ADEON Sail Cruise #2&3
June 3-8, 2019

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OASIS TECHNICAL MEMORANDUM No. 149

ADEON SAILBOAT CRUISE 19-1 REPORT

July 15, 2019

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July 8, 2019

UNH Subcontract Number: 17-018

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1. Introduction

A five-day acoustical survey in support of the BOEM Atlantic Deepwater Ecosystem Observatory Network (ADEON) program was conducted on the U. S. east coast Outer Continental Shelf (OCS) from June 3-8, 2019. The planned survey route, shown in Figure 1, was designed to sample the ambient noise environment in the vicinity of three ADEON landers located at Charleston Bump (CHB), Savannah Deep (SAV) and Wilmington (WIL).

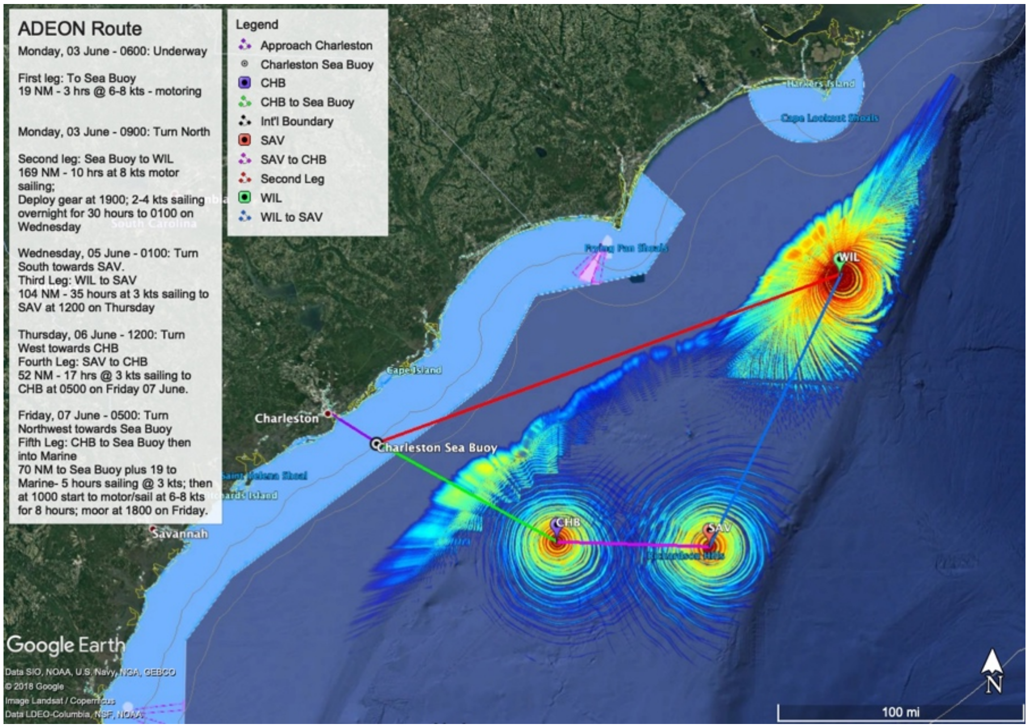

Figure 1 Originally planned ADEON route & timeline.

Survey Objectives

One of the principal ADEON program objectives is to determine the spatial and temporal distribution of the OCS soundscape through a set of four sailboat cruises employing a towed horizontal line array (HLA). For each cruise, weather permitting, a transect from one lander to the adjacent lander and back is expected to be performed. The mobile towed array provides both noise directionality and the spatial distribution of the ambient noise field. To satisfy this objective, a horizontal line array is deployed and towed from lander to lander. After recovery of the landers, the passive acoustic data from each lander can be correlated with the sailboat HLA data to provide an estimate of the spatial and temporal decorrelation length/time.

The ultimate goal of the ADEON program is to generate multi-year measurements of the natural and human factors that describe the ecology and soundscape of the U.S. east coast Outer Continental Shelf (OCS). We aim to develop standardized tools for comparing soundscapes across regions and predictive models for the soundscape and overall ecology of the southeast OCS in water depths between 100-1000 m.

2. Background

The towed array employed in this cruise is OTA3, a 16-channel hydrophone array designed by OASIS and fabricated by L-3 Chesapeake Sciences. The channels are uniformly spaced at 0.75m corresponding to an array design frequency of 1 kHz. The array is a gel-filled hose of diameter 1.1 in. The tow cable is 300' feet in length and is weighted to maximize the array depth under tow. The tow cable is also faired to mitigate the effects of strum due to vortex shedding. The entire system is shown in Figure 2 on the deck of the tow platform ready for deployment.

Figure 2 OTA3 towed hydrophone array

The tow platform used for this cruise was the catamaran S/V AQUA BOB pictured in Figure 3. The vessel is 58' in length with self-tacking jib and two spinnakers. It can also be powered with two Yanmar 4JH4-THE, V-drive ZF631IV engines with straight shaft to 4 blade feather PIY max props. The vessel electrical power plant is an Alpha Generator (21Kw).


Figure 3 Robertson & Caine Leopard Catamaran 58 AQUA BOB

The vessel was crewed by the owner/captain Alex DeSeta. The science crew was comprised of three AOS personnel, Chris Verlinden, Thomas Caero, and Reid Wiegleb, and two OASIS personnel, Dave Morton and Vitaly Kmelnitsky. Crewmembers manned a 24-hour watch rotation in 6-hour durations. On watch, members safely navigated the vessel and maintained operational status of the scientific equipment.

