Machine-Learning-Based Time-Series Forecasting for Rapid Correction of Global STOFS

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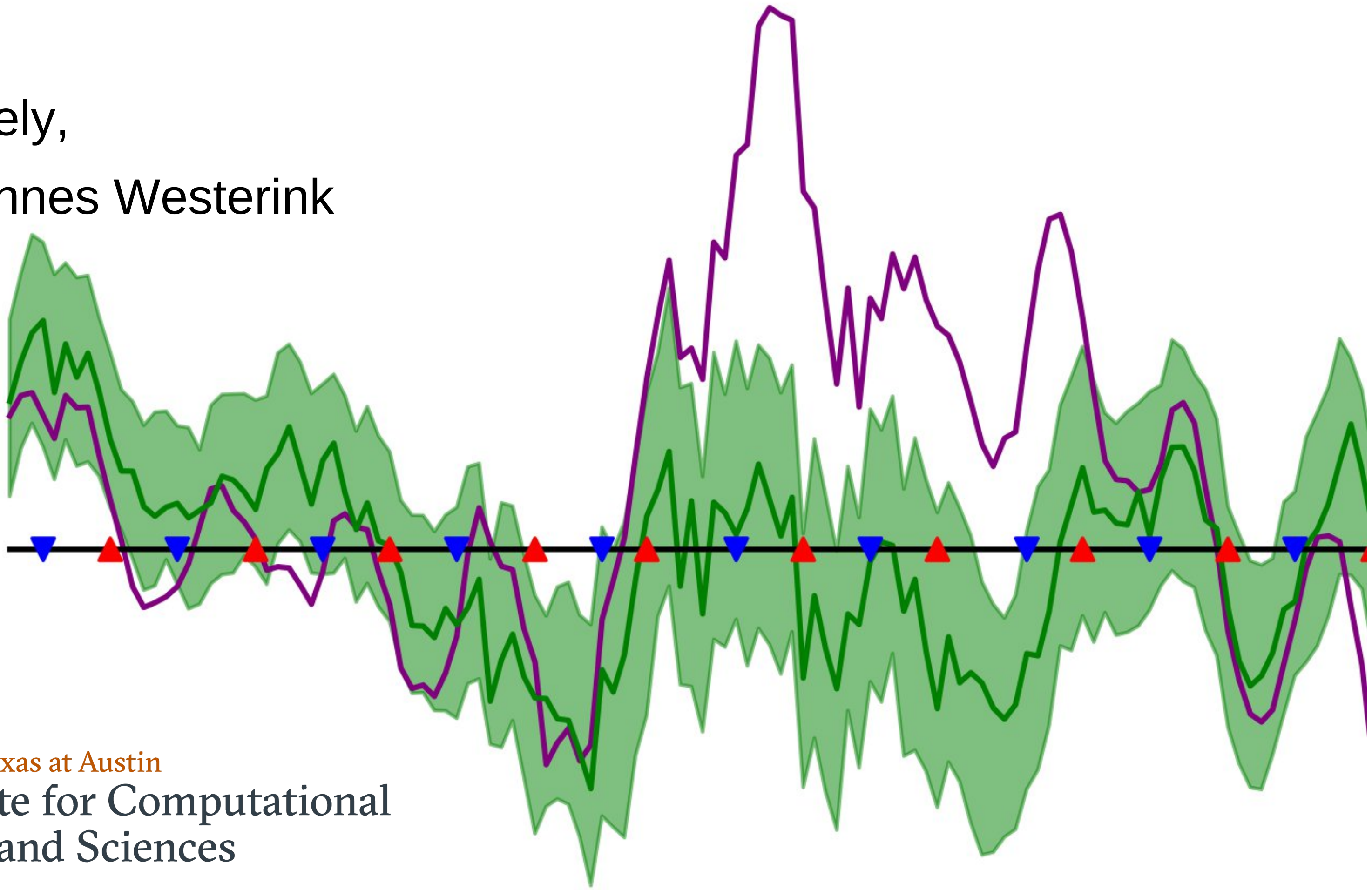

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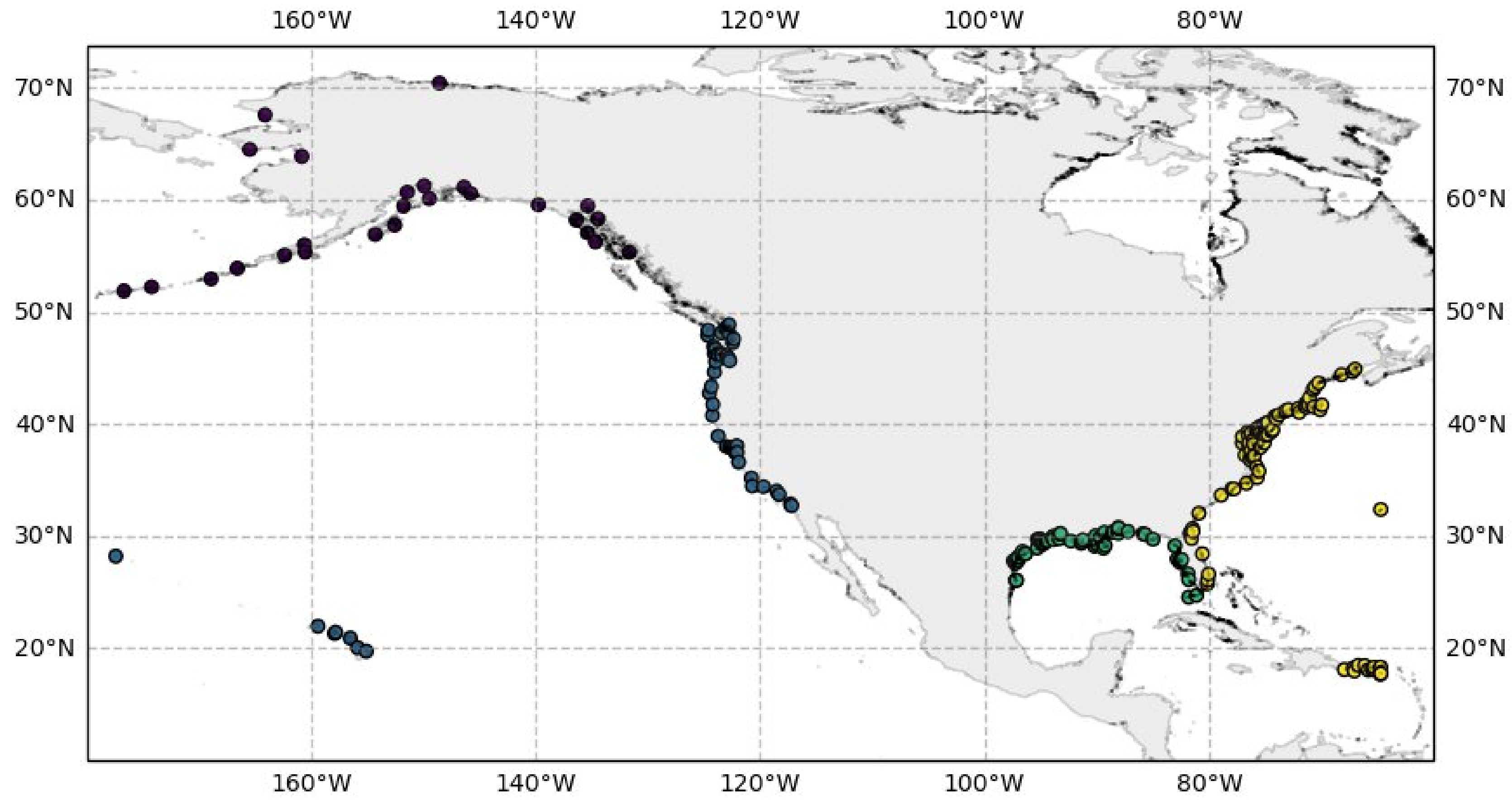
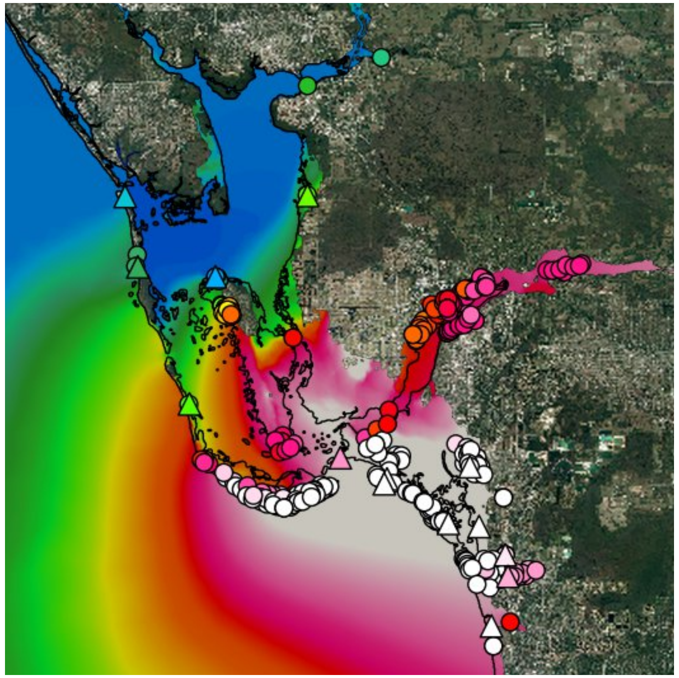
Global STOFS Overview

- Global Surge and Tide Operational Forecast System (Global STOFS) runs at NOAA 4x daily.
- Driven by ADCIRC. Total water levels reported at hundreds of stations in USA, which we focus on here.



