OVERVIEW OF SEABED CHARACTERIZATION EXPERIMENT 2017

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Abstract: *An overview of the multinational, multi-institutional, multidisciplinary research project, the Seabed Characterization Experiment, will be presented. The project is focused on studying the acoustics of fine-grained ocean bottom sediments, and took place over the course of two pilot studies, in 2015 and 2016, and through a five-week-long, three-ship effort that was completed in April 2017. The location of the study is known as the New England Mud Patch, about 95 km south of Martha's Vineyard, Massachusetts, USA, in about 70 meters of water. The goals of the project are four-fold: (1) to understand the physical mechanisms that control acoustic propagation in fine-grained sediments, (2) to quantify uncertainties in the estimation of seabed parameters, (3) to correlate the observed horizontal variations in the acoustical field with the measured horizontal variability of the seabed and (4) to assess the performance of the resulting geoacoustic models, and inversion and statistical inference methods. These goals have been pursued by obtaining direct measurements and/or inferring the values of the following parameters: compressional wave speed and attenuation, shear wave speed and attenuation, seabed roughness and volume scattering, and seabed layering and gradients. An emphasis was placed on obtaining parameter values over a wide frequency band and on understanding both the deterministic and stochastic aspects of environment. Oceanographic data were collected to support both forward and inverse modeling efforts. This presentation will provide an overview of the project and its participants, and serves to further introduce this large-scale effort to the international underwater acoustics community. [Work sponsored by the US Navy Office of Naval Research and ONR Global.]*

Keywords: *sediment acoustics, statistical inference methods, geoacoustic modeling*

INTRODUCTION

Seabed Characterization Experiment 2017 is an international, multidisciplinary, multi-institutional research project that is devoted to the following scientific goals: (1) to understand the physical mechanisms that control acoustic propagation in fine-grained sediments, (2) to quantify uncertainties in the estimation of seabed parameters, (3) to correlate the observed horizontal variations in the acoustical field with the measured horizontal variability of the seabed and (4) to assess the performance of the resulting geoacoustic models, and inversion and statistical inference methods. The site of the experiment is in approximately 70 m of water, about 95 km south of Martha's Vineyard, Massachusetts, USA, in an area historically known as the New England Mud Patch, although the results of the present project indicate that the sediment is not composed of pure mud, but rather contains various proportions of silt, sand and clay. For simplicity, within this paper, the sediment within the experimental site is referred to as mud.

Two survey cruises were conducted in 2015 and 2016 in which detailed sub-bottom profiling was performed along with the collection of more than 200 sediment cores. In the 2017 experiment, which took place during March and April, three research vessels and more than a dozen principle investigators conducted several types of experiments, including impulsive and tonal source tows received on vertical and horizontal line arrays, and direct measurement of sediment bulk acoustic waves and interface waves. A broad overview of the measurements collected to date is presented here. To begin, the location of the site is shown in Fig. 1. Table 1 contains a list of participating institutes and POCs.

