Validation Study of the GeoClaw Software: Modeling Hurricane Hugo

Riley Fisher

Faculty Mentor: Professor Kyle Mandli

Columbia-Amazon SURE Program

Columbia Engineering | The Fu Foundation School of Engineering and Applied Science

amazon

Objective

Conduct a validation study on a storm surge modeling software. Determine the ability of the model to handle estimations of missing data and detailed topography.

Background

- Modeling **geophysical flow** problems are vital in the response to future natural disasters.
- The **GeoClaw** branch of the Clawpack software package models tsunamis, **storm surges**, and debris flows.
- I **modeled Hurricane Hugo** using this software and compared the results to real-world data.

Methods

Table 1: Data needed to run simulation in GeoClaw.

Actual Data	Derived Data
Storm Data	Storm Radius
Topography and Bathymetry	Maximum Wind Radius
Water Levels at Gauges	

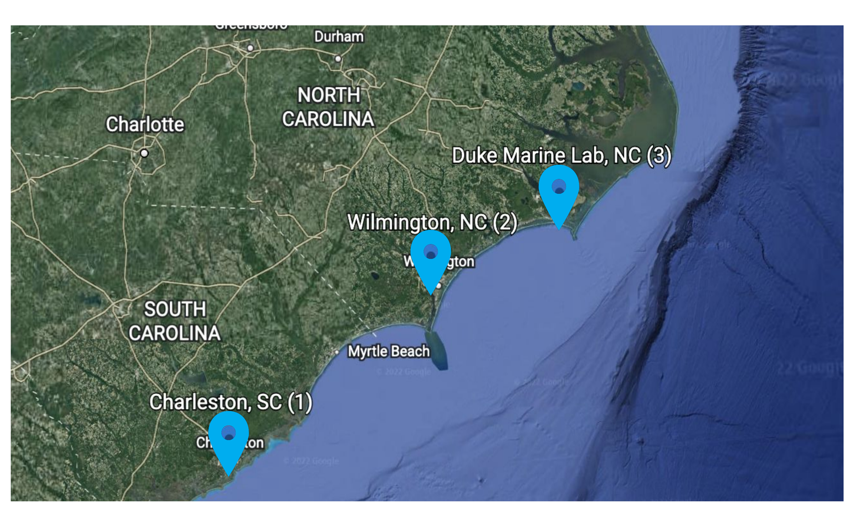

Figure 1: The 3 tidal gauges measuring water levels.

Refining Topography

- Model run at varying degrees of specificity to balance accuracy and timing efficiency
- Manually increased refinement at gauge locations (see **Figure 4**)

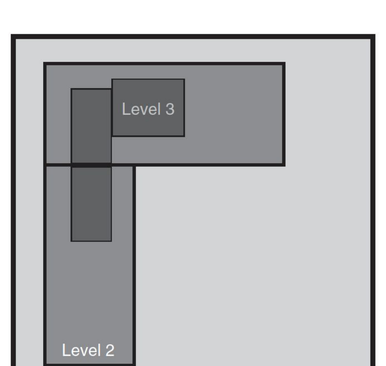

Figure 2: View of three levels of a refinement grid. A higher level of refinement correlates to higher spatial accuracy.

