Reverberation Statistics for the Straits of Korea

Data from ACT-III Test, September 1995

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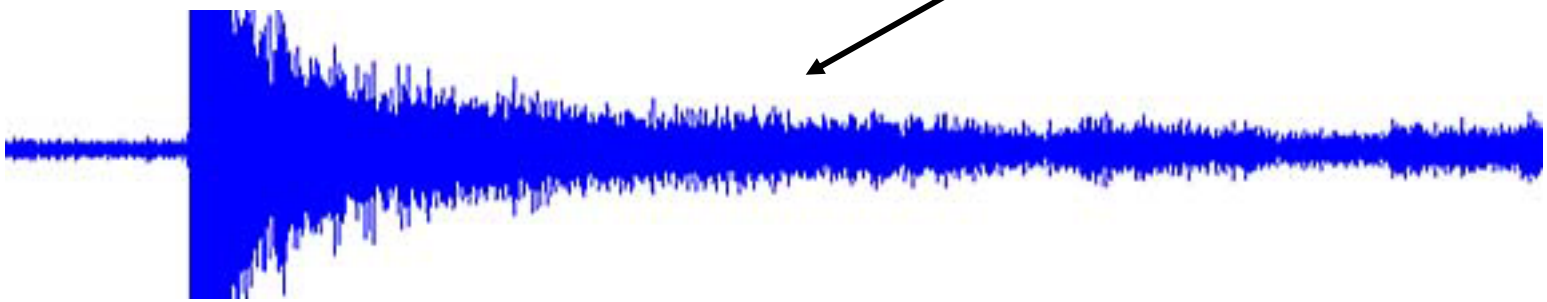
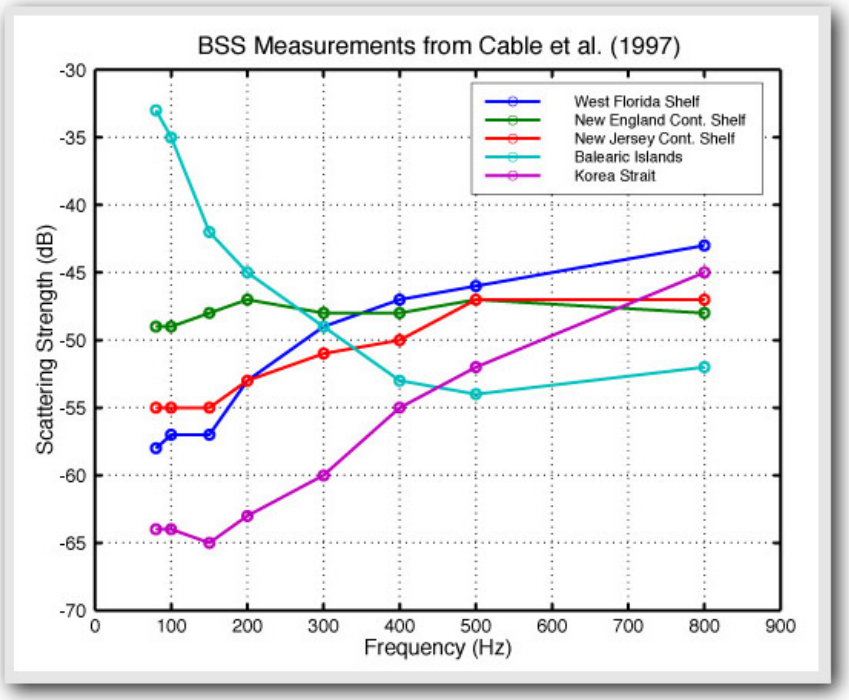
UNITES Team

Acousticians call it "reverb".
Geophysicists call it "coda".
Latin for "tail".



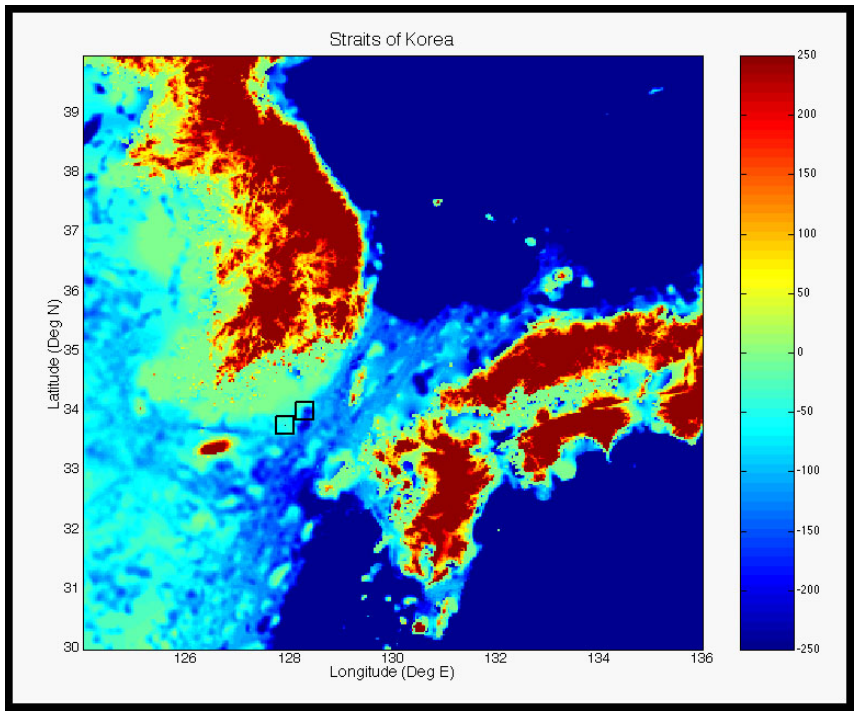
Reverberation Analysis

- Reverberation is characterized by the “back scattering strength (BSS)”
- Spatial variations occur over range, azimuth, distance from shore, source/receiver depth, etc.
- Some back-scattering strength measurements available, but mostly mean values, no statistics.
- UNITES Team effort will incorporate BSS statistics to establish *Predictive-PDF*.
- Current analysis based on ACT-III data, Straits of Korea