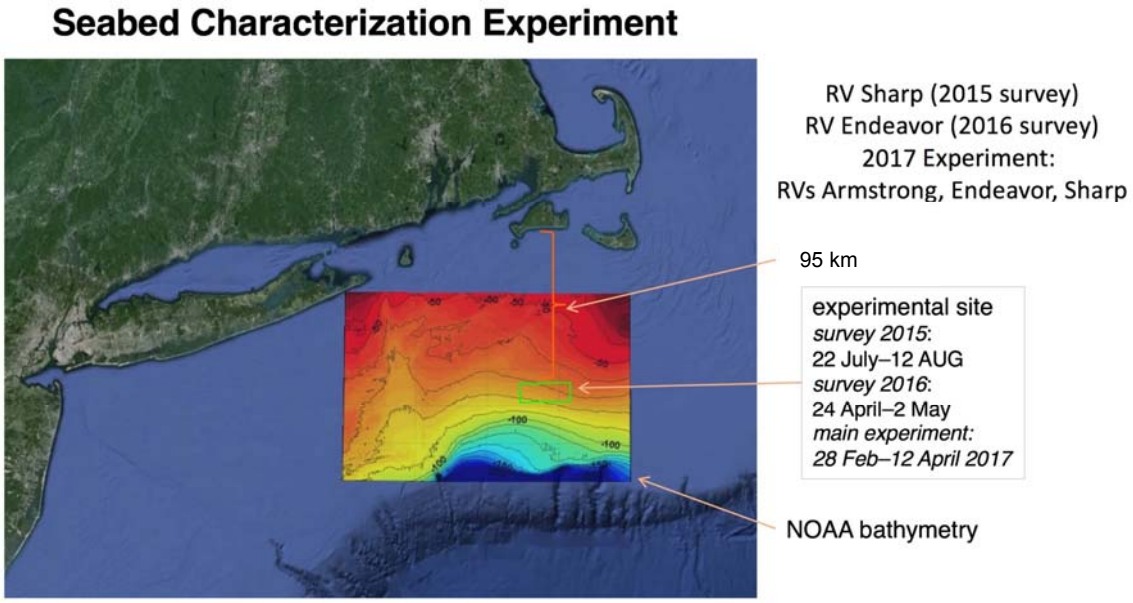

Fig.1: The site of the Seabed Characterization Experiment is shown south of the southern New England coast. The vessels that participated in various phases of the experiment are shown, along with the dates of the operations. NOAA bathymetry is also shown. The experimental site itself was within the green rectangle.

SURVEYS 2015 AND 2016: MUD THICKNESS MAP AND SEDIMENT CORES

One of the primary outputs of the 2015 survey was a mud thickness map produced by John Goff (UTIG) using a sub-bottom CHIRP profiler towed behind RV Hugh R. Sharp in July and August of 2015. A map that shows the thickness of the surficial mud layer is shown in Fig. 2. Several other layers are present, as is indicated in Fig. 3, which is a portion of a single E-W transect at about 40° 30’ N (the dashed line in Fig. 2).

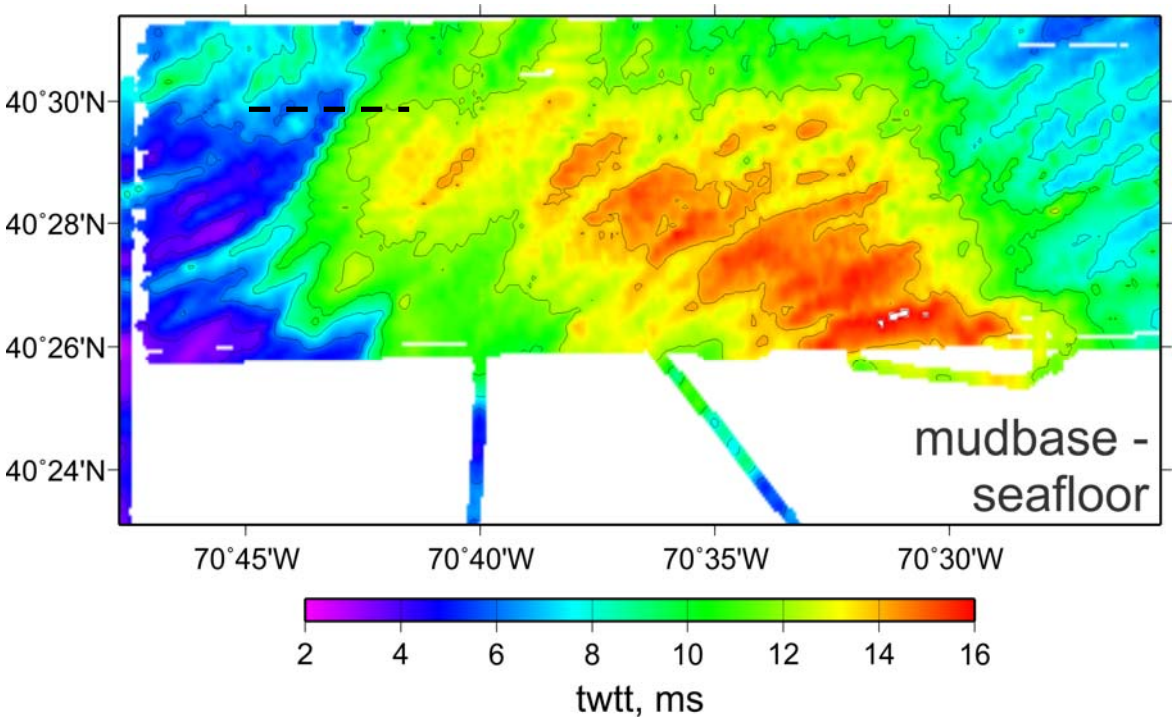

Fig.2: This figure is a close-up of the area within the green rectangle from Fig. 1. The colormap indicates the thickness of the surficial mud layer in units of two-way acoustic travel time (twtt) in milliseconds. Assuming a sound speed of 1500 m/s, the thickest part of the mud is approximately 12 m thick. The black dashed line indicates the location of the transect shown in Fig. 3. (Figure courtesy of John Goff.)