Results

Water Surface Levels

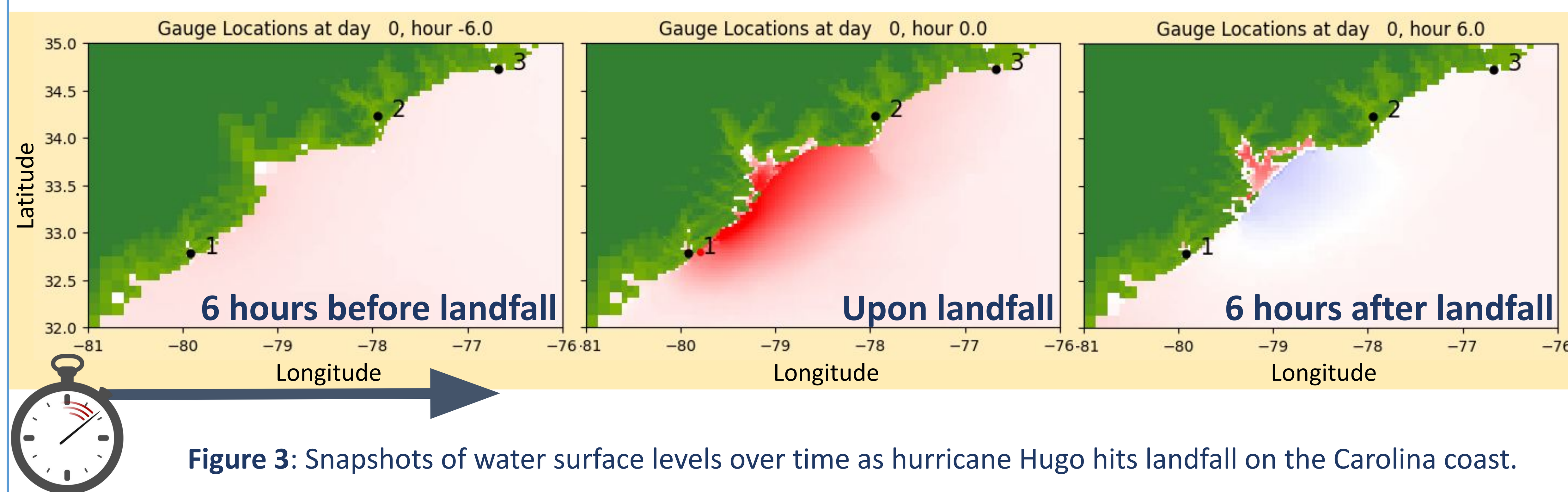

Figure 3: Snapshots of water surface levels over time as hurricane Hugo hits landfall on the Carolina coast.

Topography Refinement

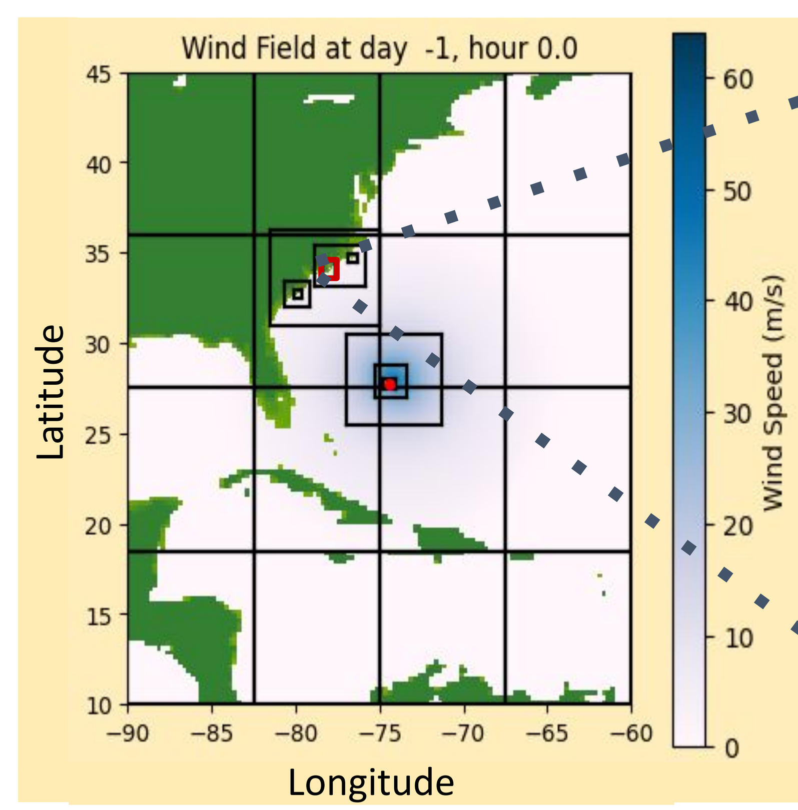

Figure 4: Boxes represent refinement areas. Smaller boxes indicate areas of forced refinement around the gauges.