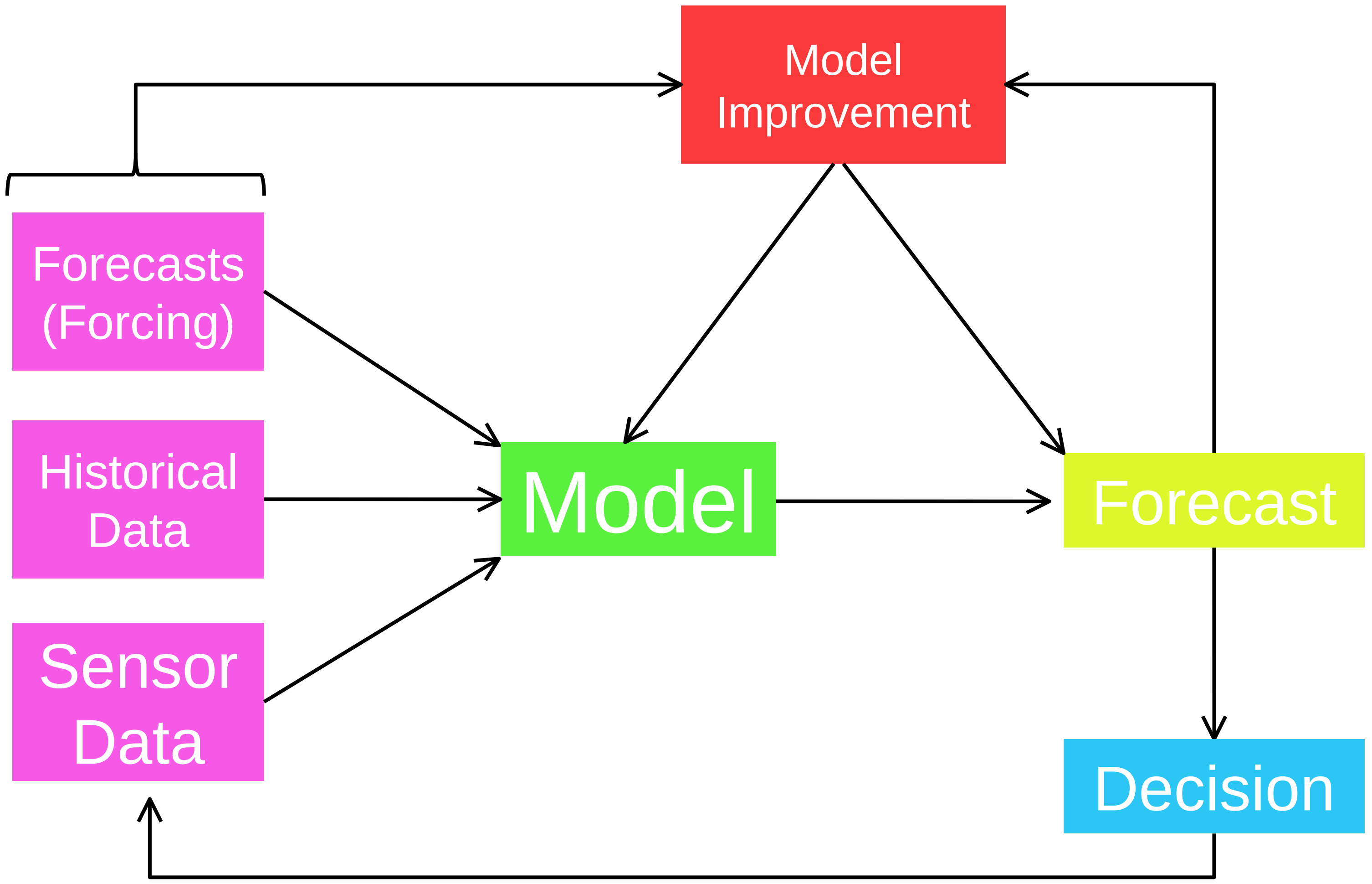
Improving Global STOFS Rapidly?

- Sources of Model Discrepancy in Global STOFS
  - lack of thermohaline circulation
  - lack of hydrology
  - poor bathymetry
  - poor mesh resolution
  - poor meteorological forcing

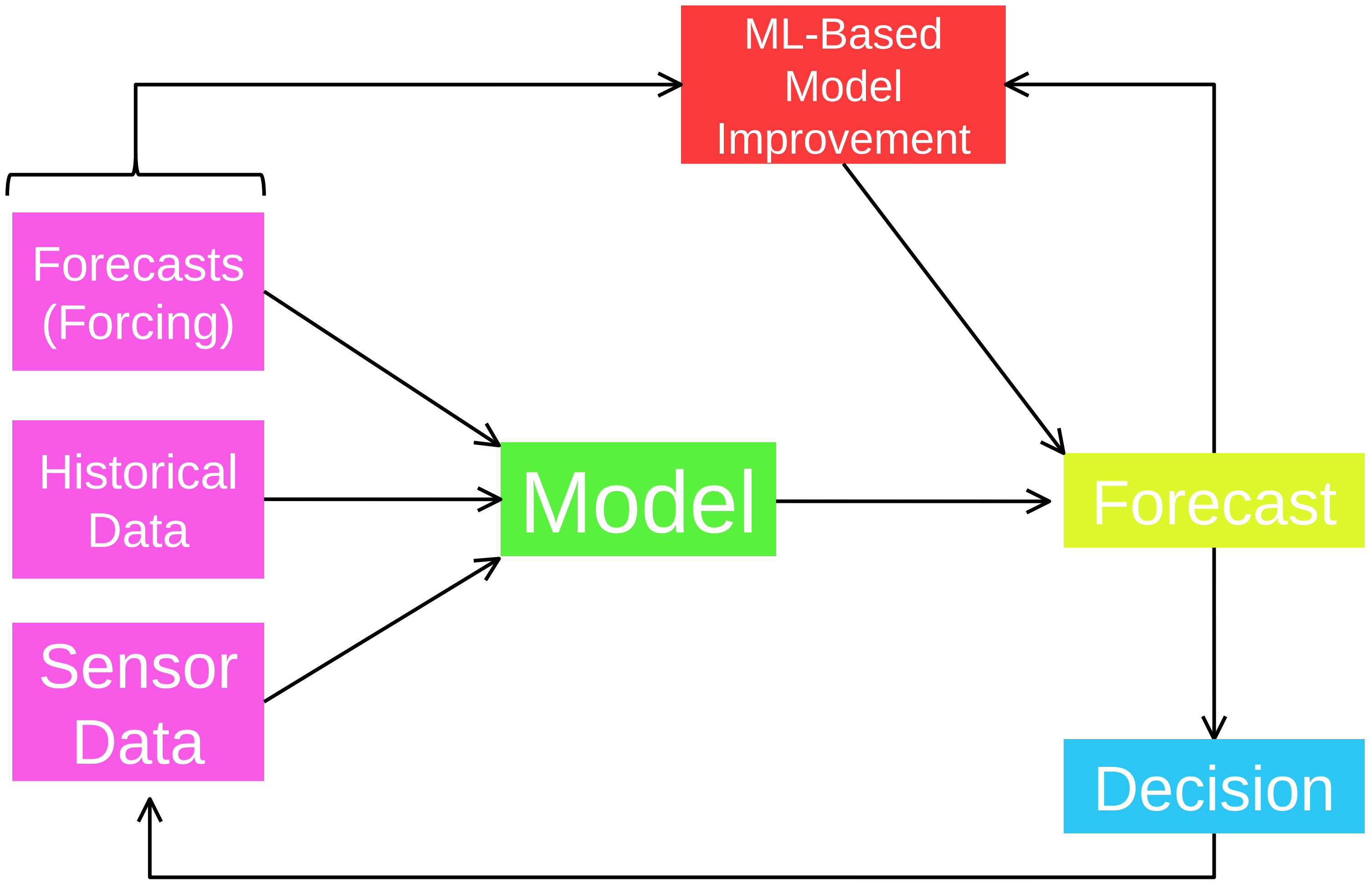


- Improvements are coming!
- However, we can improve Global STOFS “wholesale” without discriminating one error source from another...
- ... and we can do this while attending to both Global STOFS’ input and output.