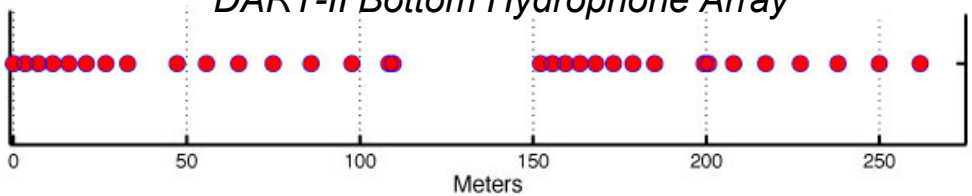


ACT-III Experiment

- Funded by DARPA
- September 1995, Straits of Korea
- Participants
  - *BBN - NOSC*
  - *U-TX - NRL Stennis*
  - *Kordi*
- Shallow water, 100-meters
- Bottom Conditions (2 sites)
  - *Silty sand bottom w/ shell traces*
  - *Silty clay bottom*
- Arrays
  - *DARPA Horiz & Vert Line Arrays*
  - *DART-I & II, 32 channels, bottom array*
- Tests
  - *Reverberation & Noise*
  - *Transmission Characteristics*
  - *Signal Excess*
- Data available for distribution.
  - *Unclassified raw waveform data for 10 events on one CDROM, Matlab format*

