SW-2015
Seabed geoacoustic characterization measurement proposal

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FORA experiments in collaboration w/ John Preston, ARL-PSU, Altan Turgut NRL
AUV experiments in collaboration w/ Peter Nielsen NURC
Analysis in collaboration with Jan Dettmer, Stan Dosso (U. Victoria), Peter Nielsen (NURC), others

Science challenge

Objective: measure sediment sound speed, attenuation dispersion

Challenge: Numerous frequency-dependent mechanisms must be separated to obtain unbiased sediment complex sound speed

Non-sediment related biases:

1. Sea surface forward scattering, roughness/bubbles
2. effects of range-dependent ocean dynamics, e.g., internal waves
3. effects of biologics

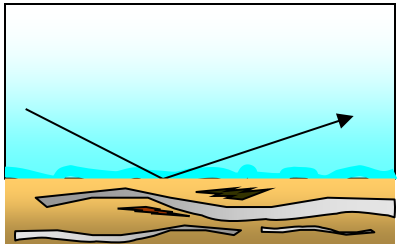
Sediment related biases:

4. Sound speed and attenuation gradients (smoothly changing from e.g., overburden pressure)
5. Discrete layers, these must be resolved down to approx $\lambda/8$
6. Scattering from layer interface roughness
7. Scattering from sediment volume inhomogeneities
8. Effects of shear waves and associated gradients, esp shear speed
9. Seabed unknown/unmodeled range-dependence

Experimental Approach

I. Single-interaction reflection, scattering to separate/quantify mechanisms

II. Long-range measurements for validation sediment results



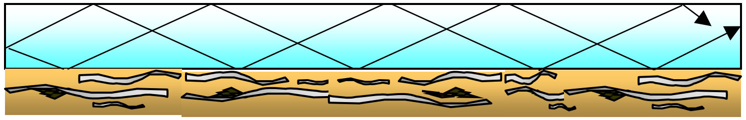
I. single-interaction measurements

a. Substantially reduces or eliminates non-sediment-related biases

- Sea surface, ocean dynamics, biologics play minor/non-existent role wrt geoacoustic uncertainties

b. Can resolve/ separate various sediment-related mechanisms, via

- High vertical resolution (~0.1 m) which permits quantifying role of layering
- Wide angular coverage, permits quantifying angular dependent phenomena, e.g., scatter, layering
- High lateral resolution (~1m scale), permits separation of range-dependent effects
- Scattering measurements can isolate role of interface vs volume scatter



II. long-range measurements

Long-range propagation and reverberation measurements provide basis for validating role of sediment dispersion (and other mechanisms)

Relevant Theories

Sediment Acoustics*

- Biot theory and variants/simplifications, e.g., Pore size distribution (Yamamoto-Turgut), EDFM (Williams), MVF (Buckingham)
- Variable Grain Shearing Model, VGS (Buckingham)

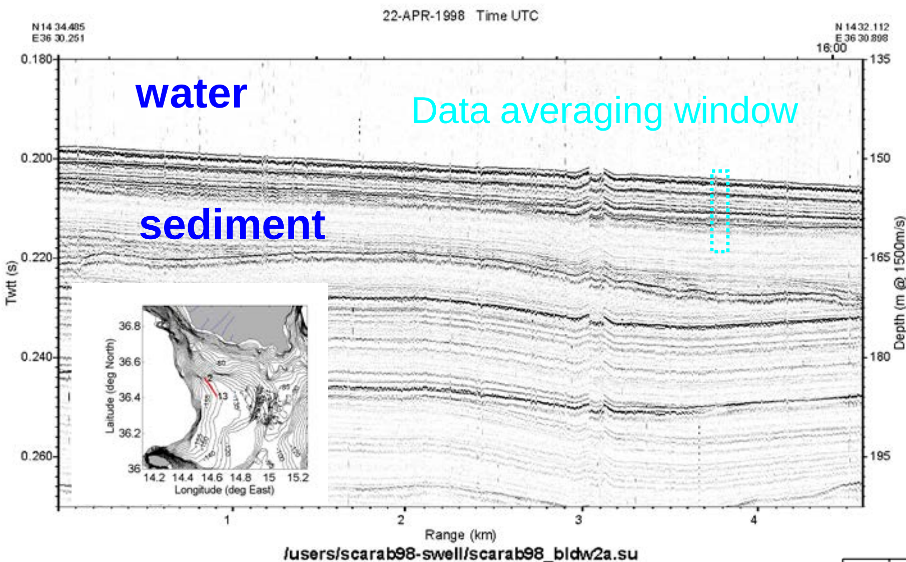
Other

- Reflection from plane-layered media and plane-layered with roughness (based on Sommerfeld integral)
- Scattering from arbitrary layered media, using perturbation theory, small slope approx, and Kirchhoff approx. (Jackson, Ivakin, Thorsos,…)

