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Pluvial and potential compound flooding in a coupled coastal modeling framework: New York City during post-tropical Cyclone Ida (2021)

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Introduction

This supplementary material provides more information on the calibration and validation process of the hydrodynamic model, and the drainage rates used to represent stormwater system in Jamaica Bay, NYC. The model was calibrated using a combination of data from Ida and another, less intense rain event with more available HWMs that happened 29 September 2023.

Rain event

On 29 September 2023, New York City experienced a significant rainfall event, resulting in widespread flash flooding. The storm produced heavy rain, leading to severe flooding in multiple boroughs, including low-lying areas around Jamaica Bay. This event was exacerbated by ground saturation from preceding rainfall associated with Tropical Storm Ophelia. The rapid onset of the storm and the high rainfall intensity caused water levels to rise quickly, overwhelming the city's drainage systems. Streets and transportation infrastructure, including parts of the subway system, were heavily impacted. The storm dropped approximately 152 to 203 mm of rain in some areas of the city, including parts of the Jamaica Bay watershed. According to the National Weather Service (NWS) (2024) the rainfall rates exceeded 40 mm/hour during the peak of the storm, compared to 80 mm/hour for Ida. This contributed to flash flooding across the city. Accumulated rain at JFK international Airport reported about 230 mm, the 150 mm reported during Ida's impact.

Model setup

Here we are using the same model setup as we used for the main paper simulations. For this rain event, the simulation starts at 27 September 2023, 00:00 and runs for five days to 02 October 2023, 00:00. Figure S1. a, b) show maximum hourly intensity and accumulated rain during this rain event for the simulation duration. The maximum hourly rainfall intensity noted is 56 mm/hour and the maximum temporal accumulated rain is 225 mm. Figure S1.c) presents time series of rainfall to show how the rain evolves over the 5-day simulation.

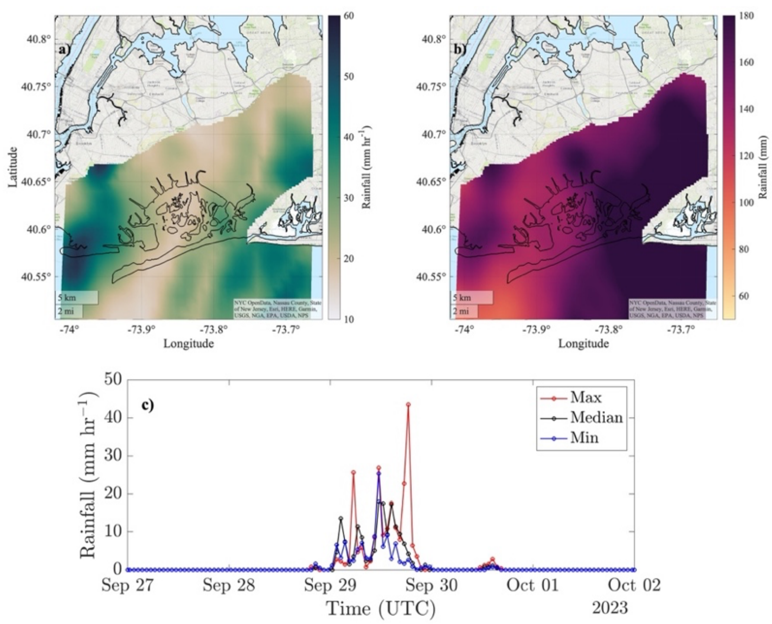

Figure S1. (a) Maximum rain intensity, (b) Total accumulated rain during the 29 September 2023 event, and (c) Rainfall time series at (Max) location with the maximum accumulated rain, (Median) location with the median accumulated rain, and (Min) location with the minimum accumulated rain over 5-day simulation. (topographic base map from MATLAB, hosted by Esri®)

Given these conditions, the 29 September 2023, rainfall event, which compared to Ida had lower maximum rain intensity but higher total accumulated rain, serves as an acceptable data point for validating the hydrodynamic model improved in this study. This way we can validate the model for various rain intensities. The event provided numerous high-water marks across the Jamaica Bay area from the FloodNet project (Mydlarz et al., 2024), offering an extensive dataset for validating the model's accuracy in simulating stormwater drainage under intense precipitation scenarios (Fig. S2).

To be able to better calibrate the model, we used both rain events and all the available HWMs from them. Figure S3 presents the model results vs observed HWMs for different drainage rates in both rain events. Assessing the performance across the three metrics with High Water Marks (HWM) data, as mentioned in the main paper, the 13 mm/hour drain rate has the highest NSE, indicating the model's best ability to explain the variance in observed HWMs. It remains the optimal choice, striking the best balance across all key performance metrics.