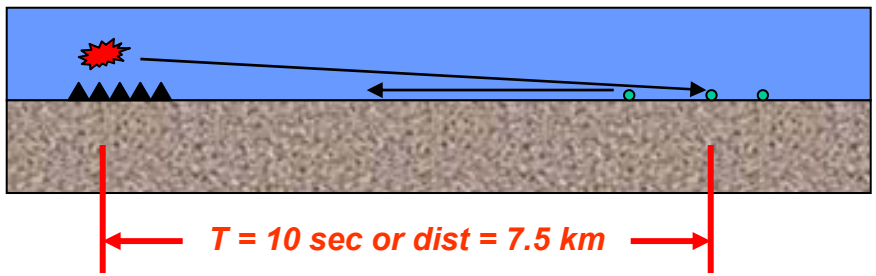


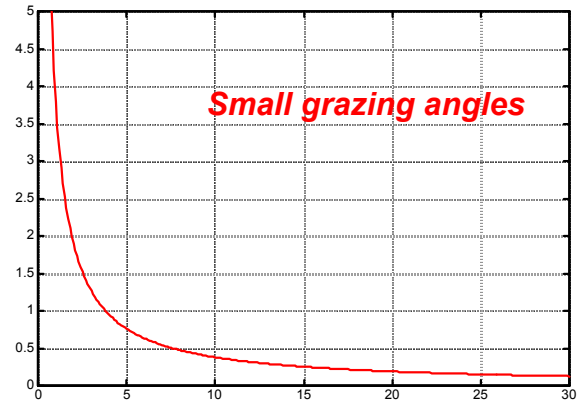
DART-II Bottom Hydrophone Array

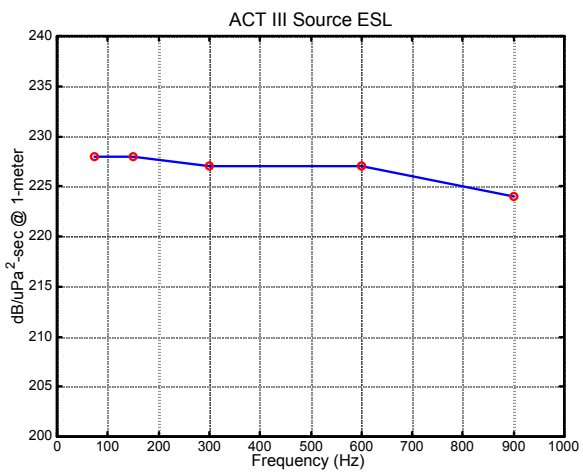


Source, Geometry, Signals, Processing

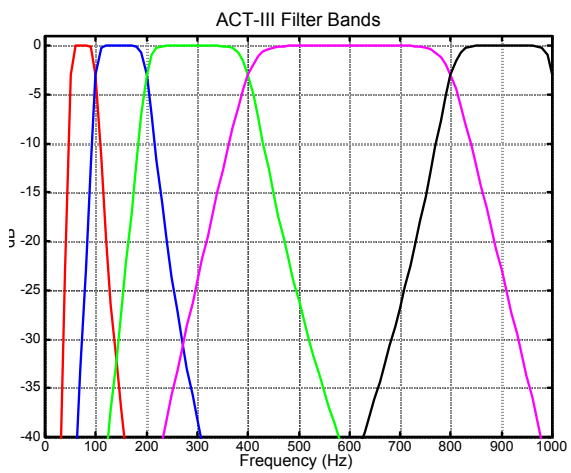
Water depth: 100 m Source depth: 50 m



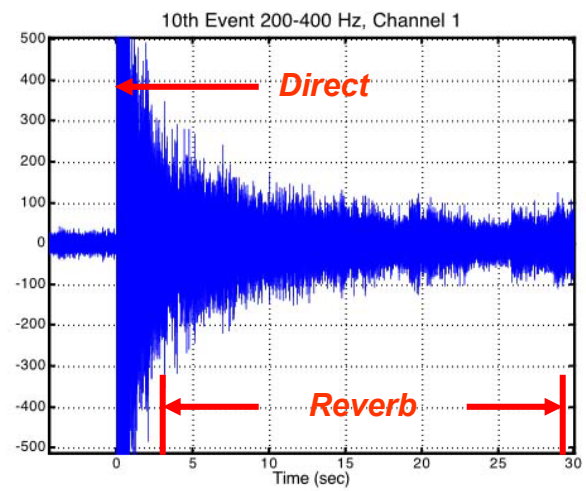




Line source, horizontal directivity

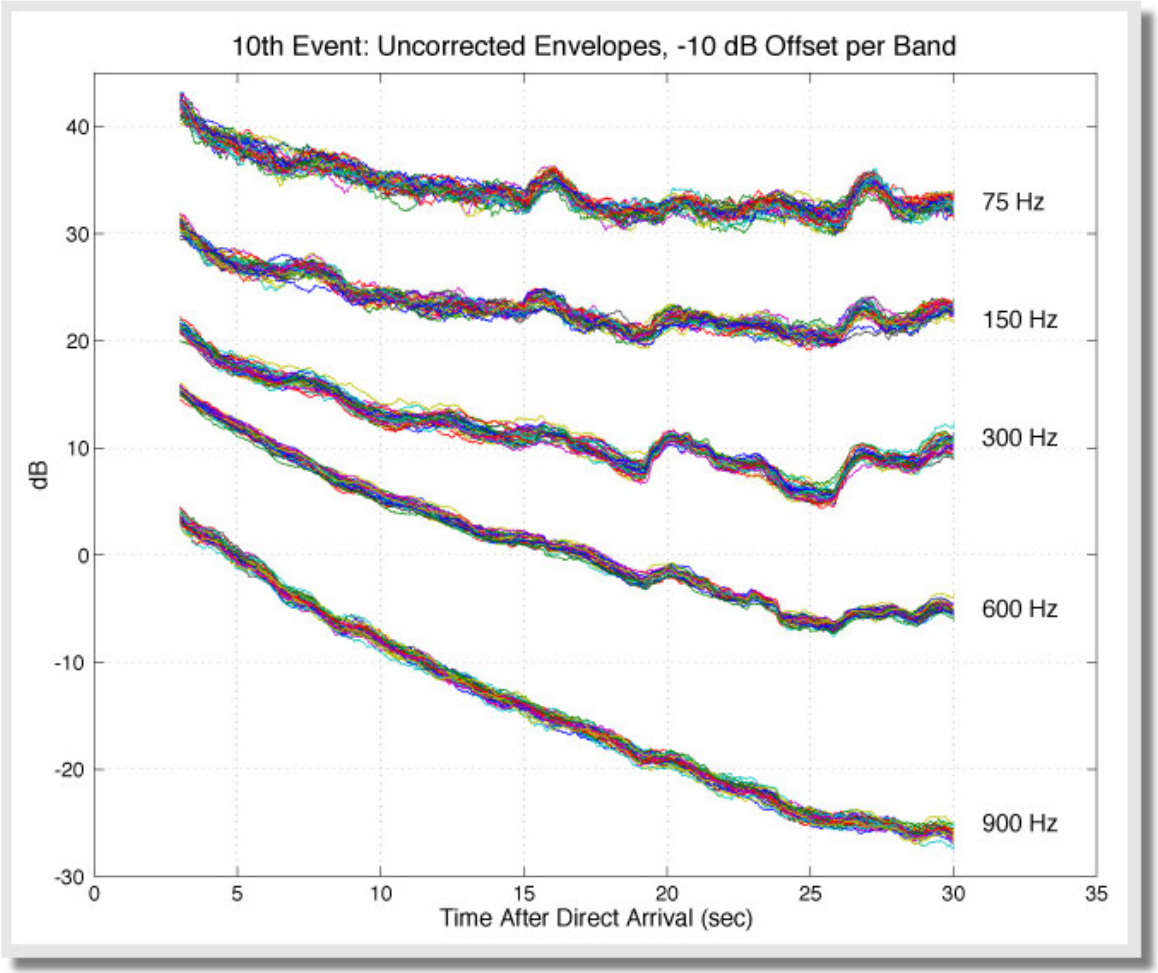


fc = 75, 150, 300, 600, 800 Hz

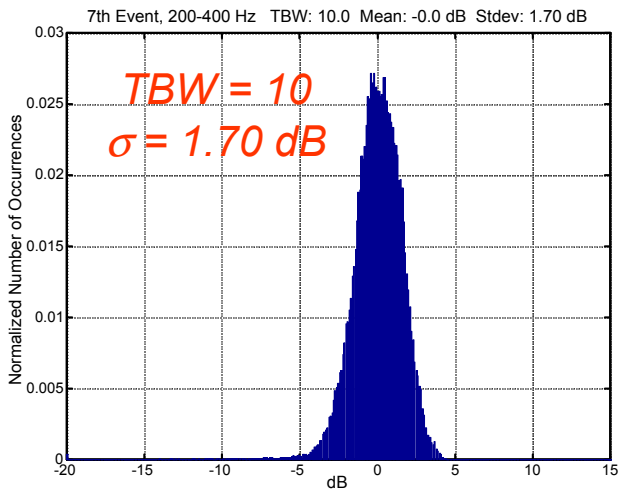


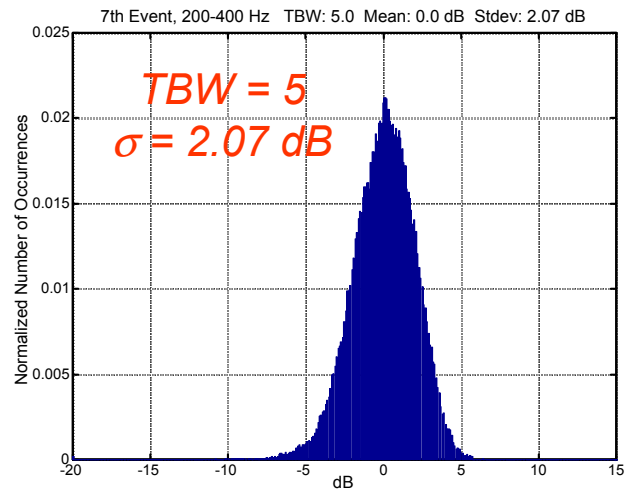
Sample data

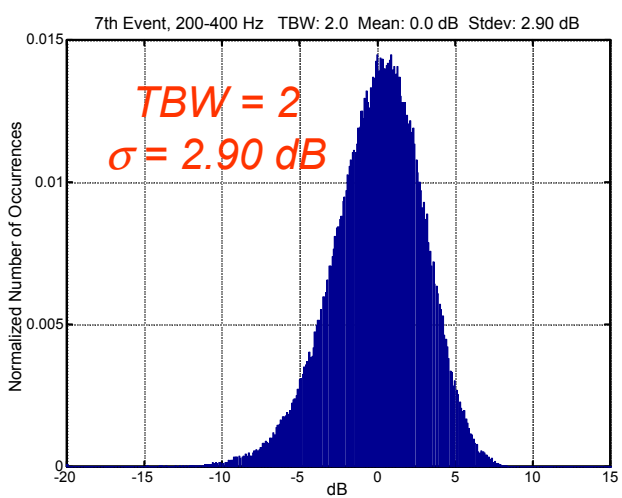
Sample Reverb Data: DART-II Array (32 channels)

