Processing Workflow of Multibeam Backscatter Data from EM 3000 for Sediment Classification Analysis

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Abstract

A multibeam echo sounder signal carries not only information about sound-target relationship, but also it consider equipment and medium noises and influence, as expressed at the sonar equation. After subtracting these information, the backscatter is prepared to receive a correction sequence. This workflow includes geometric and radiometric corrections for the EM-3000 data. The final result is a model created by the angular response analysis for grain size classification at Geocoder 4.0 software.

Introduction

Current studies about the response of the Multibeam Echo sounder (MBES) show that besides a satisfactory bathymetry, due to its 100 per cent ensonification of the seafloor, it is possible to analyze the intensity response defined by the amplitude of the acoustic signal. This response called backscatter carries important information about the sea floor morphology and its physical properties. In the sonar equation (1) the transmitted signal is different from the received, due to acoustic losses and equipment, medium and target properties. According to Zietz and Elicker, 1995, using models for the backscatter intensity, it is possible to correct the intensity data for various confounding influences. Then, remaining variation in the data is due to the scattering material, both bottom sediment type and bottom roughness.

To achieve a reliable seafloor characterization, models should consider all these acoustic features following a processing workflow, and relate them properly with prior geological information. And the result is a more accurate backscatter mosaic representing seafloor properties. This further acoustic seabed classification will contribute significantly to both scientific research and ecosystem-based management of the marine environment. (Anderson *et al* ,2008)

Method

A multibeam sonar system uses sonar beams arranged in a fan shape, port and starboard, collecting echoes from the entire swath width as a ship advances. For each beam of each ping, the system reports depth and also the echo amplitude over time, or at least its maximum (Collins *et at*, 2002). In this work, was first used CARIS HIPS 6.1 to analyze bathymetric data and create a DTM. And Geocoder 4.1 software was used to process the backscatter. The example data analyzed were collected at Guanabara Bay (Figure 1) by EM-3000, that has a 300 kHz system with a beam width of 1.5°and approximate ly 120 measurements per ping. It has a depth resolution of 1cm, with an accuracy better than 5cm RMS, excluding external sensors. In typical sea water conditions, it has a depth range of more than 150m depth and a coverage sector of 130°. That allows 100% coverage of the bo ttom, when lines are well spaced, and vessel speeds is about 10 knots, with across track coverage of up to 4 times water depth beneath the transducers with a basic system. And with differential GPS, the system is capable of centimeter resolution with an accuracy of 10-15 cm.

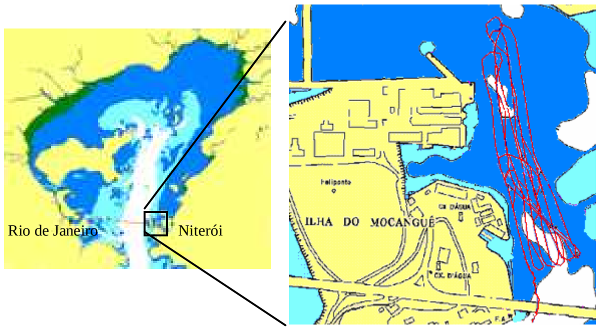

Figure 1: EM 3000 navigation lines in Guanabara bay.

Sonar Equation

The sonar equation (1) express the relationship between the transmitted acoustic pulse and received signal, considering influences of equipment, medium and target, forming the signal-noise ratio (SN). All of these parameters are expressed on a logarithmic scale in dB. (Lurton, 2004)

$$SN = SL - 2TL - NL + BS + DI \qquad (1)$$

The equipment parameters considered are the source level (SL) and directivity index (DI). Source level is a measure of the acoustic intensity. EM 3000 source level is 214 dB/µPa at 1 meter from the source. This parameter assumes that the acoustic energy spreads omnidirectionally outwards away from the source. However, as the acoustic sources are designed to focus the acoustic energy into a narrower beam in order to improve efficiency, this effect is accounted for in the sonar equations by the directivity index (DI), a measure of focusing, defined by the wavelength and the transducer diameter, for EM 3000 is150µS and 332m respectively. This property also concerns the beam pattern of the equipment.

