MGL2304 Cruise Report

Marine IGUANA
Marine Imaging of Galápagos Upwelling and Neighboring Archipelago

March 17th to April 15th, 2023
Balboa, Panama to San Cristobal, Galápagos, Ecuador

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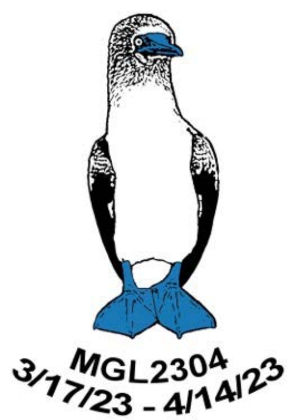
co-Chief scientist: Brandon VanderBeek (University of Padua)



An Open Access Experiment to Image Galápagos Plume-Ridge Interaction

National Science Foundation Division of Ocean Sciences Grant #1928197

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May 19, 2023

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Operations Summary

We deployed 53 broadband ocean bottom seismometers without incident and in pervasive calm weather. We completed multibeam seafloor mapping between the sites and within the northern Hermandad marine reserve. We also measured gravity, magnetics, air and seawater temperature, salinity, and ocean currents down to 400 m.

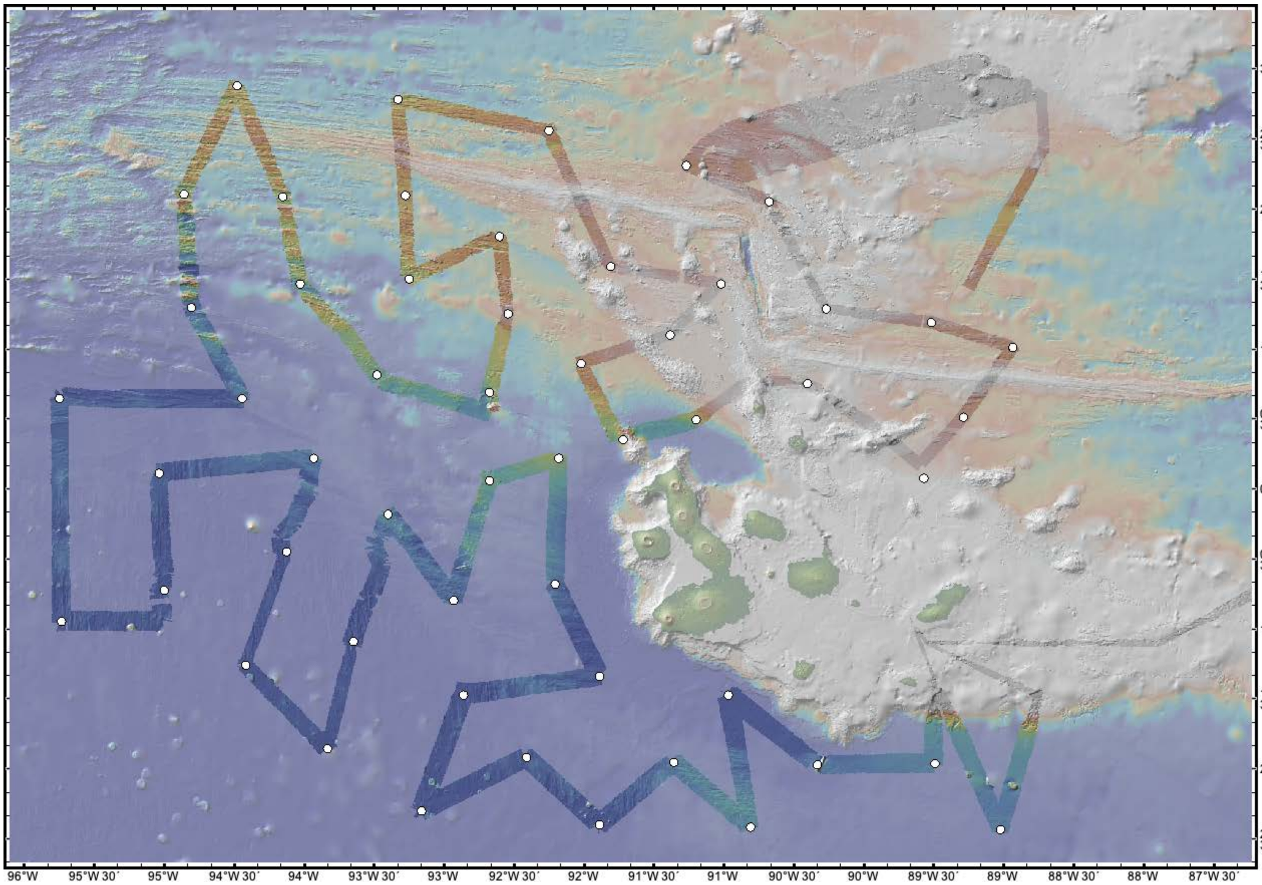


***Figure** 1. Map of ocean bottom seismometer locations (white dots) showing acquired multibeam bathymetry on top of existing global multi-resolution topography data (v 4.1).*

Science Overview

The objective of this Project is to seismically visualize the Galápagos mantle plume and its interaction with the expansion center of Western Galápagos.

The ocean bottom seismometer (OBS) experiment has three main design goals to answer three main scientific questions (SQs) (described in more detail in section 6.1):

(1) Determine the thickness of the plume reservoir material in the depth range of 50 to 300 km

(2) Map the lateral distribution of the plume reservoir over an area large enough to distinguish between channeled versus plume flow and detect possible ambient pressure-driven flows in the asthenosphere

(3) Verify the presence of small-scale convection and delineate its scale and nature and determine the spatial distribution of the molten material and the compositional heterogeneity of the associated mantle.

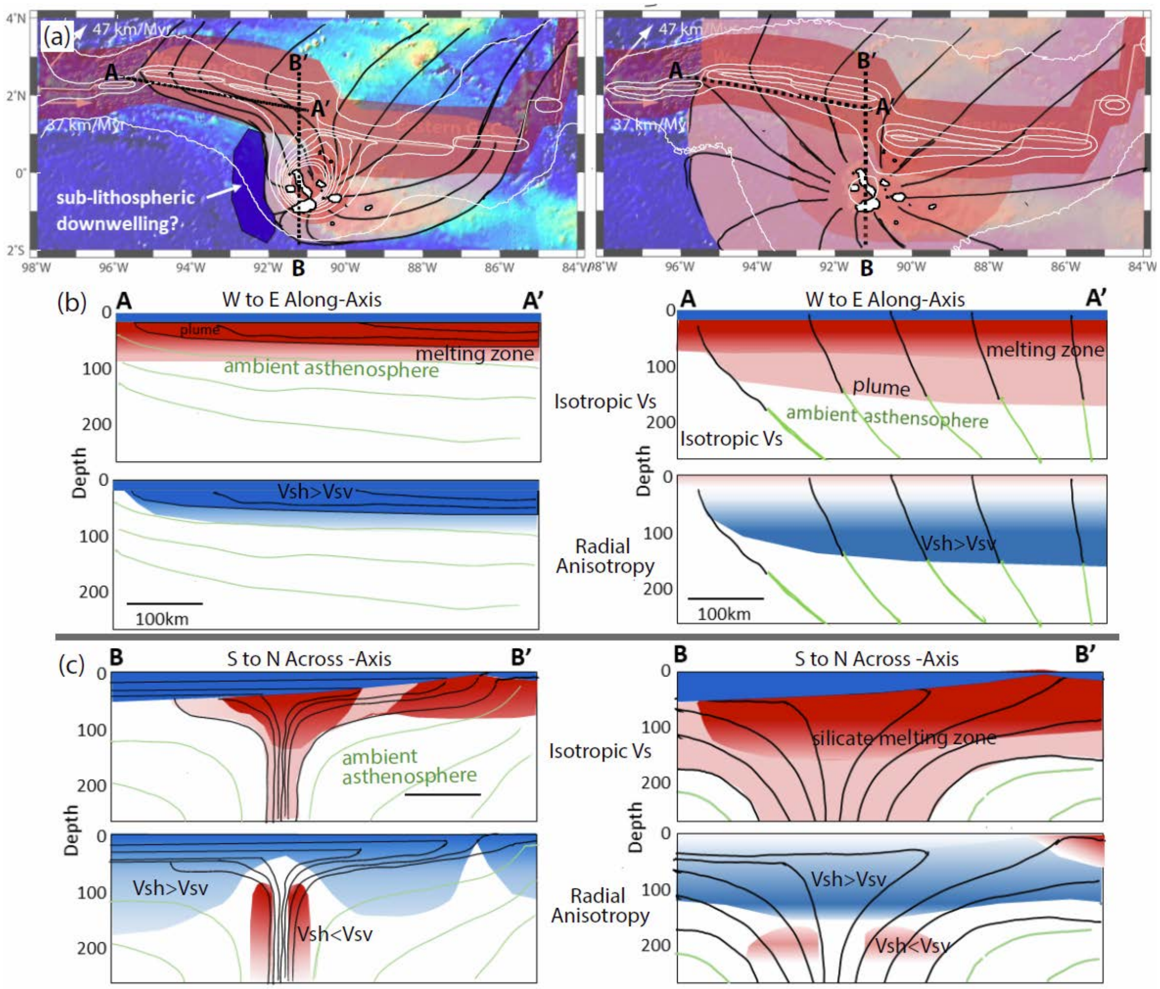


Figure 2. *Schematics of plume-ridge interaction regimes inspired by 3D geodynamic models by Ito and Bianco (2014) with seismic anisotropy calculated by Ito et al. (2014). The left column: low viscosity, thin plume with channel flow. Right column: High-viscosity surface layer dehydrated by melting silicates resulting in thick plume and radial flow. Black flux lines are from material flux from the plume, green flux lines are for asthenospheric flow. (Row a): Material maps of the plume (pink) and the fade zone (red). White contours are integrated melt volumes calculated with representative geodynamic models (model 1, left, and model 2, right). (Row b): West-East section along the GSC (A-A´). The upper panel shows schematics of the isotropic velocity structure of the lithosphere (blue), plume (pink), and molten zone (red). In the left panel, the molten zone is pink and the plume layer is red. Bottom panels show radial anisotropy patterns VSH > VSV (blue) and VSH < VSV (red) (c) Similar to (b) but for south-north sections, crossing the plume and Galápagos ridge (Galápagos spreading center, GSC). The plume material is pink and the melt zone is red.*

Experiment Design

To address the science questions, an open-access seismic experiment has been planned, designed to produce the first visualization of the interaction between the Galápagos mantle plume and the Galápagos mid-ocean ridge. 53 broadband ocean bottom seismometers will be installed for 15 months in an array covering the area between the Galápagos Islands and the Western Galápagos Spreading Center (GSC). Data from 7 existing broadband stations on the islands will also be used: the PAYG station of the Global Seismic Network (https://earthquake.usgs.gov/monitoring/operations/stations/IU/PAYG/) and 6 new stations of the permanent network operated by our collaborators in Ecuador (Geophysical Institute, IG-EPN).

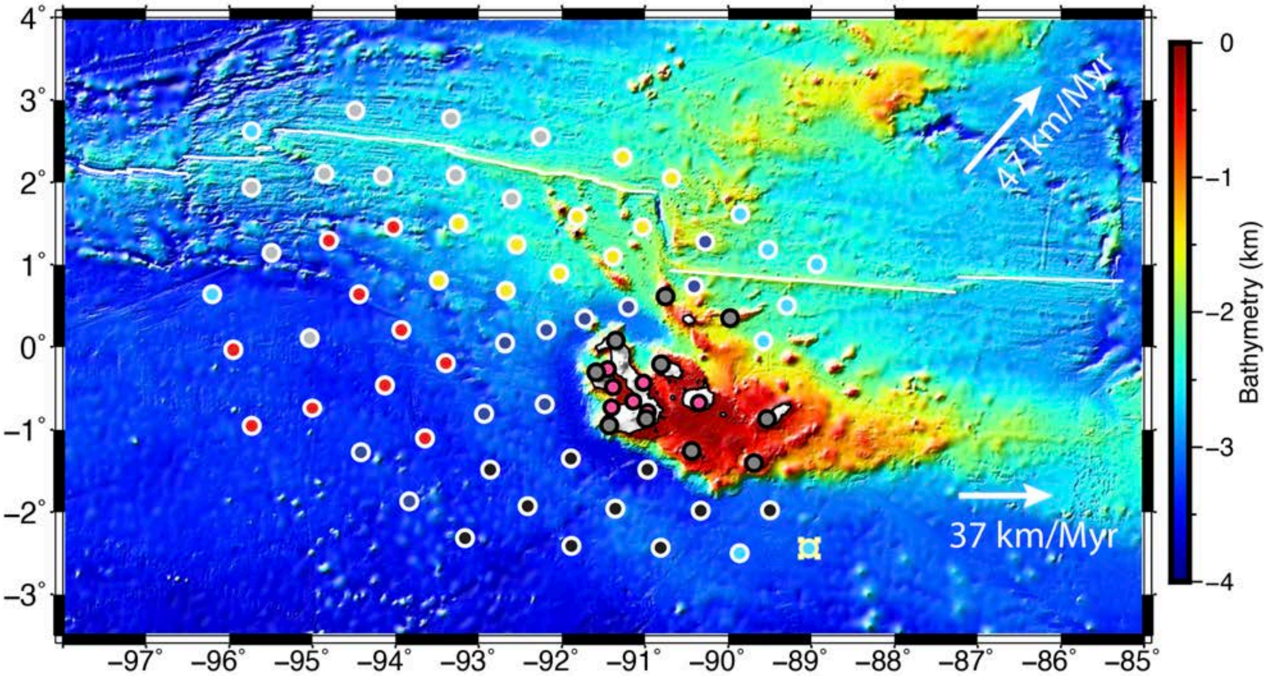


Figure 3. *Array Design. 53 Ocean Floor Seismometers will be installed from the US research vessel Marcus Langseth. 59 tentative sites are shows with white borders (colors indicate groups of 10 stations to facilitate counting) and correspond to the locations where the equipment will be installed, including some additional backup locations if necessary. The analysis will also include data from previous installations on the islands (IGUANA 1999-2003, gray circles) and existing data from the current network of seismographs of the Geophysical Institute (pink circles) and the PAYG station of the Global Seismic Network in Santa Cruz.*

The experiment and subsequent analyses are designed to answer three main scientific questions:

* SQ1) At what depths, in what geographic pattern, and by what mechanisms, does the mantle plume material flow north to the Galápagos Spreading Center (GSC) and disperse along the ridge? What is the role of the ambient mantle circulation, including the return flow to the asthenosphere? What is the implication of the thickness of the plume layer below the GSC on the origin of geochemical gradients along the GSC?
* SQ2) Does the scale and nature of the heterogeneity indicate small-scale sub-lithospheric convection of the GSC? If so, how does this influence the flow of material from the plume along the base of the lithosphere?
* SQ3) What is the spatial distribution of the melting and release of volatiles, as well as the associated heterogeneities in composition and rheology due to plume-ridge interaction?

Beyond the interaction of the Galápagos plume and the ridge, the project will fundamentally advance the understanding of the chemical and physical processes of the mantel plumes, the asthenosphere and their interactions with the oceanic lithosphere.

Research vessel

The R/V Marcus G. Langseth is a 235-foot, 3,834 gross ton US-flagged research vessel owned and operated by Columbia University's Lamont-Doherty Earth Observatory. The Langseth is classified by the US Bureau of Shipping and is inspected by the US Coast Guard; certified to transport a total of 55 people of which ~20 are the ship's crew.

Figure 4: *Photo of the research vessel, Marcus Langseth*

Originally constructed as an industry seismic vessel in 1991, the Langseth was acquired in 2004, modified, and outfitted to perform the tasks required of a general-purpose research vessel as part of the US Academic Research Fleet, operating under a cooperative agreement with the US National Science Foundation. In addition to its onboard seismic equipment, the Langseth is equipped with and onboard BGM-3 Gravimeter, a hull mounted 3.5 kHz Sub-Bottom Profiler, 12-kHz transducers, and a Kongsberg EM122 Multibeam array transducers for 3D bathymetric surveying. Langseth also tows a Geometrics G-882 Marine Magnetometer.

For this project in the Galápagos, the Langseth will be deploying 53 Ocean Bottom Seismometers. The vessel will make use of the onboard and hull mounted systems listed above and the towed magnetometer. No other systems are planned to be used for this project.

Ocean bottom seismometers

The broadband underwater seismometers would come from the US academic group, OBSIC, https://obsic.whoi.edu, and will be installed and recovered by a team of specialized technicians. The instruments are completely passive and non-invasive. The instrument is dropped over the side of the ship and sinks to the bottom of the sea by gravity. Once on the seabed, it measures very small ground movements in three spatial directions and changes in seawater pressure; this data is recorded on an internal disk. After 15 months, the ship returns to retrieve the instrument and sends out a coded acoustic signal. The instrument constantly listens for this very specific code, which causes the instrument to drop its anchor and float to the surface by its own buoyancy. Once on the sea surface, the instrument is identified by ship's personnel by means of a top-mounted flag or strobe light. It is then recovered with a stick and hook.

For this project we used three types of instruments 10 new Nanometrics T240 sensors, 18 Nanometrics Trillium Compact sensors, and 23 Nanometrics Trillium Compacts in a sphere. Details in Appendix A.

Permitting process

Galápagos National Park	*Ecuadorian Navy (INOCAR)*
• Application (14 p.) • Approval (3 p.) & Addendum (1 p.) • Certificado de Transuente (4 p.) • Aviso de Viaje & Addendum (3 p. & 1 p.) • Multibeam survey addendum (2 p.)	• Permission (3 p.) *Instituto Geofisico* • collaboration letter (3 p.) • program budgets • NSF funding proof

Overview of Results

Map and table of deployed OBS

The OBS deployment sites were first surveyed using multibeam bathymetry and sites on steep or rough topography were moved. All sensors were deployed within 3 km of the planned location. The sensor's location on the seafloor was determined by acoustic survey using seawater velocities that were taken from the Levitus database (for March) and were verified with XBT probes throughout the study region.

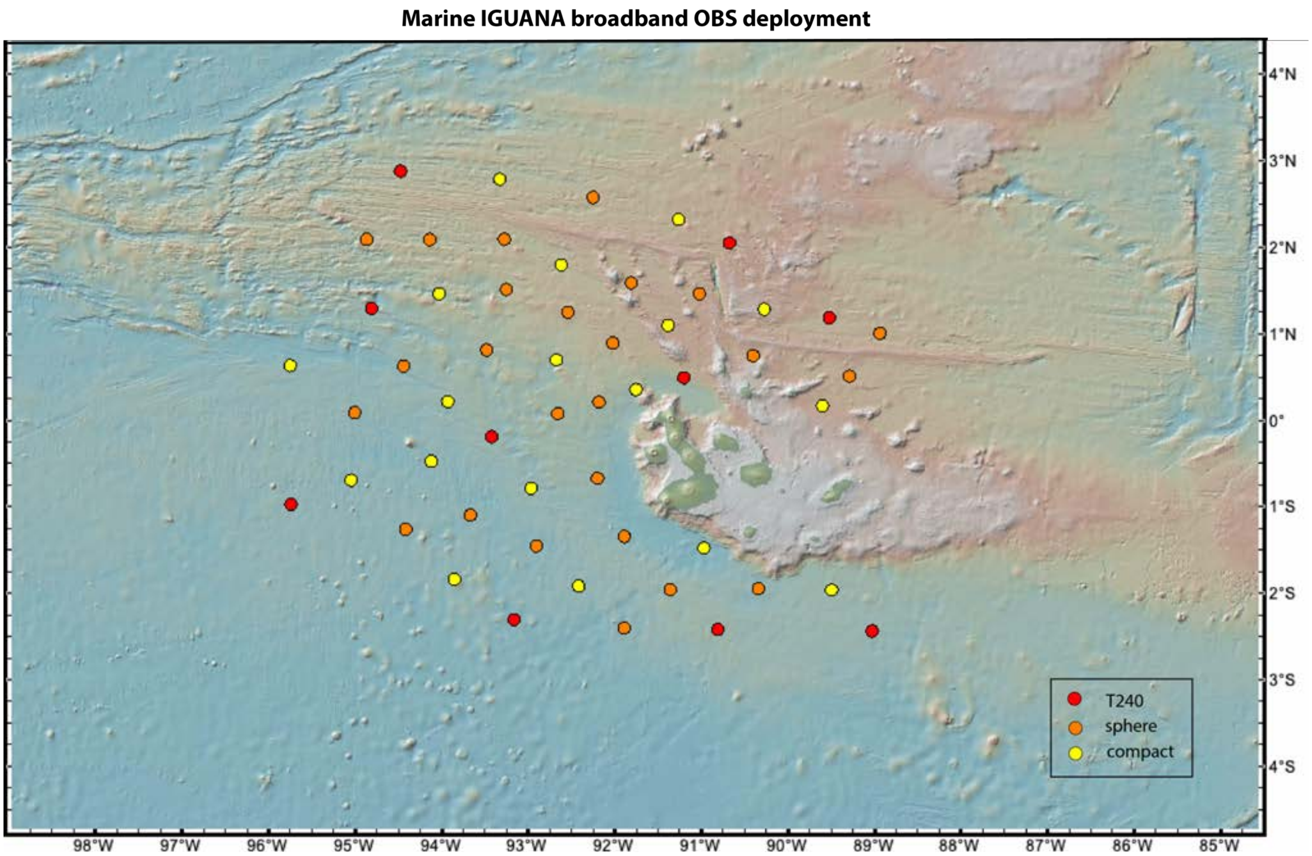


Figure 5. *Marine IGUANA array of 53 OBS deployed March & April 2023 for the Galápagos Plume-Ridge experiment.*

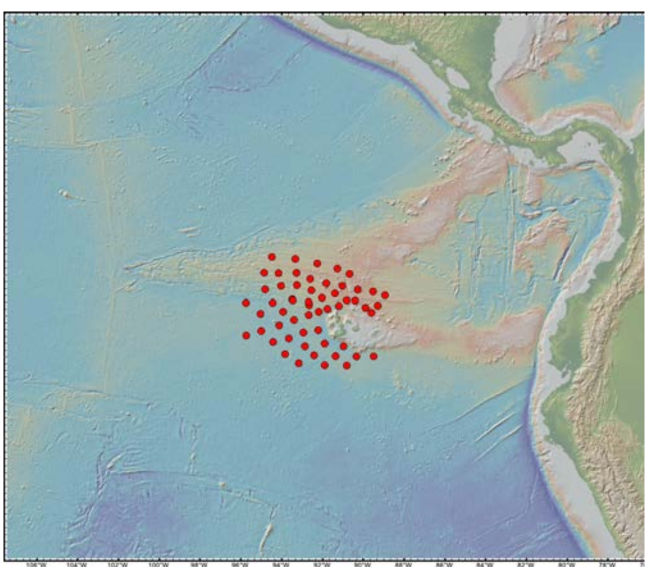


Figure 6. *The Marine IGUANA OBS array in the regional context.*

Hooft Galápagos Broadband OBS Deployment

Station Name	OBS Type	Deployment Date (UTC)	Deployment Time (UTC)	Inverted Station Latitude	Inverted Station Longitude	Station Depth (m)	95% Confidence Half-Width in E/W (m)	95% Confidence Half-Width in N/S (m)	95% Confidence Half-Width in Depth (m)
1	sphere	2023-04-08	14:00:52	1.0132	-88.9369	2352	1.4	1.5	0.4
2	sphere	2023-04-08	7:50:22	0.5157	-89.2889	2369	1.7	1.7	0.4
3	compact	2023-04-08	2:46:07	0.1747	-89.6013	2205	1.8	1.8	0.4
4	T240	2023-04-08	20:08:52	1.1931	-89.5193	2260	1.7	1.6	0.4
6	T240	2023-04-09	9:39:37	2.0564	-90.6769	2330	1.5	1.5	0.4
7	compact	2023-04-09	2:39:37	1.2915	-90.2716	1642	1.7	1.7	0.5
8	sphere	2023-04-07	18:53:37	0.7564	-90.4024	2134	2.0	1.9	0.5
9	T240	2023-04-07	11:32:37	0.4995	-91.2001	2716	1.5	1.4	0.4
10	compact	2023-04-06	16:57:07	1.1056	-91.3830	2092	1.7	1.8	0.5
11	sphere	2023-04-06	11:10:37	1.4694	-91.0228	2137	3.3	4.2	1.6
12	compact	2023-04-09	15:37:37	2.3286	-91.2637	2384	1.6	1.6	0.4
13	sphere	2023-04-06	4:15:07	1.5960	-91.8080	2313	1.5	1.7	0.5
14	compact	2023-04-04	13:35:52	1.8038	-92.6189	2489	1.5	1.4	0.4
15	sphere	2023-04-05	18:39:22	2.5843	-92.2501	2389	2.0	1.7	0.5
16	compact	2023-04-05	9:27:07	2.7949	-93.3285	2668	1.4	1.4	0.4
17	sphere	2023-04-05	2:50:52	2.0987	-93.2777	2586	1.4	1.7	0.4
18	sphere	2023-04-04	20:16:22	1.5202	-93.2519	2716	1.3	1.2	0.4
19	compact	2023-04-03	9:11:52	1.4682	-94.0306	3055	1.4	1.4	0.4
20	sphere	2023-04-03	17:29:07	0.8205	-93.4794	2939	1.5	1.5	0.4
21	compact	2023-04-04	2:30:07	0.7071	-92.6766	2980	1.5	1.5	0.4
22	sphere	2023-04-04	8:11:37	1.2568	-92.5439	2355	1.8	1.9	0.5
23	sphere	2023-04-06	23:26:37	0.9001	-92.0216	2414	1.5	1.6	0.4
24	compact	2023-04-07	6:03:07	0.3636	-91.7568	2876	1.7	1.6	0.4
25	sphere	2023-03-27	21:09:07	0.2167	-92.1838	2845	1.4	1.4	0.4
26	sphere	2023-03-28	3:47:52	0.0857	-92.6597	2945	1.3	1.3	0.4
27	T240	2023-03-28	19:52:37	-0.1830	-93.4209	3114	1.2	1.0	0.3
28	compact	2023-03-30	13:43:22	0.2231	-93.9307	3199	1.4	0.9	0.3
29	sphere	2023-04-01	18:43:52	0.6349	-94.4401	3239	1.4	1.4	0.4
30	T240	2023-04-02	2:18:22	1.2999	-94.8080	3250	1.3	1.3	0.3
31	sphere	2023-04-02	10:18:52	2.0998	-94.8660	2746	1.5	1.8	0.4
32	sphere	2023-04-03	2:28:52	2.0958	-94.1394	2821	1.5	1.4	0.4
33	T240	2023-04-02	18:07:52	2.8879	-94.4777	2628	1.6	1.6	0.4
37	compact	2023-04-01	7:37:37	0.6404	-95.7514	3312	1.4	1.4	0.4
39	T240	2023-03-31	18:28:52	-0.9632	-95.7405	3336	1.5	1.3	0.3
40	compact	2023-03-31	9:02:07	-0.6857	-95.0473	3381	1.2	1.3	0.3
41	sphere	2023-03-30	23:57:37	0.0968	-95.0055	3342	1.3	1.4	0.4
42	compact	2023-03-30	6:21:07	-0.4653	-94.1213	3390	1.4	1.4	0.4
43	sphere	2023-03-29	21:39:07	-1.2543	-94.4167	3351	1.3	1.3	0.4
44	compact	2023-03-29	13:51:52	-1.8313	-93.8518	3410	1.9	1.7	0.4
45	sphere	2023-03-29	5:40:52	-1.0878	-93.6678	3401	1.5	1.4	0.4
46	compact	2023-03-28	12:28:07	-0.7789	-92.9658	3271	1.4	1.3	0.4
47	sphere	2023-03-27	12:23:52	-0.6645	-92.2008	3210	1.4	1.3	0.4
48	sphere	2023-03-27	4:04:43	-1.3364	-91.8914	3306	1.3	1.1	0.3
49	sphere	2023-03-26	18:30:13	-1.4457	-92.9080	3413	1.3	1.3	0.3
50	T240	2023-03-26	9:29:42	-2.2971	-93.1627	3500	1.3	1.3	0.3
51	compact	2023-03-26	1:31:37	-1.9100	-92.4170	3356	1.4	1.4	0.4
52	sphere	2023-03-25	18:05:51	-2.3945	-91.8900	3431	1.3	1.3	0.3
53	sphere	2023-03-25	11:02:06	-1.9500	-91.3610	3137	1.4	1.5	0.4
54	T240	2023-03-25	4:14:36	-2.4119	-90.8120	3110	1.4	1.4	0.4
56	T240	2023-03-23	2:47:34	-2.4299	-89.0249	3161	1.2	1.3	0.4
57	compact	2023-03-24	3:17:36	-1.9576	-89.4941	3129	1.0	1.1	0.3
58	sphere	2023-03-24	11:20:36	-1.9414	-90.3423	3147	1.4	1.3	0.4
59	compact	2023-03-24	18:57:36	-1.4702	-90.9698	3606	1.3	1.3	0.3

** two OBS (S33 and S81) overheated in the sun on deck and were cooled and stabilized prior to deployment.*

OBS recovery planning

A first draft attempt to outline an OBS recovery track is shown below. The goal is to both optimize the shortness of the ship track and the amount of new multibeam bathymetry coverage. An additional goal is to constrain the tectonic history and structure of the incoming lithosphere. A particularly unknown aspect is the history of the oldest GSC or Cocos-Nazca spreading center.

