Alaska North Shore Ocean Acoustics Study

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LONG-TERM GOALS

The changing Arctic climate has been altering air-sea interaction and physical oceanographic conditions in the regions. The long-term goals of this project is to acquire better understanding of the effects of changing ice cover, wind patterns and circulation/upwelling on underwater sound propagation and ambient noise in the areas of continental shelves and shelfbreak on Alaska north shore. The potential relevance of this work to the Navy is on increasing the capability of Naval sonar systems in Arctic oceans.

OBJECTIVES

The overall research goal of our study is to understand the physical effects of the changing oceanographic conditions in Arctic oceans on sound propagation and ambient noise, and the focuses are on the influences of (1) ice cover, (2) halocline sound ducts, (3) shelfbreak circulation, and (4) bathymetric and seabed variations.

Because of the warming climate, the summertime ice extent on the Chukchi/Beaufort shelves and in the adjacent Canada Basin has decreased drastically over the last decade. As a result, the sea ice has become younger and more mobile [1]. A presumed primary acoustical consequence of this altered ice condition is reduction of transmission loss. Also, the increased ice mobility has led to stronger upwelling at the Chukchi and Beaufort shelf edge in conjunction with enhanced easterly winds [2-3]. This in turn significantly alters the hydrographic conditions of the water column, with strong ramifications for sound propagation.

Underwater sound propagation in the Canada Basin and the Beaufort Sea can be efficient through the sound duct formed within the Pacific-water halocline layer located about 50-250 m below surface (see Figure 1). In the deep basin, the structure of this water-borne acoustic duct can be perturbed by the abundant subsurface eddies with diameters on the order of 20 km. It is estimated that the Canada Basin is filled with 100-200 of these eddies at any given time [4-6]. Because of intrinsic nonlinearity in the generation and evolution of the eddies, it is extremely difficult to reproduce the exact eddy field. Here we propose an idealized model study to understand the fundamental physics of the eddy variability and validate the results against observed eddy characteristics.

As the sound propagates from the deep basin onto the shelf across the shelfbreak, two environmental factors become important: (1) the shelfbreak jet with its associated vertical motion (mostly upwelling with occasional downwelling) and (2) bathymetry of the slope and canyons. On the first factor, the water-column variability near the northern Alaskan shelfbreak is largely caused by mesoscale dynamics of the shelfbreak jet [4]. The variability of the jet may have attenuating effects on long-distance sound propagation by perturbing the Pacific-water halocline sound ducts. On the other hand, the upwelling currents may affect the sound propagation favorably by lifting the Pacific-water halocline layer away from the bottom [7] and consequently decreasing the bottom loss. In the proposed study, we will deploy moorings equipped with oceanographic sensors to measure the shelfbreak circulation, and then correlate the observed circulation with acoustic measurements to understand the relationships. On the second factor of bathymertical varibility associated with shelfbreak/slopes and canyons, it has been shown that sound reflected from the seafloor on the slope and in canyons can scatter and sometimes focus three-dimensionally in the water column [8]. It is also our research objective to understand these bathymetric effects on sound propagation across the shelfbreak and the ambient noise field.

APPROACH

Both observational and modeling approaches are taken. To make direct measurements, we will deploy four moorings equipped with hydrophone arrays and environmental sensors (temperature, salinity and pressure) for a complete year to observe seasonal variability. The planned time period is one year long, starting from late summer 2016. The numerical approach will be utilizing a three-dimensional (3-D) sound propagation model with elastic properties in the ice and the Regional Ocean Modeling System to setup a regional circulation model. These two physical oceanographic and acoustic models will eventually join together and produce numerical solutions of sound pressure field to compare with field measurements. The main effort is the deployment of acoustic receiver and environmental moorings, in coordination with concurrent ONR Arctic and Arctic acoustic projects, especially the Canada Basin Acoustic Propagation Experiment (CANAPE).

