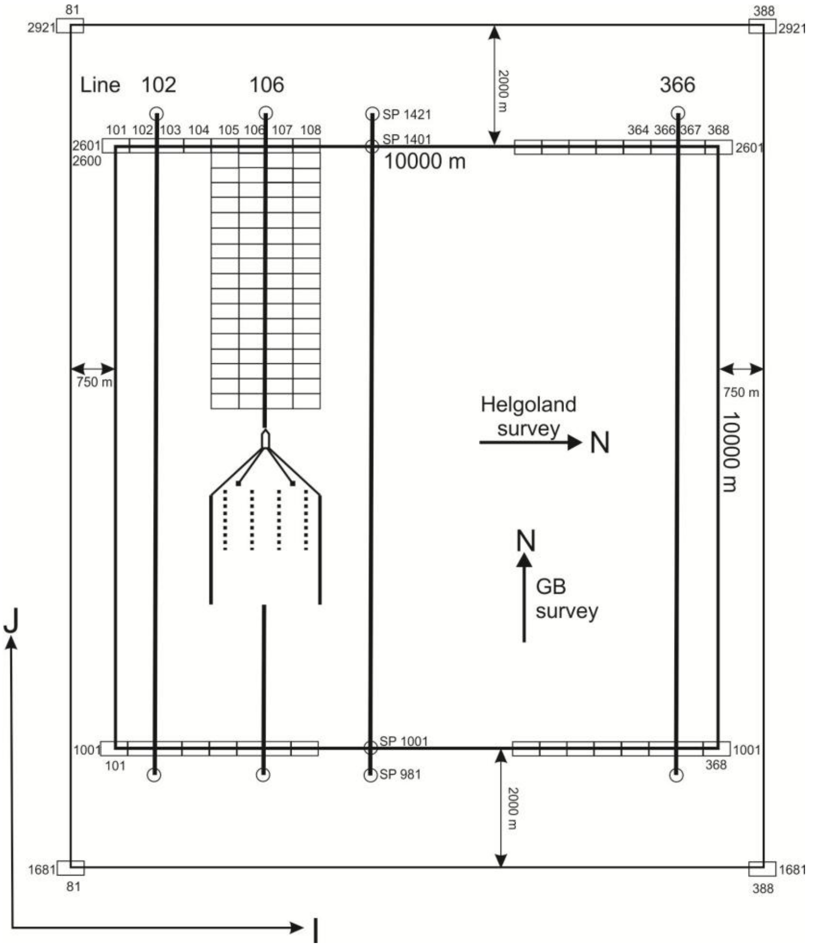


**Fig. 5.2.2.1:**

Bin grid, line numbering and shot point numbering setup used for the test survey.

For the first test lines in the UK sector of the North Sea the inline direction (J) of the bin grid pointed North with the bin grid origin in the southwest corner. For the Heligoland survey area the line direction was chosen to be from east to west. Therefore the bin grid was turned by -90° with the J-axis pointing to the West (Figure 5.2.2.1). The origin of the survey area therefore lies in the southeastern corner with line numbers increasing to the north and shot point numbers increasing to the west. The corners of the inner survey area bin grid have UTM and geographical coordinates according to Table 5.2.2.1 and Table 5.2.2.2

**Table 5.2.2.1:** Corners of the UK survey area in bin grid (I,J), UTM (zone 30), and geographical coordinates counted clockwise from the southwestern corner.

| | I | J | Easting | Northing | Lon | Lat |
|---|---|---|---|---|---|---|
| (1) | 101 | 1001 | 630000 | 6125000 | 00°57.27850’W | 55°15.25950’N |
| (2) | 101 | 2601 | 630000 | 6135000 | 00°57.01766’W | 55°20.64766’N |
| (3) | 368 | 2601 | 640000 | 6135000 | 00°47.54700’W | 55°20.48283’N |
| (4) | 368 | 1001 | 640000 | 6125000 | 00°47.84600’W | 55°15.09533’N |

**Table 5.2.2.2:** Corners of the Heligoland survey area in bin grid (I,J), UTM (zone 32), and geographical coordinates counted clockwise from the southeastern corner.

| | I | J | Easting | Northing | Lon | Lat |
|---|---|---|---|---|---|---|
| (1) | 101 | 1001 | 400945 | 6012137 | 07°28.78567’E | 54°14.85600’N |
| (2) | 101 | 2601 | 389949 | 6012150 | 07°18.66433’E | 54°14.72817’N |
| (3) | 368 | 2601 | 390058 | 6018015 | 07°18.63550’E | 54°17.89100’N |
| (4) | 368 | 1001 | 401054 | 6018023 | 07°28.76883’E | 54°18.03017’N |

The survey was performed based on UTM zone 30 (GB survey) and zone 32 (Heligoland survey) grid coordinates with false northing as zero and false easting as 500000 at the WGS84 datum. All profiles and the bin grid were positioned to lie along constant UTM grid lines with a profile spacing of 150 m as required by the seismic layout geometry. These values result in a profile direction of 88.7° in a Lat-Lon grid, e.g. in the Mercator map.

Navigation

An internal Spectra file (STANDARD.LMN) which contains the planned profiles in geographical coordinates, was reformatted to be a valid input format for the ships navigation system. On the bridge rhumb line navigation was performed using profile start and endpoints in geographical coordinates. Spectra was therefore set up in the Line Manager Node to calculate shot point distances based on rhumb line navigation. Shot point numbers including approach and run-out started at 981 and ended at 1421 on lines from East to West and were decremented from 1421 to 981 on lines from West to East.

The strategy for the actual line shooting was to perform a ‘racetrack’ shooting pattern with East-West profiles progressing from north to south (Figure 5.2.2.2). The distance between consecutive lines and therefore the turn diameter for line change was chosen to be 4050 m or 27 times the line spacing. The completion of this pattern with one complete race track would have resulted in a regularly surveyed area of 10x8 km² with 54 lines. Because we did not expect to be able surveying the whole pattern covering an area of 100 m² within the allotted time we started shooting on line S342 approx. 900 m south of the northern survey boundary.

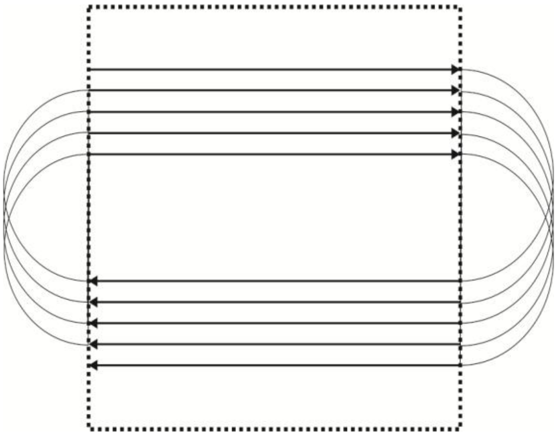


**Fig. 5.2.2.2:** Racetrack shooting scheme.

We agreed with the nautical officers of the ship for a detailed procedure on how to navigate on profiles and how to perform turns for line changes. Track navigation was always related to a current line and offsets either to the starboard or the port sides were vocally transmitted to the nautical officer on duty. In order to determine the required offset the seismic navigators in the navigation lab used the Binning Node Helmsman display of Spectra (Figure 5.2.2.3) where the coverage data for the neighboring lines that have been shot already were on display. This screen also showed the location of the four CMP lines that were presently acquired and updated the coverage data in real time. The example in Figure 5.2.2.3 shows a situation with moderate feathering to the port side where it is no more possible to obtain full coverage for each bin because CDPs from one streamer-gun combination are distributed over more than the (cross line) width of one bin.

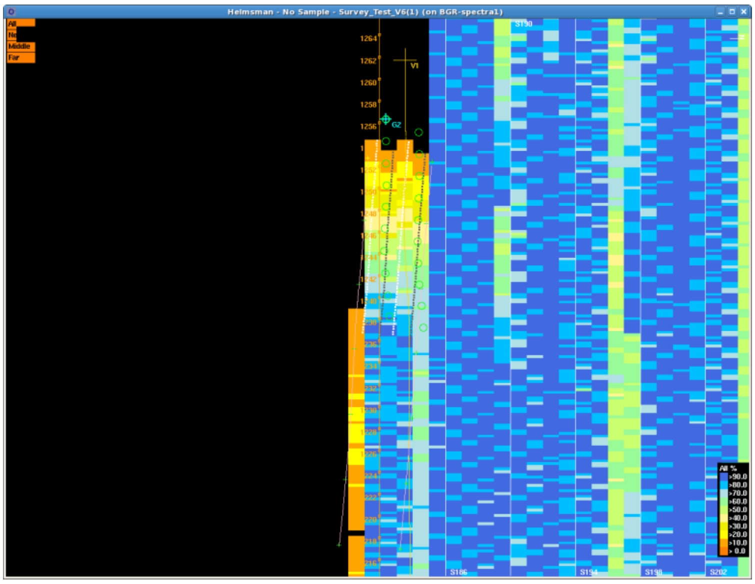


**Fig. 5.2.2.3:**
Online display (screenshot) from the Spectra Binning Node showing bin coverage for previous lines to the right of the current line (brown line with predicted shot point numbers), the vessel position (v1), alternate shot point positions (green circles) and the CMP locations for both streamers while shooting with the starboard gun (grey dots) and with the port gun (white dots). Color coding of coverage is in percent of full coverage (9 traces) from dark blue (>90 %) down to dark orange (<10%) or even no coverage (black). Coverage is calculated for all (near, middle, far) traces.

In these situations the navigators had to decide how to proceed since in such situations shown (from the Heligoland survey) an incomplete coverage is produced or even no coverage for the far traces is achieved (Figure 5.2.2.4). In this situation the highest priority was given to seamless coverage in the near traces without producing redundant data due to critical time constraints on the expense of leaving gaps at larger offsets.

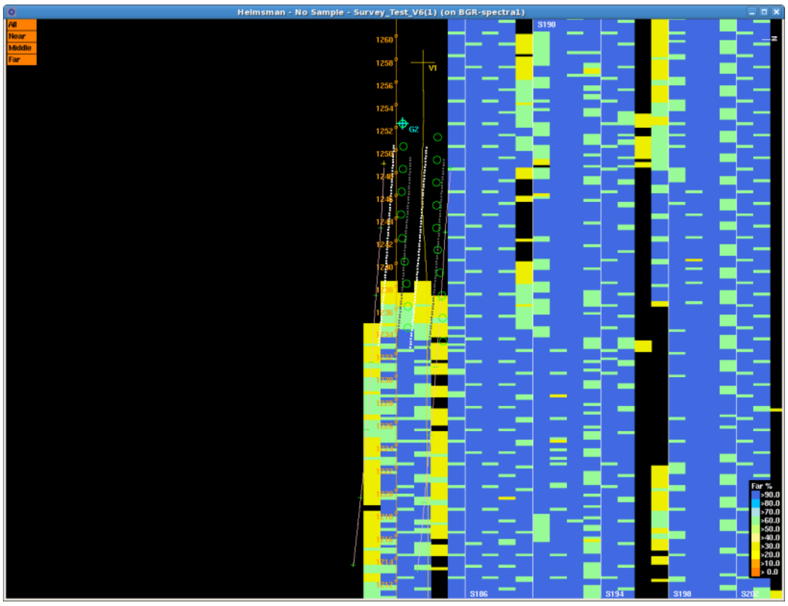


**Fig. 5.2.2.4:**

Same as Fig. 5.2.2.3 a few shots later but for far traces only. A low coverage area in Fig. 3 near line S198 is revealed to be caused mainly by missing far traces.

## Final bin coverage

Figure 5.2.2.5 shows the bin coverage after 28 lines in two blocks had been surveyed in the typical race track pattern. Due to tight time constraints the remaining gap of 13 lines had to be filled by performing turns directly within the gap but keeping a minimal turn radius at the expense of doing wider turns than going directly from one line to another.

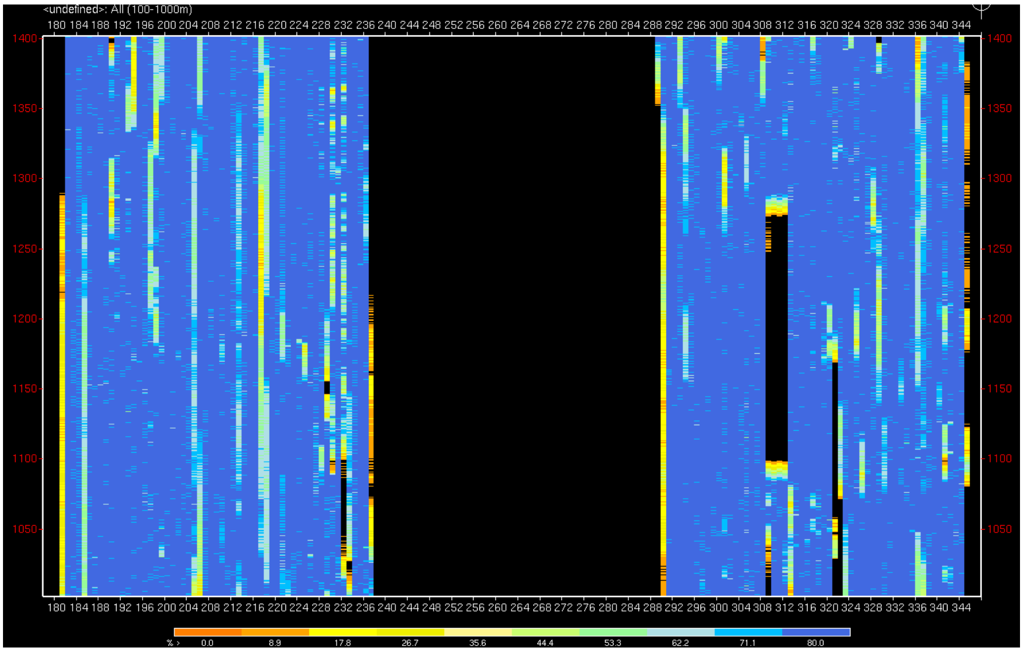


**Fig. 5.2.2.5:**

Bin coverage (all traces) after regular racetrack shooting.

Figure 5.2.2.6 shows the coverage after all 41 regular prime lines (lines S182 to S342) were surveyed displayed within in original bin grid of 10x10 km. The final extension of the survey now covers an area of 6.15 km (I) x 10 km (J).

