



Backscatter Analysis for Sediment Classification

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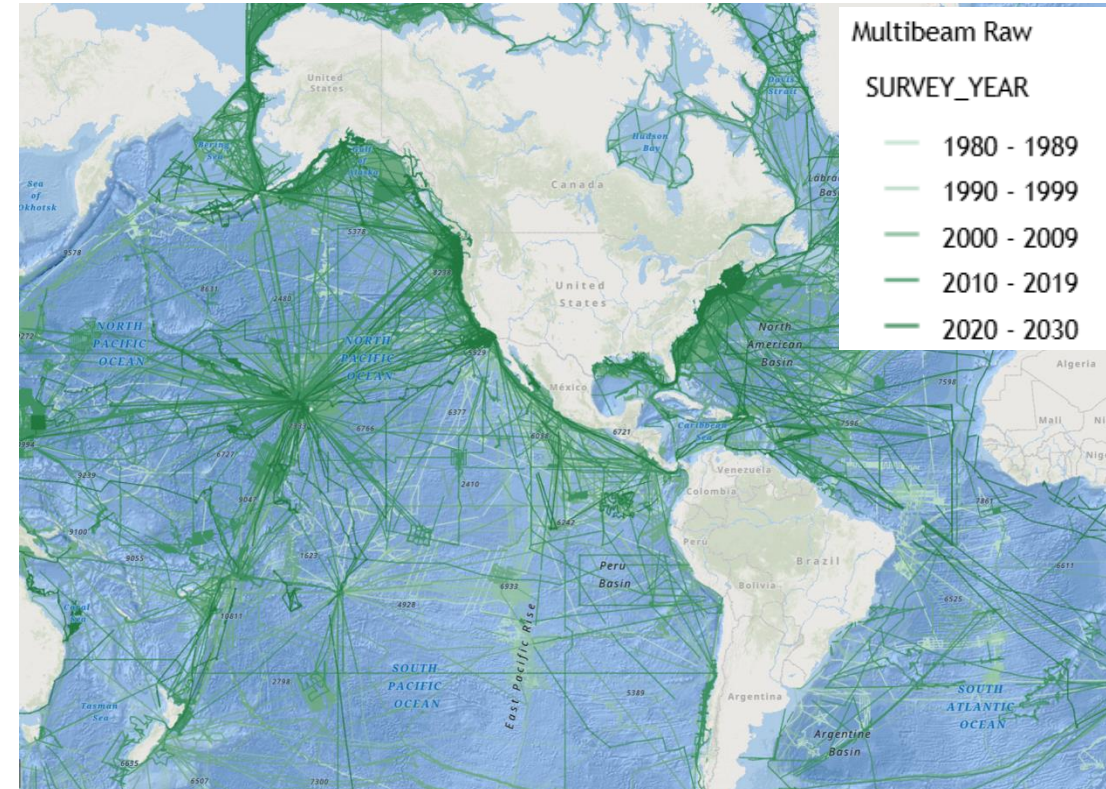
BASC

Vision: Transform decades of multibeam sonar data, originally collected to map seafloor depth, into a global seabed sediment dataset that directly improves the realism and accuracy of ocean acoustic models

Research Hypothesis: Alignment and harmonization of multibeam backscatter data from multiple surveys and systems will facilitate the creation of an accurate global sediment classification map

FY26 Objectives

- Develop method to align and harmonize measurements from multiple surveys and systems
- Process and analyze backscatter data to infer georeferenced sediment types
- Determine if angular response-based relative calibration is plausible for deepwater Multibeam Echosounder (MBES)



National Centers for Environmental Information (NCEI)
Multibeam survey footprints from 1980-present¹

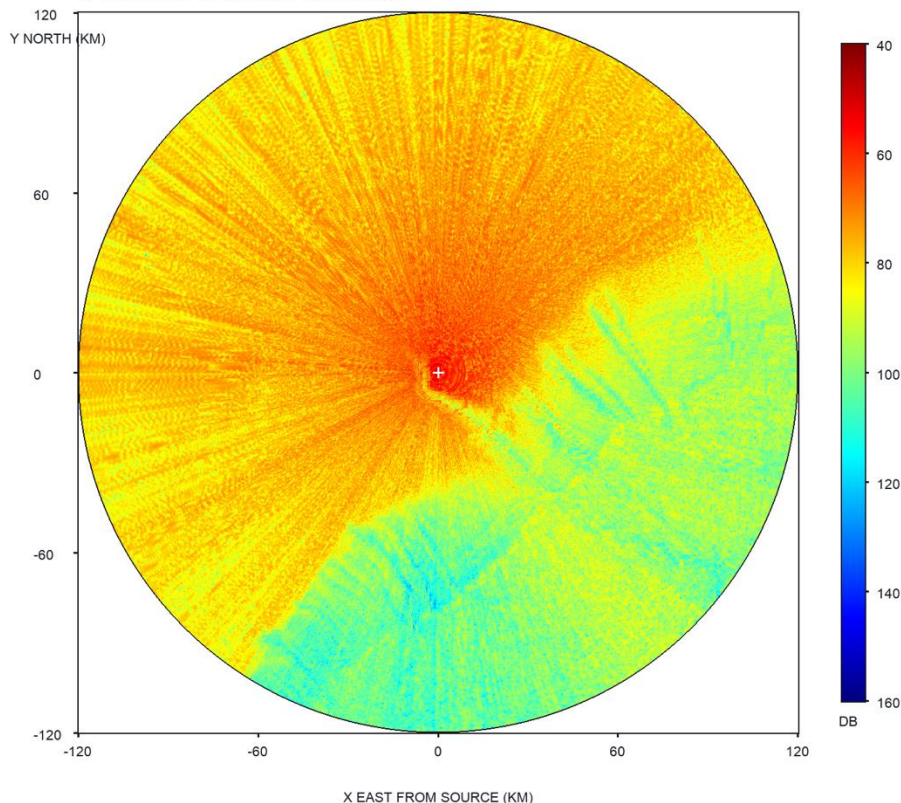
1. <https://www.ncei.noaa.gov/maps/bathymetry/>

Propagation Modeling Vignette

Sediment Type Influence on Transmission Loss (TL)

RAMX3D HARD SAND TL 5 M ABOVE SEAFLOOR

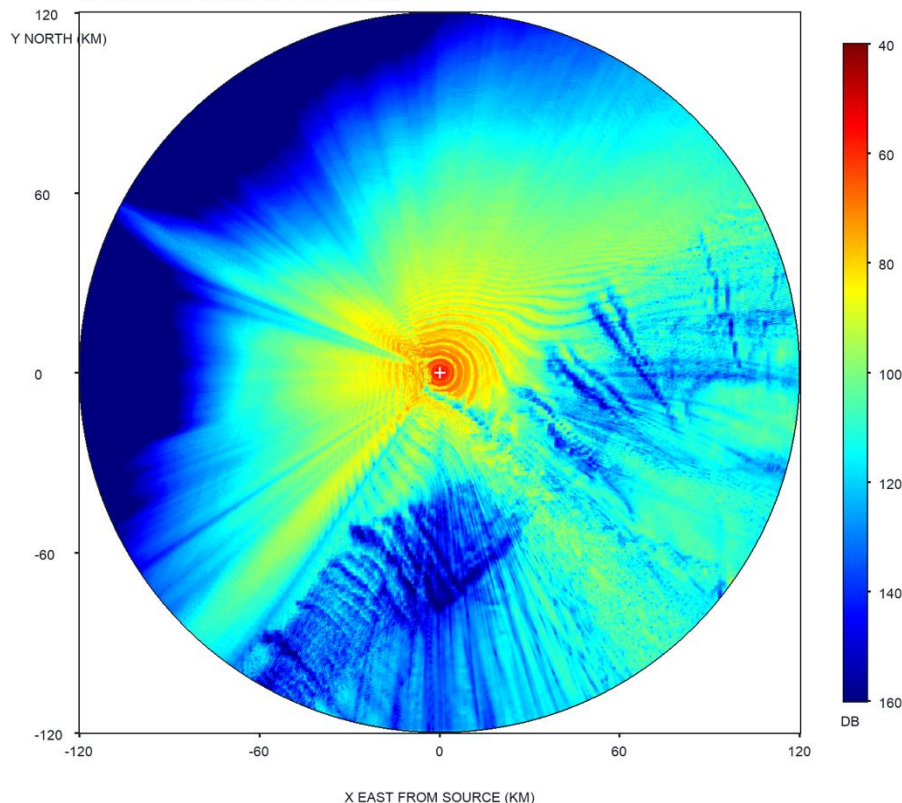
cp=1900 m/s, rho=1.90 g/cc, alpha=0.08 dB/lambda