The moorings will provide information on trans-basin, across-shelf and shallow-water propagation of sound, and on the influences of the variable circulation, hydrography, atmospheric forcing, and ice cover of this region, along with the bathymetric variations on the shelfbreak. A pervasive source of large uncertainty in sonar system performance is the ambient noise. Noise in the Arctic may be evolving due to climate change, and the noise field along the slope and in canyons is largely unexplored. Our mooring deployment plan will provide measurements of the temporal and spatial diversity of the noise field along the edge of Arctic continental shelf.

Underwater sound propagation in Arctic oceans with ice cover is influenced by the elastic properties of the ice. To take into account the elasticity, we assume here the ice cover is an elastic solid. Elastic wave motion in solids can be governed by linearized momentum equations [9], which determine the displacement field in a 3-D elastic medium. The principle of our numerical method is to transfer the equations of motion into a parabolic-type partial differential equation, so the solution of medium displacement can be calculated by a marching algorithm. This is the so-called parabolic-equation (PE) method [10].

WORK COMPLETED

The tasks completed in the year (the first six months of the grant period) are described below.

1. CANAPE 2015 cruise

Our WHOI research group joined the CANAPE 2015 cruise for deploying a shallow water mooring (see Figure 2) to make measurements of ambient noise, long-distance sound transmission from the Canada Basin and physical oceanographic properties. This effort was jointed with the University of Delaware (UDel), and the WHOI group shared evenly the cost of mooring fabrication (done at the **WHOI Mooring and Rigging Group**) and deployment (done by the **WHOI Mooring Operations, Engineering and Field Support Group** led by Mr. John Kemp) and provided a 4-channel WHOI SHRU (Several Hydrophone Receiver Unit) array. Because of the unique and excellent engineering skills that Mr. Kemp and his group possesses, this WHOI/UDel shallow water mooring was successfully deployed and recovered under an ice-covered condition.

2. SHRU system upgrade

Each of the existing SHRU data acquisition systems are equipped with 4 hydrophones. The objectives of the equipement upgrade include increasing the continuous data acquisition time to a full year and improving the stability of the SHRU time base by a factor of 100.

Our electronic enginner Mr. Keith von der Heydt has been leading this effort, and it is a work in progress. Since the grant started six months ago, Mr. von der Heydt has been implmenting the following system upgrades:

1. Replacing the existing Seascan timebase (drift 2 to 3ms/day) with a Microsemi Chip Scale Atomic Clock (CSAC) with a drift rate of 1 to 2 ms a year. This entails the design of a carrier printed circuit board that supports the CSAC and be a plug-in replacement for the existing Seascan oscillator.
2. Upgrading the data storage to 1TB.
3. Changing the deployment configuration to use dual pressure housings to augment the alkaline primary battery payload to achieve the 1 year duration.

3. Numerical models of sound propagation

Models of sound propagation in a wave guide with the Pacific-water halocline layer have been created (see Figure 3). These preliminary models are setup to study sound propagation in the Pacific-water halocline duct on a two-dimensional (2-D) vertical plane. Situations of sound propagation across a shelfbreak were also being investigated.

RESULTS

The priority of the project in the first six months was on the SHRU array upgrade and the CANAPE 2015 cruise. The data acquisition system and the hydrophone array that the WHOI mooring group deployed and recovered in the cruise are currently transported back to WHOI as the time when this report is written. We expect the shipment will arrive in early October 2015, and we are planning to analyze the data right away. The SHRU system upgrade is also following the schedule, and we anticipate the upgrade will be finished in late spring 2016.

The numerical models have also been built. Examples of surface and mid-water column ducts in a waveguid with the Pacific-water halocline layer are shown in Figure 3(a). The model clearly shows that sound trapped in the surface duct can encourter surface scattering from rough sea surface or ice caps, which will be incorporated into the model later this year. On the other hand, the mid-water column duct provides a waveguide without surface scattering. Sound propagation across a shelfbreak is also analyzed. In the case, where the halocline duct extents to the shelfbreak, see Figure 3(b), the trapped sound can impinge on the slope, and only a small portion of sound energy propagtes onto the shelf. On the other hand, when the halocline duct is somehow perturbed by shelfbreak oceanographic circulations so that the propagation condition becomes upward refracting near the shelfbreak, see Figure 3 (c), more sound can propagate onto the shelf.