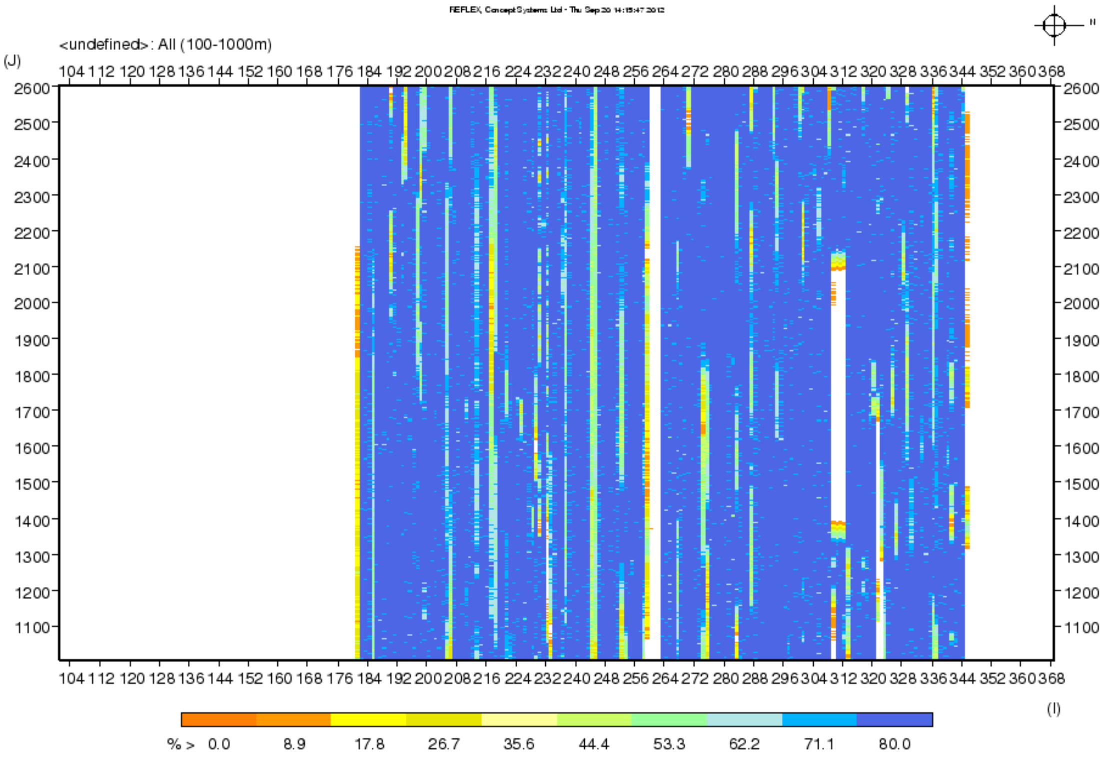


**Fig. 5.2.2.6:** Bin coverage (all traces) after completion of all prime survey lines showing the location of the final 6x10 km survey within the full preplanned (10x10 km) bin grid. Color coding similar to Fig. 5.2.2.3 with dark blue as >80% and white as no coverage.

In order to decide about the most important infill requirements we made single coverage plots for the different offset ranges of the receiver groups with and without flex binning. Figure 5.2.2.7 shows the bin sizes used for Flex binning. Inline bin size remains unchanged while the offline size is increased proportional to the offset range. Figure 5.2.2.8 shows that without flex binning many bins with low or even no coverage are remaining. Most important, line S310 contains a large gap resulting from a malfunction of the seismic recording system and in the middle of the survey area near line S258 a wide gap remains in the near traces (Figure 5.2.2.8b). This results from the strategy to close the wide gap area (Figure 5.2.2.5) in such a way that no new gaps are produced especially in the near traces at the expense that some lines are now closer together than the theoretical value of 150 m leaving the gap in the middle.

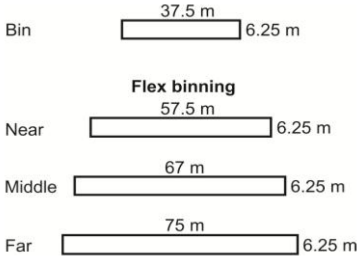


**Fig. 5.2.2.7:** Flex binning scheme.

Since it was not possible to close all gaps with low or even no coverage due to narrow time constraints, we used the procedure of flex binning to evaluate the need for the most important infill lines. Figure 5.2.2.9 shows the final coverage using flex binning. Here, the largest gaps and low coverage areas are now more distinct. It was decided that the gap on line S310 and those near lines S258 and S218 (near and middle traces) should be filled with the highest priority (infill lines S218I, S258I, S310I). S218I could not be finished because of an incident with a disrupted paravane that happened on that line. The last infill line (S322I) was surveyed near the location of the eastern part of Line S322. Figure5.2.2.10 shows the final bin coverage without flex binning, Figure 5.2.2.11 with flex binning. It can be seen that without flex binning quite a lot of low coverage stripes remain in all offset ranges but that the situation can be considerably improved by the flex binning approach.

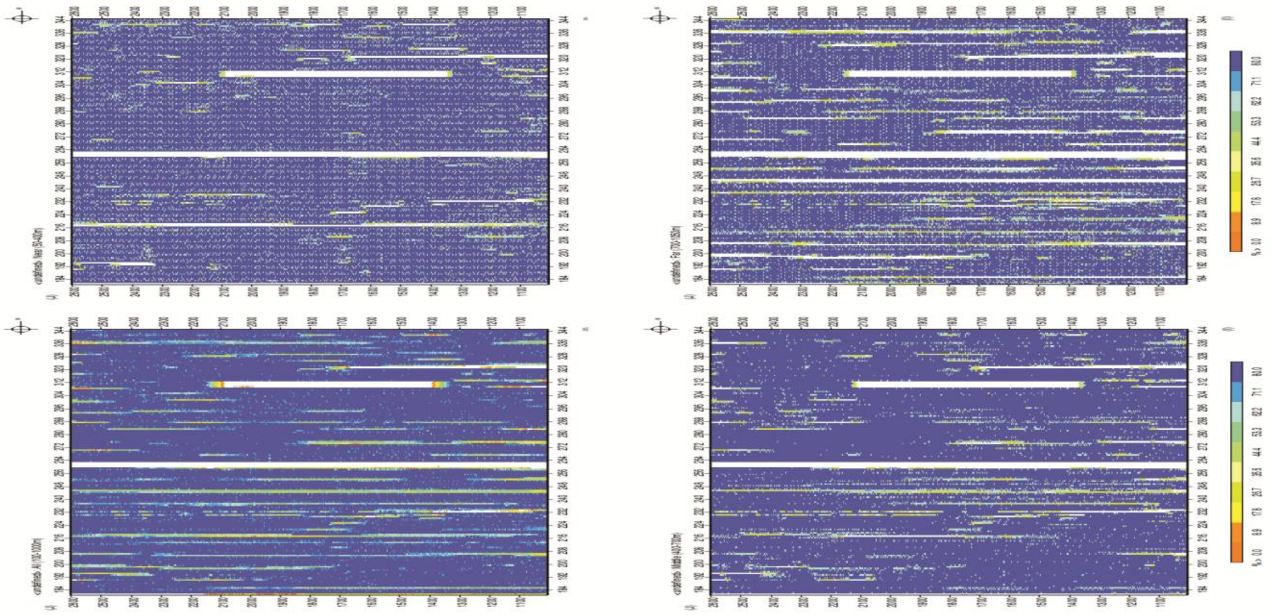


**Fig. 5.2.2.8:**
Bin coverage after completion of all regular preplanned lines for (a) all, (b) near, (c) middle, and (d) far traces.

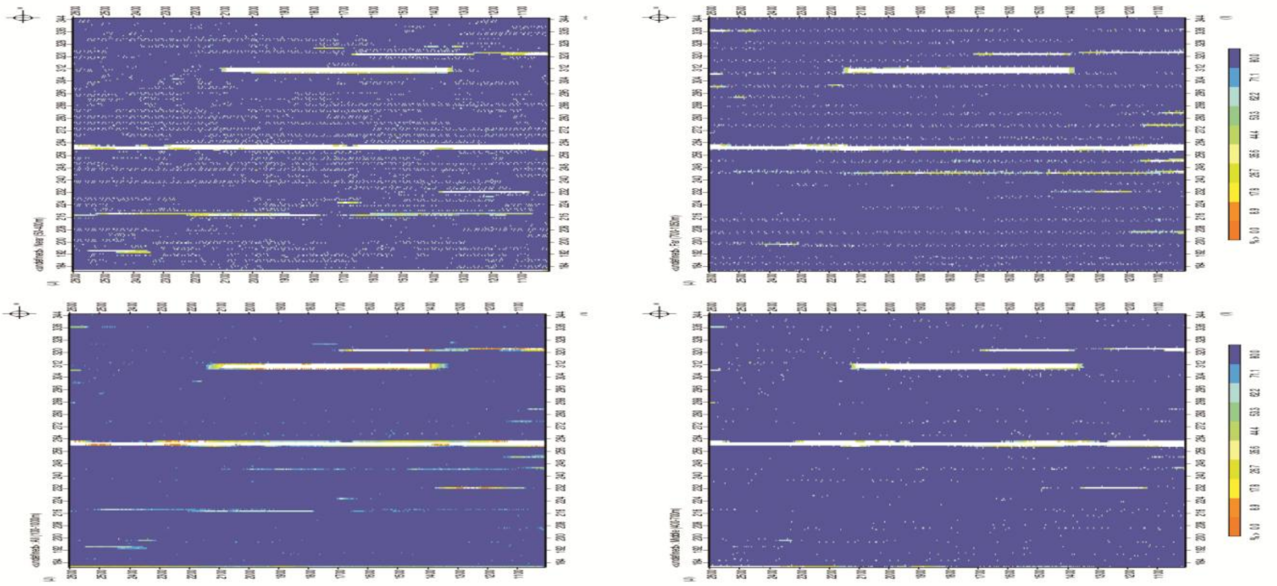


**Fig. 5.2.2.9:** Same as Fig. 5.2.2.8 calculated with flex binning

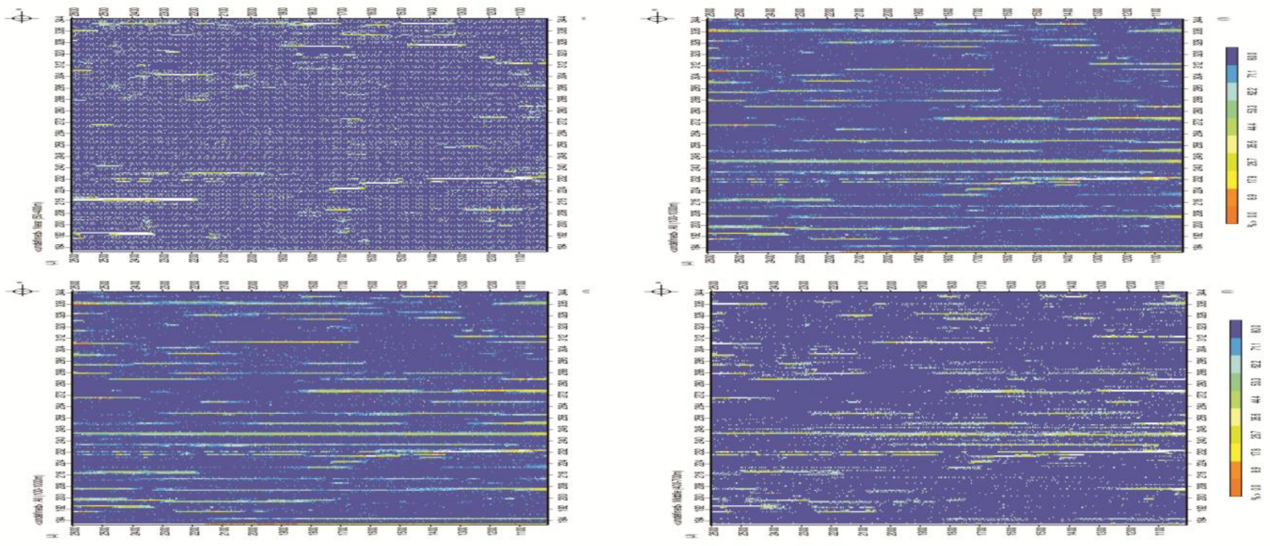


**Fig. 5.2.2.10:** Bin coverage after completion of four infill lines without flex binning).

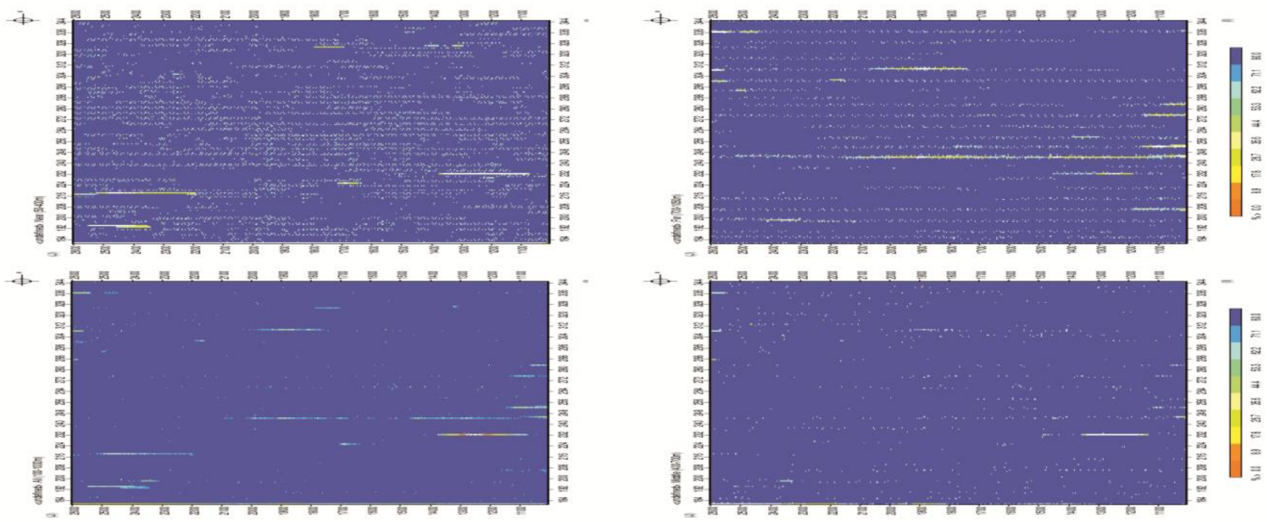


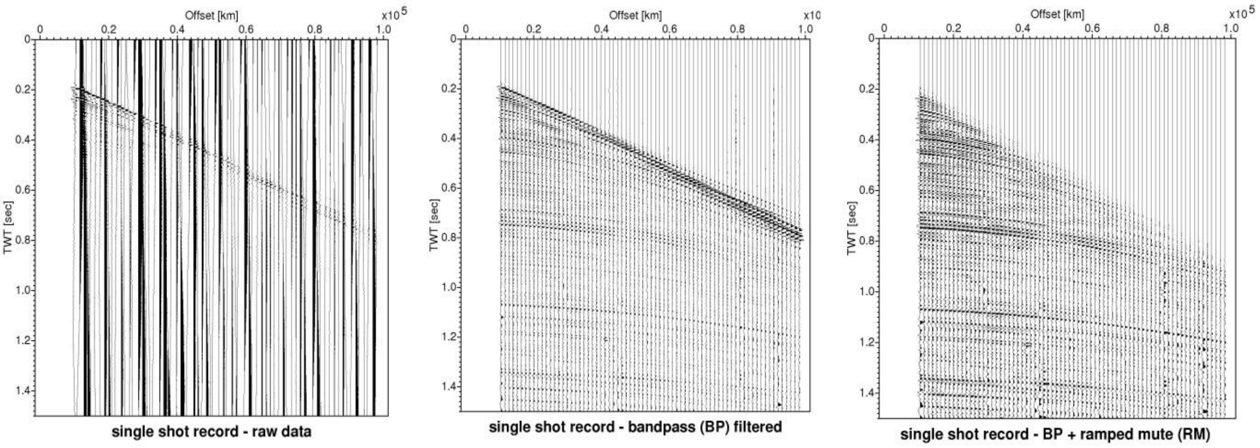
**Fig. 5.2.2.11:** Same as Fig. 5.2.2.10 calculated with flex binning.

### 5.2.3 Quality control and onboard processing of seismic data

(Papenberg, C., Schnabel, M.)

Signal quality

To monitor and process the seismic data, each seismic shot, stored in SEGD format, was synced in real time on a raid-storage system, attached to the processing workstation. Quality control (QC) and onboard seismic processing was performed with Promax and Seismic Unix. Both streamers recorded all shots fired in flip-flop mode by the GI-guns, leading to a constant 144 channel shot record, stored in SEGD, which was split into the respective streamer sections (72 channels each) for further analysis. Low frequency noise (< 6 Hz), clearly visible in the raw sections, was lowcut filtered to enhance the signal-to-noise (s/n) ratio (Figure 5.2.3.1, left and middle panel). Seafloor reflections and shallow sub-seafloor phases at ~0.2 sec TWT at near channels are interfered by the direct wave. For QC a linearly ramped and offset- and time-dependent trace mute was carefully applied to suppress the direct energy as well as the refracted arrivals at mid and far offsets (Figure 5.2.3.1, right panel). Reflections were now clearly visible down to ~1.5 sec TWT, although interfered by multiple reflection energy. In general, the signal quality remained good and stable throughout the entire survey. Sporadic noise bursts on individual channels and slightly lowered S/N ratio on lines 190, 194, 198, 298 and 302 were observed, mainly caused by changing weather conditions.



single shot record - raw data

single shot record - bandpass (BP) filtered

single shot record - BP + ramped mute (RM)

**Fig. 5.2.3.1:** Single shot records recorded by one streamer, raw (left), low-cut filtered (mid) and trace-muted (right). Low frequency noise was low-cut filtered and the direct wave and refracted phases were muted for quality control.

