Canada Basin Acoustic Propagation Experiment (CANAPE)

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LONG-TERM GOALS

The Arctic Ocean is undergoing dramatic changes in both the ice cover and ocean structure. Changes in sea ice and the water column affect both acoustic propagation and ambient noise. This implies that what was learned about Arctic acoustics during the Cold War is now obsolete. The goal of the Canada Basin Acoustic Propagation Experiment (CANAPE) is to determine the fundamental limits to the use of acoustic methods and signal processing imposed by ice and ocean processes in the new Arctic. The hope is that these first few new steps will lead to a larger, permanent acoustic monitoring, navigation, and communications network in the Arctic Ocean (Mikhalevsky et al., 2015).

OBJECTIVES

As conditions in the Arctic have changed, the greatest loss of both first-year and multiyear ice has occurred in the Canada Basin (McLaughlin et al., 2011). These changing conditions make the Canada Basin an ideal location to test the hypothesis put forward by P. Mikhalevsky (personal communication) that changing Arctic conditions will contribute to a THin-ice Arctic Acoustic Window (THAAW):

- The Arctic is now dominated by 1–2 year ice with reduced pressure ridging, resulting in lower transmission loss and allowing operation at higher frequencies.
- Reduced pressure ridging also results in more frequent periods of low ambient noise.
- Ice cover is still present throughout much of the year, insulating the ocean from wind and solar forcing and preserving the stable Arctic acoustic channel.

Ice conditions are not the only environmental changes in the Arctic. The stratification of the upper water column is also changing, affecting the vertical structure of the sound-speed profile and therefore acoustic propagation. The stratification in the Canada Basin is especially complex due to the presence of Pacific-origin waters entering the Arctic Ocean through the Bering Strait. The temperature minimum associated with the Pacific Winter Water (PWW) at 150–200 m depth between the shallower Pacific Summer Water (PSW) and deeper Atlantic layer forms a subsurface acoustic duct that was previously either weak or absent. This implies that signals can be trapped in the duct and not suffer the losses associated with scattering from the ice, although this behavior is expected to be frequency dependent.

The goals of the CANAPE experiments include (1) understanding the impacts of changing sea ice and oceanographic conditions on acoustic propagation and fluctuations; (2) characterizing the depth dependence and temporal variability of the ambient noise field; and (3) measuring the spatial and temporal variability in the upper ocean throughout the annual cycle by combining acoustic and other data with ocean models. Acoustic transmissions are being used to both study acoustic propagation and scattering and help characterize the large-scale oceanographic structure in the Beaufort Gyre.

APPROACH

The Canada Basin Acoustic Propagation Experiment (CANAPE) consists of a yearlong experiment in the Canada Basin of the Arctic Ocean during 2016–2017, preceded by a short Pilot Study in July-August 2015. During the Pilot Study a moored Distributed Vertical Line Array (DVLA) receiver recorded the transmissions from HLF-5 (250 Hz) and J15-3 (75 and 125 Hz) acoustic sources lowered from shipboard at ranges of up to about 300 km in the Canada Basin. One of the primary goals with the HLF-5 source is to determine the maximum range at which 250-Hz transmissions provide useful signal-to-noise ratios for under-ice propagation. This information will be used to design the 2016–2017 CANAPE experiment, which will use Teledyne Webb Research sources that transmit linear FM signals in approximately the 200–300 Hz band. The J15-3 source is much lower power than the HLF-5, but provides data on propagation under the ice at lower frequencies.

During 2016–2017 a DVLA receiver will be embedded within a six-element ocean acoustic tomography array approximately 200 km in diameter (Fig. 1). Pending the results of the Pilot Study, the straw man geometry has the Teledyne Webb sources located at a depth of 200 m in order to place energy in the duct formed by the PWW. All of the transceivers will transmit to one another and to the DVLA. The one-year deployment in a fixed geometry will allow measurements at least partially in open water during summer, in the marginal ice zone (MIZ) as it transitions across the array during the spring and autumn, and under complete ice cover during winter.