Rapid Improvement for Operations



Rapid Improvement for Operations



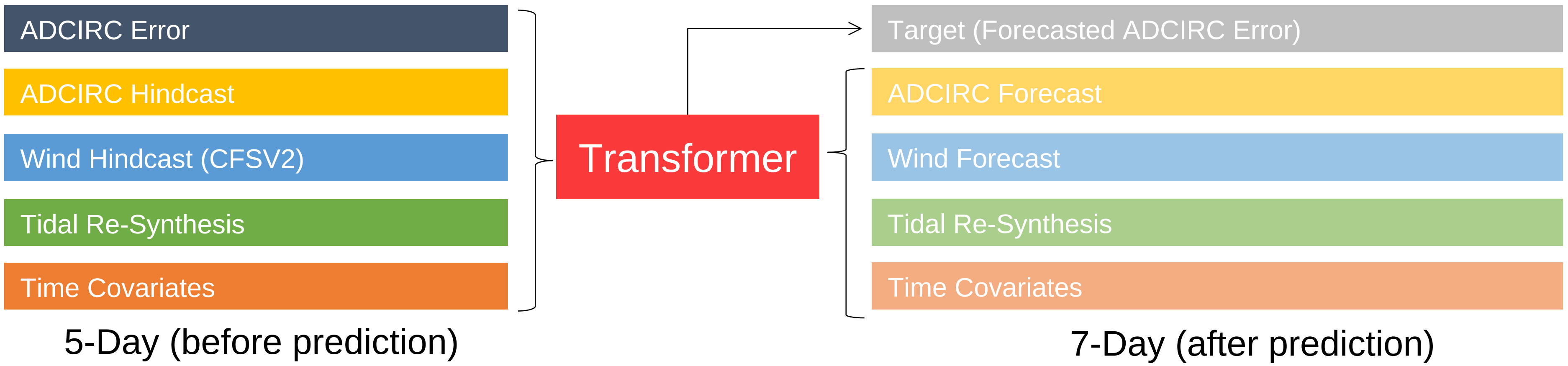
Global STOFS + ML Overview

I. Global STOFS renders 7-day forecasts. We'll consider forecasts at NOAA stations.

II. Source actual water levels and ADCIRC's previous predictions from prior 5 days.

III. Source winds and tides for previous 5 days and 7-day forecast horizon.

IV. Exercise Transformer



V. Post-Process

Training Temporal Fusion Transformer (TFT)

I. Ran 3-year Global STOFS hindcast from 2016 - 2019.

II. Sourced observed total water levels from NOAA from 2016 - 2019.

III. Sourced winds from CFSV2 from 2016 - 2019.

IV. Ran tidal re-synthesis from 2016 - 2019.

V. Merged data. 1-hour temporal resolution. Excluded time stamps with missing data.

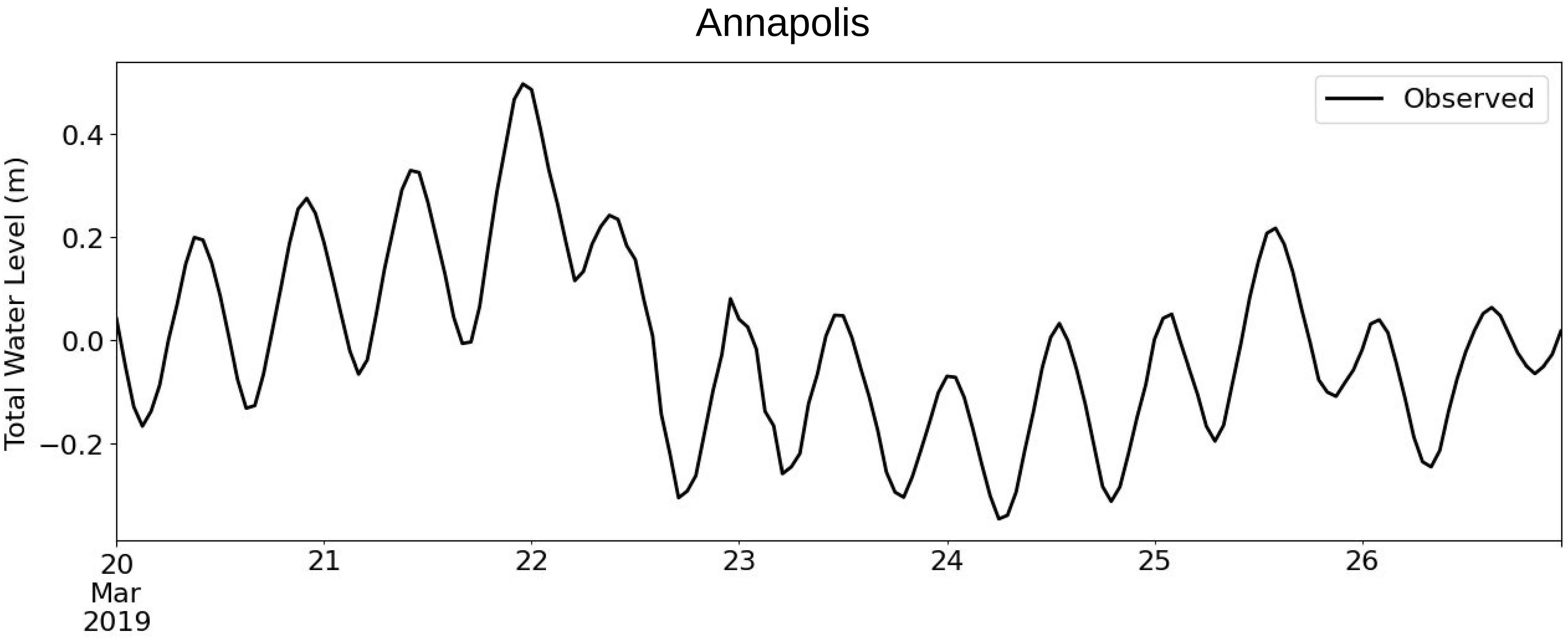
VI. Separated data into 12-day contiguous chunks. Each contained target (ADCIRC hindcasted error), 5 days of past covariates, and 7 days of future covariates. 70% of each station's chunks allocated for training.

VII. A single TFT was trained on all stations chunk by chunk. The TFT was trained to forecast ADCIRC error 7 days into the future.

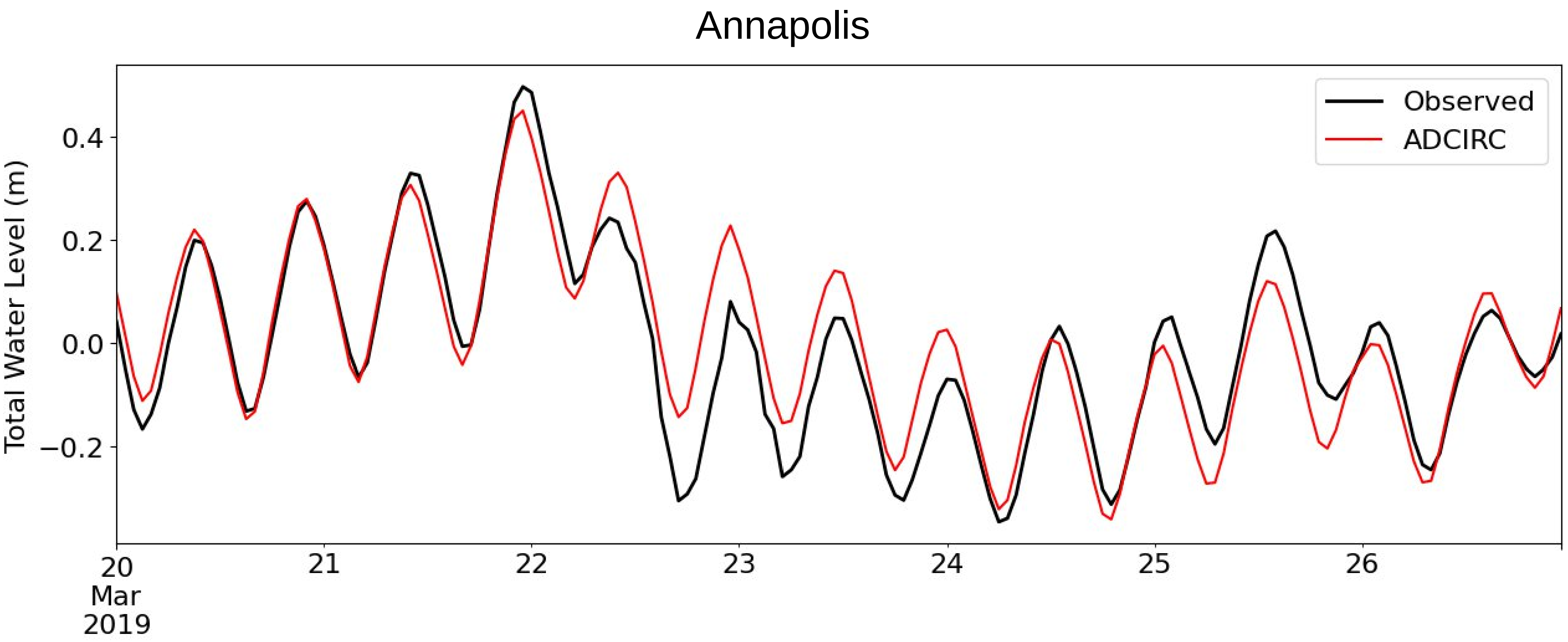
Model Tuning

- We used a tree-structured Parzen estimator to optimize the hyperparameters of the transformer model.
- The performance of the transformer was largely batch-size invariant.
- 10% dropout helped circumvent overfitting.
- Transformer trained with quantile loss.
- In general, a transformer trained on all NOAA stations was more performant than a region-centric transformer.

