Identifying environmental factors in mid-frequency reverberation using a bottom-mounted system.

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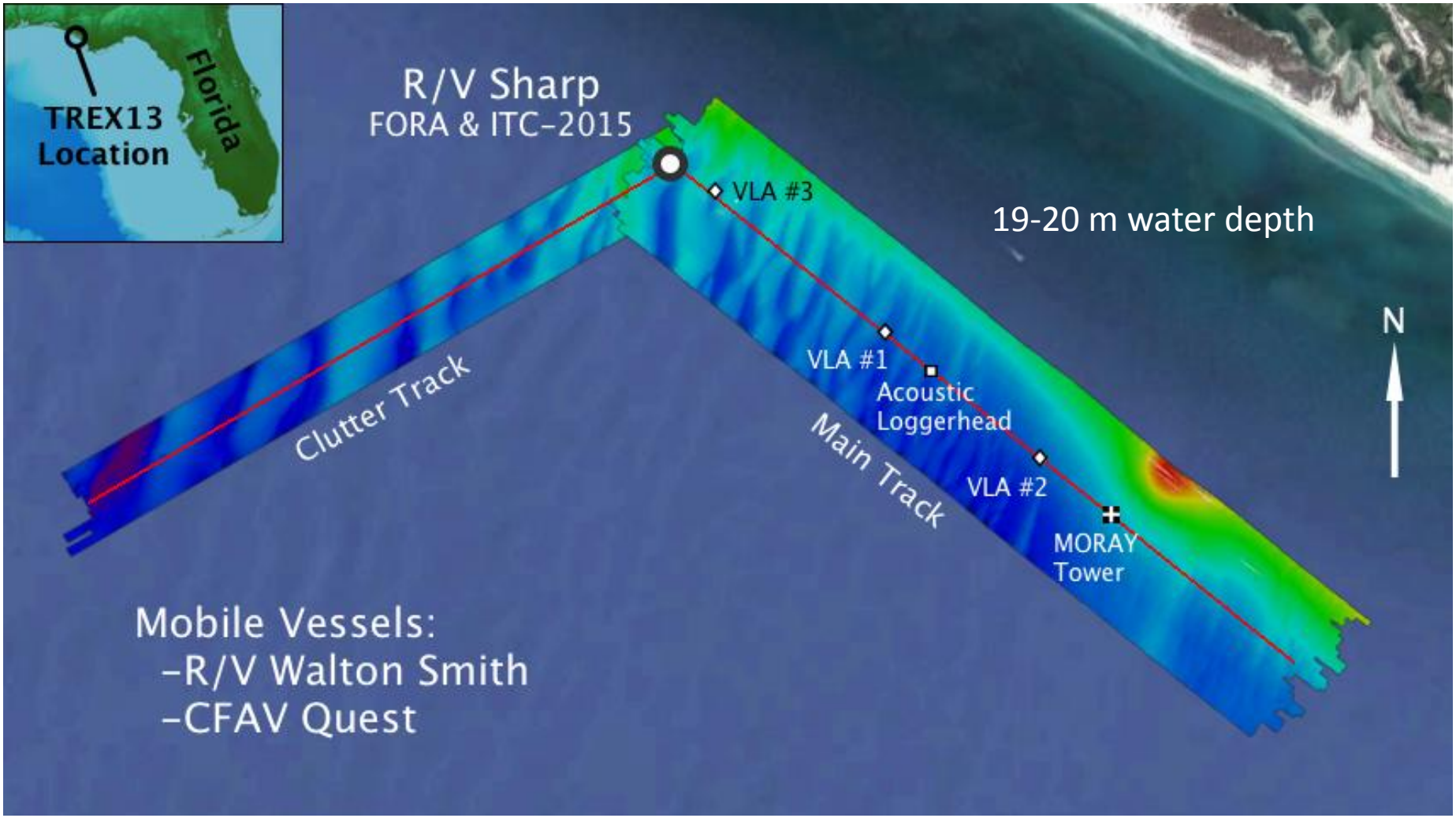
Motivation

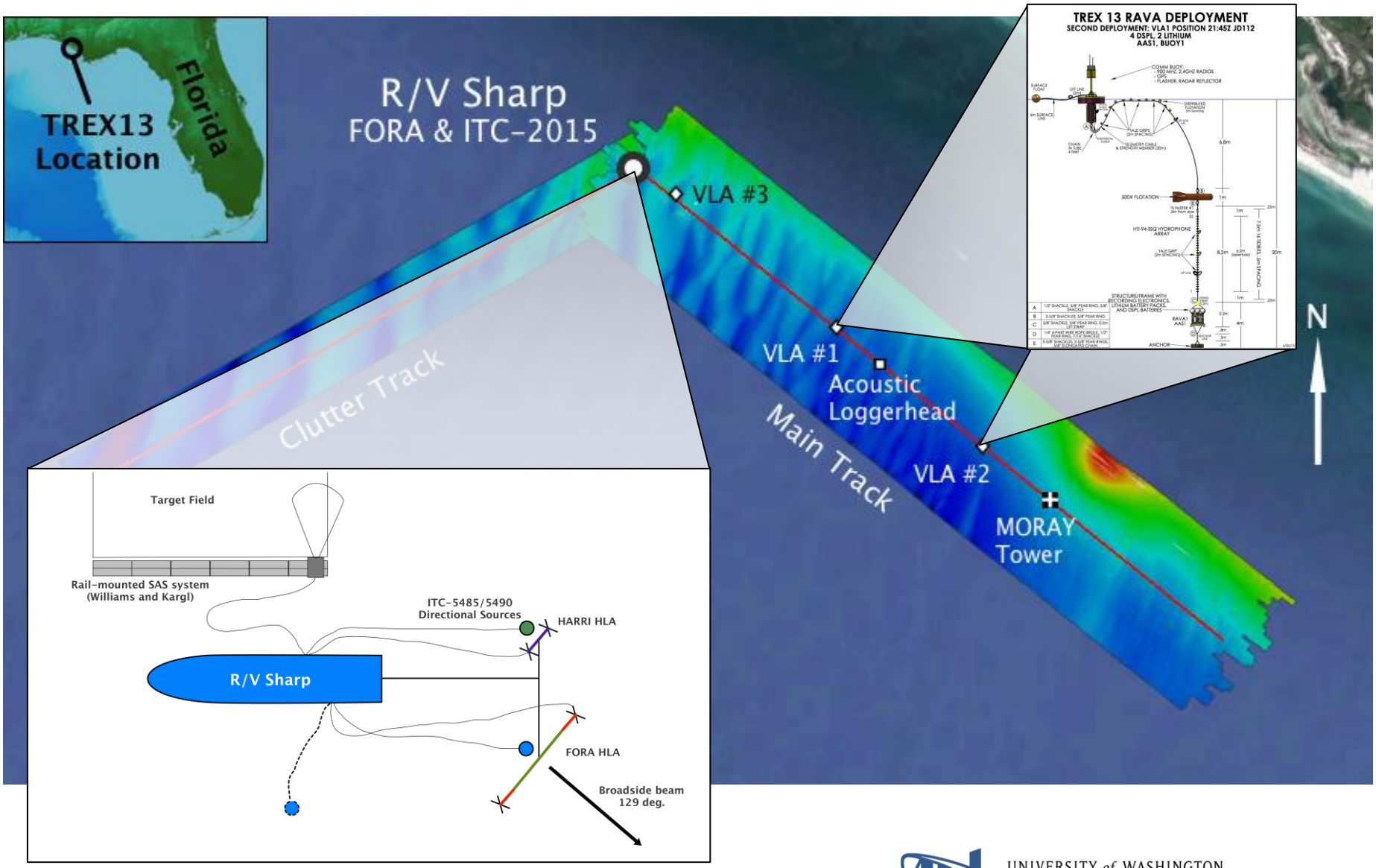
- The environment has a larger impact on propagation and reverberation at mid-frequencies (2-10 kHz) than low frequencies.
- Identification of the dominant environmental factors requires characterization of the sea surface, water column, and seafloor both spatially and temporally.
- This talk discusses two experiments where we've tried to extensively characterize the environment and fix the sources and receivers to the seafloor to minimize uncertainties in the measurement systems.

- A central goal in these experiments was to simultaneously measure transmission loss (TL) and reverberation level (RL).