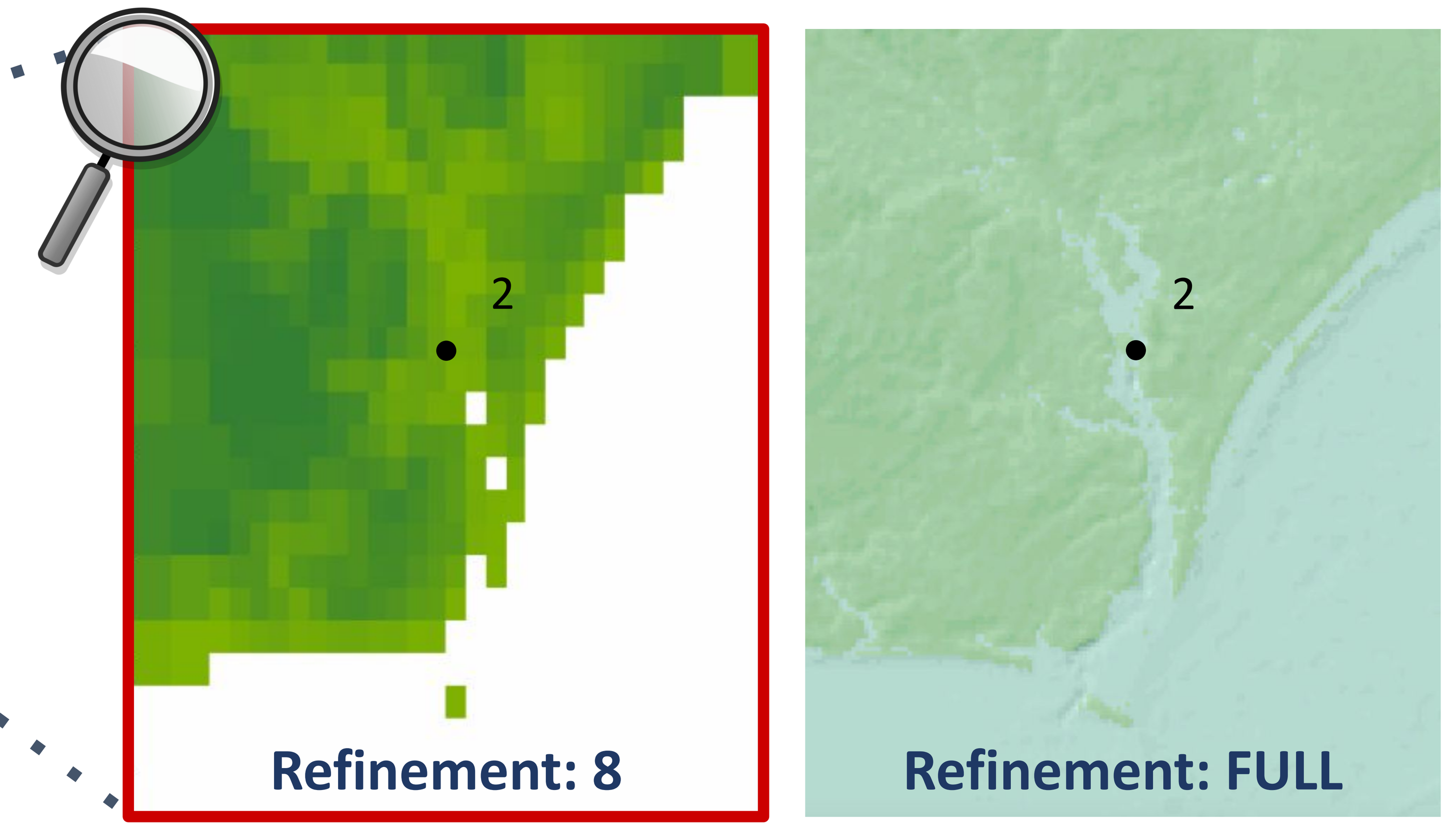

Figure 5: GeoClaw topography (left) vs. actual topography (right) of gauge 2 in river inlet.