The dataset from which Figs. 2 and 3 were derived represent a spatial acoustic record of the sub-bottom that assists in setting the bounds on geoacoustic models of the site. The core samples taken during the 2015 and 2016 surveys provide a link to the physical nature of the sediments in those layers. Figure 4 shows a map of the experimental site that includes the locations where cores were obtained in the 2016 survey cruise. The twenty-five sites of the core sampling in 2015 are not shown to save space, but complement the 2016 core sites. For the 2016 coring, 53 successful piston cores targeting mud units were obtained, but they also sampled significant sand in some locations, and 25 successful vibracores targeting thin mud regions in order to sample sands beneath were obtained. For the 2016 cores, multisensor core logging was conducted by Allen Reed of NRL on the ship immediately after recovery. Reed did the core logging on shore after the 2015 cruise. The core logging provided measurements of density and high frequency sound speed as a function of length along the cores, to complement the two-way travel time CHIRP survey records. These together provide bounds on prior knowledge for future inverse and statistical inference analyses.

Oceanographic measurements, shipboard CTD casts, additional shipboard laboratory sediment acoustics measurements, ocean bottom imagery, sediment infauna assessment, bottom water collection, direct *in situ* sediment acoustic propagation measurements and some preliminary acoustic propagation measurements were also conducted during the two survey cruises.

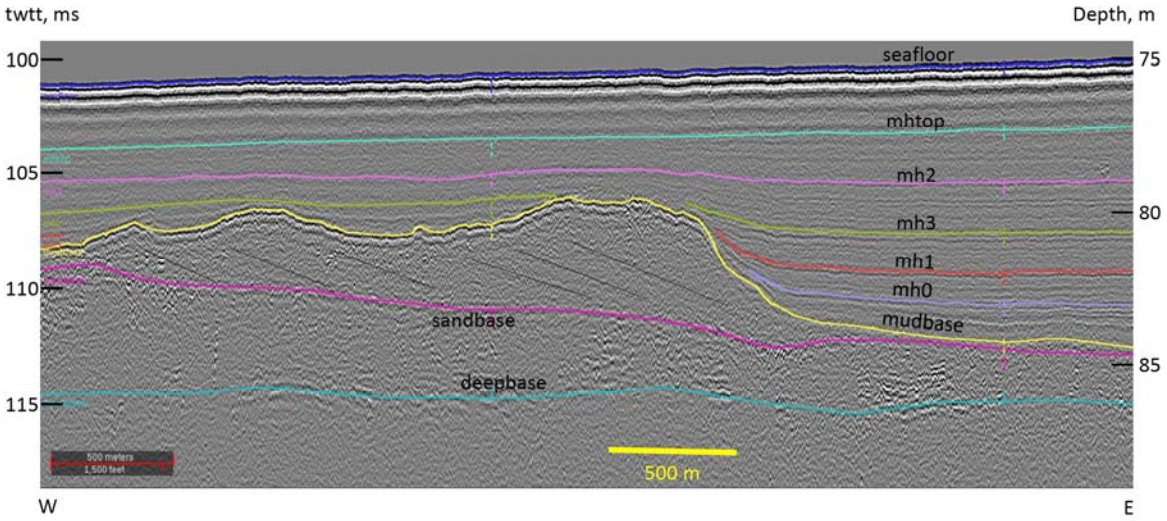

Fig.3: This figure presents the CHIRP survey line indicated in Fig. 2, along with horizon (layering) interpretation. The mud layer lies between the seafloor and the mudbase. A layer of sand is below that, followed by a deeper base layer.
(Interpretation and figure courtesy of John Goff.)