Resolution

A variable influencing resolution is source and receiver depth. The source-receiver geometry may produce short-path multiples between sources, receivers and sea-surface, and will affect the signal's frequency content. The two-way travel time of the ghost is associated with a frequency, called the ghost notch, at which signals cancel out, leaving the seismic record virtually devoid of signal amplitude at the notch frequency. During the survey the GI guns were towed at constant 3 meters depth and streamer depths were set to 4m, which was found to be necessary to stay below sea-surface influences (wind and waves) and, more importantly, to maintain the higher signal frequencies. This was tested intensively during leg 1 of the cruise. Three depths were tested, 4m , 6m and 10m. The seafloor reflection arrivals at near offset for 26 subsequent shots of three representative lines are displayed in Figure 5.2.3.2, left panels. Reflections recorded at 10m streamer depth (left panel, bottom) are severely influenced by the signal interference of the receiver ghost, which almost splits the signals (positive lobe, black) and generates a notch at ~80 Hz in the frequency spectrum (Figure 5.2.3.2, right panels). Towing the streamer at 6m depth is less vulnerable to bad weather conditions, but it creates a notch at 125 Hz, which is still in the main frequency band of the GI-gun used during the cruise. Because weather conditions were forecast to be good during the entire survey, the streamer was set to 4m (ghost notch at 188 Hz), which places the notch outside the desired bandwidth.

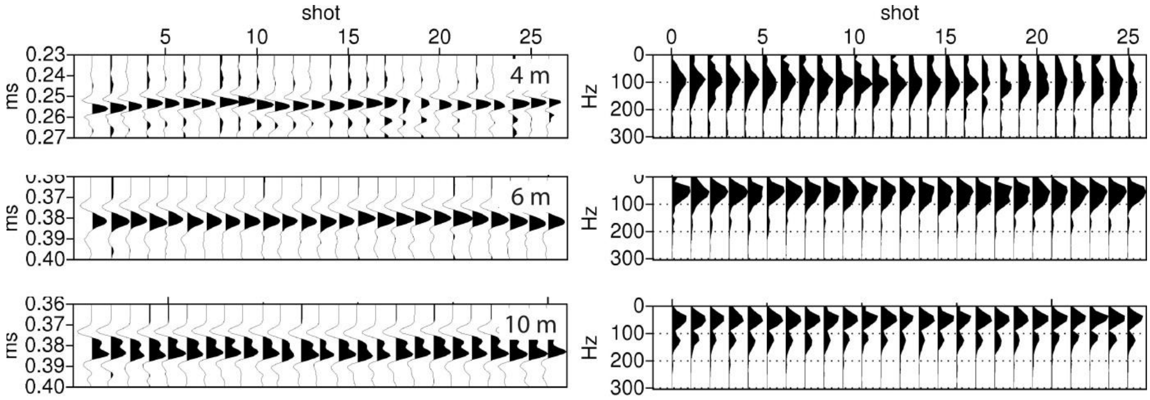


**Fig. 5.2.3.2:** Seafloor reflections, recorded with streamer, towed at different depths (4m, 6m and 10m), left panel. Frequency spectrum (right panel) shows a significant notch at 80 Hz, caused by the interference of the ghost signal

Proper geometry avoids spatial aliasing of the signal, that arises when a signal is sampled less than twice per cycle, which defines the maximum frequency that events can contain with integrity for a given dip. The signal aliases when the time shift between traces exceeds half a cycle. Noise and signal cannot be distinguished when their sampling is aliased (Figure 5.2.3.3, left).

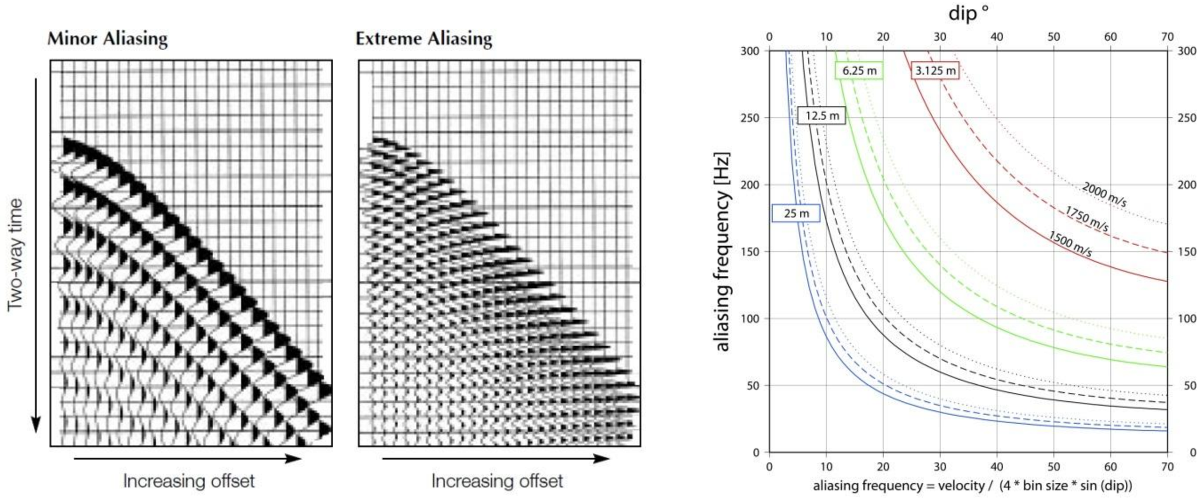


**Fig. 5.2.3.3:**

Left: Spatial aliasing of a 50Hz and 200Hz signal at dipping events. Spatial aliasing occurs when receiver spacing is more than half the spatial wavelength. With minor aliasing arrivals can be tracked at near offsets as time increases, but become difficult to follow at far offsets. With extreme aliasing arrivals even appear to be raveling backwards, toward near offsets as time increases. Relationship among dip, aliasing frequency, and bin size at different velocities (right panel) –
(modified after: 3D Seismic Survey Design, Oilfield Review April 1984, Vol. 6 Issue 2, Schlumberger)

Bin size therefore needs to be small enough to image the structual dips without aliasing the highest frequency. Figure 5.2.3.3, right, shows the relationship among dip, aliasing frequency, and bin size. Note in the aliasing formula that the aliasing frequency is directly proportional to the section velocity. During the survey a bin grid was defined at 6.25m inline and 37.5m crossline spacing. While the bin size of 6.25m inline is sufficient to image dips up to 25 degrees, a bin size of 37.5 crossline already aliases frequencies above 100 Hz at low dips below 10 Hz. In general, dips in the 3D survey area are small and expected not to exceed 5 degrees. Assuming a full fold of bins, covering the entire offset range, the bin-size of 37,5 m crossline is sufficient for the survey area. Planning surveys in a region with expected larger dips, a smaller bin size in crossline direction must be considered or the desired frequency band of the source signal must be lowered.

### Data pre-processing

Onboard processing included geometry setting, low-cut filtering, TVG , 3D CMP sorting (binning), nmo and stacking. Different schemes were tested on individual shot records, CMP gathers and in- and crossline sections to enhance S/N, eg. Median filter (coherency filter), FK Filter, trace interplation. Figure 5.2.3.4 shows the foldmap (left) and nmo-corrected CDPs (right) for crossline 2011 (red line in foldmap). S/N quality varies significantly along the section which can be explained by the different weather conditions during acquisition. Bins with double fold (arrow 1 und 2) and empty bins (arrow 3) are rare exceptions in the entire area. Due to the shallow waterdepth and a first offset distance of ~100m, seafloor and shallow subseafloor reflections are hard to recover, escpecially when bin-cells lack near-offset traces and mid-offset traces are already affected by nmo-stretch.

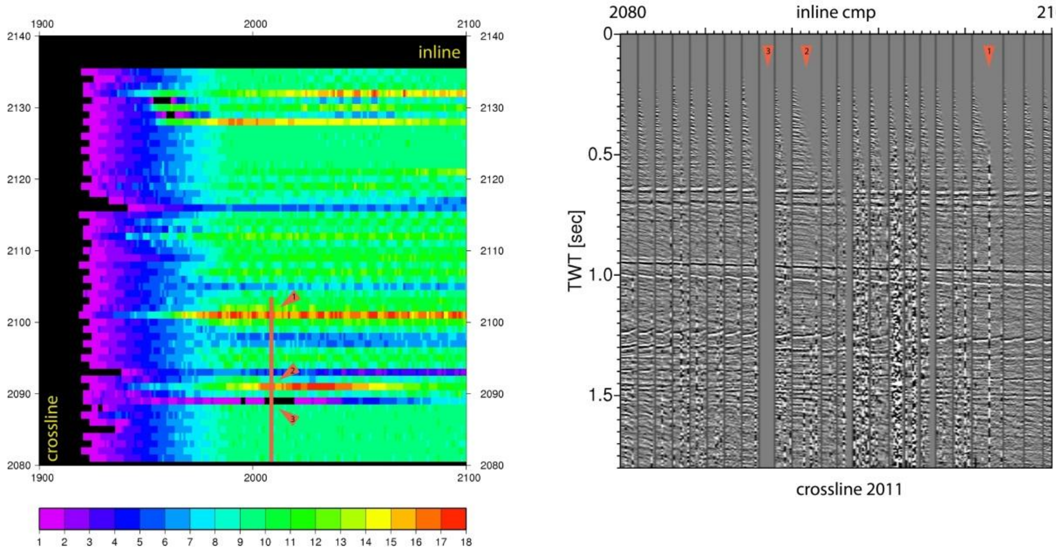


**Fig. 5.2.3.4:** Foldmap (partly), showing over-fold and empty bin cells (left). Nmo-corrected CMPs(right) for one inline , marked red in foldmap

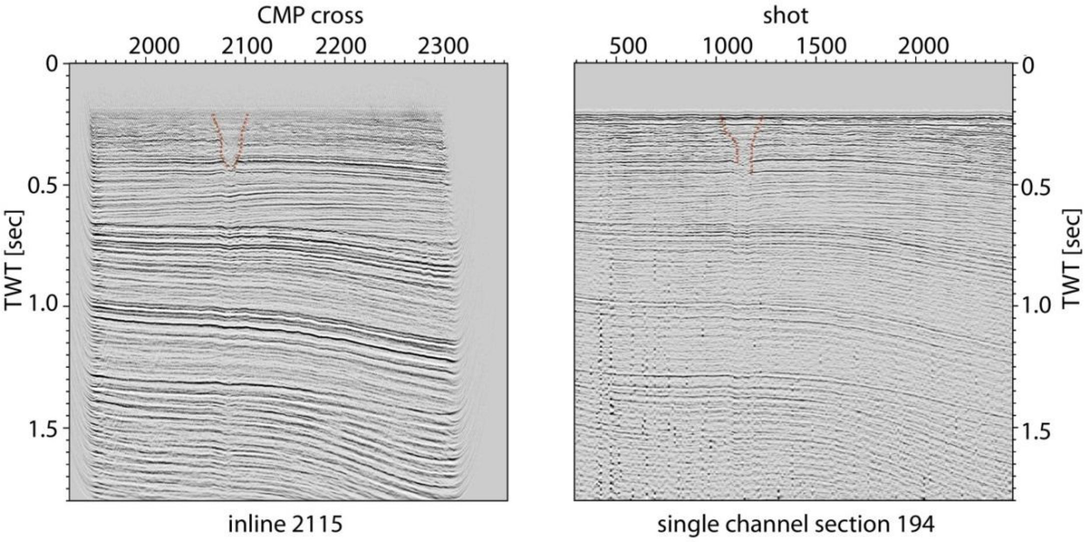


**Fig. 5.2.3.5:** Seismic section. Time migrated (stolt-migration with constant Vmig, left) and single channel section (right). A small channel is clearly visible in the upper 200 ms, badly resolved during brute pre-processing by nmo-stretch and direct wave interference. The sub seafloor is better imaged in the single-channel section (here 1 channel at 100 m offset).

Data cube

To analyse the signal and geometry quality and processing flow, a first cube was calculated onboard with the data available until they survey was forced to be stopped, due to bad weather condition, leaving a gap inbetween two subcubes. The gap was successfully filled until the end of the entire cruise. Continuous reflectors in the subsurface, especially in cross-line direction show a high quality of coherence. Undulations are probably caused by tidal effects and processing artifacts. Both can be corrected in a post-processing step.

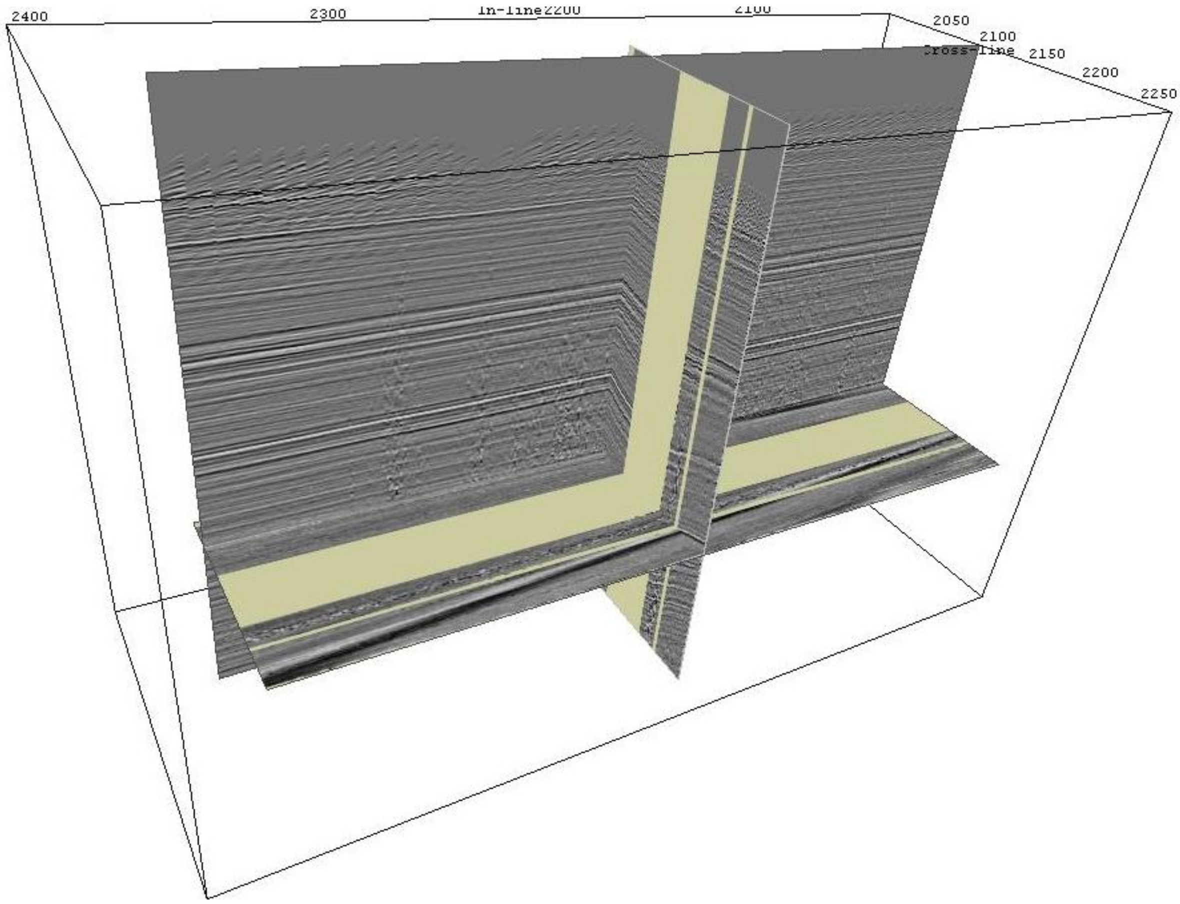


**Fig. 5.2.3.6:** Seismic data cube. The gap between the two sub-cubes was successfully filled at the end of the cruise. Showing here, the cube was processed with data only available until bad weather forced the survey to be stopped at about half-time.