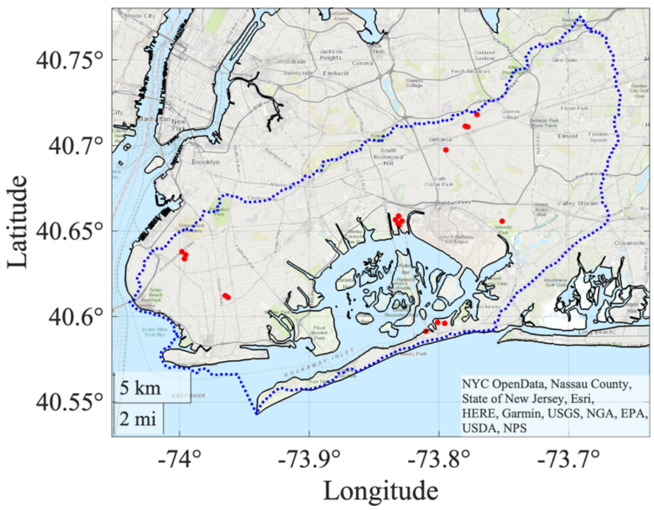

Figure S2. HWM locations in the domain (red dots show the location of the HWMs, and blue dashed line is the watershed boundary) for both Ida and 29 September 2023 rain events. (topographic base map from MATLAB, hosted by Esri®)

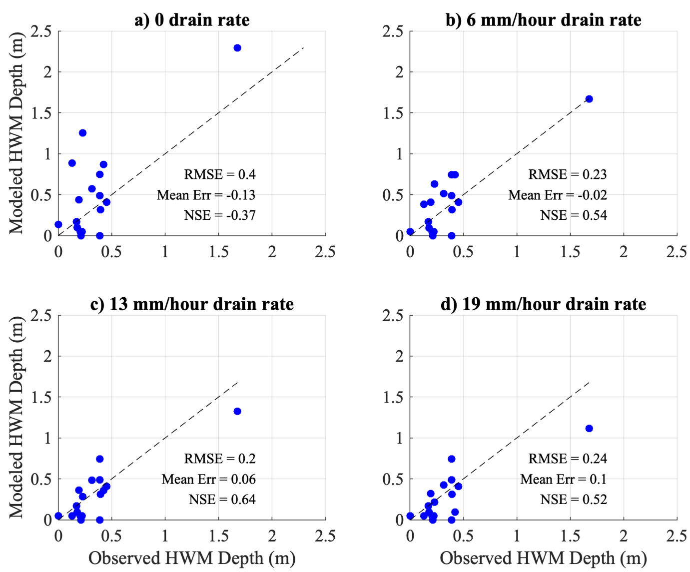

Figure S3. Model results vs observed HWMs for different drainage rates: a) no drain rate, b) 6mm/hour drain rate, c) 13 mm/hour drain rate, and d) 19 mm/hour drain rate.

Estuary water levels validation plot

In the process of calibrating and validating the model, in addition to the HWMs, we investigate the tide gauge data at three stations: Inwood (USGS station 01311850 (U.S. Geological Survey)), Rockaway (USGS 01311875 (U.S.

Geological Survey)), and Bergen Basin (a station managed by Stevens Institute of Technology) (Fig. 6 of the main paper). For the comparison of the calibrated model, we evaluate the peak water level during the simulation (the first high tide after Ida), where the model has error of +8, +7 and +6 cm for Inwood, Rockaway, and Bergen Basin gauges, respectively (Fig. S4).

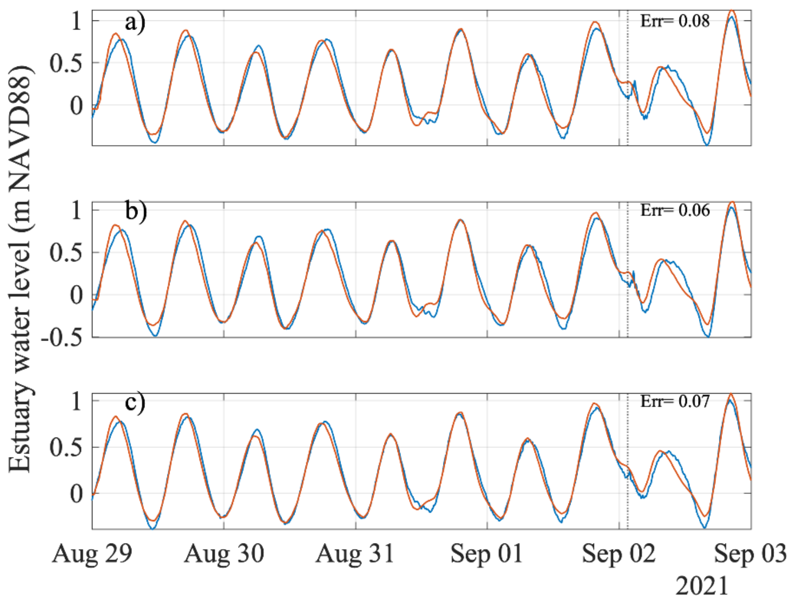

Figure S4. Estuary water level at Inwood, Bergen Basin, and Rockaway gauges are shown in panel a, b, and c, respectively. Gray dashed line is showing the time of peak rainfall during Ida.

References

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