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Applying a multi-method framework to analyze the multispectral acoustic response of the seafloor

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Improvements to acoustic seafloor mapping systems have motivated novel benthic geological and biological research. Multibeam echosounders (MBES) have become a mainstream tool for acoustic remote sensing of the seabed, and recently, multispectral MBES backscatter has been developed to characterize the seabed in greater detail, yet methods for the use of these data is still being explored. Here, we evaluate the potential for seabed discrimination using multispectral backscatter data within a multi-method framework. We present a novel MBES dataset acquired using four operating frequencies (170 kHz, 280 kHz, 400 kHz, and 700 kHz) near the Doce River mouth, situated on the eastern Brazilian continental shelf. Image-based and angular range analysis methods were applied to characterize the multifrequency response of the seabed. The large amount of information resulting from these methods confounds a unified manual seabed segmentation solution. The data were therefore summarized using a combination of dimensionality reduction and density-based clustering, enabling hierarchical spatial classification of the seabed with sparse ground-truth.

The use of multispectral technology was fundamental to understanding the acoustic response of each frequency – achieving a benthic prediction in agreement with earlier studies in this region, but providing spatial information at a much greater detail than was previously realized. For most muddy areas, the median uncalibrated backscatter values from the mosaics for all frequencies were low (slightly higher for lower frequencies). The lower frequency was presumably detecting the sub-bottom, while the higher frequency reflected primarily off the surface, potentially indicating a thick muddy deposit in this area. In these regions, the angular response curve shows high backscatter level loss, with a more pronounced backscatter level loss for the higher frequency. Over a sandy high-backscatter feature, results show high scattering across the entire swath; sediments coarser than sand were poorly resolved by comparison. The density-based clustering enabled identification of two well-defined clusters, and at a higher level of detail, the muddy region could be further divided to produce four sub-clusters. Therefore, findings suggested that the multifrequency acoustic data provided greater discrimination of muddy and fine sand sediments than coarser sediments in this area.

Backscatter data has been analyzed in several ways in the context of seafloor classification, namely: visual interpretation of mosaics, textural analysis, image-based analysis, and angular range analysis. Advantages and disadvantages of each make the choice methodology challenging; their combined use may achieve better results via consensus. Several supervised and unsupervised techniques have been applied in seabed classification, including different clustering approaches. Density-based clustering has received little attention for seabed classification, and was successfully applied here to synthesize different approaches into a classified output. Further research on the discrimination power of multispectral backscatter and comparison between clustering techniques will be useful to inform on the application of these approaches for mapping seabed sediments.