Improving ‘Sub-Grid’ Representation in the SLOSH Model

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1. What is SLOSH?

The **S**ea, **L**ake, **O**verland **S**urges from **H**urricanes or SLOSH model is the operational storm surge forecast model used by the National Hurricane Center.

- Uses a 2D curvi-linear, polar coordinate grid
- Takes storm parameters as input
- Runs probabilistic forecasts

GOAL: To improve the representation of small scale features in a SLOSH grid by correcting with information from high-resolution data sets.

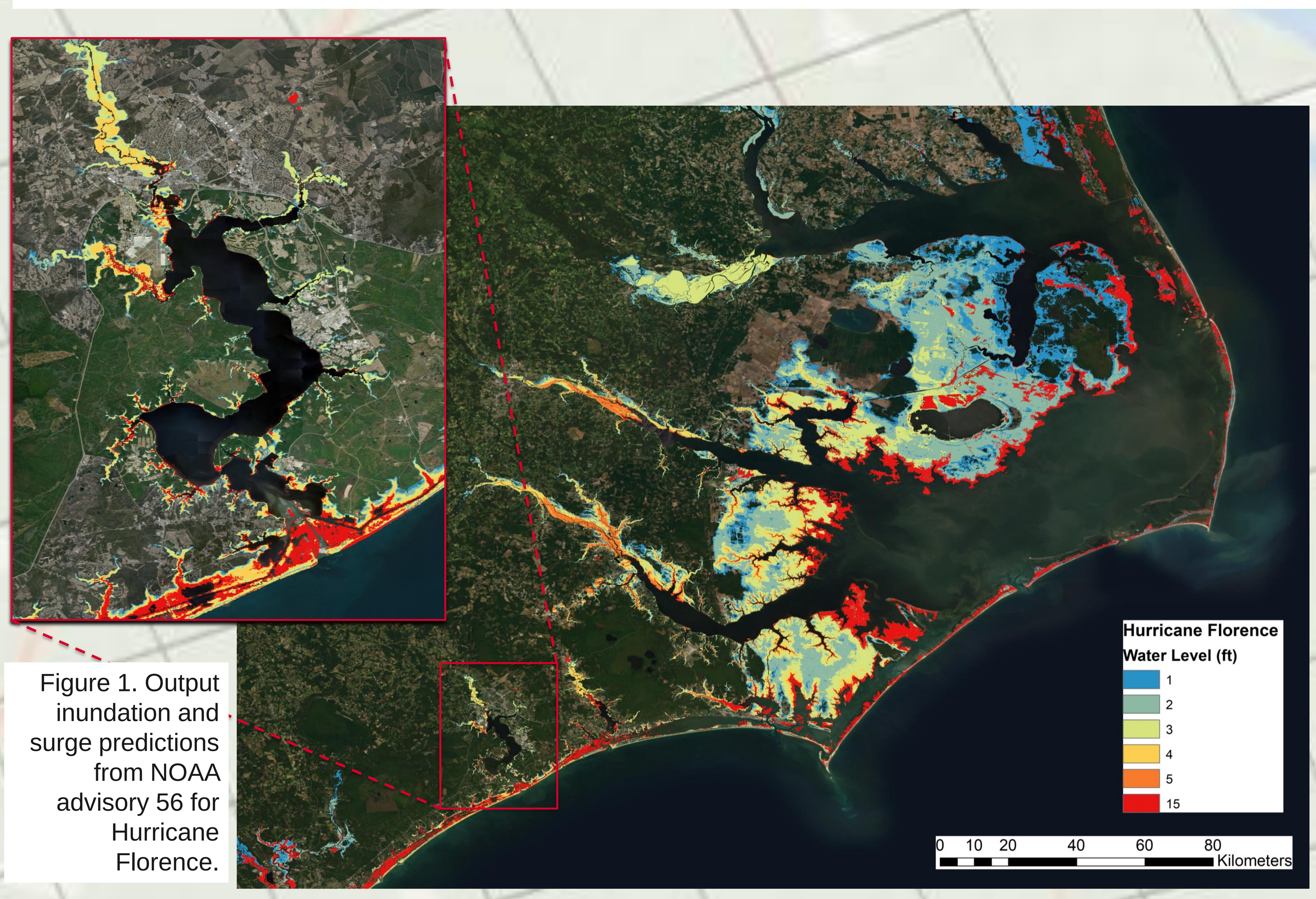


Figure 1. Output inundation and surge predictions from NOAA advisory 56 for Hurricane Florence.