Subsequently, the data of the complete survey underwent a 3D pre-processing using ProMAX software. For post-processing of source and receiver positions the Reflex software module of Spectra still has to be used to eliminate bad quality navigation data. The results showing in Figure 5.2.3.7 represent time slices of the 3D data cube at different depth levels. Please note the graben structure running in southeast-northwesterly direction best visible at 1 s TWT.

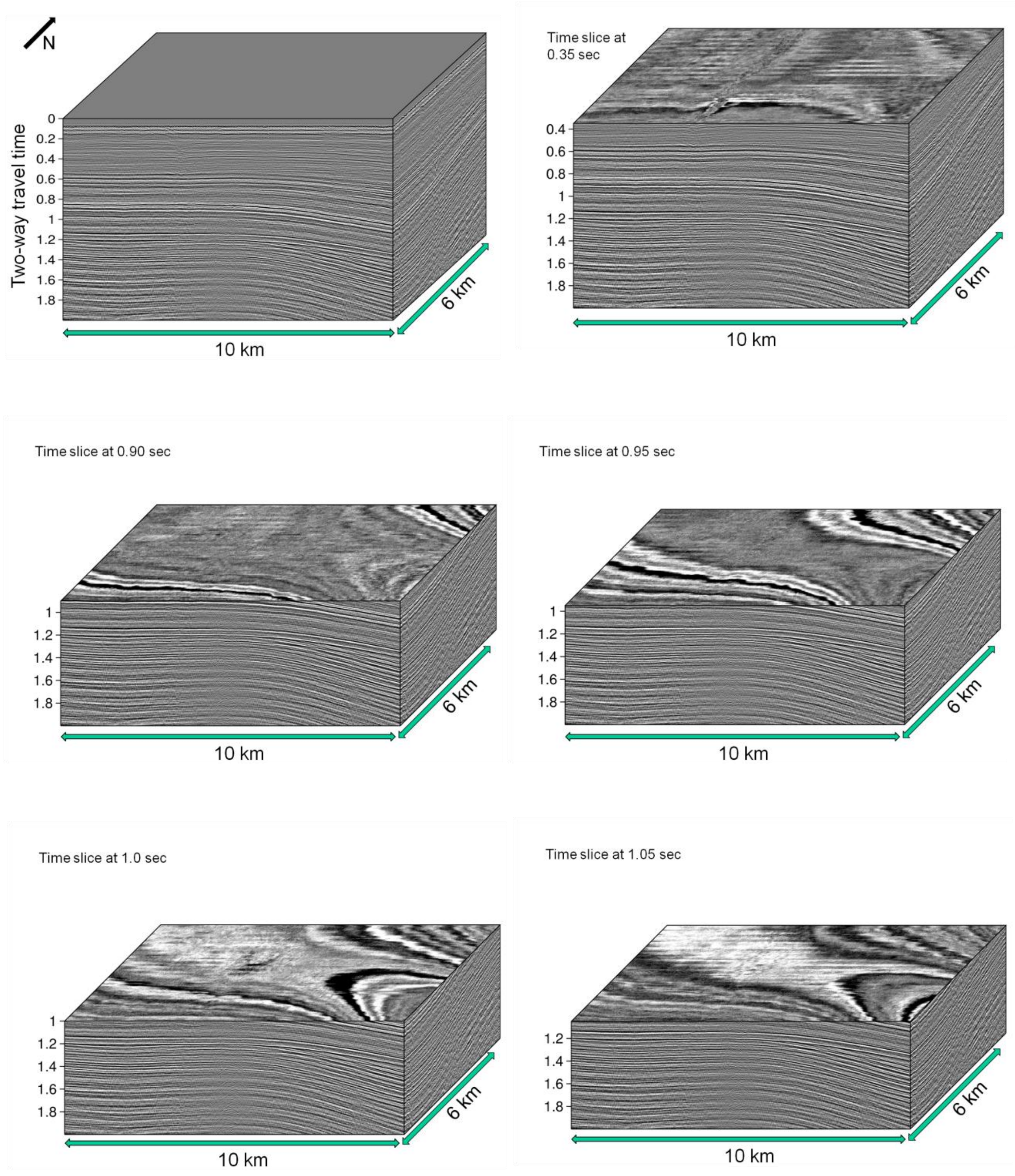


**Fig. 5.2.3.7:** 3D seismic data set and 5 time slices of the data cube. Upper left: complete data cube (first reflection represents the seafloor. Multibeam bathymetric data will be used later for high resolution seafloor imaging), upper right: time slice at 0.35 sec (the east-west running structures are artefacts of the survey line orientation and are subject to further processing), middle left to lower right: time slices at different depth levels showing an SE-NW running graben structure.

## 5.3 Bathymetric mapping

(Ladage, S., Lutz, R., Kuhlmann, C.)

### 5.3.1 Simrad EM710 multibeam system specification

On board of RV METEOR two multibeam echo sounders are installed: a Kongsberg EM122 and EM710. The EM122 is designed for the full range of ocean depths, whereas the EM710 is designed for higher resolution mapping of shallow waters less than 2000 m depth. Therefore, in the shallow North Sea the EM710 was used for bathymetric surveying during cruise M88/1. Due to interferences the ship´s DOLOG was turned off during bathymetric data acquisition.

The Kongsberg EM710 system is a multibeam swath sonar using a nominal sounding frequency between 70-100 kHz. The transmit and receive transducer arrays of the EM 710 are mounted midships near the bow in the keel of the vessel in the form of a Mills cross. Beam forming and steering is performed for each ping in the transceiver units (Figure 5.3.1.1). 400 beams with a 1° footprint are formed for each ping. The system can operate in a dual swath mode with 800 beams per ping. This mode allows for higher along track coverage density especially in mid range water depths. Depending on the water depth the angular coverage sector

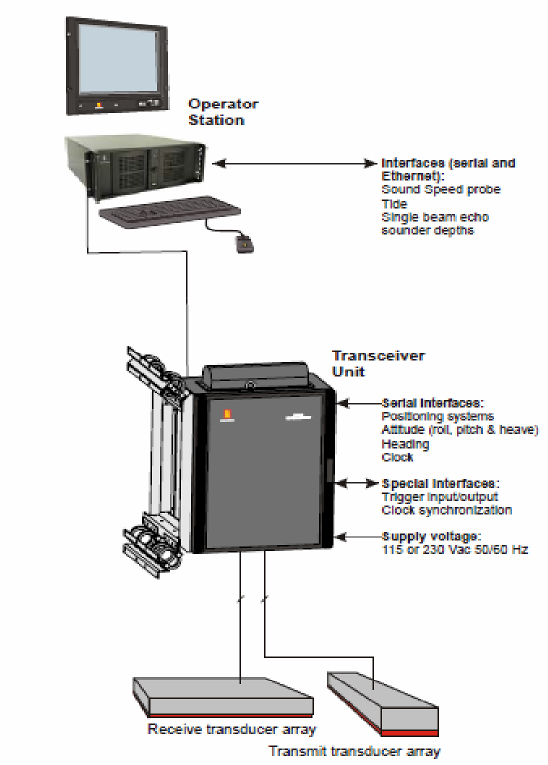


**Fig. 5.3.1.1:**

System components of EM710.

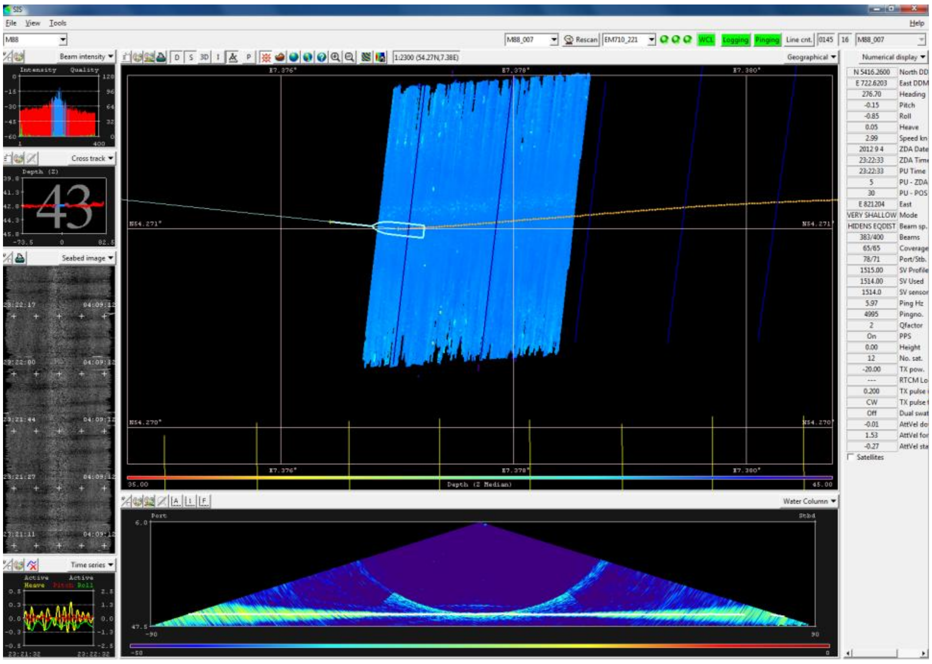


**Fig. 5.3.1.2:**

SIS operation display.

of the echo system can reach up to six times the water depth. The total width of the sounding array can reach 140°. The angular coverage, beam pointing angles and ping rate adapt to varying depth ranges. The ping rate depends on the overall round trip travel- and processing time. In shallow waters the ping rate may reach 40 Hz.

The seafloor is detected using amplitude and phase information for each beam sounding. Phase detection allows for high accuracy bottom determination even with high incidence angles of the soundings on the seafloor. Depth and position calculation is then performed per beam taking account of the beam angles and refraction in the water column using the corresponding sound velocity profile, the vessel's attitude and movement and the vessel's position. Additionally, backscatter and amplitude data of the seafloor are recorded. The system can also record the whole received acoustic signals during beam traveltimes (water column records). A Kongsberg Seapath 320 processing unit is used to deliver the necessary, real time, high accuracy navigation, motion and attitude data to the EM710. The Seapath unit processes incoming messages from several sensors. Most important to mention here is the motion sensor MRU-5, which resembles the ship's reference point. GPS-data is fed into the unit by two dedicated Seapath GPS-antennas (position of antennas see detail in Appendix A). These antennas are arranged parallel to vessel centerline on the ship's mast and thereby also deliver the ship's heading. Locations of the complete system of sensors relative to the ship's reference frame have been measured during dry dock in Oct. 2011 (detailed plan see Appendix A). Operation of the EM710 is controlled by a pc-workstation running the Seafloor Information Software by Kongsberg Maritime AS (SIS Version 3.8.3). The software performs all depth and position calculations in real-time. Several online displays allow quality control and access to the system sensors.

### 5.3.2 Sound Velocity

Water depths are calculated from beam travel times using a sound velocity model of the water column. During cruise M88-1 one sound velocity profile (Station #1486) was obtained approximately 20 nm to the north west of the 3D survey area in 34m water depth . Profile was taken at 26th August 2012, 15:28 UTC at N54°38.6´ and E006°19.6´. We used the SV plus V2 probe (Figure 5.3.2.1), provided by the ship. It measures the sound velocity by an ultra-sonic sensor, as well as pressure and temperature. The sound velocity profile shows a layer of nearly constant velocities around 1514.9 m/s down to 20 m (Figure 5.3.2.2). Further down to the bottom the sound velocity decreases to 1512.4 m/s. This sound velocity profile was used for further multibeam data acquisition.

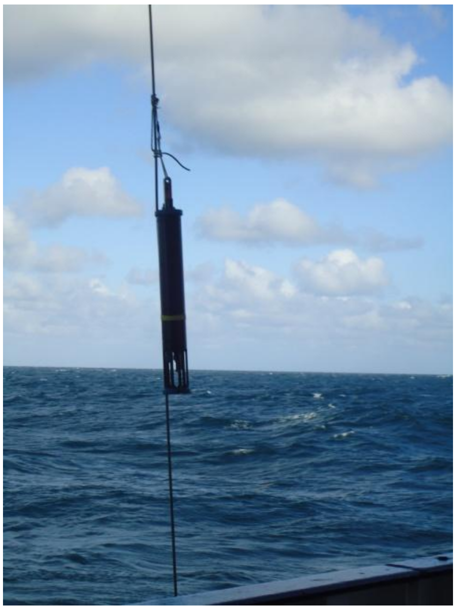


**Fig. 5.3.2.1:** Sound velocity probe.

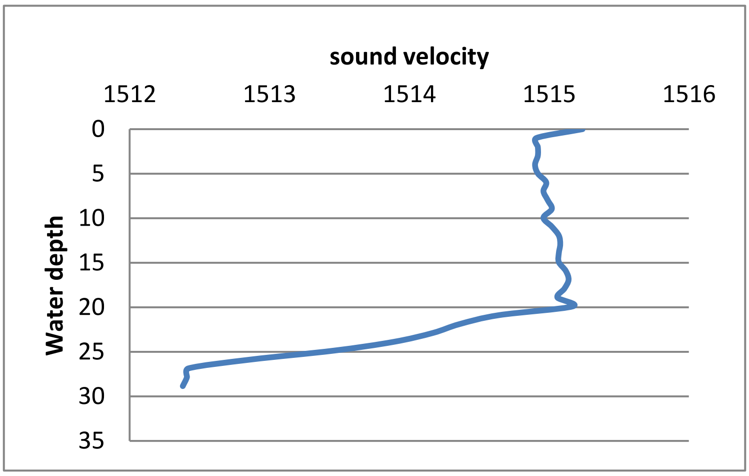


**Fig. 5.3.2.2:** Sound velocity profile, # 1486.

### 5.3.3 Data Acquisition

Multibeam data acquisition was conducted in the two survey areas off the coast of England and to the west of Heligoland (Figure5.3.3.1), as well as during transit. Survey layout was determined by 3D seismic surveying. Coverage between EM710 survey lines therefore often is insufficient. During MCS data acquisition the survey speed was slow around 4 knots. During 3D-MCS downtime multibeam surveying was conducted with adequate line spacing and increased ship speed of 8.5 knots. Due to interferences the ship's DOLOG was turned off during bathymetric data acquisition.

The swath width was set to a maximum of ± 65° resulting in seabed coverage of about 170 m in water depth of 40 m. Due to the very shallow sea west of Helgoland with an essentially flat seafloor the spike filter was set to strong mode and grid data cleaning mode was set to high, thereby flagging outlier soundings in real time. Water column data were recorded and stored together with the sounding data in the *.all files. Later on we switched to storing water column data in separate files (*.wcd). New files have been automatically generated every thirty minutes or manually by the watch keepers. The raw data volume is about 1.5 Gb for every 30 min recording. Watch keeper were responsible for monitoring and maintaining an error free operation.