This proposed track should be re-evaluated using the most up-to-date bathymetry from GMRT and by communicating with Dan Fornari. Further work also needs to be one on delineating the trace of the triple junction from existing data, deciding on an area for which to permit bathymetry and magnetic mapping, and laying out survey lines within this region.

Marine IGUANA broadband OBS deployment

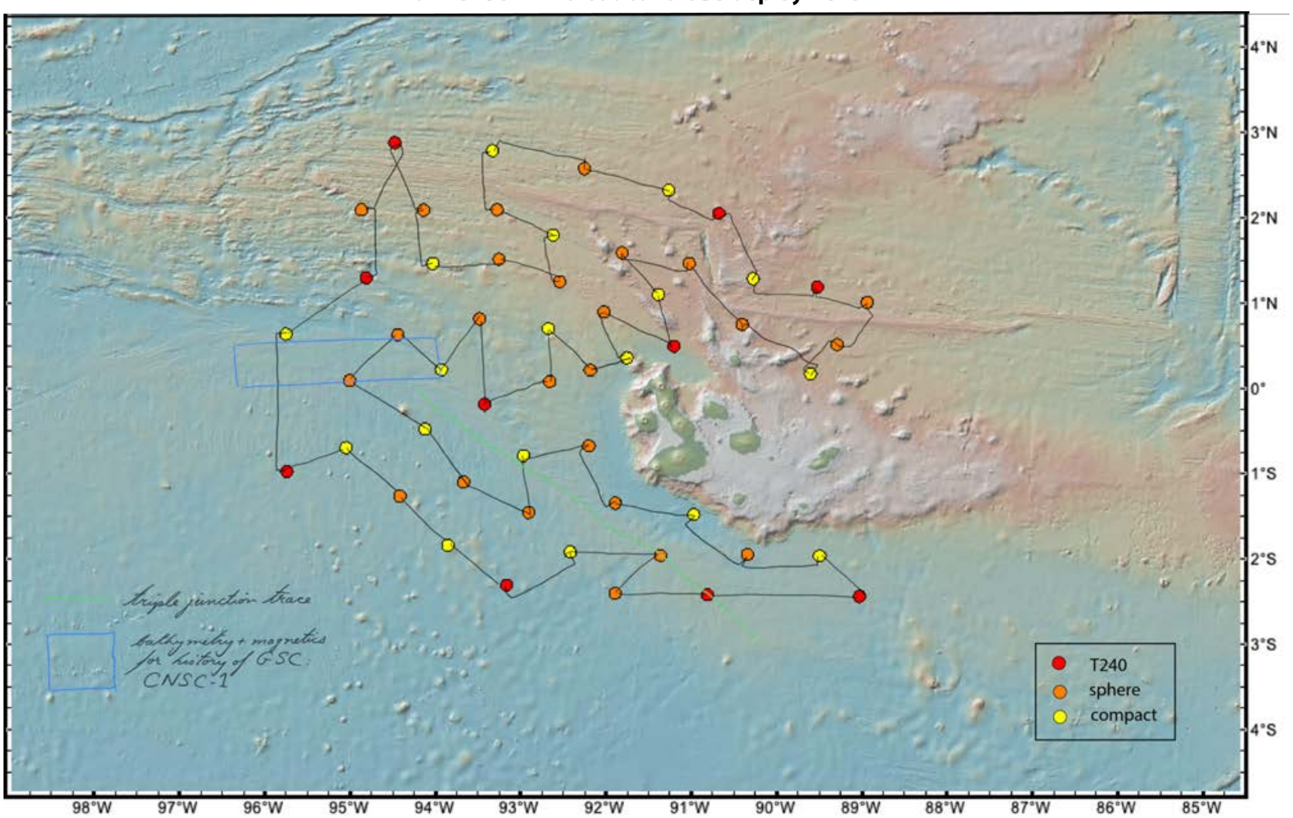


Figure 7. First draft of an OBS recovery track. The green line shows the trace of the triple junction (the join between crust formed at the EPR and at the GSC) from Brackhausen (Meschede & Brackhausen, 2000; Brackhausen et al., 2001) – uncertain portions are indicated by dashes. The blue box is a region for which we should permit additional multibeam and magnetics mapping to better map the history of the oldest portion of the GSC.

Seafloor maps

Seafloor bathymetric coverage of most of the region is sparse particularly to the south and west of the Galápagos archipelago. The OBS deployment track was designed to optimize for a short deployment time and increased bathymetric coverage. Details on multibeam bathymetry mapping and processing are provided in Appendix E. After the OBS deployments were completed, we did a 4+ day mapping program of Ecuador's new Hermandad Marine Reserve – established just 1 year ago.

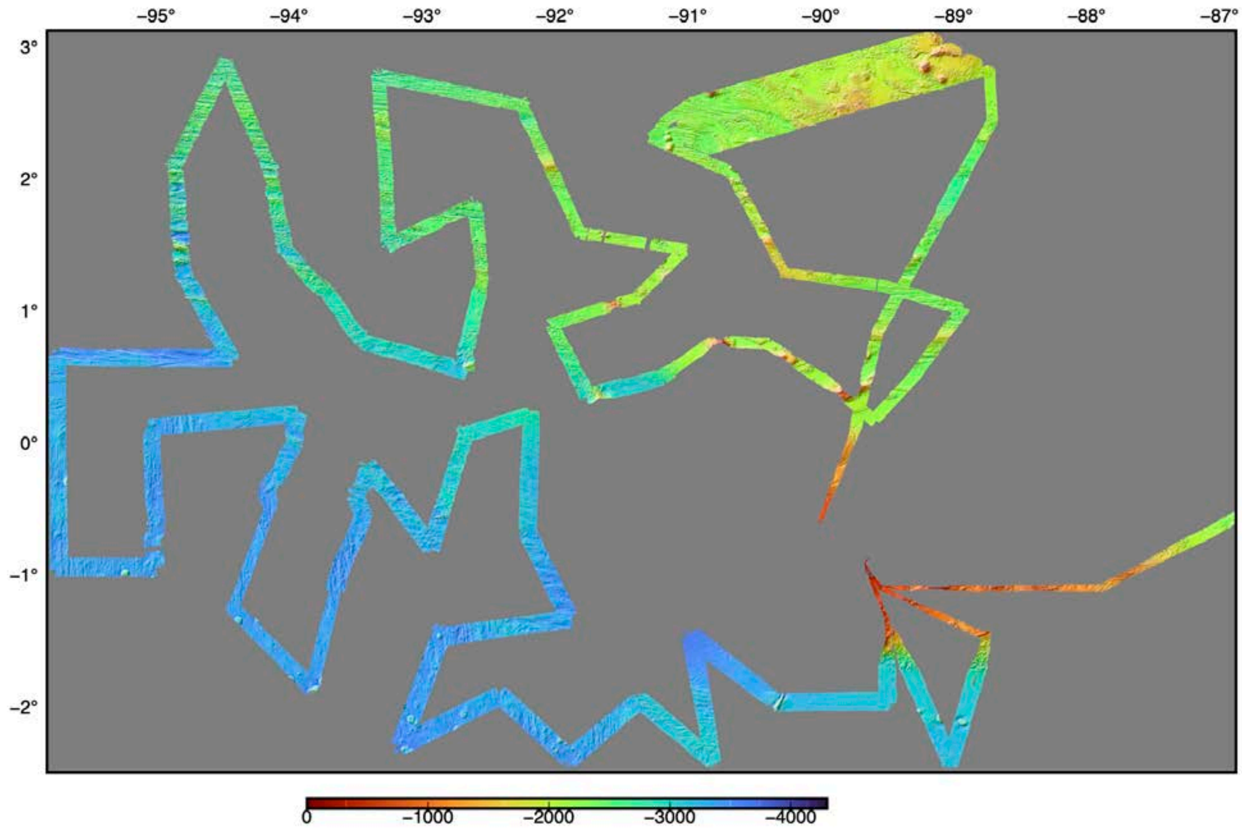


Figure 8. *Seafloor map from MGL2304.*

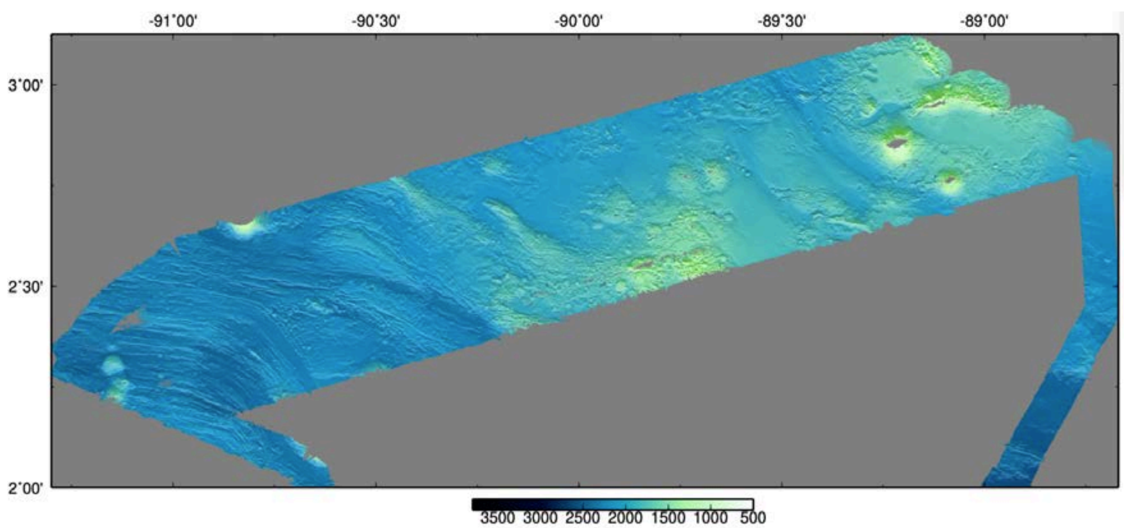


Figure 9. *Multibeam bathymetry map of the Hermandad Marine Reserve made on MGL2304. Grid is at 100 m resolution, shaded relief is lit from the south.*

Equatorial undercurrent (EUC)

On Cruise MGL2304 we also measured the Equatorial Undercurrent (EUC). The current flows along the equator in the Pacific Ocean and plays a crucial role in the Earth's climate. Upwelling is the process by which cold, nutrient-rich water rises to the surface, supporting the growth of phytoplankton and other marine life. The Galápagos Islands are a unique ecosystem that is heavily influenced by ocean currents and upwelling. Understanding these processes is critical to predicting changes in the region's climate and ecosystem.

The cruise path took us right over the EUC a few times. The ADCP measured the current and temperature at depths around 100 m where the EUC is strongest. Our data are consistent with expected values; perhaps a bit higher. At some points we measured currents above 1 m/s.

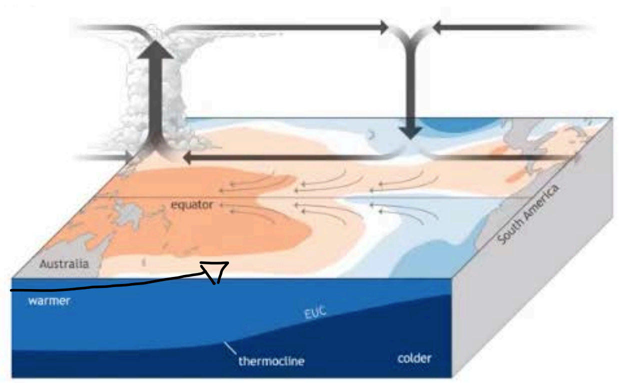


Figure 10. The EUC is a cold return flow undercurrent that travels in the opposite direction of the equatorial trade winds and causes upwelling when it hits the Galápagos.

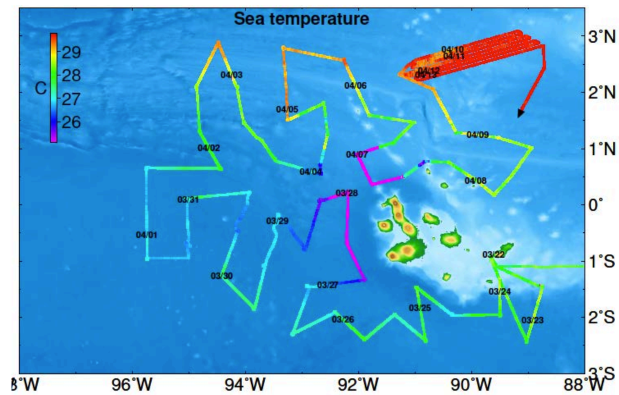


Figure 11. Surface temperatures varied consistent with regional expectations and upwelling west of Isabela.

Cruise Log

Wednesday March 15: Science team arrives in Panama and COVID testing done.

Thursday March 16: Science team prepares for cruise. Cruise related purchases made during the morning, late afternoon pre-cruise meeting (introductions, announcements, detailed instructions on boarding procedure).

Friday March 17: Boarded the R/V Marcus Langseth by motor launch in the port of Balboa, Panama. Everyone COVID tested again. Departed with warm calm weather, saw lots of wildlife.

Saturday March 18 & Sunday March 19: Transit. Everyone getting settled in. Science team did Bridge tour, Engine room tour and a tour of the onboard seismic systems as well as of the OBSs. Calm seas.

Monday March 20: Started the multibeam and 12.5 kHz echosounder once we were out of Panama and Columbia's EEZs. Weather continues warm and calm. Science watches started.

Tuesday March 21: We arrived in San Cristobal early in the morning for customs clearance and GNP inspection. Customs and all clearances went well except divers found that the hull of the R/V Langseth had not been properly cleaned. Ecuadorian participants Stephania del Cisne Añazco Rivera (GNP observer) and Francisco Mejía (Instituto Geofísico – Escuela Politécnica Nacional) joined the vessel. At the end of the day 4 divers boarded the vessel and we sailed back outside the Galápagos marine reserve during the night to a location assigned by the ship agent. Weather continues warm and calm.

Wednesday March 22: Starting at first light, the divers were in the water for 5-6 hours and worked very hard to remove seaweed and barnacles. After communications with the ship agent, Antonio Moreano, it was decided to deploy instrument 56 to the south of the Galápagos marine reserve during the night and then transit back to San Cristobal.   We developed a new deployment track that both minimizes transit time and maximizes the collection of new multibeam bathymetry.

Thursday March 23: We anchored outside the port at 10 am. The cleaning divers disembarked, and inspection divers and a GNP official came out to the vessel. This time the vessel quickly cleared hull inspect with the GNP. There was a small additional delay to disembark one person (Alan Gardner) from the science party who had a death in the family. Early afternoon we were underway again. Weather humid with rain.

Friday March 24: We deployed OBS 57, 58, and 59. We also started deployments of the magnetometer and did the first two XBTs (both T7) during transits. Weather continues warm and calm.

Saturday March 25: We deployed OBS 54, 53 and 52. We did two XBTs while the OBS sank to the seafloor, both were XBT_T5s. Weather continues warm, some rain, and calm.

Sunday March 26: Deployed OBS 51, 50, and 49. OBS51 was moved slightly due to proximity to a steep scarp. OBS50 the flag fell off during deployment. For OBS 49 the drop point was moved as the planned location was on the steep edge at the very top of a seamount. Weather continues slightly less warm and calm. Science meeting to viewed two ISC talks: one on the Geology and the other on the Physical Oceanography of the Galápagos.

Monday March 27: Deployed OBS 48, 47, and 25. OBS 47 and OBS25 were moved away from small ridges. OBS 25 overheated when the sensor package sat in the sun. The plan is that during the day we will build instruments in the shade and then move to the A-frame close to deployment time. Science meeting to view ISC talk on Geology of the Galápagos. Science meeting to view ISC talk on Biology of the Galápagos.

Tuesday March 28: Deployed OBS 26, 46, and 27. OBS 46 was moved away from a small ridge. OBS 26 and 27 were moved away from some horseshoe-shaped topographic pits. These seem quite pervasive as crescent shaped depressions on the edges of small highs that are 75 m deep and 600-700 m wide. We think they may be due to erosional slumping of soft sediments. The survey of OBS 27 was interrupted twice because the instrument appeared to stop responding. The 1st time we switched to the secondary transponder on the OBS (T240). The second time it was discovered that the Edgetech box had failed. After this was switched (from box 35793 to 59923) the entire survey was rerun without further problems. Science meeting to view ISC talk on Geophysics.

Wednesday March 29: Underway from OBS 27 to OBS 45 several fishing boats were encountered with smaller boats out with lights on the water. We deviated from the straight line track to avoid encounters and shortened the magnetometer tether until we had passed. Noise was noticed on the Knudsen and fishing line was found tangled beneath the ship – perhaps in the sonars. This was pulled up and cut.

OBS 44 deployed near the base of a large seamount and OBS 43 deployed in smooth terrain. XBTs were done at the latter two sites. The terrain continues to be speckled with occasional flat-topped seamounts especially on the crust formed at the East Pacific Rise. Science meeting to view ISC talk on the Marine Ecosystems of the Galápagos. After OBS 43 Knudsen noise came back and one of the starboard beams of the EM122 was consistently not providing data. In addition, the swath width seems narrower on the transit from 43 to 42 (4.7 to 5 km half width) than it did from 44 to 43 (6 to 6.7 km half width) even though the water depth is about the same (3.3 km).

Thursday March 30: OBS 42, 28, and 41 were deployed. Between sites 42 and 28 there were more deviations from the track to avoid fishing vessels and gear. The magnetometer was also recovered for a 40-minute period. Seas remain calm and weather warm. Fish are attracted to the lights on the water when the ship is still in the water while the OBS is sinking. Preparations were made for an Equator crossing ceremony which will start tomorrow and end on Saturday April 1 at the evening BBQ. A valve on the reverse osmosis system #1 failed, #2 was almost rebuilt and brought online later in the day. Also, some AC issues that were resolved.

Friday March 31: Deployed OBS 40 and 39 – on the far southwestern edge of the array. Some fishing vessels around OBS 40 required a move of site and many squid were observed. The transit from 40 to 39 was planned with an additional waypoint south of OBS 40 to capture a swath of bathymetry adjacent to an existing track. However, the multibeam system had to be restarted twice after leaving the site for OBS 40 and so the first corner of that track may have been lost. The seafloor dominated by gentle N-S fabric formed at the East Pacific Rise and small flat-topped seamounts. When stopped at OBS 39 no fishing lines were found and attempts to view the sonar sled with a GoPro mounted on 3 poles that were taped together were unsuccessful.

The vessel had some new AC issues today: some areas of the ship are warm, others quite cool. The RV Atlantic contacted us at dinner time asking if we had a spare membrane for their reverse osmosis system – the two Chief Engineers are in communication. Further, in ships life all the Willing Pollywogs on board were subpoenaed and their Charges were read out loud. They are currently wearing Pollywog signs and carry a personally decorated egg everywhere they go. Tomorrow they will first participate in some watery activities to find their way to Neptune's court where they will defend themselves and justify elevation to Shellback by performance of a skit or other antics.

Saturday April 1: Equator crossing celebration (95° 45′ W) and a BBQ at dinner time! The event was enjoyed by all – 14 new Shellbacks sport magnificent certificates and laminated wallet cards. We deployed OBS 37 and 29 today. All went well. A GoPro viewing of the sonar sled showed no fishing line on it at all. The seafloor terrain predominantly more prominent ridges and valleys with E-W orientation formed at the Galápagos spreading center. There was a bit more rolling during the night and into the morning and a slight bit more wind and a few more clouds - all subtle variations on warm and calm.

***Figure 12**. 14 Willing Pollywogs were christened as new Shellbacks by Neptune, Aphrodite, and the Baby.*

Sunday April 2: We deployed OBS 30, 31, and 33 and crossed the Galápagos spreading center twice just east of the 95° 30'W propagator. The terrain was rough with no clear morphological expression of the spreading axis. Its westernmost crossing seems to be a small graben between two ridges. The back scatter intensity and Knudsen reflectivity, however, were very bright. When crossing from OBS 33 to 32 we crossed the Galápagos spreading center a second time over a slight magmatic looking rise - again noted intense backscatter strength over the young seafloor.

Monday April 3: Starboard main engine clutch and the associated main power went down early on this day (UTC date and time). Speed was reduced for about 70 minutes and then we resumed. We deployed OBS 32 shortly afterwards. OBS 19 and 20 also deployed.

Tuesday April 4: Port engine down for 20 min due to clogging of fuel filters by debris. Also learned that earlier this day there was a fuel leak in the engine room from one of the L-tanks (running from the sides of the hull and down beneath the engine room floor), which pressurized the fuel. The hole was plugged and fuel pumped out of this tank. Four OBS deployed this day: OBS 21, 22, 14, and 18.

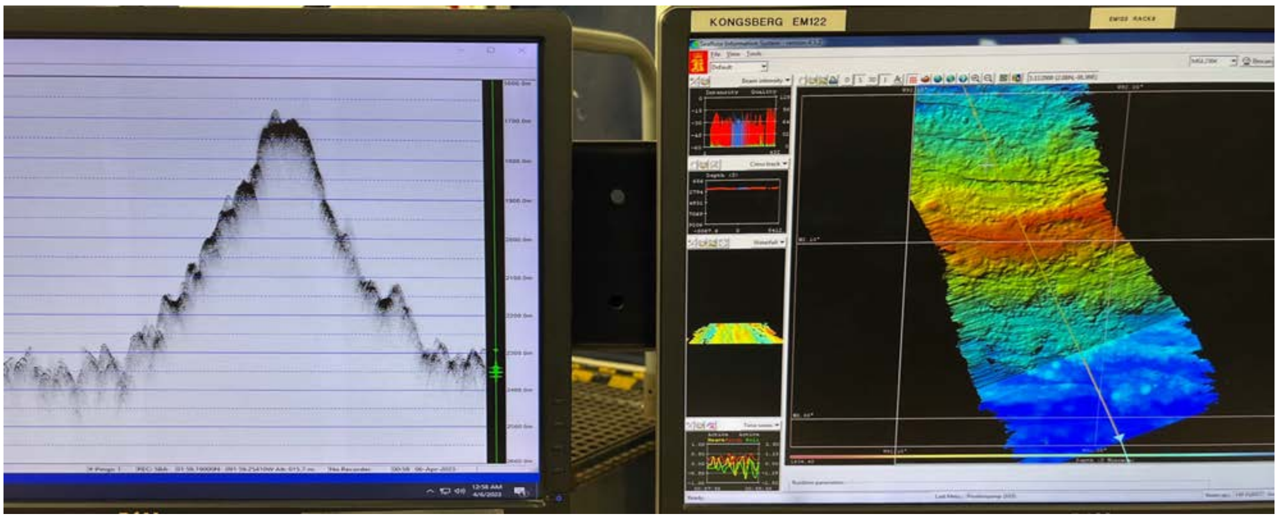


Figure 13. *Crossing of the Galápagos Spreading Center at 92°W just east of where the Wolf-Darwin lineament joins the axis.*

Wednesday April 5: OBS 17, 16, and 15 deployed. The Galápagos spreading center crossed at its westernmost crossing. The axis is a ridge broader and taller (700m) that the fast-spreading East Pacific Rise. The strong back scatter intensity on the EM122 and Knudsen was remarkable. Weather with some tropical rainstorms – some wind gusts. Still mostly calm.

Thursday April 6: OBS 13 deployed between Wolf and Darwin seamounts – no views because it was nighttime but many birds. The flat seafloor surrounding this area is quite reflective and likely magmatic in origin (sheet flows?) potentially with small amounts of sediment on top. OBS 11 deployed near the Galápagos fracture zone – the EM122 failed (red beam with no data recorded) twice during the transit from OBS 13 to OBS 11. OBS 10 and 23 also deployed. On the transit between these sites there was a clear line of ocean current changes visible on the sea surface – perhaps located at the Wolf-Darwin lineament. Crossing this boundary there was a 4°C drop in sea surface temperature and strong eastward currents on the west side.

Friday April 7: OBS 24 deployed in deep water at the base of the mostly submerged edifice of Roca Redonda just north of Volcan Ecuador. OBS 9 deployed in the deep basin north of Isabelle and OBS 8 deployed northeast of Pinta. We crossed the very shallow ridge extending northwest from Pinta island.

Saturday April 8: OBS 3, 2, 1, and 4 deployed. In the northeastern portion of the archipelago. Crossed the eastern Galápagos spreading center where it is a rise between OBS 2 and 1. Only three OBS remain to be deployed. Chief Scientist gave a talk for everyone on the science of the expedition. Another very nice BBQ and beautiful sunset.

