Correlating seafloor sediment maps and sediment grabbed samples

Aluizio Maciel de Oliveira Junior (DHN and UFF)

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Abstract

The remote characterization of seafloor types through the processing of echosounder data is a useful geophysical tool, as it allows the reduction of required sediment grabbed samples within one survey area. While traditional sampling methods require ships to stop, the remote characterization solution allows more expedite data collection during ships transit.

Few programs are now commercially available in the market, which enables the processing of echosounder and sidescan sonar data, producing seafloor sediment maps. Software analyzes the backscatter intensities through different approaches (eg. image texture, seabed angular response, power spectral analysis, etc) and each approach can be performed with distinct processing configurations. The varied methods (approach and processing configuration) used for data processing generates different seabed map solutions.

In order to evaluate the most appropriate methods for data processing, a quantitative analysis is being performed. Then, seafloor characterization maps are being correlated to sediment grabbed samples, in order to determine their agreement. Software termed SEDIMAP has been developed in this study to automatically perform this correlation task, which is described in this article. A chosen dataset with multibeam echosounder data and sediment grabbed samples, collected inside Guanabara Bay-RJ-Brazil, will be presented.

Further studies are being developed using the same correlation methodology for other datasets, using both singlebeam and sidescan sonar data, which have already been collected in the same survey area. All datasets are going to be processed with different commercial software and using distinct processing configurations. Plans are to define reliable solutions for data processing, in order to produce remote characterization sediment maps that reasonably represent the seafloor.

Introduction

Seafloor sediment classification is required in support to several marine activities. It has applications for both civilian works (eg. dredging) and military works (eg. mine warfare operations).

Traditional methods used to characterize the seafloor types require seabed sediment grab sampling, which normally are very time consuming, as ships need to stop to perform this operations. In addition, these traditional methods provide seafloor information just for the point where sample is collected.

Remote characterization of seafloor sediments can expedite seabed mapping, as data is collected while ships are running their survey lines. An entire coverage of survey area can be undertaken in lesser time than using the traditional methods. Therefore, remote sediment characterization can be a powerful tool.

Few programs are now commercially available in the market, which has been developed to perform seafloor sediment characterization. For singlebeam data processing, programs (eg. QTC impact, Roxann, etc) utilize echo-character shape to extract seabed information. For multibeam and sidescan data, programs (eg. QTC multiview, Geocoder, etc) can use several approaches. One example is the textural method (Pace and Dyer, 1979), which analyzes the gray-level intensities distribution within the backscatter mosaic image. Other example is the angular response analysis (Hughes Clarke, 1997 and Fonseca, 2008), which correlates received backscatter signal with modeled backscatter (Hamilton, 1974 and Jackson and Richardson, 2007). Besides these two approaches, there are few more described in several articles about this subject (Oliveira Jr, 2007).

Analyzing data with different software normally results different solutions, which are represented through distinct seabed maps. In addition, while using the same software, but with different processing configurations, one also can get distinct maps after analyzing the same dataset.

In order to perform studies, a test area has been established inside Guanabara Bay-RJ-Brazil, where classification software has been evaluated using different processing configurations. Several surveys have been performed within the test area, when singlebeam, multibeam, sidescan sonar and Van Veen sampler were used for data collection. In this article, only multibeam processing software is demonstrated, but it can exemplify the methodology established herein for correlating the seabed classification maps with Van Veen sediment samples. A specific algorithm termed SEDIMAP has been implemented for automated correlation, allowing quicker data analysis.

Further studies are being performed using the same methodology for the other datasets, including singlebeam and sidescan data. All datasets are going to be processed with different available commercial software and using several processing configurations. Plans are to define the most reliable methods for data processing, which would produce remote characterization sediment maps that reasonably represent the seafloor.

Ideally, these seabed maps should be correlated with sediment samples database, allowing better definition of border limits between different sediment areas. The Directorate of Hydrography and Navigation (DHN) has more than 35.000 sediment sample information stored in a database, which would be very useful for improving sediment maps for several areas in Brazil.

Multibeam processing with different configurations

In this article, only QTC multiview is used to exemplify methodology established. But, plans are to perform the same tests with other available software in the market.

