SURROGATE MODELS TO PREDICT STORM SURGE HYDRODYNAMICS OVER EVOLVING LANDSCAPES AND CLIMATE FORCINGS

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What is the storm surge

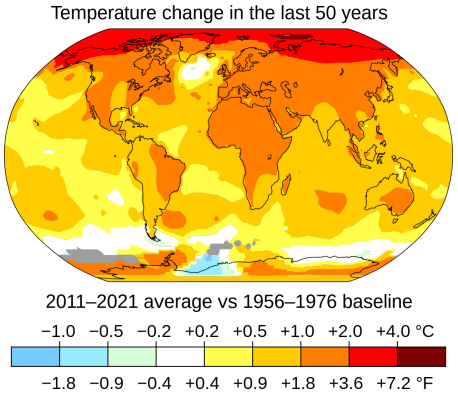
- an abnormal rise of water generated by a storm.
- caused primarily by the strong winds.
- Factors that Influence Storm Surge:
  Storm Intensity,
  Central Pressure,
  Storm Forward Speed.
- Climate Change Impact.
- Impact of future Landscape and sea level rise scenarios on storm surge

Hurricane Irma Striking Miami, Florida. Credit: Warren Faidley Getty Images.

Literature Review

What Background Support?

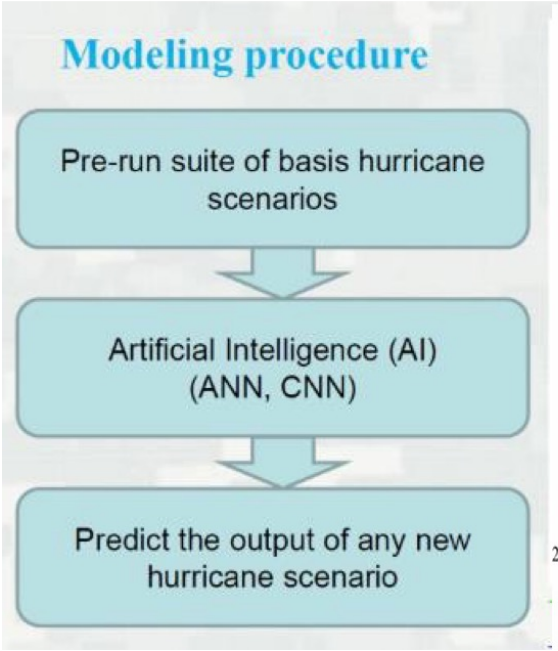
- (Jia and Taflanidis, 2013) used systematic kriging implementation in surrogate models to predict storm surge.
- (Rajasekaran et al., 2008) employed SVR for the prediction of storm surges in Taiwan
- (Hu et al., 2015). Impact of denser vegetation on storm surge.
- (Fischbach et al., 2019), effects of future landscape and sea level rise scenarious on flood damage
- Look out 50 years, how risk will change over time under different SLR trajectories
- Evaluate more possible future, and estimate the risk
- Using AI/ML as scenario generator

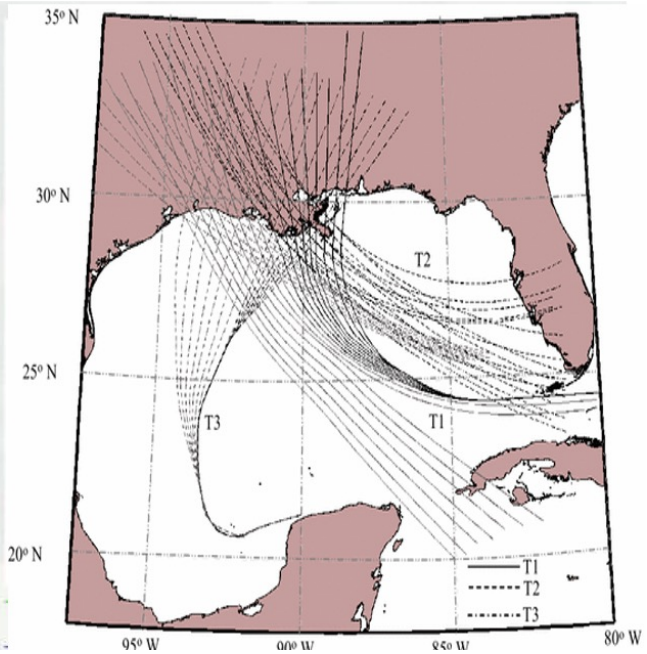


Surrogate modeling

Disadvantages of Physical-based models:

- Estimates of storm surge hazard rely on computationally expensive hydrodynamic simulations
- Costly computations
- Thousands of cores
- Biases

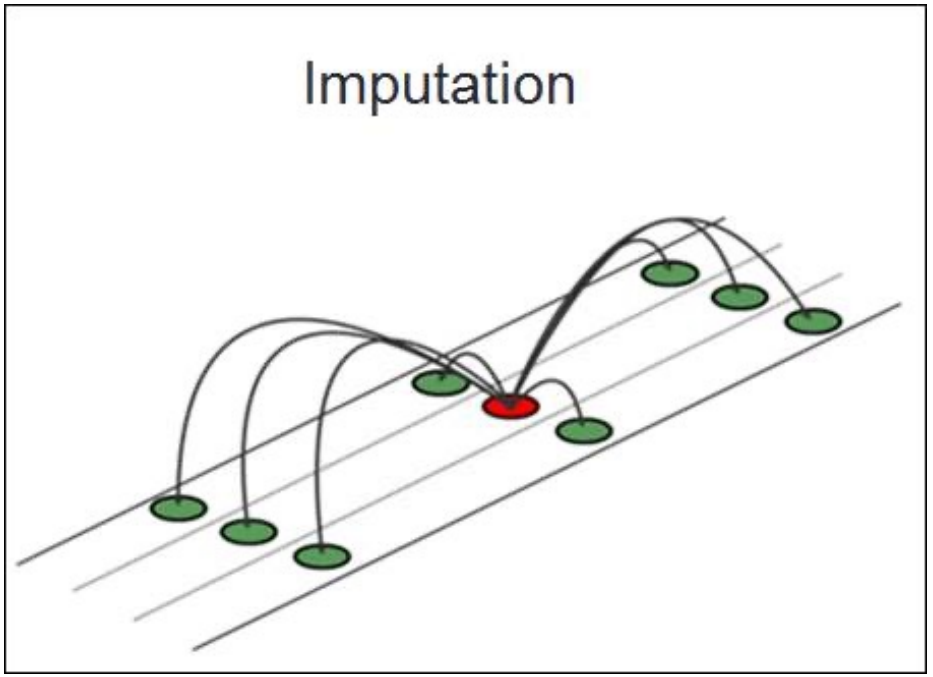




(Jia et al., 2016)

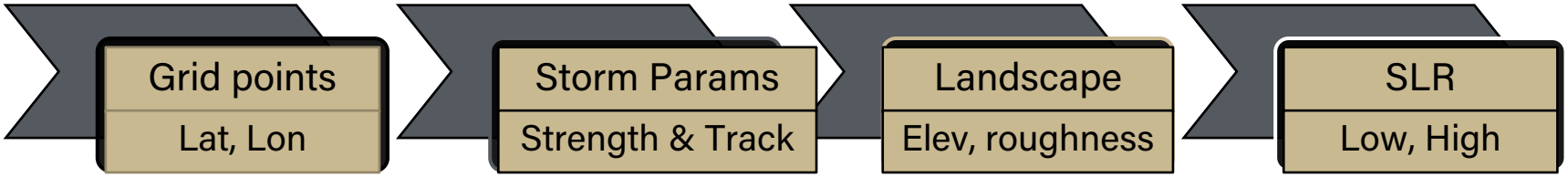
Current condition

- Preprocessing data that includes applying dry node correction
- Developing two different models with/without considering landscape parameters



