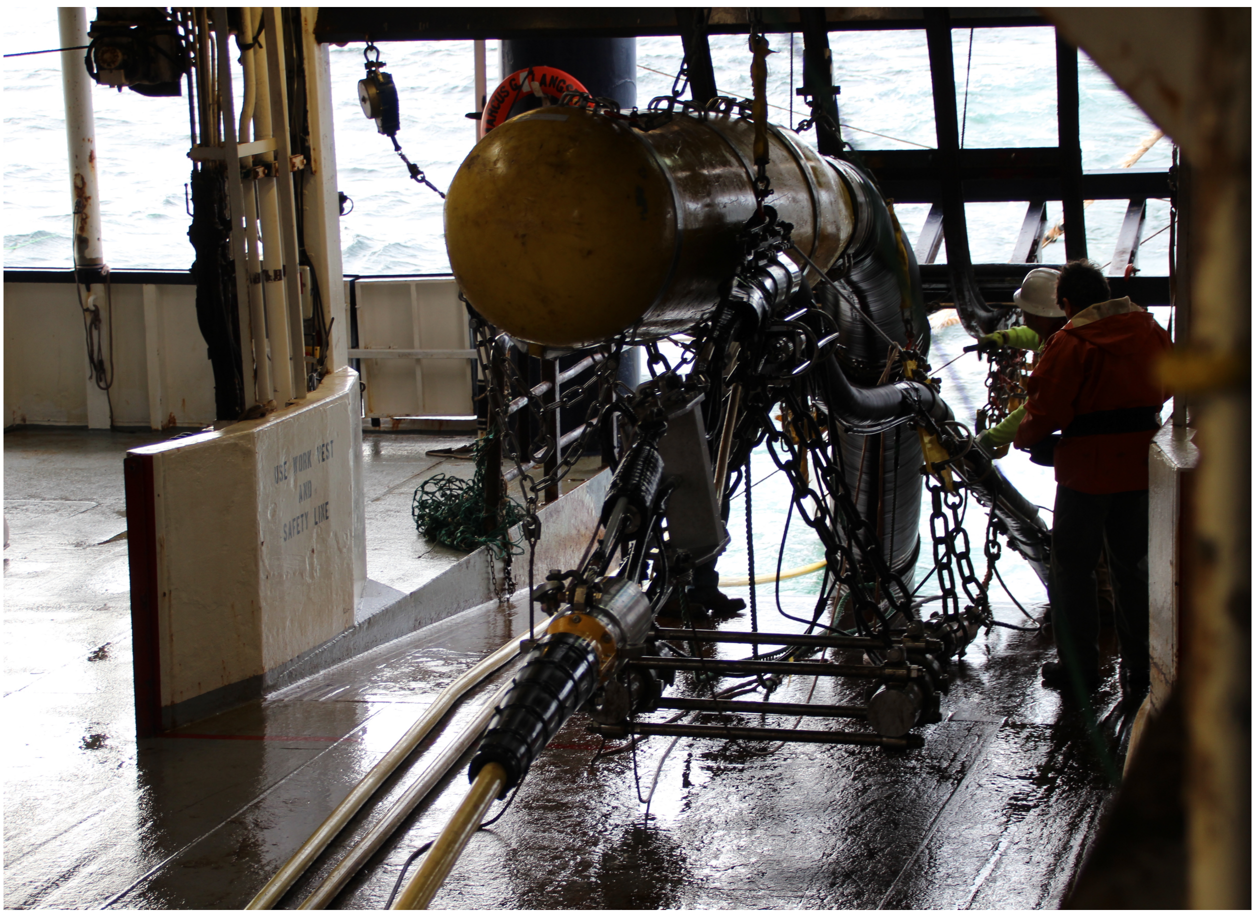
Cruise Report

Alaska Amphibious Community Seismic Experiment (AACSE)

Cruise **MGL1903**, *R/V Marcus G. Langseth*
Active source survey component



Kodiak (AK)- Kodiak (AK)
June 7 – June 24, 2019

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1. Cruise Objective

The purpose of the Alaska Amphibious Community Seismic Experiment is to collect an open-access, onshore/offshore seismic dataset across the Alaska Peninsula subduction zone that can be used by the community to tackle a broad range of the science questions related to the NSF-GeoPRISMS Subduction Cycles and Deformation initiative. The AACSE data will provide coverage across the shoreline, and over a range of length scales that are appropriate for investigations of shallow features (e.g. sediment and crust) and mantle structures as well as seismic activity.

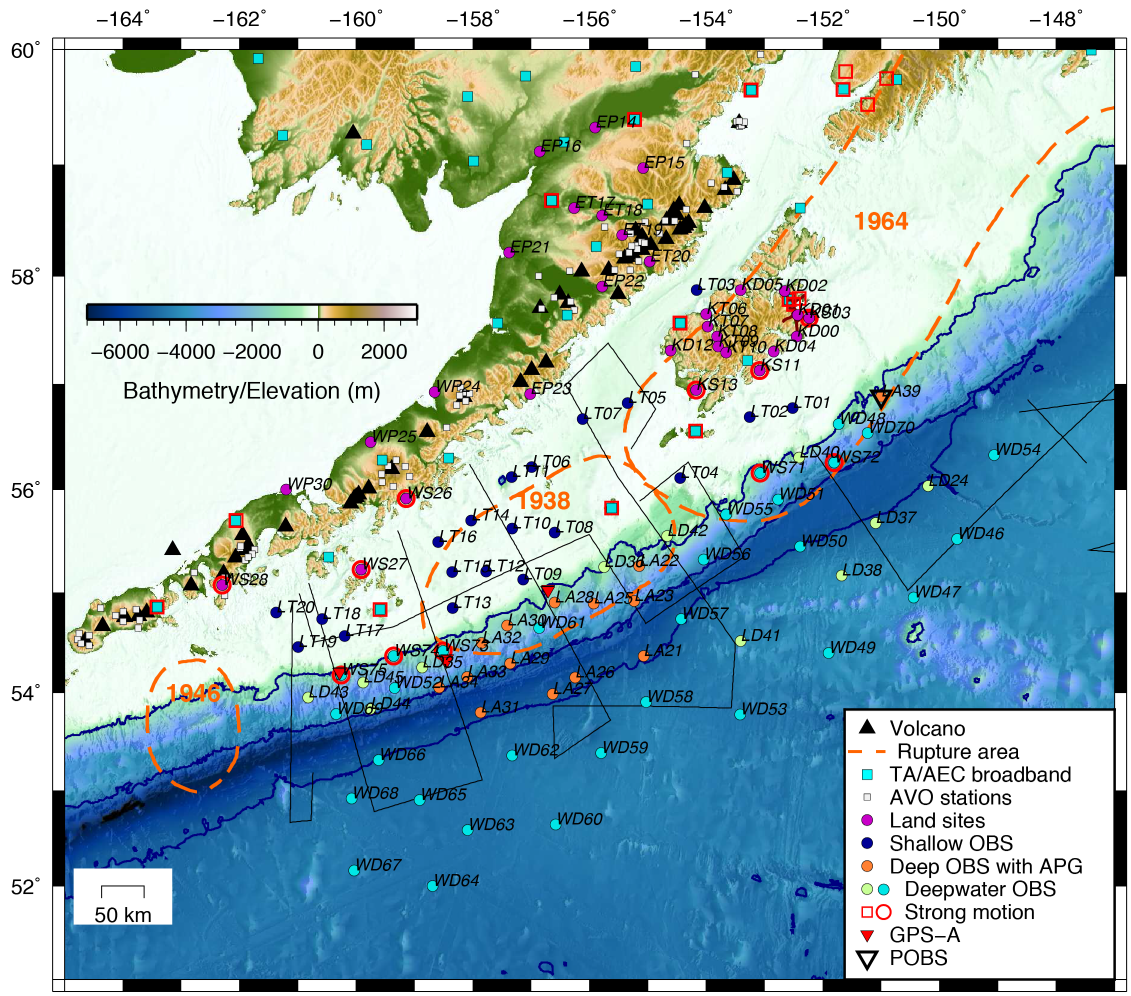


Figure 1.1: AACSE broadband seismic component (colored dots). Thinned black lines are the existing seismic data from MGL1110 (ALEUT) and MGL1109 (STEEP) seismic experiments.

The passive-source seismic part of this program, which is the core of this program, involves the one-year deployment of 75 broadband seismometers on the seafloor spanning a 850 x 350 km area offshore the Alaska Peninsula and 30 broadband seismometers onshore (Fig. 1.1). The AACSE broadband instruments operated contemporaneously with the EarthScope US Transportable Array stations installed in Alaska (Fig. 1.1 and 1.2). The AACSE data thus complement the onshore TA deployment.

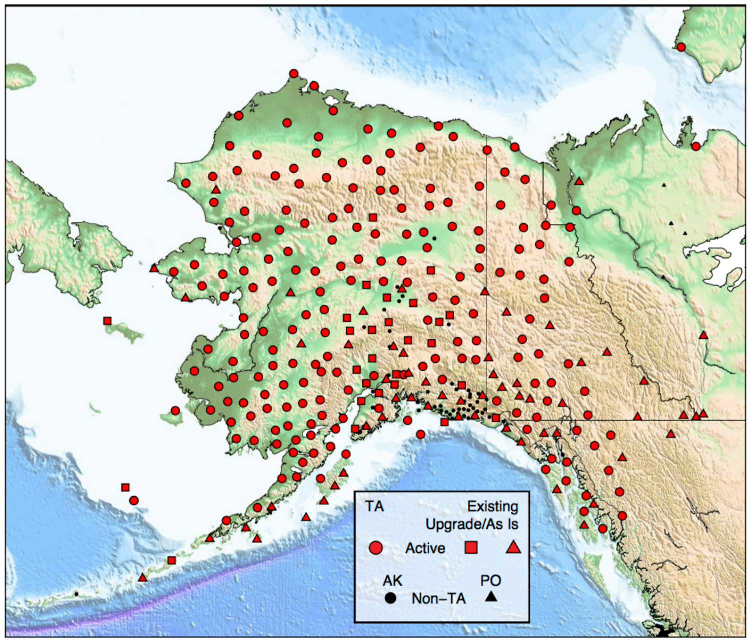


Figure 1.2: Map showing the Earthscope US Transportable Array stations.

In addition, a nodal array was deployed for a month (May 20 - June 22, 2019) along a 60 km long main profile and two smaller transects on the eastern part of the Kodiak Island. The profile comprises ~400 stations with a ~300 m spacing (Fig. 1.3).

The main scientific objectives of this active source seismic cruise is to acquire a 3D wide-angle reflection/refraction dataset by providing the shots to be recorded by the AACSE BB seismometer array (Fig. 1.4). This experiment will directly contribute to the overall AACSE project goals of imaging the architecture and understanding variability in slip behavior for the Alaska Peninsula subduction zone.

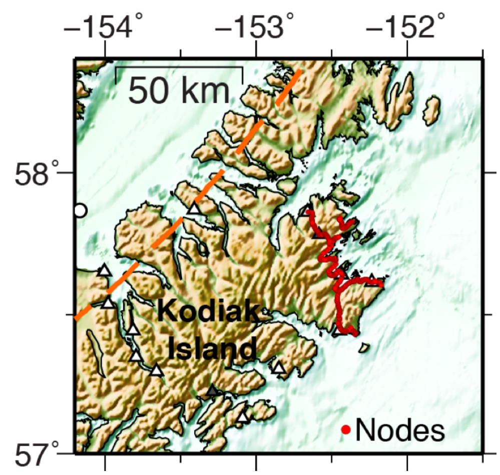


Figure 1.3: Map of the nodal array deployment

This active source experiment focuses on the Semidi segment and the Southwestern Kodiak Asperity (Fig. 1.4). The Semidi segment appears to rupture in great earthquakes (M>8) every ~50-75 years [*Davies et al.*, 1981] and to be geodetically strongly to fully coupled at present [*Fournier and Freymueller*, 2007; Li and Freymueller, 2018]. The last great earthquake (M8.2) to rupture the Semidi segment in 1938 is thought be a relatively deep rupture (~35 km) [*Estabrook et al.*, 1994]. Background seismicity from the AEIC (Alaska Earthquake Information Center) catalog is relatively sparse at all depths in this segment [*Shillington et al.*, 2015] (Fig. 1.5). The SW Kodiak asperity appears to be geodetically fully coupled [*Fournier and Freymueller*, 2007; *Li and Freymueller*, 2018]. This asperity ruptured during the M9.2 1964 earthquake [*Kanamori*, 1977] and display abundant seismicity at both shallow depths and depths greater than 120 km.

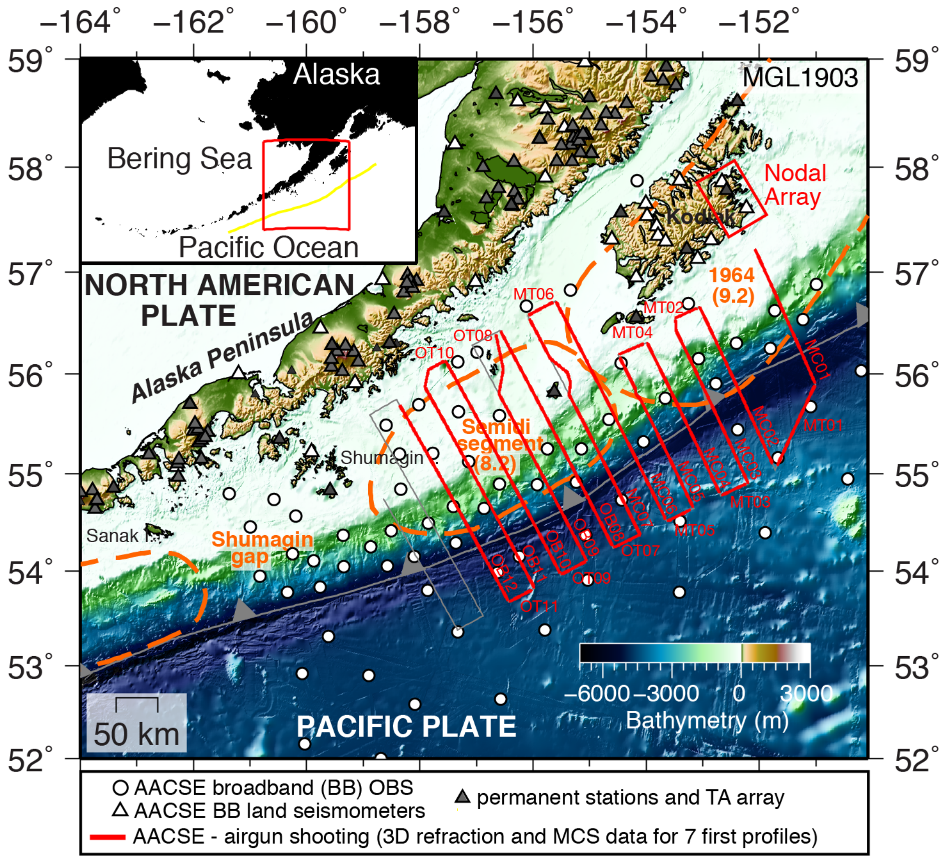


Figure 1.4: Map of the planned (grey) and accomplished (red) active source seismic experiment.

We used the 6600 cu.in tuned airgun array of the R/V *Marcus G. Langseth* to generate acoustic pulses that were recorded by a subset of the AASCE BB OBSs and onshore seismometers. The active source seismic project consists of 12 profiles (14 originally planned) that are spaced every ~34 km and oriented approximately sub-orthogonal to the trench axis ranging in length between 150 and 275 km, and extending ~60-120 km outboard of the trench onto the Pacific plate as well as shorter connecting profiles (Fig. 1.4).

In addition, multichannel seismic (MCS) data were acquired along the 7 (MC01 to MC07) first dip profiles using a 4 km long streamer. We also acquired multibeam bathymetry data as well as 3.5 kHz bottom profiler, gravity and magnetic data throughout the survey.

The survey was also used to test a new type of PAM device as a Joint Industry Program (JIP). Lead person for this equipment is Thomas Norris from BioWaves who was also sailing on the mission.

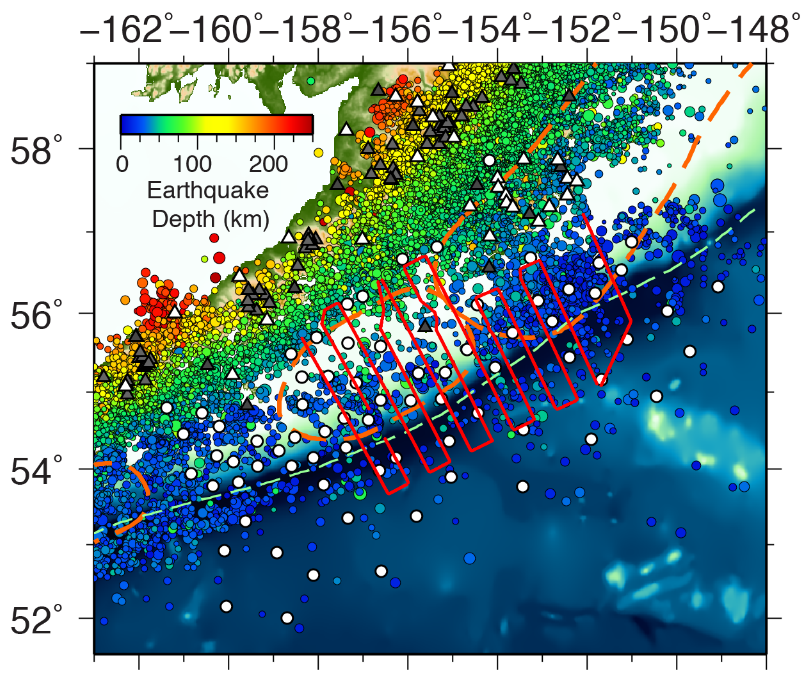


Figure 1.5: Seismicity (1970-2015) from the AEIC catalog. Red lines are the tracklines from the AACSE active source component.

The 3D P-wave velocity model derived from this active source experiment will be vital for earthquake analysis, specifically accurate locations and depth estimates, as well as the characterization of low frequency earthquakes (LFE) or non-volcanic tremor (NVT), recorded across the AASCE and permanent array. This model will be particularly important for understanding the shallow structure underneath the ocean bottom seismometers (OBS). This project will also provide an unprecedented 3D seismic data set to be used by the community to (1) perform joint inversions of shot and local earthquake data recorded at the same array and (2) develop joint inversion of 3D refraction data and ambient noise data (e.g. for the incoming oceanic plate). Gaining information on the P-wave velocity structure within and outboard the SW Kodiak asperity will be critical given that there is no previous refraction data that has been acquired within this area, the velocity depth structure is completely unknown. This will be particularly valuable given high levels of seismicity in this segment whose origin remain enigmatic. Additionally, acquisition of bathymetric data and 3.5 KHz profiles will be very also valuable to refine seismometer locations and identify geological active structures at the seafloor. The easternmost profile is positioned in line with the temporary nodal array that was deployed on Kodiak Island in May/June 2019. This dense array has ~400 sensors in a small footprint of ~50-100 km. This configuration will provide critical large shot-receiver aperture to capture megathrust and possible splay fault reflections that require shot-receiver aperture of at least 40 km and provide ray coverage for shallow structure tomography seaward of Kodiak Island. In addition, the proposed dataset has the potential to engage additional sectors of the seismological community and can act as a model for joint active-passive data acquisition as the community moves forward with plans for the SZ4D initiative [*McGuire and Plank*, 2018]. Although most of the information for 3-D tomography will come from the AACSE OBSs, the onshore broadband seismometers located on the Alaska Peninsula and the numerous stations located on Kodiak Island (including the ~400 nodes) will also provide critical ray paths with large shot-receiver aperture for better constraining forearc structure and the down-dip end of the seismogenic zone.

All data are being recorded on the AACSE OBSs, and will be immediately released once delivered to the IRIS Data Management Center as with all other AACSE data, as soon as practical after timing and other metadata corrections. Raw and Gridded bathymetry and processed 3.5 kHz profiles have been be submitted to the MDGS/IEDA and NOAA/NCEI databases.
The raw MCS data as well as raw and processed navigation files were immediately released to the LDEO-ASP after the cruise:

Becel, A.; Sheehan, A.; Foster, D.; Myers, E.; Haeussler, P.; Abers, G.; Adams, A.; Roland, E.; Schwartz, S.; Shillington, D.; Wiens, D.; Webb, S. and L. Worthington, (2019). Multi-Channel Seismic Shot Data from the Alaska-Aleutians area acquired during Langseth cruise MGL1903 (2019). Interdisciplinary Earth Data Alliance (IEDA). doi:10.1594/IEDA/324793.

Becel, A.; Sheehan, A.; Foster, D.; Myers, E.; Haeussler, P.; Abers, G.; Adams, A.; Roland, E.; Schwartz, S.; Shillington, D.; Wiens, D.; Webb, S. and L. Worthington, (2019). Raw Seismic Navigation Data (P2 format) from the Alaska-Aleutians area acquired during Langseth cruise MGL1903 (2019). Interdisciplinary Earth Data Alliance (IEDA). doi:10.1594/IEDA/324791.

Becel, A.; Sheehan, A.; Foster, D.; Myers, E.; Haeussler, P.; Abers, G.; Adams, A.; Roland, E.; Schwartz, S.; Shillington, D.; Wiens, D.; Webb, S. and L. Worthington, (2019). Processed Seismic Navigation Data (P1 format) from the Alaska-Aleutians area acquired during Langseth cruise MGL1903 (2019). Interdisciplinary Earth Data Alliance (IEDA). doi:10.1594/IEDA/324790.

Table of Acronyms:

AACSE - Alaska Amphibious Community Seismic Experiment
ASP – Academic Seismic Portal
IEDA – Interdisciplinary Earth Data Alliance
IRIS – Incorporated Research Institutions for Seismology
LDEO – Lamont Doherty Earth Observatory
MCS – Multichannel Seismic
MDGS – Marine Geoscience Data System
NCEI – National Center for Environmental Information
NOAA – National Oceanographic and Atmospheric Administration
PAM – Passive acoustic monitoring
SZ4D – Subduction zone 4D

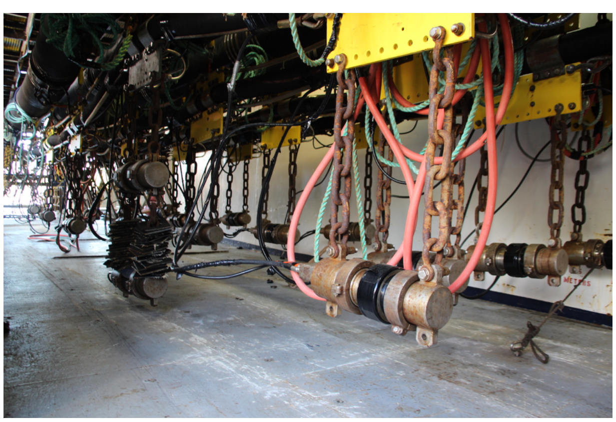
2. Cruise Summary

Cruise MGL1903 aboard the R/V Marcus G. Langseth lasted 17 days, departing Kodiak on June 7, 2018, at 4:51pm and returning to Kodiak on June 24, 2018 at ~1pm. The cruise was a success although we did not acquire as many profiles as we had hoped. This is mainly due to delayed departure from Kodiak because of engine issues while in port and difficulty in rescheduling fueling at the Kodiak Coast Guard Base. Weather during the voyage was mostly fine but a few hours of bad weather in the last part of the cruise contributed to a gap in data collection.

R/V Langseth at the USCG base in Kodiak, AK

During MGL1903, we acquired 1751 km of multichannel seismic data along 7 dip lines (called MC lines) and smaller transect lines (called MT lines). This includes four dip lines (MC01 to MC04) across the southwestern extent of the 1964 M9.2 earthquake rupture area also called the Kodiak Asperity, one dip line across the Semidi segment (MC07) and one dip line at the transition between these two segments. We did not experience any powerdown or shutdown due to marine mammal sighting within the exclusion zone during MCS data acquisition.

We provided 7864 shots along 3146 km of profiles, the first 1751 kilometers of profiles being coincident with the multichannel seismic data. These shots have hopefully been recorded by a majority of the offshore and onshore broadband seismometers that were deployed as part of the AACSE to allow for 3D refraction imaging. Because our main objective was to provide shots to be recorded by the temporary broadband seismometer and nodal arrays, we did not shoot with a smaller shot spacing for acquisition of multichannel seismic data. We kept the shot spacing fixed for the whole duration of the cruise to 400m. We chose this large source spacing because it allows for attenuation of previous-shot noise on OBS data, improving the signal-to-noise ratio of arrivals at large offsets. In addition to seismic data, we also acquired a suite of other geophysical and oceanographic data including magnetics, gravity, multibeam, sub-bottom profiles, water column temperature (via XBT) and acoustic doppler current profiling (equipment used included Kongsberg EM 122 multi-beam echosounder (MBES), Knudsen Chirp 3260 sub-bottom profiler (SBP), and a Teledyne RDI 75 kHz Ocean Surveyor acoustic Doppler current profiler (ADCP), Geometrics G822 Cesium magnetometer).



R/V Langseth 4-string, 36 element airgun array

We had no downtime at all for repairs/or maintenance of the streamer and very limited downtime for repairs/or maintenance of the guns. In total we had 7 hours of downtime for gun repairs *(JD159, Communication error, 2hr10 min, JD 159, GCM failure, 1hr12min, JD168, autofire on string 2, 3hr32min)*. The quality of the multichannel seismic data is exceptionally high and there is no noisy trace as it was the case for the previous streamer, only a couple (~2-3) of dead channels.

R/V Langseth solid-state streamer 1 and 2.

We observed a large number of marine mammals throughout the survey, though most were far away. Occasional shutdowns were required. Marine mammals were most commonly observed at the northern (landward) edge and middle part of the profiles and West of Kodiak. There were 15 detections of protected species the first week (June 8-15) and 33 detections the second week (16-24). There were no mitigation actions implemented for protected species detections during the first week (June 8-15). The first shutdown that occurred was on line MGL1903OB08. Mitigation actions totaled six hours 11 minutes *(e.g. JD 168: Dall's porpoise (41min), JD171: two fin whales (59 min), JD172: northern fur seal (36min), JD 174: unidentified otariid pinnipeds (17 min+35 min), JD174: aggregation of nine fin whales, more whales (3hr3min))*. Overall, we experienced less downtime from marine mammals than expected.

There were a few challenges during the acquisition of the data (Fig. 2.1):
- When we first started the ramp up of the airgun array at the beginning of line MC01, the ramp up had to be canceled due to a communication failure on string/subarray 1. This subarray had to be recovered, fixed and redeployed. This communication failure at ramp-up required us to make a loop to go back to the start of the line. The loop took ~4hr to be completed because of the streamer and airgun we were towing and the velocity reduction requirement at night in the North Pacific Right whale critical habitat.
- There was one instance of acoustic source testing on 08 June 2019, one 220 in^3 element was tested for one shot at 16:09 UTC.
- There is a shallow basement ridge between Tugidak and Chirkof islands. The basement ridge on the center of the shelf reached a minimum depth of ~30 m which made the science technicians a little anxious, knowing that both the streamer and guns were towed at a depth of 12m but there was no issue with the shallow water. Charts seem to be accurate for this part.
- PAM cable got wrapped up in string 4 while shooting profile MC03 (JD162, June 11). Strings 3 and 4 had to be recovered, PAM cable was untangled and then redeployed. On JD172, PAM got tangled during the acquisition of profile MC11 due to the choppy weather. PAM was recovered and we waited for less choppy weather to redeploy it. This resulted in the loss of 7 hours of data.
- For profile MGL1903MC05, we had to suddenly divert from our planned trackline due to fishing

gear and for profile MGL1903MC07, we had to slightly change our tracklines to stay out of the zone for sea otters.

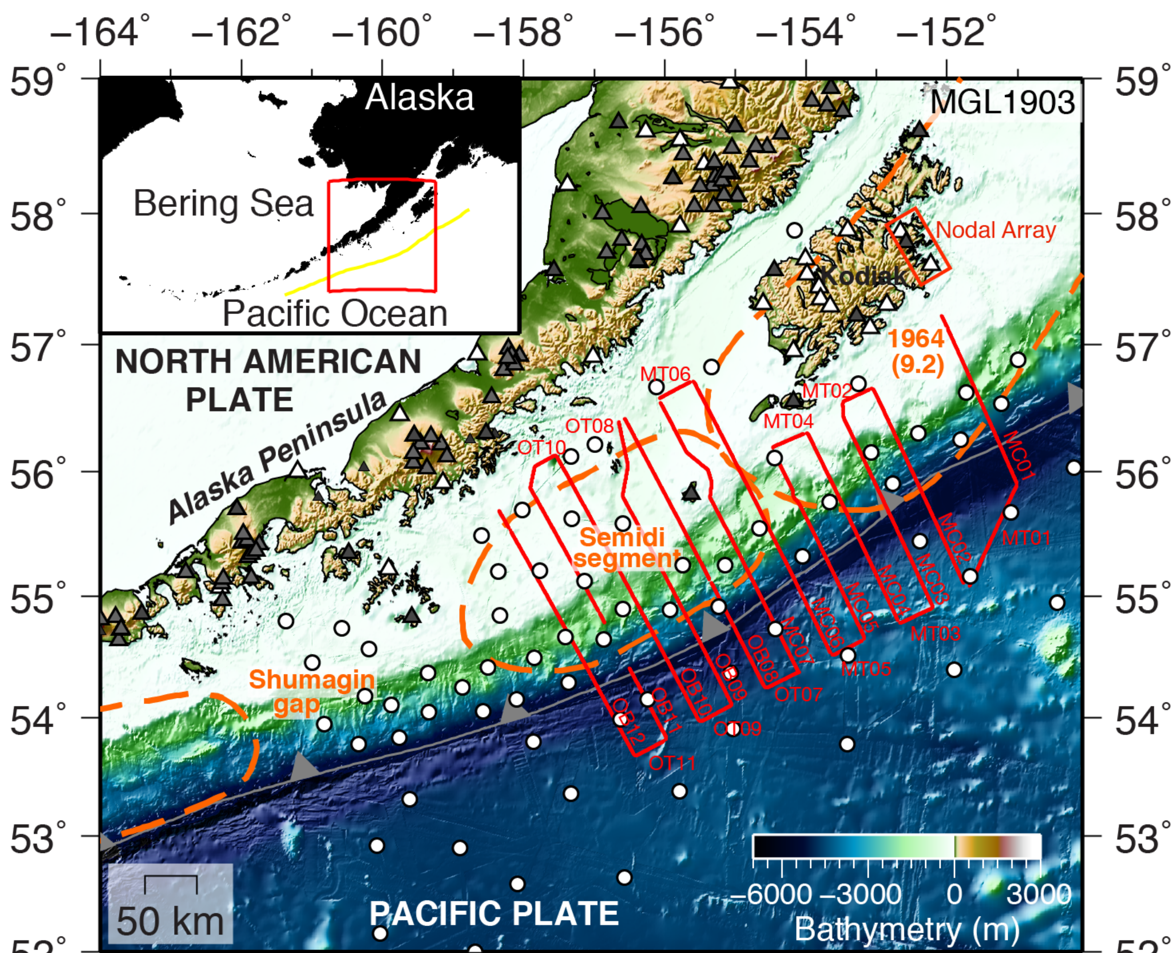
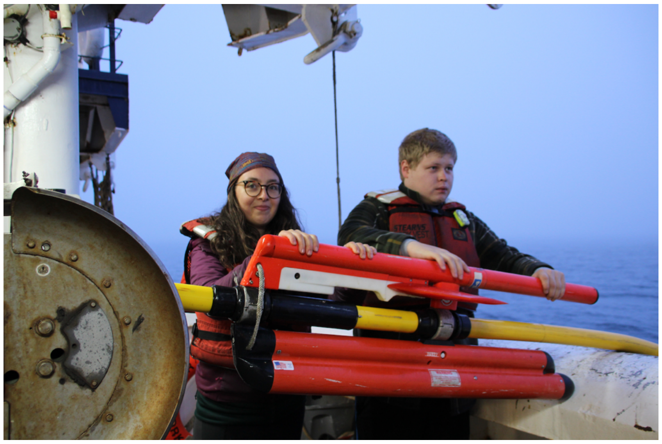


Figure 2.1: Map of offshore acquisition during MGL1903.

3. Narrative

June 5 (JD 156) Wednesday

Science party arrived onboard the R/V *Marcus Langseth* at ~10 am (local time) (1800 UTC time). R/V Langseth was docked at the USCG Kodiak base. Tried to move to fuel dock, but realized that there was a problem with main engines. We were thus unable to shift to fuel dock. At 11 am, Becel and Sheehan met with Martinsen, Captain Wolford, and PSO head observer Amanda Dubuque to discuss protected species permits, restrictions, exclusion zones, and mitigation procedures. At 1pm (2100 UTC), the science party had a safety tour and orientation briefing in the main Lab. The orientation briefing included sexual harassment information and a video on interactions that reflect professionalism, civility, and respect. At 3pm (local time) (2300 UTC time), Anne Bécel gave a presentation to the Apply to Sail (A2S) participants on the main characteristics of the Alaska-Aleutian subduction zone and Anne Sheehan gave presentation on the Alaska Amphibious Community Seismic Experiment. The science talk included discussion of the watch schedule and watch standers duties.



Apply to Sail participants, Ellyn Huggins and Mitchell Spangler helping with the streamer deployment.

June 6 (JD 157) Thursday

Engine repairs were completed by ~1-2pm (2100-2200 UTC time) but we lost our spot at the fuel dock. At 1pm (2100 UTC), Anne Sheehan finished her presentation on the Alaska Amphibious Community Seismic Experiment, including a detailed description of the various types of ocean bottom seismometers that are being used for this experiment and Anne Bécel gave a presentation describing what are the main objectives of the AACSE active source experiment including technical information about the seismic source and the 4 km long hydrophone streamer. Photos were sent to NSF for social media related to national oceans month.

June 7 (JD 158) Friday

Vessel moved to the fuel dock in the morning (8:30am local time, 1600 UTC time). At 1pm (2100 UTC), Anne S. gave an intro lecture on basics of reflection and refraction. After fueling was completed, we waited until high slack tide for departure. Abandon ship drill held. Left USCG Kodiak Base at 4:56pm (local time) (June 8, 0056 UTC time) and steamed towards the northern end of Line MC01. When we left Kodiak, it was very sunny and when we reached the open ocean, started to become foggy. Tail buoy was deployed at 10:40 pm (JD 159, 0640 UTC time). Start deploying the 4-km long streamer at 10:50pm local time (June 8, 0650 UTC), A2S participants helped deploying the streamer by attaching compass birds to the streamer. Streamer deployment took ~2hrs, faster than what we expected. Thermosalinograph was online at 11:03pm (JD 159, 0703 UTC time).

June 8 (JD159) Saturday

Head float was deployed at 0:41 (0841 UTC) followed by magnetometer (Maggie) and PAM deployments at 1:49am (0949 UTC time) and 2:08 am (1008 UTC time), respectively. At 2:21 am (1021 UTC time), it was noticed that there was a small amount of water in pins of the sound velocity uncontaminated seawater system for multibeam bathymetry causing errors. Source array deployment started at 2:46am (1046 UTC time) and the four string array was fully deployed at 6:40am (1440 UTC time). While deploying, we were slowly transiting to the northern end of Line MC01 with the streamer and source towed behind the ship at a depth of 12m. We had to wait day light hours to start shooting Line MC01 as the first part of the profile is in the North Pacific Right Whale Critical Habitat. At 6:57am local time (1457 UTC), once the area has been cleared by PSO observers, ramp up of the airgun array begun but was canceled due to a communication failure on subarray 1. Subarray 1 had to be recovered then redeployed. We had to start a big loop to come back to the beginning of the profile when the subarray 1 will be fixed. Subarray 1 was back in position at 8:42am (1642 UTC time) and ADCP, Knudsen and EM122 were online at 8:54am (1654 UTC time). At the completion of ramp up (1706 UTC time), we were still looping at slow speed (<5 knots) in the North Pacific Right Whale Critical Habitat. We started to acquire data for profile MC01 at 12:21pm local time (2021 UTC). At 1pm local time (2100 UTC), Emma M. gave a lecture on multichannel seismic (MCS) data acquisition and Anne Bécel gave a lecture on seismic data format and geometry assignment. Acquisition of MC01 continued through end of the day. At 2:14pm (0214 UTC time), we launched our first XBT (T-7) and our second one (T-5) at 9:44pm (0544 UTC time). A whale was spotted at 10:25pm (0625 UTC time) but was outside of the shutdown distance.

