

# MGL 2309 Cruise report



**FLAME**

**FLorida Atlantic Margin Evolution**

*Funded by the National Science Foundation*

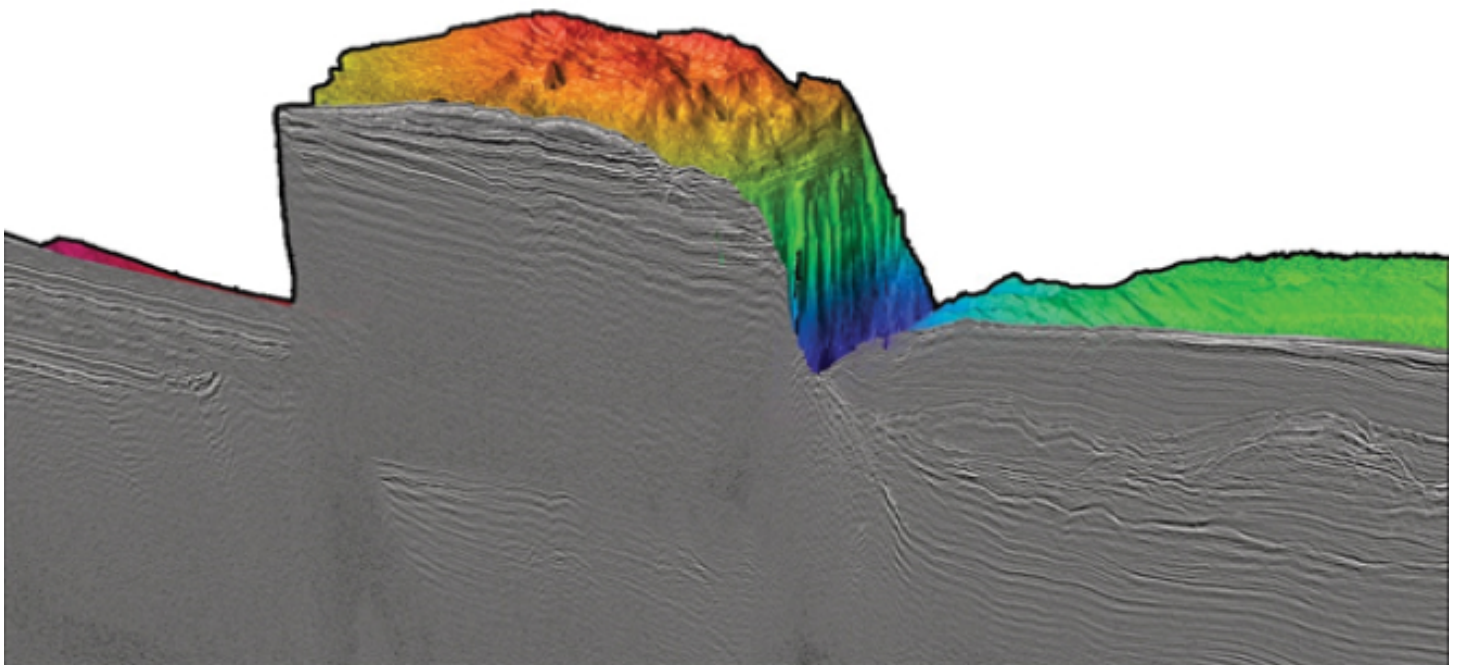
**R/V Marcus Langseth**

July 16 - August 19, 2023

Port Canaveral, FL - Charleston, SC

Principal Investigators:

Harm Van Avendonk (UTIG), Nathan Bangs (UTIG), and Anne Bécél (LDEO)



## **MGL2309 cruise summary:**

Expedition MGL2309 on the R/V *Marcus Langseth* was the first of two cruises in the Summer of 2023 on the Blake Plateau and the southern Carolina Trough. On the second cruise, MGL2310, scientists conducted an ocean-bottom seismic (OBS) refraction experiment. These two cruises were part of a project funded by the US National Science Foundation. We left Port Canaveral FL on July 16, 2023, and returned to Charleston SC on August 19. The project acronym is FLAME (FLorida Atlantic Margin Evolution).

The purpose of cruise MGL2309 was to acquire a rough grid of 2D seismic reflection profiles and other geophysical data, including swath bathymetry, gravity and magnetics data. The R/V *Marcus Langseth* is equipped with a 6600 in<sup>3</sup> acoustic source, and it can image reflectivity along profiles with a long streamer with 12.5 m channel spacing. We chose to use a 12-km long streamer, which allowed us to image deep structure, but also maintain a vessel speed over 4 knots on most transects. A 50 meter shot spacing, 12 meter depth of the streamer, and 10 meter deep acoustic array were selected to image basement structure.

Despite some setbacks with the seismic equipment, we collected the seismic lines that we needed to make this project a success. On board the ship we performed basic quality-control on the incoming seismic reflection data, and we carried out a basic processing workflow for all the new seismic lines. The quality of the shot gathers on the margins of the Carolina Trough and Blake Plateau are very high. Preliminary stacked and migrated seismic images show the detailed syn- and post-rift stratigraphy, seaward-dipping reflections that appear indicative of volcanic rifting, basement structure and Moho beneath the stretched continental margin and the adjacent oceanic crust. A comparison between the Jurassic rift structures of the margins of the Blake Plateau and Carolina Trough will give us a better understanding of the tectonic and magmatic processes during the opening of the central Atlantic Ocean basin. Seismic profiles across the margins also provided a wealth of information on older structures in the continental lithosphere, subsidence and passive margin development, sediment transport, and gas hydrates.

The science party on the R/V *Marcus Langseth* was composed of three Principal Investigators from the University of Texas Institute for Geophysics and Lamont-Doherty Earth Observatory. Furthermore, seven other sea-going participants, all from other universities, were recruited through a call-to-sail program. Two early-career scientists and five students were selected for this cruise based on their research experience and science interests. During the cruise they were involved in data acquisition, processing and interpretation of the incoming data, and a series of science discussions.

## Fact Sheet

### Cruise MGL2309 on the R/V *Marcus Langseth*

Project Acronym	Florida Atlantic Margin Evolution (FLAME)
Funding Agency	NSF Marine Geology and Geophysics
Departure from	Port Canaveral, FL: July 16, 2023
Return to	Charleston, SC: August 19, 2023.
Study area bounded by	28°N and 33°N, 80°W and 74°W.

### Acoustic source

Array	36 air guns, four strings
Maximum source volume:	6600 in <sup>3</sup> .
Depth:	10.0 meters
Offset behind center of navigation:	236.0 meters
Average pressure:	1941±11 p.s.i.
Shot spacing used:	50 meters

### Hydrophone streamer

Length:	12,000 meters
Depth:	12.0 meters
Number of channels:	960
Offset between first channel and source:	112.2 meters
Channel spacing:	12.5 meters
Record length	20.0 seconds
Sampling rate:	500 Hz

### Project Result

Total line kilometers:	4275
Profile kilometers	3841
Number of lines	20
Number of line sequences:	34
Number of shots:	88732
Number of XBT drops:	25

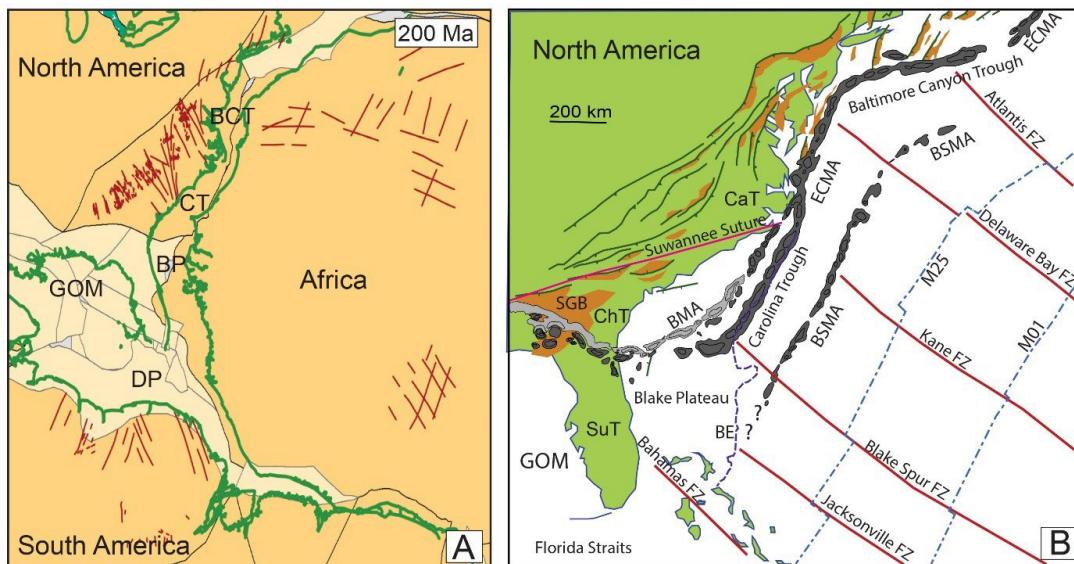
## Table of Content

Summary.....	1
MGL2309 Fact Sheet.....	2
Table of Contents.....	3
1. Introduction.....	4
2. Participants.....	7
3. Objectives.....	9
4. Seismic Equipment.....	12
5. Cruise Narrative.....	13
6. Shot Lines.....	21
7. Quality-Control Seismic Data.....	24
8. On-board Seismic Processing.....	28
9. Data Examples.....	29
10. Cruise Participation.....	33
11. Acknowledgments.....	34
<b>Appendix</b>	
A1. Protective Species.....	35
A2. Air-gun array and Streamer.....	42
A3. Serial Data.....	50
A4. Multibeam Bathymetry Processing.....	53
A5. 3.5 kHz Knudsen Mapping.....	55
A6. Gravity and Magnetics.....	56
A7. XBT drops.....	61
A8. Gulf Stream.....	65
A9. Weather.....	67
A10. Diagrams of Seismic Data Acquisition.....	

## 1. Introduction

Cruise MGL2309 on the Blake Plateau and the southern Carolina Trough is a marine multichannel seismic (MCS) reflection survey that aims to provide a picture of the deep structure and evolution of the Atlantic continental margins of the southeastern United States. The data gathered during this expedition, along with the ocean-bottom seismometer (OBS) data that will be collected during cruise MGL2310, place constraints on the syn- and post-rift stratigraphy and crustal structure of extended continental crust and igneous crust that formed after breakup between North America and northwest Africa, approximately 185 million years ago (Greene et al., 2017). The interpretation of marine seismic reflection and refraction data across these margins will help determine the role of tectonic extension and magmatism in continental rifting, and the state of the mantle during the formation of the oldest oceanic crust.

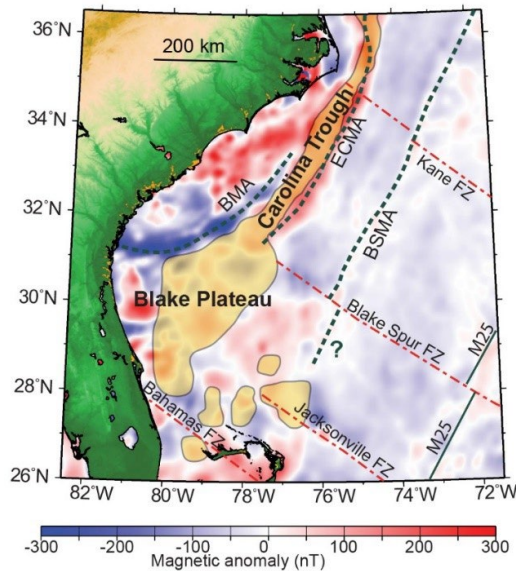
Many of the world's passive margins experienced extension, magmatism and subsidence at the time of rifting and early seafloor spreading. Normal faults, tilted strata, volcanic wedges may therefore be visible in the seismic data along the inner margin (Franke, 2013). In deeper water we may image rifted crust modified with igneous intrusions or exhumed continental mantle, depending on how much mantle melting took place before continental breakup (Shuck et al., 2019; Whitmarsh et al., 2001). These geophysical constraints on the deep structure of rifted continental margins are consistent with the geometry of active rifts. For example, in the East African rift system, normal faults accommodated thinning of the upper continental crust during the early stages of rifting (Fletcher et al., 2018), while geodetic and geological studies in the northern East African rift have found evidence that the rate of magmatic diking can account for regional plate extension in the final rift episode (Wright et al., 2006). Since the products of continental rifting are well preserved in the deep structure of passive margins, we can infer the relative importance of faulting and magmatism in deep seismic reflection images.



**Figure 1.1.** A) Configuration of the margins of the southeastern United States before the breakup of Pangea. GOM=Gulf of Mexico; DP=Demerara Plateau, BP=Blake Plateau; CT=Carolina Trough; BCT=Baltimore Canyon Trough. Red lines mark CAMP volcanic dikes. B) Geometry of North American tectonic terranes, onshore rift basins (orange), magnetic anomalies (gray), and fracture zones (red). CaT=Carolina Terrane; ChT=Charleston Terrane; SuT=Suwannee Terrane; ECMA=East Coast Magnetic Anomaly; BMA=Brunswick Magnetic Anomaly; BSMA=Blake Spur Magnetic Anomaly; BE=Blake Escarpment; SGB=South Georgia Rift Basin.

Rifting along the eastern flank of the Appalachian mountains started with extensional deformation in broadly distributed basins around 230 Ma (Withjack et al., 2013), and it initially progressed slowly. The final rift episode that led to continental breakup offshore the southeastern United States followed soon after the Late

Triassic (201 Ma) flood basalts of the Central Atlantic Magmatic Province (CAMP) (Marzoli et al., 2011). Because of the fortuitous timing (Schlische et al., 2003), it has been suggested that either high mantle temperatures, mantle dynamics, or the presence of mantle-derived melts in the extending lithosphere ultimately led to the breakup of Pangea (Dalziel et al., 2000; Wilson, 1997). However, there is no geophysical or geochemical evidence that this early Jurassic rift was caused by a plume (Whalen et al., 2015).



**Figure 1.2.** Geometry of Blake Plateau, Carolina Trough rift segments on the offshore EMAG2 magnetic map (Meyer et al., 2017). Onshore color scheme represents topography. Orange overlays on the magnetics represent areas where SDR’s have been reported. Note that the continuation of the ECMA and BSMA south of the Blake Spur Fracture Zone is tentative. M25 is the oldest central Atlantic magnetic anomaly that is prominent (Greene et al., 2017). Older magnetic isochrons lie in the Jurassic Magnetic Quiet Zone and are more difficult to identify.

The passive margins of the southeastern United States formed after North America and Africa separated (Figure 1.1). An interesting characteristic of these margins is that they decrease in width from south to north (Dillon & Popenoe, 1988). The Carolina Trough is a narrow, margin-parallel basin where volcanic wedges have been imaged as seaward-dipping reflections (SDRs) along the East Coast Magnetic Anomaly (ECMA). This geometry suggests that rifting localized rapidly in offshore basins, and led to lithospheric necking and breakup. To the south, the Blake Plateau forms a wider, circular sedimentary basin. Seismic reflection and refraction studies from the 1960s to the 1980s show evidence that rifting was magma-assisted on both Blake Plateau and the Carolina Trough, but extension did not localize in Blake Plateau (Austin et al., 1990; Holbrook et al., 1994). The difference in rifting style may have resulted from a contrast in mantle temperature or from a difference in the mechanism of melt delivery. The preexisting lithospheric structure may also play a role, since Blake Plateau lies adjacent to the relatively undeformed Gondwanan Suwannee terrane, whereas Carolina Trough lies alongside the Carolina terrane, which was more intensely sheared during Paleozoic accretion to Laurentia.

To determine the mode of crustal thinning and the role of mantle melts in rifting, we use the seismic source and long streamer of the R/V *Marcus Langseth* and OBSs of the national Instrument Center (OBSIC) to gather marine seismic reflection and refraction data along key seismic transects across Carolina Trough and Blake Plateau. With new seismic data we can investigate to what degree structural inheritance of the rifting continental crust and/or a thermal anomaly in the mantle contributed to contrasting styles of rifting offshore the southeastern United States.

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## 2. Cruise Participants



**Figure 2.1.** Group photo of the participants in cruise MGL2309

### Officers and crew

Mark Landau	Captain
David Wolford	Chief Mate
Francis Loziere	Second Mate
Joselyn White	Third Mate
Gerald Butler	Chief Engineer
Samuel Romey	1 <sup>st</sup> A/E
Vincent Rodriguez	2 <sup>nd</sup> A/E
Tristan Boro	3 <sup>rd</sup> A/E
Rodolfo Florendo	Oiler
David Hall	Oiler
George Cereno	Bosun
Clifford Lattish	AB
Bronwyn Denard	AB
Nicole Morse	OS
Marcialleo Rillera De Guzman	OS
James Davis	Steward
Ricardo Rios	Cook

### **Langseth technical team**

Cody Bahlau	Chief Tech
Gilles Guerin	Tech
Riley Lopez	Tech
Klayton Curtis	Tech
Tawfik Naas	Tech
Sara Pierson	Tech
Claire Mayorga	Tech
Aaron Martin	Tech
Josh Kasinger	Chief Mech
Brian Agee	Mech
Peter Bolt	Mech
Leonid Ometcinskii	Mech

### **Protected Species Observer team:**

Amanda Dubuque	Lead-PSO
Beatrice Cotrim	PSO
Gloria Ponce	PSO
Pablo Curiel	PSO
Avinash Maharajh	PSO

### **Science party**

Harm Van Avendonk	University of Texas Institute for Geophysics	Chief Scientist
Nathan Bangs	University of Texas Institute for Geophysics	Co-Chief Scientist
Anne Bécel	Lamont-Doherty Earth Observatory	Co-Chief Scientist
Chiara Amadori	University of Pavia	Scientist
Savas Gurcay	University of Alabama	Scientist
Susie Adams	University of North Carolina at Wilmington	Watchstander
Jue-Ying Chen	Natioanl Taiwan University	Watchstander
Anastasiia Krysova	The Ohio State University	Watchstander
Bright Osuagwu	Midwestern State University of Texas	Watchstander
Adriana Piña	California Institute of Technology	Watchstander

### 3. Cruise objectives

The objective of cruise MGL2309 was to seismically image the deep structure of the continental margins of the southeastern United States, from the inner margin to the deep seafloor east of the BSMA. This study builds on important data sets that have been collected in the 1980s on the southern Carolina Trough (Austin et al., 1990; Holbrook et al., 1994; Oh et al., 1991). Seismic studies of the Blake Plateau showed basement at depths of 12 km (Sheridan et al., 1981), but its composition and origin are not clear from the existing active-source seismic data. The stratigraphy on the landward side the basin has been drilled in Cost well G-2 (Scholle, 1979). The seismic images from long-offset marine seismic reflection lines across Blake Plateau and the southern Carolina Trough will help define the stratigraphy, crustal structure, and the nature of the transition between these two rift segments.

Currently the best constraints on the crustal structure of Blake Plateau come from gravity and magnetic data. The ~250 nT positive East Coast Magnetic Anomaly (ECMA) does not run as far south as Blake Plateau, but the -250 nT negative-polarity Brunswick Magnetic Anomaly (BMA) extends from Blake Plateau westward across the coast into Georgia. Gravity data suggest that the crust is possibly 15 km thick, much thicker than oceanic crust (Hutchinson et al., 1983). Two hundred kilometers east of the ECMA lies the weaker (~50 nT) Blake Spur Magnetic Anomaly (BSMA). Seismic imaging of the deep crustal structure of the magnetic anomalies was therefore an important science objective of cruise MGL2309.

The analysis and interpretation of the ENAM seismic data set near Cape Hatteras (Bécel et al., 2020) showed a strong contrast in basement roughness near the BSMA. This boundary may mark the onset of focused seafloor spreading after the culmination of continental rifting in the western Atlantic. One of the objectives of cruise MGL2309 was to examine the variation in crustal structure across BSMA outboard the southern Carolina Trough.

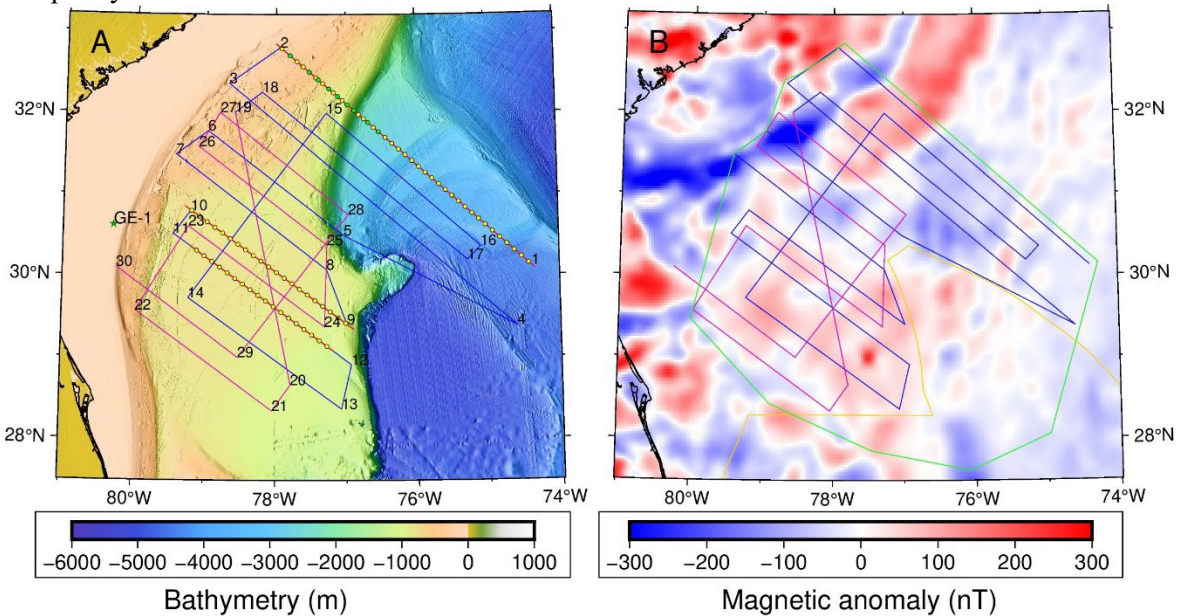
Outboard the southern Carolina Trough, drift deposits of Blake Ridge form an important gas hydrate province (Holbrook et al., 2002). It has been suggested that Blake Ridge has modest basement relief (Dove et al., 2007), though the top of basement here has not yet been imaged clearly. The data from cruise MGL2309 add seismic constraints on sediment flux across the shelf and along the margin, and they also provide evidence of past erosion from scouring by ocean currents.

We planned to achieve these science objectives with a rough grid of 2-D marine seismic reflection lines and some marine seismic refraction lines (Figure 2.1). Most of these lines were oriented along flow lines to determine rift structures with best resolution. One or two tie lines are necessary to correlate stratigraphy on the margins, and to examine along-strike continuity of the major magnetic anomalies.

To gather the marine seismic reflection and refraction data we planned for two cruises, first an expedition to obtain marine seismic reflection data with the *Langseth's* 12-km long streamer (MGL2309), followed by an OBS refraction cruise (MGL2310). We did not have permission to work in the EEZ of the Bahamas, so we designed a series of long-offset marine seismic lines in US and international waters to meet our science objectives.

- To record the full Langseth acoustic array, 36 air guns with a total volume of 3600 in<sup>3</sup> on a 12-km long streamer on a rough grid of long-offset transects with a cumulative length of 3,500 km. Though dip lines likely capture most of the structures related to tectonics, magmatism and sediment transport across the margin, we considered margin-parallel lines also to be critically important.
- The shot spacing was set at 50 meters, appropriate for seismic imaging of the deep-lying basement. Streamer (12 m) and acoustic array (10 m) depth were also adjusted specifically for imaging crustal structure.
- To monitor the incoming seismic data for quality control, to provide timely feedback to the Langseth science officer during operations.
- Preliminary seismic processing of the reflection data to evaluate the potential to meet science goals.

- Collect underway geophysical data such as multibeam, Knudsen 3.5 kHz data, gravity and magnetic data.
- Archive all geophysical data, document the data acquisition history, navigation, and any report quality issues.



**Figure 3.1.** A) Bathymetry map of the Blake Plateau and Carolina Trough. Blue lines are the primary seismic lines planned for cruise MGL2309, with waypoints showing the order of data acquisition. Purple lines are the secondary (contingency) seismic lines planned for the cruise. The three coincident refraction lines are in red with new OBS locations in yellow, and existing instrument sites (Holbrook et al., 1994) in green. B) Magnetic anomaly map of the study region. Primary and secondary MCS lines as in A). The orange line shows the Extended Economic Zone of the Bahamas, and the green polygon marks the permitted area (see Appendix A1).

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## 4. Seismic Equipment

Here we summarize the seismic equipment and acquisition parameters for the survey.

- **Acoustic source:** We used the full 6600 in<sup>3</sup>, 36-element, 4-string array of the *Langseth* towed at a 10 m depth for MCS shooting of all the primary profiles and turn lines. The strings were separated by 6m. An air pressure of 1941 psi +/- 11 psi was used to fire the air-gun array. As mentioned in the cruise narrative (see Section 5), we had some issues with the guns and for some of the profiles or part of the profiles, data were acquired with a smaller volume (see Appendix A2). The air-gun array (Center of source - COS) was towed 236 m behind the ship's navigational reference point (NRP-COS) for sequences 01 to 07 and 276.6 m for sequences 08 to 34. The airgun array was pushed back at the end of sequence 07 to avoid interference between the lead-in and the gun array. 11 near field hydrophones (NFH) were installed on the gun array at the beginning of the survey. Some of them failed during the survey and by the end of the cruise, we had 8 near field hydrophones working (i.e. 2 per string). The hydrophone data were included in the SEG-D data as auxiliary traces. There were 6 auxiliary channels for sequences 01 and 02 and 12 auxiliary channels for sequences 03 to 34. The airgun array is also equipped of 8 GPS pods. Some of the GPS became intermittent or stopped working throughout the survey.
- **Streamer:** We used the 12-km long streamer of the *Langseth* towed at 12 m depth for all the primary profiles and turn lines. 47 birds were attached to the streamer to control its depth. The streamer includes 960 hydrophones spaced at 12.5m. The distance between the Center of the Source, COS) and the Center of Near Group (CNG) was 112.2m for the first 7 sequences and 112.6m afterwards. The shot point interval was 50 m for all MCS shooting. A sampling interval of 2 ms was used for all MCS shooting. The record length was 20 s on all profiles. A SEG-D standard polarity was used. A 3 Hz digital low-cut filter and a 200 Hz High cut filter with a slope of 270 dB/octave were applied to the data. Between Line 1004 and Line 1007, 41 meters was added to the lead section of the streamer (see Section 5), adding to the distance between Center of Navigation and the Center of Source. Between Line 1007 and 1009, 2m was added to the depth rope from the front streamer float down to the lead-in as the first two birds, installed before the first section were in general too shallow. Diagrams of the acoustic source and streamer geometry are provided in Appendix A10.

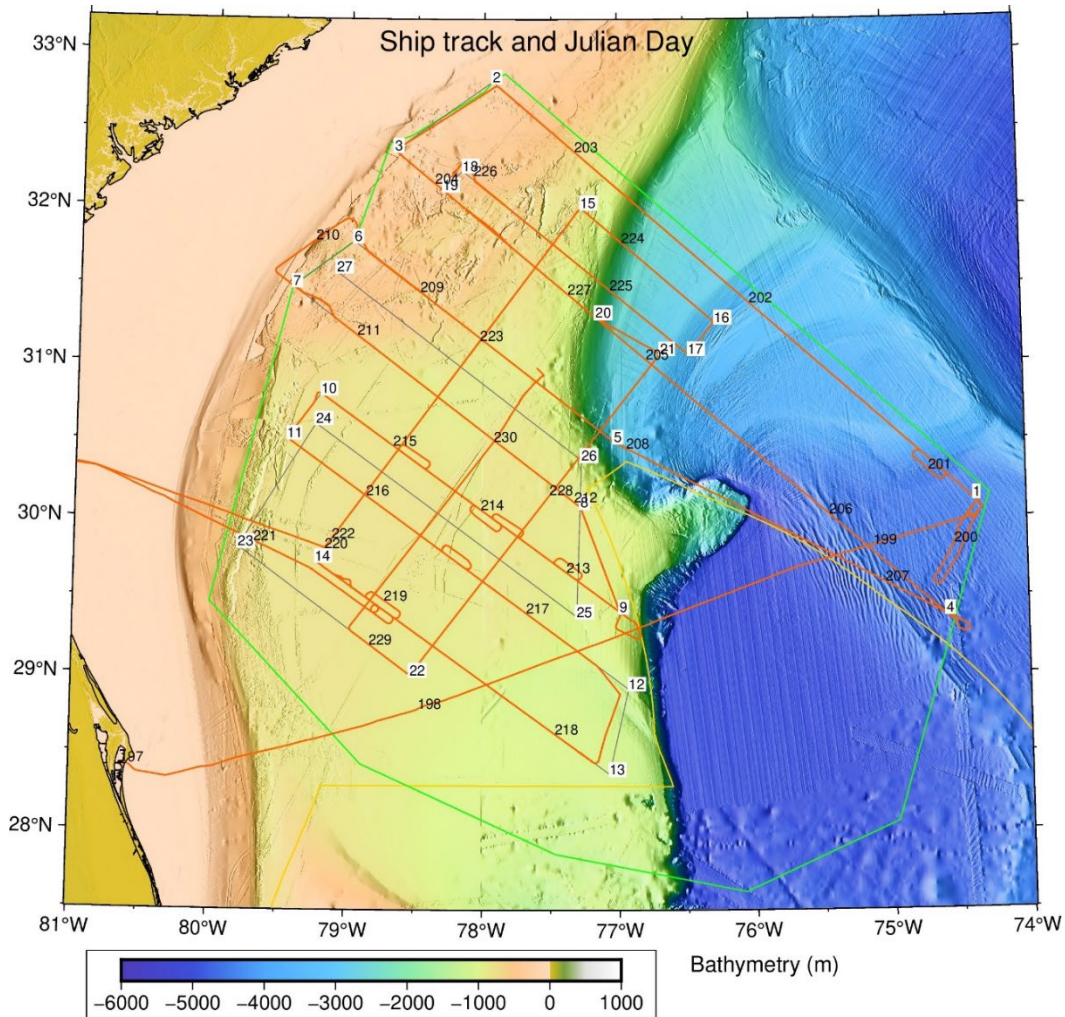
### Acquisition parameters

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Source volume	6600 cu.in
Source depth	10 m
Pressure	1950 psi
NRP-COS	236m (SEQ 01-07) / 276.6 (SEQ 08-34)
NRP-CNG	348.2m (SEQ 01-07) / 389.2 (SEQ 08-34)
Auxiliary channels with NFH data	6 (SEQ 01-02) / 12 (SEQ 3-34)
Streamer length	12 km
Group interval	12.5 m
Number of hydrophone/channels	1200
First offset	112.2m (SEQ 01-07)/112.6m (SEQ 08-34)
Sampling interval	2 ms
Record length	20 s

## 5. MGL2309 cruise narrative

Cruise MGL2309 started in Port Canaveral on July 16 (Julian Day 197), and it ended in Charleston on August 19 (Julian day 231). The expedition was by all means successful. There were some equipment challenges along the way, but with the hard work of the officers, crew and technical staff on the R/V *Marcus Langseth*, high-quality seismic reflection data kept coming in. Throughout the survey, the weather was favorable. This narrative provides the daily perspective of the science party.



**Figure 5.1.** Bathymetry map with MGL2309 cruise track in dark orange. Light orange line marks the Bahamas EEZ boundary. The green line shows the area permitted for seismic work (Appendix A1). The cruise track is annotated with the start of each Julian Day. The numbers on white labels represent original track waypoints.

**JD 194 (Th Jul13):** The science party arrived in Port Canaveral for the start of the Blake Plateau marine seismic reflection imaging cruise. By 20:00UTC, several workstations for processing seismic reflection data were brought on board.

**JD 195 (Fr Jul14):** Around 16:00 the science party settled in their quarters, and the workstations and disk drives were set up in the seismic lab. The Langseth team was still bringing in a crew member, and there was critical work left to be done in the engine room. We therefore postponed the departure time to JD 197.