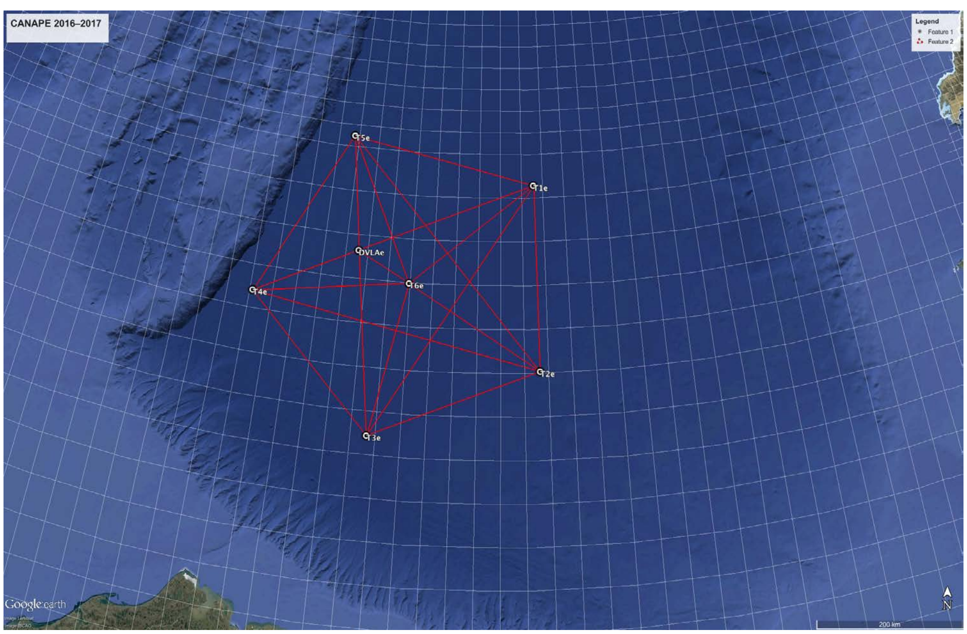

Fig. 1. The 2016–2017 CANAPE Experiment will consist of six tomographic transceivers (T1, T2, …, T6) and a DVLA receiver located approximately at the intersection of the T1-T4 and T2-T5 paths. The array radius as shown is 200 km.

The acoustic measurements will be complemented by a number of environmental measurements:

- Temperature and salinity from Sea-Bird MicroCATs and Temperature Recorders on the DVLA and the acoustic transceiver moorings (J. Colosi, NPS);
- Temperature from the Hydrophone Modules on the DVLA and the acoustic transceiver moorings;
- Ice profiling sonars on the subsurface floats on the acoustic transceiver moorings (A. Proshutinsky and R. Krishfield, WHOI); and
- CTD casts at each mooring location, plus others as time allows.

WORK COMPLETED

The 2015 CANAPE Pilot Study was conducted on the *R/V Sikuliaq*. After staging out of Dutch Harbor, Alaska, and transiting to Nome, the cruise took place 23 July – 21 August 2015 (Nome – Nome) (Fig. 2).

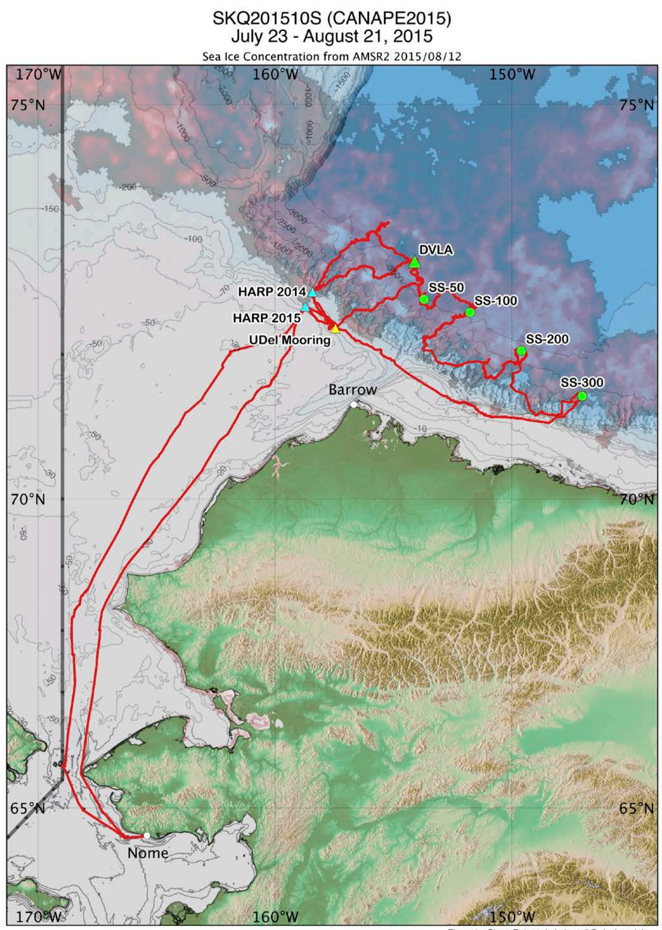

Fig. 2. Ship track for the 2015 CANAPE Pilot Study. Acoustic sources were lowered from shipboard at ship stops SS50, SS100, SS200, and SS300 to transmit to moored vertical receiving arrays in deep (DVLA) and shallow (UDel Mooring) water. In addition, a High Frequency Acoustic Recording Package (HARP) was recovered (HARP 2014) and two HARPs were deployed (HARP 2014 and HARP 2015) for J. Hildbrand (SIO). The ice concentration derived from AMSR-2 satellite data is shown for 12 August 2015. (Figure by Steve Roberts, Univ. Alaska Fairbanks.)