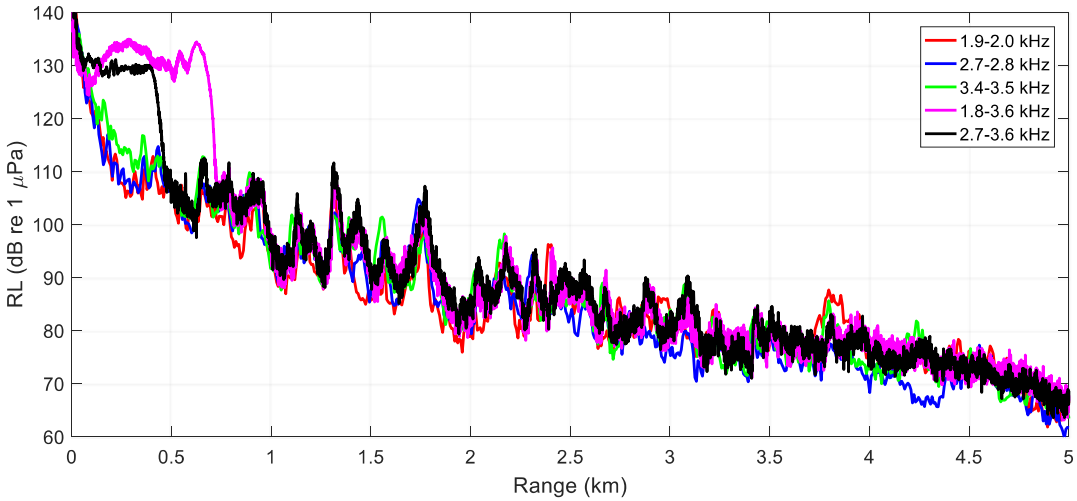
Target and Reverberation Experiment 2013



Target and Reverberation Experiment 2013



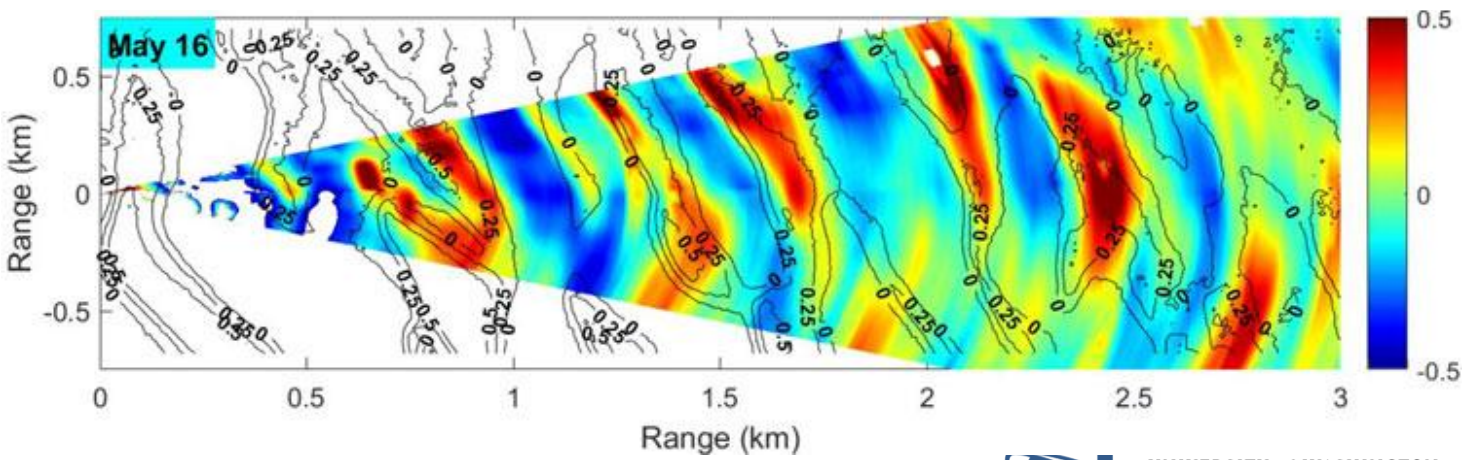
Spatial Variability in Reverberation



Example of reverberation measured during TREX13 along the main track.

Strong, deterministic variation in reverb level with range.

Trend subtracted reverberation indicates that the peaks in the reverberation level correspond to swales in the bathymetry.



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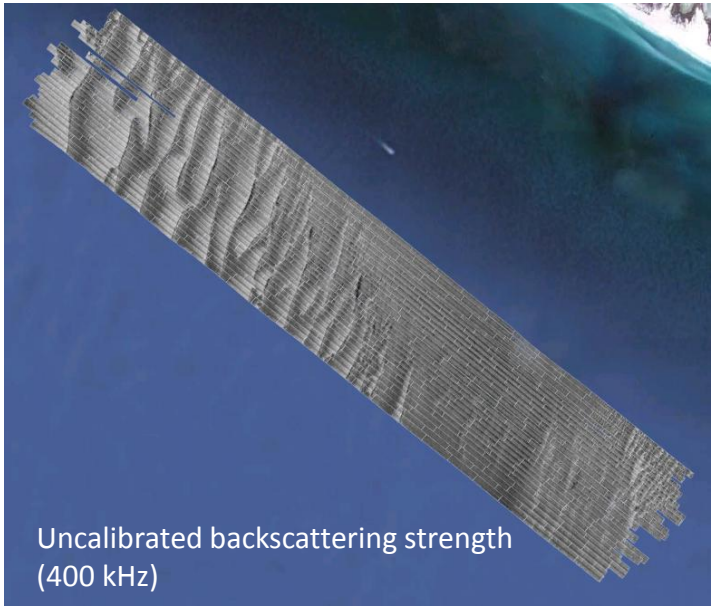
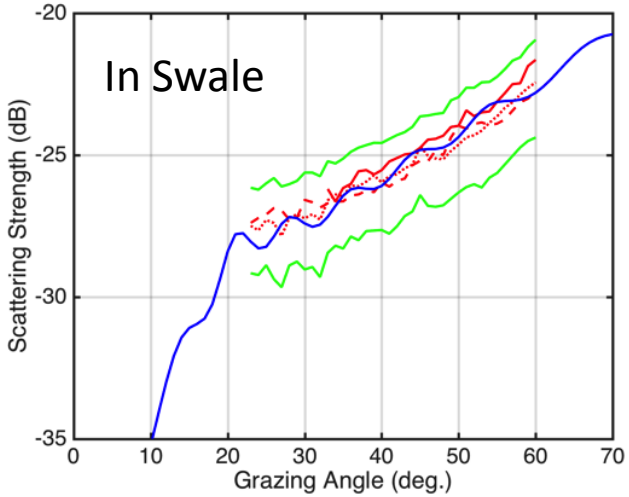


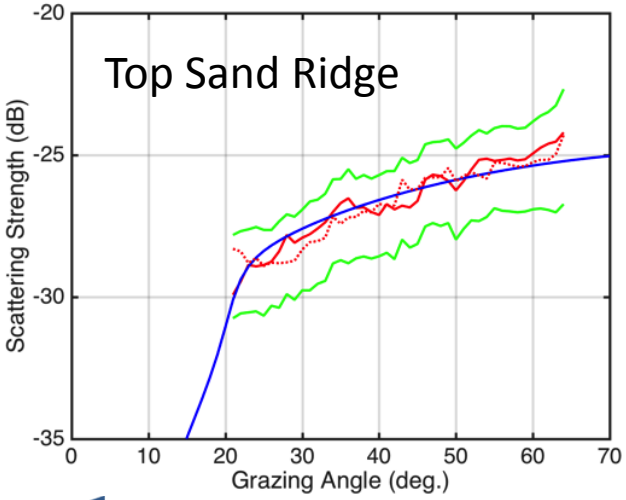
Multibeam survey found lower backscatter levels at 400 kHz within the swales.

Divers and camera systems indicated these were areas of softer sediment.

Mid-frequency backscatter sonar deployed to measure levels in and our of swales.

Model/data fits to measured backscatter indicate high levels of volume scattering within the swales.