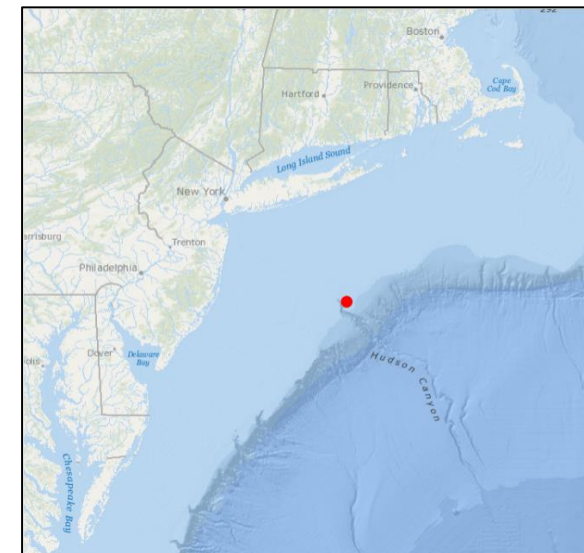
TL with **Sand** bottom

RAMX3D SOFT MUD TL 5 M ABOVE SEAFLOOR

cp=1550 m/s, rho=1.25 g/cc, alpha=0.80 dB/lambda



TL with **Mud** bottom

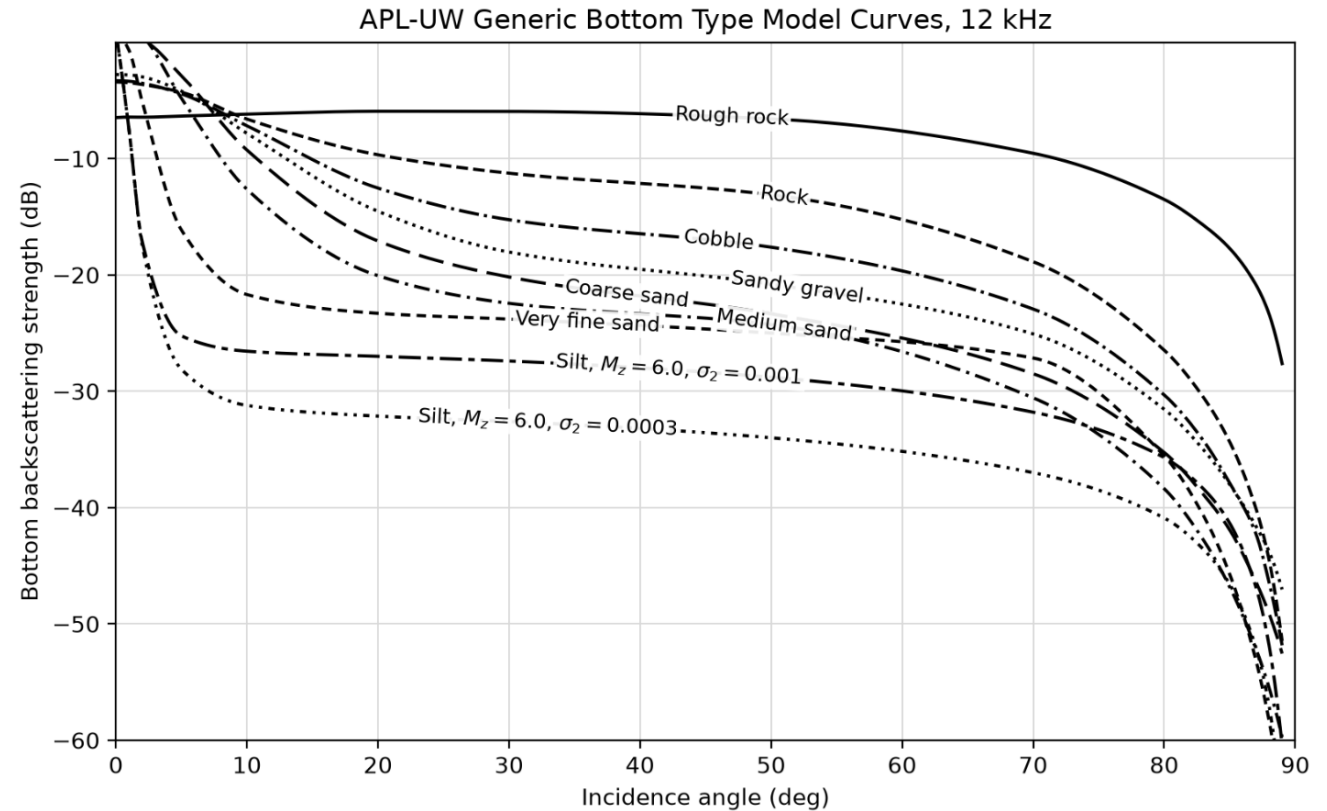


Origin

Boundary conditions informed by the seafloor sediment type have a significant impact on results of acoustic propagation modeling. The TL differences between a sand and mud seafloor are several orders of magnitudes higher over 120km at 150 Hz

Sediment Classification: Angular-Dependent Backscatter

- Sediments can be classified through the backscatter intensity levels at oblique angles
- Backscatter over oblique angles is controlled by sediment hardness and roughness, enabling better discrimination between seabed types
- Fine-grained sediments (silt/clay) are smoother, producing a strong but narrow specular peak that drops off quickly with angle
- The plateau region ($\sim 40^\circ - 45^\circ$) is often used as a reference for normalizing backscatter



Angular-dependent backscatter intensities for various sediments.
Based on model results using the Applied Physics Lab - University of Washington's High-frequency Ocean Environmental Acoustic Models Handbook

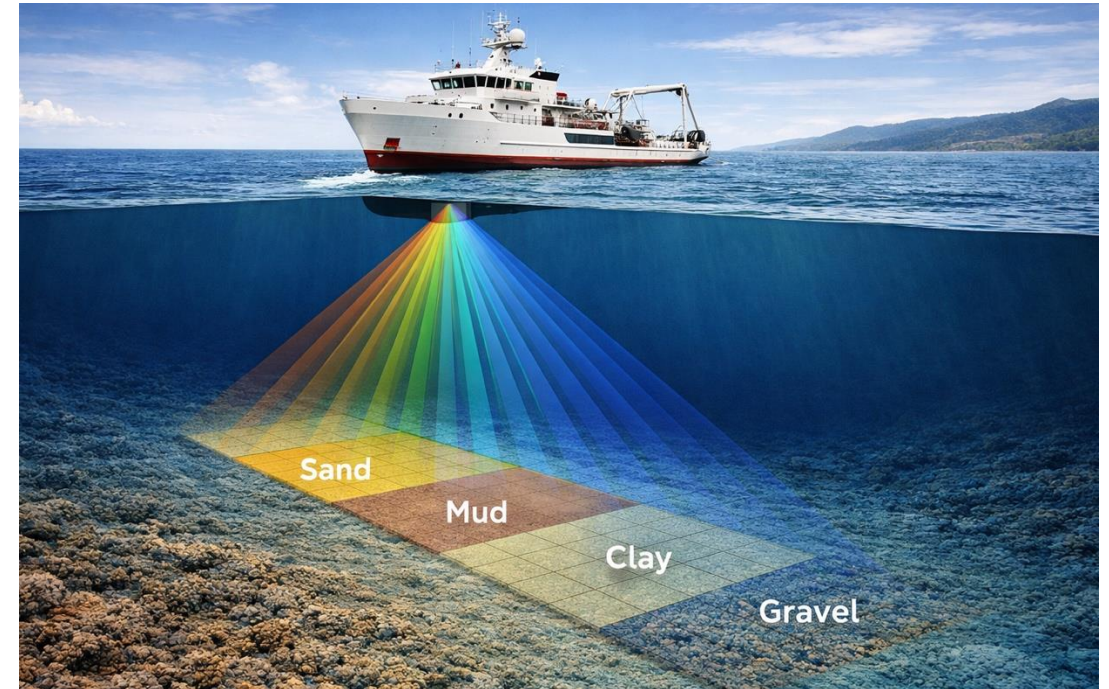
1. X. Lurton *et al.*, "Backscatter measurements by seafloor-mapping sonars. Guidelines and Recommendations," GeoHab, May 2015. doi: [10.5281/zenodo.10089261](https://doi.org/10.5281/zenodo.10089261).
2. APL-UW (1994) High-Frequency Ocean Environmental Acoustic Models Handbook (APL-UW TR 9407). Seattle, WA: Applied Physics Laboratory, University of Washington, 1994.

Multi Source Sediment Classification Depends on Consistent Data

MBES backscatter values do not reflect seafloor properties alone. They are also shaped by sonar hardware, proprietary manufacturer processing, survey practices, and post-processing software.

Why inconsistency occurs

- **System differences:** varies across manufacturers, sonar generations, and even units of the same model.
- **Operational differences:** platforms, survey settings, and acquisition procedures can differ.

