A Physics-based Bayesian inversion of seafloor properties in the GOM using calibrated water column sonar data

Towards a GoM sediment monitoring effort

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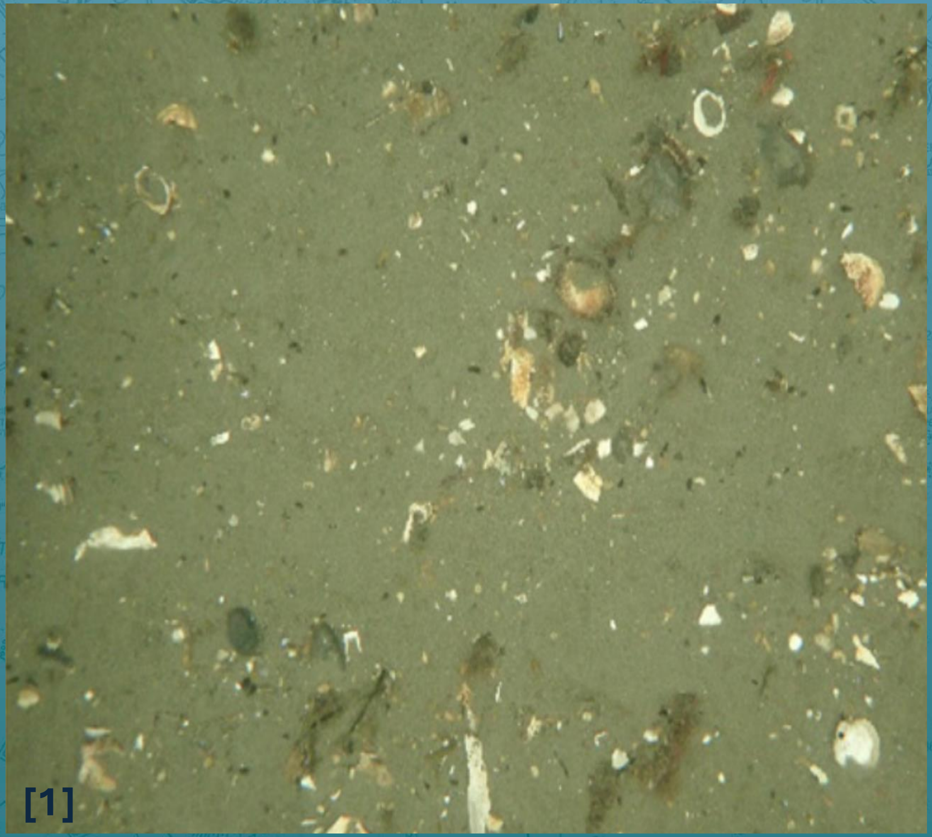
P: presenter

Why Monitor the Seafloor?



[1]

Navy

- Improved detection and communications underwater

Benthic science

- Improve models (physical/ biological/chemical)
- Monitor change

Offshore Developers

- Site selection

[1] Hare et al, 2024, JASA

Traditional sediment sampling

Advantages:

- Direct sample

Limitations:

- Invasive and destructive
- Expensive and disparate
- Is it spatially representative?

Can we use acoustics to fill in the blanks?