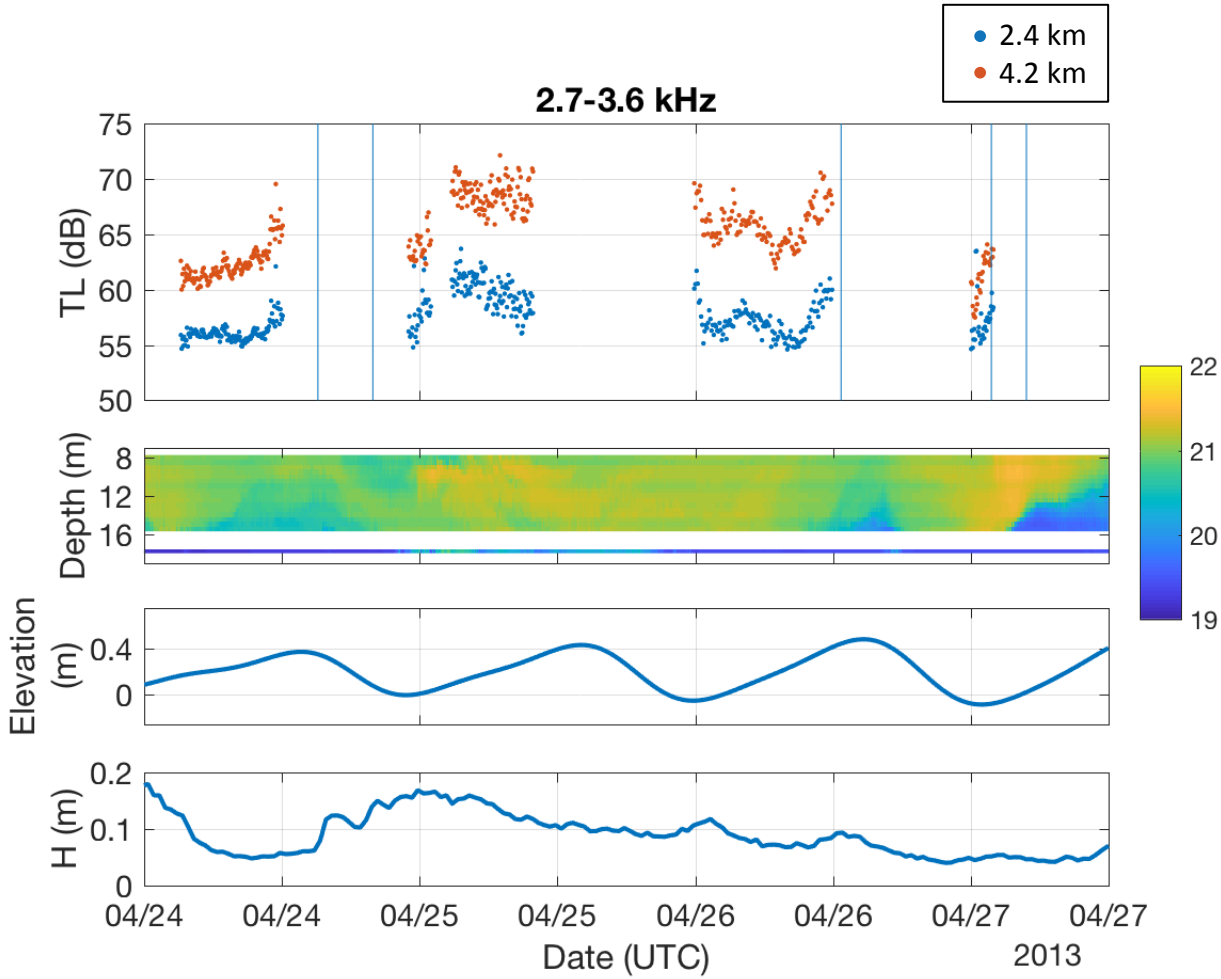
Temporal variability of TL on 2 VLAs

Comparison of 2.7-3.6 kHz TL to:

- Temperature
- Tide
- Sea surface RMS roughness

TL at each array varies by 8-10 dB over 3.5 day period

Majority of the variation is the same at both array, with difference in TL between arrays roughly 7 dB.



TL from Approximate SSP

PE used to find TL at the VLAs for attenuation of 0.78 db/λ. (1.51 db/λ shows similar variation).

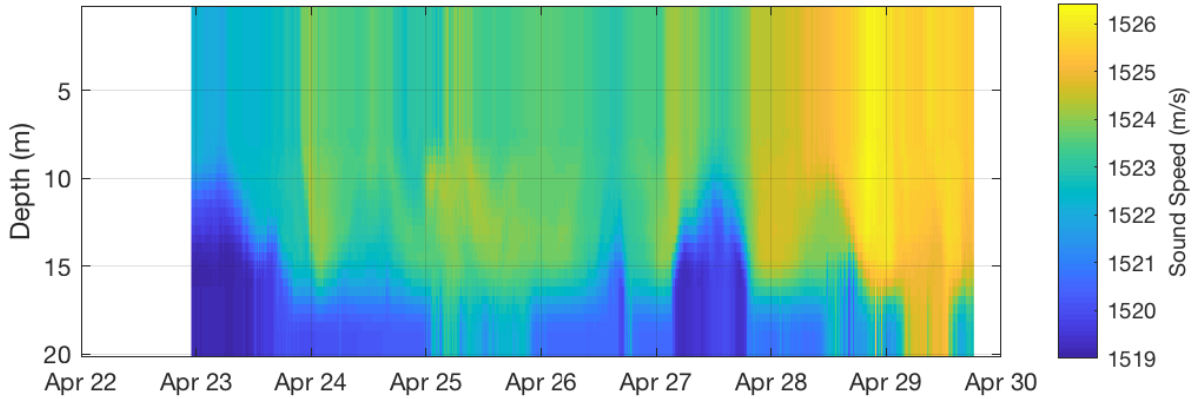
The approximate SSP leads to TL variations on the order of 10 dB.

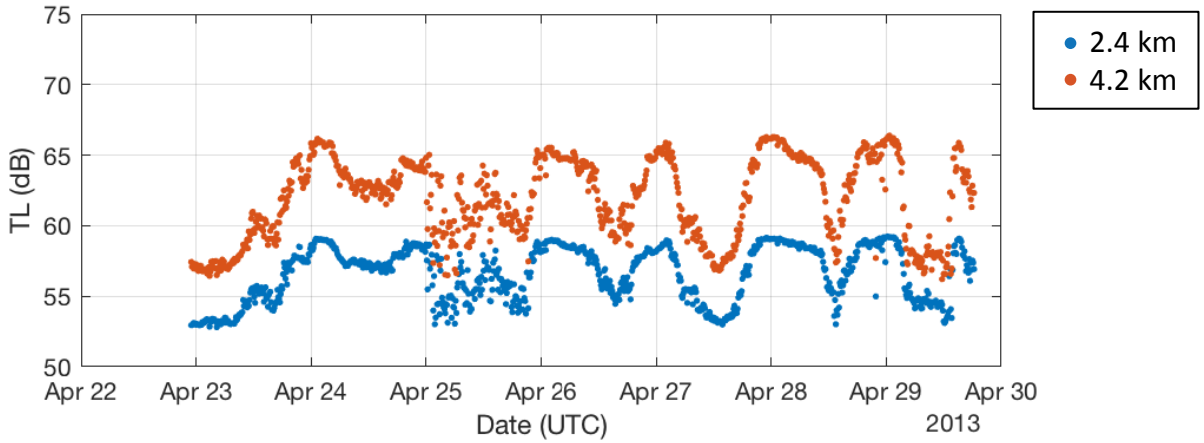
High TL occurs when thermocline drops below 16 m.

Low TL occurs when thermocline goes high.

Consistent with energy trapping in the duct.

