Geoacoustic tomography and high-resolution acoustic probe measurements during NRL MEC/ANEX2015 Experiments

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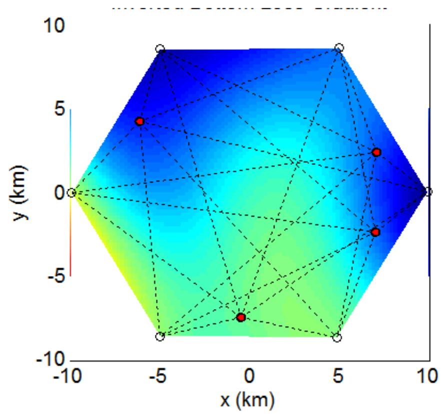
ONR SEDIMENT CHARACTERIZATION WORKSHOP



December 9-11, 2014
ARL/UTexas, Austin, TX

Outline:

Multi-static Environmental Characterization Experiment:

•**Scientific Goal:** Effects of range/bearing-dependent seafloor on signal excess (SE)

•**Experimental Goal:** Rapid characterization of seabed within 30 km x 30 km area

•**Measurements:** Broadband transmission-loss and reverberation measurements with limited number of sources and receivers

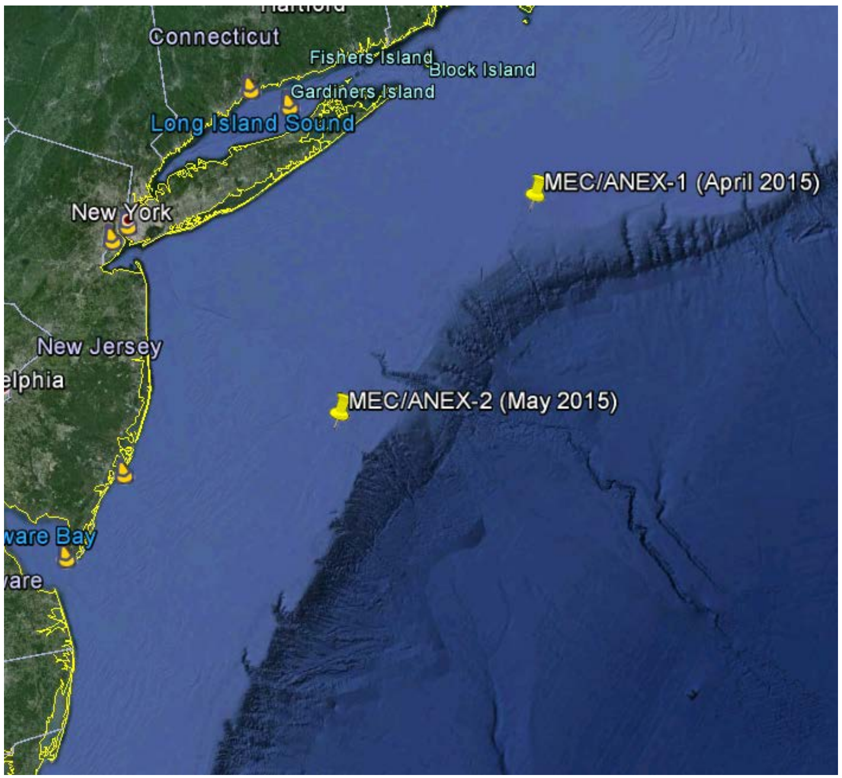
High-resolution acoustic probe measurements:

•**Scientific Goal:** Frequency dependency of sound speed and attenuation in marine sediments

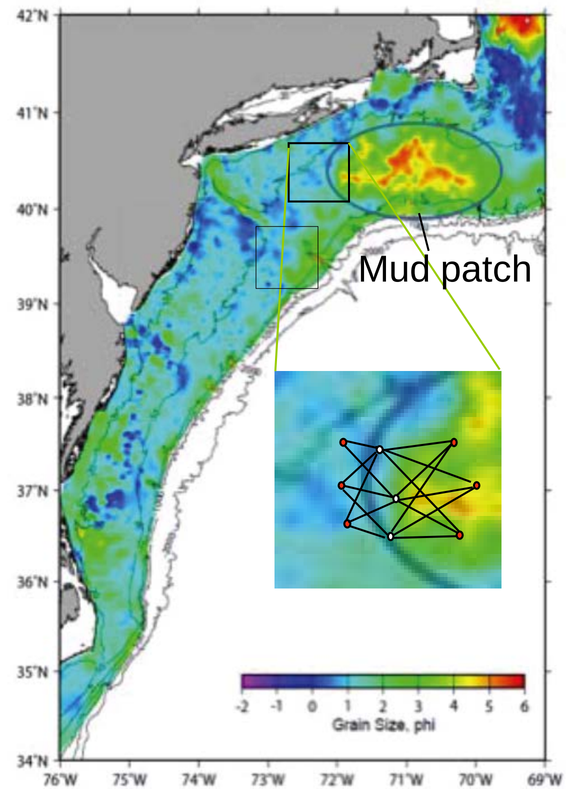
•**Experimental Goal:** In-situ sound-speed and attenuation measurements in muddy, silty, and sandy sediments