**JD196 (Sa Jul15):** The MGL2309 science party was getting ready for departure.



**Figure 5.2.** A) Langseth at the dock in Port Canaveral. B) A rack with digi-birds ready for deployment. C) Science Officer Cody Bahlau explains the upcoming streamer work, while the tailbuoy is waiting to go overboard.

**JD197 (Su Jul16):** We left the dock in Port Canaveral at 12:10. By 15:10 we reached water deeper than 100 meters, where we turned on the sonars. The weather was sunny and clear. Fire and abandon ship drill at 17:30.

**JD198 (Mo Jul17):** We entered the Bahamas Economic Exclusive Zone at the eastern edge of Blake Plateau at 8:58, and turned off the sonars. At 13:36 we deployed the tailbuoy, and slowly continued east while deploying the streamer. We had perfect weather and calm seas. The sections that we used for the 12 km streamer came from two different reels. The first half, which had been used in a recent high-resolution seismic cruise, needed adjustments to the weight of most sections. By 20:18 we reached international waters, and turned the sonars back on. The sections that would make up the inner 6 km of the streamer, had not been used for several years. Fortunately, those last added sections deployed with little effort. The last digi-bird was deployed at 22:27.

**JD199 (Tu Jul18):** At 5:22 the head float of the streamer was in the water. Next, by 6:53 the magnetometer and the Passive Acoustic Monitoring array were deployed. Hence the PSO pre-watch started up, and the mechanical team got busy on the gun deck. The airgun deployment went slower than expected, but by 10:44 the last gun string was in the water. By 10:48 we ramped up the acoustic array, while we rapidly approached Waypoint 1. Unfortunately, one of the gun-string GPS and two air guns were not ready to perform. We slowed down to 3 knots to allow for some repairs, but there was just not enough time. At 11:19 we decided to deactivate the acoustic source, and recover the air guns while we circled back counterclockwise to the start of the line. This would give the gunners time to service the acoustic array. As we approached the start of the line a second time we again slowed down to 3 knots, but the work on the acoustic array was still not finished. We steered away portside from the line a second time, but this time the tail of the streamer suddenly dove to 40 m. This triggered a digi-bird streamer recovery device (SRD), and the tail end of the streamer came to the surface. We decided that it was best to replace the last few sections and the last bird. The retrieval of the streamer started at 20:00.

**JD200 (We Jul19):** Recovery of the streamer proceeded quickly. By 7:00 the tail of the streamer had already been fixed, and the streamer was back in the water again. The sea state was barely 1.0 m. By 10:45 the air guns were in position, but we were not yet on our first seismic transect. We ramped up the acoustic source at 12:00, and shot line P1test until 13:15. By 13:40 we started line P1001. Unfortunately, by 20:40 we noticed a loss of air pressure in the guns, indicating a leak. The gunners recovered gun string 3 and 4 to fix an air leak in string 4. We circled back for 8 hours while this issue was fixed. We shot the short line P1TST2 while we circled back. Gun string 4 was fixed at 22:52.

**JD201 (Th Jul20):** The circle (P1TST2) was completed at 1:43. At 2:22 we were back on P1001, and continued with sequence 4 (P21001). We were gathering fine data, though one small air gun was down. At 13:42 the streamer suddenly lost power and did not record 40 shots between 9448 and 9492. Recycling the

power on the Sercel system brought the streamer back on-line. We decided to accept the gap of 40 shots (2.0 kilometers), and not reshoot this section of the Line P1001. At 7:18, a small air leak was reported in gun string 2, but since it did not get worse we would keep it in the water until the end of the line. At 15:44 we launched the first XBT for the cruise, which recorded to a depth of 894 m. We continued shooting line P1001 without further issues. The winds changed from calm to moderate (20 knots), but the sea state stayed at 1 m.

**JD202 (Fr Jul21):** As the day progressed we started entering the Gulf Stream from the southeast along Line P1001. The streamer feathering angle increased gradually from 10° to 40°, and briefly more than 70°. The Gulf Stream occupied just a narrow section of line P1001, roughly 100 km southeast of the end. Here a small amount of electrical leakage (4-5 mAmp) was reported on the streamer. In addition, low-frequency (~6 Hz) noise was traveling backwards from the front end of the streamer, possibly strumming noise. These issues did not need to be remedied immediately. We reached the end of the line at 10:01. At 18:56 and 20:18, XBT #2 and XBT #3 were launched successfully at the edge of the continental shelf. At 22:56 more electronic noise was reported in the streamer at shot 14330. This cross feed was reduced once the tail buoy current was turned off.

**JD203 (Sa Jul22):** After turn on line 1002 at 10:47, first gun strings 1 and 2 on board to fix air leaks, air-gun GPS, and electrical leaks. Subsequently, gun strings 3 and 4 came on deck for maintenance as well. Gun 3 of string 4, which had not been activated for much of line P1001, was also back on. The Langseth team added more weight to the lead section of the streamer to avoid collision with the acoustic source array. At 15:40 the streamer was pulled closer to the vessel for a short time to add the weight, and shooting stopped for ~15 minutes. The electrical leakage on the streamer had increased to 6-8 mAmp. By 18:00, and before the end of line P1002, gun strings 3 and 4 were deployed again, so the full 6600 in<sup>3</sup> acoustic source was in operation. By 19:47 we reached the end of Line P1002, and started the inside turn to Line P1003.



**Figure 5.3.** A) Tail buoy goes into the water. B) The digi-bird on the deck is ready to be attached to the streamer. C) Shift change on the streamer deck. The check sheet shows which streamer sections and digi-birds have been deployed.

**JD204 (Su Jul23):** In the early hours we steamed southeast on line P1003 across the continental shelf through the Gulf stream. Between 3:00 and 8:00 the strong currents, as fast as 4 knots, presented several challenges. The streamer feathering angle was large (more than 40°) as expected. The streamer tension peaked to 7000 lbs for a short period, and this caused significant noise on large sections of the streamer. The ship also had difficulty maintaining position, and strayed off the planned shot line over a significant distance starting at 03:11. Unrelated to the Gulf Stream, we also experienced more electronic noise in the shot records, which overwhelms the signal on some channels, but also creates short noise bursts at certain times across the hydrophone array. At 17:00 the Langseth technical team decided to address this cross-feed noise problem, and fortunately it was immediately under control after one of the two power lines of the streamer was shut down. The shot records now looked clean, with the exception of some dead channels. Now that we were settled into a routine, the science party held a first group meeting to discuss a science paper. At 20:08, XBT #5 was launched.

**JD205 (Mo Jul24):** A relatively uneventful day. As we continued on P1003 in deeper water, we were no longer had the Gulf Stream come in from starboard side. The *Langseth* steamed into a weaker current, which slowed us down to 3.8 kts SOG. The incoming seismic data quality was now very good. The students on board were getting busy processing the seismic reflection data from line P1001. At 20:00 the *Langseth* encountered a fishing vessel in its path. The bridge was able to make contact, and divert the fishing vessel around our towed seismic gear.

**JD206 (Tu Jul25):** We gathered excellent seismic reflection data on the east end of line P1003. The *Langseth* was no longer going into current, and COG increased to over 4.0 kts. The weather continued to improve, and by day break the sea surface was glassy blue, and the skies were clear. The air temperature would rise to 35°C. The last shot on the line was at 13:27. Because the turn to line P1004 was a very sharp angle, we decided to make a wide outside turn. This would bring the R/V *Marcus Langseth* outside the permitted area for a few hours, so the airgun source was shut down for the turn. As we started coming out of the turn at 17:00, a workboat with four people was launched to inspect the towing of the air-gun array and streamer. While they were filming the gear under water, the *Langseth* was entering the permitted area again, and we started a half-hour ramp-up of the acoustic source. First shot of Line P1004 was at 17:30. The workboat came back to the *Langseth* soon afterwards. The air-gun source and streamer were working well, but the lead section of the streamer was considered too close to some of the guns.

**JD207 (We Jul26):** The weather was good, and the air gun array and streamer were performing without any problems all day. We also made good speed on line P1004 due to favorable currents. We crossed over the tip of Blake Spur, where we launched an XBT at 15:18. In the deep water of the Blake-Bahamas basin this line grazes the Bahamas maritime border (at the narrowest approach, the border lies 4 km to the south west), so we reduced the multibeam on the portside to stay within our permitted area.



**Figure 5.4.** A) Mechanics at work on the gun deck. Deployment of the last air-gun float. B) View of the deployed air guns from the work boat. C) Air guns firing underwater.

**JD208 (Th Jul27):** At 1:11 we reached waypoint 5, where we made a slight starboard turn to steam perpendicular towards the margin ahead of us. We continued to make good speed (4.5 kts SOG) as we came onto Blake Plateau. At 12:09 we did a successful XBT launch here. By 15:17, the Gulf Stream started to become noticeable, though the feathering angle was just 10° at this time. The weather was still very calm, and not as hot as the days before. The quality of the incoming marine seismic data was very good.

**JD209 (Fr Jul28):** As we approached the end of line P1004, the Gulf Stream, as strong as 5 kts and coming from the southwest, was making data acquisition very difficult. The feathering angle increased to 54°. Our speed slowed down to 0.5 kts before we reached the end of the line. At this slow speed the time interval for shots spaced 50 m approached 2 minutes. We therefore decided to change direction to a more northerly course, where we kept shooting seismic data across the Brunswick magnetic anomaly until we left our permitted area. At 16:45 we reached the end of Line P1004. Outside the permitted area we started a gradual portside turn towards the coast, which would eventually get us to waypoint 7. At 18:30 the *Langseth* technical team increased the distance of both the lead to the streamer and air-gun array by 41 meters, which should help the streamer to ride deeper than the air guns, and avoid collisions between the gear. After this procedure we noticed at 19:10 that the streamer tension spiked briefly to 8900 lbs, and stayed at almost 8000

lbs, even when ship speed was reduced to 3.5 kts through the water. For the next hour, streamer tension would remain as high as 6000-7000 lbs. Since there was a possibility that the streamer had snagged an object we brought in air-gun strings 1 and 2, and we were prepared to bring in the streamer. However, as we came out of the Gulf Stream, and as the current decreased to 1.5 kts, the streamer tension dropped back to 5000 lbs. This suggests that currents rather than a snagged object had caused the rise in streamer tension in the hours before. We therefore deployed gun strings 1 and 2 again, and continued course to waypoint 7 with a wide portside turn west of our permitted area.

**JD210 (Sa Jul29):** At 06:07 we approached Waypoint 7, Line P1007, and started the PSO pre-watch. At 7:09 we started gathering data on Line P1007 with a ramp-up procedure that completed by 8:07. At 10:48 an XBT was launched at the start of the line. Unfortunately, the strong NNE Gulf Stream current, close to 5 kts, was slowing down the *Langseth* SOG to 0.5 kts along the first portion of line P1007. At 13:04 we decided to change to a 10° more northerly course, which worked better in the strong current. Our SOG increased to 1.2 kts. The *Langseth* changed from the portside to starboard compressor at 13:40, which caused us to lose a few shots (40187-40192). A lightning strike right in front of the R/V *Marcus Langseth* at 15:58 disabled the magnetometer, destroyed the weather station (air temperature and wind speed), and caused the air guns to misfire for a moment. After its connections were repaired, the magnetometer was deployed again. The *Langseth* was eventually able get back on the planned shot line, while the currents dropped to 3 knots. At 18:23, the *Langseth* acoustic source was stopped because of a turtle sighting, but ramped up again after 15 minutes. As the day progressed the *Langseth* was finally able to reach SOG up to 4 knots on Line P1007.

**JD211 (Su Jul30):** We continued shooting along Line P1007, southeast towards the Blake Escarpment. The SOG was 4.3-4.6 kts, initially just slightly low due to currents. The weather was good, and the guns and streamer were performing well. In the afternoon there was a sighting of bottlenose dolphins, but this did not require a shutdown.



**Figure 5.5.** A) PSO tower. B) The air guns are firing on a quiet morning.

**JD212 (Mo Jul31):** At 0:40 we reached Waypoint 8, where we turned slightly starboard (SE course), but continued collecting seismic data on the track as line P1007. At 5:32 one of the two Vaisala weather stations was back on line. Due to the currents, the ship speed was relatively high. The last shot of Line P1007 (sequence 8) was fired at 09:48. At 10:14, air gun strings 3 and 4 were brought on board to fix a small air leak. By 11:00 the technical team also started to add to the lead section to allow the streamer to ride deeper near the acoustic array. During maintenance the *Langseth* made an outside turn towards Line P1009. At 14:00 it was time for a group photo with the science party and much of the *Langseth* tech team, PSO's and crew. At 15:37 we started Line P1009, which coincides with OBS Line 2 on Blake Plateau, going west.

**JD213 (Tu Aug01):** We started the day shooting seismic reflection data westward on P1009, which coincides with OBS Line 2. This line was a high priority for the cruise, but despite the good weather we had three technical setbacks. At 02:00 gun string 3 sprang an air leak, and we decided to circle back while repairing the acoustic source. At 5:31 we were shooting Line P1009 again with the full acoustic array, and we covered some distance. But at 14:41 we had an air leak at string 3 again, more near the front of the array now. We tried to stay on course, and hoped that it could be a quick fix, but since it took over an hour to bring in the guns string and repair it, we decided to circle back a second time. The gap with just 4,950 in<sup>3</sup> airgun

array volume coverage would otherwise have been 5-6 km, which we considered too much. At 20:25 we continued on Line P1009 again. We had a barbecue on the bridge deck, which was enjoyed by all on board. At 23:35 we developed a third air leak on the same day. This time it was on gun string 1, so we needed to bring strings 1 and 2 in to start the repairs.

**JD214 (We Aug02):** The day started with a turn away from Line P1009, to bring in gun strings 1 and 2 for repairs. We shot this turn line P1TST4 with half the air-gun array (3300 in<sup>3</sup>). As we came back on Line P1009 again at 5:55, we went through a full ramp-up, and reached the full volume (6600 in<sup>3</sup>) at shot at 6:16. Fortunately, the new sequence (P41009) was much less eventful, and we made much better progress on line P1009 than the day before. However, at 15:26 we sprang an air leak in string 4 at Shot 59757, and started to circle back for repair and reshoot. By 21:06 we were back on line after a ramp-up for sequence 15, P51009.

**JD215 (Th Aug03):** We continued west on P1009 with the 36-gun source array. By 7:52 we reached the end of the line. We had anticipated that the landward end of this OBS/MCS line would be difficult again because of the Gulf stream, but it turned out fine. We turned south on the short line P1010, and acquired MCS for a good 5 hours before we had another air leak on string 2 at 13:49. We continued with three gun strings (4950 in<sup>3</sup>). By the time we reached the turn to Line P1011, string 2 was ready to deploy again. At 15:46 we started this last MCS/OBS line with sequence 17. XBT #12 was launched at 18:51. The last shot of the day was 65386.

**JD216 (Fr Aug04):** Shooting Line P1011 initially progressed smoothly. At 01:31 and 05:48, XBT 11 and 12 were launched. The weather was great. At 9:32 we developed an air leak at gun 4 of string 1, bringing back the active volume to 6420 in<sup>3</sup>. We brought strings 1 and 2 in for repair by 9:52, and at 10:36 we ended the sequence at shot 67180 with 18 guns, 3300 in<sup>3</sup>. At 12:13, string was repaired and we started to ramp up the source at 15:31 for line sequence 18. By 15:52 the full acoustic source was active again, and we continued gathering seismic data along Line P1011 eastward.

**JD217 (Sa Aug05):** Early in the day at 05:47 we launched XBT 13. By 07:11 we encountered a fishing vessel on our track of P1001, but fortunately we were already east of the planned OBS deployment, so we changed course 15 degrees starboard to avoid fishing lines. At 9:22, String 3, gun 9 disabled after it failed to fire. 35 guns at 6380 in<sup>3</sup>. At 10:20 we encountered another fishing vessel. To avoid tangling the streamer in fishing gear we turned away from line P1011 earlier than planned with another 50° starboard turn, towards a position west of waypoint 13. The line finished at 10:37 (SP 73984). At 11:05 we started line P1012, going south, with sequence 19. Because of the presence of fishing vessels near the Blake Escarpment, we would also turn 10-20 km before we reached Waypoint 13. At 15:45 we disabled gun string 3 for repair at shot 75757. At 17:46 we ended this tie line west of the planned track, largely due to the nearby fishing vessel. Our focus now was on airgun repair for Line P1013. At 18:04 we started P11013 with a 4950 in<sup>3</sup> array, but at 20:49 the gunners had completed the repairs, and we had 36 guns firing at 6600 in<sup>3</sup> again. The last shot of the day was 77959.

**JD218 (Su Aug06):** In the morning we continued shooting along Line P11013 in good weather. A first XBT ((#14) was launched, and a second XBT would follow later in the day. Thunderstorms developed around noon local time (15:51 UTC). A few lightning strikes behind the ship were visible as electronic cross-feed on the shot gathers, but without lasting effect. We gathered good data until 20:01 when we lost power on the gun-firing control box behind the seismic lab. It was replaced by 20:22, and for half an hour we gathered data with 35 guns (6560m in<sup>3</sup>). However, at 20:55 we had another air leak in string 3, and we decided to circle back for repair, and to also reshoot the portion of the line where the gun firing control box failed. By 21:38 we stopped acquisition. By 23:46 we started a soft ramp-up for a test line (P1TST5).



**Figure 5.6.** Seismic lab while the R/V *Marcus Langseth* is in production.

**JD219 (Mo Aug07):** At 1:53 the ramp-up on test line P1TST5 was completed. At 02:26 we resumed shooting line P1013 (sequence 22, P21013), but it was clear that we did not have enough air pressure. An air leak in string 2 was discovered at 3:21, and by 4:49 we circled back for a second time. Subsequently, after repairs we did another test line P1TST6 at 06:07 start, while looping back to P1013. At 07:08 we were back on Line P1013 for the third time, and sequence 24 (P31013) started at 9:25. At 13:00 the chief engineer gave us a tour of the engine room. At 17:19 we reached the end of Line P1013 (Waypoint 14). In the seismic lab we had a good discussion of the first seismic processing results on this cruise. One of the Langseth members had developed a non-emergency medical issue that required an evacuation. We therefore started to recover the guns and streamer, which proceeded quickly. The weather was calm and a bit warm.

**JD220 (Tu Aug08):** At 0:43 the streamer was on board the *Langseth*, and we set course to Jacksonville. We arrived there at the pilot station for a crew exchange at 14:02, and turned around to transit back to Waypoint 14. By 16:49 we reached deep water again and turned on the sonars.

**JD221 (We Aug09):** At 2:39 we back on Line P1013 for streamer deployment, while the *Langseth* was on a course back to waypoint 14. By 5:09, the streamer section that had caused electronic noise on Line P1003 earlier in the cruise was identified and exchanged. By 12:34 the head float of the streamer was in the water. After the magnetometer and PAM, airgun deployment started at 13:24. The front cluster of string 3 needed to be rebuilt after an air leak, which delayed the readiness of the acoustic source. The magnetometer, which had always been reliable until now, was now also showing erratic data. Fortunately, the magnetometer problem resolved itself in an hour. By 18:08, the Langseth team decided that the front cluster of string 3 could not be repaired in time, and we started shooting the test line P41013 with 34 guns, 5880 in<sup>3</sup> before turning on P1014 at 21:11. The *Langseth* progressed slower than expected here due to the currents, but we had no problems collecting data. At 23:33 we launched XBT #16.

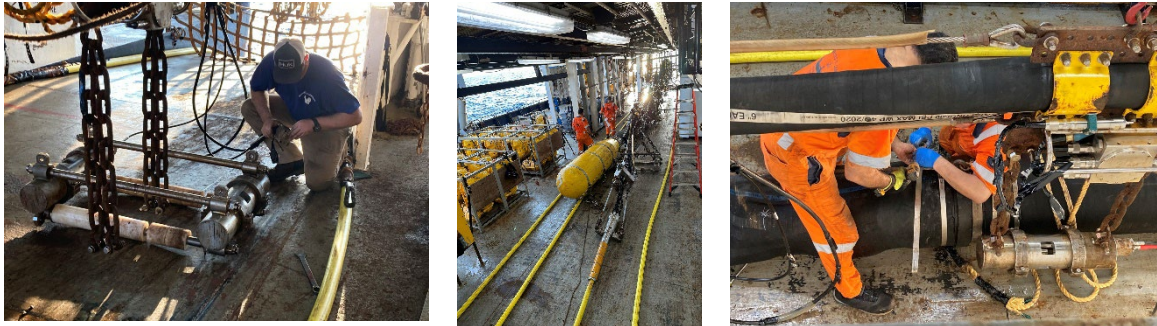
**JD222 (Th Aug10):** We continued shooting northward along P1014 with the full acoustic array, minus the front cluster of gun string 3. At 16:30 we had our second fire and abandon ship drill. The weather was calm and the seismic equipment was performing well. Unfortunately, we were going against a 1 knot current, which slowed us down. In the seismic lab all watchstanders had been very busy processing the seismic reflection data, and at 17:30 we had a good discussion of the preliminary results.

**JD223 (Fr Aug11):** We continued shooting northward along P1014 with the same 5880 in<sup>3</sup> source array. At 18:34 we finished the line, and turned east on P1015. We had originally planned this line to be longer, but after seeing the excellent seismic processing results of lines P1001 and P1003, we decided that a shorter<sup>P1015</sup> (and P1017) across the edge of the continental shelf would be sufficient.

**JD224 (Sa Aug12):** The *Langseth* progressed steadily on P1015 with the same 34-gun acoustic source that we had been using for a few days now. At 0:12 we launched an XBT, just as we had passed over the continental slope to deep water. Unfortunately, the tailbuoy started having problems keeping power at this time. We reached the end of line P1015 at 12:02. Since Line P1016 was an unimportant tie line, the tech team attempted to revive gun 2 of string 3, but to no avail. We continued with 35 guns, 6240 in<sup>3</sup>. At 15:31 we

reached the end of the short line P1016, and turned back towards the coast on line P1017. Later in the day it would be intermittently off power, and we would no longer have tailbuoy GPS.

**JD225 (Su Aug13):** Data acquisition on line P1017 progressed smoothly earlier in the day. However, as we came onto the continental shelf, the Gulf Stream current increased to approximately 4 knots. Our course was more northerly than the current, so we were able to maintain a SOG of at 1.0-1.3 knots. By 23:00 the Gulf Stream current slowed us down to 0.5 knots again, so we decided to change to a more northerly course to finish the line. String 3 was brought in at 23:14 to repair gun 2.



**Figure 5.7.** Airgun maintenance. Left, Brian Agee. Right Leonid Ometcinskii, Tawfik Naas.

**JD226 (Mo Aug14):** String 3 was redeployed, and we were firing 36 guns again at 6600 in<sup>3</sup>. After breaking off Line P1017 with a turn to the north, we finished the line by 2:30. We then made a wide portside turn and turned south for Line P1018. The strong Gulf Stream current initially made it difficult to progress in this direction, but we reached the old Line P1003 at 10:27. The reshoot of P1003 started at 11:51. Because of the southeasterly course and easterly Gulf Stream, we suddenly were going fast on the line, and the streamer was feathering almost 90° to the north. By 13:10 we also had some shot overlap at 20 seconds due to the high SOG. Fortunately, the streamer feathering fell to less than 70° soon enough, and it would continue to decrease. The last shot of the day was 76999.

**JD227 (Tu Aug15):** We made good progress on the reshoot of Line 1003, still gathering data with the full 6600 in<sup>3</sup> acoustic array. The weather continued to be excellent. By 2:55 we had passed the section of P1003 where we experienced electronic noise at the start of the project. To create a line crossing we made a dog leg to the north at Shot 77495 at 02:55. We reached the end of Line P21003 at 09:10. We turned south for tie line P1028 and started recording this line by 09:32. String 3 gun1 was disabled, so we now had a 6240in<sup>3</sup> gun array. At 12:47 we launched XBT #22 in deep water, and XBT #23 was launched on the shelf at 22:32.

**JD228 (We Aug16):** We made good progress on Line P1028 towards the south, but at 01:23 we experienced a compressor failure, and a complete shutdown of the acoustic source. By 01:33 we started to ramp up the air guns again, and by 01:55 we had the same 35 guns firing at 6240in<sup>3</sup> volume. The weather was calm and slightly cloudy, fine conditions also for a BBQ lunch. However, over the course of the day the winds would increase. XBT #24 was launched at 16:48. We reached the south end of Line P1028 at 18:53, and made an inside turn onto Line P1029 at 19:04.

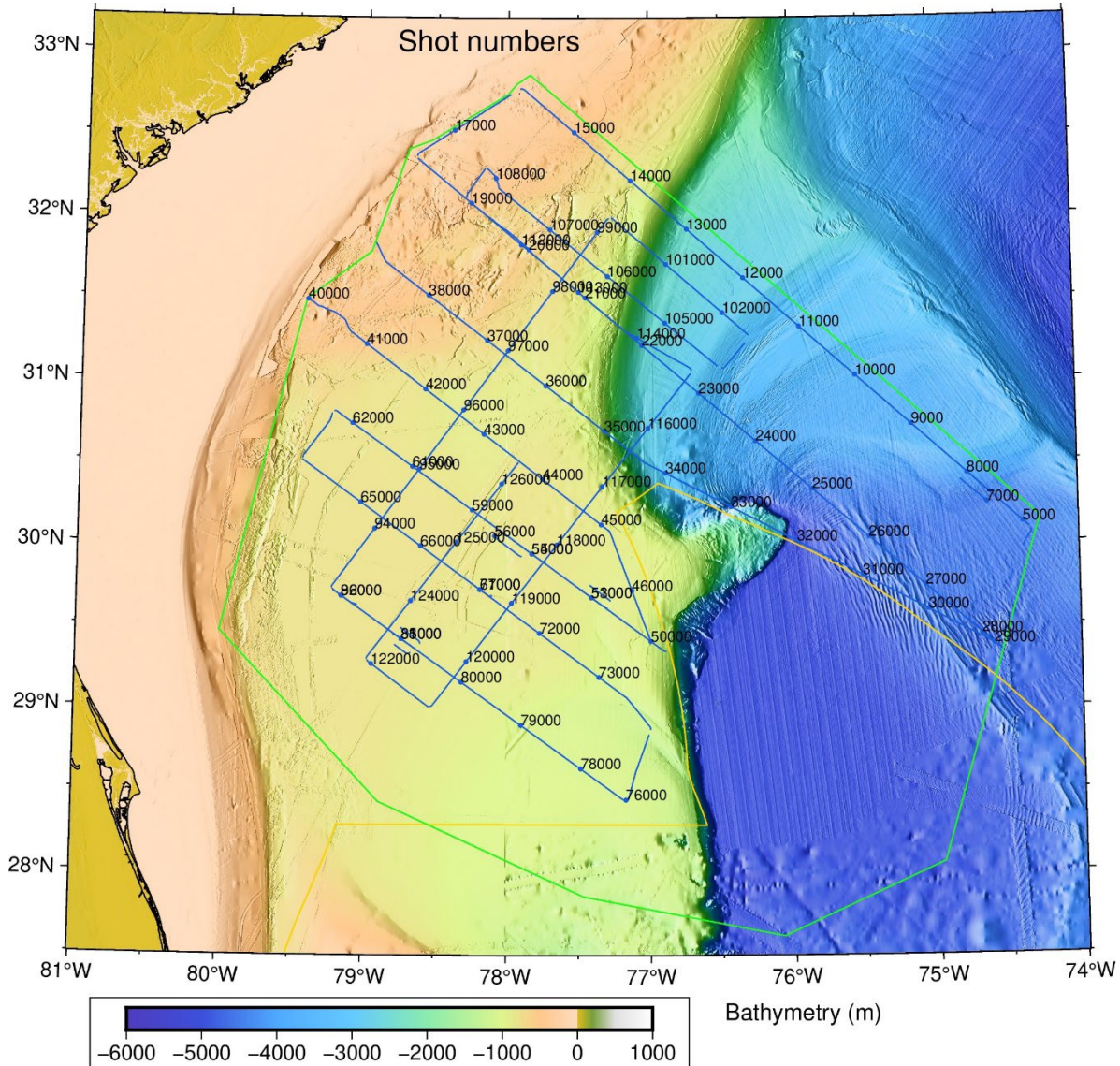
**JD229 (Th Aug17):** At 2:05 we finished shooting line P1029 westward, and turned north on our last seismic transect, line P1033. The weather conditions deteriorated a bit further in the early morning, with more wind and rain, but the sea state was still below 2.0 meters. By 12:00 it was cloudy, but not stormy. At 12:40 we would launch XBT #25, the last of the cruise. Over the course of the day we disabled two guns for auto-firing and timing errors, but acquisition went well. At 23:57 we finished Line P1033 with Shot 126361.

**JD230 (Fr Aug18):** The recovery of the air-gun array finished by 2:32, and we started bringing in the streamer at 3:03. At 10:19 the tailbuoy was secured. We set course for Charleston.

**JD231 (Sa Aug19):** Transit to Charleston, and arrival at the dock, 30 Johnson Street.

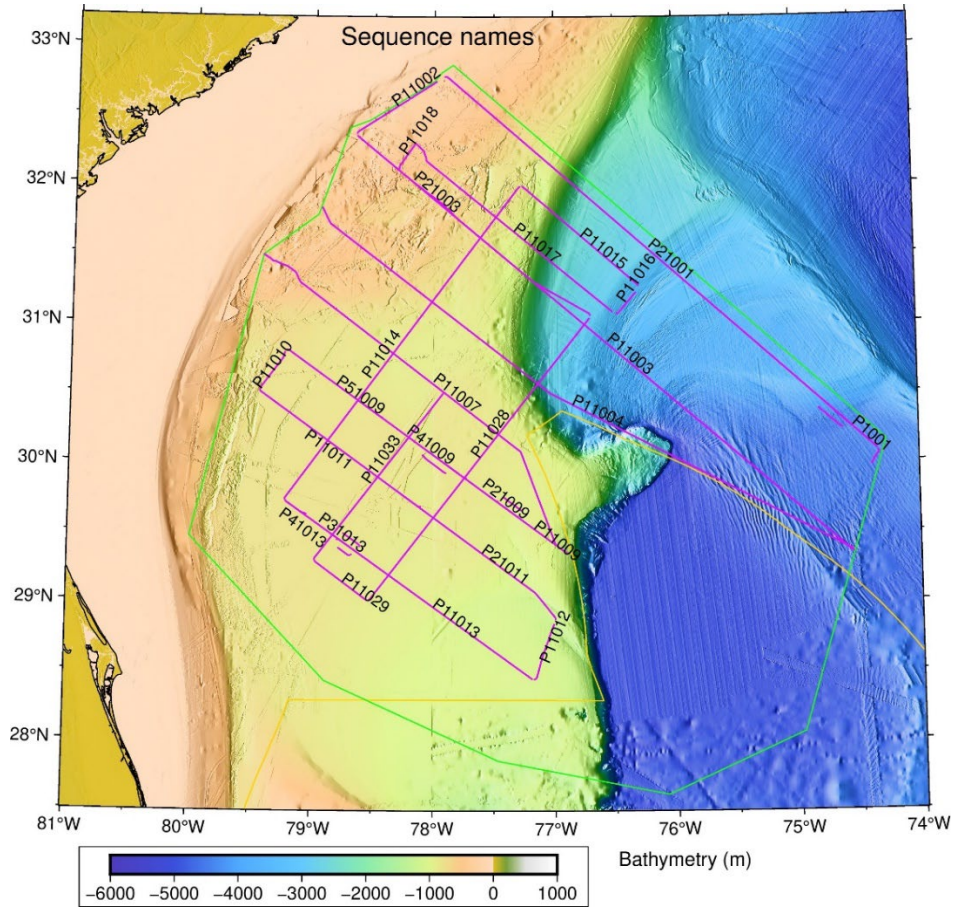
## 6. Shot Lines

The marine seismic reflection data on cruise MGL2309 were acquired as a series of shot sequences, all with a unique shot number and FFID. The shot spacing was fixed at 50 meters, and the shooting speed, though dependent on ocean currents, was 4.2 knots on average. Figure 6.1 shows the progression of the shot numbers over the course of the cruise. In this section we list the basic metrics of the shot sequences that make up the MGL2309 seismic survey (see Table 6.1).