The medium (seawater) is responsible for the attenuation of the acoustic signal caused by spherical spreading, absorption, defined as transmission loss (TL). The noise level (NL) is proportional to the bandwidth and consider medium and equipment influences.

Although seafloor influences the transmission loss, absorbing part of the signal (Mourad and Jackson, 1989), it has major importance on the backscatter strength (BS). This intensity value will depend on the seafloor depth and physical properties such as grain size, roughness and it respective angle response.

To achieve the correct relationship between the sound intensity and the real ocean floor features, it is important to consider not only the depth measured by the MBES, but all the variants according to the sonar equation.

Bathymetry

The bathymetric digital terrain model (DTM), was created at CARIS HIPS 6.1 software. The input data had a *.all format. The example data were acquired in the WGS-84 datum and a geographic coordinate system; however it was converted to UTM to create a grid for Geocoder. Navigation and the beam data were analyzed and eventual spikes, inconsistent values were eliminated. Then, tide values and sound velocity profiles were merged with the analyzed data. A DTM were exported as a *.xyz file to open in Geocoder.

Backscatter Analysis

According to Hamilton, 1980 a geoacoustic model is defined as a model of the real sea floor with emphasis on measured, extrapolated, and predicted values of those properties important in underwater acoustics and those aspects of geophysics involving sound transmission. In general, a geoacoustic model details the true thicknesses and properties of sediment and rock layers in the sea floor. To characterize this geoacoustic models of the seabed, it was used the Geocoder software. Geocoder 4.1 is a software developed by Luciano Fonseca from the Center for Coastal & Ocean Mapping, at New Hampshire University. It is designed to make fully corrected backscatter mosaics and calculate a number of statistics.

This work processing sequence is ilustrated at figure 2. As shown in the sonar equation, equipment and medium influences must be corrected to achieve only backscatter values. Calibration parameters reduced the influence of the equipment. And the medium spherical spreading that occurs when an acoustic signal propagates was corrected by a selected filter. With the only the backscatter data some geometric and radiometric corrections must be done for a more accurate mosaic and a reliable sediment classification model.

Mosaic Features

Anti-aliasing removes signal components that have a higher frequency sampling at a lower resolution. That algorithm allows the assemblage of mosaics at any required resolution (Fonseca and Calder, 2005). Also the speckle noise filter removes the light or black pixels created from out of phase wave interactions, preserving radiometric and edge information and spatial resolution (Mansourpour *et al*, 2006). Anti-aliasing and speckle removal algorithms were applied during the mosaicking, which allowed the assemblage of smaller mosaics while preserving general features.

Geometrical Corrections

Moustier and Matsumoto, 1993 defined the importance of high-resolution bathymetry, not only to determine the topography of the area surveyed, but to provide accurate bottom slope corrections needed to convert the arrival angles of the seafloor echoes received by the sonar into true angles of incidence. This geometric correction corresponds to a slant-range strip of backscatter imagery to its corresponding ground range. One possible method of performing this slant-range correction is to map portions of the time series between beam solutions on the seafloor. The intensity is logged for each beam and can be directly geo-referenced using the positioned beam footprint (azimuth and depression angle of the beam, along with two-way travel time (TWTT)). (Beaudoin *et al*, 2002).This is correction allows a more accurate visualization of the seabed, unlike the flat seafloor assumption as shown at figure 3. And final geometric correction is applied when a backscatter sample in the ship track coordinate system is mapped to a mosaic cell in a projection coordinate system. For that, the logged values of navigation, heading and attitude (pitch, row and yaw) are interpolated in time for each ping transmit time and reduced in space to the location of the transducer.