Apply to Sail participants Lucia Gonzalez and Hongda Wang attaching a bird to the streamer.

June 9 (JD 160) Sunday

At 2:23am (1023 UTC time), there was a problem with the triggering system of the airgun seismic source. Source tried to fire every second. This was fixed very quickly but we lost three shots (307-308-309). We completed acquisition of line MC01 at 7:01am (1501 UTC) then turned and started on the first transit line called MT01. The weather has picked up slightly, but still operationally good. Since most of the A2S participants were feeling a little sea sick and/or sleepy from seasickness medicine, we kept the lecture short. Emma M. talked about noise in the seismic data and how to remove or attenuate it. We slightly increased the speed of the vessel to 5-5.5 knots. Since it was Sunday, 15 minute calls home were allowed on a sign-up basis.

June 10 (JD 161) Monday

We completed acquisition of line MT01 at 6:17pm (0217 UTC) and started acquisition of line MC02 at 7:06pm (0306 UTC). XBT T-5 was launched at 7:53pm (0352 UTC). Cruise photos sent to NSF for oceans month. 1 pm lecture - MCS Processing: Amplitude corrections and stacking (Emma), First looks at MCS, chirp, and bathymetry collected during the cruise (Dave, Anne B). Anne B showed her processed results of first MCS line (MC01) to students. MC02 will be completed soon after midnight UTC (4pm local time).

June 11 (JD 162) Tuesday

We made an inside turn and started the acquisition of Line MT02 at JD161 4:28pm (0028 UTC, JD 162). MT02 was completed at 6:53pm (JD161) (0253 UTC, JD162) and acquisition of Line MC03 started at 7:05pm (JD161) (0305 UTC, JD162). Due to the choppy weather and swell direction, the PAM cable became entangled with subarray 4. To untangle it, it required recovering of subarray 3 and partially recovering subarray 4. Once the tangle was cleared both strings were redeployed. SEAL Chassis froze near EOL of line MC03 that required the reset of hardware cards, the final 11 shots of line MC03 were not recorded on streamer. Array 4 was back in position and online at 9:33pm (0533 UTC, JD 162) and Array 3 at 10:04pm (0604 UTC, JD162). The magnetometer was recovered so PAM could be deployed on the starboard side until swell direction changes (12pm local time, 2001 UTC, JD 162). XBT-T5 were launched at 2:39 AM, JD162 (1039 UTC, JD162) and another one at 4:57 PM (12:57 UTC, JD162). We completed line MC03 at 5am (1300 UTC time) and launched an XBT-5 at 5:01 AM (1301 UTC time). At 3:21 PM (2321 UTC) we started line MT03, and ended the line at 6:37 PM (0237 UTC time, JD163). At 6:50 PM (0250 UTC, JD163), we started line MC04. Wind levels were still high (>20 kts) for the most of the day.

JUNE 12 (JD 163) Wednesday
We ended line MC04 at 4:20 PM (0020 UTC, JD164). We then started line MCO5 at 4:32 PM (0032 UTC, JD164). An XBT-type 7 was launched at 6:14 PM (0214 UTC time). We diverted from the line to for traffic at 8:35 PM (0435 UTC) created by fishing gear. By 9:27 PM (0527 UTC), we had moved back on the line. A2S participant Ellyn presented on volcanoes in the Alaskan Peninsula, and A2S participant Brandon presented on multibeam and gravity data acquisition and processing.

June 13 (JD 164) Thursday
We started the turn to end line MC05 at 12:08 PM (UTC 2008). We started Line MT05 at 12:24 PM and this was completed at 3:32 PM (2332 UTC time), and we started line MC06 at 3:46 PM (2346 UTC time). Visiting marine biologist, Tom Norris, explains BioWaves project and basics of PSO's (Protected species observers).

June 14 (JD 165) Friday
Weather conditions have been deteriorating throughout the day with 30+kt winds and 2-4m seas along with intermittent fog. We entered into the Fin whale protected area at 5:08 AM (1308 UTC time). To keep chances of entanglement of the PAM cable and the source arrays, PAM was moved at 7:07 AM (1507 UTC time). It was promptly redeployed on the port side of the ship. We ended line MC06 at 5:30 PM (0130 UTC time) and started line MC07 24 minutes later. At 9:27 PM (0527 UTC), the PAM cable was moved to the starboard tow point (0527 UTC), and at 9:34 (0534 UTC) we launched an XBT Type-7. Lecture at 1pm local time: presentation from the lead PSO (Amanda), MCS Processing: Velocity analysis, NMO and stacking (Emma). Due to weather conditions, we postponed the streamer recovery to end of Line MC07 rather than end of Line MC06.

June 15 (JD 166) Saturday
At 2 AM (1000 UTC time) we entered into a protected sea otter territory and began to maneuver away from it. At 4:08 AM (1208 UTC) we successfully cleared away from the protected sea otter zone and returned to the line. We made the final turn back to the line at 4:31 AM (1231 UTC). We deployed two XBTs, one type 7 and one type 5 at 11:24 (1924 UTC time) and 12:07 (2007 UTC time), respectively. Line MC07 ended at 11:03 PM (0703 UTC, JD 167). A2S students began to present their research, starting with Carlos and Will. A2S students found old XBT copper wire and have begun playing with it. We began the process of recovering the streamers. First, we recovered PAM cable followed by air gun array 3 at 11:27 PM (0727 UTC time). By 11:51 PM (0751 UTC time), we recovered array 4.

June 16 (JD 167) Sunday
We continued with recovering the arrays and streamers. At 12:35 AM (0835 UTC time), we had recovered array 2. Array 1 was recovered at 12:56 AM (0856 UTC time). After the arrays were finally recovered, we could begin recovery of the streamer at 1:45 AM (0945 UTC time). Unfortunately, the wind level increased and reel 3 became jammed and we had to stop the recovery process for repairs at 3:18 AM (1118 UTC time). This did not take long, and streamer recovery resumed at 3:20 AM (1120 UTC time). The streamer and the tail buoy were fully recovered by 3:54 AM (1154 UTC time). Then, we could begin redeploying the air gun arrays at 4:44 AM (1244 UTC time). The arrays were fully deployed by 6:51 AM (1451 UTC time), and both PAM and MAGGIE were deployed at 7:19 AM (1519 UTC time). Soft start began at 8:04 AM (1604 UTC time). Then, we were able to begin a soft start for line OT07 at 9:09 AM (1709 UTC time). This line was completed at 12:37 PM (2037 UTC time). Then we started line OB08 at 12:45 PM (2045 UTC, JD167). The A2S student research presentations continued, with Hongda and Mitchell's talks. At

09:34 PM, the PAM cable was moved to the starboard tow point. A2S students found a Santa Claus candle, and created a cult surrounding the candle. Unfortunately, a porpoise entered into the exclusion zone at 11:24 PM (0724 UTC time) and we had to shut down the air guns. Was it the fault of the Santa Candle? We will never know. Soft ramp-up began at 11:46 PM (0746 UTC time). We are still trying to finish off the dregs of Tom S. licorice bag. Sunday 15-minute morale phone calls home. Captain 'slop chest' (t-shirt and other Langseth logo stuff) sale 1000-1030 and 1200-1230.

June 17 (JD 168) Monday
After shutting down for the porpoise yesterday, soft start ramp up of the source finished at 12:06 AM (0806 AM). At 4: 36 AM we entered into Fin whale protected area. BioWaves Pam testing began at 2:30 PM and was in the water at 2:55 PM. At 10:27 AM (1827 UTC time), we had to retrieve string 2 for autofire on gun 10. By 11:18 AM (1918 UTC time) string 2 was secured on board, and the air lines were worn through on guns 9 and 10. By 1:45 PM we began deploying string 2, and it was fully deployed at 1:56 PM (2156 UTC time). At 2:30pm (2230 UTC), we started deployed the new PAM device from BioWaves. Testing finished and on deck at 3:56 PM (2356 UTC). Line OB08 was finished at 4:27 PM (0027 UTC time). At 5:05 PM (0105 UTC time on JD 169), we started line OT08. At 11:48 PM (0748 UTC time), we ended line OT08 and began line OB09 at 11:51 PM (0751 UTC time). Lucia and Gokce presented their research during the daily science talks. Surprisingly, the day was clear and the Peninsula was visible, and some old stratovolcanoes (Kialagvik, Chiginagak, and Yarntarni) that were active in the Holocene were observed. Around 4:00 PM (0000 UTC time), the Peninsula was the clearest and more peaks were observed. Around 7 PM (0300 UTC time) we were close to the Semidi Islands. Photos sent to NSF for oceans month.

June 18 (JD 169) Tuesday
We launched one XBT (T-5) at 10:26 AM (1826 UTC time). At 9:40 PM (0540 UTC time), we ended line MGL1903OB09. 9:44 PM (0544 UTC time) we started line MGL1903OT09. The candy of the day was Sour Patch Kids. Both of the Annes presented their research during the science meeting. Anne S. presented on tsunami studies and current research on the 1946 Unimak, Alaska earthquake and tsunami. Anne B. presented on research based on research from ALEUT experiment in 2011. Weather was foggy.

June 19 (JD 170) Wednesday
The day began with ending line MGL1903OT09 at 1:05 AM (0905 UTC time). Line MGL1903OB10 was started at 1:09 AM (0909 UTC time). Tom Morris began BioWaves PAM testing at 10:03 AM (1803 UTC time) and ended at 1:16 PM (2116 UTC time). Emma M. gave a lecture about migration and other processes, and Brandon gave his research presentation. Alas, there was not time for Emma M.'s research talk. The A2S team will never know what she studies. PSOs observed 10 orcas 1.5 kilometers away around 7 PM (0300 UTC, JD171). Most A2S participants saw them—the ones that didn't were asleep. Those students learned that they should never sleep on a ship. One in particular was very upset and demanded that we turn the ship around. We did not oblige. Later, another whale was observed at 8:14 PM (0419 UTC time) within the exclusion zone. The airguns were shutdown at 8:14 PM and we began ramp-up at 8:43 PM (0443 UTC time). A2S participants trying to come up with an acronym for this expedition. The candy of the day from Tom S. was almond joys and Reese's peanut butter cups.

June 20 (JD 171) Thursday
At 1:54 AM (0954 UTC), we entered into Fin whale protected area. Line OB10 was ended at 5:35 AM (1335 UTC time). We started line OT10 at 5:40 AM (1340 UTC time). At 9:32 AM (1732 UTC time) we ended line OT10, and at 9:35 AM, we started line OB11. At 10:33 AM (1834 UTC), Tom Morris began BioWaves PAM towfish testing and was back on deck by 1:21 PM (2121 UTC time). XBT-T7 was launched at 9:03 PM (0503 UTC, JD172). The A2S team is becoming exhausted so we decided to give them a day off from science meetings. Most of the A2S participants finished processing their ALEUT line. Candy of the day were two Lindt chocolate bars. Maggie was turned offline for recovery at 10:44PM (0644 UTC time on JD 172). Maggie was on-board at 11:19 PM (0718 GMC). Shut down at 10:53 PM (0653 UTC

time) because of seal in the exclusion zone. We began ramp up again at 11:11 PM (0711 UTC). We all wished that no more animals would enter the exclusion zone while we are still shooting. At 11:45 PM (0745 UTC, JD172), we had to retrieve and redeploy PAM on the starboard side because of the increase in the sea swell. Winds and the seas started picking up to ~ 30 knots by the end of the day (~11 PM local time, 0700 UTC time on JD 172).

Sunset with Mount Veniaminof in the background

June 21 (JD 172) Friday

Winds continued to be around ~30 knots. Because of bad weather and choppy seas, the PAM cable became tangled and we had to shut down the air guns. First, at 12:09 AM, it was tangled with array 4. To untangle it, at 12:12 AM (0814 UTC, JD172), we recovered and parked array 3. Array 3 was on board by 12:25 AM. PAM was finally untangled from Array 4 and back in position at 1:03 AM (0903 UTC time). At 1:28 AM (0928 UTC time) the PAM cable became tangled with array 1. The PAM cable became untangled at 1:36 AM, and array 1 was sent back to position. At 2:33 AM (1033 UTC time), we redeployed Array 3 and it was back in position at 2:54 AM (1054 UTC time). PAM was fully deployed at 5:39 AM (1339 UTC time). Because this happened at night, so we had to keep the guns turned off for the rest of the night. A soft start up began at 6:42 AM (1442 UTC time) and the soft start was complete at 7:04 AM (1504 UTC time). We completed line OB11 at 2:35 PM (2235 UTC time). The spare strings on 1 and 2 went out at 2:47 PM, and we only had strings 3 and 4 on. There were 18 guns active. We lost 6 hours of data because of PAM. PAM cable was shut off again for recovery at 2:49 (2249 UTC time), and was fully deployed on the port side of the ship at 3:06 PM local time (2306 UTC time). At 3:16 PM (2316 UTC, JD 172), we started acquisition of OT11. At 6: 04 PM (0204 UTC time, JD173), we ended line OT11, and at 6:35 PM (0235 UTC time), we began line OB12.

June 22 (JD 173) Saturday

At 2:37 AM (1037 UTC, JD173) we launched a XBT-T5. At 5:36pm (0136 UTC, JD174), the was a shut down for marine mammal. We started ramp up at 5:53 pm (0153 UTC) but ramp up was cancelled due to another sighting. Ramp up finally started at 6:08 PM (0208 UTC) and was completed at 6:28 PM. A2S participants presented their final work processing ALEUT data during the science meeting. We were shocked that it seemed like they had learned some things during the cruise. Waves were still choppy well into the morning, but the seas calmed down in the mid-afternoon. By the evening (~7 PM local time, 0300 UTC time), the sun was out. Because it is the summer solstice, the A2S participants looked for something to sacrifice. They settled on the Santa candle. A2S participants also built the Santa a wicker man. Someone get these poor people to land. Tom S. brought down Haribo sour gummy bears and Canada's best export, Smarties for candy today. At 7:53 PM (0353 UTC, JD174), there was a shut down for marine mammals, we saw whales, seals, lots of whales, too many whales and we were never able to ramp up the source. We concluded the survey operations 2hr and 7 min earlier that what we had planned. Beautiful sunset at 11:15 pm or so with Mount Veniamimof in background. Ellyn

Santa candle found onboard.

was extremely happy to see the Veniaminof volcano as she is working on data from this volcano for her PhD thesis.

June 23 (JD 174) Sunday

We began recovering the source at 11:11 PM (0711 UTC, JD 174) by subarray 3 followed by 4, 2 and subarray 1 at 01:01 (0901 UTC, JD 174). PAM was onboard and secured at 01:13 AM (0913 UTC, JD 174). We starting transiting back to Kodiak. During transit, we made a last BioWaves towfish test around 11:03 AM (1903 UTC), which lasted for one hour. We took a Science party group photo on the muster deck. During transit, we are also working on this cruise narrative! We got back to port on June 24 (JD 175) around 3pm.

4. Summary of seismic data acquisition parameters

Here we briefly summarize the acquisition parameters for the active source seismic survey. Further detail is given in Appendix A.

- We used the full 4 string, 36 element, 6600 cu.in tuned airgun array of the *Langseth* towed at a 12 m depth for all the survey to enhance the low frequency content of the source. The array was towed 230 m behind the ship's navigational reference point (NRP) and was triggered at a nominal pressure of ~1,950 psi.
- The OBS and multichannel seismic data was shot in distance. The shot interval was kept fixed at 400 m (i.e. ranging from 141.3 s at 4.5 knots to 172s at 5.5 knots) throughout the survey. We chose this large source spacing because it allows for attenuation of previous-shot noise on OBS records, improving the signal-to-noise ratio of arrivals at large offsets. This configuration will allow offsets up to 260 km to be free of previous shot water multiples (with a shot spacing of 141s).

MCS acquisition

- We used a 4050 m long streamer that was towed at 12 m depth. The streamer comprised 324 hydrophone groups or receivers spaced every 12.5 m (Appendix A and Table 1).
- The distance from the center of the source to the nearest hydrophone group was 191.7m (channel 1).
- A sampling interval of 2 ms was used for all MCS shooting. The record length was 25s for all the MCS profiles (Table 2).
- The raw data were recorded with the SEGD standard format in directories called TAPE (table 3).

For some technical reasons and marine mammal sighting, some of the acquisition parameters slightly differ for part of some profiles.

- MGL1903MC01 (June 9): the bird data were not properly recorded at the start of the line (SOL) due to the long shot spacing. This issue was resolved at shot point (SP) 1018. In addition, the Spectra/RCTN trigger malfunctioned causing multiple shots to be recorded in file 307, 308 and 309.
- MGL1903MC02: there was an extra shot file recorded but this one has not been included in the Navigation data.
- MGL1903MC03 (June 11): because of the choppy weather, PAM cable got untangled with subarray 4. This required the recovery and redeployment of subarray 3 and 4. From SP 5027-5058 (files # 1221-1253), the source volume was of 3300 cu.in (string 1 and 2 only), from SP 5059-5070 (files # 1253 to 1264), the source volume was of 4150 cu.in (string 1, 2 and 4) and at SP 5071 (file # 1265), the array 3 was redeployed leading to a source volume of 6600 cu.in. SP 5491 is the end of SEAL recording as the SEAL chassis locked up.
- MGL1903MC05: At SP 9104, we had to divert our course starboard to avoid fishing gear and at SP 9125, once the fishing gear was avoided, we headed back to the planned trackline.

- MGL1903MC07: At the beginning of the profile, we had to turn to stay out of zones for sea otters. At 1208 UTC we moved back to line and at 1231 UTC, we rejoined line.
- MGL1903OB08: We had to shutdown for marine mammal sighting, the last shot before shutdown was 15087, we started ramp up at 07:45 UTC time (SP # 15282) and ramp up was complete at 0805 UTC (SP 15290). The SP 15291 is the first good shot at full volume. Ten hours later, at SP 15533, autofires started for gun 9 and 10 on string 2, we spared out string 2 and begin recovery, firing with a source of 4950 cu.in. (3 strings, 27 airguns). Two hours and a half later, the string 2 was repaired and fully redeployed, the first shotpoint with the full 6600 cu.in is 15623.
- MGL1903OB10: we had to shutdown due to a whale in our exclusion zone. The last good shot before whale shutdown is 19462, the first good shot point after ramp up is 19481.
- MGL1903OB11: After SP 21315, we had to shutdown due to marine mammal sighting, the first good SP after ramp up (i.e. SP with full volume) is 21331.
- For the end of MGL1903OB11, MGL1903OT11 and MGL1903OB12, the source volume was 6540 cu.in as the 60 cu.in airgun (gun 8 on string 1) stopped working.
- MGL1903OB12: We could not finished the line as many, many whales were spotted at the end of the profile.

Volume	6600 in^3	Total recording delay	0 ms
Work pressure	1950 psi +/- 100 psi	Sample rate	2 ms
Source depth	12m	Raw data file format	SEGD standard
Subarray separation	6 m	Shotpoint interval	400 m
Length (m)	4050 m	Low cut	3Hz digital, 4.5 Hz total
Record Length	25s	High cut	200 Hz, 370 dB/Octave
Offset CS-CNG	191.7 m	Group interval	12.5 m
Number of channels	324	Streamer depth	12 m

Table 1: Summary of MCS acquisition parameters

MGL1903 Seismic Configuration by sequence acquired with offsets

DR Table #	Sequence	line name	Shot spacing (m)	Number of active channels	sample rat	ecord lengtl	source sub-array used	source depth	streamer depth	NRP-COS	COS-CNG	comment
	001	MGL1903MC01	400	324	2	25	All	12m	12m	230	191.7	
	002	MGL1903MT01	400	324	2	25	All	12m	12m	230	191.7	
	003	MGL1903MC02	400	324	2	25	All	12m	12m	230	191.7	
	004	MGL1903MT02	400	324	2	25	All	12m	12m	230	191.7	
	005	MGL1903MC03	400	324	2	25	All	12m	12m	230	191.7	Multiple source array changes due to PAM tangl
	006	MGL1903MT03	400	324	2	25	All	12m	12m	230	191.7	
	007	MGL1903MC04	400	324	2	25	All	12m	12m	230	191.7	
	008	MGL1903MT04	400	324	2	25	All	12m	12m	230	191.7	
	009	MGL1903MC05	400	324	2	25	All	12m	12m	230	191.7	
	010	MGL1903MT05	400	324	2	25	All	12m	12m	230	191.7	
	011	MGL1903MC06	400	324	2	25	All	12m	12m	230	191.7	
	012	MGL1903MT06	400	324	2	25	All	12m	12m	230	191.7	
	013	MGL1903MC07	400	324	2	25	All	12m	12m	230	191.7	
	014	MGL1903OT07	400	N/A	N/A	N/A	All	12	N/A	230	N/A	Source only no streamer
	015	MGL1903OB08	400	N/A	N/A	N/A	All	12	N/A	230	N/A	Source only no streamer
	016	MGL1903OT08	400	N/A	N/A	N/A	All	12	N/A	230	N/A	Source only no streamer
	017	MGL1903OB09	400	N/A	N/A	N/A	All	12	N/A	230	N/A	Source only no streamer
	018	MGL1903OT09	400	N/A	N/A	N/A	All	12	N/A	230	N/A	Source only no streamer
	019	MGL1903OB10	400	N/A	N/A	N/A	All	12	N/A	230	N/A	Source only no streamer
	020	MGL1903OT10	400	N/A	N/A	N/A	All	12	N/A	230	N/A	Source only no streamer
	021	MGL1903OB11	400	N/A	N/A	N/A	All	12	N/A	230	N/A	Source only no streamer
	022	MGL1903OT11	400	N/A	N/A	N/A	All	12	N/A	230	N/A	Source only no streamer
	023	MGL1903OB12	400	N/A	N/A	N/A	All	12	N/A	230	N/A	Source only no streamer

Table 2: Main acquisition parameters for each profiles

		Start of line						End of line						Start		End					
Line #	Seq #	Date	Time (UTC)	Latitude* whole degrees	Latitude* decimal minutes	Longitude* whole degrees	Longitude* decimal minutes	Date	Time (UTC)	Latitude* whole degrees	Latitude* decimal minutes	Longitude* whole degrees	Longitude* decimal minutes	shot #	file #	shot #	file #	3590 tape #s	Sample Rate ms	Sample Length seconds	# Channels
MGL1903MC01	001	2019-06-08	20:21	57	13.34540	-152	05.05292	2019-06-09	15:01	55	54.05782	-151	00.80478	990	1	1393	406	1	2	25	324
MGL1903MT01	002	2019-06-09	15:08	55	53.48193	-151	01.14332	2019-06-10	02:13	55	05.32843	-151	41.17112	2004	407	2251	654	2	2	25	324
MGL1903MC02	003	2019-06-10	03:04	55	06.37142	-151	46.17700	2019-06-11	00:08	56	39.25500	-151	03.75267	3020	655	3497	1132	3	2	25	324
MGL1903MT02	004	2019-06-11	00:28	56	38.98855	-153	06.37467	2019-06-11	02:51	56	32.85942	-153	28.78802	4009	1133	4073	1197	4	2	25	324
MGL1903MC03	005	2019-06-11	02:56	56	32.41158	-153	28.97822	2019-06-11	23:13	54	54.49225	-152	12.94585	5004	1198	5491/ 5502	1685	5	2	25	324
MGL1903MT03	006	2019-06-11	23:21	54	53.96797	-152	13.81593	2019-06-12	02:34	54	47.23135	-152	40.52417	6006	1686	6084	1764	6	2	25	324
MGL1903MC04	007	2019-06-12	02:50	54	48.19697	-152	42.08878	2019-06-12	21:09	56	18.48140	-153	59.81218	7008	1765	7474	2231	7	2	25	324
MGL1903MT04	008	2019-06-12	21:23	56	18.26245	-154	01.84338	2019-06-13	00:14	56	11.42768	-154	28.51095	8008	2232	8084	2308	8	2	25	324
MGL1903MC05	009	2019-06-13	00:32	56	09.95390	-154	28.15062	2019-06-13	20:08	54	39.18767	-153	10.70997	9009	2309	9477	2777	9	2	25	324
MGL1903MT05	010	2019-06-13	20:24	54	38.31778	-153	12.33593	2019-06-13	23:32	54	31.35703	-153	37.88017	10008	2778	10084	2854	10	2	25	324
MGL1903MC06	011	2019-06-13	23:46	54	32.29633	-153	39.48157	2019-06-15	01:12	56	42.68505	-155	36.23788	11008	2855	11686	3533	11	2	25	324
MGL1903MT06	012	2019-06-15	01:25	56	42.60288	-155	36.23788	2019-06-15	04:42	56	34.76427	-156	04.49398	12007	3534	12083	3610	12	2	25	324
MGL1903MC07	013	2019-06-15	05:03	56	33.03125	-156	04.08487	2019-06-16	07:03	54	22.54785	-154	06.45395	13009	3611	13689	4291	13	2	25	324
MGL1903OT07	014	2019-06-16	17:07	54	22.84862	-154	05.75030	2019-06-16	20:37	54	15.02595	-154	34.46913	13998	N/A	14084	N/A	N/A	N/A	N/A	N/A
MGL1903OB08	015	2019-06-16	20:45	54	15.41078	-154	35.50182	2019-06-18	00:27	56	25.30272	-156	34.77420	15005	N/A	15685	N/A	N/A	N/A	N/A	N/A
MGL1903OT08	016	2019-06-18	01:05	56	23.95062	-156	39.38223	2019-06-18	07:48	55	48.34757	-156	36.00043	16010	N/A	16175	N/A	N/A	N/A	N/A	N/A
MGL1903OB09	017	2019-06-18	07:51	55	48.09683	-156	35.82967	2019-06-19	05:40	54	06.58942	-155	03.82585	17154	N/A	17685	N/A	N/A	N/A	N/A	N/A
MGL1903OT09	018	2019-06-19	05:44	54	06.33138	-155	03.99702	2019-06-19	09:05	53	58.30542	-155	30.35348	18003	N/A	18084	N/A	N/A	N/A	N/A	N/A
MGL1903OB10	019	2019-06-19	09:09	53	58.50392	-155	31.01758	2019-06-20	13:35	56	07.72185	-157	33.26193	19004	N/A	19686	N/A	N/A	N/A	N/A	N/A
MGL1903OT10	020	2019-06-20	13:40	56	07.76805	-157	34.08112	2019-06-20	17:32	55	52.20340	-157	54.49377	20004	N/A	20103	N/A	N/A	N/A	N/A	N/A
MGL1903OB11	021	2019-06-20	17:34	55	52.00697	-157	54.38152	2019-06-21	22:35	53	49.37262	-155	59.14582	21002	N/A	21649	N/A	N/A	N/A	N/A	N/A
MGL1903OT11	022	2019-06-21	22:53	53	48.45152	-156	00.68770	2019-06-22	02:04	53	41.11255	-156	25.41840	22008	N/A	22084	N/A	N/A	N/A	N/A	N/A
MGL1903OB12	023	2019-06-22	02:10	53	41.31960	-156	26.12245	2019-06-23	04:26	55	41.41403	-158	21.17465	23004	N/A	23641	N/A	N/A	N/A	N/A	N/A

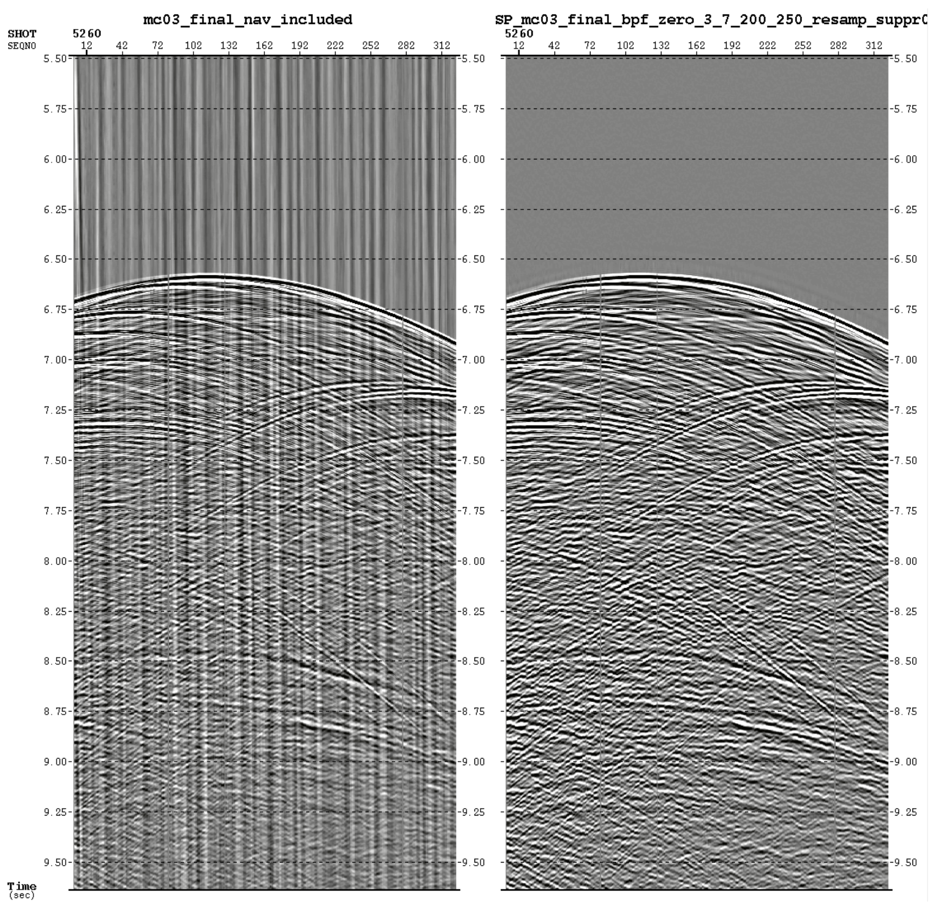
Table 3: Table summarizing timing, longitude and latitude at the start and end of the lines (SOL, EOL) and tape numbers where raw SEGD data are stored.

5. Summary of onboard multichannel seismic data analysis

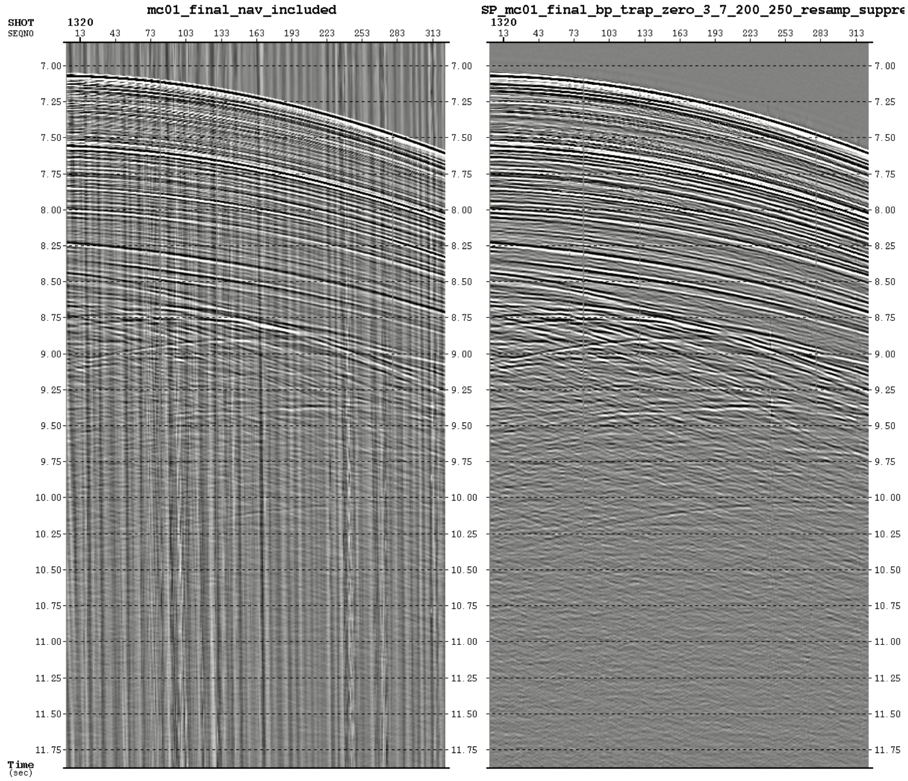
During MGL1903, we undertook a range on onboard processing activities that are briefly described here.

MCS data:

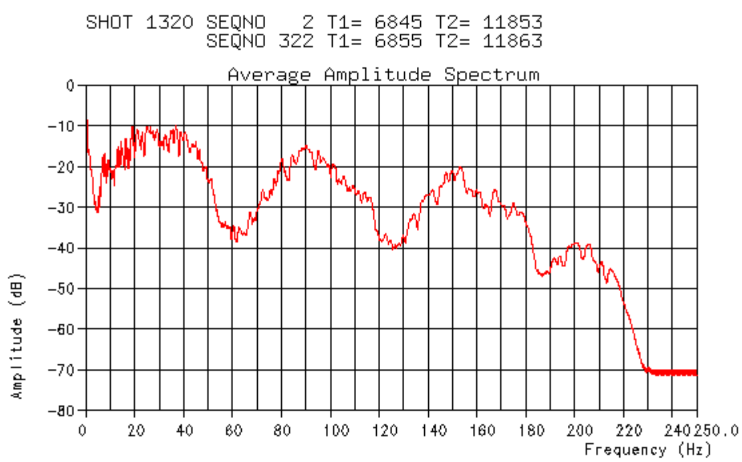
We used Echos of Paradigm to read the raw SEG-D data, check all of the navigation files (P-190s file) and merge the geometry with the raw SEG-D files. We then filtered the data, mostly to remove the swell noise and use the module 'suppress' to reduce the noise due to the currents or turns. CDP was extracted and velocity analysis was performed every 250 CDP (~1.5 km) using the first channel stack as a guideline. Because of the low fold coverage (5) due to the large shot spacing (400m), the velocity picking was quite challenging even if it was performed on supergathers. The first channel stacking helped with the velocity picking. Stretch mute was picked manually every 250 CDP. We then apply stacking using the velocity picked and time variant filtering to remove high frequency energy at large depth. After stacking, we apply a water velocity Kirchhoff time migration followed by muting everything above the seafloor, applying stronger time variant filtering and time variant gain. The multiple had a tendency to smear over the accretionary prism part so we attenuated the multiple and re-perform water velocity post-stack time migration, time variant filtering and gain.