**Figure 6.1.** Shot lines of cruise MGL2309 annotated by every 1000<sup>th</sup> shot number.

We managed to shoot several of our long transects in one sequence. However, due to problems with the acoustic source some of these lines were interrupted. Each restart would form a new sequence. As we brought the air-gun array back on board, repairs would typically take 2 hours. In order to avoid large gaps in our data, we would circle the R/V *Marcus Langseth* back in a wide turn, so the ship and the streamer would be back on line roughly 6 hours later to start a new sequence. An example of two consecutive sequences on a seismic line are sequence 24 (named P31013) and sequence 25 (P41013), which are both part of Line P1013 (Table 6.1). On some occasions we would also shoot a test line while the *Langseth* was circling back for air-gun repairs. These test lines are labeled TST, such as sequence 13, P1TST4.



**Figure 6.2.** Seismic sequence names used during cruise MGL2309.

**Table 6.1.** Shot line statistics for MCS cruise MGL2309.

Line	Seq.	Name	SP first	SP last	FFID first	FFID last	Jday1	Time1	Lat1	Lon1	Jday2	Time2	Lat2	Lon2	Dist
1000	1	Ptest	2023	2283	16	246	200	11:42	29.96248	74.38610	200	13:17	30.07143	74.32674	13.1
1001	2	P1001	4890	5976	247	1333	200	13:40	30.08627	74.34312	200	20:40	30.41540	74.76096	54.0
1001	3	P1TST2	6540	7027	1334	1821	200	21:47	30.37511	74.81209	201	1:43	30.23729	74.61414	24.2
1001	4	P21001	7508	15932	1822	10215	201	2:21	30.26850	-74.58175	203	10:01	32.77503	-77.91774	421.2
1002	5	P11002	16102	17618	10216	11703	203	10:47	32.73978	-77.98391	203	19:47	32.35929	-78.65450	75.7
1003	6	P11003	18060	28340	11704	21979	203	19:59	32.34680	-78.64830	206	13:27	29.34259	74.55132	514.3
1004	7	P11004	28896	38992	21980	32076	206	17:30	29.35845	74.55403	209	16:45	31.83245	78.93957	348.0
1007	8	P11007	39987	46738	32077	38825	210	7:33	31.49124	-79.42232	212	9:48	29.40702	-76.99248	339.0
1009	9	P11009	49756	51162	38826	40232	212	15:37	29.34676	-76.88910	213	2:00	29.72557	-77.47079	70.5
1009	10	P1TST3	51536	51885	40233	40566	213	2:50	29.75139	-77.42140	213	4:41	29.65587	-77.27693	14.6
1009	11	P21009	52748	54205	40567	42024	213	5:31	29.61268	-77.30043	213	15:48	29.99736	-77.91143	72.8
1009	12	P31009	54780	55538	42025	42783	213	20:03	29.88783	-77.73072	214	0:40	30.08580	-78.05097	36.6
1009	13	P1TST4	55983	56453	42784	43254	214	1:37	30.05709	-78.09182	214	4:30	29.92748	-77.89884	23.4
1009	14	P41009	58166	59757	43255	44846	214	5:55	29.98700	-77.89510	214	11:01	30.20698	-78.24347	79.2
1009	15	P51009	60426	62290	44847	46711	214	20:44	30.32593	-78.42365	215	7:53	30.80763	-79.21995	90.8
1010	16	P11010	63058	63777	46712	47431	215	8:22	30.78932	-79.43933	215	15:34	30.51527	-79.43933	36.4
1011	17	P11011	64023	67180	47432	50589	215	15:46	30.50965	-79.43715	216	10:36	29.68335	-78.10344	158.2
1011	18	P21011	70780	73984	50590	53794	216	15:26	29.78133	-78.27743	217	10:37	28.86764	-76.99692	161.4
1012	19	P11012	75062	76005	53795	54738	217	11:05	28.84048	-77.00838	217	17:46	28.44187	-77.17693	47.8
1013	20	P11013	77288	81258	54739	58708	217	18:04	28.44412	-77.19048	218	21:37	29.48907	-78.84448	198.4
1013	21	P1TST5	82086	82427	58709	59050	218	23:46	29.48992	-78.74006	219	1:53	29.38905	-78.60630	14.2
1013	22	P21013	82771	83120	59051	59400	219	2:26	29.36323	-78.63878	219	4:50	29.44653	-78.79237	16.3
1013	23	P1TST6	84125	84360	59401	59636	219	6:07	29.38624	-78.78178	219	7:54	29.33658	-78.67369	11.9
1013	24	P31013	84928	86135	59637	60844	219	9:25	29.40303	-78.70569	219	17:19	29.71953	-79.21656	60.2
1013	25	P41013	91754	92156	60845	61247	221	17:43	29.62944	-79.04788	221	21:04	29.72885	-79.22168	20.1
1014	26	P11014	93018	99247	61248	67477	221	21:11	29.73487	-79.22227	223	18:34	31.98898	-77.27858	311.7
1015	27	P11015	100031	102461	67478	69908	223	18:47	31.98792	-77.26389	224	12:02	31.27150	-76.29482	121.4
1016	28	P11016	103120	103575	69909	70364	224	13:01	31.21948	-76.32339	224	15:44	31.06979	-76.48700	23.1
1017	29	P11017	104085	108187	70365	74467	224	16:12	31.08667	76.51698	225	2:31	32.29282	78.15816	206.8
1018	30	P11018	109017	109470	74468	74921	225	2:48	32.28677	-78.16782	225	10:27	32.11337	-78.29572	23.0
1003	31	P21003	111234	114846	74922	78534	225	11:51	32.04342	-78.21421	226	9:10	31.05638	-76.69856	181.6
1028	32	P11028	115069	120770	78535	84223	226	9:32	31.03560	-76.70947	228	18:53	29.00937	-78.52907	285.3
1029	33	P11029	121026	122078	84224	85276	228	19:04	29.00962	-78.54203	229	2:05	29.29491	-78.97408	52.2
1033	34	P11033	123019	126361	85277	88619	22	2:12	29.30249	-79.97466	229	23:57	30.49854	-77.92157	167.2

## 7. Multichannel seismic data quality

Overall, the multichannel seismic reflection data from cruise MGL2309 are of very good quality. The very good weather during the entire survey made the noise level (e.g. swell noise) on the streamer to be very low. In this section we give a short summary of the different types of noise we encountered in the data.

### *Weak, empty or noisy traces*

The streamer had few noisy traces but there were some (2%) empty and weak traces (Figure 7.1).

- From SEQ002P1001 to SEQ005P11002:

Dead channels: 61, 85, 133, 501, 537, 624, 625, 636, 637, 668, 685, 789, 861

Weak channels: 422, 600, 708, 751, 830, 837, 900, 933

Noisy channels: 943, 944, 955, (957), 958

- From SEQ006P1003 to SEQ024P31013:

Dead channels: 61, 85, 133, 421, 501, 537, 624, 625, 636, 637, 668, 685, 789, 861, 957

Weak channels: 252, 600, 751, 830, 837, 900, 933

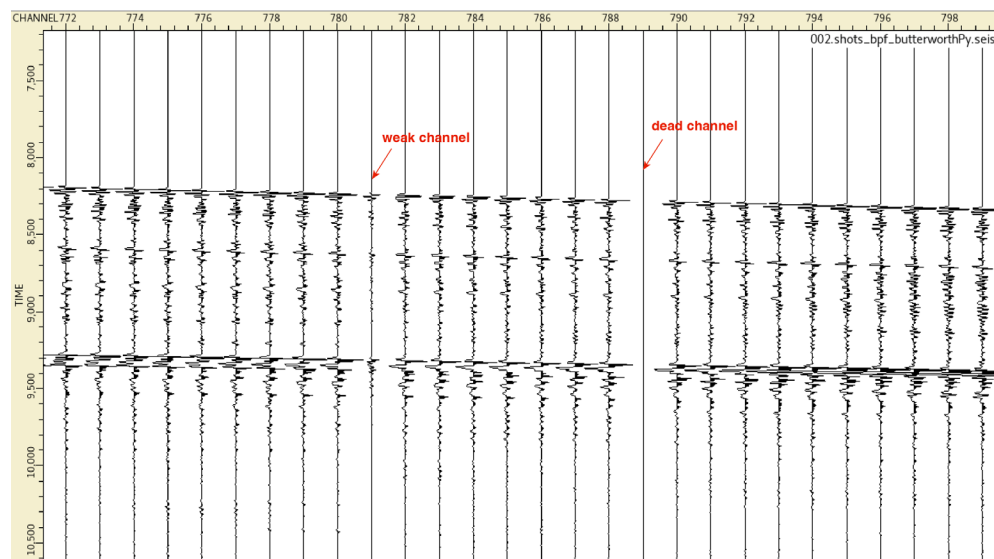
Noisy channels: N/A

- From SEQ025P41013 to SEQ034P11033:

Dead channels: 13, 37, 61, 85, 133, 241, 249, 421, 501, 537, 624, 637, 668, 685, 789, 861, 957

Weak channels: 252, 600, 708, 751, 830, 837, 900, 933

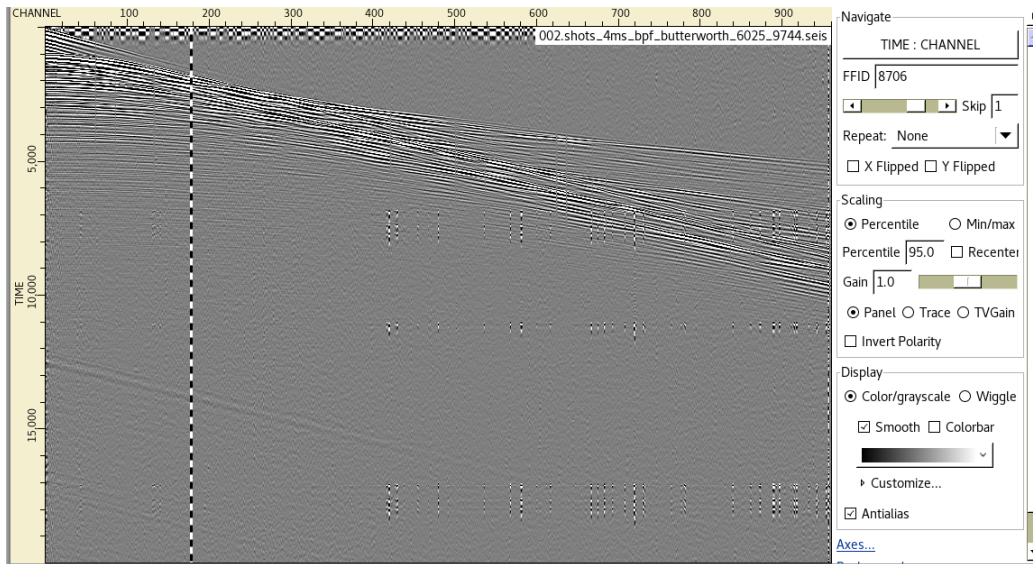
Noisy channels: N/A



**Figure 7.1.** Example of a weak and dead channels on profile P1001.

### *Electrical noise (cross-feed noise)*

For the first four sequences (2P1001, 3P1TST2, 4P21001, 5P11002) and beginning of 6P11003, we had some electrical noise on some channels (Figure 7.2). It started as bursts on one channel on random shots and eventually got worse and affected many channels for each shot.

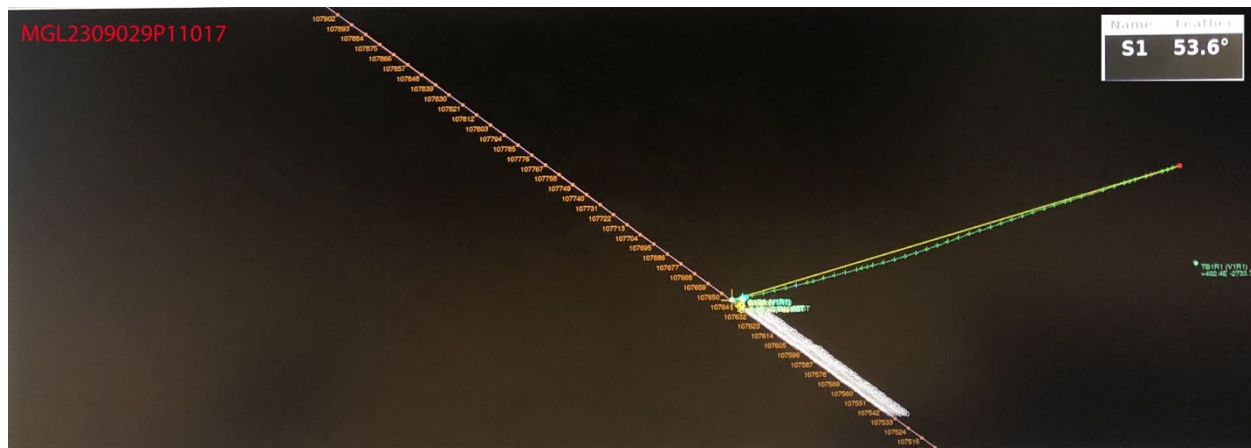


**Figure 7.2.** Example of cross-feed noise on Profile P11003 (FFID). Electronic cross feed is visible from channel 400 to channel 960.

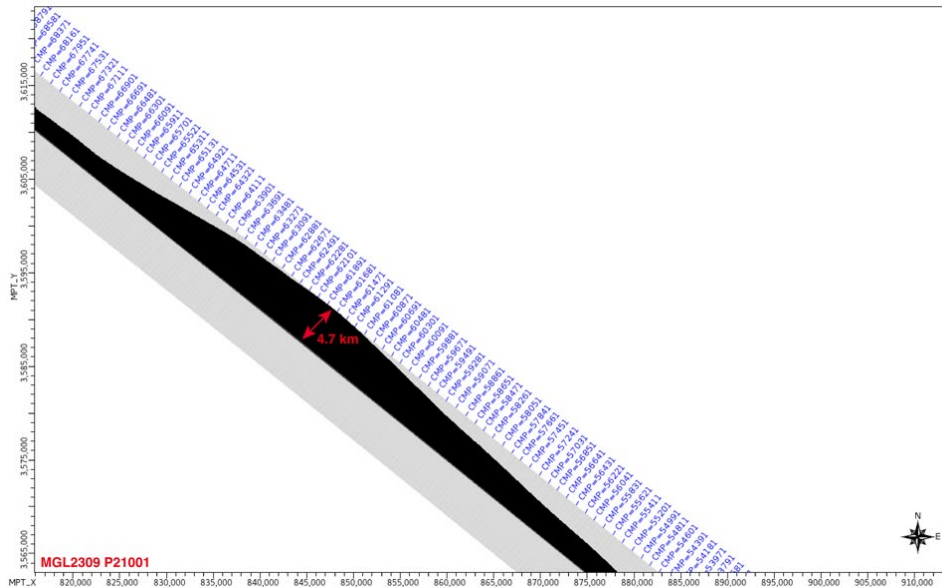
The high voltage leakage causing cross-feed was solved by disabling high voltage line 1 (HV1) around shot point 19410 on 06P11003 profile.

### ***High feathering due to the Gulf Stream***

We had extreme feathering ( $>90^\circ$ ) due to the strong Gulf stream current (Figure 7.3). The strong feathering caused strong noise on the streamer. In addition, large feathering also implies that large cross line bin width is required (Figure 7.4) when assigning a crooked-line geometry (e.g. 9.575 km for P21001, 11.188km for P1003).



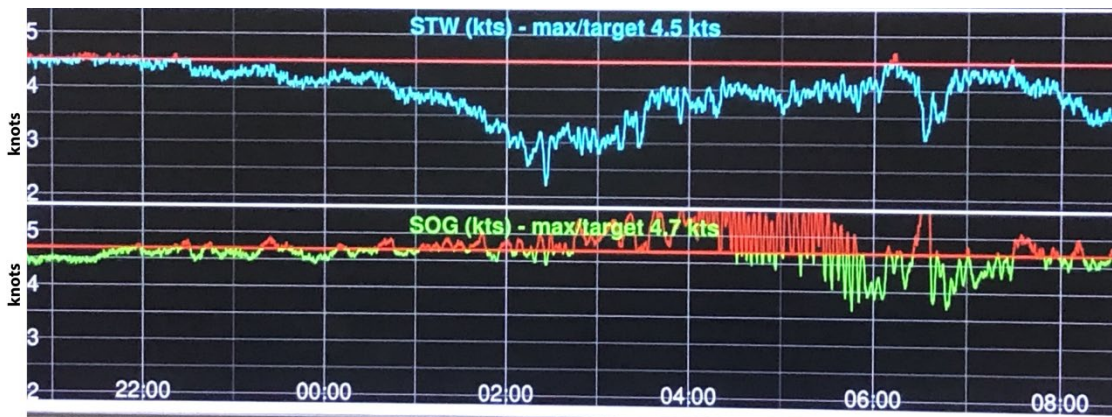
**Figure 7.3.** Example of large feathering ( $53.6^\circ$ ) due to the Gulf Stream on Line P1017. The ship is traveling northwest.



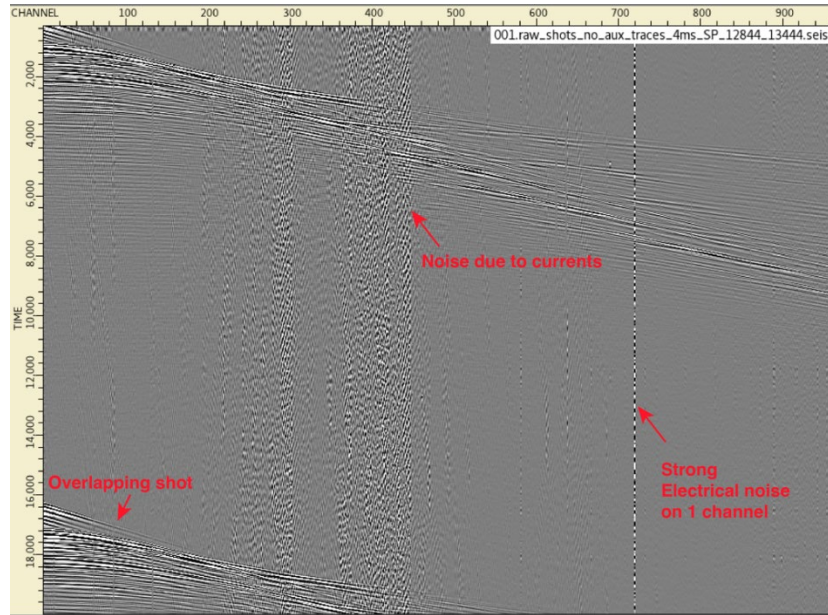
**Figure 7.4.** Example of strong feathering for profile P21001, which requires us to use a very large crossline bin width of 4.7 kilometers.

### *Shot overlapping*

Because of the strong Gulf stream current, it was not easy to maintain a constant speed over ground (SOG) (Figure 7.5). Acquiring the profile from the SW to the NE, the currents were slowing us down. We reached a minimum of ~0.3-0.2 knots of SOG. To the contrary, when we were acquiring profiles from the NE to the SW, the SOG was greater to 5.5-6 leading to shot overlapping as our shooting interval was set constant to 50 m (Figure 7.6).



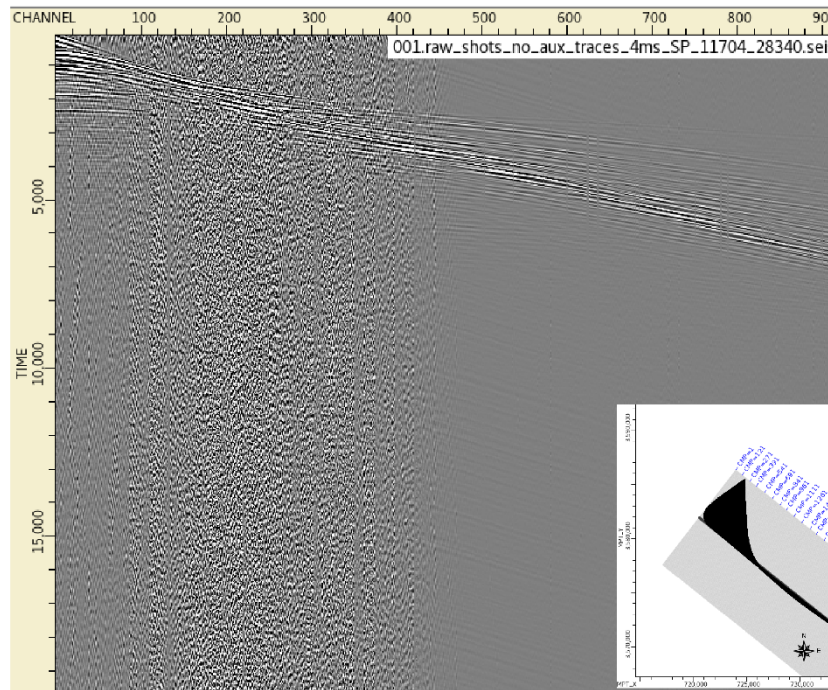
**Figure 7.5.** Dramatic effect of the strong Gulf stream current on our speed over ground.



**Figure 7.6.** Example of overlapping shot from SEQ06P1003 profile

**Turn noise**

Most of the beginnings and ends of profiles were affected by turn noise as we mostly made inside turns.



**Figure 7.7.** Example of turn noise at the beginning of sequence 6P1003 after high pass filtering. Inset shows the turn and high feathering during the turn.

## 8. On-board Seismic Processing

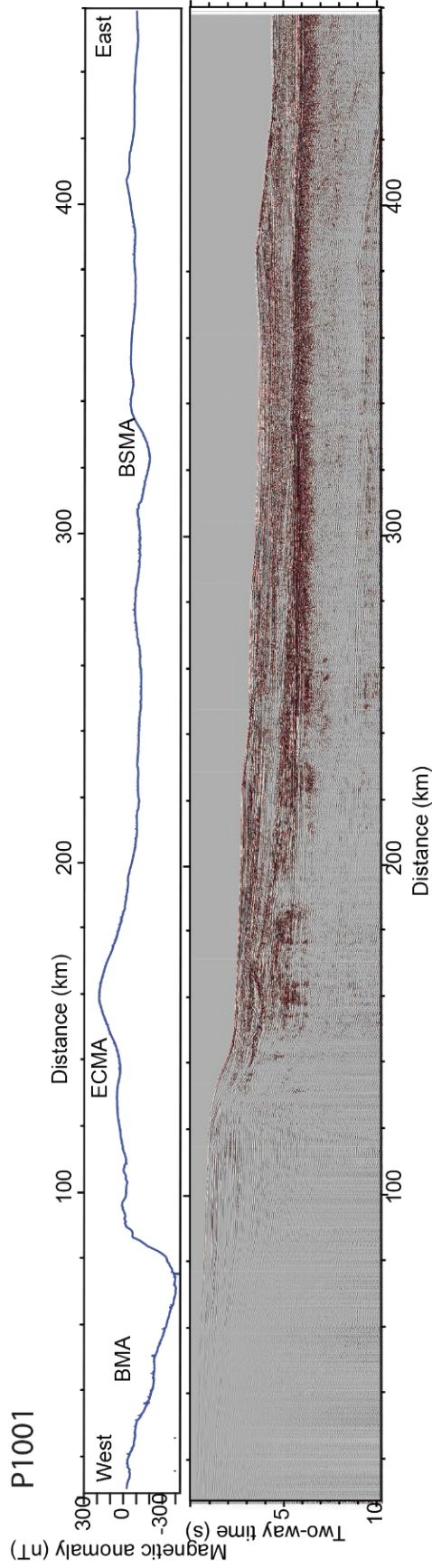
During MGL2309 we had three Linux workstations with Paradigm software (ECHOS) to use for onboard processing of the data. The main purpose of the preliminary processing was to determine if any acquisition parameters needed adjustment, to determine if reshooting was required, to have preliminary results to help guide any changes to the acquisition plan, and to assess overall quality. The processing also provided the students and postdocs a chance to learn the basics of reflection imaging and gain experience with processing techniques and software.

The preliminary processing consisted of basic steps needed to produce an image. These steps consisted of conversion of shot records from SEG-D format to internal ECHOS format with resampling from 2 to 4 milliseconds. Navigation data was not immediately available because navigation processing was conducted at Lamont by the Marine Office and returned to us on board several days after acquisition. In order to produce profiles soon after acquisition, we assumed straight line geometry for the source and receivers with regular shot spacing of 50 m and CMP bin spacing of 6.25 m, half the 12.5 m receiver spacing. Some lines were reprocessed with correct navigation, but time did not allow for very many to be reprocessed that way.

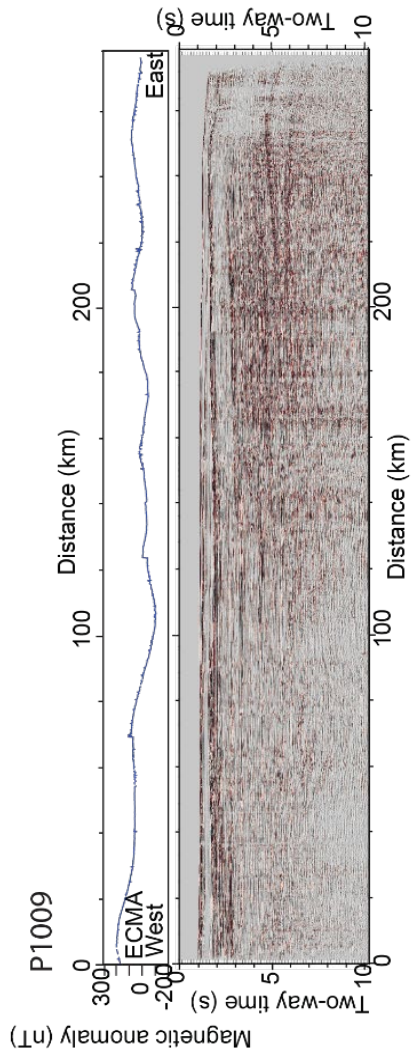
Following binning, the preliminary processing consisted of velocity analysis and muting of CMP gathers. We conducted velocity analysis using standard semblance techniques to determine moveout corrections of the reflections in CMP gathers. Moved out gathers were then muted to remove excessive distortion from stretching, refractions, and guided wave energy that appeared in the far offset. Inside mutes were also picked to remove near offset traces beginning just above the multiple in an effort to suppress multiples in the stack. Velocities and mutes were picked at 1000 CMP intervals (6,250 m) on each profile. This is the procedure used for preliminary profiles during the cruise, and for the profiles presented in this report.

## **9. Data examples**

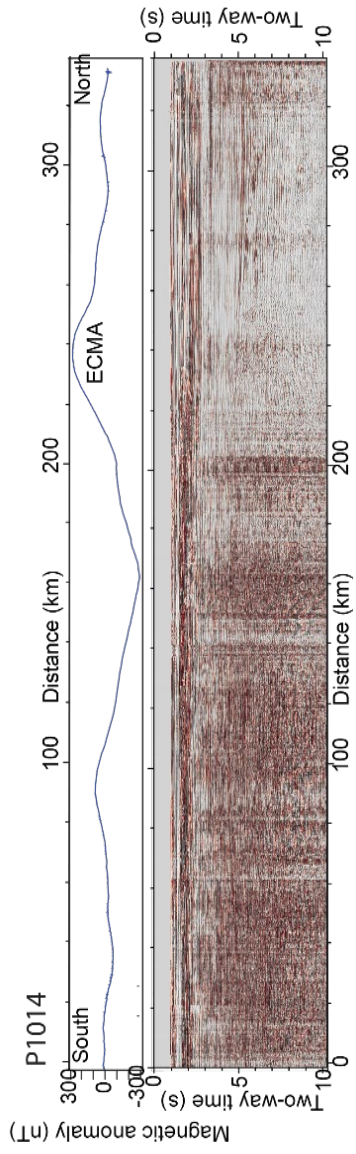
During and after the acquisition of the marine seismic reflection data we applied semblance-based seismic velocity analyses, inner and outer mutes on the shot gathers, normal move-out correction and stacking (see Section 8) to produce the first images in the time domain of the MGL2309 marine seismic reflection data. Other steps that greatly improve the marine seismic images are multiple suppression, post-stack time migration, and eventually prestack time and depth migration. The seismic reflection images of Line P1001 and P1003 on the southern Carolina trough



**Figure 9.1.** The stacked seismic reflection image of Line 1001 on the southern Carolina Trough (bottom) together with the magnetic data profile (top). Amplitudes on the continental shelf are dim because of the mutes applied to the data. The seismic reflection image shows the sediment stratigraphy and top of basement with great clarity. Seaward-dipping reflection and Moho can also be recognized, but these features will be much clearer with additional seismic processing.



**Figure 9.2.** Marine seismic reflection image of Line P1009.



**Figure 9.3.** Marine seismic reflection image of Line P1014.

## 10. Cruise Participation

The seismic investigation of the Blake Plateau and the Carolina Trough is a collaboration of scientists at the University of Texas at Austin (PIs Harm Van Avendonk and Nathan Bangs) and Lamont-Doherty Earth Observatory PI Anne Bécel). In order to give interested early-career scientists and students from other institutions a chance to participate in the marine seismic cruises, we distributed an advertisement in the wider geophysics and marine geoscience communities. In this advertisement we invited candidates to apply to sail on either the OBS or MCS cruise. When we reviewed the CV and a statement of interest from the candidates, we selected participants based on their training in geophysics, scientific interest in this project, and the potential impact that this sea-going experience may have on their career. Two early-career scientists, four graduate students and one undergraduate student came on cruise MGL2309 through the call-to-sail program.

During the cruise, these scientists and students participated in regular watchstanding duties in the seismic lab, they helped with the deployment and recovery of the streamer (three times), and they joined the daily endeavor of processing the incoming bathymetry and seismic reflection data at sea. For most of these participants this cruise was the first experience with reflection seismic processing. We brought three workstations from the University of Texas with Paradigm software for seismic data processing. After initial instructions, the participants would either work on the data by themselves, or in pairs.

The shipboard seismic processing results were generally encouraging, especially on the southern Carolina Trough. The preliminary seismic images showed details in the stratigraphy, a BSR indicating the presence of gas hydrates, basement morphology, and seaward-dipping reflections. The Moho was imaged on a few occasions too. On the Blake Plateau, seismic reflection imaging was more challenging due to strong seafloor multiples, but together these seismic reflection lines form a good first impression for the cruise participants.

During the cruise we divided the day in three 8-hour watches. This gave us continuity in the seismic lab, and it also helped the participants share time on the workstations. On many days we held a science meeting at 13:30 local, where we either discussed a relevant science paper, or we would together interpret the new seismic reflection images.

At the end of the cruise, the participants shared some impressions:

*“Participating in this research cruise was incredibly valuable and eye-opening. It provided a unique chance to learn about what it takes to acquire and process multi-channel seismic data, which greatly improved my grasp of my research and its related literature. The experience taught me unexpected lessons that went beyond my initial goals, expanding my perspective and knowledge.”*

*“I was not expecting to process bathymetry data, and during the cruise, I learned a lot about how to process it. This was very important because I have a project using bathymetry data but I did not have an idea about the data processing, was a good relief to notice that I enjoy doing that.”*

*“This research cruise has provided a valuable and comprehensive learning experience that significantly enriched my understanding of marine research. Activities like deploying the streamer for seismic reflection surveys and analyzing bathymetric data using multibeam technology have given me practical insights into marine data collection and mapping techniques. Deploying the steamer instrument expanded my practical knowledge, and processing the data enhanced my data analysis skills.”*

*“The call to sail program was a huge success offering real-time valuable experience on marine seismic technology. I now understood practically the processes involved in marine data acquisition and processing. This will make me a better seismic interpreter.”*

## 11. Acknowledgments

We want to thank the captain, officers and crew for hosting the science contingent on the R/V *Marcus Langseth* for more than a month, and for supporting the research in very possible way. We are also grateful to the full team of technicians and mechanics on board for all the hard work on the acoustic array, streamer, and seismic recording system. Thanks to you, the quality of the seismic data that we have seen here is outstanding. We thank the protected species observers for their dedication to life in the waters around us. We would not be able to do our work without you. We want to thank the shipboard scientists and students for their enthusiasm and curiosity for science.

