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Constructing an Effective Storm Surge Prediction Model

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Homeland Security Challenge

Storm surges are a large rise of sea level caused by strong winds that cause substantial damage to the coastal environment. More accurate predictions of extreme water levels can save lives and help minimize property damage in exposed areas. Knowing about potential impacts will allow the public and government to make better preparations in advance of the event. The current challenges include data driven predictions and reducing computational resources needed for making those predictions.

Approach / Methodology

The approach was to develop an Artificial Neural Network (ANN) model to predict the water level residual based on timeseries data (Kim et al, 2019). Wind, atmospheric, and water level data was gathered from an ADCIRC (Westerink et al, 2008) simulation and observations from stations along the coast. This data was used to train the ANN to perform a predictive task. This task predicts water levels given the input data sequence from the past. This project used simulated data from 9 nodes in a 3x3 geospatial grid with each node 20 km apart (Figure 1). The data was collected in 30-minute intervals.

The goal was to predict the water level at the center node from the data at all nodes. The use of the simulated data at these surrounding nodes allows for the model to account for storm surge propagation that happens during a hurricane.

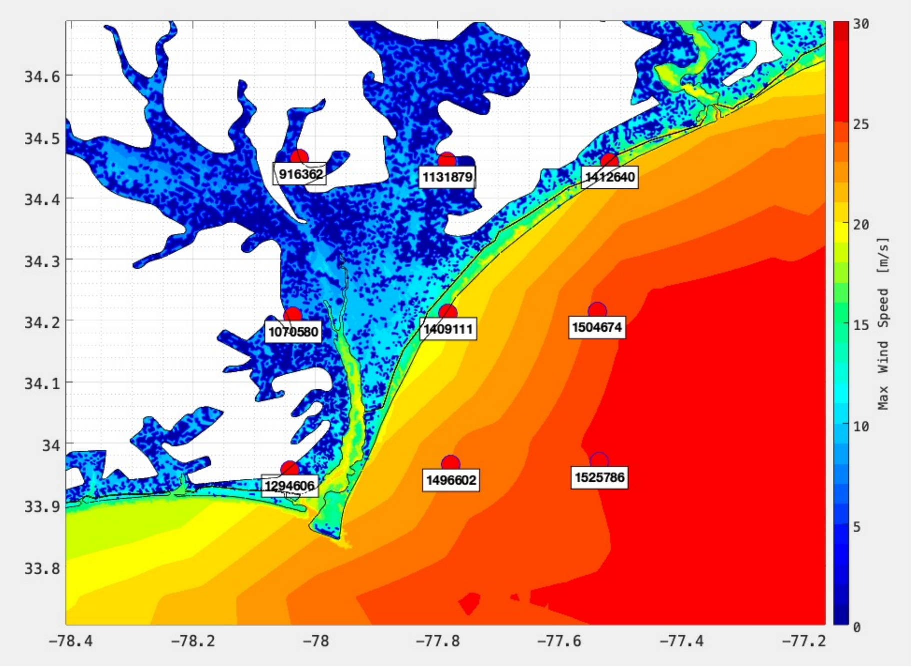

Figure 1. Locations of the nine data node locations and their identifiers.

Outcomes / Results

After evaluating the correlation, feature importance, and physical knowledge for each input used, the north-south and east-west components of the wind velocities and the residual water level (total water level minus the tidal predictions) at the central node (Tissot et al, 2008), optimal forecast times were determined. Various ablation studies were done that removed certain inputs for better understanding of how these inputs contributed to the predictions. Predictions were more accurate with different lengths of lag on the surrounding nodes as seen in the difference between Figure 2, which has no lag, and Figure 3, which has the optimal lag time incorporated.