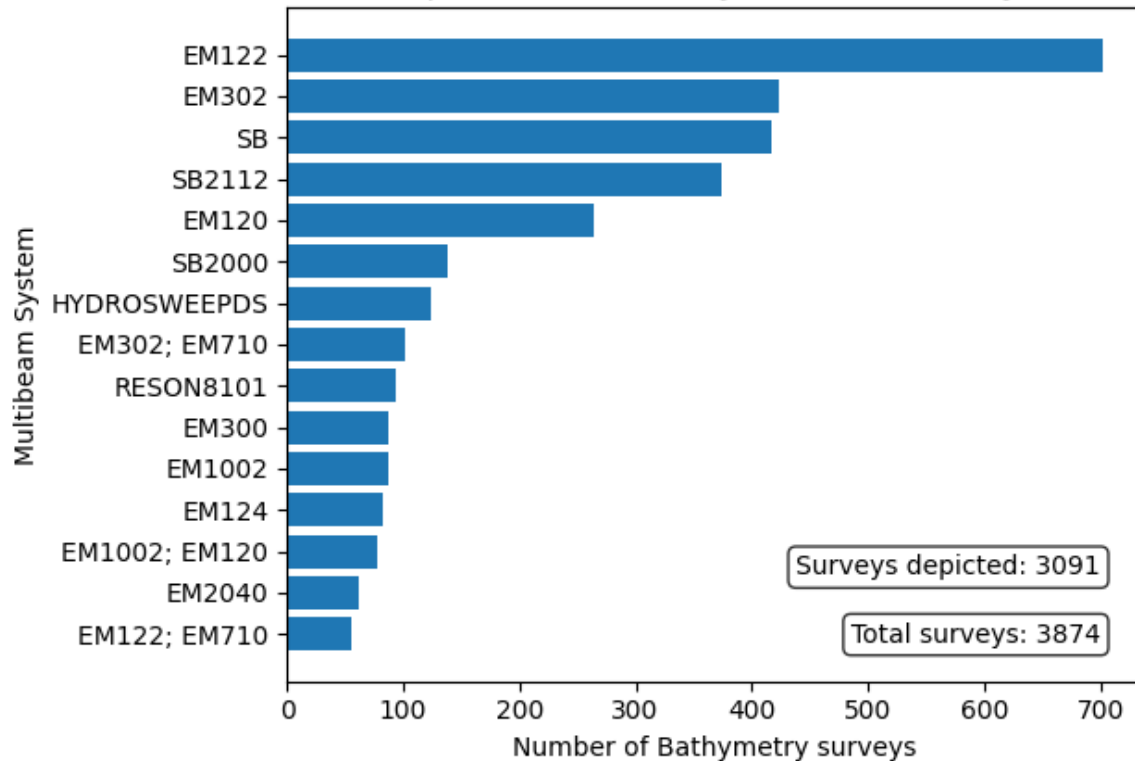


Distinguishing sediment types from backscatter data

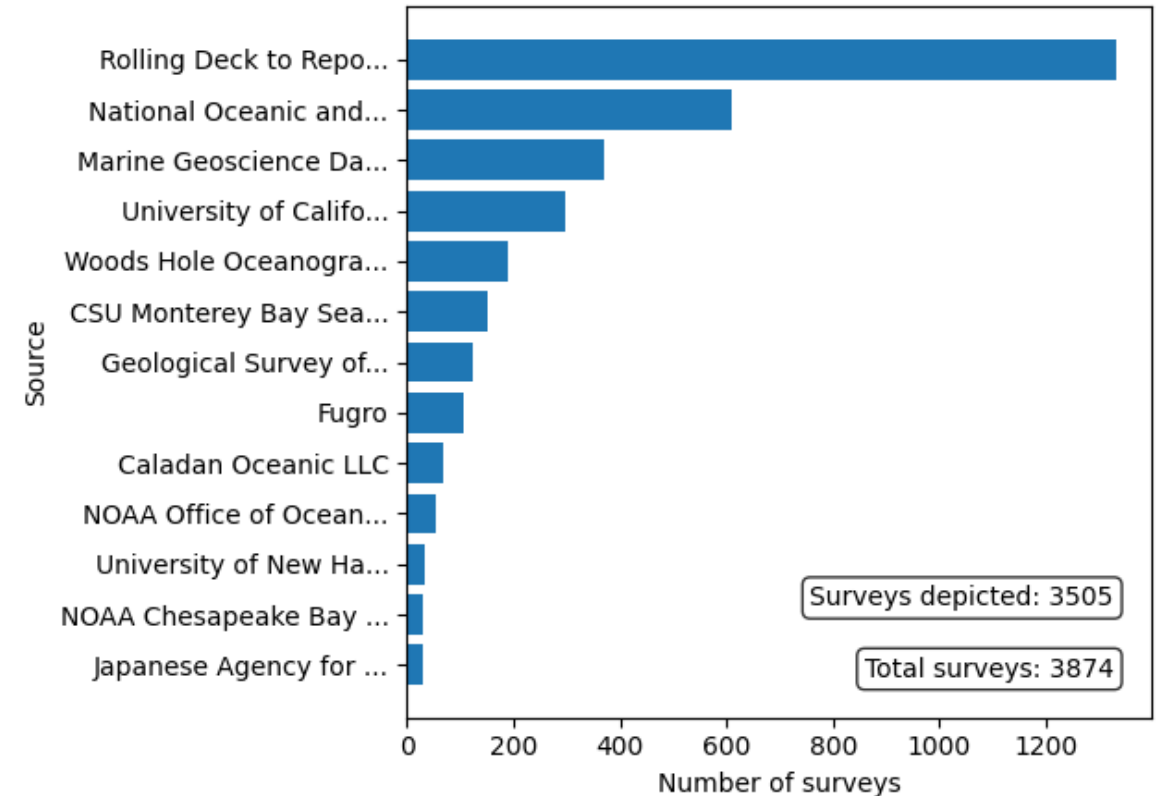
Backscatter angular response at the same location can vary quantitatively between systems or even from the same system at different times. Relative calibration enables consistent multi-system analysis and data harmonization.

Cataloging The Multibeam Bathymetry Database (MBBDB) at NCEI

NCEI Multibeam Bathymetry Database
Top 15 instruments by number of surveys



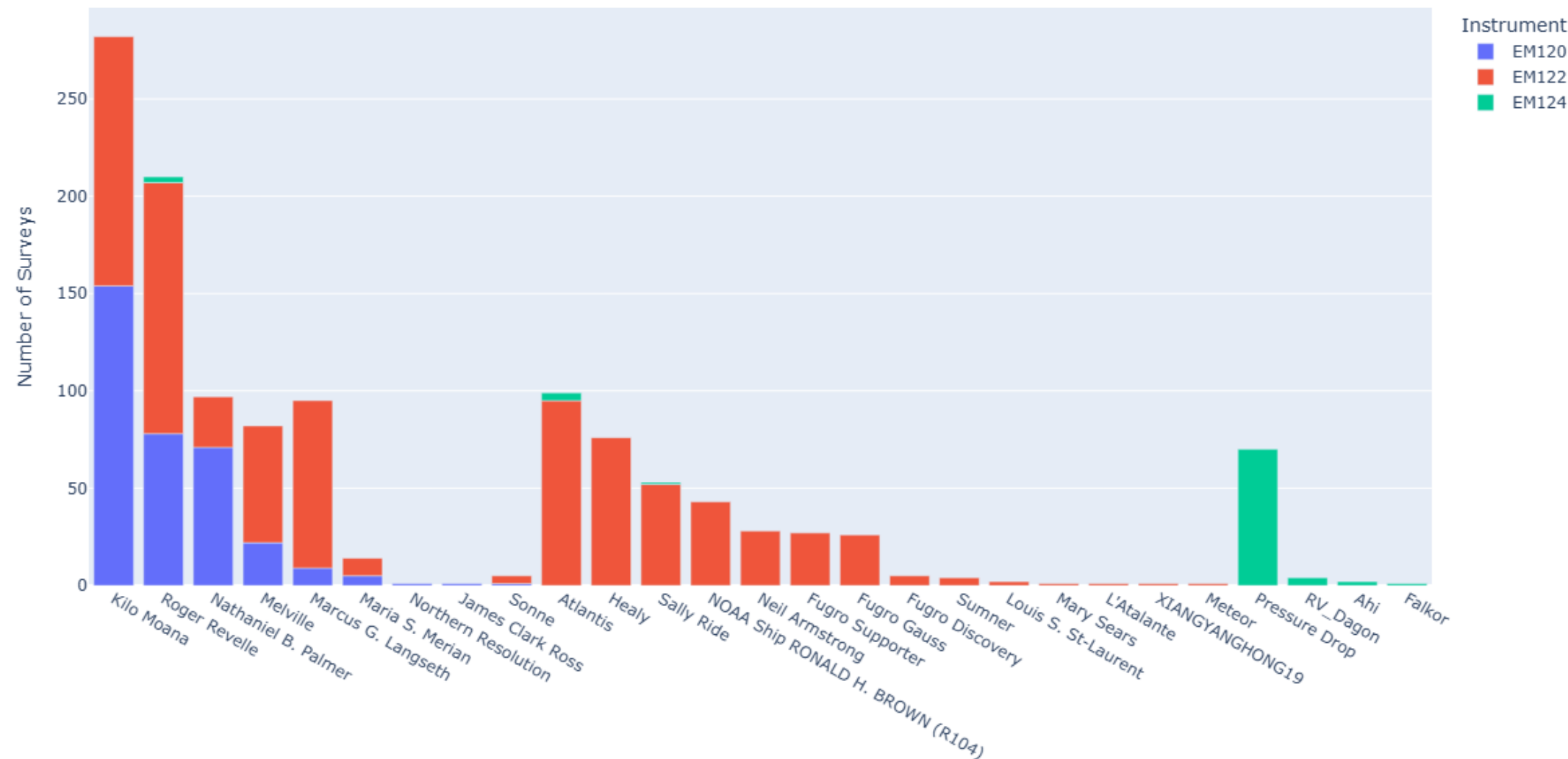
Top 15 sources by number of surveys



- List of all ships that have collected multibeam bathymetry data in the NCEI MBBDB
 - <https://www.ngdc.noaa.gov/ships/>

Focusing on deepwater 12kHz EM12x systems

Surveys by Platform and Instrument (Including Dual Instrument Listings)



Harmonization Opportunities

Location 3

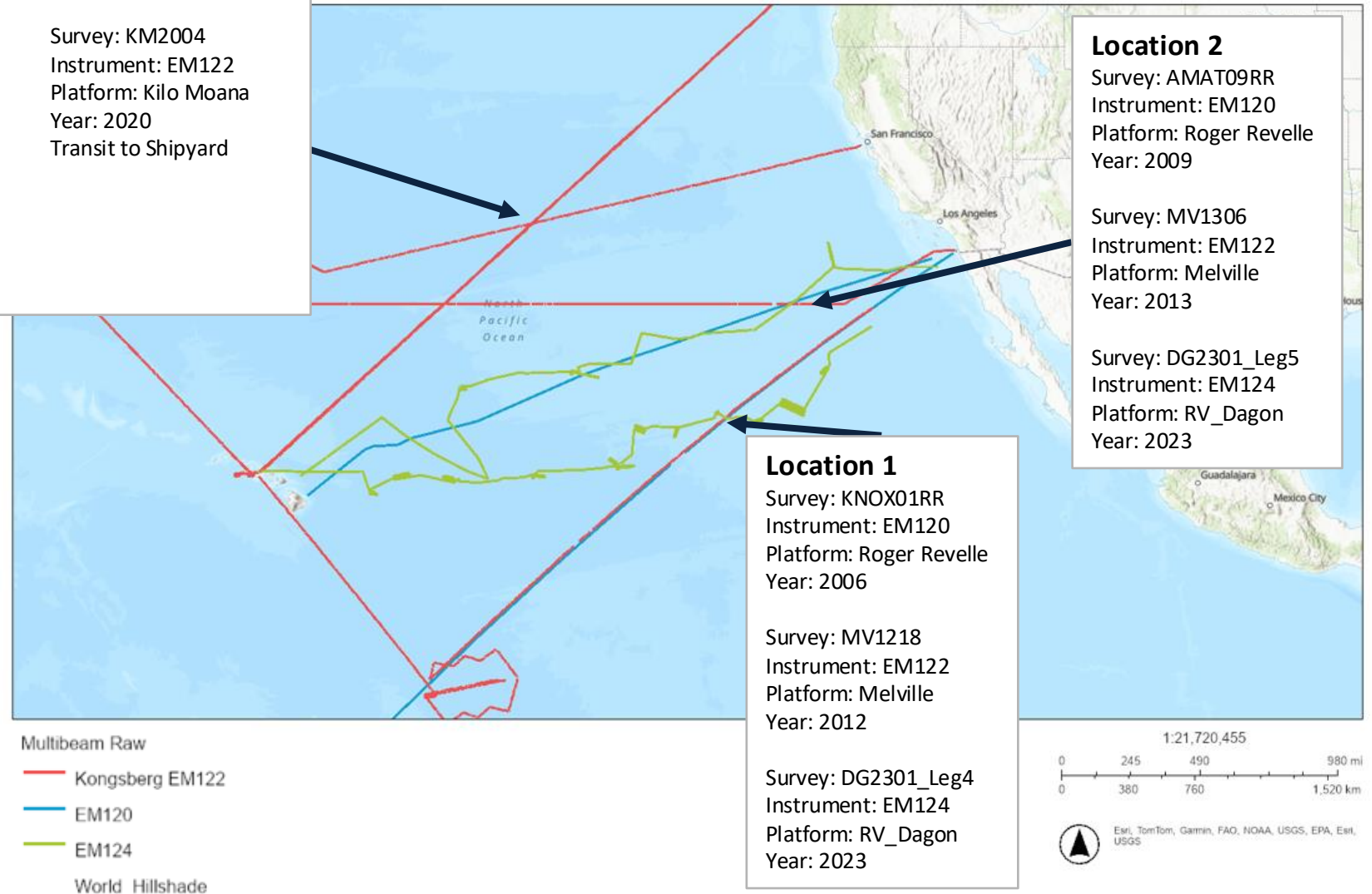
Survey: MGL1002
Instrument: EM122
Platform: Marcus G Langseth
Year: 2010
Multibeam system trials and transit

