Comparing Alternative Modeling Approaches for the Assessment of Energy Infrastructure Vulnerability to Coastal Storm Surge

Benjamin L. Preston[1], Megan C. Maloney[1], Zhaoqing Yang[2], Taiping Wang[2], Thomas J. Wilbanks[1], Sherry B. Wright[1]

[1]Oak Ridge National Laboratory

[2]Pacific Northwest National Laboratory

Oak Ridge National Laboratory

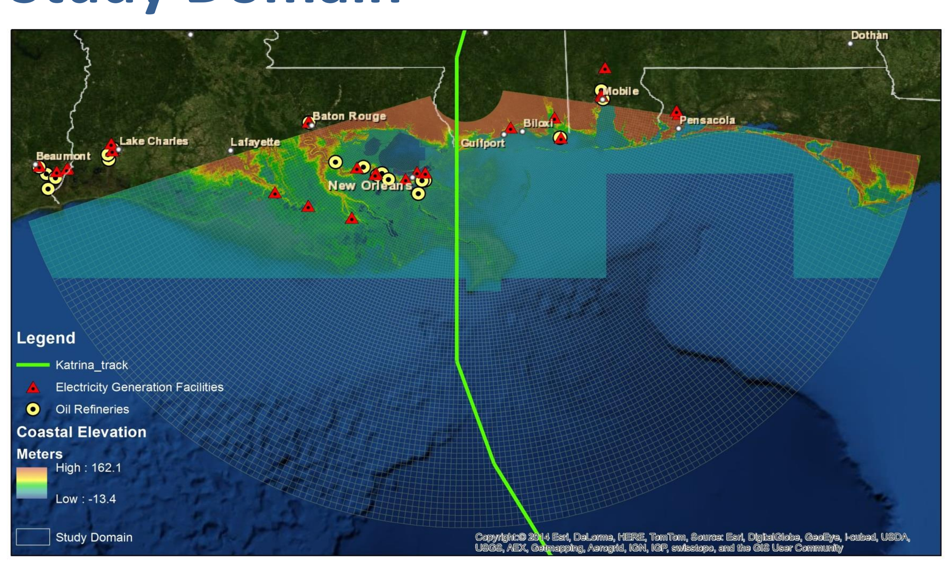
Climate Change Science Institute at Oak Ridge National Laboratory

Pacific Northwest National Laboratory

Evaluating the Vulnerability of Coastal Energy Infrastructure to Hurricane Storm Surge

- Over the past decade, tropical cyclones such as Hurricanes Katrina, Rita, and Ivan demonstrated the vulnerability of energy infrastructure to coastal storms. Sea-level rise and subsidence are projected to increase infrastructure exposure to coastal inundation.
- A wide variety of modeling approaches have been applied in the assessment of coastal vulnerability. Such approaches vary significantly in terms of complexity, computational demands, and process representation.
- Little attention has been focused on the extent to which model selection influences the accuracy of predictions of exposure and vulnerability of coastal energy infrastructure.
- This study uses Hurricane Katrina as a basis for comparing a range of methods commonly applied in coastal hazard assessments with respect to their accuracy in predicting inundation at energy facilities.

Study Domain



- The study domain for this analysis was the U.S. Gulf of Mexico region associated with the path of Hurricane Katrina.
- Results from different hazard models were restricted to the modeling domain for the SLOSH New Orleans basin to maintain comparability.

Coastal Hazard Models

- Five different empirical and process-based storm surge and inundation models were used to predict flooding of energy facilities.

