TASK 24: **Multi-frequency Seafloor Backscatter***: Undertake controlled experiments designed to understand the physical mechanism for seafloor backscatter at high frequencies (>100 kHz) commonly used on the shelf for mapping habitat, managing resources, etc. Explore the higher order statistics of backscatter (e.g., scintillation index) as potential aids to interpreting habitat, and to look at temporal changes in backscatter for a variety of substrates over a wide range of time scales. This effort includes the need for the collection of broadband, calibrated seafloor backscatter along with "ground-truth" measurements using stereo camera imagery, bottom grabs, and box cores (to examine potential contributors to volume reverberation).* PIs: ***John Hughes Clarke and Tom Weber***

Multi-Frequency Seafloor Backscatter

Center Participants: Ivan Guimaraes

NOAA Collaborators: Glen Rice and Sam Greenaway, HSTP

Other Collaborators: Anand Hiroji, USM; Dave Fabre and Rebecca Martinolich, U.S. Naval Oceanographic Office; Fabio Sacchetti and Vera Quinlan, Marine Institute, Galway, Ireland; Kjell Nilsen and Kjetil Jensen, Kongsberg Maritime; Lars Andersen and Jeff Condiotty, Simrad-KM

With the November 2019 announcement of the Presidential Memorandum on Ocean Mapping directly calling for characterization of the U.S. EEZ, NOAA's long standing efforts in seabed substrate identification have become a higher priority. To that end, using the mono-spectral seabed acoustic backscatter obtained from OCS's existing multibeam sonars, reasonable seafloor discrimination can been achieved. It is apparent however, that some seafloors that are strongly contrasting in physical character, do not show up as discrete using just a single scattering frequency. As a result, taking advantage of the wider band and multiple-multibeams now being installed on the NOAA OCS fleet (NOAA Ships *Thomas Jefferson* and *Nancy Foster*), this task investigates the improved discrimination potential achievable by using multi-spectral backscatter.

Whether mono or multi-spectral, a nationwide seabed characterization strategy requires that ship-to-ship measurements be repeatable. This raises the issue of consistency of reporting backscatter discussed in Task 22 and the long-standing problem of absolute calibration. To date, single platform measurements required extensive empirical shifting and local ground truthing. As a result, no two field programs provide equivalent measurements. With the advent of multi-spectral capability, this has only been compounded.

The seabed mapping vessels of the NOAA, NAVOCEANO and UNOLS fleet use an increasingly com-

