Sonobuoy-Based Acoustic Characterization of Shallow-Water Environments

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LONG-TERM GOALS

The long-term goal of this research is to increase our understanding of shallow water acoustic propagation and its relationship to the three-dimensionally varying seabed and water column environments.

OBJECTIVES

The scientific objectives of this research are: (1) to develop high-resolution methods for characterizing the spatial and temporal behavior of the normal mode field in shallow water; (2) to use this characterization as input data to inversion techniques for inferring the acoustic properties of the shallow-water waveguide (both the seabed and the water column); and (3) to use this characterization to improve our ability to localize and track sources.

APPROACH

An experimental technique has been developed for mapping the wavenumber spectrum of the normal mode field as a function of position in a complex, shallow-water waveguide environment whose acoustic properties vary in three spatial dimensions [1]. By describing the spatially varying spectral content of the modal field, the method provides a direct measure of the propagation characteristics of the waveguide. The resulting modal maps can also be used as input data to inverse techniques for obtaining the laterally varying, acoustic properties of the waveguide [2-7]. The experimental configuration consists of a moored, drifting, or towed source, with GPS navigation, transmitting signals to a field of several freely drifting buoys, each containing a hydrophone, GPS navigation, and radio telemetry, as shown in Fig. 1. A key component of this method is the establishment of a local differential GPS system between the ship and each buoy, thereby enabling the determination of the positions of the buoys relative to the ship with submeter accuracy [8,9]. In this manner, the drifting buoys create 2-D synthetic aperture, horizontal arrays along which the modal evolution of the waveguide can be observed in the spatial domain, or after Hankel transforming, in the horizontal wavenumber domain. In this context, two-dimensional modal maps in range *and* azimuth, as well as three-dimensional bottom inversion in range, depth, *and* azimuth, become achievable goals. In addition, a broadband variant of this method, in which impulsive signals are transmitted between a

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fixed source and receiver, has also been developed [10]. While focusing on inversion for the geoacoustic properties of the seabed, this method has also been applied to the problem of inverting for water column properties [11]. Finally, these high-resolution measurements provide new insights into source localization and tracking techniques [12].

WORK COMPLETED

To date, five successful Modal Mapping Experiments have demonstrated the effectiveness of the modal mapping technique in acoustically characterizing shallow-water waveguide environments and in tracking low-frequency sources. Furthermore, MOMAX V, conducted on 5-18 March 2011 aboard the R/V Sharp, demonstrated that the method could be successfully executed using COTS, GPS-capable AN/SSQ-53F sonobuoys, instead of the MOMAX research buoys. Specifically, narrowband and broadband signals were transmitted in the band 50-1000 Hz using a drifting and towed NUWC J15 source at 56 m depth and a drifting and towed NUWC G34 source at 8 m depth. Data were received on 4 drifting MOMAX buoys, each having hydrophones at 61 m and 64 m depths as well as several 53F sonobuoys with a hydrophone at 61 m depth. In order to assess the practicality of using sonobuoy data for geoacoustic inversion applications, the two types of buoys were deployed in a co-located configuration on several occasions by connecting the upper portions of the buoys with a 4.6 m cable. This arrangement ensured that the two types of buoys were acquiring data under the same environmental (specifically, seabed) conditions. The bathymetry for the experimental area, as well as the ship and buoy tracks for the co-located buoy deployments are shown in Fig. 2.

RESULTS

An example of data acquired in a co-located configuration is shown in Fig. 3, which shows the pressure field magnitude vs. range measured at 50, 75, 125, and 175 Hz on a sonobuoy (SB795) and a MOMAX buoy (Larry). Figure 4 shows the corresponding modal spectra obtained by Hankel transforming the pressure field data (magnitude and phase) into the horizontal wavenumber domain to obtain estimates of the depth-dependent Green's function for the waveguide. Although the pressure fields measured by SB795 are noisier than those measured by Larry, the Green's functions from both types of buoys have spectral peaks at wavenumbers that are close to one another. There are some differences in modal amplitudes which are probably due to differences in actual hydrophone depths between SB795 and Larry. Using the wavenumber spectra, the eigenvalues for the propagating modes were estimated and show excellent agreement between the two buoys (cf. Fig. 5). For each type of buoy, the eigenvalues at all four frequencies were then used as input data to a multi-frequency, perturbative inversion algorithm to obtain the bottom models shown in Fig. 6. The two seabed profiles are in excellent agreement with one another and are consistent with the results of previous experiments conducted in the same general area. Note that, based on other measurements, the density was assumed to be 1.6 g/cc, and attenuation and shear effects were not included in these inversions.