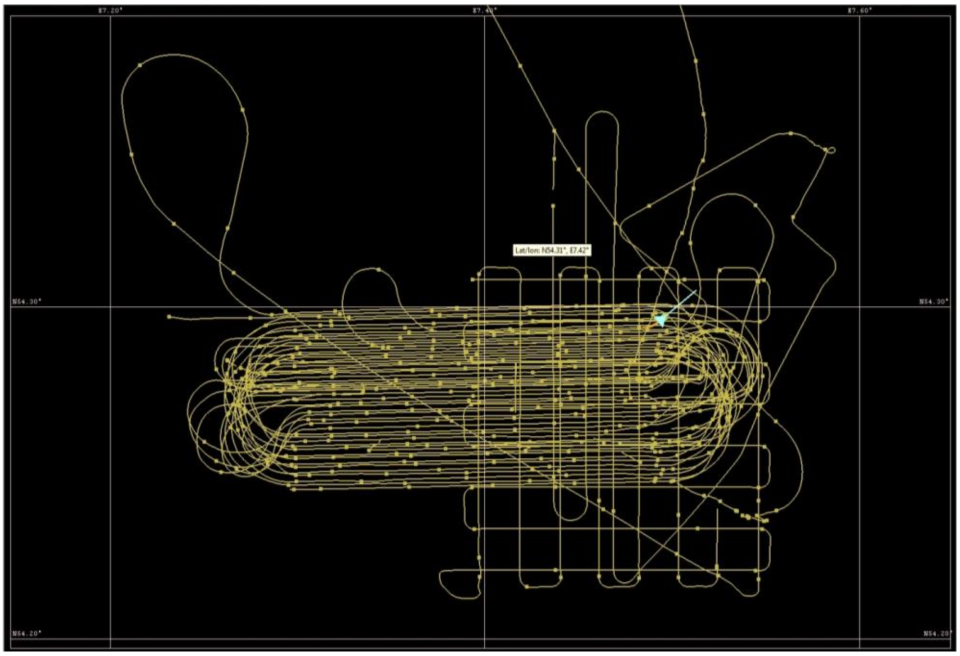


**Fig. 5.3.3.1:** Bathymetric survey lines in 3D-MCS area off Heligoland.

### 5.3.4 Quality control and preliminary results

In the survey area tides were about ± 1.0 m. Since the area is very shallow a tidal correction of the observed depths is mandatory. However, tidal correction of data could not be conducted on board. Without tidal correction grids and maps of the survey area are obfuscated by tidal offsets between the survey lines. In particular, area based statistical sounding data cleaning (CUBE processing) is unattainable without prior tide correction. Tests of applying a GPS-tide correction have been performed on board using CARIS HIPS/SIPS software (Vers. 7.21). GPS-tide can be calculated from GPS-height and geoidal separation (GS). The Seapath unit delivers GPS-Height and GS in the NMEA GGA sentence to the EM710. These values are for instance GPS-height = -4.51 and GS = 45.5 m (viewed on Seapath operator terminal; it is not stored in DSHIP). Commonly, the GPS-height refers to the antenna location and this value is 33.5m. The reference point for the GPS-height value is not documented in the Seapath manuals.

During postprocessing tidal effects were purged using the altitude data provided in 1 second intervals by the ship's DSHIP system. This DGPS altitude data was smoothed by a running avarage filter over 500 sec to eliminate the effect of sea waves. An estimate for the mean sea level was calculated using the antenna height and by averaging over all altitude values. This value of 73.8 m had to be subtracted from all altitude data to refer to sea level.

All bathymetric data were depth converted based on the velocity-depth-profile mentioned before. After tidal correction the final grid was calculated with the gridding algorythm of mb-System using spline interpolation and a blanking radius of 50 m.

In the 3D survey area off Heligoland the observed minimum water depth was 36 m. To the north east the water depth is slightly increasing up to 46 m. The seafloor is essentially flat.

Figure 5.3.4.1 shows the bathymetric data set with applied tidal corrections as described above.

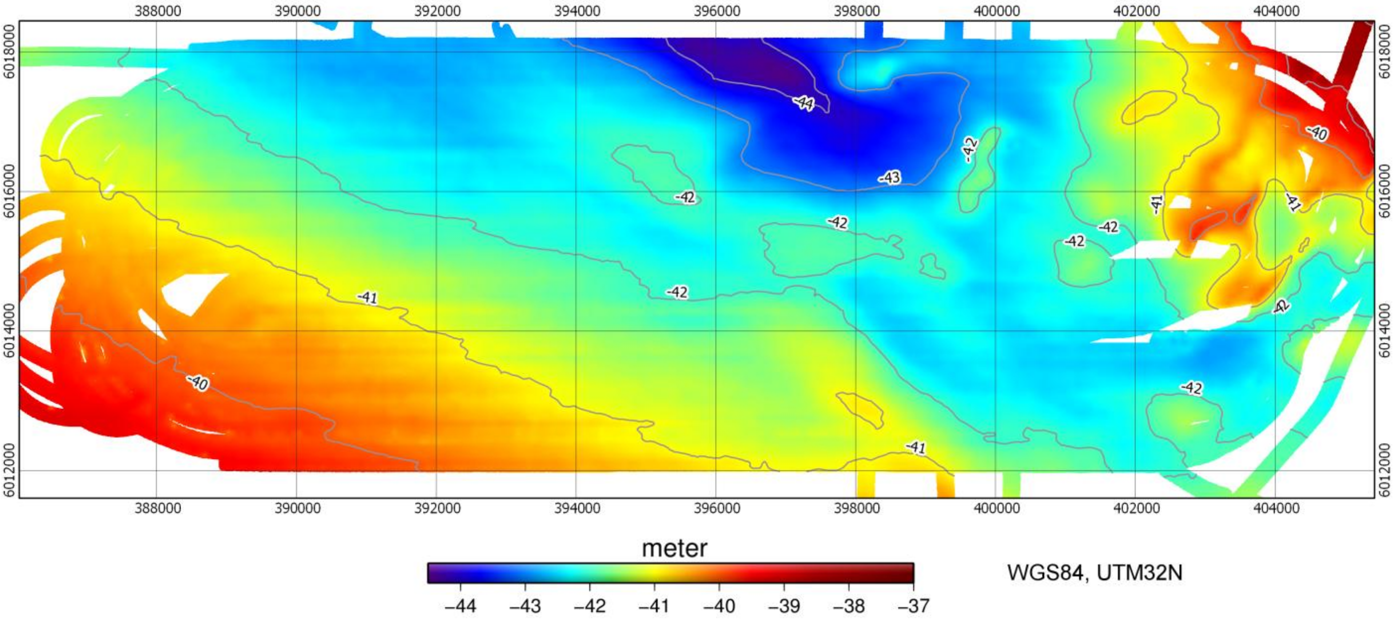


**Figure 5.3.4.1:**
Bathymetric map (UTM grid) for the Heligoland survey area. Color scale extends from 37 to 45 m depth.

A wreck until now uncharted has been identified by the survey at position 54.296°N and 7.442°E (Figure 5.3.4.2) .

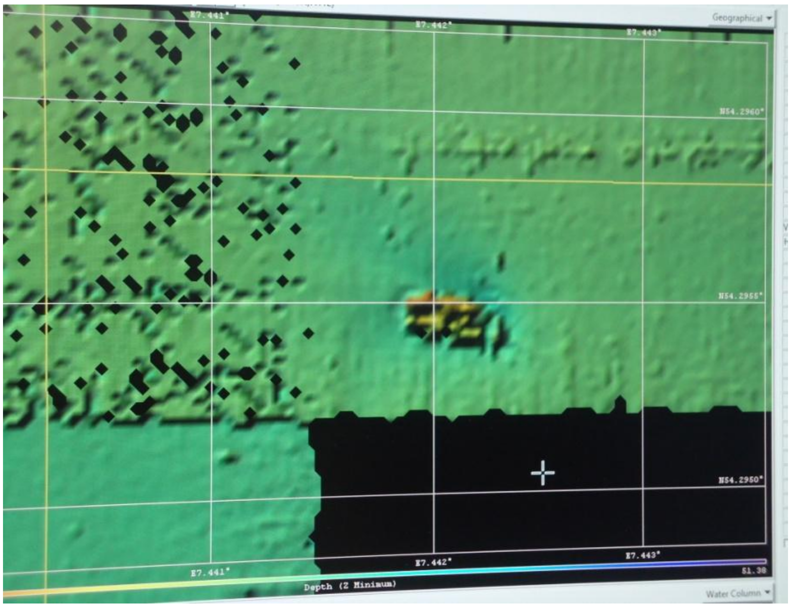


**Fig. 5.3.4.2:**

Ship wreck identified during the survey.

## 6 Ship's Meteorological Station

(Sonnabend, H.)

In the sphere of a strong high wandering from Scotland across the North Sea towards Southern Scandinavia, the cruise started with moderate northerly winds at first soon shifting east and southeast during 11.08. These southeasterly winds started to increase some little bit up to force 5 – 6 Bft during the next day. This situation also persited until 13.08. when a secondary low from the large trough over the Central East Atlantic moved northnorthwestward along the westcoast of Ireland forming a relative sharp air pressure gradient over the working areas. The wave heights reached 2 – 2.5 meters at times this day.

The next day brought more comfortable wind and sea conditions. Induced by a warm and moisty air flow above the relatively cold water some fog patches and low stratus clouds came drifting across the working area from morning until noon of 15.08. In the meantime a new and quickly intensifying secondary low, which was generated in the southern flank of the large East Atlantic trough, moved northward across the Sole Bank reaching the sea areas west of Ireland as a strong stormdepression in the afternoon of the same day with a minimum air pressure of 978 hPa. With the approach of its frontal system the wind shifted southeast to east and increased up to force 6 – 7 Bft at first and near gale 7 – 8 in the vicinity of the front lateron. Associated with heavy rain the wave heights rose up to around 3 Meters. After the passage of the front the wind decreased soon to 4 – 5 Bft and shifted back to southlery directions – interrupted by a shorth interval in the morning hours of 16.08., when once more Bft 6 where reached for a while. The rest of this day brought moderate to fresh southerly to southeasterly winds. The "cooperation" of old swell induced by the stormy winds the day before and the developing new wind sea caused an rather uncomfortable sea state with wave heights of around 2 – 2.5 meters at first, improving gradually to 1 – 1.5 meters during the rest of this day. But already the following day brought the next increase of wind and sea, when two shallow depressions from the large East Atlantic trough tracked across the Irish Sea and Scotland northnortheastward regenerating the sharp air pressure gradient over the working area. Therefore in the morning of 17.08. the wind started to increase again to force 7 with gust up to gale force 8 from southeast to south, and a short break around noon was followed by a new increase up to Bft 6 – 7 from the same direction during the first part of the night.

Instead of only very slowly decrease of wind speed during the first part of the day, the 18.08. finally presented a significant improve for working conditions when the wind direction shifted to southwesterly directions. As the working area of RV METEOR was located in the vicinity of the coast the development of wind sea was reduced correspondingly. Beginning from the early evening hours of this day and favoured by a high pressure ridge extending from the high over Poland towards Scotland the wind decreased to nearly calm conditions associated with a flat swell of less than 0.5 meters until the morning of 19.08. A thundery low which tracked from northern France across the German Bight towards Denmark caused heavy rainfall in the afternoon of this day. Afterwards the combination of nearly calm wind conditions and very moisty air produced some dense fog patches during the following night persisting until morning of 20.08., when a light breeze from the southeast started to dissipate these patches. Apart of some short intervals with moderate to fresh winds from southerly directions these fine weather- and working conditions continued until the evening of 21.08.

Located half way between a trough along the latitude of 60° North and a high pressure ridge from the subtropical high spreading across Central Europe futhermore eastward, a stronger air pressure gradient formed temporarily causing a relative strong westerly to southwesterly air flow. Especially in the afternoon of 22.08. the wind breezed up to force 6 with gusts 7 Bft. As the working area was still located close to the coast the developing wind sea didn’t exceed critical heights due to missing fetch. In the evening of this day the wind started to decrease again down to force 4 – 5 until the next morning. After having had completed all operations in this area around noon of 23.08., RV METEOR set course to the harbour of Aberdeen where the ship arrived in the morning of 24.08.2012.

The second leg of this cruise started on 25.08.2012, when RV METEOR left the harbour of Aberdeen at 08 o’clock in the morning. Due to bad weather conditions predicted for the old operation area in the British Sector of the Northsea through the next 2 days, the ship alternatively set course towards a new operation area located some miles westnorthwest of Helgoland in the German Bight. During transit time a new low moved from England across the southern Northsea towards Denmark and Sweden lateron. Soon after having left Aberdeen the wind shifted north to northeast, slowly increasing to force 5 – 6 Bft until evening and finally force 6 – 7 Bft. from north to northwest associated with wave heights up to 2 – 2.5 meters on 26.08.

During the following night the wind started to decrease gradually and became nearly calm for a while around noon of 27.08., when the axis of a high pressure ridge passed the German Bight. Soon after that had happened a fresh southerly to southeasterly breeze set in. In the meantime the northwesterly swell of around 2 Meters flattened down to 1 – 1.5 meters. In the morning of 28.08. the southerly wind increased to force 6 Bft with gusts up to 7 Bft., when the frontal system of a stormdepression near the Faeroes Islands approached. But as the wind blew offshore the wind sea didn’t exceed heights of around 1 -1.5 meters. After passage of the frontal system the wind shifted southwest and soon decreased to 4 Bft. Favoured by regenerating high pressure influence the wind- and weather conditions became fine and calm persisting until late evening of the next day. During the night to 30.08. the wind became fresh to strong from south to southwest for a while, when the coldfront of a low crossing the northern Northsea approached to the working area. Moderate southwesterly dominated after it’s passage and the swell came down from 1-1.5 meters in the beginning to 1 meter lateron this day. In the evening and during the following night some heavy showers and thunderstorms moved across the working area. Short before dusk of 30.08. the formation of a funnel cloud could be observed for a couple of minutes.

The 31.08. came up with a spectacular development, when a flat trough from the Netherlands crossed the northern parts of Lower Saxony eastsouthward. At same time a strong ridge of high pressure followed quickly from England and Scotland inducing a strong air gradient between the slow moving trough in the east and the quickly following ridge in the west. As soon as the axis of the trough had passed our working area, strong to stormy winds started very rapidly. In the morning of this day the wind shifted from eastnortheast force 3-4 at first to north 7-8 Bft within only a few minutes. Associated by heavy rain and even thunderstorms at first the wave heights rose up to 3 – 4 meters very soon. During the rest of the day the wind shifted more and more towards northwest with force 6 -7 Bft. and the sea remained very rough with wave heights between 3 and 4 meters.

Conditions began to improve during the night when the northwesterly wind decreased to force 5 – 6 Bft. gradually and became nearly fine until noon of the 2.9., when the high pressure ridge crossed the German Bight. The northwesterly swell flattened down from 2 – 2.5 meters in the early morning to around 1 meter in the evening. But these relative calm conditions didn’t last for long time. Already in the afternoon of this day the wind shifted to southwest with Bft. 5 at first and force 6 Bft with gusts up to 7 Bft. during evening and the following night, when the warmfront of a large stormdepression system over the Norwegian Sea crossed the operation area. The wind sea soon became rough again with heights of 1.5 to 2 meters. As the gradient between the frontal zone in the north and the belt of high pressure over Central Europe remained rather sharp, this strong wind situation with southwesterly winds Bft. 5-6 persisted until afternoon of 2.9., when after the passage of a weak coldfront the wind shifted west and decreased to force 4 – 5 Bft. Following soft high pressure influence regenerated over German Bight and weather conditions on 3.9. were caracterized by a gentle to moderate breeze from west to northwest and swell of less than 1 meter. In the morning of 4.9. the wind started to increase again to Bft 5 – 6 from southwest with the approach of the coldfront belonging to a stormdepression which crossed the Norwegian Sea northeastward. In the afternoon and evening of this day -after passage of the coldfront- the wind shifted west and northwest with Bft. 4 – 5 at first and northwest 5 – 6 Bft lateron. The wave heights gradually rose to 1 – 1,5 meters during this day and 1.5 – 2 meters until the morning of 5.9. when final measurements were completed. Induced by a trough swinging southeastward across southern Scandinavia the northwesterly wind increased once more up to 6 – 7 Bft. associated with wave heigts of 2.5 – 3 meters. Entering the mouth of Weser River wind and waves decreased gradually and in the morning of 6.9.2012 RV METEOR put into the harbour of Bremerhaven with a moderate to fresh breeze from northwest.