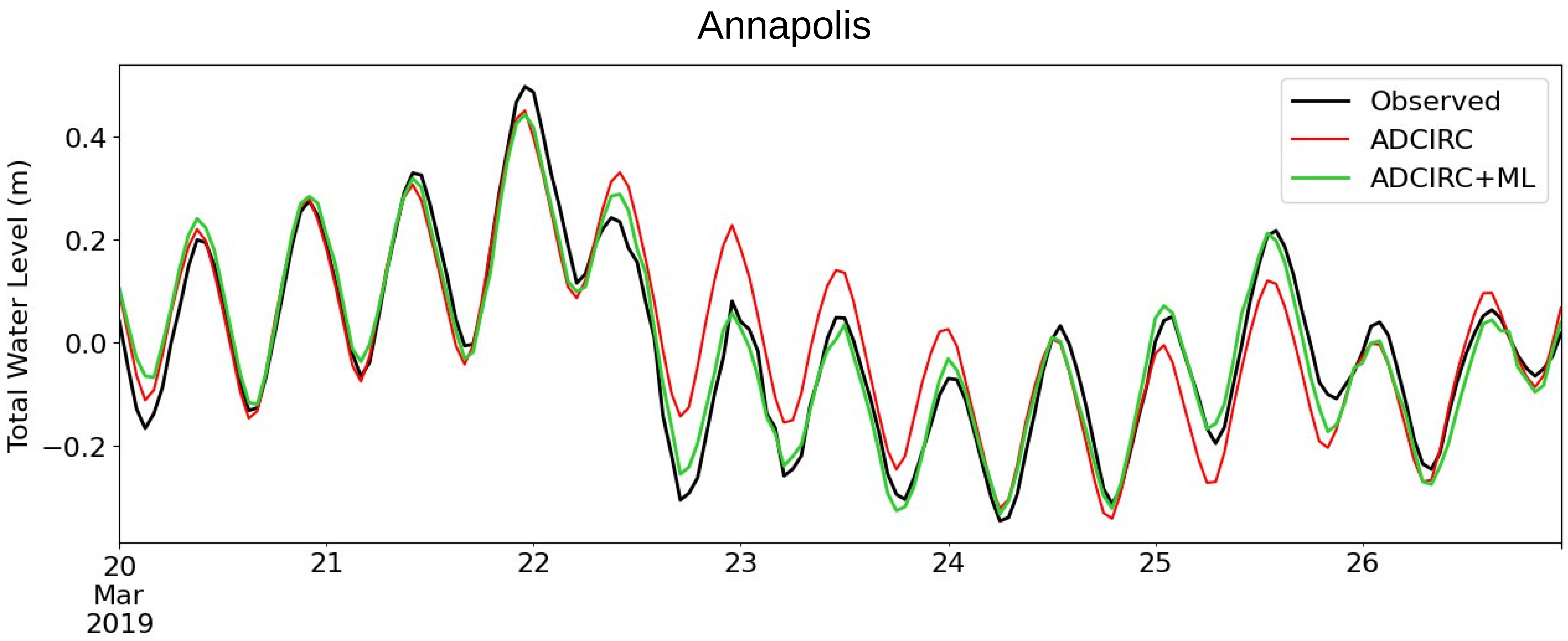
Example Global STOFS Output



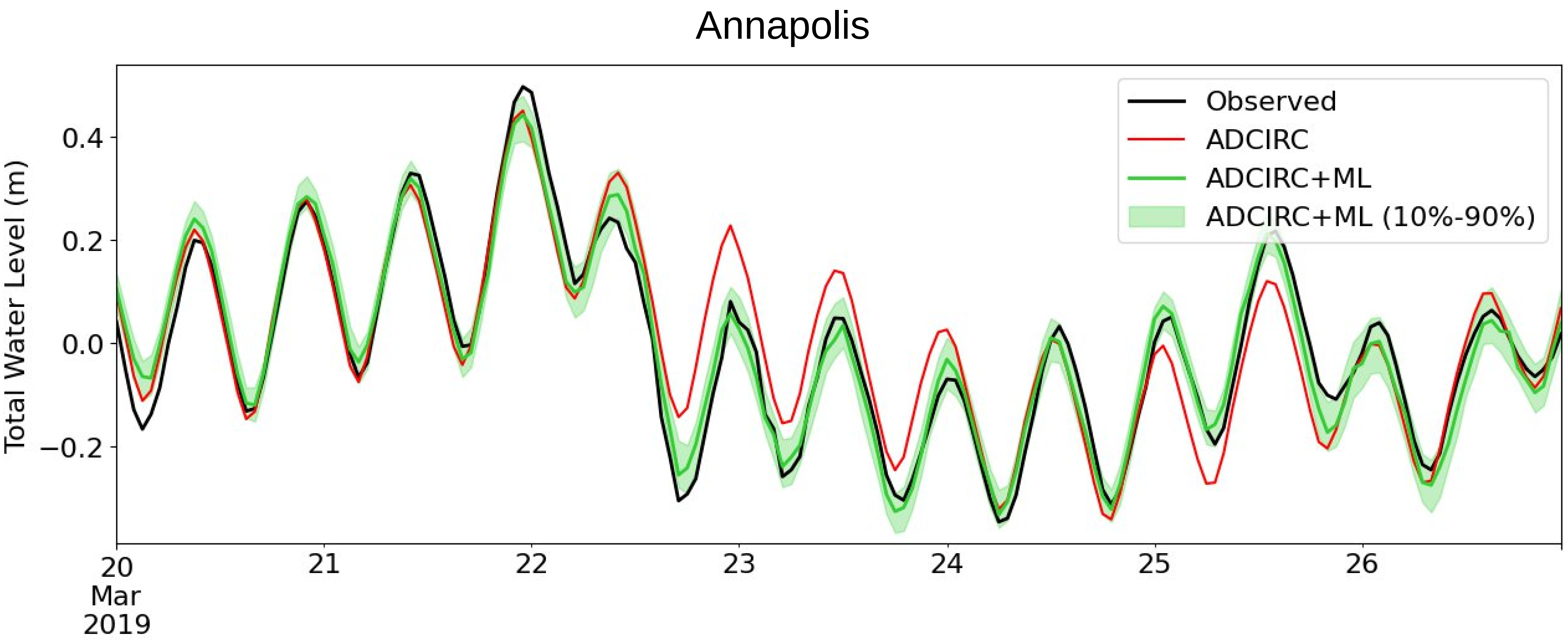
Example Global STOFS Output



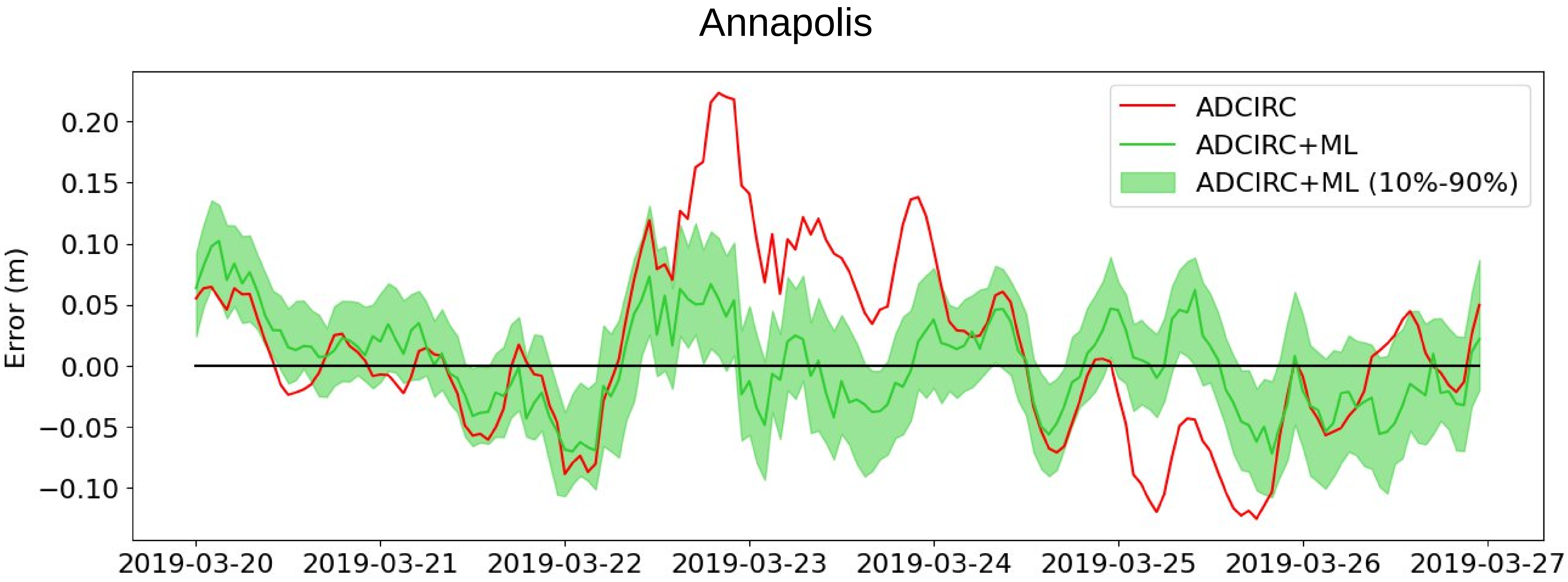
Adding ML Expected Forecast



Adding ML Confidence Bounds

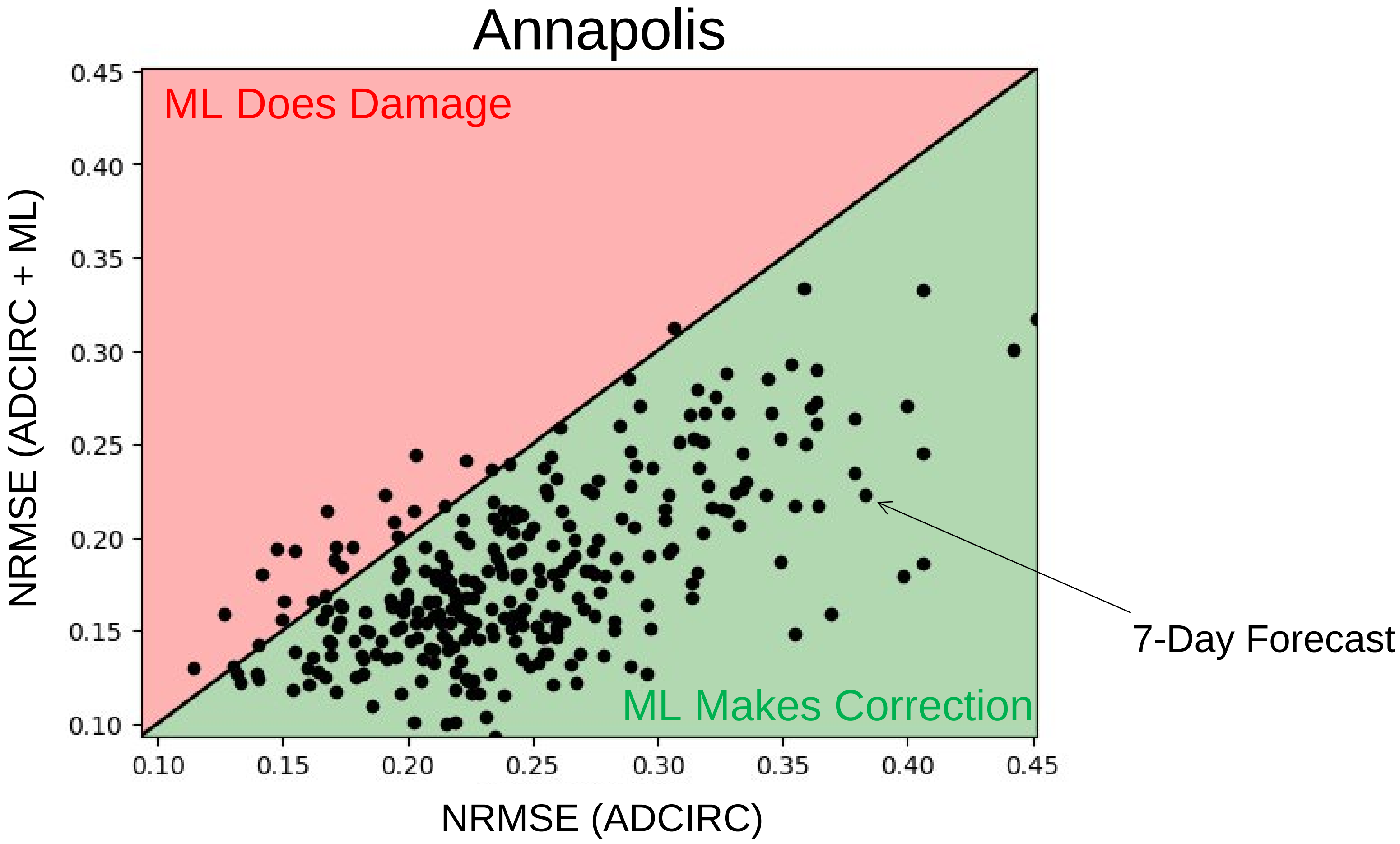