Survey: SR1917
Instrument: EM122
Platform: Sally Ride
Year: 2019
Investigating Diazotrophy in tropical and subtropical Pacific Ocean

Survey: KM2004
Instrument: EM122
Platform: Kilo Moana
Year: 2020
Transit to Shipyard

Surveys with parallel and overlapping tracks offer data useful for relative calibration

Multibeam Trackline Viewer



Location 3 Backscatter Sample Geometry Overview

Marcus G Langseth MGL 1002

- Dual swath, Pulse Form CW, Deep

Sally Ride SR1917

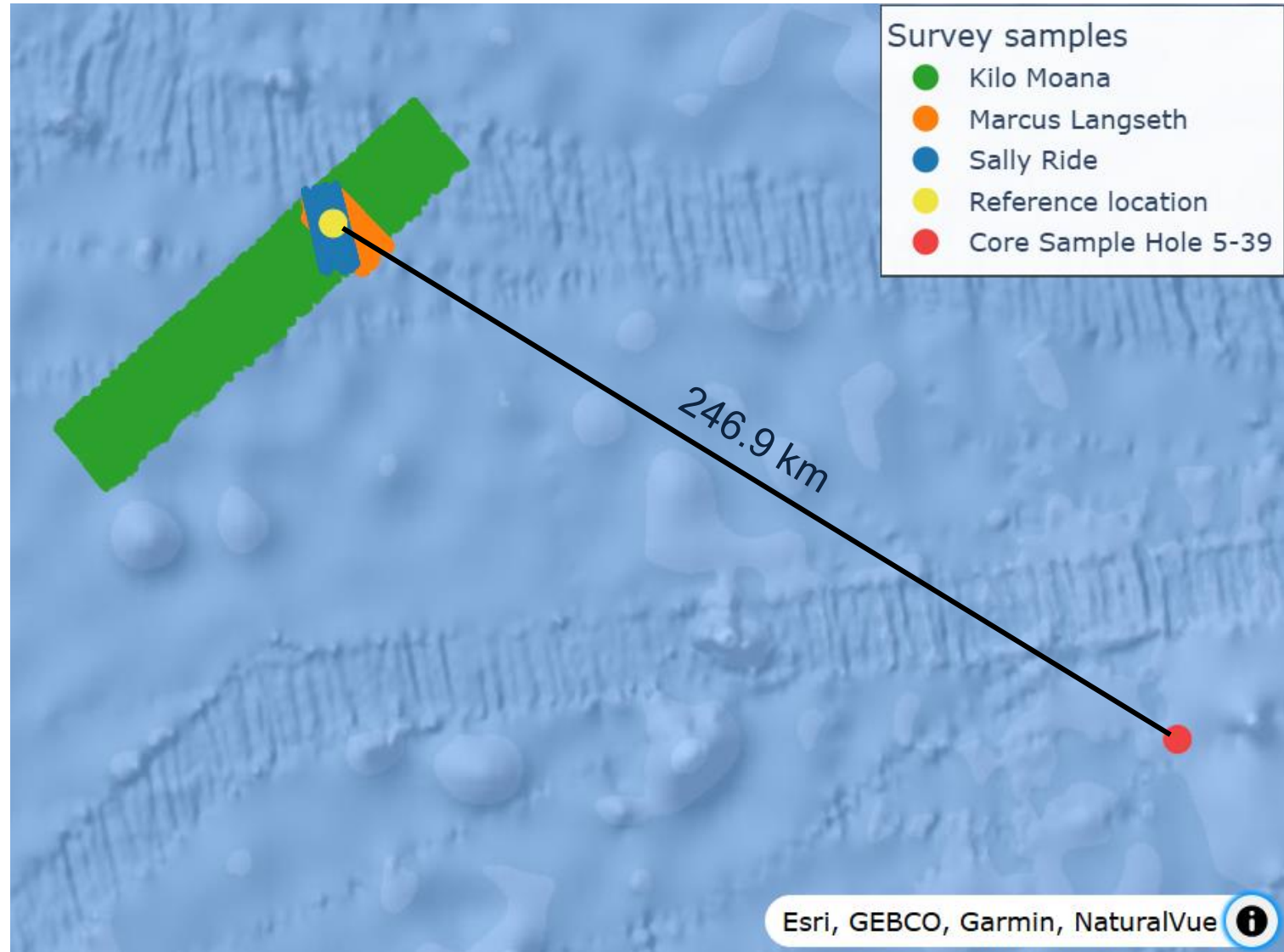
- Dual swath, Pulse Form mixed, Deep

Kilo Moana KM2004

- Dual swath, Pulse Form mixed, Deep

Reference Location

- (33.96,-141.84)
- Water Depth: ~5280m



Hole 5-39

- The dominant lithology cored at this site is a yellow brown **mud**.
- ~40m of sediment
- ~78-80% porosity

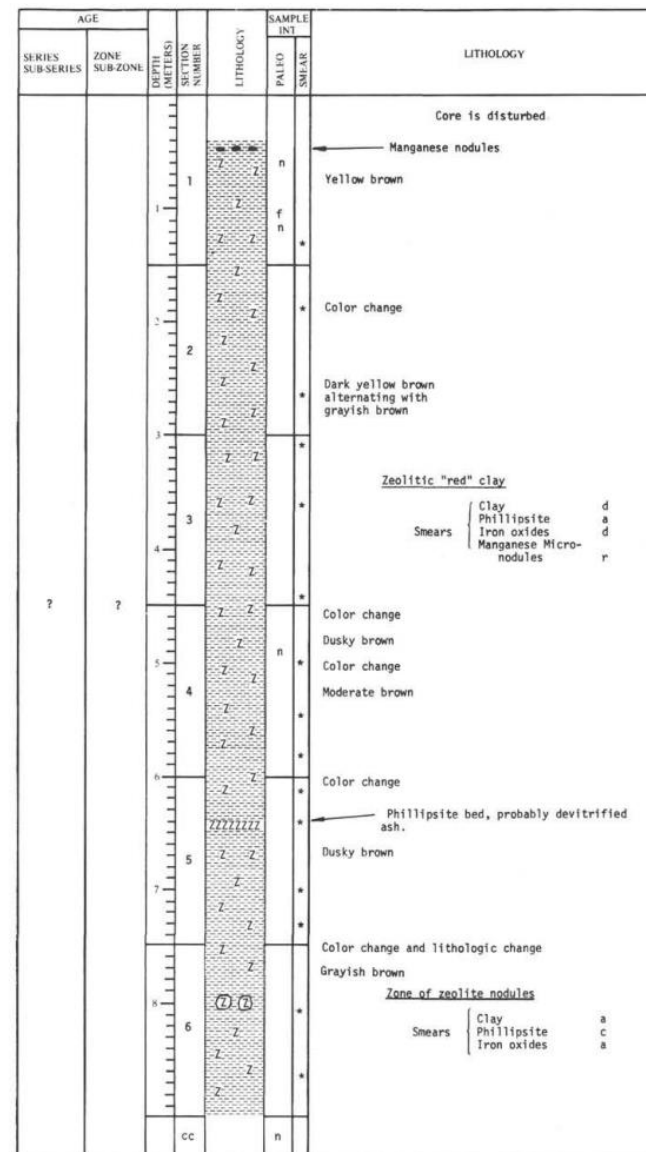


Figure 3B. Core 1, Hole 39 (0-9 m Below Seabed)

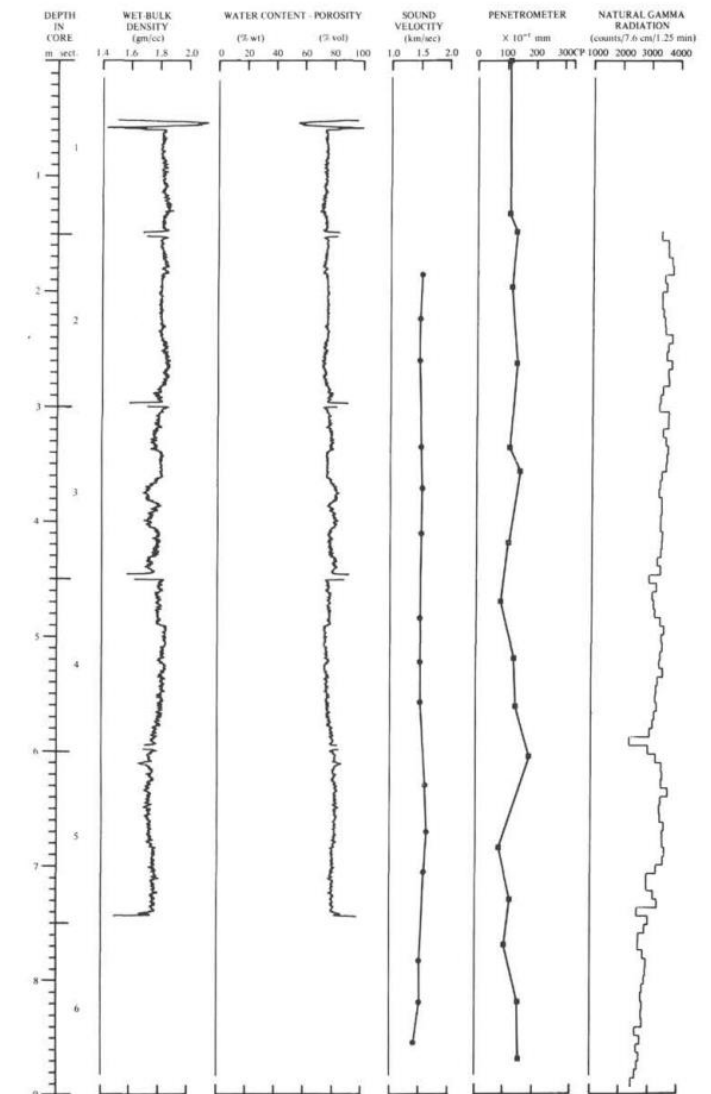
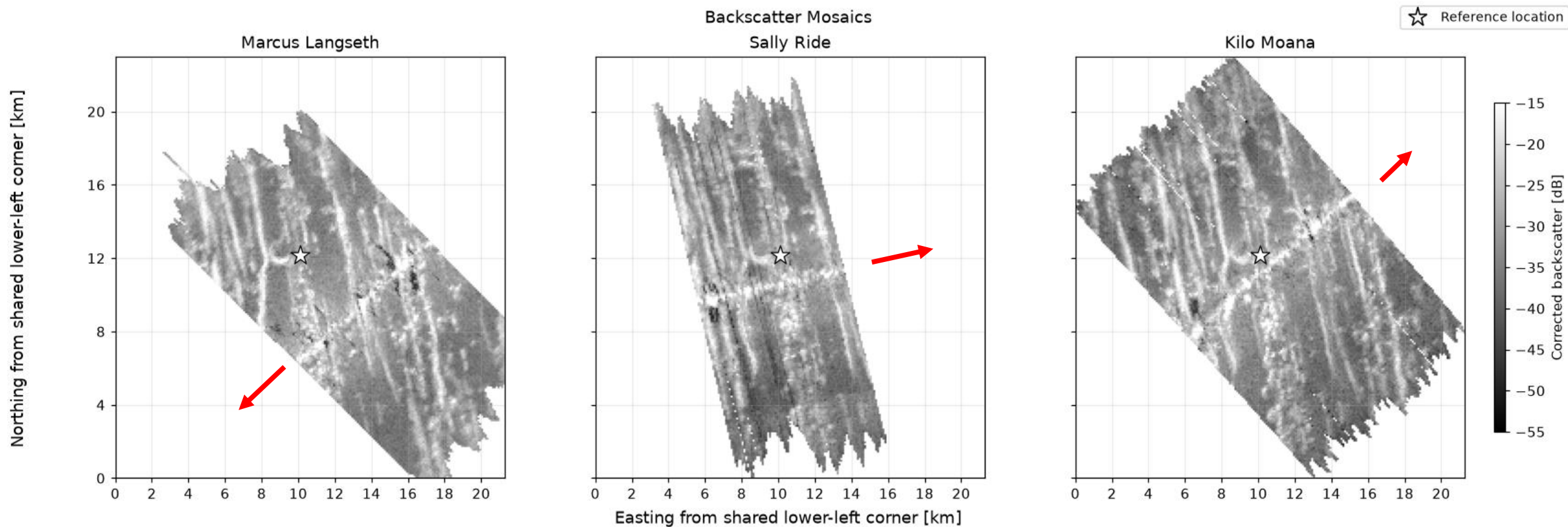