2. Motivation

SLOSH grids:

- Coarse resolution representing complex landscape features during simulations.
- Small-scale features such as channels, bays, and barriers, are input manually.
- Post-processing leads to output in Figure 1, where results are downscaled to higher resolution data sets.

PROBLEM: How do we know the current SLOSH grids are accurately representing flow through fine scale features? Can we test our corrections on grids of varying resolution?

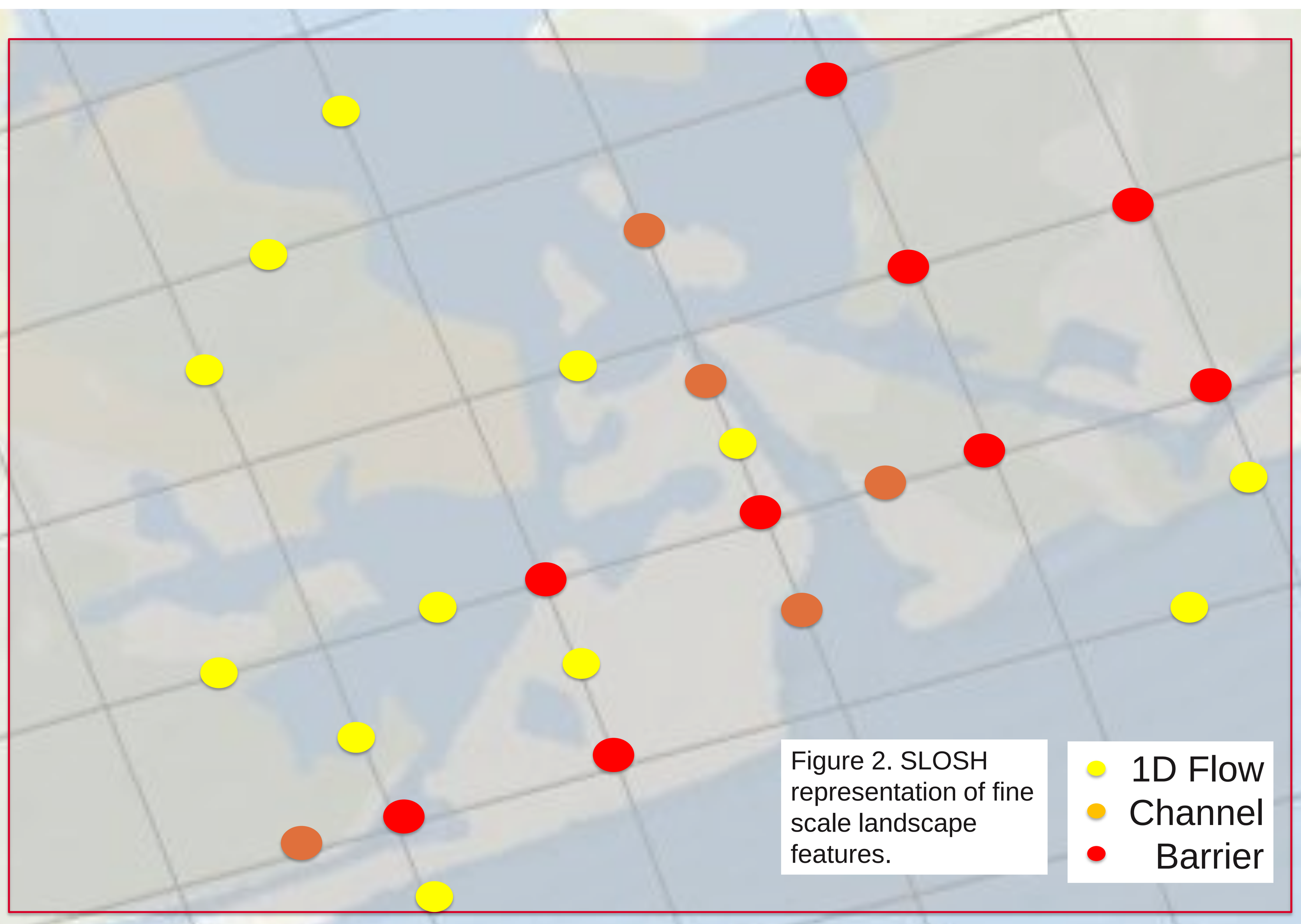


Figure 2. SLOSH representation of fine scale landscape features.

3. Methods

1. **SOLUTION**: Examine SLOSH performance on a simple grid test case with flow through a small channel through a barrier to a back bay
2. In SLOSH source code, introduce constant wind, remove Coriolis
3. Create grid using SLOSH grid descriptions and associated SLOSH code, then vary grid resolution
4. Build a high resolution Digital Elevation Model (DEM) with idealized channel to back bay
5. Interpolate average depths from DEM onto grid using Python Rasterstats
6. Run SLOSH on grids, visualize in SLOSH Display Program

4. Validation

Comparison of the analytical solution to SLOSH output with constant winds and no Coriolis on a quarter annular harbor grid.