SSP dominated by baroclinic tide





Comparing Measured TL to RL

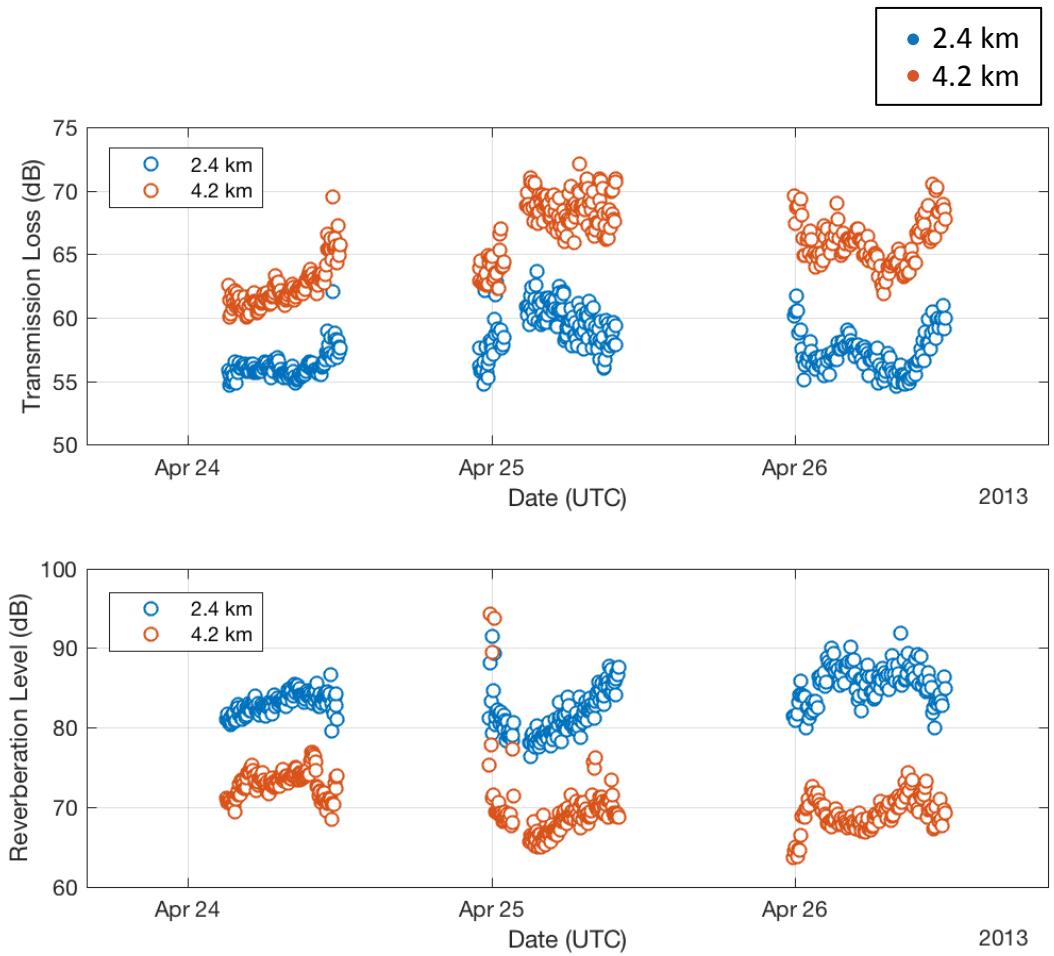
- Jie Yang took average of RL along 100 m section of main reverberation track beam at locations of VLA #1 and #2.
- TL and RL for same pings.
- Fixed Source and Receiver.

TL and RL compare quite well with Sonar Equation:

1. $\Delta RL \approx -2\Delta TL$ where Δ is difference in value between arrays.

2. Decreases in RL correspond to increases in TL.

- This highly constrains RL and TL data/model comparisons.



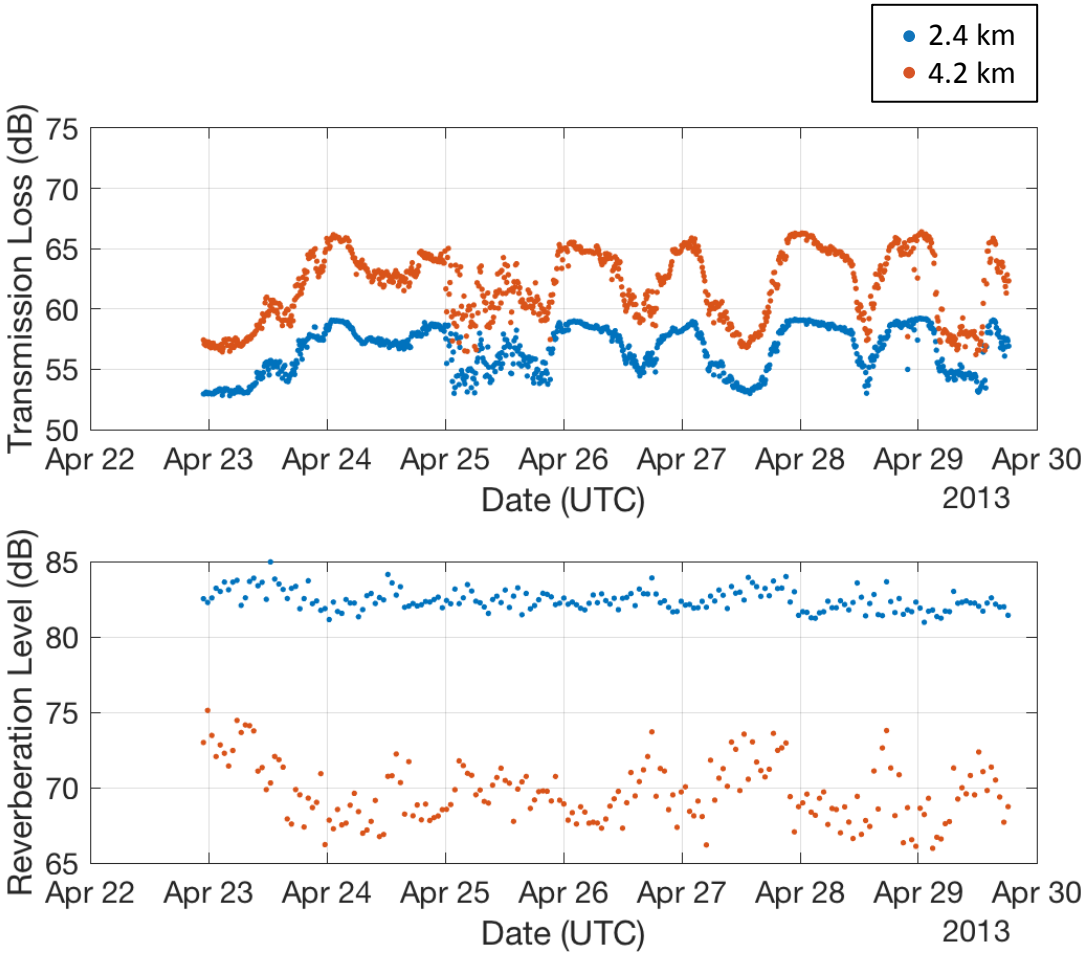
RL from Approximate SSP

Reverberation Level was also predicted for the approximate SSP.

While there is some correlation between the model TL and RL, the RL fluctuations are much weaker.

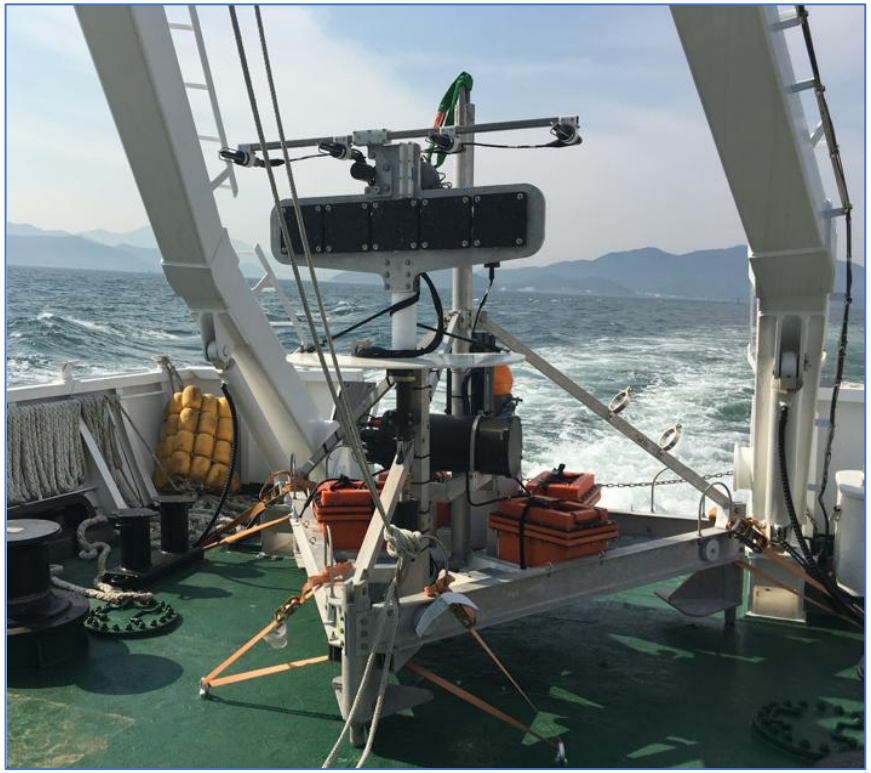
Consistent with trapping energy in the duct at the seafloor.

Contradicts the measurement results.



The Autonomous Reverberation Measurement System (ARMS)

- Benthic lander with on which is mounted a directional source and receive array on a rotating stage.
- Constructed with funding from an ONR DURIP
- Source height: 1.725 m
- Rec height: 2.0 m
- Height (at eye ring): 2.12 m
- Width: 2.185 m
- Frequency Range: 3-6 kHz
- Calibrated source and receivers
- It can be programmed to collect reverberation data as a function of angle at a pre-determined time and for a number of independent runs.