Figure 3A. Physical Properties of Core 1, Hole 39

https://deepseadrilling.org/05/volume/dsdp05_09.pdf

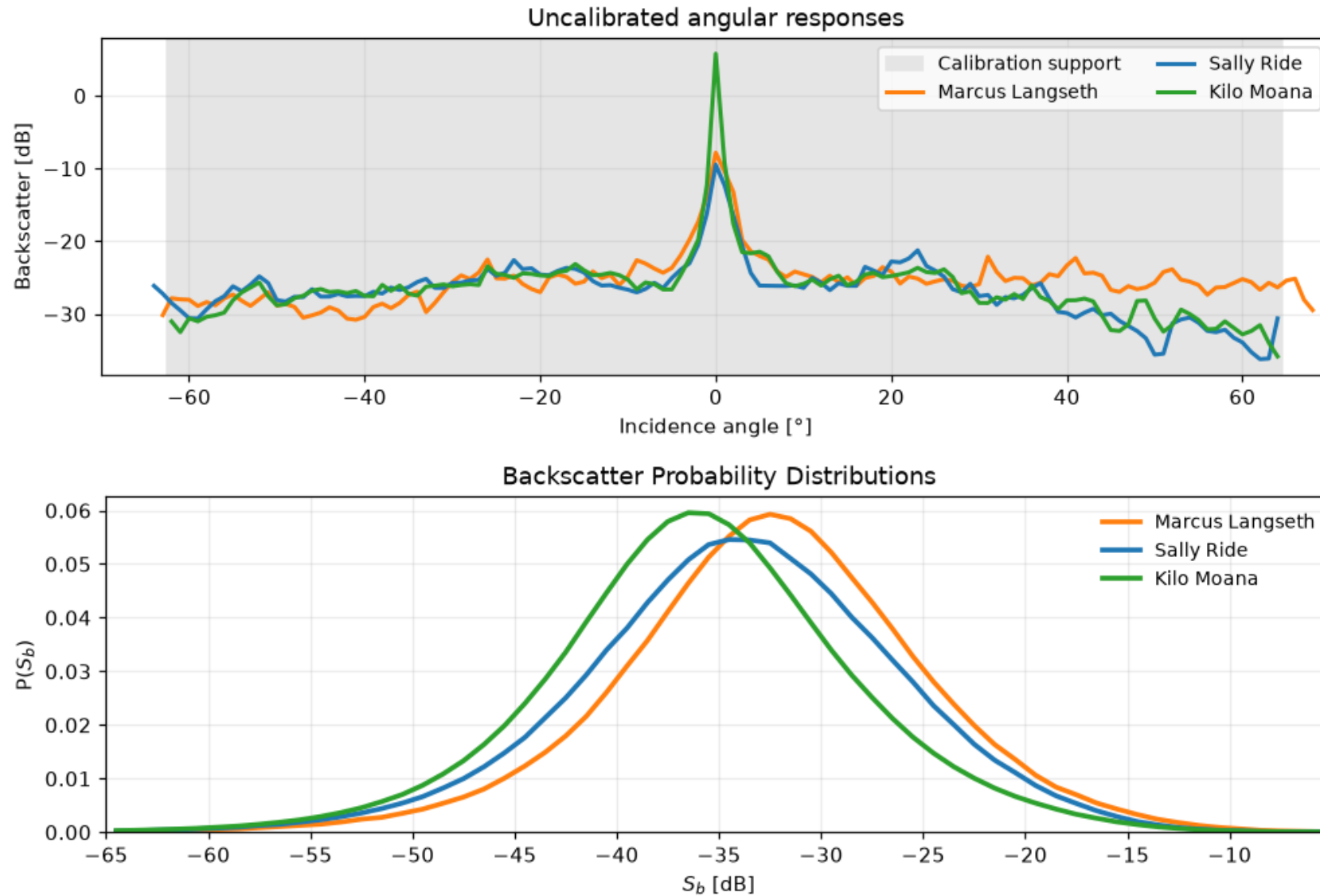
Location 3: Backscatter Mosaics of Overlapping Pings



→ Direction of Travel

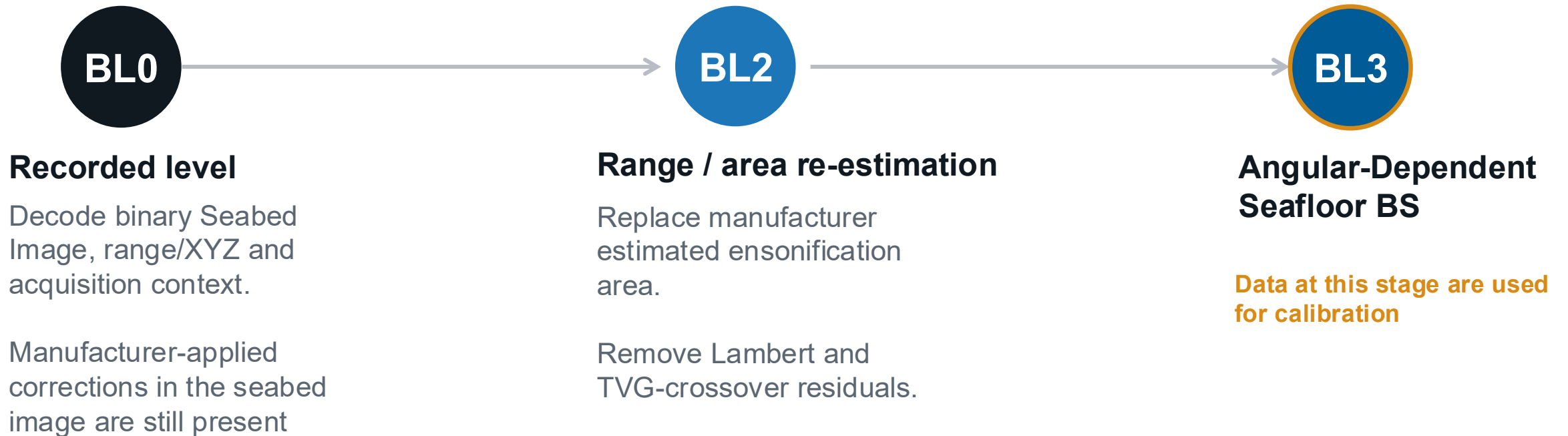
Mosaics, seen before normalizing to a reference angle, show qualitatively similar seafloors. Major features appear stationary over a decade

The harmonization problem



Data Processing chain

Data are retrieved from the raw data file and processed as follows



[1] T. C. Weber, G. Rice, and M. Smith, "Toward a standard line for use in multibeam echo sounder calibration," *Mar Geophys Res*, vol. 39, no. 1, pp. 75–87, Jun. 2018, doi: [10.1007/s11001-017-9334-3](https://doi.org/10.1007/s11001-017-9334-3).

