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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 cooperatiing 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 essentilly 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

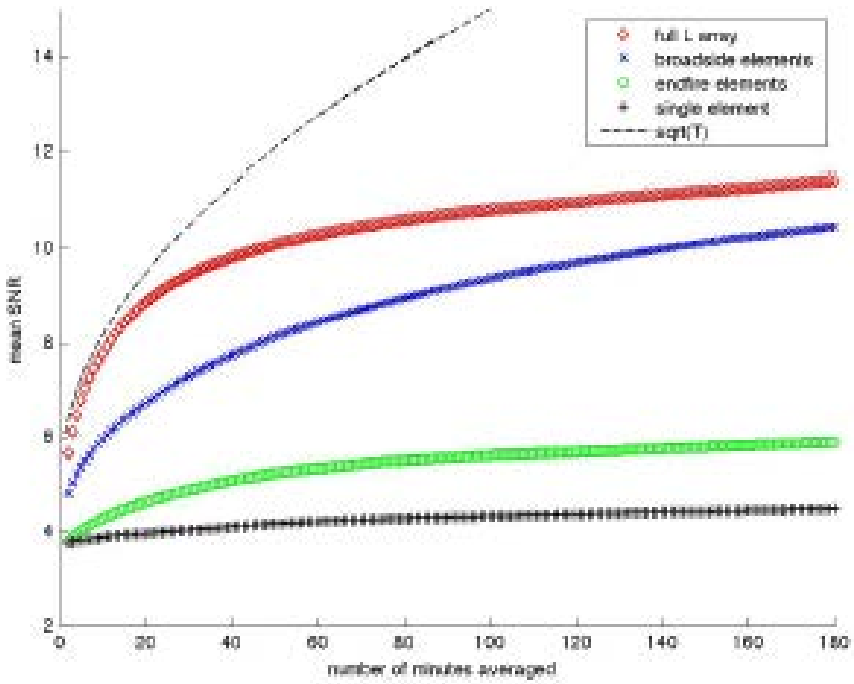
We have shown that beam to beam noise correlation from horizontal arrays speeds up the emergence of the peaks indicative of the arrival time structure of the time domain Green's fucntion between the arrays. Finally, we apply the noise correlation methods to a deep water scenario using the hydro-acoustic elements in a Comprehensive Test Ban Treaty Organization (CTBTO) installation.

RESULTS

Two experiments were condcuted off San Diego: One using vertical arrays (NOISE09) and the other using horizontal arrays (NOISE10). Results from both of these experiments are being written up for submission to JASA.

Horizontal Array Results:

Here we have shown, using L shaped arrays, the benefit of using beam to beam correlations. The results are summarized in the curves below:

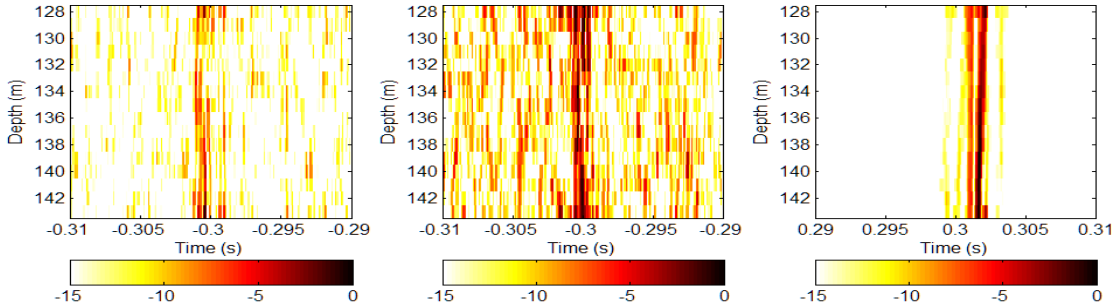


The figure above shows the mean SNR buildup for the broadside to broadside arrays, endfire to endfire, and `L' to `L' shaped arrays. The horizontal axis shows the number of minutes averaged in one beam-to-beam correlation. Each value shown is the average SNR measured at all possible segments of that many minutes throughout the same four days of data. The red diamonds show the values from the full `L' arrays, the blue x's are of beams made up of only the parallel portions of each array (i.e. the broadside beams), the green circles are of the in-line portion of the arrays (i.e. end_re beams), and the black +symbols are of a single sensor from each array. The dotted line shows a reference $T^{1/2}$ curve. Clearly, the results from correlating beams are better than those for a single sensor. That all the the results fall below the $T^{1/2}$ indicates the lack of stationarity of the ocean/noise scenario [1].