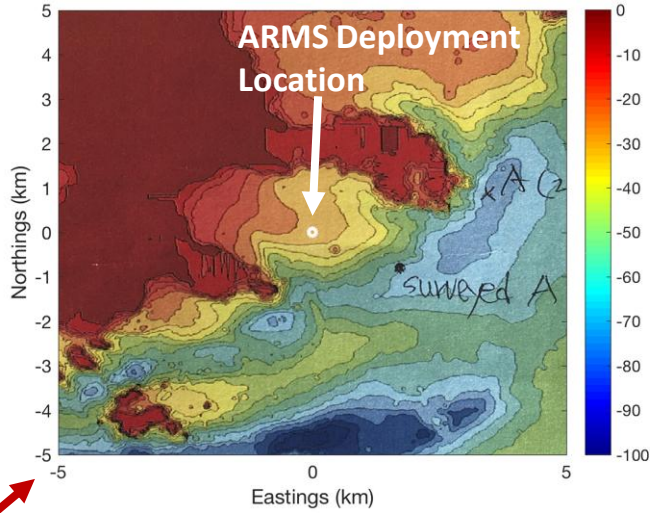
- Combined transmit/receive beampattern: 11 degrees.

Korea Reverberation Experiment 2017

KOREX17 was conducted off the island of Geoje, Republic of Korea, 23-31 May 2017.

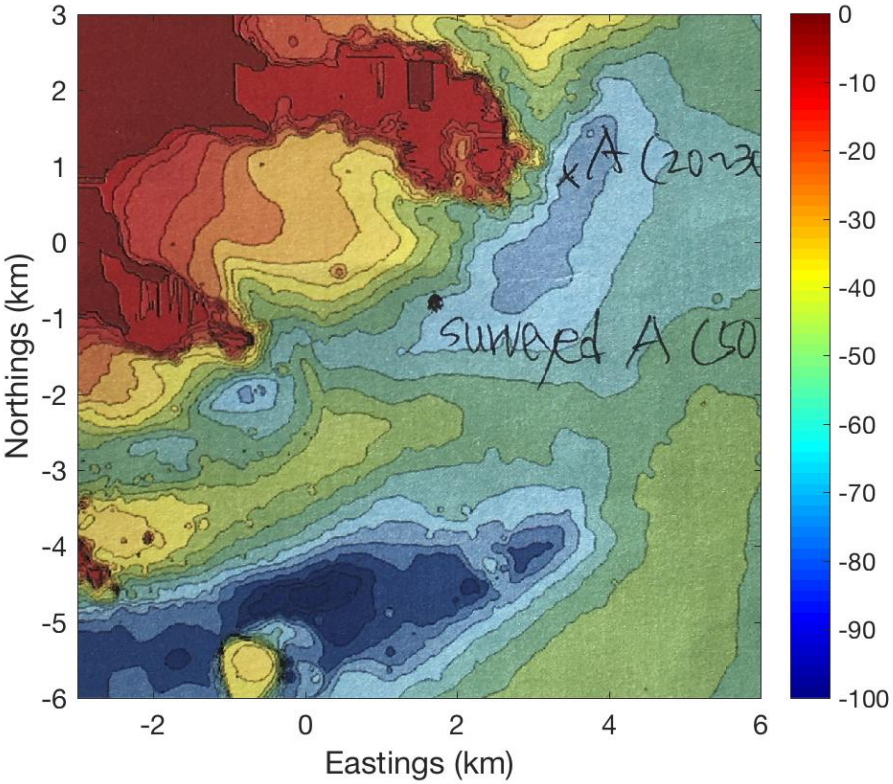
- Agency for Defense Development of S. Korea (ADD)
- The Applied Physics Laboratory, University of Washington (APL-UW)
- Hanyang University of S. Korea (HYU).

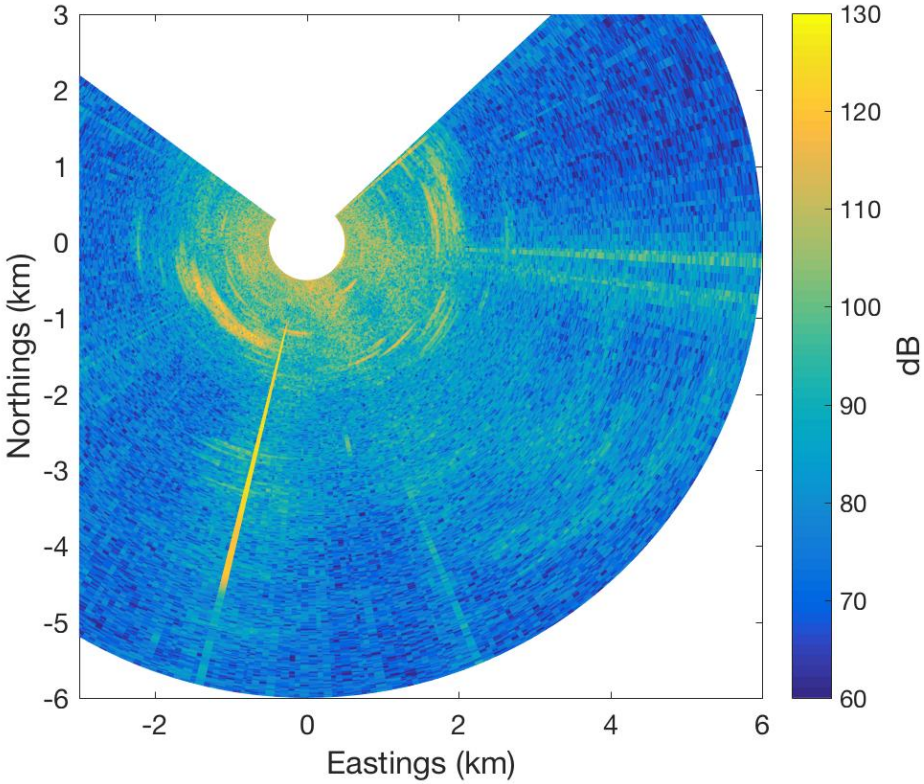
Geoje Island



- ARMS was deployed in center of bay at 30 m depth.
- Afforded protection from extensive fishing in strait
- 90 degree sector facing into open water of strait.