## 7 Station List M88/1

Station lists are given in two different formats. Table 7.1 contains station numbering of RV METEOR to meet the request of relating this nomenclature to BGR station and line numbers. Because of the outboard equipment testing during part of the cruise there is no extra station number for each specific activity.

Station lists in Tables 7.2 and 7.3 only contain profiles with acquired data. In Table 7.2 all profiles are listed which were measured in UK waters, in Table 7.3 all profiles which were measured in the German sector of the North Sea, respectively.

**Table 7.1:** Station numbering of RV METEOR and BGR line numbering

| Station No. | | Date | Gear | Time | Latitude | Longitude | Water Depth | Remarks/Recovery |
|---|---|---|---|---|---|---|---|---|
| Event label | BGR | 2012 | | [UTC] | [°N] | [°E/°W] | [m] | |
| M88-1/1481 | | 12.8. | 3D-Seismic | 06:05 | 55°29.62 N | 00°53.07 W | 82 | Test handling seismic systems paravan |
| M88-1/1482 | | 13.8. | 3D-Seismic | 08:36 | 55°30.89 N | 00°52.75 W | 87 | Test handling seismic systems airgun |
| M88-1/1483 | | 14.8. | 3D-Seismic | 04:56 | 55°32.67 N | 01°02.06 W | 89 | Test handling seismic systems buoy,streamer,paravan |
| M88-1/1484 | | 15.8. | 3D-Seismic | 07:18 | 55°33.08 N | 00°46.82 W | 89 | Test handling seismic systems buoy,streamer,paravan |
| M88-1/1485 | | 18.8. | 3D-Seismic | 06:17 | 55°31.58 N | 00°50.42 W | 83 | Test handling seismic systems buoy,streamer,paravan |
| M88-1/1485 | | 19.8. | 3D-Seismic | 00:09 | 55°30.85 N | 00°52.95 W | 87 | Test seismic systems in water |
| M88-1/1485 | | 20.8. | 3D-Seismic | 04:15 | 55°25.09 N | 00°58.48 W | 86 | Test seismic systems in water |
| M88-1/1485 | S286 - S174 | 21.8. | 3D-Seismic | 09:04 | 55°20.71 N | 00°50.41 W | 87 | 3D Seismic/Multibeam profiles |
| M88-1/1486 | | 26.8. | Sound Vel | 15:28 | 54°38.60 N | 06°19.58 E | 34 | Sound velocity profiler |
| M88-1/1487 | | 26.8. | Multibeam | 20:27 | 54°18.50 N | 07°23.67 E | 38 | Multibeam-profile |
| M88-1/1488 | | 27.8. | Multibeam | 03:00 | 54°12.89 N | 07°23.83 E | 34 | Multibeam-profile |
| M88-1/1489 | S342 - S182 | 27.8. | 3D-Seismic | 10:26 | 54°13.15 N | 07°31.47 E | 33 | 3D Seismic/Multibeam profiles |
| M88-1/1490 | | 31.8. | Multibeam | 03:15 | 54°17.86 N | 07°18.47 E | 36 | Multibeam-profile |
| M88-1/1491 | S286 - S218I | 01.9. | 3D-Seismic | 08:15 | 54°14:23 N | 07°32.81 E | 35 | 3D Seismic/Multibeam profiles |
| M88-1/1492 | | 02.9. | Multibeam | 17:20 | 54°17:61 N | 07°30.08 E | 34 | Multibeam-profile |
| M88-1/1493 | S282 – S322I | 03.9. | 3D-Seismic | 04:26 | 54°16:72 N | 07°20.01 E | 36 | 3D Seismic/Multibeam profiles |

**Table 7.2:** BGR lines measured in the UK sector of the North Sea

| BGR Line no. | Station no. | Date | Time | Shot point start/end | Latitude | Longitude | course | length | Sea (m)/ Wind (Bft) / Comments |
|---|---|---|---|---|---|---|---|---|---|
| | M88/1 | 2012 | [UTC] | | [°N/°S] | [°E/°W] | [deg] | [km] | |
| S286 | 1485-1 | 21.08 | 09:04 | 1421 | 55° 20' 46.46 N | 0° 50' 26.47 W | 180 | 11 | 0 / S 4 |
| | | | 11:05 | 981 | 55° 14' 50.84 N | 0° 50' 46.60 W | | | |
| | | | | | | | | | |
| S190 | 1485-1 | 21.08. | 11:23 | 981 | 55°14' 58.01 N | 0° 54' 05.37 W | 0 | 11 | 0 / S 5 |
| | | | 13:56 | 1421 | 55°20' 53.64 N | 0° 53' 46.56 W | | | |
| | | | | | | | | | |
| S282 | 1485-1 | 21.08. | 16:41 | 1421 | 55° 20' 46.32 N | 0° 50' 36.81 W | 180 | 11 | 0.5 / S 5 |
| | | | 17:50 | 981 | 55° 14' 51.08 N | 0° 50’ 56.24 W | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| S278 | 1485-1 | 22.08. | 05:09 | 1421 | 55° 20' 46.74 N | 0° 50' 43.43 W | 180 | 11 | 1 / WSW 6 |
| | | | 06:21 | 981 | 55° 14' 51.16 N | 0° 51' 03.46 W | | | |
| | | | | | | | | | |
| S186 | 1485-1 | 22.08. | 07:25 | 981 | 55° 14' 58.16 N | 0° 54' 13.97 W | 0 | 11 | 1 / SW 5 |
| | | | 08:57 | 1421 | 55° 20' 53.67 N | 0° 53' 55.12 W | | | |
| | | | | | | | | | |
| S274 | 1485-1 | 22.08. | 09:56 | 1421 | 55° 20' 46.84 N | 0° 50' 52.13 W | 180 | 11 | 1 / WSW 5 |
| | | | 11:53 | 981 | 55° 14' 51.32 N | 0° 51' 09.18 W | | | |
| | | | | | | | | | |
| S182 | 1485-1 | 22.08. | 12:43 | 981 | 55° 14' 58.28 N | 0° 54' 20.46 W | 0 | 11 | 1 / SW 5 |
| | | | 14:01 | 1421 | 55° 20' 53.88 N | 0° 54' 04.13 W | | | |
| | | | | | | | | | |
| S270 | 1485-1 | 22.08. | 14:55 | 1421 | 55° 20' 47.08 N | 0° 51' 00.17 W | 180 | 11 | 1 / W 5 |
| | | | 16:11 | 981 | 55° 14' 51.63 N | 0° 51' 19.68 W | | | |
| | | | | | | | | | |
| S178 | 1485-1 | 22.08. | 17:24 | 981 | 55° 14 58.53 N | 0° 54' 30.33 W | 0 | 11 | 1.5 / WSW 5 |
| | | | 19:23 | 1421 | 55° 20' 54.25 N | 0° 54' 12.85 W | | | |
| | | | | | | | | | |
| S266 | 1485-1 | 23.08. | 04:45 | 1421 | 55° 20' 47.24 N | 0° 51' 08.87 W | 180 | 11 | 1.0 / WSW 5 |
| | | | 05:58 | 981 | 55° 14' 51.73 N | 0° 51' 27.35 W | | | |
| | | | | | | | | | |
| S174 | 1485-1 | 23.08. | 07:16 | 981 | 55° 14' 58.70 N | 0° 54' 38.92 W | 0 | 11 | 1.0 / SW 5 |
| | | | 08:59 | 1421 | 55° 20' 54.16 N | 0° 54' 21.40 W | | | |

**Table 7.3:** BGR lines measured in the German sector of the North Sea

| **BGR Line no.** | **Station no.** | **Date** | **Time** | **Shot point start/end** | **Latitude** | **Longitude** | **course** | **length** | **Sea (m) / Wind (Bft) / Comments** |
|---|---|---|---|---|---|---|---|---|---|
| | **M88/1** | **2012** | **[UTC]** | | **[°N/°S]** | **[°E/°W]** | **[deg]** | **[km]** | |
| S182 | 1489-1 | 30.08. | 20:00 | 981 | 54° 14' 51.36 N | 7° 28' 47.14 E | 270 | 11 | 0 / E 2 |
| | | 30.08. | 21:53 | 1421 | 54° 14' 43.69 N | 7° 18' 39.86 E | | | |
| | | | | | | | | | |
| S186 | 1489-1 | 30.08. | 15:12 | 981 | 54° 14' 56.36 N | 7° 28' 46.61 E | 270 | 11 | 0 / SW 3 |
| | | 30.08. | 16:29 | 1421 | 54° 14' 48.78 N | 7° 18' 39.65 E | | | |
| | | | | | | | | | |
| S190 | 1489-1 | 30.08. | 09:54 | 981 | 54° 15’ 00.17 N | 7° 28 47.05 E | 270 | 11 | 0 / SW 4 |
| | | 30.08. | 11:27 | 1421 | 54° 14’ 53.08 N | 7° 18 39.20 E | | | |
| | | | | | | | | | |
| S194 | 1489-1 | 30.08. | 04:31 | 981 | 54° 15' 05.47 N | 7° 28' 46.53 E | 270 | 11 | 0 /SW 5 |
| | | 30.08. | 06:20 | 1421 | 54° 14' 59.46 N | 7° 18' 39.25 E | | | |
| | | | | | | | | | |
| S198 | 1489-1 | 29.08. | 22:58 | 981 | 54° 15' 14.93 N | 7° 28' 46.50 E | 90 | 11 | 0 /SW 4 |
| | | 30.08. | 00:23 | 1421 | 54° 15' 03.22 N | 7° 18' 38.63 E | | | |
| | | | | | | | | | |
| S202 | 1489-1 | 29.08. | 17:23 | 981 | 54° 15' 14.93 N | 7° 28' 46.31 E | 270 | 11 | 0.5 / ESE 3 |
| | | 29.08. | 19:25 | 1421 | 54° 15' 07.66 N | 7° 18' 38.86 E | | | |
| | | | | | | | | | |
| S206.2 | 1489-1 | 29.08. | 12:01 | 985 | 54° 15' 20.10 N | 7° 28' 40.11 E | 270 | 11 | 0.5 / SE 4 |
| | | 29.08. | 13:12 | 1421 | 54° 15' 11.80 N | 7° 18' 38.33 E | | | |
| | | | | | | | | | |
| S210 | 1489-1 | 29.08. | 04:39 | 981 | 54° 15' 24.85 N | 7° 28' 45.96 E | 270 | 11 | 0.5 / S 4 |
| | | 29.08. | 06:38 | 1421 | 54° 15' 17.70 N | 7° 18' 38.48 E | | | |
| | | | | | | | | | |
| S214 | 1489-1 | 28.08. | 23:19 | 981 | 54° 15' 28.86 N | 7° 28' 45.35 E | 270 | 11 | 0 / SW 3 |
| | | 29.08. | 00:33 | 1421 | 54° 15' 20.88 N | 7° 18' 37.99 E | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| S218 | 1489-1 | 28.08. | 17:24 | 981 | 54° 15' 35.35 N | 7° 28' 45.67 E | 270 | 11 | 0.5 / W 4 |
| | | 28.08. | 19:25 | 1421 | 54° 15' 27.70 N | 7° 18' 38.12 E | | | |
| | | | | | | | | | |
| S222 | 1489-1 | 28.08. | 12:02 | 981 | 54° 15' 39.05 N | 7° 28' 44.93 E | 270 | 11 | 0.5 / SSW 5 |
| | | 28.08. | 13:20 | 1421 | 54° 15' 31.33 N | 7° 18' 97.79 E | | | |
| | | | | | | | | | |
| S226 | 1489-1 | 28.08. | 06:06 | 981 | 54° 15' 43.52 N | 7° 28' 45.15 E | 270 | 11 | 0.5 / S 5 |
| | | 28.08. | 08:01 | 1421 | 54° 15' 36.77 N | 7° 18' 37.67 E | | | |
| | | | | | | | | | |
| S230.1 | 1489-1 | 28.08. | 00:58 | 981 | 54° 15' 50.85 N | 7° 28' 45.51 E | 270 | 11 | / SSE 6 |
| | | 28.08. | 02:19 | 1421 | 54° 15' 41.38 N | 7° 18' 37.68 E | | | |
| | | | | | | | | | |
| S234 | 1489-1 | 27.08. | 19:42 | 981 | 54° 15' 53.55 N | 7° 28' 44.62 E | 270 | 11 | 1 / WNW 5 |
| | | 27.08. | 21:11 | 1421 | 54° 15' 44.30 N | 7° 18' 37.14 E | | | |
| | | | | | | | | | |
| S238 | 1493-1 | 03.09. | 16.06 | 981 | 54° 15 58.08 N | 7° 28 44.47 E | 270 | 11 | 0 / W 3 |
| | | 03.09 | 17:15 | 1421 | 54° 15 49.21 N | 7° 18 36.97 E | | | |
| | | | | | | | | | |
| S242 | 1493-1 | 03.09. | 21:42 | 981 | 54° 16 02.51 N | 7° 28 44.63 E | 270 | 11 | / W 4 |
| | | 03.09. | 23:47 | 1421 | 54° 15 55.12 N | 7° 18 36.88 E | | | |
| | | | | | | | | | |
| S246 | 1493-1 | 04.09. | 03:53 | 981 | 54° 16 08.45 N | 7° 28 44.16 E | 270 | 11 | / SW 4 |
| | | 04.09. | 05:08 | 1421 | 54° 15 59.38 N | 7° 18 36.71 E | | | |
| | | | | | | | | | |
| S250 | 1493-1 | 04.09. | 09:53 | 981 | 54° 16 12.10 N | 7° 28 44.31 E | 270 | 11 | 1 / SW 5 |
| | | 04.09. | 12:03 | 1421 | 54° 16 04.49 N | 7° 18 36.74 E | | | |
| | | | | | | | | | |
| S254 | 1493-1 | 04.09. | 15:54 | 981 | 54° 16 15.76 N | 7° 28 19.43 E | 270 | 11 | 1 / WNW 5 |
| | | 04.09. | 17:09 | 1421 | 54° 16 08.41 N | 7° 19 06.86 E | | | |
| | | | | | | | | | |
| S258 | 1493-1 | 04.09. | 22:07 | 983 | 54° 16 20.62 N | 7° 28 19.25 E | 270 | 11 | / WNW 5 |
| | | 05.09. | 00:13 | 1421 | 54° 16 13.26 N | 7° 19 06.66 E | | | |
| | | | | | | | | | |
| S262 | 1493-1 | 04.09. | 18:41 | 1421 | 54° 16 18.11 N | 7° 19 06.46 E | 90 | 11 | 1 / NW 5 |
| | | 04.09. | 20:22 | 981 | 54° 16 25.47 N | 7° 28 19.07 | | | |
| | | | | | | | | | |
| S266 | 1493-1 | 04.09. | 13:04 | 1421 | 54° 16 22.96 N | 7° 19 06.26 E | 90 | 11 | 1 / WSW 5 |
| | | 04.09. | 14:26 | 981 | 54° 16 30.32 N | 7° 28 18.89 E | | | |
| | | | | | | | | | |
| S270 | 1493-1 | 04.09. | 06:16 | 1421 | 54° 16 28.61 N | 7° 18 41.44 E | 90 | 11 | 1 / SW 5 |
| | | 04.09. | 08.10 | 981 | 54° 16 36.90 N | 7° 28 49.25 E | | | |
| | | | | | | | | | |
| S274 | 1493-1 | 04.09. | 01:02 | 1421 | 54° 16 33.82 N | 7° 18 41.00 E | 90 | 11 | / WSW 4 |
| | | 04.09. | 02:35 | 981 | 54° 16 41.48 N | 7° 28 48.78 E | | | |
| | | | | | | | | | |
| S278 | 1493-1 | 03.09. | 18:42 | 1421 | 54° 16 38.36 N | 7° 18 41.06 E | 90 | 11 | 0.5 / W 5 |
| | | 03.09. | 20:11 | 981 | 54° 16 47.29 N | 7° 28 48.94 E | | | |
| | | | | | | | | | |
| S282 | 1493-1 | 03.09. | 13:20 | 1421 | 54° 16 43.05 N | 7° 18 40.92 E | 90 | 11 | 0.5 / WSW 4 |
| | | 03.09. | 14:57 | 981 | 54° 16 51.73 N | 7° 28 48.52 E | | | |
| | | | | | | | | | |
| S286 | 1491-1 | 01.09. | 15:12 | 1421 | 54° 16' 47.22 N | 7° 19' 05.28 E | 90 | 11 | 0.5 / SW 5 |
| | | 01.09. | 17:11 | 981 | 54° 16' 54.58 N | 7° 28’ 17.99 E | | | |
| | | | | | | | | | |
| | | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| S290 | 1489-1 | 30.08. | 17:33 | 1421 | 54° 16' 52.07 N | 7° 19' 05.08 E | 90 | 11 | 0 / ENE 2 |
| | | 30.08. | 18:47 | 981 | 54° 16' 59.43 N | 7° 28' 17.81 E | | | |
| | | | | | | | | | |
| S294 | 1489-1 | 30.08. | 12:28 | 1421 | 54° 16' 55.75 N | 7° 18' 40.36 E | 90 | 11 | 0.5 / SW 4 |
| | | 30.08. | 14:02 | 981 | 54° 17' 03.30 N | 7° 28' 48.16 E | | | |
| | | | | | | | | | |
| S298 | 1489-1 | 30.08. | 07:26 | 1421 | 54° 16' 59.62 N | 7° 18' 40.47 E | 90 | 11 | 0.5 / WSW 4 |
| | | 30.08. | 08:41 | 981 | 54° 17' 09.07 N | 7° 28' 48.21 E | | | |
| | | | | | | | | | |
| S302 | 1489-1 | 30.08. | 01:28 | 1421 | 54° 17' 05.48 N | 7° 18' 39.86 E | 90 | 11 | / SW 5 |
| | | 30.08. | 03:12 | 981 | 54° 17' 12.42 N | 7° 28' 47.88 E | | | |
| | | | | | | | | | |
| S306 | 1489-1 | 29.08. | 20:30 | 1421 | 54° 17' 9.65 N | 7° 18' 40.08 E | 90 | 11 | / WSW 4 |
| | | 29.08. | 21:45 | 981 | 54° 17' 18.26 N | 7° 28' 47.78 E | | | |
| | | | | | | | | | |
| S310 | 1489-1 | 29.08. | 14:17 | 1421 | 54° 17' 15.13 N | 7° 18' 39.56 E | 90 | 11 | 0.5 / SE 3/ no seismic registration for SP 1272 - 1088 |
| | | 29.08. | 16:02 | 981 | 54° 17' 23.63 N | 7° 28' 47.57 E | | | |
| | | | | | | | | | |
| S314 | 1489-1 | 29.08. | 07:46 | 1421 | 54° 17' 19.76 N | 7° 18' 39.56 E | 90 | 11 | 0.5 / SSW 4 |
| | | 29.08. | 09:07 | 981 | 54° 17' 27.64 N | 7° 28' 47.34 E | | | |
| | | | | | | | | | |
| S318 | 1489-1 | 29.08. | 01:40 | 1421 | 54° 17' 25.03 N | 7° 18' 39.15 E | 90 | 11 | / SW 3 |
| | | 29.08. | 03:20 | 981 | 54° 17' 31.88 N | 7° 28' 47.11 E | | | |
| | | | | | | | | | |
| S322 | 1489-1 | 28.08. | 20:28 | 1421 | 54° 17' 29.20 N | 7° 18' 39.14 E | 90 | 11 | / W 3 |
| | | 28.08. | 22:01 | 981 | 54° 17' 39.46 N | 7° 28' 46.74 E | | | |
| | | | | | | | | | |
| S326 | 1489-1 | 28.08. | 14:28 | 1421 | 54° 17' 34.32 N | 7° 18' 38.96 E | 90 | 11 | 0.5 / SW 4 |
| | | 28.08. | 15:50 | 981 | 54° 17' 43.95 N | 7° 28' 46.88 E | | | |
| | | | | | | | | | |
| S330 | 1489-1 | 28.08. | 09:04 | 1421 | 54° 17' 39.84 N | 7° 18' 38.64 E | 90 | 11 | 1.5 / S 5 |
| | | 28.08. | 10:41 | 981 | 54° 17' 46.83 N | 7° 28' 46.54 E | | | |
| | | | | | | | | | |
| S334 | 1489-1 | 28.08. | 03:26 | 1421 | 54° 17' 43.82 N | 7° 18' 38.64 E | 90 | 11 | / S 6 |
| | | 28.08. | 04:36 | 981 | 54° 17' 52.20 N | 7° 28' 46.63 E | | | |
| | | | | | | | | | |
| S338 | 1489-1 | 27.08. | 22:15 | 1421 | 54° 17' 49.44 N | 7° 18' 38.09 E | 90 | 11 | / SSE 5 |
| | | 28.08. | 00:03 | 981 | 54° 17' 56.77 N | 7° 28' 46.23 E | | | |
| | | | | | | | | | |
| S342 | 1489-1 | 27.08. | 17:23 | 1421 | 54° 17' 53.46 N | 7° 18' 38.13 E | 90 | 11 | 1 / SE 5 |
| | | 27.08. | 18:41 | 981 | 54° 18' 01.81 N | 7° 28' 46.13 E | | | |
| | | | | | | | | | |
| S218 I | 1491-1 | 01.09. | 18:29 | 981 | 54° 15 32.64 N | 7° 28 45.45 E | 270 | 9 | 1 /SW 5/ Paravan-break |
| | | 01.09. | | 1345 | 54 °15 30.82 N | 7° 20 14.10 E | | | |
| | | | | | | | | | |
| S258 I | 1493-1 | 05.09. | 01:33 | 1421 | 54° 16 13.26 N | 7° 19 06.66 E | 90 | 11 | / NW 5 |
| | | 05.09. | 03:04 | 981 | 54° 16 20.62 N | 7° 28 19.25 E | | | |
| | | | | | | | | | |
| S310 I | 1493-1 | 05.09. | 04:10 | 981 | 54° 17 23.69 N | 7° 28 16.91 E | 270 | 9 | / WNW 5 |
| | | 05.09. | 05:11 | 1339 | 54° 17 16.32 N | 7° 19 04.09 E | | | |
| | | | | | | | | | |
| S322 I | 1493-1 | 05.09. | 06:11 | 1264 | 54° 17 30.88 N | 7° 19 03.50 E | 90 | 7 | 1.5 / NW 5 |
| | | 05.09. | 07:23 | 981 | 54° 17 38.24 N | 7° 28 16.37 E | | | |