•**Measurements:** Simultaneous measurements of acoustic probes and chirp sonar. Geotechnical measurements of sediment cores.

NRL MEC/ANEX2015 Experimental Sites:

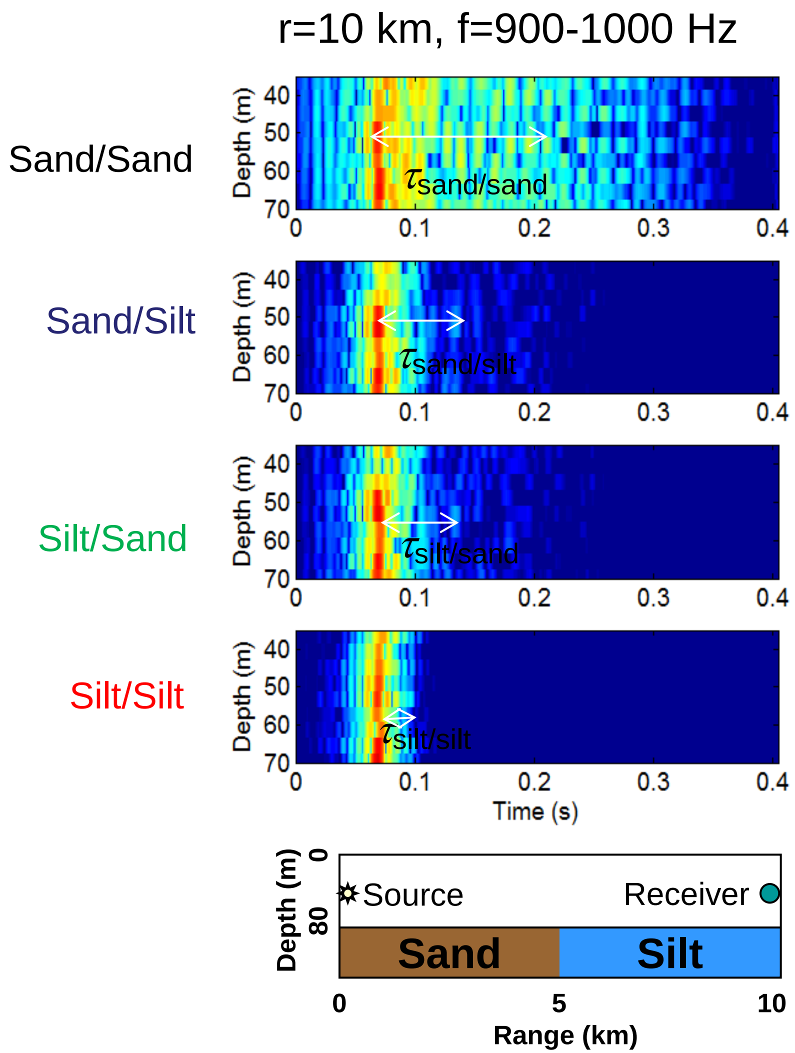


Mid Atlantic Bight
(Grain size distribution)



Palamara et al., in prep, (from J. Goff)

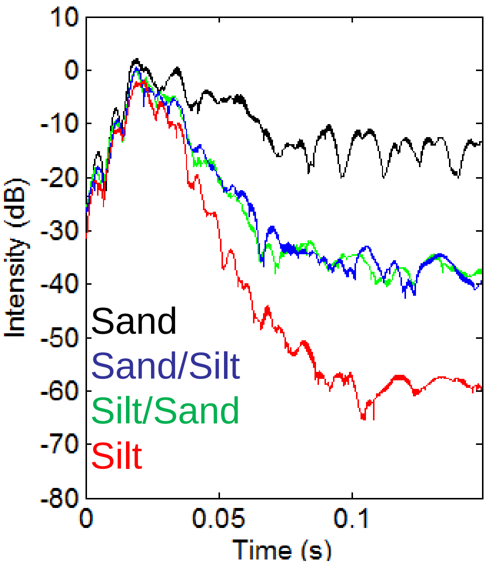
Pulse Decay vs. Bottom Type (Simulation)



$$p(\tau) = \left(\frac{c}{2r\tau}\right)^{1/2} \exp\left(-\frac{c}{H}\alpha_{eff}\tau\right), \qquad \alpha_{eff} = \frac{1}{R}\int_0^R \alpha(r)dr$$

