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Multi-hazard analysis of tropical cyclone return periods

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1 Abstract

Tropical cyclones are multi-hazard events capable of simultaneously affecting structures with wind, storm surge and rainfall. In practice, these concurrent hazards are typically treated independently using separate return level curves. Understanding this joint exposure, however, is critical for accurately assessing the structural vulnerability of buildings. We present such an analysis in study by investigating the joint and conditional return periods of two major cyclone hazards—wind and storm surge. To do so, a database of 566 synthetic cyclone events passing within 250 km of The Battery in New York City is first generated. Next, the Holland gradient wind profile and the ADvanced CIRCulation (ADCIRC) hydrodynamic model are used to simulate the maximum wind speed and peak storm tide for each synthetic event respectively. Finally, a bivariate copula is used to statistically estimate the joint and conditional return periods of the two hazards.

Keywords: multi-hazard; tropical cyclones; storm surge; flood; wind; return period; copula

2 Introduction

Tropical cyclones are multi-hazard events capable of simultaneously affecting structures with wind, storm surge and rainfall. This joint exposure to hazards is a critical component of structural vulnerability. Severe flood damage due to storm surge, for example, is frequently preceded by breaching of a building's envelope by strong wind [1]. In many coastal areas, riverine flooding from rainfall discharge is compounded by flooding due to storm surge [2]. Finally, the entry of wind-driven rain through building openings is a primary contributor to interior content losses [3].

The treatment of cyclones as multi-hazard events has received considerable attention, particularly when assessing damage to structures for a given historical or hypothetical event. The frequently used HAZUS-MH model, for example, can estimate combined losses from wind and coastal flooding using a database of fragility curves and the assumption that the two damage mechanisms are independent [4]. The Florida Public Hurricane Loss Model extends this approach to consider the timing of maximum wind and flood inundation on combined losses [5]. Comparative analyses of riverine and coastal flooding damage in Bocca di Magra, Italy have been used to identify elements of the building stock vulnerable to either or both hazards [6]. Finally, a modeling framework for combining building envelope failure and rain trajectory has been used to develop fragility curves for the volume of rainwater intrusion [7].

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