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Efficient and accurate modeling of wave-driven flooding on coral reef-lined coasts: Case Study of Majuro Atoll, Republic of the Marshall Islands

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Many coral reef islands are low-lying, which in combination with population growth, sea level rise and possibly more frequent extreme weather events is likely to result in increased coastal risk (e.g. Storlazzi et al., 2015). On smaller scales of O(10 km) wave-driven coastal inundation can be accurately predicted with advanced models such as XBeach (Roelvink et al., 2009), at already high computational costs. For larger scales, larger number of islands, for scenario modelling, and for implementation in early warning systems, computationally faster methods are needed. Reduced physics models, which neglect some of the processes (e.g. non-hydrostatic pressure gradient term and viscosity), are a potential solution. However, their accuracy and the best method to force them has not been established.

In this research we propose a new methodology to model wave-driven flooding on coral reef-lined coasts. A look-up-table (LUT), composed of XBeach model runs, is combined with a reduced-physics model, SFINCS (Leijnse et al., 2021), to achieve high accuracy predictions at limited computational expense. The LUT consists of pre-run 1D XBeach simulations for several reef profiles from Scott et al. (2020), forced with different offshore wave and water level conditions. Wave conditions close to the shore as predicted by the LUT are used to force SFINCS which then simulates the wave runup, overtopping and flooding. These are forced in SFINCS using random wave timeseries from an interpolated parameterized wave spectrum following Athif (2020).

The accuracy of the method is investigated for 6 distinctive cross-shore profiles from Scott et al. (2020), for two wave scenarios (gentle swell and stormy conditions). Results of complete XBeach simulations are compared to LUT-SFINCS simulations with different boundary forcing locations. The sensitivity analysis shows that the preferred boundary location to initialize the SFINCS model is at a water depth between 0.5 m and 2.5 m, preferably shoreward of the reef edge. Errors introduced by the generated parameterized spectra lead to runup estimation errors of up to around 40% depending on reef geometry. The developed methodology will be applied to a case study of Majuro Island, the Republic of Marshall Islands, as proof of concept.

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