The actual execution of the experiment deviated slightly from the original cruise plan in that the ship took a “counter clockwise” route, as pictured in Figure 4, instead of the originally planned “clockwise” route due to sea state and predicted winds. The change increased time spent under sail. The route took less time than originally planned because of the significant influence from the Gulf Stream. It is estimated that the vessel speed through the water while towing the array was maintained at or below 4 knots. However, speed over ground was 5-7 knots.

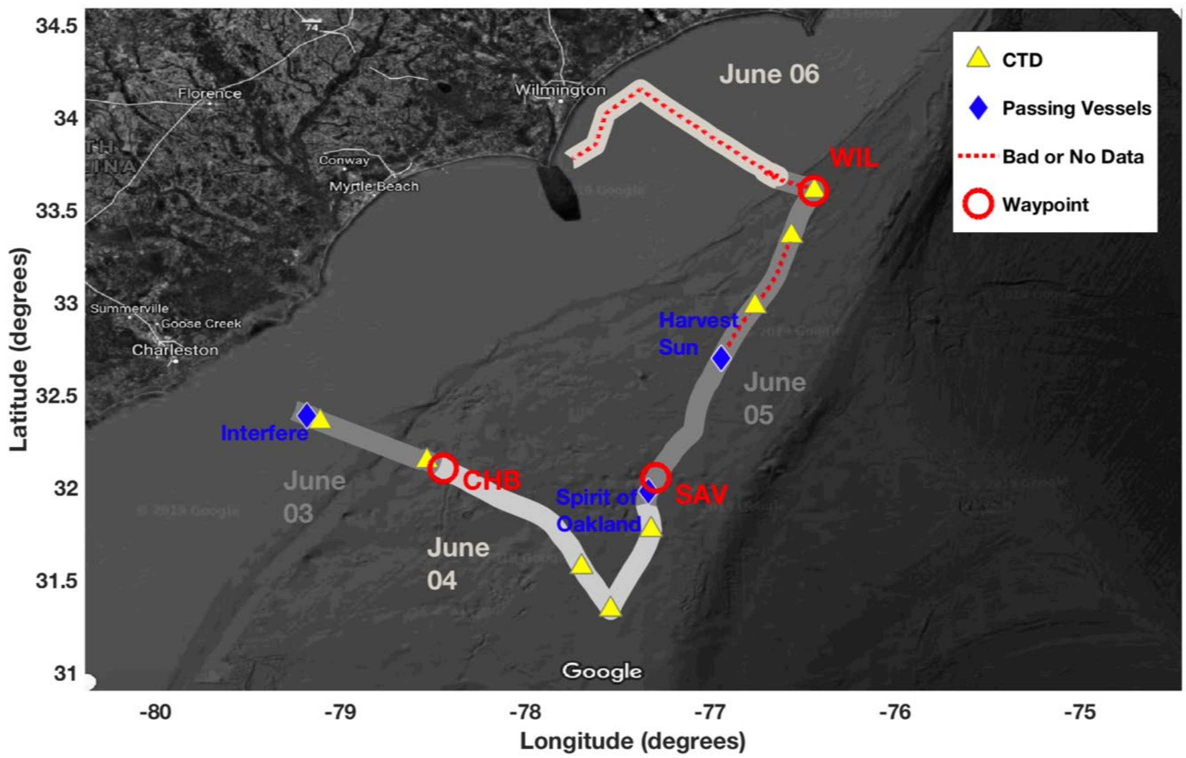

Figure 4 Actual route taken by S/V AQUA BOB

There were a few lines of squalls the crew contended with during the survey. Furthermore, pleasure craft and ship traffic remained light to none for the duration of the experiment. Passing vessel traffic was logged in the experiment log, noting vessel type, speed, and approximate Closest Point of Approach (CPA). Whenever possible, images of the vessels were captured and/or their corresponding Automated Identification System (AIS) information was captured. A screenshot illustrating an example of this information is shown in Figure 5.

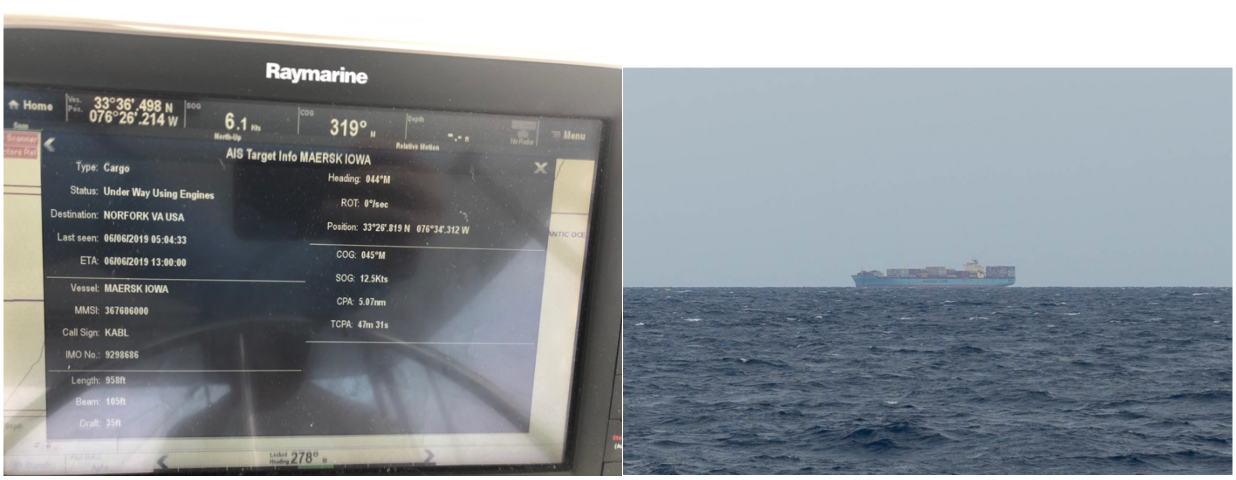

Figure 5 Depiction of onboard AIS capture and corresponding vessel.