Sunday April 9: Easter Sunday! Last OBS deployed (6 and 12). Starting multibeam survey of Hermandad marine reserve (HMR) on Line 1.

Monday April 10: Continued multibeam, magnetic, and gravity mapping of the HMR. Lines 1 and 2 completed, Line 3 started. Weather continues calm and warm.

Tuesday April 11: Continued multibeam, magnetic, and gravity mapping of the HMR. Lines 3 and 4 completed, Line 5 started. Weather continues calm and warm.

Wednesday April 12: Continued multibeam, magnetic, and gravity mapping of the HMR. Lines 5 and 6 completed, Line 7 started. Weather continues calm and warm.

Thursday April 13: Line 7 completed. Started on transit to Puerto Ayora. Track designed to run between two existing multibeam tracks. Weather continues calm and warm.

Friday April 14: The Galápagos Spreading Center was crossed again at ~89.5°W during the transit to Puerto Ayora. Arrived at port at 9 am. Science party disembarks around 11 am. Chief Scientist Hooft and Chief Science officer Bahlau do tours of the ship with visiting scientists, Director of the IG-EPN Mario Ruiz. Hooft and Ruiz meet with the Executive Director of the Charles Darwin Foundation research station, Rakan Sahawi in the late afternoon.

Saturday April 15: Science debriefing meetings for the science team.

Sunday April 16: AM - Science team travels by boat to Puerto Villamil on Isabela island. PM - Tour of coastal volcanic structures and ecosystem.

Monday April 17: Science team does a field trip to the caldera of Sierra Negra volcano to view the products of the recent volcanic eruptions. PM return by boat to Santa Cruz island.

Tuesday April 18: Most of the science team starts their return trip crossing Santa Cruz island and the Itabaca canal, then to the airport on Baltra island. From there return flights pass via the international airports on mainland Ecuador. Chief Scientist Hooft and co-Chief Scientist VanderBeek prepare reports and data sets for the scientists at the Charles Darwin Foundation research station and the Parque Nacional Galapagos.

Wednesday April 19: Chief Scientist Hooft and co-Chief Scientist VanderBeek leave the Galapagos. VanderBeek returns home. Hooft travels to Quito, Ecuador.

Thursday April 20: Chief Scientist Hooft meets with colleagues at the Instituto Geofisico, Escuela Politecnica Nacional and presents a talk on the Galápagos project and results from magma system imaging at Santorini volcano.

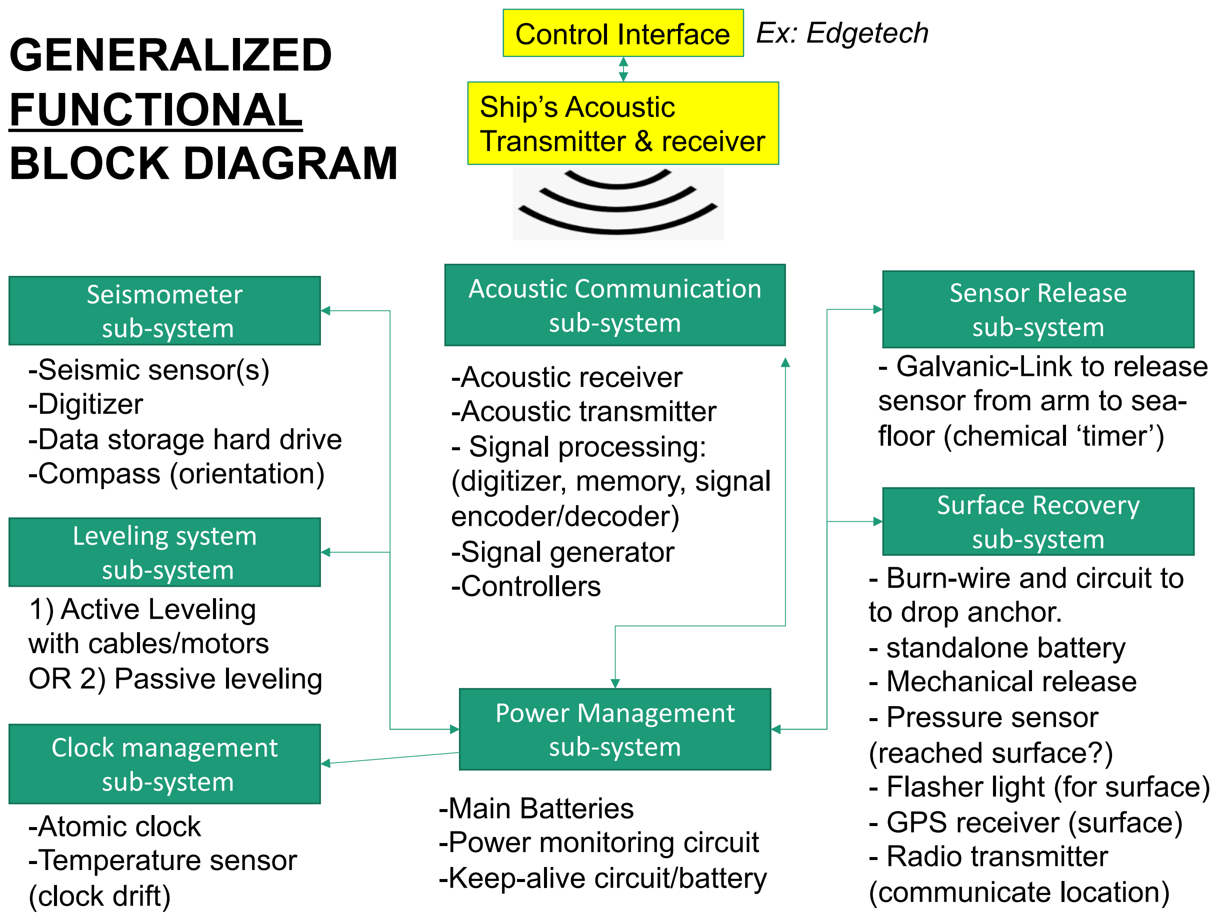
Friday April 21: Chief Scientist Hooft travels back to the US.

Appendices

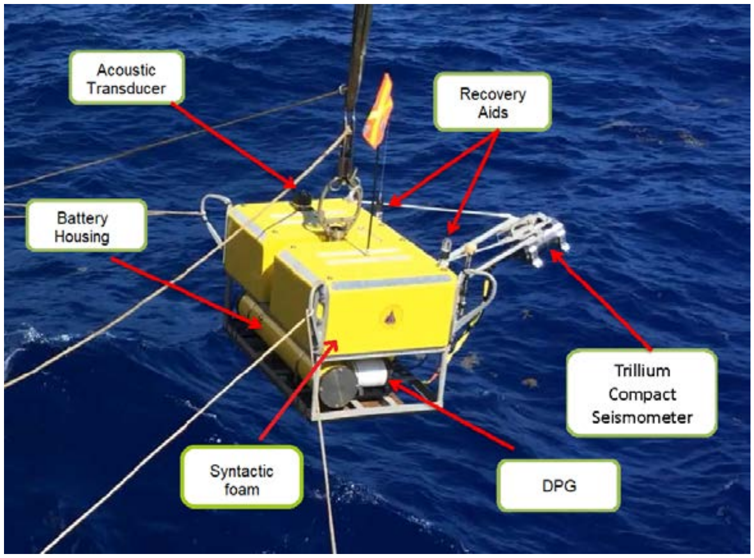
A: Ocean bottom seismometer stations

For this project we used three types of instruments 10 new Nanometrics T240 sensors, 18 Nanometrics Trillium Compact sensors, and 23 Nanometrics Trillium Compacts in a sphere.

A.1 Functional Block Diagram



A.2 ARRA Ocean-Bottom Seismometer



The ARRA OBS carries a Nanometrics Trillium Compact seismometer and a chip-scale atomic clock (CSAC), and is used for year-long monitoring of teleseismic and regional earthquakes.

Item	Specifications
Physical Attributes	Two 7075-T6 aluminum pressure housings holding: (i) 8.25” ID x 23.25” internal - data-logger, storage device, WHOI-designed controllers; (ii) 7” ID x 38.6” internal - acoustic-release board, and lithium batteries. Syntactic foam floatation: 52”x32”x15” / Finished Mass: 557 lbs nominal / Buoyancy 300 ± 27 lbs in seawater. A 257 mm long, 158 mm diameter titanium tube holds seismometer and leveling system. Leveling is via motorized gimbals. Air-weight (less 220 lb. anchor but with one-year battery pack) is 1,000 lbs. Water-weight on bottom (less sensor) is 93 lb. Buoyancy (less anchor) is 75 lb. Expected descent rate of ~55 m/min. Expected ascent rate of ~48 m/min.
Data Logger	Quanterra Q330 6-channel data engine with 24-bit A/Ds. Simultaneous sample rates of 200, 100, 50, 40, 20, 10, and 1 Hz. Quanterra Packet Baler 44 storage device with dual 16 GB flash disks (optional 64 GB capacity).
Clock	Symmetricom Chip-Scale Atomic Clock (CSAC). Drift : <~20 ms after 1 year.
Sensors	Nanometrics Trillium Compact OBS 3-axis seismometer with a velocity response that is flat from 120 s to 50 Hz. When deployed, the seismometer package is mechanically decoupled from motion of the OBS frame. Seismometer package has a water weight of 24.5 lb. Differential Pressure Gauge (DPG) long-period pressure sensor.
Recording Duration	Lithium battery pack for ~15 months recording at 40 Hz. Separate keep-alive battery for clock.
Operation	Operated in closed-housing mode i.e., programming of acquisition parameters, offloading of data, clock setting, etc., all done through penetrators. Pressure tubes carry an electronic vacuum gauge to check if the housings are sealed prior to deployment.

Information source: https://obsic.whoi.edu/instrumentation/arra-obs/

A.3 Angler Ocean-Bottom Seismometer	
	
The ANGLER OBS carries a Nanometrics T240 seismometer and a chip-scale atomic clock (CSAC), and is used for year-long monitoring of teleseismic and regional earthquakes.	
Item	**Specifications**
Physical Attributes	Two 7075-T6 aluminum pressure housings holding: (i) 8.25” ID x 23.25” internal - data-logger, storage device, WHOI-designed controllers; (ii) 7” ID x 38.6” internal - acoustic-release board, and lithium batteries. Syntactic foam floatation: 52”x32”x15” / Finished Mass: 557 lbs nominal / Buoyancy 300 ± 27 lbs in seawater. A 257 mm long, 158 mm diameter titanium tube holds seismometer and leveling system. Leveling is via motorized gimbals. Air-weight (less 220 lb. anchor but with one-year battery pack) is 1,000 lbs. Water-weight on bottom (less sensor) is 93 lb. Buoyancy (less anchor) is 75 lb. Expected descent rate of ~55 m/min. Expected ascent rate of ~48 m/min.
Data Logger	Quanterra Q8 6-channel data engine with 24-bit A/Ds. Simultaneous sample rates of 200, 100, 50, 40, 20, 10, and 1 Hz. Quanterra Packet Baler 44 storage device with dual 16 GB flash disks (optional 64 GB capacity).
Clock	Symmetricom Chip-Scale Atomic Clock (CSAC). Drift : <~20 ms after 1 year.
Sensors	Nanometrics T240 OBS 3-axis seismometer with a velocity response that is flat from 240 s to 35 Hz. When deployed, the seismometer package is mechanically decoupled from motion of the OBS frame. Seismometer package has a water weight of ~75 lb. Differential Pressure Gauge (DPG) long-period pressure sensor.
Recording Duration	Lithium battery pack for ~15 months recording at 40 Hz. Separate keep-alive battery for clock.
Operation	Operated in closed-housing mode i.e. programming of acquisition parameters, offloading of data, clock setting, etc, all done through penetrators. Pressure tubes carry an electronic vacuum gauge to check if the housings are sealed prior to deployment.

Information source: adaptation of https://obsic.whoi.edu/instrumentation/arra-obs/

Angler System Layout

Angler Instrument

- Angler Frame
- Acquisition Tube Assembly
- Battery Tube Assembly
- T240 Sensor
- Cable, Battery + RS232
- Cable, DPG, 5-Pin
- Cable, Sensor, 21-Pin
- Cable, Single Burnwire
- Cable, Single Burnwire
- Cable, Transducer, Low Profile
- Cable, Transducer, Low Profile
- DPG
  - Bulkhead, DPG, 5Pin
- Flasher
- Recovery Radio Transmitter
- Transducer, Solid
- Transducer, Solid

Angler Frame

- 9 in. Tube
- 9 in. Tube
- Half Float Pack

Assembly, Angler Acquisition Tube

- Angler Release End Cap
  - Battery, 19 Cell Release
  - Bulkhead, Burn, Low Profile
  - Bulkhead, Transducer, Low Profile
- Assembly, Angler Acquisition Chassis
  - Angler Release End Cap
    - Battery, 19 Cell Release
    - Bulkhead, Burn, Low Profile
    - Bulkhead, Transducer, Low Profile
    - PCB, Acoustic Release
  - Assembly, Angler Acquisition Tube Connector End Cap
    - Bulkhead, AT Battery
    - Bulkhead, AT DPG
    - Bulkhead, AT, Sensor
    - Bulkhead, Ser Uplink
    - Seal Vent Plug
  - Battery, Standard, Keep Alive
  - Cable, Clock Board
  - Cable, Internal Battery
  - Cable, POE Power
  - Cable, Power C-GRID
  - Cable, Q8, Network
  - Cable, Q8, Power
  - Cable, Q8, Timing
  - Cable, Q8, USB
  - Cable, Serial C-GRID
  - Cable, Serial C-GRID
  - Gigabit Ethernet Switch
  - PCB, POE Splitter
  - PCB, Power Cycled Clock Board
    - CSAC Element, Teledyne
    - PCB, Seascan with PLL
    - PCB, Q8, Main Controller
      - Serial to Ethernet Module
    - Q8
      - PCB, Q8 to Pressure Breakout
        - PCB, DPG Driver Card
      - PCB, Q8 to Seismometer Breakout
      - Thumb Drive
- Assembly, Angler AT Battery Chassis
  - Battery, 20 Cell Main, Electrochem or Battery, 20 Cell Main, Tadiran (number depends on experiment)
  - PCB, 9-Port Battery Monitor Board

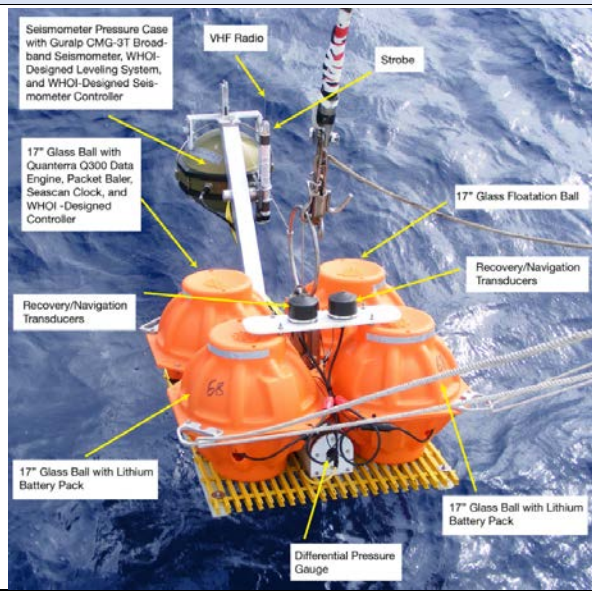
Assembly, Angler Battery Tube

- Angler Release End Cap
  - Battery, 19 Cell Release
  - Bulkhead, Burn, Low Profile
  - Bulkhead, Transducer, Low Profile
  - PCB, Acoustic Release
- Assembly, Angler BT Battery Chassis
  - Angler Battery Tube Connector End Cap
    - Bulkhead, Battery
    - Seal Vent Plug
  - Battery, 20 Cell Main, Electrochem or Battery, 20 Cell Main Tadiran (number depends on experiment)
  - PCB, 9-Port Battery Monitor Board

Assembly, T240 Sensor

- Sensor Housing Equatorial Ring Trillium
  - Bulkhead, Sensor Housing, Sensor
  - T240 Gimbal System
    - Cable, T240, Harness
    - PCB, Motor Controller for Leveler
  - T240 OBS
    - ALS, Fine Tilt Sensor
    - Cable, T240, Analog
    - Cable, T240, Digital
    - PCB, T240, Breakout
    - PCB, T240, Leveler
  - Sensor Housing Hemisphere Trillium
  - Sensor Housing Hemisphere Trillium

A.4 Broad Band Ocean-Bottom Seismometer (BBOBS)



These instruments are equipped with a Nanometrics Compact broadband seismometer and used for year-long monitoring of teleseismic and regional earthquakes.

Item	**Specifications**
Physical Attributes	Three 17" Nautilus glass ball pressure housings holding: (i) data-logger, storage device, controllers; (ii) acoustic-release board, WHOI recovery board, and lithium batteries; (iii) lithium batteries. One 17" Benthos ball for floatation. A 14" I.D. Al sphere holds seismometer and leveling system. Leveling is via a gravity-driven, 2-axis gimbal system that can be locked in place by motor-driven disk brakes mounted on each gimbal axis in order to record ground motion with high fidelity. A WHOI-designed controller is capable of locking/unlocking the seismometer masses, centering the masses, and activating/de-activating the disk brakes. The controller also carries a compass, temperature, and tilt sensor. The controller is capable of automatically monitoring seismometer tilt and initiating a leveling procedure if necessary. Air-weight (less 175 lb. anchor but with one-year battery pack) is 530 lbs. Water-weight on bottom (less sensor) is 65 lb. Buoyancy (less anchor) is 66 lbs. Descent rate: ~55 m/min. Ascent rate: ~ 48 m/min.
Data Logger	Quanterra Q330 6-channel data engine with 24-bit A/Ds. Simultaneous sample rates of 200, 100, 50, 40, 20, 10 and 1 Hz. Quanterra Packet Baler storage device with 20 GByte rotary disk drive.
Clock	Seascan low-power, digitally-temperature-compensated (DTCXO), clock with drift rate, before end-point correction, of <5 ms/day.
Sensors	Nanometrics Compact broadband seismometer with a velocity response that is flat from 120 s to 50 Hz. When deployed, the seismometer package is mechanically decoupled from motion of the Differential Pressure Gauge (DPG) long-period pressure sensor.
Recording Duration	Lithium battery pack for ~15 months recording at 40 Hz. Keep-alive battery for clock.
Operation	Operated in closed-ball mode i.e. programming of acquisition parameters, offloading of data, clock setting, etc., all done through penetrators. Glass spheres carry an electronic vacuum gauge to that can be monitored to check if the spheres are sealed prior to deployment.

Information source: https://obsic.whoi.edu/instrumentation/broadbandobs/

BBOBS System

BBOBS Instrument

- Assembly, Battery Ball 1, 17 in.
- Assembly, Battery Ball 2, 17 in.
- Assembly, Broadband Acquisition Ball
- Passive OR Active Leveling System
- Frame
  - Buoyancy Ball
- Cable, DPG 50 in. OR Cable, DPG 60 in.
- Cable, Guralp Sensor
- Differential Pressure Gauge
  - Connector, DPG Sensor
- Flasher (strobe)
- JBox
- Recovery Radio Transmitter
- Transducer, Solid
- Transducer, Solid

Assembly, Battery Ball 1, 17 in.

- Battery Ball 17 in.
  - Penetrator, BB, OBS Battery
  - Penetrator, BB, OBS Transducer
- Battery, Main Tadiran Quad (Number determined by experiment)
- Battery, Release, Alkaline Quad
- Cable, BB, JP3 Auxiliary
- Cable, BB JP4 Sense
- PCB, Acoustic Release
- PCB, Commoning Board
  - Cable, Commoning Board Fuse
- PCB, Recovery

Assembly, Battery Ball 2, 17 in.

- Battery Ball 17 in.
  - Penetrator, BB, OBS Battery
  - Penetrator, BB, OBS Transducer
- Battery, Main Tadiran Quad (Number determined by experiment)
- Battery, Release, Alkaline Quad
- PCB, Acoustic Release
- PCB, Commoning Board
  - Cable, Commoning Board Fuse
- PCB, Recovery

Assembly, Broadband, Acquisition Ball

- Assembly, AB, Core System
  - Baler 14
    - Hard Drive
  - Battery, Standard, Keep Alive
  - Cable, AC Board to Lander Board
  - Cable, Hydrahead (2way and 4way, or 5way)
  - PCB, Auxiliary Controller Board
    - Timebase
  - PCB, Glass, Lander Board
  - Q330
- GPS Antenna
- Acquisition Ball (Broadband or Keck)
  - Penetrator, AB, Broadband Battery
  - Penetrator, AB, OBS, Sensor 1
  - Penetrator, AB, OBS, Sensor 2
  - Penetrator, AB, Shore
- Ethernet Cable (Not recorded in Roundabout)

Assembly, Passive Leveling System Guralp CMG-3T

- Sensor Housing Hemisphere 14.5 in.
- Sensor Housing Hemisphere 14.5 in.
- Sensor Housing Equatorial Ring 14.5 in.
  - Bulkhead, PSL, Sensor Sphere
  - Guralp Sensor
    - PCB, Guralp PSL, Control Board
      - PCB, PSL, Compass
      - PCB, PSL, Persistor
        - Compact Flashcard
      - PCB, PLS, Tilt Sensor
  - PSL, Gimbal System
    - Cable, PSL Harness
  - PCB, PLS, Vacuum Board

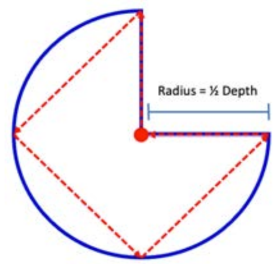
Assembly, Active Leveling System Guralp CMG-3T

- Sensor Housing Equatorial Ring 14.5 in.
  - ALS Gimbal System
    - Cable, ALS, Harness
  - Bulkhead, ASL, Sensor Sphere
  - Guralp Sensor
    - ALS, Fine Tilt Sensor
    - Battery, ALS, EGL
    - PCB, ALS, Guralp Motherboard
      - MicroSD Card
  - PCB, ALS, Motor Controller
- Sensor Housing Hemisphere 14.5 in.
- Sensor Housing Hemisphere 14.5 in.

B: Station location & acoustic survey

Acoustic Survey design: The travel time data used for the OBS relocation is two-way water wave travel times from an Edgetech transponder box. The Edgetech box was connected to the sonar pod on the hull of the ship. It is programmed to emits signals at a frequency - always 11 kHz for the OBSIC stations – and listens to a response from the OBS at a defined frequency – between 11.5 and 13 kHz for the OBSIC stations.

The instruments were deployed "enabled" to respond. The ship holds station over the OBS as it sinks to the seafloor. The OBS reaches the seafloor when the two-way travel time for the response no longer increases.



After the OBS is on the seafloor, the acoustic survey is started and the two-way travel time is recorded every 15 seconds together with GPS navigation strings. The pattern for the acoustic survey that was sailed by the ship is shown by the red dashed line in the diagram. This pattern includes variations in range to measure OBS depth and variations in azimuth to locate the OBS in mapview. Any bad lines or errors in headers were removed.

After the survey was completed the code to "disable" the OBS was sent. Following a successful response to this command at least 3 ranging commands were sent to ensure that it was in fact "disabled".