Methodology

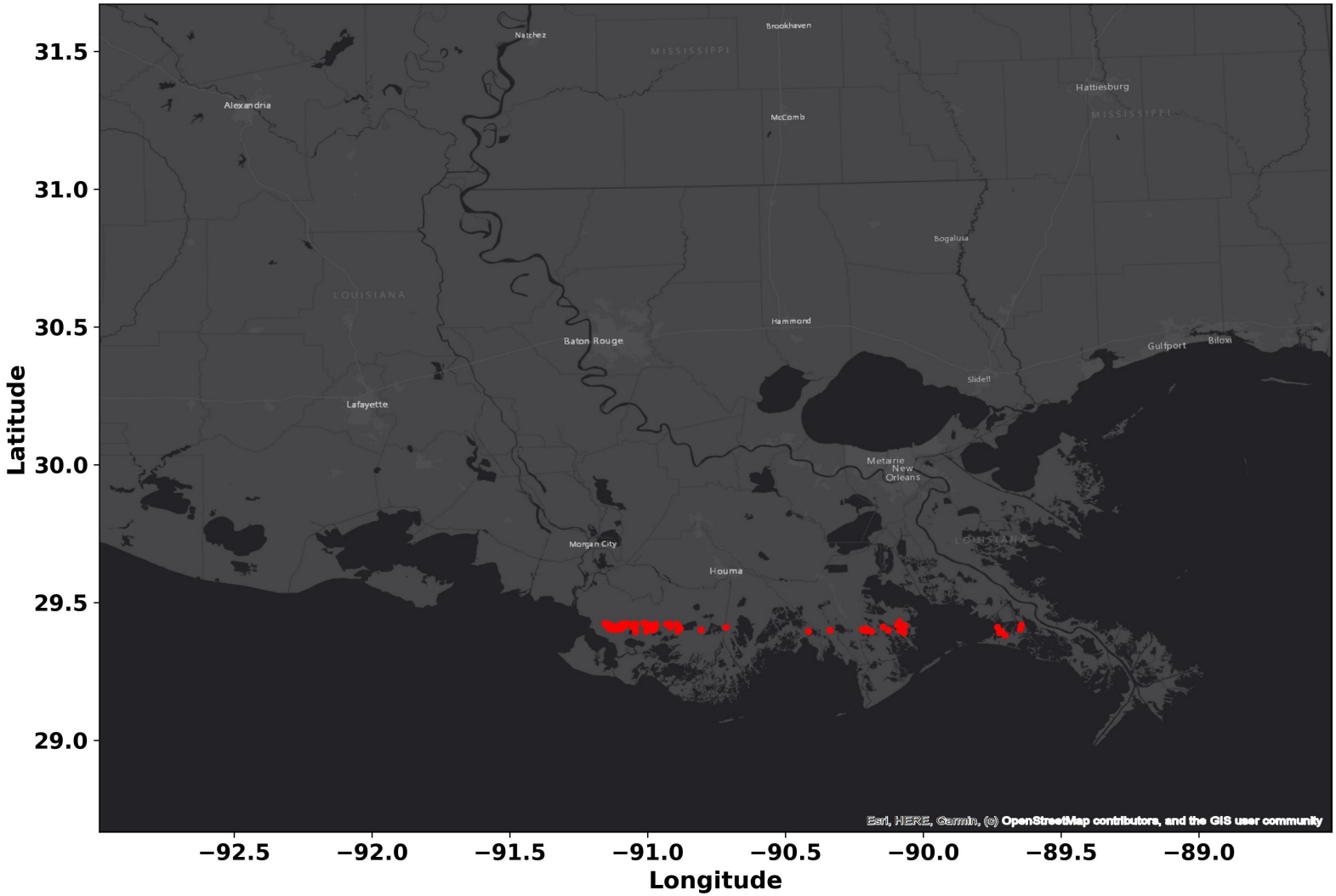
Artificial neural network prediction model