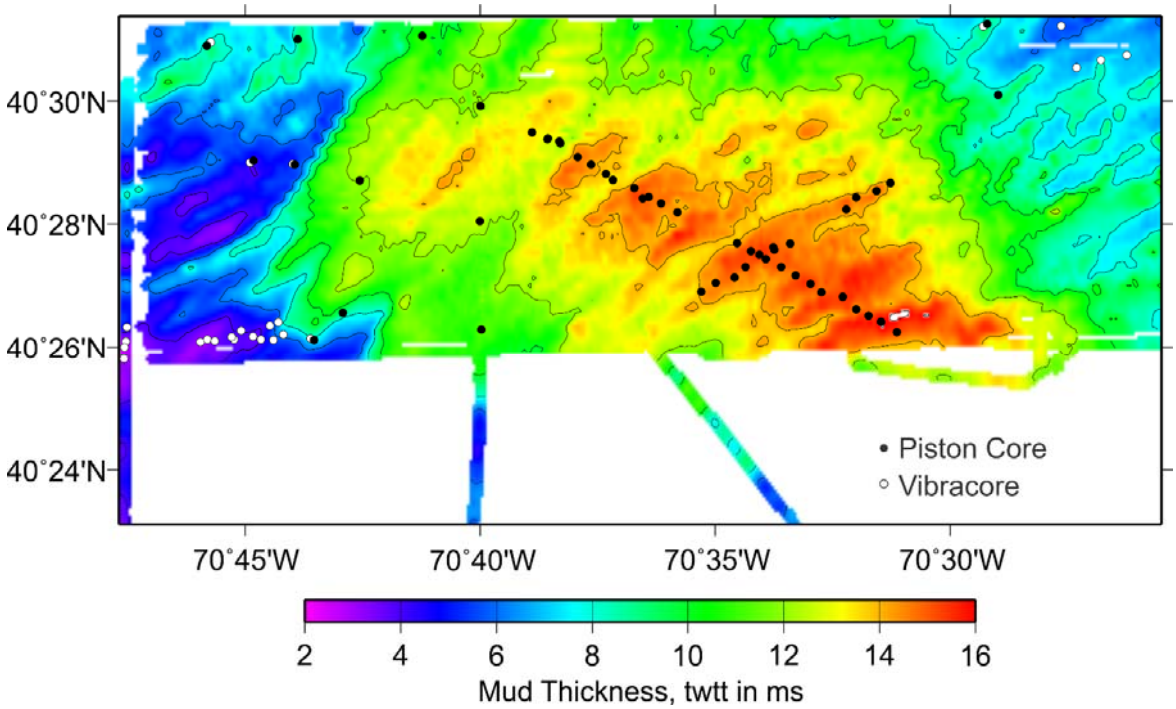

Fig.4: This figure shows the locations of the piston core sites (filled circles, obtained by USGS Jason Chaytor) and the Vibracore sites (open circles, obtained by John Goff UTIG) from the 2016 survey.

THE MAIN EXPERIMENT: MARCH AND APRIL 2017

The main experiment was primarily focused on conducting sound propagation measurements using both impulsive and tonal towed sources. Oceanographic measurements were also conducted to provide the necessary water column environmental model inputs. To this end, a number of moorings were deployed during SCE2017 and they are shown in Fig. 5 and described briefly in the Fig. 5 caption.