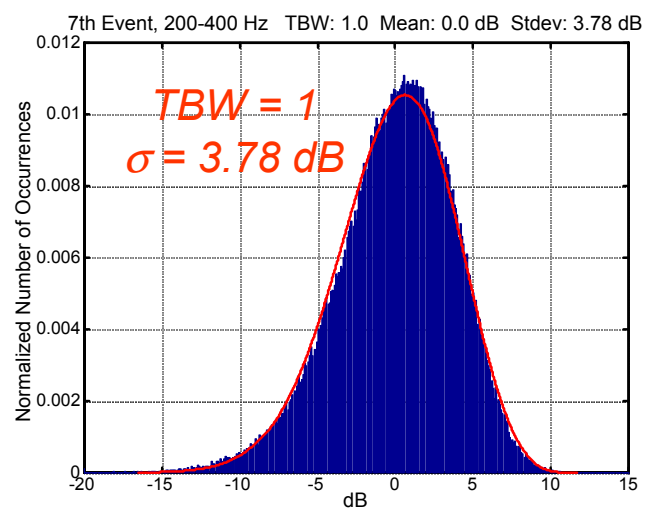


Noise Statistics: fc = 300 Hz, Variation w/ TBW



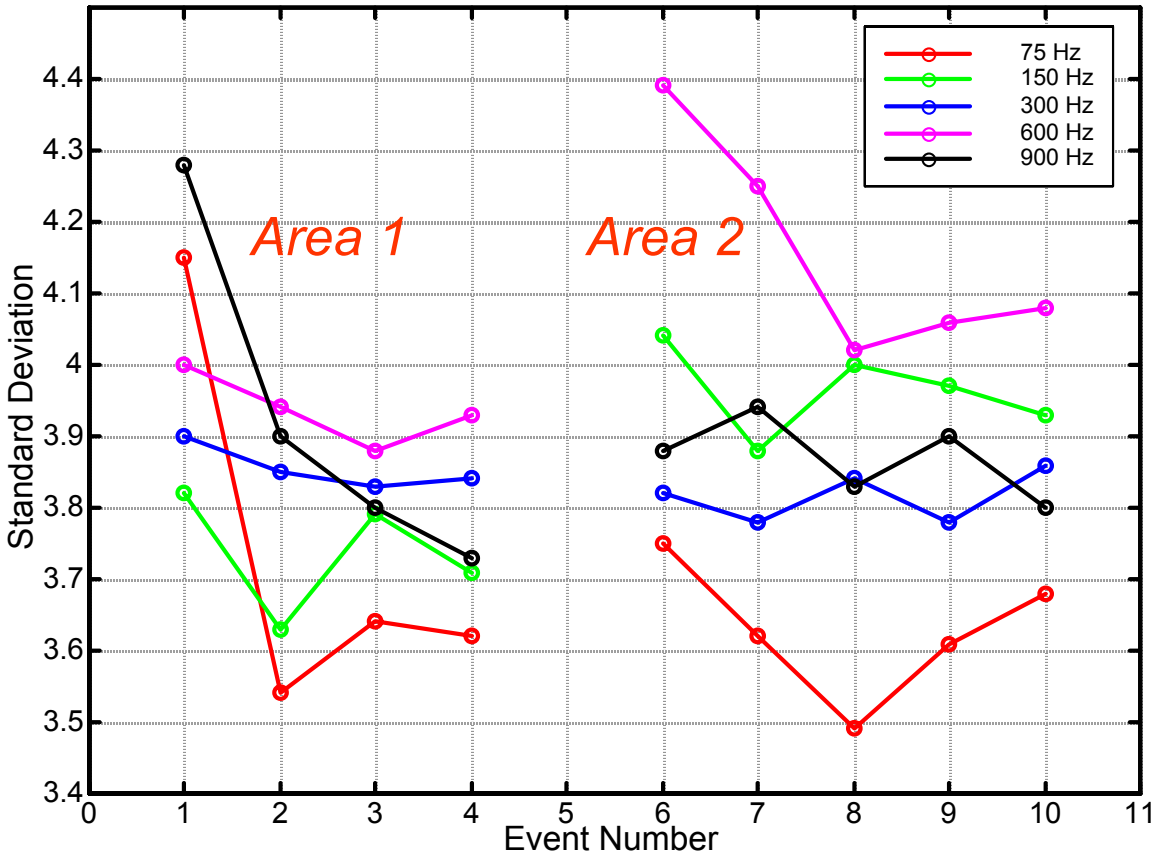






Ambient Noise Statistics for Nine Events

Five frequencies, TBW = 1.0, $\sigma \sim 3.9$ dB



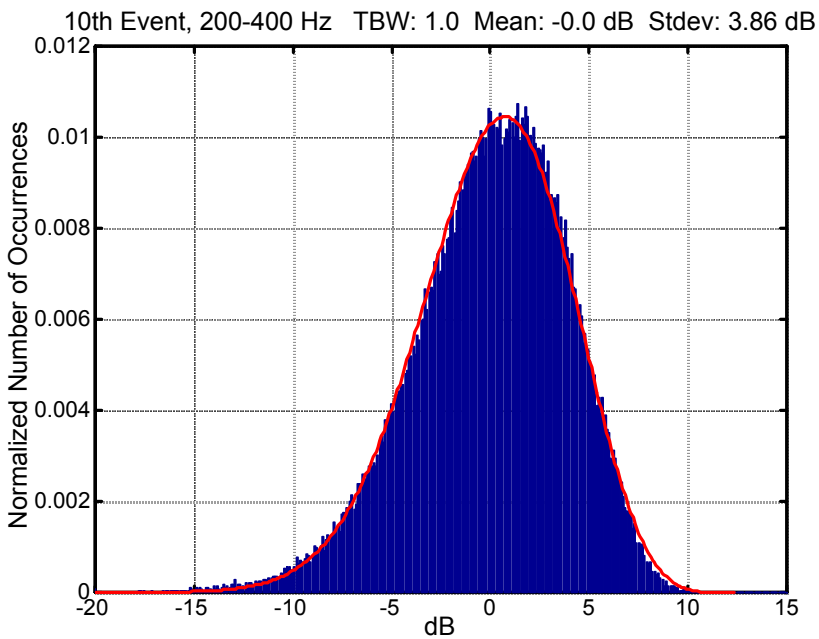
Ambient Noise *vs*. Reverb: fc = 300 Hz, TBW = 1.0