3. Data Collection

The data collection system employed during the cruise is summarized in Figure 6. The system was designed by OASIS for vessel towed array deployments and has been used on a number of sailboat collections in the past. The array and tow cable are secured to the stern of the vessel and the tow cable is routed to a weather proof case containing the array receiver and associated power conditioning electronics. The array telemetry is received by a Linux laptop and written to hard drive where it is backed up on multiple USB passport drives. Other relevant metadata feeds such as GPS, AIS, StarOddis (external depth sensors for array), and CTD casts are also archived for post-processing.

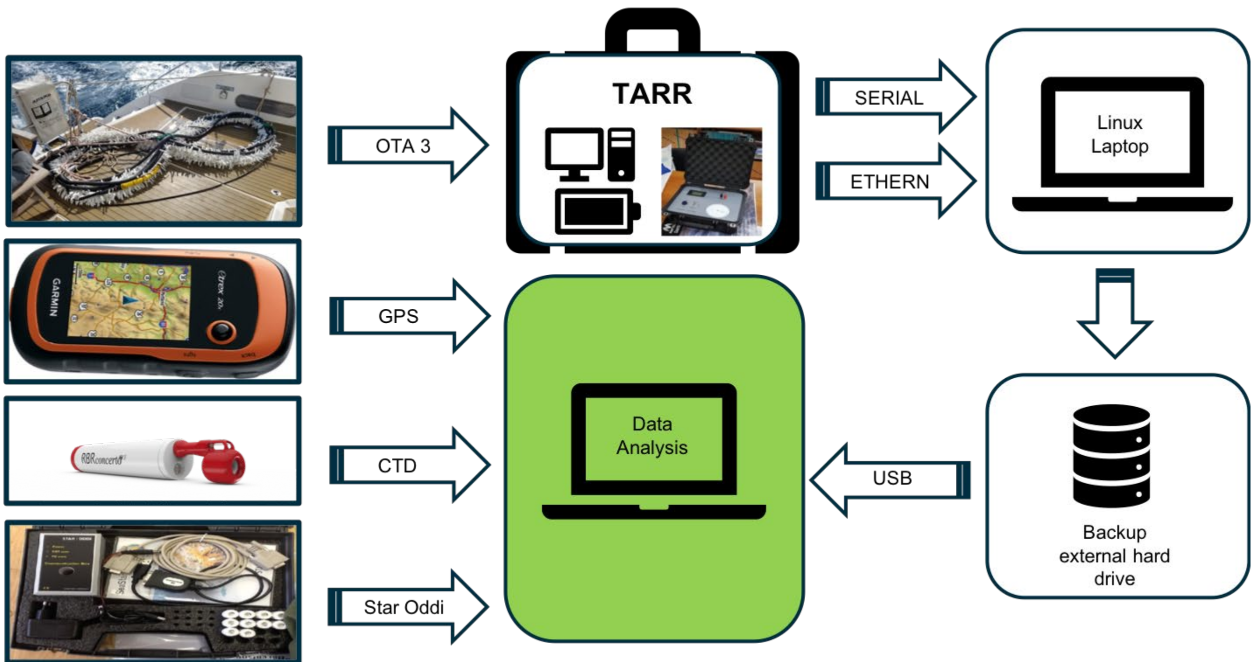

Figure 6 OASIS data collection system

The total amount of acoustic data collected during the cruise was 43 hours 58 minutes. The array spent a total of 47 hours 53 minutes deployed in the water. Table 1 describes array deployment events in detail.

Whenever environmental conditions allowed, all attempts were made to collect data. Conditions that specifically prevented array deployment or necessitated its recovery included sea state, onset of nighttime, and wind speed or direction. During a couple of brief intervals during the cruise, heavy winds (in excess of 20 kts) or wind directions unfavorable for sailing caused the array to be recovered temporarily.

Date	Time (Z)	Event	Elapsed time deployed (hh:mm)	CTD's
3-Jun	1625	Array deployed	\\\\\\	1600, 1725, 1843
3-Jun	1840	Array Recovered	2:15	
3-Jun	2228	CTD Cast	\\\\\	2228
3-Jun	2247	Array deployed	\\\\\\	
4-Jun	1620	Array Recovered	17:33	
4-Jun	1610	CTD Cast	\\\\\	1610
4-Jun	2155	Array deployed	\\\\\	
6-Jun	1902	Array Recovered	24:10 [28:08]	1445, 1500, 1846, 2150
	Total Time Deployed:		43:58 [47:53]	

Table 1 Experimental events and array deployment time.

Figure 7 shows a timeline of array depth, vessel heading, and vessel speed over ground (SOG) throughout the entire deployment. Note that array speed through the water (STW) was not directly available as a measurement. The depth of the array is correlated with speed through the water, so that when the speed decreases the array depth increases. The goal was to tow the array at STW of not more than 3-4 kts to balance array stability against flow noise (flow noise increases with STW). These data were also archived to disk.