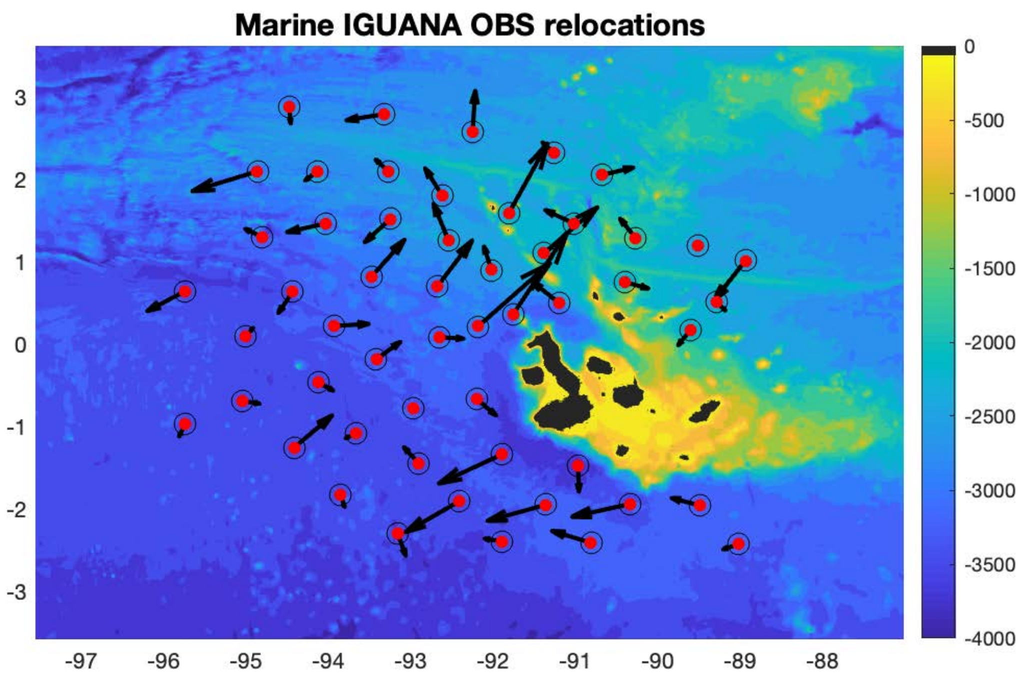


Figure 14. *Plots of OBS relocation result. The initial and final positions of the OBS (open and red circles, respectively) and an arrow representing the motion of the OBS are shown.*

Relocation: is done by least squares inversion or grid search.
The code used is: *MGL2304/Public/OBSLocations_AUTO/m-files/run_obs_relocation.m*.
Parameters used were:

Horizontal offset of transducer from GPS location (m)	**Azimuth of transducer relative to GPS location (degrees clockwise from ship's bow)**	**Transducer Depth (m)**	**OBS transducer Height above seafloor (m)**
20.2	0	7	0.7

Table of OBS relocations

Hooft Galapagos Broadband Deployment Cruise

Station Name	OBS Type	OBS I.D.	Deployment Date (UTC)	Deployment Time (UTC)	Deployment Latitude (decimal degrees)	Deployment Longitude (decimal degrees)	Deployment Depth (m)	Sounding Speed from Levitus Database (m/s)	InvertedStation Lat	InvertedStationLon	Inverted Depth (m)	Inverted Distance Shift (m)	Inverted Direction Shift (deg. East of	Initial Misfit (ms)	Final Misft (ms)	95% Confidence Half-Width in E/W (m)	95% Confidence Half-Width in N/S (m)	95% Confidence Half-Width in Depth (m)
56	T240	AN106	2023-03-23	2:47:34	-2.429672	-89.024328	3181	1494.7	-2.4299	-89.0249	3154	62	251	15	1	1.2	1.3	0.4
57	compact	T117	2023-03-24	3:17:36	-1.957820	-89.493092	3141	1494.6	-1.9576	-89.4941	3121	113	285	19	1	1.0	1.1	0.3
58	sphere	S69	2023-03-24	11:20:36	-1.907598	-90.340268	3155	1494.4	-1.9414	-90.3423	3139	232	257	30	2	1.4	1.3	0.4
59	compact	T116	2023-03-24	18:57:36	-1.469313	-90.969650	3616	1497.1	-1.4702	-90.9698	3599	104	178	16	2	1.3	1.3	0.3
54	T240	A107	2023-03-25	4:14:36	-2.412370	-90.810570	3110	1494.3	-2.4119	-90.8120	3102	160	287	22	1	1.4	1.4	0.4
53	sphere	S38	2023-03-25	11:02:06	-1.949110	-91.358628	3151	1493.9	-1.9500	-91.3610	3129	239	255	34	1	1.4	1.5	0.4
52	sphere	S70	2023-03-25	18:05:51	-2.394610	-91.889355	3449	1495.6	-2.3945	-91.8900	3424	71	279	17	1	1.3	1.3	0.3
51	compact	T120	2023-03-26	1:31:37	-1.908943	-92.415143	3369	1495.4	-1.9100	-92.4170	3348	242	240	38	2	1.4	1.4	0.4
50	T240	AN108	2023-03-26	9:29:42	-2.296338	-93.162998	3503	1496.1	-2.2971	-93.1627	3493	93	160	13	2	1.3	1.3	0.3
49	sphere	71	2023-03-26	18:30:13	-1.446222	-92.907443	3420	1495.5	-1.4457	-92.9080	3405	86	318	13	2	1.3	1.3	0.3
48	sphere	S33	2023-03-27	4:04:43	-1.335397	-91.889202	3319	1495.3	-1.3364	-91.8914	3298	274	245	41	1	1.3	1.1	0.3
47	sphere	S67	2023-03-27	12:23:52	-0.663887	-92.201450	3218	1494.8	-0.6645	-92.2008	3202	100	131	17	1	1.4	1.3	0.4
25	sphere	S81	2023-03-27	21:09:07	0.214493	-92.186367	2853	1493.5	0.2167	-92.1838	2837	378	49	52	1	1.4	1.4	0.4
26	sphere	S65	2023-03-28	3:47:52	0.085757	-92.660577	2955	1493.6	0.0857	-92.6597	2937	97	93	17	2	1.3	1.3	0.4
46	compact	T118	2023-03-28	12:28:07	-0.779025	-92.965850	3278	1494.6	-0.7789	-92.9658	3263	12	4	9	1	1.4	1.3	0.4
27	T240	AN109	2023-03-28	19:52:37	-0.183657	-93.421785	3122	1494.2	-0.1830	-93.4209	3107	117	54	16	1	1.2	1.0	0.3
45	sphere	S88	2023-03-29	5:40:52	-1.087675	-93.667430	3405	1495.6	-1.0878	-93.6678	3394	44	247	8	2	1.5	1.4	0.4
44	compact	T104	2023-03-29	13:51:52	-1.830885	-93.851897	3425	1492.5	-1.8313	-93.8518	3402	49	163	15	2	1.9	1.7	0.4
43	sphere	S37	2023-03-29	21:39:07	-1.255440	-94.418035	3349	1495.3	-1.2543	-94.4167	3343	195	50	27	1	1.3	1.3	0.4
42	compact	T107	2023-03-30	6:21:07	-0.465040	-94.121783	3392	1495.1	-0.4653	-94.1213	3383	65	119	9	2	1.4	1.4	0.4
28	compact	S48	2023-03-30	13:43:22	0.223047	-93.931917	3209	1494.4	0.2231	-93.9307	3191	136	87	18	2	1.4	0.9	0.3
41	sphere	S61	2023-03-30	23:57:37	0.096458	-95.005775	3342	1494.9	0.0968	-95.0055	3334	43	41	8	1	1.3	1.4	0.4
40	compact	S53	2023-03-31	9:02:07	-0.703963	-95.047925	3384	1495.6	-0.6857	-95.0473	3374	68	100	11	1	1.2	1.3	0.3
39	T240	AN102	2023-03-31	18:28:52	-0.962755	-95.740237	3338	1495.1	-0.9632	-95.7405	3328	57	206	9	1	1.5	1.3	0.3
37	compact	T113	2023-04-01	7:37:37	0.641120	-95.750072	3310	1495.3	0.6404	-95.7514	3305	167	242	22	1	1.4	1.4	0.4
29	sphere	S59	2023-04-01	18:43:52	0.635638	-94.439558	3246	1495.0	0.6349	-94.4401	3231	100	214	16	2	1.4	1.4	0.4
30	T240	AN103	2023-04-02	2:18:22	1.299613	-94.807383	3254	1494.9	1.2999	-94.8080	3243	75	296	11	2	1.3	1.3	0.3
31	sphere	S66	2023-04-02	10:18:52	2.100475	-94.863693	2747	1492.4	2.0998	-94.8660	2738	268	253	41	1	1.5	1.8	0.4
33	T240	AN110	2023-04-02	18:07:52	2.888530	-94.477707	2635	1492.4	2.8879	-94.4777	2620	67	176	11	1	1.6	1.6	0.4
32	sphere	S23	2023-04-03	2:28:52	2.096063	-94.138965	2826	1492.6	2.0958	-94.1394	2813	58	234	10	1	1.5	1.4	0.4
19	compact	S42	2023-04-03	9:11:52	1.468547	-94.029178	3059	1493.5	1.4682	-94.0306	3047	158	257	22	1	1.4	1.4	0.4
20	sphere	S01	2023-04-03	17:29:07	0.819208	-93.480620	2940	1493.5	0.8205	-93.4794	2931	195	42	26	1	1.5	1.5	0.4
21	compact	T105	2023-04-04	2:30:07	0.705497	-92.677837	2986	1493.4	0.7071	-92.6766	2972	225	37	28	2	1.5	1.5	0.4
22	sphere	S84	2023-04-04	8:11:37	1.255495	-92.543385	2365	1491.4	1.2568	-92.5439	2348	158	338	20	2	1.8	1.9	0.5
14	compact	T111	2023-04-04	13:35:52	1.802778	-92.618277	2490	1492.1	1.8038	-92.6189	2481	128	328	20	1	1.5	1.4	0.4
18	sphere	S19	2023-04-04	20:16:22	1.520982	-93.250967	2721	1493.2	1.5202	-93.2519	2708	136	228	20	2	1.3	1.2	0.4
17	sphere	S85	2023-04-05	2:50:52	2.098267	-93.277247	2588	1492.2	2.0987	-93.2777	2579	68	314	12	1	1.4	1.7	0.4
16	compact	S45	2023-04-05	9:27:07	2.795160	-93.327188	2673	1492.8	2.7949	-93.3285	2661	149	261	22	1	1.4	1.4	0.4
15	sphere	S86	2023-04-05	18:39:22	2.582903	-92.250187	2400	1491.8	2.5843	-92.2501	2381	160	4	24	2	2.0	1.7	0.5
13	sphere	S05	2023-04-06	4:15:07	1.593523	-91.809348	2318	1491.5	1.5960	-91.8080	2305	312	29	40	2	1.5	1.7	0.5
11	sphere	S73	2023-04-06	11:10:37	1.468952	-91.021745	2139	1491.4	1.4694	-91.0228	2129	123	295	21	2	3.3	4.2	1.6
10	compact	S87	2023-04-06	16:57:07	1.103928	-91.384888	2091	1491.4	1.1056	-91.3830	2084	277	49	43	1	1.7	1.8	0.5
23	sphere	S82	2023-04-06	23:26:37	0.899308	-92.021358	2416	1491.9	0.9001	-92.0216	2406	98	342	14	1	1.5	1.6	0.4
24	compact	AN112	2023-04-07	6:03:07	0.360765	-91.758733	2888	1492.5	0.3636	-91.7568	2869	384	33	57	1	1.7	1.6	0.4
9	T240	AN111	2023-04-07	11:32:37	0.498747	-91.199172	2727	1492.8	0.4995	-91.2001	2709	134	309	23	1	1.5	1.4	0.4
8	sphere	S27	2023-04-07	18:53:37	0.756673	-90.403243	2140	1491.4	0.7564	-90.4024	2126	97	106	14	1	2.0	1.9	0.5
3	compact	S30	2023-04-08	2:46:07	0.175228	-89.600835	2213	1491.4	0.1747	-89.6013	2197	78	219	13	1	1.8	1.8	0.4
2	sphere	S68	2023-04-08	7:50:22	0.516055	-89.289193	2373	1492.1	0.5157	-89.2889	2361	50	134	8	2	1.7	1.7	0.4
1	sphere	AN113	2023-04-08	14:00:52	1.014617	-88.935752	2346	1491.9	1.0132	-88.9369	2344	198	218	28	2	1.4	1.5	0.4
4	T240	AN104	2023-04-08	20:08:52	1.193102	-89.519342	2267	1491.7	1.1931	-89.5193	2253	8	52	9	2	1.7	1.6	0.4
7	compact	T114	2023-04-09	2:39:37	1.290783	-90.271058	1648	1491.7	1.2915	-90.2716	1635	98	321	16	1	1.7	1.7	0.5
6	T240	AN105	2023-04-09	9:39:37	2.056183	-90.677993	2333	1491.6	2.0564	-90.6769	2322	126	77	18	1	1.5	1.5	0.4
12	compact	T121	2023-04-09	15:37:37	2.328233	-91.263345	2392	1491.8	2.3286	-91.2637	2376	60	312	11	2	1.6	1.6	0.4

** two OBS (S33 and S81) overheated in the sun on deck and were cooled and stabilized prior to deployment.*

C: Expendable bathythermograph - XBT

An XBT is an expendable bathythermograph and is used to measure temperature throughout the water column. It's a small probe that is dropped over the side of the ship and collects temperature data as it falls through the water. Small wires attached to the probe transmit the temperature data back to the ship. We can calculate the depth at which the probe is recording because the speed of the probe is known, and the time the probe is launched is recorded.

Using this temperature profile and the salinity of the water, the speed of sound through the water column is calculated. This is an important value to know for multibeam mapping of the seafloor, because the speed that the sonar wave travels through the water needs to be precise for accurate seafloor measurements.

The Langseth uses the MK-21/ISA Bathythermograph Data Acquisition System, a portable data acquisition system that measures and outputs ocean temperature, conductivity and sound velocity versus depth using expendable probes that are launched from surface ships. The Sippican expendable probe is a small oceanographic sensor, which measures the water temperature. The probes free-fall in the ocean at a known rate while collecting the data.

To launch a probe from a vessel, the canister containing the probe is first inserted into a Sippican Hand-Held Launcher. Contacts on the canister provide the electrical connections to the launcher which is connected by cable to the MK21 interface board. When the probe is ready to be launched, the operator pulls a release pin out of the canister, and the probe slides out of the canister into the water. The probe's hydrodynamic shape allows it to descend through the water at a stable and known rate, enabling continuous calculation of its depth throughout the entire descent. As the probe descends, its sensors continuously measure the water temperature. The measurements are transmitted by a wire back to the MK21 interface board. The wire de-reels both from a spool in the probe as the probe descends and from a spool in the canister as the vessel from which the probe was launched moves along the surface. This dual spooling technique enables the wire to remain stationary in the water. Soon after the probe reaches its maximum depth, its wire breaks and the probe continues its descent to the ocean floor.

For the XBTs launched on the Marcus G. Langseth, there were two varieties used, the XBT-5 and the XBT-7. The XBT-5 is a bit bigger than the 7, weighing 46 lbs compared to the XBT-7 at 34 lbs. The XBT-5 can probe deep into the water, giving an accurate profile up to 1830m, but can only be launched if the ship is traveling at 6 kts or less. The XBT-7 on the other hand can be used at speeds up to 15 knts, but can only give an accurate profile up to 760 m depth. The XBT-5 was frequently used when the ship was stopped to drop an OBS, at speeds of 0 knts. The XBT-7 was used when transiting between station locations, as the ship speed was ~10knts during transit.

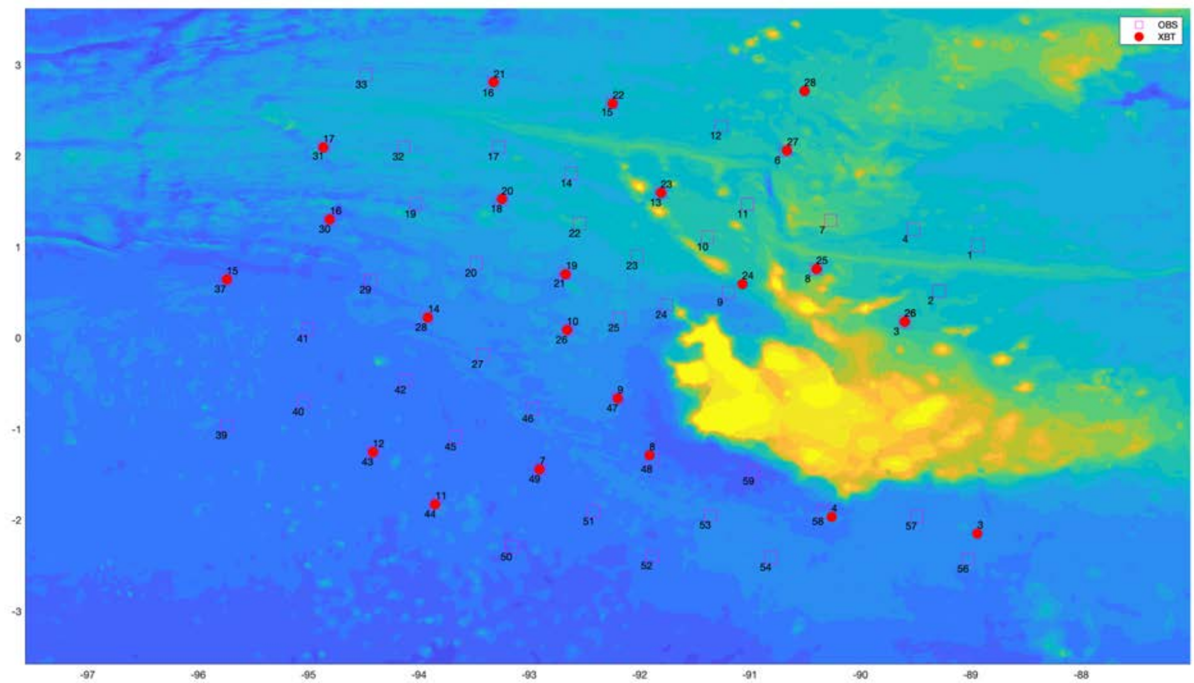


__Figure 15.__ Map of good XBTs in this study (red dots with number to upper right) and OBSs (squares with number to lower left).

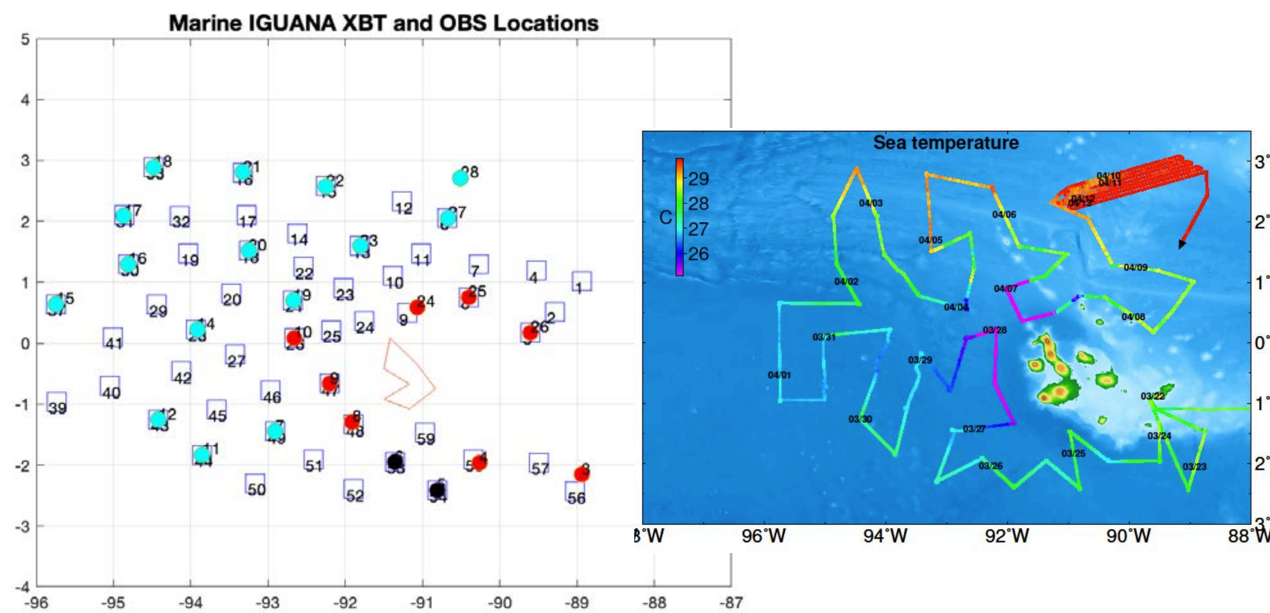


__Figure 16.__ Assessment of thermal structure at XBT and OBS locations (circles and squares, respectively). (Left) Blue circles are XBTs showing an EUC-related reduction in temperature at 100 m depth, red circles are warmer profiles, black circles are outside the study region or for 5 and 6 had good thermal profiles but velocity profiles that were too slow, we think because the wrong salinity was used. (Right) Sea surface temperature patterns along the ship's track. There is no clear correlation between a strong thermocline and pronounced EUG with reduced temperatures at 100 to 200 m depth and sea surface temperature.

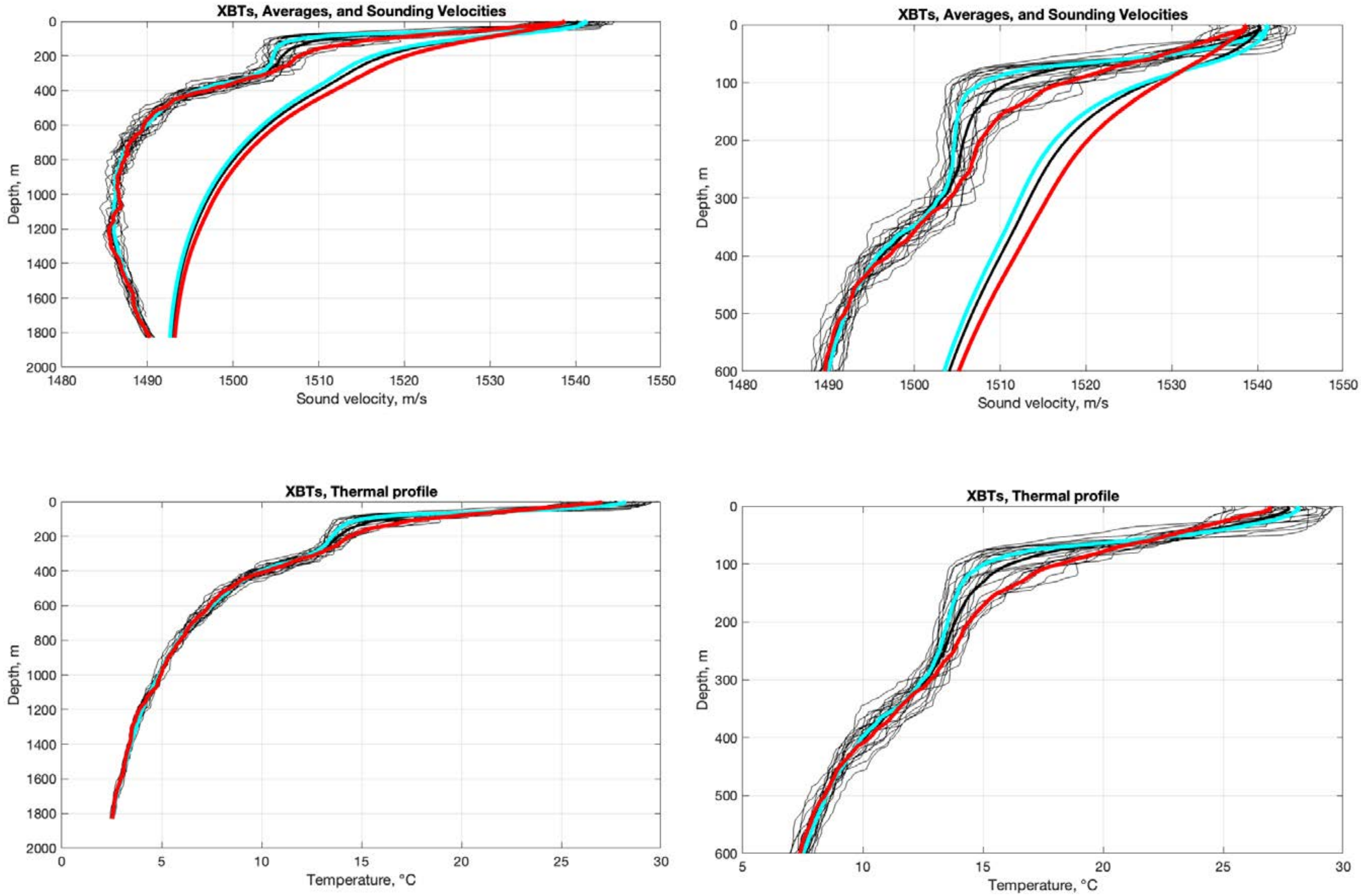


Figure 17. *Plot of all water velocity and temperature from EDF files (left) from 0 to 2000 m; and (right) 0 to 600 m. Averages are shown for all profiles (thick black), profiles showing a significant downward step in temperature at the thermocline (EUC, thick blue); and the other warmer profiles (thick red). The sounding velocity as a function of depth is also shown for each of these averages.*

MGL2304- Expendable Logs

Date	*Time UTC*	*Seq. #*	*Lat deg*	*Lat min*	*Long deg*	*Long min*	*Probe Type*	*EM122 CBD (m) @ launch*	*Export Salinity Value (ppt)*	*Surface SV m/s*	*6.1m SV m/s*	*Last Good Depth m*	*Water T° (C)at LGD*	*Sound Velocity at LGD*	*Imported to SIS*	*Comments*
3/20/2023	22:20:00	1	-0'	-47.12	-87	17.3	T7	1935	33.552	1538.78	1536.99	760.06	6.03	1482.92	yes	first drop of MGL 2304
		2														seq 2 was a bad launch
3/22/2023	0:31:50	3	-2	9.0899	-88	56.4416	T7	3271	34.578	1541.83	1541.76	760.06	6.21	1487.59	yes	successful launch
3/24/2023	10:14:21	4	-1	57.999	-90	15.7272	T7	3128	34.778	1538.77	1539.08	760.06	5.77	1485.82	yes	succesful launch, lat lon had to be manually updated
3/25/2023	5:02:14	5	-2	24.7178	-90	48.614	T5	3104	30.000	1535.1	1540.75	1830.52	2.45	1483.7	yes	Initial delay with edf. Mevan transmitted data to EM122
3/25/2023	11:32:08	6	-1	56.9673	-91	21.51953	T5	3151	34.706	1534.54	1535.19	1830.52	2.59	1484.29	yes	succesful T5 launch, lat lon began updating again
3/26/2023	18:41:15	7	-1	26.7543	-92	54.46973	T5	3420	34.953	1538	1538.39	1202.12	3.77	1485.39	yes	successful
3/27/2023	7:48:00	8	-1	17.2507	-91	54.7149	T7	3383	35.000	1535.5	1534.2	760.06	6.03	1487.36	yes	successful T7
3/27/2023	12:35:15	9	-0'	39.7958	-92	12.0961	T5	3217	35.093	1534.15	1534.77	1830.52	2.52	1490.64	yes	successful T5
3/28/2023	3:57:25	10	+0'	5.1495	-92	39.6298	T5	2965	35.001	1535.21	1535.3	1830.52	2.47	1490.41	yes	successful T5
3/29/2023	14:21:58	11	-1	49.8353	-93	51.16504	T5	3422	34.793	1539.01	1540.37	1830.52	2.57	1490.87	yes	successful T5
3/29/2023	22:12:18	12	-1	15.2847	-94	25.0988	T5	3349	34.96	1540.66	1538.18	1830.52	2.41	1489.88	yes	successful T5
3/30/2023	14:19:30	13														failed
3/30/2023	16:16:54	14	+0'	13.4232	-93	55.1162	T7	3209	34.893	1539	1538.96	760.06	5.8	1486.2	yes	successful T7
4/01/2023	8:45:37	15	0	38.4609	-95	44.531	T5	3312	34.88	1538.69	1523.13	1830.52	2.62	1490.81	yes	successful T5
4/02/2023	2:35:17	16	+1'	18.0012	-94	48.4293	T5	3265	34.787	1540.8	1541.31	1830.52	2.48	1490.3	yes	successful T5

Date	*Time UTC*	*Seq. #*	*Lat deg*	*Lat min*	*Long deg*	*Long min*	*Probe Type*	*EM122 CBD (m) @ launch*	*Export Salinity Value (ppt)*	*Surface SV m/s*	*6.1m SV m/s*	*Last Good Depth m*	*Water T° (C)at LGD*	*Sound Velocity at LGD*	*Imported to SIS*	*Comments*
04/02/2023	11:46:25	17	2	5.4266	-94	51.9678	T5		34.785	1541.52	1542.89	1830.52	2.59	1490.78	yes	successful T5
04/02/2024	18:51:21	18	+2'	53.3282	-94	28.6543	T5			1544.2	1544.53	1713.22	2.86	1489.95	no	successful T5 but not imported to sis
04/04/2024	3:44:04	19	+0'	41.8267	-92	40.3173	T7	2986	35.007	1536.83	1535.7	760.06	6.28	1488.22	yes	successful T7
04/04/2023	20:28:13	20	+1'	31.2727	-93	15.05469	T5	2725	34.377	1542.39	1533.43	1642.83	2.89	1488.28	yes	successful T5
04/05/2023	11:03:31	21	2	48.3101	-93	19.4648	T5		34.61	1541.89	1539.63	1830.52	2.57	1490.04	yes	successful T5
04/05/2023	20:46:24	22	2	34.382	-92	14.82129	T7	2433	34.21	1543.62	1538.62	760.06	6.29	1487.39	yes	succesful T7
04/06/2023	4:39:49	23	1	35.5946	-91	48.49609	T5	2312	34.268	1541.96	1534.97	1830.52	2.58	1489.91	yes	successful T5
04/07/2024	14:35:57	24	+0'	35.4465	-91	4.2752	T7	2270	34.649	1539.22	1539.81	760.06	6.26	1487.36	yes	successful T7
04/07/2023	20:43:46	25	0	45.3667	-90	24.0107	T5	2138	34.602	1541.46	1530.58	1830.52	2.54	1490.18	yes	successful T5
04/08/2023	3:10:37	26	0	10.4939	-89	36.01172	T5	2208	34.341	1451.15	1532.63	1830.52	2.57	1490	yes	successful T5
04/09/2023	11:12:51	27	2	3.3359	-90	40.01607	T5	2338	33.995	1541.83	1543.21	1830.52	2.54	1489.85	yes	successful T5
04/09/2023	22:50:19	28	2	42.7271	-90	30.4919	T7	2207	32.7	1542.87	1541.67	760.06	6.31	1485.57	yes	successful T7 launch
04/11/2023	7:30:10	29	2	58.2447	-89	8.33	T7	1306	32.14	1542.25	1531.59	760.06	6.33	1485.62	yes	successful T7 launch

D: Sounding velocity

The sounding velocity is the net seawater velocity above each OBS and is the average slowness (*1/v*) of the water column above the depth of the instrument.