Error Across Horizon

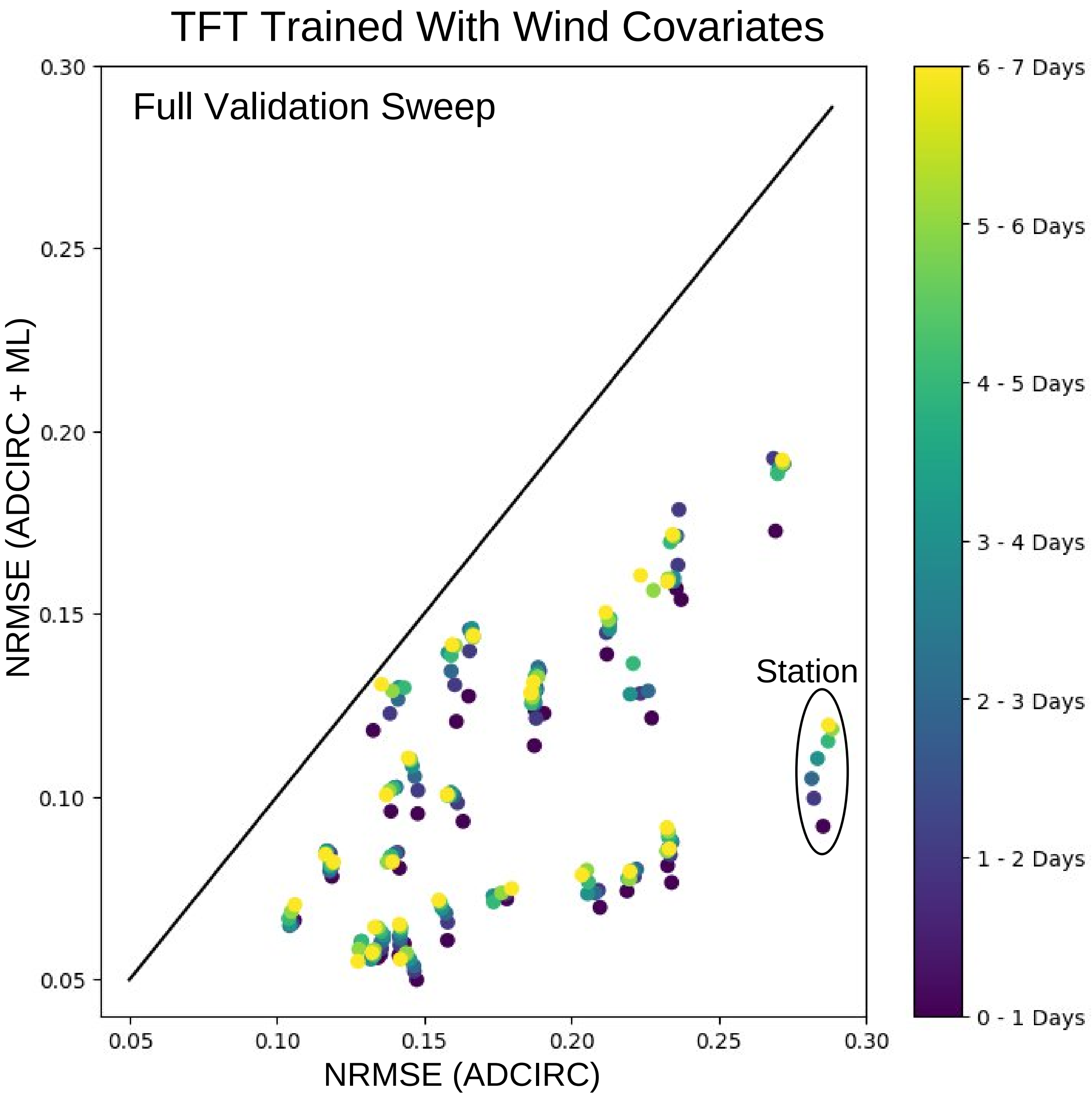


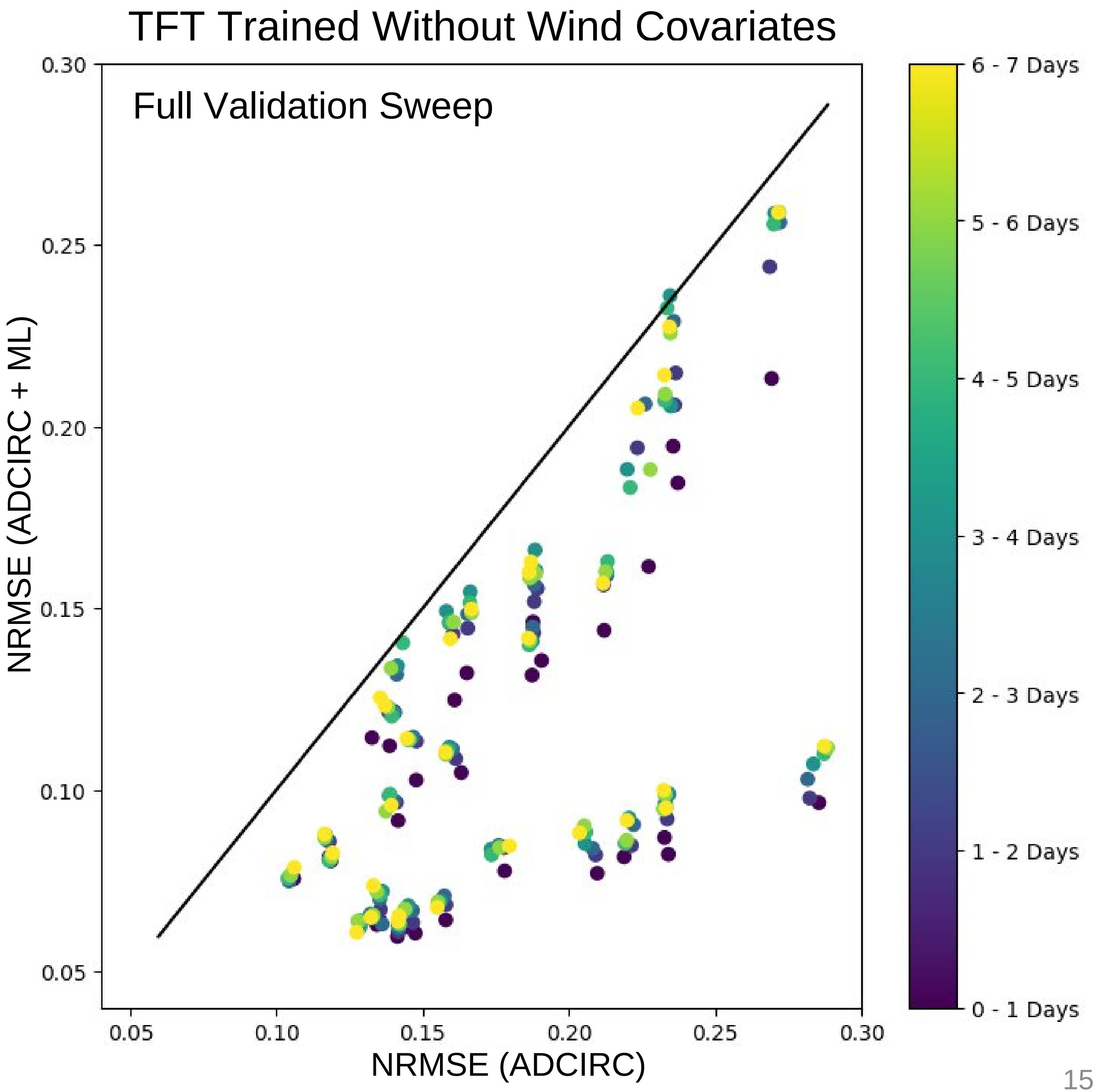
Assessing Performance

- To help quantify performance, we consider normalized root mean square error (NRMSE).
- NRMSE calculated for each 7-day validation period (hundreds per station).



