

## **Extracting Coherent Information from Noise Based Correlation Processing**

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### **LONG-TERM GOALS**

The goal of this research is to establish methodologies to utilize ambient noise in the ocean and to determine what scenarios are best suited for applying these methods.

### **OBJECTIVES**

Because noise-based correlation processing is based on equilibrium related stationary statistics, the ocean does not really provide a cooperating scenario for such processing. The objectives of this research is to develop array and signal processing that overcome the effects of the fluctuating ocean by essentially developing techniques that speed up the processing to time scales shorter than those of ocean fluctuations.

### **APPROACH**

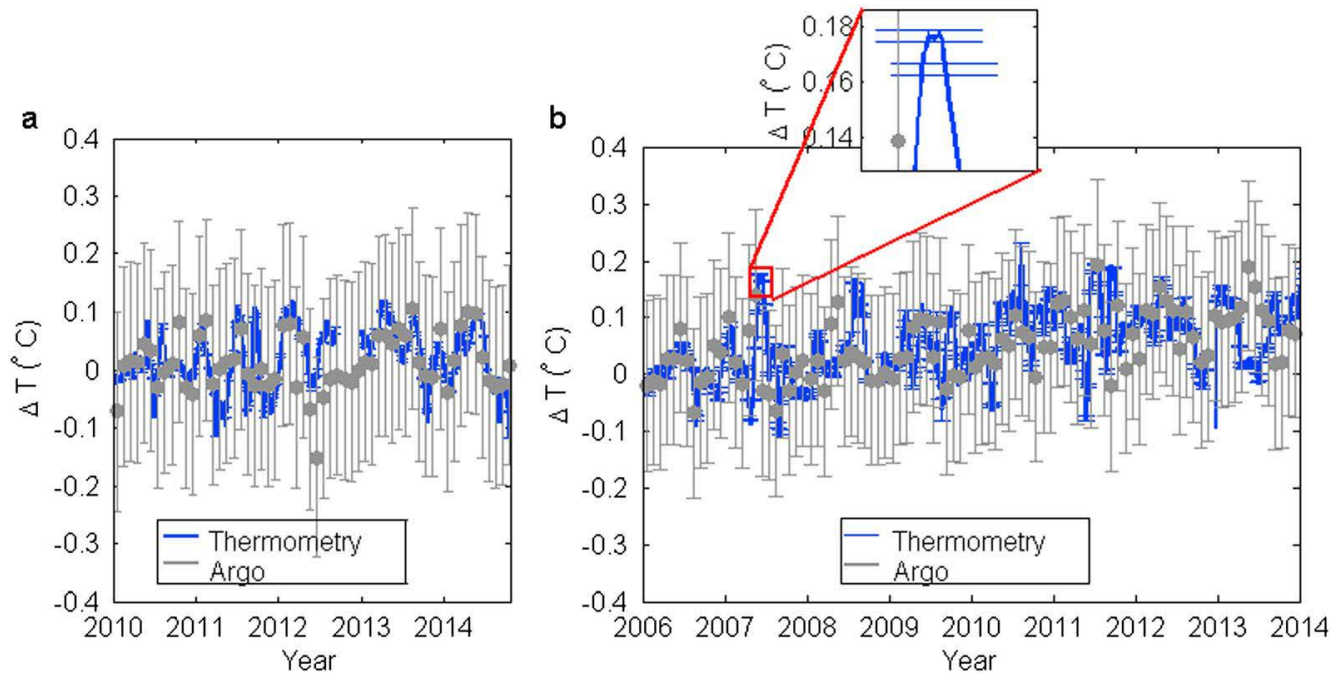
The approach has been a combination of experiment/data analysis and the development of appropriate signal processing methods.

### **WORK COMPLETED**

There have been two thrusts –the first has been related to extending the range/ validity of the ocean noise correlation processing in a collaborative research effort with Georgia Tech (Sabra et al). Some of that results have been reported [1,2] and more recently our Summer 2015 North Atlantic experiment had two vertical arrays drifting for a few days in which noise was recorded [Information on experiment in Ref[3]). We are beginning to process the noise correlation data in the mid frequency band. The second thrust is an outgrowth of our noise correlation processing in which we use a similar methodology to determine the structural acoustic properties of an object. Initial experimental results of this effort has been obtained and a manuscript is in preparation. The theory has already been published and reported in last years annual report in which we had derived the the scattering properties of an object immersed in a random noise field.