Using broadband data acquired during MOMAX V, this inversion method has also been applied successfully to the problem of inversion for the acoustic properties of the water column. Specifically, this approach has provided estimates of the temporal and spatial variability of the ocean sound speed on the New Jersey Shelf [M.S. Ballard *et al*, submitted to *J.Acoust.Soc.Am.* (2013)].

IMPACT/APPLICATIONS

This work shows that an experimental configuration consisting of a drifting or towed source and freely drifting receivers, all with precision GPS navigation, can provide an effective way to characterize the modal characteristics and acoustic properties of a shallow-water waveguide (both the seabed and the water column). Furthermore, the results show that this technique can be implemented using COTS sonobuoy receivers and potentially can be applied during routine operations conducted by NAVAIR. In addition, the creation of synthetic aperture, horizontal receiving arrays, which constitute the cornerstone of this method, may offer an effective new technique for localizing and tracking sources of unknown, quasi-stable frequency in shallow water.

TRANSITIONS

This work represents a major step toward transitioning the experimental method to NAVAIR (POC: David Seevers) and the modal inversion technique to NAVOCEANO (POC: David Harvey), thereby providing the capability for NAVOCEANO to upgrade/populate shallow-water LFBL databases in existing/new operational areas. The implementation of the MOMAX methodology and geoacoustic inversion technique in a NAVAIR operational scenario could occur in conjunction with the following schedule [13]:

The Navy plans to incorporate GPS into the ADAR sonobuoy receiver in the fourth quarter of FY14, with Fleet availability in the third quarter of FY16, and to incorporate GPS into the coherent 950 Hz, MAC (SSQ-125) sonobuoy source in the fourth quarter of FY14, with Fleet availability after FY16.

RELATED PROJECTS

These efforts are being closely coordinated with the planning and design of an ONR-sponsored seabed characterization experiment to be conducted in the FY 14-15 timeframe. Specifically, the design of a possible future experiment using a large number of sonobuoys (e.g., 15-20), with the goal of inferring the 3-D geoacoustic properties of the waveguide, has been initiated. Plans for the sonobuoy experiment are being coordinated with a project led by Altan Turgut at the Naval Research Laboratory.

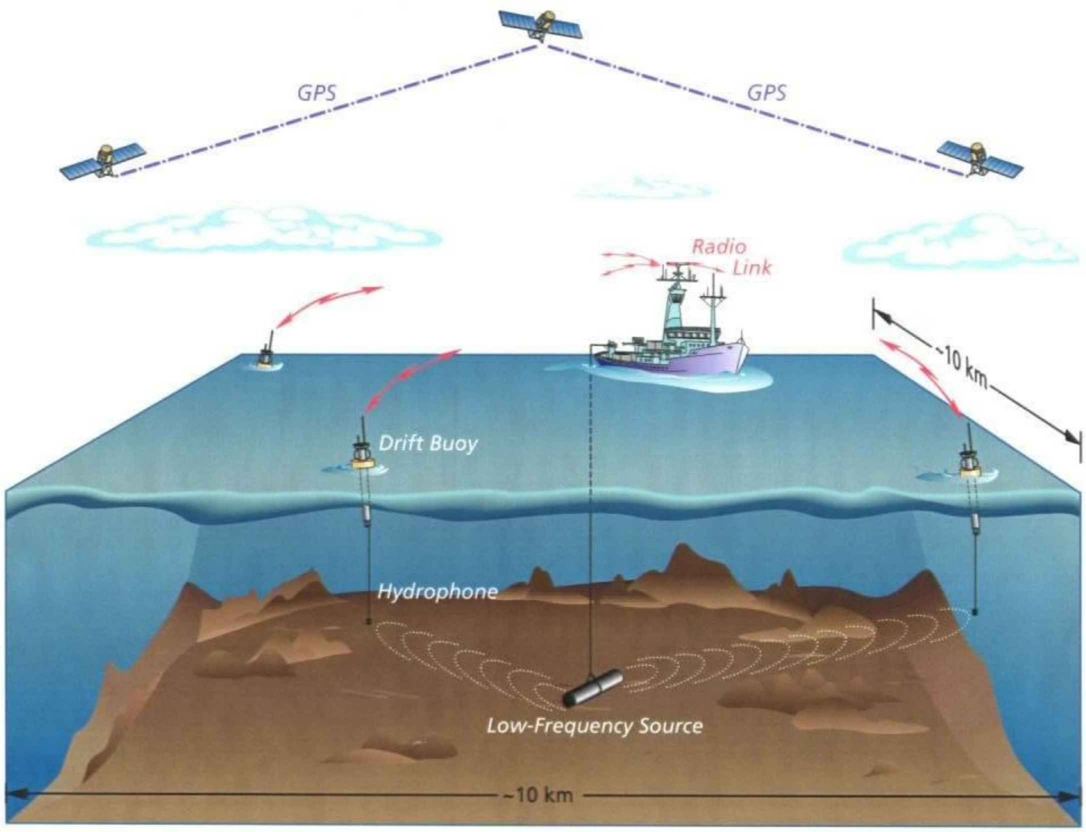

Figure 1: MOMAX experimental configuration.