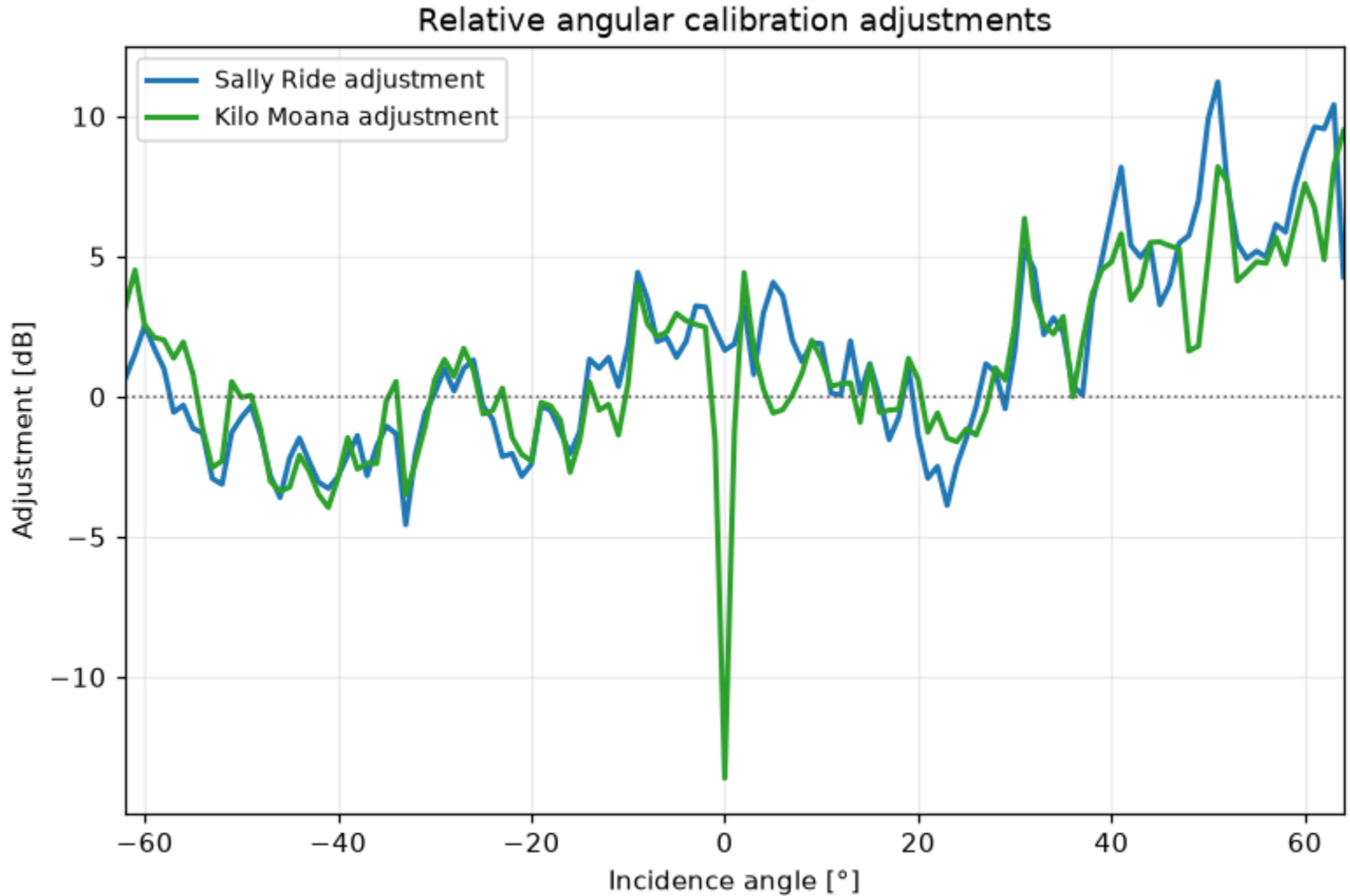
[2] Schimel, A. C. G., Beaudoin, J., Parnum, I. M., Le Bas, T., Schmidt, V., Keith, G., and Ierodiaconou, D. (2018). Multibeam sonar backscatter data processing. *Marine Geophysical Research*, 39, 121-137. <https://doi.org/10.1007/s11001-018-9341-z>. Relevant: stages 1-3, Fig. 2, and BL0-BL3 definitions on pp. 124-129 and 133-134.

Location 3: Calibration adjustments

- The Marcus G. Langseth survey was used as the relative calibration reference
- The survey was conducted in 2010 and does not utilize a BSCorr.txt for backscatter corrections

Current Hypothesis

The Sally Ride and Kilo Moana calibration curves appear similar because they both implement BSCorr.txt corrections to the seabed image data



Calibration curves for the Kilo Moana and Sally Ride

Location 3: Calibrated Distribution of Backscatter

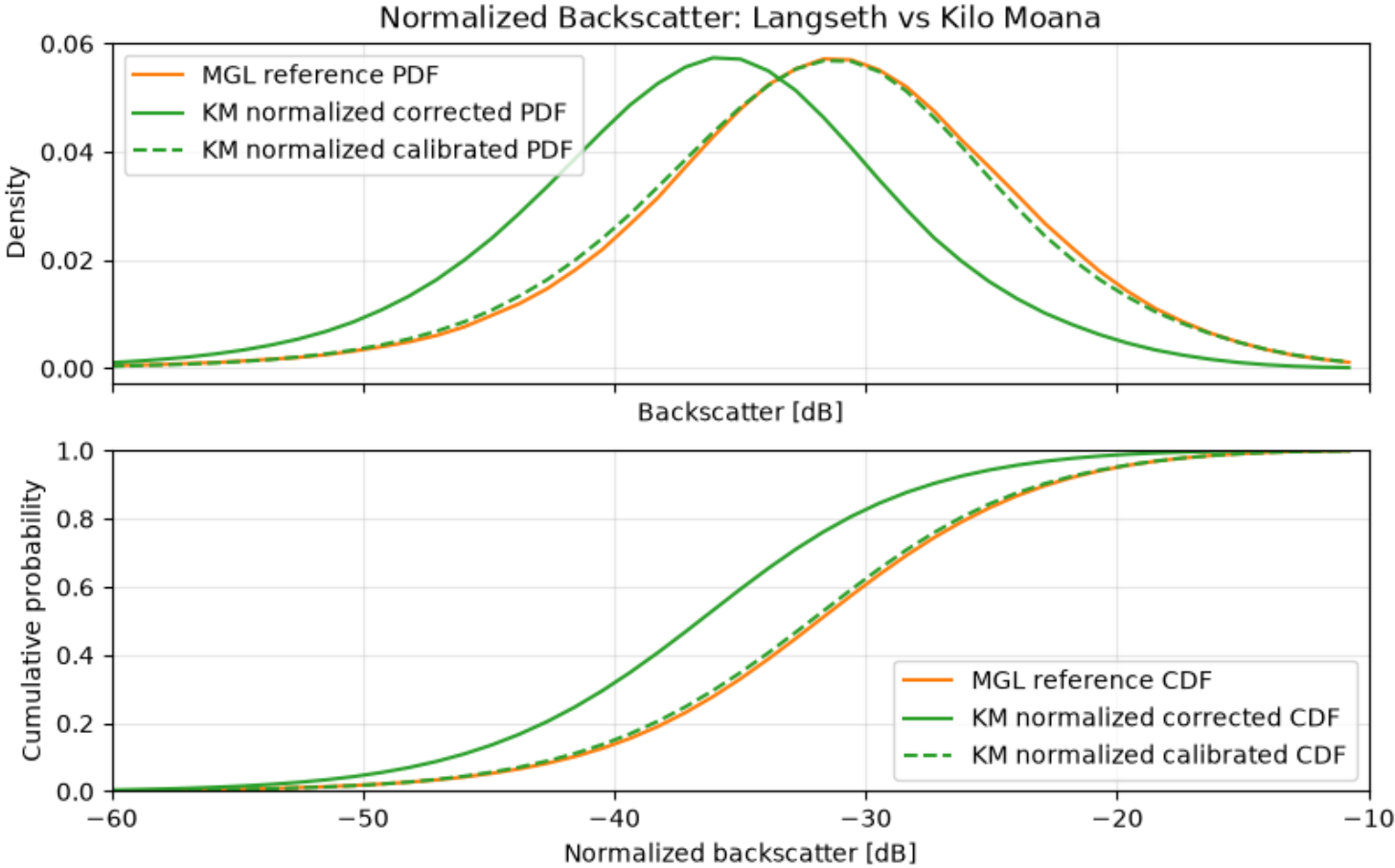
Samples 201 ping Window

Two-sided Kolmogorov-Smirnov (KS)
test results

Comparison	KS statistic (D)	p-value
KM normalized-corrected vs. MGL reference	0.2667	< 0.001
KM normalized-calibrated vs. MGL reference	0.0181	< 0.001

After calibration, the KS statistic (D) decreased by 93 % between the reference and calibration distributions.

A decreasing D value means the calibration made the distributions more similar, confirming the hypothesized outcome



KM Full File Calibration performed using a 201-ping window

KM = Kilo Moana; MGL = Langseth; Reference = normalized-corrected Langseth backscatter.

Location 3: Calibrated Distribution of Backscatter

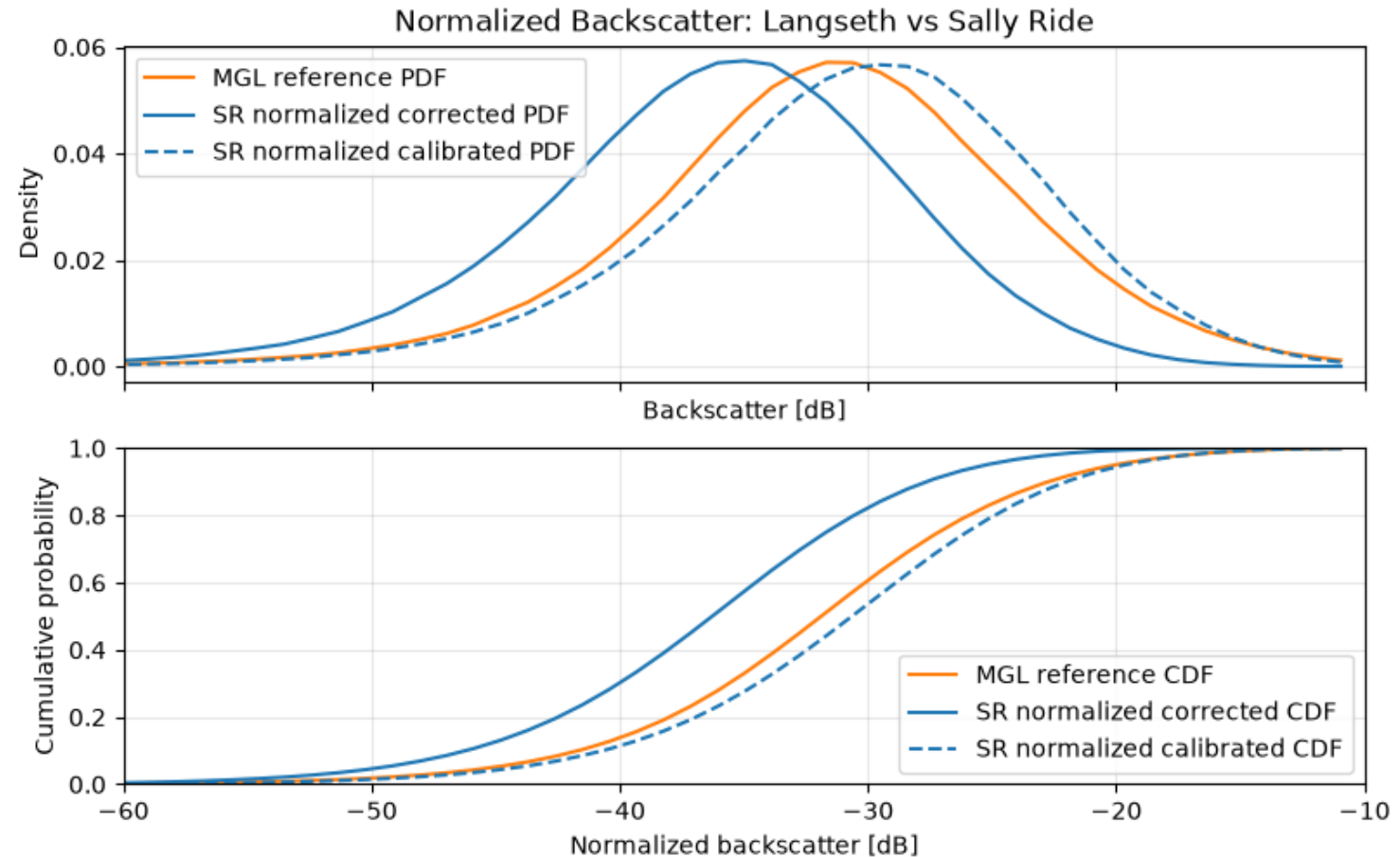
Samples 201 ping Window

Two-sided Kolmogorov-Smirnov (KS)
test results

Comparison	KS statistic (D)	p-value
SR normalized-corrected vs. MGL reference	0.2498	< 0.001
SR normalized-calibrated vs. MGL reference	0.0703	< 0.001

After calibration, the KS statistic (D) decreased by 72% between the reference and calibration distributions.