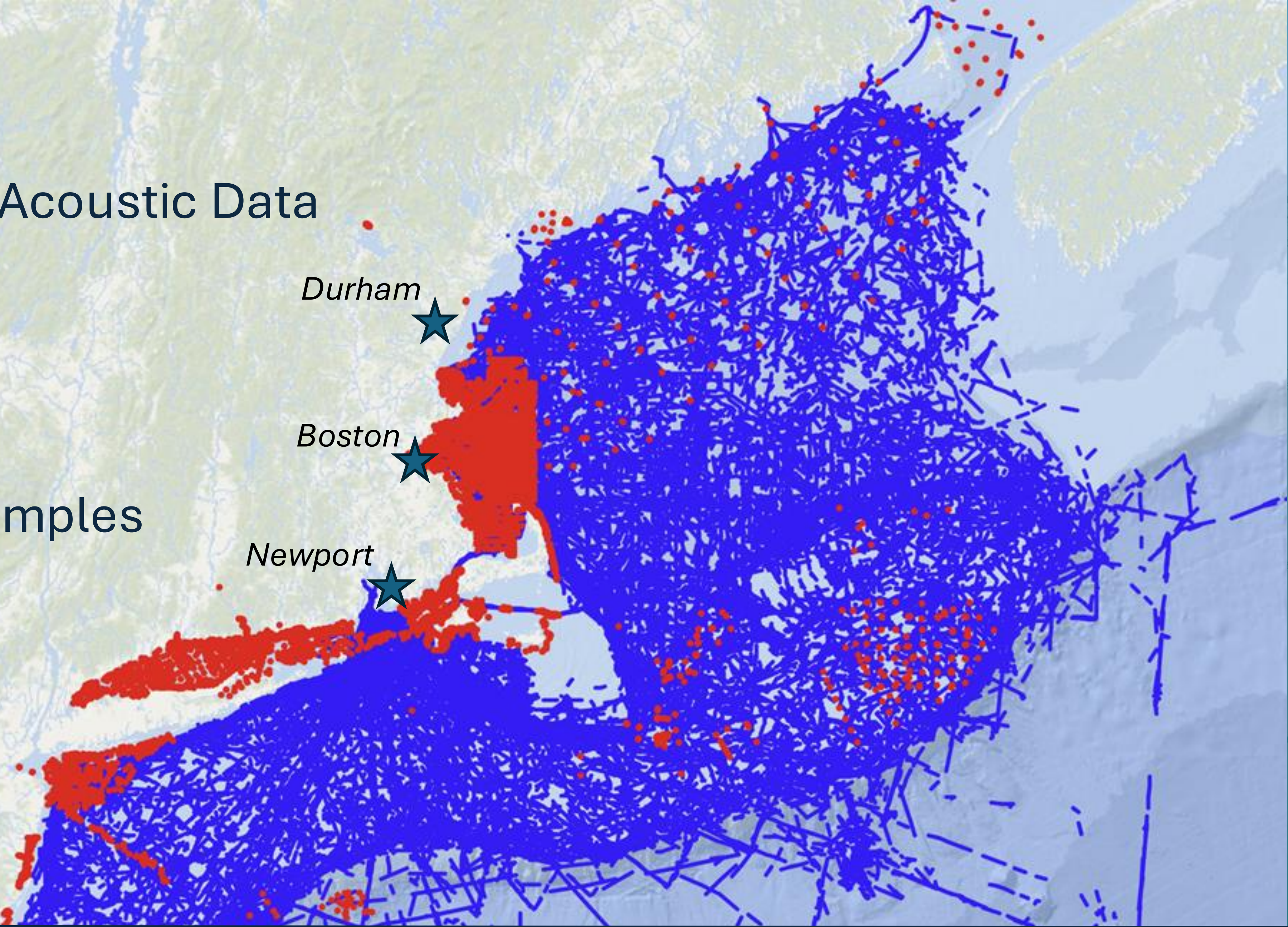
Data

NOAA Fisheries Acoustic Data

- Calibrated Sonars
- Multi Frequency
- Decades of Data

USGS & UNH Samples

- 10,000+ Samples
- Decades of Data



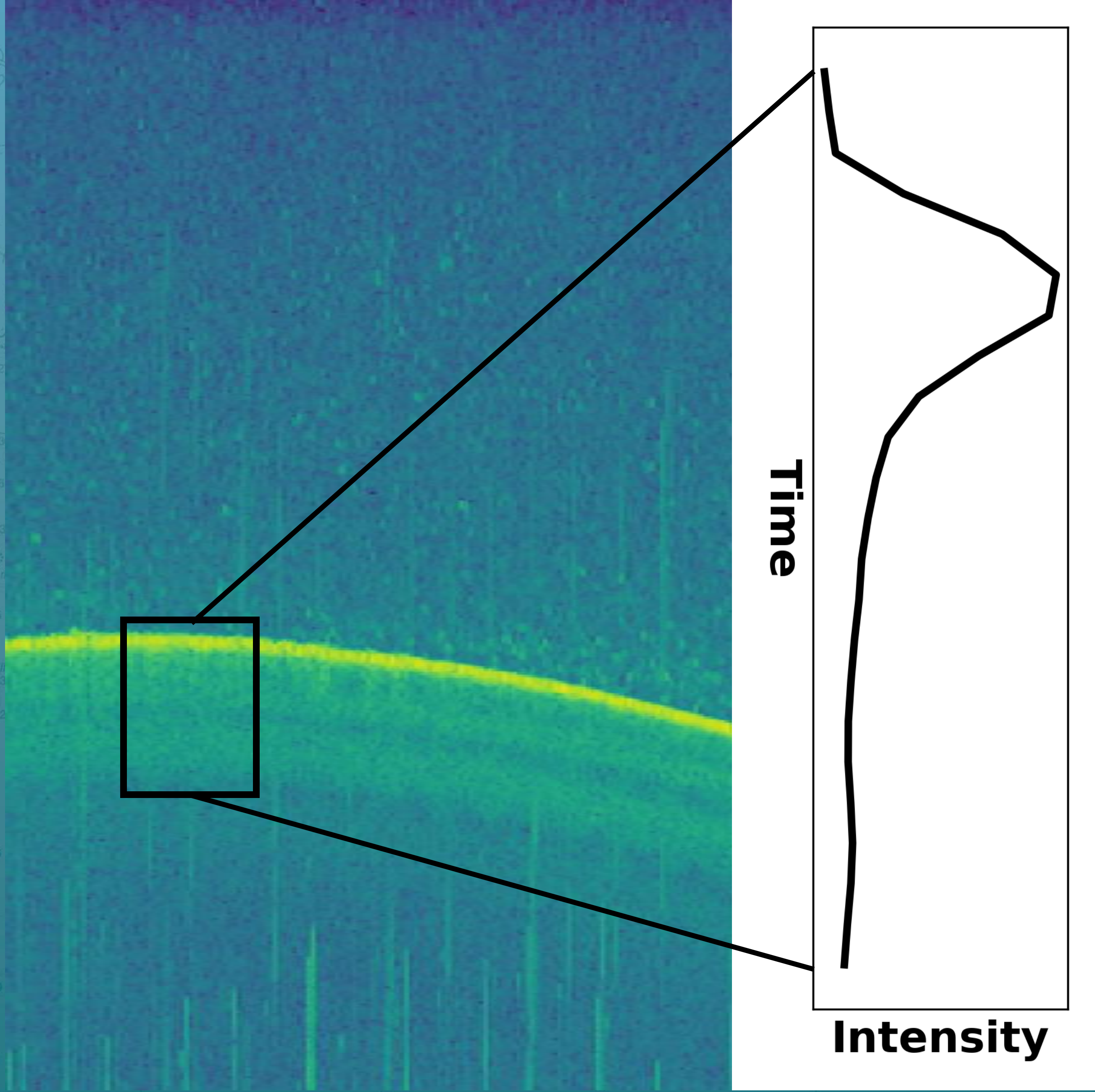
Acoustic Seafloor Characterization

Advantages:

- Standardized method to sense the seafloor
- High spatial/temporal coverage
- Physics-based scattering models transforms data into physical sediment properties

Limitations:

- Data information content
- Computationally expensive



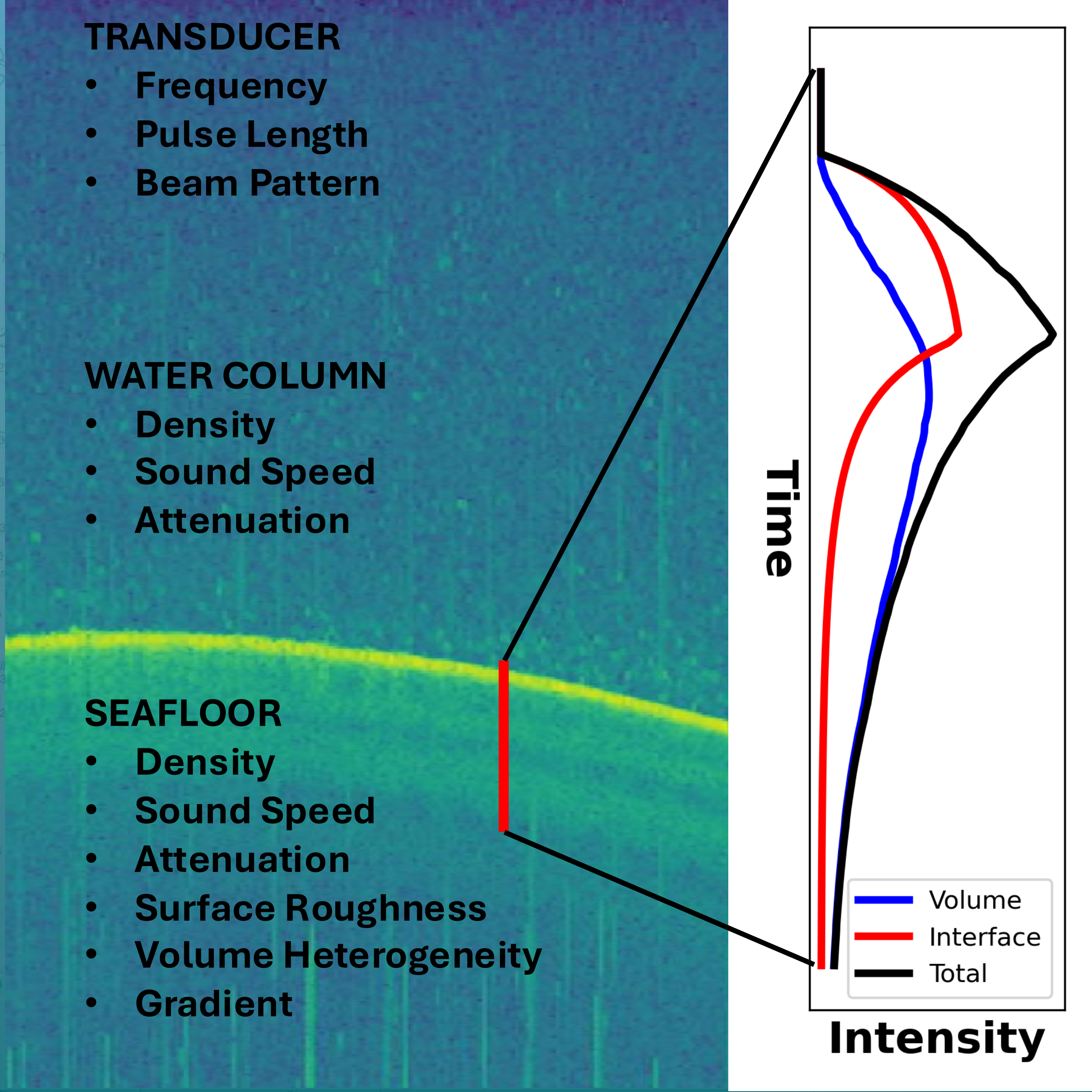
Scattering Model [2]

Augmented with:

- Empirical relationships coupling acoustic/bulk properties [3]
- density depth gradient [4]

Model Inputs

- Transducer (known)
- Water Column (known)
- Sediment (unknown)



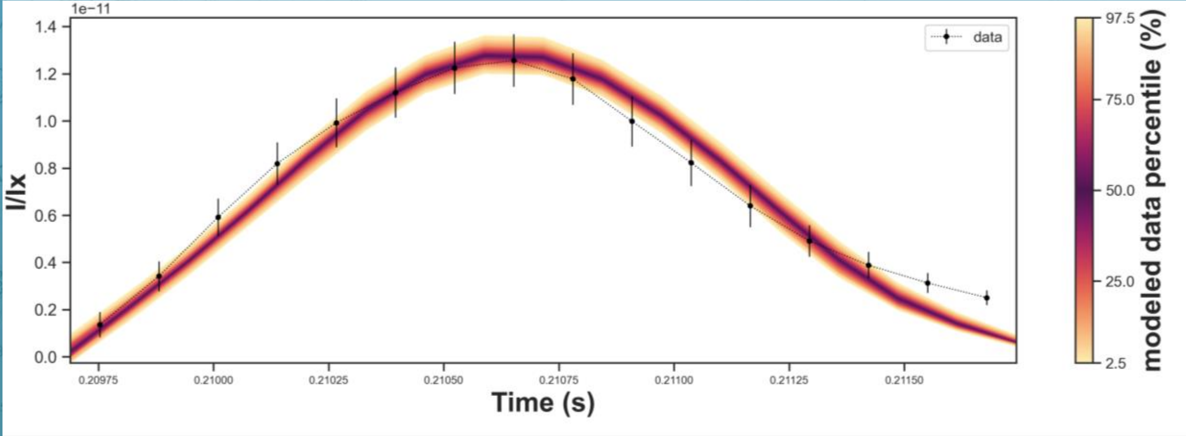
[2] D. Sternlicht and C. de Moustier, 2003, JASA
[3] D. Jackson and M. Richardson, 2007
[4] A. Lyons and T. Orsi, 1998, IEEE.