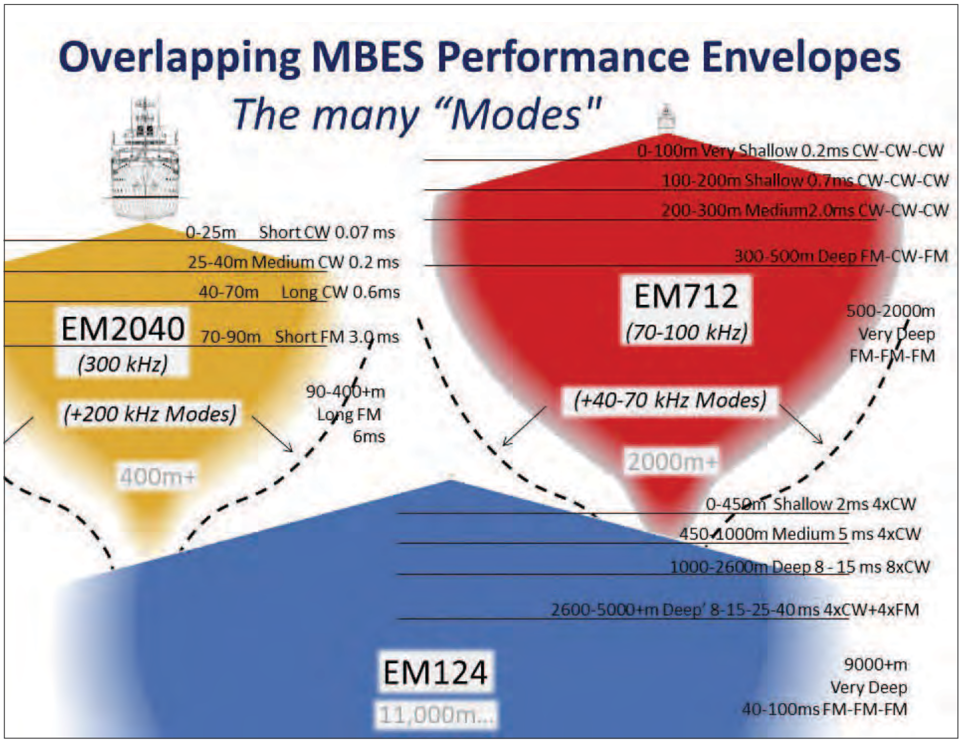

Figure 24-1. Showing the depth ranges and corresponding modes for the three common multi-sector multibeams utilized by the NOAA, NAVOCEANO and UNOLS fleets.

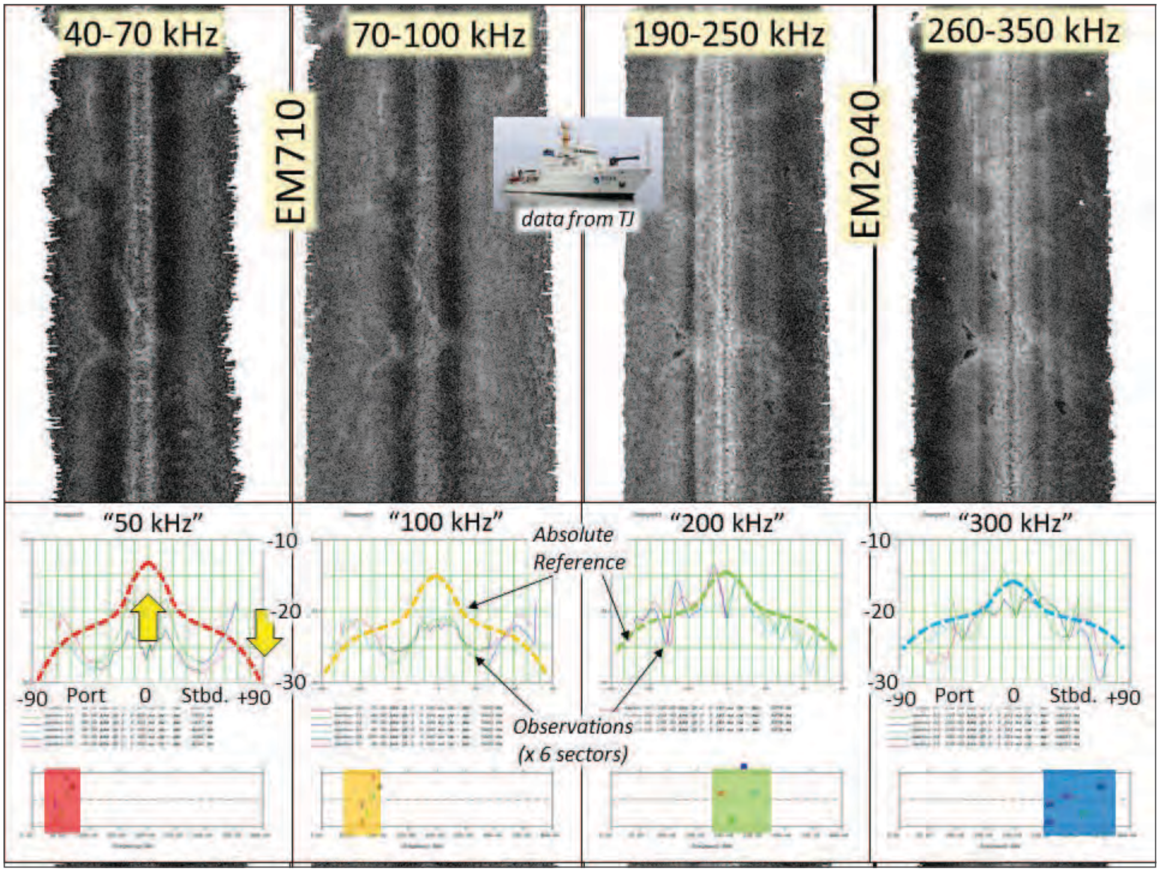

Figure 24-2. Showing the along-track beam pattern residuals (before correction) from EM710 and EM2040 data for their two main modes. For each mode, the average backscatter strength is sorted by sector and vertically referenced angle (sonar referenced for the 2040). The gross seabed angular response is already reduced using an empirical model. As can be seen there is over 5 dB of within-sector and inter-sector variability that is related to the beam pattern and not the seabed response.