IMPACT/APPLICATIONS

The potential relevance of this work to the Navy is on increasing the capability of sonar systems in Arctic oceans by better understanding the sound propagation physics and ambient noise conditions in this changing environment

RELATED PROJECTS

A DURIP project is funded to provide a complementary support of ~$75k to the SHRU system upgrade.

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PUBLICATIONS

None in the first six months of the grant period.

HONORS/AWARDS/PRIZES

Recipient: Ying-Tsong Lin
Recipient's Institution: Woods Hole Oceanographic Institution
Award Name A. B. Wood Medal and Prize of the Institute of Acoustics
Award Sponsor: Institute of Acoustics

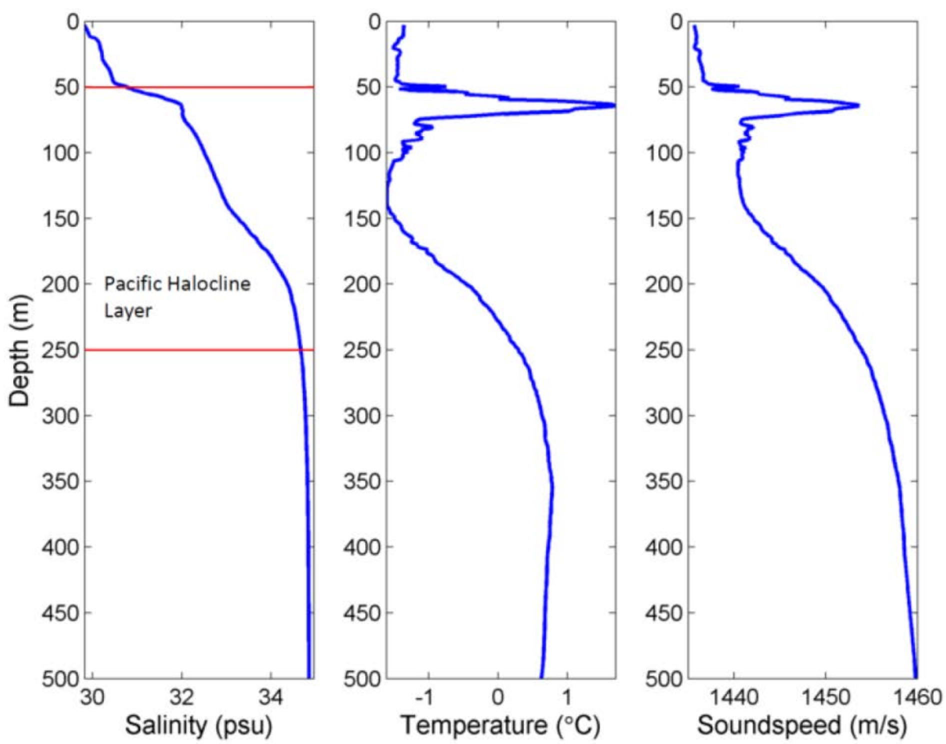

Figure 1. Water column profilers of salinity, temperature and soundspeed showing the sound duct formed within the Pacific-water halocline layer.
[The salinity and temperature profiles were taken from a CTD cast on the northern Alaskan shelf. The warmer Pacific Summer Water layer at ~60 m formed a water-borne sound duct between 60 and 225 m and provided a barrier preventing the ducted sound from interacting with the sea surface boundary, which can be ice-covered or open water.]