Water Levels at Gauge Stations

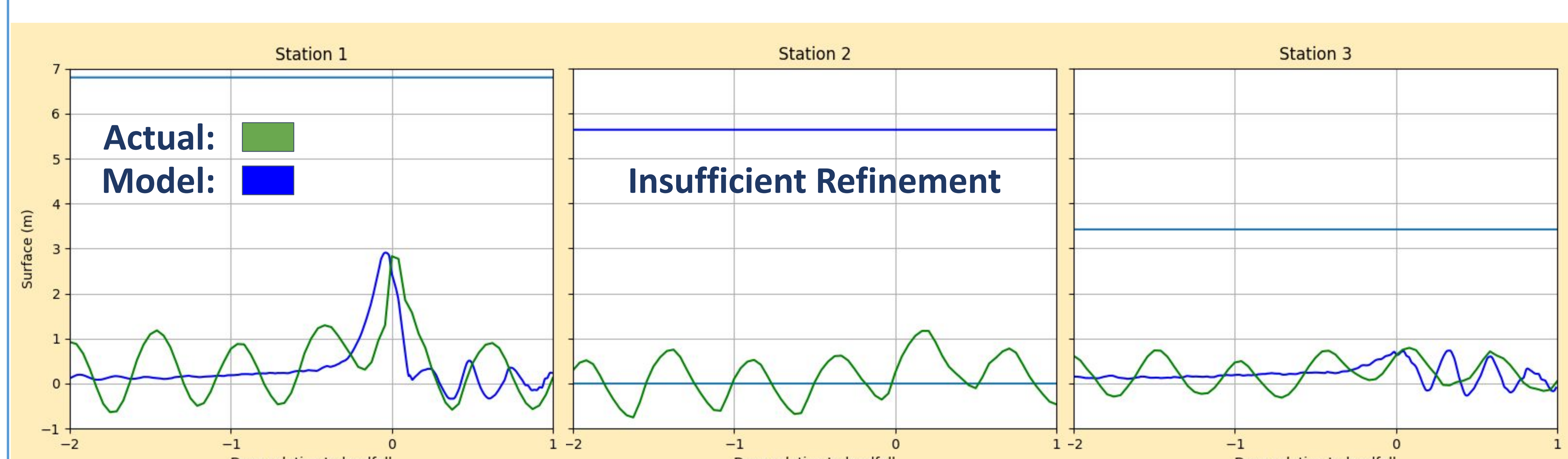

Figure 6: Comparison of simulated and actual water levels at three gauge locations.

Findings

Table 2: Evaluation of results.

Strengths	Limitations
Simulation returns data for gauges 1 and 3	Refinement along river for gauge 2
General timing and height of the surge match at gauges 1 and 3	Simplifications in extracting the missing data
Estimating the missing data did not significantly affect accuracy	
Forced refinement at the gauges worked 2/3 times without loss of efficiency	

Conclusion

The model ran using estimations of missing data without significant loss of accuracy. The model was able to refine areas with detailed topography while maintaining efficiency to an extent.

Future Work

- Run with higher refinement levels
- Modify model to account for river topography
- Extend estimations of missing data to create fully synthetic storms
- Use these storms to model effects due to climate change

Acknowledgements

I would like to thank Columbia Engineering and Amazon for sponsoring this research through the SURE program. I would also like to thank Professor Mandli for his guidance this summer and the group of undergraduates that also completed validation studies.

References

1. Ahmadia, A et al. (2022). *Clawpack repositories*. GitHub. https://github.com/clawpack
2. *Coastal inundation dashboard*. (2022). NOAA Tides & Currents. https://tidesandcurrents.noaa.gov/inundationdb/
3. *GEBCO gridded bathymetry data download*. (2022). GEBCO. https://download.gebco.net/
4. *Google Earth*. (2022). Google Earth. https://earth.google.com/web/
5. *Index of /atcf/archive/1989*. (2014). NHC Data Archive. https://ftp.nhc.noaa.gov/atcf/archive/1989/bal111989.dat.gz
6. Mandli, K. T., & Dawson, C. N. (2014). Adaptive mesh refinement for storm surge. *Ocean Modelling*, 75, 36–50. https://doi.org/10.1016/j.ocemod.2014.01.002