To: Dr. Robert Headrick, Office of Naval Research Code 321 Ocean Acoustics

From: David Knobles and Preston Wilson, The University of Texas at Austin

Subject: Report for the Seabed Characterization Experiment (SBCEXP) Workshop II

Table of Contents

1. Executive Summary

This report briefly describes discussions and decisions made during the Seabed Characterization Experiment (SBCEXP) Workshop II held at MANDEX, Arlington, VA, January 11–12, 2012. It is expected that an Office of Naval Research (ONR) funded survey will occur in April 2014 followed by the main experiment in April 2015. The Workshop accomplished two significant goals. First, two sites in the Gulf of Mexico off the south Texas coast were selected for the 2015 experiment. The *northern* site will be about 30–50 miles from the ports of Corpus Christi and Port Aransas and the *southern* site will be about 50 miles off the coast from Brownsville. The northern and southern sites have muddy and silty-sand sediments, respectively. Second, on the basis of individual principle investigator (PI) research plans representing 14 institutes, a draft experimental plan was created for the 2014 survey and the main 2015 experiment.

An FTP site is under development that will have presentations and measurements plans along with previous presentations, reports, and other relevant material associated with the seabed characterization experiment. The FTP site is located at http://ftp.arlut.utexas.edu. Once you have logged in (a username and password will be provided in a separate e-mail communication), go to priv/ESL/onrseabed. There, you can read and download files.

2. Introductory remarks by Dr. Robert Headrick, Office of Naval Research

The following paraphrases the main points made by Dr. Headrick in his opening remarks and in post-Workshop discussions.

Dr. Headrick made note of the Basic Research Challenge (BRC) and encouraged PIs to submit new high-risk ideas that are at the leading edge of science. Further, he noted that there is now a peer-review program for ocean acoustics that examines previous work.

Approximately one year from the experiment, an environmental impact study will be required. For the survey in April 2014 there should be a short record of consideration of environmental impact. For the main experiment in 2015 a much larger statement will be required. If the seabed characterization experiment occurs off New Jersey or north of the Hudson Canyon area in what is known as the mud patch, then it will be necessary to take into account harbor porpoises. The Workshops participants were reminded of the article, "Human generated sound and marine mammals," by Peter Tyack in Physics Today **62**(11), 39 (2009). Number density plots of harbor porpoises were shown for the upper New England coast. Also, number density plots of beaked whales were shown for both the New England coastal area and the Gulf of Mexico. It appeared from these number density plots, that with careful planning, the harbor porpoises would not represent a serious problem for the experiment. Nevertheless, these marine mammals would enter into the impact studies.

It will be necessary to make reservations for a *UNOLS* RESEARCH VESSEL (RV) in the spring of 2013 for the survey experiment and to make reservations for three RVs in the spring of 2014 for the main experiment.

3. Remarks by Dr. Stan Dosso and Dr. Eliza Michalopoulou on uncertainty and variability

One of the factors that makes geoinversion in ocean acoustics somewhat unique is the large degree of temporal and spatial inhomogeneity of waveguides in shallow seas. Acoustic propagation models generally do not capture this variability in a sufficient manner; i.e. we are plagued with the problem of model error. Attempts to increase the complexity of models to capture such variability can lead to large-scale increases in the size of the model parameter space. This has well-known consequences in the field of statistical inference. How does our group address this issue?

Stan Dosso and Eliza Michalopoulou discussed uncertainty and variability (their presentations can be found on the FTP site). It is expected that each PI funded for the experiment will give serious consideration to the measurements and analyses they propose and how they plan to address the issue of uncertainty and variability. The experimental plans should reflect the issues of uncertainty and variability.

4. Individual presentations

Several of the attendees of the SBCEXP Workshop II were not only representing their own interests, but also the interests of their institute and colleagues with whom they have scientific collaboration. Below is a list of researchers that presented material. These research scientists represent fourteen research institutions: 1. University of Victoria, British Columbia, 2. Florida Atlantic University, 3. Woods Hole Oceanographic Institute, 4. Marine Physics Laboratory, Scripps Institution of Oceanography 5. New Jersey Institute of Technology, 6. University of Rhode Island, 7. NATO Naval Undersea Research Center, 8. The Norwegian *Defence Research Establishment (Forsvarets forskningsinstitutt* – FFI*)*, 9. Naval Research Laboratory: DC, 10. Applied Research Laboratory: Penn State, 11. University of Texas at Austin [Applied Research Laboratories, Jackson School of Geophysics, and Dept. of Physics], 12. Portland State University, 13. Applied Physics Laboratory: University of Washington, and 14. University of Delaware.