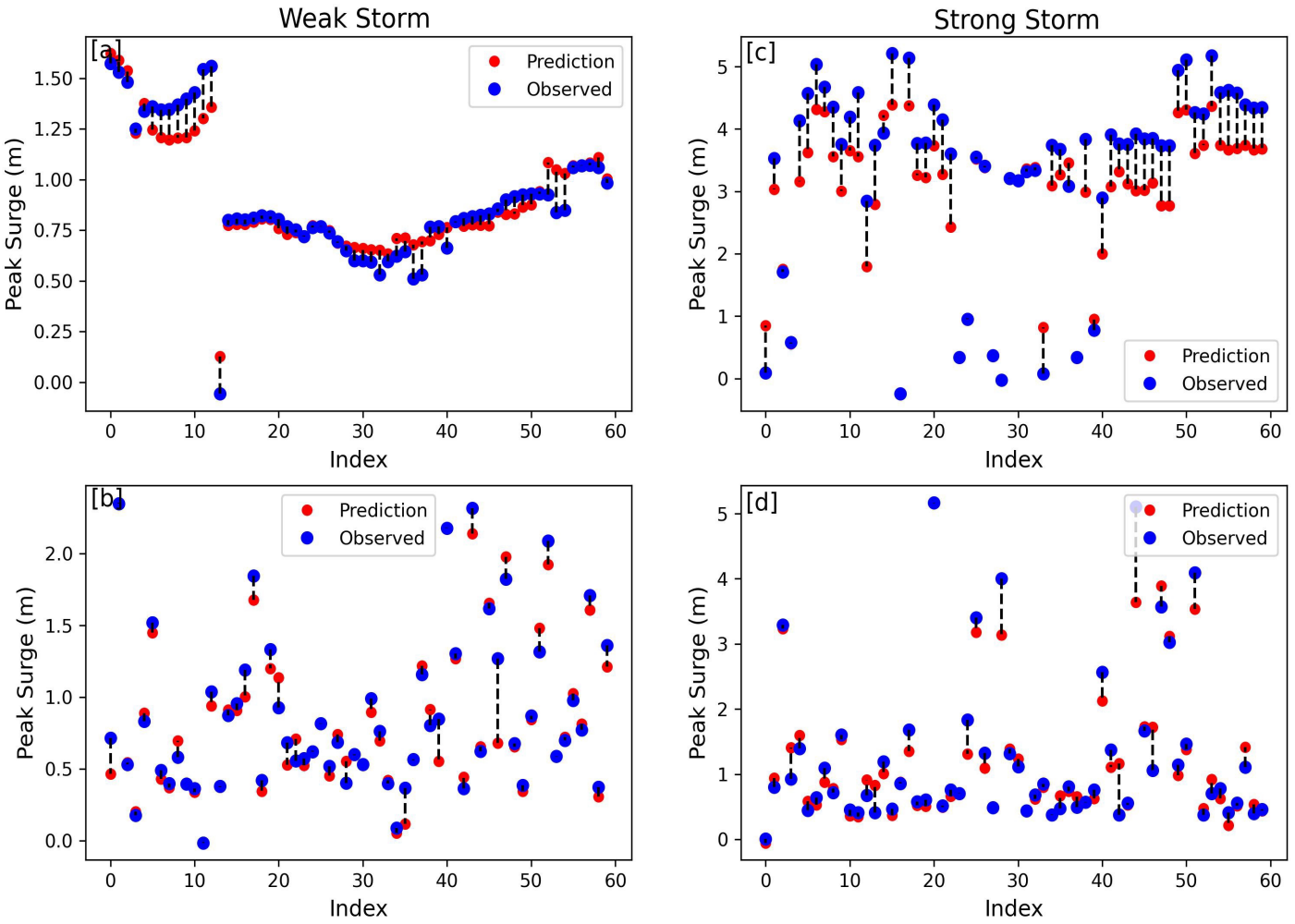
- Surge predicted at 94,013 points across coast
- Model trained using current conditions (2020) and 2023 Coastal Master Plan's Lower and Higher environmental scenarios
  - Storm parameters: track, central pressure, radius of maximum wind speed, forward velocity
  - Landscape parameters: lat/lon, topobathy elevation, Manning's *n*, canopy, z_0
  - Boundary conditions: eustatic sea level