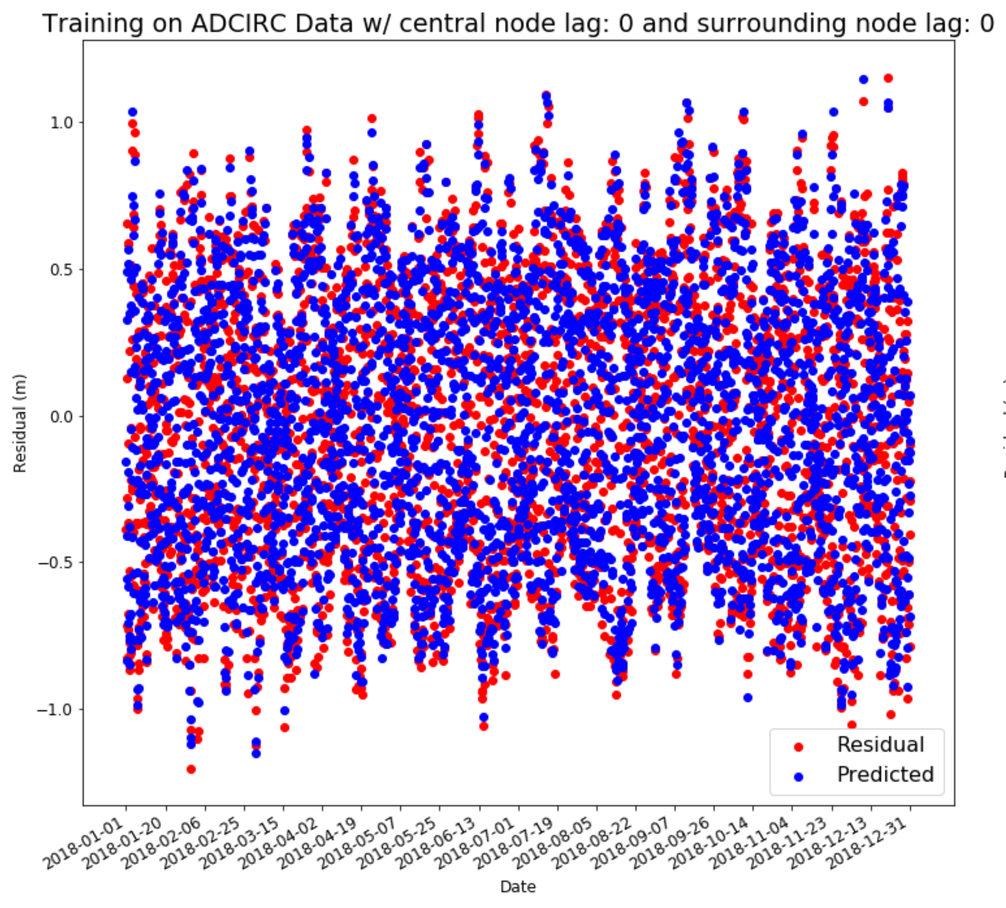

Figure 2. Graph showing predictions (blue) and actual water levels (red) With no lag on the surrounding nodes.

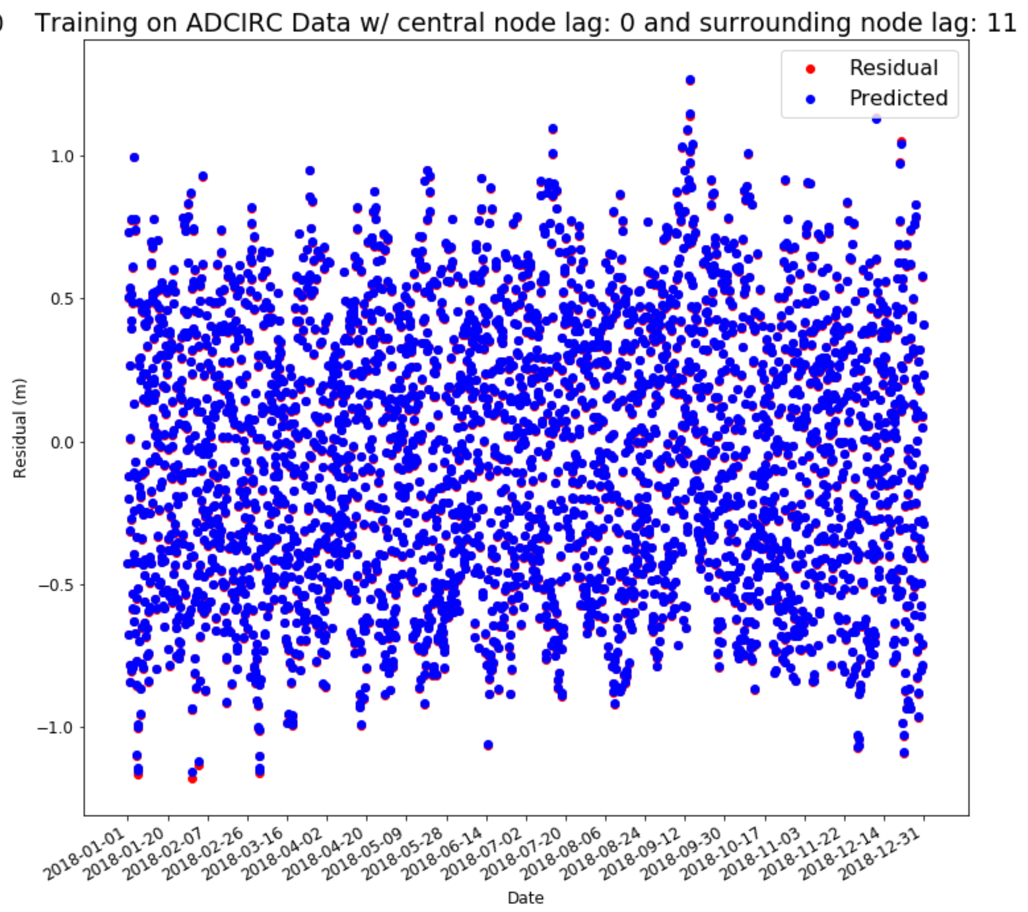

Figure 3. Graph showing predictions (blue) and actual water levels (red) With optimal lag on the surrounding nodes.

