AUTOMATIC CLASSIFICATION OF BEDFORMS USING PHASE DIFFERENCING BATHYMETRIC SONAR

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Abstract: *This paper classifies bedforms and habitat using side scan images from a phase differencing bathymetric sonar. The study area is the inner shelf, between 3 and 15 m depth, of Barra da Lagoa – Moçambique beaches located on the northeast of Santa Catarina's island, Brazil. The data was collected with an EdgeTech® 4600 540 KHz interferometric system (phase differencing bathymetric sonar) which outputs side scan sonar images and swath bathymetry, proving images that are 3 and 4 times the width of the water depth. The data covered an area of approximately 12 km² and was collected using the softwares Hypack®2013 and Discover®, and processed with SonarWiz5® and SonarClass® for side scan and Hypack® for bathymetry. The preliminary results show an inner shelf dominated by finer sediments, but containing 0.5 to 0.7m lower elevation patches of coarse grain rippled sediments, validated comparing automatic and manual classification of the images on the SonarClass®, which uses textural parameters. The different bottom types were classified using SonarClass® and also validated with ground-truthing station besides the bedforms in accordance of literature classification.*

Keywords: *Inner shelf, Bedforms, Habitat Classification, Interferometry.*

INTRODUCTION

The inner continental shelf is dominated by waves, currents and tide. These processes have the capability to generate variations over the grain size and the bed morphology along and/or across this area (SHORT, 1999). Cachione *et al.* (1984) identified that ripple scour depressions occur globally on the inner continental shelf, which consists of rippled scour depressions composed of poorly sorted gravely and coarse sand adjacent to a well-sorted fine sand sheets. Murray and Thieller (1994) recognized the coarse and fine sand as being part of larger bedforms features developed in heterogeneous sediments, and hence coined the term 'sorted bedforms'.

In this study, the interferometric sonar EdgeTech 4600™ was used to provide side scan and bathymetry data which were used to classify the seafloor habitats. The mosaicked SSS records were classified, in both supervised and unsupervised manner, using the SonarClass® Matlab tool (FAKIRIS & PAPATHEODOROU 2003 and 2009) and the results were validated via sediments ground-truthing stations.

The study area is in a microtidal (0.4m to 1.2m), east coast swell environment, Barra da Lagoa and Moçambique headland bay beaches. They are 12 km long and limited by headlands, in north and south (Figure 1). The inner continental shelf is smooth sloped, dominated by waves and characterized by medium to fine sand, with the particles tending to be finer offshore. (SCHMIDT, 2010).

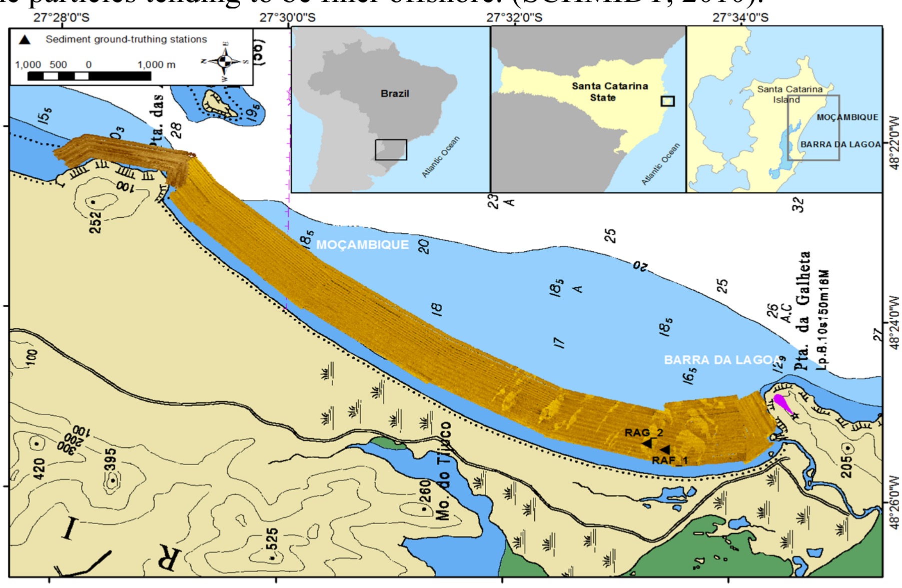

Figure 1: Survey area and sediment ground-truthing stations positions.