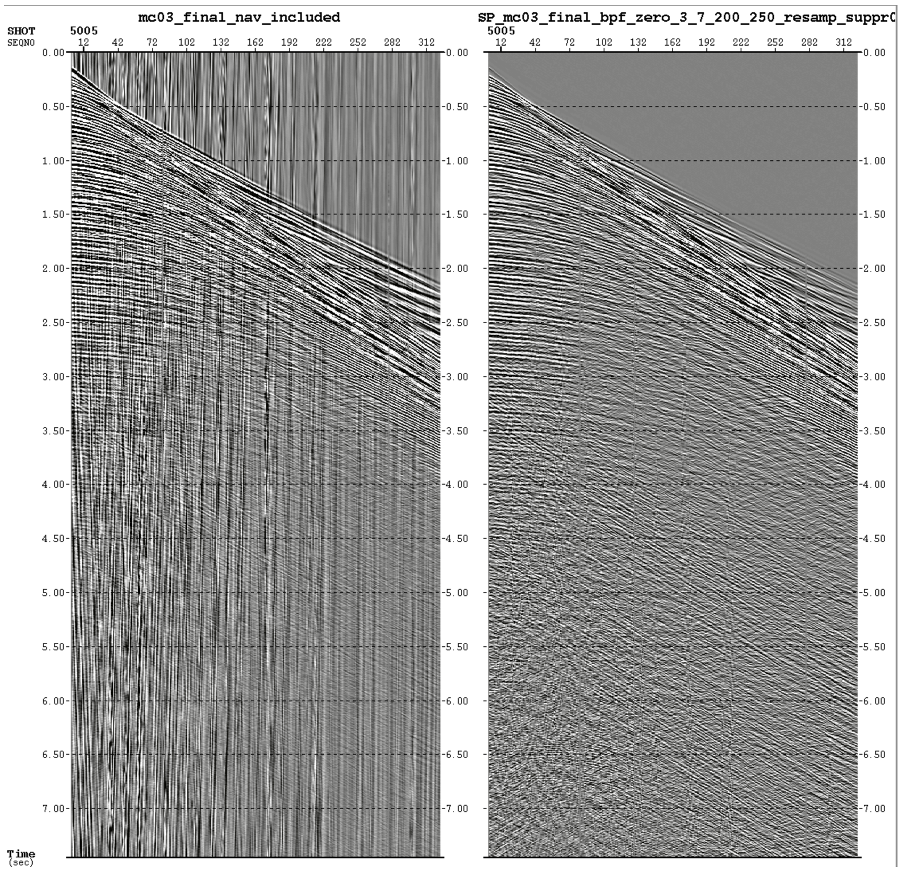
Example of shot point gather (left) raw and (right) after band pass filtering, noise suppression, resampling and spherical divergence correction. Décollement is seen around 8.5 s two way *traveltime and the top of the subucting plate 0.25s below the Décollement.*



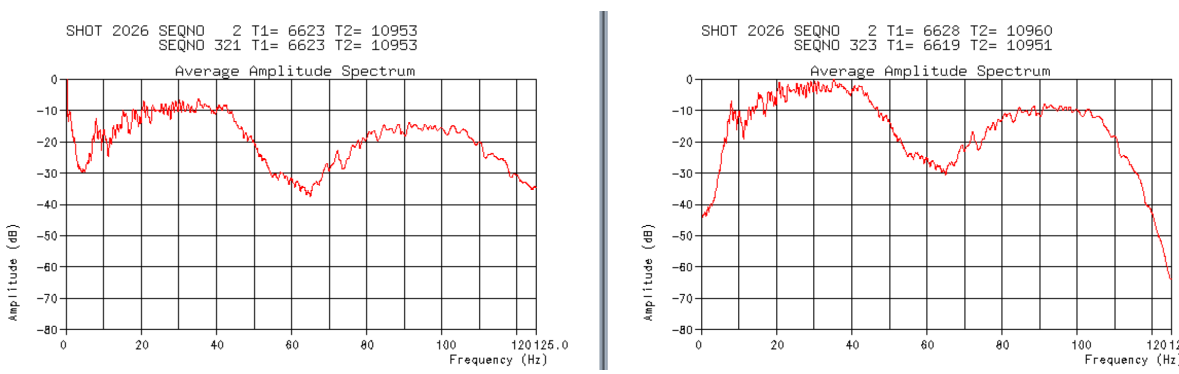
Example of shot point near the trench axis (left) raw and (right) after band pass filtering, noise suppression, resampling and spherical divergence correction.



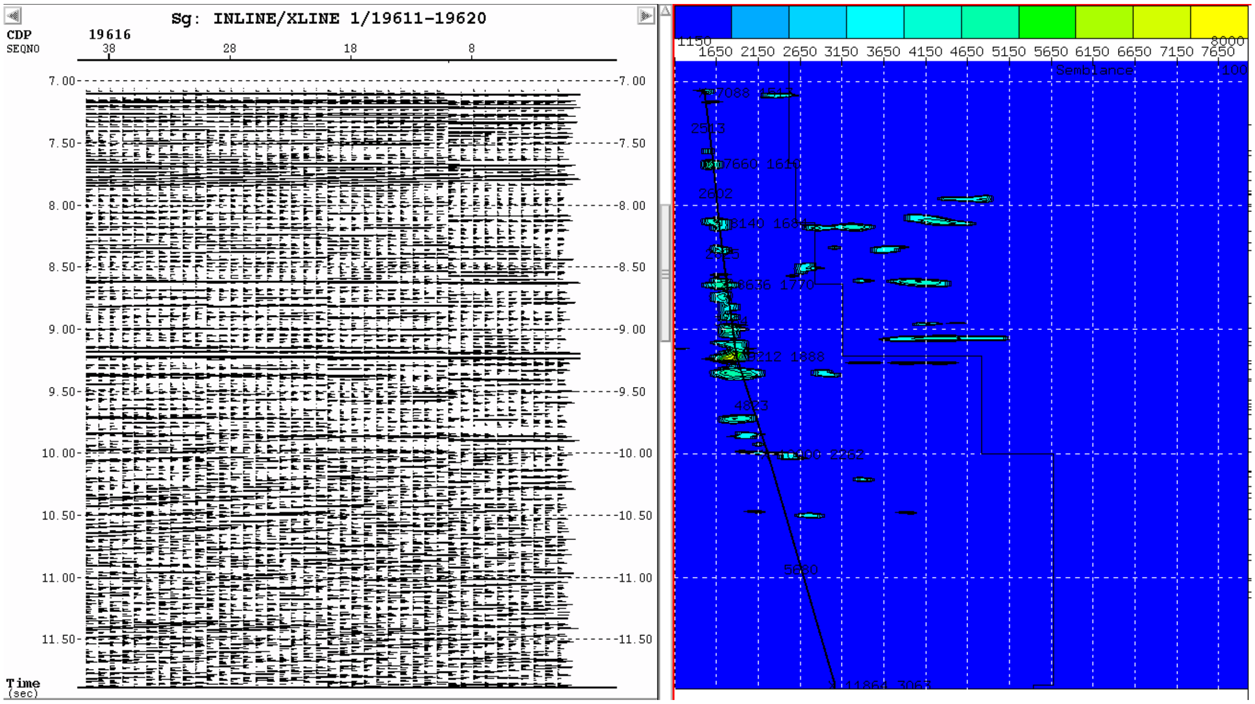
Typical Spectrum of one of the shot points from MGL1903 MC01 before filtering



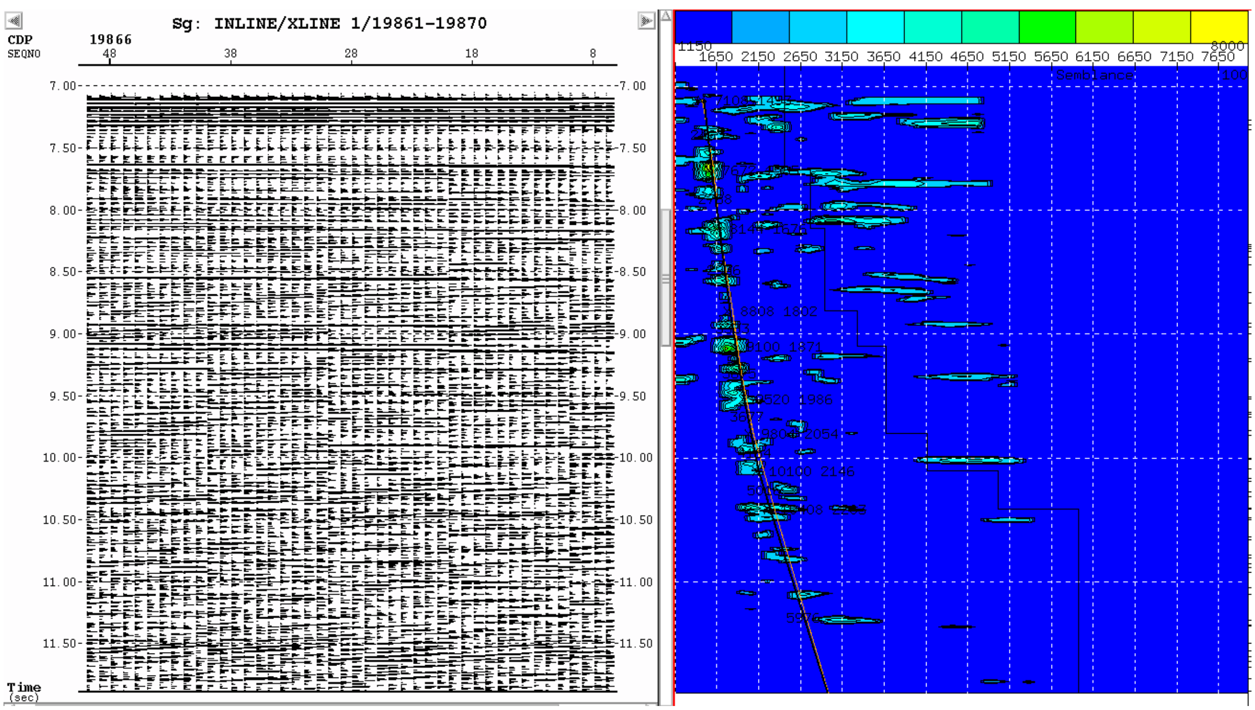
Example of a shot point in shallow water (left) with navigation included in the headers and (right) after band pass filtering, noise suppression, resampling and spherical divergence correction.



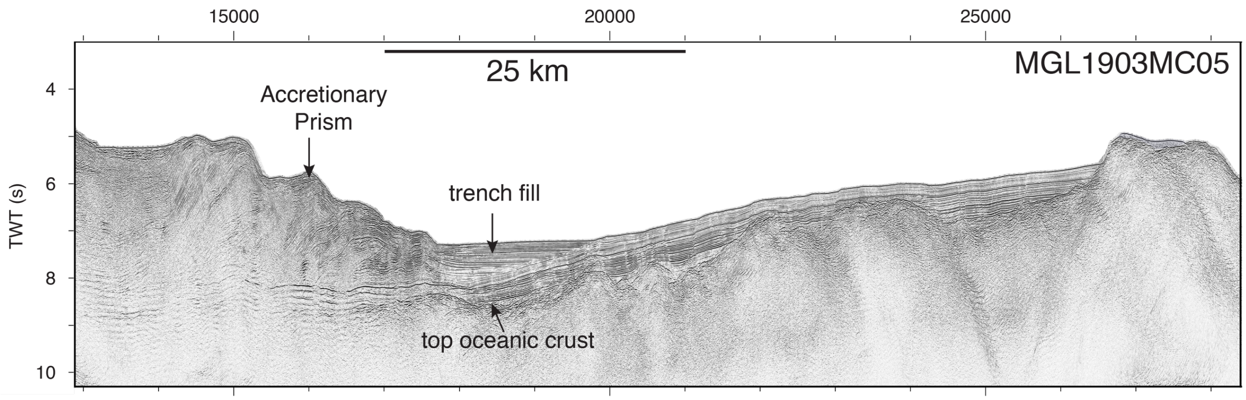
Example of spectra (left) before and (right) after band pass filtering.



Example of velocity analysis performed on supergathers (15 consecutive gathers)



Example of velocity analysis performed on supergathers (15 consecutive gathers)



Example of onboard processed multichannel seismic profile (profile MGL1903MC05). Processing includes: (1) pseudo 3D geometry assignment, (2) noise removal on shot point gathers (band pass filtering and band-limited noise suppression and linear frequency domain signal enhancement), (3) applying normal move out corrections to the CDP gathers and picked stretched mute on the supergathers (4) stacking (4) water velocity Kirchhoff time migration (5) applying time variant filtering and time variant gain.

6. Summary of acquisition parameters and processing of Knudsen 3.5 kHz Chirp data

David S. Foster, USGS Woods Hole, MA dfoster@usgs.gov

System and GPS to transducer offsets

Chirp data were collected using a Knudsen Engineering Limited (KEL) 3260 Chirp echosounder. The 3260 is configured with a four-by-four, array of sixteen 3.5 kHz Massa TR-1075 transducers. The transducer array is located in the sonar pod of the R/V Lanseth adjacent to the EM122 multibeam transducers. The transducers are 20.2 m forward of the navigation reference point and C-Nav GPS antenna.

Knudsen Chirp Acquisition

KEL SounderSuite (v.2.73) software was used to record the data. Table 1 summarizes the parameters used in the SounderSuite software. The chirp data were acquired continuously along the cruise track and recorded within a 200 m or 500 m window, in water depth < 200 m and > 200 m respectively. A manual deep-water delay was applied to keep the seafloor and subbottom reflections within the data window. Ping rates were variable depending on water depth. At the beginning of the cruise we attempted to trigger the chirp system internally and use the multiple pings mode to increase spatial resolution. The system was only able to ping about every 5 seconds, regardless of trace lengths and ping rates in both deep and shallow water. As a result, the ping rate was set by external ping rates of the EM122 MBES. This resulted in good spatial resolution in shallow water. Raw data consist of (a) KEL Binary (KEB) envelope detected trace data, (b) KEL ASCII (KEA), and (c) SEG-Y format trace data, which are recorded on the acquisition computer hard drive. SEG-Y files recorded the correlate (match filtered) trace data. These files were remotely copied via rsync to the *Langseth* network file server (fserve). Data were then copied from the server to a workstation computer for processing. KEB files can be played back or converted to SEG-Y format using KEL software. KEA files recorded user selected attributes and for this cruise include record number (original FFID), date, time (hhmmss), depth in meters, transmit power, pulse length, latitude, longitude, and position time in seconds.

Table 1. SounderSuite Echo Control Client (v 2.35) settings

Transmit Parameters	Settings
Tx Pulse	8, 16, and 32.0 ms (longer pulse length with depth)
Tx Power	Variable 1-3 (Generally Powers 1on the shelf, 2on the slope, 3 for deep > 3000 m)
Gain Mode	Manual
Gain Value	Variable 10-48 dB
TVG Mode	None
Process Shift	None
Draft	None
Tx Blanking	25.0 m
Global Tx	Mixed

Range (data window)	200 m (266 ms) or 500 m (666 ms)
Phase (deep-water delay)	Manual (depth dependent)
Depth Limits	0-9000 m
Multiple Pings	Enabled (did not work, internal trigger didn't work)
Sound Speed	1500 m/s
Ping Rate	The internal ping rate was not working
Tracking Gate	20 to 50 m
Echogram	Uncompressed
Sync Mode	External slave to EM122
Channel Parameters	Settings
Waveform	Chirp: Envelope Detect Square Law
Center Frequency Band	3.5 kHz
Frequency Bandwidth	3 kHz
Filter Windowing	Decimation, Main Signal, Analytic, Lowpass, Transmit all set to rectangular
SEG-Y Carrier Type	Filtered (match filtered – correlate)

Processing

Preliminary processing and QA/QC of the KEL Chirp data was accomplished using a series of scripts that utilize the seismic processing packages SIOSeis (sioseis.ucsd.edu) and SeismicUnix (github.com/JohnStockwellJr/SeisUnix). The following process steps were applied, and SEG-Y files written at each step as indicated.

1) Shot numbers (FFID) were renumbered consecutively for each file starting with one and written to a SEG-Y file. The original FFID numbers in the SEG-Y trace headers and KEA files will not match the renumbered shots; however, trace sequence number was changed in the trace header to match the original FFID as shot number within reel. These files have the original trace lengths and varying deep-water delays as wel as the original correlate trace data.
2) The raw correlate traces were converted to envelope detected traces using SIOSeis as described by Paul Henkart (sioseis.ucsd.edu/examples) and written to a SEG-Y file.
3) SIOSeis read the envelope SEG-Y files, set a common trace length, and a common deep-water delay time for each file, which resulted in traces that were padded with zero sample values outside of the original data window. The resulting trace length depended on the range of data and delay times for each file. The exception to this was in shallow water where no delays were applied. Some files that had total padded trace lengths that exceeded the SEG-Y format maximum number of samples (65,536) had to be split so as not to exceed this limitation. The split files were also padded and set to a common delay. All files with common trace lengths and delays were written to a SEG-Y file.
4) SeismicUnix was used to extract SEG-Y trace headers (shot number, geographic coordinates, date and time, which were parsed using Unix utilities and were concatenated into ASCII navigation files (East, North, Lon, Lat, Filename, ImageName, Shot, Year, JD_UTC). Easting and Northings (WGS 84 UTM Zone 3 North) were derived from the geographic coordinates using the program "proj". The ASCII navigation files were

concatenated for import to GIS and Kingdom Suite (v.2017.0, MS SQL 2012). FFID in these files match FFID in the processed SEG-Y trace headers that be useful for loading navigation to similar interpretation software.

5) SeismicUnix was used to plot 8-bit gray scale PNG images of the envelope and padded trace data. These images are useful for browsing trace data from each file.
6) SIOSies was used to remove sea-surface swell (heave) from the trace data. Water-bottom picking using the SIOSeis process WBT; however, this did not work well due to dropouts in the trace data. As a result, the water bottom was auto picked and edited in Kingdom Suite (v.2017.0, MS SQL 2012). The picked horizon was exported and used in the SIOSeis process WBT and Swell. The static shifted traces resulted in significant improvement in the resolution of the data (Figure 6.1). 8-bit gray scale PNG images of the swell filtered data were also created for browsing purposes. The swell filtered SEG-Y files were saved and loaded to Kingdom Suite as an additional data type (envelope-swell).

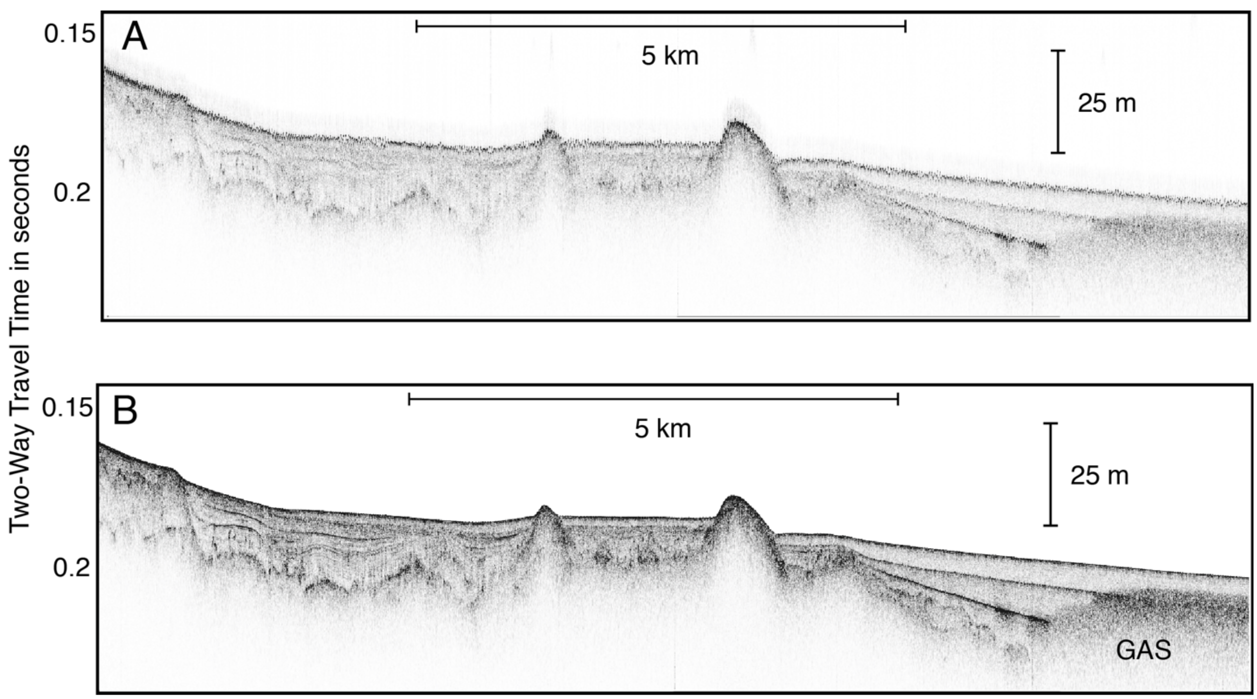


Figure 6.1. A, subset of chirp 0012_161_2357 after application of common deep-water delay and padding trace data to a common length. B, the same profile after application of a 19-point swell filter to apply a static correction to the traces caused by vessel heave. Swell filtering was applied to data collected on the shelf and shelf break. Vertical scale assumes a velocity of 1500 m/s. See figure 6.2 for profile location.

Known Problems

The overall quality of the KEL chirp data was good. There was periodic cross talk (amplitude spikes) from the multibeam system, though it does not significantly degrade the data. Also, there are trace dropouts (zero amplitude) traces throughout the profiles. The source of these dropouts is not known but has been observed in previous *Langseth* cruises. Manual delays set by watch standers resulted in some sections of the data to be truncated (very difficult to track around seamounts and continental slope), but the overall method of changing the delay manually and maintain a relatively small data window resulted in good vertical resolution by keeping the sample rate small. The internal trigger for the KEL Chirp was not working, thus the chirp system was triggered from the ping rate of the EM122 MBES. This resulted in limited spatial resolution in deep water (> 500 meters). Shot intervals in deep water were up to 20 meters, while in shallow water they were about 2 meters apart. Deep water data were not swell filtered due to ping rates of several seconds and sea surface swell with similar periods.

Data Summary

A total of 3,462 line kilometers of KEL Chirp profiles were acquired and processed. Table 2 gives the information about file names, shot range, trace length, date and time. Table 3 summarizes the data types from raw to output from various process steps.

Table 2. Processed KEL Chirp files (File#_Day_HourMinute), relation to MCS/OBS lines, renumbered shot starting at 1, ending shot number, beginning trace time in seconds (common delay), ending trace time (seconds), Julian day, start file time (hours:minutes:seconds). Note this was the acquisition computer time, which was about 8 minutes behind UTC. Rows shaded in gray are files that were split where maximum number of samples were exceeded.

MCS/OBS Line	Knudsen Chirp File	Start Shot	End Shot	Start Tace Time (sec)	End Tace Time (sec)	Julian Day	Start Time	End Time
NA	0001_159_1647	1	52	0.066	0.199	159	16:47:06	16:50:50
NA	0002_159_1652	1	1159	0	0.199	159	16:52:58	18:47:19
NA	0003_159_1849	1	104	0	0.199	159	18:49:46	19:00:45
NA	0004_159_1904	1	8870	0	0.267	159	19:04:06	20:14:28
MC01	0005_159_2014	1	19999	0	0.267	159	20:14:32	22:53:11
MC01	0005_159_2253	1	19999	0	0.267	159-160	22:53:12	1:32:04
MC01	0005_160_0132_KEB	1	7515	0	2.4	160	1:32:05	5:27:17
MC01	0005_160_0132_KEB	1	1061	2.4	5.3	160	5:27:23	7:51:57
MC01	0005_160_0132_KEB	1	3246	5.4	7.1	160	7:52:53	15:26:30
MT01	0005_160_0132	1	8577	0	5.333	160	1:32:05	7:51:57
MT01	0006_160_1526	1	3127	5.866	7.2	160	15:26:55	22:19:39
MT01	0007_160_2219	1	9047	4.266	7.333	160-161	22:19:54	17:10:54
MC02	0009_161_1715	1	225	3.2	4.4	161	17:15:39	17:39:32
MC02	0010_161_1740	1	970	0.333	3.667	161	17:40:15	19:27:03
MC02	0011_161_1927	1	19999	0	0.667	161	19:27:20	22:17:47
MC02	0011_161_2217	1	12505	0	0.267	161	22:17:48	23:57:47
MT02	0012_161_2357	1	19999	0	0.4	161-162	23:57:49	3:13:52
MC03	0012_162_0313	1	2485	0	0.267	162	3:13:53	3:34:43
MC03	0013_162_0334	1	19999	0	0.267	162	3:34:45	6:13:24
MC03	0013_162_0613	1	7000	0	0.5	162	6:13:25	7:13:29
MC03	0013_162_0613	1	3201	0.5	4.133	162	7:13:30	11:33:48
MC03	0013_162_1134	1	4470	3.666	8	162	11:34:02	23:08:38

MT03	0014_162_2308	1	1972	3.666	6	162-163	23:08:50	2:52:54
MC04	0015_163_0253	1	3000	4.4	7.4	163	2:53:14	13:12:16
MC04	0015_163_0253	1	942	1.333	4.6	163	13:12:29	15:01:52
MC04	0015_163_1502	1	2352	0	2	163	15:02:33	16:27:25
MT04	0016_163_1627	1	19999	0	0.4	163	16:27:43	19:56:22
MC05	0016_163_1956	1	7776	0.133	0.4	163	19:56:23	21:10:10
MC05	0017_163_2110	1	19626	0	0.4	163-164	21:10:13	0:13:46
MT05	0018_164_0013	1	18158	0	0.4	164	0:13:48	3:16:51
MT05	0018_164_0316	1	8974	0	7.667	164	3:16:53	20:04:02
MC06	0019_164_2004	1	10945	0	7.667	164-165	20:04:18	16:26:07
MC06	0020_165_1626	1	35	0	0.667	165	16:26:11	16:26:38
MC06	0021_165_1626	1	19999	0	0.4	165	16:26:55	19:11:49
MC06	0021_165_1911	1	9260	0	0.267	165	19:11:49	20:13:01
MC06	0001_165_2034	1	19999	0	0.267	165	20:34:37	22:52:06
MC06	0001_165_2252	1	14758	0	0.533	165-166	22:52:07	1:32:16
MT06	0002_166_0132	1	12092	0.266	0.533	166	1:32:20	4:49:37
MC07	0022_166_0449	1	19999	0	0.667	166	4:49:55	8:39:50
MC07	0022_166_0839	1	19999	0	0.267	166	8:39:51	11:12:38
MC08	0022_166_1112	1	19999	0	0.267	166	11:12:38	13:22:39
MC09	0022_166_1322	1	11015	0	0.533	166	13:22:40	15:07:48
MC10	0022_166_1507	1	1051	0.666	1.333	166	15:07:50	15:40:03
MC11	0023_166_1540	1	3600	0.7	2	166	15:40:08	18:27:09
MC11	0023_166_1540	1	4900	1.8	5.34	166	18:27:14	21:37:36
MC12	0024_166_2137	1	1304	4.666	7.667	166-167	21:37:50	3:55:02
MC13	0025_167_0355	1	2802	5.666	6.667	167	3:55:20	16:58:57
OT07	0026_167_1659	1	986	5.666	6.667	167	16:59:14	21:43:21
OB08	0027_167_2143	1	1100	3	6	167	9:08:58	12:02:11
OB08	0027_167_2143	1	1685	6	7.9	167-168	21:43:39	9:08:50
OB08	0027_168_1202	1	19999	0	0.533	168	12:02:12	15:35:41
OB08	0027_168_1535	1	19999	0	0.4	168	15:35:41	18:42:19
OB08	0027_168_1842	1	19999	0.133	0.533	168	18:42:20	23:21:28
OT08	0027_168_2321	1	13619	0.133	0.4	168	23:21:28	1:59:44
OT08	0028_169_0159	1	19999	0.133	0.4	169	1:59:47	6:01:04
OB09	0028_169_0601	1	19999	0.133	0.4	169	6:01:05	10:53:03
OB09	0028_169_1053	1	17242	0.133	1.067	169	10:53:04	15:10:16
OB09	0028_169_1510	1	2490	0.8	3.867	169	15:10:21	19:04:22
OB09	0029_169_1904	1	2200	6	7.9	169	19:04:36	22:57:43
OB09	0029_169_1904	1	1100	3	6	169-170	21:47:27	5:53:51
OT09	0030_170_0554	1	2200	1.666	7.867	170	5:54:09	16:28:06
OT09	0030_170_0554	1	1618	1.8	5.7	170	16:28:23	21:09:54
OB10	0031_170_2110	1	3069	0.333	2.333	170-171	21:10:04	0:22:10
OB10	0031_171_0022	1	16926	0	0.8	171	0:22:11	3:13:46
OB10	0032_171_0313	1	19999	0	0.267	171	3:13:56	5:52:36
OB10	0032_171_0552	1	19999	0	0.267	171	5:52:36	8:31:16
OB10	0032_171_0831	1	19999	0	0.267	171	8:31:16	11:09:58

OB10	0032_171_1109	1	19999	0	0.4	171	11:09:58	14:19:44
OT10	0032_171_1419	1	19999	0	0.267	171	14:19:44	17:18:42
OT10	0032_171_1718	1	1393	0	0.267	171	17:18:43	17:29:45
OB11	0033_171_1729	1	19999	0	0.267	171	17:29:49	20:31:53
OB11	0033_171_2031	1	19999	0	0.267	171	20:31:54	23:22:07
OB11	0033_171_2322	1	19999	0	0.267	171-172	23:22:08	2:00:47
OB11	0033_172_0200	1	19924	0	1.333	172	2:00:48	6:11:47
OB11	0034_172_0612	1	3000	1.2	4.8	172	6:12:05	10:56:27
OB11	0034_172_0612	1	2391	4.8	8	172	10:56:42	22:22:39
OT11	0035_172_2222	1	963	5	6.667	172-173	22:23:14	3:02:39
OB12	0036_173_0302	1	2206	1.7	4.7	173	11:42:41	15:56:15
OB12	0036_173_0302	1	1750	4.7	8	173	3:02:57	11:42:28
OB12	0037_173_1556	1	2030	0.333	2.333	173	15:56:20	17:02:44
OB12	0038_173_1702	1	19999	0	0.533	173	17:02:56	19:56:57
OB12	0038_173_1956	1	19999	0	0.267	173	19:56:57	22:35:36
OB12	0038_173_2235	1	17621	0	0.267	173-174	22:35:37	0:56:25
OB12	0038_174_0119	1	19999	0	0.267	174	1:19:04	4:46:52
OT12	0038_174_0446	1	19999	0	0.267	174	4:46:52	7:52:49
OT12	0038_174_0752	1	346	0	0.267	174	7:52:49	7:56:29

Table 3. Summary of raw and processed data.

Data type	Trace length	Deep water Delay	Comment
Level 0 Seismic (KEB)	Variable	Variable	Read or convert with KEL software
Level 0 Seismic (SEG-Y)	Variable	Variable	Correlate (match filtered) traces
Level 0 Seismic (SEG-Y)	Variable	Variable	Correlate (match filtered) traces
Level 0 Attribute (KEA)	N/A	N/A	Select attributes in ASCII format
Level 1Seismic (SEG-Y)	Variable	Variable	Envelope traces
Level 2 Seismic (SEG-Y)	Common	Common	Padded traces with common delay
Level 3 Swell filtered (SEG-Y	Common	Common	Swell filtered static shifted
Images of chirp data	Common	Common	PNG format
GIS (Esri shape and ASCII CSV)	N/A	N/A	Trackline, Unique shot point, and 500 shot-point intervals

Initial Results

This section gives some examples of the KEL Chirp data that illustrate some of the records acquired during MGL1903. Figure 6.2 shows a map of the chirp tracklines and the locations of these examples.

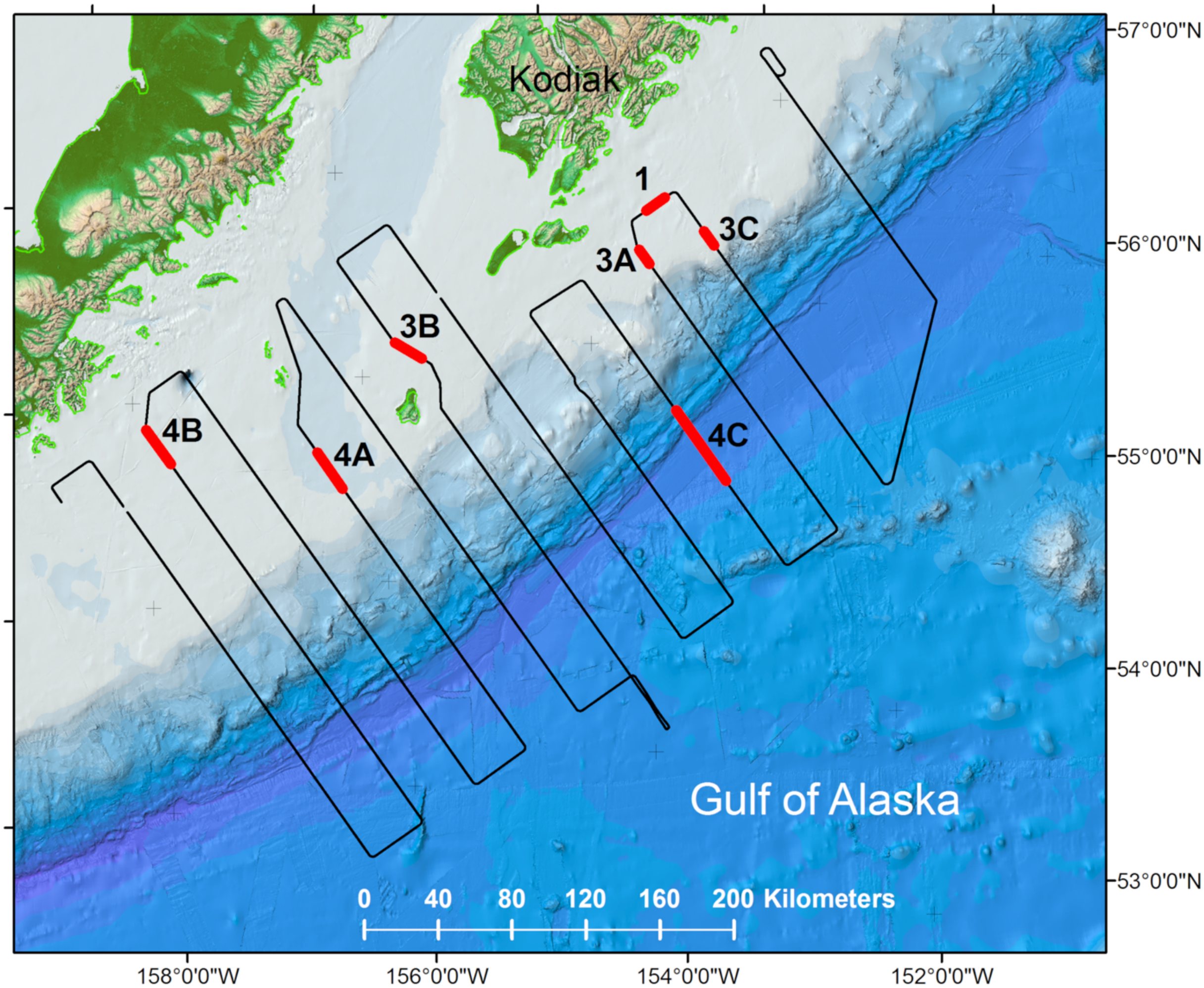


Figure 2. Map showing trackline locations of KEL Chirp profiles for MGL1903. Figure locations are labeled and shown with bold red line segments.