## 8 Data and Sample Storage and Availability

After the acquisition the seismic and navigation data were separated according to the two streamers and underwent a first 2D processing and stacking. This 2D processing was carried out by C. Papenberg, A. Ehrhardt, H. Koopmann, S. Steuer, C. Kuhlmann and S. Breuer. Its aim is to give a first quality control on the data.

The full 3D processing will be carried out inhouse BGR in Hannover after the cruise.

The metadata for this cruise including positions, station logs from DSHIP and data types acquired will be made publicly available immediately after the cruise through BGR data management.

Bathymetric data will be committed to the German Hydrographic Survey (BSH) immediately after the cruise.

After the final 3D processing of the seismic data, they will be incorporated into the database of the research project "Geopotential Deutsche Nordsee (GPDN)". The processed and raw data will also be stored in the seismic archive of BGR and will be made publicly available according to the terms of this research project.

Additionally, until June 2013 the metadata of the aquired data will also be made available via the Web-portal of the pan-European infrastructure GeoSeas for management of marine geological and geophysical data (www.geoseas.eu).

## 9 Conclusions

RV METEOR demonstrated itself as almost perfectly suited to accommodate the mobile 3D seismic equipment of BGR. All modifications of prior the cruise which were necessary to operate the outboard components perfectly fitted the requirements.

The navigation data provided by the ship and by the own sensors were fed into the seismic navigation system after solving all problems arising of usage the appropriate data protocols and interfaces.

Navigation during the survey, which has to be coordinated from the seismic lab based on the seismic coverage needs a permanent and good communication with the nautical officers to meet all quality standard.

In general, the BGR mobile 3D seismic system in its version of two 1500 m streamers at maximum and 2 GI guns is ready to be operated at several vessels.

In case of using other ships than RV METEOR major special demands are sufficient space at working deck, cranes to handle the heavy outboard equipment and availability of winches to drag the trawling doors and others which have to clarified well in advance.

## 10 Acknowledgements

Out of the normal schedule we got the opportunity from the Leitstelle Deutsche Forschungsschiffe, Institut für Meereskunde der Universität Hamburg to test the new multi-channel 3D seismic system during cruise M88/1. We are grateful for this opportunity.

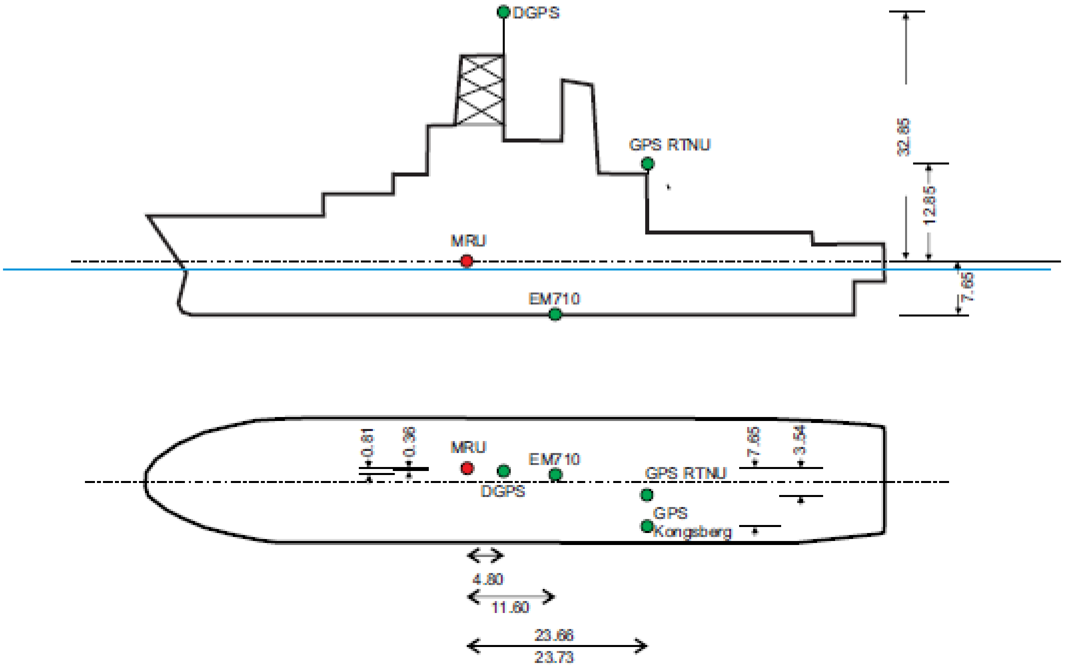
Preparing the cruise there was a long task list to be solved in very short time. We would like to thank the Reederei Laeisz for assistance and the Leitstelle Deutsche Forschungsschiffe for coordination of all necessary modifications at the vessel prior the cruise.

Many thanks go to Master Thomas Wunderlich and the entire crew of RV METEOR for their great support to solve all problems arising from handling our new equipment, to meet our special demands on navigation during the 3D data acquisition and finally to complete our program successfully, and last but not least for making our stay onboard highly convenient and comfortable.

We would also like to thank the colleagues of the German Meteorological Service for continuously providing high resolution weather forecasting during the expedition.

## Appendix A

### Location of navigation sensors onboard RV METEOR and examples of data strings



Reference point for all navigation data is the Motion Reference Unit (MRU)
– see Chapter 5.1.3

Example 1

```
$GNGGA,121830.00,5532.52522,N,00047.93918,W,2,19,0.7,82.33,M,0.00,M,4.0,0025*
48<CR><LF>
$GNVTG,150.0,T,,M,3.88,N,7.18,K,D*1F<CR><LF>
```

Example 2

```
$PRDID,+000.90,+000.33,153.84<CR><LF>
```

Example 3

```
$HEHDT,154.89,T*1E<CR><LF>

$TIROT,00020.4,A*3D<CR><LF>

$PPPRP,-00.3,-00.9*58<CR><LF>
```

Example 4

```
$EMDPT,87.35,4.5*40<CR><LF>
```

## Appendix B

## Configuration of BigShot Seismic Source Controller (BSSC)

The LSCPU Real Time Control Prcessor board coordinates the contol and data acquisition functions of the LongShot Control Processor:

- receives trigger from navigation
- fires solenoid power supply units (PSU)
- gathers data from solenoid power supply units
- processes data from guns and updates psu for next shot
- displays graphical data to user for current shot
- sends serial header to recording system
- receives manifold pressure data for display (not used)

The BSSC receives the SPECTRA-trigger from the PRTNU2 trough the trigger-in BNC-Connector to fire the guns.
The two GI-Guns were fired by the BigShot Seismic Source Controller.
JP11 – used to select external trigger mode was new configured to receive the SPECTRA-trigger which is a high going TTL-pulse. The TTL high-going pulse configuration is optically isolated.

Original Configuration of JP11 :

| Pins | 1 - 2 | 3 - 4 | 5 - 6 | 7 - 8 |
|---|---|---|---|---|
| connection | open | open | short | short |

Configured for SPECTRA

| Pins | 1 - 2 | 3 - 4 | 5 - 6 | 7 - 8 |
|---|---|---|---|---|
| connection | short | short | open | open |

Each GI-Gun represents two guns. Starboard: GI -gun-generator represents gun 1 and the injector gun 2. Same for the backboard gun. So in flip-flop mode gun1 and 2 were fired as gun-string 1 for odd shot numbers and gun 2 and 3 were fired as gun-string 2 at even shot numbers.
For the GI-guns do not produce a sensor signal, the fire pulse output of 40V was connected by a 330 kohm resistor to sensor input for simulating a sensor signal which was sent to SPECTRAs PRTNU2 by the trigger-out BNC-connector.
The com1 port is used to transmit the gun status string and is also used receive commands for setting the Line Name and Shot Point number.
The command to set the line number is SLllllllll<CR><LF> where lllllll is the line name up to 8 characters.
The command to set the ShotPoint is SPnnnnnn<CR><LF> where nnnnnn is the shot point up to 8 characters.

After each shot the gun header is transmitted as follows via com1.