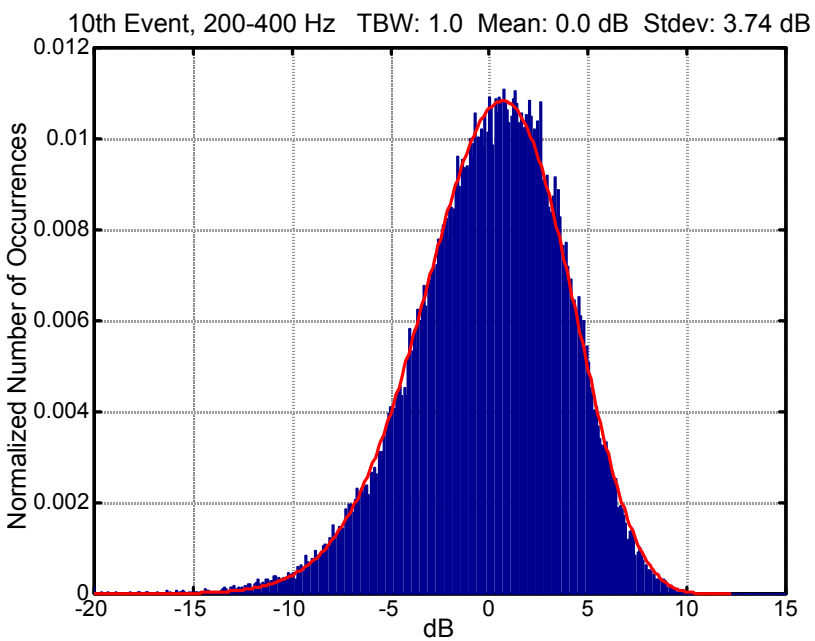
Noise: T = -3 sec

σ = 3.78 dB
DOF = 6.40
Stretch = 5.50, Offset = 12.25

Reverb: T = 10 sec

σ = 3.74 dB
DOF = 6.50
Stretch = 5.30, Offset = 12.15





Chi-squared fit, best fit in Kolmogorov-Smirnov sense.