## RESULTS

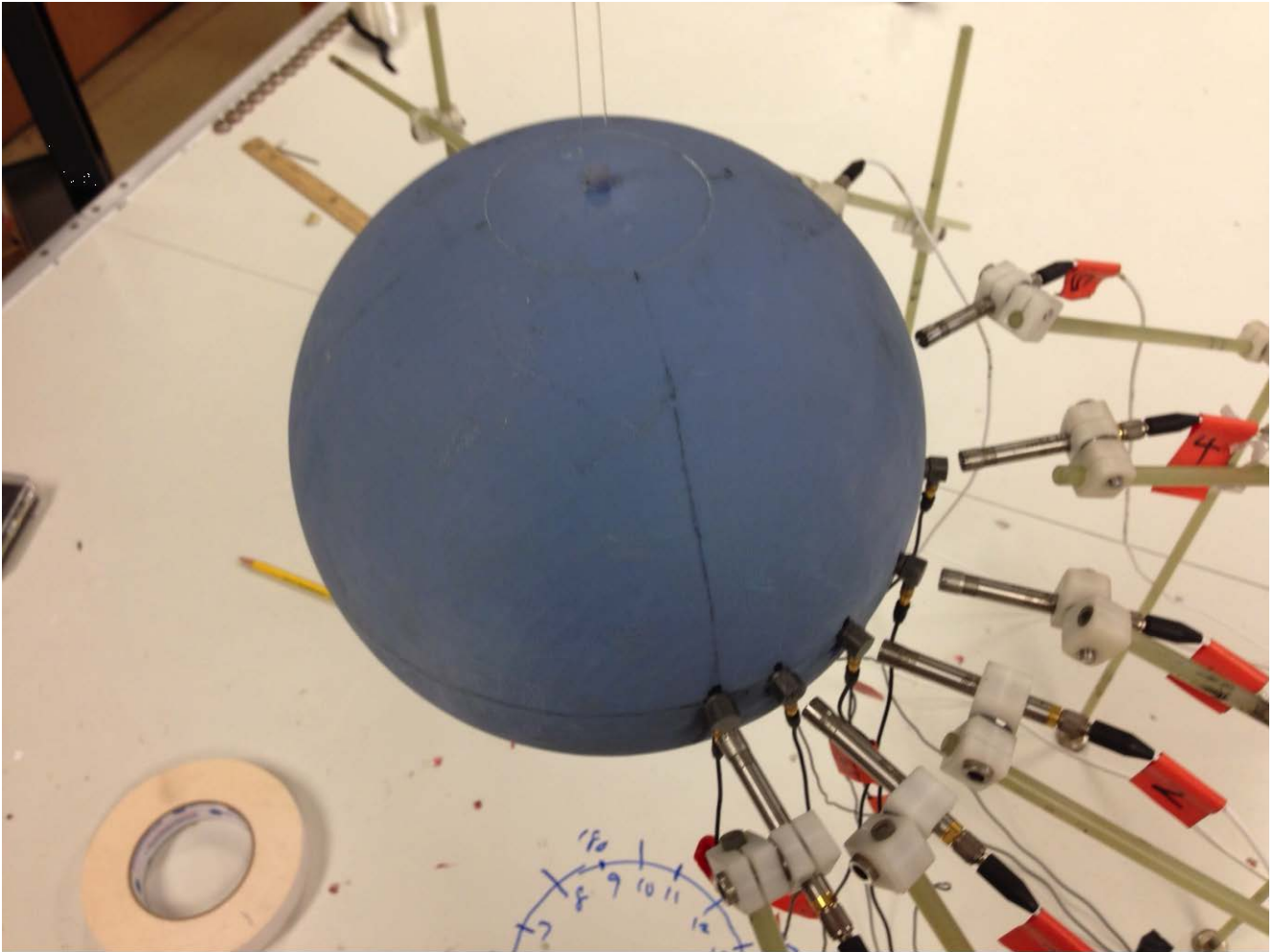
Ref [1] is a GRL letter in which we show that noise data taken from CTBT stations can be used to study temperature change in the water column. Figure 1 show (a) Comparison of the deep-ocean temperature variations at the Wake Island site estimated from passive thermometry (blue line)—using the SOFAR arrival time variations shown in Figure 2a—with free-drifting profiling oceanographic Argo float measurements (grey dots), along with corresponding error bars (b) Same as Figure a but for the Ascension Island site using the SOFAR arrival time variations.