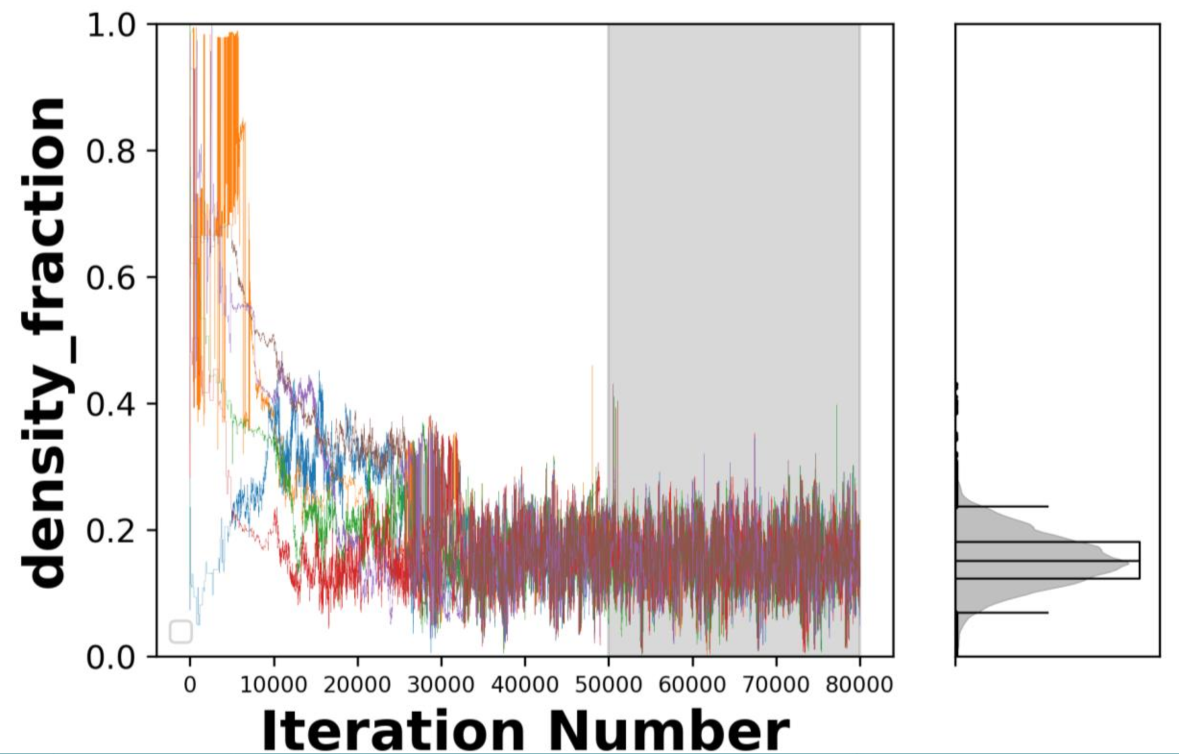
Bayesian Inversion [5]

Method to find most probable inputs *and uncertainty* of a "forward model" by matching its output with data

Samples posterior probability distribution for each sediment property

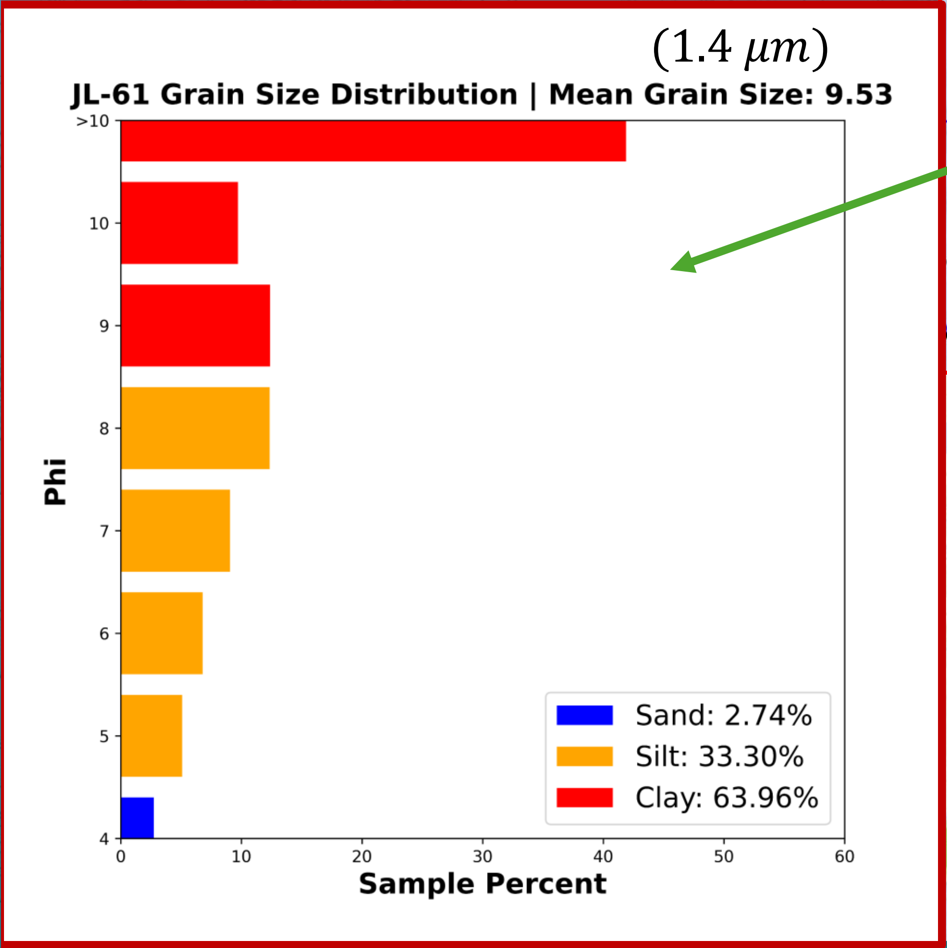
Accounts for uncertainty and information content of the data