Importance of Winds in Chesapeake & Delaware





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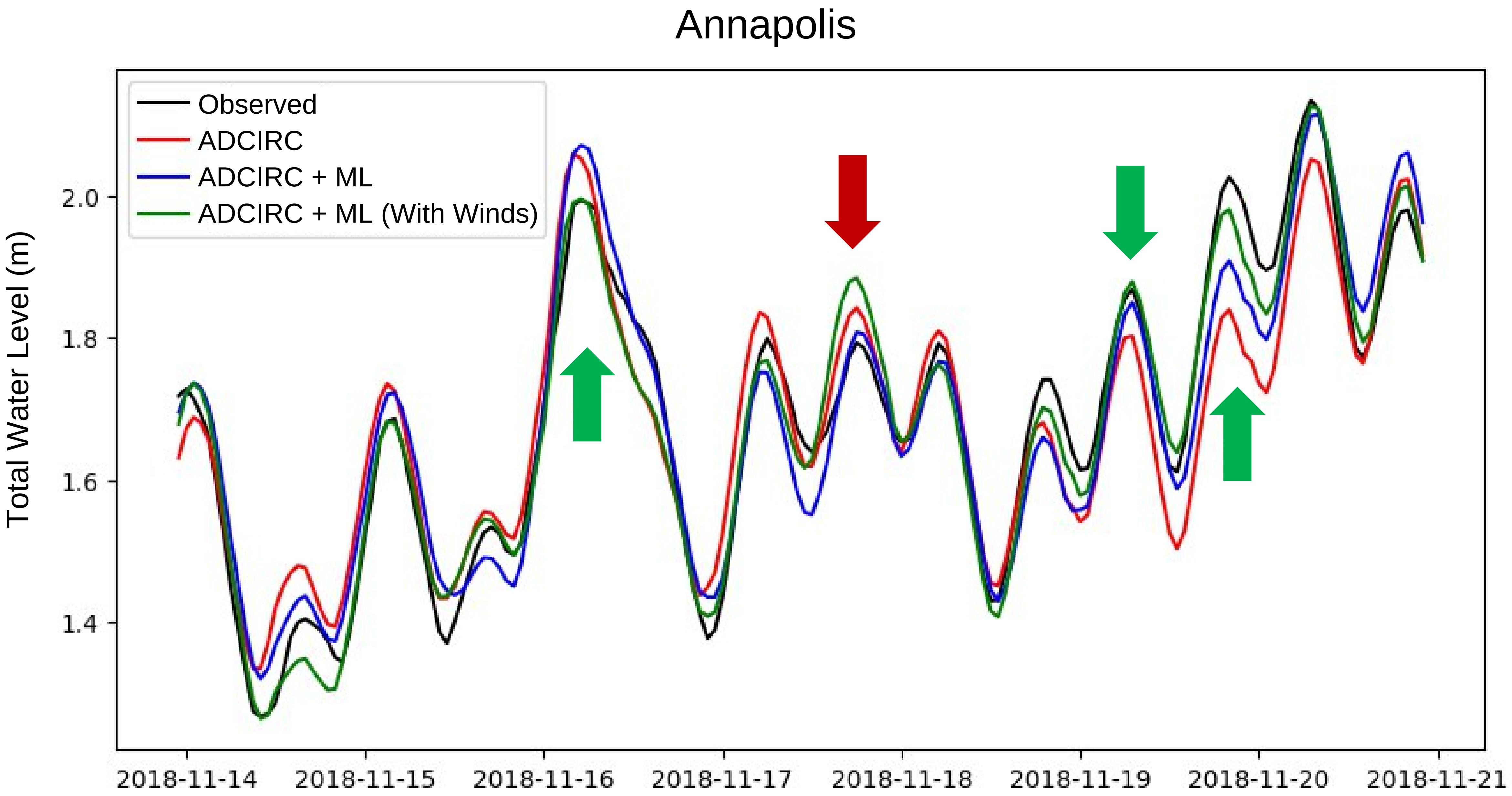
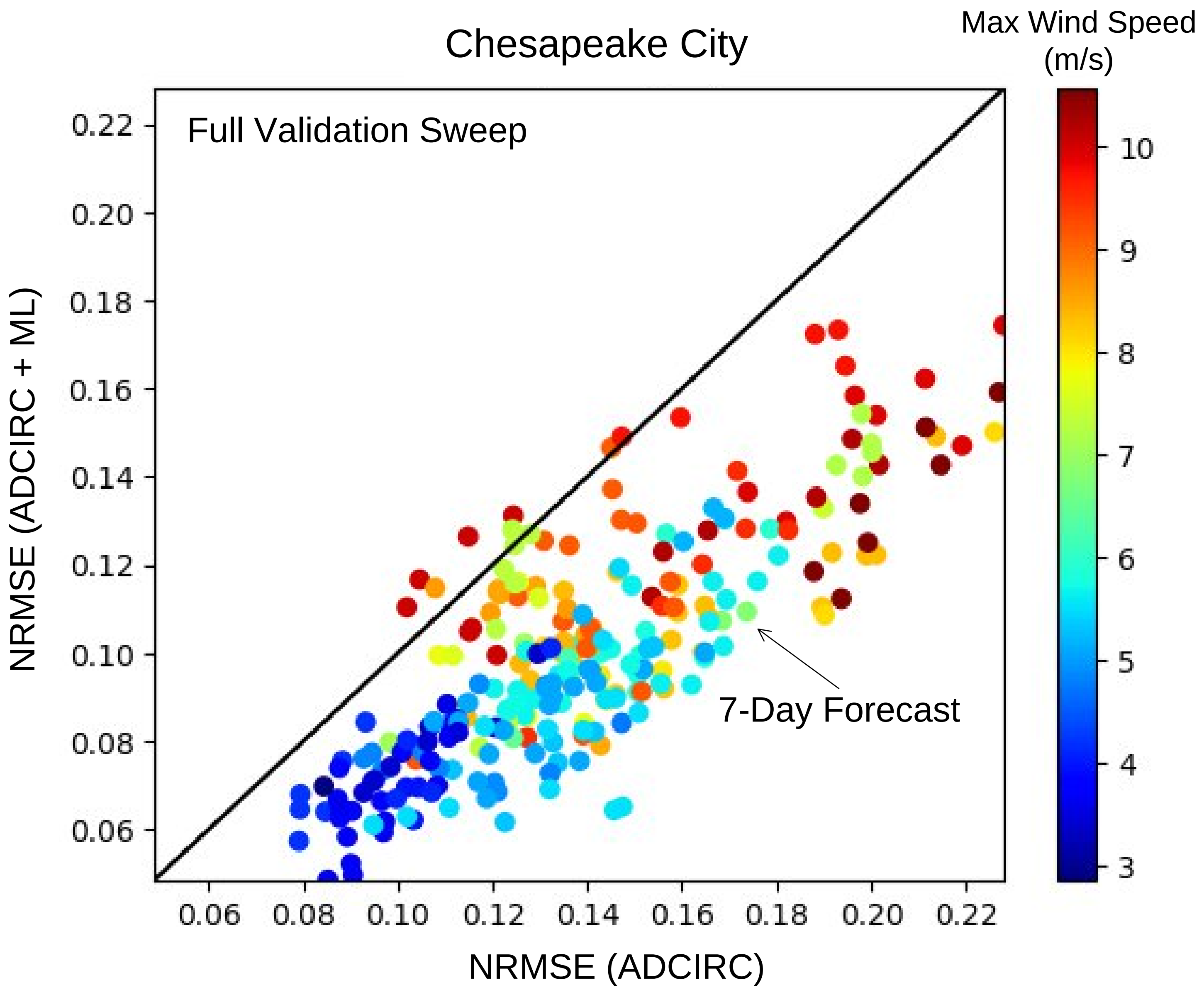