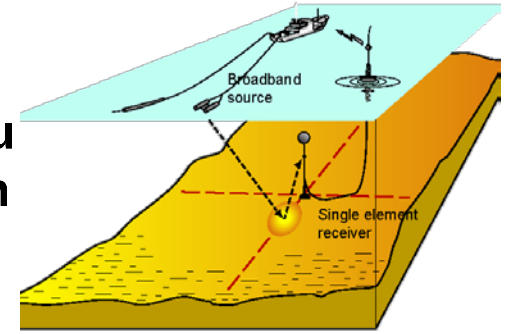
*NB: theories developed for sandy fabrics, not necessarily cohesive (clays, muds)

Geoacoustic Characterization Example

Uniboomer data

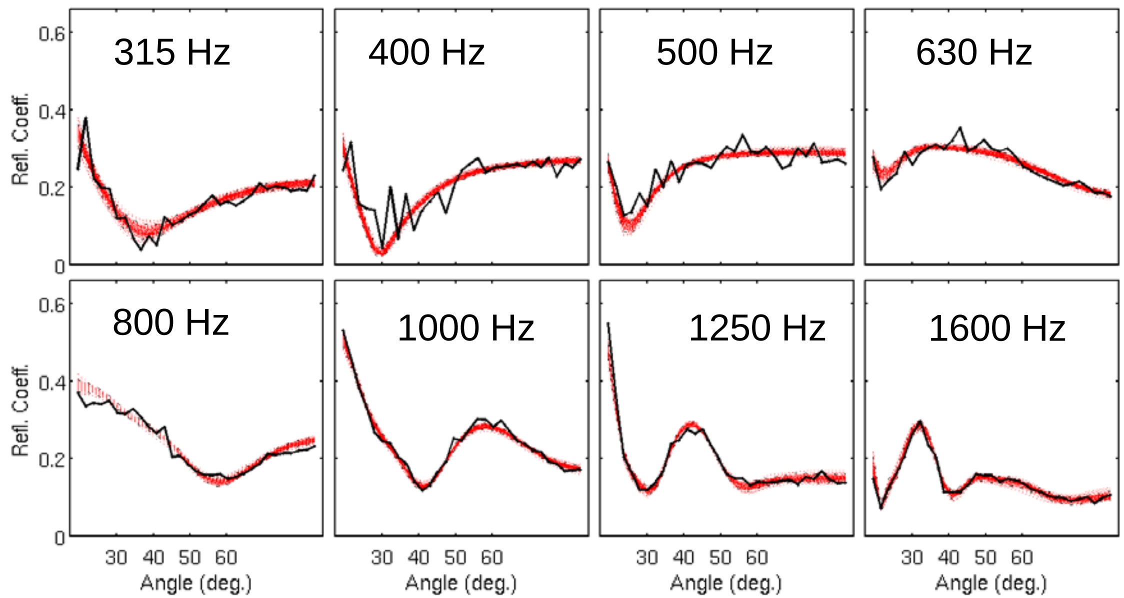


Site: Malta Plateau
150 m water depth



Reflection data and models

—data —MVF model (~EDFM)