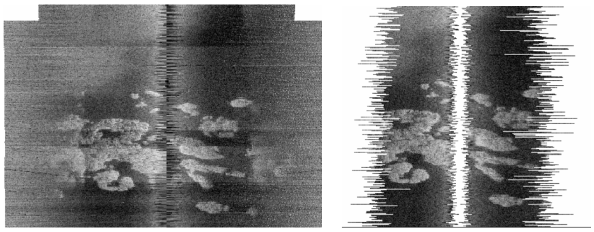

Figure 3: Flat seafloor assumption vs. slant-range correction with the bathymetric profile (on the left and right, respectively). (Beaudoin et al, 2002)

Angular Correction

The AVG (Angle Varying Gain) correction, compensates the amplitude values reduced by the attenuation of the signal with the distance, analyzing the angular response. The AVG Trend, applied in this data, consider not only the angle distance from the nadir but also the bathymetry, assuming uniformity across the swath and for a certain number of pings in the along-track direction (Figure 4). There is a more robust way of analyzing angular responses, by separating areas with similar angular response on the seafloor (defined as themes) and calculate one AVG table per theme, rather than across the sonar swath (Fonseca and Calder, 2007). But the 4.0 version of Geocoder does not divide the backscatter signal by themes.

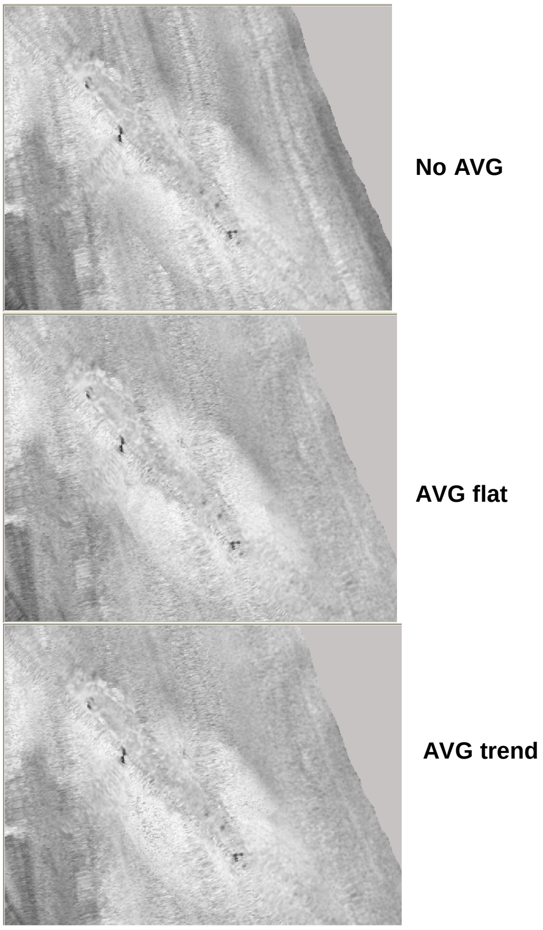

Figure 4: no AVG, AVG flat and trend. AVG correction improves mosaic data. At AVG trend, note a better boundary definition. Pixel size =0.20m.

Angular Response Analysis (ARA)

The analysis of angular responses improves our ability to characterize the seafloor, however its spatial resolution is limited to the swath width of the sonar. (Fonseca and Calder, 2007) The parameters extracted from the angular response curve are frequency, velocity, density, roughness, volume, grain size, tortuosity, porosity, permeability and loss and gamma factors. These features were analyzed into seafloor patches, which are defined as stack (average per angular bin) of 30 consecutive sonar pings, chosen to approximate the dimension of the swath width in the along-track direction. Then a formal inversion was accomplished adjusting model curves to the observed ones.
Statistics were calculated with a better spatial resolution then the model, so it is possible to compare ARA grain size model with the statistic results (Figure 6).

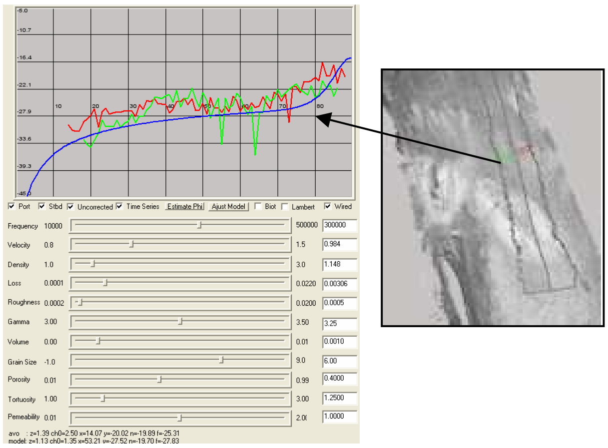

Figure 5: ARA patch window. It shows angular response at both portside (red) and stbd side (green), and the model (blue) with its wired parameters to adjust.