mon set of sonars (Figure 24-1). The two main systems used on the continental shelf are the 40-100 kHz EM710/712 and the 200-400 kHz EM2040. Both these systems can be operated in discrete frequency bands (712 – 40-70 kHz and 70-100 kHz, 2040 – 190-240 kHz, 260-350 kHz and 350-400 kHz). For each of these frequency bands, slightly different center frequency and sector source level and beam patterns are employed as the depth changes (modes illustrated in Figure 24-1). All this severely complicates the calibration.

For each mode, there are specific beam pattern residuals unique to each sector (usually six operating per mode). The typical shape of these beam patterns is illustrated in Figure 24-2. These residual patterns overprint the true angular response curve resulting in ship track following (and sometimes rolling in the ship reference frame) residuals superimposed on the uncalibrated backscatter strength. While there are empirical methods to remove the gross shape of these residuals, even after reduction, the data are not tied to an absolute reference.

Absolute Broadband Seabed Backscatter for Multibeam Beam-Pattern Calibration: To address the need for absolute calibration covering the full range of frequencies used for shelf surveys (40-400 kHz), a field experiment deploying four EK-80 split beam systems was undertaken in June 2019. In 2020, the main achievement has been the processing and analysis of that broadband backscatter calibration experiment. This involved using FM chirps sweeping through 45-90, 90-160, 160-260 and 300-450 kHz respectively, thereby almost completely covering the frequency range of interest. Each of the transducer/transceiver pairs have to be separately calibrated over their full bandwidth. Once calibrated, those split beam sonars (5 degree two-way beam width) are then mechanically

