

Developments in storm surge estimation using surrogate modeling techniques

Alexandros Taflanidis, University of Notre Dame, ataflani@nd.edu
Jize Zhang, Lawrence Livermore National Lab, zhang64@llnl.gov
Aikaterini Kyprioti, University of Notre Dame, akyriot@nd.edu
Andrew Kennedy, University of Notre Dame, akenned4@nd.edu
Tracy Kijewski-Correa, University of Notre Dame, tkijewsk@nd.edu

MOTIVATION

Numerical advances in storm surge prediction over the past couple of decades have produced high-fidelity simulation models that permit a detailed representation of hydrodynamic processes and therefore support high-accuracy forecasting. Unfortunately, the computational burden of such numerical models is large, requiring thousands of CPU hours for each simulation, something that limits their applicability for hurricane risk assessment. Use of Kriging-based surrogate modeling techniques has been examined to address the aforementioned challenge Jia et al. [2016], Zhang et al. [2018]. This approach can provide fast predictions using a database of high-fidelity, synthetic storms, with the goal of maintaining the accuracy of the numerical model utilized to produce this database, while offering computational efficiency.

SURROGATE MODELS

This contribution overviews initially recent research developments for the application of Kriging for storm surge predictions. Topics discussed include: enhancement of the initial database for nodes (i.e., geographical locations) that have remained dry in some of the database storms; adaptive selection of storms forming the initial database; use of different surrogate modeling tuning techniques and their impact on the metamodel predictive capabilities for storm surge estimation; implementation for estimation of impact due to near-shore processes (breaking waves), something that requires coupling of different numerical models.

APPLICATION

Application of these surrogate modeling concepts is discussed for the development of the Storm Hazard Projection (SHP) Tool for the NJcoast (<https://njcoast.us/>) web-based visualization environment, developed to insure risk-responsive and data-informed decision making. NJcoast offers to municipalities of New Jersey simulation tools and geospatial data information through a basic web browser accessible on their computer, smartphone or tablet. The SHP tool (Figure 1,2) enables users to simulate wind fields, storm surge and wave run-up for hurricanes through the use of fast-to-compute surrogate models. The North Atlantic Coast Comprehensive Study (NACCS), completed by the US Army Corps of Engineers (USACE), is the underlying database of high-fidelity storm simulations used in the model development. The NACCS database was enhanced with wave run-up simulations using a one-dimensional Boussinesq model to capture the interaction of the waves with shoreline and coastal protective features and project the total run up inland, along transects at specific locations over the New Jersey coast.

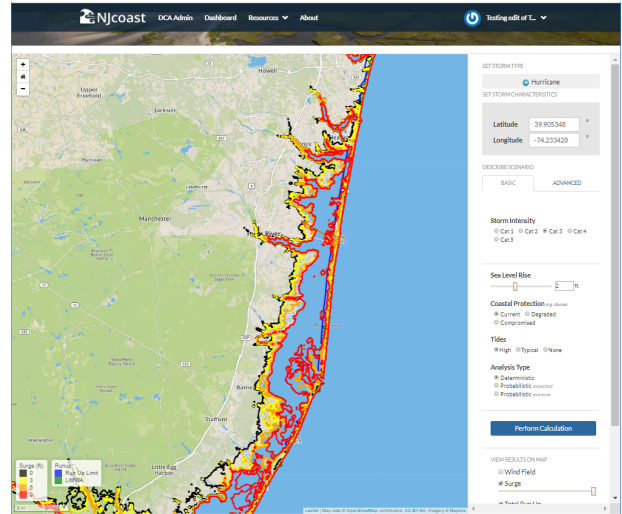


Figure 1- Screenshot of Storm Hazard Projection tool displaying storm surge and run up result.

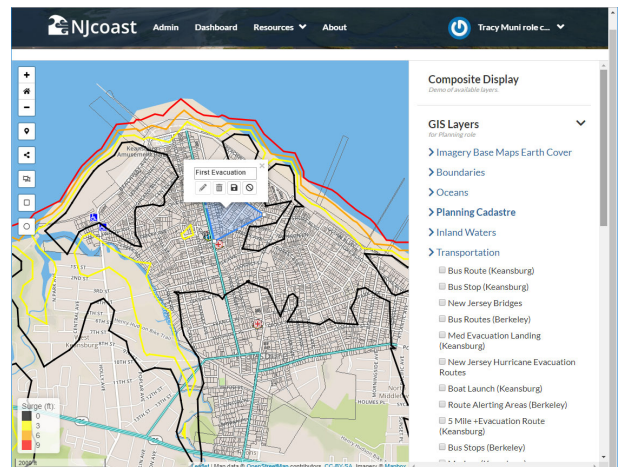


Figure 2- Screenshot of NJcoast map with nested drop down menus of available data layers

REFERENCES

- Jia, Taflanidis, Nadal-Caraballo, Melby, Kennedy, Smith (2016). "Surrogate modeling for peak and time dependent storm surge prediction over an extended coastal region using an existing database of synthetic storms." *Natural Hazards*, 81:909-938.
- Zhang, Taflanidis, Nadal-Caraballo, Melby, Diop (2018). "Advances in surrogate modeling for storm surge prediction: storm selection and addressing characteristics related to climate change." *Natural Hazards*, 94(3): 1225-1253.