Using the XBT temperature and salinity profiles, we can get a sound velocity profile of the water column above each OBS deployed. With the coordinates of all the OBS and XBT locations, we find the XBT profile closest to each OBS. Locations of both are plotted in the previous section. For each XBT we use the ASVP profiles that are generated in the EM122 multibeam software because this extrapolates the water velocity profile to greater depth that the XBT probe (12 km).

The sounding velocity from the XBT varies negligibly from that determined using the Levitus database for the region and during the month of March.

Table of each OBS, its location, and the of Sounding velocity from Levitus and from XBTs

Station Name	*Station Longitude*	*Station Latitude*	*Station Depth (m)*	*Levitus Sounding Velocity (m/s)*	*Closest XBT*	*XBT Sounding Velocity (m/s)*	*XBT - Levitus (m/s)*	*%error*
1	-88.9357	1.0148	2458	1492.1	26	1493.9	1.8	0.12%
2	-89.2894	0.5163	2352	1491.9	26	1493.7	1.8	0.12%
3	-89.5723	0.0801	2017	1491.4	26	1493.5	2.1	0.14%
4	-89.5193	1.1929	2280	1491.7	25	1493.5	1.8	0.12%
5	-89.8553	1.6291	1947	1491.4				
6	-90.6777	2.0564	2317	1491.7	27	1493.2	1.5	0.10%
7	-90.2709	1.2908	1698	1491.6	25	1493.9	2.3	0.16%
8	-90.4035	0.7567	2058	1491.4	25	1493.4	2.0	0.14%
9	-91.1994	0.4985	2727	1492.8	24	1494.1	1.3	0.09%
10	-91.3850	1.1039	2116	1491.4	24	1492.9	1.5	0.10%
11	-91.0225	1.4688	2134	1491.4	27	1493.0	1.6	0.11%
12	-91.2701	2.3145	2387	1491.8	27	1493.3	1.5	0.10%
13	-91.8095	1.5935	2249	1491.5	23	1493.4	1.9	0.13%
14	-92.6053	1.8071	2542	1492.1	20	1493.2	1.1	0.07%
15	-92.2516	2.5638	2413	1491.8	22	1493.0	1.2	0.08%
16	-93.3304	2.7864	2736	1492.8	21	1494.1	1.3	0.08%
17	-93.2773	2.1009	2581	1492.2	20	1493.3	1.1	0.07%
18	-93.2508	1.5045	2851	1493.2	20	1494.2	1.0	0.07%
19	-94.0289	1.4688	2943	1493.5	20	1494.5	1.0	0.07%
20	-93.4807	0.8190	2942	1493.5	20	1494.5	1.0	0.07%
21	-92.6760	0.6944	2911	1493.4	19	1494.3	0.9	0.06%
22	-92.5434	1.2552	2198	1491.4	19	1492.4	1.0	0.07%
23	-92.0217	0.8991	2443	1491.9	19	1492.8	0.9	0.06%
24	-91.7211	0.3561	2656	1492.5	24	1493.9	1.4	0.09%
25	-92.1809	0.2226	2958	1493.5	10	1495.0	1.5	0.10%

Station Name	*Station Longitude*	*Station Latitude*	*Station Depth (m)*	*Levitus Sounding Velocity (m/s)*	*Closest XBT*	*XBT Sounding Velocity (m/s)*	*XBT - Levitus (m/s)*	*%error*
26	-92.6760	0.0623	2976	1493.6	10	1495.0	1.4	0.10%
27	-93.4011	-0.1780	3121	1494.2	14	1494.9	0.7	0.05%
28	-93.9317	0.2226	3158	1494.4	14	1495.1	0.7	0.05%
29	-94.4445	0.6499	3281	1495.0	14	1495.7	0.7	0.05%
30	-94.8071	1.2997	3259	1494.9	16	1495.8	0.9	0.06%
31	-94.8601	2.1098	2663	1492.4	17	1493.9	1.5	0.10%
32	-94.1527	2.0920	2711	1492.6	17	1494.0	1.4	0.10%
33	-94.4799	2.8843	2633	1492.4	17	1493.8	1.4	0.09%
34	-95.7444	2.6439	2936	1493.4				
35	-95.7355	1.9496	2888	1493.2				
36	-95.4968	1.1573	3378	1495.4				
37	-96.2130	0.6499	3361	1495.3	15	1496.4	1.1	0.08%
38	-95.9566	-0.0178	3162	1494.3				
39	-95.7355	-0.9436	3325	1495.1	12	1496.1	1.0	0.06%
40	-95.0016	-0.7211	3406	1495.6	12	1496.5	0.9	0.06%
41	-95.0370	0.1157	3274	1494.9	15	1496.0	1.1	0.07%
42	-94.1262	-0.4451	3313	1495.1	14	1495.9	0.8	0.05%
43	-94.4180	-1.2552	3346	1495.3	12	1496.2	0.9	0.06%
44	-93.8344	-1.8516	2721	1492.5	11	1493.6	1.1	0.07%
45	-93.6487	-1.0861	3404	1495.6	11	1496.6	1.0	0.07%
46	-92.9325	-0.7923	3215	1494.6	7	1495.7	1.1	0.07%
47	-92.2074	-0.6766	3253	1494.8	9	1496.2	1.4	0.09%
48	-91.8891	-1.3353	3325	1495.3	8	1496.4	1.1	0.08%
49	-92.8617	-1.4688	3383	1495.5	7	1496.5	1.0	0.07%
50	-93.1624	-2.2967	3500	1496.1	11	1497.1	1.0	0.07%
51	-92.4108	-1.9139	3348	1495.4	7	1496.4	1.0	0.06%
52	-91.8891	-2.3947	3391	1495.6	8	1496.8	1.2	0.08%
53	-91.3585	-1.9496	3011	1493.9	8	1495.0	1.1	0.07%
54	-90.8103	-2.4125	3098	1494.3	4	1495.6	1.3	0.08%
55	-89.4928	-1.9585	3121	1494.4				
56	-89.0241	-2.4303	3181	1494.7	3	1495.8	1.1	0.08%
57	-89.8641	-2.4837	3165	1494.6	3	1495.7	1.1	0.08%
58	-90.3328	-1.9674	3120	1494.4	4	1495.7	1.3	0.09%
59	-90.9695	-1.4688	3643	1497.1	4	1498.7	1.6	0.10%

E: Multibeam bathymetry mapping

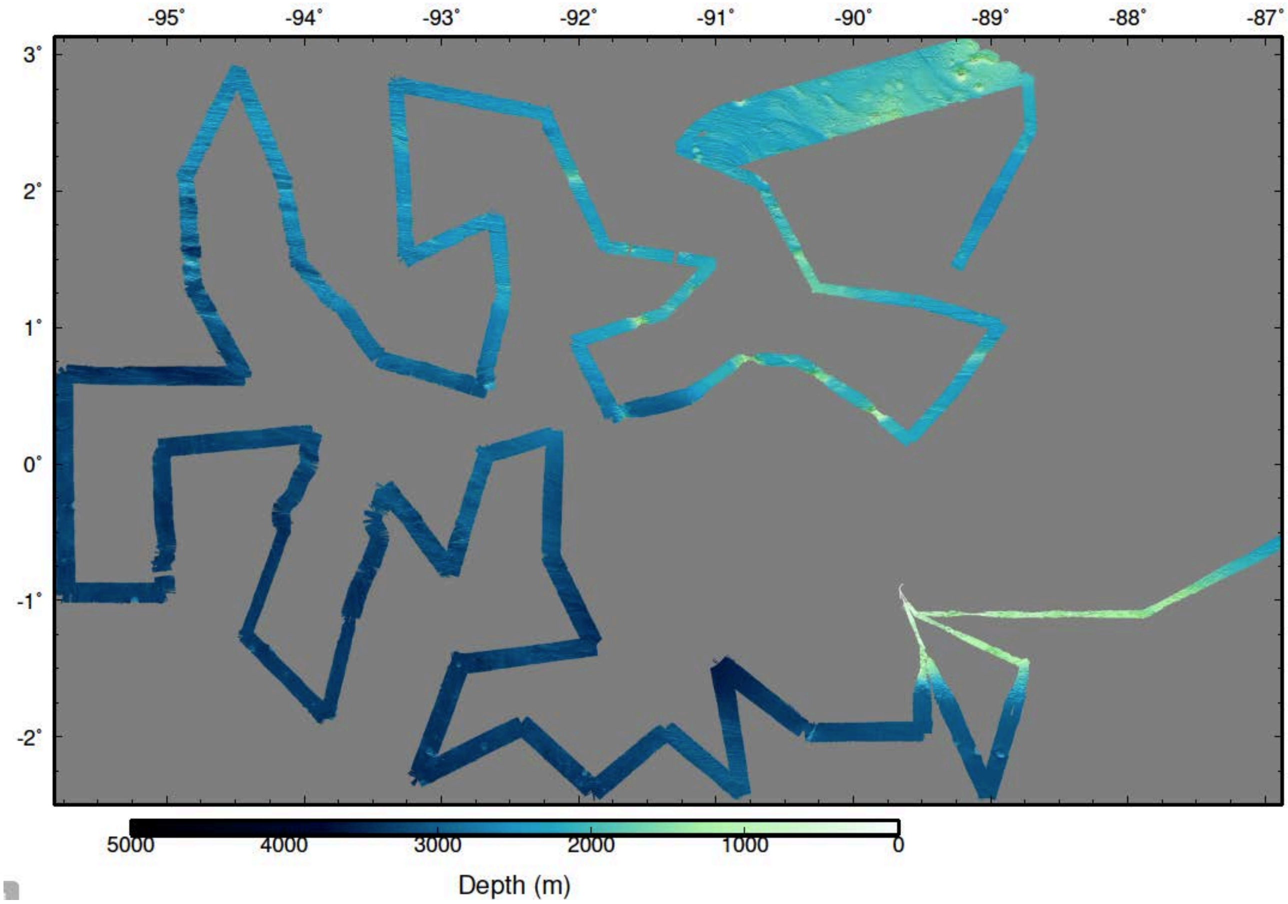


Figure 18. *Along track multi-bathymetry from MGL2304.*

The OBS deployment track was designed to optimize for a short deployment time and increased bathymetric coverage.

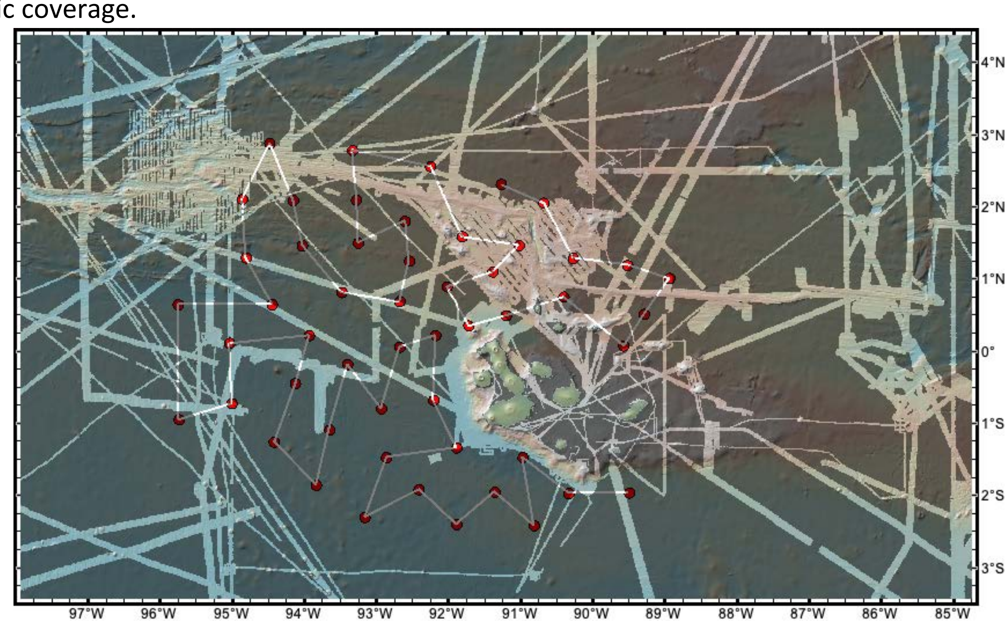


Figure 19. *OBS deployment track on masked GMRT v 4.1 bathymetric data.*

Data Collection

The bathymetric data was collected using R/V Marcus Langseth's Simrad EM122 12kHz multibeam echo sounder. The EM 122 has a maximum swath width up to 6 times the water depth depending on the sea state. Data was acquired by the EM 122 system into half hour Simrad ".all" files with the filenames ####_YYYYMMDD_HHMMSS_Langseth, where "####" is a sequential file starting with "0001" on 03/19/2023 and ending with "0501".

The files were processed with MB-SYSTEM using a script, *mb_processing*, developed by LDEO Science Officer Giles Guerin.

At each site, following OBS deployment and while the OBS was acoustically surveyed, the EM 122 was disabled to avoid interference with the acoustic ranging of the OBSs.

The water column velocity structure was determined by XBT throughout the study area and input into the EM122 processing software. The EM122 system converted the XBT EDF file formats into ASVP format by applying smoothing to the XBT profiles and extended them from the last sampled depth down to 12 km.

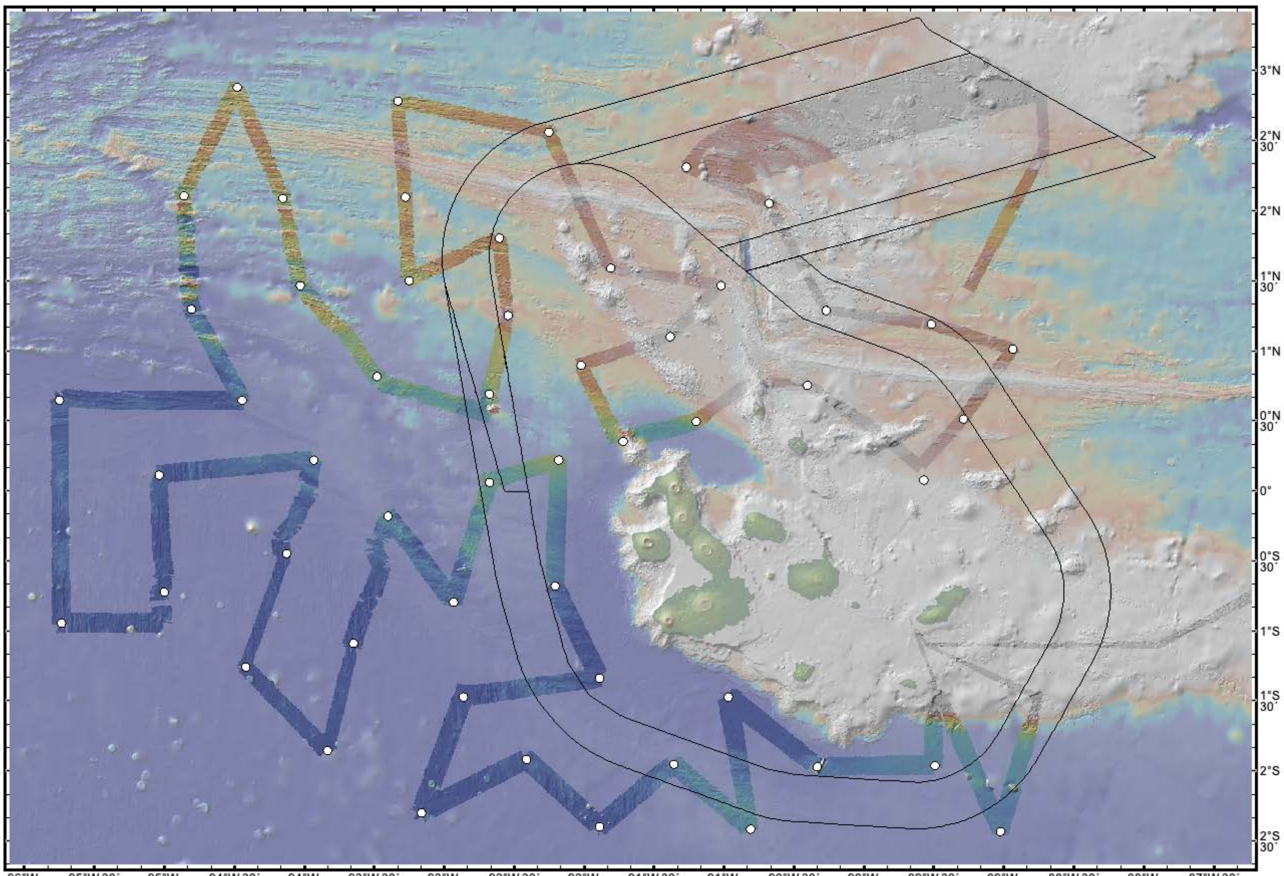


Figure 20. *Map of ocean bottom seismometer locations (white dots) showing acquired multibeam bathymetry on top of existing global multi-resolution topography data (v 4.1). The Shapefile for the Galápagos and Hermandad marine reserves and their buffer boundaries were obtained from Stuart Banks, CDF (black lines).*

The Hermandad Marine Reserve mapping program was designed to lie within the outline of the reserve using a shapefile obtained from Stuart Banks at the Charles Darwin Foundation research station. The GeoMapApp Waypoints and Surveyor planning tool was used to design the lines. We were able to complete lines 1 through 7.

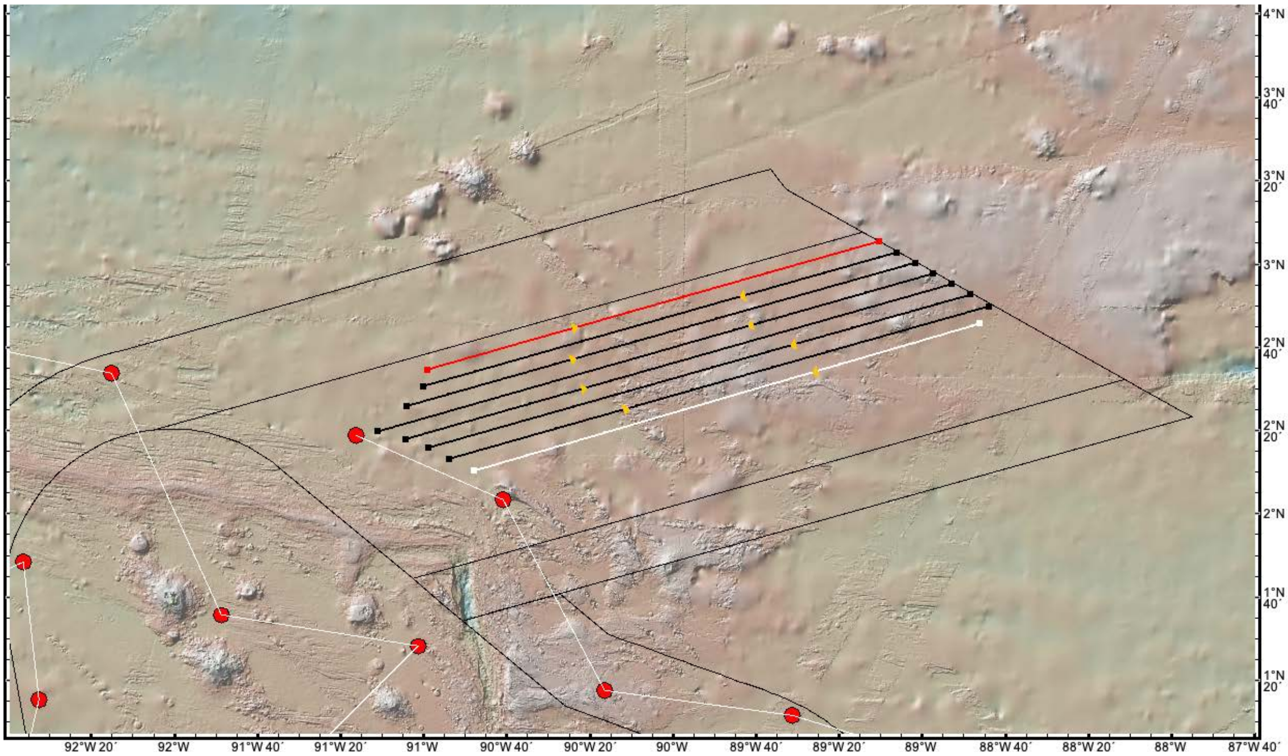


Figure 21. *Design of the multibeam mapping survey of the northern part of the Hermandad Marine Reserve.*

Line Number	*Start Longitude*	*Start Latitude*	*End Longitude*	*End Latitude*	*Km Cumulative Distance*	*Duration (hrs) at 10 kts*
1	-90.984	2.577	-89.173	3.090	209	11.29
2	-89.101	3.046	-90.998	2.511	427	23.12
3	-91.066	2.431	-89.025	3.005	663	35.84
4	-88.955	2.961	-91.182	2.329	920	49.73
5	-91.070	2.299	-88.880	2.919	1173	63.39
6	-88.804	2.877	-90.980	2.264	1424	76.96
7	-90.894	2.220	-88.732	2.830	1674	90.44
8	-88.767	2.761	-90.798	2.171	1909	103.13

MULTIBEAM PROCESSING GUIDE

The objective of the multibeam processing is to clean the raw data and combine it into one continuous bathymetry map. Processing is done with MB-system, an open-source software package base in command-line/GUI: https://www.mbari.org/technology/mb-system/. The resulting map is a .grd grid file that can be plotted with GMT, but the .pdf version is often more convenient to access. The processing creates a copy of the raw data files for a specific date, and then converts them from raw format (mb58) to a new format (mb59). The copied data is then cleaned based on criteria defined in the processing function. Things that are edited out are excessive spikes (bad pings), excessive slopes and depths, and overlapping turns. Excessive slopes and depths may be caused by the multibeam losing the bottom, shadows from seafloor features, etc. Overlapping turns may create strange features or textures which do not reflect the true bathymetry of the seafloor. A resolution is also defined to smooth out the swath pixels while still maintaining detail in the map. The final data files are generated ending with p.mb59, signaling that they have been processed. The final step in the processing is to combine and re-grid all your data into one map. If desired, a new resolution can be applied to the final bathymetry map. Now, you have a complete and accurate map of the seafloor!

1) **On MGL iMac:** Type proc5 in terminal (sciparty user password is sciparty)
2) **Change directory:** Type cd CruiseData/public/mb_processing (same public folder as shared server, FYI).

   Then type mkdir “YOURNAME” and cd into new directory. This will be your working directory.

   The processing command is written to point to a specific data directory, so that will need to be changed based on your own setup.
3) **Processing command:** type only mb_process to display options…
   - Want specific date (mm/dd)
   - Change spike limit to 30°
   - Change max slope to 60°
   - 50% depth range (default)
   - Change resolution to 50 meters
   - Specify turn speed limit at 13°/min

   To start, *do not* specify a turn speed to be cut from the data. Read option descriptions carefully so that you understand each of their functions.

   Full command is mb_process mm/dd -res50 -slope60 -spike30
4) **Output:** Takes form in .grd (grid) files which can be plotted with GMT, and .pdf files that can be opened right away. PDF is located in MGL2304 on Desktop under working directory path.

   Output save location will also need to be changed within the script to match your own setup.

5) **Workflow:**
   a. First, try processing data with the above option parameters.
   b. Then, open the PDF and look for any bad pings, false topography, or features being cut off. It may be useful to compare your results to the MB display (if on ship). Examine any turns, looking for strange overlapping of the swaths.
   c. Make a copy of the PDF so you can reference the original version later.
   d. Change input parameters based on your observations and reprocess the data, with -turn13 option if needed. For example, spike/slope counts of over 100 or 200 may indicate your cutoff parameter is too low. Refer to your original copy of the PDF and repeat until you are satisfied.
   e. If auto-processing isn’t fixing the bad pings, make a note next to the date so it can be manually fixed later.

6) **Plotting:** If you want to replot the data from a specific processed day, you can use mb_plot to change the plot limits and the azimuthal lighting. The function requires a resolution to be defined. Output is a new PDF. This is helpful when you are having plotting issues, but do not want to reprocess the data.
7) **Regridding:** After *all* the days are processed, use -regrid option to combine them with a specified resolution. When gridding, specific date ranges can be defined if you do not want to combine all your processed data.
8) **Manual processing:** If the auto-processing did not fix everything in the data, it needs to be edited manually using mb_edit. This function provides a GUI graphical interface for editing the multibeam data.

The typical the parameters used were: *mb_process mm/dd -res50 -spike30 -slope60*

- For some days, the processed data had excessively high spikes and slopes, so we increased the spike and slope parameters to 50 and 80, respectively.
- For some days, there was overlapping of the data and Stephania usually added -turn13. The higher the turn, the less data you lose.