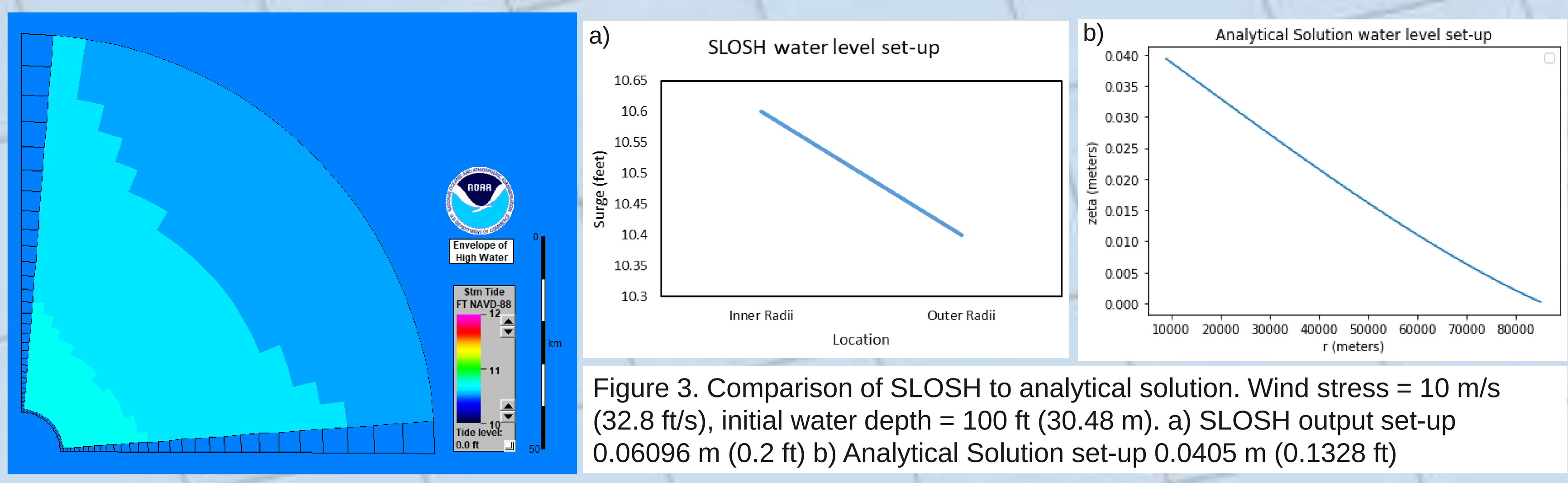
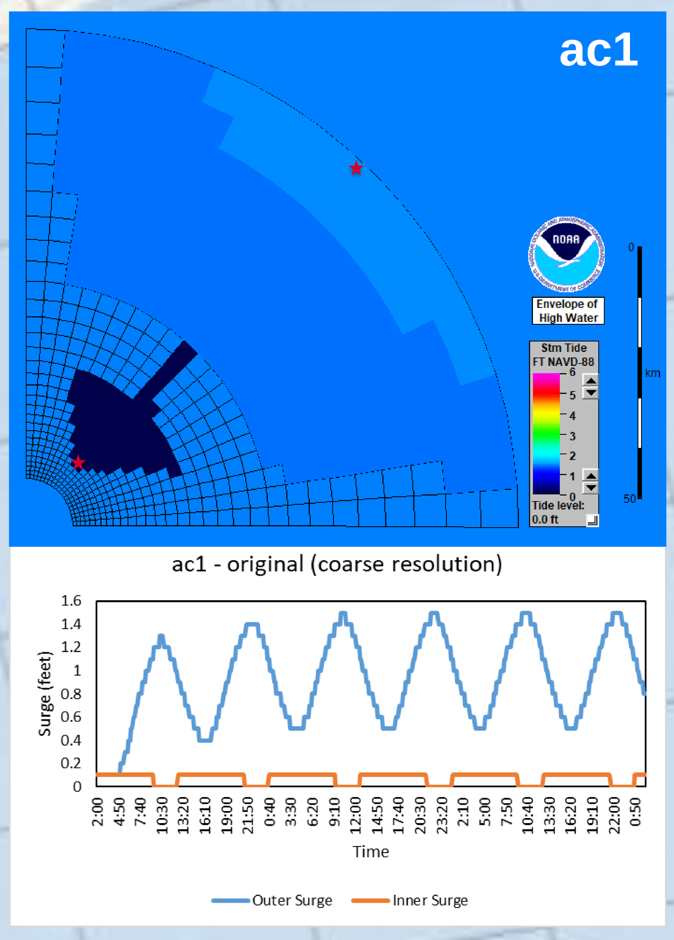