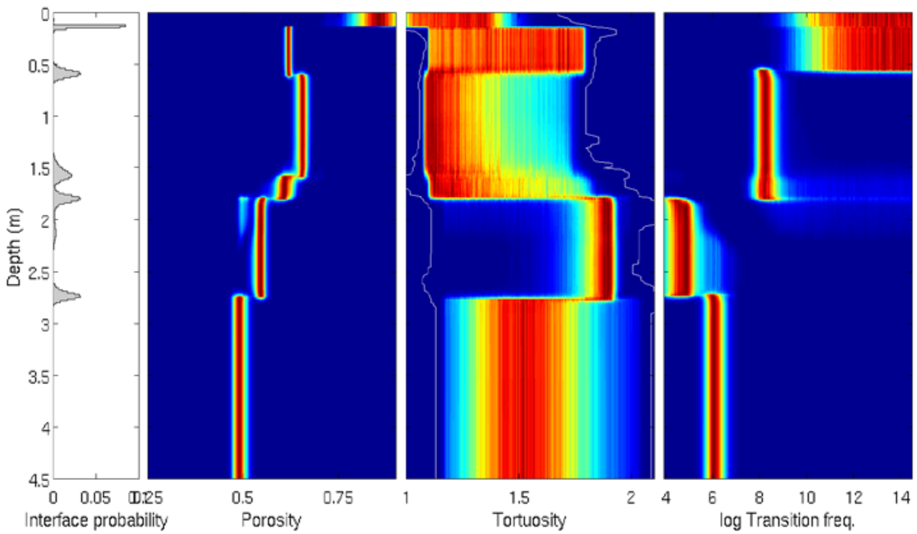
Analysis goal: separate effects of sound speed/attenuation dispersion from layering/grads

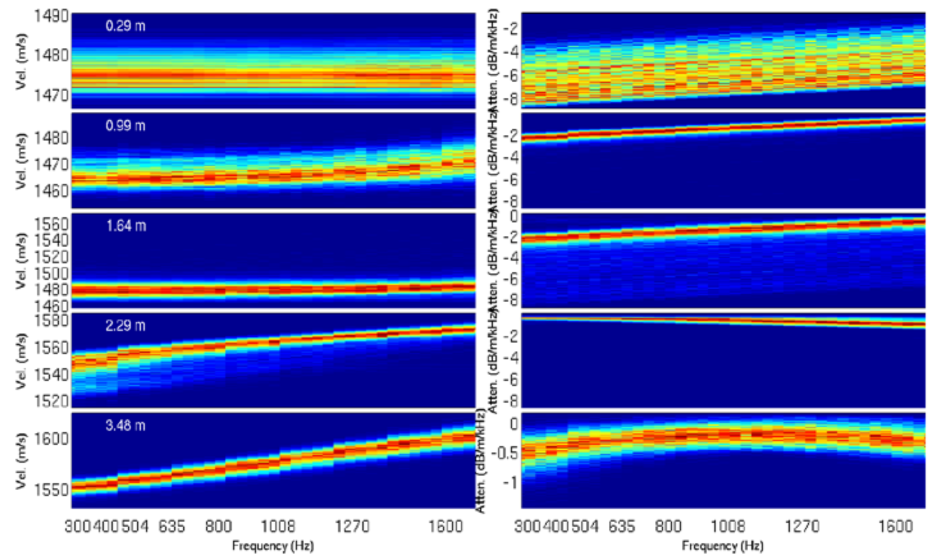
- data integration depth 4 m
- data averaged in 1/15 octave bandwidths

inversion in collaboration with Jan Dettmer, Stan Dosso, UVic

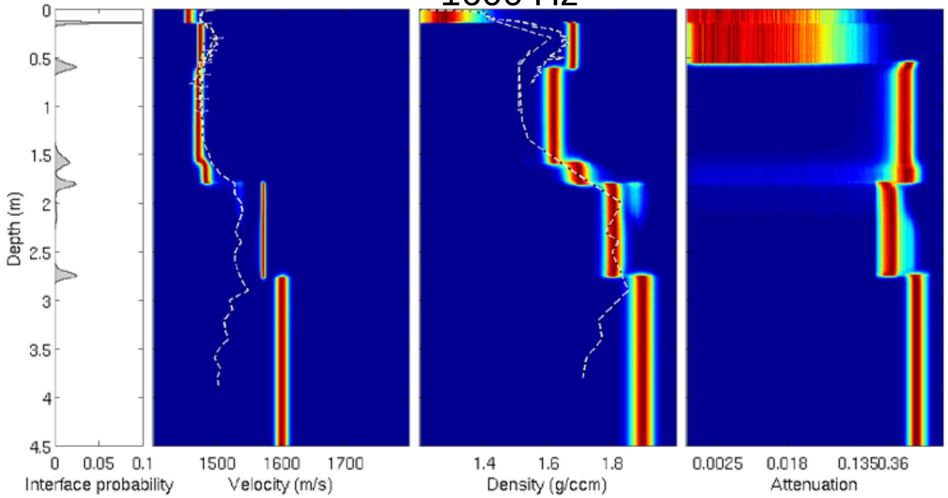
Modified Viscous Fluid Model (MVF~EDFM)

