Improving the Accuracy of a Real-Time ADCIRC Storm Surge Downscaling Model

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1. Introduction

- End-users such as DHS, FEMA, and NCEM rely on storm surge models for decision-making during storms (i.e. hurricanes)
- This research focuses on **improving the 1) applicability and 2) physics of existing storm surge downscaling (resolution enhancement) methods**
- Downscaling allows emergency managers to analyze flood risk at small-scale features such as buildings and roads
- Runs every six hours during an approaching storm
- Uses **ADCIRC** (ADvanced CIRCulation model) maximum water elevation output
- In NC, emergency managers use the **NC9** ADCIRC model; this is used as input for downscaling
- Typical resolutions used in forecasting:
  - ADCIRC NC9 model → as fine as 100-200 m
  - Downscaled → 15 m (or ~50 ft)

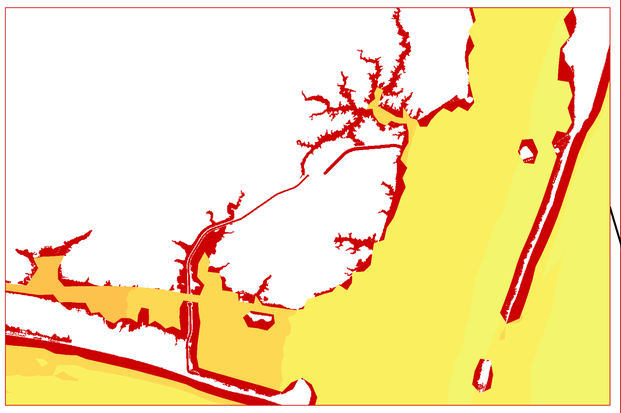


Figure 1. ADCIRC (yellow, orange) vs. downscaled water level extents (red) near Wilmington, NC.

Downscaling Process

NC9 ADCIRC Water Elevations → Downscaling Method → Enhanced Resolution Results

2. Increasing Method Applicability

- Integrated downscaling method with Kalpana, an ADCIRC output visualization tool
- Method was created for a NC-specific ADCIRC mesh and DEM
- Now applicable for any ADCIRC mesh, DEM, and resolution
- Created a user-friendly interface that allows users to download the downscaling code and create their own simulation
- Hindcasts for Hurricane Dorian were shared with end-users for FL, GA, SC, and NC (Figure 3)

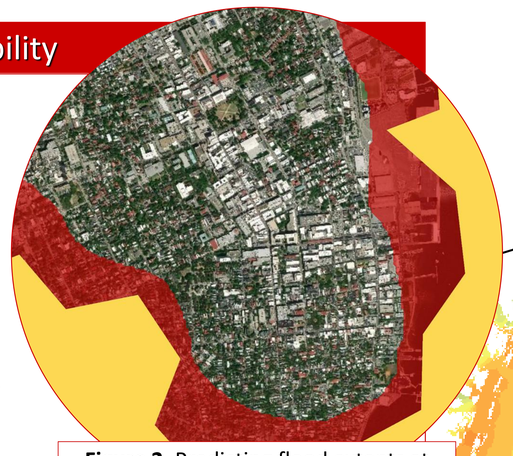


Figure 2. Predicting flood extents at building-sized scale in Charleston, SC.

3. Existing Downscaling Method

- Method proposed by former student in the master's thesis Tull 2018
- Referred to as the **static method** because ADCIRC maximum water levels are extrapolated horizontally until reaching an equivalent DEM elevation (Figure 4)
- Method currently used by emergency managers in NC
- Does not incorporate physics; tends to over-estimate flood extents