A moored DVLA with 60 Hydrophone Modules spaced 9 m apart (~ 1 ½ wavelengths at 250 Hz) was deployed at 73º 10.66'N, 154º 06.05'W in water 3853 m deep. The hydrophone array spanned approximately 98–629 m, although the depths of course varied with time as the mooring responded to ocean currents. Mooring motion was measured using a long-baseline acoustic navigation system. The DVLA recorded continuously at a sample rate of 1953.125 Hz.

In addition, a receiver mooring was deployed on the continental shelf at 72º 20.26'N, 157º 26.95'W in water 161 m deep for the University of Delaware (M. Badiey) and Woods Hole Oceanographic Institution (Y.-T. Lin and T. Duda).

An HLF-5 source was lowered from shipboard to a depth of 92 m at ranges from the DVLA of approximately 50, 100, 200, and 300 km (SS50, SS100, SS200, and SS300). The source transmited periodic repetitions of phase-coded linear maximal shift register sequences with a carrier frequency of 250 Hz. Transmissions started at HH:00:00 and HH:30:00 and lasted 589.248 s.

A J15-3 source was lowered from shipboard to a depth of 90 m at ranges from the DVLA of about 50, 100, and 200 km (SS50, SS100, and SS200). The source transmited periodic repetitions of phase-coded linear maximal shift register sequences with carrier frequencies of 75 and 125 Hz. Transmissions started at HH:50:00 and lasted 2992 s at 75 Hz (even hours UTC) and 2992.416 s at 125 Hz (odd hours UTC).

The ship drifted with the ice during all transmissions. The signal processing therefore needs to account for the Doppler shift caused by the motion of the sources.

RESULTS

Preliminary processing of the HLF-5 (250 Hz) receptions at about 190 and 309 km ranges give the results in Fig. 3. All 36 periods of the transmitted m-sequence were processed using integrated autocorrelation phase processing to correct for Doppler. At 190 km range early time fronts from steep raylike arrivals are clearly evident at about 129.9 s and 130.4 s. These time fronts are in agreement with parabolic equation predictions, except that the predicted arrivals have slightly shorter travel times than measured. There is significant energy in the finale out to about 132.1 s, again more or less in agreement with predictions. The predictions used a sound-speed profile derived from a CTD cast conducted during the experiment and assumed a perfectly reflecting surface.

At 309 km range early time fronts are evident at about 211.1 and 211.7 s, in good agreement with the predictions. The predicted finale is largely missing, however, presumably because it has been stripped off by interactions with the ice.

At both ranges the ambient noise level at about 150 m depth appears enhanced. The higher noise levels are present on more than one hydrophone, suggesting that the enhancement is real. The sound-speed minimum associated with the PWW is in the vicinity of 150 m, and one possibility is that the enhanced noise level is associated with the sound-speed duct formed by the PWW.