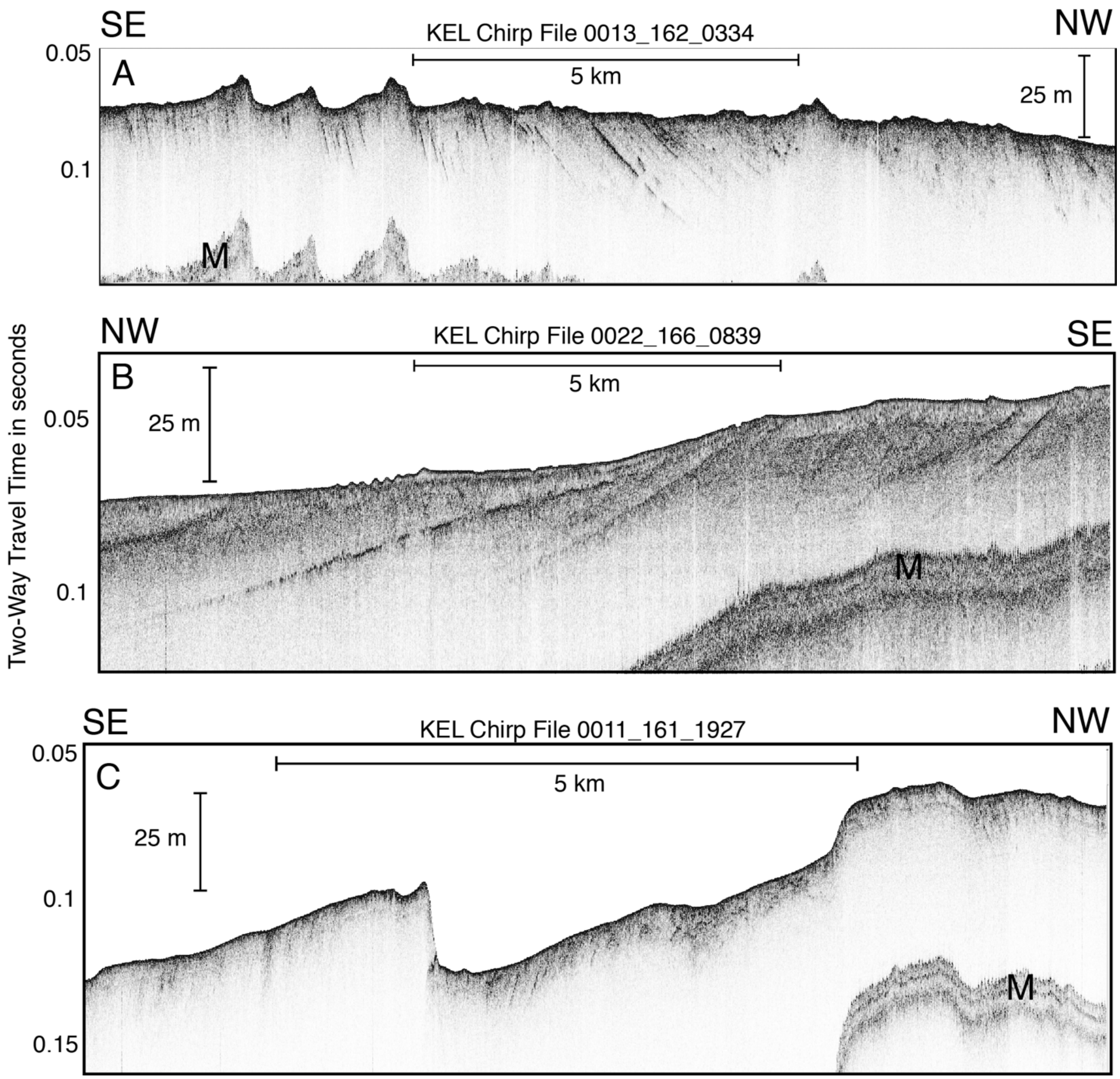


Figure 6.3. A, subset of chirp profile 0013_162_0334 showing near vertical to inclined bedding planes and possible deformation to the right on the profile. B, a subset from 0022_166_1839 also showing inclined bedding that steepens (maybe deformed) to the right on the profile. A thin (1 to 2 m) sediment at the seafloor and center of the profile. C, a subset from 0011_161_1927 shows a well-defined scarp with about 20 meters relief, near vertical bedding and deformation to the right on the profile. All these examples are from the shelf where recent sediment is sparse and folds and dipping beds occur. M, multiple reflection. Vertical exaggeration is about 50X. Vertical scales assume a velocity of 1500 m/s. See figure 6.2 for profile locations.

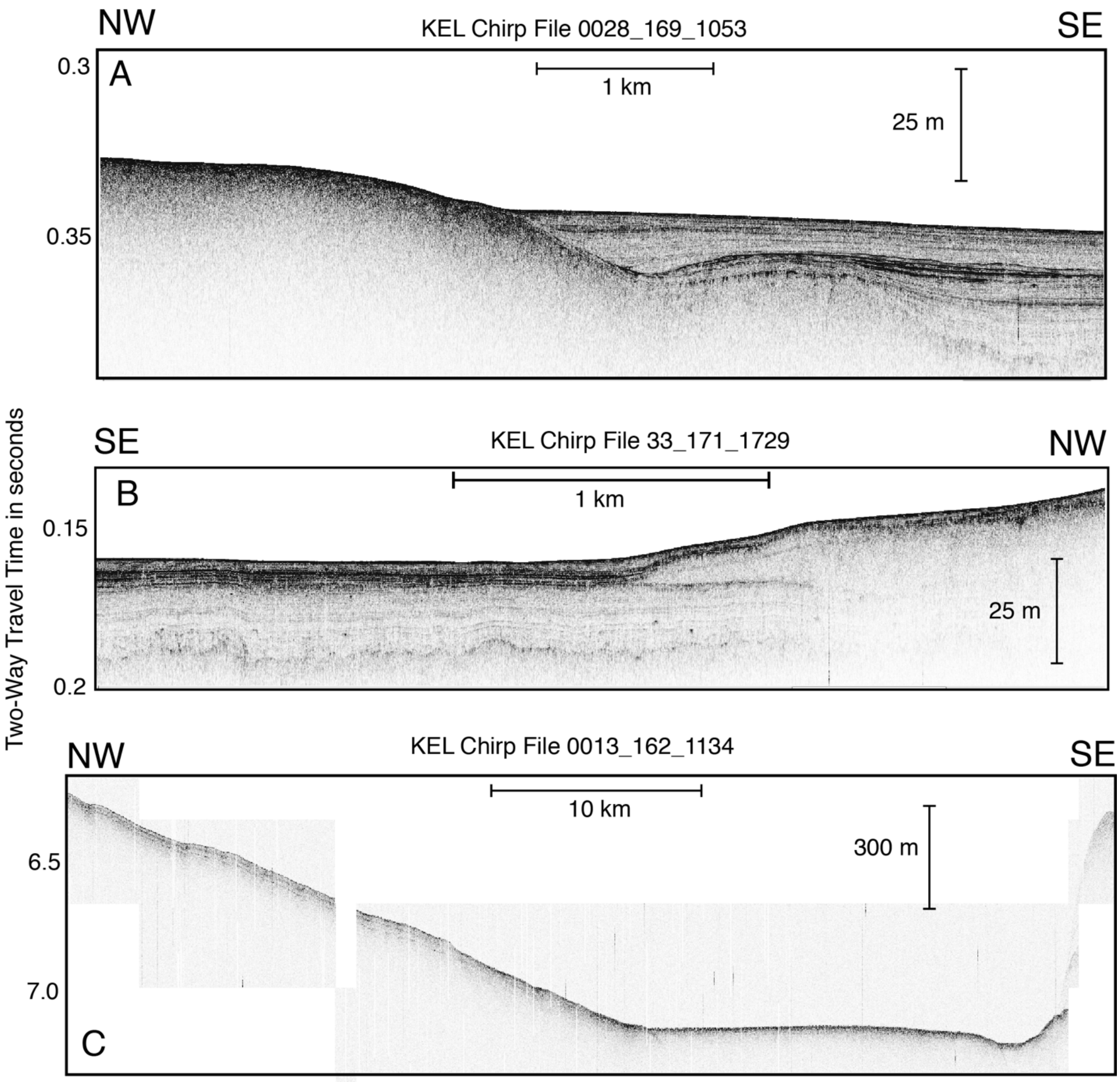


Figure 4. A, chirp profile from 0028_169_1053 showing about 25 m of sediment with horizontal bedding that pinches out where there is no acoustic penetration. Areas of the inner shelf have thick sediments, whereas the mid to outer shelf shows little to no penetration. B, a glacial moraine on the right side of the profile. The till tongue is interbedded between glacial marine sediment. C, chirp profile from 0013_162_1134 shows some indication of acoustic penetration and sediment thickness to the SE of the profile. There is no penetration seen at the base of the Aleutian Trench. Although the deep-water profiles have limited spatial resolution, the vertical resolution is the same as shallow water profiles. Swell filtering was not applied due poor continuity of the seafloor reflection. Vertical scales assume a velocity of 1500 m/s. See figure 6.2 for profile locations.

Recommendations

The Knudsen Chirp system should be able to trigger internally, but we were not able to make that work. Knudsen support should be able to diagnose that problem. It would benefit in using the multiple pings option, which should increase spatial resolution. Triggering internally might help limit some of the noise in the EM122 MBES data, but perhaps add another noise component.

Processing the correlate trace data is something to consider. At least the data is there to look at subsets of the data. Time migration would likely improve the profiles from deeper water and areas of variable seafloor morphology.

The processed Knudsen data are available on the MGDS/IEDA website.
http://www.marine-geo.org/tools/entry/MGL1903 (Seismic:Active:Subbottom)

7. Summary of acquisition parameters and processing of Multibeam Echo Sounding (MBES) and Backscatter data

David S. Foster, USGS Woods Hole, MA dfoster@usgs,gov

Acquisition

Bathymetry and backscatter data were collected using a Kongsberg EM-122 multibeam echosounder and SIS (v3.9.2) acquisition software. The system consists of two hull-mounted transducer arrays (Figure 7.1a), a transmit unit (150° x 1°) located along the ship centerline, and a receive unit (1° x 30°) that is abaft and oriented athwart-ships. The transducer pod is tilted 4 degrees towards the bow to reduce noise from cavitation and bubbles. The system forms a swath of 288 beams that produce an across-track profile of 432 soundings.

The last full patch test was done in 2012. Evaluations of roll and heading was done in 2015 and 2018 and it was determined that the parameters for roll and heading did not need to be changed. As a result, the vessel configuration was not changed for MGL1903 (Figure 7.1b).

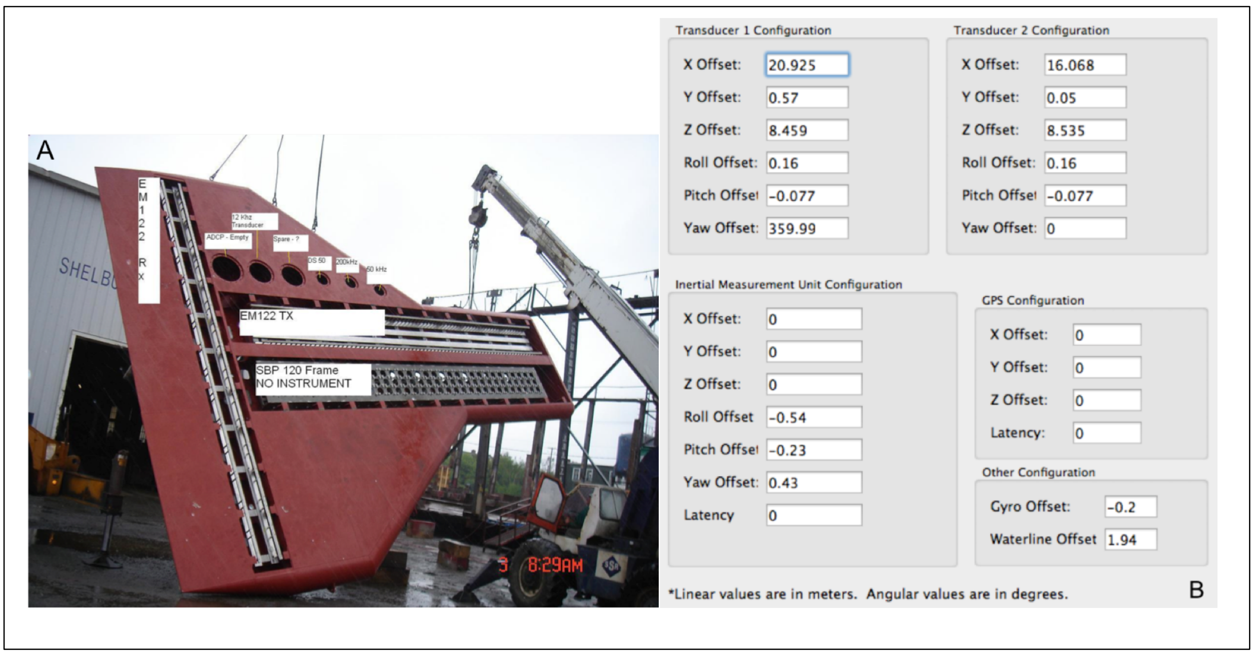


Figure 7.1. A, bottom view of the Kongsberg EM122 transmit and receive arrays. B, Settings used for MGL1903: offset, roll, pitch, yaw, and heading values for both transmit and receive transducers and values for the IMU (POS MV).

The SIS software processes range/angle data from each ping during acquisition, merging position and motion sensor data and the current sound velocity profile to derive a solution for vessel motion and raybending, and calculating sounding depths and positions. Sound velocity (SV) information entered into SIS was obtained from the Applied Micro Systems Micro SV mounted on the transducer pod and a total of eleven expendable bathy thermograph (XBT) probes deployed throughout the cruise (Figure 7.2). Of the eleven, seven XBT profiles were processed with the python program SVP Editor (v.1.0.2; Jonathan Beaudoin, UNH) to augment cast data with values from the World Ocean Atlas (2009) at the same coordinates, extending profiles to 12 km depth and sending them to the SIS acquisition system. Four other profiles were imported to Qimera. The sound velocity profiles were applied to the bathymetry data by time of day. Data were collected nearly continuously throughout the cruise, effectively mapping the seafloor along the course of the ship's track. Kongsberg raw sonar data (.all) and water column (*.wcd) files (Table 1) were copied from the *Langseth* network file server (fserve) to a local computer for processing.

Table 1. Summary of raw and processed data.

Data type	Comment
Level 0: Raw Kongsberg Sonar (*.all)	Direct import to QPS Qimera and FMGT
Level 0 Raw Water Column (*.wcd)	Correlate (match filtered) traces
XBT (*.EDF) ASCII profile data	Qimera imports XBT from *.all files, can import EDF
Qimera Project	Requires Qimera software
Grid and Raster Exports	SD, GeoTIFF, GMT Grid

Processing

QPS Qimera (v1.7.6) was used to post-process the bathymetric data. The measurement offsets between the multibeam transducer and the motion reference unit (MRU), the multibeam transducer and the navigation reference point (NRP), and angular offsets (roll, pitch, and heading) of the transducer were imported from the Konsberg raw sonar (.all) files. Though this information was used to calculate the sounding depths in SIS, it is also necessary in Qimera for subsequent calculation of total propagated uncertainty (TPU) and reapplication of sound velocity corrections.

The processing flow consisted of first using Qimera to add Kongsberg (.all) files into the project database, where Qimera creates an internal QPD format. Navigation was visually inspected, soundings were referenced to instantaneous sea level at the time of observation, and sound velocity information was re-applied. Data from each file were then added to a dynamic surface enabled with a combined uncertainty and bathymetric estimator (CUBE) surface. The slice editing tool was used to apply a very weak to medium spline filter to remove erroneous soundings. Some manual selection and rejecting of soundings, particularly in shallow water water (< 100 m), were done in the slice editor. There was consistent noise in deep water along the nadir line and just adjacent to either side of nadir. This was presumed to be noise from the Knudsen Chirp, which was being triggered by the EM122. Most of this noise was cleaned from the data without adverse effects on the gridded surface. Particular problem areas were along nadir and where slope abruptly changed on the shelf slope and around seamounts. After cleaning, a final static surface was created in Qimera that was exported as 32-bit GeoTIFF.

The QPS Fledermaus Geocoder Toolbox (FMGT v7.8.9) was used to post-process the backscatter data. Data were imported from the Kongsberg raw (.all) files, and the automatic processing option was utilized with the EM122 beam time series selected as the backscatter source. A single tile mosaic was computed using a 100 m per pixel resolution, and the histogram of the resulting image was manually stretched to accentuate the contrast between zones of high and low backscatter.

Water column data was not systematically processed, though some files (*.all and *.wcd) were imported to QPS FMMidwater where they were viewed. Most of the water column showed cross talk from the Knudsen chirp, possibly where the Knudsen was pinging internally. These data can be easily checked for anomalies using FMMidwater, except where water column data was not collected in shallow water (< 200 m).

Known Problems

Kongsberg EM122 data exhibit a "washboard" artifact on the outer edges of the swath, likely caused by latency in the transmission of attitude data, or errors in offset measurements. The artifact worsened as sea state increased. While noticeable on sun-illuminated, vertically exaggerated surfaces, the error induced by this artifact is less than one percent of the depth. This artifact is documented in previous MGL cruise reports.

Artifacts caused by the Knudsen Chirp is an issue. Perhaps the only way to deal with it is to not acquire the chirp where there are abrupt changes in slope.

Artifacts in the backscatter, apparently caused by the Auto Mode in the SIS software, might be alleviated by setting the water depth modes manually, but this would require extra attention from watch standers.

Initial Results

Multibeam bathymetry and backscatter were acquired along approximately 3,400 km of trackline with swath widths up to 18 km across, generally 3 to 4 times water depths between 30 and 5900 m. Edited bathymetry data were used to create a 100-m per pixel Qimera static surface. This surface was exported to QPS Fledermaus SD and 32-bit GeoTIFF formats for display (Figure 7.2). Backscatter data were exported from FMGT as a single tile mosaic in Fledermaus SD and GeoTIFF formats also at 100 m per pixel (Figure 7.3).

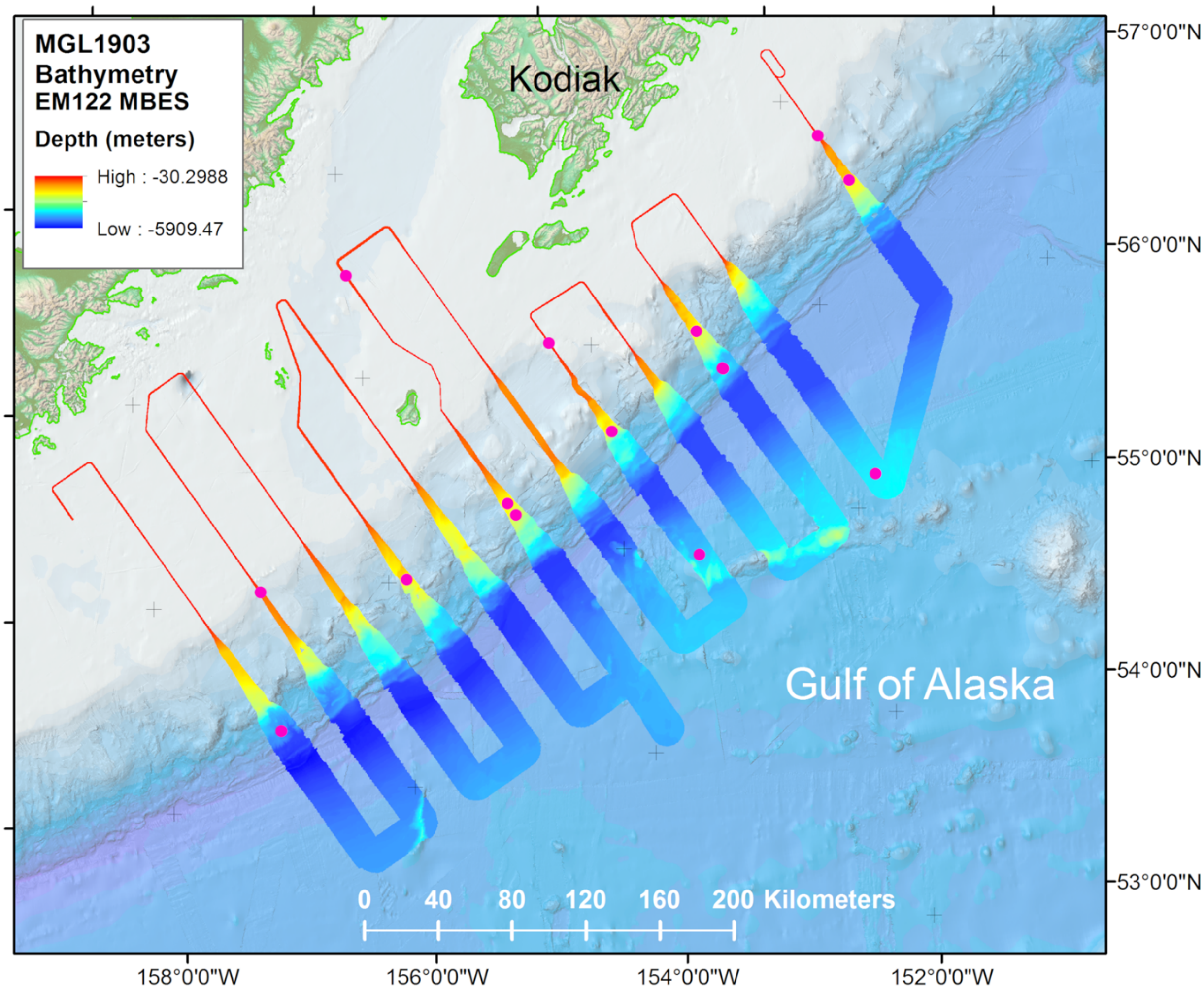


Figure 7.2. Map showing sea floor coverage and depths resulting from the Kongsberg EM122 survey. Magenta dots show the locations of the XBT profiles acquired during the cruise.

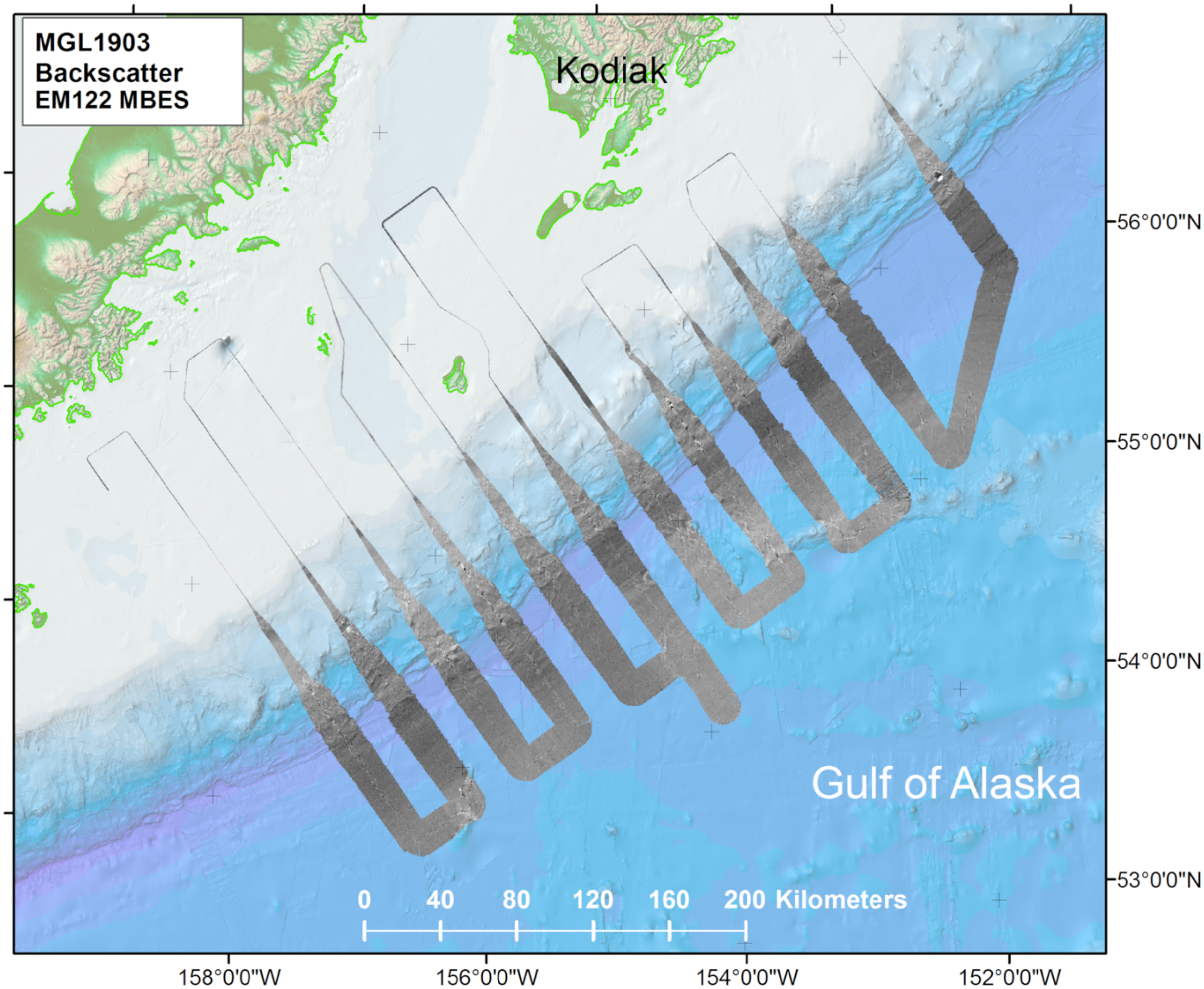


Figure 7.3. Map showing sea floor coverage of acoustic backscatter resulting from the Kongsberg EM122 survey. Darker tones are low backscatter while lighter tones are high backscatter.

The multibeam data are of generally excellent quality and imaged a variety of geologic features of interest while traversing the Aleutian Margin (Figure 7.4). Other high quality multibeam bathymetry exists for much of the surveyed area and was also acquired for purposes of and hazards research. Many of the swaths acquired during MGL1903 offer much improvement and fills data gaps where swath data was absent.

The backscatter data appear to be useful even with minimum auto processing with FMGT. Perhaps more can be derived from these data with further processing.

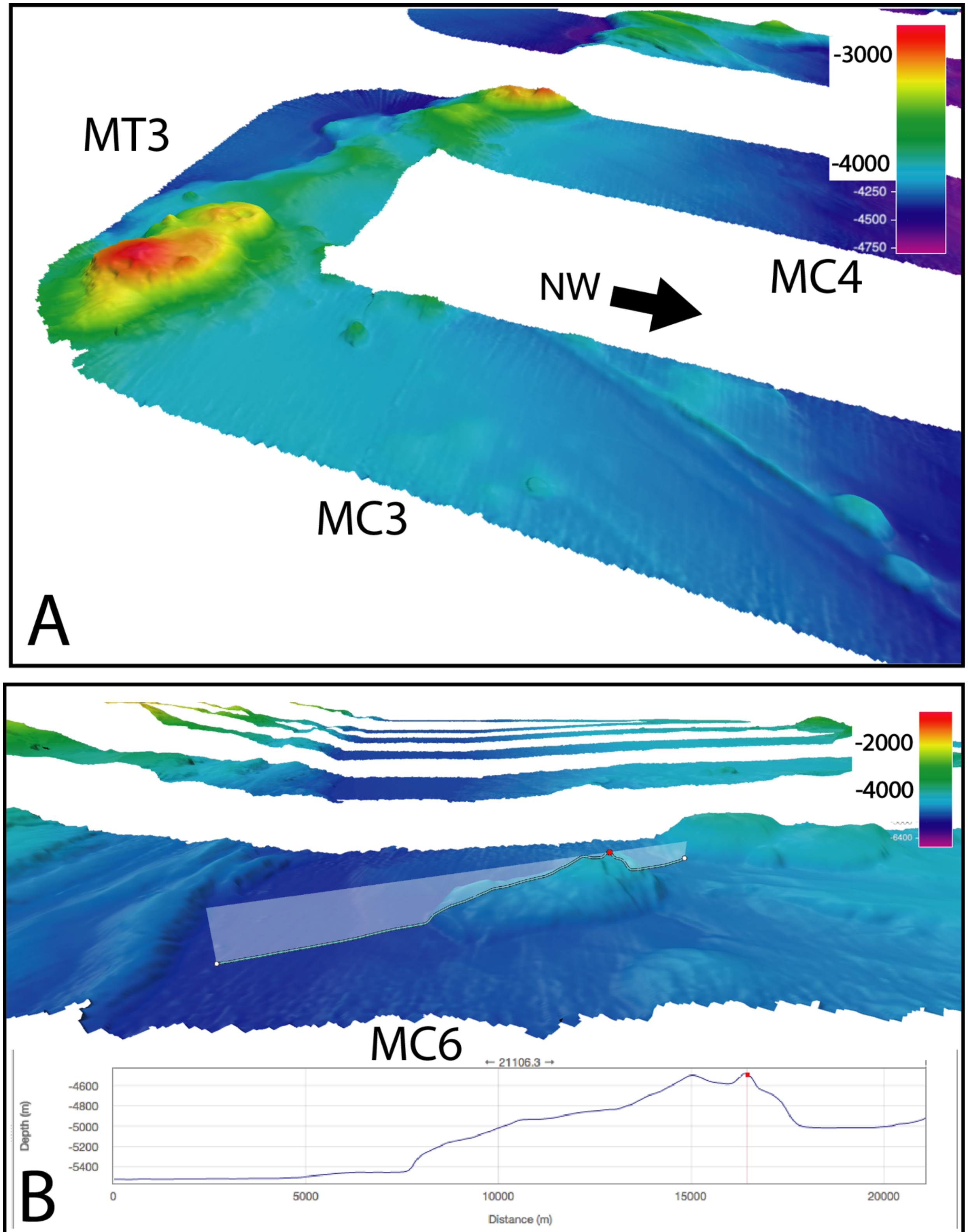


Figure 4. A, oblique view from the northeast of the seaward extent of MBES data collected during acquisition of MC03, MT03, and MC04. A complete image of a volcano is seen where MC03 turns towards MT03. Another volcano is partially imaged on Line MC04. B, a perspective view from

the southwest looking along the axis of the Aleutian Trench. Much of the trench is featureless except along Line MC06 where a seamount rises 800 m above the trench (see the profile and red dot on the profile and view).

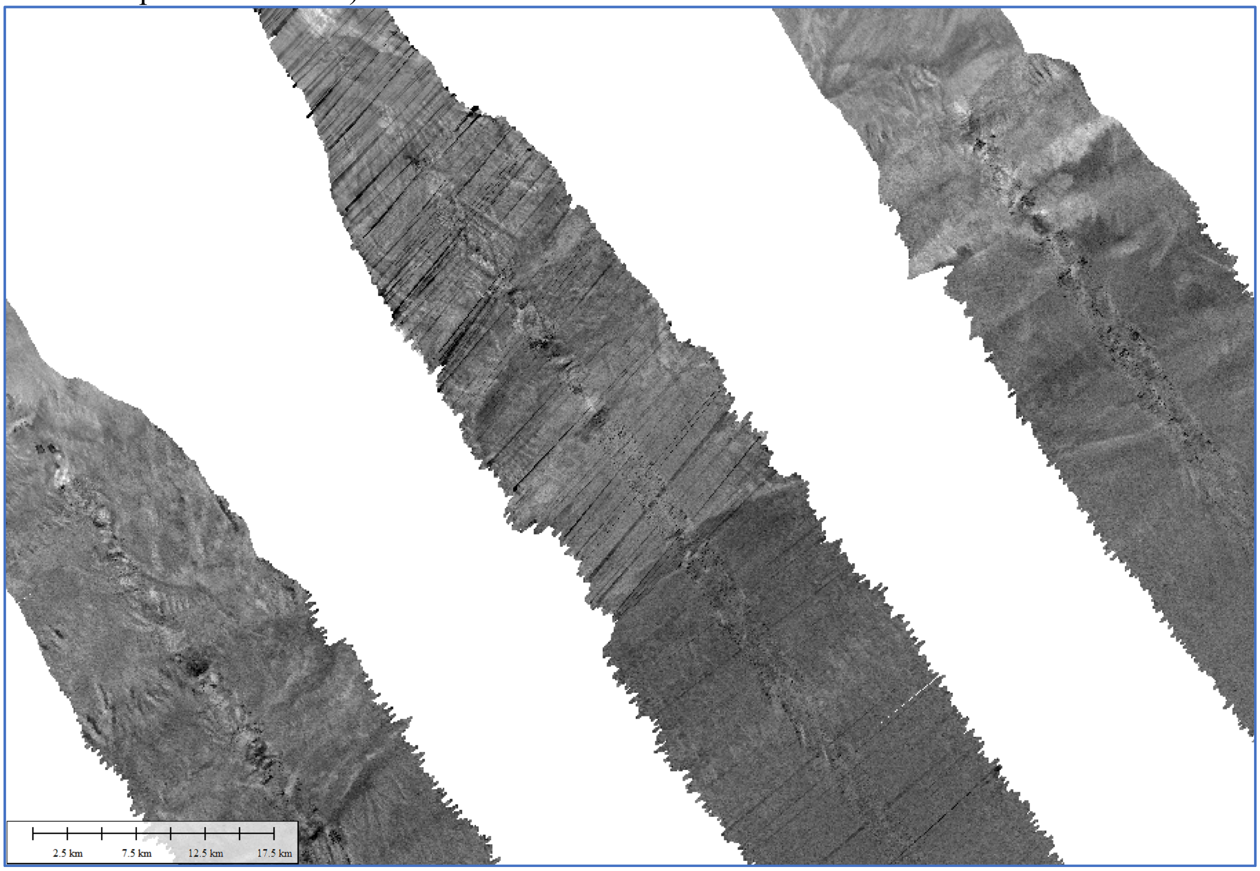


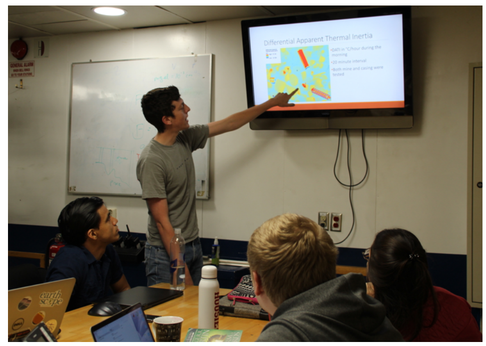
Figure 5. Backscatter imagery along the middle sections, from left to right, Lines OB12, OB11 and OB10. The data show low backscatter (darker tone) in the area of the Aleutian Trench (lower right corner) and higher back scatter (lighter tone) in the upper left, the area of the slope. The line in the middle (OB11) shows linear cross-track artifacts that appear in some of the data for the entire data set. Apparently, the artifacts occur when using the Auto Mode settings in the SIS acquisition software. The scale bar, lower left, is 17.5 km, about the swath width in deep water

Processed Multibeam bathymetry and backscatter data have been made available through the MGDS/IEDA website (cruise=MGL1903).
http://www.marine-geo.org/tools/search/entry.php?id=MGL1903
Becel, A.; Sheehan, A.; Foster, D.; Myers, E.; Haeussler, P.; Abers, G.; Adams, A.; Roland, E.; Schwartz, S.; Shillington, D.; Webb, S.; Wiens, D. and L. Worthington, (2019).

- Processed Acoustic Backscatter data from the Alaska-Aleutians area acquired during Langseth cruise MGL1903 (2019). Interdisciplinary Earth Data Alliance (IEDA). doi:10.1594/IEDA/324792.
- Processed multibeam swath bathymetry and backscatter data from the Alaska-Aleutians area acquired during Langseth cruise MGL1903 (2019) as part of the Alaska Amphibious Community Seismic Experiment (AACSE). Interdisciplinary Earth Data Alliance (IEDA). doi:10.1594/IEDA/324823.

8. AACSE Active Source Survey Training Component

The training component for this cruise was aimed at teaching the 8 Apply-to-Sail students (undergraduates/graduate students and one postdoc) about the science objectives and background research driving this cruise, as well as familiarize everyone with the foundational geophysics and seismology concepts essential to understanding the acquisition and data processing being done. Daily lectures and meetings were held to provide instruction, discuss relevant papers, and also allow students to share their background and research areas of expertise. Backgrounds included an ambient noise tomographer, an earthquake travel time tomographer, a geodynamicist, a volcanologist/geochemist, two students using seismic reflection techniques to study BSR's and subglacial dynamics, remote thermal detection of landmines, and multi-wavelet particle motion analysis.



