# Subgrid-Scale Corrections to Increase the Accuracy and Efficiency of Storm Surge Models


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PREEVENTS PI Meeting
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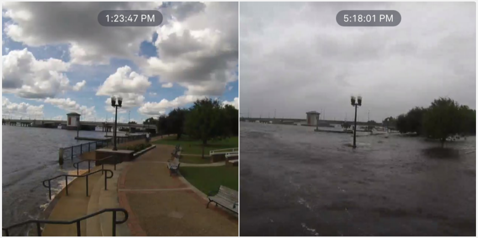
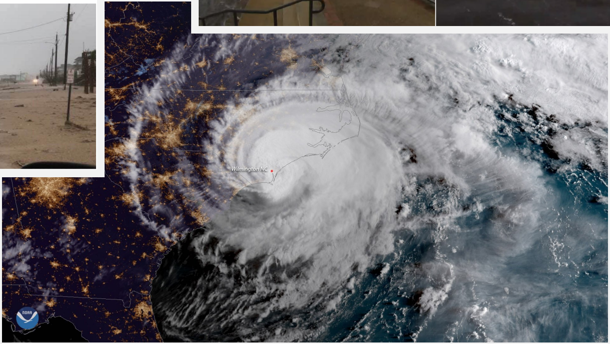
# 0. Motivation

Surf City NC (@AdamWGME)


Union Point in New Bern NC (@NWSEastern)

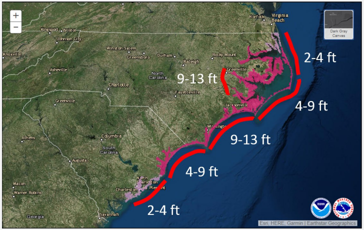


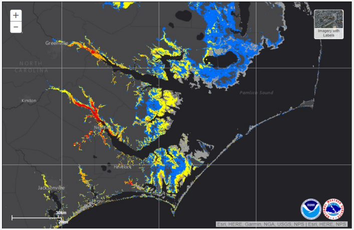



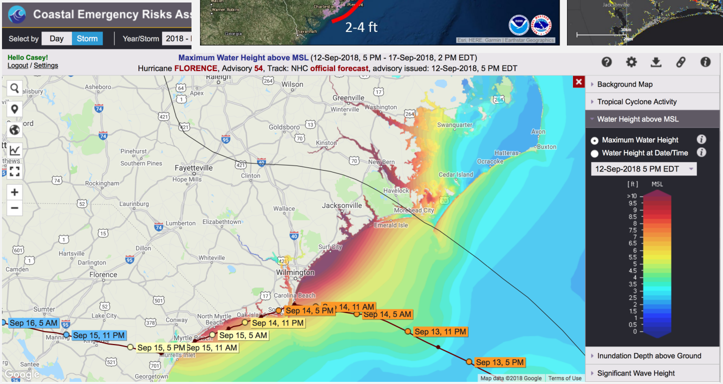

Florence making landfall on Fri Sep 14 (@NOAASatellites)

# 0. Motivation

Surge and flooding guidance from the National Hurricane Center (NHC)






ADCIRC maximum water levels for Advisory 54 (CERA)

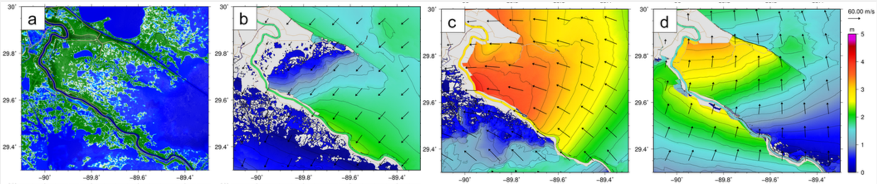
# 1. Objectives

Storm surge models must balance accuracy and efficiency

- Question of resolution – how much detail to include?

Can we improve predictions by correcting for fine-scale processes?

1. Understand how storm surge can vary at and across spatial scales;
2. Derive and test subgrid corrections to increase flooding accuracy;
3. Implement and test corrections in operational surge models;
4. Transfer techniques to stakeholders in academia and industry.




Caernarvon Marsh in southeast Louisiana: (a) bathymetry and topography, and water levels during Hurricane Isaac (2012) at (b) 8 hr before, (c) at landfall, and (d) 16 hours after.