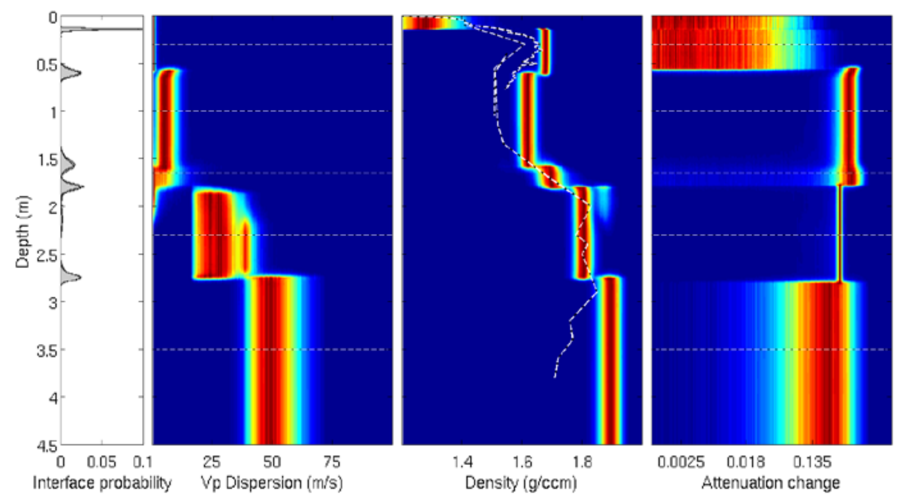
300-1600 Hz; plane wave





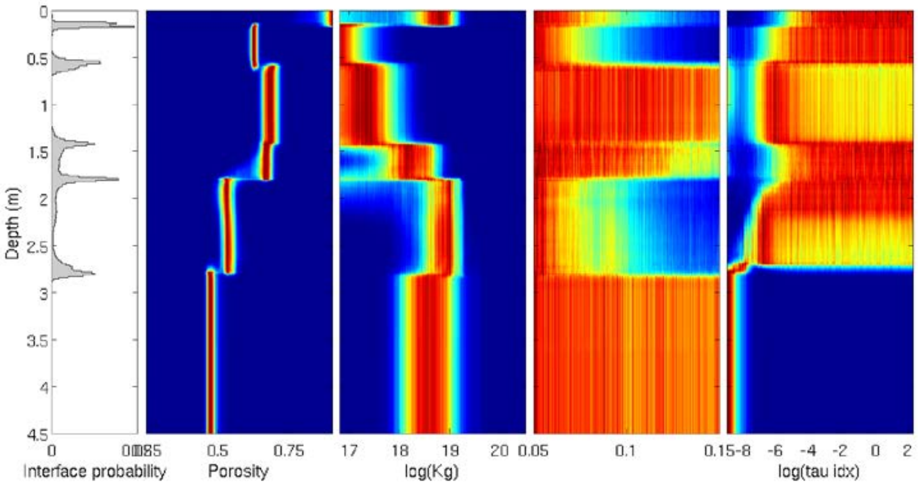
1600 Hz

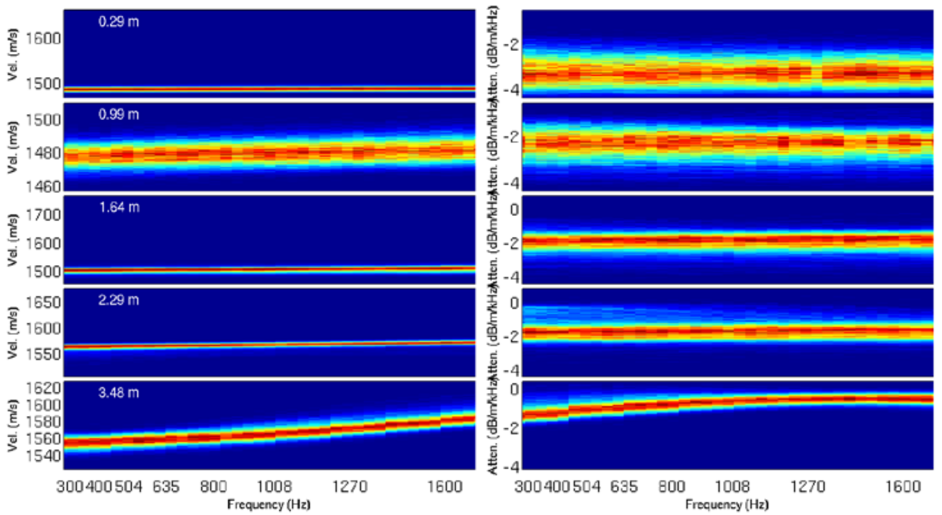




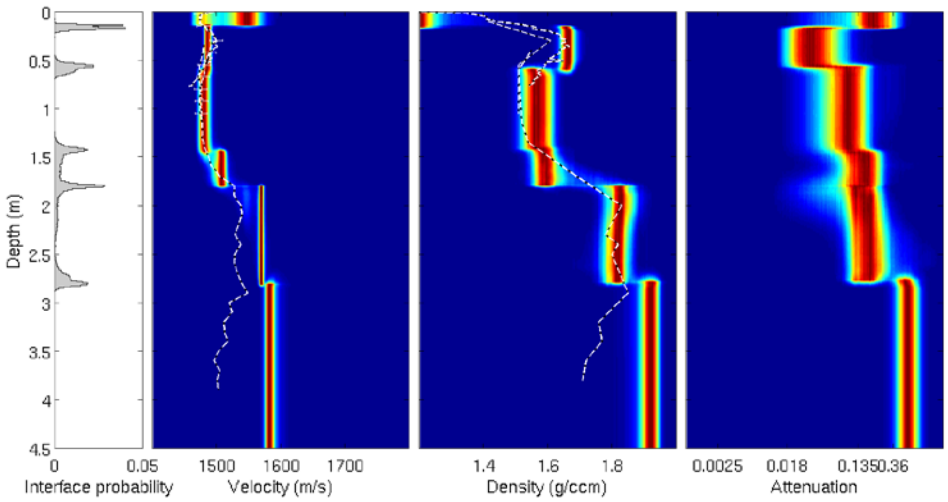
Viscous Grain Shearing Model (VGS)