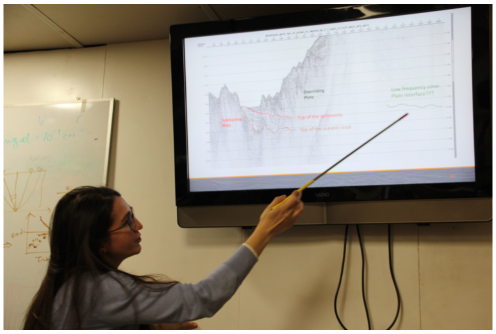
Apply 2 Sail participant William Frazer presenting his research project.

Below is a detailed summary of the lectures and topics covered throughout the cruise as well as the lab activities/assignments that the students carried out.

Lecture Schedule:
6/5 – Alaska Peninsula subduction zone background and AACSE background (Anne B, Anne S)
6/6 – AACSE Active Source Supplement background (Anne B)
6/7 – Basics of refraction and reflection (Anne S)
6/8 – MCS Acquisition (Emma, Anne B)
6/9 – MCS Processing: Noise and filters (Emma)
6/10 – MCS Processing: Amplitude corrections and stacking (Emma), First looks at MCS, chirp, and bathymetry collected during the cruise (Dave, Anne B)
6/11 – Discuss 2011 ALEUT experiment and Shillington et al., 2015 paper (Anne B)
6/12 – Basics of multibeam bathymetry and gravity data acquisition and processing (Brandon), Student research presentation (Ellyn)
6/13 – Visiting marine biologist explains BioWaves project and basics of PSO's (Tom Norris)
6/14 – Expanded presentation from the lead PSO (Amanda), MCS Processing: Velocity analysis, NMO and stacking (Emma)
6/15 – Student research presentations (Carlos, Will)
6/16 – Student research presentations (Hongda, Mitchell)
6/17 – Student research presentations (Lucia, Gökçe)
6/18 – MCS Processing: Migration, deconvolution, DMO (Emma)
6/19 – Tsunami monitoring/research and the 1946 tsunami earthquake (Anne S), Shumagin gap tsunamigenic structures/downdip constraints on the plate interface (Anne B)
6/20 – No lecture, allowing students to finish processing
6/21 – Short student presentations on ALEUT line processing/interpretation results
6/22 – No lecture, allowing students to finish processing
6/23 – Short student presentations on AACSE line interpretation results

Labs/Activities:

1. Students explored navigation files (P190) and practiced plotting shot point vs. depth, shot point locations, and receiver locations for multiple shots to look at feathering.
2. Each student presented on an assigned topic within GeoMapApp for our study location (i.e. slab geometry, regional geology and tectonics, gravity, seismicity, etc.)
3. Completed a lab within Echos focused on evaluating the noise, frequency spectra, and remove bad traces within the shot domain of a particular line collected during the ALEUT survey (each student chose a line).
4. Using their filtered and cleaned data, students then completed a lab creating their first stack of their data using near-offset traces. They then muted refractions in shallow portions of the overriding plate, performed semblance velocity analysis, view/edited their velocity profiles, applied NMO, investigated proper stretch mutes, and stacked their ALEUT data.
5. Using their stacked data, students then applied migration to a smoothed version of their velocity model and presented screenshots of their final ALEUT plots with initial interpretations of major structural features (i.e. subducting sediment/topography, evidence of the down-going plate past the trench, an obvious Moho, incoming faults or splay faults, etc.)
6. Finally, students chose a line of the newly collected AACSE MCS data and explored the previous techniques they used to see the differences that result from changed profile locations and acquisition set-ups. Rather than apply and run these programs as they did before, they instead used either raw shots or preprocessed data from Anne B to explore and interpret. They looked at the binning geometry and feathering, noise and frequency spectra, velocity analysis on a low fold dataset, migration using a constant water velocity, and interpreted the final stacked data. Students presented screenshots of their findings and interpretations.



Apply 2 Sail participant Gokce Astekin presenting her interpretation of multichannel seismic data collected during this survey.

Cruise Blog:

Students and other members of the science party contributed to the cruise blog at
https://alaskaamphibious.wordpress.com
This gave participants an opportunity to write about different aspects of the at-sea experience and science for a general audience.

June 6 – Anne Sheehan - Preparing to set sail on the AACSE Active Source seismic expedition!
June 9 – Anne Sheehan – Acquisition ON!
June 11 – Emma Myers – Communicating Science at Sea
June 12 – Will Frazer - Life at Sea
June 14 – Gokce Astekin – Food at Sea
June 15 – Carlos Gomez – Downtime aboard the Langseth
June 16 – Emma Myers – Belly of the Beast (ship engine tour)

June 18 – Mitchell Spangler – Expendable Bathythermograph (XBT)
June 20 – Ellyn Huggins – Waiting for Veniaminof
June 21 – Lucia Gonzalez – Deployment and Recovery of the Streamer and Birds
June 22 – Hongda Wang – Work at Sea
June 24 – Anne Bécel – The end of a successful cruise

Cruise Report:
Students also contributed to the cruise report:
Narrative: Ellyn Huggins (w/ Anne Bécel and Anne Sheehan)
Summary of Seismic Acquisition Parameters: Gokce Astekin (w/ Anne Bécel)
Langseth Crew and Science Party: Lucia Gonzalez (w/ Anne Bécel)
Appendix on Gravity Measurements: Brandon VanderBeek (w/ Anne Bécel)
Appendix on XBT data: Mitchell Spangler and Emma Myers

9. *Langseth* Crew and Science Party and watches

Crew List

David Wolford	Captain
Jeff Chrjapin	Chief Mate
Tyler Sterling	2nd Mate
Jason Woronowitz	3rd Mate
Ricardo Redito	Bosun
Michael Romero	1st A/E
Joseph Nasta	2nd A/E
Vicente Rodriguez	3rd A/E
Josellyn White	AB
Robert Hammond	AB
Inocencio Rimando	AB
Annie Kurek	OS
Bobby Fry	OS
Jay Butler	Chief Engineer
Rodolfo Florendo	Electrician/Oiler
Malcolm Donohoe	Oiler
Michael Mallard	Oiler
Hervin McLean-Fuller	Steward
Ricardo Rios	Cook
Ana Saloman	PSO
Karla Rios	PSO
Amanda Dubuque	PSO
Yesenia Balderas	PSO
Andrea Zavala	PSO
Bianca Mares	PSO
Brian Agee	Tech
Chris Abdouch	Tech
Alan Thompson	Tech
Tom Spoto	Tech
Max Skalko	Tech
Edmond St Amant	Tech
David Martinson	Chief Science Officer
Anne Bécel	Chief Scientist
Anne Sheehan	co-Chief Scientist
Emma Myers	Science Party / MCS co-instructor
Tom Norris (BioWaves)	Science Party
Brandon Vanderbeek	Science Party
Dave Foster (USGS)	Science Party
Carlos Gomez	Science Party
Hongda Wang	Science Party
William Frazer	Science Party

Mitchell Spangler	Science Party
Lucia Gonzalez	Science Party
Ellyn Huggins	Science Party
Gokce Astekin	Science Party

Science Party Shifts

Watch Leaders:

2 pm - 2 am	Anne Bécel
2 am -2 pm	Anne Sheehan
6am -6 pm	Emma Myers

Watch Standers:

12 am-4 am/ 12 pm-4 pm	Lucia Gonzalez, Hongda Wang
4 am-8 am/4 pm-8 pm	Gokce Astekin, Carlos Gomez, William Frazer
8 am-12 pm/8 pm-12 am	Ellyn Huggins, Mitchell Spangler, Brandon Vanderbeek

Science Technical Staff Shifts:

12 am-12 pm	David Martinson L-DEO OMO Chief Science Officer Tom Spoto L-DEO OMO Chief Source Mechanic Chris Abdouch, Contract Personnel Marine Science Technician, Navig Max Skalko, Contract Personnel Marine Science Technician, Source
12 pm-12 am	Alan Thompson, L-DEO OMO Marine Science Technician, Navigator Edmond St Amant, Contract personnel Marine Science Technician, Source Brian Agee, Contract Personnel Marine Science Technician, Source

Contact information for the Science Party

Anne Becel	annebcl@ldeo.columbia.edu
Anne Sheehan	anne.sheehan@colorado.edu
Emma Myers	ekmyers@uw.edu
Tom Norris (BioWaves)	thomas.f.norris@bio-waves.net
Brandon VanderBeek	brandon.p.vanderbeek@gmail.com
Dave Foster (USGS)	dfoster@usgs.gov
Carlos Gomez	carlos.gomez.666@my.csun.edu
Hongda Wang	hongda.wang@colorado.edu
William Frazer	wfrazer1@binghamton.edu
Mitchell Spangler	mispangl@iu.edu
Lucia Gonzalez	lfgonzalez5@miners.utep.edu
Ellyn Huggins	eghuggins@nevada.unr.edu
Gokce Astekin	gokce.astekin@okstate.edu

MGL1903 Group Photo

Top raw from left to right: Dave Foster, Hongda Wang, Carlos Gomez, Brandon VanderBeek, Brian Agee, David Martinson, Chris Abdouch, Alan Thompson
Bottom raw from left to right: William Frazer, Bianca Mares (back), Ana Saloman (front), Amanda Dubuque (back), Gokce Astekin (front), Emma Myers, Lucia Gonzalez, Ellyn Higgins, Mitchell Spangler, Andrea Zavala, Karla Rios, Yesenia Balderas, Anne Bécel, Anne Sheehan

10. Performance of the Langseth

Overall, we found the Langseth to be in great condition, and the technical staff and crew are excellent. Below we briefly summarize our experience with different aspects of operations and facilities.

MCS equipment

The data that we were able to acquire using the large, tuned air-gun array and 8-km-long streamer are of very good quality. We had very little downtime due to seismic equipment failure during our cruise.

Lab facilities and onboard computing

Overall, the computational facilities on the Langseth are very good and met our purposes. The Langseth possesses two fast workstations that can be used by the science party for onboard multichannel seismic processing. We decided to use these workstations (plus our Mac laptops) for our onboard processing rather than bring our own workstations. We were able to use the Langseth's machines to complete a range of onboard processing jobs, including basic processing of all of the multichannel seismic profiles from both the ALEUT and MGL1903 survey. the workstations performed very well and we had enough disk space to perform the processing.

Apply to Sail student Carlos Gomez using on of the onboard workstation to process the 2011-ALEUT MCS data.

As the ship's staff are already aware, the internet is extraordinarily slow. The lack of passable internet makes many aspects of the scientific endeavor at sea very difficult, and also makes it difficult for shipboard scientists to keep up with necessary correspondence and work from home (correspondence with students, journals, funding agencies, etc). It also limits the ability for us to do outreach like blogs for our cruise since it is impossibly slow to upload photographs. In particular, NSF requested that we send photos and videos weekly to document our cruise for NSF social media for 'Oceans Month'. Even with the broadband internet, we were only able to send low resolution photos. Live video feeds to NSF for Oceans Month were not possible. We strongly suggest that alternatives are sought or upgrades are made to improve internet speed.

Technical staff and crew

The technical staff aboard the Langseth are uniformly dedicated, professional and capable, and did a truly excellent job. As always, Dave Martinson provided excellent advice and counsel to shipboard scientists, sensible planning for the data collection effort and leadership to the scientific technical team. All of the technical staff were very responsive to all our requests and needs. The files and information that we needed to conduct onboard data analysis (e.g. processed p190 files) were provided in a very timely manner.

Likewise, the Captain and crew of the Langseth are a pleasure to work with. We found everyone to be professional, hardworking and responsive to any topics that arose. The tenants of professionalism, courtesy, and respect that were emphasized in our science party orientation are adhered to by all shipboard staff and crew.

Living conditions

The accommodation spaces, galley and other leisure spaces (movie room) were in great shape. The cooks did an excellent job of preparing food to satisfy everyone's dietary needs and tastes. Some scientists commented that a little more variety could have been included and more fresh vegetables. The midnight meal is nice for the night shift.

10. References

Davies, J., L. Sykes, L. House, and K. Jacob (1981), Shumagin Seismic Gap, Alaska Peninsula - History of Great Earthquakes, Tectonic Setting, and Evidence for High Seismic Potential, *J Geophys Res*, *86*(Nb5), 3821-3855, doi:10.1029/Jb086ib05p03821.

Estabrook, C. H., K. H. Jacob, and L. R. Sykes (1994), Body Wave and Surface-Wave Analysis of Large and Great Earthquakes Along the Eastern Aleutian Arc, 1923-1993 - Implications for Future Events, *J Geophys Res-Sol Ea*, *99*(B6), 11643-11662, doi:Doi 10.1029/93jb03124.

Kanamori, H. (1977), The energy release in great earthquakes, *Journal of Geophysical Research (1896-1977)*, *82*(20), 2981-2987, doi:10.1029/JB082i020p02981.

Li, S., and J. Freymueller (2018), Spatial Variation of Slip Behavior beneath the Alaska Peninsula along Alaska-Aleutian Subduction Zone, *Geophys Res Lett*, *45*, 3453-3460, doi:10.1002/2017GL076761.

McGuire, J.J., T. Plank, et al. 2017. The SZ4D Initiative: Understanding the Processes that Underlie Subduction Zone Hazards in 4D. Vision Document Submitted to the National Science Foundation. The IRIS Consortium, 63 pp.

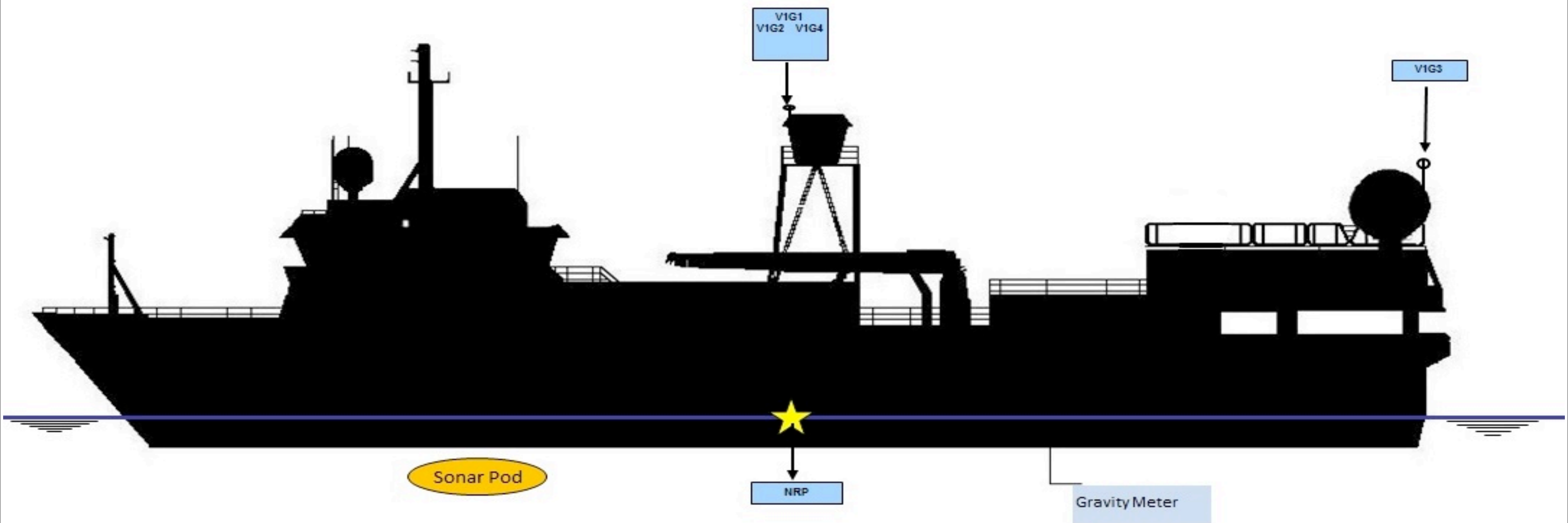
Shillington, D. J., A. Bécel, M. R. Nedimovic, H. Kuehn, S. C. Webb, G. A. Abers, K. M. Keranen, J. Li, M. Delescluse, and G. A. Mattei-Salicrup (2015), Link between plate fabric, hydration and subduction zone seismicity in Alaska, *Nat Geosci*, *8*(12), 961-U98, doi:10.1038/Ngeo2586.

Appendix A – Specification of MCS data acquisition

Company: L-DEO - Lamont - Doherty Earth Observatory
Vessel: Marcus G. Langseth
Client: Bécel /NSF

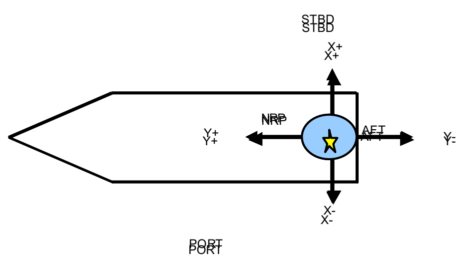
Project: MGL1903
Area: AACSE - Kodiak Alaska
Start Date: 4-Jun-19

R/V Marcus G. Langseth - Vessel Sensor Offsets



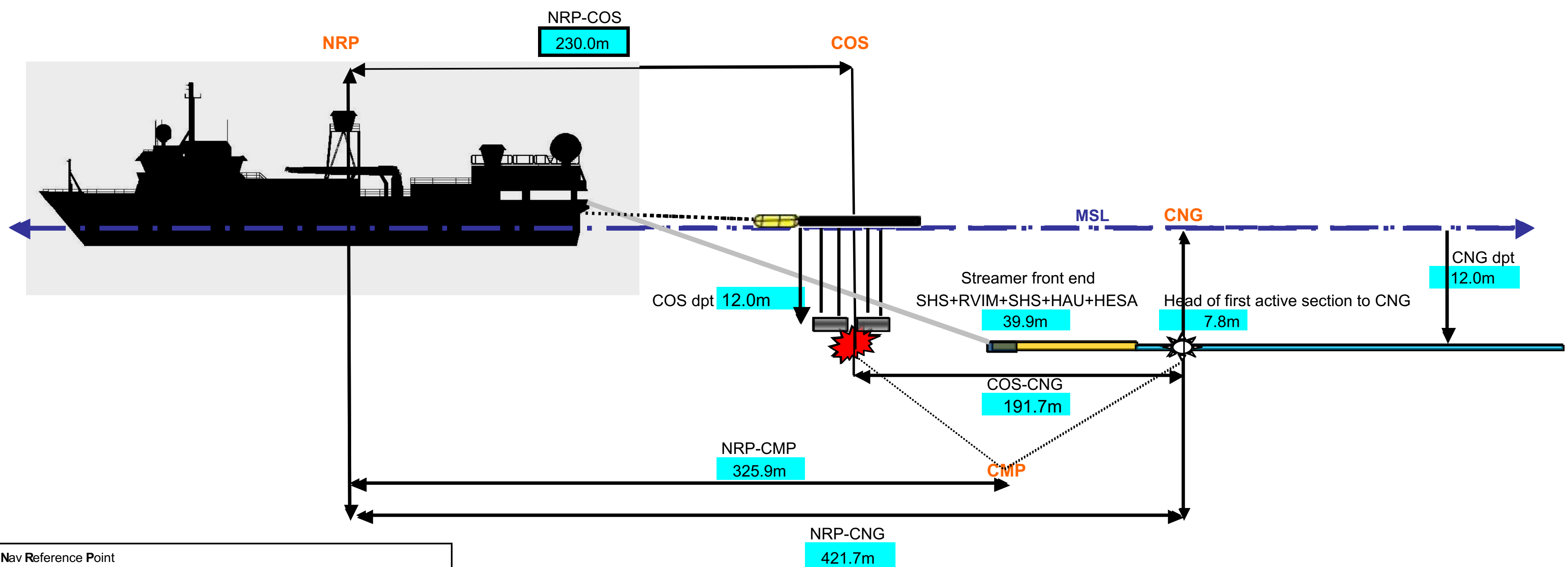
Negative values are above water line

All measurements in meters



		STBD/PORT (X)	FORE/AFT (Y)	UP/DOWN (Z)
NRP	NAVIGATION REFERENCE POINT	0.00	0.00	0.00
V1G1	C-Nav 3050	0.00	0.00	-16.90
V1G2	SeaPath 200	0.00	1.50	-16.90
V1G3	C-Nav 2000	-2.10	-29.20	-14.50
V1G4	Pos MV	-1.30	1.20	-16.90
V1R1	PosNet	-1.30	0.00	-16.90
Sonar Pod	EM122 Knudsen ADCP	0.00	20.20	7.49
	EM122 Center Beam offset (in Spectra)	0.00	13.4	7.49
MRU	Seapath MRU	2.30	14.16	-4.30
BGM	Bell Gravity Meter	0.00	-13.10	1.10

R/V Marcus G. Langseth - Towing Offsets



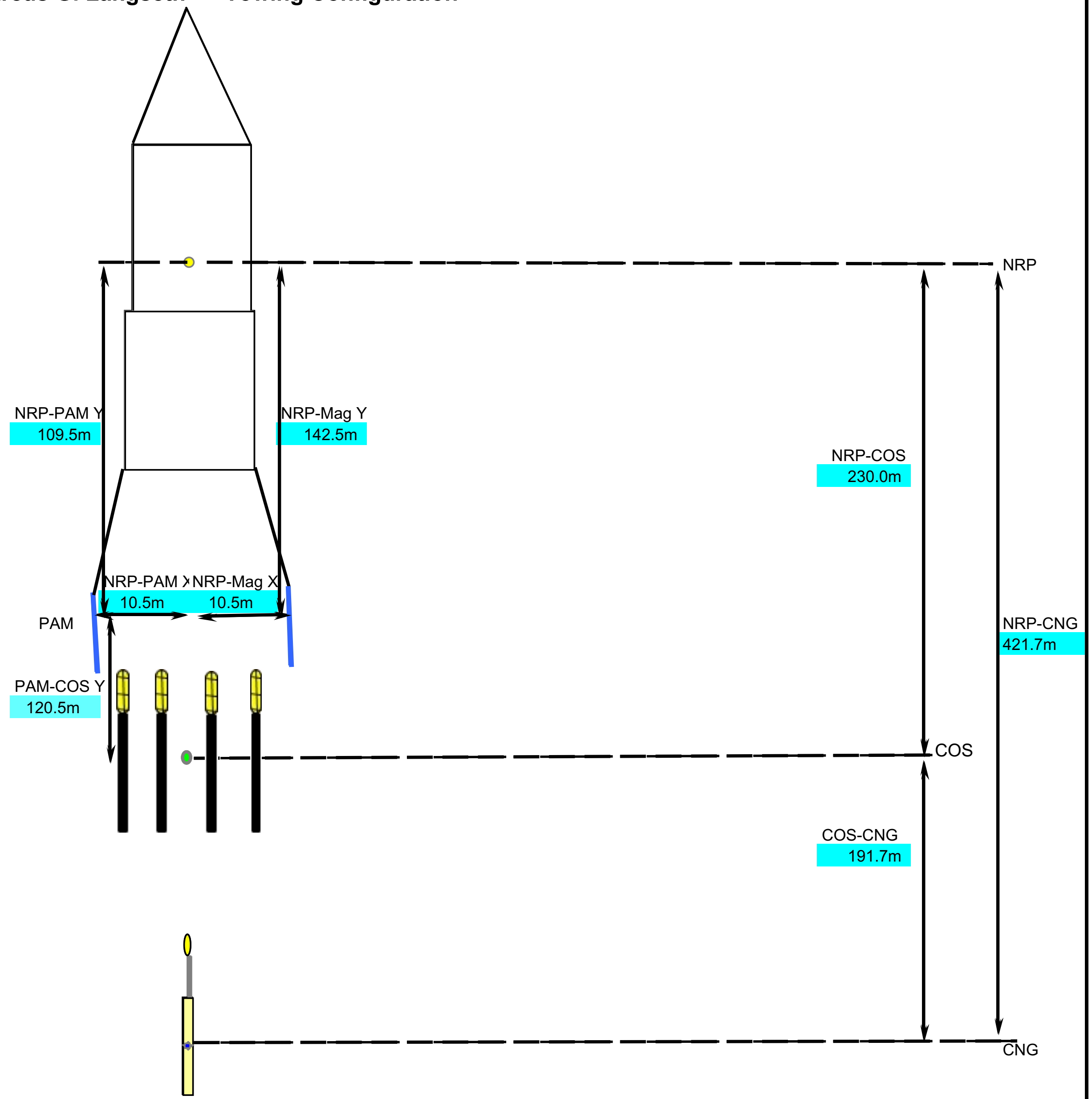
NRP	Nav Reference Point			
COS	Centre of Source			
CNG	Centre of Near Group	**Trace #**	**1**	**Of S1**
CMP	Common Mid-Point			
MSL	**Mean Sea Level**			
NRP-Stern	**29.5m**			
NRP-COS	**230.0m**			

All measurements in meters

Cell contents referenced from Config_offsets tab

R/V Marcus G. Langseth - Towing Configuration

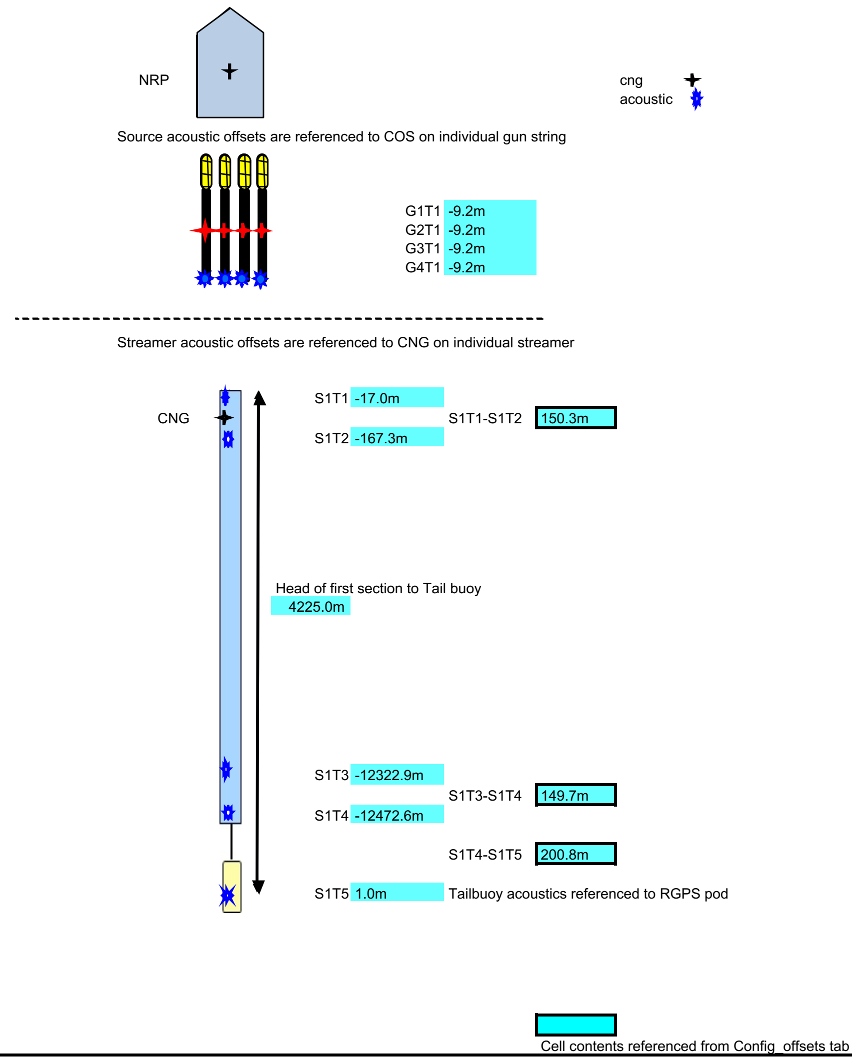
	# Streamers	Length	Channels	Spacing
SEAL	1	4050	324	12.5m
# Gun Strings Used	4		Vol (in^3)	6600



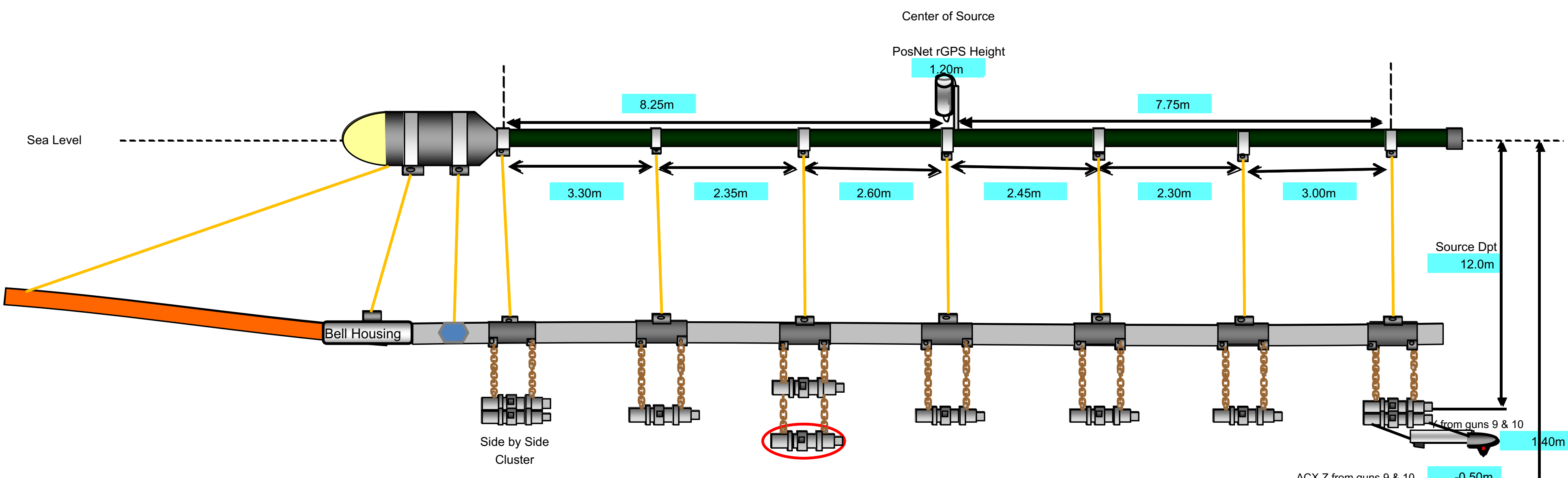
NOT to Scale

Cell contents referenced from Config_offsets tab

R/V Marcus G. Langseth - Acoustic Offsets



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	180 cu. in.	Spare
Gun 6	90 cu. in.	Primary
Gun 7	120 cu. in.	Primary
Gun 8	60 cu. in.	Primary
Gun 9	220 cu. in.	Primary
Gun 10	220 cu. in.	Primary

Array total volume (without spares) is 6600 cu. in. Total volume/string (without spare) 1650 cu. in.
Guns (1 &2) & (9&19) in a horizontal cluster. Guns (5 & 6) in a vertical cluster but #6 is spare only
Gun clusters have 0.75m between guns and hang 0.95m from center of hanger
Horizontal Clusters are 1m from gun port to gun port
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

ACX = Acoustic

Center of Source

Spare Gun

Gun Clusters

Guns 1 & 2 horizontal array

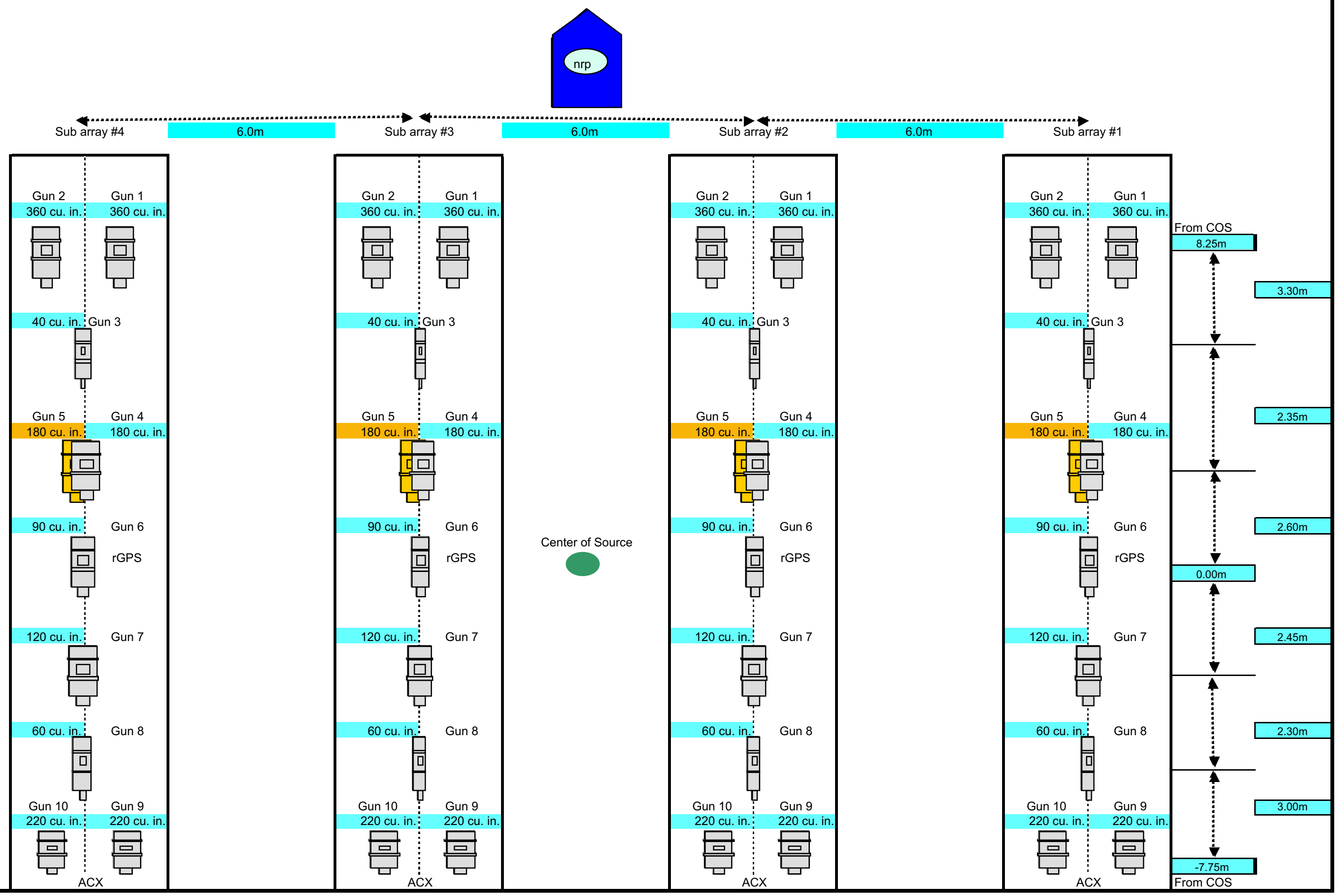
Guns 4 & 5 vertical - lower gun is spare only

