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Application of Multibeam Sonar Bathymetry and Backscatter in Coastal Sediment Transport Modelling: Implications for Nautical Charting

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Abstract:

The growing human activity and reliance on coastal ocean resources have driven a sharp rise in scientific interest in understanding and predicting coastal ocean processes. The Port of Belledune is a four-berth marine terminal specializing in bulk material handling and cargo, situated on the Bay of Chaleur in northern New Brunswick, Canada [1]. It lies within a highly productive coastal ocean environment, supporting a rich ecosystem and significant fisheries. Moreover, the variety of commodities processed through the Port has led to a general increase in cargo throughput. The potential expansion of the Port to handle a proposed hydrogen production facility will encounter several challenges, including the effects of climate change, alterations in sedimentation patterns, updates to navigational charts, and modifications in vessel maneuvering practices.

In that context, a project has started focusing on coastal ocean modelling in the region to predict the physical oceanography and sediment transport which are crucial for understanding the dynamics of this area. Models that simulate physical processes, including sediment transport, in coastal areas have made great progress, mainly due to improvements in computing power and advances in numerical methods. Likewise, advancements in data collection technologies have resulted in more precise underlying datasets, greatly enhancing the ability to construct and evaluate the models.

Various studies have explored how bathymetry and backscatter data can be used to analyze seabed sediments [2-4]. However, in the field of coastal ocean modelling the integration of the multibeam sonar bathymetry and backscatter data with the physical oceanography conditions of the area, along with the use of a 3D high resolution coastal ocean sediment transport model, appears to be relatively unexplored. Therefore, the goal of this study is to understand the dynamic of sediment transport in the Port of Belledune using an integrated modelling approach. The simulation will be carried out using the Delft3D Flexible Mesh model in conjunction with the bathymetry and backscatter data, from the multibeam sonar, collected within the port area. This will represent an advancement in the field, as this novel integration will improve the spatial classification of surficial sediment types using multibeam sonar bathymetry and backscatter data. It will address existing gaps in dynamic port environments, where traditional approaches relying only on point sediment samples are expected to miss a lot of the spatial variability of the seabed.

In this work, a long record of backscatter and bathymetry data from multibeam sonar are used along with a coastal ocean model to predict and validate the sediment transport around the Port of Belledune. The sediment grain size distribution is estimated from multibeam sonar data in the area and is integrated with point sediment analysis observations to establish the initial conditions of the coastal sediment transport model in the region of the Port. These spatially varying estimates of sediment classes are augmented with physical oceanographic observations – such as water levels, temperature, salinity, and currents – to generate high-resolution 3D numerical ocean model simulations using the Delft 3D FM modelling suite. The model results will be validated by comparing simulated sediment distribution and transport patterns against recent multibeam sonar surveys. Specifically, the comparison between

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historical and contemporary multibeam sonar data allows for an assessment of long-term seabed changes, providing insights into model accuracy and sediment dynamics in the area. In this way, sediment transport estimates are validated against modern multibeam sonar data to assess the relationship between observed and modelled seabed data and evaluate the reliability of the model simulations. This study aims to improve data integration for sediment modelling by improving the inputs of the Delft3D FM, with a focus on both bathymetric change and the temporal evolution of seabed grain size distribution.

Results from the integration of multibeam sonar data with sediment transport modelling conducted in the Port of Belledune are presented to demonstrate the potential benefits of incorporating bathymetric and backscatter data with sediment transport modelling to inform seabed mobility estimates. These estimates can guide navigational chart update rates, port dredging requirements, and vessel pilotage. It, therefore, can help with both safety and cost-efficiency in port operations, especially in coastal and shallow water regions where sediment transport is a dynamic process. Additionally, the results of this research will be available to improve coastal prediction systems and connect statistical climate models with more detailed coastal sediment transport model simulations to plan climate adaptation strategies. Beyond operational safety, this integrated approach enhances the spatial and temporal resolution of sediment distribution mapping, offering a valuable decision-support tool for sustainable port development and for policymakers to establish regulations on dredging frequency, environmental impact assessments and coastal development zoning. The research also contributes to environmental management by enabling more precise identification of possible sediment accumulation and erosion zones, which can inform shoreline stabilization efforts, habitat protection, and turbidity effects on marine ecosystems.

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