F: Gravity data

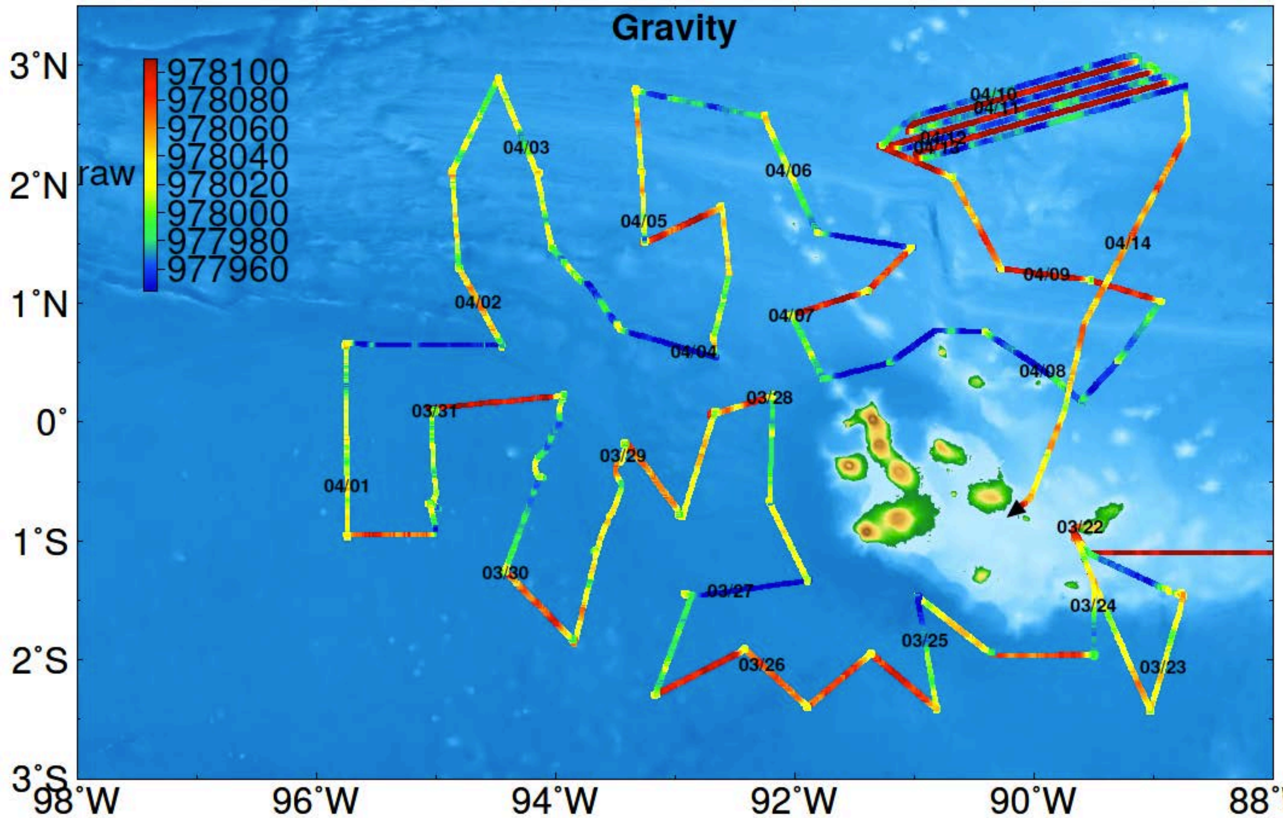


__Figure 22.__ Along track raw gravity data in mGal from MGL2304. The difference in raw gravity between the ship moving eastward and westward is most pronounced at the equator and explains the ~150 mGal differences in the raw gravity – details in section on EOTVOS correction.

The gravity field was recorded using a Bell Aerospace BGM-3 marine gravimeter. Gravity data was collected throughout the duration of the experiment with measurements taken every 1-second. Gravity measurements were displayed in real-time on a monitor in the main lab. The gravimeter appeared to be functioning properly and producing good quality data. Only the raw data is available upon completion of the cruise. All data processing is performed by LDEO science support staff following the cruise.

The raw data can be found in: *MGL1521/raw/serial/*. All the file names are formatted as follows:

MGL-vc01.yxxxxdzzz where *xxxx* is the year and *zzz* is the Julian day on which the samples were collected.

Instrument Detail

Bell Aerospace BGM-3 Marine Gravity Meter

Data is output at 1-second intervals and logged on a LDEO logger system

The raw gravity measurements are stored as counts. Counts are linearly mapped to mGals using routines kept by LDEO.

The raw data for each day is stored in a text file. These files have the following format:

vc01 year:Julian_day:hour:min:sec (to 4 decimal place) XX:counts YY

The leading "vc01" identifies the document as gravity readings; "XX" is the output frequency (Hz); The "counts" value is the raw gravity reading (unitless); and "YY" is the sensor status (unitless).

The location of the gravimeter relative to the navigation reference point (NRP) of the *R/V M. G. Langseth* is detailed in the section on Sensor Configuration.

Gravity Ties

BGM3 ship-to-shore gravity tie report

cody, vessel: R/V Langseth

Release Date: 2023/03/07 17:46:20 UTC

Sensor: S213
Software version: 1.2
Port/Pier/Berth: Texas AM West pier Galveston, Tx

Gravity station number	AW0587
Station name	Galveston Texas Seawall
mGal at pier	979261.95
Tie start time UTC	2023/03/07 16:42:25.107
Samples used	3600
Land tie used	No
Water height to pier 1	8 ft 10 in
Water height to pier 2	8 ft 11 in
Water height to pier 3	9 ft 0 in
Average of filtered counts	24865.951804222
Filter length	361
Scale factor	5.096606269
NEW BIAS	**852530.82**

BGM3 ship-to-shore gravity tie report

Bahlau, vessel: R/V Langseth

Release Date: 2023/05/05 15:19:51 UTC

Sensor: S213
Software version: 1.2
Port/Pier/Berth: Norfolk VA - NOAA AMC Wharf

Gravity station number	0001.61
Station name	NOAA AMC Wharf
mGal at pier	979859.3
Tie start time UTC	2023/05/05 14:14:25.523
Samples used	3600
Land tie used	No
Water height to pier 1	6 ft 6 in
Water height to pier 2	6 ft 8 in
Water height to pier 3	6 ft 9 in
Average of filtered counts	24983.614953805
Filter length	361
Scale factor	5.096606269
NEW BIAS	**852528.28**

Drift: Based on the first gravity tie (2023/03/07), the initial DC shift calculated on 2023/03/07 is 852530.82 mGals. Based on the second gravity tie (2023/05/05), the final DC shift calculated on 2023/05/05 is 852528.28 mGal. From the initial and final DC shifts, the estimated drift of the gravimeter is -0.052 mGals/day. Potsdam correction was removed from the absolute gravity tie point as the BGM-3 outputs uncorrected gravity values.

Processing Methodology

NOTE! All processing and data reduction is performed by LDEO science support staff following the completion of the cruise. None of the processing routines are available aboard the Langseth. At the time of the cruise completion, only the raw data is available.

The raw 1-second gravity counts are filtered with a 360-second Gaussian filter. Counts are converted to mGal via a linear relationship. The gravity data is merged with the navigation attributes (latitude, longitude, course, and velocity) via the GPS time stamp. Eotvos correction is then applied to the dataset. Data plots are generated and visually checked to determine satisfactory Eotvos corrections. Data spikes caused by turns and other anomalies are deleted from the dataset. The Free-air anomaly (FAA) is then calculated using the 1987 International Gravity Formula (IGF). The final dataset is decimated to one-minute samples.

EOTVOS Correction:

The EOTVOS correction is the change in Earth's gravity due to a difference in centrifugal acceleration when the gravity measurement platform is moving eastward or westward. In mGal the EOTVOS correction is:

*EOTVOS = [7.5038 * VE* cos(phi)] + [0.004154 * VT]* where VT is the ship speed in knots, VE is the eastward component of the ship's velocity, and phi is latitude in degrees. During data processing the EOTVOS effect is determined from a smoothed GPS navigation using LDEO developed scripts.

For our study area at the equator phi is zero and so the influence of eastward velocity is largest (cos 0 = 1). This is because at the equator we are farthest from the Earth's axis of rotation. Eastward velocity versus westward velocity difference is 2* 10 knts. EOTVOS correction difference at the equator when moving eastward versus westward is 7.5*20 = 150 mGal.

The EOTVOS correction for eastward/westward velocity is most pronounced at the equator because you are farthest from Earth's rotational axis. For our study the observed differences are from red to blue are 978100 - 977960 = 140 mGal consistent with the predicted EOTVOS effect.

Free-air Anomaly: The FAA reduces the gravity measurements by removing the gravitational effects of the reference ellipsoid. This will be done using an LDEO program. The 1987 IGF is:

*g(phi) = 978032.68 * [1 + 0.00193185138639 * sin2(phi)]/sqrt[1 - 0.00669437999013 * sin2(phi)]*

Where *g* is absolute gravity and *phi* is latitude.

Historical Note: Earlier cruises have used the 1980, 1967, and 1930 gravity formula in calculating the FAA. Since these all differ by a constant, it is necessary to check the formula used in a particular survey prior to merging data across multiple experiments.

G: Magnetic data

Data Collection:

The magnetic field was recorded using a GeoMetrics 882 magnetometer towed nominally 110 meters astern of the vessel on starboard side. Data was logged to the LDEO data logging system. The system performed well during the survey. The instrument is called 'Maggie' on the ship (photograph below).

Figure 23. *Photograph of GeoMetrics magnetometer and towing cable.*

The magnetic data were collected during transit between each OBS deployment. The magnetometer was recovered around 15 minutes before reaching an OBS station and put out to the ocean again after finishing the OBS deployment.

Instrument details:

Name: GeoMetrics 882 Cesium Marine Magnetometer System Specifications
Operating Principle: Self-oscillating split-beam Cesium Vapor (non-radioactive)
Operating Range: 20,000 to 100,000 nT
Operating Zones: The earth's field vector should be at an angle greater than 6° from the sensor's equator and greater than 6° away from the sensor's long axis. Automatic hemisphere switching is standard.
CM-221 Counter Sensitivity: <0.004 (nT/πHz) rms. Up to 10 samples per second
Heading Error: ±1 nT (over entire 360° equatorial and polar spin)
Absolute Accuracy: <3 nT throughout range
Output: RS-232 at 1,200 to 19,200 Baud
Mechanical: Sensor Fish: Body 2.75 in. (7 cm) dia., 4.5 ft (1.37 m) long with fin assembly (11 in. cross width), 40 lbs. (18 kg) Includes Sensor and Electronics and 1 main weight. Additional collar weights are 14lbs (6.4kg) each, total of 5 capable.
Tow Cable: Kevlar Reinforced multiconductor tow cable. Breaking strength 3,600 lbs, 0.48 in OD, 200 ft maximum. Weighs 17 lbs (7.7 kg) with terminations.
Operating Temperature: -30°F to +122°F (-35°C to +50°C)
Storage Temperature: -48°F to +158°F (-45°C to +70°C)
Water Tight: O-Ring sealed for up to 9000 ft (2750 m) depth operation

Data file:

The file is: *MGL2304/raw/ MGL2304_serial_data_1min.csv*. There is also *MGL2304_serial_data_10s.csv.* These merge the following serial data feeds in 1 min and 10 sec averages with columns:

JD
date(UTC)
Time(UTC)
Lat
min
N-S
Long
min
E-W
Heading(deg)
Speed(kts)
Wind(kts)
Wind(direction)
Depth(m)
Magnetics
Gravity
Sea Temp(C)
Salinity
Sound velocity(m/s)
Air Temp(C)
Speed Through Water(kts)
Course over ground(deg)
Air Pressure (mBar)

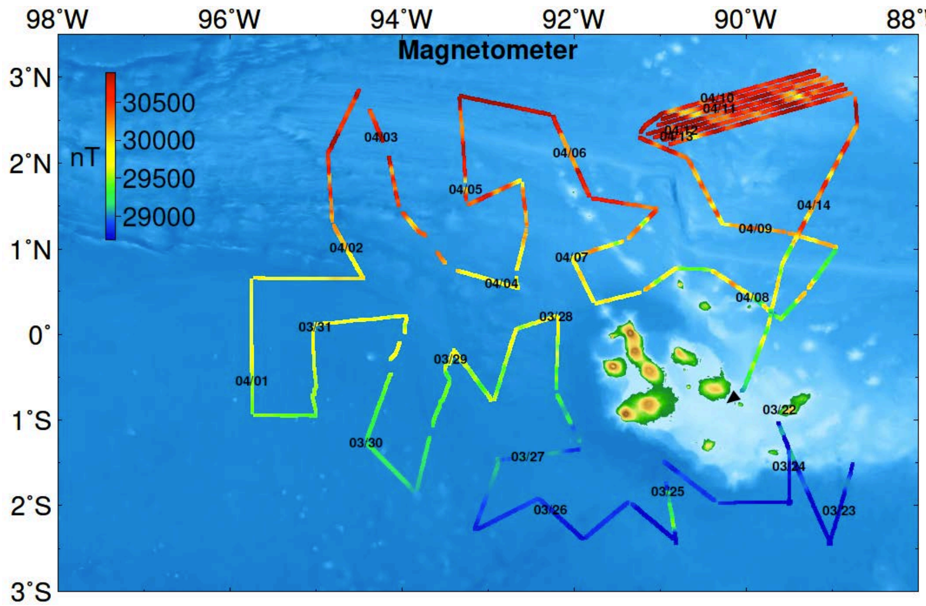


Figure 24. Raw magnetometer data from MGL2304.

Data processing:

To extract magnetic data that pertains to specific features of interest, such as the ocean floor, the Earth's magnetic field is typically eliminated from the collected data as a primary processing step. This process is commonly referred to as the removal of regional trends, as it is necessary to eliminate the background magnetic field to focus on the magnetic data caused by the features of interest.

The International Geomagnetic Reference Field, also known as the IGRF, serves as the global reference model for the magnetic field of the Earth at any given location. This model is a mathematical representation that accounts for the field's characteristics, including its secular changes or how it varies over time. The IGRF was created and is maintained by the International Association of Geomagnetism and Aeronomy (IAGA), with the original version developed in 1968. The IGRF undergoes updates every five years to reflect any changes in the Earth's magnetic field.

The total magnetic intensity data as a grid for the our study area was downloaded from the website, https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml#igrfgrid (Figure below). The elevation was set at mean sea level and model was updated until the year 2024. Overall, the acquired marine magnetic data correlate to the total magnetic field of the earth.

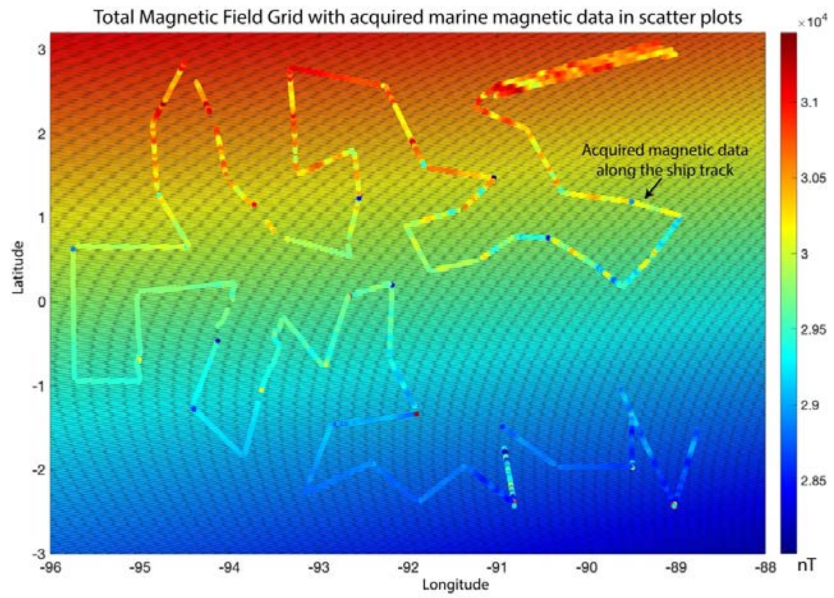


Figure 25. *The collected marine magnetic data in scatter plots with a background representing the total magnetic field of the earth.*

As a preliminary step before subtracting the Earth's magnetic field, a cutoff filter was applied to the acquired data, with 31500 and 28000 nanoTesla serving as the upper and lower cutoff points, respectively. These cutoff values were selected based on a visual inspection of all the data in a 3-D grid. Subsequently, a median filter was applied, specifically the 'medfilt1' function in Matlab, with a median value of only 5. The filtering steps were carried out with care to ensure that the frequency of oscillations in the data remained consistent, given the presence of magnetic reversals in the sea floor magnetic stripes.

After that the earth's magnetic field was removed from the acquired data to observe local variation as the residual magnetic anomaly (Figure below). In the figure below, the collected data were at 1 minute interval.

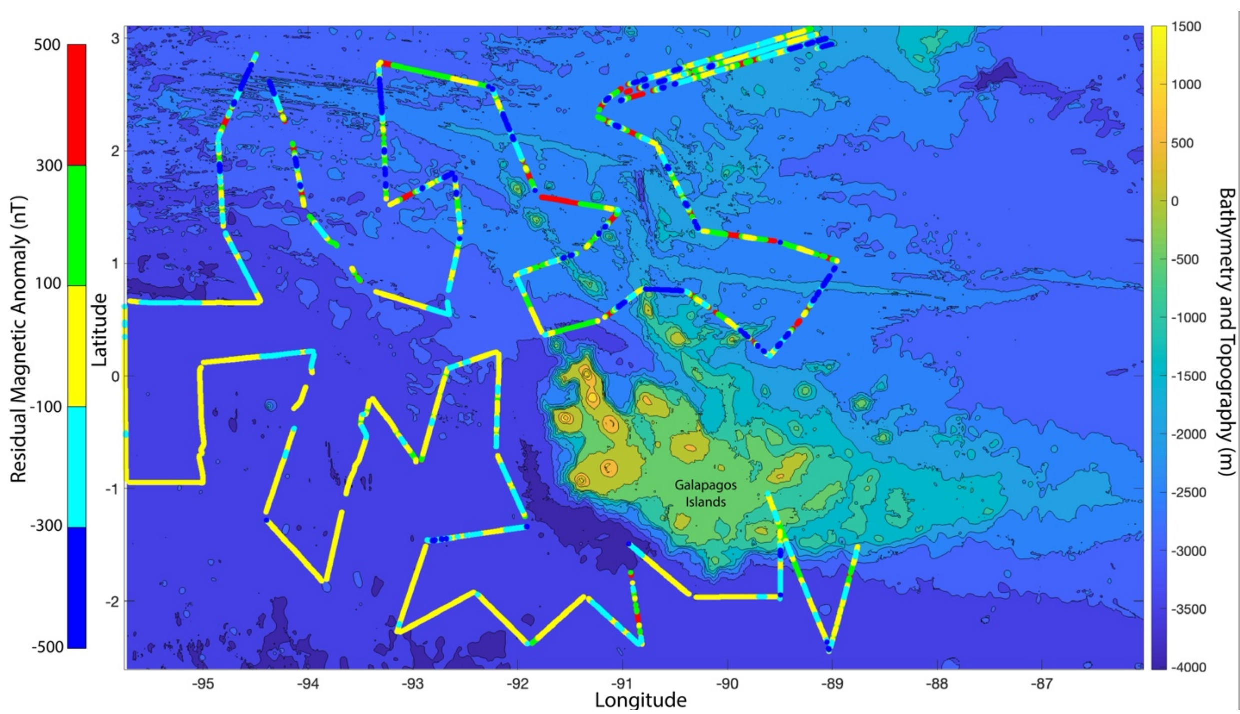


Figure 26. *The residual magnetic anomaly after removing the earth's magnetic field is shown as a scatter plot while the surrounding bathymetry and topography are shown in a contour plot.*

H: Oceanography: Sea-surface temperature, salinity, currents

H.1 Salinity and temperature

The Thermosalinograph data from the Seabird SBE-45 Thermosalinograph integrated temperature and conductivity unit includes the Seabird SBE-38 Remote Temperature Sensor and is 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*

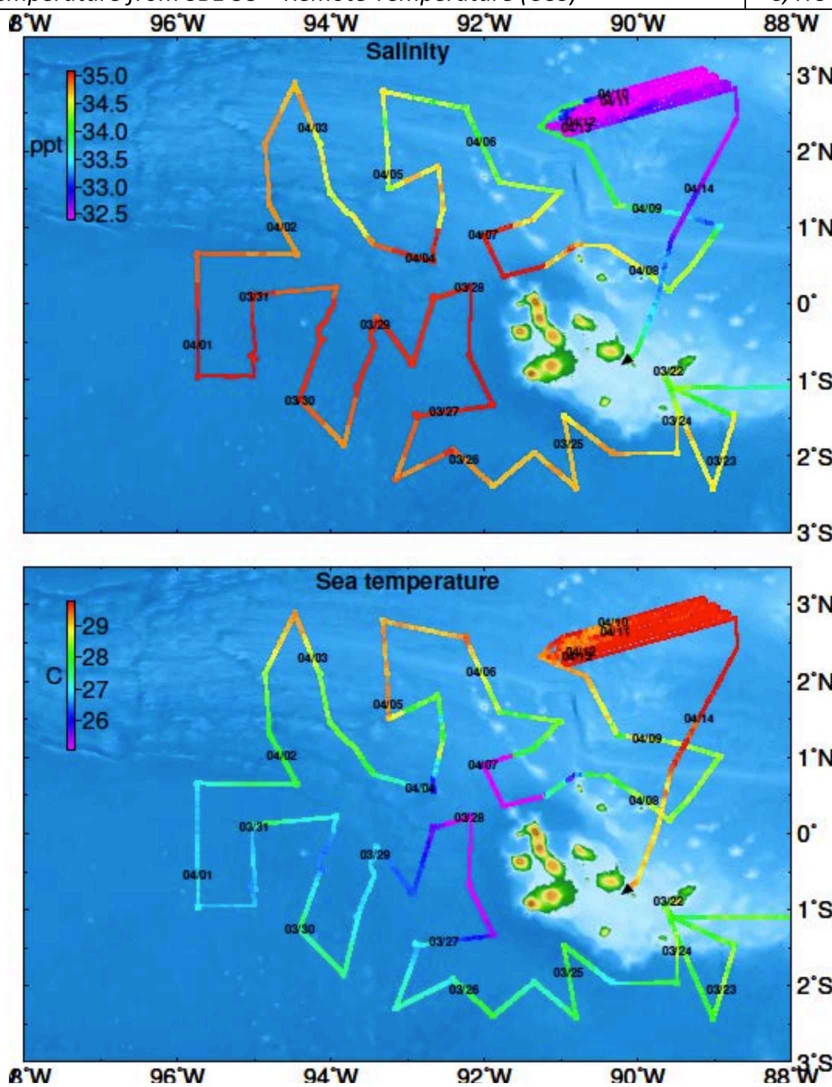


Figure 27. *Salinity and sea surface water temperature along the track*

H.2 Ocean currents

On Cruise MGL2304 we used the ADCP to measure the Equatorial Undercurrent (EUC). Acoustic Doppler Current Profilers send acoustic pings in different directions that reflect off bugs and density gradients in the water returning subject to the Doppler effect. This allows for the measurement of the water's velocity in the direction of the acoustic pulse. The current profilers measure the frequency shift of the returning signals and use the Doppler Effect to determine the magnitude and direction of ocean currents.

We were inspired by Kris Karnauskas's description of the EUC, particularly the upwelling it causes as it pushes into the westmost island of Isabela.

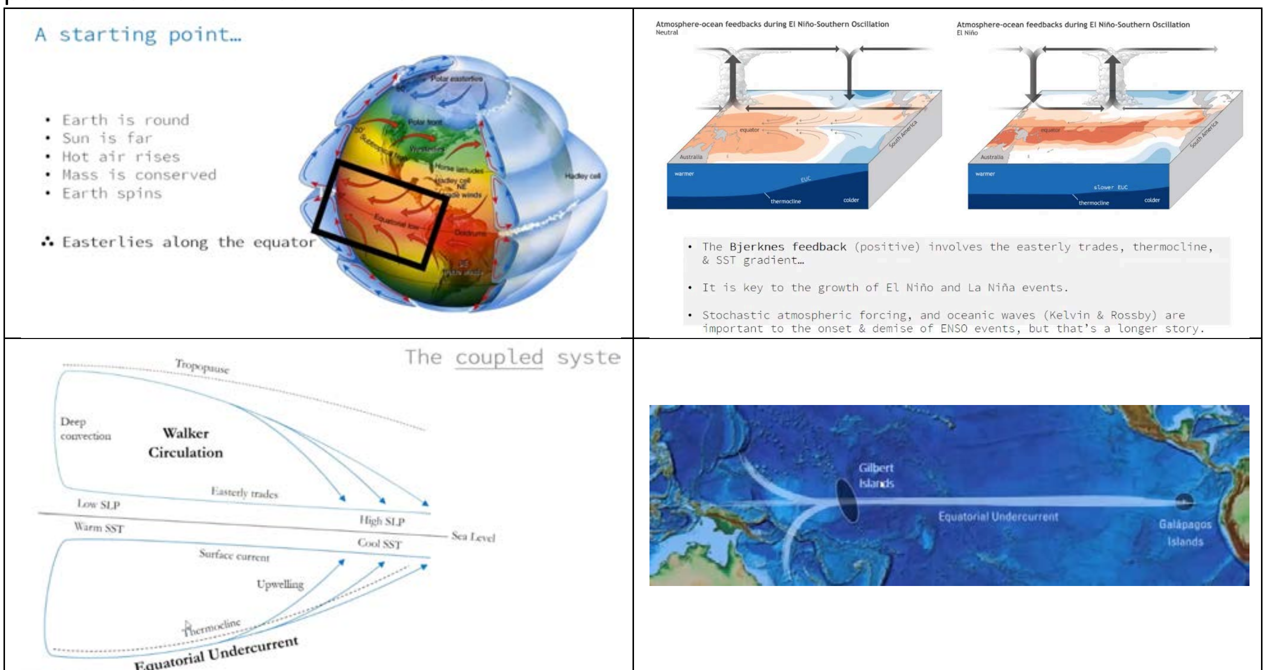


Figure 28. *Slides from Kris Karnauskas's talk titled "Overview of the physical oceanographic and modern climatic setting of the Galápagos" at the Island Systems Integration Consortium (ISIC) All-Hands Meeting in Cincinnati (and online) in October 2022.*

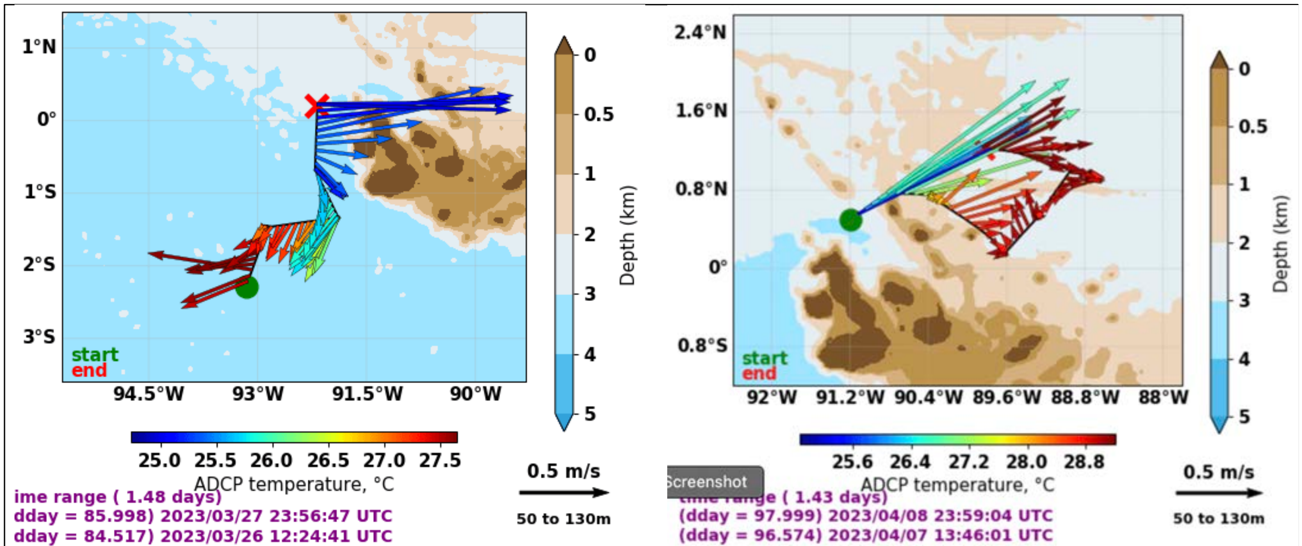
The ADCP system is an OS75: Ocean Surveyor manufactured by Teledyne RD Instruments; frequency model 75kHz. The system requires ancillary datastreams such as GPS for ship's velocity. Data acquisition and processing done by [UHDAS (University of Hawaiʻi Data Acquistion System).]