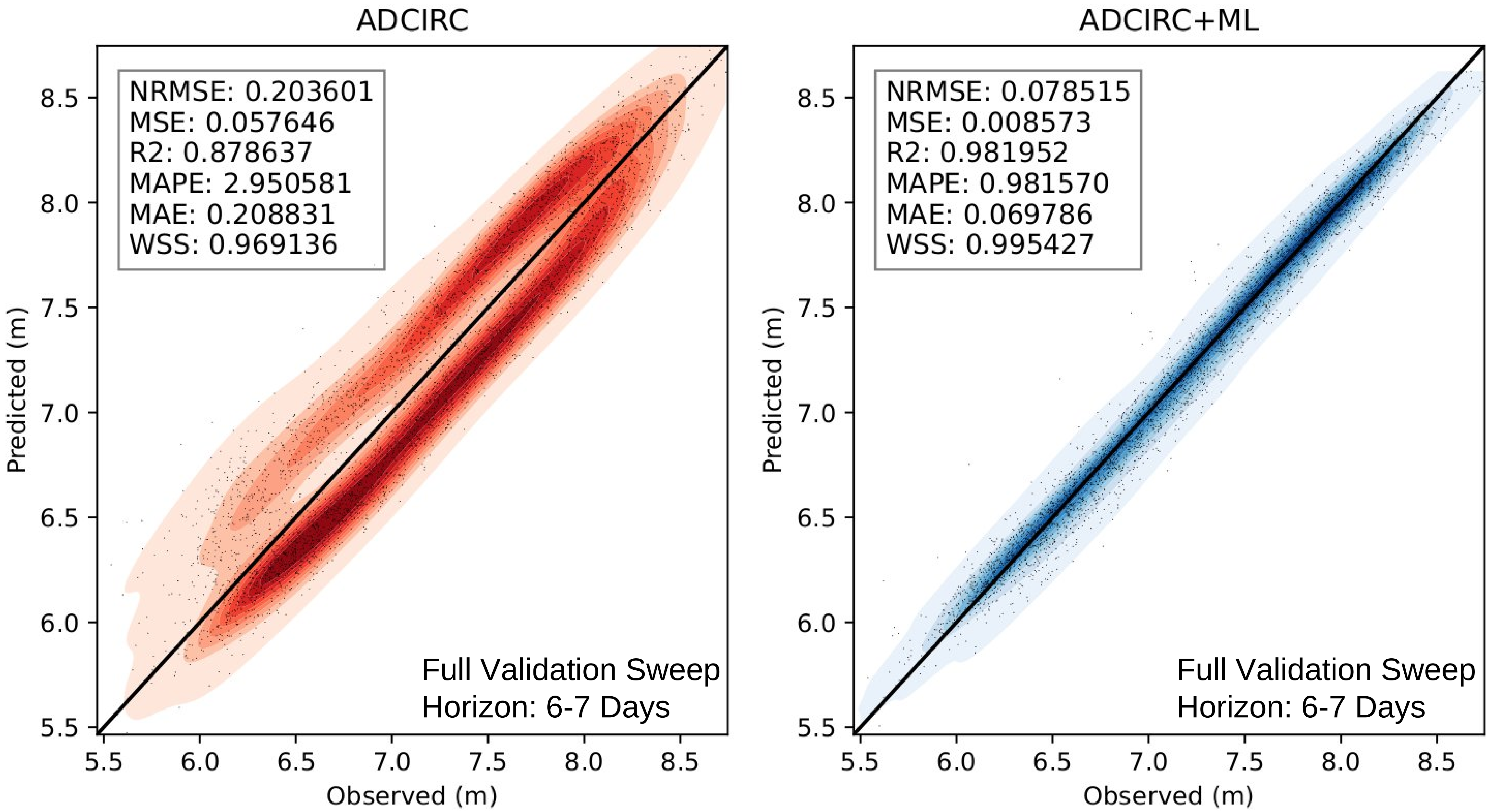


Live and Die by Winds



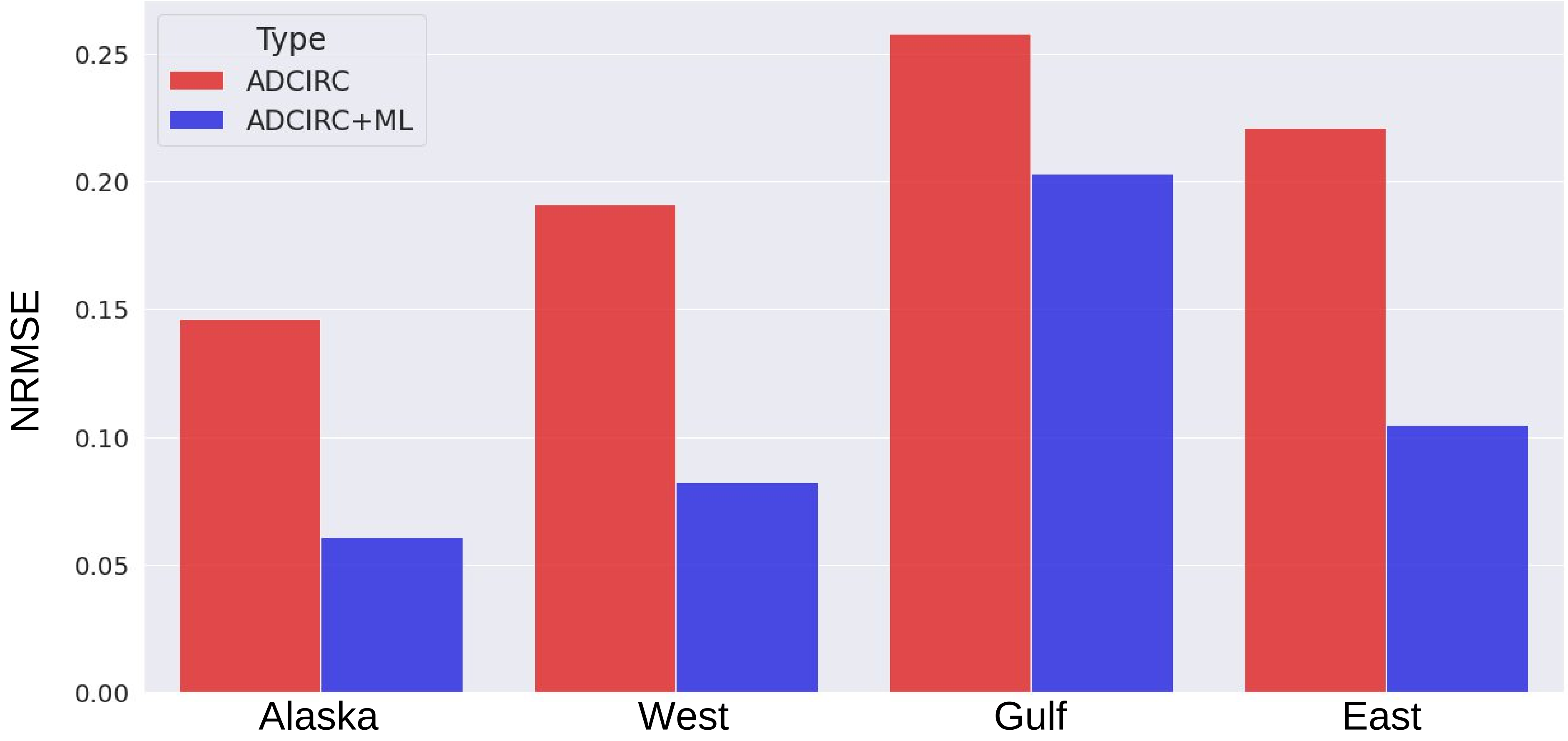
Large ADCIRC errors strongly correlated to winds!