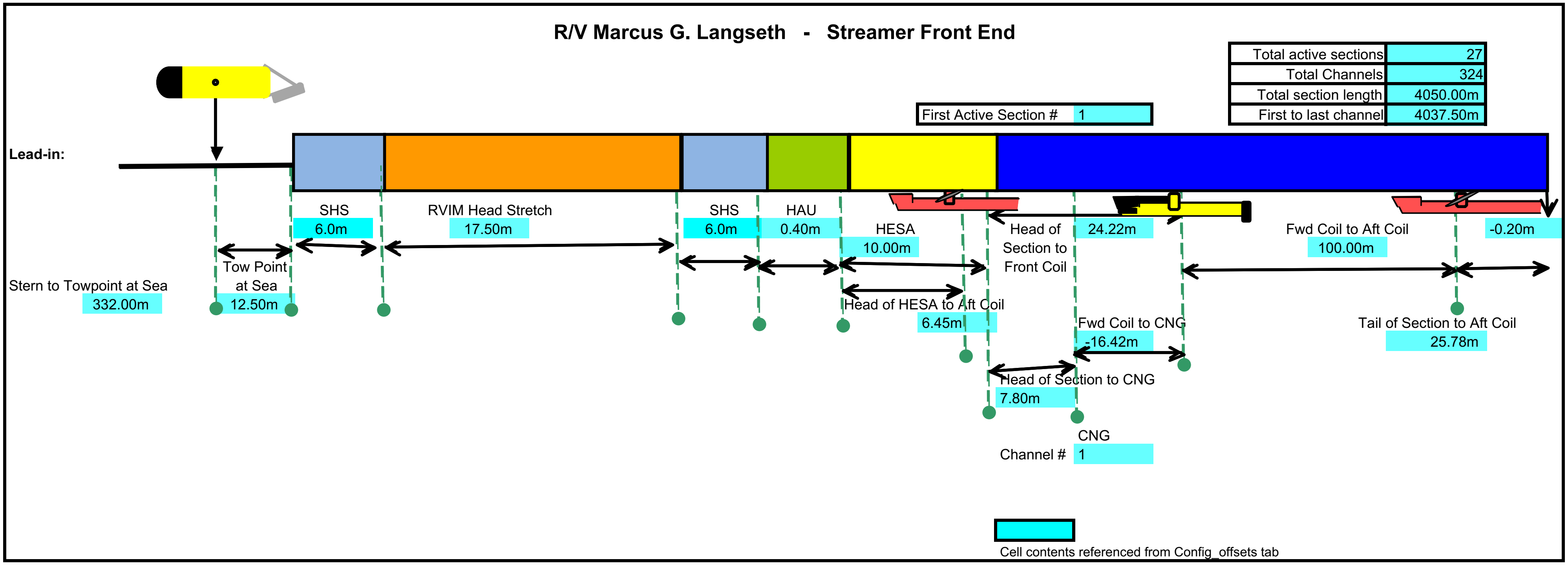
Guns 9 & 10 horizontal array

Gun Offsets relative to Center of String

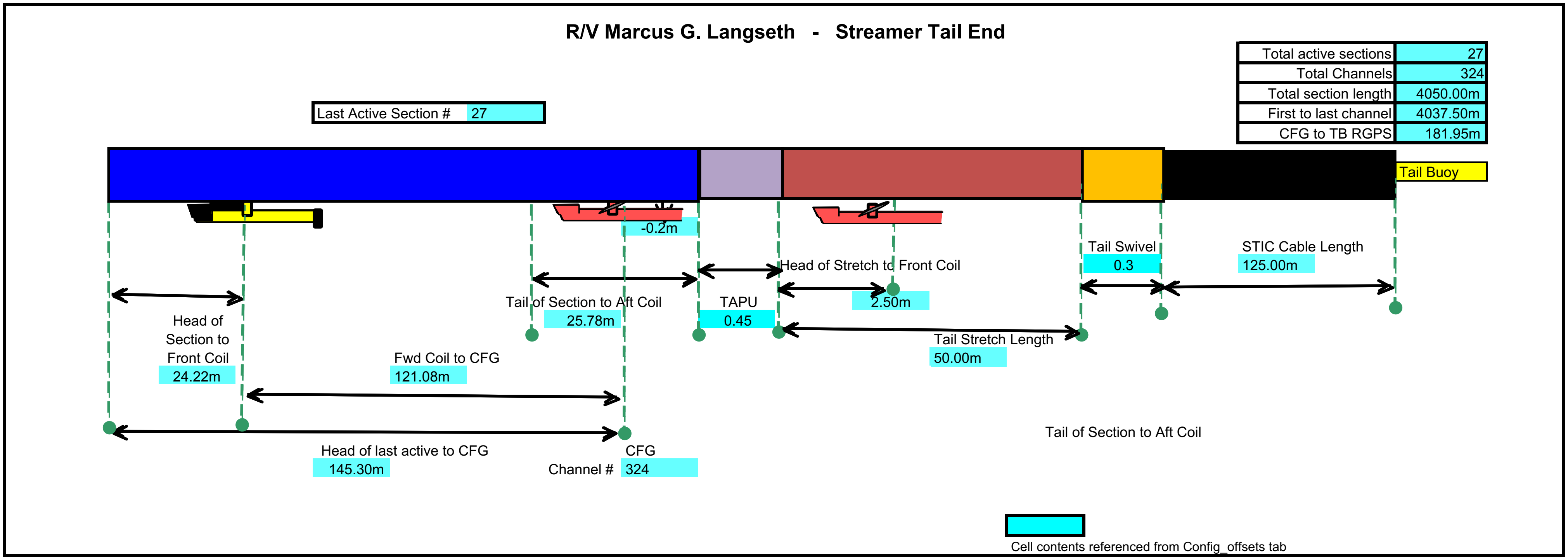
	X	Y
Gun 1	0.50m	8.31m
Gun 2	-0.50m	8.31m
Gun 3	0.00m	5.03m
Gun 4	0.00m	2.60m
Gun 5	0.00m	2.60m
Gun 6	0.00m	0.00m
Gun 7	0.00m	-2.74m
Gun 8	0.00m	-5.09m
Gun 9	0.50m	-8.21m
Gun 10	-0.50m	-8.21m

All measurements in meters



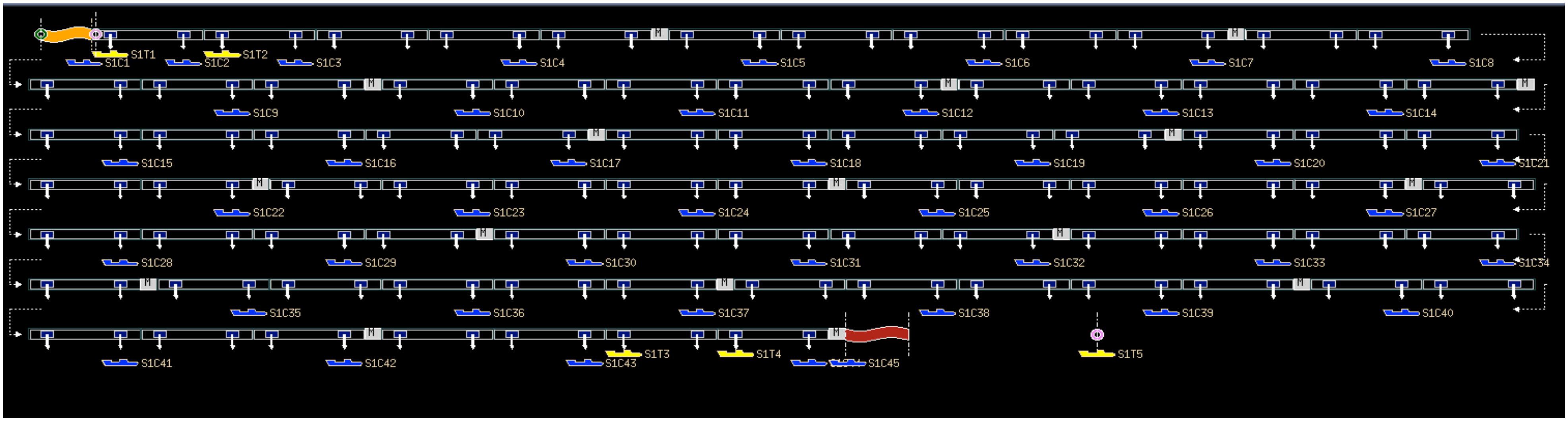


R/V Marcus G. Langseth - Streamer Front End
Total active sections 27
Total Channels 324
Total section length 4050.00m
First to last channel 4037.50m
First Active Section # 1
Lead-in:
SHS
6.0m
RVIM Head Stretch
17.50m
SHS
6.0m
HAU
0.40m
HESA
10.00m
Head of Section to Front Coil
24.22m
Fwd Coil to Aft Coil
100.00m
-0.20m
Stern to Towpoint at Sea
332.00m
Tow Point at Sea
12.50m
Head of HESA to Aft Coil
6.45m
Fwd Coil to CNG
-16.42m
Tail of Section to Aft Coil
25.78m
Head of Section to CNG
7.80m
CNG
Channel # 1
Cell contents referenced from Config_offsets tab


R/V Marcus G. Langseth - Streamer Tail End
Total active sections 27
Total Channels 324
Total section length 4050.00m
First to last channel 4037.50m
CFG to TB RGPS 181.95m
Last Active Section # 27
Tail Buoy
-0.2m
Tail Swivel
0.3
STIC Cable Length
125.00m
Head of Stretch to Front Coil
2.50m
Tail of Section to Aft Coil
25.78m
TAPU
0.45
Tail Stretch Length
50.00m
Head of Section to Front Coil
24.22m
Fwd Coil to CFG
121.08m
Tail of Section to Aft Coil
Head of last active to CFG
145.30m
CFG
Channel # 324
Cell contents referenced from Config_offsets tab

R/V Marcus G. Langseth - Streamer Complete

Total active sections	27
Total Channels	324
Total section length	4050.00m
First to last channel	4037.50m

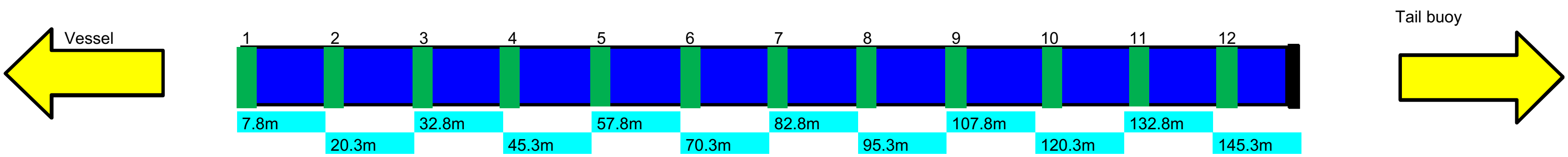


Cell contents referenced from Config_offsets tab

R/V Marcus G. Langseth - Hydrophone Offsets

Sercel 150meter SSAS

Number of SSAS Sections	27
Channels per active section	12
Total channels	324



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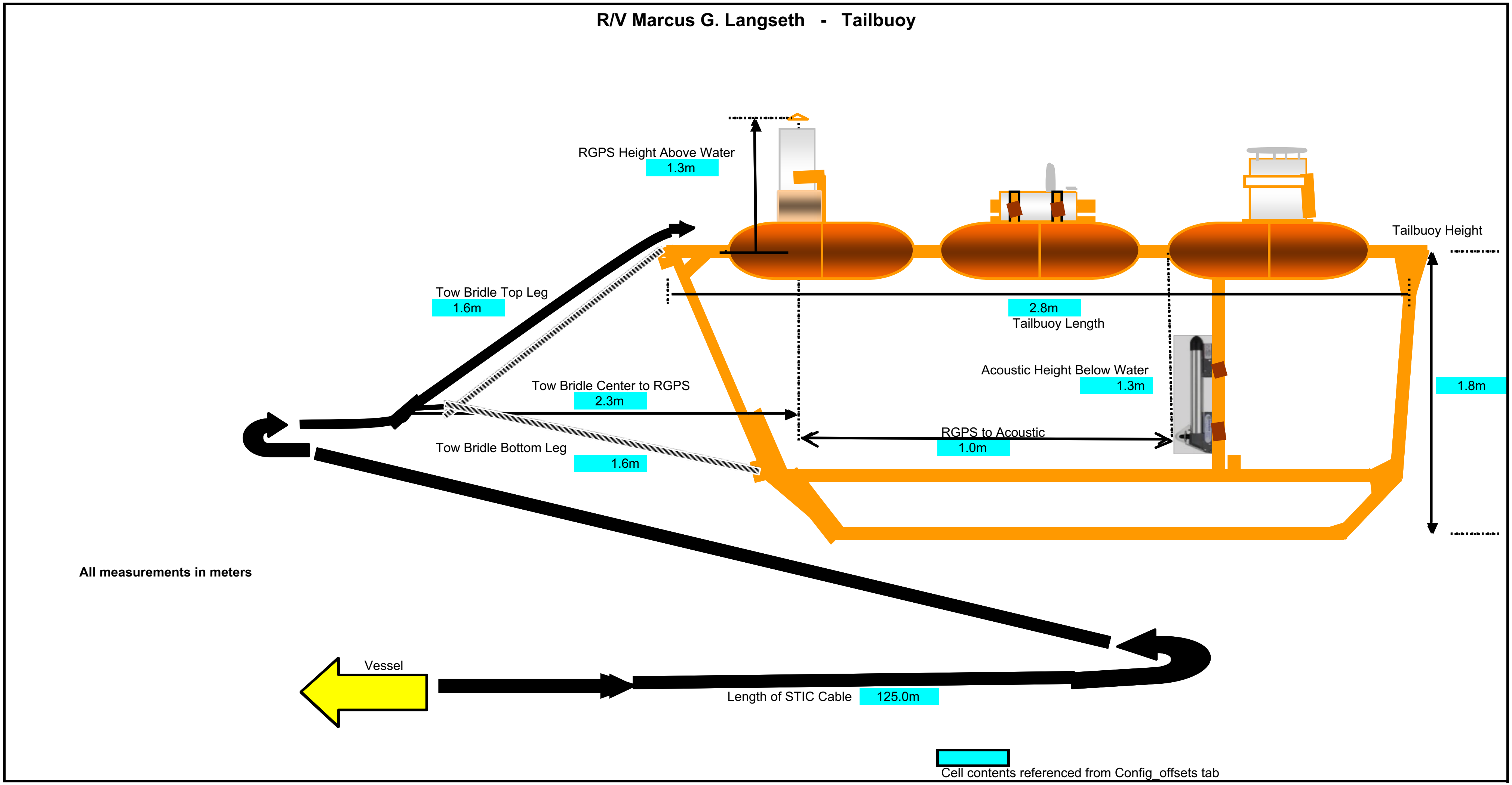

R/V Marcus G. Langseth - Tailbuoy
RGPS Height Above Water
1.3m
Tailbuoy Height
Tow Bridle Top Leg
1.6m
2.8m
Tailbuoy Length
Acoustic Height Below Water
1.3m
1.8m
Tow Bridle Center to RGPS
2.3m
RGPS to Acoustic
1.0m
Tow Bridle Bottom Leg
1.6m
All measurements in meters
Vessel
Length of STIC Cable
125.0m
Cell contents referenced from Config_offsets tab

Job Specific	
NRP to COS Y	230
NRP to COS X	0
Source Depth	12
Streamer Depth	12
# streamer sections	27
# channels	324
CNG Channel #	1
CFG Channel #	324
#MCS Streamers	1
lead-in: stern to tow point at sea	332
MCS Streamer Sep.	0
Gun volume total	6600
Volume per string	1650
# of guns used	36
# Gun Strings	4
gun string separation	6
PAM Y from stern	80
PAM X - (outside of stern rail)	3
Stern to MAG Y	113
Stern to MAG X - (outside of stern rail)	3

Derived Offsets (formula)	
NRP to CMP	325.85
COS-CNG	191.7
CNG-CFG	-4037.5
NRP-Mag Y	142.5
NRP-Mag X	10.5
NRP to tail buoy RGPS	4616.9
Total Length of Streamer sections	4050
PAM-COS Y	120.5
PAM-COS X	10.5
NRP-PAM Y	109.5
NRP-PAM X	10.5
NRP-CNG	421.7

Derived Offsets (formula)	
Towing Offsets Tab	
NRP-COS	230
NRP-CNG	421.7
NRP-CMP	325.85
COS-CNG	191.7
CNG Channel #	1
NRP-Stern	29.5
Distance from Head of first section to CNG	7.8
Source Depth	12
Streamer Depth	12
Front End Length	39.9

Derived Offsets (formula)	
Towing Configuration TAB	
NRP-COS	230
NRP-CNG	421.7
COS-CNG	191.7
NRP-Pcable CNG	0
COS-Pcable CNG	0
P-Cable Streamer Sep	0
NRP-PAM Y	109.5
NRP-PAM X	10.5
PAM-COS Y	120.5
PAM-COS X	10.5
# Gun Strings	4
gun volume	6600
Gun separation	6
# 2D Streamers	1
2D Streamer Ch Spacing	12.5
Number 2D Channels	324
2D Streamer Length	4050
2D Streamer Sep	0
NRP-MAG X	10.5
NRP-MAG Y	142.5

Derived Offsets (formula)	
Acoustic Overhead TAB	
G1T1	-9.15
G2T1	-9.15
G3T1	-9.15
G4T1	-9.15
S1T1	-16.95
S1T2	-167.28
S1T3	-12322.92
S1T4	-12472.6
S1T5	1
S1T6	0
S1T7	0
S2T1	0
S2T2	0
S2T3	0
S2T4	0
S2T5	0
S2T6	0
S2T7	0
S3T1	0
S3T2	0
S3T3	0
S3T4	0
S3T5	0
S3T6	0
S3T7	0
S4T1	0
S4T2	0
S4T3	0
S4T4	0
S4T5	0
S4T6	0
S4T7	0
Front to TB	4225
S1T1-S1T2	150.33
S1T3-S1T4	149.68
S1T4-S1T5	200.777

Derived Offsets (formula)	
Gun array offsets	
Bracket distance 1-2	0
Bracket distance 2-3	3.3
Bracket distance 3-4	2.35
Bracket distance 4-5	2.6
Bracket distance 5-6	2.45
Bracket distance 6-7	2.3
Bracket distance 7-8	3
SourceGPS-COS Y	0
COS - Acoustic Y	-5.47
rGPS height above water	1.2
G1 Volume	360
G2 Volume	360
G3 Volume	40
G4 Volume	180
G5 Volume	180
G6 Volume	90
G7 Volume	120
G8 Volume	60
G9 Volume	220
G10 Volume	220
G-Depth 1	0.95
G-Depth 2	0.95
G-Depth 3	1.15
G-Depth 4	0.95
G-Depth 5	0.75
G-Depth 6	1.15
G-Depth 7	1.15
G-Depth 8	1.15
G-Depth 9	0.95
G-Depth 10	0.95
G10 to Acx Z	1.4
G10 to Acx X	-0.5
Surface to Acx	13.4
Fwd bracket to COS	8.25
Aft bracket to COS	7.75

Derived Offsets (formula)	
Streamer Front End	
Stern-towpoint at sea	332
towpoint at sea to end of lead-in	12.5
SHS Length	6
rvim length	17.5
HAU/STU length	0.4
HESA Lgth	10
Fwd Coil to Aft Coil	100
Head to First RX	7.8
Fwd Coil to CNG	-16.423
Head to Fwd Coil	24.223
Tail to Aft Coil	25.777
CNG Channel #	1
Center of streamer to Acx transducer	-0.2
First Section #	1
# channels	324
section length	4050
# sections	27
channel spacing	12.5
First to last	4037.5
HESA Head to aft coil	6.45

Derived Offsets (formula)	
Streamer Tail End	
Head to Fwd Coil	24.223
Tail to Aft Coil	25.777
Head to CFG	145.3
Coil to Coil	100
TAPU Lngth	0.45
Tail Stretch Length	50
Tswivel Lngth	0.3
STIC Length	125
Last active	27
# channels	324
# sections	27
total section length	4050
First to last	4037.5
Stretch Coil	
Center of streamer to Acx transducer	-0.2
channel spacing	12.5
CFG #	324
Fwd coil to CFG	121.077
CFG to TBRGPS	181.95
Stretch head to fwd coil	2.5
Stretch head to aft coil	47.5

Derived Offsets (formula)	
Streamer complete	
#Sections	27
# Channels	324
First to last	4037.5
Total section length	4050

Derived Offsets (formula)	
Hydrophone Offsets	
Channel 1	7.825
2	20.325
3	32.825
4	45.325
5	57.825
6	70.325
7	82.825
8	95.325
9	107.825
10	120.325
11	132.825
12	145.325
# channels	12
# Active's	27
Total Channels	324

Derived Offsets (formula)	
Tailbuoy offsets	
RGPS height above water	1.3
TB length	2.8
TB height	1.83
RGPS-ACX	1
Bridle-RGPS	2.25
Top Leg	1.55
Bottom Leg	1.6
STIC	125
ACX below water line	1.3

Streamer	
NRP to Stern	29.5
tow point at sea to end of lead-in	12.5
STU/module length	0.4
Coil to coil	100
head of section to coil	24.223
tail of section to coil	25.777
channel spacing	12.5
NRP to Port/STBD Rail	7.5
Head to First RX	7.8
Head to Last RX	145.3
Channels per section	12
Center of section to Acx transducer	-0.2
First Section Number	1
HAU/HAPU Length	0.4
SHS Length	6
RVIM length	17.5
HESA Length	10
Active Section Length (SSAS)	150
TES tail stretch length	50
STIC	125
TES Fwd Coil	2.5
TES Aft Coil	47.5
HESA Aft Coil	6.45

Tailbuoy offsets	
RGPS height above water	1.3
TB length	2.8
TB height	1.83
RGPS-ACX	1
Bridle-RGPS	2.25
Top Leg	1.55
Bottom Leg	1.6
STIC	125
ACX below water line	1.3

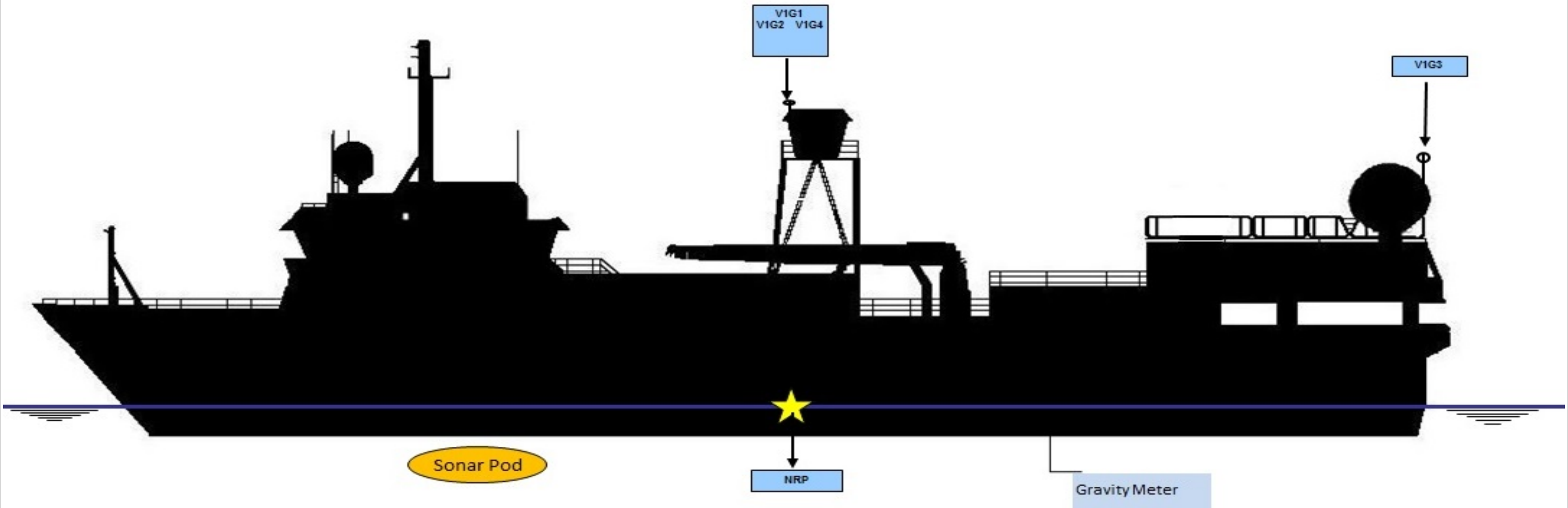
Guns					
Source GPS-COS Y	0			G1 X	0.5
				G1 Y	8.31
Bracket distance 2-3	3.3			G2 X	-0.5
Bracket distance 3-4	2.35			G2 Y	8.31
Bracket distance 4-5	2.6			G3 X	0
Bracket distance 5-6	2.45			G3 Y	5.03
Bracket distance 6-7	2.3			G4 X	0
Bracket distance 7-8	3			G4 Y	2.6
COS - Acoustic Y	-5.47	G10 to Acx Z	-0.5	G5 X	0
rGPS height above water line	1.2	G10 to Acx Y	1.4	G5 Y	2.6
G1 Volume	360	G-Depth 1	0.95	G6 X	0
G2 Volume	360	G-Depth 2	0.95	G6 Y	0
G3 Volume	40	G-Depth 3	1.15	G7 X	0
G4 Volume	180	G-Depth 4	0.95	G7 Y	-2.74
G5 Volume	180	G-Depth 5	0.75	G8 X	0
G6 Volume	90	G-Depth 6	1.15	G8 Y	-5.09
G7 Volume	120	G-Depth 7	1.15	G9 X	0.5
G8 Volume	60	G-Depth 8	1.15	G9 Y	-8.21
G9 Volume	220	G-Depth 9	0.95	G10 X	-0.5
G10 Volume	220	G-Depth 10	0.95	G10 Y	-8.21

Acoustics referenced to CNG or COS	
G1T1	-9.15
G2T1	-9.15
G3T1	-9.15
G4T1	-9.15
S1T1	-16.95
S1T2	-167.28
S1T3	-12322.92
S1T4	-12472.6
S1T5	1
S1T6	0
S1T7	0
S2T1	0
S2T2	0
S2T3	0
S2T4	0
S2T5	0
S2T6	0
S2T7	0
S3T1	0
S3T2	0
S3T3	0
S3T4	0
S3T5	0
S3T6	0
S3T7	0
S4T1	0
S4T2	0
S4T3	0
S4T4	0
S4T5	0
S4T6	0
S4T7	0

Company: L-DEO - Lamont - Doherty Earth Observatory
Vessel: Marcus G. Langseth
Client: Abers/Becel / NSF

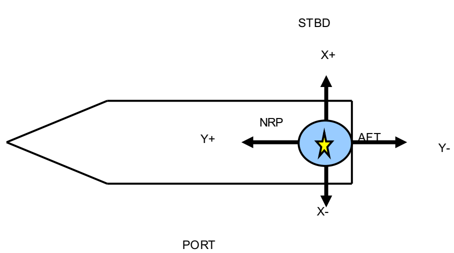
Project: MGL1903
Area: AACSE / Kodiak Alaska
Start Date: 4-Jun-19

R/V Marcus G. Langseth - Vessel Sensor Offsets



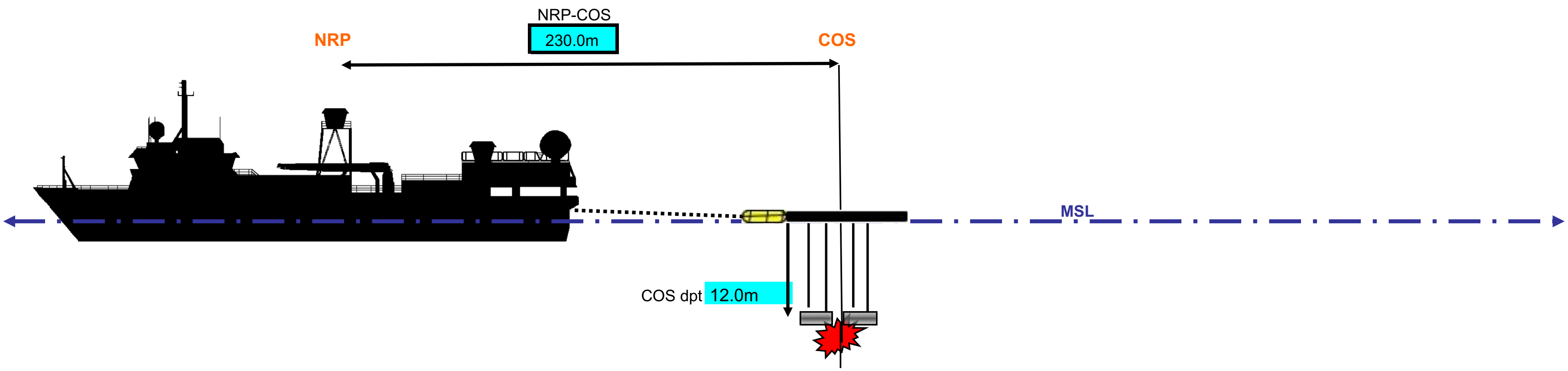
Negative values are above water line

All measurements in meters



		STBD/PORT (X)	FORE/AFT (Y)	UP/DOWN (Z)
NRP	NAVIGATION REFERENCE POINT	0.00	0.00	0.00
V1G1	C-Nav 3050	0.00	0.00	-16.90
V1G2	SeaPath 200	0.00	1.50	-16.90
V1G3	C-Nav 2000	-2.10	-29.20	-14.50
V1G4	Pos MV	-1.30	1.20	-16.90
V1R1	PosNet	-1.30	0.00	-16.90
Sonar Pod	EM122 Knudsen ADCP	0.00	20.20	7.49
	EM122 Center Beam offset (in Spectra)	0/00	13.4	7.49
MRU	Seapath MRU	2.30	14.16	-4.30
BGM	Bell Gravity Meter	0.00	-13.10	1.10

R/V Marcus G. Langseth - Towing Offsets



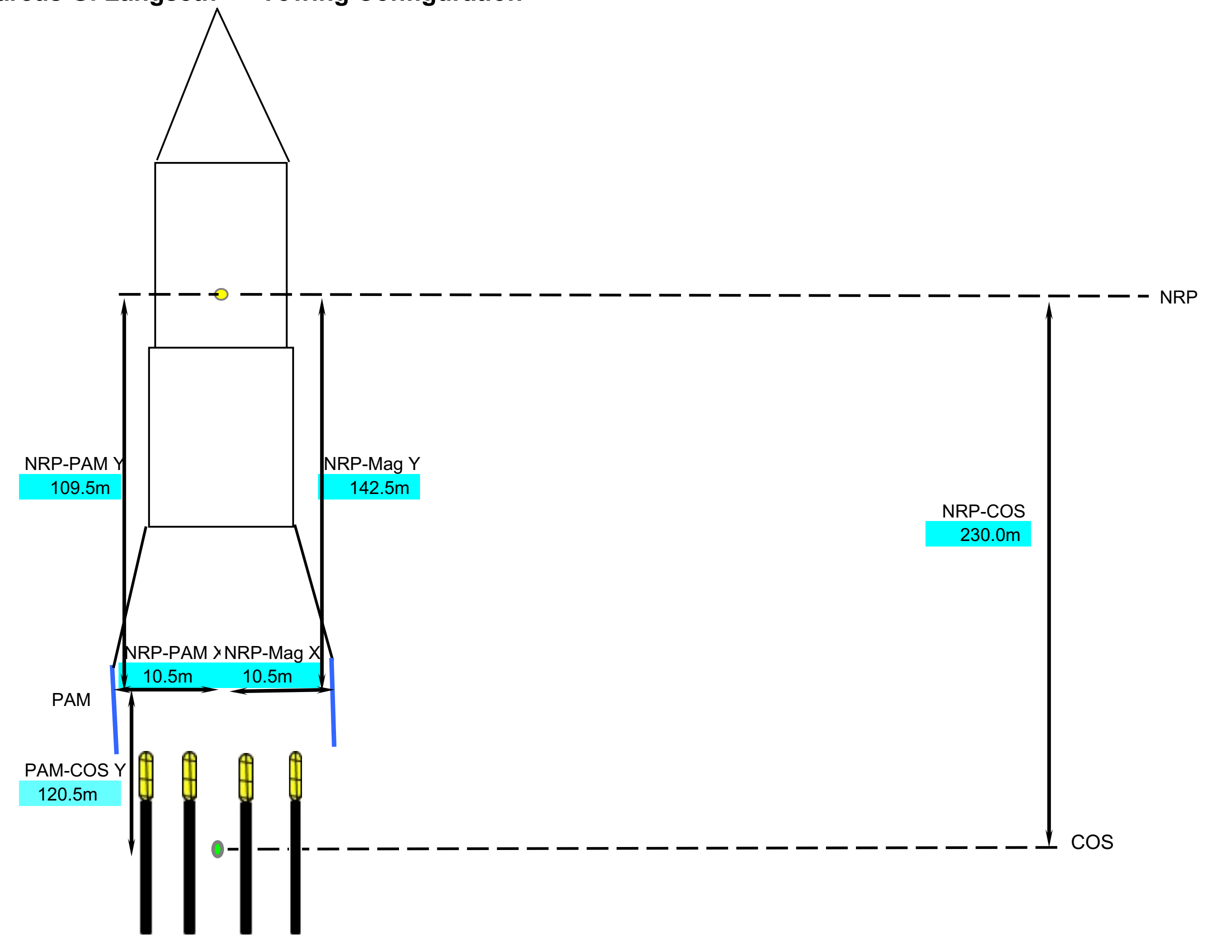
NRP	Nav Reference Point
COS	Centre of Source
CMP	Common Mid-Point
MSL	Mean Sea Level
NRP-Stern	29.5m
NRP-COS	230.0m

All measurements in meters

Cell contents referenced from Config_offsets tab

R/V Marcus G. Langseth - Towing Configuration

	# Streamers	Length	Channels	Spacing
# Gun Strings Used	4	Vol (in^3)	6600	



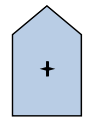
CNG

NOT to Scale

Cell contents referenced from Config_offsets tab

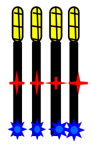
R/V Marcus G. Langseth - Acoustic Offsets

NRP



cng
acoustic

Source acoustic offsets are referenced to COS on individual gun string

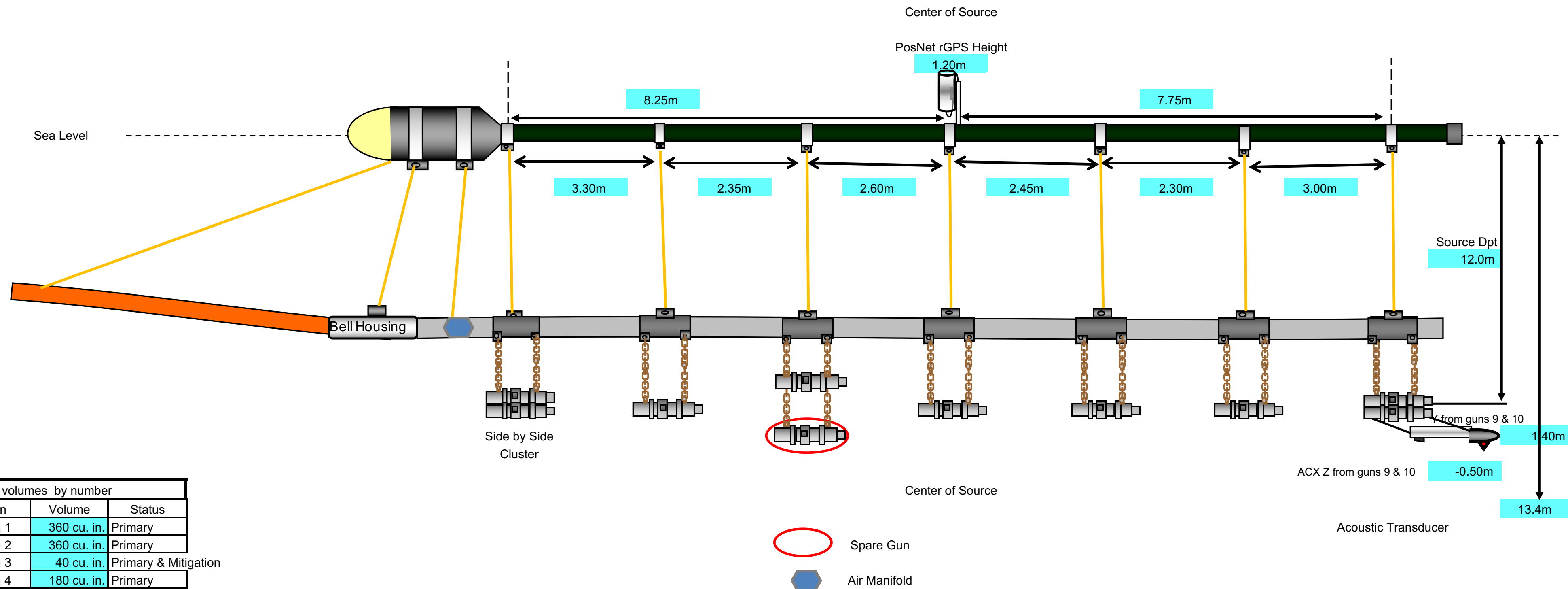


G1T1	-9.2m
G2T1	-9.2m
G3T1	-9.2m
G4T1	-9.2m

Streamer acoustic offsets are referenced to CNG on individual streamer

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	180 cu. in.	Spare
Gun 6	90 cu. in.	Primary
Gun 7	120 cu. in.	Primary
Gun 8	60 cu. in.	Primary
Gun 9	220 cu. in.	Primary
Gun 10	220 cu. in.	Primary

Array total volume (without spares) is 6600 cu. in. Total volume/string (without spare) 1650 cu. in.