Reverberation Statistics: Area 1 *vs.* Area 2

Area 1

T = 10 sec, fc = 300 Hz

σ = 3.79 dB, DOF = 6.60

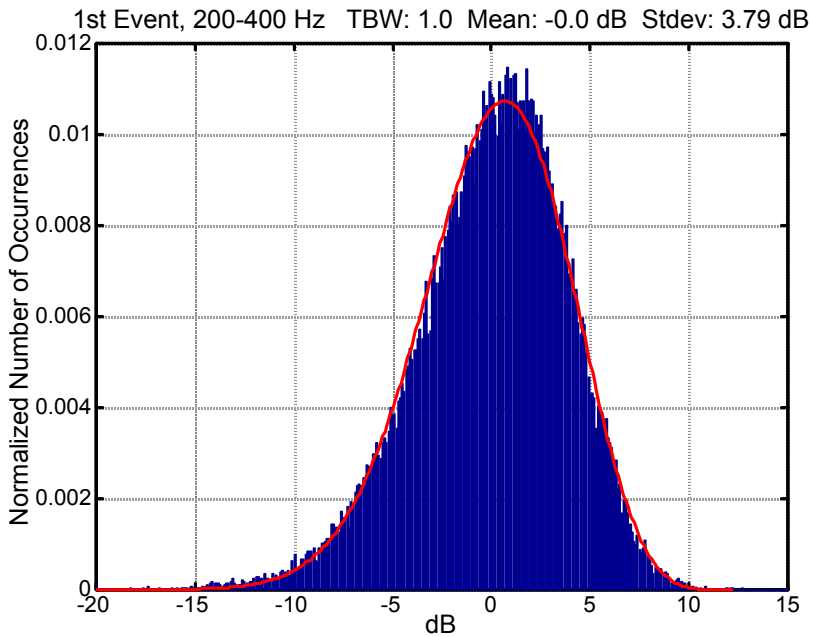
Stretch = 5.35, Offset = 12.15

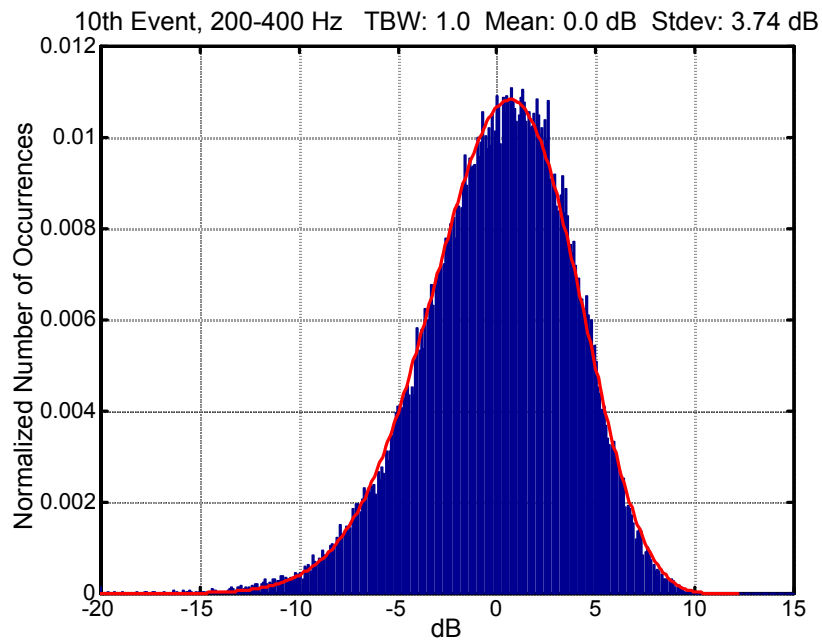
Area 2

T = 10 sec, fc = 300 Hz

σ = 3.74 dB, DOF = 6.70

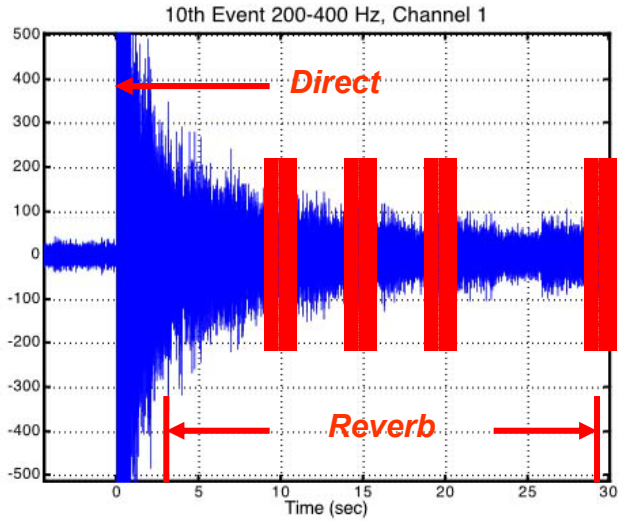
Stretch = 5.30, Offset = 12.15

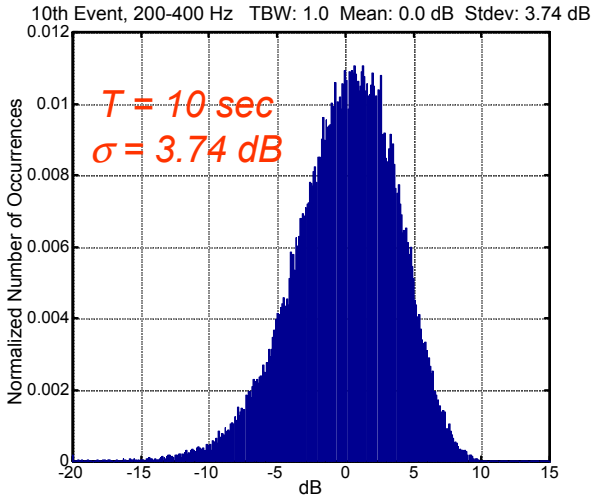


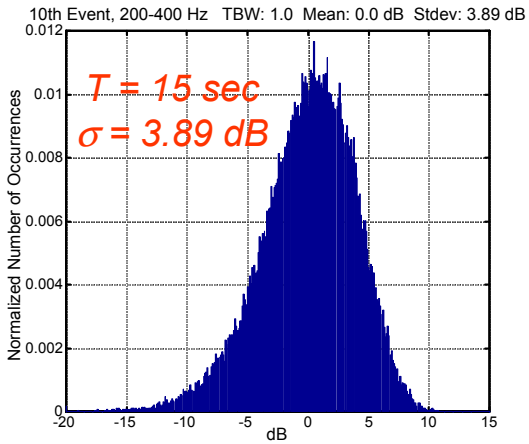


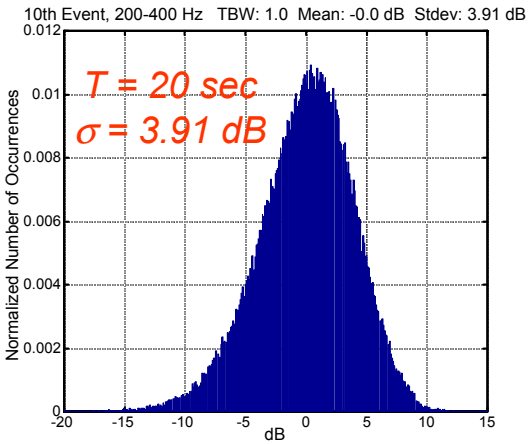
Chi-squared fit, best fit in Kolmogorov-Smirnov sense.

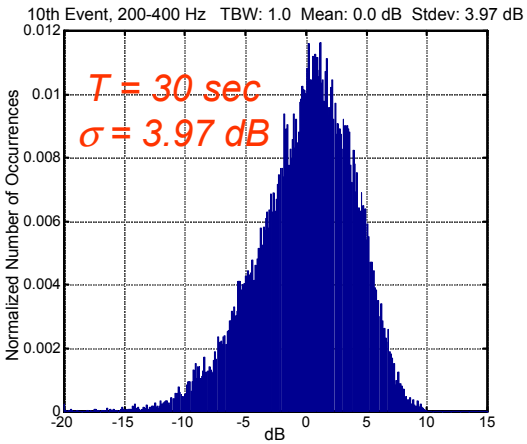
Reverberation Statistics *vs.* Travel-Time