Scenario	Year	Sea Level (NAVD88 ft)
Low	2030	1.43
Low	2040	1.71
Low	2050	2.03
Low	2060	2.41
Low	2070	2.83
High	2030	1.52
High	2040	1.91
High	2050	2.40
High	2060	3.02
High	2070	3.71

Prediction of Storm Surge for the current condition

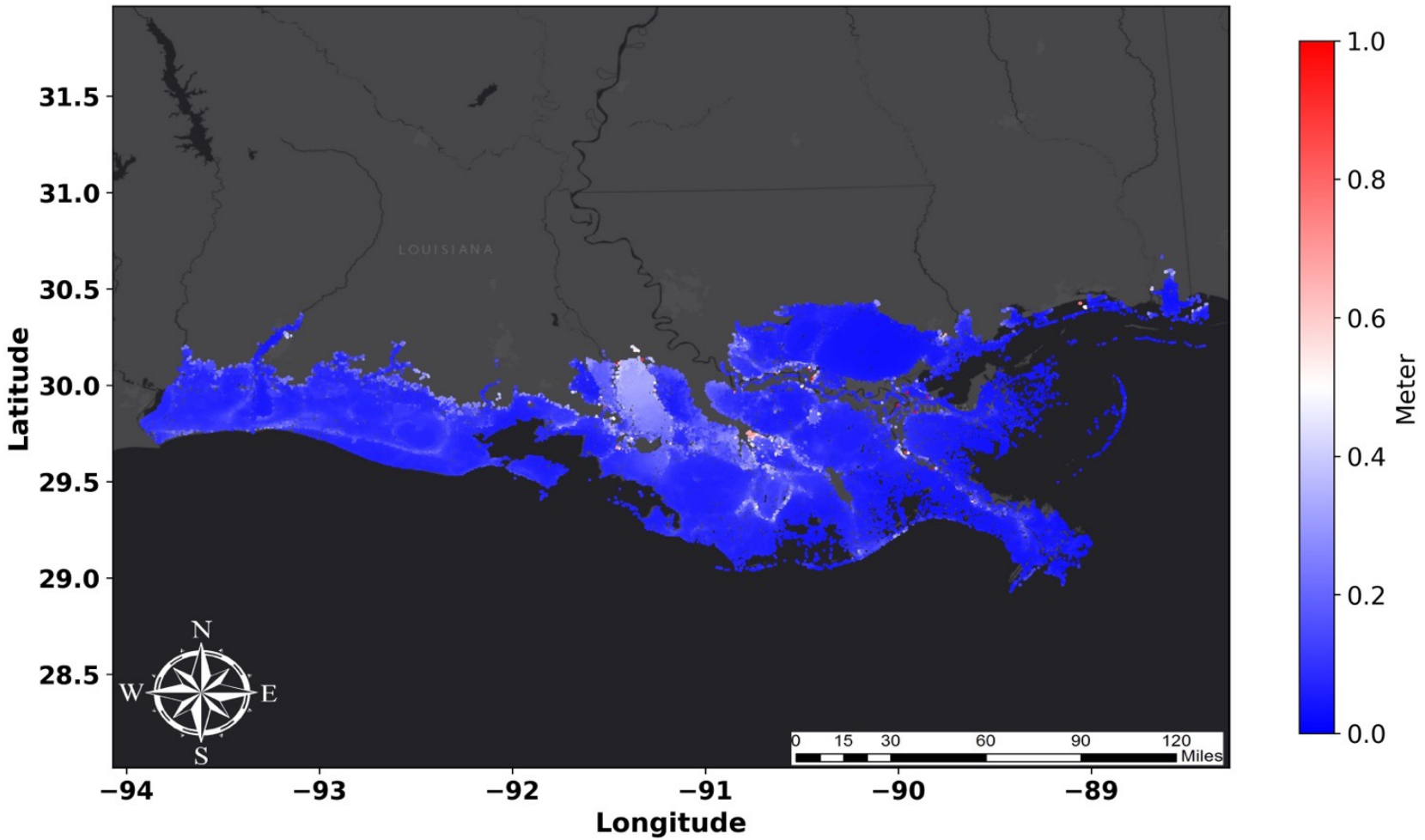