References

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Westerink, J., Luettich, R., Feyen, J., Atkinson, J., Dawson, C., Roberts, H., Powell, M., Dunion, J., Kubatko, E., and Pourtaheri, H. (2008). A basin- to channel-scale unstructured grid hurricane storm surge model applied to Southern Louisiana. Mon. Weather Rev., 136:833–864.

Conclusions

Our ANN with 28 meteorological inputs has been able to predict storm surges of similar magnitude within the relative time frame of their observed occurrence. As seen in Figure 4 of the 2018 Hurricane Florence surge.

Continued progress with this short-term surge prediction will require additional physical constraints applied to the model.

Results also reveal that the short-term storm surge predictions provide possibility of greater forecasting abilities. Continued data analysis will allow for the use of different model types such as Recurrent Neural Networks (RNN) or and Long short-term memory (LSTM) networks.

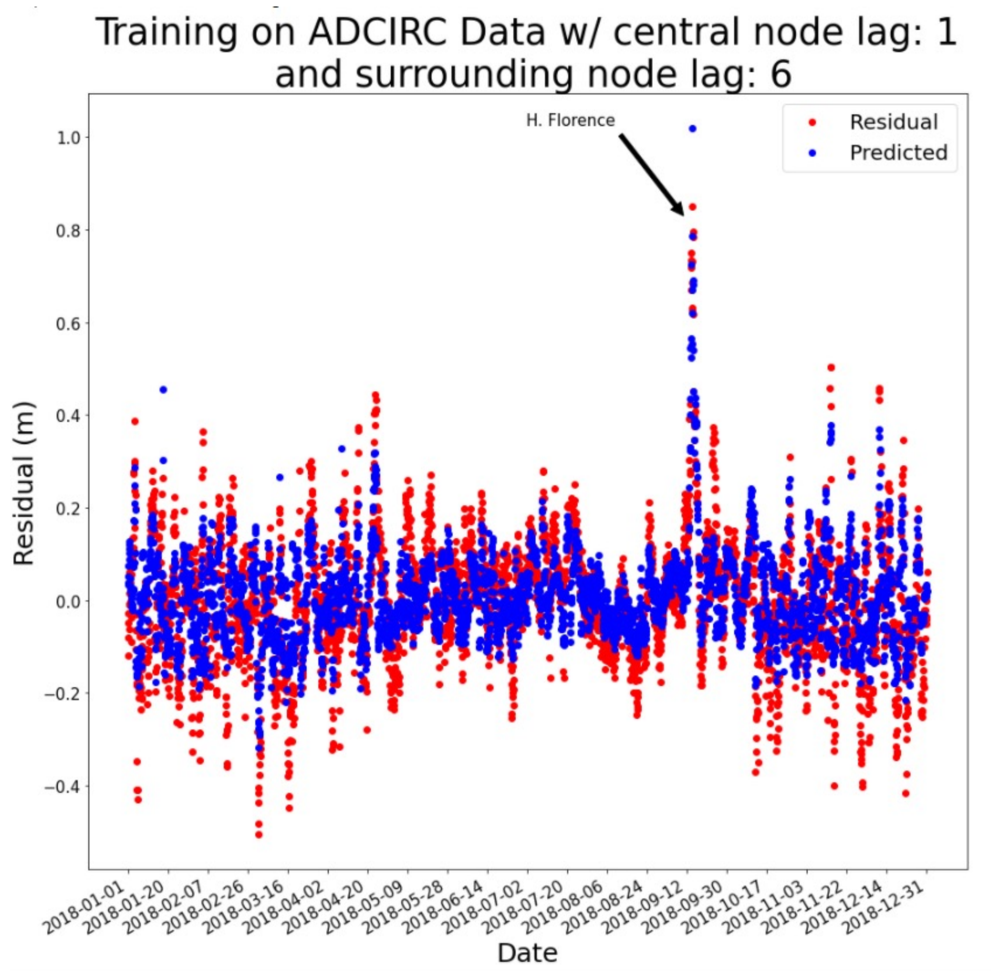

Figure 4. Graph showing predictions (blue) and actual water levels (red) with optimal lag on the central and surrounding nodes. Also highlights the surge prediction for the 2018 Hurricane Florence.

Acknowledgements

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