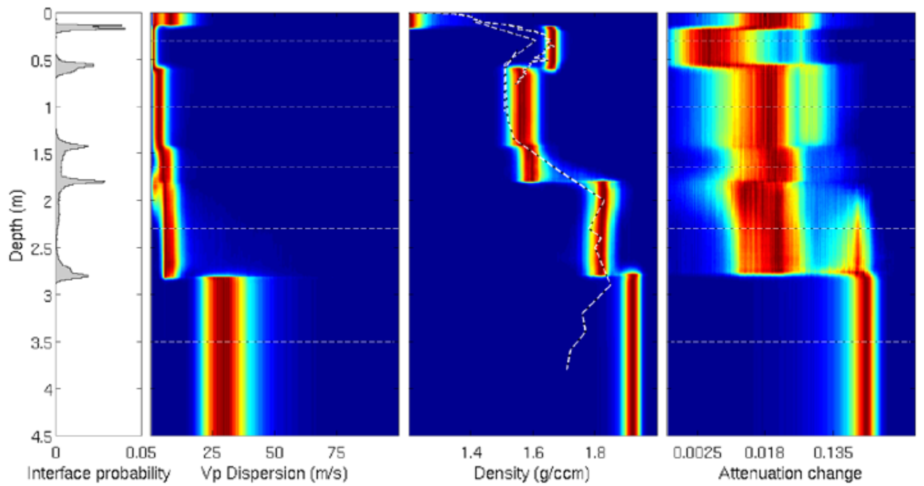
300-1600 Hz; plane wave





1600 Hz





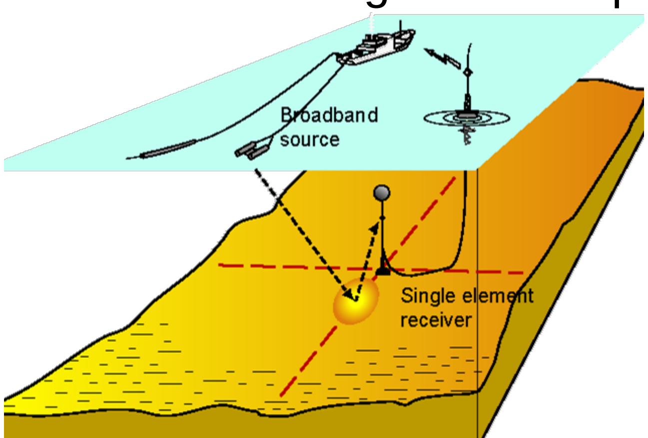
Proposed Experiments

Reflection $R(\theta, f, \boldsymbol{r})$ and scattering $S(\theta_i, \theta_o, \phi, f, \boldsymbol{r})$ *single interaction*