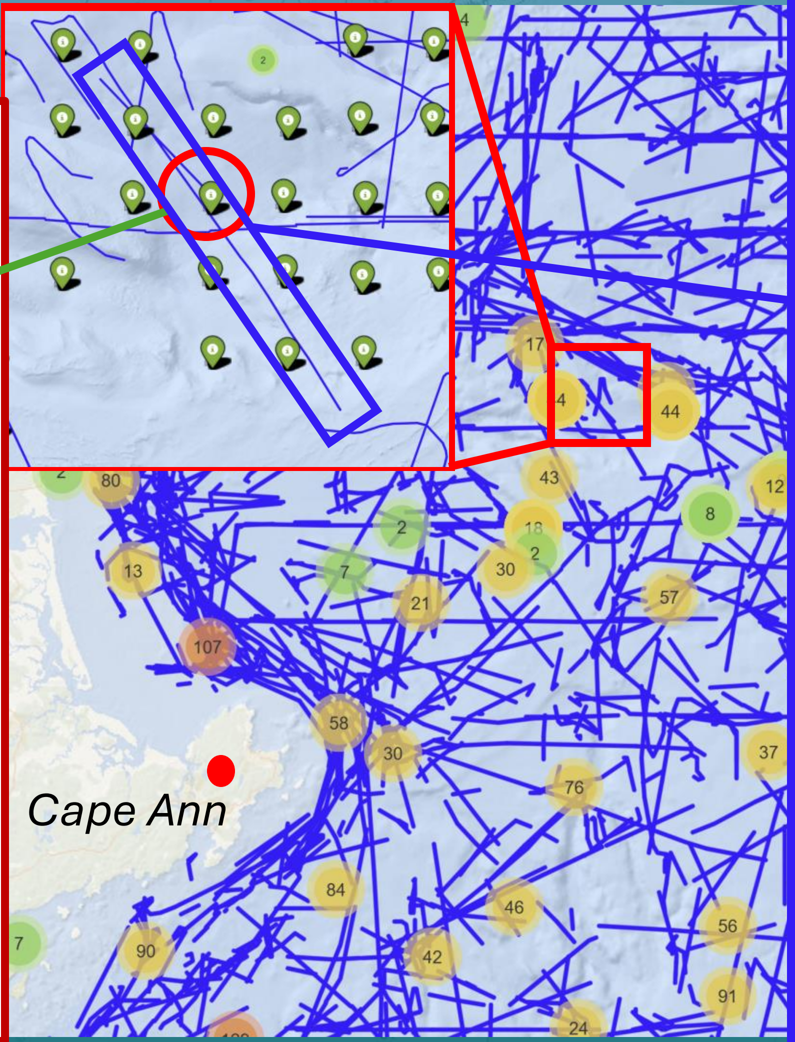


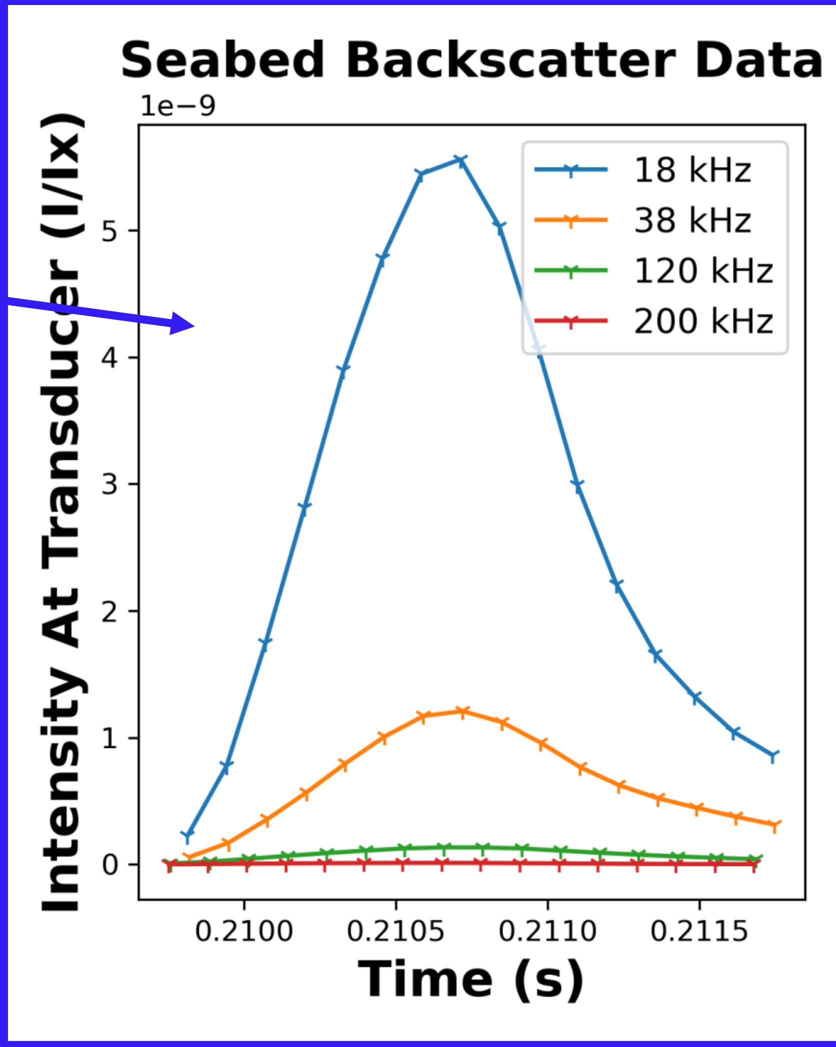


Inversion Example: Scantum Basin