This project was funded by the US National Science Foundation, Marine Geology and Geophysics Program.

## Appendices

### Appendix A1. Protected species

The waters offshore the southeastern United States and the Bahamas are home to various species of whales and dolphins, sea turtles, several vulnerable fish species such as sturgeons, and sea birds. As a first measure to minimize the impact of our survey on protected species, we avoid the winter season, when marine mammals migrate through the study area. In addition, we avoided the coastal areas of Georgia and South Carolina with our seismic lines, a sensitive environment with several marine sanctuaries.

During the early planning of the *Langseth* OBS and MCS cruises in 2022, LDEO and NSF prepared an Environmental Assessment (AE) of the project. This AE described the seismic lines that we aimed to gather, the equipment that we would use, the sound levels that we would create in the water column, and the species that may be affected. Subsequently, NSF and LDEO applied for permits to conduct the marine seismic surveys following the process with the Endangered Species Acts (ESA) and Marine Mammal Protection Act (MMPA). Besides the National Marine Fisheries Service (NMFS), the states of Florida, South Carolina and Georgia were also consulted. NMFS issued the Incidental Harassment Authorization (IHA) for both the MGL2309 and MGL2310 cruise on July 10, 2023, well before the start of cruise MGL2309. The monitoring procedures of Protected Species Observers (PSOs) during the seismic cruise, the ramp-up and shutdown procedures for the Langseth's acoustic array, and the animal/vessel strike avoidance measures that were taken during the cruise are all consistent with the conditions stated in the IHA.

We received a permit to gather marine seismic data along 6682 km of 2-D seismic lines in an area marked by the green polygon in Figure 3.1B. The number of primary and contingency lines on our plan gave us good options and alternatives during the project. For some of our seismic lines the run-out would lie outside the permitted area. In that case we would shut down the acoustic area, and ramp-up again once we entered the permit area on the run-in for the next seismic line.

During cruise MGL2309 we encountered relatively few protected species. We had a short shutdown of the seismic operation on Day 210 because of a nearby turtle sighting near the vessel.

In this Appendix we include a copy of the *Finding of No Significant Impact* (FONSI) statement from NSF, which succinctly lists the steps in the permitting process.

**National Science Foundation  
Geosciences Directorate  
Division of Ocean Sciences  
Alexandria, Virginia**

**FINDING OF NO SIGNIFICANT IMPACT (FONSI)  
PURSUANT TO THE NATIONAL ENVIRONMENTAL POLICY ACT (NEPA)  
AND EXECUTIVE ORDER 12114  
AND DECISION DOCUMENT (DD)**

**Marine Geophysical Research by R/V *Marcus G. Langseth*  
of the Blake Plateau, Northwest Atlantic Ocean, 2023**

**Award:** OCE 2112597

**Principal Investigators/Institution:** Harm Van Avendonk, University of Texas, Austin

**Co-Principal Investigator/Institution:** Nathan Bangs, University of Texas, Austin

**Award:** OCE 2112598

**Principal Investigator/Institution:** Anne Becel, Columbia University, Lamont-Doherty Earth Observatory (LDEO)

**Project Title:** Rift dynamics during the formation of the Carolina Trough and Blake Plateau

A Final Environmental Assessment/Analysis (Final EA) was prepared for the above noted proposed research project funded by the National Science Foundation (NSF) (Proposed Action). The Proposed Action would involve marine geophysical surveys (or “seismic surveys”) and use of ocean bottom seismometers (OBSs) in the Northwest Atlantic Ocean within International Waters and the U.S. EEZ, but entirely outside of state waters. The Proposed Action would involve the Principal Investigators (PI) noted above, as well as academic participants and technical staff, including other collaborators not funded by NSF. The Proposed Action would involve R/V *Marcus G. Langseth* (*Langseth*) which is owned and operated by Columbia University’s Lamont-Doherty Earth Observatory (LDEO).

The Final EA entitled, “*Final Environmental Assessment/Analysis of Marine Geophysical Research of the Blake Plateau, Northwest Atlantic Ocean*” (Attachment 1) analyzed the potential impacts on the human and natural environment associated with the Proposed Action pursuant to the National Environmental Policy Act (NEPA) and Executive Order 12114, “Environmental Effects Abroad of Major Federal Actions” (EO 12114). The EA tiers to the Programmatic Environmental Impact Statement/Overseas Environmental Impact Statement for Marine Seismic Research Funded by the National Science Foundation or Conducted by the U.S. Geological Survey (June 2011) and Record of Decision (June 2012), referred to herein as PEIS. This Finding of No Significant Impact/Decision Document (FONSI/DD) also incorporates by reference the analyses and conclusions set forth in the Incidental Harassment Authorization (IHA) and Biological Opinion (BiOp)/Incidental Take Statement (ITS) issued by the U.S. National Oceanic and Atmospheric Administration’s National Marine Fisheries Service (NMFS) for this Proposed Action. The conclusions from the Final EA, and other federal regulatory processes, were consistent with the conclusions of the PEIS and were used to inform the Division of Ocean Sciences (OCE) management of potential environmental impacts of the surveys. OCE has reviewed and concurs with the Final EA findings. The Final EA is incorporated into this FONSI/DD by reference as if fully set forth herein.

**Project Objectives and Context**

The primary goal of the seismic surveys is to investigate the structure and evolution of the rifted margins of the southeastern U.S., including the rift dynamics during the formation of the Carolina Trough and Blake

Plateau. By imaging the sediments and crystalline crust of the margins, the science team would better understand the interaction between tectonic and magmatic processes that led to continental breakup and the onset of seafloor spreading in the central Atlantic Ocean 200 million years ago. The researchers are particularly interested in the stratigraphy of sediments that formed during and after rifting, the degree of crustal stretching at the continental margins, crustal faults that formed during extension of the margin, and the geometry of lava flows that were placed on the crust before the start of seafloor spreading. To achieve the project's goals, the researchers would conduct seismic surveys utilizing the airgun capabilities of R/V *Langseth*, as well as OBSs. Representative seismic survey tracklines shown in Attachment 1, Figure ,1 were revised as clearance to operate within the EEZ of the Bahamas was not obtained. Revised tracklines are depicted below in Figure 1; however, as originally proposed, the tracklines could occur anywhere within the defined survey area (except within the EEZ of the Bahamas). Revisions to the tracklines did not change the anticipated impacts, including marine mammal take estimates, of the Proposed Action. No land-based activities are proposed.

### **Summary of Proposed Action and Alternatives**

The procedures of the Proposed Action would be similar to those used during previous 2-D seismic surveys carried out by NSF and would use conventional seismic methodology. The seismic surveys would involve one source vessel, R/V *Langseth*, which would deploy an array of 36 airguns as an energy source with a total volume of approximately (~)6600 cubic inch (in<sup>3</sup>). The receiving system would consist of a 15-kilometer (km) hydrophone streamer and ~40 OBSs. The OBSs would be deployed and retrieved twice on different sections of the survey. As the airgun array is towed along the survey lines, the hydrophone streamer would receive the returning acoustic signals. In addition to the operations of the airgun array, other acoustic sources, including a multibeam echosounder (MBES), sub-bottom profiler (SBP), and an Acoustic Doppler Current Profiler (ADCP), would be operated continuously from R/V *Langseth* during the seismic surveys; acoustic pingers would also be used at times during the survey. The proposed seismic surveys would occur in water depths ranging from greater than (>)100–5200 m.

The proposed surveys would take place during summer or fall 2023 for a period of ~61 days, spread between two operational legs, with ~40 days of seismic operations. One leg would include ~32 days of MCS seismic operations and ~4 days of transit time, whereas the other leg would consist of ~8 days of seismic operations with OBSs, ~13 days of OBS deployment and retrieval, and 4 days of transit. Some deviation in the duration of the surveys and ports of call may be required, depending on logistics, weather, COVID-19, etc.; however, seismic survey operations would only occur in the area noted and timeframe allowable under the IHA and other relevant documentation.

Another alternative to conducting the Proposed Action would be the “No Action” alternative (i.e., the proposed research operations would not be conducted). The “No Action” alternative would result in no disturbance to marine species attributable to the Proposed Action, but geological data of scientific value and relevance increasing our understanding of the structure and evolution of the rifted margins of the southeastern U.S., and geohazards of submarine landslides, would not be collected. The purpose and need for the proposed activity would not be met through the “No Action” alternative.

### **Summary of environmental consequences**

The Final EA includes analysis on the affected environment (Chapter III) and the potential effects of the Proposed Action on the environment (Chapter IV). Potential impacts of the Proposed Action on the environment would be primarily a result of the operation of the airgun array. The potential effects of sounds from airguns on marine species, including mammals and sea turtles of particular concern, are described in detail in Attachment 1 (Chapter IV and PEIS Chapters 3 & 4) and might include one or more of the

following: tolerance, masking of natural sounds, behavioral disturbance, and, at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects. It is unlikely that the Proposed Action would result in any cases of temporary or especially permanent hearing impairment, or any significant non-auditory physical or physiological effects. Some behavioral disturbance is expected if animals are in the general area during seismic operations, but this would be localized, short-term, and involve limited numbers of animals. The potential effects from the other proposed acoustic sources were also considered; however, they would not be likely to have a significant effect on the environment (Attachment 1, Chapter IV; and PEIS Chapter 3). Generally, any bottom disturbances from OBS activities would be anticipated to be minor and temporary; although small OBS anchors would not be retrieved, they would degrade overtime.

The Proposed Action includes an extensive monitoring and mitigation program to minimize potential impacts on the environment. Mitigation efforts include pre-cruise planning activities and operational activities (Attachment 1, Chapters II and IV; and PEIS Section 2.4.1.1). Pre-cruise planning mitigation activities included consideration of energy source optimization/minimization; survey timing (i.e., environmental conditions: seasonal presence of animals and weather); and calculation of mitigation zones.

The operational mitigation program would further minimize potential impacts to marine species that may be present during the conduct of the proposed research to a level of insignificance. As detailed in Attachment 1 (Chapters II and IV), the IHA and BiOp/ITS issued by NMFS, the Proposed Action would include operational monitoring and mitigation measures, such as, but not limited to: visual observations; passive acoustic monitoring; enforcement of exclusion and buffer zones; pre-clearance, ramp-ups, shutdowns of the airguns; monitoring and reporting. The fact that the airgun array, as a result of its design, directs the majority of the energy downward, and less energy laterally, would also be an inherent mitigation measure. The acoustic source would also be powered down (or, if necessary, shut down) in the event Endangered Species Act (ESA)-listed sea turtles and seabirds (diving/foraging) were observed within a designated EZ. Observers (and vessel crew) would monitor for any impacts the acoustic sources may have on fish. Per the IHA, LDEO would also notify NMFS Southeast Regional Office via email the start and end date of seismic operations in the survey area. LDEO would follow additional monitoring and mitigation measures required by the IHA and BiOp for enhanced protections of North Atlantic right whale (e.g., limited timeframes for use of airguns and conducting specific tracklines; submission of daily reports during certain timeframes). LDEO and its contractors are committed to applying these measures in order to minimize any effects on marine mammals, sea turtles, seabirds, and fish, and other potential environmental impacts.

With the planned monitoring and mitigation measures, unavoidable impacts to marine species that could be encountered would be expected to be minimal, and limited to short-term, localized changes in behavior and distribution near the seismic vessel. At most, effects on marine mammals may be interpreted as falling within the U.S. Marine Mammal Protection Act (MMPA) definition of Level B Harassment for those species managed by NMFS. Although NSF calculated predicted distances to the Level A thresholds based on current NMFS Technical Acoustic Guidance<sup>1</sup>, per the IHA, NMFS instead established a fixed operational 500 m exclusion zone and 1,000 m buffer zone for the surveys. In the IHA, NMFS also required an extended 1500-m EZ to be established for beaked whales, dwarf and pygmy sperm whales, a large whale with a calf, and groups of six or more large whales encountered during the survey effort. During operations, the IHA requirement (extended 1500-m EZ) would be followed for these special conditions and species. Per the IHA, the shutdown requirement would be waived for small dolphins including *Delphinus*,

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<sup>1</sup> 2018 Revision to: Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (version 2.0). Underwater thresholds for onset of permanent and temporary threshold shifts. Office of Protected Resources, NMFS, Silver Spring, MD.

*Lagenodelphis*, *Stenella*, *Steno*, and *Tursiops*. Level A takes were requested for the remote possibility of low-level physiological effects; however, because of the characteristics of the Proposed Action and proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds, Level A takes are considered highly unlikely. The predicted distances for the Level B zones are based on the 160 dB re 1  $\mu$ Pa SPL isopleth, per current NMFS approach on Level B harassment.

Mitigation, monitoring, and reporting requirements were incorporated into the Final EA, the FONSI/DD, and/or the LDEO Science Support Plan; protected species observers (PSOs) would take the lead in ensuring compliance with all monitoring and mitigation measures. NMFS included vessel strike avoidance measures in the IHA; however, as noted in the Final EA, R/V *Langseth* (and other vessels in the U.S. Academic Research Fleet) have no history of marine mammal strikes. No long-term or significant effects from the Proposed Action would be expected on individual marine mammals, sea turtles, seabirds, fish, the populations to which they belong, or their habitats.

The results of the cumulative impacts analysis in the PEIS indicated that there would not be any significant cumulative effects to marine resources from the proposed NSF-funded marine seismic research, including the combined use of airguns and other acoustic sources (e.g., multibeam echosounders, etc.). However, the PEIS also stated that cruise-specific cumulative effects analysis would be conducted, “allowing for the identification of other potential activities in the area of the proposed seismic surveys that may result in cumulative impacts to environmental resources.” The potential cumulative effects of the Proposed Action were evaluated in Section 4.1.6 of the Final EA. Due to the location of the Proposed Action, activities in the area around the survey vessel would be anticipated to include other research, military, offshore energy development, vessel traffic, fisheries, and whale watching activities. Although there are a number of shore-accessible SCUBA diving sites off the southeastern U.S. (Final EA, Section 3.8), the proposed activities would occur in water depths >100 m, outside the range for typical recreational SCUBA diving. Most whale watching activities are conducted close to the coast. Given the distance from shore to the survey area, the likely distance from any marine mammal watching activities, and the short and temporary duration of the surveys, it would be unlikely that the marine mammal watching industry would be affected by the Proposed Action. Fisheries activities would not be precluded in the survey area; however, a safe distance would need to be kept from R/V *Langseth* to avoid possible entanglement with the towed airgun array and OBS activities. No fish kills or injuries were observed during any previous NSF-funded seismic survey activities. NSF coordinated the Proposed Action with the US Navy. Any potential conflicts with ocean users would be avoided through Notice to Mariners and direct radio communications during the surveys. Considering the limited time that the planned seismic surveys would take place close to shore, the brief period of operations, and the temporary nature of potential environmental impacts, the proposed project is not expected to have any significant impacts on other activities in the area.

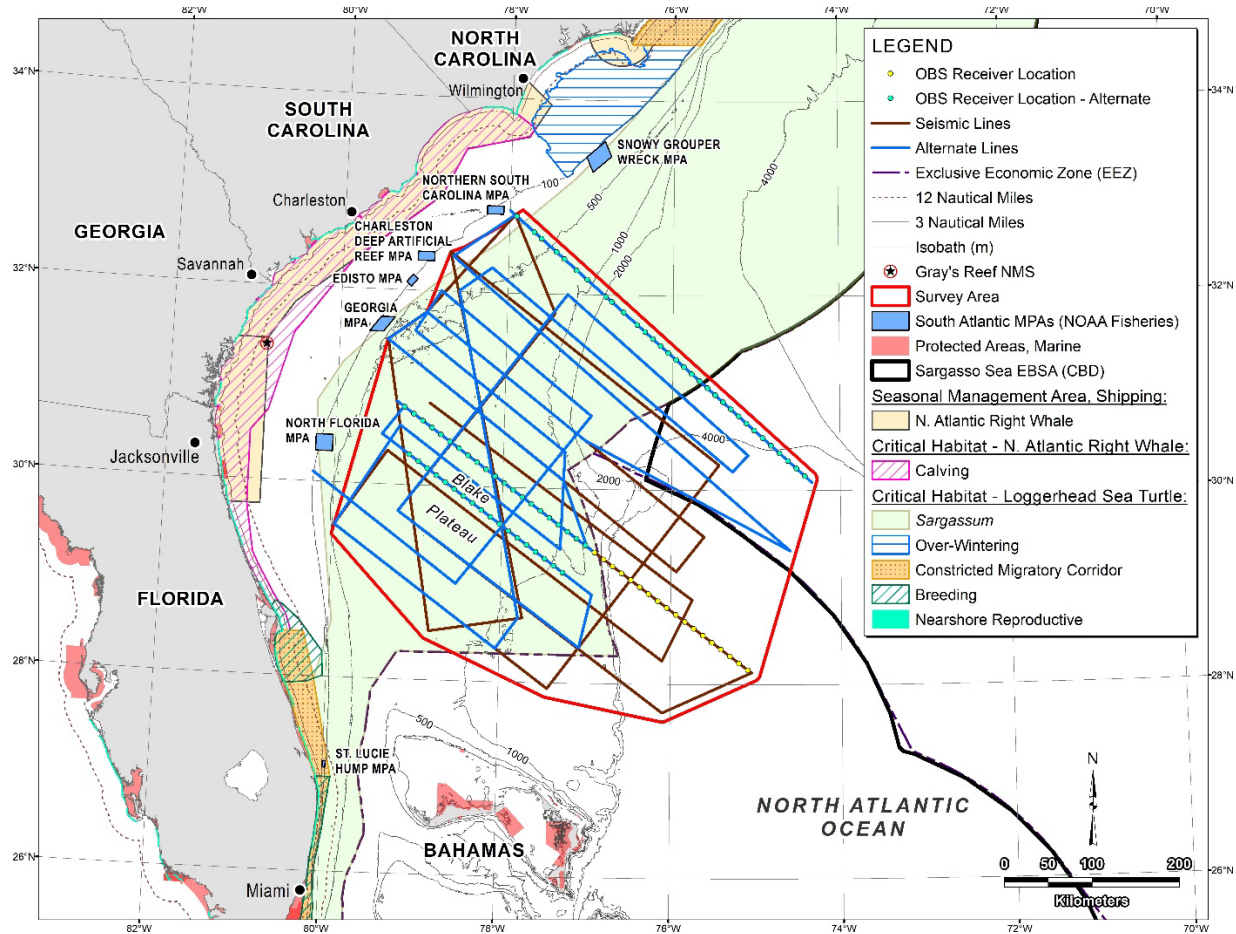
The “No Action” alternative would remove the potential for the limited direct and indirect environmental consequences as described above. However, the “No Action” alternative would preclude important scientific research from going forward that would provide information on the structure and evolution of the rifted margins of the southeastern U.S. and new constraints for examining tsunami hazards associated with submarine landslides. The “No Action” alternative would result in a lost opportunity to obtain important scientific data and knowledge relevant to the geosciences and to society in general. The collaboration, involving academic researchers, students, and collaborators would be lost, as would the opportunity to collect and interpret new data and provide new results to the greater scientific community. Loss of NSF support often represents a significant negative impact to the academic infrastructure, including the professional and academic careers of the researchers, students, ship technicians and crew who are part of the U.S. Academic Research Fleet. The “No Action” alternative would not meet the purpose and need of the Proposed Action.

#### **Coordination with Other Agencies and Processes**

Based on discussions with NMFS during MMPA and ESA processes, minor refinements to the information provided in the Draft EA were made. The new information, which was included in the Final EA, did not

alter the overall conclusions of the Draft EA and remained consistent with the PEIS. NSF coordinated with NMFS to complete the Final EA prior to issuance of the IHA and BiOp/ITS.

Compliance with other federal statutes and regulatory processes are summarized below and in further detail in the Final EA, Section 4.1.8.



**Figure A1-1.** Location of the proposed seismic surveys (blue alternate lines), OBS deployments, marine conservation areas, and marine critical habitat in the Northwest Atlantic Ocean. Representative survey tracklines are included in the figure; however, the tracklines could occur anywhere within the survey area (outside of the EEZ of the Bahamas). MPA = marine protected area; NMS = National Marine Sanctuary; EBSA = Ecologically or Biologically Significant Marine Areas.  
 CBD = Convention on Biological Diversity.

**(a) Endangered Species Act (ESA)**

On 17 November 2022, NSF submitted a formal ESA Section 7 consultation request, including the Draft EA, to NMFS for the proposed activity. On 10 July 2023, NMFS issued a BiOp and ITS (Attachment 2).

**(b) Marine Mammal Protection Act (MMPA)**

On 22 November 2022, on behalf of the action proponents, including NSF, LDEO submitted to NMFS an IHA application pursuant to the U.S. MMPA for “taking by harassment” (disturbance) of small numbers of marine mammals during the proposed seismic surveys. On 7 June 2023, NMFS issued in the Federal Register a notice of intent to issue an IHA for the surveys and a 30-day public comment period. NMFS

issued an IHA for the proposed activity on 10 July 2023 (Attachment 3).

**(c) Essential Fish Habitat (EFH) (Magnuson-Stevens Act)**

NSF submitted an EFH consultation request on 26 January 2023 to NMFS. On 17 February 2023, NMFS responded noting any effects on EFH from the proposed surveys would be minimal, and accordingly, provided no EFH conservation recommendations for the Proposed Action.

**(d) Coastal Zone Management Act (CZMA)**

NSF submitted a negative determination pursuant to Subpart C of the CZMA to the State of Georgia on 17 February 2023, and to the State of South Carolina on 3 March 2023. On 6 March, the State of Georgia agreed the proposed action was consistent with the applicable enforceable policies of the Georgia Coastal Management Program and concurred with NSF's negative determination (Appendix E). Although the State of South Carolina confirmed receipt of the negative determination, no further response was received by NSF; therefore, NSF presumed concurrence on 2 May 2023 after 60 days. On 24 January 2023, an email was sent to the State of Florida requesting identification of any applicable enforceable policies; NSF received a response from the State of Florida Department of Environmental Protection on 25 January 2023 noting the state did not select the project for review and the project may proceed (Appendix E).

**Conclusion and Decision**

NSF has reviewed and concurs with the conclusions of the Final EA (Attachment 1) that implementation of the Proposed Action will not have a significant impact on the environment. Consequently, implementation of the Proposed Action will not have a significant direct, indirect or cumulative impact on the environment within the meaning of NEPA or EO 12114. Because no significant environmental impacts will result from implementing the Proposed Action, an environmental impact statement is not required and will not be prepared. Therefore, no further study under NEPA or EO 12114 is required. As described above, NSF's compliance with the ESA, MMPA, EFH, and CZMA is completed.

In sum, NSF concludes that implementation of the Proposed Action will not result in significant impacts after full consideration of the Final EA; the PEIS; the IHA and BiOp/ITS issued by NMFS; and the entire environmental compliance record. Accordingly, on behalf of NSF, I authorize the issuance of a Finding of No Significant Impact for the Proposed Action, the marine geophysical research and OBSs proposed to be conducted on board Research Vessel *Marcus G. Langseth* in the Northwest Atlantic Ocean, during the effective time period of the IHA, and hereby approve the Proposed Action to commence.



07/11/23

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James McManus  
Division Director  
Division of Ocean Sciences

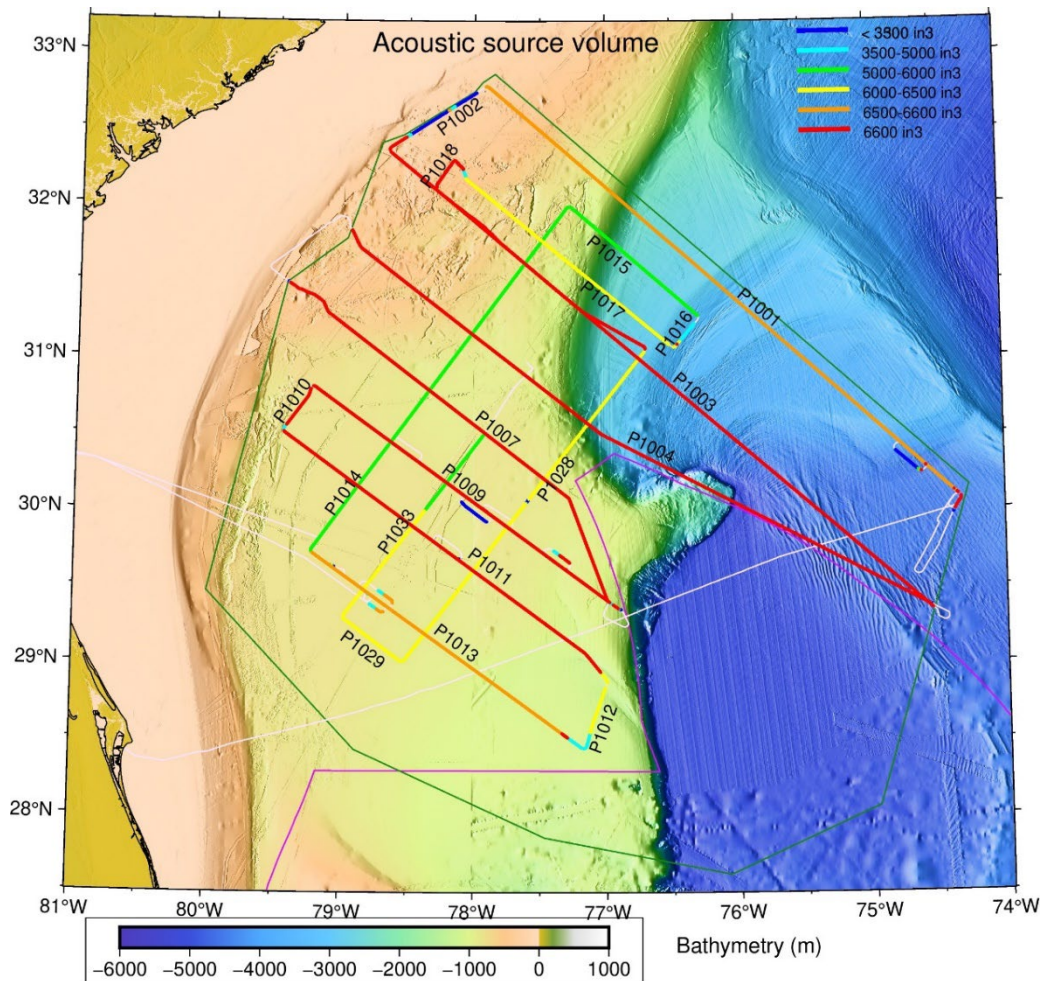
Date

Attachment 1: Final Environmental Assessment/Analysis of Marine Geophysical Research of the Blake Plateau, Northwest Atlantic Ocean. Attachment 2: NMFS Biological Opinion/Incidental Take Statement Attachment 3: NMFS Incidental Harassment Authorization

## Appendix A2. Performance of the acoustic source and streamer

After some difficulties on the first line of the project, the R/V *Marcus Langseth*'s 36-gun array with a volume of 6600 in<sup>3</sup> started to perform well. Over the course of the project, the acoustic source pressure was 1941±11 psi, and pressure drifted slightly over time. After one week of shooting it was the highest (1956±8 psi), and at the end of the cruise it had slowly declined to 1930±13 psi. We changed air compressors twice due to an abrupt failure, but both compressors worked well throughout the seismic shoot. On Line P1009, which coincides with OBS Line 2, we experienced four air leaks, which is much more than usual. Due to the importance of this line we chose to reshoot all gaps to maintain coverage with the full 36-gun source on this line. A complete list of the air-gun volume and pressure is given in the files MGL2309[Line\_name].source.csv . Figure A.2.1 gives a graphic display of the changes in air gun volume during the project.

The first deployment of the 12 km-long streamer was not smooth, and we experienced some electronic noise until the first portion of line P1003, before it was remedied. The Gulf stream posed a very difficult but local challenge for the R/V *Langseth* and the streamer throughout the survey, but the digi-birds kept the streamer very steady at 10 m depth. Of the 960 streamer hydrophone channels, on the order of 30 were dead, noisy or weak. However, we replaced a bad streamer section before the start of P1014.



**Figure A2.1.** Shot lines colored by the volume of the acoustic source. Dark green thin line marks the permitted area. Thin purple line is the boundary of the Bahamas EEZ.

Below we summarize the major milestones and incidents with the acoustic array and streamer during the cruise, all organized by line name and sequence number.

**Line 1000 (test):**

Sequence 1, Ptest.

Dead channels: 61, 85, 501, 537, 624, 625, 636, 637, 668, 685, 789, 861.

- First shot 2023, JD200, 11:42. 36 guns at 6600 in<sup>3</sup>.
- Last shot 2283, JD 200, 13:17: Acquisition stopped before the end waypoint. 36 guns at 6600 in<sup>3</sup>.

**Line P1001:**

Sequence 2, P1001

Dead channels: 61, 85, 501, 537, 624, 625, 636, 637, 668, 685, 789, 861.

- First shot 4890, JD200, 13:40: Full air-gun array 36 guns at 6600 in<sup>3</sup>.
- Shot 4922: Disabled string 4 gun 3 after several failures. Volume 35 guns at 6560 in<sup>3</sup>.
- Shot 5927: String 2, cluster 3-4 gun fires 2.0 msec late.
- Shot 5961: Disabled gun string 3 and 4 for bringing on deck.
- Last shot 5976, JD200, 20:40: Air leak on gun string 4 ends the line, recovery of strings 3,4. 18 guns at 3300 in<sup>3</sup>.

Sequence 3, PITST2

Dead channels: 61, 85, 501, 537, 624, 625, 636, 637, 668, 685, 789, 861

- First shot 6540, JD200, 21:47: Start the line with strings 1 and 2, 18 guns at 3300 in<sup>3</sup>.
- Air leak on string 4 fixed at Shot 6664. Strings 3 and 4 now also active, 36 guns at 6600 in<sup>3</sup>.
- Last shot 7027, JD201, 01:43. 36 guns at 6600 in<sup>3</sup>.

Sequence 4, P21001

Dead channels: 61, 85, 501, 537, 624, 625, 636, 637, 668, 685, 789, 861.

- First shot 7508, JD 201, 02:21. Full air-gun array, 36 guns at 6600 in<sup>3</sup>.
- String 4, gun 3 disabled shortly after start of line. Most of line with 35 guns, 6560 in<sup>3</sup>
- Shot 9448 to Shot 9461 not valid/missing because of complete Seal 428 failure. No data.
- Shot 9493: Streamer and digicourse back online after power cycle.
- Timing errors on string 2, gun 4. Continues to operate. 35 guns, 6560 in<sup>3</sup>.
- Shot 10246: Strumming 6Hz noise visible, moving few km back from head of the streamer.
- Shot 10483: Strumming noise gone.
- Shot 13145: Vessel in heavy weather front, difficulty maintaining heading.
- Shot 14305-14331: Start of cross-feed electronic noise on streamer.
- Shots 14421, 14423, and 14425 also affected by cross-feed noise.
- Shot 14375: Channel 957 becomes noisy, channel 690 spikey.
- Shot 14900 and later: Noise on streamer because of ocean current.
- Shot 15894: Vessel has started inside turn.
- Last shot 15932, JD203, 10:01. 35 guns, 6560 in<sup>3</sup>.

**Line P1002:**

Sequence 5, P11002

Dead channels: 61, 85, 501, 537, 624, 625, 636, 637, 668, 685, 789, 861.

This short tie line was used mostly for significant gun array maintenance.

- First shot 16102, JD203, 10:47: Maintenance on acoustic source. Gun strings 1 and 2, gun 4 on string 4 disabled for maintenance. 17 guns active at 3260 in<sup>3</sup>. Shot record overlap.
- Shot 16116: Shot timing (Shot Record Value, SRV) greater than 20 sec.
- Shot 16489: Gun string 1 in position and enabled. 26 guns at 4910 in<sup>3</sup>.
- Shot 16546: Brief 20° portside turn to deploy gun string 2.
- Shot 16561: Return to Line 1002 heading.