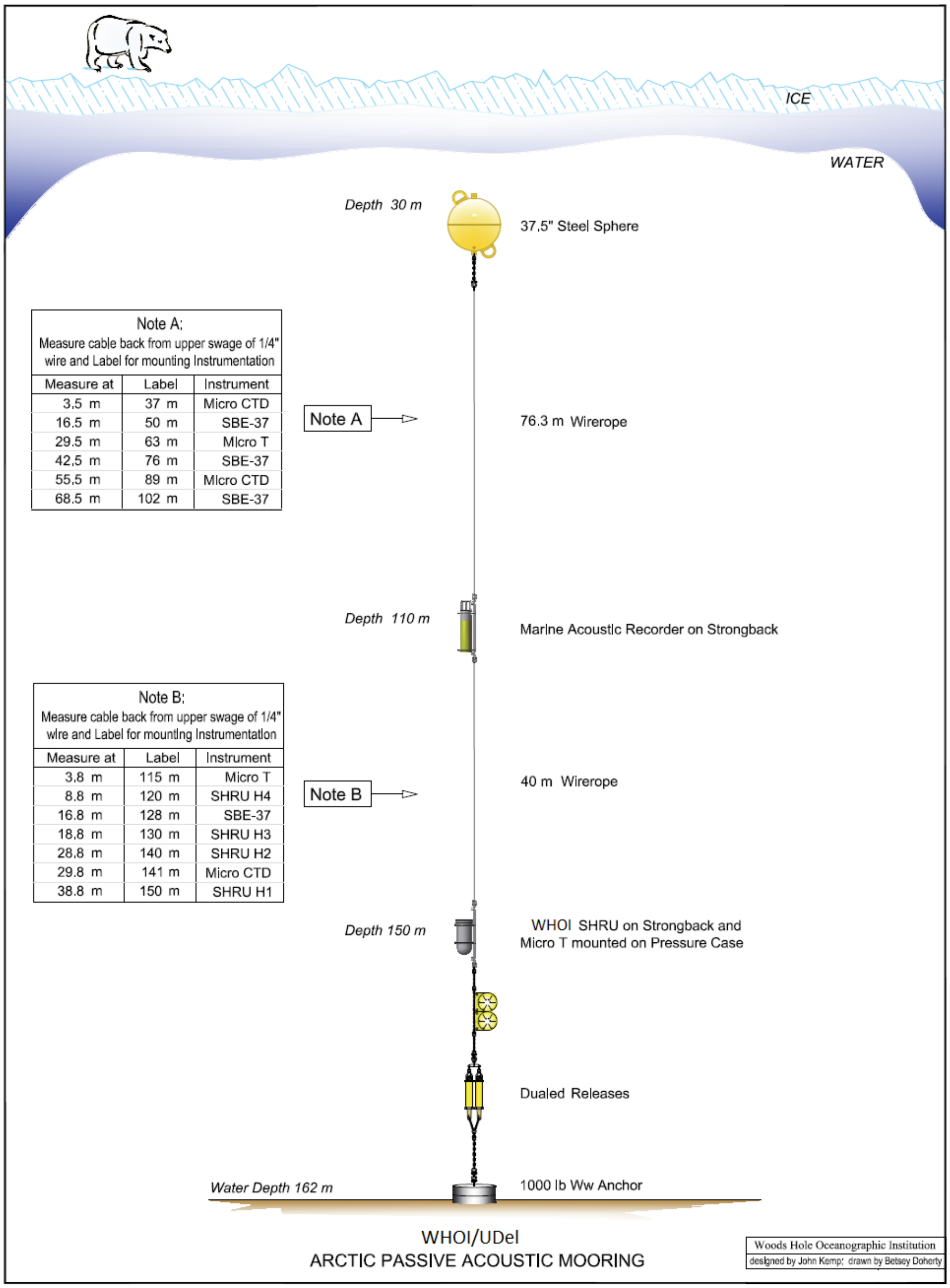

Figure 2. Shallow water acoustic and physical oceanographic mooring deployed in the CANAPE 2015 cruise.
[This mooring was designed by the WHOI Mooring Operations, Engineering and Field Support Group Leader Mr. John Kemp, and also deployed by Mr. Kemp and his group under an ice-covered condition.]