## 2. Challenges

This year, we have been working to overcome two main challenges:

A. Average governing equations to derive subgrid-scale corrections

B. Quantify corrections by upscaling from fine-scale models / data

Consider the mass conservation:

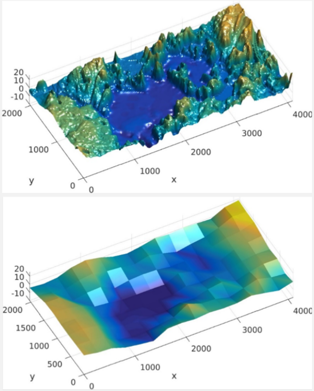
$$\frac{\partial \eta}{\partial t} + \nabla \cdot (H\mathbf{U}) = 0$$

which can be averaged/upscaled by using the 'wet-area fraction' $\phi$:

$$\phi \frac{\partial \langle \eta \rangle}{\partial t} + \nabla \cdot (\phi C_\eta \langle H \rangle \langle U \rangle) = 0$$

but which has several challenges:

- How to pre-compute $\phi$ and $C_\eta$?
- What about momentum equations?

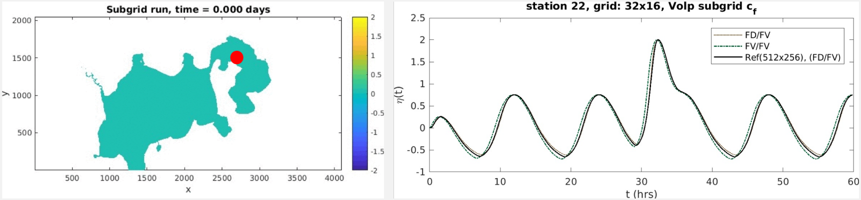



Upscaling bathy/topo from (top) 16 m to (bottom) 256 m.

# 3. Accomplishments

Progress has been promising in both areas:

B. Testing corrections for tidal propagation in Buttermilk Bay MA




Improved hydrographs on coarse mesh with wet-area fraction and Volp-style friction.

A. Deriving a momentum conservation with correction terms

- Need to develop $\phi$, $C_\eta$, $C_U$, and $n_{M,V}$ from fine-scale models

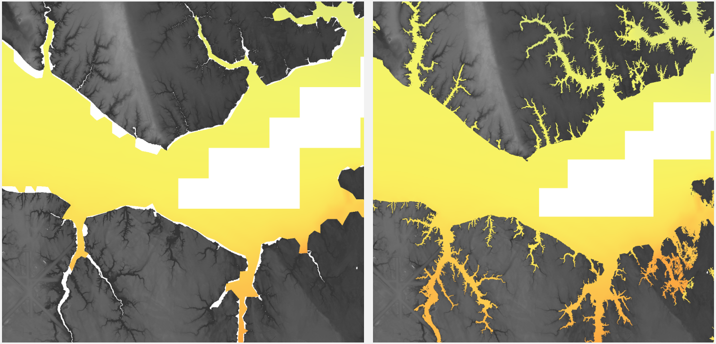
$$\frac{\partial \langle \mathbf{U} \rangle}{\partial t} + gC_\eta \nabla \langle \eta \rangle + \frac{1}{\phi \langle H \rangle}\left[\nabla \cdot \left(\phi \left(C_U - 1\right) \langle H \rangle \langle \mathbf{U} \rangle^T\right) \langle \mathbf{U} \rangle\right] + C_U \langle \mathbf{U} \rangle^T \cdot \nabla \langle \mathbf{U} \rangle$$

$$= \frac{\langle \tau \rangle}{\rho \langle H \rangle} - \frac{g \langle \mathbf{U} \rangle \left|\langle \mathbf{U} \rangle\right| n_{M,V}^2}{\langle H \rangle^{4/3}} - \frac{\nabla P_A}{\rho} - f_c \left[\langle V \rangle, -\langle U \rangle\right]$$

## 4. Engagement

Working closely with NC Emergency Management

- Real-time predictions shared in 2017 and 2018 hurricane seasons
- Flooding was downscaled to 15-m DEM for decision support
- Continue to provide guidance and solicit feedback



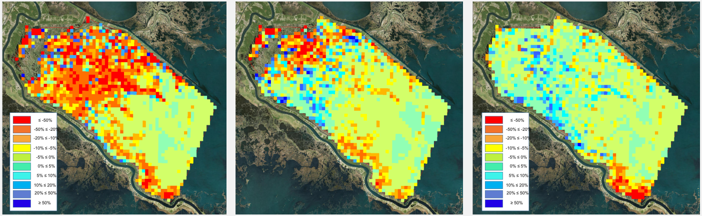
Storm surge predictions for Hurricane Matthew (2016)
for lower Neuse River (a) before and (b) after enhancing resolution.

## 5. Next Steps

During the next project year, we will push in three directions:

A. Develop corrections for mass and momentum conservation
  - Finalize the theory and formulation
  - Implement and test for controlled flow situations

B. Quantify relationships from fine-scale models / data




During Isaac, percent differences between 'coarse' bottom stresses from upscaled quantities (water levels, water velocities, Manning's n), and 'true' bottom stresses upscaled directly from the surge model.

C. Implement corrections within operational models
  - We are working with both SLOSH and ADCIRC