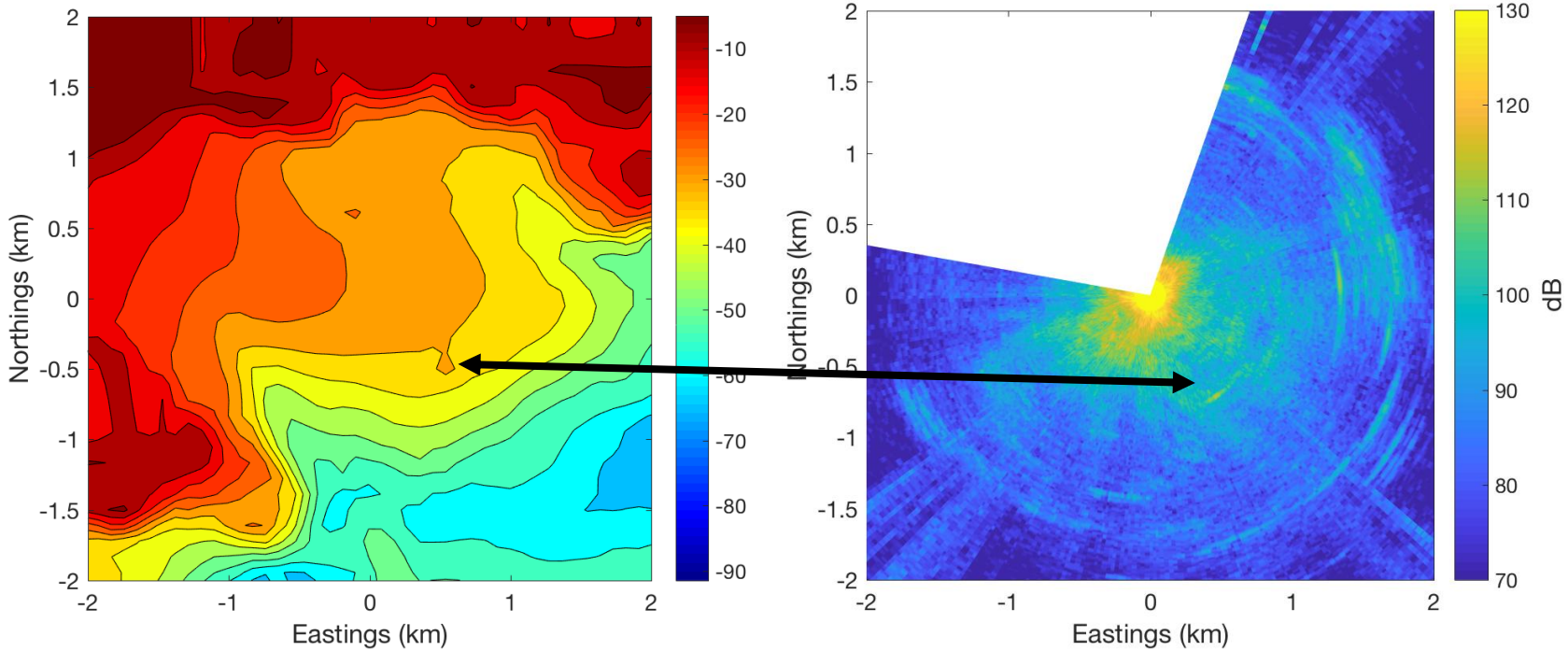
Reverberation at KOREX17

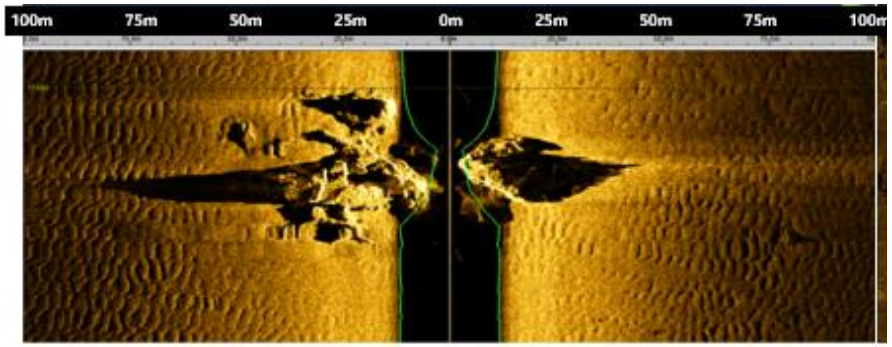




- Transmitted Waveform: 3.5 kHz, 100 Hz LFM, 1 s
- Rotation increment: $\Delta\phi$ = 1 degree

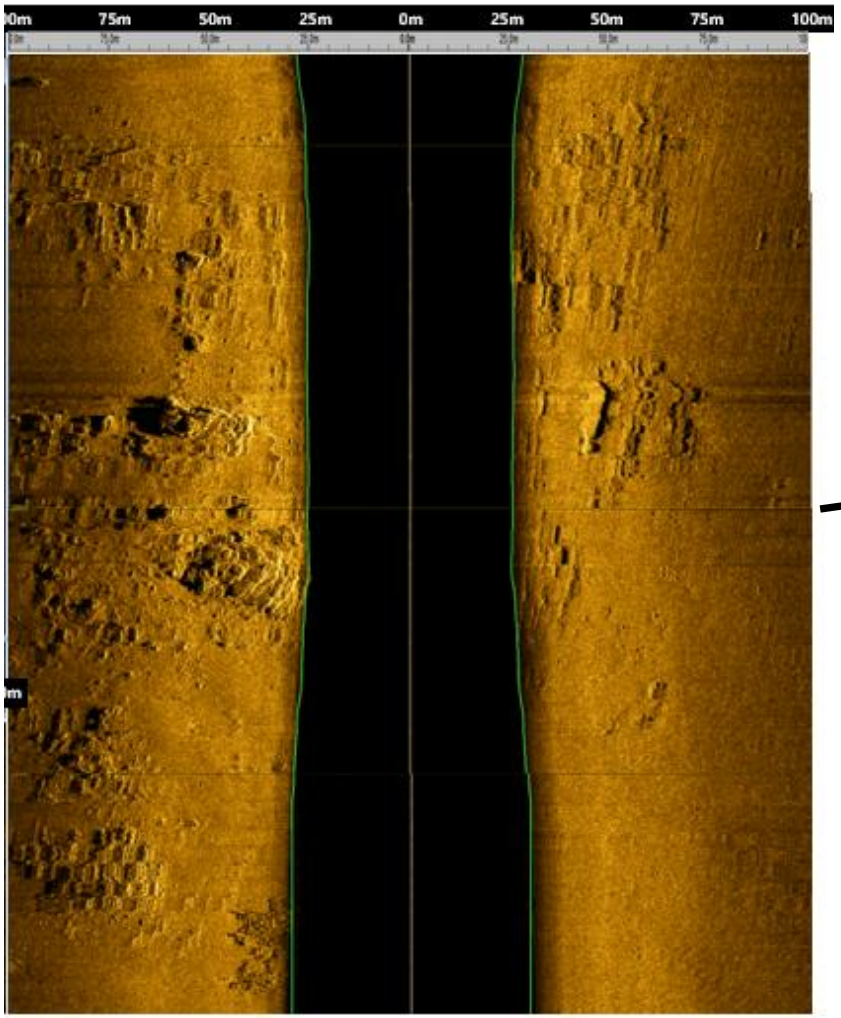
Reverberation Within the Bay

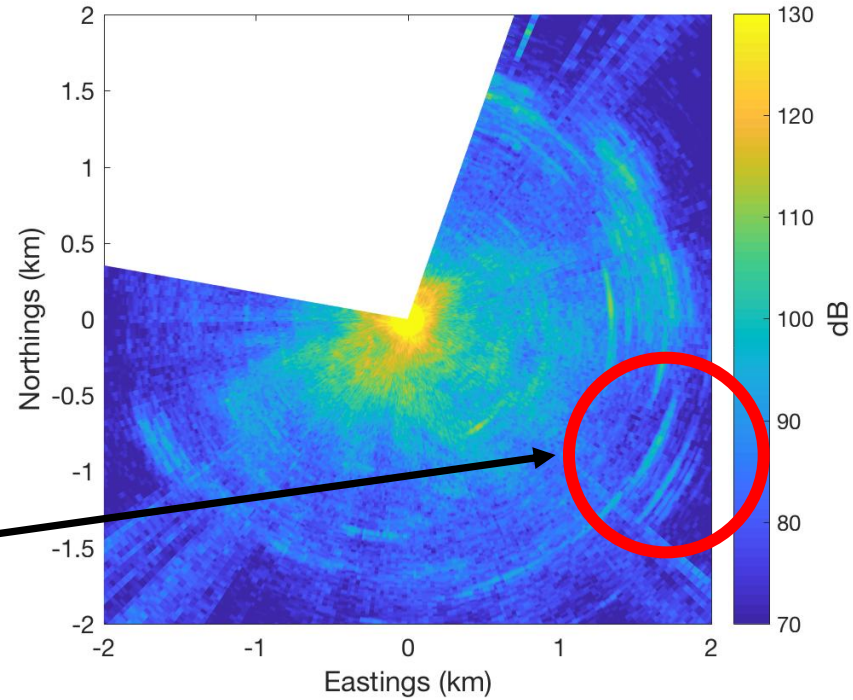




- Significant amount of clutter within the bay likely due to rock outcroppings and artificial reefs.
- One of the clutter objects is an exposed rock which shows up in the bathymetry and is marked as a hazard to navigation.

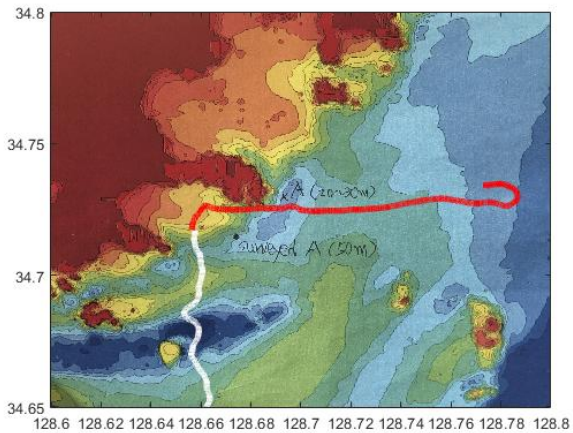
Reverberation Within the Bay





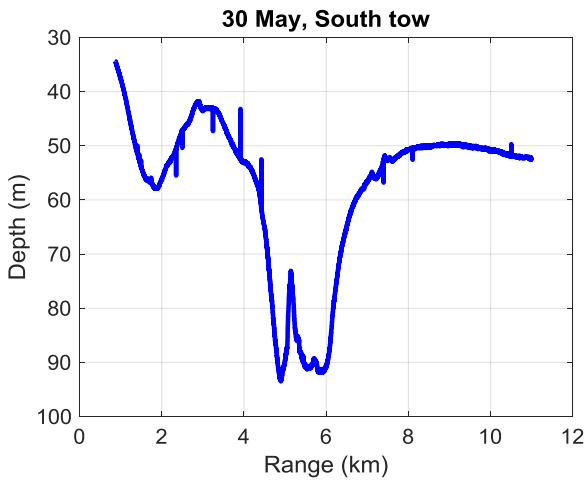
- Side Scan indicates areas of clutter due to exposed rock close to seafloor.

