SANDY BEACH DYNAMICS IN ATOLL ENVIRONMENTS UNDER OBLIQUE LOW ENERGY WAVES AND SEA LEVEL RISE: A CASE STUDY IN ADDU CITY, THE MALDIVES

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INTRODUCTION

Atoll environments, characterized by their unique geological and ecological features, are vulnerable to the adverse effects of climate change and are often subject to distinct coastal processes (Barnett, 2003). Sandy beaches within atolls can play a pivotal role in ensuring the stability of shorelines, providing habitat for diverse ecosystems, and sustaining the well-being of local communities. Furthermore, the implementation of sandy solutions can minimize the need for rock in coastal protection strategies. However, the interactions between oblique low energy waves, storm conditions, sea level rise and beach morphology in atolls are complex and relatively understudied.

This research presents an investigation of the dynamic coastal processes in the context of the recently created land reclamations and sandy beaches in the Small Island Development State (SIDS) of Addu City, the Maldives, see Figure 1.

Figure 1 – Reclamation works and beach development at Hithadhoo Zone 2 in Addu City, the Maldives

METHODS

Employing a multi-disciplinary approach, the study combines field observations, remote sensing data, numerical modeling, and empirical analyses to explore the spatiotemporal evolution of the recently constructed sandy beaches under the influence of waves and sea level rise.

First, a digital elevation model (DEM) is created based on a satellite derived bathymetry (SDB) and local bathymetric and topographic surveys.

Timeseries of offshore wave and wind data are obtained from the ERA5 database (Hersbach, 2020) and combined with water level data from the FES tidal model (Carrère, 2015). The wave conditions are simulated to nearshore by means of a detailed SWAN model (Booij, 1996). The model has been calibrated and validated using local wave buoy measurements.

The development of the beaches along the newly constructed reclamation areas in Addu City is simulated by use of a ShorelineS model (Roelvink, 2020), which is able to describe coastal transformations based on the main principles of alongshore transport gradient driven changes as a result of coastline curvature and longshore transport disturbance by hard structures. Empirical data is used to determine stable cross-shore beach profiles.
Storm erosion and complex patterns such as rip currents behind the reef are assessed by means of an XBeach 2D model (Roelvink, 2009).
The beach development will be validated in the coming months through the analysis of satellite-derived coastlines, covering a span of about one year following the completion of construction.

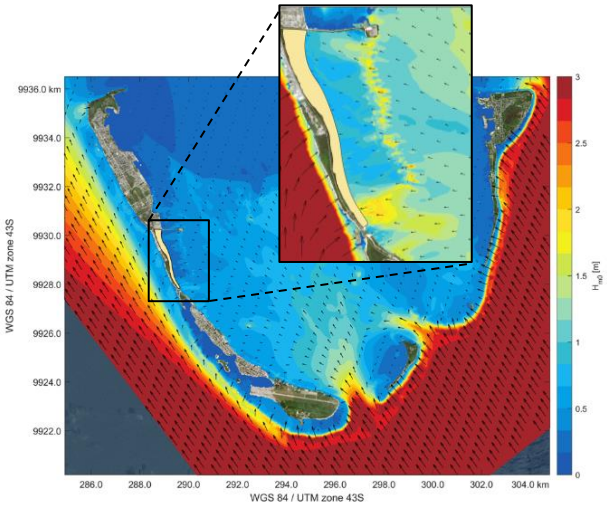

Figure 2 – Simulation of swell wave penetration into ring-shaped atoll using a SWAN model

RESULTS

Key findings of the study include understanding of the process of swell wave penetration into the ring-shaped atoll along with local generation of wind waves, see Figure 2. Furthermore, the study provides insight into the mechanisms of sediment transport, the impact of seasonal variations and storms, and the role of local bed level variations (such as reefs) in shaping beach morphology. The research also sheds light on the

potential implications of climate change and sea-level rise on atoll sandy beaches, emphasizing the need for proactive adaptation strategies to safeguard these sensitive coastal environments. The results underscore the role of periodic maintenance in preserving beach width and stability in the face of the wave conditions and sea level rise.

CONCLUSIONS

This analysis offers actionable insights into designing sandy solutions and defining effective periodic maintenance strategies, taking into account the distinctive challenges posed by oblique low energy waves, storm waves and sea level rise in atoll settings. The research contributes to the broader understanding of coastal resilience in SIDS, supporting sustainable development practices and adaptive measures for safeguarding these vital ecosystems.

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