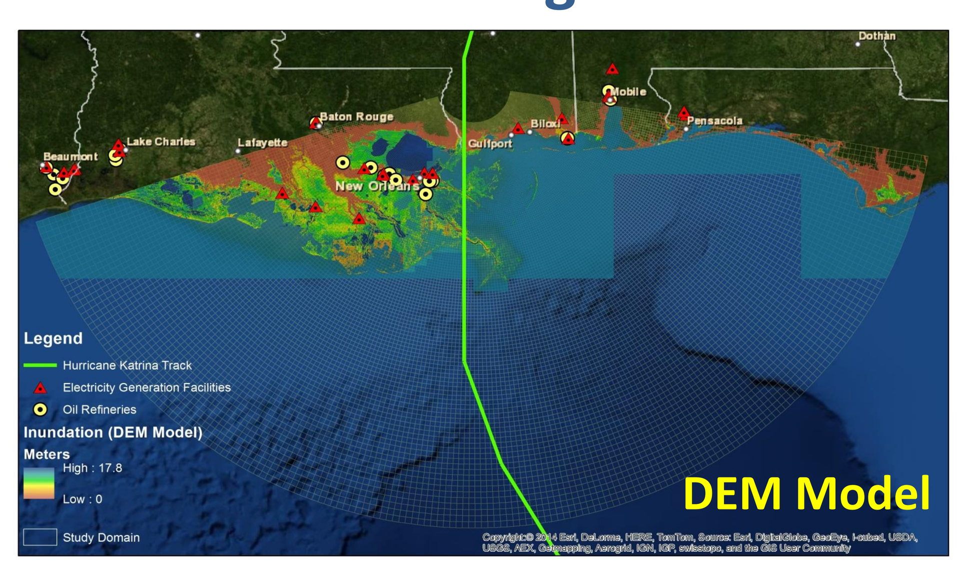
Model Name	Description	Complexity
DEM	Inundation hazard map was based on an assumed 24 ft (8.5 m) storm surge elevation throughout the analysis domain as indicated by a 1/3 arc second digital elevation model (DEM)	Low
Reanalysis	Hazard map was based on the interpolation of 1,024 observed high water marks associated with Hurricane Katrina	Low
SLOSH-Generic	Hazard map based on the maximum inundation projected by NOAA's Sea, Land and Overland Surge from Hurricanes (SLOSH) model for an ensemble simulation of category 3 storms	Intermediate
SLOSH-Katrina	Hazard map based on the maximum inundation projected by NOAA's SLOSH model for the Hurricane Katrina track	Intermediate
FVCOM	Hazard map for Hurricane Katrina was simulated by the Finite-Volume, primitive equation Community Ocean Model (FVCOM)	High

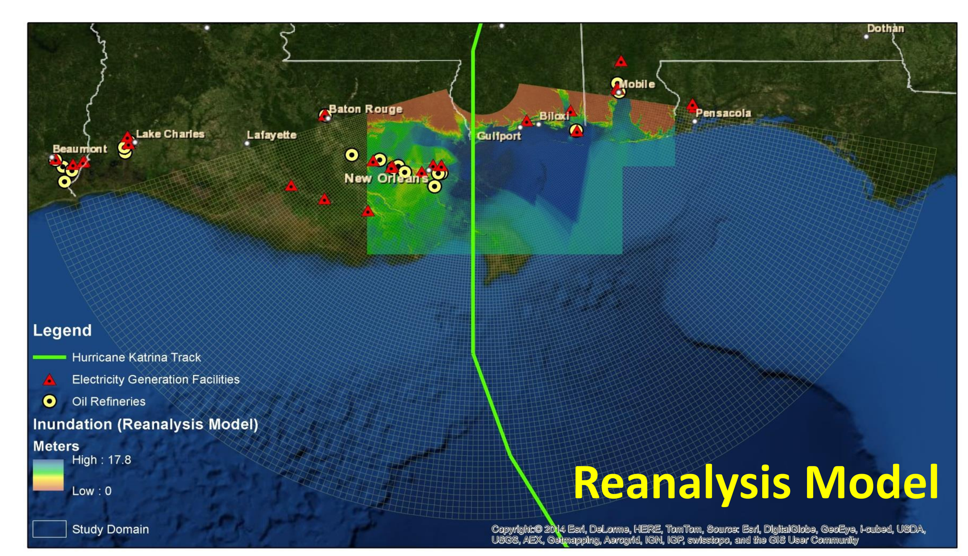
Results: Observed Flooding of Energy Facilities