The string is 90 bytes + (number of strings * 4 bytes) + (number of guns * 22) + 2

The first 90 bytes:

```
struct gcs90_hdr_struct
{
char header[6]; /* Syntron header characters *GCS90 */
char blk_siz[4]; /* Status block size */
char line[8]; /* Line number */
char shot[10]; /* Shot point */
char mask[2]; /* Active array mask */
char trg_mode; /* Trigger mode: ‘I’=internal, ‘E’=external */
char time[17]; /* Shot time tag */
char seq_number; /* Sequence number */
char num_subarray; /* Number of subarrays */
char num_guns[2]; /* Number of guns */
char num_active[2]; /* Number of active guns */
char num_delta[2]; /* Number of delta errors in shot */
char num_auto[2]; /* Number of autofires in shot */
char num_miss[2]; /* Number of miss-fires in shot */
char spread[3]; /* Delta spread accross array in 1/10 msecs */
char volume[5]; /* Total volume fired */
char avg_delta[5]; /* Average Delta */
char std_delta[5]; /* Standard Deviation of Delta */
char spare[4]; /* spare for expansion */
char manifold[4]; /* Manifold Pressure */
char deep_tow[4]; /* Manifold Pressure */
};
```

Now 4 bytes of presure for each string. (not used)

The whole string is terminated by a CR and LF.

## Appendix C:

### Ship’s crew of RV METEOR during M88/1

| No. | Name | Rank |
|---|---|---|
| 1. | Wunderlich, Thomas | Captain |
| 2. | Dugge, Heike | Chiefmate |
| 3. | Volland, Helge | 2. Offc. |
| 4. | Falkenhagen, Patrick | 2. Offc. |
| 5. | Hinz, Michael | Doctor |
| 6. | Hartig, Volker | Ch. Eng. |
| 7. | Heitzer, Ralf | 2. Eng. |
| 8. | Boy, Martin | 3. Eng. |
| 9. | Willms, Olaf | Ch. Electron. Eng |
| 10. | Hebold, Katharina | Elektron. Eng. |
| 11. | Nasis, Ilias | Sys. Man. |
| 12. | Freitag, Rudolf | Electrical Eng. |
| 13. | Loidl, Rainer | Boatswain |
| 14. | Sebastian, Frank | Fitter |
| 15. | Behlke, Hans-Joachim | Sailor |
| 16. | Grabbert, Steve | Sailor |
| 17. | Neitzsch, Bernd | Sailor |
| 18. | Weiß, Eberhard | Sailor |
| 19. | Wolf, Alexander | Sailor |
| 20. | Zimmermann, Dirk | Sailor |
| 21. | Lamm, Gerd | Sailor |
| 22. | Krüger, Frank | Mot-man |
| 23. | Pagels, Christian | Mot-man |
| 24. | Schroeder, Manfred | Mot-man |
| 25. | Grün, Franz | Cook |
| 26. | Götze, Rainer | Cooksmate |
| 27. | Wege, Andreas | Chief Steward |
| 28. | Jürgens, Monika | 2. Steward |
| 29. | Hoppe, Jan | 2. Steward |
| 30. | Zhang, Guo Min | Laundrym. |
| 31. | Marschke, Dennis | Apprentice SM |
| 32. | Schulz, Tjark | Apprentice SM |
| 33. | Genser, Leif | Trainee Nautic |
| 34. | Salb, Sylvester | Trainee Nautic |

## Appendix D

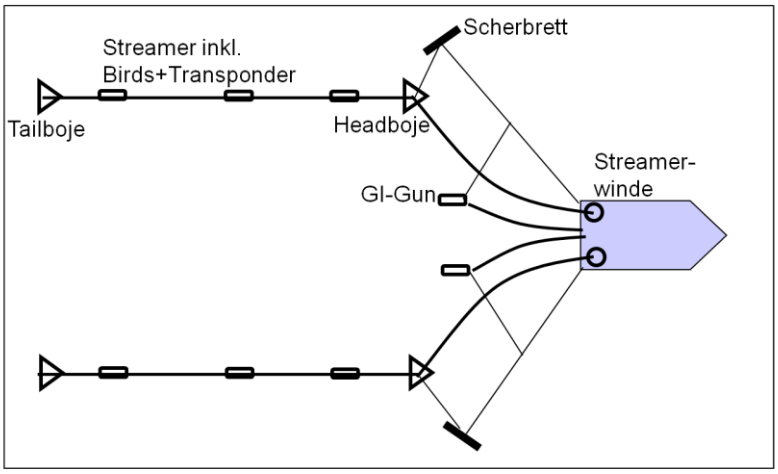
## 3D-Seismik BGR- M88/1

### Außenbordsysteme der BGR-3D-Seismik und Arbeitsabläufe im Messbetrieb

Die 3D-seismischen Geräte der BGR setzen sich zusammen aus:

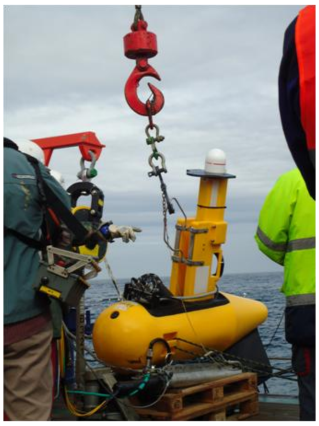
- 2 Scherbrettern (je 2150 kg)
- 2 Streamerwinden (je 7 t)
- 2 Fairlead-Blöcke (je 200 kg)
- 2 Endbojen für Streamer
- 2 Kopfbojen für Streamer
- 2 GI-Guns
- 2 Auftriebsbojen für GI-Guns
- 2 Versorgungssträngen für GI-Guns (je 100 m)

Die beiden Streamer werden im Abstand von 150m zueinander, die GI-Guns im Abstand von 75m zueinander hinter dem Schiff geschleppt. Die Schleppweite wird durch die Scherbretter, die ca. 100m Scherweite von Mittschiffslinie erzeugen, sichergestellt. Das Layout ist der Abbildung zu entnehmen.

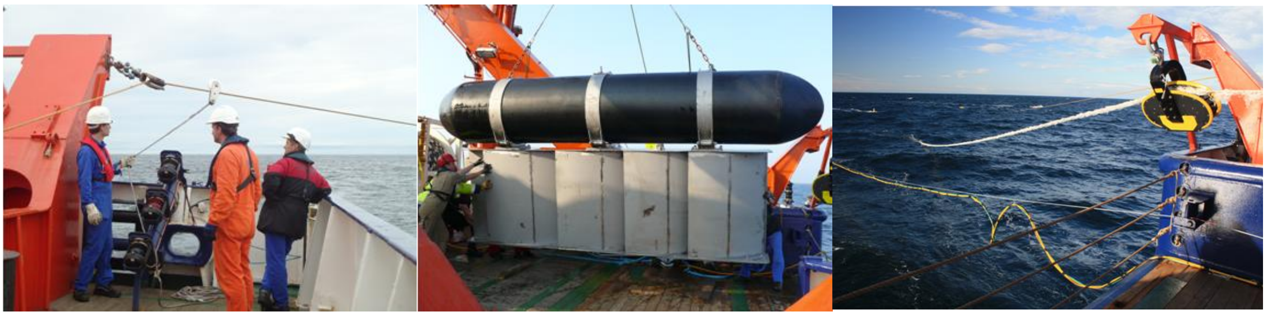


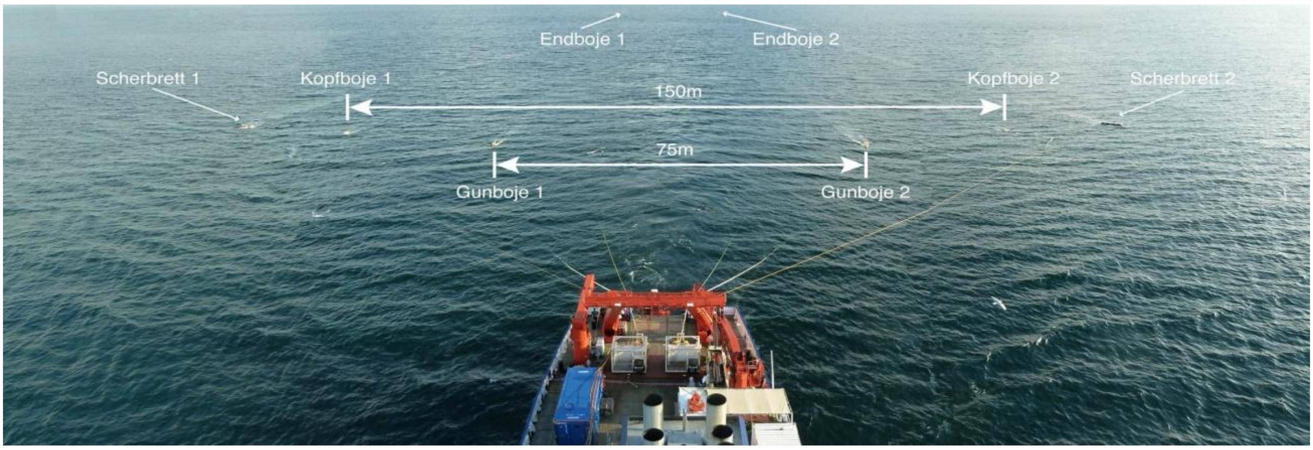
Schleppanordnung der Außenbordsysteme der 3D-Seismik (oben) und Streamerwinden (Abbildungen rechts); unter den Winden werden die Zugdrähte für die GI-Gun durchgeführt (siehe Abb. rechts unten), Streamer-Endboje (unten links), Mehrrrollen-Block, Fairleadblock und Bendprotektor (unten Mitte) zum Anschlagen von Scherbrett und Kopfboje (unten rechts)

GI-Gun-Boje (rechts),



Rollenblock zum Scheren der GI-Gun (unten links), Scherbrett (unten Mitte), Heckausleger an A-Rahmen und Fairlead-Block für Streamer und Rollen-Halterung am Schanzkleid zur Führung des Zugdrahtes für GI-Gun (unten rechts)





Schleppanordnung von Scherbrettern, Streamern und Airguns

## Handling der Außenbordsysteme

Voraussetzung für Einsatz sind 2 Heckgalgen an A-Rahmenauflage mittschiffs für Fairledblöcke, 2 Rollenblöcke an A-Rahmenaufleger außen für Kurrleinen, 2 Drahtführungen mit Rollen an Innenseite Schanzkleid achtern für Versorgungsstränge GI-Guns, 4 auf Deck montierte Adapterplatten für die beiden Streamerwinden, die mobile Winde der LDF und Verfügbarkeit der 3 Mooringwinden achtern, zzgl. Kompressor

Aussetzen von Scherbrettern, Streamern und GI-Guns

1. beide Kurrleinen auf die Mooringwinden aufspulen (bis 300m Speicherseite, dann auf Arbeitsseite wechseln)
2. Ausbringen und Einholen der Bretter nur mit Bugstahler
3. alle Leinen an Riggblock anschlagen, Sorgleine und Verbindungsleine zum Bendprotektor anschlagen, Laufrolle für GI-Gun auf Kurrleine, dann fieren.
4. beide Bretter bei 1 – 1,5kn z.W., Fahrt leicht erhöhen und die Bretter bis auf ca. 5 Wicklungen auf Arbeitsseite fieren. Fahrt auf 4kn und die Bretter langsam ranhieven, damit Kurrleinen straff auf Mooringwinden liegen
5. Fahrt auf 2,5kn reduzieren
6. Endboje aktiviert mit 2,5kn z.W., danach den Streamer über Mehrrollenblock z.W., Fahrt d.W. max. 3,5kn
7. Streamer in Fairleadblock übernehmen
8. Kopfboje mit Leine festhalten bis der Bendprotektor unter Wasser ist, dann erst slippen
9. Kurrleine und LeadIn synchron auf 128m fieren
10. Sicherheitsleine an Kurrleine befestigen, alle 6 Std. die Kurrleine um die Umschlingungslänge im Block bewegen
11. Gun an die über dem LeadIn laufende Leine der Laufrolle anschlagen, aussetzen und auf 90m-Marke am Schleppdraht fieren
12. zweite Endboje z.W., Fahrt d.W. beachten, ggf. kurzfristig Fahrt reduzieren, dann Streamer z.W. wie oben

Einholen von Scherbrettern, Streamern und GI-Guns

1. Fahrt auf 3 – 3,5kn verringern,
2. beide GI-Guns druckfrei an Bord hieven
3. Scherbrett und Streamer synchron bis Bendprotektor hieven, Kopfboje an Bord nehmen
4. bei Erreichen des Bendprotektors Streamer aus Fairleadblock in Mehrrollenblock übernehmen, Leinen mit Schäkel abnehmen. Verbindungsleine Riggblock-Bendprotektor achtern festlegen
5. Streamer vollständig auftrommeln und Endboje an Bord nehmen
6. analog für den zweiten Streamer
7. Fahrt auf ca. 1 kn verringern (Bugstrahlruder – s. oben)
8. Scherbretter an Bord nehmen,

Im Havariefall, dass Kurrleine reißen sollte, wird die Schleppkraft vom Scherbrett auf das LeadIn übergeben. Somit muss die Streamerwinde diese Kräfte halten.

Maßnahmen:

1. Brücke informieren, Geschwindigkeit reduzieren
2. GI-Gun‘s drucklos einholen
3. bei minimaler Geschwindigkeit Scherbrett mit dem Streamer hieven (hohe Querkraft auf der nicht dafür ausgelegten Streamerführung)

## Ablauf für Profilmessungen 3D-Seismik –

## Hinweise für Brücke, Nav.-Lab. und Seismik-Lab.

Alle Wegpunkte des vorgesehenen 3D-Surveys werden in das Navigationssystem der Brücke übertragen. Alle Profilnummern und Wegpunkte sind in der Nomenklatur mitgeteilt worden. Auf der Brücke wird eine Navigationsdisplay installiert, das es ermöglicht, den Kurs des Schiffes auf dem aktuellen Profil und die aktuelle Überdeckung zu beobachten.
Profilstart bzw. -wechsel (im laufenden Messbetrieb):

- möglichst bereits während der Profilmessungen, spätestens jedoch bis Ende des laufenden Profils meldet **Nav.-Labor** den Namen des nächsten Profils an Brücke und den Waypoint für den ersten Shotpoint.
- **Brücke** legt einen Aim Point fest, der 0.7 nm in direkter Verlängerung des Profils VOR dem übermittelten Waypoint liegt,
- Bei Erreichen des Profilendes (letzter Waypoints im laufenden Profil) gibt **Brücke** Meldung an Nav.-Labor,
- **Nav.-Lab** protokolliert EOL,
- **Brücke** navigiert Schiff auf geradem Kurs noch 0.7 nm über das Profilende hinaus,
- 20 SP nach EOL meldet **Nav.-Lab** den letzten Schusspunkt (LGSP) an Seismik-Lab
- **Brücke** meldet Nav.-Labor, dass Run Out beendet ist und fragt Nav.-Lab, ob Drehung auf neue Profillinie beginnen kann,
- **Brücke** navigiert Schiff zu Aim Point der neuen Profillinie, SOG ca. 4-4.5 kn
- Wenn Aim Point erreicht ist, gibt **Brücke** Meldung an Nav.-Lab.,
- **Nav.-Lab** gibt Meldung an Seismik-Lab über bevorstehendes Erreichen des SOL,
- **Seismik** stellt Schussbereitschaft her
- **Nav.-Lab** gibt (falls erforderlich) Info an Brücke zu eventuell notwendigem crossline Offset von der Profillinie
- **Brücke** meldet Nav.-Lab das Erreichen des ersten Waypoints (1. Shotpoint) des Profils.
- **Seismik-Lab** meldet Nav.-Lab erfolgten 1. Schuss
- **Brücke** navigiert Schiff entlang der Profillinie nach Vorgaben des Nav.-Labs zu eventuellen crossline Offsets (Offsets werden von Nav.-Lab. in 10 m-Schritten mitgeteilt) – hierzu sie unten,
- **Brücke** hält Fahrtgeschwindigkeit während der Profilmessungen auf 4,5 STW (Fahrt durchs Wasser) bzw. nach Anweisungen der Seismik,
- Gegen Ende des Profils gibt **Nav.-Lab** der Brücke die Informationen zur nächstfolgenden Profillinie (Name des Profils, Waypoint für Profilbeginn),

anschließend wiederholt sich der Ablauf wie oben beschrieben.