4.1 Individual research plans presentations

1. Mohsen Badiey (University of Delaware) (presentations made by Lin Wan) *

2. Kyle Becker (NURC)

3. Ross Chapman (Univ. of Victoria)

4. George Frisk (FAU)

5. Peter Gerstoft (MPL) (includes discussions for William Hodgkiss (MPL) and Martin Siderius (Portland State))

6. Charles Holland (ARL:PS) (included discussions for Stan Dosso (University of Victoria))

7. David Knobles (ESL: ARL:UT)

8. James Lynch (WHOI)

9. Eliza Michalopoulou (NJIT)

10. Gopu Potty (Univ. RI) (includes discussions for James Miller (NURC))

11. John Preston (ARL:PS)

12. Dag Tollenfsen (FFI Norway)

13. Altan Turgut (NRL:DC)

14. Preston Wilson (ESL: ARL:UT) (includes discussions for Megan Ballard, Nicholas Chotiros, and Marcia Isakson)

15. Jie Yang (APL:UW) (includes discussions for DJ Tang)

* Due to time constraints the Badiey presentation was not made, however, the slides may be found on the FTP site and also the ideas of Badiey and Wan are contained in the draft experimental plan.

The Workshop emphasized the importance of experimental teams providing a rationale to their proposed measurements and analysis. For example, what parameters do they expect to measure either directly or infer from the acoustic measurements and what is the importance of determining these parameters? Which model representation of the seabed do these parameters support? How do these measurements support the basic scientific goals of the seabed characterization experiment?

Each potential PI submitted (post-Workshop) a document whose template was created by Gopu Potty and Ross Chapman (with input from Charles Holland) that gives the experimental technique that they plan to use and the seabed parameters that can be measured or inferred from the technique. Also included is the frequency band of the measurements. Models of the seabed that are mentioned include fluid, elastic, Biot-Stoll-based, and etc. *Microscopic* models such as a Biot model or grain-shearing models introduced by Buckingham deduce sound speed and attenuation from more microscopic parameters such as grain size and porosity. It was recognized that there does not exist an adequate microscopic model for muddy sediments. In contrast, *macroscopic* models such as fluid and elastic require an empirical inference of sound speed, shear speed, and attenuation from the acoustic measurements. Such models can be applied to both sands and muds. An example of such a parameter/model file is shown below (taken from A. Turgut). Prospective PI model parameterization files may be found on the FTP site.

Model Parameterization

Turgut

Parameter/ Mechanisms	Geoacoustic tomography	geoprobe
Sediment interface scattering	possible	no
Sediment volume scattering	no	possible
Compressional sound speed	yes	yes
Sediment density	possible	possible
Layering/sound speed gradients	Yes	Possible, small scale
attenuation	possible	possible
range-dependence	3D.	Yes
Shear	no	no
Sediment models	Biot, EDSM, MVF	fluid
Frequency band	1-4 kHz	5-100 kHz

Example model parameterization provided by the PIs.

Each individual who wants to participate in the experiment needs to submit a proposal to ONR. It is suggested that one should first submit a planning letter to the ONR OA group within the next year. Participation in this Workshop does not guarantee participation in the experiment, nor does non-participation in the Workshop guarantee non-participation in the experiment. For further details one should have direct discussions with the ONR OA team.

5. Site Selection

After a presentation and discussion led by John Goff and Glen Gawarkiewicz, the majority of Workshop participants recommended two locations off the south Texas coast for the SBCEXP. Figures 1–2 are concerned with the Gulf of Mexico South Texas shelf. There is a distinction between a northern versus a southern location. The northern location shown in Fig. 1 (off Port Aransas and Corpus Christi, TX) has a soft mud layer sediment that becomes thicker as the water depth increases. For example in previous experiments by Rubano and Frisk/Lynch in what has been referred to as the *Gemini location* the sediment thickness is on the order of 10 m in about 40 m of water whereas the sediment thickness is on the order of 40–50 m in about 100 m of water. The southern location shown in Fig. 2 (just to the north of Brownsville, TX) has a silty-sand patch of about 15 m thickness. The northern and the southern sites are separated by about 120 miles and thus do not pose any serious logistical issues for a recovery and a redeployment.