Guns (1 &2) & (9&19) in a horizontal cluster. Guns (5 & 6) in a vertical cluster but #6 is spare only

Gun clusters have 0.75m between guns and hang 0.95m from center of hanger

Horizontal Clusters are 1m from gun port to gun port

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

ACX = Acoustic

Center of Source

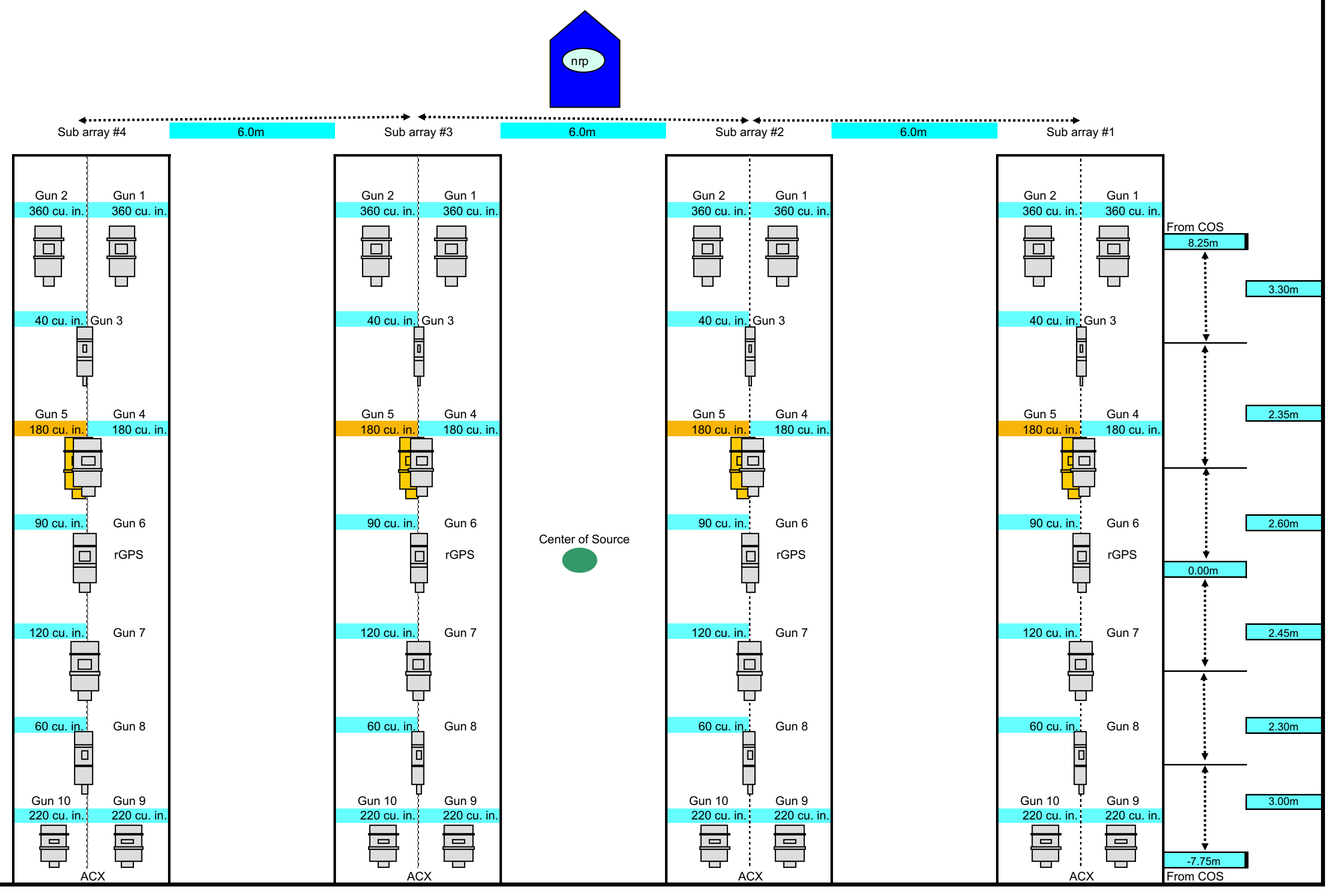
Spare Gun

Gun Clusters

Guns 1 & 2 horizontal array
Guns 4 & 5 vertical - lower gun is spare only
Guns 9 & 10 horizontal array

Gun Offsets relative to Center of String

	X	Y
Gun 1	0.50m	8.31m
Gun 2	-0.50m	8.31m
Gun 3	0.00m	5.03m
Gun 4	0.00m	2.60m
Gun 5	0.00m	2.60m
Gun 6	0.00m	0.00m
Gun 7	0.00m	-2.74m
Gun 8	0.00m	-5.09m
Gun 9	0.50m	-8.21m
Gun 10	-0.50m	-8.21m



All measurements in meters

Job Specific	
NRP to COS Y	230
NRP to COS X	
Source Depth	12
Streamer Depth	
# streamer sections	
# channels	
CNG Channel #	
CFG Channel #	
#MCS Streamers	
lead-in: stern to tow point at sea	
MCS Streamer Sep.	
Gun volume total	6600
Volume per string	1650
# of guns used	36
# Gun Strings	4
gun string separation	6
PAM Y from stern	80
PAM X - (outside of stern rail)	3
Stern to MAG Y	113
Stern to MAG X - (outside of stern rail)	3

Derived Offsets (formula)	
NRP to CMP	159.85
COS-CNG	-140.3
CNG-CFG	0
NRP-Mag Y	142.5
NRP-Mag X	10.5
NRP to tail buoy RGPS	259.9
Total Length of Streamer sections	0
PAM-COS Y	120.5
PAM-COS X	10.5
NRP-PAM Y	109.5
NRP-PAM X	10.5
NRP-CNG	89.7

Derived Offsets (formula)	
Towing Offsets Tab	
NRP-COS	230
NRP-CNG	89.7
NRP-CMP	159.85
COS-CNG	-140.3
CNG Channel #	0
NRP-Stern	29.5
Distance from Head of first section to CNG	7.8
Source Depth	12
Streamer Depth	0
Front End Length	39.9

Derived Offsets (formula)	
Towing Configuration TAB	
NRP-COS	230
NRP-CNG	89.7
COS-CNG	-140.3
NRP-Pcable CNG	0
COS-Pcable CNG	0
P-Cable Streamer Sep	0
NRP-PAM Y	109.5
NRP-PAM X	10.5
PAM-COS Y	120.5
PAM-COS X	10.5
# Gun Strings	4
gun volume	6600
Gun separation	6
# 2D Streamers	0
2D Streamer Ch Spacing	12.5
Number 2D Channels	0
2D Streamer Length	0
2D Streamer Sep	0
NRP-MAG X	10.5
NRP-MAG Y	142.5

Derived Offsets (formula)	
Acoustic Overhead TAB	
G1T1	-9.15
G2T1	-9.15
G3T1	-9.15
G4T1	-9.15
S1T1	-16.95
S1T2	-167.28
S1T3	-7820.88
S1T4	-7970.56
S1T5	-1
S1T6	0
S1T7	0
S2T1	0
S2T2	0
S2T3	0
S2T4	0
S2T5	0
S2T6	0
S2T7	0
S3T1	0
S3T2	0
S3T3	0
S3T4	0
S3T5	0
S3T6	0
S3T7	0
S4T1	0
S4T2	0
S4T3	0
S4T4	0
S4T5	0
S4T6	0
S4T7	0
Front to TB	200
S1T1-S1T2	150.33
S1T3-S1T4	149.68
S1T4-S1T5	225.777

Derived Offsets (formula)	
Gun array offsets	
Bracket distance 1-2	0
Bracket distance 2-3	3.3
Bracket distance 3-4	2.35
Bracket distance 4-5	2.6
Bracket distance 5-6	2.45
Bracket distance 6-7	2.3
Bracket distance 7-8	3
SourceGPS-COS Y	0
COS - Acoustic Y	-5.47
rGPS height above water	1.2
G1 Volume	360
G2 Volume	360
G3 Volume	40
G4 Volume	180
G5 Volume	180
G6 Volume	90
G7 Volume	120
G8 Volume	60
G9 Volume	220
G10 Volume	220
G-Depth 1	0.95
G-Depth 2	0.95
G-Depth 3	1.15
G-Depth 4	0.95
G-Depth 5	0.75
G-Depth 6	1.15
G-Depth 7	1.15
G-Depth 8	1.15
G-Depth 9	0.95
G-Depth 10	0.95
G10 to Acx Z	1.4
G10 to Acx X	-0.5
Surface to Acx	13.4
Fwd bracket to COS	8.25
Aft bracket to COS	7.75

Derived Offsets (formula)	
Streamer Front End	
Stern-towpoint at sea	0
towpoint at sea to end of lead-in	12.5
SHS Length	6
rvim length	17.5
HAU/STU length	0.4
HESA Lgth	10
Fwd Coil to Aft Coil	100
Head to First RX	7.8
Fwd Coil to CNG	-16.423
Head to Fwd Coil	24.223
Tail to Aft Coil	25.777
CNG Channel #	0
Center of streamer to Acx transducer	-0.2
First Section #	1
# channels	0
section length	0
# sections	0
channel spacing	12.5
First to last	-12.5
HESA Head to aft coil	6.45

Derived Offsets (formula)	
Streamer Tail End	
Head to Fwd Coil	24.223
Tail to Aft Coil	25.777
Head to CFG	145.3
Coil to Coil	100
TAPU Lngth	0.45
Tail Stretch Length	50
Tswivel Lngth	0.3
STIC Length	150
Last active	0
# channels	0
# sections	0
total section length	0
First to last	-12.5
Stretch Coil	
Center of streamer to Acx transducer	-0.2
channel spacing	12.5
CFG #	0
Fwd coil to CFG	121.077
CFG to TBRGPS	206.95
Stretch head to fwd coil	2.5
Stretch head to aft coil	47.5

Derived Offsets (formula)	
Streamer complete	
#Sections	0
# Channels	0
First to last	-12.5
Total section length	0

Derived Offsets (formula)	
Hydrophone Offsets	
Channel 1	7.825
2	20.325
3	32.825
4	45.325
5	57.825
6	70.325
7	82.825
8	95.325
9	107.825
10	120.325
11	132.825
12	145.325
# channels	12
# Active's	0
Total Channels	0

Derived Offsets (formula)	
Tailbuoy offsets	
RGPS height above water	1.3
TB length	2.8
TB height	1.83
RGPS-ACX	1
Bridle-RGPS	2.25
Top Leg	1.55
Bottom Leg	1.6
STIC	150
ACX below water line	1.3

Fixed Positions Streamer	
NRP to Stern	29.5
tow point at sea to end of lead-in	12.5
STU/module length	0.4
Coil to coil	100
head of section to coil	24.223
tail of section to coil	25.777
channel spacing	12.5
NRP to Port/STBD Rail	7.5
Head to First RX	7.8
Head to Last RX	145.3
Channels per section	12
Center of section to Acx transducer	-0.2
First Section Number	1
HAU/HAPU Length	0.4
SHS Length	6
RVIM length	17.5
HESA Length	10
Active Section Length (SSAS)	150
TES tail stretch length	50
STIC	150
TES Fwd Coil	2.5
TES Aft Coil	47.5
HESA Aft Coil	6.45

Tailbuoy offsets	
RGPS height above water	1.3
TB length	2.8
TB height	1.83
RGPS-ACX	1
Bridle-RGPS	2.25
Top Leg	1.55
Bottom Leg	1.6
STIC	150
ACX below water line	1.3

Guns					
Source GPS-COS Y	0			G1 X	0.5
				G1 Y	8.31
Bracket distance 2-3	3.3			G2 X	-0.5
Bracket distance 3-4	2.35			G2 Y	8.31
Bracket distance 4-5	2.6			G3 X	0
Bracket distance 5-6	2.45			G3 Y	5.03
Bracket distance 6-7	2.3			G4 X	0
Bracket distance 7-8	3			G4 Y	2.6
COS - Acoustic Y	-5.47	G10 to Acx Z	-0.5	G5 X	0
rGPS height above water line	1.2	G10 to Acx Y	1.4	G5 Y	2.6
G1 Volume	360	G-Depth 1	0.95	G6 X	0
G2 Volume	360	G-Depth 2	0.95	G6 Y	0
G3 Volume	40	G-Depth 3	1.15	G7 X	0
G4 Volume	180	G-Depth 4	0.95	G7 Y	-2.74
G5 Volume	180	G-Depth 5	0.75	G8 X	0
G6 Volume	90	G-Depth 6	1.15	G8 Y	-5.09
G7 Volume	120	G-Depth 7	1.15	G9 X	0.5
G8 Volume	60	G-Depth 8	1.15	G9 Y	-8.21
G9 Volume	220	G-Depth 9	0.95	G10 X	-0.5
G10 Volume	220	G-Depth 10	0.95	G10 Y	-8.21

Acoustics referenced to CNG or COS	
G1T1	-9.15
G2T1	-9.15
G3T1	-9.15
G4T1	-9.15
S1T1	-16.95
S1T2	-167.28
S1T3	-7820.88
S1T4	-7970.56
S1T5	-1
S1T6	0
S1T7	0
S2T1	0
S2T2	0
S2T3	0
S2T4	0
S2T5	0
S2T6	0
S2T7	0
S3T1	0
S3T2	0
S3T3	0
S3T4	0
S3T5	0
S3T6	0
S3T7	0
S4T1	0
S4T2	0
S4T3	0
S4T4	0
S4T5	0
S4T6	0
S4T7	0

Appendix B: Marine Gravity Acquisition

Summary

Gravity data was collected throughout the duration of the cruise using a Bell Aerospace BGM-3 gravimeter. Measurements were taken every 1-second and displayed in real-time on monitors in the main lab. The gravimeter appeared to be functioning properly throughout the cruise as indicated by visual inspection of the data (Figure F1-F2). In MGL1903/raw/ there are two files (MGL1903_serial_data_1min.csv and MGL1903_serial_data_10s.csv) that are updated continuously throughout the cruise with the ships position, heading, and speed, wind, depth, magnetics, gravity, sea temperature, salinity, and sound velocity at 1 minute and 10 second intervals. The raw gravity data can be found in MGL1903/raw/serial and the filenames follow the format MGL-vc01.yxxxxdzzz where xxxx is the year and zzz is the Julian day on which the data was collected.

Instrument Detail

- Bell Aerospace BGM-3 Marine Gravity Meter
- 1 Hz sampling frequency
- The raw data is stored as a text file (MGL-vc01.yxxxxdzzz) with columns
    - vc01, year:Julian_day:hour:min:sec XX:counts YY

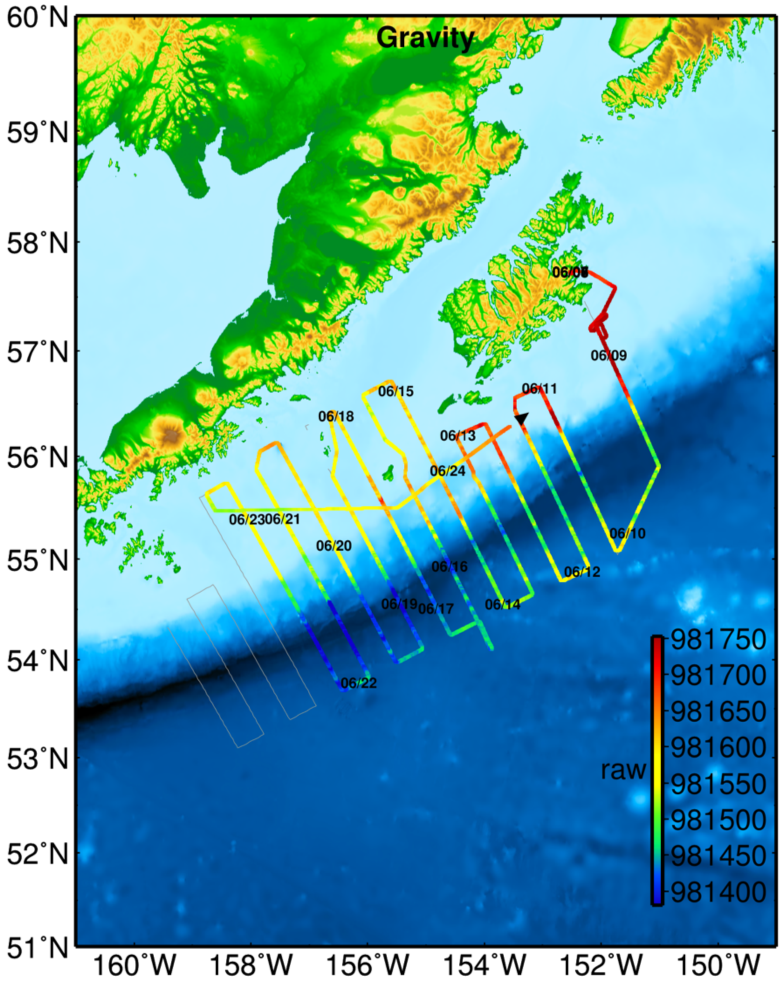


Figure B1: Raw gravity measurements collected throughout cruise.

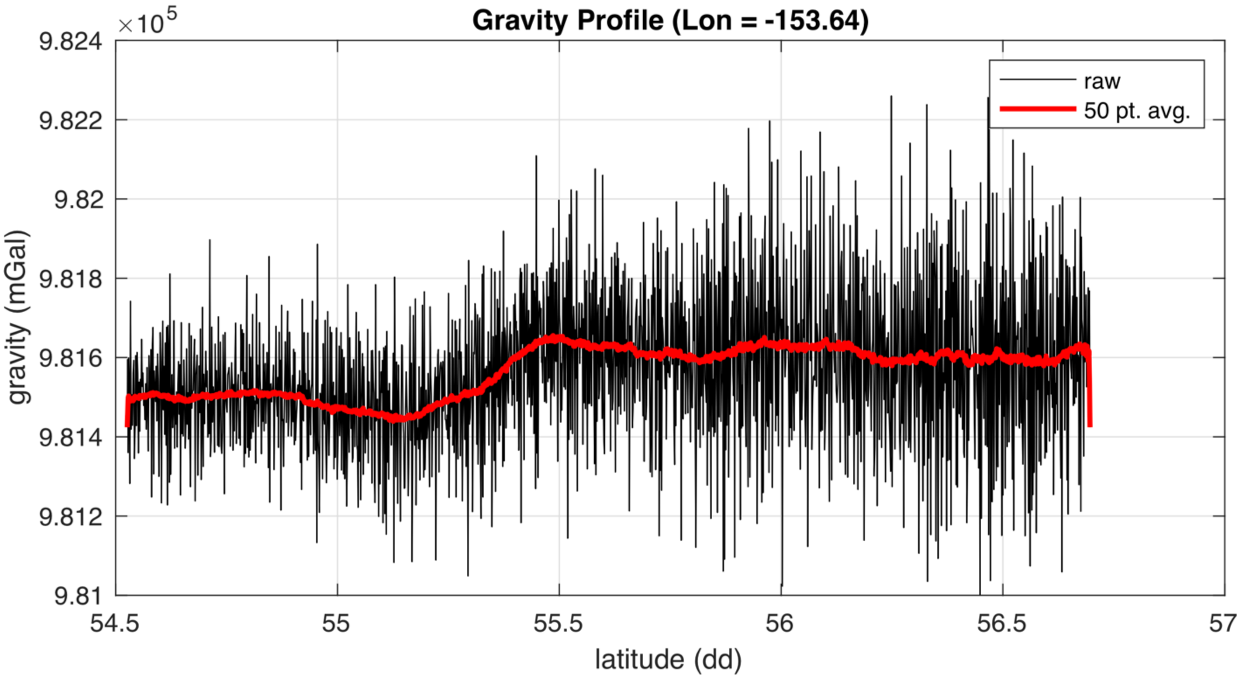


Figure B2: Raw gravity profile along line MC06.

<u>Gravity Ties</u>
A gravity tie is performed at the start and end of the cruise. The gravity tie is used to make a drift correction and to tie in the data to an absolute datum.

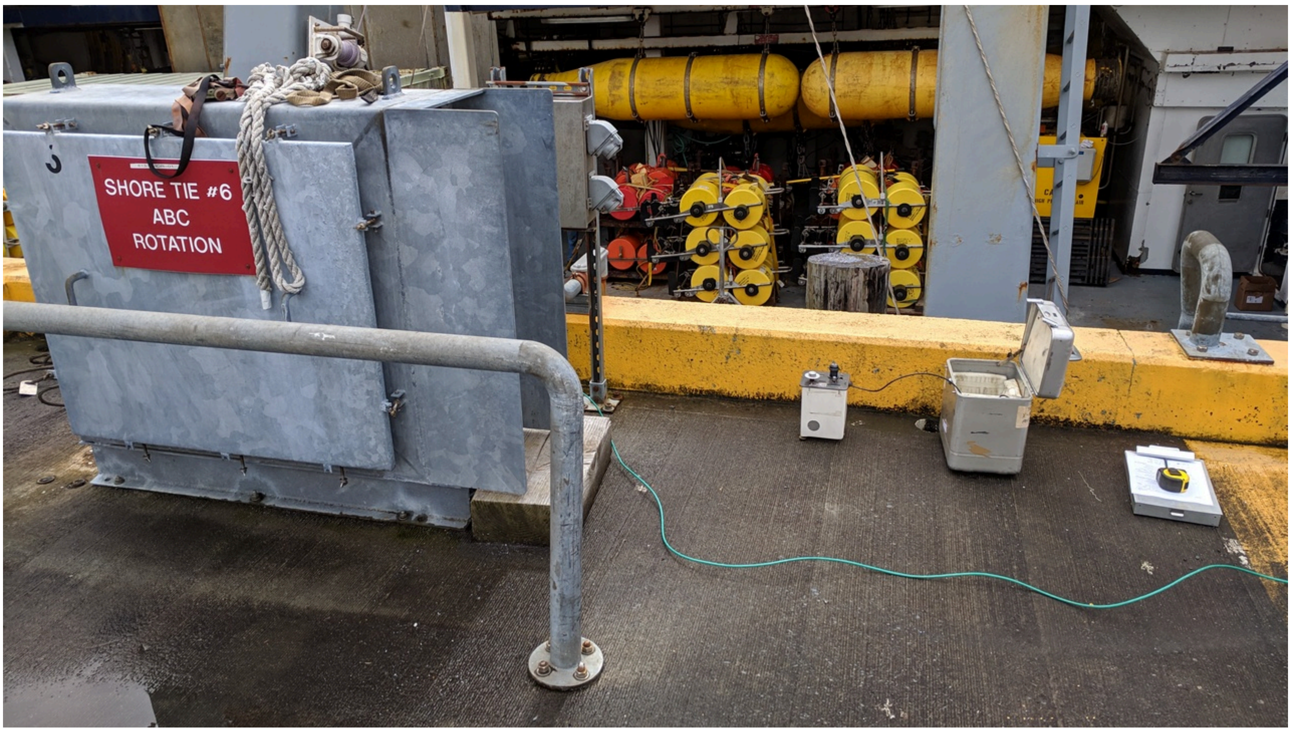


Figure B3: Pre-cruise gravity tie

GRAVITY STATION DESCRIPTION

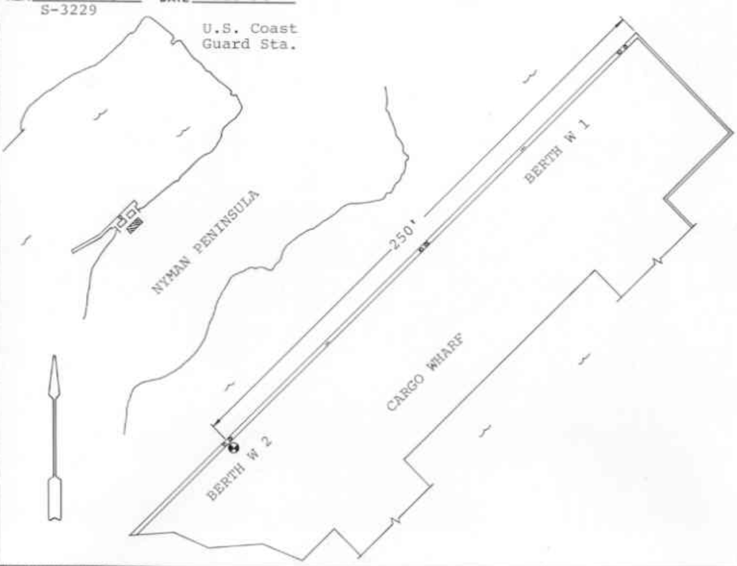
LAT. 57° 43' 51.5" N
LONG. 152° 30' 49.0" W
POSIT. REF 16595, 12th Ed.
ELEV. 18.5' MLW
ELEV. REF U.S.C.G. FAC
TYPE Harbor
CROSS REF. DoD 0235-4

STATION NO. 0005.19
COUNTRY U.S.A.
STATE Alaska
CITY U.S.C.G. Station, Kodiak
STATION NAME Cargo Wharf, Berth W 2
1971 DATUM g 981,732.93 ±0.08 Mgals

REF. 116 DATE May 97

The station is located at berth W 2, on the Cargo Wharf, U.S. Coast Guard Station, Kodiak, Alaska. It is in front of the third double bit from the northeast end of the wharf.

REF. C.G. Dwg S-3229 DATE Dec 94



NAVOCEANO 3145/6 (REV. 07-90)

STATION NO. 0005.19 1971 DATUM g = 981,732.93 ±0.08 Mgals

DATE	OBSERVER	METER	SOURCE	STATION OF REF.	1971 VALUE	Δg	TIE
25 May 97	J. Newman	G-872	116	0005.17	981,732.49	+0.42	ABA.BA
25 May 97	B. Thurmond	G-872	116	0005.17	981,732.49	+0.43	ABA.BA
25 May 97	J. Newman	G-207	116	0005.17	981,732.49	+0.44	ABA.BA
25 May 97	B. Thurmond	G-207	116	0005.17	981,732.49	+0.43	ABA.BA
25 May 97	J. Newman	G-872	116	0005.18	981,735.53	-2.55	A.B.AB
25 May 97	B. Thurmond	G-872	116	0005.18	981,735.53	-2.59	A.B.AB
25 May 97	J. Newman	G-207	116	0005.18	981,735.53	-2.60	A.B.AB
25 May 97	B. Thurmond	G-207	116	0005.18	981,735.53	-2.61	A.B.AB

RV Langseth Gravity Tie Form

CruiseID	MGL 1902	PRE	POST (circled)
Date	June 2nd 2019		
Port	Kodiak Alaska USCG Cargo pier		
Operator	Thompson		

Pier side Reading #1

Ship's position (C-Nav)	LAT 57° 43. 7595 'N	LONG 152° 30. 9691' W	ALT 32.59m
Shipboard BGM	Shipboard BGM reading (mGal) 981726	Height of Pier over Main Deck (m)[1]	
Portable GPS Time	TIME 20:00		
Portable GPS Position	LAT 57° 43.768' N	LONG 152° 30.971' W	ALT 85.9
L&R Readings	Reading 1 5211.62	Reading 2 5211.80	Reading 3 5211.80
	20:04	20:10	20:18
Height	-2.64M	-2.73 m	-2.72 m

Tie Point

Tie Point Description (also include relevant documentation/maps/pictures)	No marker, followed description for tie location. Above 4-cut off bolts that form a square in the road deck		
Portable GPS Time	TIME 20:28		
Portable GPS Position	LAT 57°43.846' N	LONG 152°30.807' W	ALT 18.4
L&R Readings	Reading 1 5212.16	Reading 2 5212.20	Reading 3 5212.19
	20:33	20:38	20:44

Pier side L&R reading #3

Shipboard BGM	Shipboard BGM reading (mGal) 981726	Height of Pier over Main Deck (m)		
Portable GPS Time	TIME 20:57			
Portable GPS Position	LAT 57° 43.771' N	LONG 152° 30.977' W	ALT 41.3	
L&R Readings	Reading 1 5211.96	Reading 2 5212.58	Reading 3 5212.38	reading 4 5212.24
	20:57	21:08	21:12	21:17
Height	-2.26m	-2.16m	didn't measure	-2.11m

L&R unit got bumped between readings 1 and 2

Notes

Vessel pier side tie – Vessel on south west end of pier, located on peninsula side of the pier. 3.78 m west of double bit, near shore power box directly behind wooden piling

1. Height of pier over main deck should be entered in meters. Use a negative value to indicate pier is below main deck.
Form v1.1 2008-08-18

Figure B4: Pre-cruise gravity tie

RV Langseth Gravity Tie Form

CruiseID	MGL1903	☐ PRE ☑ POST
Date	June 25th 2019	
Port	Kodiak Alaska USCG Cargo pier	
Operator	Thompson	

Pier side Reading #1

Ship's position (C-Nav)	LAT 57°43.759383'N	LONG 152°30.969313	ALT 33.43m
Shipboard BGM	Shipboard BGM reading (mGal) 981728, raw 25353	Height of Pier over Main Deck (m)[1]	
Portable GPS Time	TIME 17:45	17:55	18:05
Portable GPS Position	LAT 57°43.773'N	LONG 152°30.981'W	ALT 65.1ft
L&R Readings	Reading 1 5211.82	Reading 2 5211.71	Reading 3 5211.71
	−2.23 M	−2.30m	−2.33

Tie Point

Tie Point Description (also include relevant documentation/maps/pictures)	No marker, followed description and GPS On top of 4 cut off bolts, 1 meter in from double bollard near sewer 30		
Portable GPS Time	TIME 18:20	18:30	18:40
Portable GPS Position	LAT 57°43.848'N	LONG 152°30.807"W	ALT -11.4
L&R Readings	Reading 1 5211.98	Reading 2 5211.97	Reading 3 5211.98

Pier side L&R reading #3

Shipboard BGM	Shipboard BGM reading (mGal) 981728, raw 25353	Height of Pier over Main Deck (m)	
Portable GPS Time	TIME 18:52	19:02	19:12
Portable GPS Position	LAT 57°43.767'N	LONG 152°30.973'W	ALT 32.8ft
L&R Readings	Reading 1 5211.73	Reading 2 5211.72	Reading 3 5211.72
	−2.56	−2.58	−2.66

Notes

Vessel pier side tie on end of pier located on peninsula side of the pier

1. Height of pier over main deck should be entered in meters. Use a negative value to indicate pier is below main deck.

Form v1.1 2008-08-18

Figure B5: Post-cruise gravity tie

Appendix C. Expendable Bathythermographs

Accurate temperature profiles of the world's oceans are vital to many scientific research efforts. Because heat fluctuations in the ocean span multiple decades rather than short-term variations, changes in temperature in the oceans are useful for tracking the impacts on climate change, thermal expansion, and regional differences in ocean temperatures (Fig. C1). These velocities are also essential for datasets collected underway during a cruise, such as seafloor imaging with multi-beam data, chirp data, etc, as were collected during MGL1903. Because multi-beam bathymetry uses sound waves to create a picture of the seafloor, velocities of these sound waves is required. It is known that the velocity of the soundwaves through the water column is affected by the density of the water, and the density is in turn affected by the salinity and the temperature of the water. Thus, temperature profiles are used to help infer the velocity through the water column for correcting depth measurements collected via mapping operations.

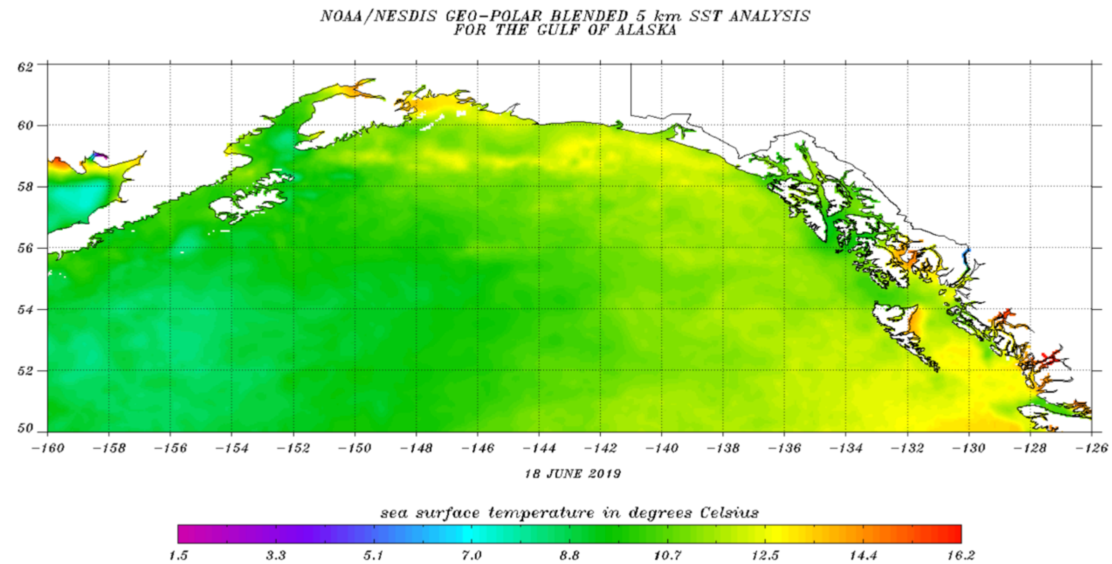


Figure C1. *The temperature of the sea surface in the Gulf of Alaska on June 18th, 2019 (https://www.ospo.noaa.gov).*

To gain these temperature profiles, many researchers rely on a device called an eXpendable BathyThermograph (XBT). An XBT is a small, torpedo-like probe that is used to record the temperature of the water. Because the XBT is shaped in a specific, hydrodynamic way with a specific weight, it is known at which speed the probe will fall through the water column and we can infer the depth of the probe based on the time of its entry into the ocean. This allows us to obtain a profile temperature with depth.

When we are ready to launch our probe, we prepare by putting the XBT in a launcher. The launcher itself is what is used to send the data to the computers onboard the ship. It has a series of wires within that are used to communicate the data once it receives it from the XBT. The launcher that we use is handheld, so it is easier to move into position and get the XBT into the ocean. We use a plastic pipe to help guide the XBT into the ocean. The pipe hangs off the side of the ship and is tied to the vessel through a series of ropes. When we are ready to launch the XBT, we aim the launcher down the pipe so that we are more certain of a clean entry. We then simply unlatch the pin holding back the probe, and we watch the XBT slide down the pipe and into the water.

The XBT is connected to the launcher through a spool of copper wire that unravels as it travels through the water column. The data it records is transmitted to the launcher via the copper wire. Some attempts are not successful, as sometimes the probes get snared in the propellers or in the streamers pulled by the vessel. Once we are done collecting data, we simply snap the copper wire off. This is why the devices are called "expendable."

During the MGL1903 cruise, we collected 15 different XBT profiles (Table C1, Figure C2), at various locations along the survey which span a range of depth environments (Figure C3).

