Are calibrated MBES backscatter data necessary for the construction of mosaics that are both pleasing to the eye and useful for pinpointing changes in the character of the seafloor?

The answer is a resounding NO!

Construction of a high resolution, high quality backscatter mosaic starts with acquiring the backscatter data with a MBES that is capable of providing a set of densely spaced measurements of backscatter data over a wide range of amplitudes. It does not matter if the backscatter data are calibrated, or just "well behaved" such that a doubling in the received backscatter signal level results in a doubling of the numerical representation of the signal level. The truth behind that statement lies in the fact that in order to produce mosaics that are both pleasing to the eye and useful for pinpointing changes in the character of the seafloor, the backscatter must undergo several post-survey processing steps, one of which is designated as "normalization", or possibly the more descriptive designation of "cross-track normalization".

A large body of research has been dedicated to identifying, understanding, quantifying, and modeling the several physical phenomena that are responsible for cross-track variations in the amplitude of MBES backscatter. First and foremost; the dominate cause of such variations in backscatter is not the increased slant range from the sonar to different points on the seafloor, as the cross-track distance from the track line to those points increases. The two most important causes are: (1) the angle between the sonar beams and the perpendicular to the seafloor surface at those cross-track points is increasing as the cross-track distance from the track line to those points increase, and (2) backscatter from a natural seafloor exhibits a definite non-uniform angular response.

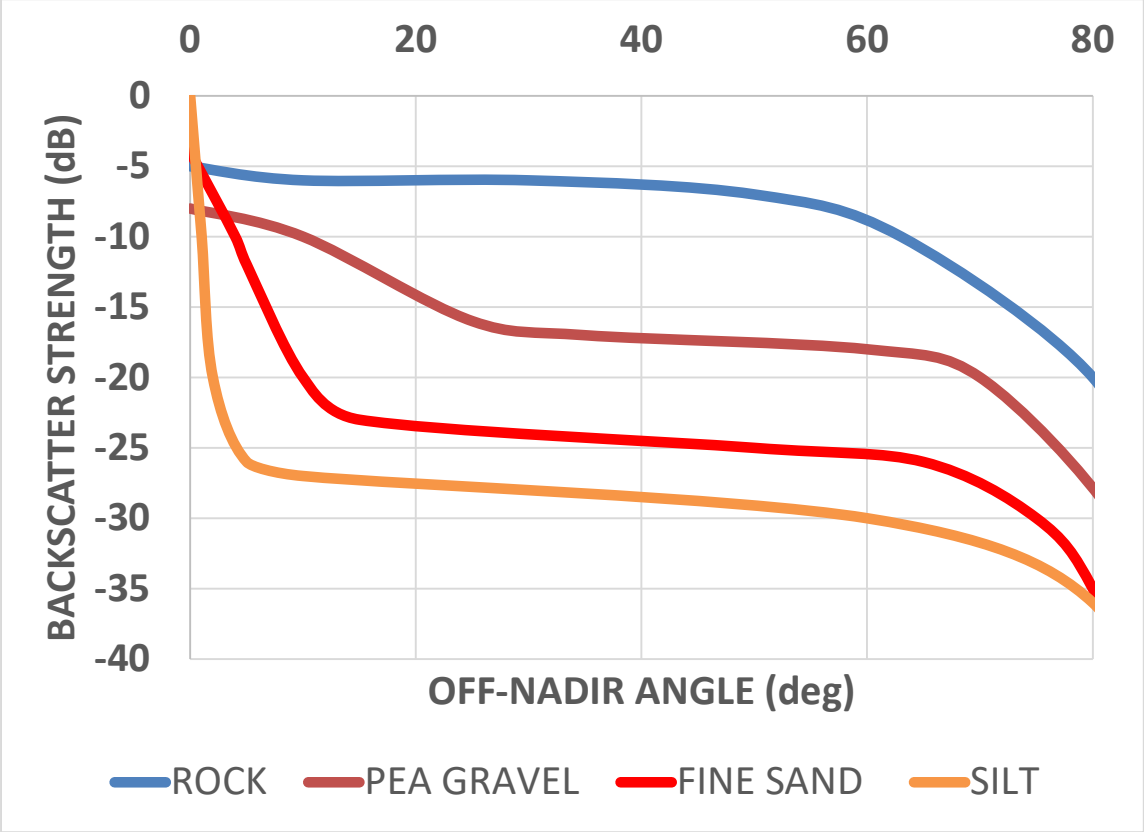
If a set of backscatter strengths were developed after applying all of the required system and radiometric corrections to the actual MBES measurements (aka "calibrated backscatter") from one installation, of one specific make and model of MBES, and one were to create a mosaic

based on the geographical (spatial) distribution of that set, the dependency of true backscatter on off-nadir angle would result in distinct strips throughout the mosaic, with amplitude variations appearing perpendicular to the vessel track lines. Such stripping in a mosaic significantly hinders even expert visual interpretation and makes it difficult to identify specific areas in the mosaic that may be associated with changes in the character of the seafloor. A similar result would also occur if the MBES backscatter was not calibrated, but was merely well behaved, because the underlying issue of the stripping would not be not whether, the backscatter data were calibrated, or not. The real underlying issue of the stripping would be the off-nadir dependence of backscatter from a natural seafloor.