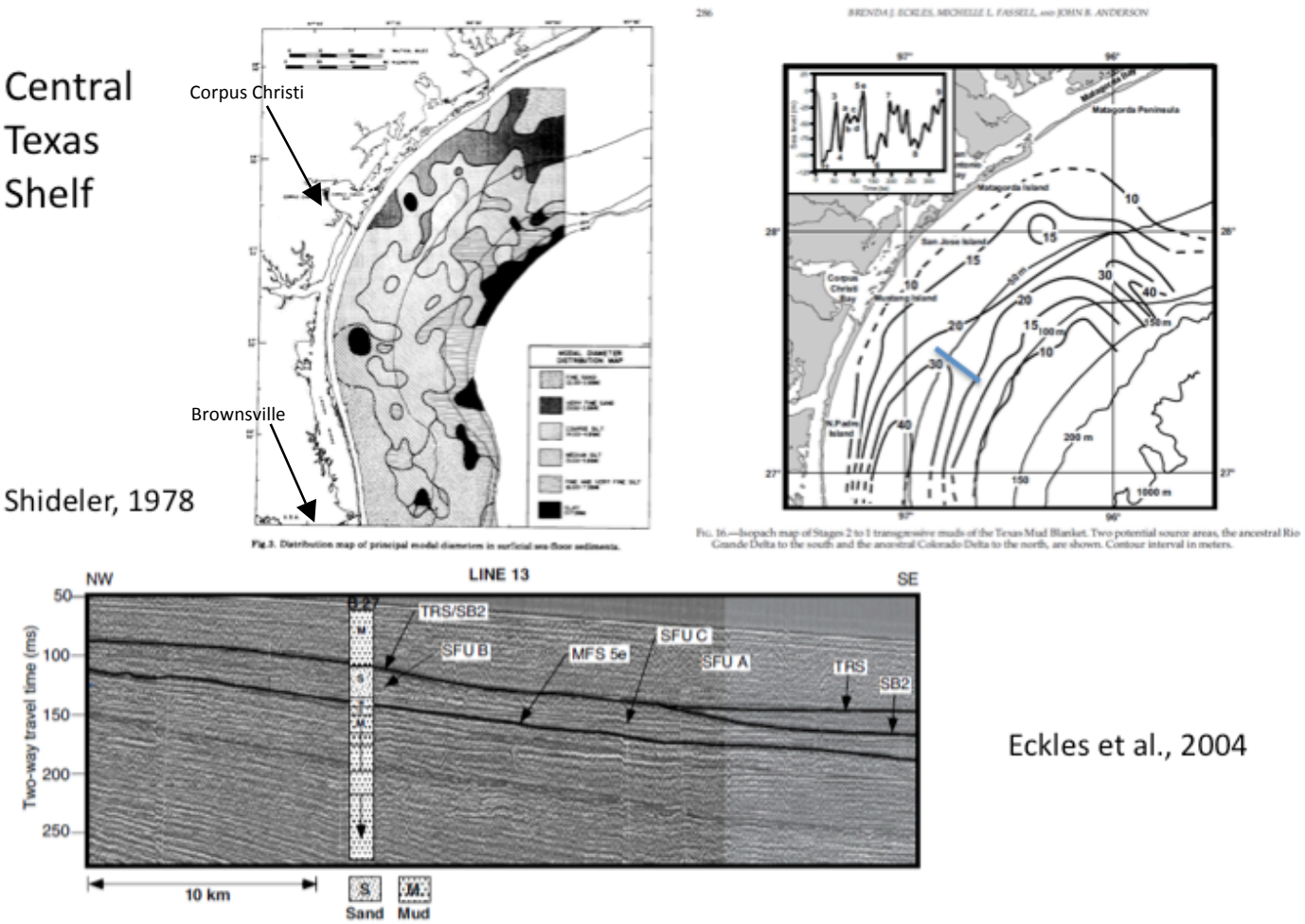


Fig. 3. Distribution map of principal modal diameters in surficial sea-floor sediments.