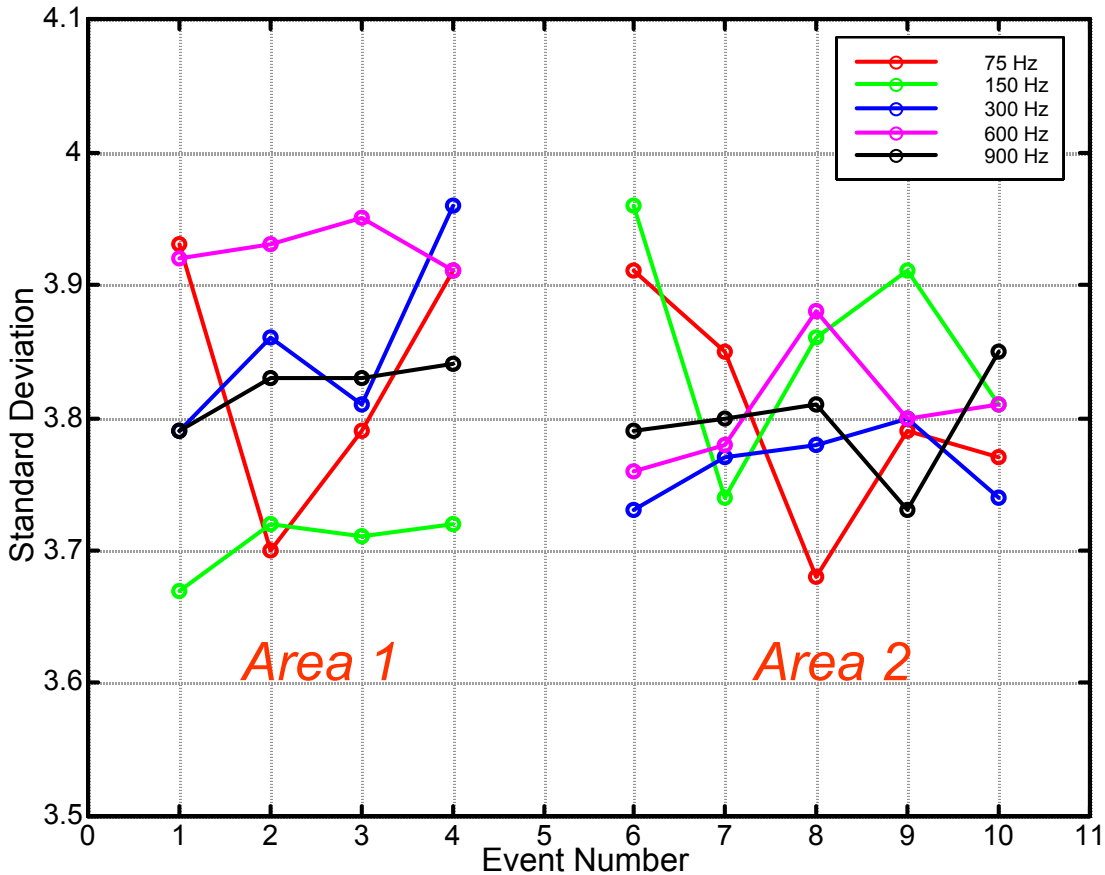






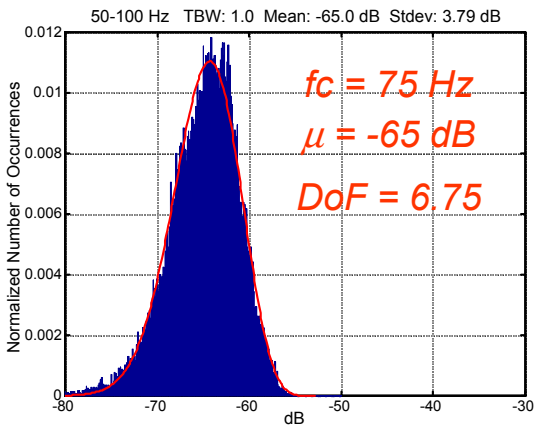
Reverberation Statistics for Nine Events

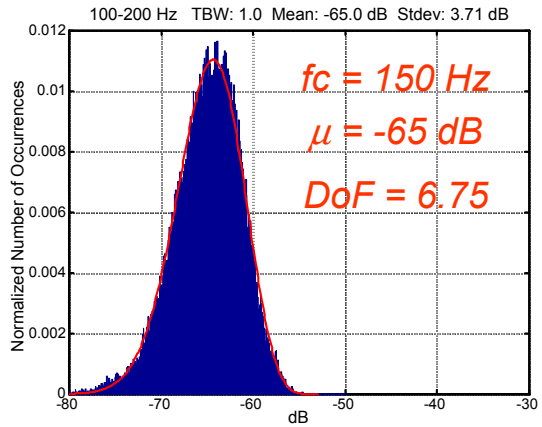
Five frequency bands, T = 10-sec, TBW = 1.0, σ ~ 3.8 dB

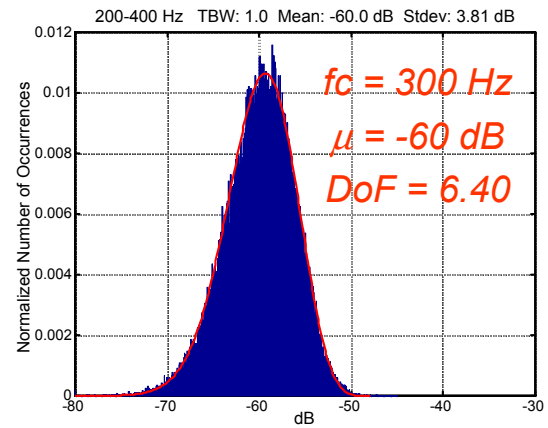


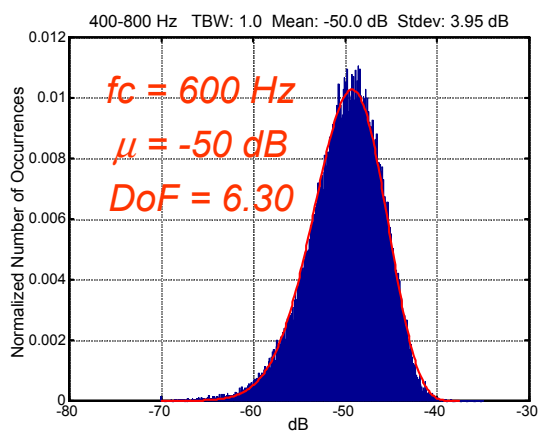
Back-Scattering Strength Statistics

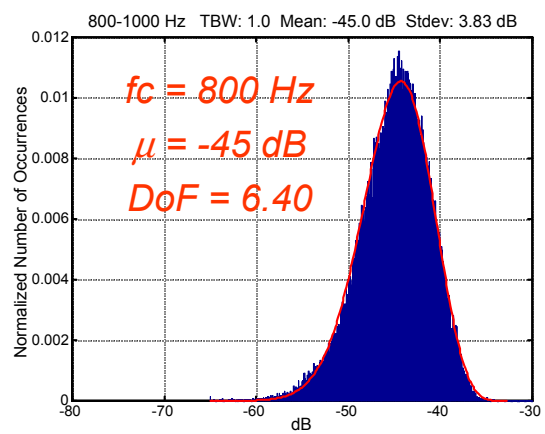
Five frequency bands, T = 10-sec, TBW = 1.0, $\sigma \sim 3.8$ dB