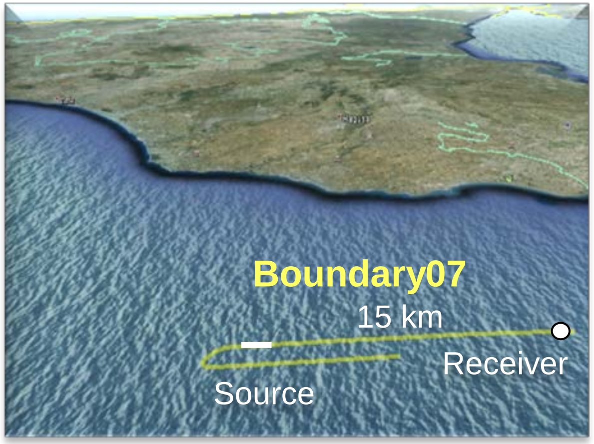
c : Sound speed
r: Range
H : Water depth
τ: Pulse-decay time
α: Bottom-loss gradient

Pulse decay vs. sediment type:

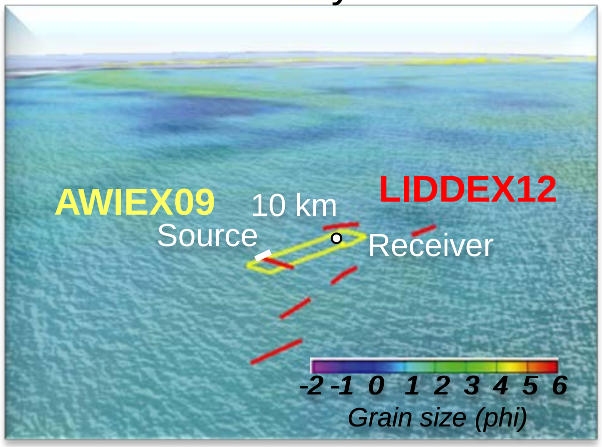


Pulse Decay vs. Bottom Type (Data)