Fig. 16.—Isopach map of Stages 2 to 1 transgressive muds of the Texas Mud Blanket. Two potential source areas, the ancestral Rio Grande Delta to the south and the ancestral Colorado Delta to the north, are shown. Contour interval in meters.

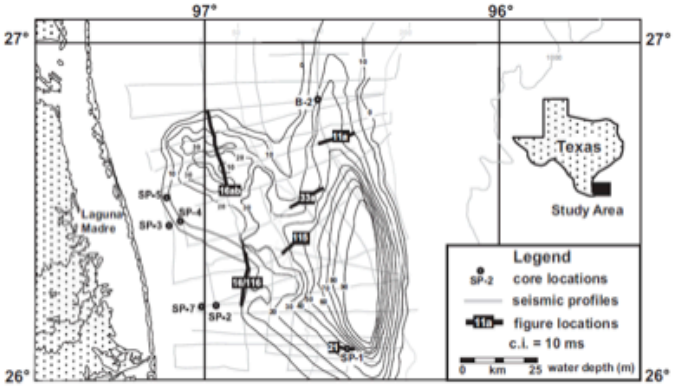
FIG. 6.—Dip-oriented seismic profile (Line 13) illustrating character of seismic facies SFU A, SFU B, and SFU C. Platform boring B-27 illustrates the muddy nature of SFU A and the sandy nature of the SFU B facies. See Figure 3 for location. MFS 5e = Stage 5e maximum flooding surface.

Figure 1: Northern Texas shelf site for soft silt sediment

Texas Mud Blanket
(southern sector)
Isopach

FIG. 17.—Isochron map of seismic unit Tst 4, which is interpreted as a hemipelagic mud blanket. Seismic lines 16ab (Fig. 17) and 3 (Fig. 18) are used to illustrate the seismic character of this unit.

Rio Grande Delta
Sands Isopach



Banfield and
Anderson, 2004

FIG. 10.—Isochron map of the Hst 2 and Hst 3 delta. Also shown are the locations of seismic lines, used to illustrate the seismic character of the delta, and the locations of platform borings that provide lithological information about the delta.

Figure 2: Southern Texas shelf site for sand and mud sediments

6. Draft Experimental Plan

A rough draft of a plan for both the survey in 2014 and the main experiment in 2015 were made by three focus groups on the 2nd day of the workshop. These focus groups included (1) direct measurements, (2) wide area long-range forward measurements, and (3) short-range forward measurements involving towed arrays and sources and bistatic reverberation from wide band sources.

(1) Direct measurements

In short, the survey experiment is designed to make direct measurements of the seabed and to also make an adequate number of physical oceanography measurements that provide support for the main experiment in 2015. The survey measurements provide prior information on certain seabed parameters for specific model representations and can also serve as ground truth (with the usual caveats).

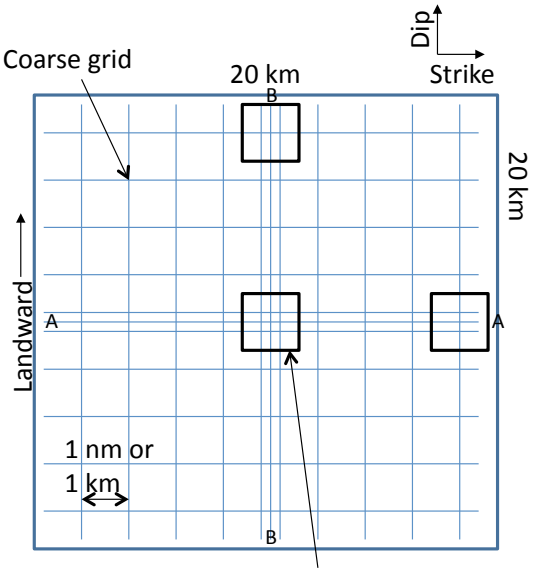
The survey measurements are made in two phases. In the 1st phase (April 2014) CHIRP surveys are made on a coarse grid along with physical oceanography measurements. Direct measurements of the sediment are made via cores and grab samples and various geoprobes. During the 2nd phase additional CHIRP and AUV bathymetry measurements are made in "focused boxes". Additional geoprobe measurements and coring are made as needed. Also, during the 2nd phase bottom roughness measurements and glider and AUV environmental measurements are made. Additional measurements in the form of Raman spectroscopy might be made to quantify sediment chemistry of the upper portions of the sediment. Environmental moorings (CTD chains, surface buoys, etc) will be deployed at this time.