These data could be useful in studying ENSO (El Niño Southern Oscillation) effects during March and April of 2023 and could be compared to data from our recovery cruise in 2024.

Plots are stored in the MGL2304 folder in our shipboard server smb://192.168.3.19, path MGL2304/raw/adcp/proc/os75nb/png_archive. The os75nb can be replaced by os75bb for the broadband files which focus on lesser depth.

For more detailed data and processing, explore the UHDAS ADCP website, such as this page:

https://currents.soest.hawaii.edu/docs/adcp_doc/codas_doc/index.html



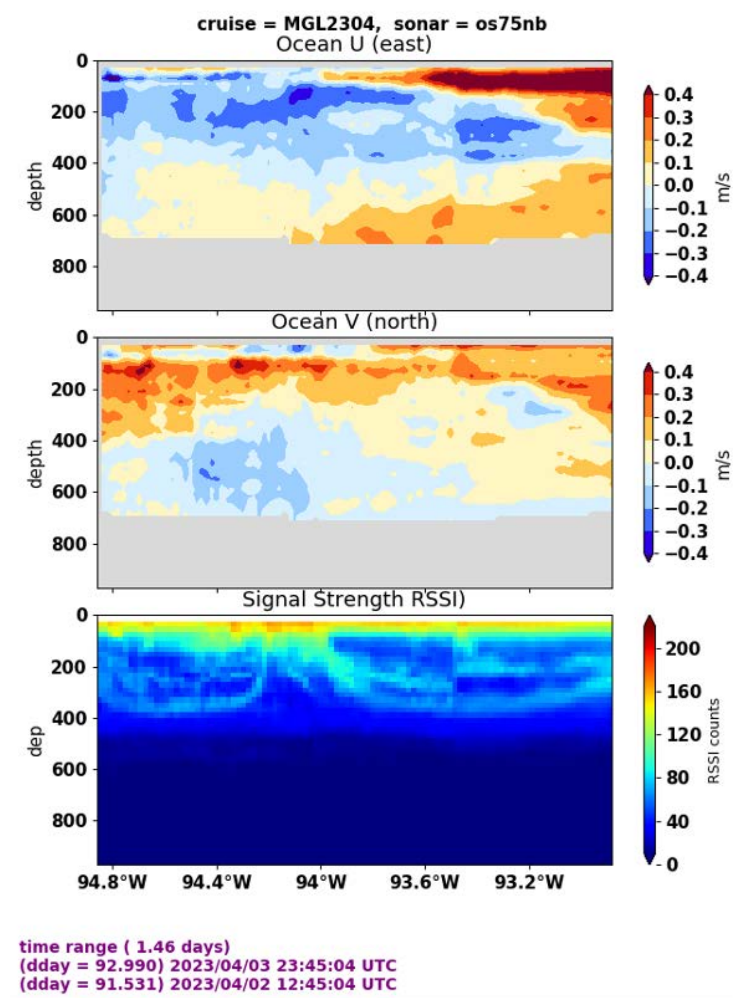


Figure 29. *Example plots generated by the onboard software. Notice the plots also show temperature.*

How the data might be displayed further:

The files would be *"*allbins_*.mat or the netCDF file. Those have the ocean velocities, longitude, latitude".

They output matlab files of 2 sorts

- old, more averaged, (1 hour or 15min, with vertical averaging)
  - accessible from the web site
  - called *_uv.mat and *_xy.mat
  - there are instructions about reading them on the web site
- newer (but still old) "allbins*.mat"
  - every bin and every 5-min average
  - not accessible by clicking
  - accessible as a samba (windows) share or nfs share
  - if you can 'ping' the UHDAS computer you can probably get them that way
- newest (recommended) netCDF file
  - every bin and every 5-min average
  - you can get it by clicking on the right link on the web sit
  - At: *MGL2304/raw/adcp/proc/os75bb/contour/os75bb.nc*
    MGL2304/raw/adcp/proc/os75nb/contour/os75nb.nc

Matlab code can be found at:
https://urldefense.com/v3/__https://currents.soest.hawaii.edu/hgstage/__;!!C5qS4YX3!EgT1sgyG5ae5_oxQg8jNw3kXw49sd1UE5BBH4VgKnisDpemgmtbnTG8Q6M4BNpEiuK9GKRK_mTx_3z_Ykg$

CODAS python software use following the Option#2 miniconda installation process and then get the the netCDF file and use dataviewer.py to make the plots. With that commandline tool, you can make vectors and pcolor plots of specific time ranges and depths.

I: Ship

I.1 Track

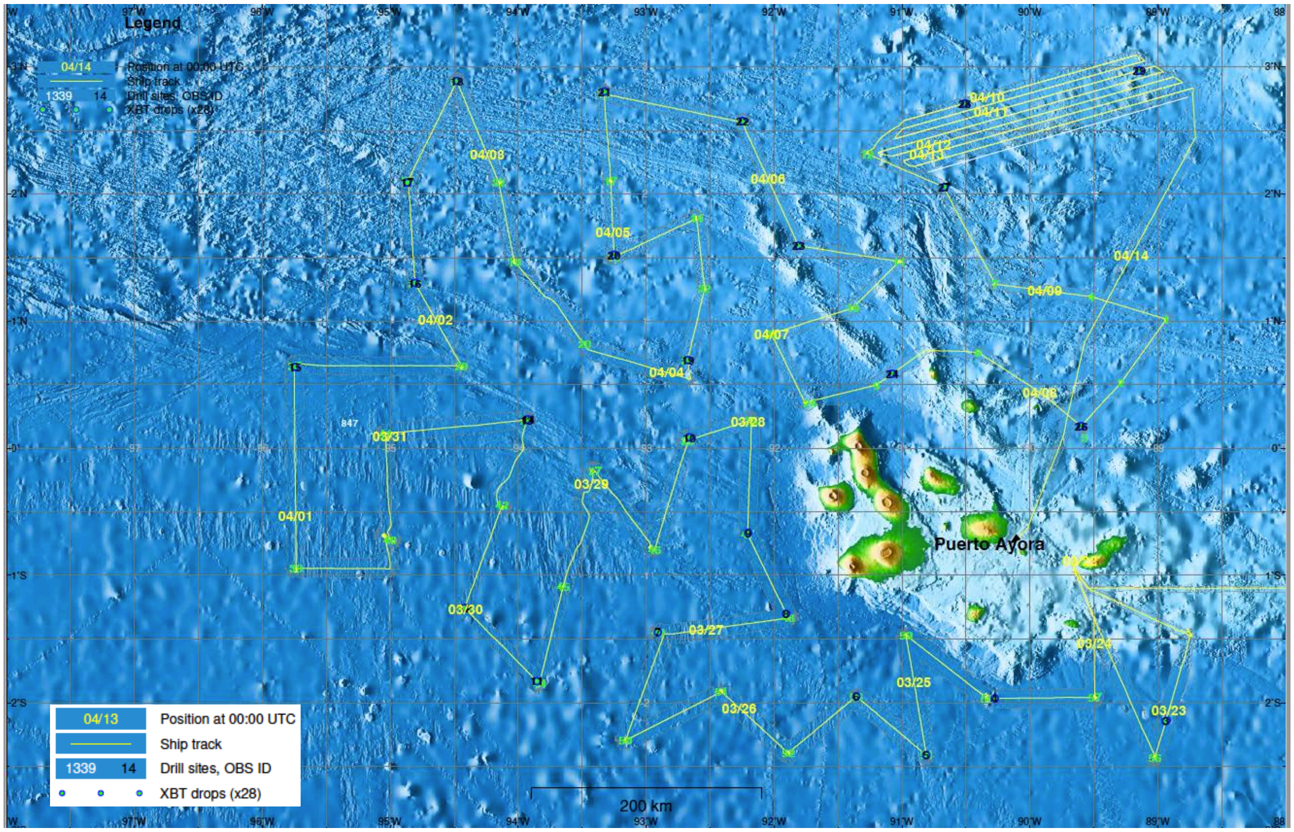


Figure 30. *MGL2304 ship track showing OBS locations (green numbers), XBT drop points (dark outlined circles) and the position at the start of each GMT day (yellow label).*

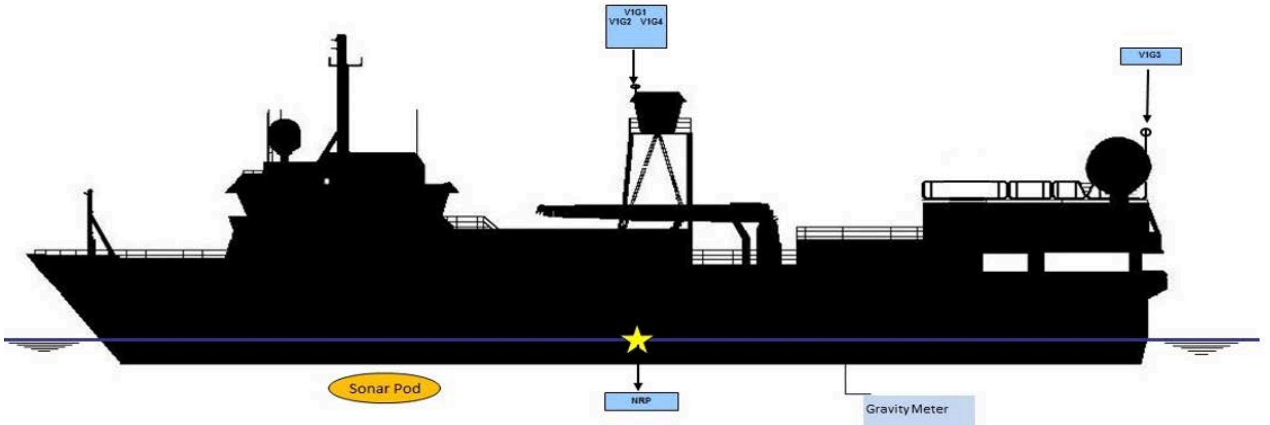
I.2 OBS Deployment Routine

Sequence of tasks to be completed:

1. XBT during transit (*optional; Science Party + Cody/Todd*)
   - 1.1 Make eLog entry
2. Maggie Recovery (*Cody/Todd + Science Party*)
   - 2.1 Disable maggie (switch on rack #10 in the server room behind the Main Lab)
   - 2.2 Make eLog entry
   - 2.3 Unclick 'Maggie deployed' in the Chrome browser tab 'MGL Maggie Status'
3. Confirm drop location over radio (*Main Lab*)
   - 3.1 Once site bathymetry is checked either (a) confirm planned drop location or (b) notify Bridge that drop location will be changed
   - 3.2 If drop location is changed, call bridge and provide a distance and bearing <u>from old site to new site</u>. This can be measured on the multibeam display in Main Lab.
4. OBS Ready on Deck (*Communicated by OBS Team*)
   - 4.1 Make eLog entry (*Science Party*)
5. OBS Deployed (*Communicated by OBS team/viewed from monitors in Main Lab*)
   - 5.1 Take photo of Nav Data screen when the OBS is deployed
   - 5.2 Make eLog entry (*Science Party*):
     - 5.2.1. Record seafloor depth in the Seafloor field
     - 5.2.2. Add drop coordinates in DD MM.MMMM S/N/E/W in the Comments.
6. Three Sonars Off (*Main Lab*): EM122, Knudsen, ADCP
   - 6.1 Make eLog entry (*Science Party*)
7. Start OBS Pinging (*Dry Lab*)
   - 7.1 Instructions in Dry Lab. Use switch to turn on the ping instrument.
   - 7.2 Monitor that OBS responds as it sinks
   - 7.3 OBS is on bottom when ~5 consecutive pings with constant depth are observed
8. OBS on Bottom/Start OBS Survey (*Dry Lab*)
   - 8.1 Start python program that creates ping file
   - 8.2 Confirm that pings are recorded correctly (i.e. observe ~3 good records)
   - 8.3 Radio Bridge that OBS is on bottom and they can start the survey
   - 8.4 Monitor pinging throughout survey
   - 8.5 Make eLog entry for start of survey (*Science Party*)
9. End OBS Survey (*Dry Lab*)
   - 9.1 Bridge will communicate end of survey. Dry lab responds that they are shutting down instrument
   - 9.2 Stop python program that records pings.
   - 9.3 Make eLog entry for end of survey (*Science Party*)
10. <u>Disable the instrument</u> **(***Dry Lab*)
    - 10.1 Follow instruction sheet
    - 10.2 Confirm that the instrument is no longer responding
    - 10.3 Now the ping instrument can be switched off
    - 10.4 Radio bridge that OBS is disabled and we are ready to move to the next site
    - 10.5 Make eLog entry for OBS disabled (*Science Party*)
    - 10.6 Copy ping file to the MGL2304 shared folder
11. Three Sonars On (*Main Lab*): EM122, Knudsen, ADCP
    - 11.1 Make eLog entry
12. Maggie Deployment (*Cody/Todd + Science Party*)
    - 12.1 Enable maggie (switch on rack #10 in the server room behind the Main Lab)
    - 12.2 Make eLog entry
13. Run OBS Location (*Main Lab*)
    - 13.1 Run MATLAB script to locate OBS; update spreadsheet
    - 13.2 Not time-critical

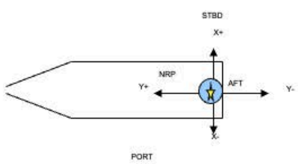
I.3 Sensor offsets

R/V Marcus G. Langseth - Vessel Sensor Offsets



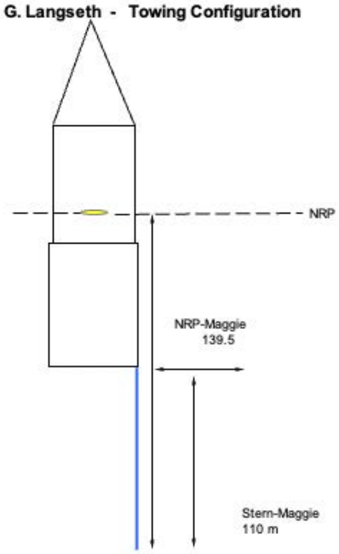
Negative values are above water line

All measurements in meters



			STBD/PORT (X)	FORE/AFT (Y)	UP/DOWN (Z)
NRP	NAVIGATION REFERENCE POINT		0.00	0.00	0.00
V1G1	SeaPath 330	Orca	0.00	0.00	-16.90
V1G2	C-Nav3050 MMO Tower	Orca	0.00	0.00	-16.90
V1G3	C-Nav3050 Stern	Orca	-1.95	31.83	-14.50
V1G4	Pos MV	Orca	2.39	12.75	-16.90
	PosMV Output position is IMU mounted in stbd drylab				
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		2.39	12.75	-4.30
BGM	Bell Gravity Meter		0.00	-13.10	1.10

R/V Marcus G. Langseth - Towing Configuration



I.4 Timeline

MGL 2304 Time Plan (South to North) 53 OBS's

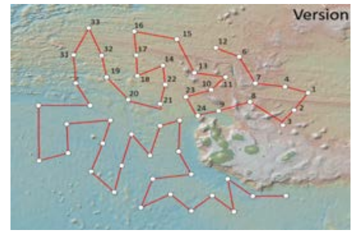
(ALL TIMES ARE LOCAL)

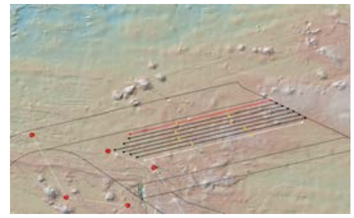
Action	Nautical Miles	Onsite Prep. Time (hours)	Water Depth (m)	Drop Rate (m/min)	Drop Time (hours)	Radius (Km)	Circumference (Km)	Survey Travel (NM)	Survey Speed (Kts)	OBS Survey Time (hours)	Duration	Stat Date & Time	End Data & Time	Speed
Transit: Panama to Puerto Moreno	420													
Leave Puerto Baquerizo Moreno														
Transit to Work Area	90													10
OBS_56		0.3	3181										3/22/23 20:47	
Drop Time				44.0	1.2									
Survey		0.3				1.6	10.0	5.8	4.8	1.2				
Transit														9.5
OBS_57		0.3	3121										3/23/23 21:17	
Drop Time				44.0	1.2									
Survey		0.3				1.6	9.8	5.6	4.8	1.2				
Transit	50.5													9.5
OBS_58		0.3	3120										3/24/23 5:20	
Drop Time				44.0	1.2									
Survey		0.3				1.6	9.8	5.6	4.8	1.2				
Transit	48.5													9.5
OBS_59		0.3	3643										3/24/23 12:57	
Drop Time				44.0	1.4									
Survey		0.3				1.8	11.4	6.6	4.8	1.4				
Transit	57.2													9.5
OBS_54		0.3	3098										3/24/23 22:14	
Drop Time				44.0	1.2									
Survey		0.3				1.5	9.7	5.6	4.8	1.2				
Transit	43.0													9.5
OBS_53		0.3	3011										3/25/23 5:02	
Drop Time				44.0	1.1									
Survey		0.3				1.5	9.5	5.4	4.8	1.1				
Transit	42.0													9.5
OBS_52		0.3	3391										3/25/23 12:05	
Drop Time				44.0	1.3									
Survey		0.3				1.7	10.6	6.1	4.8	1.3				
Transit	43.0													9.5
OBS_51		0.3	3348										3/25/23 19:31	
Drop Time				44.0	1.3									
Survey		0.3				1.7	10.5	6.1	4.8	1.3				
Transit	50.6													9.5
OBS_50		0.3	3500										3/26/23 3:29	
Drop Time				44.0	1.3									
Survey		0.3				1.8	11.0	6.3	4.8	1.3				
Transit	52.6													9.5
OBS_49		0.3	3383										3/26/23 12:30	
Drop Time				44.0	1.3									
Survey		0.3				1.7	10.6	6.1	4.8	1.3				
Transit	59.0													9.5
OBS_48		0.3	3326										3/26/23 22:04	
Drop Time				44.0	1.3									
Survey		0.3				1.7	10.4	6.0	4.8	1.3				
Transit	44.0													9.5
OBS_47		0.3	3253										3/27/23 6:23	
Drop Time				44.0	1.2									
Survey		0.3				1.6	10.2	5.9	4.8	1.2				
Transit	53.7													9.5
OBS_25		0.3	2958										3/27/23 15:09	
Drop Time				44.0	1.1									
Survey		0.3				1.5	9.3	5.3	4.8	1.1				
Transit	31.3													9.5
OBS_26		0.3	2976										3/27/23 21:48	
Drop Time				44.0	1.1									
Survey		0.3				1.5	9.3	5.4	4.8	1.1				
Transit	53.3													9.5
OBS_46		0.3	3215										3/28/23 6:28	
Drop Time				44.0	1.2									
Survey		0.3				1.6	10.1	5.8	4.8	1.2				
Transit	46.3													9.5
OBS_27		0.3	3121										3/28/23 13:52	
Drop Time				44.0	1.2									
Survey		0.3				1.6	9.8	5.6	4.8	1.2				
Transit	56.2													9.5
OBS_45		0.3	3404										3/28/23 23:40	
Drop Time				44.0	1.3									
Survey		0.3				1.7	10.7	6.2	4.8	1.3				
Transit	47.1													9.5
OBS_44		0.3	2721										3/29/23 7:51	
Drop Time				44.0	1.0									
Survey		0.3				1.4	8.5	4.9	4.8	1.0				
Transit	50.0													9.5
OBS_43		0.3	3346										3/29/23 15:39	
Drop Time				44.0	1.3									
Survey		0.3				1.7	10.5	6.1	4.8	1.3				
Transit	51.5													9.5
OBS_42		0.3	3313										3/30/23 0:21	
Drop Time				44.0	1.3									
Survey		0.3				1.7	10.4	6.0	4.8	1.2				
Transit	42.0													9.5
OBS_28		0.3	3158										3/30/23 7:43	
Drop Time				44.0	1.2									
Survey		0.3				1.6	9.9	5.7	4.8	1.2				
Transit	66.7													9.5
OBS_41		0.3	3274										3/30/23 17:57	
Drop Time				44.0	1.2									
Survey		0.3				1.6	10.3	5.9	4.8	1.2				
Transit	50.0													9.5
OBS_40		0.3	3406										3/31/23 3:02	
Drop Time				44.0	1.3									
Survey		0.3				1.7	10.7	6.2	4.8	1.3				
Transit	46.0													9.5
OBS_39		0.3	3326										3/31/23 12:28	
Drop Time				44.0	1.3									
Survey		0.3				1.7	10.4	6.0	4.8	1.3				
Transit	95.2													9.5
OBS_37		0.3	3361										4/1/23 1:37	
Drop Time				44.0	1.3									
Survey		0.3				1.7	10.6	6.1	4.8	1.3				
Transit	78.5													9.5
OBS_29		0.3	3281										4/1/23 12:43	
Drop Time				44.0	1.2									
Survey		0.3				1.6	10.3	5.9	4.8	1.2				
Transit	45.0													9.5
OBS_30		0.3	3259										4/1/23 20:18	
Drop Time				44.0	1.2									
Survey		0.3				1.6	10.2	5.9	4.8	1.2				
Transit	48.5													9.5
OBS_31		0.3	2663										4/2/23 4:18	
Drop Time				44.0	1.0									
Survey		0.3				1.3	8.4	4.8	4.8	1.0				
Transit	52.0													9.5
OBS_33		0.3	2633										4/2/23 12:07	
Drop Time				44.0	1.0									
Survey		0.3				1.3	8.3	4.8	4.8	1.0				
Transit	51.3													9.5
OBS_32		0.3	2711										4/2/23 20:28	
Drop Time				44.0	1.0									
Survey		0.3				1.4	8.5	4.9	4.8	1.0				
Transit	38.0													9.5
OBS_19		0.3	2943										4/3/23 3:11	
Drop Time				44.0	1.1									
Survey		0.3				1.5	9.2	5.3	4.8	1.1				
Transit	51.0													9.5
OBS_20		0.3	2942										4/3/23 11:29	
Drop Time				44.0	1.1									
Survey		0.3				1.5	9.2	5.3	4.8	1.1				
Transit	62.0													9.5
OBS_21		0.3	2911										4/3/23 20:30	
Drop Time				44.0	1.1									
Survey		0.3				1.5	9.1	5.3	4.8	1.1				
Transit	34.5													9.5
OBS_22		0.3	2198										4/4/23 2:11	
Drop Time				44.0	0.8									
Survey		0.3				1.1	6.9	4.0	4.8	0.8				
Transit	33.2													9.5
OBS_14		0.3	2543										4/4/23 7:35	
Drop Time				44.0	1.0									
Survey		0.3				1.3	8.0	4.6	4.8	1.0				
Transit	43.0													9.5
OBS_18		0.3	2851										4/4/23 14:16	
Drop Time				44.0	1.1									
Survey		0.3				1.4	9.0	5.2	4.8	1.1				
Transit	35.7													9.5
OBS_17		0.3	2581										4/4/23 20:50	
Drop Time				44.0	1.0									
Survey		0.3				1.3	8.1	4.7	4.8	1.0				
Transit	41.0													9.5
OBS_16		0.3	2736										4/5/23 3:27	
Drop Time				44.0	1.0									
Survey		0.3				1.4	8.6	4.9	4.8	1.0				
Transit	66.2													9.5
OBS_15		0.3	2413										4/5/23 12:39	
Drop Time				44.0	0.9									
Survey		0.3				1.2	7.6	4.4	4.8	0.9				
Transit	63.7													9.5
OBS_13		0.3	2249										4/5/23 22:15	
Drop Time				44.0	0.9									
Survey		0.3				1.1	7.1	4.1	4.8	0.8				
Transit	47.9													9.5
OBS_11		0.3	2135										4/6/23 5:10	
Drop Time				44.0	0.8									
Survey		0.3				1.1	6.7	3.9	4.8	0.8				
Transit	30.8													9.5
OBS_10		0.3	2116										4/6/23 10:57	
Drop Time				44.0	0.8									
Survey		0.3				1.1	6.6	3.8	4.8	0.8				
Transit	40.2													9.5
OBS_23		0.3	2443										4/6/23 17:26	
Drop Time				44.0	0.9									
Survey		0.3				1.2	7.7	4.4	4.8	0.9				
Transit	35.8													9.5
OBS_24		0.3	2656										4/7/23 0:03	
Drop Time				44.0	1.0									
Survey		0.3				1.3	8.3	4.8	4.8	1.0				
Transit	34.6													9.5
OBS_09		0.3	2727										4/7/23 5:32	
Drop Time				44.0	1.0									
Survey		0.3				1.4	8.6	4.9	4.8	1.0				
Transit	50.3													9.5
OBS_08		0.3	2058										4/7/23 12:53	
Drop Time				44.0	0.8									
Survey		0.3				1.0	6.5	3.7	4.8	0.8				
Transit	59.5													9.5
OBS_03		0.3	2017										4/7/23 20:46	
Drop Time				44.0	0.8									
Survey		0.3				1.0	6.3	3.6	4.8	0.8				
Transit	27.6													9.5
OBS_02		0.3	2352										4/8/23 1:50	
Drop Time				44.0	0.9									
Survey		0.3				1.2	7.4	4.3	4.8	0.9				
Transit	36.6													9.5
OBS_01		0.3	2458										4/8/23 8:00	
Drop Time				44.0	0.9									
Survey		0.3				1.2	7.7	4.4	4.8	0.9				
Transit	36.7													9.5
OBS_04		0.3	2280										4/8/23 14:08	
Drop Time				44.0	0.9									
Survey		0.3				1.1	7.2	4.1	4.8	0.9				
Transit	45.6													9.5
OBS_07		0.3	1698										4/8/23 20:39	
Drop Time				44.0	0.6						0:38:35	4/8/23 20:39	4/8/23 21:18	
Survey		0.3				0.8	5.3	3.1	4.8	0.6	0:56:23	4/8/23 21:18	4/8/23 22:14	
Transit	51.2										5:23:22	4/8/23 22:14	4/9/23 3:38	9.5
OBS_06		0.3	2317								0:18:00	4/9/23 3:38	4/9/23 3:56	
Drop Time				44.0	0.9						0:52:40	4/9/23 3:56	4/9/23 4:48	
Survey		0.3				1.2	7.3	4.2	4.8	0.9	1:10:22	4/9/23 4:48	4/9/23 5:59	
Transit	38.8										4:05:03	4/9/23 5:59	4/9/23 10:04	9.5
OBS_12		0.3	2387								0:18:00	4/9/23 10:04	4/9/23 10:22	
Drop Time				44.0	0.9						0:54:15	4/9/23 10:22	4/9/23 11:16	
Survey		0.3				1.2	7.5	4.3	4.8	0.9	1:11:57	4/9/23 11:16	4/9/23 12:28	
Transit to Line 1	23.0										2:18:00	4/9/23 12:28	4/9/23 14:46	10
Line 1	113.0										11:18:00	4/9/23 14:46	4/10/23 2:04	10
Transit to Line 2	5.0										0:31:35	4/10/23 2:04	4/10/23 2:36	9.5
Line 2	118.0										11:48:00	4/10/23 2:36	4/10/23 14:24	10
Transit to Line 3	6.0										0:37:54	4/10/23 14:24	4/10/23 15:02	9.5
Line 3	127.0										12:42:00	4/10/23 15:02	4/11/23 3:44	10
Transit to Line 4	6.0										0:37:54	4/11/23 3:44	4/11/23 4:21	9.5
Line 4	139.0										13:54:00	4/11/23 4:21	4/11/23 18:15	10
Transit to Line 5	7.0										0:44:13	4/11/23 18:15	4/11/23 19:00	9.5
Line 5	137.0										13:42:00	4/11/23 19:00	4/12/23 8:42	10
Transit to Line 6	5.0										0:31:35	4/12/23 8:42	4/12/23 9:13	9.5
Line 6	136.0										13:36:00	4/12/23 9:13	4/12/23 22:49	10
Transit to Line 7	6.0										0:37:54	4/12/23 22:49	4/12/23 23:27	9.5
Line 7	**135.0**					To complete line 7 is 135 Nautical Miles					13:30:00	4/12/23 23:27	4/13/23 12:57	10
Transit to Line 7											0:00:00	4/13/23 12:57	4/13/23 12:57	9.5
Line 8											0:00:00	4/13/23 12:57	4/13/23 12:57	10
Transit to Puerto Ayora	225										22:30:00	4/13/23 12:57	4/14/23 11:27	10

Arrival time in Puerto Ayora is still To Be Determined, based on pilot, port availability, etc.