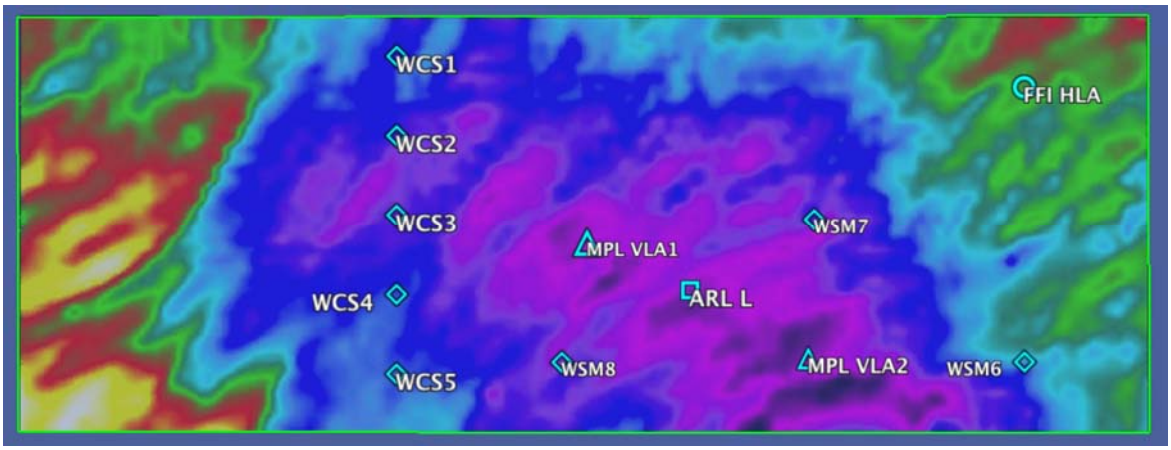

Fig.5: This figure shows the locations of the environmental and acoustic moorings deployed in SCE2017: eight oceanographic moorings (with labels that being with "W"), moorings WCS1, 3, and 5 include an acoustic Doppler current profiler, WCS2 includes a low frequency source, WCS4 includes a single hydrophone recording unit, and WSM6, 7 & 8 each include a low frequency source. Scripps MPL deployed two vertical line arrays (VLA). ARL:UT deployed an L-array. FFI deployed a horizontal line array (HLA). UDEL also deployed a vertical line array very close to the ARL:UT array.

The source tows were conducted throughout the experimental area and followed east-west lines, north-south lines, diagonal lines, and circular tracks centred on the ARL:UT array. A number of other measurements were conducted independently of the moored assets. These included, (a) Interface wave measurements conducted by The Univ. of Rhode Island, (b) Vector sensor measurements conducted by APL:UW, (c) Oceanographic and acoustic gliders deployed by CMRE, (d) REMUS AUV deployed by WHOI for physical oceanography measurements, (e) REMUS AUV with a towed line array deployed by National University of Singapore, (f) SAMS system for direct, broadband *in situ* measurement of sediment sound speed and attenuation deployed by APL:UW, (g) a normal incidence bottom reflectometer deployed by ARL:UT, (h) towed arrays and sources to conduct bottom bounce measurements deployed by ARL:PS, and (i) utilization of a ship mounted echo sounder to investigate oceanographic fronts conducted by WHOI.

SUMMARY

A broad overview of the field work conducted during Seabed Characterization Experiment was provided. This included a comprehensive sub-bottom CHIRP profile of the experimental area, about 200 sediment cores, and a number of direct *in situ* measurements of the acoustic properties of the seabed. These will come as close as possible to providing

ground truth knowledge of the layering, composition, and the acoustic properties of the sediment. Numerous acoustic propagation measurements throughout the experimental site will provide data for inversion processes and statistical inference techniques that will seek to remotely sense the acoustic properties of the bottom. The scientific plan of these measurements and the supporting oceanographic and environmental measurements is to allow the various principal investigators to achieve the goals outlined in the Introduction of this paper, and thereby greatly increase the community's understanding of the acoustic properties of the fine-grained sediment at the site. The experiment ended in April of 2017 and the analysis is underway at the time of publication.

ACKNOWLEDGEMENTS

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Table 1. List of participating institutions and associated points of contact

Acronym	Institute Name	Points of Contact
APL:UW	Appl. Physics Lab. Univ. of Washington	Peter Dahl and Jie Yang
ARL:PS	Appl. Res. Lab, The Pennsylvania State Univ.	Charles Holland
ARL:UT	Appl. Res. Labs, The Univ. of Texas at Austin	Preston Wilson
CMRE	Centre for Maritime Res. and Experimentation	Yong-Min Jiang
FFI	Forsvarets forskningsinstitutt	Dag Tollefsen
KSA	Knobles Scientific and Analysis, LLC	David Knobles
MPL	Marine Physics Lab., Scripps Inst. of Oceanography	William Hodgkiss
NRL	Naval Research Laboratory	Allan Reed
NUS	National University of Singapore	Venugopalan Pallayil
UDEL	Univ. of Delaware	Mohsen Badiey
URI	Univ. of Rhode Island	Jim Miller and Gopu Potty
USGS	United States Geographic Survey	Jason Chaytor
UTIG	Inst. for Geophysics, The Univ. of Texas at Austin	John Goff
WHOI	Woods Hole Oceanographic Institute	YT Lin