- Shot 16578: Gun string 2 in position and enabled. 35 guns at 6560 in<sup>3</sup>.
- Shot 16593: Gun strings 3 and 4 disabled for maintenance. 18 guns, 3300 in<sup>3</sup>.
- Shot 16707: Shot Record Value < 20sec (time overlap in record).
- Shot 16710: SRV > 20.
- Shot 16988: Acoustic source off to add weight to lead-in to stop it from rubbing against air gun array. 0 guns at 0 in<sup>3</sup>.
- Shot 16992: Seal acquisition stopped while silent (no active source).
- Shot 17020: Gun string 1 and 2 active. 18 guns, 3300 in<sup>3</sup>.
- Shot 17022: Seal acquisition resumes. 18 guns, 3300 in<sup>3</sup>.
- Shot 17252: Gun string 4 active. 27 guns, 4950 in<sup>3</sup>.
- Shot 17317: Gun string 3 active. 36 guns, 6600 in<sup>3</sup>.
- Shot 17584: Inside turn deviation from line.
- Last shot 17618, JD203,19:47. 36 guns, 6600 in<sup>3</sup>.

### **Line P1003:**

#### Sequence 6, P11003

Dead channels 61,85,133,421,501,537,624,625,636,637,668,685,789,861,957

Weak channels 422, 600, 708, 751, 781, 830, 837, 900, 933.

Noisy channels: 943, 944, 955, 958.

- First shot 18060, JD203,19:47: 36 guns, 6600 in<sup>3</sup>.
- Shot 18060: Intermittent cross-feed electronic noise, and it gets progressively worse.
- Shot 18739, JD204, 0:00: 36 guns, 6600 in<sup>3</sup>.
- Shot 19000: Noise from Gulf stream ocean current starts.
- Shot 19000: High SOG with some shot overlap at 20 sec. 36 guns, 6600 in<sup>3</sup>.
- Shot 19200: High feathering angle, greater than 60 degrees.
- Shot 19301: Strong sideways current forces the *Langseth* off track towards NW.
- Shot 19561: Course deviation 632 m.
- Shot 19840: Max deviation from course 1,100 m.
- Shot 19930: Apparent rip current. SOG 6.4, STW 3.5.
- Shot 19943: Birds 1-20, compass problem, depth changes due to current.
- Shot 20000: Cross-feed noise still getting worse, causing bad channels and short bursts across entire streamer. Noise likely caused by voltage leakage.
- Shot 21686: Last good shot before trouble-shooting of leakage/electronic noise.
- Shot 21695: First good shot after cross-feed noise problem appears to be solved.
- Shot 22634: First shot of JD205. Good weather, good data, but <4 kts SOG in ocean current.
- Shot 26042: First shot of JD206. Perfect sea state, COG > 4 kts.
- Last shot 28340, JD206, 13:27. 36 guns, 6600 in<sup>3</sup>.

### **Line P1004:**

#### Sequence 7, P1004

Dead channels: 61,85,133,421, 501,537,624,625,636,637,668,685,789,861, 957

Weak channels: 252, 600, 708, 751, 830, 837, 900, 933

Noisy channels: 943, 944, 955, 958.

- First shot 28959, JD206, 17:52. 36 guns, 6600 in<sup>3</sup>. Good weather.
- Shot 29967: First shot of JD207. Good weather, good data, COG 4.5 kts.
- Shot 34109: First shot of JD208. Good weather, good data, COG 4.5 kts.
- Shot 34320: 1:14. Line bearing adjusted to 306.0 to stay on line at waypoint 5.
- Shot 37219, JD208, 19:14: Unidentified noise.
- Shot 37784: First shot of JD209.
- Shot 38000, JD209, 02:00: Struggling with Gulf Stream, low speed.

- Shot 38175: Feathering 23° and increasing.
- Shot 38231, JD209, 209, 5:04: SOG 2.0, STW 5.2 kts, deviating 10 m from line.
- Shot 38512: SOG 0.9-1.0 kts due to current.
- Shot 38730, JD209, 13:19: Deviation from the line to escape current.
- Shot 38992, JD209, 16:45: End of Line. 36 guns, 6600 in<sup>3</sup>.

### **Line P1007:**

#### Sequence 8, P1007.

Dead channels: 61,85,133,421, 501,537,624,625,636,637,668,685,789,861, 957

Weak channels: 252, 600, 708, 751, 830, 837, 900, 933

Noisy channels: 943, 944, 955, 958

- Start of Line at JD210, 7:12, Shot 39987. 36 guns, 6600 in<sup>3</sup>.
- Shot 40018: Difficulty to maintain heading in current.
- Ramp-up completed at JD210, 8:07.
- Shot 40090: Langseth consistently at SOG 0.4-0.5 kts due to strong Gulf Stream current, 8:58.
- Shot 40163: Change heading by 10° portside (north) to progress in 5 kts current. 13:04.
- Shot 40182: 489 m deviation to the north from planned track at 13:27. Feathering 85°.
- Shot 40187, missed shots because of compressor failure. JD210, 13:45 compressor switch.
- Shot 40192: Compressor issue resolved at 13:43.
- Shot 40505: JD210, 18:23 turtle sighting, shutdown and gap in shots.
- Shot 40523: Ramp-up finished, 36 guns, 6600 in<sup>3</sup>.
- Shot 40680: Noise at the front of the streamer due to crabbing.
- Shot 40730: Langseth back on line after deviation at JD210, 21:27.
- Shot 41133: Last Shot of JD210.
- Shot 45025: Last Shot of JD211.
- Shot 45025: First Shot of JD212.
- Shot 45146, JD212, 00:40: At waypoint 8, small starboard turn to new course.
- Shot 45767: Minor shot overlap due to high ship speed.
- Shot 46738, JD 212, 09:47: End of Line P1007, 36 guns, 6600 in<sup>3</sup>.

### **Line P1009:**

#### Sequence 9, P1009.

Dead channels: 61,85,133,421, 501,537,624,625,636,637,668,685,789,861, 957.

Weak channels: 252, 600, 708, 751, 830, 837, 900, 933.

Noisy channels: 943, 944, 955, 958.

- Shot 49756, JD 212, 15:37: Start of Line at east end with ramp-up.
- Shot 49804: First shot with 36 guns, 6600 in<sup>3</sup>.
- Shot 49897, JD 212, 16:38: Gun string 3 disabled. 27 guns firing at 4950 in<sup>3</sup>.
- Shot 39027, JD 212, 17:16: Back to acoustic source with 36 guns, 6600 in<sup>3</sup>.
- Shot 50930: First shot of JD213.
- Shot 51071: Gun string 3 disabled with air leak. 27 guns firing at 4950 in<sup>3</sup>.
- Shot 51162, JD 213, 02:00: End of Line due to air leak. Circling back while repair.

#### Sequence 10, P1TST3.

Dead channels: 61,85,133,421, 501,537,624,625,636,637,668,685,789,861, 957.

Weak channels: 252, 600, 708, 751, 830, 837, 900, 933.

Noisy channels: 943, 944, 955, 958.

- Shot 51536, JD 213, 02:50: Start of line, loop back. String 3 out. 27 guns, volume 4950 in<sup>3</sup>.
- Shot 51705: Full volume, 36 guns, 6600 in<sup>3</sup>.
- Shot 51774: Gunlink froze, missed shots 51775-51790.
- Shot 51791: String 4 not firing. 27 guns, 4950 in<sup>3</sup>.

- Shot 51796: Full volume. 36 guns, 6600in<sup>3</sup>.
- Shot 51885, JD 213, 04:41: End of line, coming back on planned line. Airgun volume 6600 in<sup>3</sup>.

Sequence 11, P21009

- Shot 52748, JD213, 5:31: Start of the Line. 36 guns, airgun volume 6600 in<sup>3</sup>.
- Shot 52930: Significant noise on streamer from turning.
- Shot 54083, JD213, 14:41: String 3 powered down with air leak, shooting 27 guns, 4950 in<sup>3</sup>.
- Shot 54205, JD213, 15:48: End of line, turn around. 27 guns, 4950 in<sup>3</sup>.

Sequence 12, P31009

- Shot 54780, JD213, 20:03 ramp-up 40 in<sup>3</sup>.
- Shot 54834, JD213, 20:25. Continuing line P1009 with 36 guns, 6600 in<sup>3</sup>.
- Shot 55379, JD213, 23:34. No Fire due to air leak, string 1. 35 guns at 6240 in<sup>3</sup>.
- Shot 55445: Gun strings 1 and 2 disabled.
- Shot 55446: First shot of JD214.
- Shot 55538, JD214, 0:40. Break off for repair. Last shot before circling back. 18 guns, 3300 in<sup>3</sup>.

Sequence 13, P1TST4

- Shot 55983, JD214, 01:37: Start of test line, circling back for repairs. 18 guns, 3300 in<sup>3</sup>.
- Shot 56453, JD214, 04:30. End of test line. 18 guns, 3300 in<sup>3</sup>.

Sequence 14, P41009

Dead channels: 61,85,133,421, 501,537,624,625,636,637,668,685,789,861, 957.

Weak channels: 252, 600, 708, 751, 830, 837, 900, 933.

Noisy channels: 943, 944, 955, 958.

- Shot 58166, JD214, 05:55: Start of ramp-up. 2 guns, 80 in<sup>3</sup>.
- Shot 58212, JD214, 06:16. Ramp-up complete. 36 guns, 6600 in<sup>3</sup>.
- Shot 59757, JD214, 15:26. Sequence ends because of air leak in string 4. Circling back.

Sequence 15, P51009

- Shot 60426, JD214, 20:44: First shot of ramp-up at 40 in<sup>3</sup>.
- Shot 60485, JD214, 21:06: Ramp-up complete. 36 guns, 6600 in<sup>3</sup> volume.
- Shot 60985: First shot of JD215.
- Shot 62173, JD215, 7:39: One shot at 6240 in<sup>3</sup>. Other shots not affected.
- Shot 62258, JD215, 7:52: Last good shot before turn.
- Shot 62290, JD215, 7:53: End of line, and halfway into the inside turn.

**Line P1010**

Sequence 16, P11010

- First shot 63058 at JD215, 8:22. 36 guns, 6600 in<sup>3</sup> volume.
- Shot 63689, JD215, 13:49: Air leak on string 2. Repairs while shooting 27 guns, 4950 in<sup>3</sup>.
- Shot 63757, JD215, 15:04: String 2 ready for redeployment, ship starting inside turn. 4950 in<sup>3</sup>.
- Shot 63777, JD215, 15:34: End of line with 27 guns, 4950 in<sup>3</sup>.

**Line P1011**

Sequence 17, P11011

Dead channels: 61,85,133,421, 501,537,624,625,636,637,668,685,789,861, 957.

Weak channels: 252, 600, 708, 751, 830, 837, 900, 933.

Noisy channels: 943, 944, 955, 958.

- Shot 64033, JD215, 15:46: Start of the line with 36 guns, 6600 in<sup>3</sup>.
- Shot 65386, the last shot of JD215.
- Shot 67022, at JD216, 09:32 air leak at gun 4, string 1. 35 guns firing at 6240 in<sup>3</sup>.
- Shot 67075: Bringing strings 1 and 2 in for repair.
- Shot 67180, JD216, 10:36: End of line, circling back. 18 guns firing at 3300 in<sup>3</sup>.

Sequence 18, P21011

- Shot 70780, JD216, 15:26: Start of line with ramp-up, 1 gun at 40 in<sup>3</sup>.
- Shot 70839: End of ramp-up. 36 guns, 6600 in<sup>3</sup>.
- Shot 72215: First Shot of JD217.
- Shot 73464: Change of course 15° starboard to avoid fishing vessel.
- Shot 73818, JD217, 9:22: String 3, gun 9 no fire, air leak, disabled. 35 guns firing at 6380 in<sup>3</sup>.
- Shot 73959, JD217, 10:20: Deviating another 50° starboard to avoid fishing vessels and gear.
- Shot 73984, JD217, 10:37: End of the line, 35 guns firing 6380 in<sup>3</sup> volume.

### **Line P1012**

#### Sequence 19, P11012

- Shot 75062, JD217, 11:05: Continue portside turn. 35 guns firing 6380 in<sup>3</sup> volume.
- Staying clear of fishing vessels on both sides of the line.
- Shooting 20 km west of Waypoints 12 and 13.
- Shot 75758: Disabled gun string 3 for recovery. 27 guns firing 4950 in<sup>3</sup> volume.
- Shot 76005, JD217, 17:46: End of line with 50° starboard turn. 27 guns, 4950 in<sup>3</sup> volume.

### **Line P1013**

#### Sequence 20, P11013

Dead channels: 61,85,133,421, 501,537,624,625,636,637,668,685,789,861, 957

Weak channels: 252, 600, 708, 751, 830, 837, 900, 933.

Noisy channels: 943, 944, 955, 958.

- Shot 77288, JD217, 18:04: Start of the line, 27 guns, 4950 in<sup>3</sup> volume.
- Shot 77539: Repair of string 3 complete. 36 guns firing 6600 in<sup>3</sup> volume.
- Shot 77960: First shot of JD218.
- Shot 80373, 15:51: Lightning strikes behind ship visible on streamer data, no damage.
- Shot 81059, 20:01: Failure of fire control box gun string. 27 guns firing 4950 in<sup>3</sup> volume.
- Shot 81092: While fixing GCU, string 4 also disabled. 18 guns firing 3300 in<sup>3</sup> volume.
- Shot 81103, 20:22: Acoustic array restored, except gun 3: 35 guns firing 6560 in<sup>3</sup> volume.
- Shot 81156, JD218, 20:44: Air leak string 3, gun 9: 34 guns firing 6340 in<sup>3</sup> volume.
- Shot 81209: Getting ready for circling back for repairs, and reshoot GCU and air leak.
- Shot 81258, JD218, 21:38: End of line, 26 guns firing 4910 in<sup>3</sup> volume.

#### Sequence 21, P1TST5

- Shot 82086, JD218, 23:46: Start of test line, while circling back. Ramp-up, 40in<sup>3</sup>.
- Shot 82124: First shot of JD219.
- Shot 82267, JD219, 0:51: 35 guns firing 6560 in<sup>3</sup> volume.
- Shot 82427, 01:53: End of line, 35 guns firing 6560 in<sup>3</sup> volume.

#### Sequence 22, P21013

- Shot 82771, JD219, 2:26: Start of the line, 35 guns firing 6560 in<sup>3</sup> volume.
- Shot 83120, JD219, 4:49: Air leak string 2. End of line, circle back. 26 guns 4910 in<sup>3</sup> volume.

#### Sequence 23, PTST6

- Shot 84125, JD219, 06:07: First shot of test line, while circling back. 26 guns, 4910 in<sup>3</sup> volume.
- Shot 84261: String 2 back in position, 35 guns, 6560 in<sup>3</sup>.
- Shot 84360, JD219, 07:54: End of line. 35 guns, 6560 in<sup>3</sup>.

#### Sequence 24, P311013

- Shot 84928, JD219, 09:25. Start of line, continues on P1013. 35 guns at 6560 in<sup>3</sup>.
- Shot 86123: Start deviation from line with inside turn north.
- Shot 86135, JD219, 17:19: End of line, 35 guns at 6560 in<sup>3</sup>. Start streamer recovery.

#### Sequence 25, P411013

Dead channels: 13,37,61,85,133, 241, 249, 421, 501, 537, 624, 637, 668, 685, 789, 861, 957

Weak channels: 252, 600, 708, 751, 830, 837, 900, 933

- Shot 91754, JD 221, 17:43. Start of test line with soft ramp-up. 1 gun, 40 in<sup>3</sup>.
- Shot 60882, 18:05. Ramp-up complete. 36 guns at 6600 in<sup>3</sup>.
- Shot 60889, 18:08: Front cluster (guns 1 and 2) of string 3 no fire. 34 guns at 5880 in<sup>3</sup>.
- Shot 60961, 18:43: Turned off streamer power to tail buoy to eliminate electrical noise, in the last few streamer sections.
- Shot 61247, JD221, 21:04: End of line, starting turn. 34 guns at 5880 in<sup>3</sup>.

### **Line P1014**

#### Sequence 26, P11014

Dead channels: 13,37,61,85,133, 241, 249, 421, 501, 537, 624, 637, 668, 685, 789, 861, 957

Weak channels: 252, 600, 708, 751, 830, 837, 900, 933

- Shot 93018, JD 221, 21:11, start of the line. 34 guns, 5880 in<sup>3</sup>.
- Shot 93393, Last shot of JD221.
- Shot 96903, last shot of JD222.
- Shot 99222, JD223, 18:21: Start deviating from line.
- Shot 99247, JD223, 18:34: End of line. 34 guns, 5880 in<sup>3</sup>.

### **Line P1015**

#### Sequence 27, P11015

Dead channels: 13,37,61,85,133, 241, 249, 421, 501, 537, 624, 637, 668, 685, 789, 861, 957

Weak channels: 252, 600, 708, 751, 830, 837, 900, 933

- Shot 100031, JD223, 18:47: Start of the line. 34 guns, 5880 in<sup>3</sup>.
- Shot 100512, 22:04: Electrical noise on last few channels. Tail buoy GPS intermittent.
- Shot 100762: First shot of JD224.
- Shot 100851, JD224, 00:43: Tail buoy power turned off, electrical noise on streamer ends.
- Shot 101254, 03:54: Tailbuoy power restored.
- Shot 10246, JD224, 12:02: End of the line. 34 guns, 5880 in<sup>3</sup>.

### **Line P1016**

#### Sequence 28, P11016

Dead channels: 13,37,61,85,133, 241, 249, 421, 501, 537, 624, 637, 668, 685, 789, 861, 957

Weak channels: 252, 600, 708, 751, 830, 837, 900, 933.

- Shot 103120, JD224, 13:01: Start of the line, with string 3 on deck. 27 guns, 4950 in<sup>3</sup>.
- Shot 103457, 14:49: String 3, gun 1 works, but gun 2 does not fire. 35 guns, 6240 in<sup>3</sup>.
- Shot 103464, 15:02: String 3 disabled to address gun 2. 27 guns, 4950 in<sup>3</sup>.
- Shot 103471, 15:04: String 3, gun 2 still does not fire. 35 guns, 6240 in<sup>3</sup>.
- Shot 103478, 15:07: String 3 disabled to address gun 2. 27 guns, 4950 in<sup>3</sup>.
- Shot 103509, 15:17: String 3, gun 2 still does not fire. 35 guns, 6240 in<sup>3</sup>.
- Shot 103522, 15:22: String 3 disabled to address gun 2. 27 guns, 4950 in<sup>3</sup>.
- Shot 103548, 15:31: String 3, gun 2 still does not fire, for good. 35 guns, 6240 in<sup>3</sup>.
- Shot 103575, JD224, 15:31: End of line. 35 guns, 6240 in<sup>3</sup>.

### **Line P1017**

#### Sequence 29, P11017

Dead channels: 13,37,61,85,133, 241, 249, 421, 501, 537, 624, 637, 668, 685, 789, 861, 957

Weak channels: 252, 600, 708, 751, 830, 837, 900, 933

- Shot 104085, JD224, 16:12: Start of line. 35 guns, 6240 in<sup>3</sup>.
- Shot 104928, 21:08: Two shots with low pressure (1730 psi) due to compressor problem.
- Shot 105424: Last shot of JD224.
- Shot 107600, JD225, 16:35: Current 4.2 kts, SOG 1-1.5 kts. Feathering 55°.
- Shot 107856, JD225, 22:00: Current 4.1 kts, SOG 1.0 kts. Feathering 46°.

- Shot 107899, 23:14: Recovered string 3 for repair of gun 2. 27 guns, 4950 in<sup>3</sup>.
- Shot 107947: First shot of JD226.
- Shot 74292, 00:46: String 3 enabled. Array firing 36 guns, 6600 in<sup>3</sup>.
- Shot 74467, JD226, 02:31. End of Line P1017.

### **Line P1018**

#### Sequence 30, P11018

- Shot 109017, JD 226, 02:48: Start of line. Array firing 36 guns, 6600 in<sup>3</sup>.
- Shot 109470, JD 226, 10:27: End of line. Array firing 36 guns, 6600 in<sup>3</sup>.

### **Line P1003**

#### Sequence 31, P21003

Dead channels: 13,37,61,85,133, 241, 249, 421, 501, 537, 624, 637, 668, 685, 789, 861, 957

Weak channels: 252, 600, 708, 751, 830, 837, 900, 933

- Shot 111234, JD226, 11:51: Start of the reshoot P21003. 36 guns, 6600 in<sup>3</sup>.
- Shot 111580, 13:50: Shot overlap due to high SOG.
- Shot 113311: Start of JD228.
- Shot 113807: Dog leg, heading 119°, slight portside turn, north of old P1003.
- Shot 114846, JD228, 09:10: End of line. 36 guns, 6600 in<sup>3</sup>.

### **Line P1028**

#### Sequence 32, P11028

Dead channels: 13,37,61,85,133, 241, 249, 421, 501, 537, 624, 637, 668, 685, 789, 861, 957

Weak channels: 252, 600, 708, 751, 830, 837, 900, 933

- Shot 115069, JD227, 09:32: Start of the Line. Gun 1 of string 3 disabled. 35 guns, 6240 in<sup>3</sup>.
- Shot 117544: First shot of JD228.
- Shot 117784, JD228, 01:23: Compressor problem: 0 air guns, 0 in<sup>3</sup>.
- Shot 117798: Shots missing until Shot 1117808.
- Shot 117809, JD228, 01:33: Soft ramp-up: 1 gun, 40 in<sup>3</sup>.
- Shot 1117866, 01:55: Soft start complete: 35 guns, 6240 in<sup>3</sup>.
- Shot 120770, JD228, 09:32: End of the line. 35 guns, 6240 in<sup>3</sup>.

### **Line P1029**

#### Sequence 33, P11029

Dead channels: 13,37,61,85,133, 241, 249, 421, 501, 537, 624, 637, 668, 685, 789, 861, 957

Weak channels: 252, 600, 708, 751, 830, 837, 900, 933

- Shot 121026, JD228, 19:04: Start of the line. 35 guns, 6240 in<sup>3</sup>.
- Shot 84925: First shot of JD229.
- Shot 122078, JD229, 02:05: End of the line. 35 guns, 6240 in<sup>3</sup>.

### **Line P1033**

#### Sequence 34, P11033

Dead channels: 13,37,61,85,133, 241, 249, 421, 501, 537, 624, 637, 668, 685, 789, 861, 957

Weak channels: 252, 600, 708, 751, 830, 837, 900, 933

- Shot 123019, JD 229, 02:12: Start of the Line. 35 guns, 6240 in<sup>3</sup>.
- Shot 123030: Noise on the streamer from several nearby lightning strikes.
- Shot 124960, 15:42: gun 1 of string 2 autofires, disabled. 34 guns, 5880 in<sup>3</sup>.
- Shot 125826, 20:48: String 2, gun 1 disabled with timing errors: 33 guns, 5520 in<sup>3</sup>.
- Shot 126361, JD229, 23:57: End of the line and seismic reflection shoot. 33 guns, 5520 in<sup>3</sup>.

### Appendix A3. Serial data

During surveys, the R/V *Marcus Langseth* continuously records navigation, weather data, oceanographic and geophysical data. The serial data streams are made available continuously to the science party. LDEO science tech Gilles Guerin maintained a file in csv format where these data streams were merged at 10 seconds and one-minute intervals. These files are named MGL2309\_serial\_data\_1min.csv and MGL2309\_10sec.csv, respectively. We used this record extensively to track our progress, to process gravity and magnetic field data, and to update our data acquisition maps.

Data fields in merged serial data are: Julian Day, Date, Time (UTC), Latitude, Longitude, Ship Heading, Ship Speed, Wind Speed, Wind Direction, Depth, Magnetic Field Magnitude, Gravity, Sea Temperature, Salinity, Sound Velocity, Air Temperature, Speed through Water, Course over Ground, Air Pressure,

Below we summarize the format of various time series data sets that we used during cruise MGL2309, and that form the basis of the merged serial data output. This is not a complete list of all time series and data types that are made available

#### Navigation.

CNAV 3050 outputs data in NMEA 0183 compatible format at a 1-second interval. This includes the GPVTG (GPS velocity, track made good and ground speed data) and GPGGA (Global Positioning System fix data).

File format : MGL-cnav.y\*\*\*d\*\*

*\$GPVTG, xxx.x, T, M, m.mm, N, n.nn, K\*hh*

*xxx.x* course over the ground COG). Degrees from true North.

*T* Flag course relative to North

*M* Degrees from magnetic North.

*m.mm* SOG, nautical miles per hour, knots.

*N* Flag that speed is in knots.

*n.nn* SOG in km/h.

*K* Flag speed in km/h.

*\$GPGGA, hhmmss.ss, ddm. mmmmm, a, ddm. mmmmm, a, x, xx, x.x, xx.xx, M, xx.xx, M, x.x, xyy\*hh*

*hhmmss.ss* UTC time of position

*ddm. mmmmm* Latitude

*a* Flag N/S

*ddm. mmmmm* Longitude

*a* Flag E/W

*x* Flag GPS quality (0=bad)

*xx* Number of satellites

#### POS/MV Position and Heading

POS/MV outputs data using the NMEA 0183 format at rates of up to fifty sentences per second. The following seven different sentence formats are available.

*\$INGGA*-Global System Position Fix Data

*\$INHDT*-Heading - True data

*\$INVTG*-Course over ground and Ground speed data

*\$INGST*-GPS pseudorange noise statistics

*\$PRDID*-Attitude data

*\$INZDA*-Time and date.

File format : MGL-posmv.y\*\*\*d\*\*

*\$INGGA, hhmmss.sss, llll.llll, a, yyyy.yyyy, b, t, nn, v.v, x.x, M,,c.c,rrrr\*hh*  
*hhmmss.sss* UTC time of position  
*llll.llll* Latitude  
*a* Flag North or South  
*yyyy.yyyy* Longitude  
*b* Flag East or West  
*t* GPS quality factor  
*nn* Number of satellites in fix

*\$INHDT, x.x, T\*hh*  
*x.x* True vessel heading in vessel frame (degrees)

*\$INVTG, x.x, T, M, n.n, N, k.k, K\*hh*  
*x.x* True vessel track in frame (degrees)  
*n.n* Speed (knots)

*\$INZDA, hhmmss.ss, DD, MM, YYYY,, \*hh*  
*hhmmss.ss* GPS time  
*DD* Day of month  
*MM* Month  
*YYYY* Year

### **Bathymetry.**

The center beam depth is extracted from the Kongsberg EM122 multibeam data.

File format: MGL---bath02.y\*\*\*\*d\*\*\*

*bath02 2015:233:00:14:27.1279 \$KIDPT,4840.83,5.60,12000.0\*73*  
*bath02 yyyy:ddd:hh:mm:ss.ssss \$KIDPT,xxxx.xx,z.zz,rrrr.r\*##*  
*xxxx.xx* Seafloor bottom depth from transducer face.

### **Magnetics.**

The G-822 Cesium Marine Magnetometer converts the cesium Larmor signal (70 kHz to 350 kHz) into magnetic field strength in nano-Tesla (20,000 nT to 100,000 nT) by using a CM-221 counter module.

File name: MGL---mag01.y\*\*\*\*d\*\*\*

*mag012015:114:00:17:32.7965 \$ 49034.313,0781,0876*  
*mag01yyyy:ddd:hh:mm:ss.ssss \$ xxxxx.xxx,aaaa,bbbb*  
*xxxx.xxx* Magnetic Field Strength (nano Teslas)

### **Gravity.**

Gravity data are recorded continuously on the R/V *Marcus Langseth* with a Bell Aerospace BGM-3 gravimeter. Gravity measurements are logged as counts at a 1 second interval in the raw serial data. There is no manual on the Langseth for the conversion of raw gravity counts to SI units.

File format: MGL-vc01.y\*\*\*\*.d\*\*\*

*vc01 2015:234:00:00:53.7862 04:024326 00*  
*vc01 yyyy:ddd:hh:mm:ss.ssss xx:yyyyyy ff*  
*xx* Output frequency  
*yyyyyy* Raw gravity counts

## Water temperature and salinity

The Thermosalinograph data from the Seabird Electronics SBE-45 integrated temperature and conductivity unit is output in the following sentence formats that includes the Seabird SBE-38 Remote Temperature Sensor located at the Uncontaminated Seawater System intake in the bow of the RV *Marcus G. Langseth*.

File format: *MGL---tsgraw.y\*\*\*\*d\*\*\**

*tsgraw 2015:234:00:04:28.6392 t1=27.7779, c1= 5.75784, s=36.1196, sv=1541.693, t2=27.6301*  
*tsgraw yyyy:ddd:hh:mm:ss.ssss t1= tt.tttt, c1=cc.cccccc, s= ss.ssss, sv=vvvv.vvv, t2=tt.tttt*

<i>t1</i>	Temperature from SBE 45 – TSG
<i>c1</i>	Conductivity (S/m)
<i>s</i>	Inferred salinity (psu)
<i>sv</i>	Inferred acoustic wavespeed (m/s)

## Weather

The meteorological data from the Vaisala WXT-520 integrated weather station includes wind speed and direction, air temperature, humidity, pressure, and precipitation.

File format: *MGL-vaisala1.y\*\*\*\*.d\*\*\**

*\$WIXDR,A,105,D,0,A,105,D,1,A,105,D,2,S,3.7,N,0,S,3.8,N,1,S,3.9,N,2,C,27.2,C,0,C,28.4,C,1,H,70.5,P,0,*  
*P,1 013.5,H,0,V,0.00,M,0,Z,0,s,0,R,0.0,M,0,V,0.0,M,1,Z,0,s,1,R,0.0,M,1,R,1.7,M,2,R,0.0,M,3\*6D*  
*\$WIXDR,A,xxx,D,0,A,xxx,D,1,A,xxx,D,2,S,x.x,N,0,S,x.x,N,1,S,x.x,N,2,C,xx.x,C,0,C,xx.x,C,1,H,xx.x,P,0,P,x*  
*x xx.x,H,0,V,x.xx,M,0,Z,0,s,0,R,x.x,M,0,V,x.x,M,1,Z,0,s,1,R,x.x,M,1,R,x.x,M,2,R,x.x,M,3\*6D*

<i>x.x</i> (following second S):	Average wind speed (knots)
<i>xx.x</i> (following C):	Temperature (°C).

## Appendix A4. Multibeam Bathymetry Processing

**Data Acquisition:** Bathymetric data acquisition was performed using a Kongsberg EM-122 multibeam echosounder system (Figure A4.1), with control and monitoring facilitated by the Kongsberg SIS (Seafloor Information System) acquisition software on board the R/V *Marcus Langseth*. The system comprises hull-mounted transducer arrays, including a transmit unit ( $150^\circ \times 1^\circ$ ) positioned along the ship's central axis, emitting signals at a frequency of 12.0 kHz. The receive unit ( $1^\circ \times 30^\circ$ ) is located aft of the transmit unit, oriented athwart-ships.

Continuous data acquisition was maintained throughout the cruise, ensuring comprehensive mapping of the seafloor along the vessel's trajectory. Survey lines were gathered at speeds ranging from 3 to 5 knots during seismic data acquisition and up to 8 to 10 knots while in transit. The maximum beam angles were typically configured at  $65^\circ$  for both the port and starboard sides. This configuration results in a swath of 288 beams, generating an across-track profile consisting of 432 soundings. In waters approximately 2000 m deep, the system operated with a ping rate of  $\sim 0.32$  Hz. processing computer.