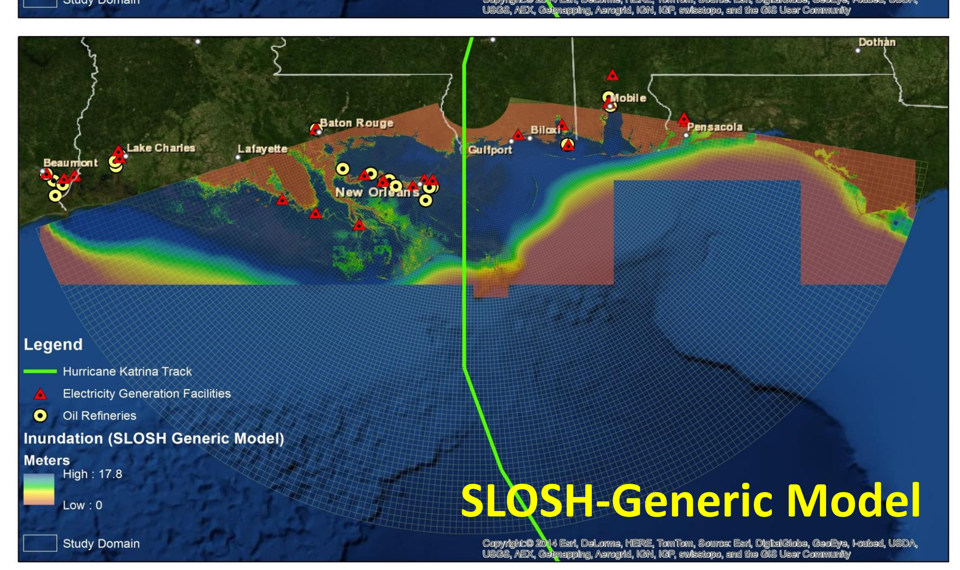
Energy Facilities within the Study Domain			
Electricity Generation Facilities		**Oil Refineries**	
Facility Name	**Flooding Reported?**	**Facility Name**	**Flooding Reported?**
A B Paterson	Yes	Chalmette Refining	Yes
Chevron Cogenerating Plant	No	Chevron Pascagoula	Yes
Houma	No	ConocoPhillips Belle Chasse	Yes
Jack Watson	Yes	Marathon Ashland Petroleum	No
Kaiser Aluminum	No	Motiva Enterprises Convent	No
Little Gypsy	No	Motiva Enterprises Norco	No
Michoud	Yes	Murphy Oil Meraux	Yes
Morgan City	No	Shell Chemical LP Saint Rose	No
Nine Mile Point	No	Valero Saint Charles	Yes
Teche	No		
Victor J Daniel Jr	No		
Waterford	No		

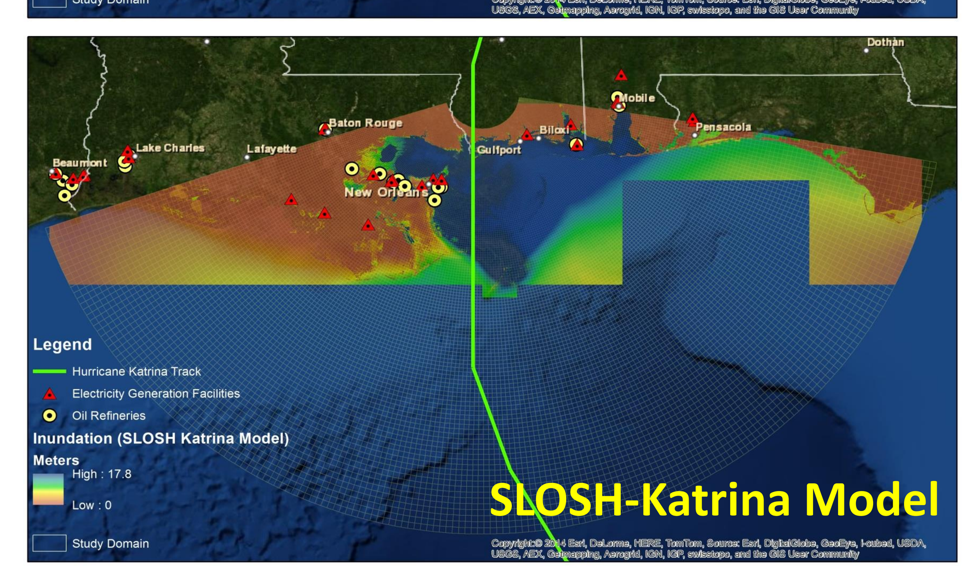
Note: *Reports of facility flooding were derived from state and federal reports, peer reviewed and grey literature, and personal communications with energy utilities.*