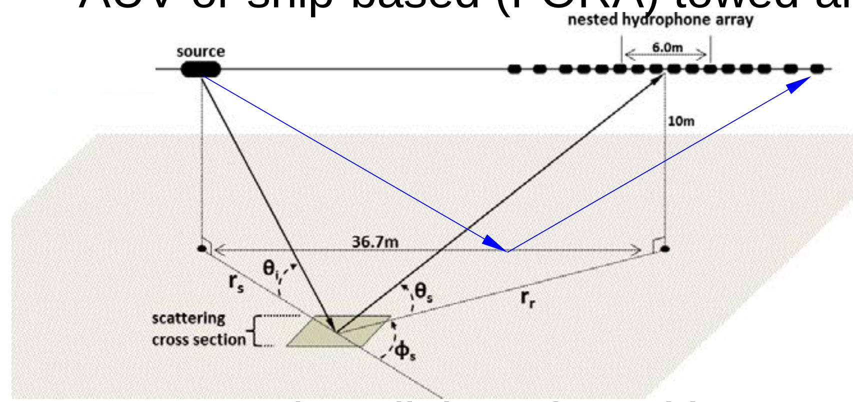
1. Boomer R(5–90º,0.1–10 kHz), conducted at 'key' locations in experiment area yielding *c(z,f), a(z,f), rho(z)* spatially averaged laterally over a few hundred meters of seabed, information to ~100m sub-bottom, depth resolution ~0.1 m

2. AUV R(25–50º,0.8–4+ kHz, ***r***), S(5–30º, 90–170º, 0.8–4+ kHz, ***r***)
   FORA R(8...60º,?–4 kHz, ***r***), S(10–50º, ~110–175º, ?–4 kHz, ***r***) {'typical'}
   yielding *c(z,f,r), a(z,f,r), rho(z,r)* and estimates of interface and volume scattering parameters from bi-static scattering.

Boomer with single or multi phone rcvr

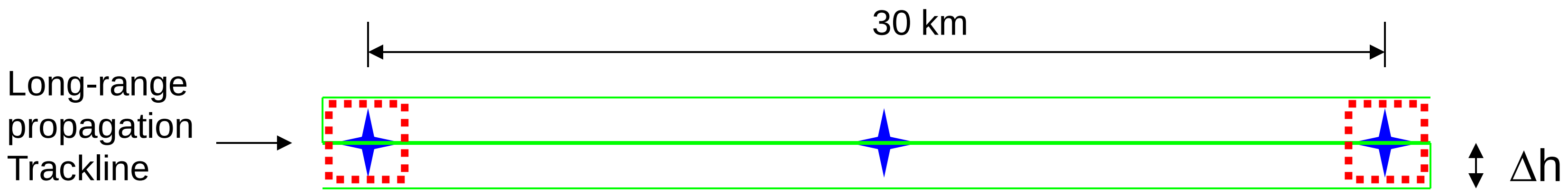


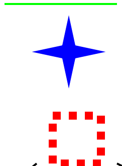
AUV or ship-based (FORA) towed array



AUV system in collaboration with NURC

Experiment Design

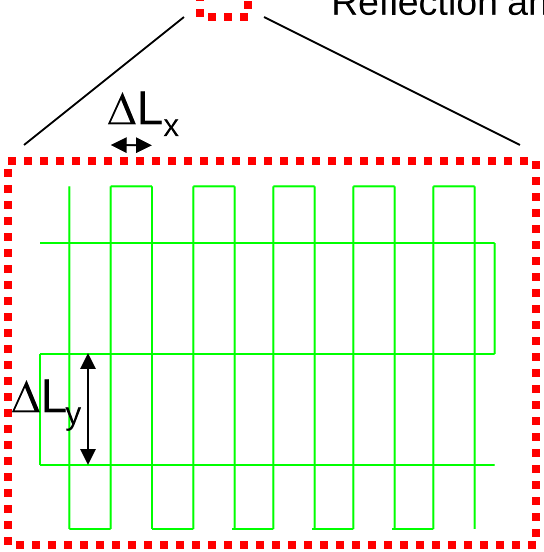




Reflection and scattering measurements (AUV and/or FORA), @ 3-4 knots

Reflection measurements boomer and vertical array (or even single phone), ~7 hours per site (requires low sea state)

