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The role of coral reef rugosity in dissipating wave energy and coastal protection

Daniel Harris (1,2), Alessio Rovere (1,2), Valeriano Parravicini (3), and Elisa Casella (2)

(1) Center for Marine Environmental Sciences (MARUM), Bremen University, Bremen, Germany (daniel.harris@zmt-bremen.de), (2) Leibniz Center for Tropical Marine Ecology (ZMT), Bremen, Germany, (3) CNRS-EPHE CRIOBE, University of Perpignan, Perpignan, France

Coral reefs are the most effective natural barrier in dissipating wave energy through breaking and bed friction. The attenuation of wave energy by coral reef flats is essential in the protection and stability of coral reef aligned coasts and reef islands. However, the effectiveness of wave energy dissipation by coral reefs may be diminished under future climate change scenarios with a potential reduction of coral reef rugosity due to increased stress environmental stress on corals. The physical roughness or rugosity of coral reefs is directly related to ecological diversity, reef health, and hydrodynamic roughness. However, the relationship between physical roughness and hydrodynamic roughness is not well understood despite the crucial role of bed friction in dissipating wave energy in coral reef aligned coasts. We examine the relationship between wave energy dissipation across a fringing reef in relation to the cross-reef ecological zonation and the benthic hydrodynamic roughness. Waves were measured by pressure transducers in a cross-reef transect on the reefs flats and post processed on a wave by wave basis to determine wave statistics such as significant wave height and wave period. Results from direct wave measurement were then used to calibrate a 1D wave dissipation model that incorporates dissipation functions due to bed friction and wave breaking. This model was used to assess the bed roughness required to produce the observed wave height dissipation during propagation from deep water and across the coral reef flats. Changes in wave dissipation was also examined under future scenarios of sea level rise and reduced bed roughness. Three dimensional models of the benthic reef structure were produced through structure-from-motion photogrammetry surveys. Reef rugosity was then determined from these surveys and related to the roughness results from the calibrated model.

The results indicate that applying varying roughness coefficients as the benthic ecological assemblage changes produces the most accurate assessment of wave energy dissipation across the reef flat. However, the modelled results of bed roughness (e.g. 0.01 for the fore-reef slope) were different to the directly measured rugosity values (0.05 for the fore-reef slope) from three dimension structure-from-motion surveys. In spite of this, the modelled and directly measured values of roughness are similar considering the difficulties outlined in previous research when relating the coral reef structural complexity to a single value of hydrodynamic roughness.

Bed roughness was shown to be a secondary factor behind wave breaking in dissipating wave energy. However, without bed friction waves could be an order of magnitude higher in the back-reef environment. Bed friction is also increasingly important in wave dissipation at higher sea levels as wave energy dissipation due to wave breaking is reduced at greater depths. This shows that maintaining a structurally diverse and healthy reef is crucial under future sea level rise scenarios in order to maintain the protection of coastal environments. These results also indicate that significant geomorphic change in coastal environments will occur due to reduced wave dissipation at higher sea levels unless reefs are capable of keeping up with forecasted sea level rise.