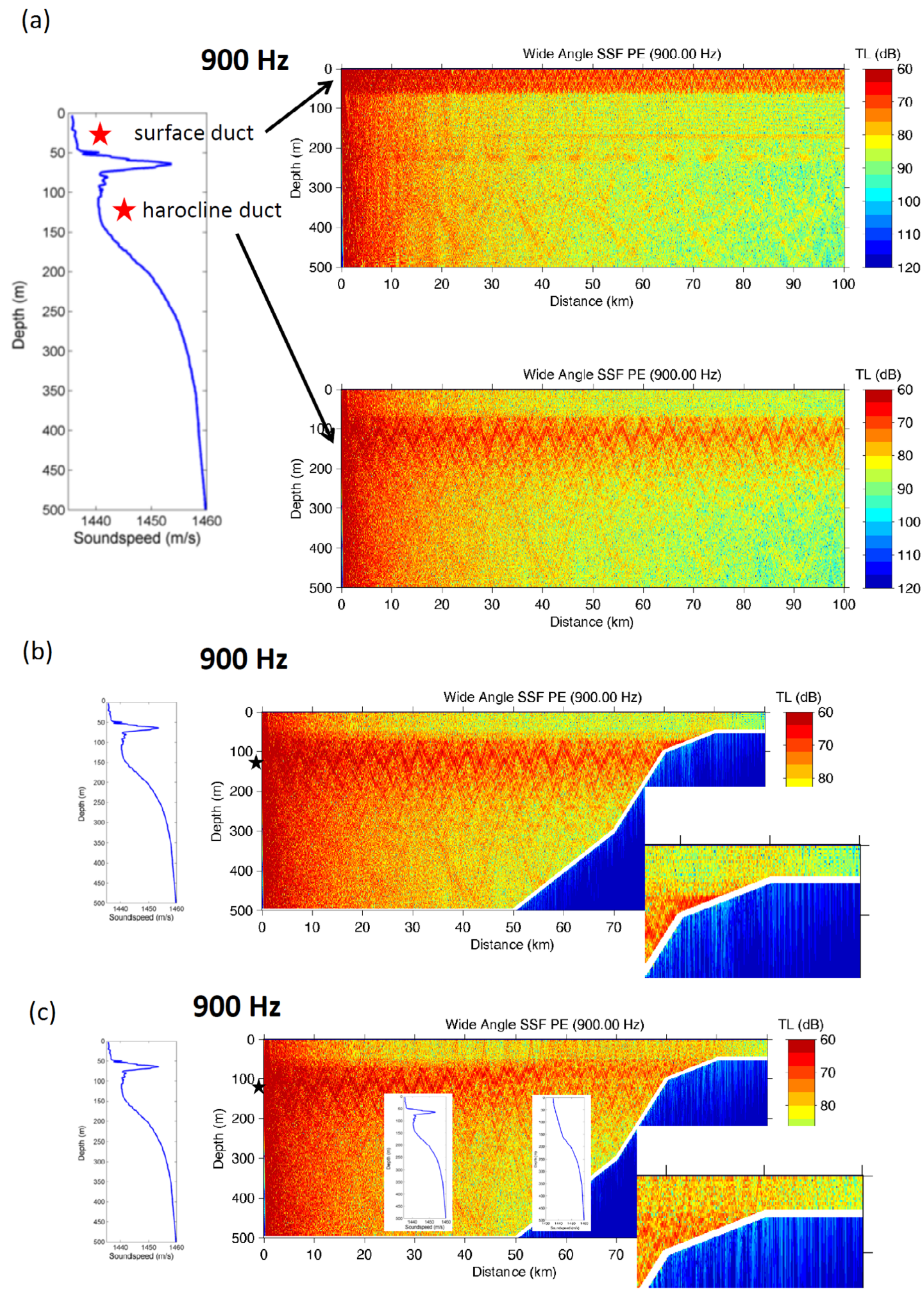

Figure 3. Models of sound propagation in a Pacific-water halocline duct.
[(a) Numerical examples of surface and mid-water column ducts. Sound trapped in the surface duct can encourter surface scattering from rough sea surface or ice caps. The mid-water column duct provides a waveguide with no surface scattering effects. (b) and (c) Sound propagation across a shelfbreak. In the case, where the halocline duct extents to the shelfbreak (b), the trapped sound can impinge on the slope, and only a small portion of sound energy propagtes onto the shelf.
On the other hand, when the halocline duct is perturbed by shelfbreak oceanographic circulations, the propagation condition can become upward refracting (c), and more sound can propagate onto the shelf.]