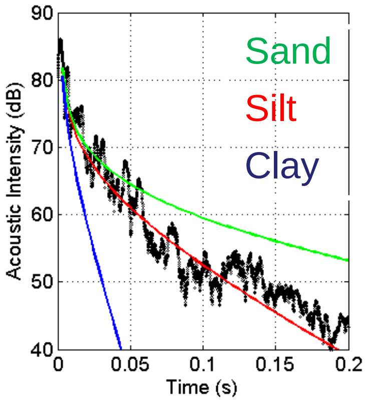
Malta Plateau



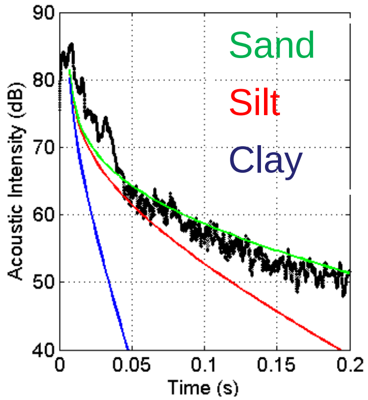
New Jersey Shelf



BOUNDARY07



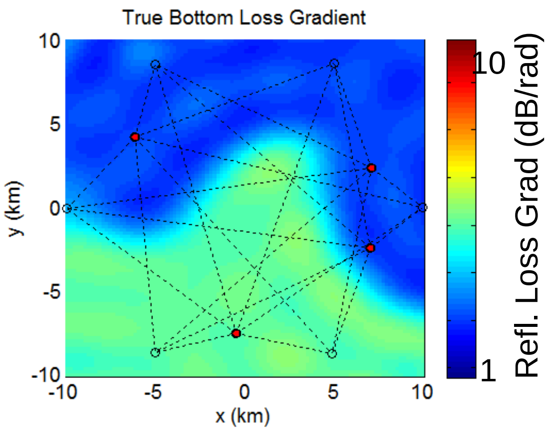
AWIEX09

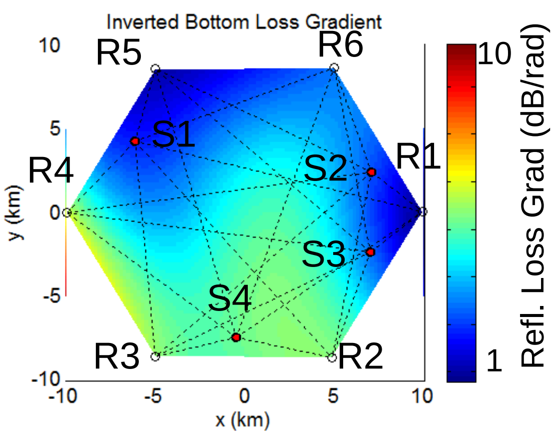


	Sound Speed (m/s)	Absorp (dB/λ)	α (Np/rad)	θ_c (deg)
Sand	1700	0.5	0.3	30
Silt	1600	0.3	0.8	20
Clay	1510	0.1	5.0	5

Geoacoustic Tomography:

Example:
Bottom-Loss-Gradient Tomography:





$$\log 10[\sqrt{\tau}\, p(\tau)] = -\log 10(e)\frac{c\tau}{rH}\sum_{i}^{N}\alpha_i \Delta r$$

Underdetermined minimization problem:

$$\bar{\mathrm{m}} = \arg\min_{\mathrm{m}} \| \mathrm{Am\text{-}d} \|^2 \qquad \text{(may diverge)}$$

A: measurement matrix, m: model, d: data

l_2- norm penalty:

$$\bar{\mathrm{m}} = \arg\min_{\mathrm{m}} \| \mathrm{Am\text{-}d} \|^2 + \mu \| \mathrm{m} \|^2$$

(Tikhonov regularization)

l_1- norm penalty:

(Sparse model in wavelet basis, a few non-zero coefficient)

$\mathrm{w=Wm}$ wavelet coefficients of m

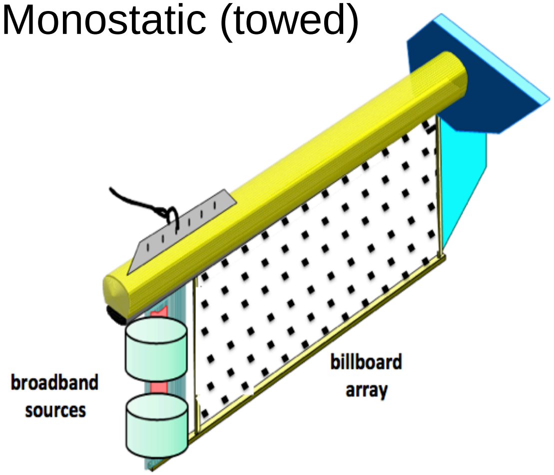
$$\bar{\mathrm{w}} = \arg\min_{\mathrm{m}} \| \mathrm{Aw\text{-}d} \|^2 + 2\mu \| \mathrm{w} \|_1, \quad (\bar{\mathrm{m}} = \mathrm{W}^{-1}\bar{\mathrm{w}})$$

W: wavelet decomposition matrix, $\mathbf{W^{-1}}$: wavelet synthesis operator

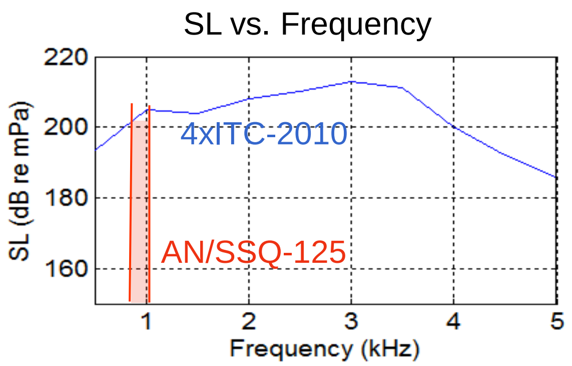
Noise-free model reconstruction (noise may not be sparse)

MEC/ANEX2015 Acoustic Experimental Assets (1)

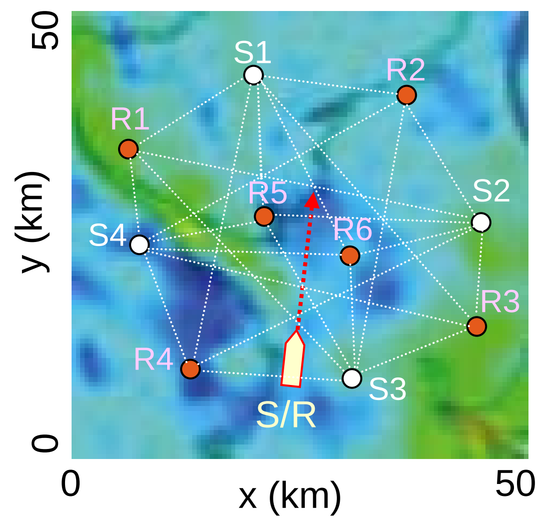
Monostatic (towed)