MATERIALS AND METHODS

The data consists of side scan images, bathymetry and ground-truthing stations. The classification is based on the side scan images as well as sediment samples.

Acoustics data were collected with an EdgeTech 4600™ 540 KHz bathymetric sonar, in depth ranging between 3 and 15 meters and line spacing between 3 to 4 times the water depth. It was used a DGPS/Heading Novatel FlexPack6 antenna and also a MRU SMC-108. The Novatel outputs uncertainties at the order of 0.15m horizontal and 0.25m vertical, using Omnistar XP corrections, and the MRU 0.03° RMS for pitch, roll and 5 cm or 5% for heave.

On SonarWiz®, the water column (bottom track) was extracted, the signal was adjusted using a time variation gain (TVG) and the bedforms were measured. The corrected sonar records were mosaicked and exported in GEO-TIFF format for use in SonarClass® for habitat classification. This software utilizes three feature extraction algorithms, namely first order grey-level statistics, descriptors extracted from grey level co-occurrence matrices (GLCMs) and 2D power spectrum specifications, constituting feature vectors of totally 11 descriptors (FAKIRIS & PAPATHEODOROU, 2009). More information can be found in Fakiris & Papatheodorou (2007 and 2009).

In order to validate this classification, sediment samples were collected by Van Veen grab sampler in places where different sea-bed textures were realized in the side scan data (Figure 1). Those samples were washed and dried to eliminate salt and humidity, and then on stereo microscope, on the same scale, pictures were taken in order to visualize the particle's sizes, consisting in a qualitative analysis.

All features were classified in accordance to Society for Sedimentary Geology (SEPM) and Short (1999).

RESULTS

BATHYMETRY

Analysing the bathymetry (Figure 2**Error! Reference source not found.**), verified that the isobaths are parallel to the shoreline, with a shallower southern area associated to the headland. Along the central to north shore, there are a few bars where the wave breaking formed different bottom features during the survey. In the north, there is an island, almost in front of the headland, that causes a narrowing channel increasing the velocity of the current, generating larger bedforms.

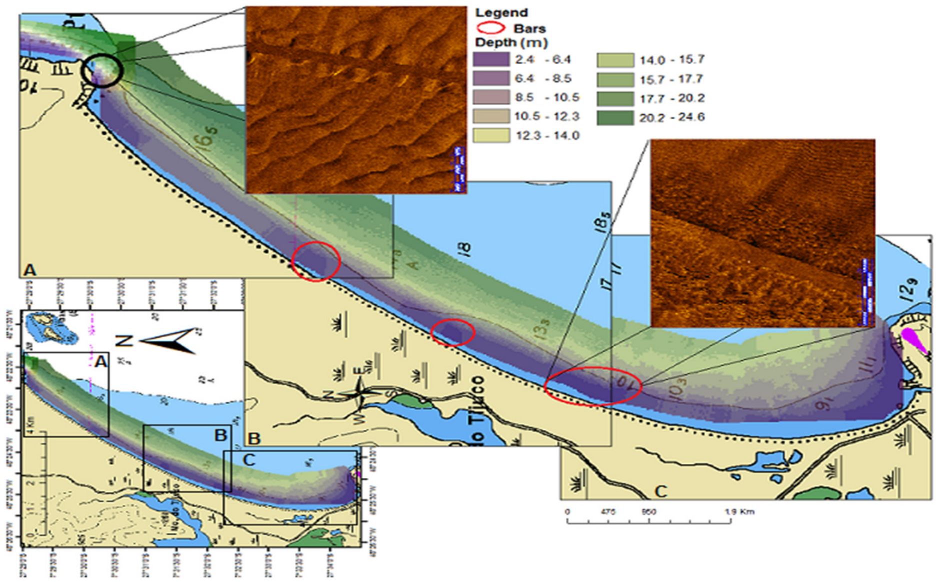

Figure 2: Bathymetry and bedforms examples. (A) Magnify of the north area with the larger bedforms, (B) Magnify of the centre area with bars, and (C) Bars and the bedforms associated.