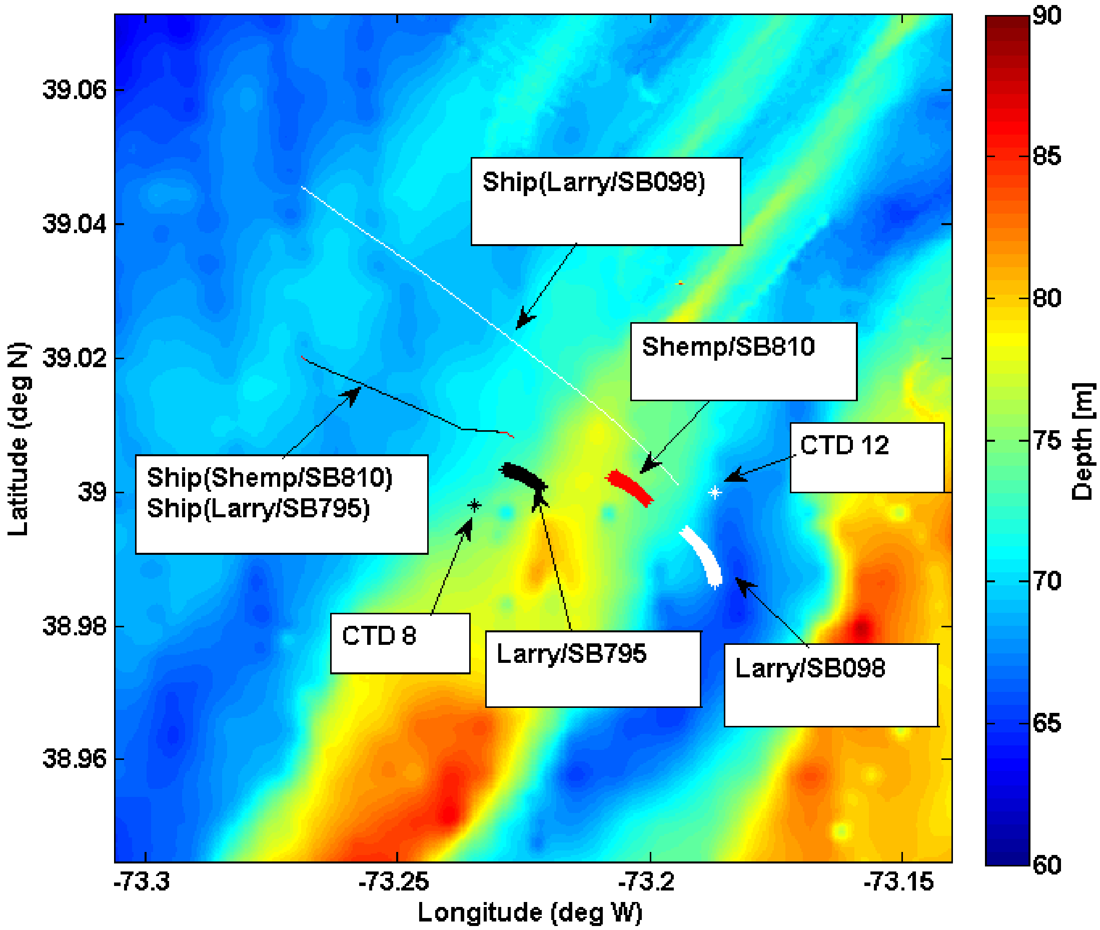

Figure 2: Bathymetry of the experimental area showing ship and buoy tracks for the co-located buoy deployments in MOMAX V.