Vertical Array Results (with K. Sabra, GT):

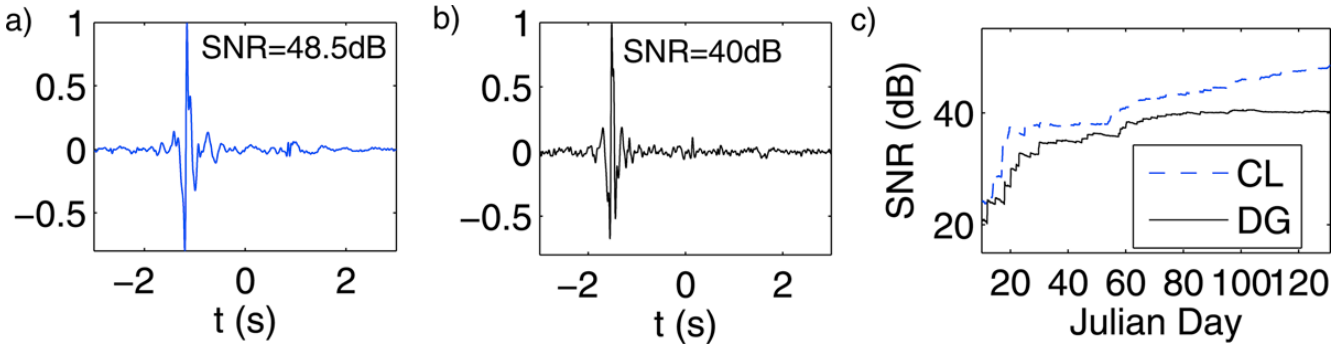
The vertical arrays presented a challenge in that the azimuthal symmetry of vertical line arrays (VLA's) slows down the emergence rate of the correlation peaks between two VLA's since it is only the region angularly close to the line connecting the arrays that contribute to these peaks while in this case, all azimuths provide the background "noise" that must be overcome in the correlation process. In this case, we therefore used a signal processing method developed in this program that employs long term noise data for the construction of beams to process shorter term correlations. The figure below is a slection of results. The relevant arrival at +- ~.3 seconds was not extractable by either point to point

or beamforming without applying the pre-processed long term noise data analysis mentioned above and described in [2] using data from an earlier SWAMSI experiment.



CTBTO Noise correlations (with K. Sabra, GT):

The distance between signal elements are ~ 2 km in deep water. The major component of the noise at ~10 Hz at these Indian Ocean (Diego Garcia, Cape Leeuwin) installations is from Antarctic ice calving.



This figure shows averaged cross-correlation waveforms between the north-south oriented hydrophones using 130 day-long averaging for the hydroacoustic stations CL (a) and DG (b). Each waveform was normalized by its maximum value. (c) Evolution of the peak signal-to-noise ratio SNR. Among the take home results is that point to point correlations build-up of this length over the 2 km separation distance indicates that either longer separations or higher frequencies would be problematic without some kind of additional processing [3].

Multiscale Seismic Processing:

A spinoff of the research in this program resulted in the development of a spatial (as opposed to temporal as in VLA processing) multiscale processing method. In this case, there were weak noise sources masked by strong noises. The idea was that the strong noise sources were correlated over a large aperture array. By constructed the cross-spectral density matrix of this noise field over the large array we could contract a projection matrix that was orthogonal to this loud noise space. We then project out the loud noise data from the individual hydrophones and then do subaperture processing over smaller arrays to detect the weak, local noise sources. The method proved successful [4].

IMPACT/APPLICATIONS

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

RELATED PROJECTS

None

PUBLICATIONS

[1] Stephanie Fried, "Using ambient noise to extract coherent environmental information," Ph. D. Thesis, (2011).

[2] C. Leroy, S. Lani, K.G. Sabra, W.S. Hodgkiss , W. A. Kuperman and P. Roux, "Enhancing the emergence rate of coherent wavefronts from ocean ambient noise correlations using spatio-temporal filters," J. Acoust. Soc. Am. , 132, 883-893 (2012).

[3] K. G. Sabra, S. Fried,m W. A. Kuperman and M. Prior, "On the coherent component of low-frequency noise in the Indian Ocean," J. Acoust. Soc. Am. , 133, EL20 (2013).

[4] Margherita Corciulo, Philippe Roux, Michel Campillo, Dominique Dubucq, and W. A. Kuperman "Multiscale matched-field processing for noise-source localization in exploration geophysics," Geophysics, 77, p. KS33-KS41 (2012).