Probe Number	Date Launched	Time of Launch (UTC)	Shot Number	Probe Type	Last Good Depth (m)
1	6/9/19	2:14:00	1117	t7	219
2	6/9/19	5:44:00	1191	t5	1294
3	6/10/19	3:35:00	3032	t5	1825.6
4	6/11/19	10:31:48	5173	t5	236.8
5	6/11/19	12:57:56	5234	t5	339
6	6/11/19	13:01:02	5235	t5	367.4
7	6/13/19	2:08:52	9049	t7	212
8	6/13/19	8:07:02	9194	t5	1829.9
9	6/13/19	16:38:48	9397	t5	1830.5
10	6/15/19	5:34:37	13023	t7	269
11	6/15/19	19:24:59	13400	t7	750.2
12	6/15/19	20:07:20	13419	t5	1829.9
13	6/18/19	18:26:58	17405	t5	1830.5
14	6/21/19	5:03:00	21269	t7	292
15	6/22/19	10:31:49	23212	t5	651

Table C1. Probe number and the corresponding date and time of launch, shot number during the launch, probe type and the deepest depth at which the probe was able to successfully record (Last Good Depth).

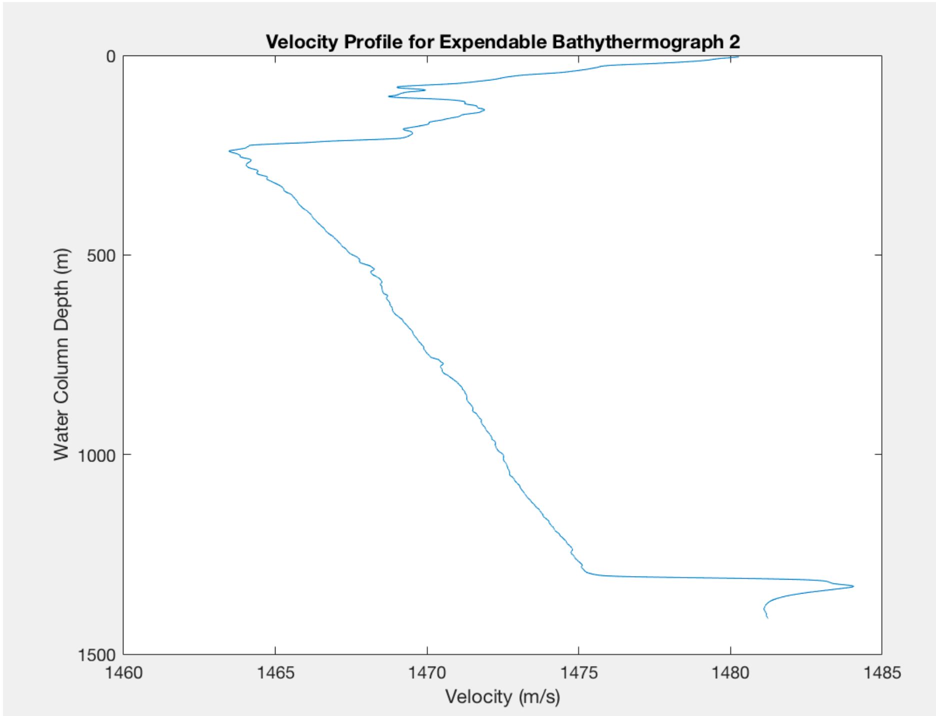


Figure C2. Velocity profile with depth that was taken from the second probe launched.

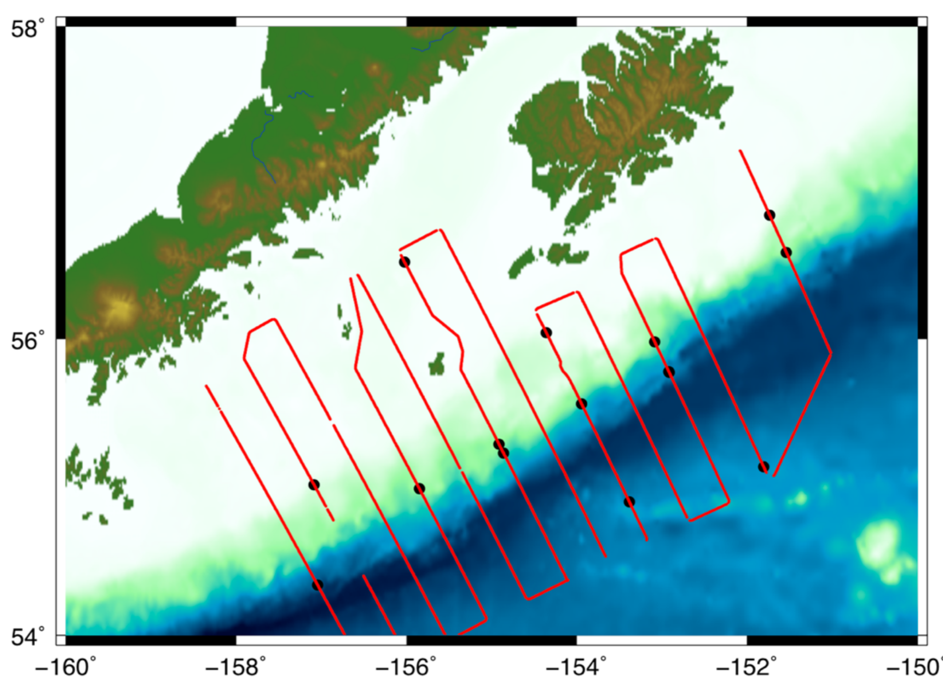


Figure C3. Locations where each of the XBT's (black dots) was launched on the ship's path (red line). The last two probes were launched very closely together, spatially.

An expendable bathythermograph (XBT) is a probe used to measure temperature throughout the water column. Retrieved from https://oceanexplorer.noaa.gov/facts/xbt.html

Cowley, R., S. Wijffels, L. Cheng, T. Boyer, and S. Kizu, 2013: Biases in Expendable Bathythermograph Data: A New View Based on Historical Side-by-Side Comparisons.*J. Atmos. Oceanic Technol.,* **30**, 1195–1225, https://doi.org/10.1175/JTECH-D-12-00127.1

Appendix D: Information on Data Format

This appendix provides information on the format of the following data files:

- POS/MV Position and Orientation System for Marine Vessels
- BGM-3 Gravimeter Data
- CNAV GPS receiver data
- CNAV 3050 GPS receiver data
- Furuno DS-50 Doppler Speedlog Data
- FE700 Navigational Echosounder data
- Geometrics G-882 Cesium Marine Magnetometer Data
- Kongsberg EM122 Multibeam – Center Beam Depth Data
- SEAPATH 200 Intertial Navigation System
- LDEO PCO2 + CNav + TSG + WX01 + SBE38 Systems
- LDEO PCO2 System
- Seabird Electronics SBE-45 Thermosalinograph Station Data
- Gyroscope data
- Streamer Tension Unit Data
- Vane Tension Load Cell Units Data

POS/MV Position and Orientation System for Marine Vessels

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.

- 1. $INGGA-Global System Position Fix Data
- 2. $INHDT-Heading - True data
- 3. $INVTG-Course over ground and Ground speed data
- 4. $INGST-GPS pseudorange noise statistics
- 6. $PRDID-Attitude data
- 7. $INZDA-Time and date

$INGGA, hhmmss.sss, llll.lllll, a, yyyyy.yyyyy, b, t, nn, v.v, x.x, M,,,c.c,rrrr*hh

$INGGA-Global System Position Fix Data

Item	Definition	Value	Units
$INGGA	Header	$INGGA	
hhmmss.sss	UTC time of position	n/a	Hours/Minutes/Seconds.decimal. Two fixed digits of hours. Two fixed digits of minutes. Two fixed digits of seconds. Three digits for decimal fractions of a second.
llll.lllll	Latitude	-90 to +90	DegreeslMinutes.decimal. Two fixed digits of degrees Two fixed digits of minutes Five digits for decimal minutes.
a	N (north) or S (south)	N or S	
yyyyy.yyyyy	Longitude	-180 to +180	Degrees/Minutes.decimal. Three fixed digits of degrees. Two fixed digits of minutes. Five digits for decimal minutes.
b	E (east) or W (west)	E or W	
		0 = Fix not available or	

t	GPS Quality Indicator	invalid 1 = CIA standard GPS; fix valid. 2 = DGS mode; fix valid. 3 = PPP mode; fix valid. 4 = RTK fixed 5 = RTK float 6 = free inertial	
nn	Number of satellites used in fix	0 to 32	
v.v	Horizontal dilution of precision		
x.x	Altitude of the IMU above or below the mean sea level. A negative value indicates below sea level.	n/a	Metres
M	Units of measure = metres	M	
Null	Null		
Null	Null		
c.c	Age of differential corrections in records since last RTCM-104 message.	0 to 99.9	Seconds
rrr	DGPS reference station identity	0000 to 1023	
*hh	Checksum	00 - FF	
/CR/LF	Carriage return and line feed	/CR/LF	

Note that, in the case of the HDOP, IMU altitude and age of differential connections, POS/MV adds leading digits as required (i.e. if the value exceeds 9.9). Also, note that commas separate all items, including null fields. The information is valid at the location of the vessel frame.

$INHDT, x.x, T*hh

$INHDT-Heading - True data

Item	Definition	Value	Units
$INHDT	Header	$INHDT	
x.x	True vessel heading in the vessel frame	o to 359.99	degrees
*hh	Checksum	n/a	
/CR/LF	Carriage return and line feed	/CR/LF	

$INVTG, x.x, T,, M, n.n, N, k.k, K*hh

$INVTG-Course over ground and Ground speed data

Item	Definition	Value	Units
%INVTG	Header	$INVTG	
x.x	True vessel track in the vessel frame	0 to 359.99	degrees
T	True	T	
null	Not supported	null	
M		M	
n.n	Speed in the vessel frame	n/a	Knots
N	Knots	N	
k.k	Kilometres	K	
*hh	Checksum	n/a	
/CR/LF	Carriage return and line feed	/CR/LF	

Note that, in the case of the track and the speed fields, POS/MV adds the leading digits as required (i.e. if the value exceeds 9.9). ALso, note that commas separate all items in the including null fields.

$INGST, hhmmss,sss,,smjr.smjr,smnr.smnr, o.o, l.l, y.y, a.a *hh

$INGST-GPS pseudorange noise statistics

Item	Definition	Value	Units
$INGST	Header	$INGST	
hhmmss.sss	UTC time of position	n/a	Hours/Minutes/Seconds.decimal. 2 fixed digits of hours. 2 fixed digits of minutes. 2 fixed digits of seconds. Three digits for decimal fractions of a second.
null	Not supported	null	
smjr.smjr	Standard Deviation of semi-major axis of error ellipse	n/a	Metres
smnr.smnr	Standard deviation of semi-minor axis of error ellipse	n/a	Metres
o.o	Orientaion of semi-major axis ellipse	0 to 359.9	Degrees from true north

l.l	Standard deviation of latitude	n/a	Metres
y.y	Standard deviation of longitude	n/a	Metres
a.a	Standard deviation of Altitude	n/a	Metres
*hh	Checksum	n/a	
/CR/LF	Carriage return and line feed	/CR/LF	

Note that, in the case of all fields POS/MV adds leading digits as required (i.e. if the value exceeds 9.9). Also, note that commas separate all items, including null fields. The information is valid at the location of the vessel frame.

Note that commas separate all items

Two attitude data strings are available. The strings are identical except for the definition of roll and pitch angles. One string uses Tate-Bryant angles and the

other uses TSS angles. Use the POS/MV Controller program to set the required angle convention.

$PRDID, PPP.PP, RRR.RR, xxx.xx*hh

$PRDID-Attitude data

Item	Definition	Value	Units
$PRDID	Header	$PRDID	
PPP.PP	Pitch	-90.00 to +90.00	Degrees
RRR.RR	Roll	-90.00 to +90.00	Degrees
xxx.xx	Sensor heading	0 to 359.99	Degrees
*hh	Checksum	n/a	
/CR/LF	Carriage return and line feed	/CR/LF	

Note that commas separate all items

Two attitude data strings are available. The strings are identical except for the definition of roll and pitch angles. One string uses Tate-Bryant angles and the

other uses TSS angles. Use the POS/MV Controller program to set the required angle convention.

$INZDA, hhmmss.ss, DD, MM, YYYY,, *hh

$INZDA-Time and date

Item	Definition	Value	Units
$INZDA	Header	$INZDA	
			Hours/Minutes/Seconds.decimal.

hhmmss.sss	UTC time	n/a	2 fixed digits of hours 2 fixed digits of minutes 2 fixed digits of seconds Three digits for decimal fractions of a second
DD	Day of month	01 to 31	
MM	Month of year	01 to 12	
YYYY	Year		
Null	Null		
Null	Null		
*hh	Checksum	n/a	/CR/LF

BGM-3 Gravimeter Data

The BGM-3 Gravimeter outputs the gravitational force in the following serial sentence format:

FILE NAME: ***MGL-vc01.y****d******

vc01 2015:234:00:00:53.7862 04:024326 00
vc01 yyyy:ddd:hh:mm:ss.ssss xx:yyyyyy ff

Item	Definition	Units
xx	Output Frequency	Hz
yyyyyy	Raw Counts	n/a
ff	Sensor Status (00 – Null) See manual for other Error Codes.	n/A

CNAV GPS receiver data

CNAV outputs data in NMEA 0183 compatible format. Currently* the following sentence types are enabled:

- $GPVTG-GPS Velocity, Track made good and Ground speed data (computed by the CNAV GPS receiver).
- $GPGGA-Gobal Positioning System Fix data (computed by the CNAV GPS receiver).

  *Note: there are other sentence types available from CNAV. Please consult the software manual for more options.

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

$GPVTG Sentence Fields

Item	Definition	Units
xxx.x	Course over ground (COG)	Degrees from True North
T	Indicates course relative to True North	n/a
M	COG	Degrees from Magnetic North
m.mm	Speed over ground (SOG)	Nautical miles per hour (knots)
N	Indicates that the speed over ground is in knots	n/a
n.nn	SOG	km/h
K	Indicates that the SOG is in km/h	n/a /td>
*hh	Checksum (hexadecimal representation)	n/a

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

$GPGGA Sentence Fields

Item	Definition	Units
hhmms.ss	UTC time of position	Hours/Minutes/Seconds.decimal.
ddmm.mmmmm	Latitude	Degrees/Minutes.decimal.
a	Direction of Latitude N = North S = South	n/a
ddmm.mmmmm	Longitude	Degrees/Minutes.decimal
a	Direction of Longitude E = East	n/a

	W = West	
x	GPS Quality indicator 0 = fix not valid 1 = GPS Autonomous fix 2 = GcGPS Corrected Fix	n/a
xx	Number of GPS satellites used in solution fix	n/a
x.x	Horizontal Dilution of Precision (HDOP)	n/a
xx.xx	C-NAV GPS receiver antenna altitude reference to Mean Sea Level (MSL)	n/a
M	Altitude units--M indicates meters	n/a
xx.xx	WGS-84 Geoidal separation distance from MSL based on the NIMA/NASA EGM96 15-minute (Earth Gravity Model)	Meters
M	Geosoidal separation units--M indicates meters	n/a
x.x	Age of GcGPS corrections used in solution fix	n/a
xyy	C-NAV GPS receiver reference identification	x is downlink satellite communication beam in use yy is the GPS correction signal mode/type being used
*hh	Checksum (hexadecimal representation) followed by CRLF terminator pair	n/a

CNAV 3050 GPS receiver data

CNAV 3050 outputs data in NMEA 0183 compatible format. Currently* the following sentence types are enabled:

- $GPVTG-GPS Velocity, Track made good and Ground speed data (computed by the CNAV GPS receiver).
- $GPGGA-Gobal Positioning System Fix data (computed by the CNAV GPS receiver).

  *Note: there are other sentence types available from CNAV. Please consult the software manual for more options.

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

$GPVTG Sentence Fields

Item	Definition	Units
xxx.x	Course over ground (COG)	Degrees from True North
T	Indicates course relative to True North	n/a
M	COG	Degrees from Magnetic North
m.mm	Speed over ground (SOG)	Nautical miles per hour (knots)
N	Indicates that the speed over ground is in knots	n/a
n.nn	SOG	km/h
K	Indicates that the SOG is in km/h	n/a /td>
*hh	Checksum (hexadecimal representation)	n/a

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

$GPGGA Sentence Fields

Item	Definition	Units
hhmms.ss	UTC time of position	Hours/Minutes/Seconds.decimal.
ddmm.mmmmm	Latitude	Degrees/Minutes.decimal.
a	Direction of Latitude N = North S = South	n/a
ddmm.mmmmm	Longitude	Degrees/Minutes.decimal
a	Direction of Longitude E = East	n/a

	W = West	
x	GPS Quality indicator 0 = fix not valid 1 = GPS Autonomous fix 2 = GcGPS Corrected Fix	n/a
xx	Number of GPS satellites used in solution fix	n/a
x.x	Horizontal Dilution of Precision (HDOP)	n/a
xx.xx	C-NAV GPS receiver antenna altitude reference to Mean Sea Level (MSL)	n/a
M	Altitude units--M indicates meters	n/a
xx.xx	WGS-84 Geoidal separation distance from MSL based on the NIMA/NASA EGM96 15-minute (Earth Gravity Model)	Meters
M	Geosoidal separation units--M indicates meters	n/a
x.x	Age of GcGPS corrections used in solution fix	n/a
xyy	C-NAV GPS receiver reference identification	x is downlink satellite communication beam in use yy is the GPS correction signal mode/type being used
*hh	Checksum (hexadecimal representation) followed by CRLF terminator pair	n/a

Furuno DS-50 Doppler Speedlog Data

The FURUNO DS-50 is a highly advanced, precision Doppler Speed Log incorporating FURUNO's advanced computer technology. The DS-50 provides accurate display of speed over a wide range from dead slow to 40 kt. Speeds are detected relative to ground or water both fore/aft and athwart ship.

The speed logger data from the Furuno DS-50 is output in the following sentence formats:

FILE NAME: ***MGL-slog01.y****d****

$VDVHW,90.0,T,95.0,M,11.07,N,20.50,K*47
$VDVHW,x.x,T,y.y,M,n.n,N,s.s,K*hh

Item	Definition	Units
x.x	Vessel Heading	Degrees True
T	Units	n/a
y.y	Vessel Heading	Degree Magnetic
M	Units	n/a
n.n	Speed of vessel relative to water	Knots
N	Units	n/a
s.s	Speed of vessel relative to water	Km/hour
K	Units	n/a
*hh	Checksum	n/a

$VDVLW,0005293.53,N,0005293.53,N*5F
$VDVLW,xxxxx.xx,N,yyyyy.yy,N*hh

Item	Definition	Units
xxxxx.xx	Total cumulative distance of vessel travel	knots
N	Units	n/a
yyyyy.yy	Distance recorded since reset of DS-50 unit	knots
N	Units	n/a
*hh	Checksum	n/a

$VDVBW,011.04,000.09,A,011.04,000.09,V*46
$VDVBW,xxx.xx,yyy.yy,A,zzz.zz,ttt.tt,V*hh

Item	Definition	Units
xxx.xx	Longitudinal water speed	knots
yyy.yy	Transverse water speed	knots

A	**Status: water speed, A=data valid, V=data invalid**	**n/a**
zzz.zz	**Longitudinal ground speed**	**knots**
ttt.tt	**Transverse ground speed**	**knots**
V	**Status: ground speed, A=data valid, V=data invalid**	**n/a**
***hh**	**Checksum**	**n/a**

FE700 Navigational Echosounder data

The FE700 Navigational Echosounder outputs data in the following formats

- $PFEC - unspecified
- $SDDBT - Depth Below Transducer
- $SDDBS - Depth Below Surface

$PFEC ,aaaa,x,x*hF

PFEC sentence format

Item	Definition	Units
aaaa	unspecified	unspecified
x	unspecified	unspecified
x	unspecified	unspecified
*hF	unspecified	unspecified

$DBT,x.x,f,x.x,M,x.x,F*hh

SDDBT sentence format

Item	Definition	Units
x.x	Water depth	feet
f	f = feet	n/a
x.x	Water depth	meters
M	M = meters	n/a
x.x	Water depth	fathoms
F	F = fathoms	n/a
*hh	Checksum	n/a

$DBS,x.x,f,x.x,M,x.x,F*hh

SDDBS sentence format

Item	Definition	Units
x.x	Water depth	feet
f	f = feet	n/a
x.x	Water depth	meters
M	M = meters	n/a
x.x	Water depth	fathoms
F	F = fathoms	n/a
*hh	Checksum	n/a

Geometrics G-882 Cesium Marine Magnetometer Data

The G-822 Cesium Marine Magnetrometer converts the cesium Larmor signal (70 kHz to 350 kHz) into magnetic field strength in nano-Teslas (20,000 nT to 100,000 nT) by using a CM-221 counter module. The G-882 outputs magnetic field strength in the following serial sentence format:

FILE NAME: ***MGL-mag01.y****d****

mag01 2015:114:00:17:32.7965 $ 49034.313,0781,0876
mag01 yyyy:ddd:hh:mm:ss.ssss $ xxxxx.xxx,aaaa,bbbb

Item	**Definition**	**Units**
xxxxx.xxx	Magnetic Field Strength (nano Teslas)	nT
aaaa	A/D channel 0 (9999 full scale, 0 to +5 volts) *Not Used	n/a
bbbb	A/D channel 1 (9999 full scale, 0 to +5 volts) *Not Used	n/a

Kongsberg EM122 Multibeam – Center Beam Depth Data

The EM122 multibeam depth datagram from a single beam echo sounder are output for logging in the following NMEA 0183 DPT serial sentence format:

FILE NAME: ***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,rrrrr.r*##

Item	*Definition*	*Units*
KIDPT	**Talker identifier and sentence formatter**	**n/a**
xxxx.xx	**Seafloor bottom depth from transducer face**	**Meters**
z.zz	**Offset of transducer from waterline of vessel calculated using heavy compensation from Kongsberg Seapath 200 MRU**	**Meters**
rrrrr.r	**Maximum range scale in uses by system**	**Meters**
***##**	**Checksum**	***hh**

SEAPATH 200 Intertial Navigation System

SEAPATH outputs data in NMEA format using the following sentence formats:

- 1. $INGGA-Global System Position Fix Data
- 2. $INHDT-Heading - True data
- 3. $INVTG-Course over ground and Ground speed data
- 4. $INZDA-Time and date

$INGGA, hhmmss.sss, llll.lllll, a, yyyyy.yyyyy, b, t, nn, v.v, x.x, M,,,c.c,rrrr*hh

$INGGA-Global System Position Fix Data

Item	Definition	Value	Units
$INGGA	Header	$INGGA	
hhmmss.sss	UTC time of position	n/a	Hours/Minutes/Seconds.decimal. Two fixed digits of hours. Two fixed digits of minutes. Two fixed digits of seconds. Three digits for decimal fractions of a second.
llll.lllll	Latitude	-90 to +90	DegreeslMinutes.decimal. Two fixed digits of degrees Two fixed digits of minutes Five digits for decimal minutes.
a	N (north) or S (south)	N or S	
yyyyy.yyyyy	Longitude	-180 to +180	Degrees/Minutes.decimal. Three fixed digits of degrees. Two fixed digits of minutes. Five digits for decimal minutes.
b	E (east) or W (west)	E or W	
t	GPS Quality Indicator	0 = Fix not available or invalid 1 = CIA standard GPS; fix valid. 2 = DGS mode; fix valid. 3 = PPP mode; fix valid. 4 = RTK fixed 5 = RTK float 6 = free inertial	
nn	Number of satellites used in fix	0 to 32	
v.v	Horizontal dilution of precision		
x.x	Altitude of the IMU above or below the mean sea level. A negative value indicates below sea level.	n/a	Metres
M	Units of measure = metres	M	

Null	Null		
Null	Null		
c.c	Age of differential corrections in records since last RTCM-104 message.	0 to 99.9	Seconds
rrr	DGPS reference station identity	0000 to 1023	
*hh	Checksum		
/CR/LF	Carriage return and line feed	/CR/LF	

$INHDT, x.x, T*hh

$INHDT-Heading - True data

Item	Definition	Value	Units
$INHDT	Header	$INHDT	
x.x	True vessel heading in the vessel frame	o to 359.99	degrees
*hh	Checksum	n/a	
/CR/LF	Carriage return and line feed	/CR/LF	

$INVTG, x.x, T,, M, n.n, N, k.k, K*hh

$INVTG-Course over ground and Ground speed data

Item	Definition	Value	Units
$INVTG	Header	$INVTG	
x.x	True vessel track in the vessel frame	0 to 359.99	degrees
T	True	T	
null	Not supported	null	
M		M	
n.n	Speed in the vessel frame	n/a	Knots
N	Knots	N	
k.k	Kilometres	K	
*hh	Checksum	n/a	
/CR/LF	Carriage return and line feed	/CR/LF	

$INZDA, hhmmss.ss, DD, MM, YYYY,, *hh

$INZDA-Time and date

Item	Definition	Value	Units
$INZDA	Header	$INZDA	

hhmmss.sss	UTC time	n/a	Hours/Minutes/Seconds.decimal. 2 fixed digits of hours 2 fixed digits of minutes 2 fixed digits of seconds Three digits for decimal fractions of a second
DD	Day of month	01 to 31	
MM	Month of year	01 to 12	
YYYY	Year		
Null	Null		
Null	Null		
*hh	Checksum	n/a	
/CR/LF	Carriage return and line feed	/CR/LF	

UDP Datagrams

In addition to the serial logs, each data stream is broadcast over the local ship's network via UDP.

```
UDP MESSAGES

33103 (C-Nav World DGPS +RTCM)
 cnav    2008:013:02:15:33.7076  $GPGGA,021533.00,2710.75894,N,09511.75255,W,2,7,1.3,10.86,M,-26.31,M,10,0108*5D
 cnav    2008:013:02:15:33.7276  $GPVTG,166.4,T,,M,3.74,N,6.93,K*69

33104 (Applanix POS/MV INS)
 posmv   2008:013:02:15:01.7342  $INGGA,021501.498,2710.78491,N,09511.75611,W,1,10,0.8,-1.51,M,,,,*11
 posmv   2008:013:02:15:01.7344  $INHDT,171.2,T*20
 posmv   2008:013:02:15:01.8504  $INVTG,168.1,T,,M,3.9,N,7.3,K*70
 posmv   2008:013:02:15:01.9667  $INGST,021501.498,,1.2,1.1,75.1,4.0,4.0,6.1*6C
 posmv   2008:013:02:15:02.0849  $PASHR,021501.498,171.25,T,0.38,-1.11,0.02,0.068,0.068,1.906,1,1*39
 posmv   2008:013:02:15:02.0850  $INZDA,021501.0000,13,01,2008,,*78

33106 (Simrad Seapath 200 INS)
 seapath 2008:013:02:14:15.7873  $INZDA,021415.73,13,01,2008,,*78
 seapath 2008:013:02:14:15.9036  $INGGA,021415.73,2710.833433,N,09511.767381,W,2,10,0.8,-28.43,M,,M,0.8,0291*79
 seapath 2008:013:02:14:15.9036  $INVTG,169.86,T,,M,4.0,N,,K,D*02
 seapath 2008:013:02:14:15.9037  $INHDT,170.23,T*12

33111 (Simrad GC-80 aka "Tokamak" gyrocompass)  NOTE: NOT Sperry MK027
 gy01    2008:013:02:16:10.7810  $HEHDT,170.1,T*28
 gy01    2008:013:02:16:10.7812  $HEROT,002.86,A*17
 gy01    2008:013:02:16:11.5544  $PTKM,HEALM,0000,0,G1*09

33121 (Furuno DS50 speedlog)
 slog01  2008:013:02:16:53.9002  $VDVHW,,T,,M,04.10,N,07.59,K*49
 slog01  2008:013:02:16:54.0185  $VDVBW,004.08,-00.47,A,004.08,-00.47,V*46
 slog01  2008:013:02:16:54.0186  $VDVLW,0000966.85,N,0000966.85,N*5F

33602 (Simrad EM120 centerbeam depth)
 bath02  2008:014:17:22:01.2949  $KGDPT,1143.40,0.0,12000.0*4e

33701 (RMYoung 26700)
 wx01    2008:013:02:18:26.9205    3.0   2.8   4.2   6.3  58  58   5   0.0   0.0   0.0   0.0 355 355   0  21.1  21.0  20.9  21.1  7  7  7 1015.0

33711 (RMY relative wind to the DP autopilot)
 mwv01   2008:013:02:19:00.9197  $INMWV,57.0,R,4.4,N,A*08

33611 (Bell BGM-3 gravimeter)
 vc01    2008:013:02:19:30.9852  01:024904 01
```

LDEO PCO2 + CNav + TSG + WX01 + SBE38 Systems

PCO2 merge is a combination of outputs of various serial data in the following sentence format:

yyyyjjj.jjj aaaa.aa bb.bb cccc.cc ddd.dd e.ee fff.f gggg.gg hh i k, llll.llllllm, nnnnn.nnnnnno, pp.pppp, q.qqqqq, rr.rrrr, ss.s, ttt, uu.u, vvvv, w.ww, xxx.x, yy.yyyy

PCO2 Data

Item	Definition	Value	Units
yyyyjjj.jjj	pco2 Computer Date/Time	n/a	Year/Julian Day.decimal Four fixed digits of year. Three fixed digits of julian day. Five fixed digits for decimal fractions of a julian day.
aaaa.aa	CO2 Raw Signal	n/a	mVolts
bb.bb	CO2 Analyzer Cell Temperature	n/a	Celcius
cccc.cc	PCO2 Barometer	n/a	mbar
ddd.dd	VCO2	n/a	ppm
e.ee	Equilibrator Water Temp	n/a	Celcius
fff.f	pCO2	n/a	uatm
gggg.gg	Flow Controller	n/a	mVolts
hh	Flow Meter	n/a	cc/min
i	Sample ID #	0 to 16	integer
k	Sample ID	Equil, Atmos, Nitrogen, CC18798, CA07163, CC15551, or CC63668	alphanumeric
llll.llllllm	CNav Latitude	0 to 90, N/S	degrees/minutes.decimal/direction
nnnnn.nnnnnno	CNav Longitude	0 to 180, E/W	degrees/minutes.decimal/direction
pp.pppp	TSG Internal Temperature	n/a	Celcius
q.qqqqq	TSG Conductivity	n/a	S/m
rr.rrrr	TSG Salinity	25 to 40	ppm
ss.s	WX01 Bird 1 Wind Speed 60 sec avg	n/a	knots
ttt	WX01 Bird 1 Wind Direction 60 sec avg	0 to 360	degrees
	WX01 Temperature		

uu.u	Instantaneous	n/a	Celcius
vvvv	WX01 Ship Barometer Instantaneous	n/a	mbar
w.ww	CNav Speed Over Ground / Speed Made Good	0 to 15	knots
xxx.x	CNav Course Made Good	0 to 360	degrees
yy.yyyy	SBE38 Temperature Probe	n/a	Celcius

LDEO PCO2 System

PCO2 outputs data in the following sentence format:

yyyyjjj.jjj aaaa.aa bb.bb cccc.cc ddd.dd e.ee fff.f gggg.gg hh i k

PCO2 Data

Item	Definition	Value	Units
yyyyjjj.jjj	pco2 Computer Date/Time	n/a	Year/Julian Day.decimal Four fixed digits of year. Three fixed digits of julian day. Five fixed digits for decimal fractions of a julian day.
aaaa.aa	CO2 Raw Signal	n/a	mVolts
bb.bb	CO2 Analyzer Cell Temperature	n/a	Celcius
cccc.cc	PCO2 Barometer	n/a	mbar
ddd.dd	VCO2	n/a	ppm
e.ee	Equilibrator Water Temp	n/a	Celcius
fff.f	pCO2	n/a	uatm
gggg.gg	Flow Controller	n/a	mVolts
hh	Flow Meter	n/a	cc/min
i	Sample ID #	0 to 16	integer
k	Sample ID	Equil, Atmos, Nitrogen, CC18798, CA07163, CC15551, or CC63668	alphanumeric

Seabird Electronics SBE-45 Thermosalinograph Station Data

* Includes SBE-38 Remote Temperature Sensor Data

The Thermosalinograph data from the Seabird 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 NAME: ***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.ccccc, s= ss.ssss, sv=vvvv.vvv, t2= tt.tttt

Item	**Definition**	**Units**
T1	Temperature from SBE 45 - TSG	°C, ITS-90
C1	Conductivity from SBE 45 - TSG	S/m
S	Salinity calculated from T1 and C1 by SBE 45	psu
SV	Calculated sound velocity based on S (or T1 and C1) from the SBE 45 and Temperature (T2) from the SBE 38. Using the Chen-Millero calculation.	Chen-Millero, m/sec
T2	Temperature from SBE 38 – Remote Temperature (USS)	°C, ITS-90

Gyroscope data

The gyroscope serial data is output in the following sentence formats:

- PTKM,HEALM -- Unspecified
- HEHDT -- Heading - True
- HEROT -- Rate Of Turn

$PCICM,HEALM,xxxx,x,xx*hh

ALM sentence format

Item	Definition	Units
xxxx	unspecified	n/a
x	unspecified	n/a
*hh	unspecified	n/a

$HEHDT,xxx.x,T*hh

HDT sentence format

Item	Definition	Units
xxx.x	Heading true	degrees
T	T = true	n/a
*hh	Checksum	n/a

$HEROT,-xxx.x,A*hh

HEROT sentence format

Item	Definition	Units
xxxx.x	Rate of turn	Degrees per minute, Note: "-" means bow turns to port
A	A = data valid	n/a
*hh	Checksum	n/a

Streamer Tension Unit Data

STU outputs data in the following sentence format:

aaa bbb cc dd ee f g hhhh iiii jjjj kkkk l m nnnn oooo pppp qqqq r s tttt uuuu vvvv wwww x y zzzz !!!! @@@@

STU Data

Item	Definition	Value	Units
aaa	na	n/a	n/a
bbb	Julian Day	1 to 366	day
cc	Hour	0 to 24	integer
dd	Minutes	0 to 60	integer
ee	Seconds	0 to 60	integer
f	# 1 ID	1	integer
g	# 1 Channel #	0	integer
hhhh	# 1 Peak Tension	n/a	lbs
iiii	# 1 Average Tension	n/a	lbs
jjjj	# 1 Delta Tension	n/a	n/a
kkkk	# 1 Temperature	n/a	Celcius
l	# 2 ID	1	integer
m	# 2 Channel #	1	integer
nnnn	# 2 Peak Tension	n/a	lbs
oooo	# 2 Average Tension	n/a	lbs
pppp	# 2 Delta Tension	n/a	n/a
qqqq	# 2 Temperature	n/a	Celcius
r	# 3 ID	1	integer
s	# 3 Channel #	2	integer
tttt	# 3 Peak Tension	n/a	lbs
uuuu	# 3 Average Tension	n/a	lbs
vvvv	# 3 Delta Tension	n/a	n/a
wwww	# 3 Temperature	n/a	Celcius
x	# 4 ID	1	integer
y	# 4 Channel #	3	integer
zzzz	# 4 Peak Tension	n/a	lbs
!!!!	# 4 Average Tension	n/a	lbs

@@@@	# 4 Delta Tension	n/a	n/a
####	# 4 Temperature	n/a	Celcius

Vane Tension Load Cell Units Data
(Omega DP41-S High Performance Strain Gauge Indicators)

The Omega DP41-S Strain Gauges are directly linked to the Port and Starboard Seismic Streamer Barovane Tension Load Cells, the units are calibrated and output voltages to the Omega unit for conversion into Pounds (Lbs.) The Vane Tension Load data is output in the following serial format:

FILE NAME: ***MGL-vanep.y****d*** / MGL-vanes.y****d****

vanep 2015:171:23:59:59.9061 029096.
vanep yyyy:ddd:hh:mm:ss.ssss xxxxxxx.

Item	Definition	Units
xxxxxx	Strain force measured by load cell (pounds) to the nearest whole number	lbs