IMPROVING HURRICANE-INDUCED COMPOUND FLOOD RISK ASSESSMENT IN LONG ISLAND, BAHAMAS: THE ROLE OF LOCAL DIGITAL TERRAIN MODELS

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INTRODUCTION

The Bahamas has been severely affected by powerful hurricanes, notably Hurricane Joaquin in 2015, which inflicted significant damage, particularly to Long Island. Being part of the Small Island Developing States (SIDS), the Bahamian islands, are vulnerable to flooding, primarily due to their low-lying terrain. These flood hazards cause damage and impact on assets, economic activities and public infrastructure. Moreover, indirect consequences, including inadequate emergency responses and environmental hazards, are integral aspects of the overall disaster risk. Considering the imminent threat of climate change and rising sea levels, accurate flood risk assessments become imperative. A comprehensive flood risk assessment has been conducted, for which an accurate Digital Terrain Model (DTM) has been generated through a special calibration method, integrating global datasets with locally acquired survey data and detailed land use maps.

METHODS

A comprehensive flood risk assessment was conducted for Long Island, incorporating hazard, exposure, and vulnerability mapping based on risk definition by Kron (2005). Utilizing the SFINCS model, the compounding effects of rainfall and storm surge were modelled imposing synthetic hurricane tracks (Leijnse, 2021). An extensive hurricane assessment has been conducted by analysis of a large number of synthetic hurricane tracks generated using the TCWiSE toolbox (Nederhoff, 2021). The assessment has been done for the present climate (2022) and separately for 2050 and 2100 including the impact of climate change for IPCC scenario SSP5 8.5 (AR6) and RCP 8.5 (AR5).

DIGITAL TERRAIN MODEL

A correct representation of the bathymetry and the topography is essential for the quality and accuracy of the flood modelling and subsequent risk assessment. Long Island's intricate topography demanded special attention for the composition of an accurate DTM. Global datasets are commonly applied for flood modelling, including for example the MERIT (Yamazaki, 2017) and FABDEM (Uhe, 2022) databases. Global datasets derived from satellites are improving but currently lack accuracy (radar-based) or resolution (LiDAR-based). Also, combinations of the two (e.g. FABDEM) show limitations, especially in densely vegetated areas (Vernimmen, 2023). To overcome these limitations, local surveys are essential for enhancing DTM quality. However, conducting comprehensive local surveys covering the entire project area is both expensive and time-consuming. In this study, we utilized limited targeted local surveys, employing (local) LiDAR, GPS-RTK, echo-sounder, and tidal gauge measurements, to calibrate the global FABDEM dataset. Substantial disparities were observed between the local survey data and FABDEM data, particularly in densely vegetated regions, as illustrated in Figure 1.

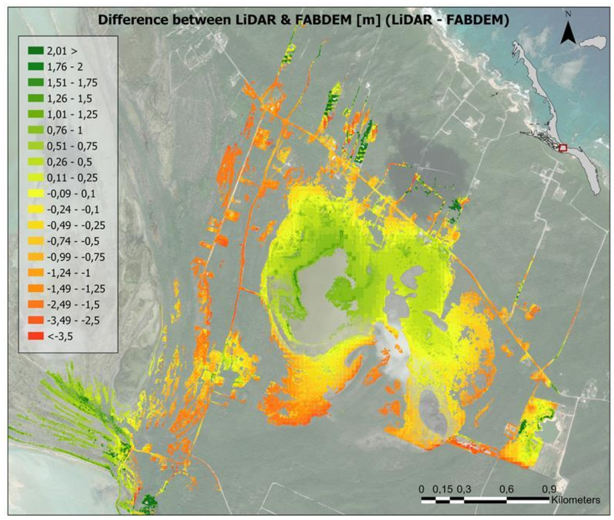

Figure 1. Local difference between LiDAR data and FABDEM data at White Pond, Long Island.

By integrating the local survey data with advanced statistical analysis and land-use maps, we developed a calibrated, accurate, and crucially, area-covering DTM.