**Figure A4.1.** Kongsberg EM122 transmit (EM122 Tx) and receiver (EM122 Rx).

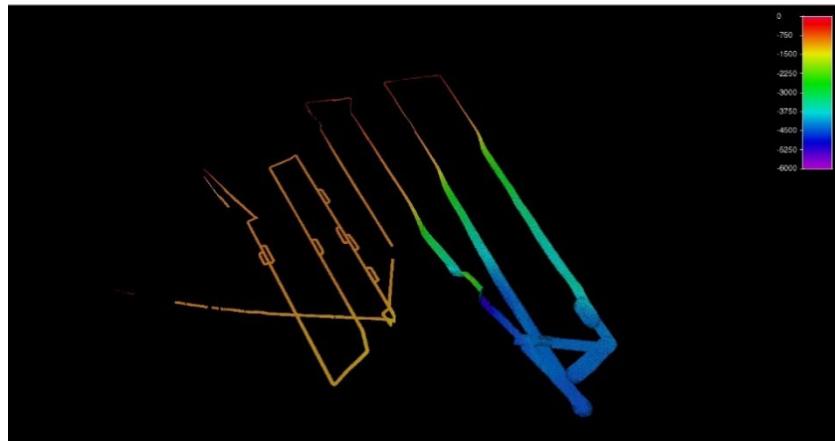
processing we made use of QPS Qimera version 2.5.3 (Figure A4.2). The measurement offsets between the multibeam transducers and the inertial measurement unit (IMU), along with the angular offsets encompassing roll, pitch, and heading values for both the transducer and IMU, were imported from the Kongsberg raw sonar (.all) files. While these parameters were initially utilized for the computation of sounding positions and depths within the Seafloor Information System (SIS), their relevance extended to Qimera for subsequent tasks, including the determination of total propagated uncertainty (TPU) and the application of sound velocity corrections to raw range/angle data.

The processing workflow commenced with the incorporation of Kongsberg (.all) files into the project database using Qimera. In this step, Qimera generated an internal QPD format. Each file's information was integrated into a dynamic surface characterized by a node spacing of 50 meters (Figure A4.2). This integration was achieved using a Combined Uncertainty and Bathymetric Estimator (CUBE) algorithm.

To measure water sound speed, an AML Oceanographic Micro SV instrument was employed at the transducer. The system's sound velocity profile (SVP) was derived from the XBT profiles obtained during the cruise (see Appendix A7). These profiles underwent error checking, smoothing, and depth extension before being imported into the SIS environment. Both the Dual Swath Mode and Ping Mode were configured to operate in "auto" mode. The original Kongsberg sonar data files are in .all format, water column data in .wcd format.

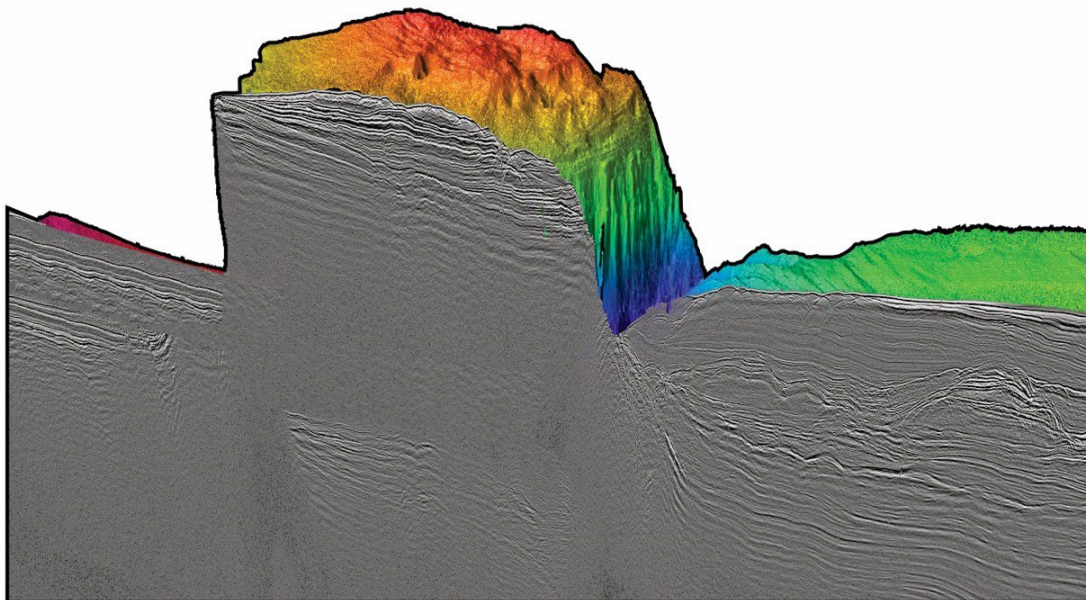
For bathymetric data

The subsequent phase involved manual assessment and culling of soundings through the utilization of Qimera's swath editor and its suite of 2D and 3D editing tools.



**Figure A4.2.** Processing bathymetry data gathered during cruise MGL2309 with Qimera.

We acquired a total of ~4000 kilometers of multibeam data. One of the important features that we found within the data is the Blake Spur (Figure A4.3). This structure is located on the outer shelf of the Blake Plateau at ~2400 m depth, and it stands ~2500 m above the seafloor of the Blake-Bahamas basin. The detailed bathymetry image of the surface of the Blake Spur exhibits karst features. In Figure A4.2, a multichannel seismic reflection image of Line P1004 reveals internal sedimentary layering. Furthermore of note are the steep edges located on the north and south of the Blake Spur.



**Figure A4.3.** Composite image of the Blake Spur viewed from the northeast. Left is southeast, right is northwest. Seismic reflection data re a detail of Line P1007. The bathymetry data on top were gathered with the Kongsberg echosounder on the Langseth during cruise MGL2309, and processed with Qimera.

## **Appendix A5. Knudsen 3.5 kHz sub-bottom profiler**

The Knudsen sub-bottom imaging system was active throughout the cruise. We shut down the Knudsen system in the Extended Economic Zone of the Bahamas, but we recorded data in US and international waters. The incoming data were stored in segy, kea and keb formats in the raw data folder of cruise MGL2309. The Knudsen data show very shallow sediment structure along our track lines. The 3.5 kHz data did not play a role in the objectives of the marine seismic cruise, but they may be valuable to other scientists that want to integrate them with the seismic reflection profiles and bathymetric data from cruise MGL2309.

## Appendix A6. Gravity and magnetics

On board the R/V *Marcus Langseth* we gathered continuous gravity data with the Bell Aerospace BGM-3 gravimeter. The raw data were stored with a 1.0 s rate in the serial data files MGL-vc01.y\*\*\*\*d\*\*\* (for formats, see Appendix A7). Towed magnetic data were gathered during seismic data acquisition on the R/V *Marcus Langseth* with a Geometrics G-882 Cesium marine magnetometer. These data were stored at a 0.1 s rate in the serial data files MGL-mag01.y\*\*\*\*d\*\*\*. Both data streams were also concatenated in the merged serial data streams at 10 s and one-minute intervals.

### Corrections and Filtering

During cruise MGL2309 we used the *MGL2309\_serial\_data\_1min.csv* merged serial file to extract the time series for bathymetry, gravity, and magnetics data, but also the ship's latitude and heading. The gravity, magnetics, and bathymetry time series had a few gaps.

To remove high-frequency noise we applied a Gaussian filter to the gravity data in the time domain with a 2-hour length. Next, we applied a Eotvos correction, using the ship's speed and heading, and calculated gravity anomalies by subtracting the International Gravity Formula (IGF). The international gravity formula (Eq. 1) and Eotvos effect (Eq. 2) were calculated for all latitudes in our survey area.

$$IG(\phi) = 978032.7 (1 + 0.0053024 \sin^2(\phi) - 0.0000058 \sin^2(2\phi)) \text{ mGal} \quad (1)$$

$$Et = 7.5038 \times sp \times \sin(hd) \times \cos(\phi) + 0.004154 \times sp \quad (2)$$

Here  $\phi$  is the latitude in decimal degrees, **sp** is the ship's speed in knots per second (Kts), and **hd** is the ship's heading in degrees. The corrected free-air gravity anomaly was then calculated using Eq. 3.

$$\text{Free - air gravity anomaly} = \text{measured gravity} - IG + Et \quad (3)$$

For the Langseth's shipboard magnetic data, we subtracted the International Geomagnetic Reference Field (IGRF) to obtain magnetic anomalies. The magnetic anomaly was then calculated through Eq. 4

$$\text{Magnetic anomaly} = \text{measured intensity} - \text{total intensity} \quad (4)$$

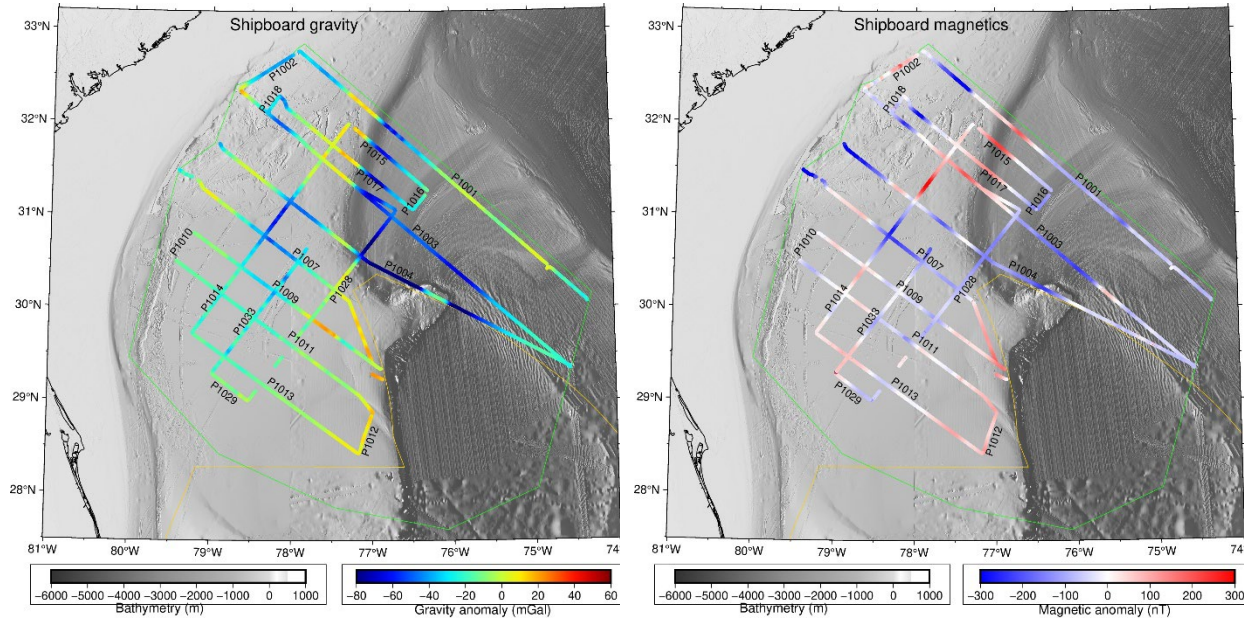
### Results

We gathered gravity and magnetic data on most of our track lines (Figure A5.1). Gravity measurements were made continuously between Port Canaveral and Charleston. A gravity tie was made on ... in Port Canaveral, and a second gravity tie in Charleston is scheduled after the MGL2310 cruise. We gathered magnetic data on all our seismic lines, but not in transit. The gravity data that we collected along the eastern portion of seismic Line P1009, from July 31 until August 2, are suspect. The shipboard gravity data in this area deviate from the gridded gravity data (Sandwell et al., 2014) significantly, and they also do not match the crossing profiles P1007 and P1028.

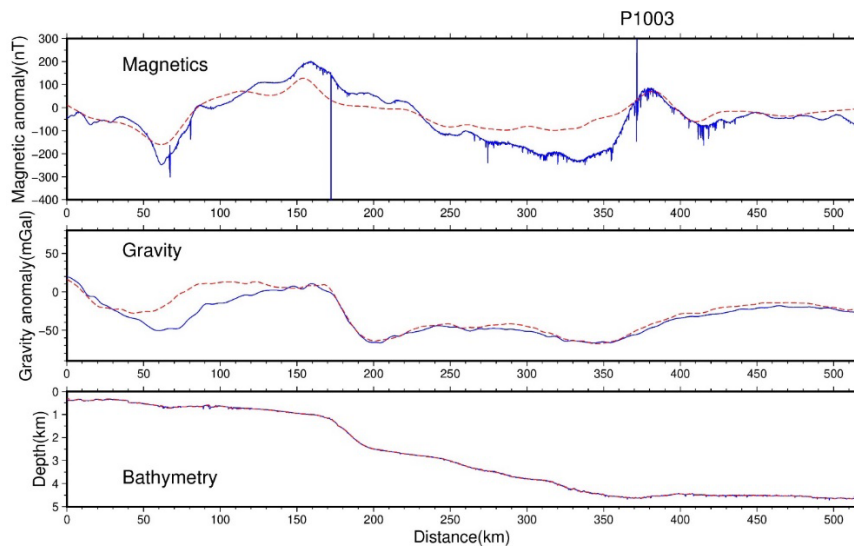
We compare the shipboard bathymetry (Appendix A3), gravity and magnetic data gathered along MGL2309 seismic lines with global compilations. For bathymetry we use the Global Multi-Resolution Topography (GMRT) grid, version 4.1; the magnetic data we compare with the Earth Magnetic Anomaly Grid, 2-arc minute resolution (EMAG2, version 3) (Meyer et al., 2017); gridded gravity data are from Cryo-Sat-2 and Jason-1 (Sandwell et al., 2014).

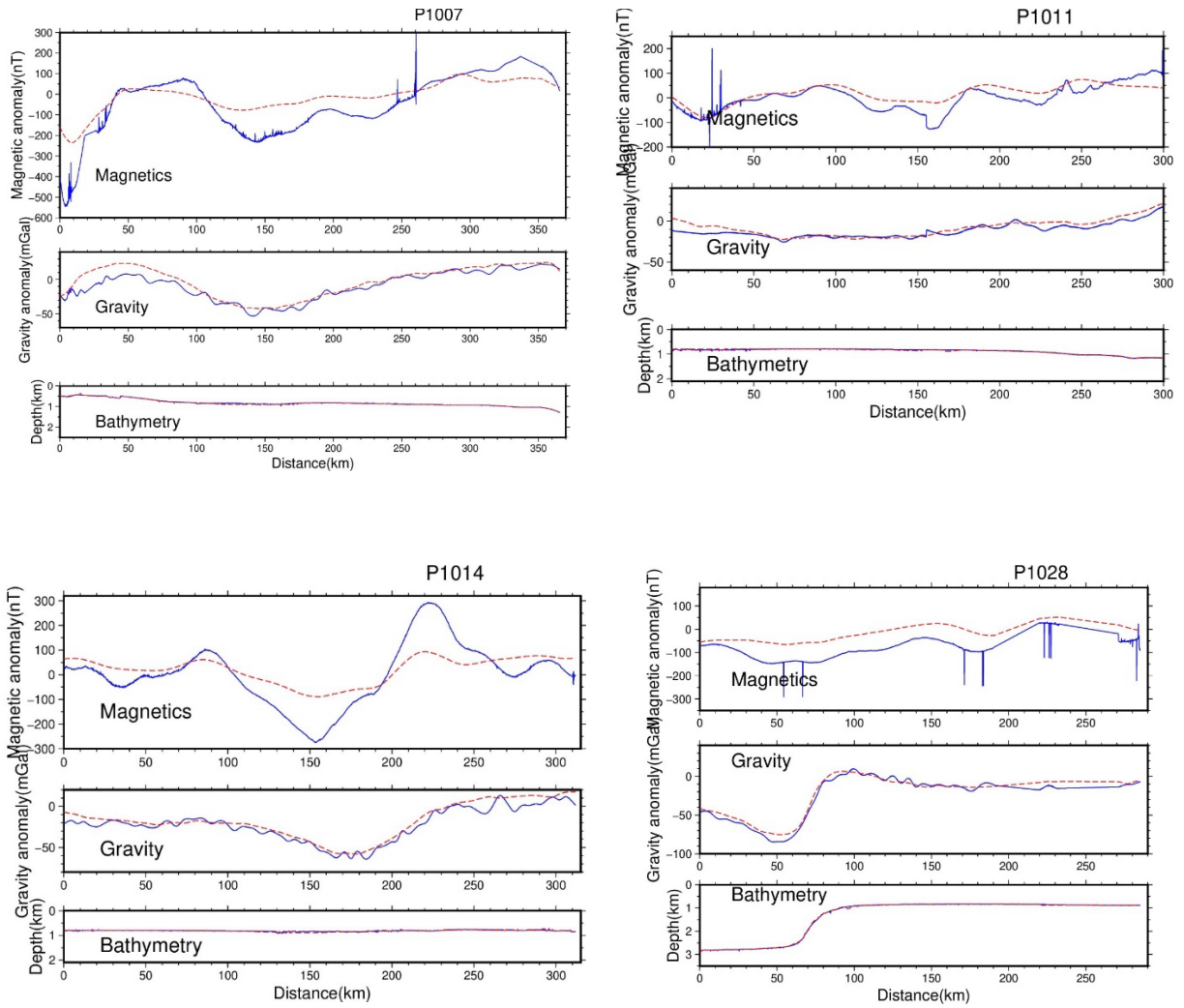
Our profiles (Figure A5.2) show consistent misfit patterns between the shipboard gravity, magnetic and bathymetry data and gridded data. The bathymetry data fit very well. Multibeam mapping during the

MGL2309 cruise covered some areas where high-resolution bathymetric data were not yet available (Appendix A3), but much of the Blake Plateau and southern Carolina Trough is well surveyed. The shipboard gravity data generally fits the Sandwell et al. (2014) compilation well too, but we found deviations on the order of 50 mGal in a few areas. The shipboard magnetic data show much more pronounced magnetic anomalies. For example, we found a much larger negative Brunswick anomaly (-500-300 nT), and a more positive magnetic anomaly at the eastern Blake Plateau (150-200 nT). A direct comparison between gridded and shipboard magnetic data in map view (Figure A5.3) shows that the spatial distribution of magnetic anomalies is consistent.

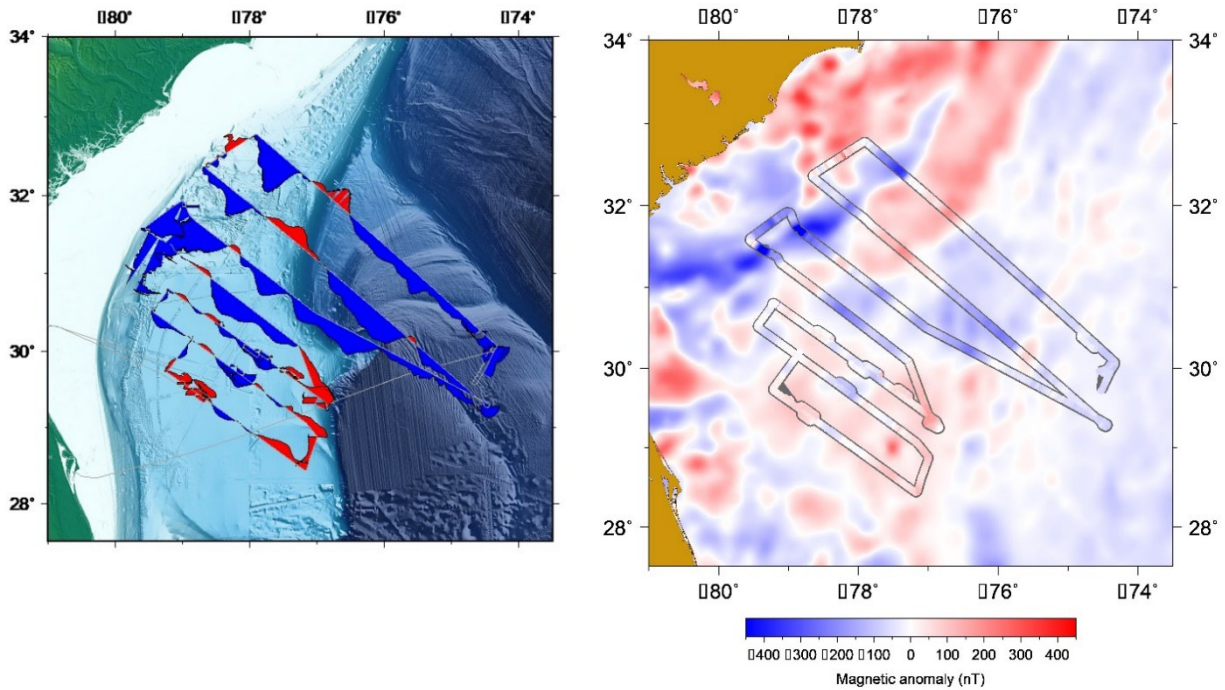


**Figure A6.1.** Inventory of a) gravity and b) magnetic data gathered during MGL2309.





**Figure A6.2.** Five profiles of magnetic anomaly, free-air gravity anomaly and bathymetry acquired during acquisition of seismic lines P1003, P1007, and P1011, P1014, and P1028. The blue curves are shipboard data, and the red curves are extracted from global compilations for comparison. The elevated topography at 180 km offset on P1004 is the Blake Spur. Data fits are discussed in the text.



**Figure A6.3.** A) Magnetic anomalies plotted as wiggles along ship tracks. B) Comparison of shipboard magnetic data with the EMAG2 model in map view.

**Table A6-1. Acquisition of gravity and magnetics data.**

Line	Date1	Time1	Lat1	Lon1	Date1	Time2	Lat2	Lon2	Distance
P1001	19-Jul	13:10	30.06204	-74.32386	22-Jul	10:01	32.77540	-77.91673	259.5
P1002	22-Jul	10:48	32.73942	-77.98457	22-Jul	19:48	32.35903	-78.65445	76.5
P1003	22-Jul	20:00	32.34541	-78.64630	25-Jul	13:27	29.34294	-74.55177	514.2
P1004	25-Jul	17:29	29.35814	-74.55341	28-Jul	15:10	31.77407	-78.90657	499.2
P1007	29-Jul	13:00	31.48940	-79.41952	31-Jul	12:57	29.23753	-76.86832	365.6
P1009	31-Jul	15:38	29.34879	-76.89232	3-Aug	7:53	30.80769	-79.21921	277.9
P1011	3-Aug	15:47	30.50903	-79.43681	5-Aug	10:37	28.86784	-76.99682	299.6
P1012	5-Aug	11:05	28.83819	-77.00933	5-Aug	17:46	28.43950	-77.17764	48.2
P1013	5-Aug	18:05	28.44590	-77.19328	7-Aug	17:20	29.71935	-79.21640	242.4
P1014	9-Aug	21:12	29.73576	-79.22221	11-Aug	18:35	31.98904	-77.27821	311.8
P1015	11-Aug	19:49	31.94562	-77.20362	12-Aug	12:02	31.27210	-76.29521	114.2
P1016	12-Aug	13:02	31.21886	-76.32396	12-Aug	15:44	31.06974	-76.48645	23.1
P1017	12-Aug	16:13	31.08696	-76.51739	14-Aug	2:31	32.29276	-78.15784	206.9
P1018	14-Aug	2:49	32.28624	-78.16831	14-Aug	10:27	32.11368	-78.29577	23.0
P1019	15-Aug	2:46	31.30846	-77.18255	15-Aug	9:09	31.05772	-76.69868	54.3
P1028	15-Aug	9:33	31.03481	-76.71018	16-Aug	18:53	29.00953	-78.52832	285.2
P1029	16-Aug	19:05	29.00987	-78.54297	17-Aug	2:06	29.29509	-78.97413	52.8
P1033	17-Aug	2:13	29.30363	-78.97450	18-Aug	2:46	30.64505	-77.81183	186.6

### References for Appendix A6.

Meyer, B., Chulliat, A., & Saltus, R. (2017). Derivation and Error Analysis of the Earth Magnetic Anomaly Grid at 2 arc min Resolution Version 3 (EMAG2v3): EMAG2 version 3. *Geochemistry, Geophysics, Geosystems*, *18*(12), 4522–4537. <https://doi.org/10.1002/2017GC007280>

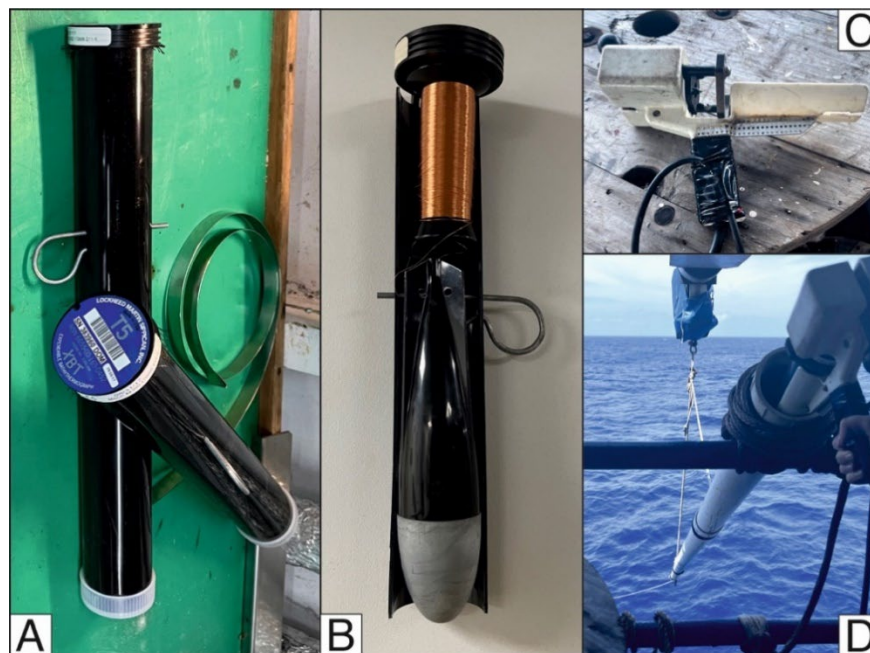
Sandwell, D. T., Müller, R. D., Smith, W. H. F., Garcia, E., & Francis, R. (2014). New global marine gravity model from CryoSat-2 and Jason-1 reveals buried tectonic structure. *Science*, *346*, 65–67. <https://doi.org/10.1126/science.1258213>

## Appendix A7. Expendable Bathythermographs (XBT)

During cruise MGL2309, the water temperature and salinity versus depth were measured with XBT's (T-5 and T-7). The speed of sound in water can be estimated from these properties, which aids marine seismic reflection processing and multibeam bathymetry mapping (see A4. Multibeam report). Along with temperature and salinity, also resistivity is measured. The two probe models (Figure A7.1), T-5 and T-7, have the same vertical data recording resolution of 65 cm but are used under different sea water depth and ship speed. T-5 is used during slower ship transit (5 knots) in deep ocean, and can collect data down to a maximum depth of 1830 m. Instead, T-7 is the most appropriate in shallow water (760 m maximum) and faster ship transits (10 knots). The XBT's were dropped on average once per day, at various points in the survey area but often in water less than 1000 m deep. We anticipated that acoustic wave speed would be most variable on the continental shelf and slope. Complete dataset collected during the cruise is shown in Table A7.1. and provided in a .kml file.

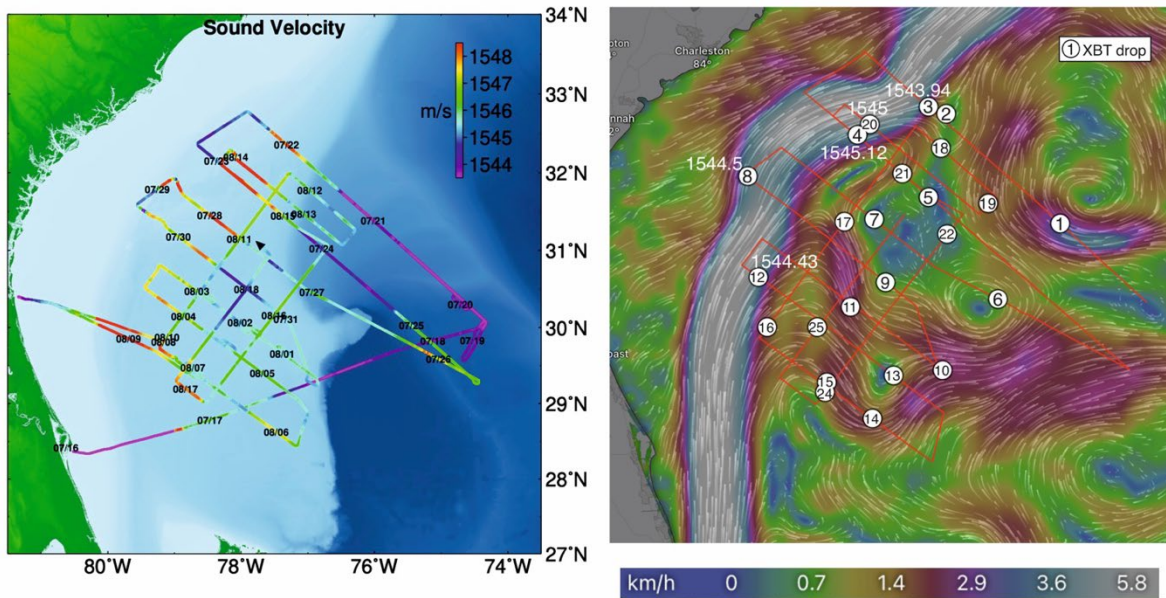
Because the probe falls through the water at a known rate, the depth of the probe can be inferred from the time of launch. It is then possible to plot temperature as a function of depth to create a temperature profile of the water which plays an important role in multibeam mapping operations. The speed at which sound travels changes as the density of water varies through the water column. Temperature and salinity are the two main variables that affect the density of seawater.

The software WinMK21 is used to test the probe as soon as it is detected by the gun (Fig. A7.1C and D) and to visualize the depth-temperature path after the launch. At the end of the acquisition, raw data need to be checked to cut off some wrong values generated in case the probe hits the air gun array, the streamer or the seafloor. These events are imaged as sharp changes in the path of all properties measured. Following, the Sound Speed Manager (v.2022.1.0) software is used to transmit the correct data to the multibeam software, the Kongsberg EM122 aboard the Langseth, which uses the sound velocity to calibrate the seafloor depth.



**Figure A7.1.** A) Example of T-5 probes. B) Internal structure of the probe showing the canister wire spool (copper wire) to the top and the thermistor to the bottom. C) Gun used to load and deploy the probe. D) Picture of the launching tube located on the streamer deck (port side) at 15 m above sea level.

**Results:** During cruise MGL2309, 25 XBT drops were carried out by the science party between July 7<sup>th</sup> and August 17<sup>th</sup>, 2023. The general XBT drop distribution, line position, weather, and currents conditions were checked before every launch along with the seafloor depth. The position of the streamer and air gun line with respect to the currents (and thus, the deployment location on the port) deserves particular attention because the currents can drive the probe toward the instruments, compromising the data collection.



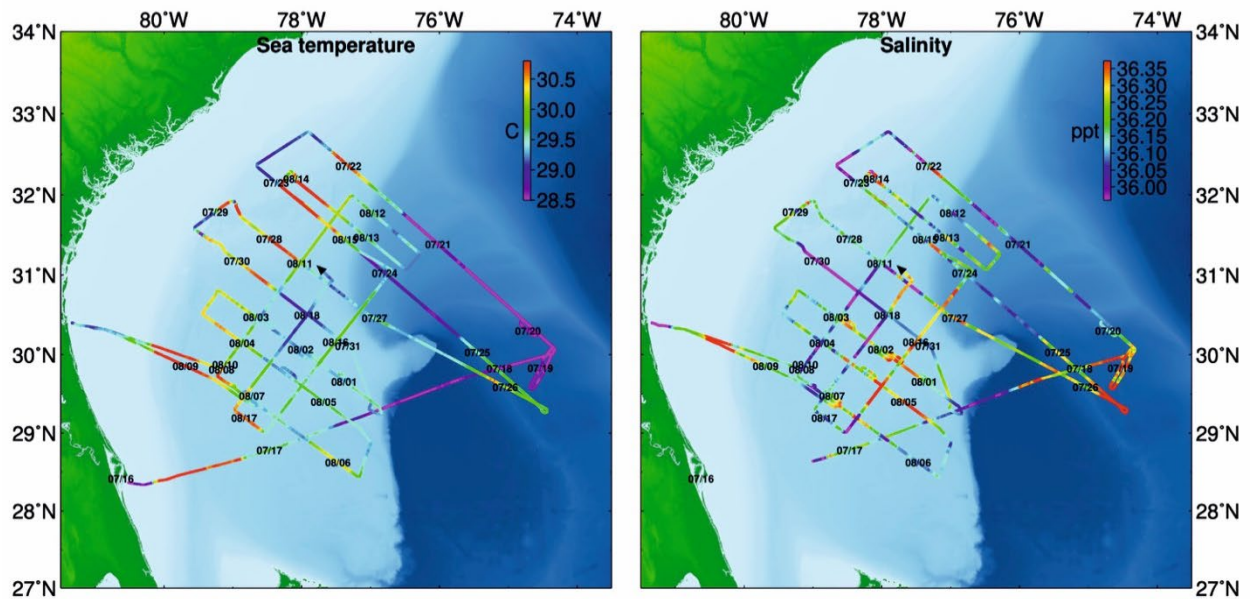
**Figure A7.2.** Left: Shipboard measurements of the speed of sound in water (at 6.1 meters below the surface) along the cruise transit. Purple dots mark the XBT locations. Right: XBT drops and lines plotted on a map showing the Gulf Stream wave speeds (from Windy.com). Note that the sound velocity (white numbers) from XBT within or nearby the Gulf Stream (n. 3, 4, 8 and 20) are generally faster (see also Table A7.1).