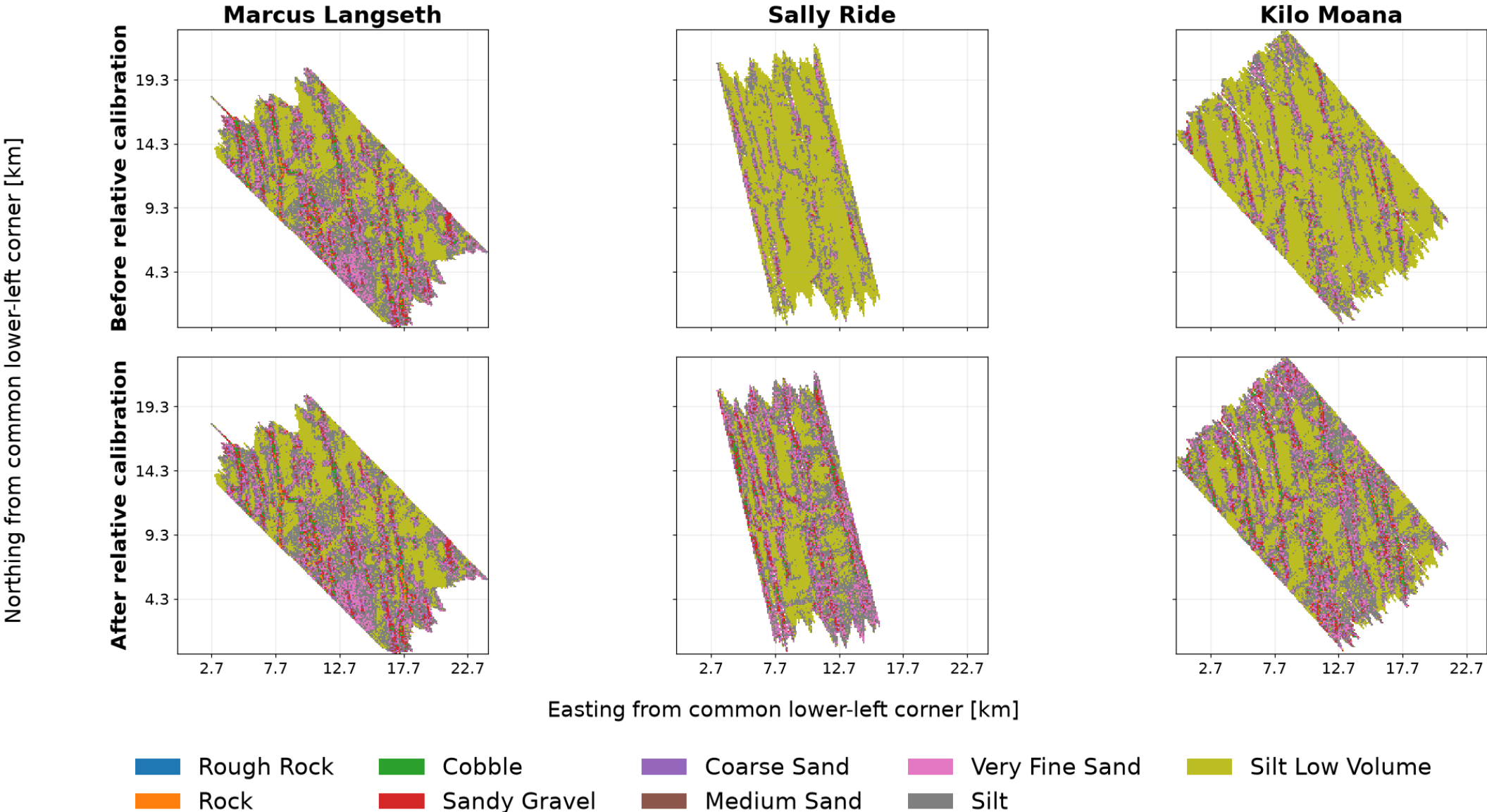
A decreasing D value means the calibration made the distributions more similar, confirming the hypothesized outcome



SR Full File Calibration performed using a 201-ping window

SR = Sally Ride; MGL = Langseth; Reference = normalized-corrected Langseth backscatter.

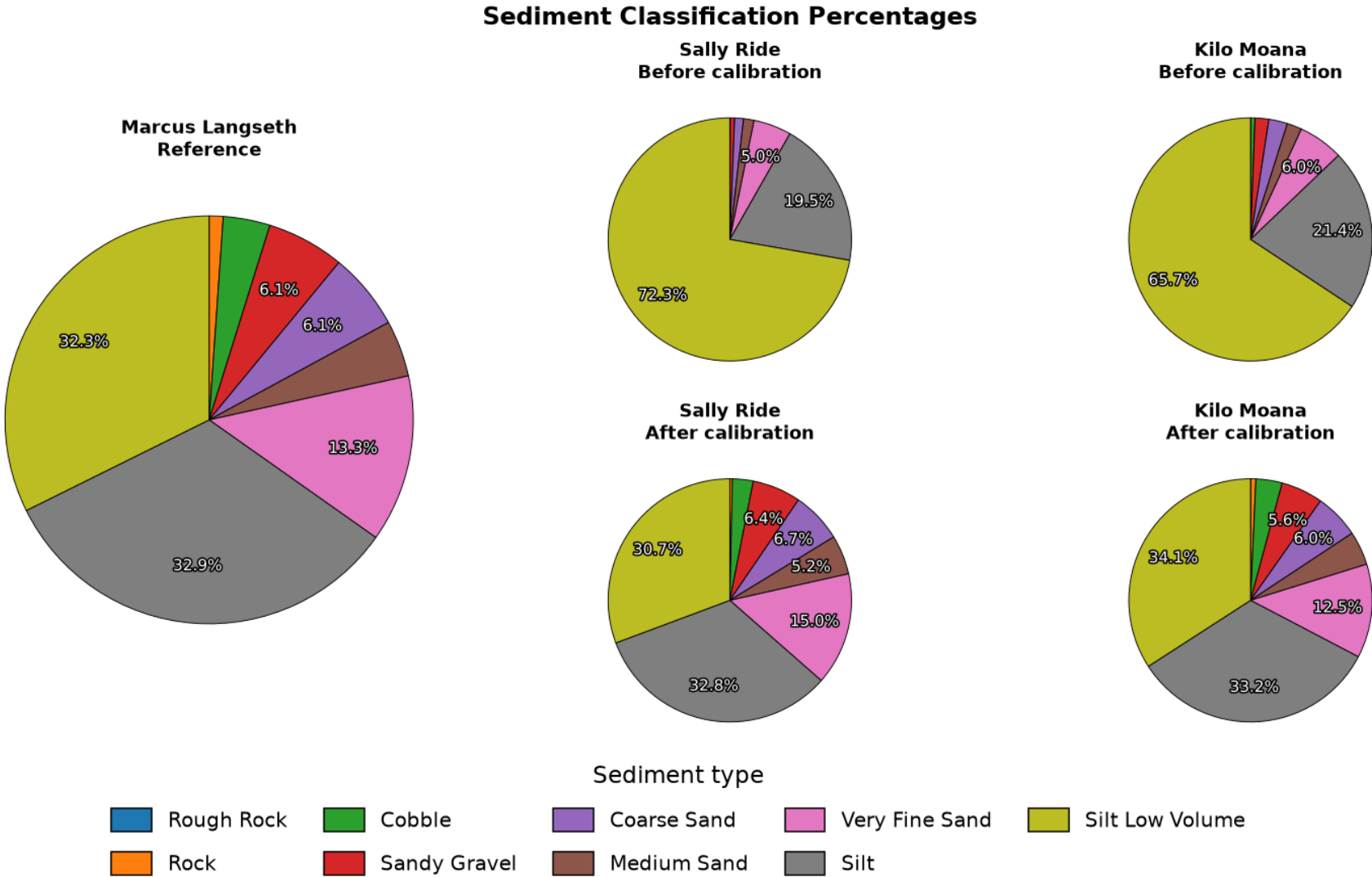
Classification Before and After Calibration



Classification Before and After Calibration

Before Relative Calibration			
Sediment type	Marcus Langseth	Sally Ride	Kilo Moana
Rough Rock	0.0%	0.0%	0.0%
Rock	1.1%	0.0%	0.0%
Cobble	3.7%	0.1%	0.6%
Sandy Gravel	6.1%	0.6%	1.8%
Coarse Sand	6.1%	1.2%	2.5%
Medium Sand	4.5%	1.4%	2.0%
Very Fine Sand	13.3%	5.0%	6.0%
Silt	32.9%	19.5%	21.4%
Silt Low Volume	32.3%	72.3%	65.7%

After Relative Calibration			
Sediment type	Marcus Langseth	Sally Ride	Kilo Moana
Rough Rock	0.0%	0.0%	0.0%
Rock	1.1%	0.3%	0.7%
Cobble	3.7%	2.7%	3.5%
Sandy Gravel	6.1%	6.4%	5.6%
Coarse Sand	6.1%	6.7%	6.0%
Medium Sand	4.5%	5.2%	4.5%
Very Fine Sand	13.3%	15.0%	12.5%
Silt	32.9%	32.8%	33.2%
Silt Low Volume	32.3%	30.7%	34.1%



Assumptions and Questions

Assumptions

- The deep seafloor is stationary over time
 - There are areas where this isn't true

Open Questions

- What scale of sediment classification is useful?
 - What grid and grid size is useful for sediment type classification?
 - Would relatively calibrated data be useful for sediment database projects like dbSEABED?
 - What is the best platform and system to use as a reference for calibration?
 - Should it be a platform and survey where a BSCorr.txt calibration is used?
 - Can a single reference be used for the entire database or are references geographically specific
 - How does relative calibration perform with respect to the EM120 and EM124 data?