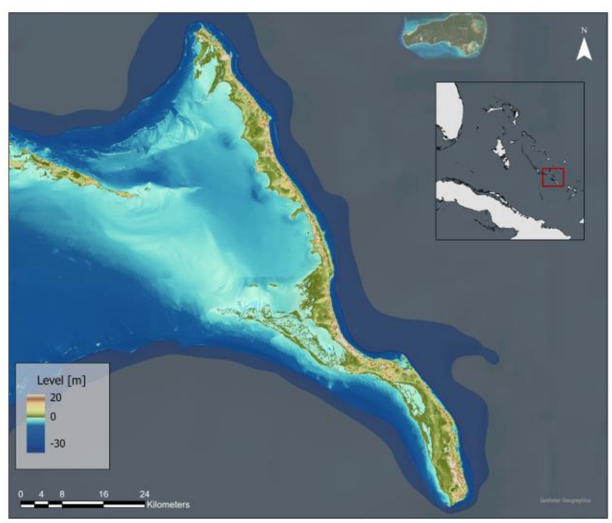

Figure 2. Combined elevation model of Long Island, Bahamas.

Furthermore, the shallow barrier reef system at the project area was not well represented in any available global data sets. Therefore, a dedicated satellite derived bathymetry has been developed for the surrounding project area. The bathymetry was calibrated by targeted local surveys employing SBES covering all relevant depth ranges in the area. The integrated elevation model, combining both bathymetry and topography (as depicted in Figure 2), was instrumental in deriving precise flood hazard maps.

RESULTS

The flood model, utilizing the calibrated DTM, produced hazard maps (flood depth and duration) for various return periods and projection years. The model results showed a significant better representation of the flood extent and duration of historical events compared to modelling results applying global data sets only. These flood maps have in turn been used to derive the flood risk in terms of direct damages (annual expected damages) and indirect damages such impact on accessibility and ecosystem degradation. These maps were pivotal in deriving direct and indirect flood risks, aiding the identification of resilient strategies against climate impacts.

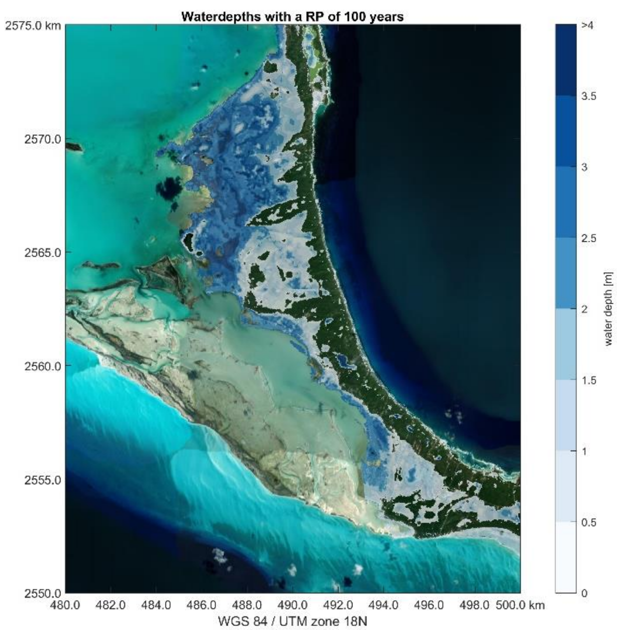

Figure 3 – Maximum flood depth map with return period of 100 years

CONCLUSIONS

This study emphasizes the critical role of an accurate DTM in simulating hurricane-induced compound flooding events. Importantly, the case study demonstrated the cost-efficiency of our method, eliminating the need for extensive and expensive surveys of the entire project area. Further, the case study underscores the importance of exercising caution when solely relying on global datasets for flood risk assessments. By integrating local surveys and advanced modeling techniques, our approach enhanced the flood risk assessment. The resulting flood risk maps not only offer a detailed understanding of the threats faced by Long Island but also provide valuable insights for the selection and validation of climate-resilient measures.

ACKNOWLEDGMENTS

We would like to thank the Ministry of Works and Utilities of the Bahamas, and in particular the PIU, for the opportunity to perform this study. Further we would like to acknowledge the IDB for the funding.

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