This specific software uses four main steps (Preston et al. 2005) for multibeam data processing:

a) Backscatter signal compensation, where radiometric and geometric effects are reduced.

b) Build the classification boxes, which are regular sized boxes where pixel intensities are analyzed inside them. The several features calculated by this analysis build the full-feature vector (FFV) for each box.

c) Performs principal component analysis in order to establish the three more representative features, which are used to segment the different seafloor types. Similar seafloor types theoretically are grouped as having the same feature characteristics.

d) Build sediment geographical maps, where the same sediment types are represented using the same color.

While accomplishing the steps previously listed, users are able to apply different processing configurations. For example, when performing the step B, classification boxes can be defined with different sizes, as showed in Figure 1. This image presents a survey line backscatter strength represented in gray-level intensities. Four box-sizes (~1.5m, ~3.5m, ~6.5 and ~13m) were used, which are represented in the images in green color (starboard) and red color (port).

Notice that bigger boxes are able to group more pixels. While performing pixels analysis inside this box, one FFV will be generated for this large area box. In the other hand, smaller boxes are able to generate many FFV for the same geographical area. Therefore, smaller boxes would be able to define smaller seabed structures. But, theoretically, bigger boxes should allow more robust statistical analyses. In the manufacturer website, there is a hint explaining that box sizes need to be configured according to the geological feature required to be detected.

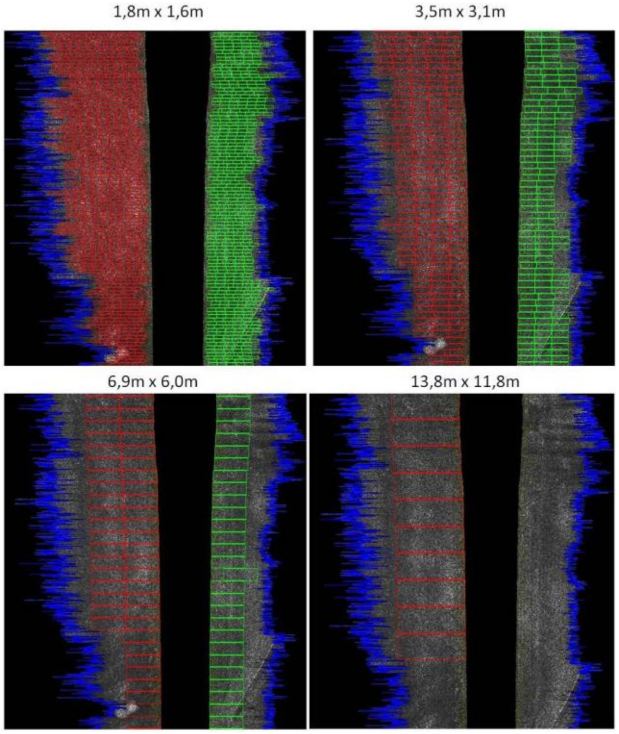

***Fig. 1 –** Building classification boxes with different sizes.*

In the test area where this experiment has been performed, it has been observed that different box sizes produce distinct seabed maps, as showed in Figure 2. Each color in the images represents a particular sediment type or class. From left to right are presented the seabed maps generated with box-sizes ~1.5, ~3.5m and ~6.5m respectively.

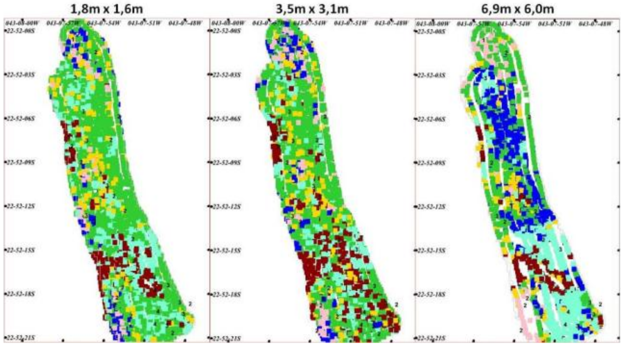

***Fig. 2 –** Seabed maps built with different box-sizes.*

Seafloor maps and sediment samples comparison

A total of 36 Van Veen samples have been collected within this same test area. Samples have been analyzed in laboratory, where their properties (eg. grain size) were defined. After cataloguing their properties, they could be correlated with the seabed maps. Idea was to evaluate which map should better represent grabbed sample distribution, performing a coherent agreement between their information. Figure 3 represents the geographical locations of sediment samples which have been plotted against the seafloor map. The percentage of each sediment grain size is also represented in the graphical area.