•2-channel source array (XF4)
•72-channel receiver array



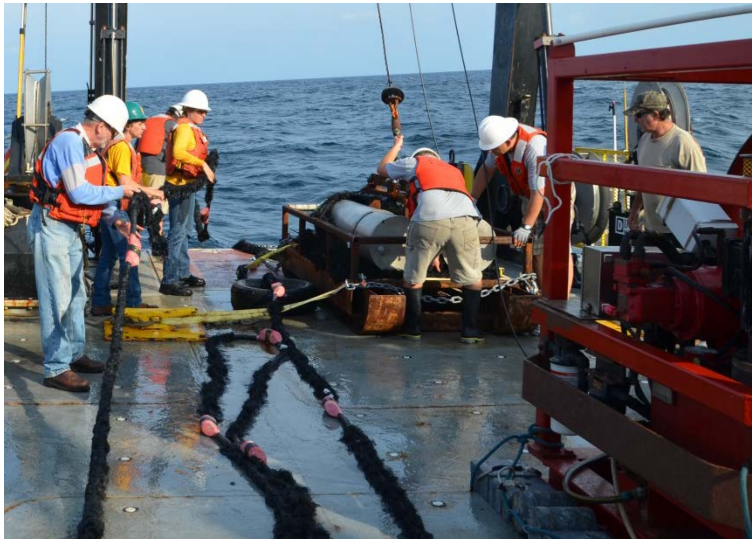
Multistatic (moored)



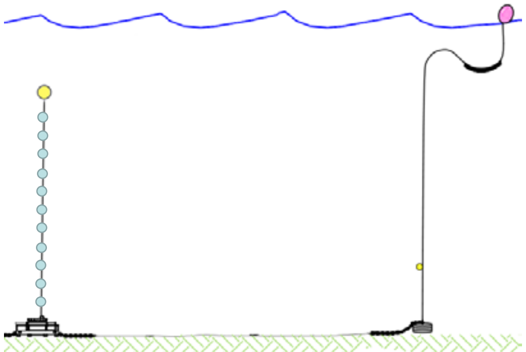
•Four moored source/4-ch receivers
•One 32-channel VLA
•Four 4-ch receiver arrays
•Several 2-ch acoustic data loggers

MEC/ANEX2015 Acoustic Experimental Assets (2)

NRL VLA (1)

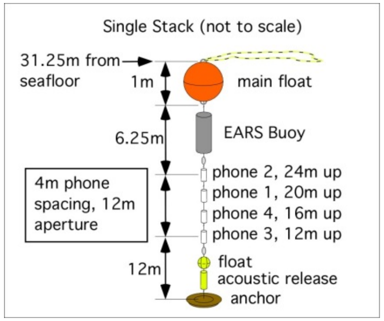


Vertical Array, 32 ch, d=2.5m
Thermistors placed between phones

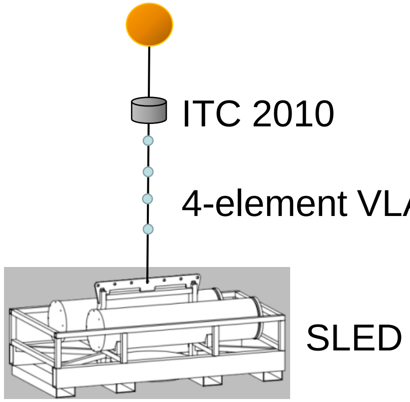


EARS Buoys (3)

- 4-element hydrophone array
- 10-day deployment @ 50 kHz sampling
- Deep-water capability (3000 m)