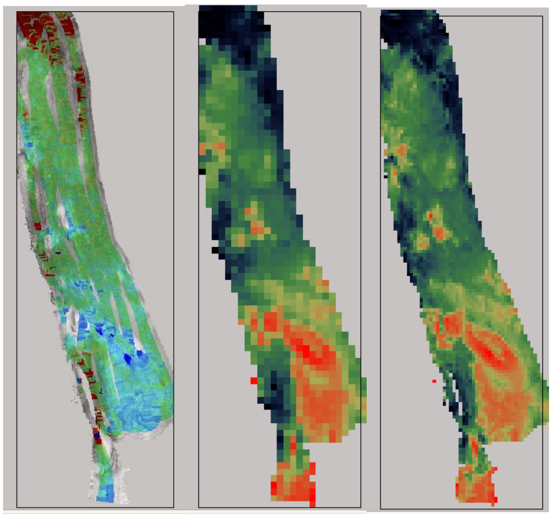

Figure 6: ARA grain size analysis (*phi*) with a 30 ping patch and statistic mean parameter with a 10 meter bin size and 5 meter bin size, respectively**.** Note that features are similar in ARA and statistics.

Results

The final mosaic exhibits low noise, while preserve regional data continuity and local seafloor features. Figure 7 shows the difference between a raw data and the improved after all corrections backscatter mosaic Sediment classification performed by ARA model correlates with geological interpretation and may further associates with benthic habitats, for example. (Anderson et al, 2008; Kostylev et al, 2001;)

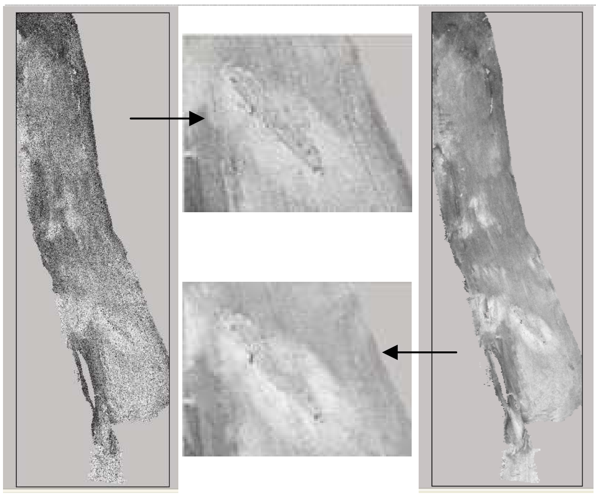

Figure 7: Raw data and the improved backscatter mosaic after all corrections backscatter mosaic, respectively. For huge impedance contrast, like this sunk ship, raw data identify better the contrast. However, for sediment classification analysis it is necessary to apply corrections.

Conclusions

A multibeam echo sounder signal carries not only information about sound-target relationship, but also it consider equipment and medium noises and influence, as expressed at the sonar equation. After subtracting these information, the backscatter value of the EM 3000 received a correction sequence. This workflow includes geometric and radiometric corrections. Then a model was computed by the Geocoder software and result data enabled grain size distribution. This processing workflow helps to apply all corrections linked to a logic and understandable sequence of processing steps. Final product carries important information about the seafloor morphology and its physical properties, which can help further studies of the marine environment.

Acknowledgments

Luciano Fonseca from the Center for Coastal & Ocean Mapping, granted a Geocoder 4.1 software license. Data used in this work were provided by Aluízio de Oliveira Junior from CHM (Centro de Hidrografia da Marinha) that is affiliate to DHN (Diretoria de Hidrografia e Navegação), a Brazilian navy organization.