Moasicking of MBES backscatter typically follows some form of "normalization" processing steps which are intended to remove the off-nadir angular dependence of acoustic backscatter, while retaining spatial changes in backscatter amplitudes that can be meaningful indications of changes in the type and morphology of the seafloor. *Ideally and unfortunately, directly removing off-nadir angular dependence of acoustic backscatter requires that one know much more information about the seafloor than is likely to be available.* However, to date, there are no universally accepted methods for making off-nadir "normalization" adjustments to MBES backscatter, whether the backscatter is calibrated, or is merely well behaved.

Nevertheless, proprietary algorithms, for removing off-nadir angular dependence of acoustic backscatter prior to constructing a mosaic are included in many commercial post-survey processing packages. Because the exact techniques are not disclosed, it is difficult to explain differences between commercial post-survey processing packages, when it comes to "normalization", "cross-track normalization", or simply "removal of off-nadir angular dependence of acoustic backscatter". However, despite the minor differences, each of the resulting mosaics might be described as being pleasing to the eye and useful for pinpointing changes in the character of the seafloor. It is important to remember that such results do not depend on whether the backscatter data are calibrated, or just "well behaved". The broad outline for "normalization" with the intent to suppress the impact of off-nadir variations in MBES backscatter from a natural seafloor for the purpose of constructing a backscatter mosaic is based on the regular manner in which backscattering amplitudes from a natural seafloor vary with off-nadir angle.

The following figure is a stylization of the off-nadir angular response of four different natural bottom types that might be encountered by a modern high-frequency MBES. That stylization depicts three different bands in the response curves. The first band is nominally between off-nadir angles of 0 and 20 degrees and is where the acoustic backscatter strength tends to be notably higher, compared to the other two bands. The acoustic/bottom interact mechanisms in the first band includes specular reflection and surface scattering and its width depends on the particulars of the seafloor. The primary acoustic/bottom interact mechanism in the third band is volume scattering, if it exists at the particular acoustic frequency employed by the MBES. In the third band, there tends to be a rapid fall-off in backscatter at off-nadir angles beyond 60 to 75 deg. The second band is predominately surface scattering and includes those angles between the outer edge of the first band and the inner edge of the third band. The second band is characterized as being a "central plateau" in the backscatter strength, where the scattering strength depends more strongly on particulars of the seafloor, than the specific off-nadir angle.



The broad outline for “normalization” assumes that over certain areas, which may include the entire survey area, or selected subsets of the MBES measurement swaths in a survey, the particulars of the seafloor are uniform and nominally represent the entire survey area. That assumption then provides a justification for using those data to develop a baseline angular response function for the particular MBES and the particular geographical location. Because the backscatter levels and off-nadir breakpoints in the baseline angular response function depend on the particulars of the MBES, the baseline angular response function also inherits a dependency on the operating acoustic frequency of the MBES.

During the actual normalization process for each swath (or a small number of sequential swaths) of MBES backscatter, the average level of the backscatter in multiple narrow angular subsections are computed and compared to corresponding narrow angular subsections of the baseline angular response function. The baseline function is subtracted from the nominal function undergoing normalization and the “central plateau” value of the baseline function is added to each of those differences. This scheme for normalization of MBES backscatter replaces the angle-dependent backscatter values with angle-independent backscatter values, while retaining a scaled semblance of any localized fluctuations in backscatter that may result from changes in the properties of the seafloor. When the resulting “normalized” swaths are employed in the construction of a mosaic, there may be faint stripes that remain. They result from the inherent uncertainties that arise from the assumption that the baseline function adequately represents the totality of the properties of the seafloor in the survey area. However, as previously stated, one can readily recognize changes in the character of the seafloor in a mosaic that has been constructed from normalized backscatter and because there are no glaring strips in the mosaic, it is pleasing to the eye.

A mosaic of normalized backscatter basically, albeit imperfectly, presents the spatial variations in backscatter strength within a specific set of survey data under the imaginary circumstance that each and every backscatter data sample represented in the mosaic was acquired at an angle within the “central plateau” in the baseline function.

About Lloyd Huff

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