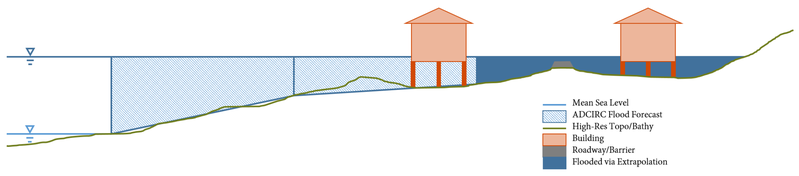
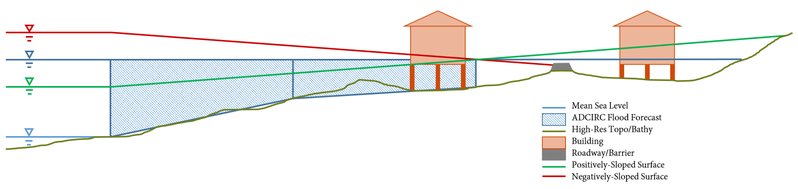


Figure 4. Static method.

4. Improving Downscaling Method Physics



Method 1: Slopes Method

- Rather than horizontally extrapolating water levels, this method takes into account the slope of the water surface
- Calculated using the following equation:

$$\zeta_{slopes} = \zeta_{static} \pm c(m_x \Delta x) \pm c(m_y \Delta y)$$

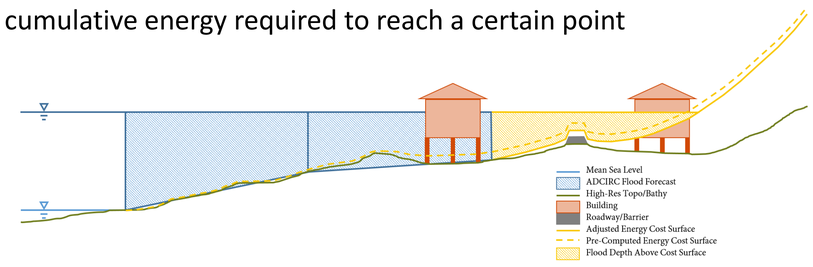
Method 2: Head Loss Method

- Water is extrapolated horizontally but, instead of extrapolating the water levels until they intersect the DEM surface, the water levels are extrapolated until they intersect an energy cost surface
- The energy cost surface is calculated by adding elevation to cumulative head loss:

$$cost_{total} = \Delta z + \sum L \left(\frac{n * U}{k * R^{2/3}} \right)^2$$

where n=Manning's n, U=depth-averaged velocity, k=conversion factor, R_H=hydraulic radius