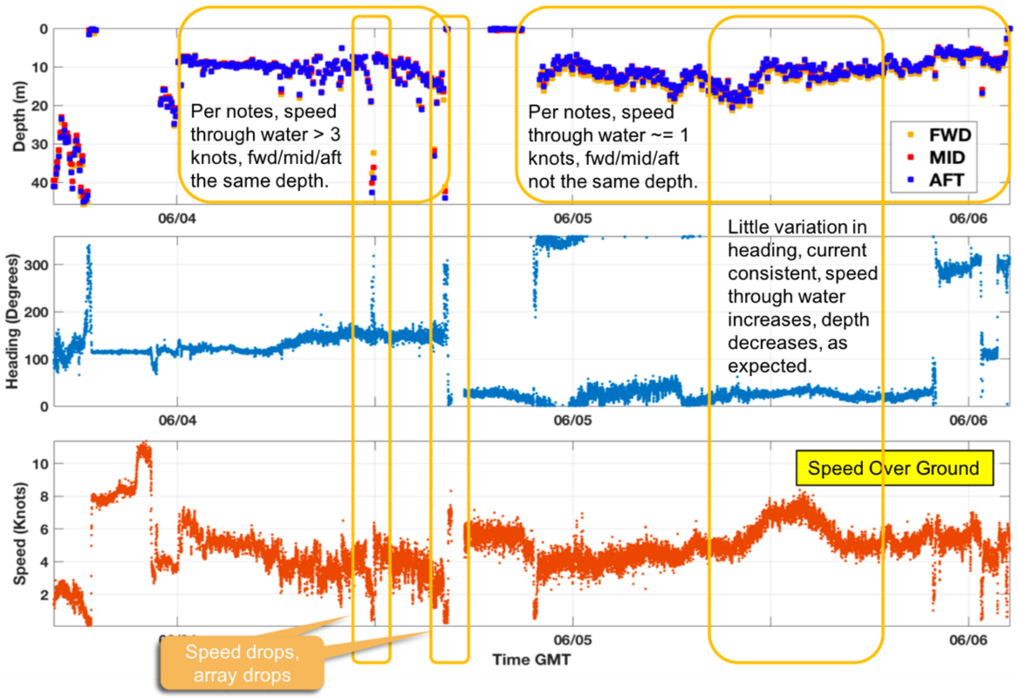

Figure 7 Depth, heading, and speed over ground (SOG) during the array deployment.

Finally, in order to calibrate the sound speed environment and provide the necessary inputs for transmission loss modeling, periodic CTD casts were conducted through the duration of the experiment as shown in Figure 8. Sound speed profiles along the route were generally downward refracting, with a mixed layer varying in depth from 20 to 60 m, typical of the North Atlantic continental shelf environment in spring. The number of CTD casts performed was reduced from what was originally planned to limit disturbance of the acoustic data. It was also a tradeoff to collect CTD data due to the fact that meaningful depth was only achieved when the vessel was DIW. The maximum depth of the CTD casts varies because some of the tows were conducted without stopping the vessel. CTD casts were conducted using an RBR Concerto CTD logger. The logger was lashed to a 400 ft line and 30 pounds of diving weights. Deployment and recovery were greatly assisted using the ships onboard power winch.

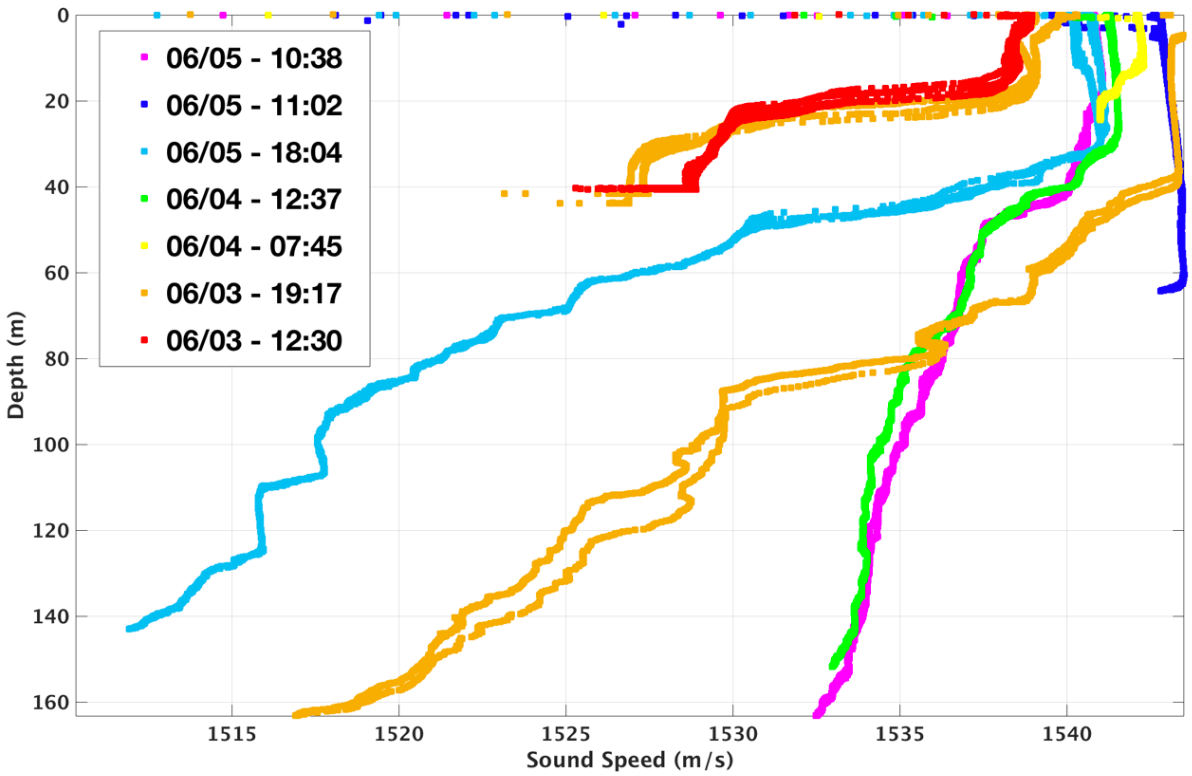

Figure 8 Sound speed profiles from CTD casts conducted between 3 June and 5 June.