Prediction of Storm Surge for the current condition



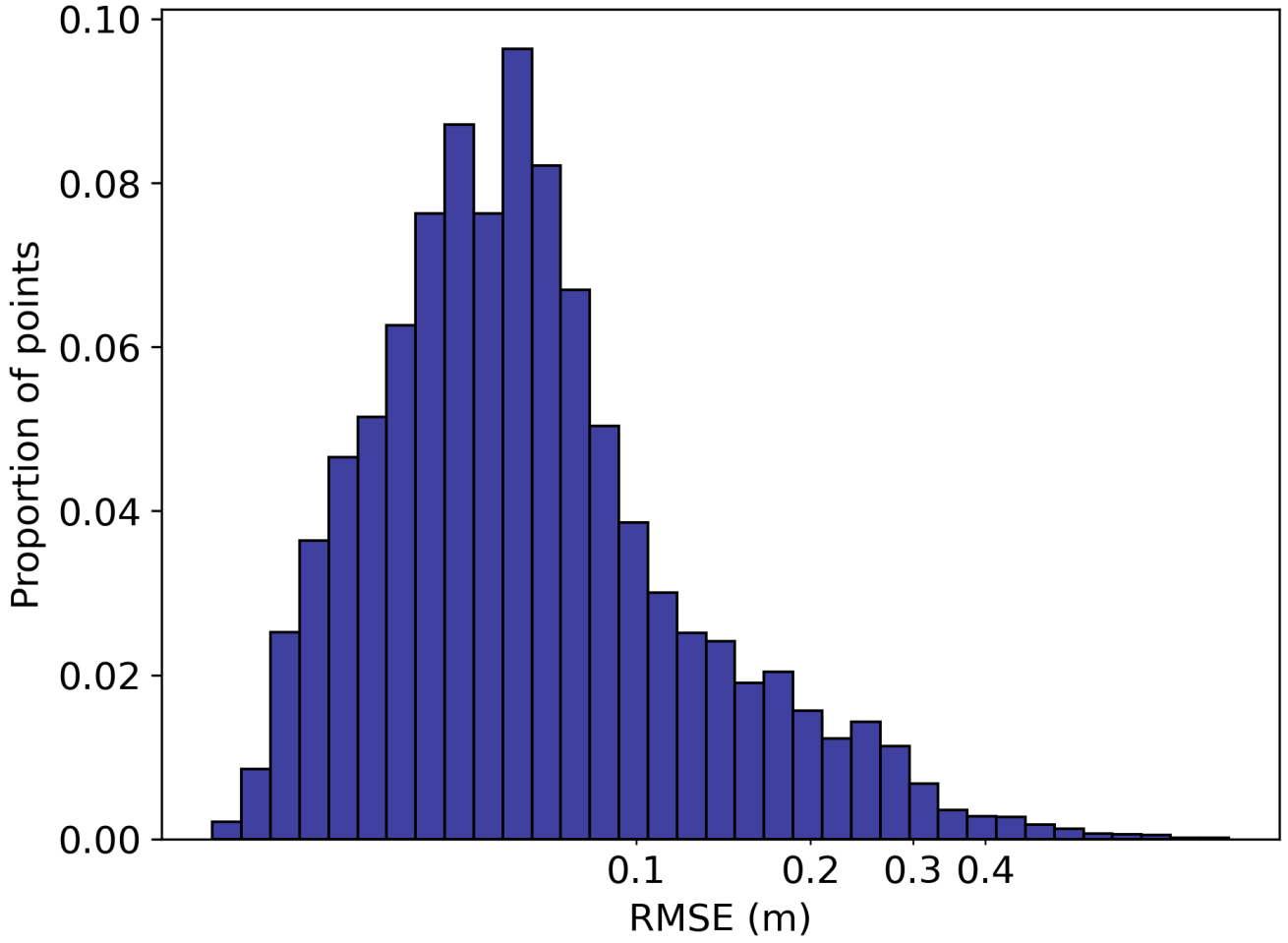
Storm surge prediction for the case where the ANN model input only includes storm parameters [a, c] and [b, d] which also includes the landscape parameters.