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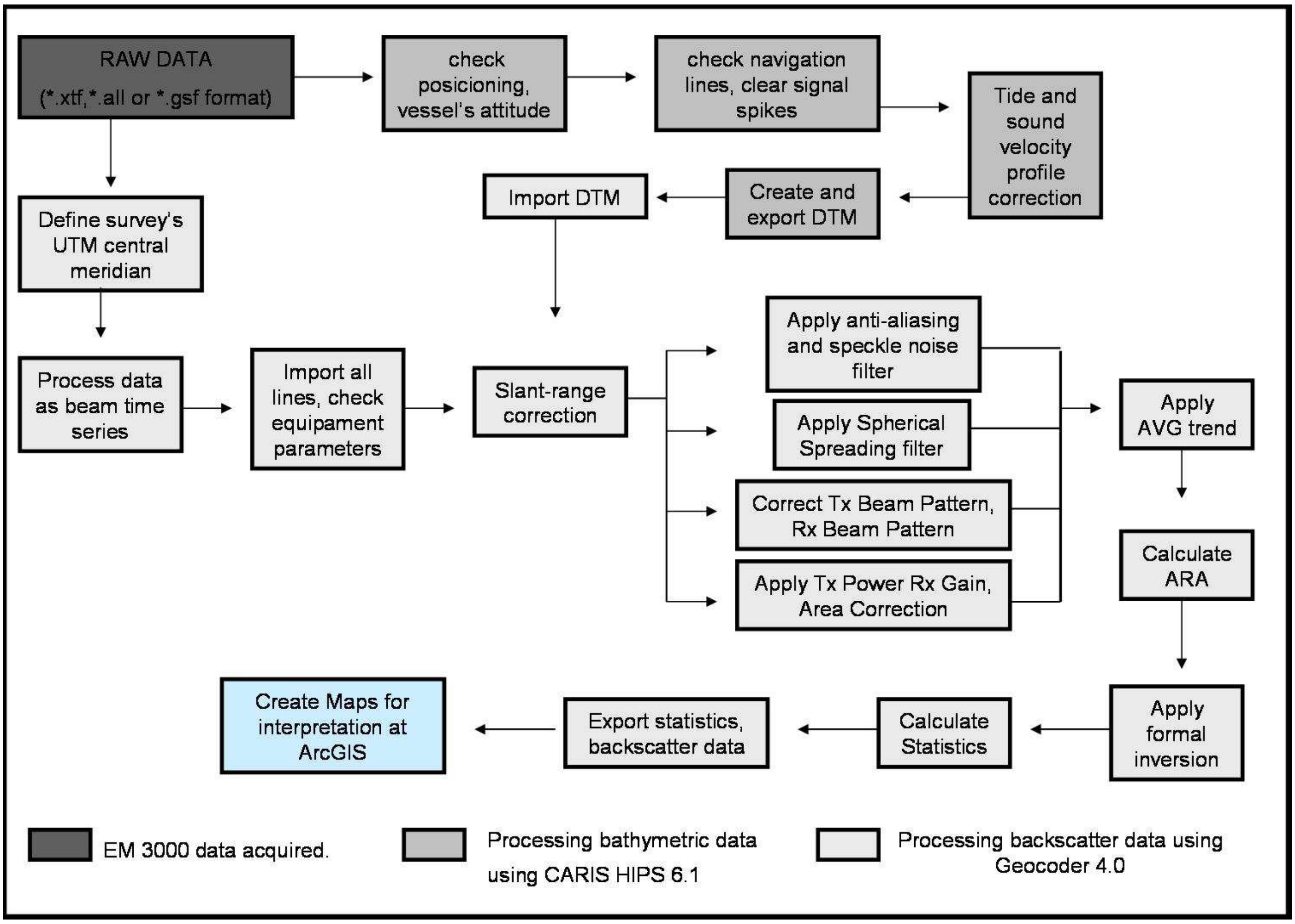

Figure 2: Processing workflow of multibeam backscatter data. Map creation at ArcGIS is important for further correlation with geology and/or biological data for studies of the marine environment.