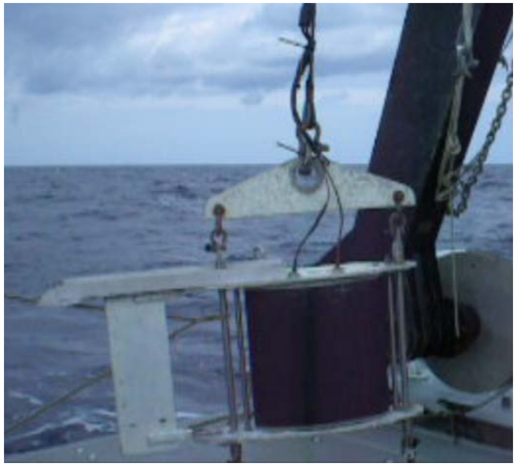


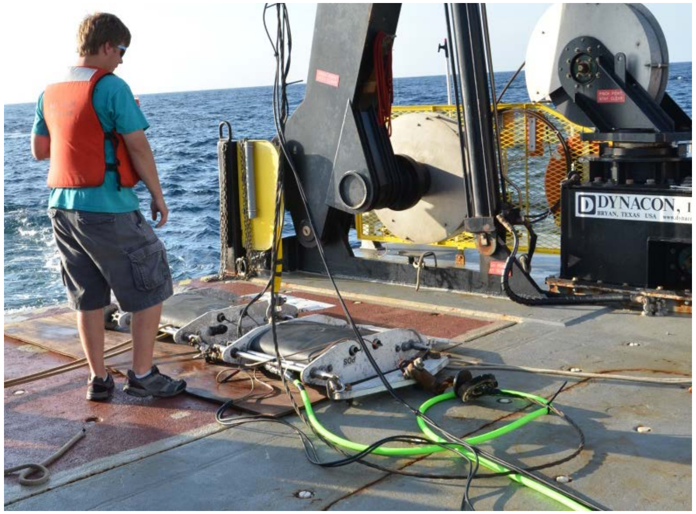
ITC-2010/ 4-elm. VLA (4)

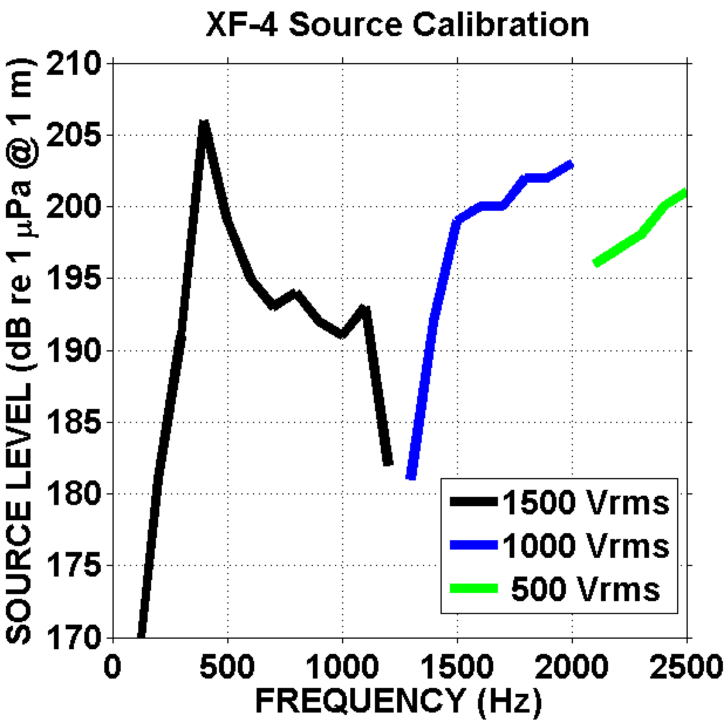


MEC/ANEX2015 Acoustic Experimental Assets (3)

XF-4 (2)