Reflection and scattering measurements survey, @3-4 knots



Measurement goal: obtain geoacoustic properties and uncertainties

- Vertical resolution ~0.1m
- Lateral resolution ~5 m along track
- Total depth in sediment, 40-100m (sediment dependent)

Δh, ΔL_x ΔL_y number of survey lines all TBD: strawman values 500m, 100m, 300m, 14 lines. ~20 hours for 3 main lines; ~5 hours per survey box. Desire repeatability on several track sections to examine robustness of method.

Uncertainties

Evidence

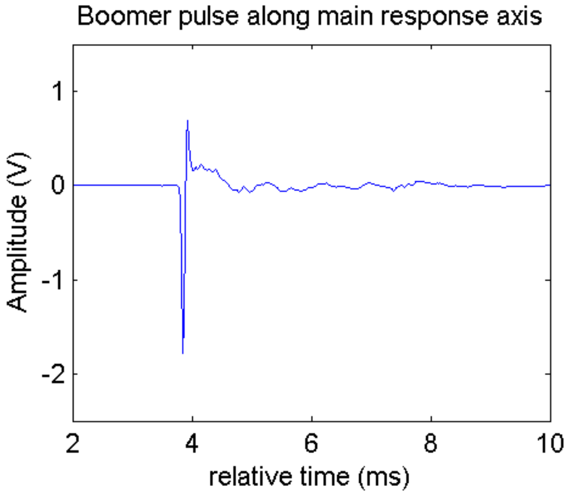
Research Group	Prior Information	Model Selection	Data misfit	Parameter Estimation	Uncertainty estimation
Dettmer/ Dosso/ Holland	1) Several physics theories under consideration, including fluid, visco-elastic and poro-elastic layers 2) Physical parameter upper and lower bounds 3) Empirical parameter inter-relationships based on Hamilton's compilations	1) Evidence computation to determine physics model best supported by data 2) Trans-dimensional inversion for environmental parameterization (e.g., sample over number of layers)	1) Likelihood function based on estimated data error statistics and/or sampling over variance/covariance	1) Maximum a posteriori model from trans-dimensional PPD sampling (see uncertainty estimation)	1) Bayesian uncertainty analysis 2) Trans-dimensional PPD sampling (Markov-chain Monte Carlo, importance sampling, and sequential Monte Carlo) 3) Hierarchical data error models

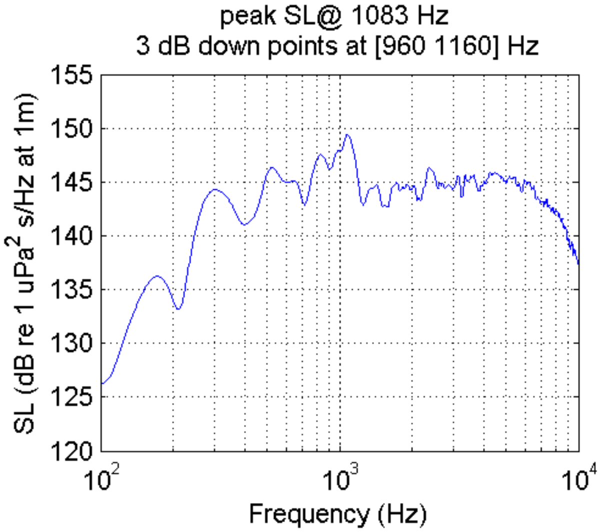
Model Parameterization

Parameter	Reflection	Scattering
Sediment interface scattering	no (but possible by 2015)	yes
Sediment volume scattering	no (but possible by 2015)	yes
Layering/sound speed gradients	yes	yes, expect low sensitivity
attenuation gradients	yes	yes , expect low sensitivity
range-dependence	resolve to 100m laterally for Uniboom; 1-10 m for moving source-receiv.	resolve range-dependence down to 5-10 m for moving source moving receiver
Shear	in progress, lack of sensitivity, *best from OBS data*	yes - in some cases expect low sensitivity
Sediment models	fluid, EDFM, MVF, GS, VGS	fluid, solid
water-air roughness	not applicable	Not applicable