The details of the XBT deployments can be found in Table A7.1, including the nearby shot points on the seismic lines, and the depth to which sound speed could be determined. Figure A7.2 compares the shipboard measurements of the speed of sound in water collected during the whole transit and the sound velocity (at 6.1 meters below the surface) from XBT drops plotted on a map of the Gulf Stream wave speeds (from Windy.com). We note that the sound velocity from XBTs, within or nearby the Gulf Stream, are generally faster than the others located further (see also Table A7.1). Figures A7.2 and A7.3 show shipboard measurements of sea temperature and sound velocity measured at 6.1 m depth to be compared to sea temperature and sound velocity vs. depth profiles from XBT's measurements (Figure A7.4).

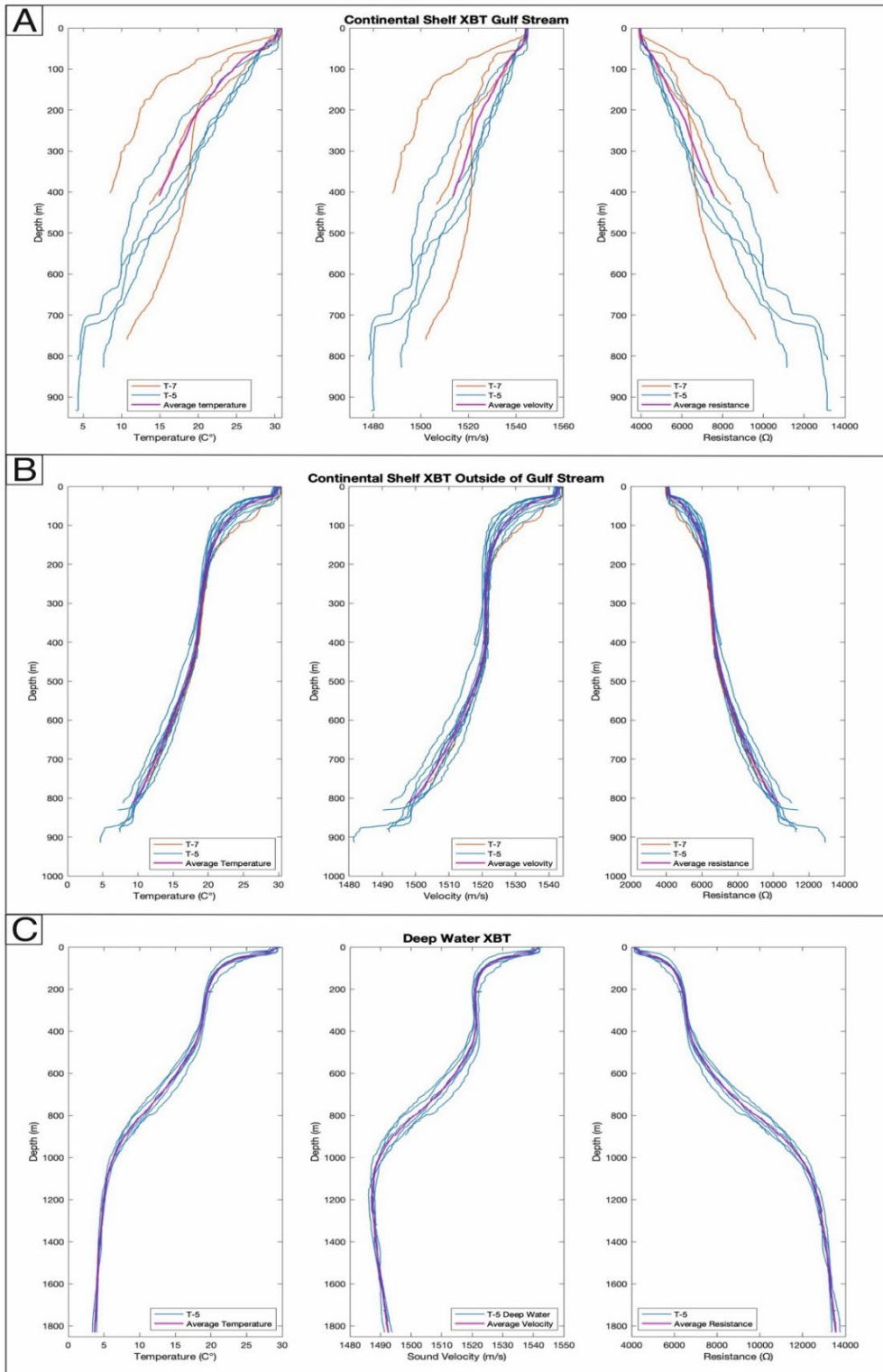
Twenty-one T-5 probes were used in seafloor depths ranging from 807 m to 3629 m, eight of which reached the sea bottom (n. 2, 7, 9, 12, 13, 23, 24, 25) recording complete temperature, sound velocity, and profiles. The other thirteen deployments did not reach the seafloor, possibly due to strong currents (n. 14 and 15) or because the seafloor was deeper than the T-5 maximum depth. The last good seafloor depth recorded by T-5 launches ranges from 407 m to 1830 m. Four T-7 probes were deployed in the shallowest portion of the investigated area, but none of them reached the seafloor, with the last good seafloor depth recorded ranging from 402 m to 760 m. Figure A.7.4 Shows the temperature, velocity, and resistance vs. depth profiles in three groups: A: XBTs launched in the Gulf Stream, B: XBTs launched on the shelf, but outside of the Gulf Stream, and C: the deep water. The Gulf Stream profiles have a greater variation in all three properties measured, than the deep water and shallow water profiles, which all follow a similar trend.

**Table A7.1.** Details of the XBT deployments.

XBT	type	Lon	deg/min	Lat	deg/min	Line	Shot	Day	Time
1	T5	75	27.659	30	57.582	1001	9786	201	15:46
2	T5	77	2.335	32	8.997	1001	13779	202	18:46
3	T5	77	6.817	32	12.314	1001	13966	202	20:18
4	T5	77	59.851	31	54.254	1003	19626	204	4:54
5	T5	76	59.995	31	10.574	1003	22118	204	20:08
6	T5	76	14.972	30	8.762	1004	32608	207	15:18
7	T5	77	47.604	31	0.553	1004	36151	208	12:09
8	T7	79	22.525	31	27.896	1007	39987	210	8:49
9	T5	77	39.076	30	19.805	1007	44234	211	19:28
10	T5	76	56.414	29	22.449	1010	49866	212	16:24
11	T5	78	5.511	30	3.689	1010	55518	214	1:31
12	T5	79	14.369	30	23.066	1011	64493	215	18:51
13	T5	77	33.252	29	19.118	1011	72517	217	1:43
14	T5	77	49.255	28	50.848	1013	78805	218	6:14
15	T5	78	27.666	29	15.036	1013	80340	218	15:39
16	T7	79	8.3467	29	50.429	1014	93303	221	23:22
17	T5	78	10.239	30	58.762	1014	96438	222	19:52
18	T5	76	57.531	31	45.973	1015	100787	223	0:12
19	T5	76	22.221	31	10.327	1016	103257	224	13:50
20	T7	77	50.772	32	1.0151	1017	107344	225	12:11
21	T7	77	26.651	31	29.802	1017	113130	226	22:56
22	T5	76	52.9	30	50.858	1028	115598	227	12:47
23	T5	77	25.554	30	14.852	1028	117289	227	22:32



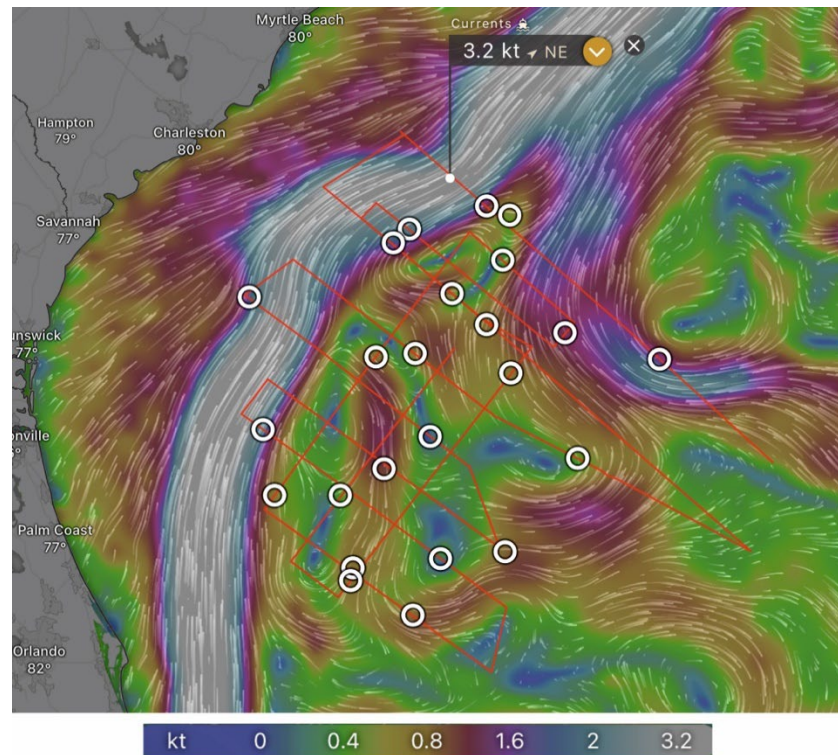
**Figure A7.3.** Shipboard measurements of the sea temperature (Celsius degree) (left) and salinity (part per thousand) at 6.1 meters below the sea surface (right).



**Figure A7.4.** A) XBT temperature, velocity, and resistance vs. depth profiles with the average profile measured in the Gulf Stream. B) XBT temperature, velocity, and resistance vs. depth profiles with the average profile measured on the continental shelf outside the Gulf Stream. C) XBT temperature, velocity, and resistance vs. depth profiles with the average profile measured in the deep water.

## Appendix A8. Gulf Stream

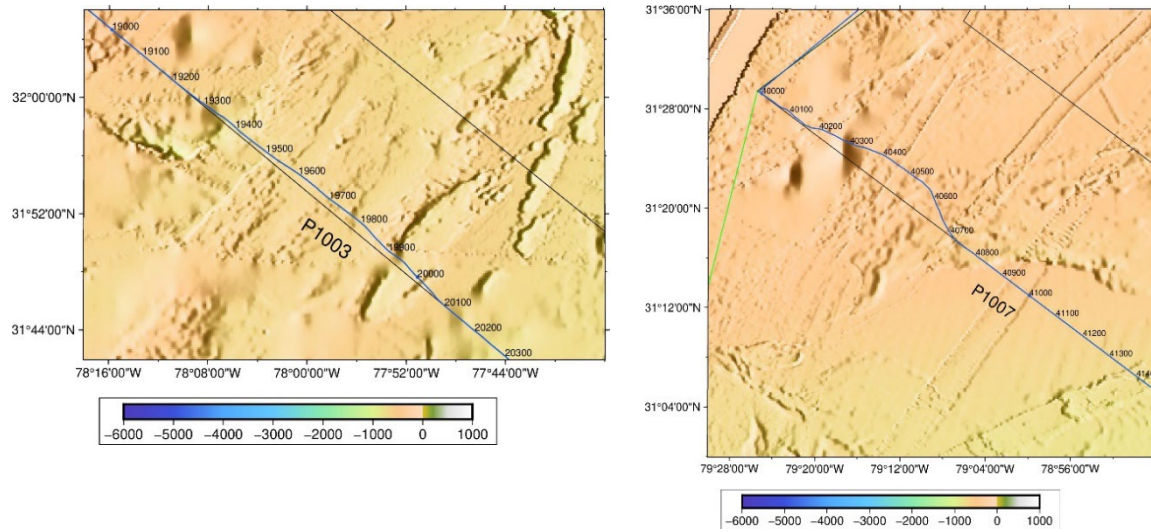
The Gulf stream meanders from the Florida Straits to the northeast across Blake Plateau and the continental shelf of Georgia and South Carolina. During cruise MGL2309 we experienced steady and strong ocean currents at the landward end of the seismic survey. The currents that we encountered outside the Gulf Stream typically did not exceed 1.5 knots, but in the Gulf Stream they easily reached 3.5 knots, and sometimes as high as 5.0 knots. Approximately 50 km east of the Gulf Stream we often found a countercurrent to the southwest, but usually not stronger than 1.0 knots. In Figure A8.1 we show a typical Gulf Stream pattern. Small shifts in the Gulf Stream happened over the course of days or weeks.



**Figure A8.1.** Ocean current map from the Windy app, taken on JD 230. Gulf stream currents (white to light blue) vary between 2.5 and 5.0 knots. The final seismic line plan for MGL2309 is shown by the red lines. XBT drops are shown by white circles.

The maximum tension that the *Langseth* 12-km long streamer can handle is 8,000 lbs, which limits the ship's speed through the water to approximately 5 knots. On the NW-SE oriented seismic lines, the R/V *Marcus Langseth* was crabbing through the Gulf Stream, often at a speed over the ground of just 1.0 knots or less. On some occasions, when the Gulf Stream approached 5.0 knots in strength, the only way for us to make progress was to deviate from the planned track line. For example, on Line P1003 and P1007, transects that we acquired from northwest to southeast, a 5-knot current forced us to deviate by 100-1000 m towards the northeast over a distance of roughly 10 kilometers (Figure A8.2). The  $\sim 10^\circ$  degree course change would make it much easier to progress through the Gulf Stream.

The Gulf Stream would affect the quality of the marine seismic reflection data in two significant ways: As the ship is mostly battling the Gulf Stream current instead of maintaining speed along the track line, the streamer would feather by more than  $40^\circ$ , sometimes even  $90^\circ$ . The large feather angle degrades our ability to image 2-D structure beneath the seismic line. Secondly, by dragging the streamer in the strong current, we would see more noise in the shot gathers.

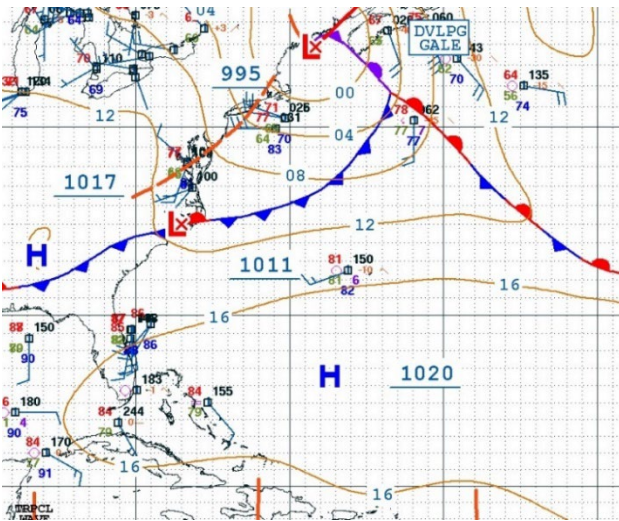


**Figure A8.2.** Deviations from the planned track on Line P1003 (left) and P1007 (right) due to a 5 knot Gulf Stream to the northeast. In both cases, the Langseth was unable to maintain course. A deviation of  $\sim 10^\circ$  in course towards the east would allow

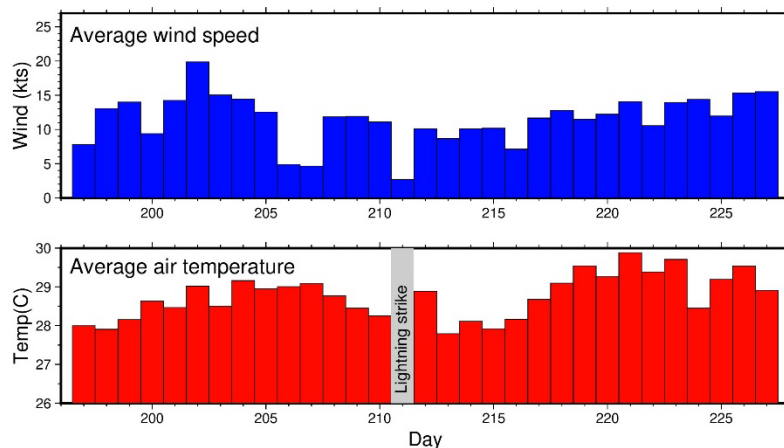
## Appendix A9. Weather

The acquisition of marine seismic data requires fairly calm seas, as both the data quality and equipment suffer in rough waves. Cruise MGL2309 took place offshore the southeastern United States between July 16 and August 19, 2023. Though this time window marks the start of the hurricane season in an average year in the western Central Atlantic Ocean, the impact of hurricanes varies widely from year to year. We had both high-priority and secondary seismic lines in our cruise plan, so we were prepared to work in either good or bad weather conditions for seismic data acquisition on the R/V *Marcus Langseth*.

During cruise, the weather was remarkably stable. Not a single tropical depression developed in the Central Atlantic over this time. High pressure systems dominated, especially farther offshore (Figure A9.1). In the first week we encountered a few thunderstorms with moderate (20-25 knots) winds and 1.0-1.5 m seas when we approached the South Carolina coast at the landward end of lines P1001 and P1003. Otherwise the average wave height was often less than 1.0 meter. Perhaps a greater challenge for the seismic operations were the high temperatures. During work on the streamer and air guns the teams made sure to have water and sports drinks available. However, the hot weather was not a constant factor either, because relatively cool ( $< 25^{\circ}\text{C}$ ) and cloudy weather came our way a few times during the cruise as well (Figure A9.2).



**Figure A9.1.** Weather map, taken on August 8, 2023, with a pattern of high and low pressure systems that typical for the entire cruise. Thunder storms developed along the coast of South Carolina, but further south and offshore the weather was usually calm and sunny.



**Figure A9.2.** Daily variation in temperature and wind speed during cruise MGL2309.

## **Appendix A10. Diagrams of seismic data acquisition**

The towing configuration of the shipboard GPS, acoustic source, and streamer is shared here for two deployments: 1) Sequence 1 to 7, and 2) Sequence 8 to 34.

Company: L-DEO - Lamont - Doherty Earth Observatory  
Vessel: Marcus G. Langseth

Client: UTIG

Project: MGL2309  
Area: Blake Plateau  
Scope:  
Start Date: 7/15/2023

# SEQ 01 to 07

## Vessel Sensor Offsets

## Towing Offsets

## Towing Configuration

## Gun Array Offsets

## Streamer Front End

## Streamer Tail End

## Streamer Complete

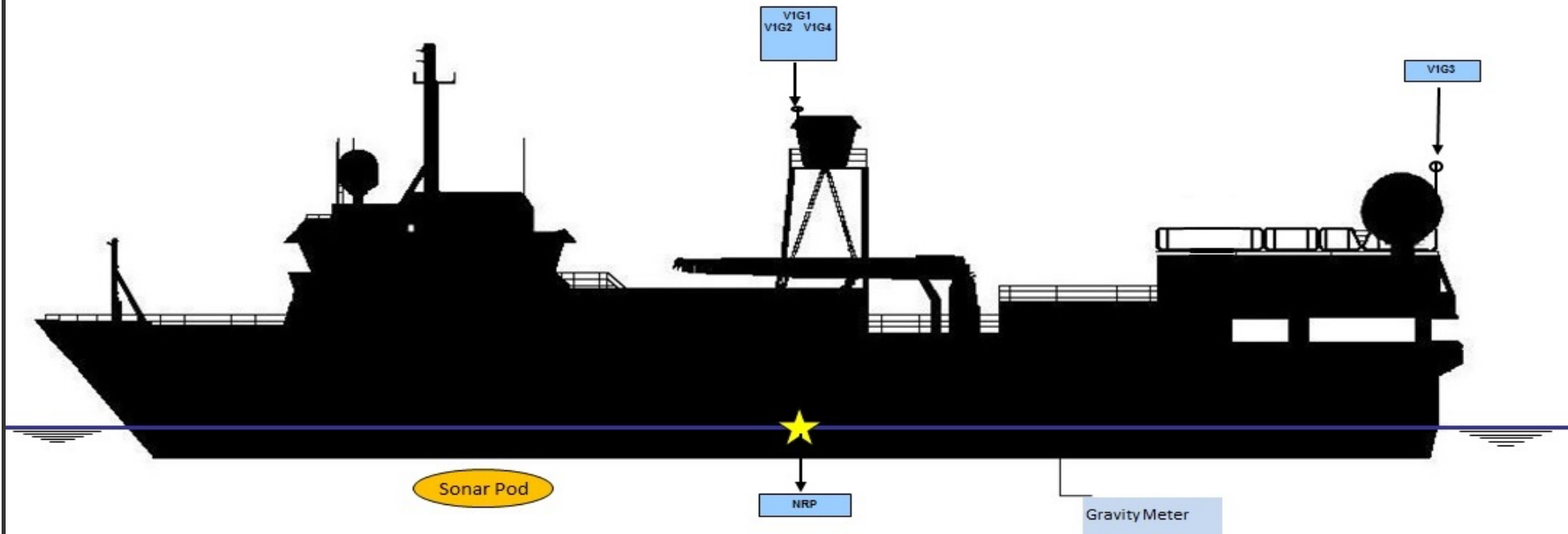
## Hydrophone Offsets

## Tailbuoy Offsets

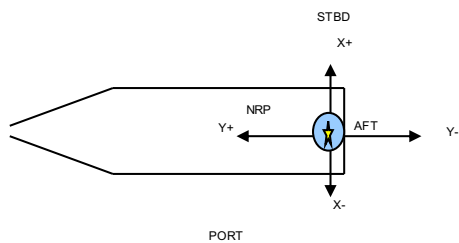
## Timing



# R/V Marcus G. Langseth - Vessel Sensor Offsets

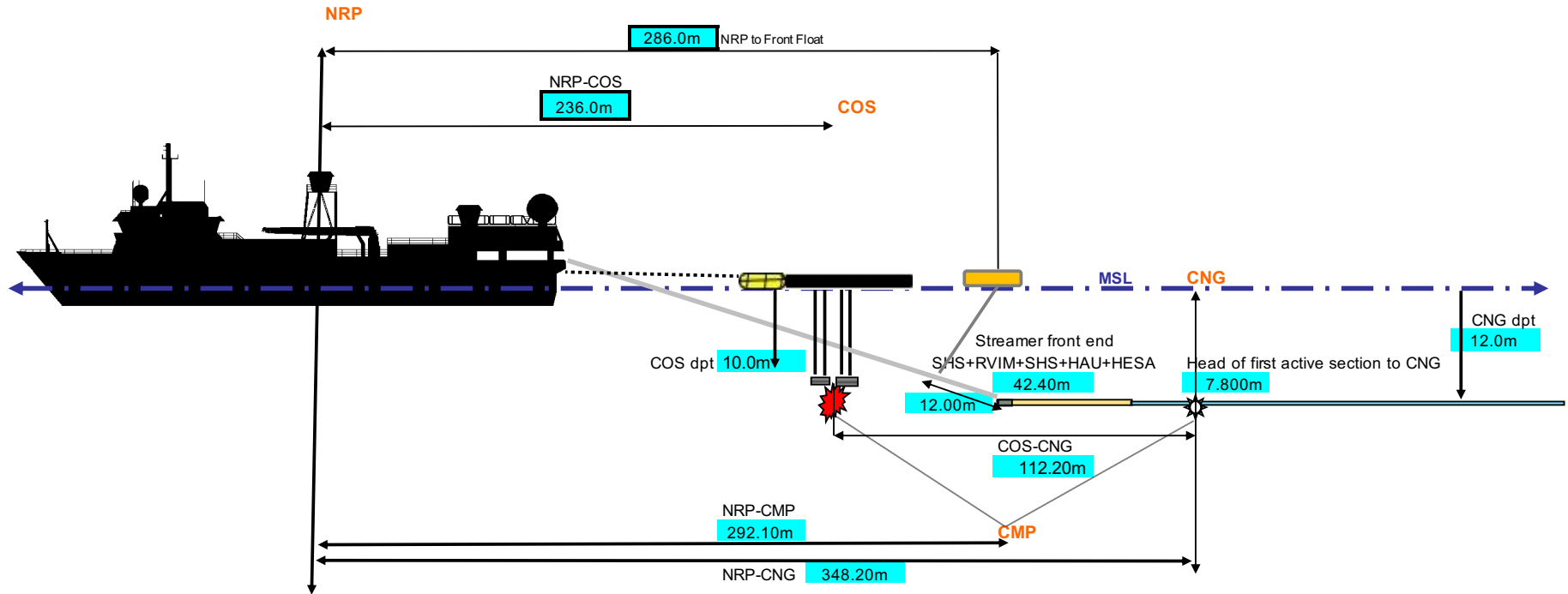


Negative values are above water line  
All measurements in meters



			STBD/PORT (X)	FORE/AFT (Y)	UP/DOWN (Z)
<b>NRP</b>	NAVIGATION REFERENCE POINT		0.00	0.00	0.00
<b>V1G1</b>	SeaPath 330	Orca	0.00	0.00	-16.90
<b>V1G2</b>	C-Nav3050 MMO Tower	Orca	0.00	0.00	-16.90
<b>V1G3</b>	C-Nav3050 Stern	Orca	-1.95	-31.83	-14.50
<b>V1G4</b>	Pos MV	Orca	2.39	12.75	-16.90
	PosMV Output position is IMU mounted in stbd drylab				
<b>V1R1</b>	PosNet		-1.30	-0.02	-16.90
<b>Sonar Pod</b>	EM122 Knudsen ADCP		0.00	20.20	7.49
	EM122 Center Beam offset (in Spectra)		0.00	13.4	7.49
<b>MRU</b>	Seapath MRU		2.39	12.75	-4.30
<b>BGM</b>	Bell Gravity Meter		0.00	-13.10	1.10

## R/V Marcus G. Langseth - Towing Offsets



<b>NRP</b>	Nav Reference Point
<b>COS</b>	Centre of Source
<b>CNG</b>	Centre of Near Group      Trace # <b>1</b> Of S1
<b>CMP</b>	Common Mid-Point
<b>MSL</b>	Mean Sea Level
<b>NRP-Stern</b>	29.2m
<b>NRP-COS</b>	236.0m

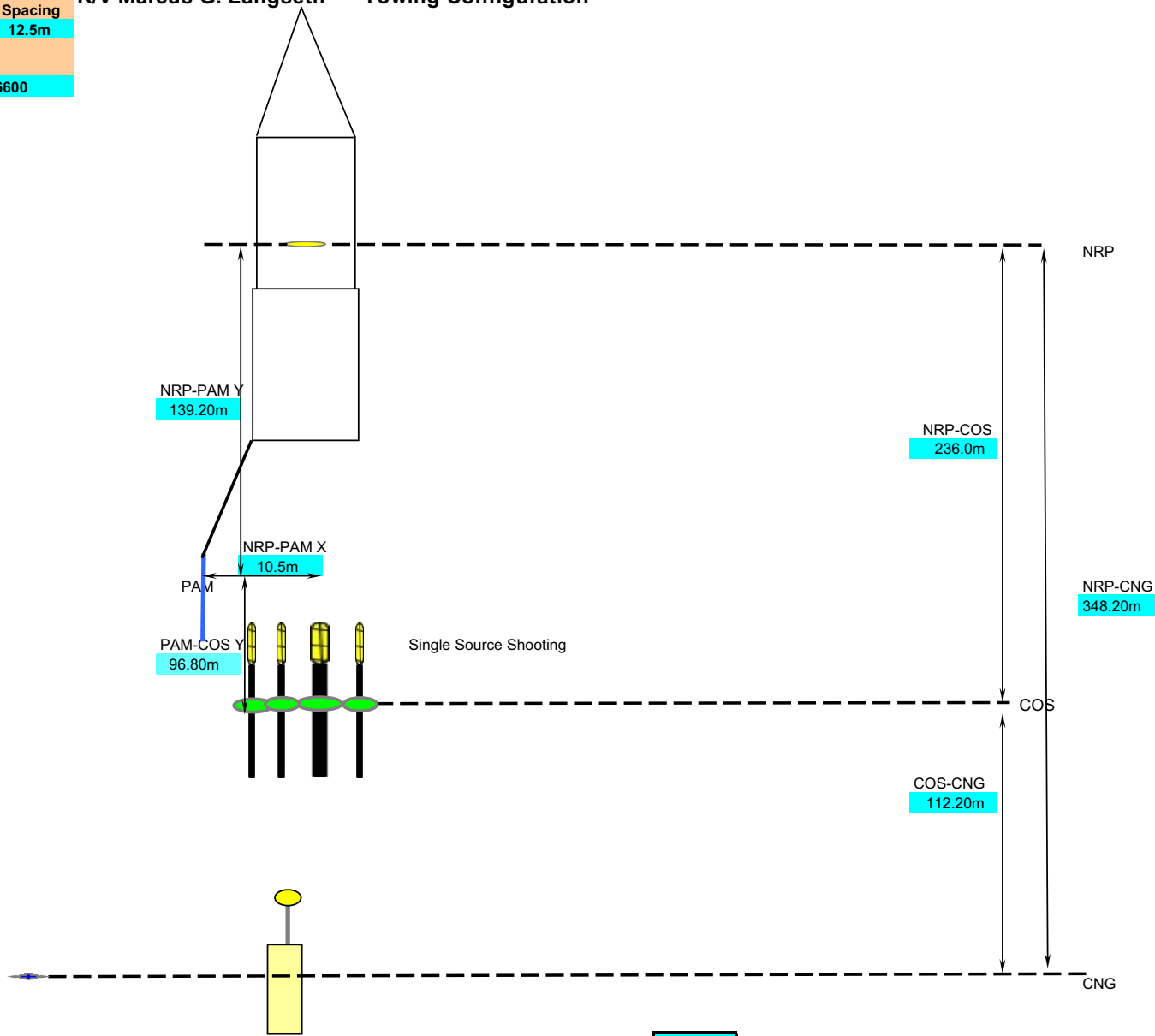
All measurements in meters



Cell contents referenced from Config\_offsets tab

### R/V Marcus G. Langseth - Towing Configuration

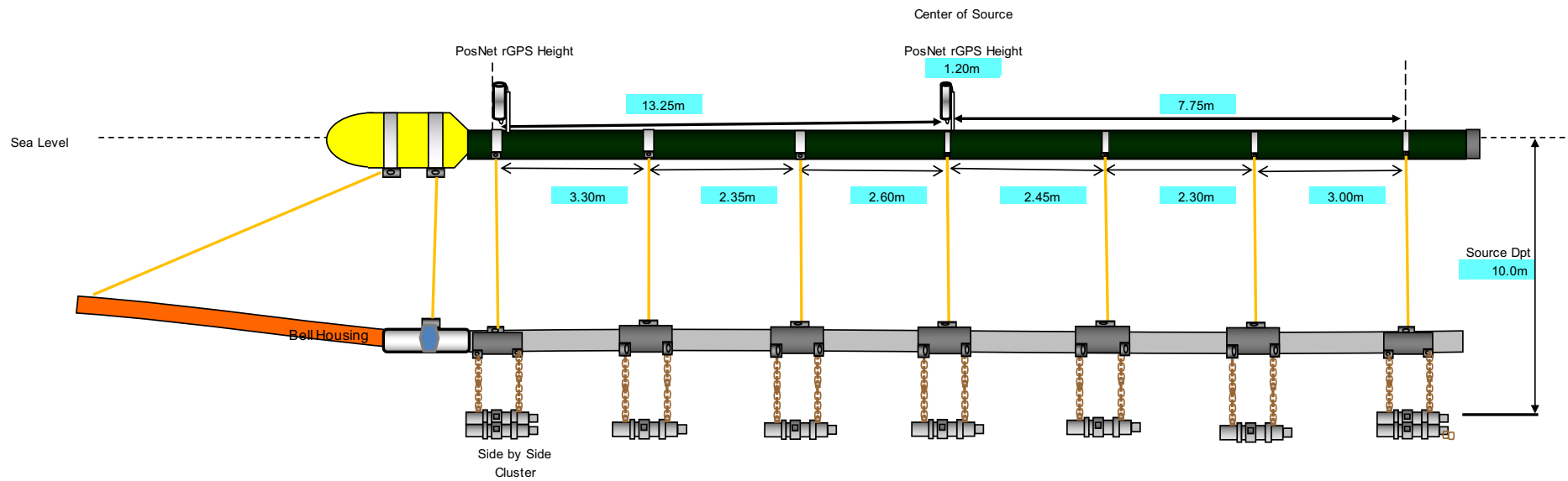
	# Streamers	Length	Channels	Spacing
SEAL	1	12000	960	12.5m
# Gun Strings Used	4		Vol (in^3)	6600



NOT to Scale

Cell contents referenced from Config\_offsets tab

### R/V Marcus G. Langseth - Gun Array Offsets



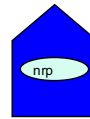
Gun volumes by number		
Gun	Volume	Status
Gun 1	360 cu. in.	Primary
Gun 2	360 cu. in.	Primary
Gun 3	40 cu. in.	Primary & Mitigation
Gun 4	180 cu. in.	Primary
Gun 5	90 cu. in.	Primary
Gun 6	120 cu. in.	Primary
Gun 7	60 cu. in.	Primary
Gun 8	220 cu. in.	Primary
Gun 9	220 cu. in.	Primary

Array total volume (without spares) is 6600 cu. in.      Total volume/string (without spare) 1650 cu. in.  
 Guns (1 & 2) & (8 & 9) in a horizontal cluster.  
 Gun clusters have 0.75m between guns and hang 0.95m from center of hanger  
 Horizontal Clusters are 1m from gun port to gun starboard  
 Single guns hang from hanger 1.15m  
 All gun volumes, numbering, locations, and offsets were inspected and verified by Chief Source Mechanic.