Environmental Characterization Plan

Phase 1: Recon Spring 2014 (same time of year as main experiment).
-1 ship = R/V Sharp; 2 weeks + transit
-Coarse-grid chirp survey, ship-towed
-Gliders/Remus PO (best on Sharp = low freeboard, familiarity)
-Cores, grabs, geoprobe w/logging, grain size, etc.
-Multibeam (best on Sharp = transducer well)
~~~~~~

Phase 2: Spring 2015 w/main experiment
-Ship(s) TBD subject to overall logistics
-AUV-based bathy & chirp in focus boxes
-SAMS
-As needed: geoprobe and coring
-Roughness measurements/waveriders/XBTs
-Glider/Remus/moorings PO.
-Raman Spec, AIS logging
-Thermister strings w/CTDs, and bottom mounted ADCP in all focus boxes

Experimental Geometry
(x2: one for sand and one for mud sites)



3 focus boxes ~1 km by 1 km:
Location TBD after Phase 1

Exact location and orientation of focus lines A-A and B-B (which correspond w/tow lines) TBD after 2014 recon cruise.

Figure 3: Phase 1 and 2 Survey measurements. Same plan for both sites A and B.
~~~~~~

(2) Wide area long-range measurements

The acoustic measurements during the 2015 experiment are illustrated/outlined in Figs. 4–5. For both the northern and the southern site, an experimental area is selected (on the basis of Phase 1 survey) that is approximately 400 km^2 in size. The center location is occupied by an L-array (provider TBD), a large HLA (provided by FFI), and the URI geophone array. Three other arrays (VLAs and L-arrays) are deployed at distances of about 10 km from the centered arrays. In addition, there exist numerous drifting arrays and sonobuoys. Tow paths (for J15s, ITC250s, etc) coincide with deployments of impulsive sources such as the combustive sound source. Also, a circular tow and impulsive deployment path (radius TBD) is included. Random paths also serve the purpose of generating ensemble sets of measurements and sampling variability. The details of the time and spatial scale of these measurements remain to be determined.