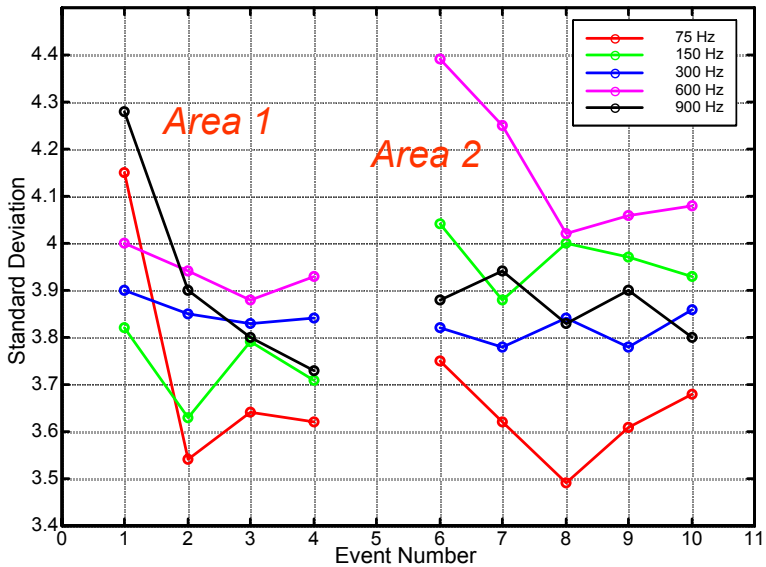


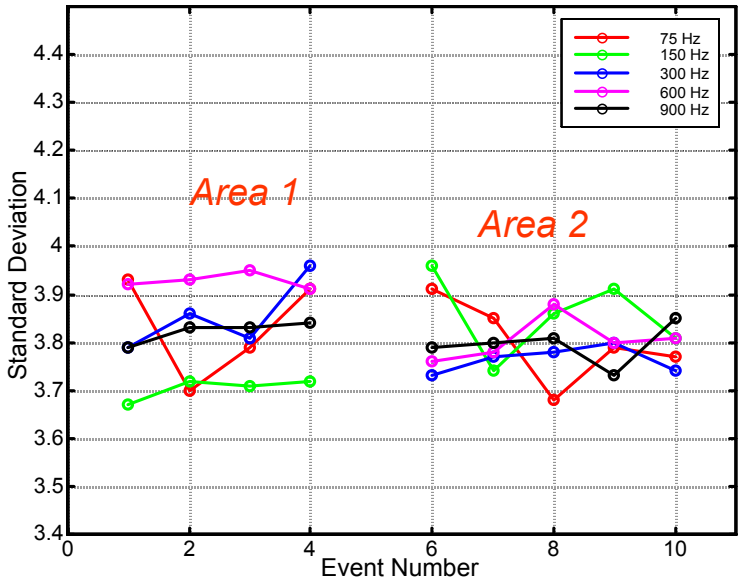
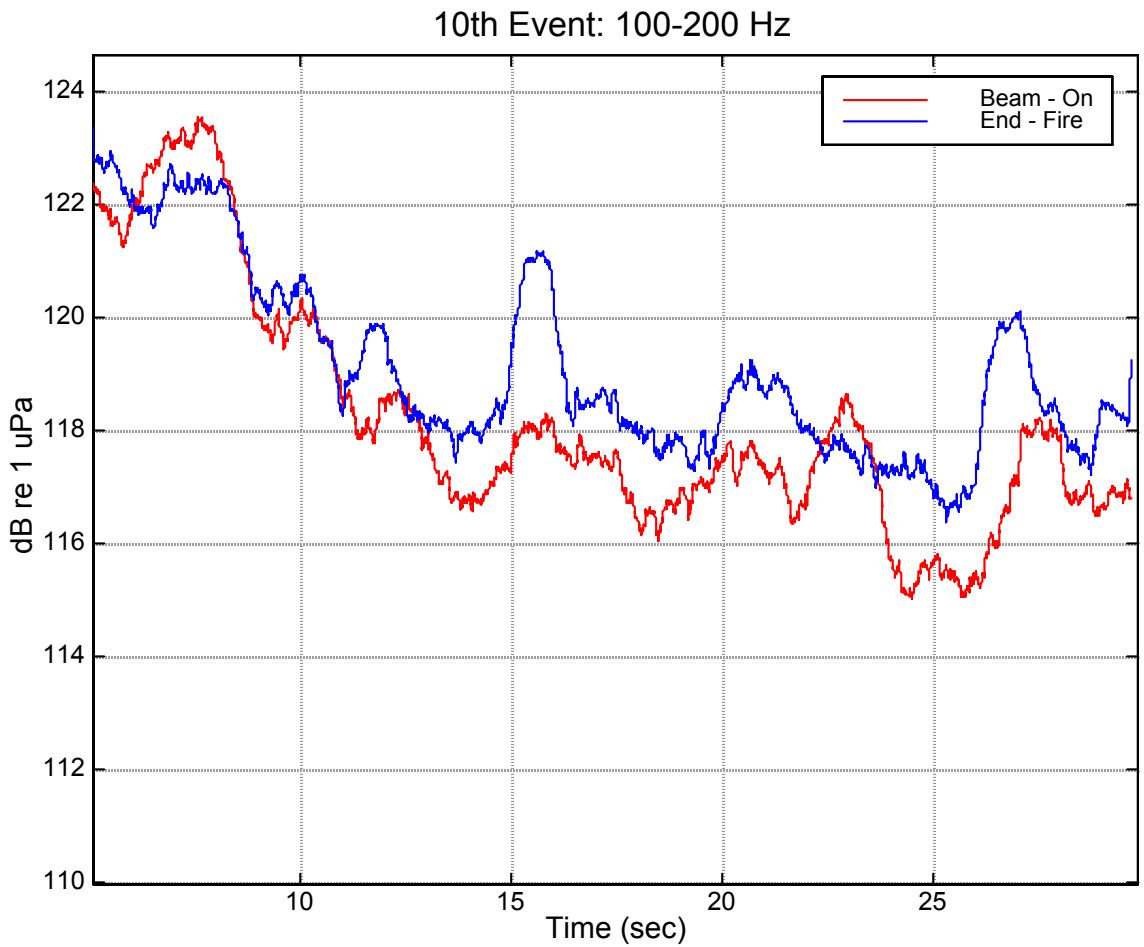
Summary and Plans

- For the Straits of Korea:
  - *Reverberation statistics indicate behavior that is a random process (no big surprise)*
  - *Reverberation σ increases slightly with travel-time; σ = 3.74 at 10-sec, 3.97 at 30-sec*
  - *Backscattering strength increases from -65 dB at 75 Hz to -45 dB at 800 Hz; σ ~ 3.8*
  - *Estimate tens of thousands of scatterers per 1-second annulus at T = 10 sec, based on de-correlation length and mean-free-path models*
- Plans:
  - *Evaluate time-bandwidth effects as they apply to specific sonar processors*
  - *Investigate azimuthal and range effects*
  - *Further study of the physics behind the statistics of ambient noise and reverberation*
  - *Apply to ASIA-EX data*
  - *Handoff results to UNITES E2E in East China Sea*
- Data Sharing
  - *Unclassified raw waveform data available in Matlab .mat files, yours for the asking*

Backup Material

Ambient Noise *vs.* Reverberation





Directional Variability: Beam-On *vs*. End-Fire