

BOTTOM ROUGHNESS DEFINITION IN CORAL REEF CONTEXT (LA REUNION ISLAND, FRANCE)

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INTRODUCTION

Tropical coastlines and small islands are particularly vulnerable because of their physical exposure to climate change hazards and their limited adaptive capacity. Located in oceanic regions, low-latitude low-lying islands are subject to tropical cyclones, storms, flooding and drought, leading the UNESCO (2014) initiative to carry strategies for building Small Islands resilience in the context of global change. Many of these tropical islands and coastlines are bordered by coral reefs that can provide substantial defense by reducing as much as 98% of incident wave energy. Coral reefs reduce the risk by inducing the breaking at the reef crest and by dissipating the remaining energy by bed friction linked to the architectural complexity of the reef system. The predictions regarding future climates over the global ocean point towards a rise in sea levels, an increase of storm intensities, and the alteration of coral reefs induced by the climate change in combination to anthropogenic stresses at global and local scales, contributing to more severe wave-driven flooding events in tropical islands and atolls. In order to predict submersion risks in such conditions, numerical modelling is used, such as BEWARE dataset (Pearson et al. 2020), knowing water depth over the reef flat, incident wave conditions, reef flat width, beach slope and bed friction. The quantification of this latter parameter remains a challenge. This is often done by calibrating numerical model with in-situ dataset (Bruch et al. 2022) but this is an heavy process and not transposable. Carlot et al. (2023) have reported at Moorea a strong correlation between structural complexity of coral species and wave dissipation, and hence the reduction of wave run-up height on the coast. Unhealthy reef conditions result in wave run-up heights about 10% higher compared to healthy ones, leading to an increase of the frequency of extreme overwash. A power function is found between Nikuradse roughness and the surface complexity estimated from 3D shapes. A similar dataset from La Reunion Island is here studied. La Reunion experienced extreme submersion events (about 3 m of runup for 8 m offshore significant wave height). Its fringing reef is less than 500-m wide and is quite deteriorate on some parts. 4 years of 3 months pressure sensors measurements as well as 3D reconstruction of the bottom roughness over several cross-shore profiles are analysed in order to study the influence of coral complexity on wave transformation, mainly the wave dissipation (Bruch et al., 2022). An innovant, low-cost, low-tech platform is used to reconstruct the 3D bottom shape in an efficient way (Jaud et al., 2023).

METHODS

The focus of this study is La Saline coral reef, located in the West of La Reunion Island (France) in the Indian Ocean. The area is microtidal and frequently exposed to Southern Ocean swell as well as cyclonic events. Field measurements were carried-out using wave gauges placed on the reef slope and three on the reef flat during 50 days in 2017, 2018, 2019 and 2020. A 3D reconstruction of the coral over the reef flat has been performed in order to obtain the structural complexity defined as the ratio of 3D distance to 2D distance. Jaud et al. (2023) have developed a low-cost low-tech platform called POSEIDON (for Platform Operating in Shallow-water Environment for Imaging and 3D reconstruction). This prototype combines a floating support (typically a bodyboard), two imagery sensors (here, GoPros® cameras) and an accurate positioning system using Real Time Kinematic GNSS (Fig. 1). In order to compare the adapted Nikuradse roughness k_s to the structural complexity (SC) and the one adapted to the wave dissipation, f_w is calculated between pairs of wave gauges on the reef flat, assuming only bed friction occurs. A numerical model (XBeach) is also used for deeper understanding of wave transformation, wave setup and runup.