- Treated as cumulative energy required to reach a certain point



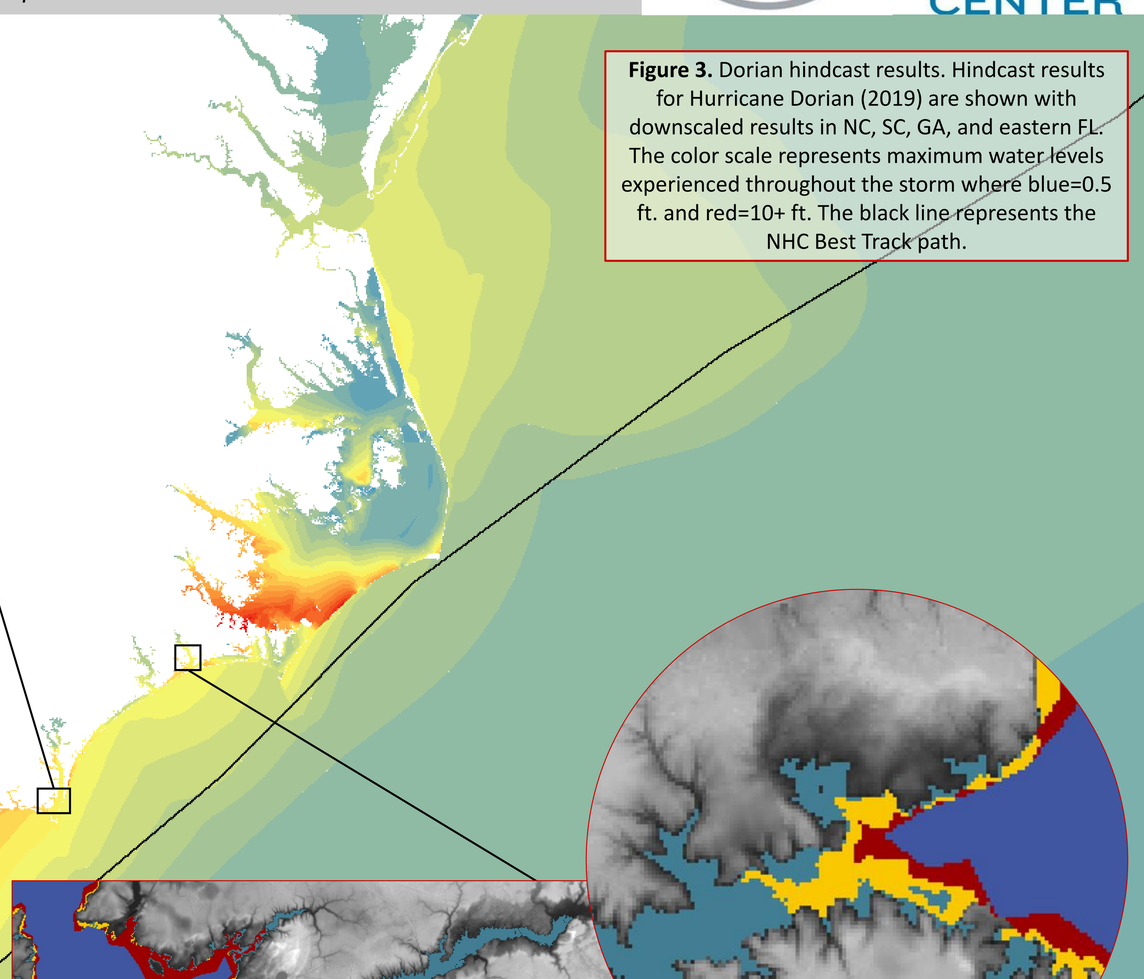


Figure 3. Dorian hindcast results. Hindcast results for Hurricane Dorian (2019) are shown with downscaled results in NC, SC, GA, and eastern FL. The color scale represents maximum water levels experienced throughout the storm where blue=0.5 ft. and red=10+ ft. The black line represents the NHC Best Track path.

Figure 5. NC9 (indigo), truth (red), head loss method (yellow), and static method (blue) output. The slopes method is not pictured. Each layer is listed from top to bottom.

5. Results

Table 1. Output raster cell counts. "Flooded" considers any cell at an elevation above MSL. The final three columns only compare results outside the extents of NC9 since NC9 is input for the downscaling methods. The final two columns represent over- and under-estimations in comparison to the truth. Cell resolution is 50x50 ft.

Raster	Flooded	Flooded (outside NC9)	Over-estimation (outside NC9)	Under-estimation (outside NC9)
NC9	2,741,038	---	---	---
Truth	2,205,760	164,026	---	---
Static Method	3,035,320	406,403	243,747	1,370
Slopes Method	3,055,440	418,285	255,341	1,083
Head Loss Method	2,832,769	204,360	97,101	56,767

6. Summary/Findings

- Goal: Build methods that "enhance the resolution" of relatively coarse ADCIRC water level output; these data will be used to forecast storm surge and inform emergency managers
- Existing static method code was integrated with Kalpana to easily apply the method to any geographical region, ADCIRC mesh, DEM, and downscaling resolution
- In addition to the static extrapolation method, two methods were proposed to add physics:
  1) Slopes method – extrapolate using the water surface slope, rather than horizontally
  2) Head loss method – incorporate head loss due to land cover during extrapolation
- The head loss method performed best with 204,360 cells flooded outside NC9 compared to the truth (164,026)
- The slopes method performed poorest with 418,285 cells flooded outside NC9
- Each of the new methods was run using the most basic set of input parameters; these can be modified to produce more favorable results