4. Preliminary Analysis Results

Preliminary analysis of hydrophone array data has been performed in order to develop an initial understanding of the measured noise distribution in the mid-Atlantic outer continental shelf region surveyed in this cruise. Figure 9 depicts histograms of measured omni-averaged noise level, beamformer output (broadside beam) noise level, and array gain during representative daytime and nighttime intervals. Such analysis products provide a synoptic description of noise field characteristics that can be used to infer first-order trends in the data, as well as give feedback on array performance.

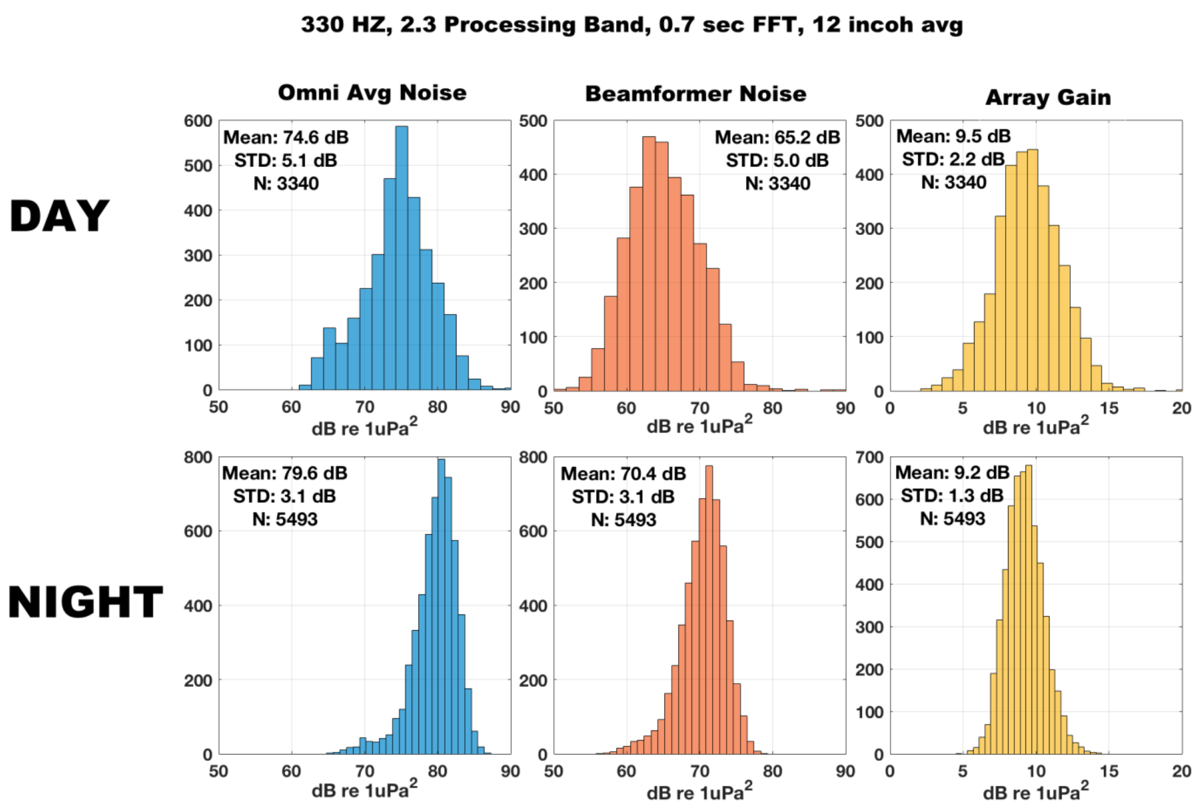

Figure 9 Histograms of omni-averaged and beamformer output noise levels, and array gain, at 330 Hz during daytime and nighttime intervals. All measurements are in a 2.3 Hz window-corrected processing band—for spectrum level subtract 3.6 dB.

Similar to earlier noise measurements made on the North Atlantic continental shelf in 2011 [1], the results in Fig. 9 reveal a pronounced diurnal dependence to the mean ambient noise level. Our preliminary analysis supports the finding that this elevation in noise level at night is due to the onset of croakers, known to chorus in the 100-1 kHz band [2]. This noise phenomenon occurs in marine environments around the world and has been observed directly by the OASIS team in Southern California, Gulf of Oman, and the western North Atlantic near Hudson Canyon. Chorusing behavior normally commences just after sunset and persists until dawn. Histograms depicted in Fig. 9, show the (a) omni-averaged noise level in 2.3 Hz band, (b) beamformer output noise in 2.3 Hz band, and (c) the measured array gain. The array gain (AG) is defined as,

$$AG = \frac{\overline{\sigma}_n^2}{\sigma_b^2},$$

where σ_n^2 is the average noise power taken over all hydrophones in the sensor array, and σ_b^2 is the beamformer output power, for simplicity taken at broadside. In isotropic noise, the theoretical AG can be shown to be equal to the directivity index (DI), or $10\log_{10}N$, where N is the number of sensors in the array [3]. From Fig. 9, we see that the during daytime, the mean omni-averaged noise level is approximately 71 dB in spectrum level, consistent with observations of low to moderate shipping density and moderate winds of 10-20 kts. The mean nighttime omni-average noise level of 76 dB spectrum level reflects an increase of 5 dB. This is consistent with the findings in Ref. 1 made in 2011 in the same general vicinity of the North Atlantic continental shelf.