Equipment

Boomer



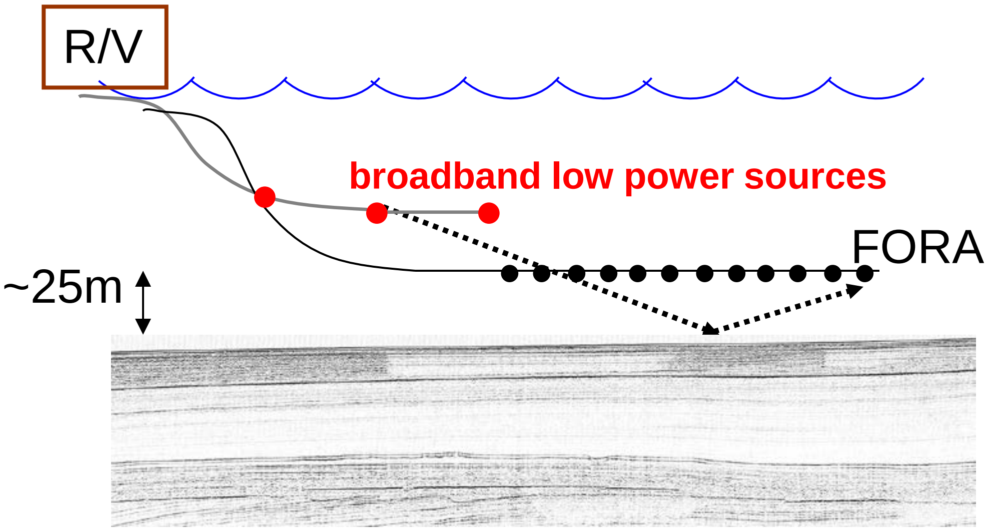


Desirable measurements for method validation:

- deep cores with porosity/density, sound speed, attenuation measurements, grain size analysis vs depth in core. Permeability and tortuosity, would also be very useful.
- sediment interface roughness, volume heterogeneity measurements

Seabed reflection and scattering measurements from FORA (proxy for AUV with towed array)

Background: direct path reflection/scattering measurements are a powerful method for quantifying sediment acoustic properties, and separating competing mechanisms, and identifying their role in controlling propagation & reverberation



~500-4000 Hz

Measure:

Reflection (12-13,16-18,23-29, 47-59 ,

Scatter (10-50º vert, ~110-175º az)

Analysis:

yields *c(z,f,r), a(z,f,r), rho(z,r)*

geoacoustic property resolutions: depth ~0.1 m; lateral ~1 m

Down to ~50m sub-bottom

Proposed hardware to include

- 3 sources (+ 1 spare), cable and transmit system (6 sources R(8-35º 47-90º) ; 8 sources R(8-90º)

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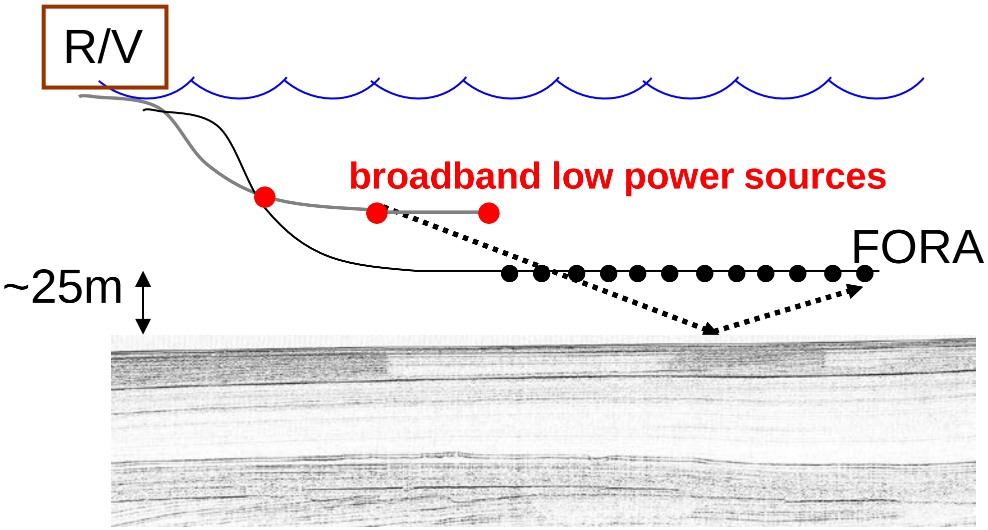

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