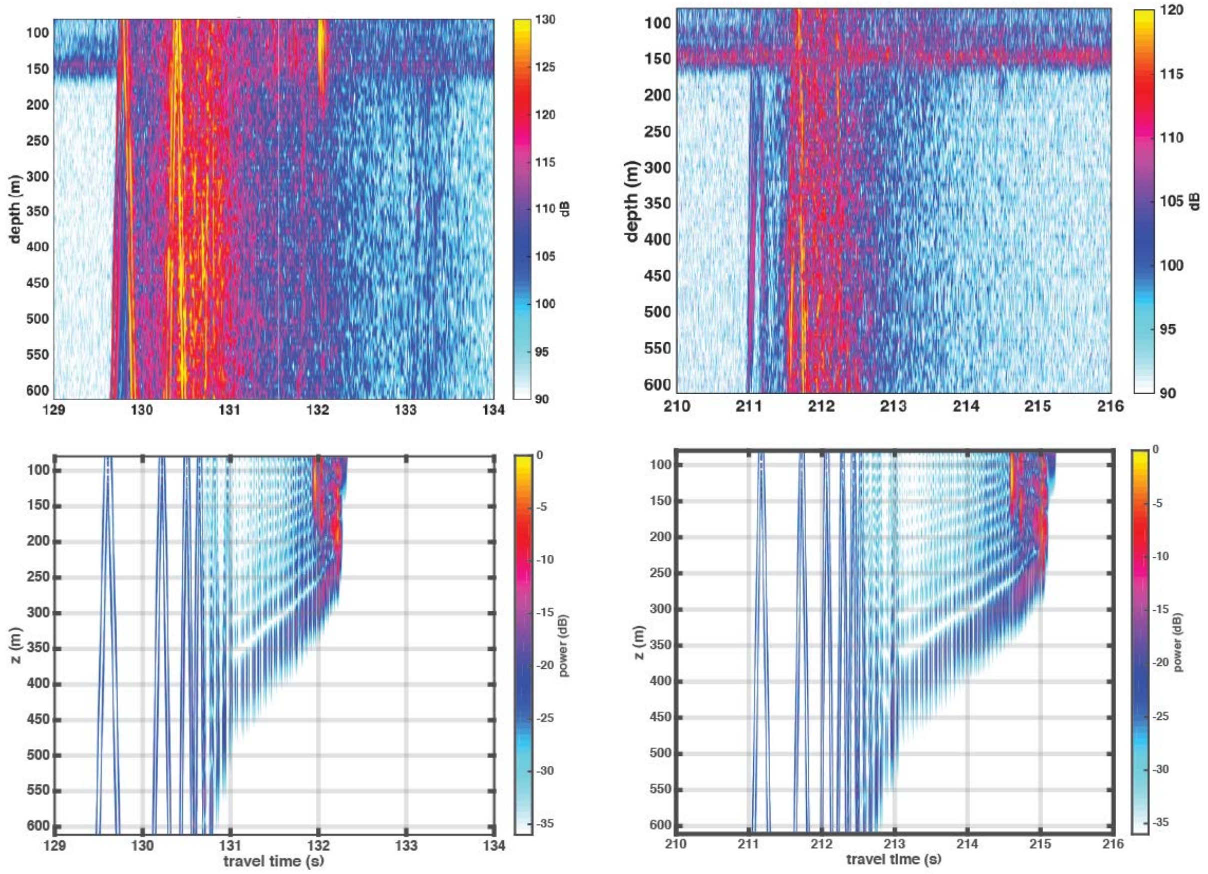

Fig. 3. Measured (top) and predicted (bottom) arrival patterns on the DVLA for HLF-5 transmissions on year day 222 at 1500 UTC at about 190 km range (left) and on year day 224 at 1000 UTC at about 309 km range (right).

IMPACT/APPLICATIONS

This research has the potential to affect the design of deep-water acoustic systems in the Arctic, whether for sonar, acoustic communications, acoustic navigation, or acoustic remote sensing of the ocean interior.

RELATED PROJECTS

The 2015 CANAPE pilot study was a joint effort by SIO-UCSD (M. Dzieciuch, P. Worcester), NPS (J. Colosi), University of Delaware (M. Badiey), and WHOI (T. Duda, J. Kemp, Y.-T. Lin). The deep water component of the 2016–2017 CANAPE experment is a joint effort by SIO-UCSD (B. Cornuelle, M. Dzieciuch, P. Worcester), NPS (J. Colosi), and WHOI (J. Kemp, R. Krishfield, A. Proshutinsky). The shallow water component of the 2016-2017 CANAPE experiment involves a large number of institutions and individuals: ARL-UT (M. Ballard, D. Knobles, J. Sagers), DRDC (D. Hutt), NRL (A. Turgut), University of Delaware (M. Badiey), and WHOI (T. Duda, Y.-T. Lin).

REFERENCES

McLaughlin, F., Carmack, E., Proshutinsky, A., Krishfield, R. A., Guay, C., Yamamoto-Kawai, M., Jackson, J. M., and Williams, B. (**2011**). "The rapid response of the Canada Basin to climate forcing: From bellwether to alarm bells," Oceanography **24**, 146–159.

Mikhalevsky, P. N., Sagen, H., Worcester, P. F., Baggeroer, A. B., Orcutt, J., Moore, S. E., Lee, C. M., Vigness-Raposa, K. J., Freitag, L., Arrott, M., Atakan, K., Beszczynska-Möller, A., Duda, T. F., Dushaw, B. D., Gascard, J. C., Gavrilov, A. N., Keers, H., Morozov, A. K., Munk, W. H., Rixen, M., Sandven, S., Skarsoulis, E., Stafford, K. M., Vernon, F., and Yuen, M. Y. (**2015**). "Multipurpose acoustic networks in the Integrated Arctic Ocean Observing System," Arctic **68**, 11-27.

PUBLICATIONS

Mikhalevsky, P. N., Sagen, H., Worcester, P. F., Baggeroer, A. B., Orcutt, J., Moore, S. E., Lee, C. M., Vigness-Raposa, K. J., Freitag, L., Arrott, M., Atakan, K., Beszczynska-Möller, A., Duda, T. F., Dushaw, B. D., Gascard, J. C., Gavrilov, A. N., Keers, H., Morozov, A. K., Munk, W. H., Rixen, M., Sandven, S., Skarsoulis, E., Stafford, K. M., Vernon, F., and Yuen, M. Y. (**2015**). "Multipurpose acoustic networks in the Integrated Arctic Ocean Observing System," Arctic **68**, 11-27. [published, refereed]