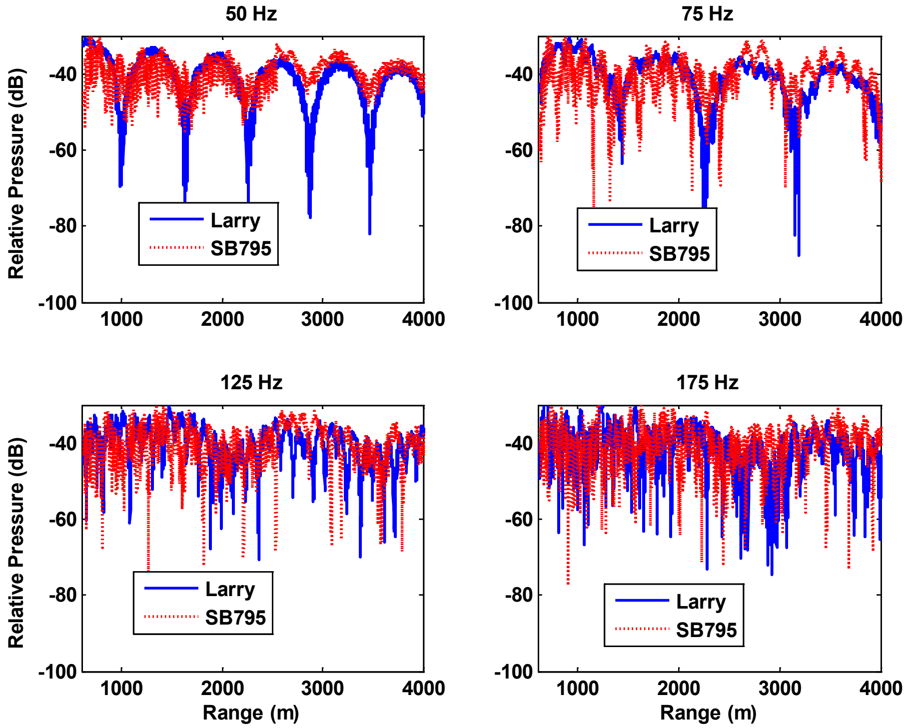

Figure 3: The pressure vs. range data at the four frequencies as measured by Larry and SB795.

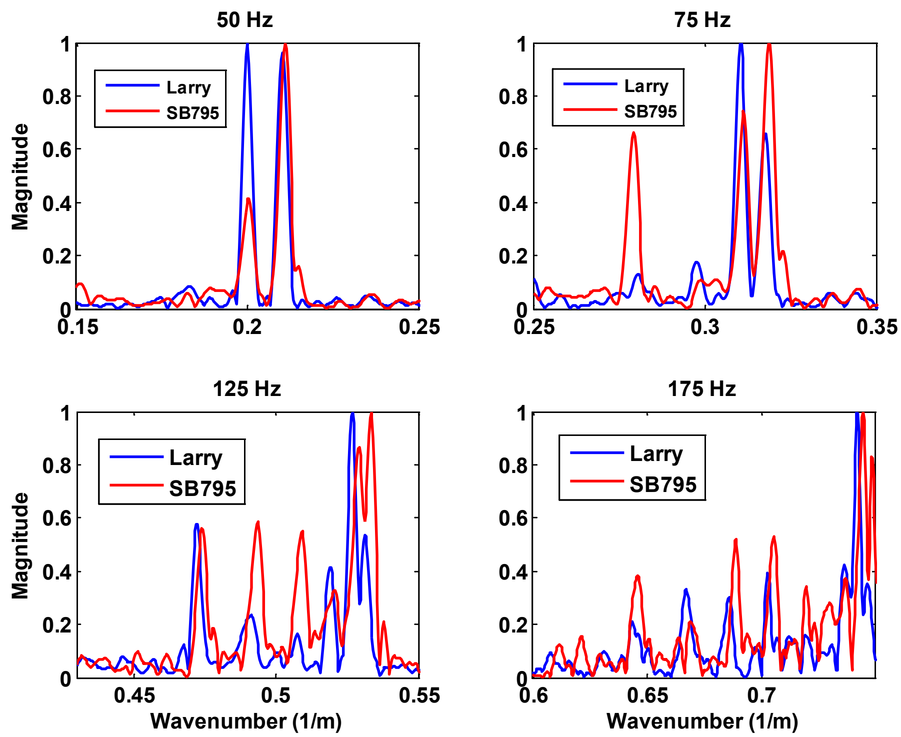

Figure 4: Green's functions for the pressure fields measured by Larry and SB795 for the four frequencies.