RMSE Map



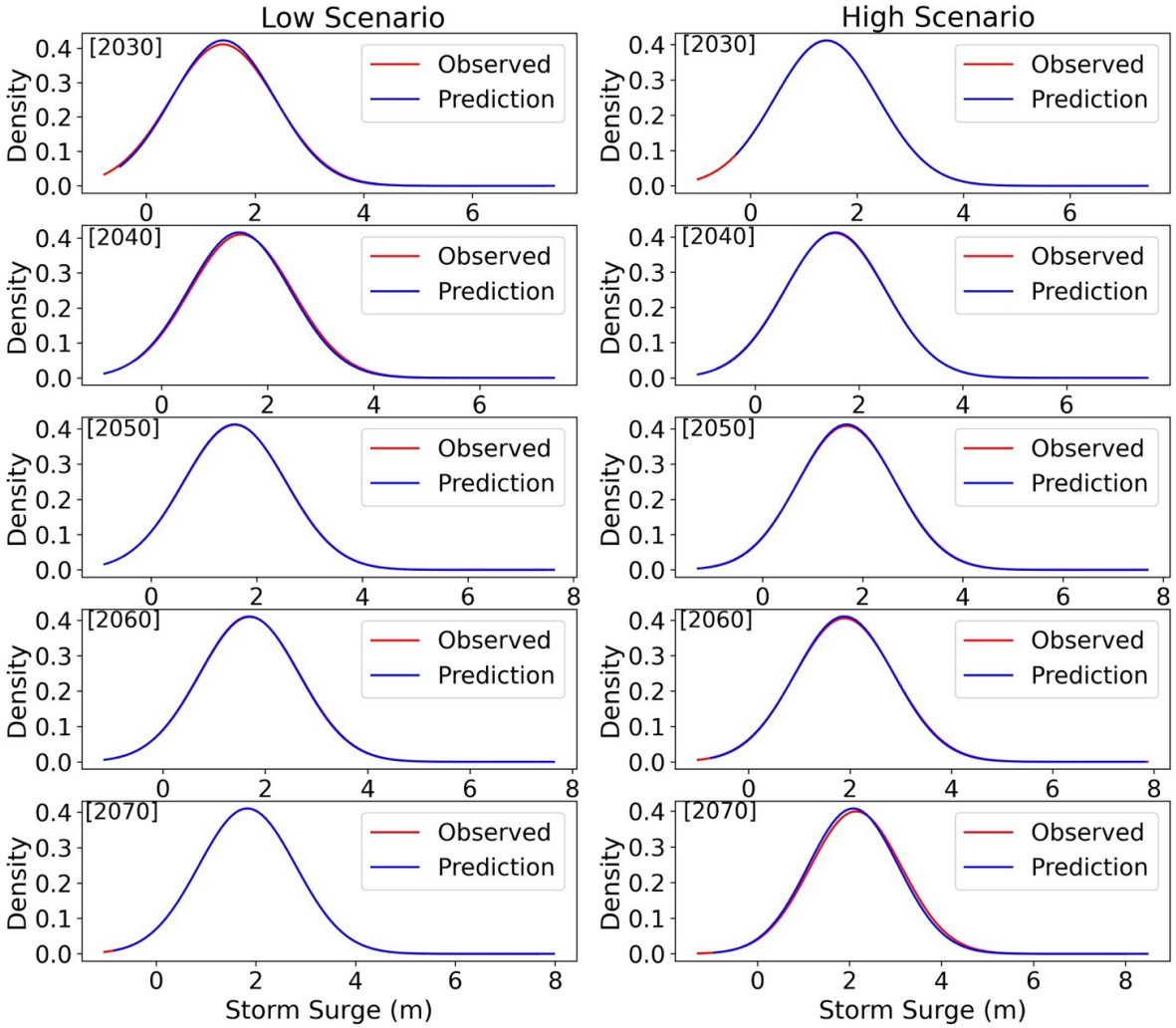
Scatter plot of average RMSE values across all scenarios in the entire domain for all grid points.