SIDE SCAN IMAGES

It is possible to detect differences in the intensity of the images (Figure 3), sometimes associated to the nadir zone or some noise originated from the ship motions, in response to the side boat mounted pole, but mainly related to different sediment types.

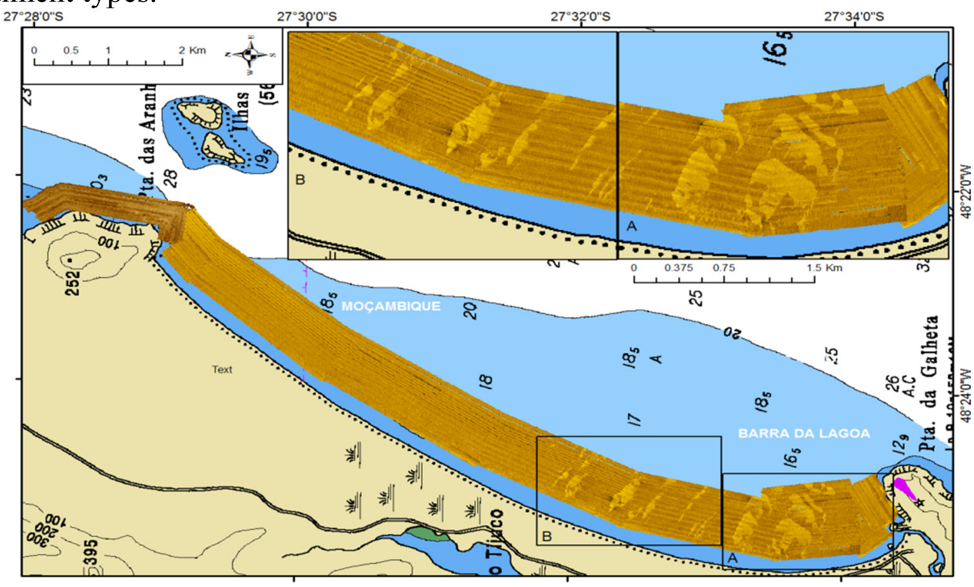

Figure 3: Mosaic of side scan images presenting the contrast difference between features. (A) e (B) are a magnify of the lower elevation brighter patches.

Brighter patches are detected, aligned perpendicularly to the shoreline, most of them occur in the inner continental shelf from the centre to south, while random and smaller patches are detected over the north side. They are asymmetrical, long-crested rippled coarse sand areas that present a wave length of 0.70 to 1.2m and a height from 0.3 to 0.6m, with approximately 0.5-0.7m scour depressions (Figure 4A).

Over the darker area, the ripples found are asymmetrical, long-crested with wave length between 0.6 and 1m and height range from 0.20 to 0.4m (Figure 4B).

The bedforms in front of the north headland are asymmetrical, caternary, presenting lengths in the order of 6 to 12m and height between 0.8 to 1.6m (Figure 4C)

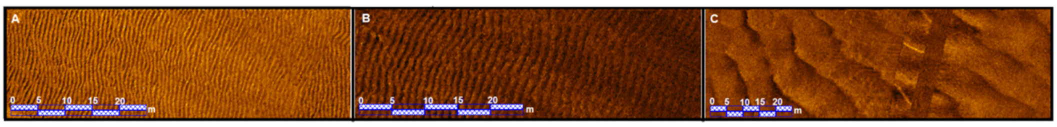

Figure 4: (A) Rippled coarse sand; (B) Rippled fine sand; (C) Bedforms in front of the headland

SEABED SEDIMENT SAMPLES

In this study the sediment was qualitative analyzed. Two different samples are shown (Figure 1); one represents the brighter areas related to the coarser particles (rag_2) and the other, the darker, corresponding to the finer particles (raf_1) (Figure 5). These results are in accordance to the literature (CACHIONE *et al.*, 1984; MURRAY and THIELLER, 1994; RAINEALT *et al.*, 2013).