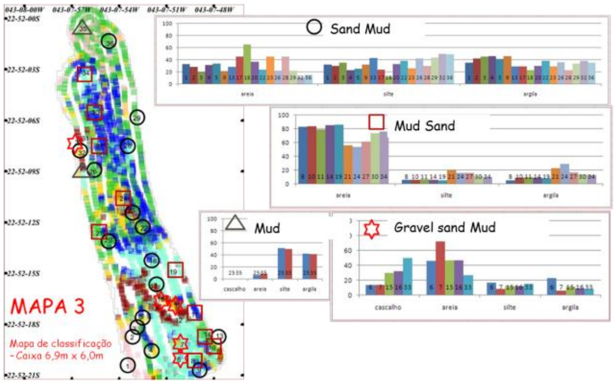

***Fig. 3 –** Correlating one seafloor map with sediment samples.*

After performing the same correlation studies with other maps, comparisons have been performed to define which map presented the best agreements. As showed in Figure 4, in this situation, the map 1 (built with ~1.5m boxes) presented better results than the map 2 (built with 3.5m boxes).

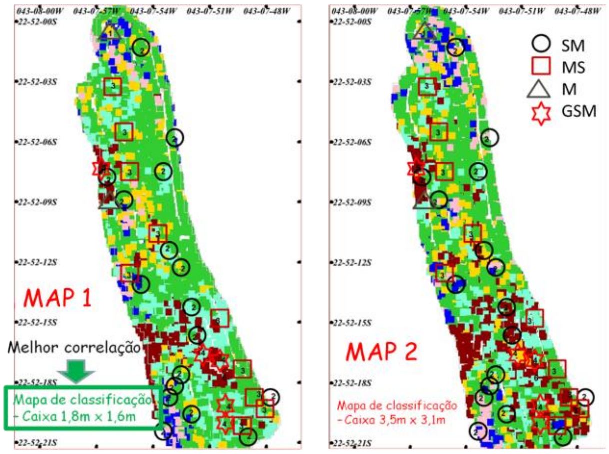

***Fig. 4 –** Comparison between correlations results using two different maps.*

In this case, the selection of the most adequate configuration was simple, as only one processing configuration (ie. box size) has been modified. But, if more parameters are changed (eg. number of seabed classes), the number of seafloor maps would considerably increase. Then, manual comparison would become more complicate, as showed in Figure 5, where both box size and seabed class configurations have been modified, resulting 12 seafloor maps to be analyzed. In order to solve this problem, a program had to be developed, which enables an automatic correlation analysis, facilitating and accelerating the studies being performed here.

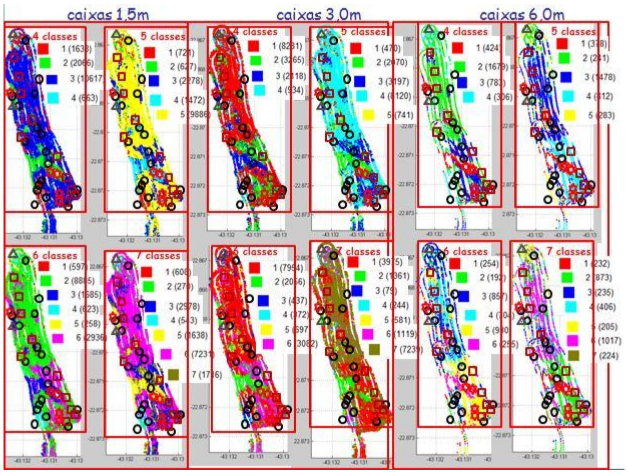

***Fig. 5 –** Comparison between correlations results using twelve different maps.*

Automatic evaluation of seafloor map

Software, termed as SEDIMAP, has been developed in this study to perform seabed map analysis. It allows a comparison of each sediment grabbed sample with seabed classes information located within the same geographical region. Software has several facilities as, for example, considering sampling position uncertainty to evaluate the analyzed area radius.