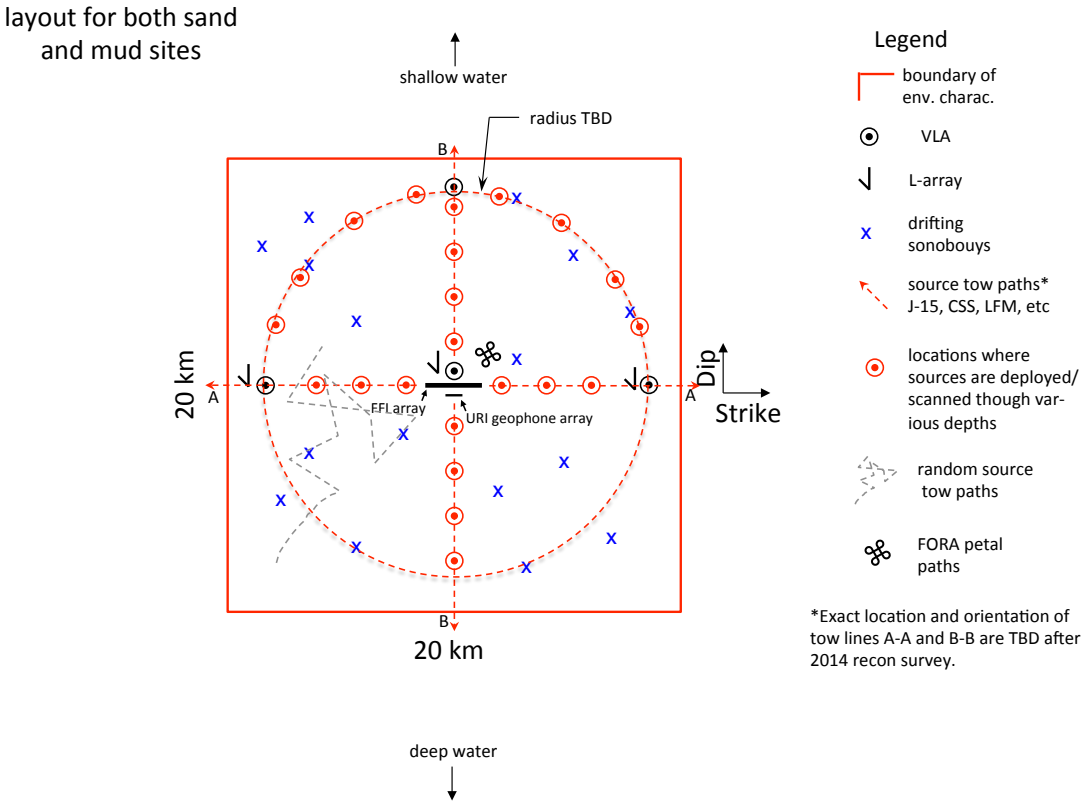


Figure 4: Experimental measurements using fixed and drifting arrays and sonobouys: Same plan for both sites A and B.

Many of these measurements will be designed to provide adequate data for sound speed and attenuation dispersion studies. It is useful to examine Fig. 4 along with the measurement parameterization files provided by the experimenters and analysts.

(3) Short range measurements with towed arrays and sources and reverberation

The FORA array and a source provided by NRL:DC allow for a variety of short-range measurements. Further, the combustive sound source (CSS) can serve as an additional wideband source. Both the NRL and the CSS source serve to generate reverberation fields that can be measured on the FORA array (monostatic mode) and on a bottom mounted fixed array (bistatic mode).

Another measurement type utilizing towed arrays is provided by towed arrays with Remus AUVs. WHOI can provide Remus AUVs. Both WHOI and ARL:UT possess towed arrays that can be driven by the Remus 100. There may be an opportunity for NURC to also provide an AUV towed array. Sound sources for these experiments would include the towed sources and sources that can be fixed to the AUV or deployed on the bottom.

Acoustic Measurements with towed arrays

1. AUV, Remus 100-1.5m, Remus 600-3m, DEX-3
    a. source + towed array
       700–5000 the WHOI source|array 36 elements 36 m / 16 elemnnts 16 m
       800–3600 the NURC source|array 32 elements 32 m, 128 elements?
    b. fixed source on bottom
    c. source + vertical array
2. Towed array (FORA), Gauss source (1.5–10 kHz), 1–3 days each site, 100–3750 Hz rcv
    a. wide area characterization
       (including bistatic src/rcv)
       CSS (0.01–3 kHz), NRL (1–4 kHz)
    b. direct path reflection/scattering, FORA, ITC (1–3.5 kHz), 3 days
       SWAMI for bistatic

Figure 5: Experimental measurements using towed arrays: Same plan for both sites A and B.

7. Appendix: Workshop agenda

Tuesday Jan 10

•8:00 am – 8:10 am Robert Headrick

•8:10 am – 9:00 am Knobles and Wilson lead discussion on scientific goals and what can be inferred/learned in the seabed characterization experiment?

•9:10 am – 9: 20 am Michalopoulou and Dosso discuss uncertainty and variability

•9:30 am –12:00 pm Individual experimental plans/analysis

•12:00 pm – 12:45 Lunch

•12:45 pm – 2:00 pm Complete individual presentations

•Break

•2:15 pm – 4:15 pm (Goff and Gawarkiewicz) Complete site selection

•Break

•4:30 pm – 5:30 pm Discussion of matrix of model parameters and measurements types

•5:30 pm adjourn

Wednesday Jan 11

•8:00 am – 10:00 am Generation of matrix of measurements types / model parameters

•Break

•10:00 am – 12:00 pm Merging individual/collaborative plans into draft Seabed Characterization experimental plan

•Lunch

•12:45 pm – 3:00 pm Strawman experimental plan discussion and link to measurement and parameter matrix

•3:00 pm adjourn