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Encl: (1) Final Performance/Technical Report with SF298

The attached enclosures constitute the final technical report for ONR Grant# N00014-14-1-0239 & N00014-16-1-2371, "TREX 13 Data analysis/Modeling"

cc: Grant & Contract Administrator, APL-UW
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TREX13 data analysis/modeling

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LONG-TERM GOALS:

The long-term objective is to improve prediction of target-to-reverberation ratio for mid-frequency sonar systems. In the band of 1-10 kHz, sound transmission loss and reverberation level show strong variability over space and time, often fluctuate as much as 20 dB, hampering sonar performance. The fluctuation is caused by environmental variabilities. However, it is often nebulous how specific environmental processes quantitatively impact sound behavior. To gain quantitative knowledge, TREX13 was designed to contemporaneously measure acoustics quantities and environmental parameters over an extended period of time, so model/data comparisons can be achieved on both propagation together with reverberation without ambiguity.

OBJECTIVES:

Sea surface, water column sound speed, and bottom impact on transmission loss and reverberation.
TREX13 (Target and REverberation eXperiment) was conducted during April-June, 2013 off the coast of Panama City, Florida where the water depth is approximately 20 m. The frequency range covered is 1-10 kHz, emphasizing 3-4 kHz. The Navy relevance is reflected in the fact that detection using mid-frequency sonar is in most cases reverberation limited. This project addresses a clear need in basic research for a 6.1 level measurement program, using well-controlled geometries and high resolution environmental measurements, designed (1) to test models predicting reverberation and (2) to quantify the most important environmental measurements to make in order to maintain accuracy in those predictions. With extensive TREX13 data in hand, the objective now shifts to realizing the long-term goals using data analysis and modeling.

APPROACH

- Fixed-fixed (source and receiver), simultaneous measurements of TL Reverberation, and Local backscatter over time and changing environment
- Contemporaneous environmental data to allow tight model/data comparison

WORK COMPLETED

- Experiment was successfully conducted which involved multiple institutions.
- Two TREX13 workshop were held, reporting results.

- A special collection of the Journal of Oceanic Engineering was dedicated to the results from TREX13 where over 20 papers were included.

RESULTS

1. A special collection of papers dedicated to TREX13 is published on IEEE Journal of Oceanic Engineering
2. The TREX13 data covers a period of more than a month, and were categorized so the effect of the *seafloor*, the *sea surface*, and the *water column* could be separately analyzed quantitatively allowing the following conclusions:
   - *Seafloor* variability causes clutter-like fluctuations, and uncertainty of bottom attenuation has a strong impact on modeling reverberation.
   - *Water column* variability has appreciable impact on TL and reverberation. This in spite of the fact that tides and currents lead to overall change of sound speed profile over the entire experiment of less than 5m/s.
   - *Sea surface roughness* has major impact on reverberation, and the quantitative impact depends on the details of the rough surface spectra.

IMPACT/APPLICATIONS

Naval active sonar detection is often reverberation limited. Understanding the main mechanisms that cause the diffuse reverberation will lead to better sonar performance.Theoretical and numerical progress inspired by the field work is being applied to STTR projects for NAVOCEANO and NAVAIR.

RELATED PROJECTS

1. STTR Topic N13A-T026: Improving the Physics of Applied Reverberation Models (APL-UW)

2. STTR Topic N17A-T026: Improved High-Frequency Bottom Loss Model (APL-UW)

PUBLICATIONS

1. Yang, J., D. Tang, B. T. Hefner, K. L. Williams, and J. R. Preston, "Overview of mid-frequency reverberation data acquired during the Target and Reverberation Experiment 2013," IEEE J. Oceanic Engineering (in press).

2. Tang, D., D. R. Jackson, "A time-domain model for seafloor scattering," *J. Acoust. Soc. Am.* **142**, 2968-2978 (2017).

3. Tang, D., B. T. Hefner, and D. R. Jackson, "Direct-Path Backscatter Measurements Along the Main Reverberation Track of TREX13", IEEE J. Oceanic Eng., TREX13 Special Issue, (under review).

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13. SUPPLEMENTARY NOTES

14. ABSTRACT
The Target and Reverberation EXperiment 2013 (TREX13) included a comprehensive reverberation field project in the frequency band of 2-10 kHz, and was carried out off the coast of Panama City, Florida, from 21 April to 16 May, 2013. A spatially fixed transmit and receive acoustic system was used to measure reverberation over time under diverse environmental conditions, allowing study of reverberation level dependence on bottom composition, sea surface conditions, and water column properties. Extensive in situ measurements, including a multibeam bathymetric survey, chirp sonar sub-bottom profiling, gravity/diver cores, sediment sound speed and attenuation, interface roughness, wind-generated sea surface waves, and water column properties, were made to support studies of environmental effects on reverberation. Data analysis from TREX13 resulted in a set of publications which documents progress made under this project.

15. SUBJECT TERMS
Mid-frequency, reverberation, shallow water

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