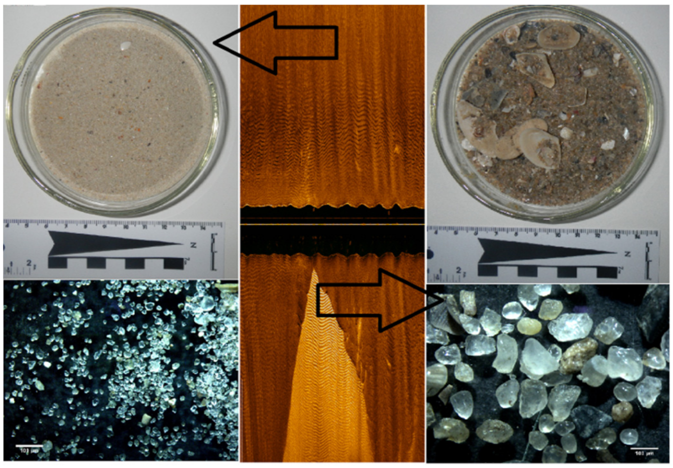

Figure 5: Relation between particle's size, image contrast and bedforms. Magnifications at the order of 20X.

HABITAT CLASSIFICATION

The supervised classification recognized both classes, namely the higher intensity patches of coarse grain rippled sediments and the other, which is the fine sediment with random occurrence of bedforms. The unsupervised classification recognized those features, validating the supervised one (Figure 6). So, comparing the seabed sediment samples and both classifications, it is possible to identify that the coarse particles has a different acoustic signature if compared to the fine sediments area.

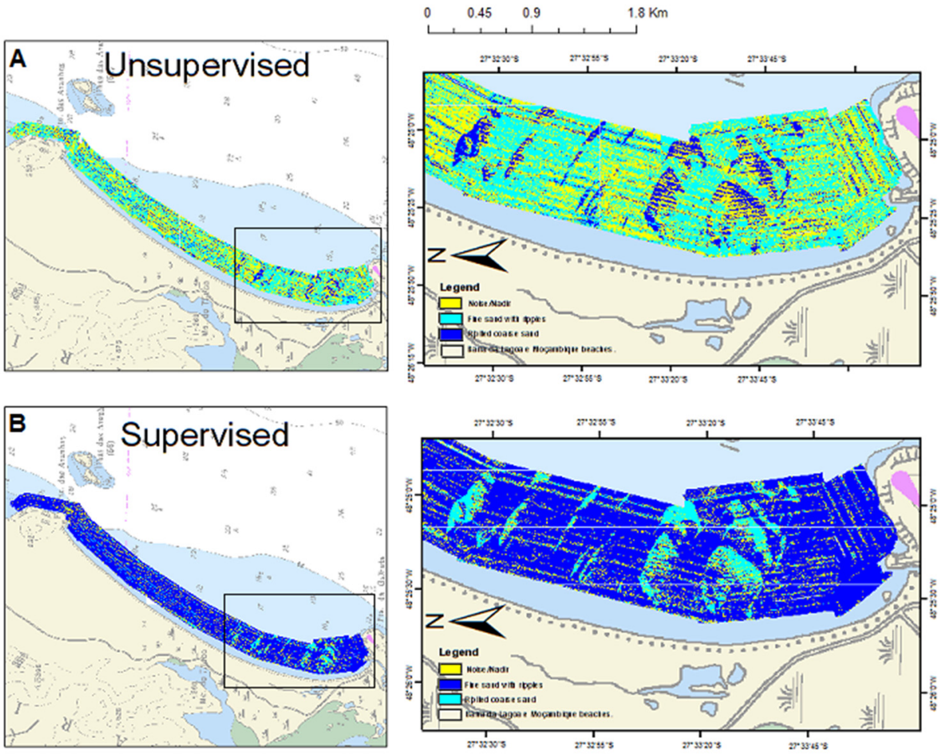

Figure 6: (A) Unsupervised and (B) Supervised classification.

CONCLUSIONS

Based on the results it is possible to affirm that those brighter patches of lower elevation rippled coarse sand have a different acoustic signature when compared with the predominantly finer area, which was validated with the seabed sediments and also by literature. Those patches are all formed by bedforms, different from the predominant darkest area, which presents random bedforms. SonarClass® seems to be a good classifier because it didn't recognize only both classes but it also classified in different classes the noise associated to the survey conditions and the water column extraction, making them easy to be excluded from the analysis.

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