The daytime noise level distribution exhibits a higher standard deviation relative to nighttime, and a heavier-tailed array gain distribution, consistent with the presence of occasional discrete interferers coming within close proximity to the array. The narrower nighttime array gain histogram exhibits less tail content, consistent with the more isotropic distribution of the biologic noise source. The measured array gain of 9 dB for both day and night is a little higher than theory predicts—mean array gain typically tends toward the directivity index (DI). In the case of OTA3, which consists of 16 elements, DI is 12 dB. The measurements in Fig. 10 are made at 330 Hz, which is nearly two octaves down from the aperture design frequency, giving a theoretical DI of 7.2 dB. This slight discrepancy is likely due to departure of the actual noise distribution from isotropic.

Figures 10 and 11 depict representative energy detection surfaces and scissorgrams computed from data collected during the cruise. They illustrate in bearing-time record (BTR) format the variation of the noise distribution over time as well as the frequency support associated with discrete interferers or other acoustic energy sources sampled by the array during the deployment. For these results, the data is processed using a 2048-point FFT with 50% overlap and a Hanning window to yield a window-corrected frequency resolution of 2.3 Hz. The energy detection BTR represents in-band power level in units of dB re 1 μPa^2 integrated over the band 100-1,000 Hz.

Figure 10 shows the detection surface (left hand panel) at 1800 GMT on 3 June, during a period dominated by a passing ship. The scissorgram (right hand panel) corresponding to this track illustrates the evolution in spectrum content along the ship track over time. Narrowband features are clearly present, as well as broadband radiated noise striated by coherently interacting multipath.

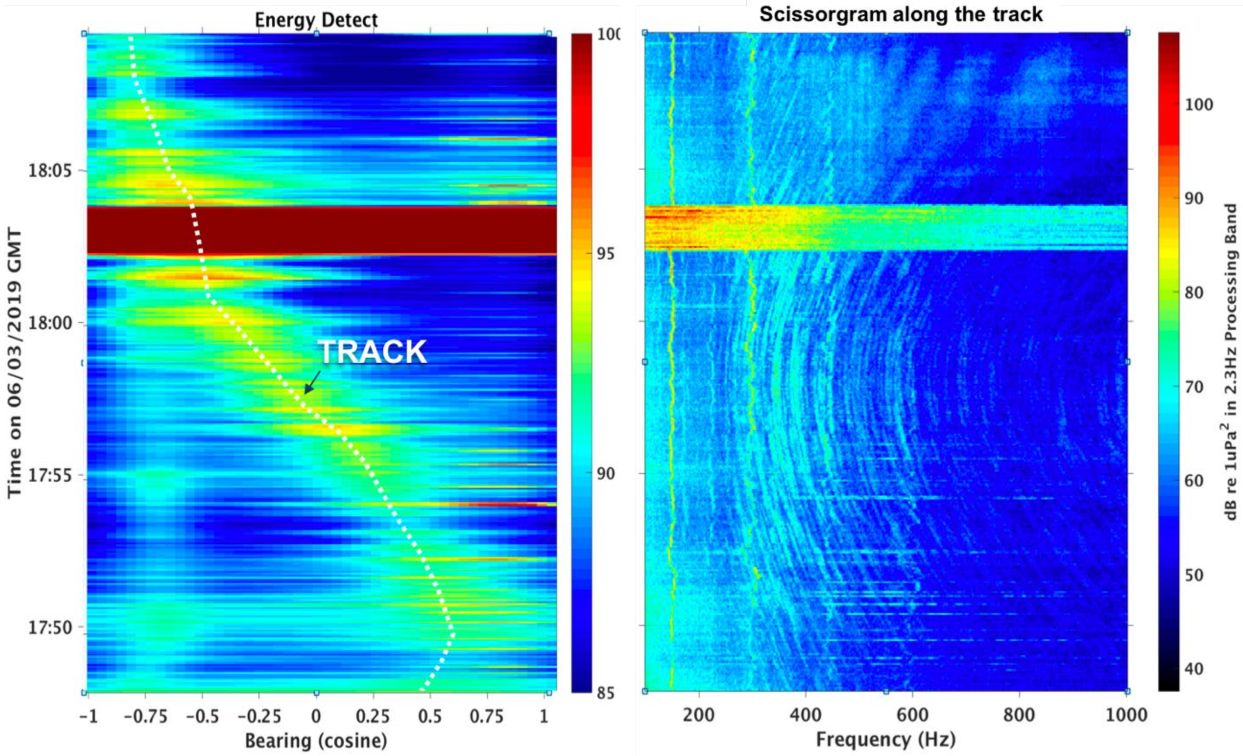

Figure 10 Energy detection BTR and scissorgram illustrating passing discrete interferer measured by OTA3 on June 3, 2019.

Figure 11 shows a detection surface and scissorgram at 0245 GMT on 4 June during a period dominated by biologic noise during the overnight hours. The lack of spatial structure of the noise field reflected in the energy detection BTR, as well as the uniformity of the broadband noise spectrum sampled versus bearing are consistent with the hypothesis of croaker noise as the dominant effect driving the ambient noise distribution during nighttime hours.

Post-analysis also revealed that the OTA3 array had two bad channels during this deployment as described in Figure 12. Inspection of the element-level power spectrum in the upper left panel shows that channels 9 and 10 exhibit harmonics of 60 Hz. The righthand panels illustrate the difference in broadside beam response when these two channels are excluded from the beamformer operation. The difference in theoretical beampatterns (at lower left) is included to illustrate that the exclusion of two bad hydrophones has a modest impact on beamformer sidelobe levels, but does not adversely impact the use of the array for measuring and understanding the spatial distribution of the noise field.