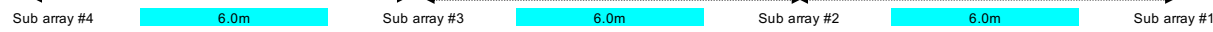
**All measurements in meters**  
**NOTE: drawing not to scale**

Cell contents referenced from Config\_offsets tab

# R/V Marcus G. Langseth - Gun Configuration



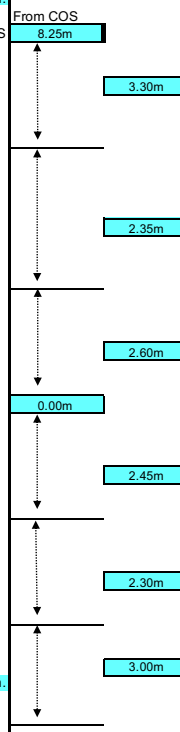
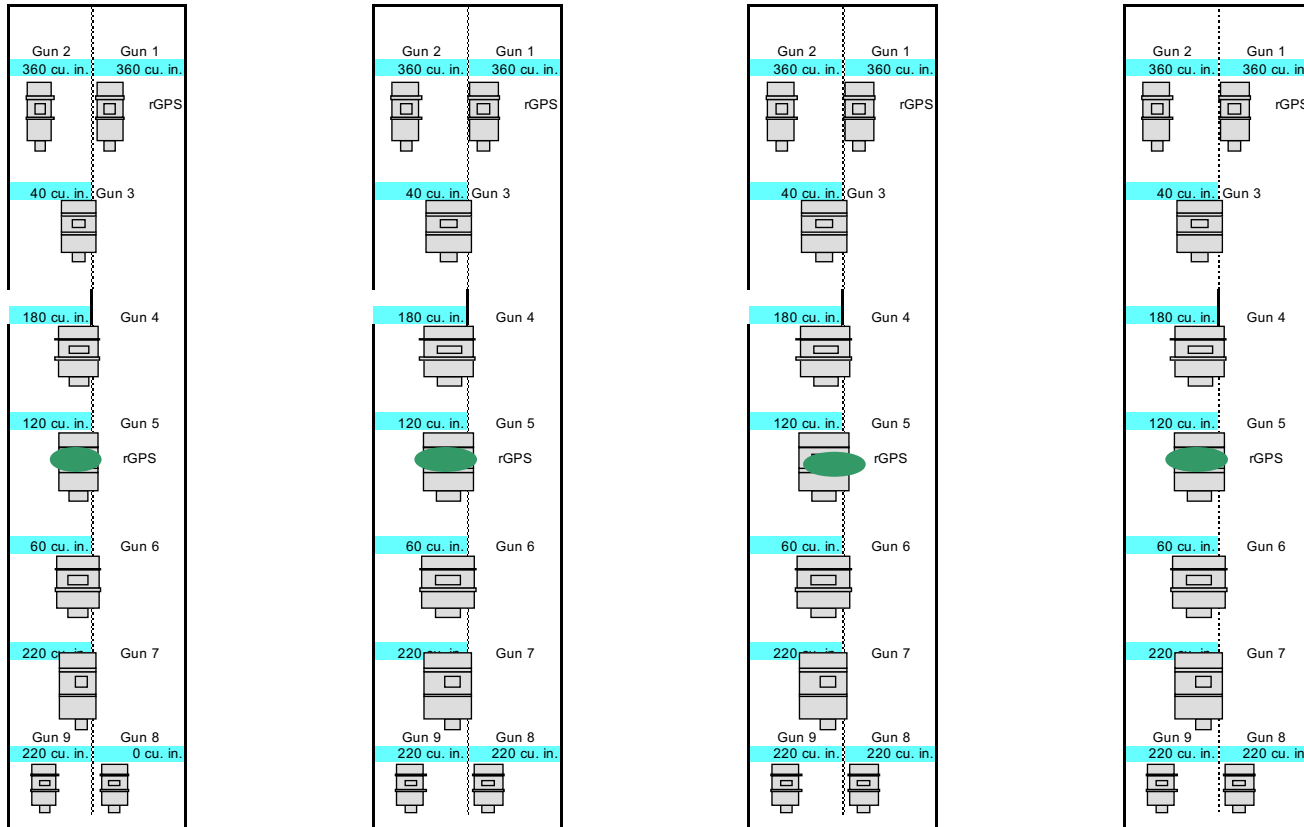
Center of Source



Gun Clusters  
Guns 1 & 2 horizontal array  
Guns 8 & 9 horizontal array

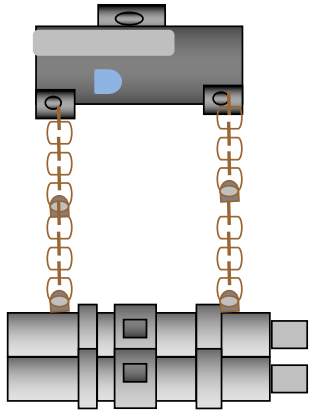
Gun Offsets relative to Center of String

	X	Y
Gun 1	0.50m	8.23m
Gun 2	-0.50m	8.23m
Gun 3	0.00m	5.00m
Gun 4	0.00m	2.60m
Gun 5	0.00m	-2.46m
Gun 6	0.00m	-4.77m
Gun 7	0.50m	-7.77m
Gun 8	-0.50m	-7.77m
Gun 9	0.50m	8.23m

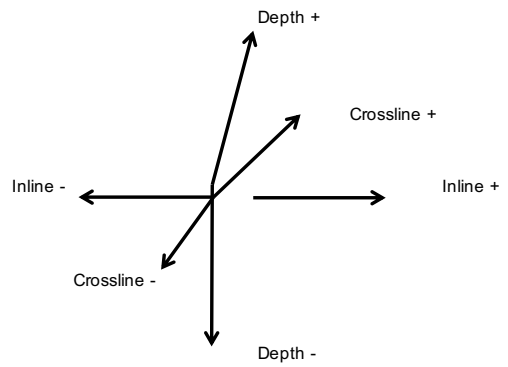


All measurements in meters

**Gun Plate**



**Center of ports between guns 1 and 2 is the reference point**



**Distances in Meters**

**Hydrophone Offsets**

Gun String 1				
Plate	Phone	Inline	Crossline	Depth
1	1			
2	2	3.35	0.00	1.00
3	3	5.50	0.00	1.00
4	4			
5	5	10.68	0.00	1.00
6	6			
7	7			

Gun String 2				
Plate	Phone	Inline	Crossline	Depth
1	1			
2	2	3.35	0.00	1.00
3	3	5.50	0.00	1.00
4	4			
5	5	10.68	0.00	1.00
6				
7	7			

Gun String 3				
Plate	Phone	Inline	Crossline	Depth
1	1			
2	2	3.35	0.00	1.00
3	3	5.50	0.00	1.00
4	4			
5	5	10.68	0.00	1.00
6				
7	7			

Gun String 4				
Plate	Phone	Inline	Crossline	Depth
1	1			
2	2	3.35	0.00	1.00
3	3	5.50	0.00	1.00
4	4			
5	5	10.68	0.00	1.00
6				
7	7			

**Depth Transducer Offsets**

Gun String 1				
Plate	DT	Inline	Crossline	Depth
1	1	0.00	0.00	1.20
2				
3	2	5.75	0.00	1.08
4				
5				
6				
7	3	16.30	0.00	1.23

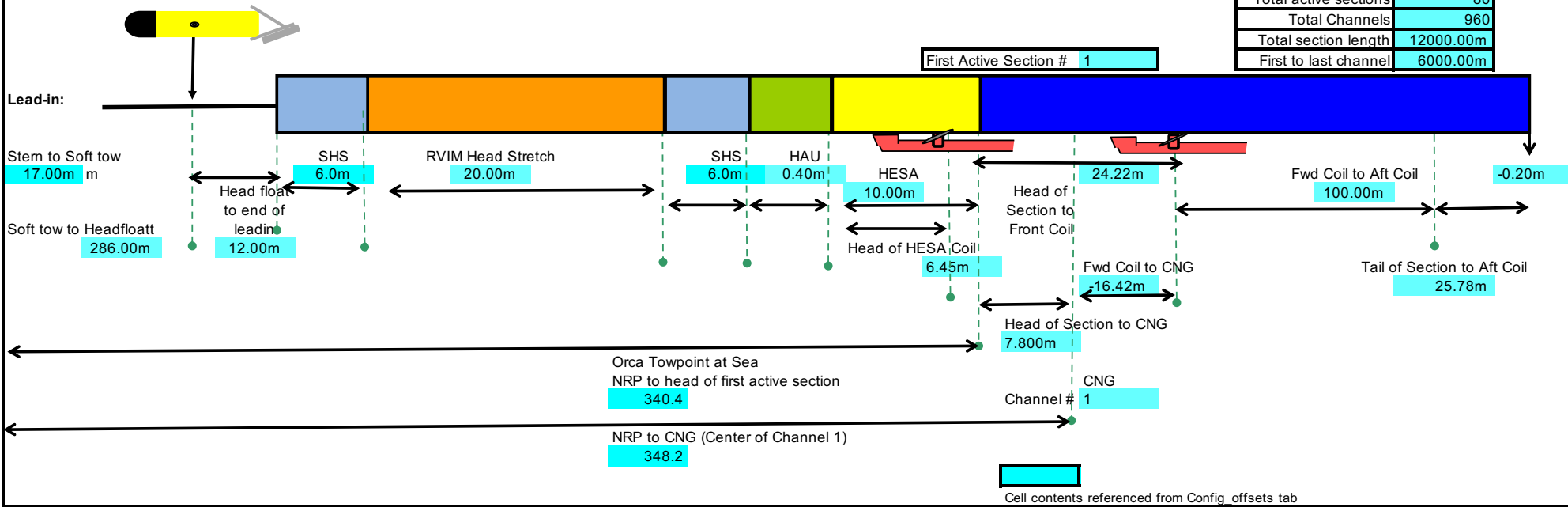
Gun String 2				
Plate	DT	Inline	Crossline	Depth
1	1	0.00	0.00	1.20
2				
3	2	5.75	0.00	1.08
4				
5				
6				
7	3	16.30	0.00	1.23

Gun String 3				
Plate	DT	Inline	Crossline	Depth
1	1	0.00	0.00	1.20
2				
3	2	5.75	0.00	1.08
4				
5				
6				
7	3	16.30	0.00	1.23

Gun String 4				
Plate	DT	Inline	Crossline	Depth
1	1	0.00	0.00	1.20
2				
3	2	5.75	0.00	1.08
4				
5				
6				
7	3	16.30	0.00	1.23

# R/V Marcus G. Langseth - Streamer Front End

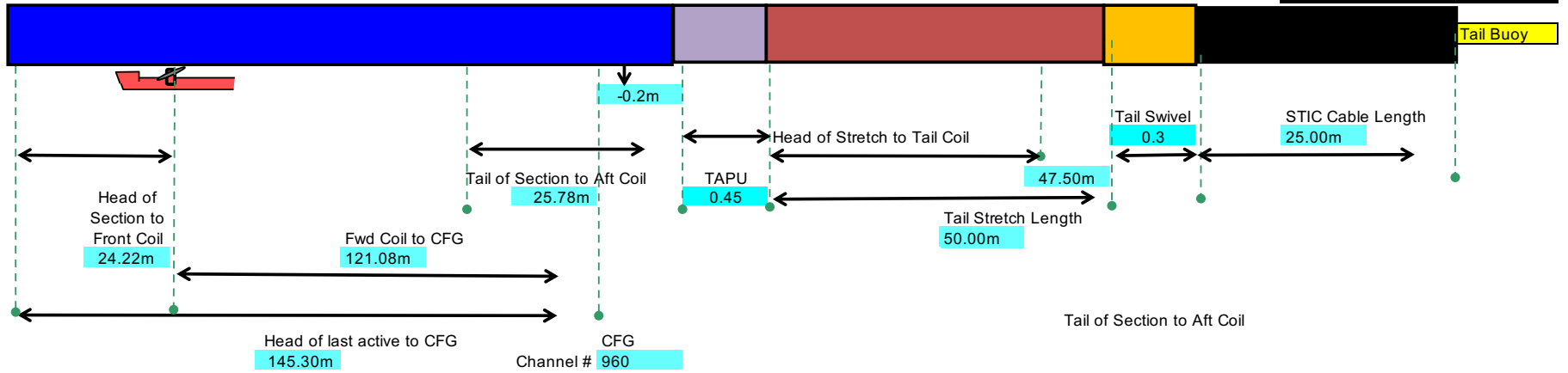
Total active sections	80
Total Channels	960
Total section length	12000.00m
First to last channel	6000.00m



### R/V Marcus G. Langseth - Streamer Tail End

Last Active Section # 80

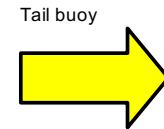
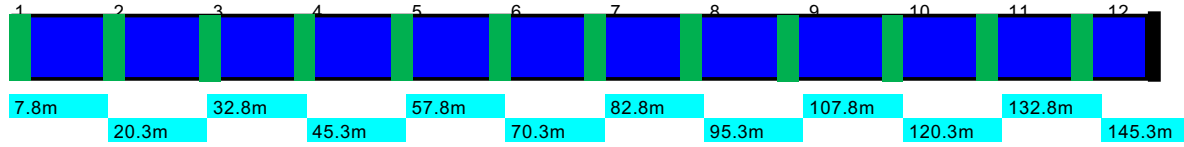
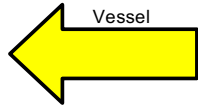
Total active sections	80
Total Channels	960
Total section length	12000.00m
First to last channel	6000.00m
CFG to TB RGPS	81.95m



Cell contents referenced from Config\_offsets tab

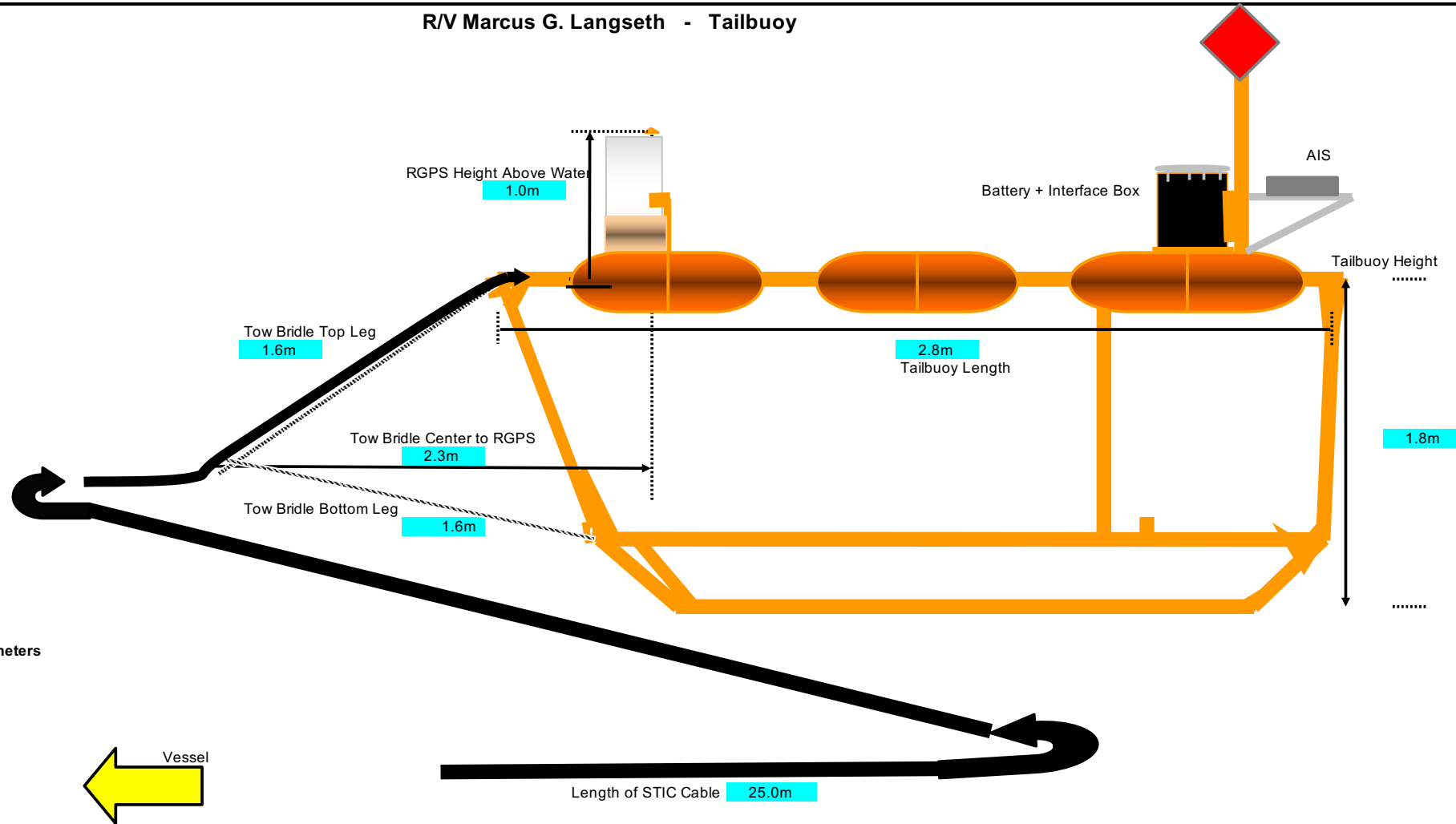
R/V Marcus G. Langseth - Hydrophone Offsets  
Sercel 150meter SSAS

Number of SSAS Sections 80  
Channels per active section 12  
Total channels 960

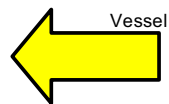


Cell contents referenced from Config\_offsets tab

# R/V Marcus G. Langseth - Tailbuoy



All measurements in meters



Cell contents referenced from Config\_offsets tab



Company: L-DEO - Lamont - Doherty Earth Observatory  
Vessel: Marcus G. Langseth  
Client: UTIG

Project: MGL2309  
Area: Blake Plateau  
Scope:  
Start Date: 7/15/2023

# SEQ 08 to SEQ 34

## Vessel Sensor Offsets

## Towing Offsets

## Towing Configuration

## Gun Array Offsets

## Streamer Front End

## Streamer Tail End

## Streamer Complete

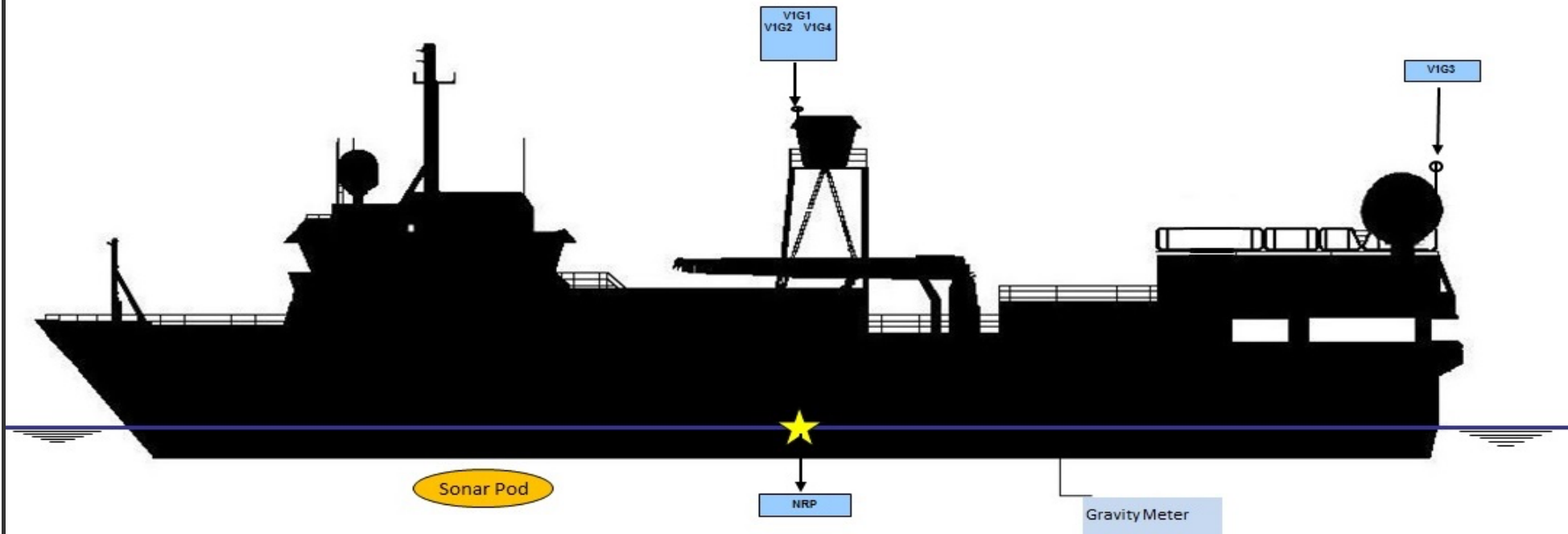
## Hydrophone Offsets

## Tailbuoy Offsets

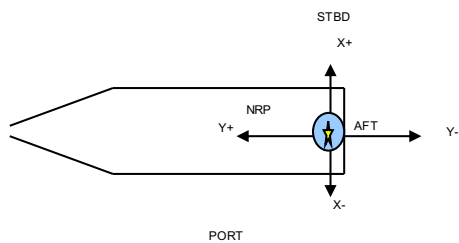
## Timing



# R/V Marcus G. Langseth - Vessel Sensor Offsets

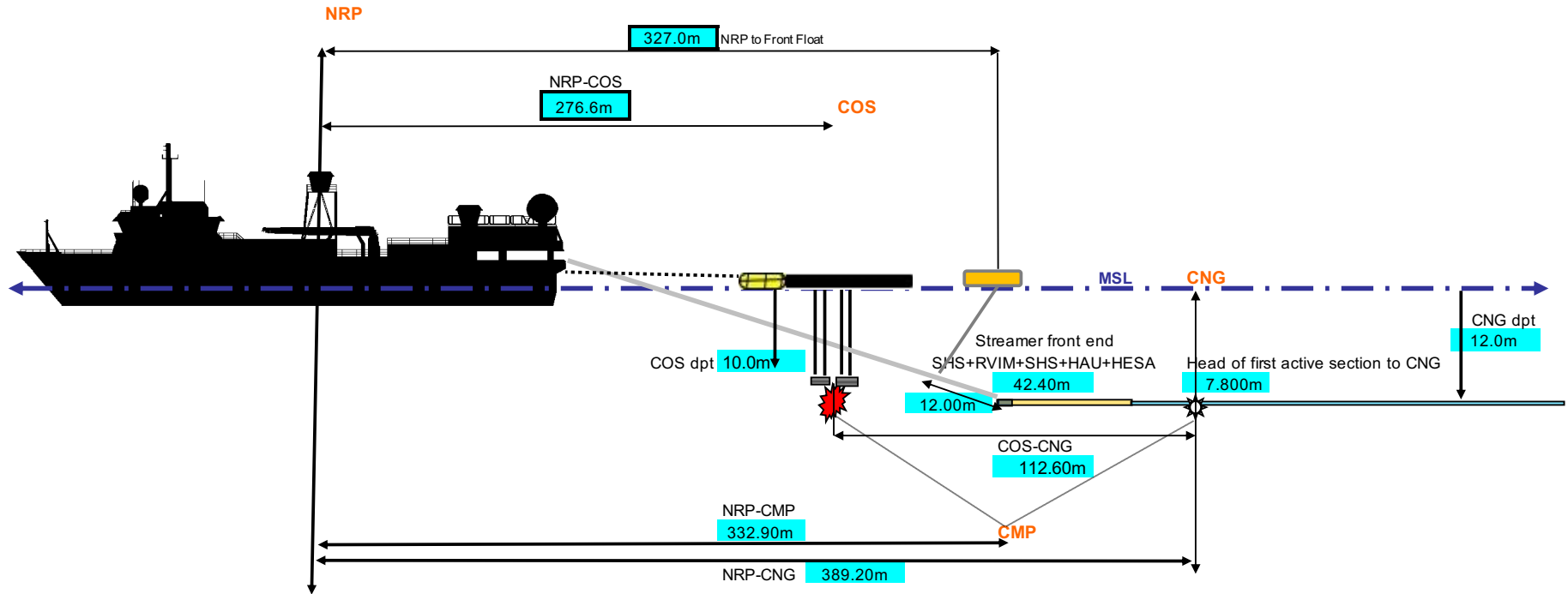


Negative values are above water line  
All measurements in meters



			STBD/PORT (X)	FORE/AFT (Y)	UP/DOWN (Z)
<b>NRP</b>	NAVIGATION REFERENCE POINT		0.00	0.00	0.00
<b>V1G1</b>	SeaPath 330	Orca	0.00	0.00	-16.90
<b>V1G2</b>	C-Nav3050 MMO Tower	Orca	0.00	0.00	-16.90
<b>V1G3</b>	C-Nav3050 Stern	Orca	-1.95	-31.83	-14.50
<b>V1G4</b>	Pos MV	Orca	2.39	12.75	-16.90
	PosMV Output position is IMU mounted in stbd drylab				
<b>V1R1</b>	PosNet		-1.30	-0.02	-16.90
<b>Sonar Pod</b>	EM122 Knudsen ADCP		0.00	20.20	7.49
	EM122 Center Beam offset (in Spectra)		0.00	13.4	7.49
<b>MRU</b>	Seapath MRU		2.39	12.75	-4.30
<b>BGM</b>	Bell Gravity Meter		0.00	-13.10	1.10

### R/V Marcus G. Langseth - Towing Offsets



NRP	Nav Reference Point
COS	Centre of Source
CNG	Centre of Near Group
CMP	Common Mid-Point
MSL	Mean Sea Level
NRP-Stem	29.2m
NRP-COS	276.6m

Trace # 1 Of S1

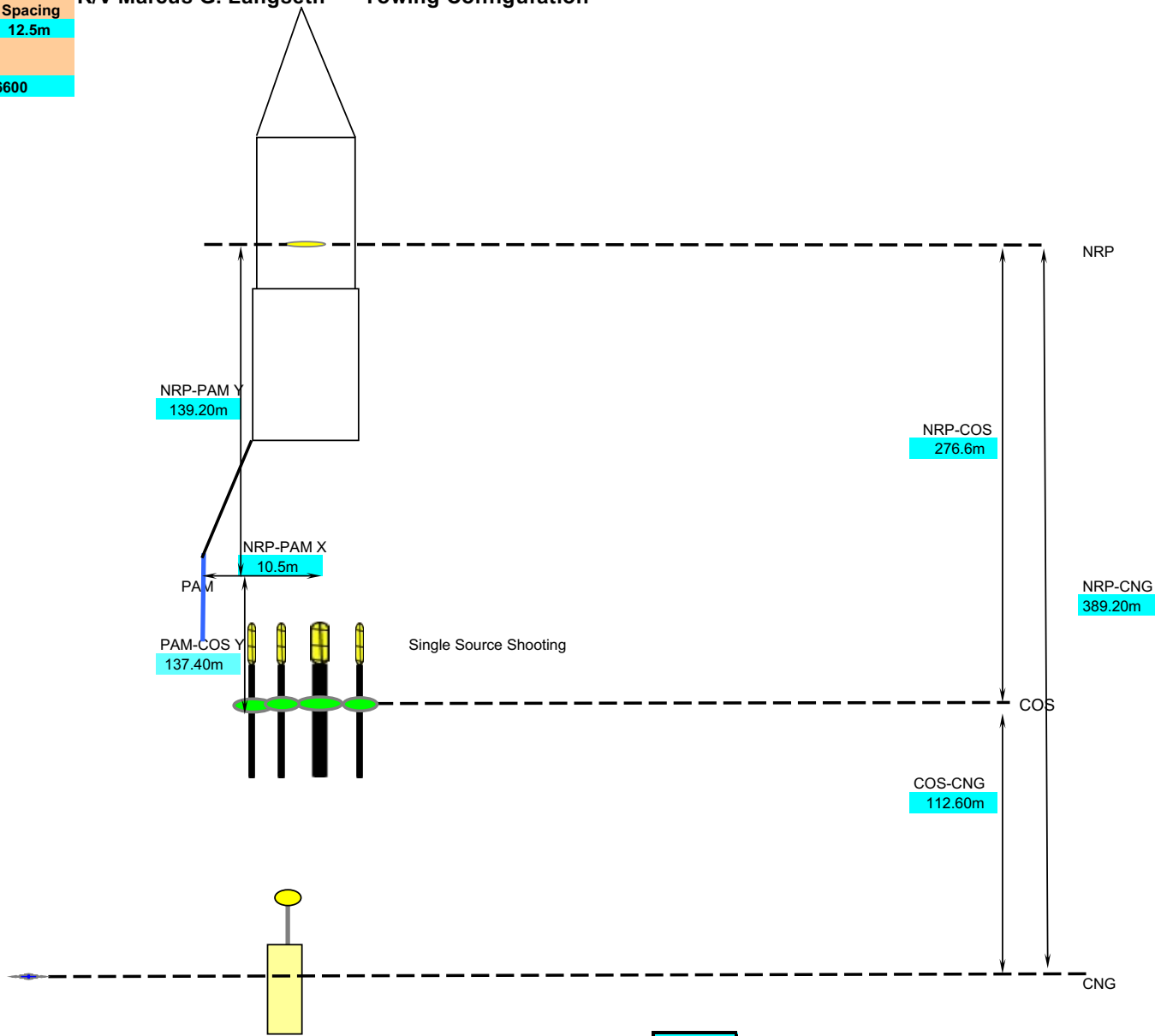
All measurements in meters



Cell contents referenced from Config\_offsets tab

### R/V Marcus G. Langseth - Towing Configuration

	# Streamers	Length	Channels	Spacing
SEAL	1	12000	960	12.5m
# Gun Strings Used	4		Vol (in^3)	6600



NOT to Scale

Cell contents referenced from Config\_offsets tab