The Acoustic Signatures Of Proud And Buried Mine-like Objects And Their Temporal Variation

Kevin L. Williams
Applied Physics Laboratory
University of Washington
Seattle, WA 98105
phone: (206) 543-3949 fax: (206) 543-6784 email: williams@apl.washington.edu
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LONG-TERM GOAL

My long term goal is to understand, for different environments, the biological and hydrodynamic processes important to the changes seen in the acoustic scattering from proud and buried mines as a function of time after deployment.

OBJECTIVES

My objective in this effort is to process and interpret acoustic monitoring data taken on both mine shapes and localized biological treatments during the 1995 ORCAS experiment. The ORCAS data allows examination of the acoustic scattering from mines and biological treatments for up to two months. Four types of results can be produced using the data: backscattering, scan-to-scan decorrelation, cumulative decorrelation relative to a reference scan, and bathymetry. The goal is to examine the results in combination to quantify, interpret, and guide future research on the temporal variations of scattering from bottom deployed mines. Of particular interest to me are the temporal variations of scattering from buried objects.

APPROACH

Data on mine-like objects and localized biological treatments were acquired by the Benthic Acoustic Measurement System (BAMS)[1] as part of the ORCAS experiment. BAMS operates at 40 and 300 kHz, and acquires acoustic backscattering data from a circular region of about 50 meters radius. The array apertures are divided into upper and lower halves to allow interferometric measurement of sea-bed bathymetry. Digitization and signal generation are controlled by a single clock, making it possible to make sensitive phase comparisons between echoes acquired in separate scans, even when the scans are separated by times on the order of weeks. Such phase-coherent processing can be used to observe small changes in the sea bed.

My approach has been to concentrate on the BAMS 40 kHz data since 40 kHz penetrates further into ocean sediments than 300 kHz and since the 300 kHz data has been exploited more fully by A'Hearn et.al.[2] than has the 40 kHz data. However, in examining localized biological treatments I have used the 300 kHz data to pinpoint the location of the treatment since the 300 kHz sonar has higher spatial resolution than the 40 kHz sonar. The general approach has been to form four different types of images from

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the data (scattering strength, bathymetry, scan-to-scan decorrelation, cumulative decorrelation) and use them to determine which pixels to examine further. The temporal variation in scattering, bathymetry and correlation for those pixels were then more closely examined and compared to one another.

WORK COMPLETED

Images[3] (scattering, bathymetry, and correlation) were first formed of all 585 scans at 40 kHz and all 62 scans at 300 kHz acquired during the 2 month deployment. Further processing involved forming similar images in the immediate vicinity of each object or treatment. Constructing movies of these images then allowed a better qualitative assessment of time variations and were used to determine the pixel or pixels to examine quantitatively via plots of its scattering, bathymetry, and correlation values as a function of time. The only treatments examined at 40 kHz were those also observable in the 300 kHz images, i. e., bait, acila, and cockle treatments[2].

RESULTS

The results on the man-made objects demonstrate that, when used in combination, the different types of images allow easy determination of the vertical location of the object as classified into volume, proud, or buried. The scattering strength alone does not allow this discrimination in the 40 kHz data but the bathymetric information has high enough resolution that it easily discriminates a proud object from a buried one. Furthermore, the increased ping-to-ping decorrelation is a robust discrimination of a volume mine from a proud or buried one even in the absence of bathymetric information.

The buried object in the experiment was a 24 inch diameter stainless steel sphere. Since buried objects and the variation in time of their signatures was of particular interest to me I compared those signatures to the variations seen in three undisturbed control areas and to two bait treatment areas in which a treatment effect was detectable. Figure 1 shows the results for the six different sites. The figure shows backscattering strength (measured via a Lambert parameter[3]), bathymetry relative to the mean level of the seafloor, scan-to-scan decorrelation, and cumulative decorrelation (decorrelations are indicated by the reduction of the correlation coefficient below one). The horizontal axis for all plots is time (in number of scans) relative to an initial scan chosen separately for each site. In the case of the buried sphere and the control sites the choice was based on when the sphere was first introduced into the environment by divers. For the bait treatments, where a marker sphere was put down for one day and then the treatment carried out and the marker sphere removed, the initial scan chosen was the one in which the marker sphere was introduced. One hundred scans represents ten days worth of data. The correlation calculations started with the first scan after divers had finished all activity in the area and thus start one day (10 scans) after the scattering strength and bathymetry plots.

Comparison of the buried sphere (red), control (black), and bait (green) curves reveal several things. First, after burial the scattering strength of the sphere takes about two days to drop to the background levels. This can be seen by first noting that the bathymetry curve indicates that the sphere was buried at scan 10 since the red curve drops to within a few centimeters of the seafloor reference level at that point. However, the scattering strength curve for the sphere continues to drop from scan 10 to scan 30 to arrive at the control curve level. By contrast, the scattering strength curves for the bait remain above the control curves from the time the bait is inserted (scan 10 - scans 1 through 10 are high due to the marker sphere) until at least seven days after the treatment. Note that the bait was placed a few centimeters above the sediment/water interface at the end of a 1 meter length of rebar that was pushed into the sediment[2].