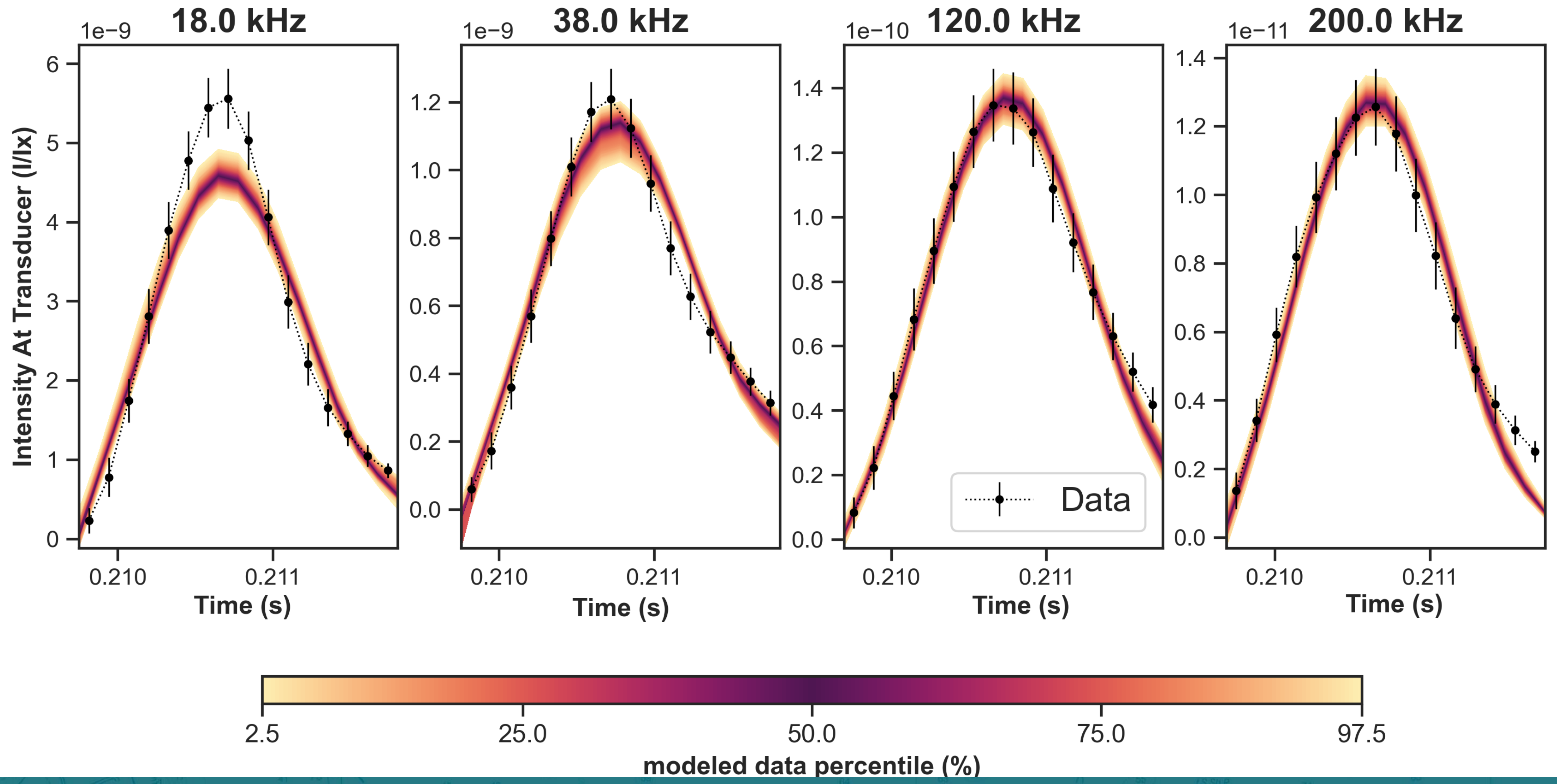
Separation between ground truth/acoustics
38 m | 6 yrs



