Modeling and Forecasting of Wave-driven Coastal Hazards

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When large gravity wave swells, generated by distant storms, impinge on coastlines during high tides, the resulting reach of the seawater is greater than by the tides alone, and the movement of the water onshore is more violent. While these events don't have the devastating impact of large tsunamis, their amplitudes are pushing into the range of moderate tsunamis and they occur more often, such that their impacts on coastal erosion, freshwater aquifers, infrastructure and populations are already significant. These events will grow more acute as their numbers and duration increase due to rising sea level and wave energy expected from climate change. In order to strengthen the resilience of communities to mitigate the impacts of episodic flooding events, quantitative forewarning is needed. Conventional wave forecasts are based on computations from spectral models or measurements from wave buoys. These techniques can provide sufficient accuracy for open beaches. Irregular reef-fringed shorelines and harbor basins, however, are often subject to infra-gravity (IG) oscillations, which can drastically change the wave environment nearshore; thus, requiring a more sophisticated approach and the use of phase-resolving numerical models.

We will show the validation with field data and assess the applicability of three phase-resolving numerical models (Xbeach, FUNWAVE, BOSZ) for characteristic swell events to wave processes at beaches and harbors along the Northshore of Oahu (Hawaii) and the Atlantic coast near Biarritz. We will also highlight critical features of the models and explain how they can be utilized for operational nearshore wave and runup forecasting.

Long calculations over large numerical domains demonstrate that coastal flooding and nearshore currents are dominated by both swell wave forcing and IG wave patterns. Wave breaking and transfer of energy to low-frequencies are critical processes. While coastal reef features and man-made structures can efficiently protect the nearby shoreline and harbors from energetic swell waves, freely propagating IG waves can cause flooding and erosion far away from their location of origin. These IG waves can be of over 20 min period - resembling the nature of tsunamis.

Our findings have important implications on flood risk assessment and future model development strategies.