Remaining Duration	5 Days 14 Hour 47 Minutes

*** NOTE ***
The last line of the Multibeam Survey will be stopped at a point where we can reach Puerto Ayora no later than 1200 on April 14th.





Galapagos Cruise Dates
21 Mar - 14 Apr

Assumptions	
Average Transit Speed (kts)	9.5
Average Survey Speed (kts)	4.8
Average Drop Rate (m/min)	44
Drop Prep Time (hrs)	0.3
Survey Prep Time (hrs)	0.3

Remaining Duration	OBS Stats	
	Deployed	Remaining
5 Days 14 Hour 47 Minutes	51	2

Notes

Completion Tracker		
March 18th	4/11/23 18:00	Start of Job
March 19th	4/11/23 13:03	Tweaked order to make more efficient
March 24th	4/11/23 14:00	After Divers and re-order to maximize MB paths and changed transit Speed
March 25th	4/10/23 23:42	Changed Transit Speed to 10 kts
March 26th	4/9/23 16:47	Most of the Assumptions were tweaked slightly after looking at the real data after 8 drops.
March 27 th	4/9/23 16:16	
March 28 th	4/10/23 4:39	Changed the Transit speed to 9.5 to match the last 5 drops
March 29th	4/10/23 8:40	
March 30th	4/10/23 8:45	
March 31st	4/10/23 8:49	
Apr 1st	4/10/23 10:59	Slight delays due to fishing boats
Apr 2nd	4/10/23 10:19	Ver 10 Plan
Apr 2nd	4/10/23 13:02	Ver 11 Plan with No MB Lines entered
Apr 3rd	4/10/23 13:26	
Apr 4th	4/10/23 12:46	
Apr 5th	4/10/23 10:44	Ver 11 with no MB Lines
Apr 5th	4/14/23 12:44	With Multibeam lines, not final version
Apr 6th	4/14/23 11:52	Complete Multibeam lines 1-6, **120** Nautical Miles on Line 7
Apr 7th	4/14/23 11:58	Complete Multibeam lines 1-6, **118** Nautical Miles on Line 7
Apr 8th	4/14/23 11:58	Complete Multibeam lines 1-6, **132** Nautical Miles on Line 7
Apr 9th	4/14/23 11:27	Complete Multibeam lines 1-7

*** NOTE ***
The last line of the Multibeam Survey will be stopped at a point where we can reach Puerto Ayora no later than 1200 on April 14th.

J: List of Contacts

J.1.1 Ship Agent contact information

J.1.1.a ***Panama Ship Agent***

Francis X. Zeimetz
Panama Agencies Co. Inc.
Tel: (507) 314-1580
Cel: (507) 6616-3117 (Whatsapp)
Email: ops@panage.net
Web: www.multiport.org

J.1.1.b ***Galápagos Ship Agent***

Mr. Antonio Moreano
Sea Masters Group - Yacht Support for Galápagos
Cell. +(593) 999 11 6066
WhatsApp 593 9 99116066
Agency. www.seamastersGalápagos.com
Provisions. www.Galápagosprovisions.com
Villa Rental. www.blueheronGalápagos.com
AYSS Member: www.ayss.org

J.1.2 Contact information for Ecuadorian and Galápagos collaborators

J.1.2.a ***Charles Darwin Research Foundation (CDRF)***

Dr. Maria-José Barragán
Directora de Ciencias / Science Director
Fundación Charles Darwin/Charles Darwin Foundation
Puerto Ayora, Islas Galápagos, Ecuador
Tel. +593 5 2 526 146 Ext. 225
Email: mariajose.barragan@fcdarwin.org.ec
www.facebook.com/darwinfoundation
www.twitter.com/darwinfound
www.darwinfoundation.org

Ms. Marta Romoleroux
Visiting Scientists Program/Programa de Científicos Visitantes
Fundación Charles Darwin/Charles Darwin Foundation
Puerto Ayora, Islas Galápagos, Ecuador
Tel. +593 5 2 526 146 Ext. 105
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Dr. Stuart Banks
Senior Marine Scientist - Investigatora Marina Profunda
Charles Darwin Foundation - Fundación Charles Darwin
Puerto Ayora, Santa Cruz Island, Galápagos - Ecuador
Email: stuart.banks@fcdarwin.org.ec
Office Phone: (+593)-5-2526-146/147

J.1.2.b ***Instituto Geofísico – Escuela Politécnica Nacional***

Dr. Mario Ruiz
Director, Instituto Geofísico de la Escuela Politécnica Nacional
*mruiz@igepn.edu.ec; cell: +593-0*984 524695

J.1.2.c Galápagos National Park

Jennifer Suarez
Email: jmsuarez@Galápagos.gob.ec

J.1.3 INOCAR – Ecuadorian Navy

Capt. Edwin Pazmino
Capitán Edwin Pazmino
Director de Oceanografía y Meteorología Marina
Instituto Oceanográfico y Antártico de la Armada
Guayaquil-Ecuador
npazmino@armada.mil.ec; +593 93 984 4938

Dr. Pritha Tutasi, Ph.D.
Investigador Oceanográfico 3
Responsable de la División de Oceanografía Operacional
Dirección de Oceanografía y meteorología Marina
Av. 25 de Julio vía Pto. Marítimo. Base Naval Sur
Email: pritha.tutasi@inocar.mil.ec
Tel.: + (593-4) 3813440 Fax: (593-4) 2485166
Código Postal: 8940 - Guayaquil-Ecuador; www.inocar.mil.ec

*J.1.4 US Embassy in Ecuador Contacts ***
*** (added for future use on May 23, 2023)*

Alex "Sash" Lewis
handles RATS State Department requests for permits
US Embassy in Quito
Email: LewisAG@state.gov

Stater, Timothy M (Guayaquil)
Consul General
U.S. Consulate General in Guayaquil, Ecuador
Email: StaterTM@state.gov

Genevieve "Genny" Vidlak-Masura
Political Economic Officer
U.S. Consulate General in Guayaquil, Ecuador
Email: MasuraGM@state.gov; +593 098 531 5130

J.2.1 Contact information for NSF program and research vessel managers

J.2.1.1 NSF Program Manager

Gail Christeson
Program Director for Marine Geology and Geoophysics, Directorate for Geosciences
Division of Ocean Sciences, National Science Foundation, USA
gchriste@nsf.gov; +1-703-292-2952

J.2.1.2 Ship Managers – R/V Marcus Langseth

Mr. Sean Higgins
Director, Office of Marine Operations, Marine/Large Programs; Senior Research Scientist
Borehole, P.O. Box 1000
61 Route 9W, Palisades, NY 10964
(w) +1-845-365-8528 | (c) +1-914-260-6759 | sean@ldeo.columbia.edu

Mr. Jesus Gaytan
Technical Services Manager, Office of Marine Operations, Sr. Staff Associate
L-DEO /Columbia University, 61 Rt. 9W Palisades, NY 10964
cell: +1 (832) 528-7815; work: +1 (845) 365-8367
jg4362@columbia.edu; jgaytan@ldeo.columbia.edu

Primary RV Contact Person arranging vessel entry details For Panama and Galápagos
Mr. John Kinkela
Senior Staff Associate II, Office of Marine Operations
61 Route 9W, 104 Administration, Palisades, NY 10923 USA
jkinkela@ldeo.columbia.edu

J.2.1.3 Science Officers for MGL2304 R/V Marcus G Langseth

Cody Bahlau
cbahlau@ldeo.columbia.edu

Todd Jensvold
jensvold@ldeo.columbia.edu

K: Participants

K.1 Participant List

Name	Surname	Email	Role	Organization
Emilie	Hooft	emilie@uoregon.edu	Chief Scientist	University of Oregon
Brandon	vanderBeek	brandon.p.vanderbeek@gmail.com	Scientist CoChief	University of Padua
Rebeckah	Hufstetler	beckh@uoregon.edu	Student Graduate	University of Oregon
Asif	Ashraf	aashraf@uoregon.edu	Student Graduate	University of Oregon
Kaisa	Autumn	kautumn@uoregon.edu	Student Graduate	University of Oregon
Mevan	Ranasinghe	mevan_ranasinghe@yahoo.com	Educator K-12	Honolulu Community College
Austin	Anderson	austina@hawaii.edu	Educator K-12	Kapi`olani Community College
Hannah	Brewer	hbrewer@whoi.edu	Marine Technician	OBSIC - WHOI
Timothy	Kane	tkane@whoi.edu	Marine Technician	OBSIC - WHOI
~~Alan~~	~~Gardner~~	~~agardner@whoi.edu~~	~~Marine Technician~~	~~OBSIC - WHOI~~
Peter	Liljegren	peterl@ldeo.columbia.edu	Marine Technician	OBSIC - LDEO
Shuyang	Sun	sysun@vt.edu	Scientist PostDoc	Virginia Technical University
Francisco	Mejía	fmejia@igepn.edu.ec	Engineer	Instituto Geofísico – Escuela Politécnica Nacional
Stephania	del Cisne Añazco Rivera	sdanazco@espol.edu.ec	International Observer	Galápagos National Park
Cody	Bahlau	cbahlau@ldeo.columbia.edu	Langseth marine tech	Lamont Doherty Earth Observatory
Todd	Jensvold	jensvold@ldeo.columbia.edu	Langseth marine tech	Lamont Doherty Earth Observatory
Joshua	Kasinger	joshk@ldeo.columbia.edu	Langseth marine tech	Lamont Doherty Earth Observatory
Brian	Agee	agee@ldeo.columbia.edu	Langseth marine tech	Lamont Doherty Earth Observatory

K.2 Watch Schedule

	Scientist	***OBSIC***	***OBSIC***	***Science Officer***	***Observer***
Noon to Midnight	Emilie Hooft	Tim Kane	Francisco Mejia	Todd	Stephania Anazco Rivera
Midnight to Noon	Brandon VanderBeek	Hannah Brewer	Peter Liljegren	Cody	

Times AM and PM	***Watch stander 1***	***Watch stander 2***
12 to 4	Asif Ashraf	Mevan Rannashinge *(lectures M/W/F 3-4:45 pm)*
4 to 8	Rebeckah Hufstetler	Kaisa Autumn
8 to 12	Austin Anderson	Shuyang Sun

K.3 Pre-cruise briefings

- MGL2304_README.pdf

  <u>Important Addition:</u> <u>Zero</u> <u>tolerance</u> <u>for alcohol and illegal drugs including marijuana.</u>

  The Master of the vessel is legally authorized and empowered to search any part of the ship at any time for alcoholic beverages or any other contraband (based on reasonable suspicion). Any person in violation of this policy is subject to immediate removal from the ship as well as additional actions that may include, but are not limited to, administrative actions involving the person involved, their research group, their employer, their funding agency, and UNOLS.

  Chief Scientists are responsible for the behavior of all members of the scientific party, under authority delegated by the Master. Chief Scientists must ensure that all members of the scientific party are aware of the rules, and take action to ensure compliance and report any violations to the Master.

- Welcome Onboard the Marcus G. Langseth.pdf

MGL2304 aboard the R/V Marcus G Langseth

Mobilization: Port: Balboa Panama, morning of March 17 by motor launch
Demobilization: Puerto Ayora, Galápagos, April 15 by motor launch
At sea: March 17 – April 15, 2023

Timeline:

- **March 16th (Thursday):** Night in hotel in Panama City
- **March 17th (Friday):** Depart Balboa Port, Panama City, Panama
- **March 21st (Tuesday):** Ship inspection in San Cristobal, Galápagos, Ecuador
- **April 15th (Saturday; estimated):** Return to Puerto Ayora, Santa Cruz Island, Ecuador

Departure from Port of Balboa:

All cruise participants must arrive in Panama City by March 15th to be ready to depart for the ship on the morning on March 17th. Embarkment will be by motor launch. Dr. Hooft and University of Oregon group will stay at the *Radisson Hotel Panama Canal* on the night of March 16th. Participants should book their own accommodations for the night of March 15th and 16th either here or elsewhere nearby the Port of Balboa.

Ecuadorian participants will embark in San Cristobal on March 21st and should arrive there on March 19th. Participants should book their own accommodations.

Disembarking in Puerto Ayora, Santa Cruz island, Galápagos, Ecuador:

All cruise participants will disembark in Puerto Ayora by motor launch on April 15th. We will stay in rooms at the Charles Darwin research station and depart the Galápagos on March 18th unless you have arranged for an earlier departure.

1. Science

The overarching goal of this expedition is to collect data that will allow for seismic imaging of Galápagos plume-ride interaction. To this end, we will deploy 53 ocean bottom seismometers primarily to the east of the Galápagos archipelago and along the southern flank of the Galápagos spreading center. These data will be used to address key science questions regarding the dynamics plume-ridge interaction and of hotspot systems more broadly. These questions include:

i. At what depths, in what geographic pattern, and by what mechanism does mantle plume material flow northward to the Galápagos Spreading Center (GSC) and disperse along the ridge? What is the role of ambient mantle circulation, including asthenospheric return flow? What does the thickness of the plume layer beneath the GSC imply about the origin of geochemical gradients long the GSC?

ii. Do the scale and nature of heterogeneity indicate small-scale, sub-lithospheric convection (SSC)? If so, how does that influence the flow of plume material along the base of the lithosphere?

iii. What is the spatial distribution of melting and volatile release, as well as the associated heterogeneity in composition and rheology due to plume-ridge interaction? Beyond Galápagos plume-ridge interaction, the project will substantially advance a broad understanding of the chemical and physical processes of mantle plumes, the asthenosphere, and their interactions with the oceanic lithosphere.

2. Life at Sea

We will work 24 hours a day while at sea. There will likely be two 12-hour shifts (though still TBD), and every person will be assigned one shift. When you are on shift, your primary responsibility is to assist in the cruise science activities which will include keeping shift notes, monitoring and logging data from the instrument panels in the science lab, processing of bathymetric and/or gravimetric data, deploying XBT (Expendable Bathythermograph) probes, and assisting in the preparation and deployment of OBS (Ocean Bottom Seismometers).

When you are off shift, enjoy your free time! The ship has several common spaces including a small library, movie room, and a small gym. Please remember that the ship's common areas are used by both science party and crew and are often near a crew's berth, so we need to respect them as shared spaces.

Keep in mind that internet access is limited.

You will be assigned a berth with a bunk mate, and a shared bathroom between a couple of berths. The berths have two bunks (an upper and lower) with a curtain and bed light, a small sink, and a shared cabinet for your belongings. Bedding and towels are provided. There is also a life vest, and survival ("gumby") suit in the berths for each occupant that you will need for the fire drill, and in the case of an emergency. Generally, bunk mates are on different shifts in which case it is important to not disturb your roommate during their rest hours.

There are 3 scheduled meals a day (breakfast, lunch, and dinner) at set times – these never change, unless we're in port. The crew who are about to go on shift have priority at the start of meal times. There are leftovers, snacks, coffee, and tea available in the fridge and galley at any time.

Overall, keep in mind that we are visitors to the ship, and we want to be as clean and respectful as possible to the crew. If you have <u>any</u> questions or concerns, at <u>any</u> time, let the Chief (Emilie Hooft) or co-Chief (Brandon VanderBeek) Scientist, or the Captain know! We will do all we can to be sure you feel comfortable aboard.

3. Medical

Bring your personal medicines. However, not everything should, or can, be anticipated. If something comes up, however small, physical or mental, please let the Chief (Emilie Hooft) or co-Chief (Brandon VanderBeek) Scientist know or talk to the Captain or First Mate. They should be able to find medicines and can access the medical services for any questions you have. A health and food allergies survey will be sent around soon. Below are details on seasickness, medical emergencies, and importantly the COVID protocol for the cruise.

Seasickness: Seasickness is normal and not necessarily predictable. The most common seasickness medication is Dramamine. Another option is Bonine and if you know you are prone to motion sickness you could ask your doctor about getting a Scopolamine patch prior to boarding. Usually, one does not require sickness medication for the entire cruise but please bring enough in case you find yourself in that unlucky situation. Some prefer to take medication 24 hours before and a few days into the cruise before going without while others simply take it on an as-needed basis (e.g. take Dramine if you start feeling sick and take a nap). Generally, not eating too heavily before departure is helpful (dry crackers and ginger ale can help settle the stomach).

Medical Emergencies: The Captain and or First Mate are fully trained in emergency medicine, the ship has a sick bay with medicines and medical tools, the ship subscribes to an onshore medical service, and the vessel has a helicopter deck for extreme emergencies.

COVID Protocol: Cruise participants should be fully vaccinated and will be need to show their COVID vaccination cards. Fully vaccinated means:

- Completed 2-dose series of Pfizer or Moderna or 1-dose of Johnson & Johnson (Janssen) at least 14 days prior to embarkation.
- At least one booster dose of a U.S. authorized COVID vaccine is required if more than 6 months has passed since receiving the 2-dose series of Pfizer or Moderna or greater than 2 months has passed since receiving the 1-dose of Johnson & Johnson (Janssen).

For further information on UNOLS COVID-19 guidelines, including rules for non-vaccinated personnel: https://www.unols.org/sites/default/files/Update%20to%20UNOLS%20COVID-19%20Guidance-Vers1.3-23May2022.pdf

According to the U.S. Embassy there are no COVID entry restrictions for Panama. However, the ship requests that everyone get a rapid COVID tests before travelling and to follow best practices while travelling. These include:

- Avoid contact with anyone who is sick or shows symptoms
- Avoid crowds and maintain distance in indoor public spaces
- Wear mask in indoor public spaces
- Clean your hands often and avoid touching eyes, nose, and mouth

Everyone should also expect to be tested upon embarkation, at least once aboard the vessel with weekly testing according to the captain's schedule. If needed, more advanced testing is available on a case-by-case basis.

4. Packing List

Clothing

Plan to bring enough for 5-6 days. There are laundry facilities and detergent on the vessel. Think in layers – for any given day, you'll want short sleeve shirts, long sleeve shirts, and fleece/puffy jackets/sweatshirts. The lab of the ship can feel chilly, and the deck can get windy. Bring clothing that you don't mind getting dirty or, possibly, damaged.

- Masks
- Close-toed work shoes are a must-have! Required while moving about the ship. Ideally, a waterproof hiking-type boot. Consider bringing an extra pair of more comfortable close-toed shoes for use while off-shift.
- Work pants (e.g., jeans)
- Shirts
- Underwear
- Jacket
- Waterproof windbreaker (ideally one that can get a bit dirty/that you don't care much about)
- For abandon ship practice/scenarios you need:
    - hat with a brim
    - sunglasses
    - long-sleeved shirt and pants
    - a flashlight
- Sleeping clothes
- Flip-flops (convenient for showers)
- Gym cloths if you would like to use the exercise room during your free time

Toiletries

- The ship will have towels.
- Otherwise bring all toiletries needed for the trip – the ship does not have soap, shampoo, etc.
- Any personal medications required.
- Seasickness medication
- Earplugs if you are a light sleeper
- Sunscreen – the sun is very strong at the equator because it travels straight down through the atmosphere and not along a longer angled path.

Other

- Your computer, backup disks, and everything necessary to work without internet
- Books/reading material
- Comfort snacks – sometimes the best way to ward off minor seasickness is to snack on salty or sweet things, and having your favorite snack helps. Ginger candies are always nice for the stomach.
- Laptop and charger
- Phone and charger
- Headphones
- Camera
- Notebooks and writing utensils
- Pre-download any movies/music/podcasts/shows you might want to enjoy (do not expect to download/stream such material via the ship's internet)
- Any other items that you find improve your quality of life and are portable!

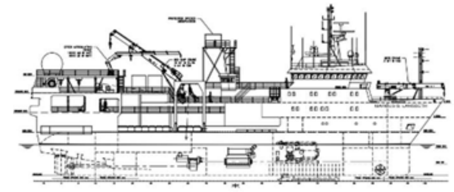
6. Useful Contacts and Resources

Chief Scientist, Project Principal Investigator: Emilie Hooft: emilie@uoregon.edu

Co-Chief Scientist Brandon VanderBeek: brandon.p.vanderbeek@gmail.com

Science Party Briefing and Safety Orientation:
https://lamont.columbia.edu/sites/default/files/content/Science%20Party%20Briefing%20and%20Safety%20Orientation%202015.pdf

Technical detail regarding the R/V Langseth can be found here: https://lamont.columbia.edu/research-divisions/marine-large-programs/office-marine-operations/langseth



Welcome Onboard the MGL!

We hope that your preparations are going well, your sea bags are packed and you are ready to start the expedition. Below are few items that you may find helpful the first day or two onboard.

Arrival:

Once in Panama we will be taking a crew boat/small boat out to the Langseth which is at anchor. From there we will have to climb (2-3 steps) up the pilot ladder to board the vessel. More details will follow the closer we get to arrival however it will go something like this.

- You will board the crew boat from the dock.
- The crew boat will head out to the Langseth, could be 10–30-minute ride.
- Life jackets will be given to the crew as they climb the pilot ladder, no luggage when doing this.
- All luggage will stay on the crew boat and be passed over after the crew are safely on the Langseth.

*** As we get closer to arrival the exact instructions and more detail will be sent. ***

Once onboard you will be met by one of the ships crew. They will take your names, and inform you where your cabin is. Please have your passport ready to give to the captain/mate. They will ask for it right away. At first the vessel will feel like a maze. Don't worry we've all been there! Pick a couple of paths that you know, and if you get lost don't worry just stop and ask for directions.

Berthing:

We are not a big ship so you will most likely have to share a room or a bathroom with some of your team members. Just like back in the college dorm days a few things may be needed.

- Shower sandals
- Ear plugs
- etc

COVID:

The captain will do a COVID test either when you arrive or first thing the next morning. This will be based on, time of arrival and his work load. We will let you know where and when the COVID test is going to be.

Medication/Hospital:

If you have any prescription medication, please ensure you have enough for the length of the cruise and a good buffer if we have to stay out longer due to bad weather etc.

PLEASE ensure you have sea sickness medicine with you, whether it's patches, pills or bracelets. **PLEASE** read the box to know when you need to start taking the medicine. It is very uncomfortable to be sick out here the first several days of the cruise. However, sea sickness is also a normal part of going to sea. It is quite common, so if it hits you just let the chief scientist know that you are not feeling well. Make sure you drink plenty of fluids etc.

Clothing / Shoes / Laundry:

We only have 2 laundry machines and two dryers onboard. It is good practice to set the alarm on your phone so you can cycle your own clothes.

There are no open toed shoes allowed on board. Only in your cabin.

It can be quite chilly in the main lab and your room. So, ensure you bring some warmer clothes.

Langseth Hoodies and Tshirt:

We have a small store onboard where the team can purchase hoodies and t-shirts. The captain only excepts cash so make sure you have some walking around money so you can get some swag.

PPE (Personal Protective Equipment):

If you are going to be working on the open deck, steel/composite toed shoes are needed.

The Langseth has;

- Hard Hats
- Gloves
- Eye protection
- Ear protection
- Coveralls

Internet:

While our internet is much faster than a couple of years ago it is still not like home.

Make sure you do all of your downloading at home; movies, podcasts, audiobooks, work, papers, etc We have wifi on board:

- Langseth Science
- PW: mglXXXXsci (XXXX = the Cruise Number) (Although in port phone service is better)

Orientation / Drill:

Depending on arrival time we will have a vessel orientation the same day or the following day. This will last ~1.5 hours. There will be a presentation followed by a tour.

Once we sail there will be a drill. This will be explained during the orientation.

Sailing Time:

Please ensure you know when the vessel will sail and that you are onboard and reported such to your lead chief scientist. The vessel will not wait for a missing crew member….

Down Time:

We have a saying in seismic that "Good Seismic is Boring Seismic". You will find that there will be times when there is not a lot to do; transits, sitting on station etc.

It may be good to bring that book you've been putting off to read, some work, studies, puzzles etc

We hope that you have a good trip to the vessel and we look forward to starting the cruise and working with you. The Langseth Crew

K.4 COVID protocols

- Pre-cruise
    1. **OMO Covid-19 Health Assessment form**
    2. **Covid Vaccine Cards:** scan and email your COVID vaccine Card
    3. **Pre-Trip Covid Test:** schedule a PCR test for as close as logistically feasible to your departure. Email me the results.

COVID scenarios update from ship operator

From: *Jesus Gaytan* *jgaytan@ldeo.columbia.edu*

We continue to discuss scenarios you have asked about in other emails, so to consolidate here:

1. *Everyone needs to test negative PCR pre-travel. If there is a positive test pre-travel, they should not travel.* The UO team will move their PCR tests to earlier this week so we have results prior to departure.
2. *For those arriving on 13th, please ensure they take an at home antigen test with them to get tested on the 15th. If anyone tests positive in Panama, we will need to see what options we have to bring onboard with as much isolation as possible.*
3. *All participants will be tested once you get onboard. If anyone tests positive, we will need to shuffle berthing around to have an isolation cabin so they can isolate 5-7 days during cruise.*

Please discuss with your team the importance of the cruise and to use masks and avoid crowds as much as possible during travel and during the stay in Panama to avoid having to go through any positive case scenarios.

L: Cruise T-shirt

Marine IGUANA

Marine Imaging of the Galapagos Upwelling Asthenosphere and Neighboring Archipelago

Marine IGUANA

Marine Imaging of the Galapagos Upwelling Asthenosphere and Neighboring Archipelago