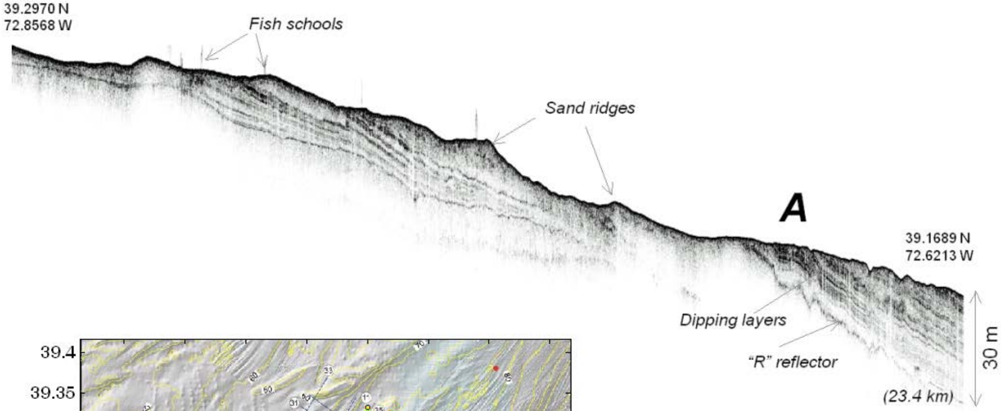


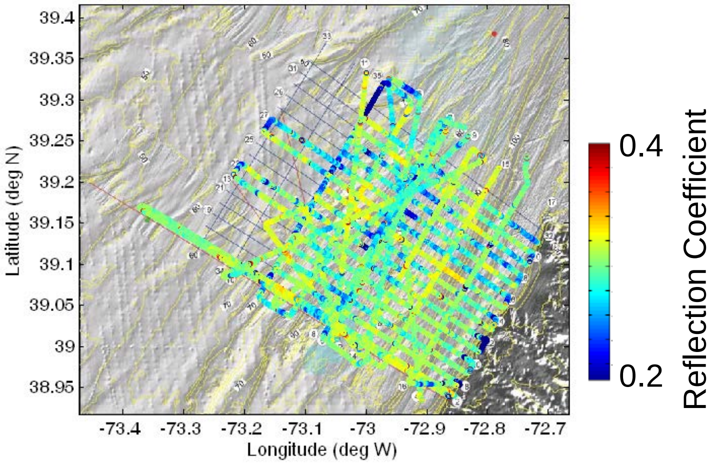


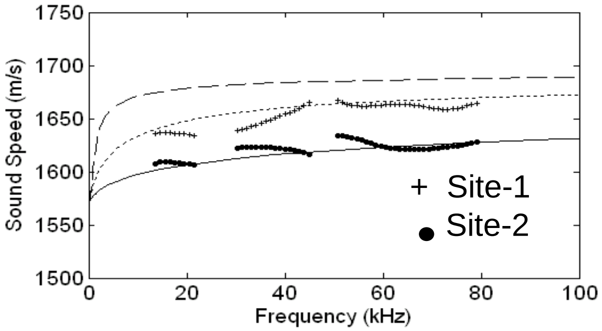
NRL Chirp Sonar and GeoProbe

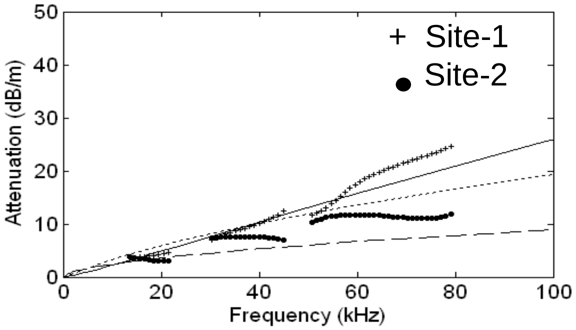
NRL Chirp Sonar

NRL Geoprobe



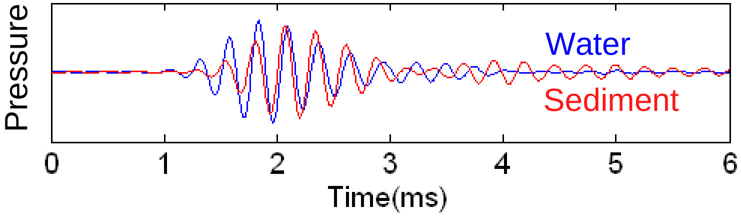




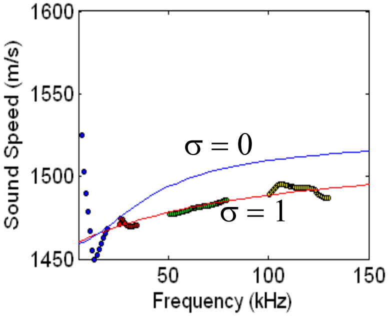


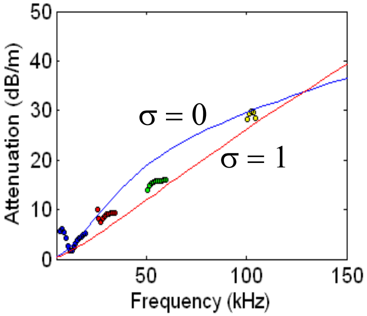
GeoProbe Measurements

NRL Deep-Sea GeoProbe System



BLUE10 Gulf of Mexico experiment (d=900 m)