**Figure 1. Comparison of Noise Correlation Method and ARGO data**

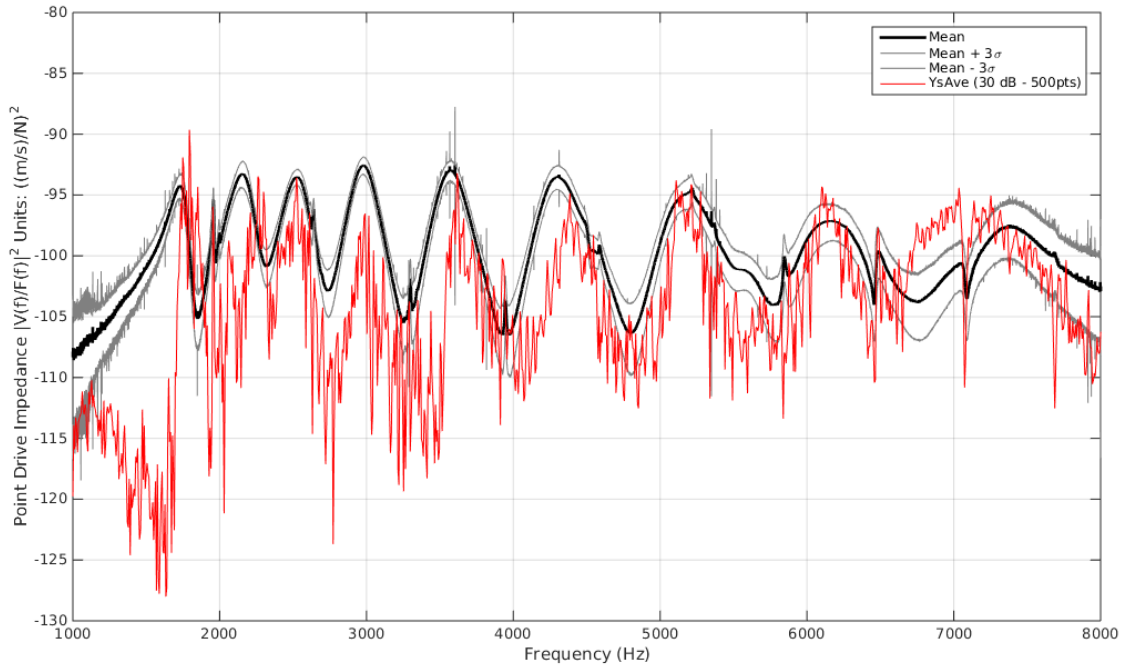
Ref [2] is a JASA article in which we showed that combining the data analyzed in Ref[1] with an optimization method (in this case we initially used a Genetic Algorithm) could reduce the correlation time by as much as a factor of 10. This results suggest that we may be able to apply the noise correlation based inversions in media with space-time fluctuation scales not amenable to the baseline homogeneous statistics' dependent noise correlation processing.

We have analyzed laboratory data taken from measurements on which a spherical shell (Fig 2) (set-up shown last year, data shown below taken this year) . The initial results from the experiment shows agreement with theory and also shows the relationship between the plane wave structural impedance and the point drive impact measured impedance (Fig 3). The results of these experiments are being written up now for journal submission. The importance of this result is that the noise derived impedance results dereived from a noise correlation mesurement should be sufficient for predicting the scattered field as opposed to the more difficult total structural impedance which contains compoents that couple into the evanescent scattered field and therefore do not radiate (anyway).



***Figure 2. Experimental setup for noise correlation of acceerometers and pressure sensors. Experiments were done with air filled and water filled shell.***

We have recently done experiments on an instrumented shell that was produced by a 3D printer (a new experience for us). The shell was instrumented as shown in Figure 3 and the preliminary results confirm our theory. These will be reported in the future.



**Figure 3.** *The red line are the results obtained from the noise experiment.*

## IMPACT/APPLICATIONS

The potential impact of this research is directed toward developing passive methods to study ocean acoustics.

## RELATED PROJECTS

None

## PUBLICATIONS

- [1] “Monitoring deep-ocean temperatures using acoustic ambient noise,” K. W. Woolfe, S. Lani, K.G. Sabra, W. A. Kuperman, *Geophys. Res. Lett.*, 42, 2878–2884, doi:10.1002/2015GL063438 (2015).
- [2] “Optimized extraction of coherent arrivals from ambient noise correlations in a rapidly fluctuating medium,” K. W. Woolfe, K.G. Sabra, *J. Acoust. Soc. Am.* 138 (4), EL375, October 2015.
- [3] “Mid-frequency attenuation estimates from deep-water experiments using eigenrays. Jit Sarkar, Christopher M. Verlinden, Jefferey D. Tippmann, William S. Hodgkiss, and W.A. Kuperman ASA abstract in Jackson, Nov 2015 and manuscript in preparation.