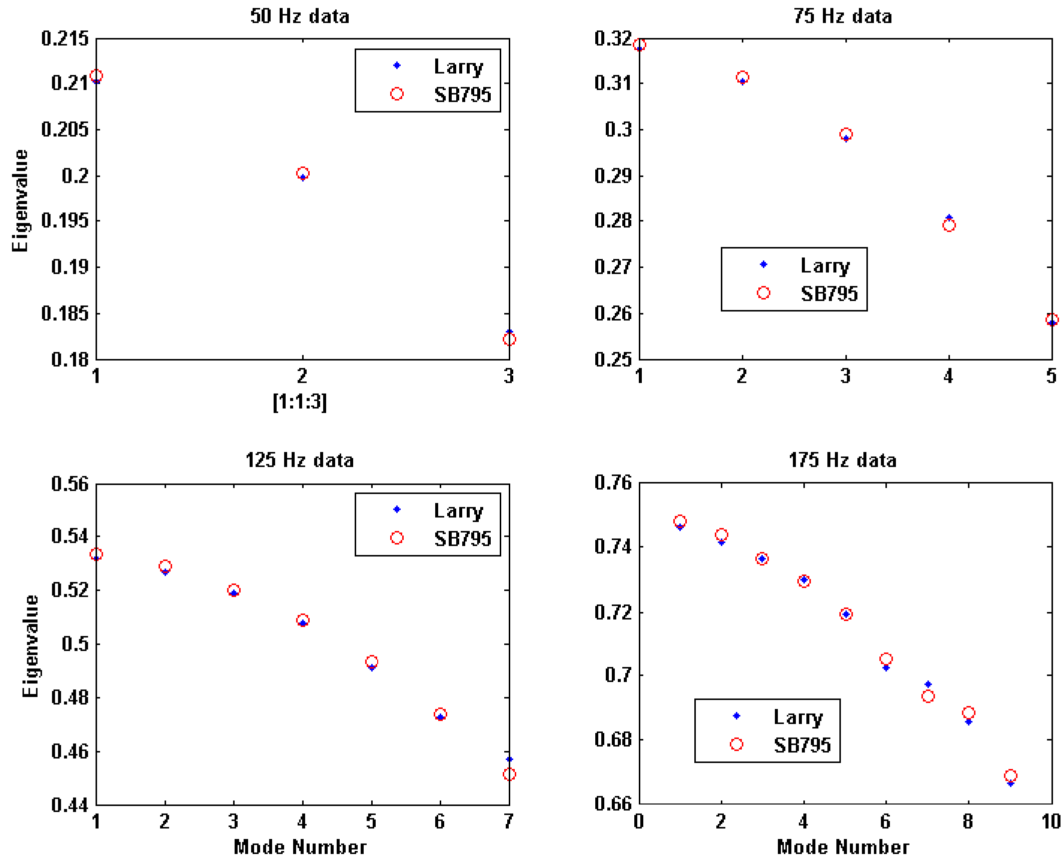

Figure 5: Eigenvalues estimated from the wavenumber spectra and used as input data in the inversion scheme: Larry/SB795 deployment.

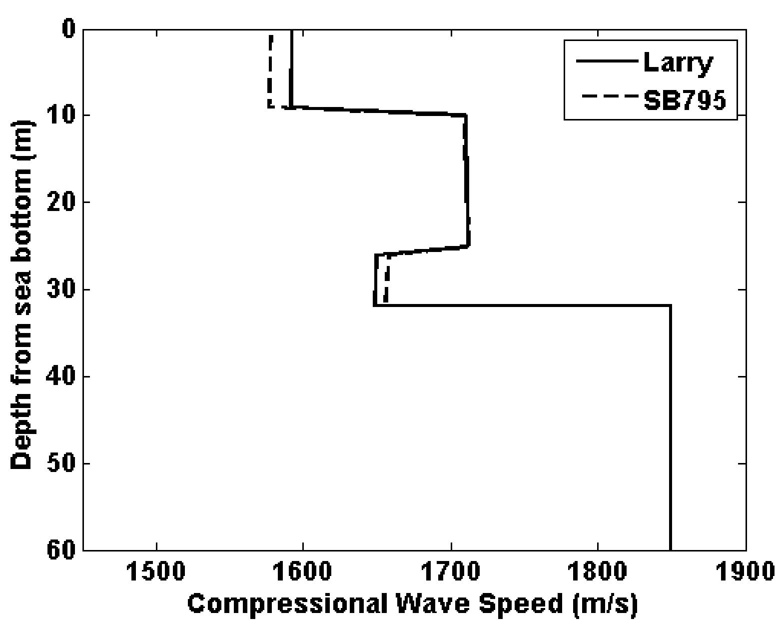

Figure 6: Bottom models estimated from data collected by Larry and SB795.

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HONORS/AWARDS/PRIZES

G.V. Frisk, Past President of the Acoustical Society of America.

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G.V. Frisk, Chair, International Organization for Standardization/Technical Committee 43/ Subcommittee 3 (ISO/TC 43/SC 3) on Underwater Acoustics.