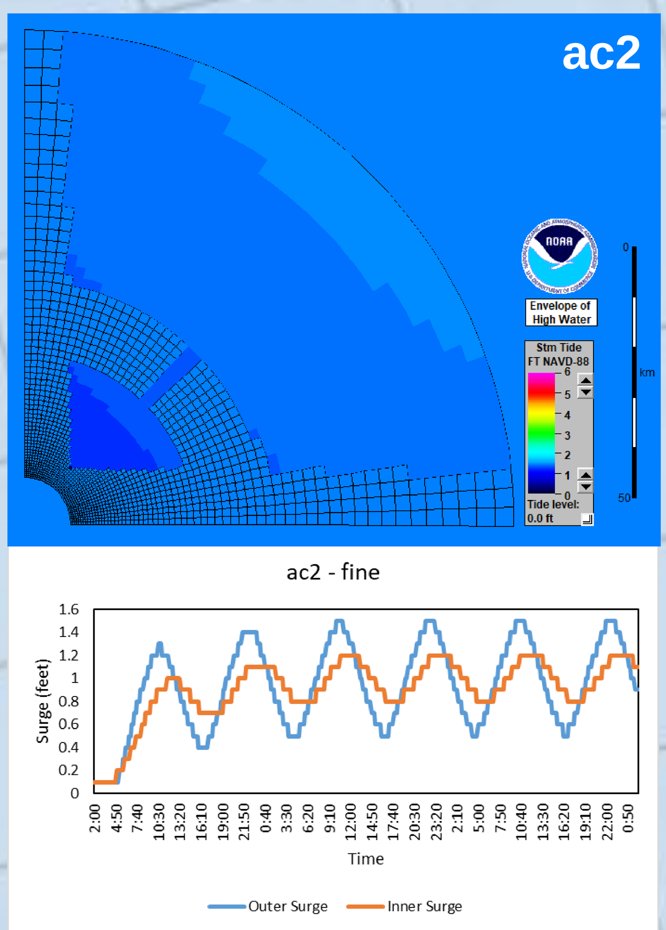
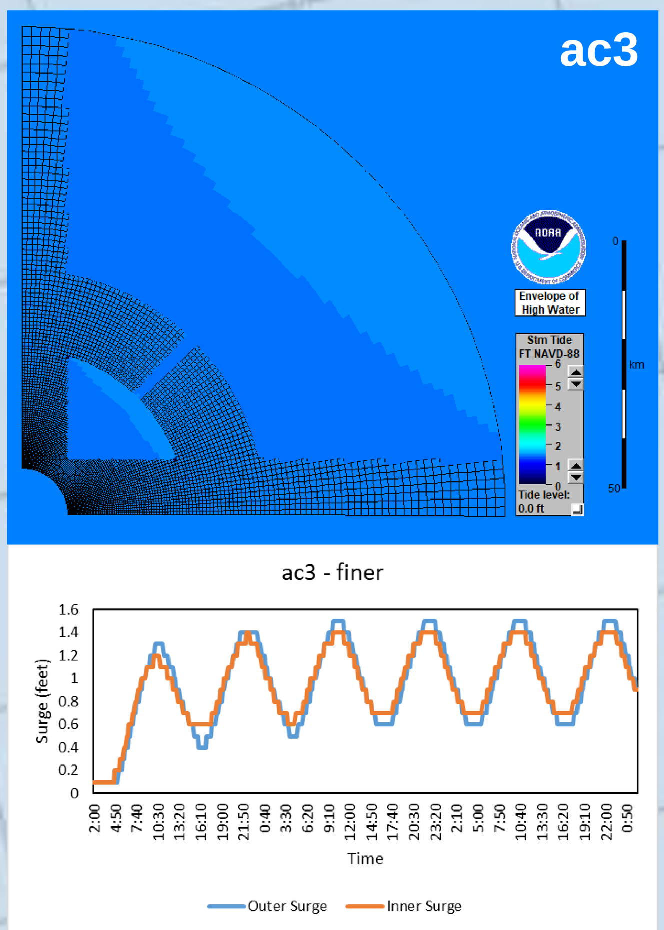