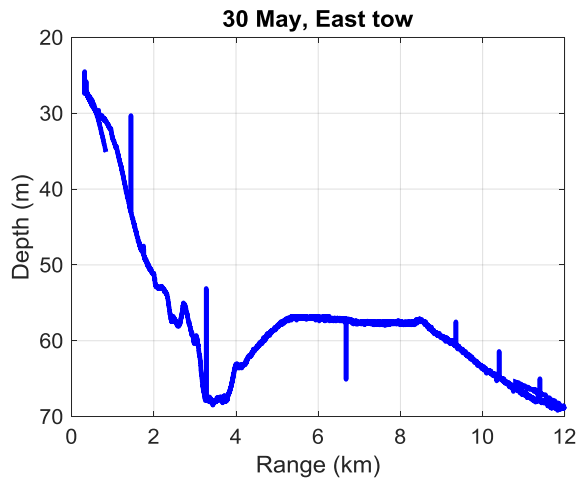
ARMS Transmissions with Receiver Tows

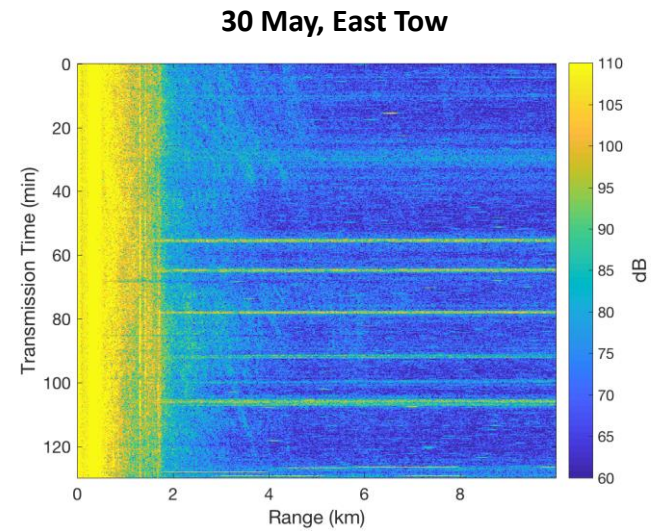


Joint TL/Reverberation measurements

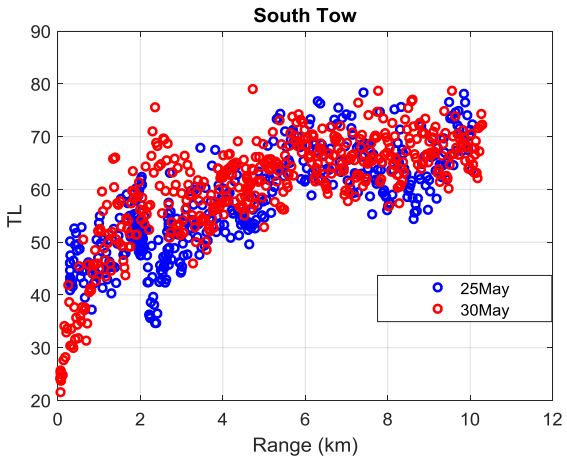
On two days (May 25, 30, 2017), the ARMS transmitted 3.5 kHz signal at 200 dB while aimed at South or East directions. ADD towed a receiver @ ~ 20 m depth along tracks as shown, receiving ARMS signal for TL.

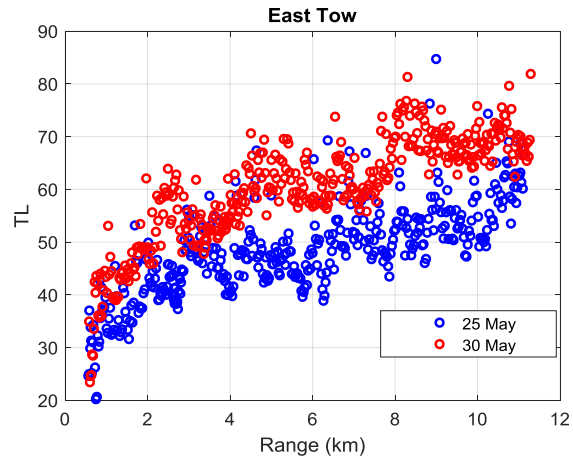


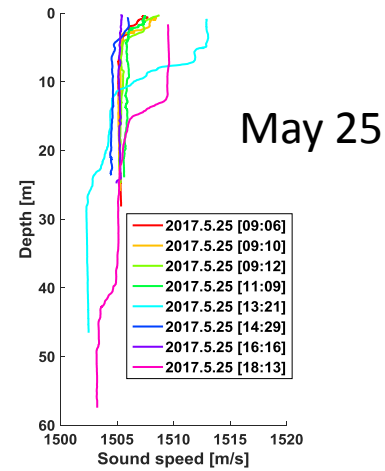


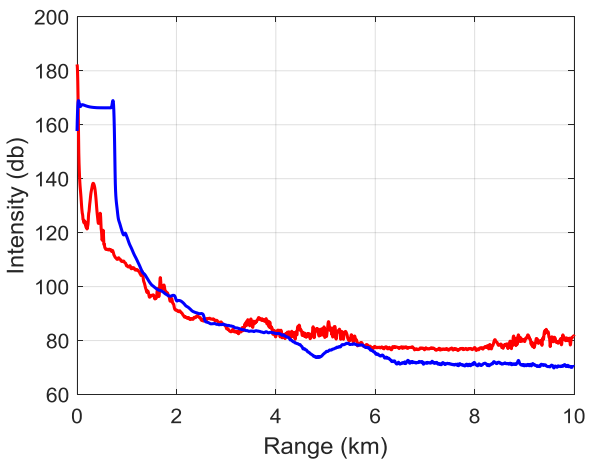


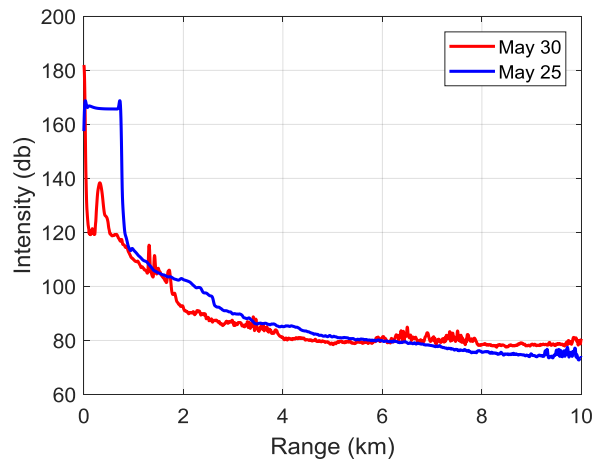
TL/RL observations for the two days and two tracks