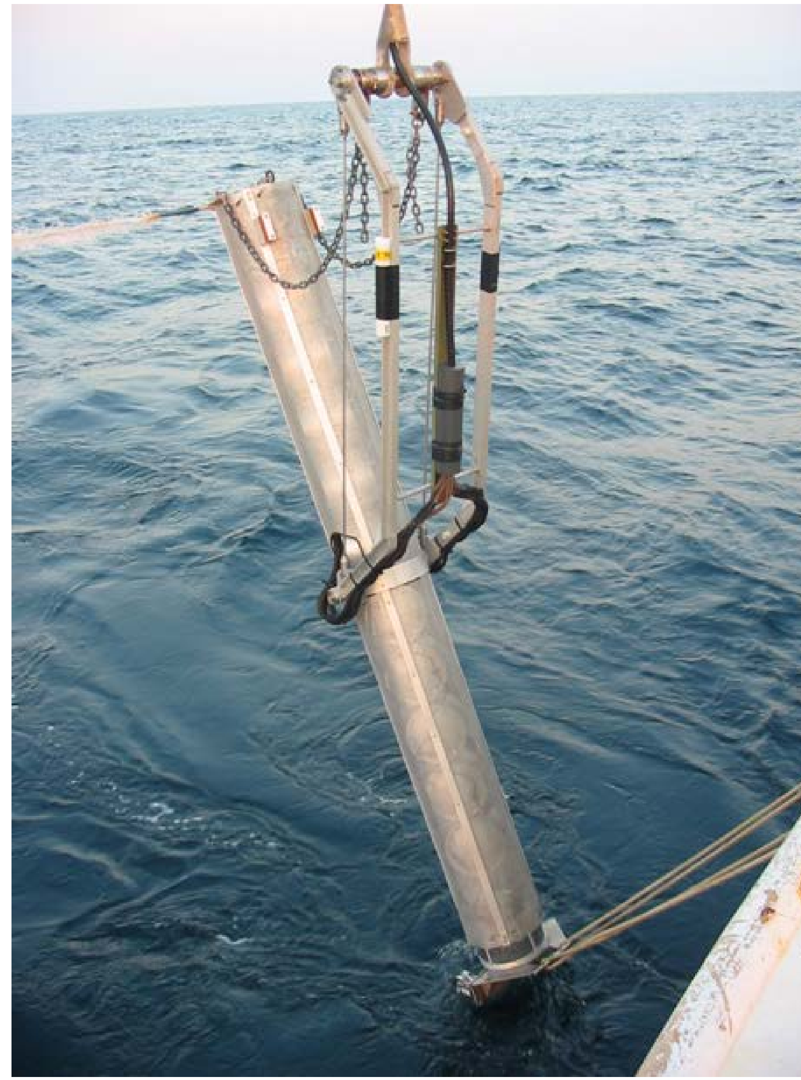
Latest additions:

1) Linear actuator for probe penetration
2) Sidescan/chirp sonar

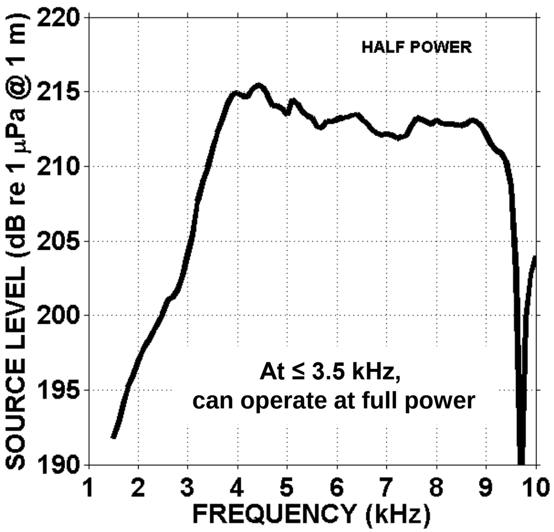
MF Source Array (Gauss)

10-transducer VLA
cut for ~3 kHz

- Frequency: 1.5-9.5 kHz
- Towable at up to 4 kts
- Depths 20-200 m
- 2 NAS suites (depth, tilt, etc.)
- ’Quasi-omni’ azimuthally
- 10-% duty cycle
- Elements individually controllable
- 440-V power



NRL MF VLA Source Calibration



f (kHz)	Max SL(dB)
1.5	196
2.0	201
2.5	204
3.0	208
3.5	215
3.8-5.5	216
5.5-9.0	213
9.5	210

Summary:

•Transmission Loss measurements up to 30 km range (0.3-5.0 kHz)

•Multistatic Reverberation Level measurements (0.3-5.0 kHz)

•Ambient Noise Level measurements (0.1-10.0 kHz)

•Moored VLA with thermistor pods, towed source/array with CTD

•Limited Chirp/Sidescan Sonar measurements

•Limited Geoprobe measurements