Figure 3. Comparison of SLOSH to analytical solution. Wind stress = 10 m/s (32.8 ft/s), initial water depth = 100 ft (30.48 m). a) SLOSH output set-up 0.06096 m (0.2 ft) b) Analytical Solution set-up 0.0405 m (0.1328 ft)

5. Results







Grid name	Channel Width (miles)
ac1-Original	1.6 to 2.3 - 1 cell
ac2-fine	1.7 to 2.56 - 2 cells
ac3-finer	1.2 to 1.8 - 3 cells
Channel	1.0 to 1.5

TAKE AWAY: Resolution maters. As we increase resolution, run times increase, however back bay water levels match with the open ocean.

6. Future Work

FULL SOLUTION: Add correction term, ϕ into the SLOSH governing equation as an alternative to the inclusion of ‘sub-grid’ features in the SLOSH grids.

$$\phi = \frac{A_W}{A_G}$$

The wet area fraction

$$\frac{\partial\langle\mathcal{V}\rangle_G}{\partial t} = -g\langle H\rangle_G\left(B_r\frac{\partial\langle h\rangle_W}{\partial Q} - B_i\frac{\partial\langle h\rangle_W}{\partial P}\right) + f(A_r\langle\mathcal{U}\rangle_G + A_i\langle\mathcal{V}\rangle_G) + \phi r cos\theta\langle y_T\rangle_W + \phi r sin\theta\langle x_T\rangle_W$$

$$\frac{\partial\langle\mathcal{U}\rangle_G}{\partial t} = -g\langle H\rangle_G\left(B_r\frac{\partial\langle h\rangle_W}{\partial P} - B_i\frac{\partial\langle h\rangle_W}{\partial Q}\right) + f(A_r\langle\mathcal{V}\rangle_G + A_i\langle\mathcal{U}\rangle_G) + \phi r cos\theta\langle x_T\rangle_W + \phi r sin\theta\langle y_T\rangle_W$$

The averaged momentum equations in the P and Q-directions