# COASTAL FLOOD PROTECTION: THE PHYSICS BEHIND OPTIMAL BERM STRUCTURES

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## INTRODUCTION

Human constructed dunes (i.e., 'berms') play a critical role in protecting urbanized coastal communities. US coastal flood losses in 2020 were approximately $31.2 billion and are expected to increase to $40.6 billion by 2050 because of climate change (Wing et al., 2022). Beach-berm systems serve as a natural, dynamic defense system against energetic waves and high-water levels.

Berm characteristics are typically a function of the sand's angle of repose and available heavy equipment. Placements may also have access or aesthetic aspects and, in some cases, may be limited by elevation constraints. Although wave overtopping has been studied extensively, coastal models either ignore or overly simplify groundwater and swash processes, resulting in significant underestimation of flood event magnitudes (Rotzoll and Fletcher, 2013). Targeted berm designs, intended to alter the flow field and reduce wave runup, present an attractive, innovative sea level rise adaptation strategy.

Computational fluid dynamic models have gained popularity within coastal engineering to fully resolve near-shore flow properties, but efforts to include berms have been limited. An in-depth analysis of coastal berm defense structure physics has yet to be explored. Insights from highly resolved computational fluid dynamic models are crucial for improving computationally efficient, lower order models where flow physics can be parameterized to improve near-shore hydro/morpho-dynamics modeling. Beach modifications through foreshore berm profiling and inclusion of natural cobble reduce wave runup flooding (Bayle et al., 2021) but the physical mechanism controlling this behavior is unknown. Existing research lacks information on optimal beach-berm configurations for wave and tidally dominated coastlines. Developing innovative, resilient nature-inspired solutions and quantifying their role in protecting coastal communities is imperative.

## PRELIMINARY RESULTS

The quantification of varying beach-berm conditions using high resolution numerical models is necessary to accurately assess the efficiency of coastal flood protection structures. SedOlaFlow (Delisle et al., 2023), an open-source OpenFOAM solver, accurately captures swash-groundwater dynamics as it solves the Reynolds-averaged, Eulerian Navier-Stokes equations for multi-phase (air, water, sediment) flows. The model grid consists of irregular, boundary-conforming cells to create a smooth sand interface to accurately capture boundary layer dynamics. Figure 1 shows preliminary model results for a beach-berm configuration with (a.) and without (b.) a trench and the boundary layer turbulent kinetic energy (TKE). Preliminary results show the small trench decreases wave runup by 15%. These results suggest that modifications to beach topography generate TKE which is a measure of dissipated energy. TKE generation removes energy from the flow which decreases wave runup, overtopping, and backshore flooding. Various beach-berm modifications will be investigated to understand the physical mechanisms behind small, yet effective, changes coastal communities can make to decrease wave runup and flooding during storm events. Realistic beach-berm configurations will be constructed using design guidelines with varying sand qualities (grain size, porosity), topography, berm characteristics (volume, height, geometry), and hole configuration (position, size, shape). Qualitative analyses using plots and statistical correlations between hole size, wave height, grain size, and wave runup will be performed to characterize the berm efficiency at reducing coastal flooding. Coastal engineers will be able to swiftly adopt and apply these cost-effective modifications, which are crucial for servicing underfunded and disproportionately affected communities worldwide.

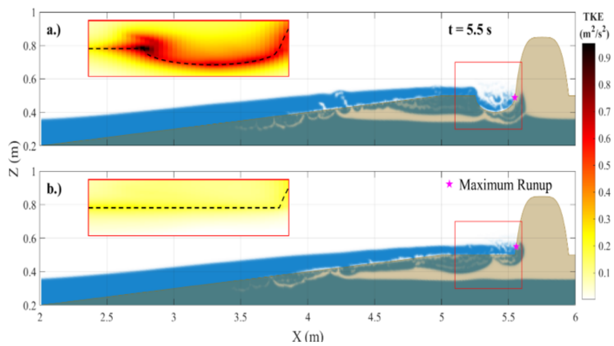


Figure 1 – Snapshot of **a.)** modified and **b.)** non-modified beach-berm profiles under identical wave forcings at the same time. Insert shows enlarged spatial TKE and beach profile (dashed lines) for the red box.

## REFERENCES

Bayle, Kaminsky, Blenkinsopp, Weiner, Cottrell (2021): Behaviour and performance of a dynamic cobble berm revetment during a spring tidal cycle in North Cove, Washington State, USA, *Coastal Engineering*, vol. 167, pp. 103898.

Delisle, Gallien, Kim (2023): A Numerical Study of Dam-Break Driven Swash and Beach Groundwater Interactions, *JGR: Oceans*, vol. 128, pp. e2022JC019615.

Rotzoll, Fletcher (2013): Assessment of groundwater inundation as a consequence of sea-level rise, *Nature Climate Change,* vol. 3, pp. 477-481.

Wing, Lehman, Bates, Sampson, Quinn, Smith, Neal, Porter, Kousky (2022): Inequitable patterns of US flood risk in the Anthropocene, *Nature Climate Change*, vol. 12, pp. 156-162.