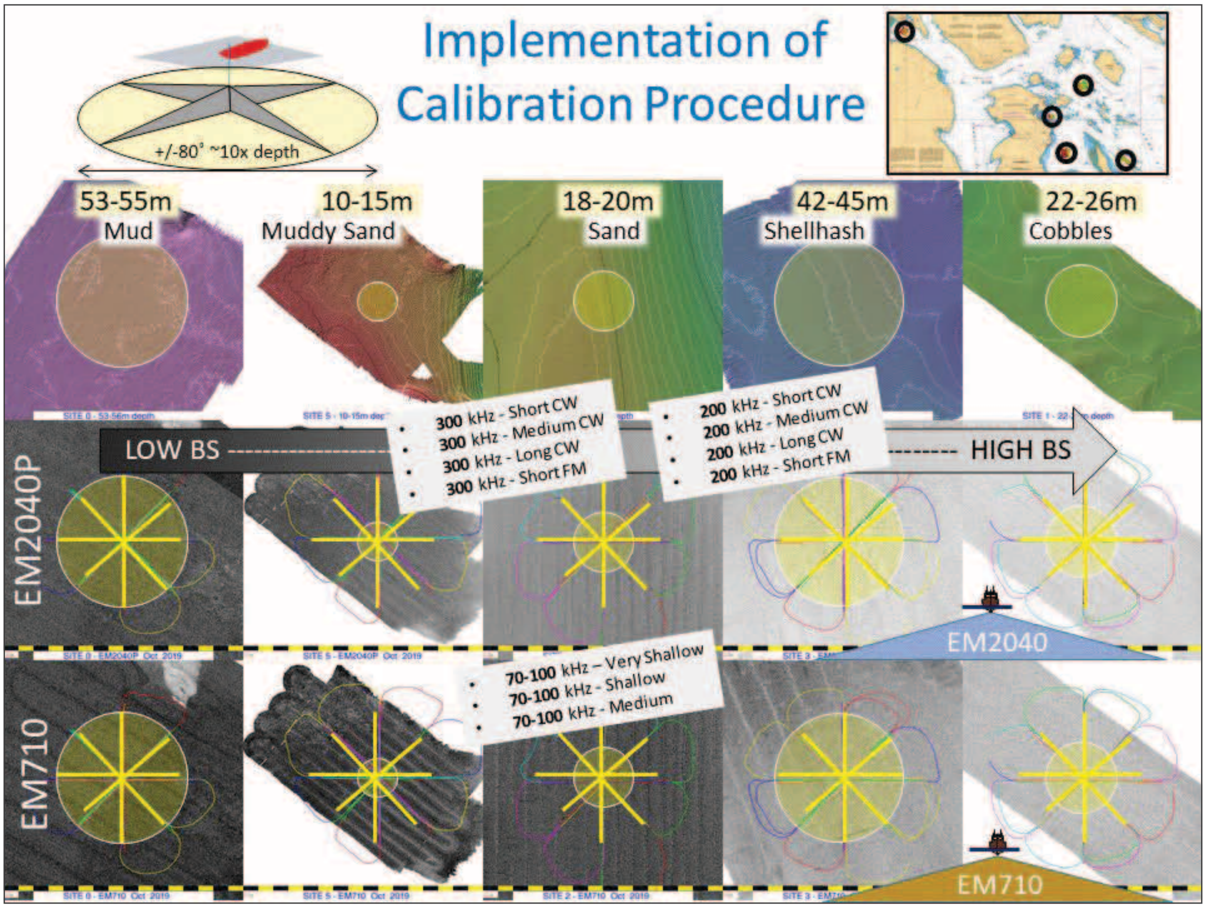

Figure 24-3. Showing Location, Bathymetry, Sediment Type and EM710/EM2040 backscatter for five backscatter calibration sites in British Columbia.

rotated to obtain bottom backscatter strength measurements over the range 90 to 10 degrees grazing.

To undertake calibration, suitable seabed sites have to be selected over which the calibrated sonars are deployed, after which the backscatter data from the desired multibeams of interest are collected. Five locations were selected in the shallow water around the Saanich Peninsula in British Columbia (Figure 24-3). The sites were selected because: they were logistically close to the Institute of Ocean Sciences, the Canadian Hydrographic Service's west coast operating base (home of the CSL Heron); the waters are well protected from open ocean sea conditions; the seafloors had all been previously surveyed by the CHS to identify areas of spatially homogenous sediments; and each of the five areas were chosen to be of significantly different sediment types.

After deploying the four EK reference sonars, the CSL Heron with an EM710 and an EM2040P under-took a radial pattern of data acquisition (Figure 24-3) going through all the common pulse lengths and center frequencies that they would employ on the continental shelf. This included the Very Shallow, Shallow and Medium modes of the EM710 and the Shallow, Medium, Deep and Very Deep (FM) modes of the EM2040 (at both 200 and 300 kHz).

For each of the five areas, first results of the absolute backscatter response over the full frequency range are presented in Figure 24-4. This work forms the recently defended MSc thesis of Ivan Guimaraes.

The sites chosen have widely different surficial sediment compositions (mud, muddy sand, sand, shell hash, and gravel/cobbles). Figure 24-4 shows the