Acknowledgements

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- Kongsberg

Questions?

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Backup

Location 3 Dual Swath Ping Separation

Research Question: Determine if the dual swath pings always operate at the same frequency per sector/swath

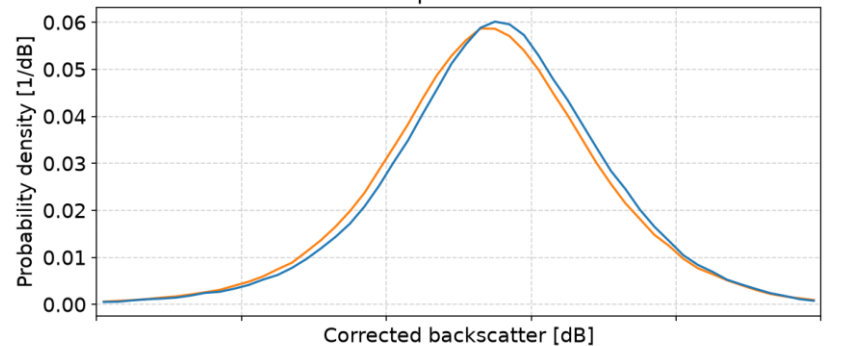
- The sector-center frequencies are identical across Kilo Moana, Langseth, and Sally Ride at two independent locations and times
- Each dual-swath pair differs by a consistent 300 Hz for Swath 1.

Sector	Swath 0 (kHz)	Swath 1 (kHz)	Difference (kHz)
0	11.600	11.900	+0.300
1	11.000	11.300	+0.300
2	12.800	13.100	+0.300
3	12.200	12.500	+0.300
4	12.950	13.250	+0.300
5	12.350	12.650	+0.300
6	11.750	12.050	+0.300
7	11.150	11.450	+0.300

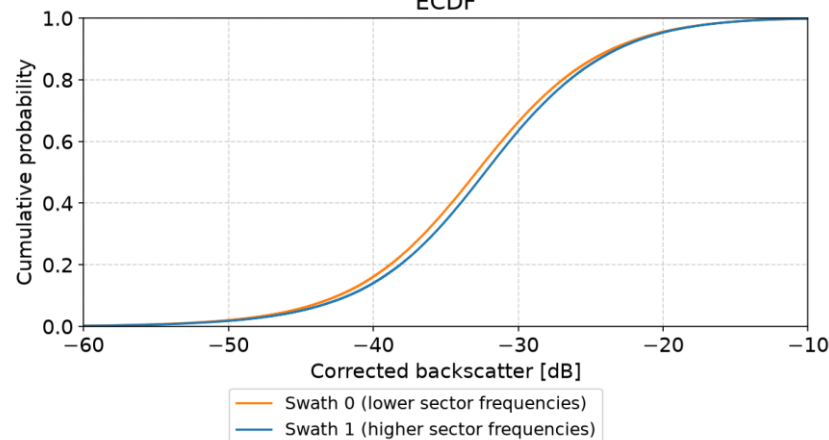
Location 3 Dual Swath Distributions

Langseth Location 3 Dual Swath Distributions

Empirical PDF

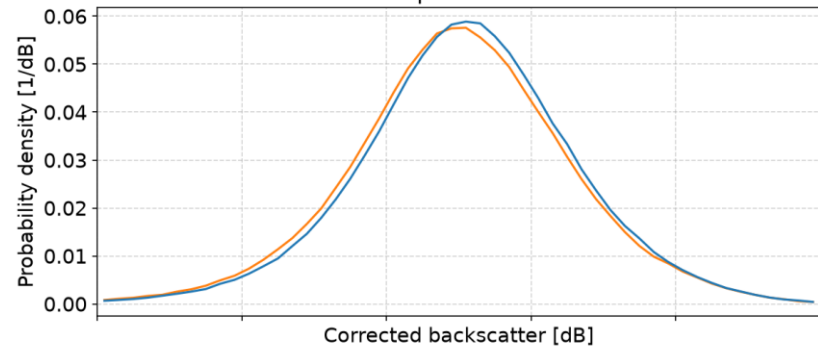


ECDF

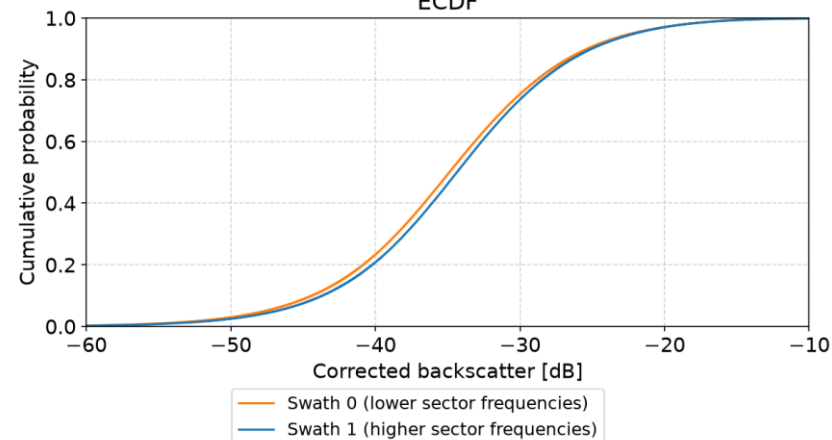


Kilo Moana Location 3 Dual Swath Distributions

Empirical PDF

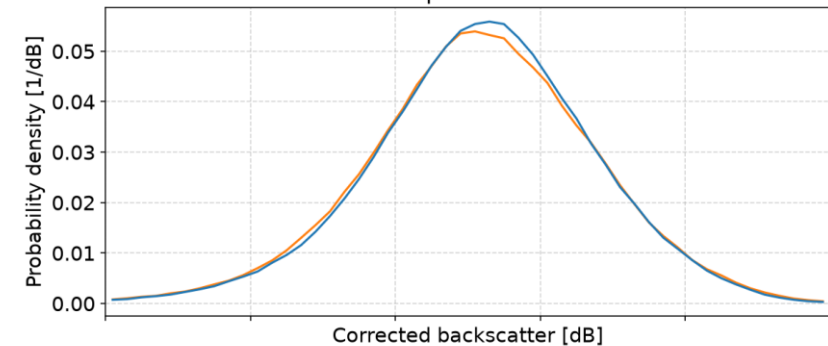


ECDF

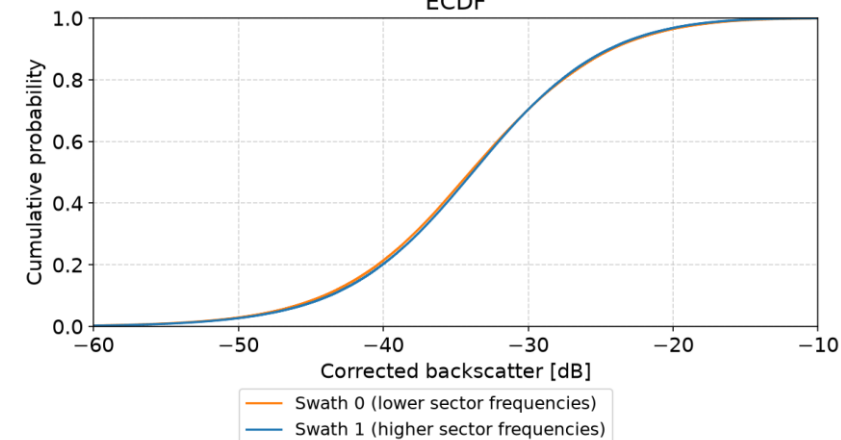


Sally Ride Location 3 Dual Swath Distributions

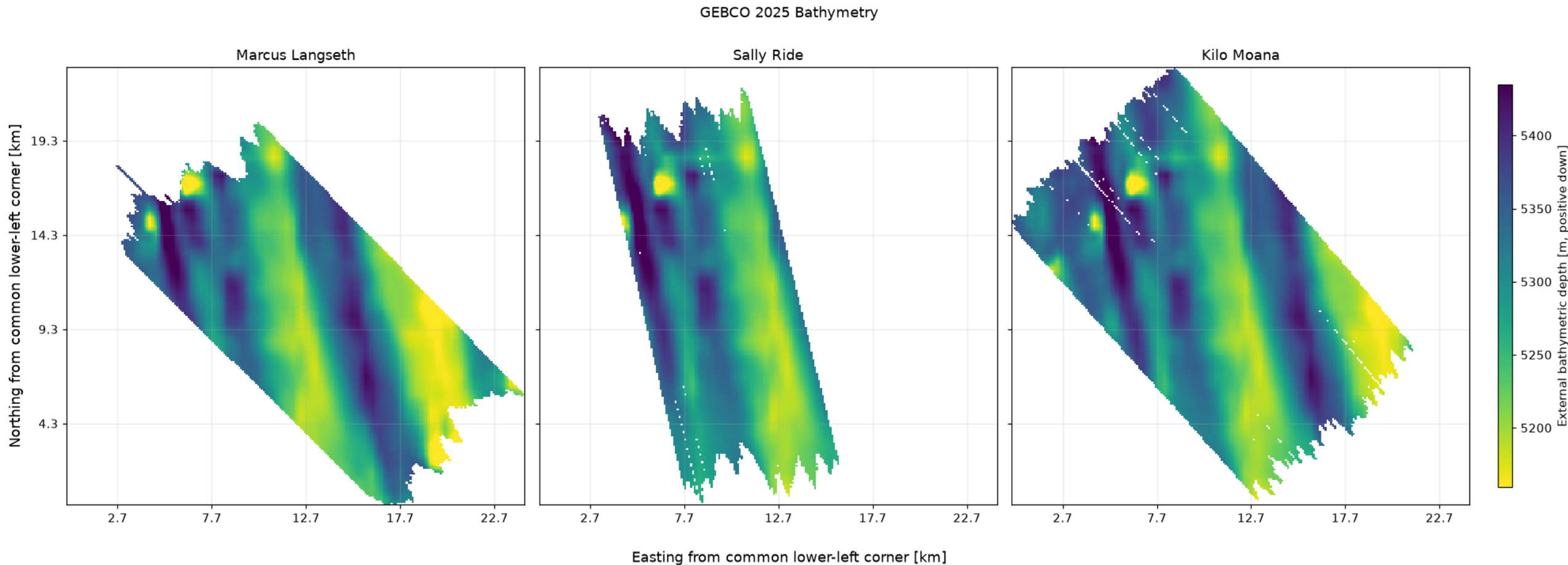
Empirical PDF



ECDF



GEBCO Bathymetry Values at Location 3



Bathymetry Values from Source Files at Location 3