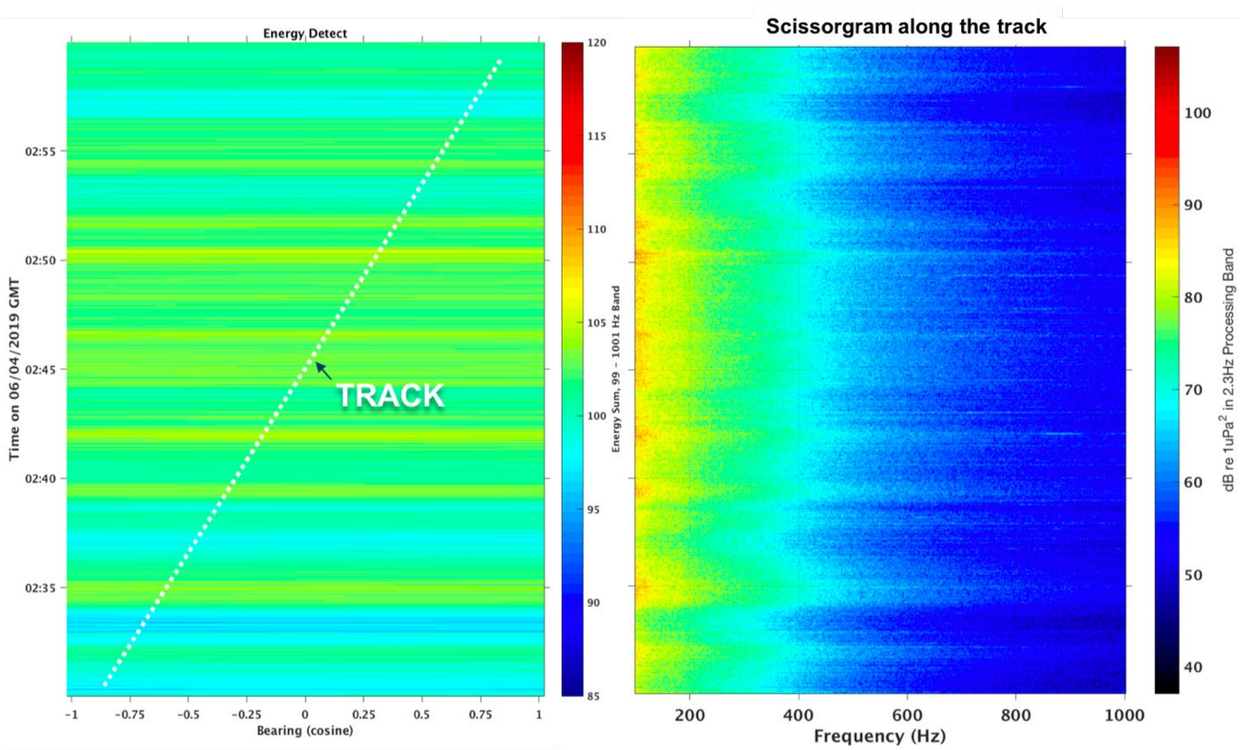

Figure 11 Energy detection BTR and scissorgram illustrating croaker noise measured by OTA3 on June 4, 2019.