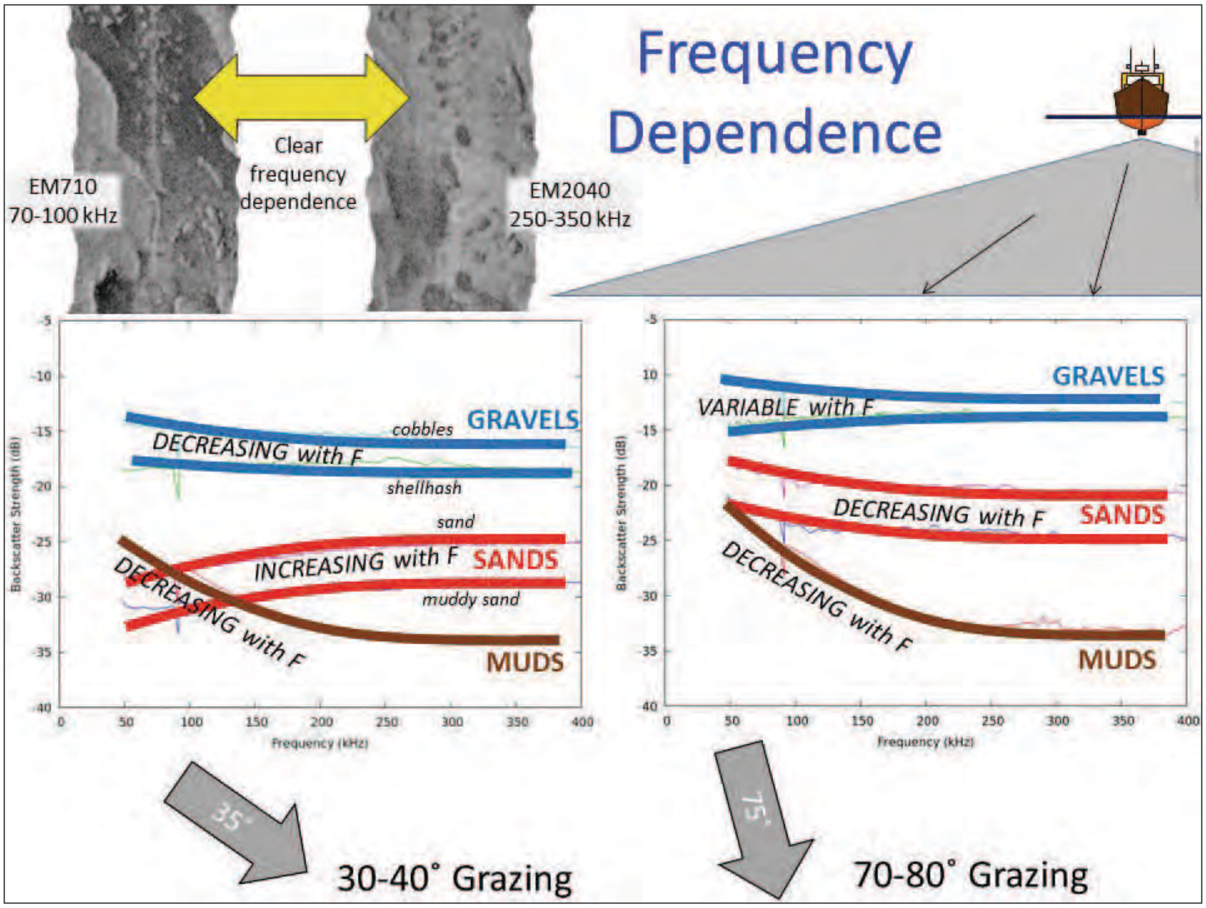

Figure 24-4. Showing Frequency Dependent Angular Response of the five discrete sediment types in the BC Calibration areas. Two grazing angles illustrated showing change in frequency dependence with grazing angles.

difference in the frequency dependence. The left-hand plot in Figure 24-4 shows the backscatter strength frequency trends at between 30 and 40 degrees grazing (just above the critical angle). For the roughest, highest impedance sediments, the backscatter strength clearly drops with increasing frequency. For the sandy sediments, in contrast, the backscatter strength generally rises with frequency, flattening though at the higher end of the frequency range. The muddy sediment uniquely has a much stronger frequency dependence, decreasing rapidly from 50 to 200 kHz. As the grazing angle increases, however, (Figure 24-4, right showing 70-80 degrees) the sand frequency trend reverses.

Future work beyond Guimaraes's thesis will be to compare these reference data to the EM710 and EM2040 data. Those comparisons will take place at the specific center frequencies of each of the six sectors of each mode (Figure 24-2). Should there be the opportunity in the future, it would be good to design a remote lowerable plate on which the EK sonars could be mounted so that the calibration can take place at deeper depths. Ultimately, the aim would be to establish a series of calibration sites in stable seabed areas close to NOAA operating areas.

COVID Impacts

All field acquisition and laboratory testing was curtailed. Fortunately, the main effort envisaged for 2020 was analysis and write-up of the BS calibration experiment. Only refinements of the calibration steps were not achievable since the Chase tank was not accessible.