Histogram of Average RMSEs



Histogram of average RMSE values across all scenarios in the entire domain for all grid points.

PDFs of Storm Surge Prediction



PDFs of storm surge for all future scenarios.

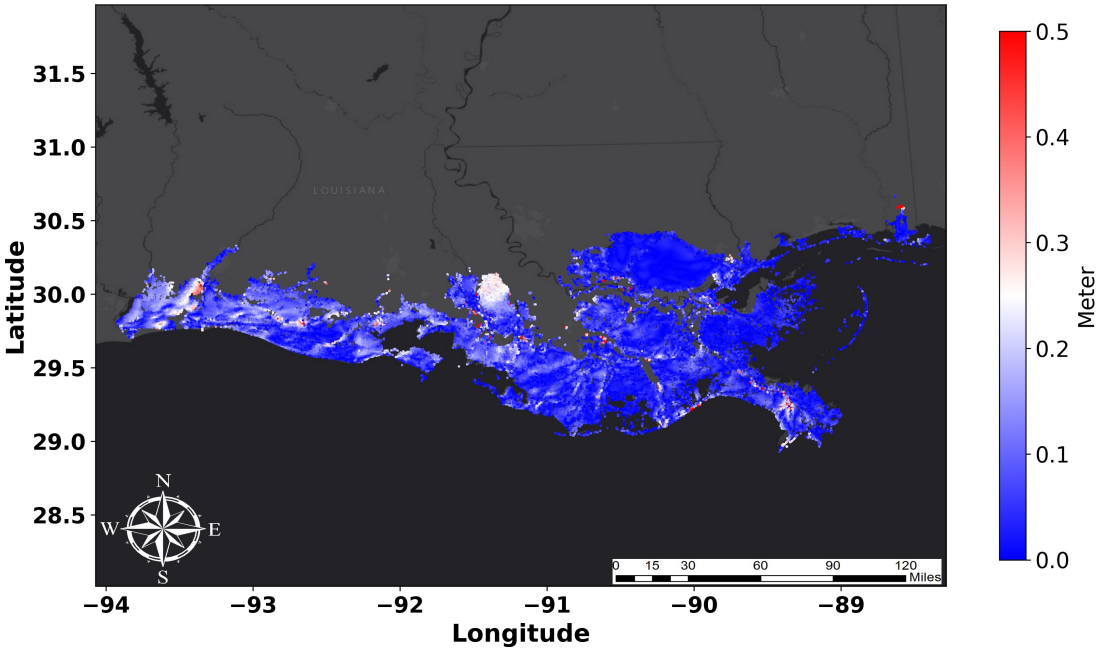
Statistical Metrics

Table1 Statistical metrics (RMSE, MAE, and Correlation Coeff) for all scenarios.

Scenarios	Years	RMSE (m)	MAE (m)	Corr
High Scenario	2030	0.063	0.036	0.998
	2040	0.069	0.037	0.998
	2050	0.076	0.041	0.997
	2060	0.082	0.047	0.997
	2070	0.206	0.134	0.983
Low Scenario	2030	0.057	0.035	0.998
	2040	0.089	0.044	0.996
	2050	0.064	0.037	0.998
	2060	0.073	0.040	0.997
	2070	0.081	0.045	0.997

Conclusion

- Efficiency of Surrogate modeling (NN) on storm surge prediction.
- Quantification of the impact of Climate change on Landscape parameters and sea level rise on storm surge prediction.
- Predictive accuracy that is on par with the magnitude of bias and uncertainty in the ADCIRC model.
- Scenario generator to explore alternative landscape



Storm surge difference map for a single storm between observation and prediction

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THANK YOU