Next, the scan-to-scan decorrelations of the bait and the sphere are significantly greater than for the control sites. Even so, the cumulative decorrelation rates at the bait sites are similar to that of the control sites but the cumulative decorrelation rate at the sphere site is much faster (red curve in bottom plot).

The reason for the increased scan-to-scan decorrelation at the bait site cannot be unambiguously determined in this experiment but the two major sources are hypothesized to be near-bottom biologics feeding on the bait and small amount of contamination by water/air interface scattering due to a sonar sidelobe. Both these effects would lead to increased scan-to-scan decorrelation but would not affect the cumulative rate since the main reason for the long-term cumulative decorrelation is attributed to changes within the sediment[4].

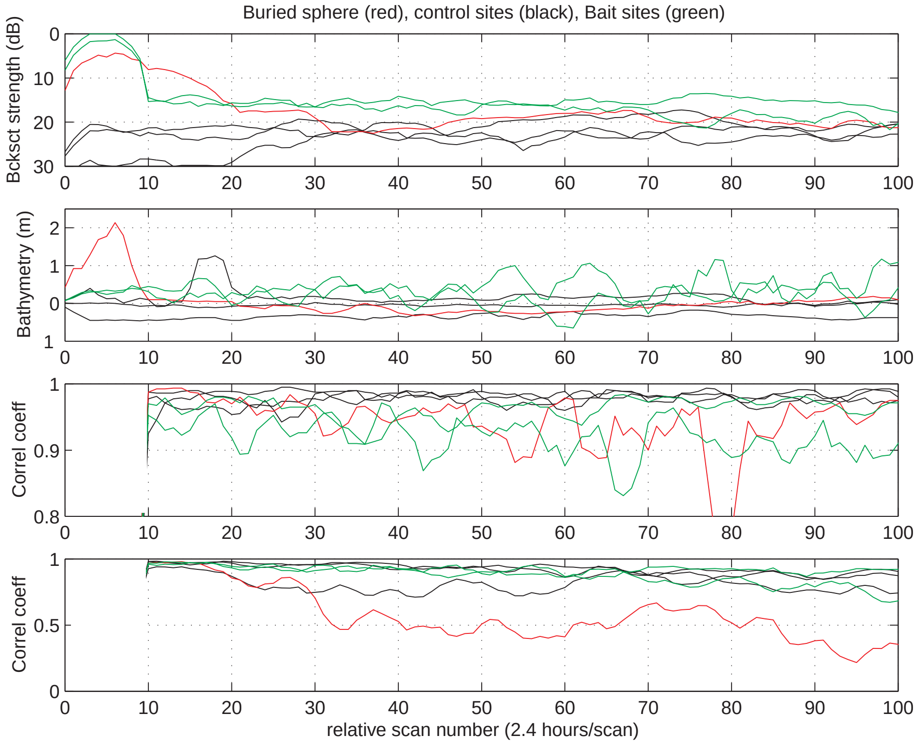

Figure:1 Data analysis results for 6 different sites within the field of view of the BAMS 40 kHz sonar at ORCAS. From top to bottom: backscattering strength (measured via a Lambert parameter[3]), bathymetry relative to the mean level of the seafloor, scan-to-scan decorrelation, and cumulative decorrelation (decorrelations measured via the reduction of the correlation coefficient below one). See text for discussion.

For the sphere, the scan-to-scan decorrelation is hypothesized to be due to increased activity in the sediment surrounding the sphere. This is because of the increased cumulative decorrelation rate of the sphere relative to the control sites. Cumulative decorrelation rates have been used in biological diffusion models[4] to quantify biological reworking. The sphere data indicate that if the activity level, as predicted by such models, were used to predict the rate at which the sphere would be "incorporated" into the environment a large error would result. Qualitatively, this result (increased activity near the sphere) is perhaps to be expected. However, the ability to quantify the increased activity is a unique aspect of the data taken at ORCAS. Reference 4 shows that decorrelation to a correlation coefficient of 0.5 in the natural ORCAS environment takes longer than the 58 days of the experiment whereas this correlation coefficient value (0.5) is reached in a little over three days for the buried sphere site. After that point the decorrelation rate of the buried sphere site is similar to that of the control sites. The prevalent benthic biology seen in the ORCAS area are mysids[5] and it is reasonable to assume that they are responsible for the activity seen in the data.

IMPACT/APPLICATION

Combining the information obtainable from relatively simple transducer arrangements provides a novel way of examining the benthic environment. In addition, the same information can give valuable classification clues. The possibility of increased activity near proud and buried objects should be taken into account if monitoring of operational areas are to be carried out.

TRANSITIONS

RELATED PROJECTS

This work has motivated a continued effort along the same lines in the upcoming "High Frequency Sound Interaction in Ocean Sediments" Departmental Research Initiative (DRI).

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