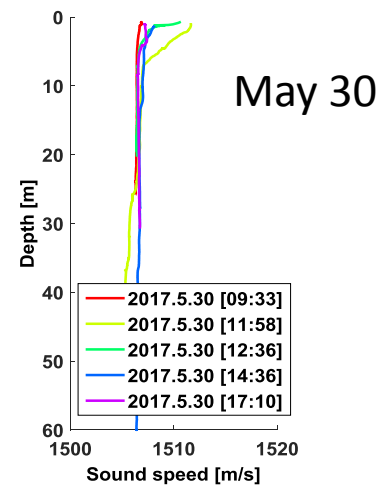






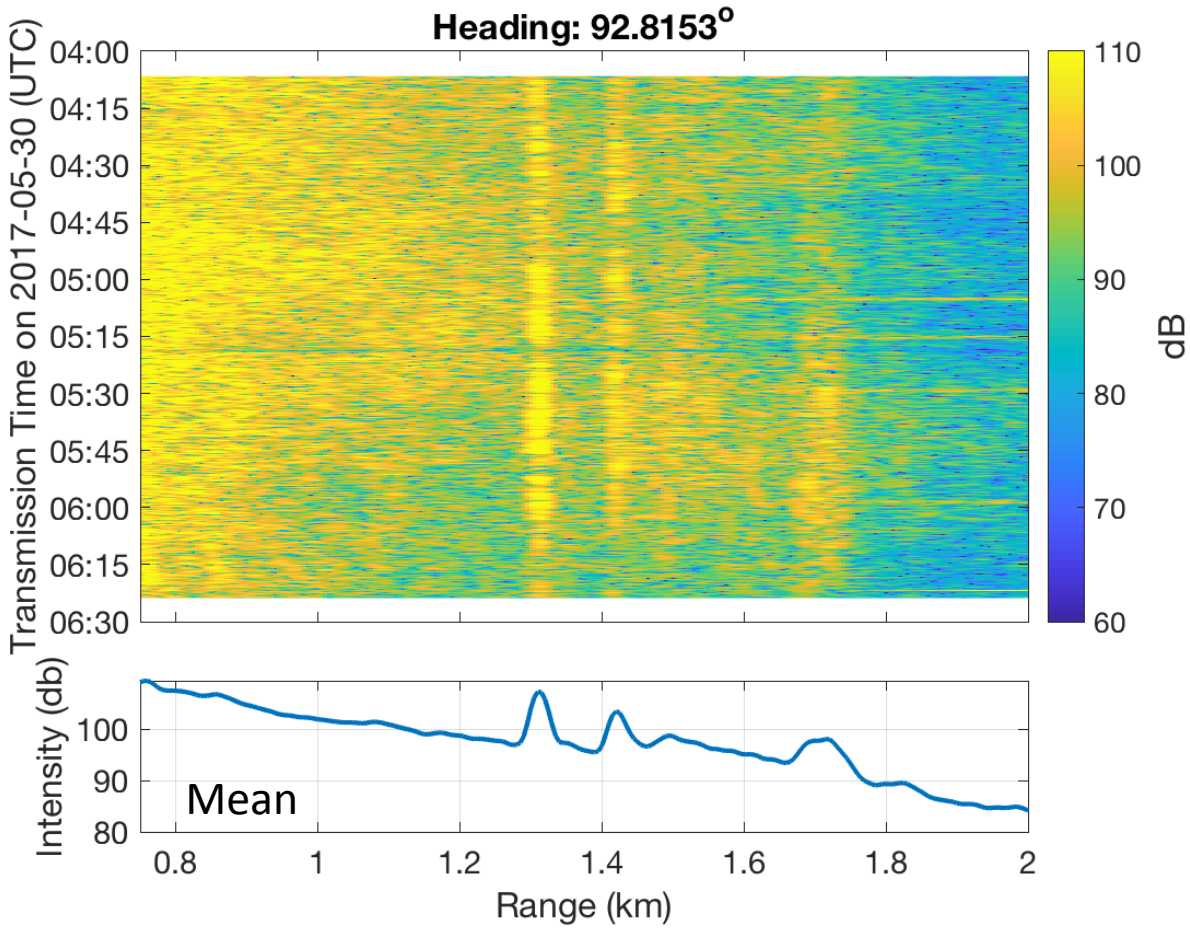






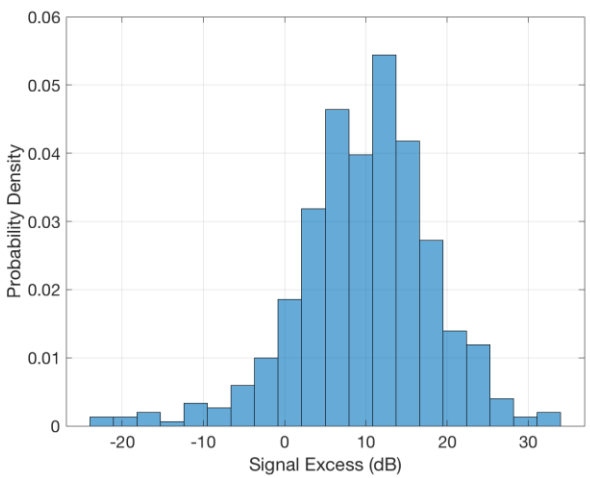
Temporal Variation of Signal Excess

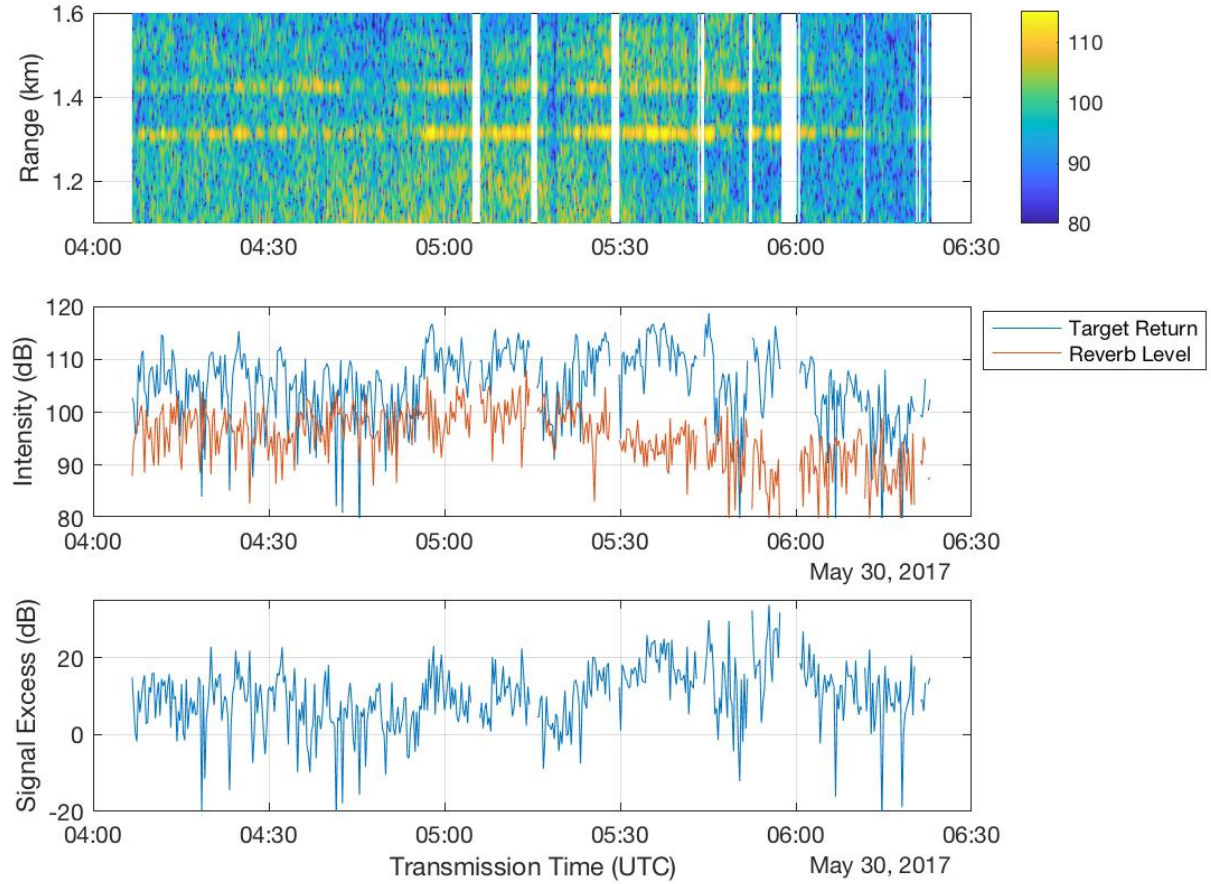
- Reverb measured on the eastward track, fixed-angle transmission.
- Transmitted LFM (1s long/100 Hz BW) every 15 s.
- Clutter object in view of ARMS.
- Significant variation in scattering level and reverberation over 2-hr transmission time.



Temporal Variation of Signal Excess

- Significant variation in scattering level and reverberation over 2-hr transmission time.
- Signal Excess has a mean of 10.5 dB and standard deviation of 7.1 dB.





Summary/Future Work

- Discussed two experiments where we've simultaneously measured both TL and RL at mid-frequencies using seafloor mounted systems with extensive environmental characterization.
- Simultaneous TL and RL measurements highly constrains the modeling.
- Both TREX13 and KOREX-17 indicate a need to improve our spatial and temporal measurements of the oceanography even for seemingly benign areas.
- Need a reference target for signal excess modeling in varying environments.
- Efforts underway to address these need for the upcoming KOREX-19 and other, proposed efforts discussed tomorrow (Tang).