COMMUNITY-ENGAGED COASTAL FLOOD MODELING TO EVALUATE SEA LEVEL RISE ADAPTATION STRATEGIES

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INTRODUCTION

As sea levels continue to rise, coastal communities are searching for strategies to reduce flooding of low-lying roads, property, and stormwater drainage networks. Here we focus on the development of adaptation strategies for communities that experience flooding outside of extreme storms like hurricanes due to sea level rise (SLR). Processes that contribute to these floods can include tides, rainfall, wind setup, groundwater, and infrastructure failure (Gold et al., 2023). Even at present-day sea levels, these shallow, chronic flood events cause traffic delays (Hauer et al., 2023), damage property (Moftakhari et al., 2018), and disrupt businesses (Hino et al., 2019). Given the hyper-local nature of these floods, strategies for adaptation are often site-specific and can include raising infrastructure (e.g., bulkheads, roadways, and stormwater networks), adding pumps, or abandoning flood-prone areas.

Because these floods are an emerging phenomenon, frameworks for simulating the effectiveness of adaptation strategies – both now and in the future – are limited. While studies have shown that multiple processes can contribute to flooding, we do not yet understand how flooding drivers interact, nor how these interactions might change with future SLR. Furthermore, strategies to mitigate chronic flooding will only be accepted and implemented if these strategies align with the affected community's vision for their future. New frameworks to both identify locally tailored flooding adaptation strategies preferred by coastal communities and test the flood prevention efficacy of these strategies are necessary as low-lying coastal areas face more frequent flooding with SLR.

OBJECTIVES

Here we present a framework to test the effectiveness of adaptation strategies in reducing multi-driver chronic flooding at both current and future sea levels. This framework integrates coastal engineering and stakeholder input to 1) identify adaptation strategies that are preferred by a community that frequently floods and 2) test the effectiveness of these strategies with a numerical model under both current and future conditions.

For this work, we have partnered with local officials in Carolina Beach, North Carolina, USA. Carolina Beach already experiences frequent flooding from SLR; water level sensors installed within storm drains on a low-lying roadway recorded 45 floods over one year (April 2022 - April 2023). The engineering component of this community-engaged modeling framework is a high resolution coupled hydrodynamic and stormwater model that simulates flooding in Carolina Beach from tides, wind setup, rainfall runoff, and the interactions between these flooding drivers. This model has been validated with data from the storm drains and images of flood extent for multi-driver flood events. Stakeholder involvement in the modeling activities is achieved first through an online survey (to better understand flood impacts and adaptation preferences) and then through focus groups. These two framework components are discussed in more detail below.

CHRONIC FLOODING MODEL

We simulate coastal flooding from multiple interacting drivers using a coupled model framework. The hydrodynamic model ADCIRC (Luettich et al., 1992) simulates ocean-scale contributions to water levels, including tides, wind, and future sea level rise. Water level time series from ADCIRC are boundary conditions for the 1D/2D stormwater model 3Di (Casulli & Stelling, 2013; Volp et al., 2013), which simulates community-scale flooding drivers like rainfall runoff and stormwater networks, plus potential adaptation strategies. Coupled model simulation results show flood duration, depths, and extents at 1 m spatial resolution. We have validated the model by comparing modeled flood depths to in-situ pressure measurements and images recorded during three separate flood events with different drivers. Figure 1 shows an example hindcast simulation result, where modeled flood extents agree with a drone image from the same time step.

COMMUNITY-ENGAGED MODELING

To select the flood reduction strategies to test in the coupled model, we developed a survey that assesses how Carolina Beach residents perceive the risks and hazards associated with chronic coastal flooding, as well as ideas for adaptation. The survey was deployed in Fall 2023. Questions about perceived flood frequency and impacts will be used to identify the hazards that proposed adaptations should mitigate. Follow-up questions ask residents to rank their support for potential flood reduction strategies. In Spring 2024, we will convene a working group of Carolina Beach residents and town officials to discuss survey results and identify priority flood reduction strategies. We will then use the coupled model to quantify the effectiveness of flood

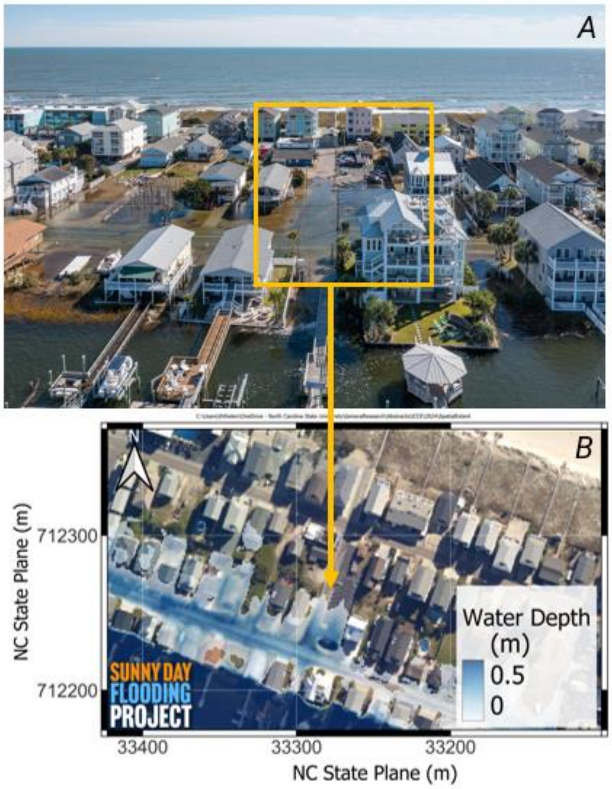

Figure 1 – November 2021 coastal flooding in Carolina Beach, North Carolina, USA. Drone image (A) and 1 m resolution coupled model result (B) agree that flooding extends halfway up the boxed parking lot.

reduction strategies in eliminating flood occurrence or reducing flood depth. Model results at sea levels corresponding to present day and future flooding scenarios will help to identify adaptation pathways that are both in line with community vision (i.e., what community members want their community to look like) and effective in mitigating flood hazards (i.e., hazards that community members want to reduce).

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