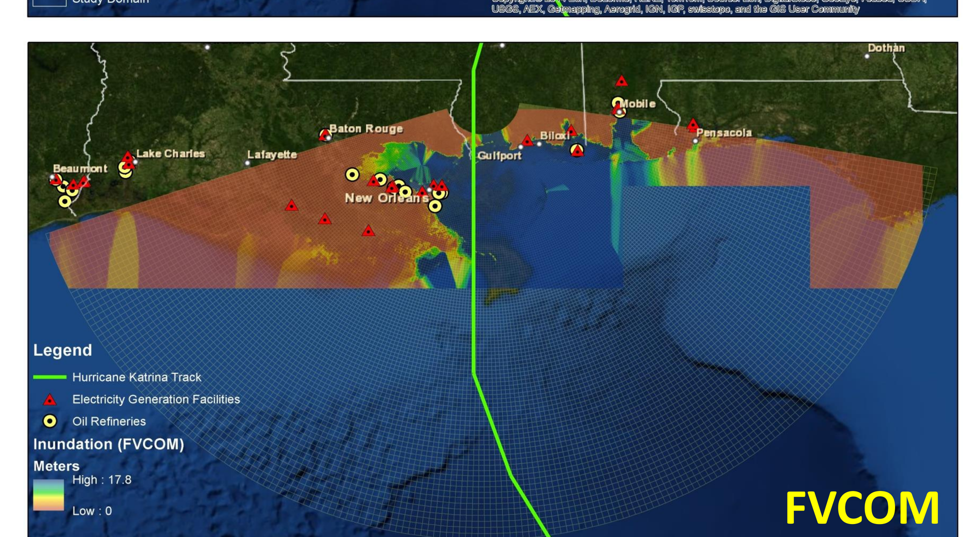
Results: Storm Surge Inundation Models









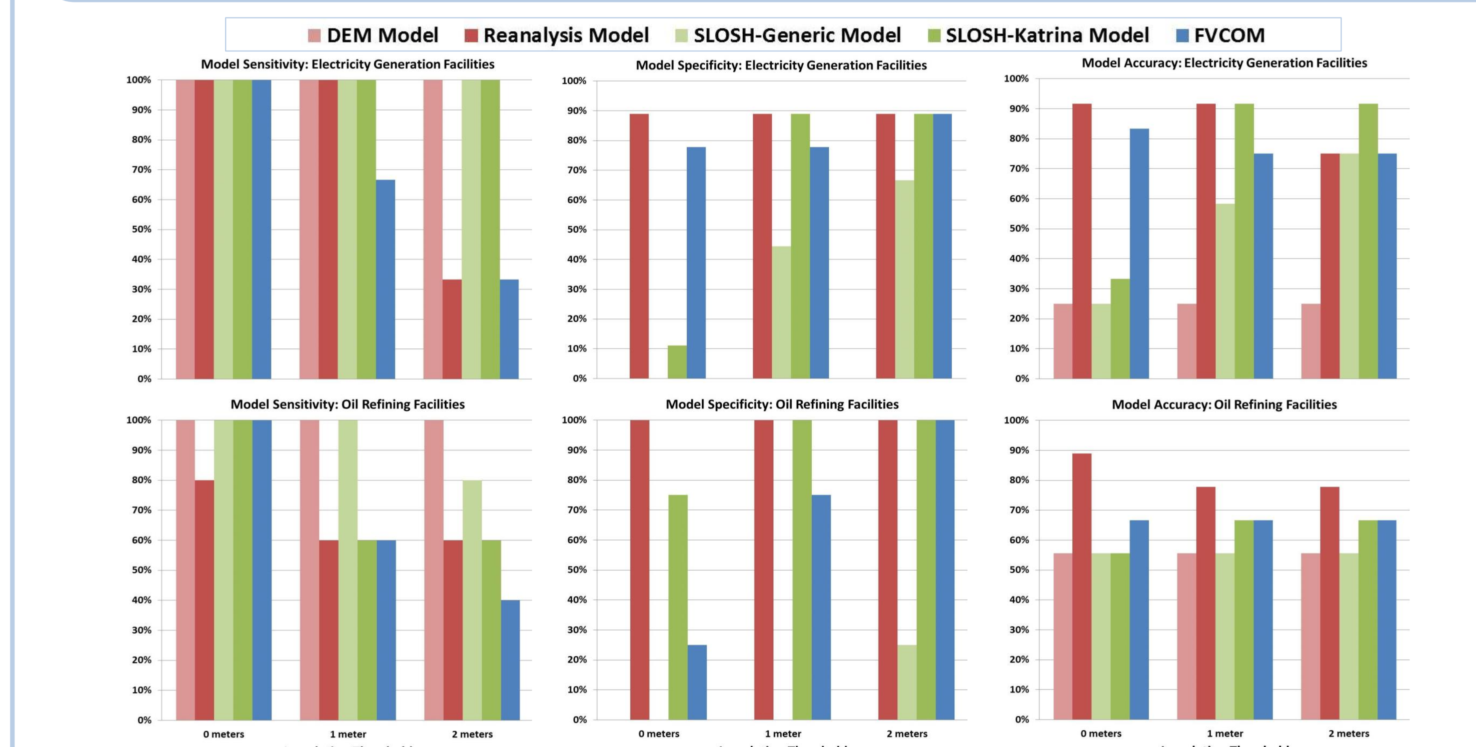


- All modeling approaches generate high-resolution information regarding the depth of storm surge inundation over land areas.
- Simple modeling approaches (e.g., *DEM & SLOSH-Generic*) generate unrealistically high inundation due to their embodied assumptions.
- The *Reanalysis Model* is restricted to a significantly smaller area than other approaches due to the spatial distribution of observations.
- The spatial distribution of inundation generated by *FVCOM* is comparable to that generated by the *Reanalysis Model* and the *SLOSH-Katrina Model.*

Results: Sensitivity, Specificity, and Accuracy

- Various metrics were used to evaluate the fidelity with which different approaches to modeling Hurricane Katrina storm surge inundation predicted flooding at energy facilities in the study domain.

- *Sensitivity* = #True Positives/(#True Positives + #False Negatives)
- *Specificity* = #True Negative/(#False Positives + #True Negatives)
- *Accuracy* = (#True Positive + #True Negative)/Total Number of Facilities



- Most models demonstrate trade-offs between sensitivity and specificity, yet the *Reanalysis* and *FVCOM* models scored well against both metrics.
- Application of storm surge thresholds for facility flooding reduced sensitivity and increased specificity, but had mixed effects on overall accuracy.
- The *Reanalysis Model* and the *FVCOM Model* were the most consistent in terms of accuracy, followed by the SLOSH-Katrina model.

Conclusions

- Comparison of different modeling approaches for predicting storm surge inundation of energy facilities reveals significant disparities among models with respect to sensitivity, specificity, and accuracy.
- Simple models perform well in terms of sensitivity, but can generate a large false positive bias due to unrealistic assumptions (e.g., *DEM* model).
- Greater specificity and accuracy is obtained from models grounded in observations and models with higher process complexity (e.g., *FVCOM*).
- All models have weaknesses in terms of missing processes (e.g., wave action) and unpredictable events (e.g., levee failure).

References:

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