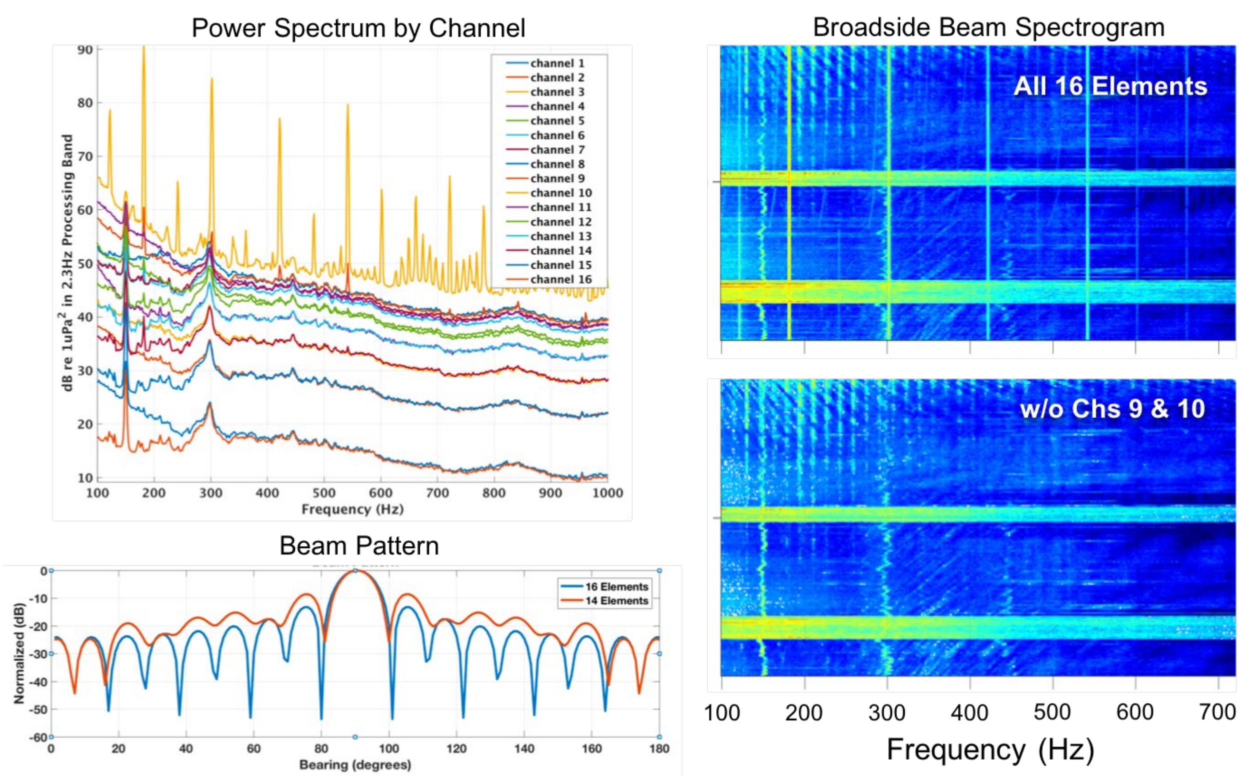

Figure 12 Element level power spectra showing bad channel response on elements 9 and 10.

5. Summary

This quick-look report summarizes a five-day acoustical survey conducted from June 3-8, 2019 on the U. S. east coast Outer Continental Shelf (OCS) in support of the BOEM Atlantic Deepwater Ecosystem Observatory Network (ADEON) program. The ultimate goal of this measurement and modeling program is to generate multi-year measurements of the natural and human factors that describe the ecology and soundscape of the U.S. east coast OCS.

Post-cruise data analysis has been performed to verify data quality and develop a preliminary understanding of the ambient noise distribution in the survey area. The analysis reveals the presence of several discrete interferers in the acoustic timeseries. The data analysis also reaffirms the diurnal dependence of low frequency broadband noise due to the presence of biologics during the nighttime hours.

References

[1] V. Premus, P. Abbot, M. Helfrick, C. Emerson, and T. Paluskiewicz, "Passive Sonar Performance Characterization and Transmission Loss Measurement Using a Calibrated Mobile Acoustic Source," The 2nd International Conference and Exhibition on Underwater Acoustics (UA2014), Rhodes, GREECE, 2014, 8 pp.

[2] Cato, D.H., "Marine Biological Choruses Observed in Tropical Waters near Australia," *J. Acoust. Soc. Am.*, 64 (3), September, 1978.

[3] Dyer, I., "Ocean Ambient Noise," *Handbook of Acoustics*, ed. M. Crocker, Wiley, New York, 1998.

Appendix A: Daily Operations Summary

All times in in Zulu. L = Z – 4

Monday 03JUN2019

0600 All members embarked aboard AQUA BOB. Safety, weather, and experimental plan discussed. The decision is made to deviate from the original navigation plan by taking the track in a counterclockwise direction to make the best use of available weather conditions. The first day underway was spent working out problems and finalizing experimental procedures. There were two three deployments of the array; one of which was followed by an immediate recovery because the depth sensors were not installed. In addition to working out the procedures for the scientific experiment, the crew worked to determine how to best trim the sails to make 1-4 kts through the water while the array was in tow. The Gulf Stream created a SOG of 5-7 kts. There were four CTD casts throughout the day. A 24-hour watch rotation was established. Watches were 6 hrs in duration and manned by two crew members at a time.

Tuesday 04JUN2019

0001 Sail configurations still being tested to make the speed within the parameters of the experimental design. Several different combinations of sails and reefs were tested. All onboard with sailing experience were challenged by creatively sailing as poorly as possible. The crew has been alternating between autopilot and hand-steering the vessel until it is certain that the autopilot is not detrimental to the acoustic data. 0053 Arrived at CHB. Wind direction necessitates maintaining a southeasterly course well past CHB to make a course for SAV. Winds and sea state increased through the early morning hours. 1418 Generator started; onboard batteries had been depleted to 53%. 1620 Array recovered to begin motoring. Spent most of the day motoring to be in position for a run on SAV. 2139 Arrive at the start of sailing point for the SAV array. 2155 The array is redeployed on track for the SAV mooring ~16nm south of SAV mooring. Noted that boat speed approaching 4 kts resulted in the array being too shallow; depth averaged 2.86 m. New target boat speed will be less than 2 kts. Throughout this deployment, the wind and sea state increased to be 2-3’ and 15-20 kt winds. Sail adjustments continued attempting to maintain boat speed at < 2 kts.

Wednesday 05JUN2019

0003-0018 Observed that the screws were not properly feathered and had been spinning for an unknown amount of time. Several attempts made to feather the screws by starting the engines; unsuccessful. 0200 Pass CPA with SAV mooring at 2.4 nm; maintained course for WIL mooring. Boat speed holding between 1.4-2.2 kts. SOG maintaining at 6-7 kts. Increased commercial shipping traffic noted on this leg of the tow. 1435 Generators turned on; ships battery status at 53%. 1548 Seas observed to be settling. 1.8 kt boat speed, 5.4kts over ground. 2140 Cross over WIL mooring with an 81’ CPA. 2204 Turned to west. 2220 Bonus leg with shelf break, attempting to cross multiple times. Four CTD casts conducted.

Thursday 06JUN2019

0200 Decision is made to secure the experiment. Wind and sea state were set to increase or be in a way that would be detrimental to crew health and safety through the night; not worth it for the bonus data. 0220 Array onboard; sailing for the Port of Charleston. Through the day of Thursday data processing and report began to be compiled. AQUA BOB was under motor for the majority of the day.

Friday 07JUN29019

1451 AQUA BOB safely moored at Patriots Point Marina; offload of crew and equipment completed.