Storm Surge Predictions at Hyperlocal Sites

A Systematic Approach to the Worst-Case Scenario for Naval Station Norfolk

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1. Introduction

Background

- Storm surge is the leading cause of damages by hurricanes and other coastal storms.
- At regional and local scales, predictions are not optimized for a single home or infrastructure. The results are averaged.
- Models used for potential impacts over-estimate the inundated area.
- The location and shape of a site affects the storm surge distribution over the area. [1]
- Models used for storm surge impacts do not include offshore hydrodynamics of a storm.[2]

Local Community in Norfolk, VA

1.1m Sea Level Rise Projection for 2080 on Medium Rate[3,5]

2.2m Peak Storm Surge from Hurricane Irene 2011[4,5]

Research Questions

- How can one optimize storm surge predictions at a specific site?
- **What is the worst case at that site?**

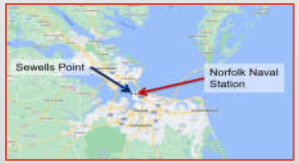
2. Study Area

Norfolk, VA

- Highest rate of SLR on east coast (4.5mm/yr)
- Inundation Hours increased from 100hrs in 1992 to 275hrs in 2009
- Mid- Continental Shelf

Naval Station Norfolk (NSN)

- Largest Naval Station in the world (21.6 sq. km)
- Located on Land Subsidence (Settling Land)
- Surrounded by Narrow Channels and Bulkheads



Location Map

3. Methodology

Mesh Generation

- 3 Nested Digital Elevation Model (DEM)
- 100m Min. Resolution Mesh in OceanMesh2D

ADCIRC + SWAN Simulations

- Tide Simulation
  - Major 8 Tidal Constituents
    - K1, O1, Q1, P1, M2, N2, K2, and S2
  - 18-day spin up (8/6/2011 to 8/24/2011)
- Storm Simulation - Hurricane Irene (2011)
  - Parametric Vortex Wind Model
    - GAHM (NWS=20) with NHC best-track
  - 6-day winds (8/24/2011 to 8/30/2011)
    - Landfall Date = 8/27/2011

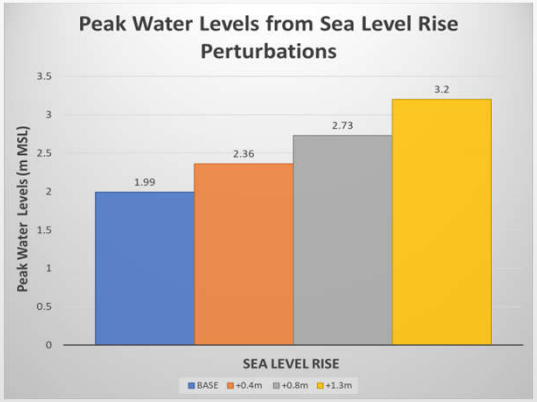
Variable Testing

Perturbations	BASE	Test 1	Test 2	Test 3
Sea Level Rise (m)[6]	0.0	0.4	0.8	1.3
Storm Track Deviation[7] (±km)	0.0	100	178	255
Central Max. Wind Speed[8] (mph)	105	113	121	129
Central Min. Pressure[9] (mbar)	942	933	925	916

4. Results

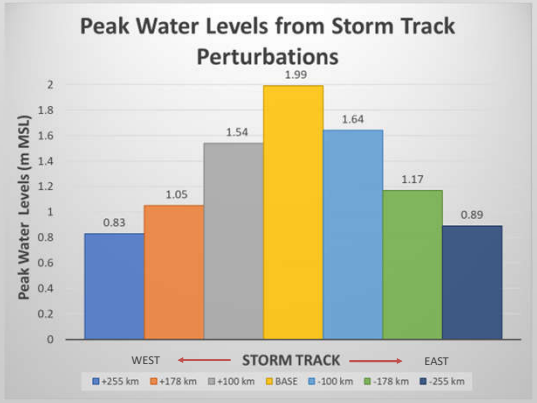
SEA LEVEL RISE – Peak Flood increases with SLR

- Linear relationship between Sea Level Rise & Peak Flood



STORM TRACKS – How is the Base the worst?

- Eastward deviations are further into the Atlantic Ocean.
- Westward deviations are further inland of Virginia.
- West deviations slightly higher water levels than east deviations.
- Deviations along lines of longitude do not give worse case.

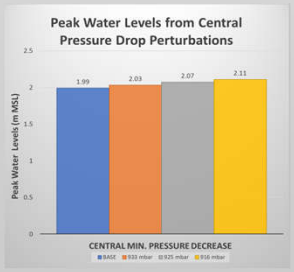


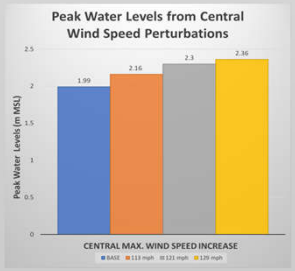
SEA LEVEL RISE – Inundated Area Increases with SLR but not linearly

- Total Boundary Area = 21.6 sq. km
- Non- linear relationship between Flooded Area & Sea Level Rise

STORM PARAMETER PERTURBATIONS – Peak Flood Increases with Decreasing Pressure & Increasing Winds

- As minimum central pressure drops, water levels increases.
- As maximum central wind speed increase, water level increases.





5. Conclusions and Future Work

- The sea level rise scenario had the greatest impact to the flooded area and peak water levels in storm perturbations.
- Further storm perturbations will be needed to determine the worst case for NSN.
  - Synthetic storms will be assessed for a worst storm track scenario.
- Higher-Resolution Models (Minimum 10m and 20m) will be developed to test the framework of the model.

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7. References

1 - Baugh et. al. (2018)
2 – Castrucci et. al. (2018)
3 – Sweet et. al. (2022)
4 – Hover et al. (2004)
5 – NOAA Sea Level Rise Viewer
6 - Sweet et. al. (2022)
7 – Salehi (2018)
8 – Camelo et. al. (2020)
9 – Mousavi et. al. (2011)