RESULTS & DISCUSSION

Fig. 2 shows an example of 3D reconstruction of the bed, composed mainly of crest and trough. Over the considered cross-shore transect, the mean cross-shore length of bed structures is 2 m and average height is 0.7 m. The Mean Sea Level is 0.3 m above these structures. The standard deviation is 0.31 m. The average Surface Complexity SC is found to be 1.25 ± 0.3 . Graham & Nash (2013) reported value from 1.0 to 2.65 from 150 study sites and Carlot et al. (2023) values from 1 to 4 depending on the year at Moorea, oscillating between unhealthy and healthy coral reef cover. The structural complexity of our study site is thus quite low which corresponds to unhealthy reef as defined by Carlot et al. (2023). f_w is then estimated between pairs of sensors over the reef flat, assuming only dissipation by bed friction occurs (Fig. 3). Our results are compared to literature formulas function of Ab/k_s with Ab the orbital excursion (Soulsby, 1997). To fit Soulsby (1997) formula, k_s is taken equal to 0.7 m, as two times the standard deviation of bed variability or as the bed structures average height. Besides, Xbeach

numerical modelling gives reliable fit (R^2 higher than 0.8) for significant gravity wave height, infragravity wave height and setup over the reef flat using an average friction factor of 0.27 (and all default values for other parameters). This value is comparable to healthy coral reef in Harris et al. (2018) at Tahiti and Moorea. The direct estimates of friction factors over coral reefs fall in the range 0.1-5 (Lentz et al., 2016). Thus, the bed structures at La Reunion island remains efficient to dissipate the gravity wave energy. Only very low frequency wave are badly reproduced by the model for extreme event (reef slope significant wave height above 4 m) (Bruch et al., 2022). Bed structures at La Reunion island have size comparable to the water depth and thus, they can be considered as bathymetry variability instead of only bed roughness. Is the drag produced by such huge structures is comparable to the dissipation by bed roughness? The particular shape of reef flat bed at La Reunion island lead to discuss the definition of roughness compare to bathymetry variability in numerical modelling.

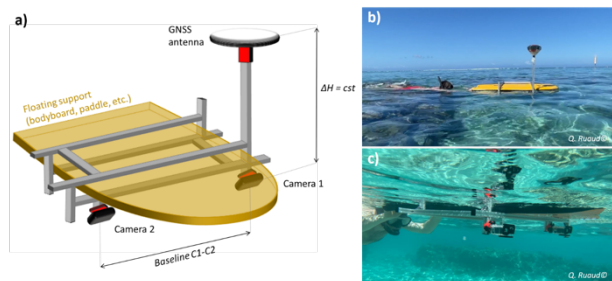


Figure 1 - Platform POSEIDON to measure micro-bathymetry in very shallow environments efficiently (Jaud et al., 2023)

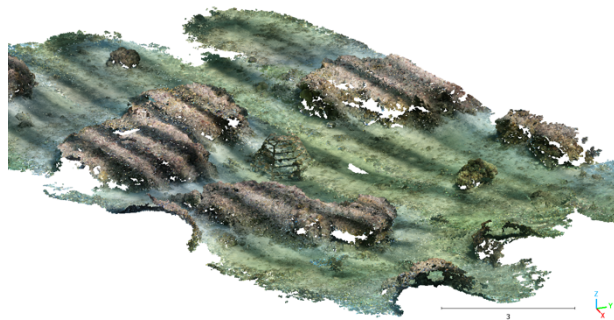


Figure 2 - Sample of 3D reconstruction of bedforms. A wave gauge mooring frame is visible in the middle.

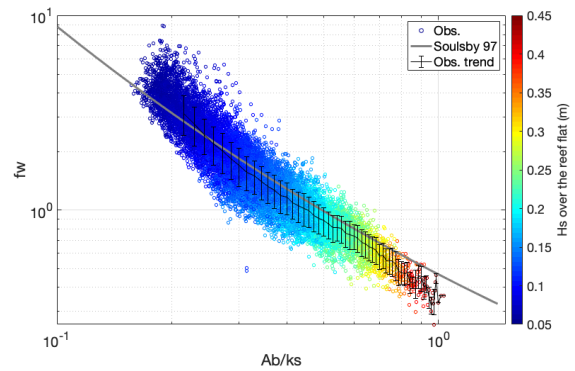


Figure 3 - f_w as a function of Ab/ks compared with Soulsby (1997) formula with $ks = 0.7$ m.

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