The twelve maps presented in Figure 5 were automatically processed using the SEDIMAP software. As presented in Figure 6, results indicated that the best solution in this case study would be using the tenth configuration, which applied ~6.5 m box-size and 5 valid sediment classes.

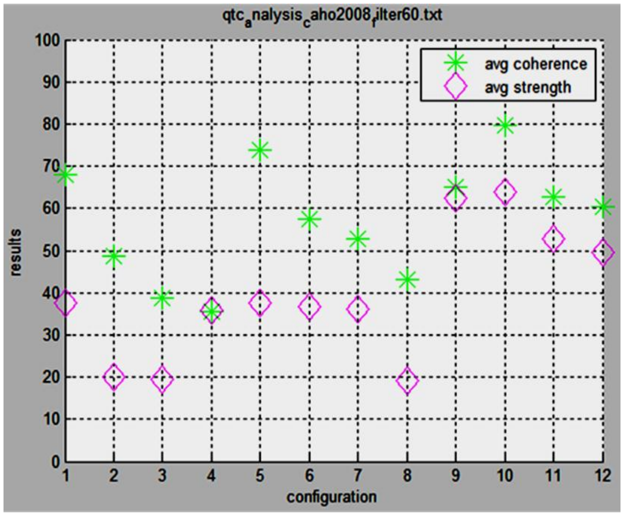

***Fig. 6 –** SEDIMAP software, developed in this study, analysed the 12 seafloor maps, indicating that the 10^{th} map solutions should be the best solution, correlating with sediment samples.*

Future works

After performing studies in test area 1, data has also been collected in test area 2, both presented in Figure 7. In the two areas, data from multibeam, singlebeam, sidescan and Van Veen has been collected. Sediment sampling distribution has been planned to allow dense geographical sampling, so a reliable quantitative analysis would be performed. Plans are to define an appropriate processing workflow, which would produce accurate seafloor sediment maps.

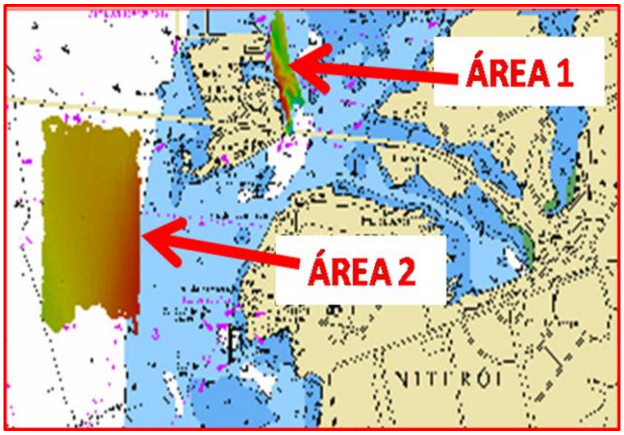

Fig. 7 – *The 2 test-areas established for seafloor characterization experiments.*

In future studies, other sediment sample information (eg. acoustic impedance) will also be compared with the seafloor maps, as presented in Figure 8. Therefore, it will be possible to determine which sediment properties would correlate better with the seafloor maps.

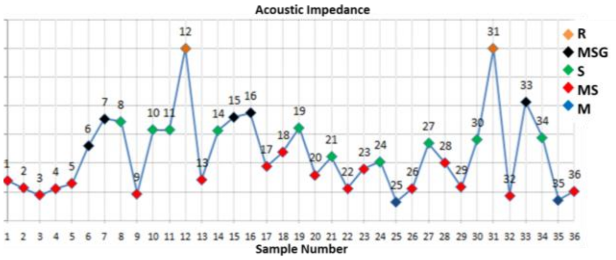

Fig. 8 – *Acoustic Impedance properties of sediment samples collected in area 1.*

Conclusions

Few programs are available in the market to process echosounder and sidescan sonar data, in order to remotely characterize the seabed sediment types.

This experiment developed a methodology to correlate the remote characterized sediment maps with grabbed sediment samples.

Results should indicate which processing configurations would be more reliable for producing accurate seabed sediment maps.

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