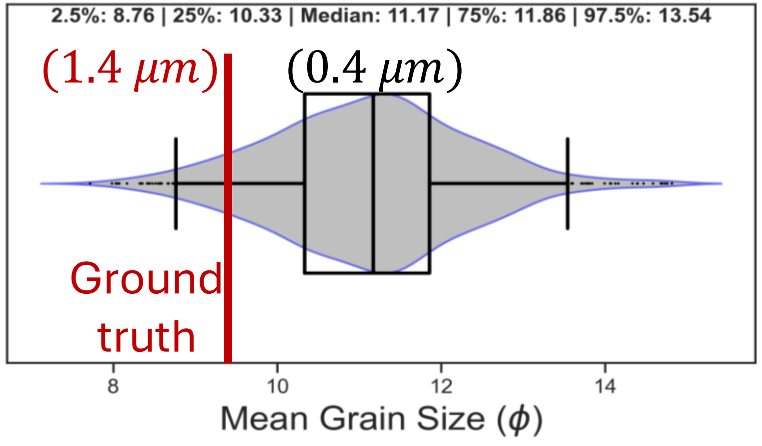


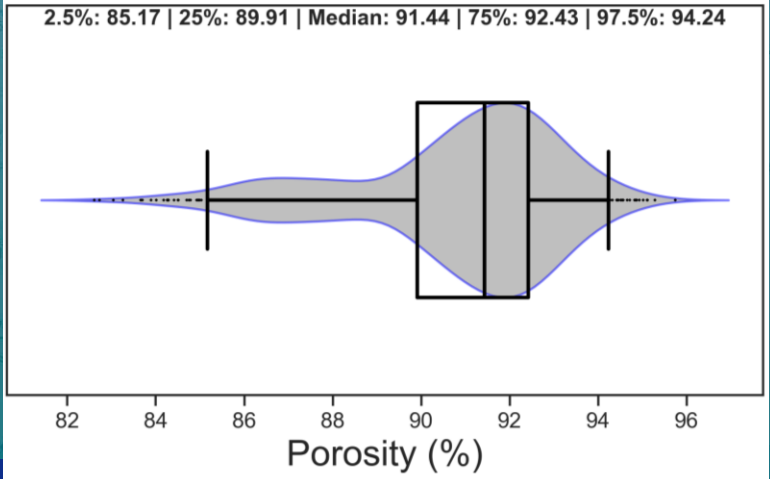


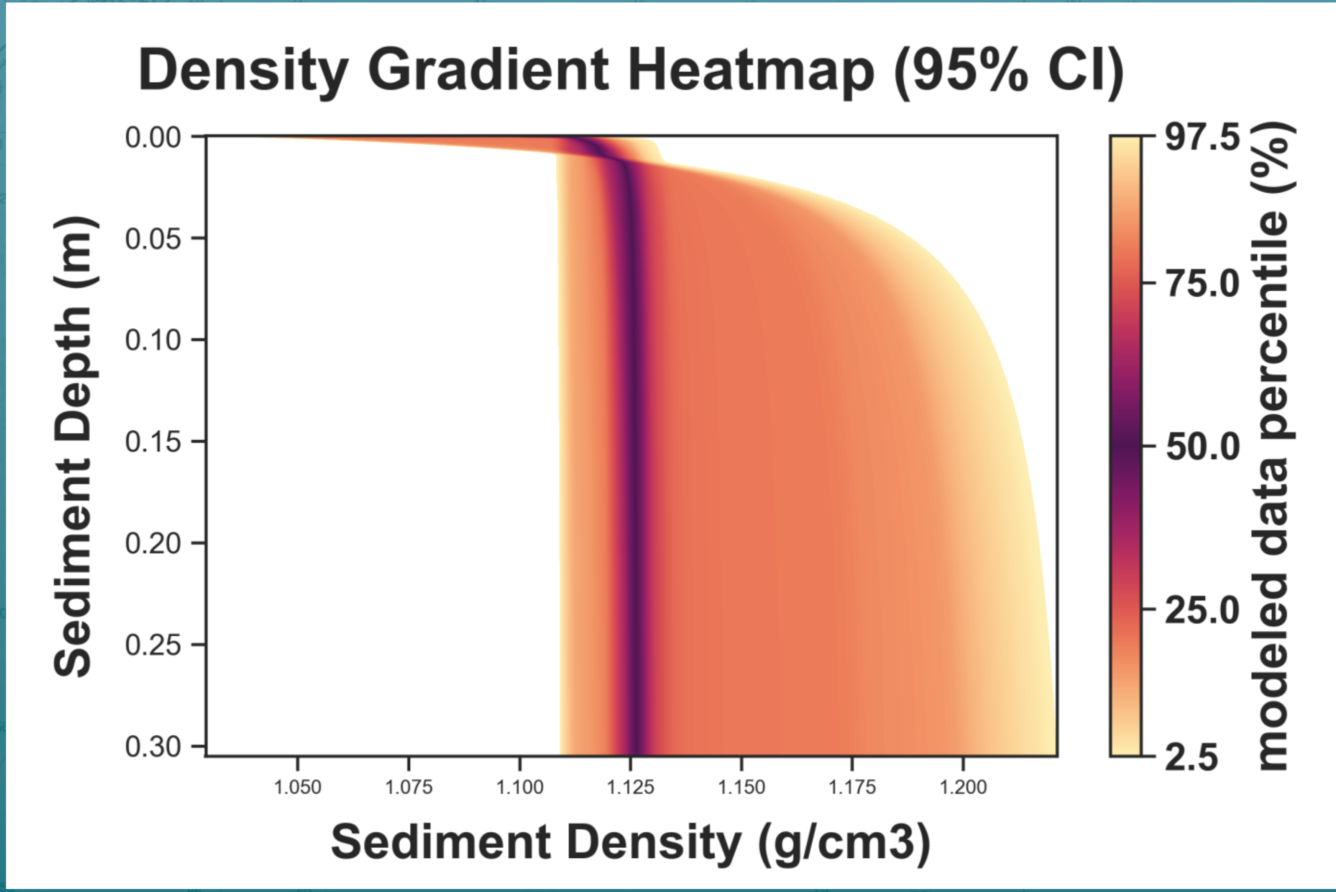
Modeled Seabed Backscatter



Inferred bulk properties

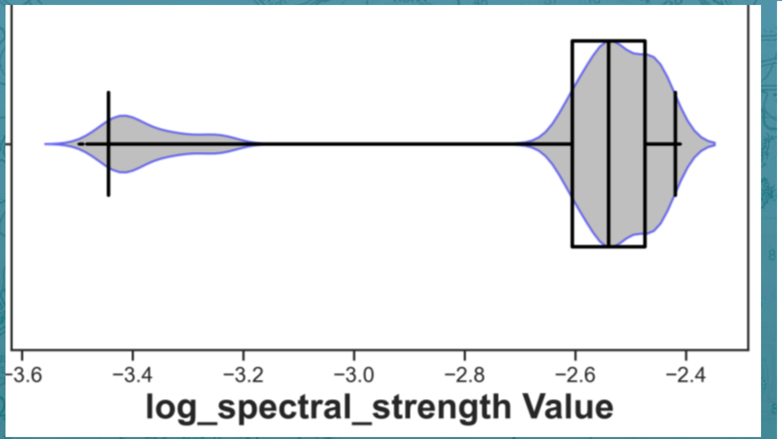


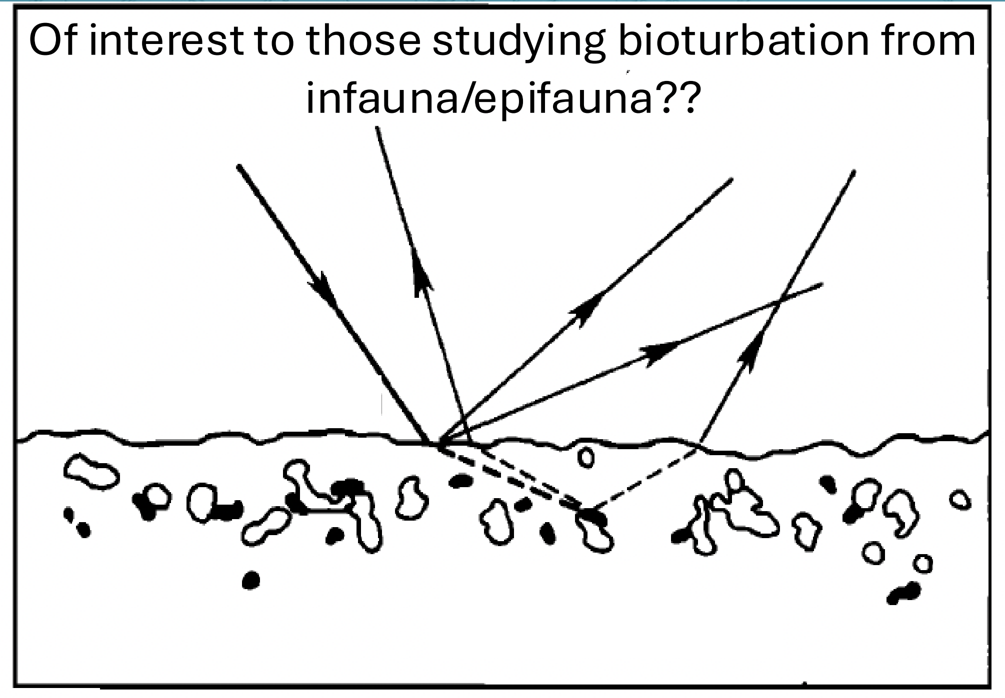




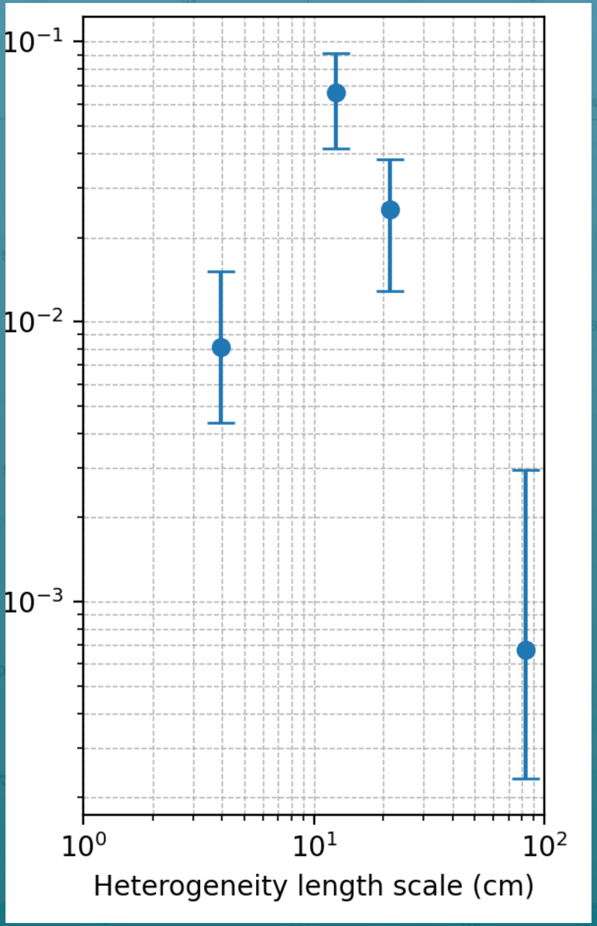
Surface/Subsurface Characteristics

Strength of roughness





Strength of
volume heterogeneity



The Possibilities

Opportunity to characterize sediments at regional scale

- More information to those who use it
- Need porosity ground truth for better benchmarking

Compare characterization across time

Can find new relationships

- Between surface/volume heterogeneity and habitat monitoring metrics

References

[1] J. Hare, A. Lyons, M. Catoire, and G. Venegas, "Measurements of temporal variability of acoustic scattering from the seafloor in shallow-water sandy sites," *JASA*, vol. 156, no. 4, pp. 2727–2742, Oct. 2024.

[2] D. Sternlicht and C. de Moustier, "Time-dependent seafloor acoustic backscatter (10–100 kHz)," JASA, vol. 114, pp. 2709–2725, 2003.

[3] D. Jackson and M. Richardson, High Frequency Seafloor Acoustics. in Underwater Acoustics. New York: Springer, 2007.

[4] A. Lyons and T. Orsi, "The Effect of a Layer of Varying Density on High-Frequency Reflection, Forward Loss, and Backscatter," IEEE, vol. 23, no. 4, pp. 411–422, 1998.

[5] S. Dosso, C. Holland, and M. Sambridge, "Parallel tempering for strongly nonlinear geoacoustic inversion," Journal of the Acoustical Society of America, vol. 132, pp. 3030–3040, 2012.

Inferred bulk properties: based on IOI regressions

IOI: Index of Impedance (acoustic hardness).

Based on > 1,000 measurements made around the world

Collocated sediment porosity desired for ground truth!

IOI correlated with organic carbon content!