TFT in Delaware River: Bridesburg, PA



ML Performance Across USA

- The TFT performs well for tidally-dominant stations.
- It does not perform as well in the Gulf of Mexico where stations are wind-driven and surrounded by relatively shallow water.



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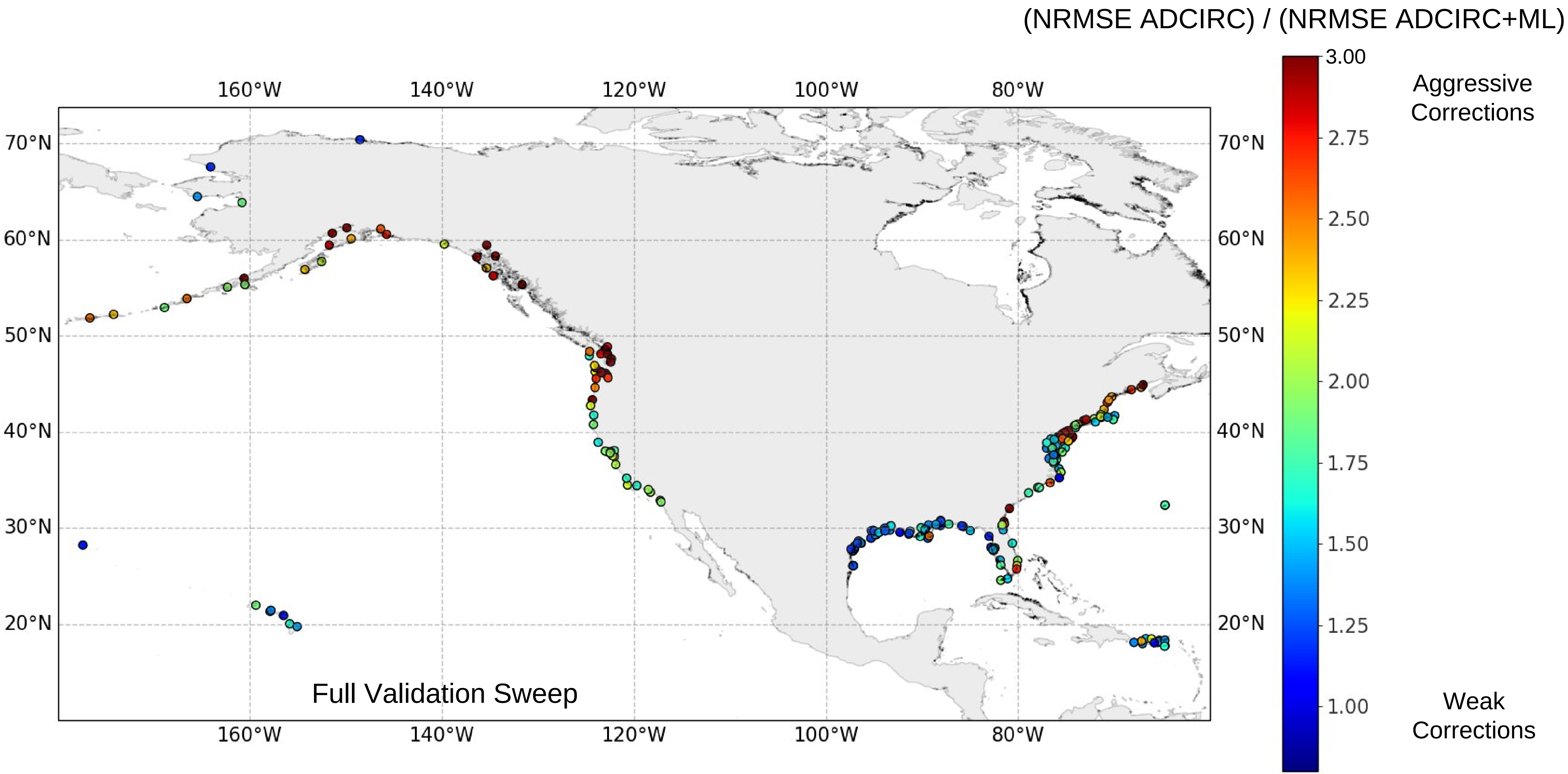
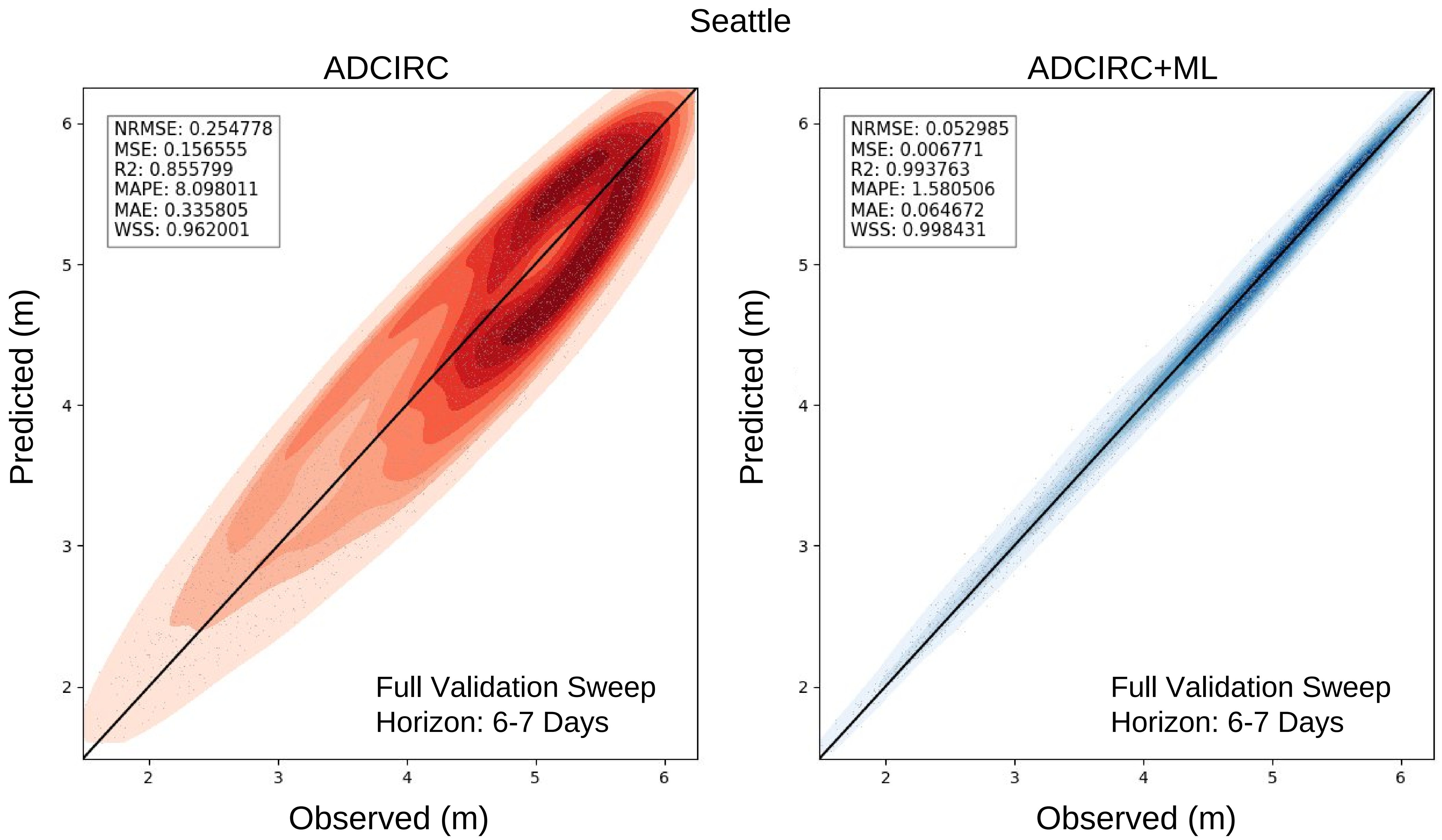
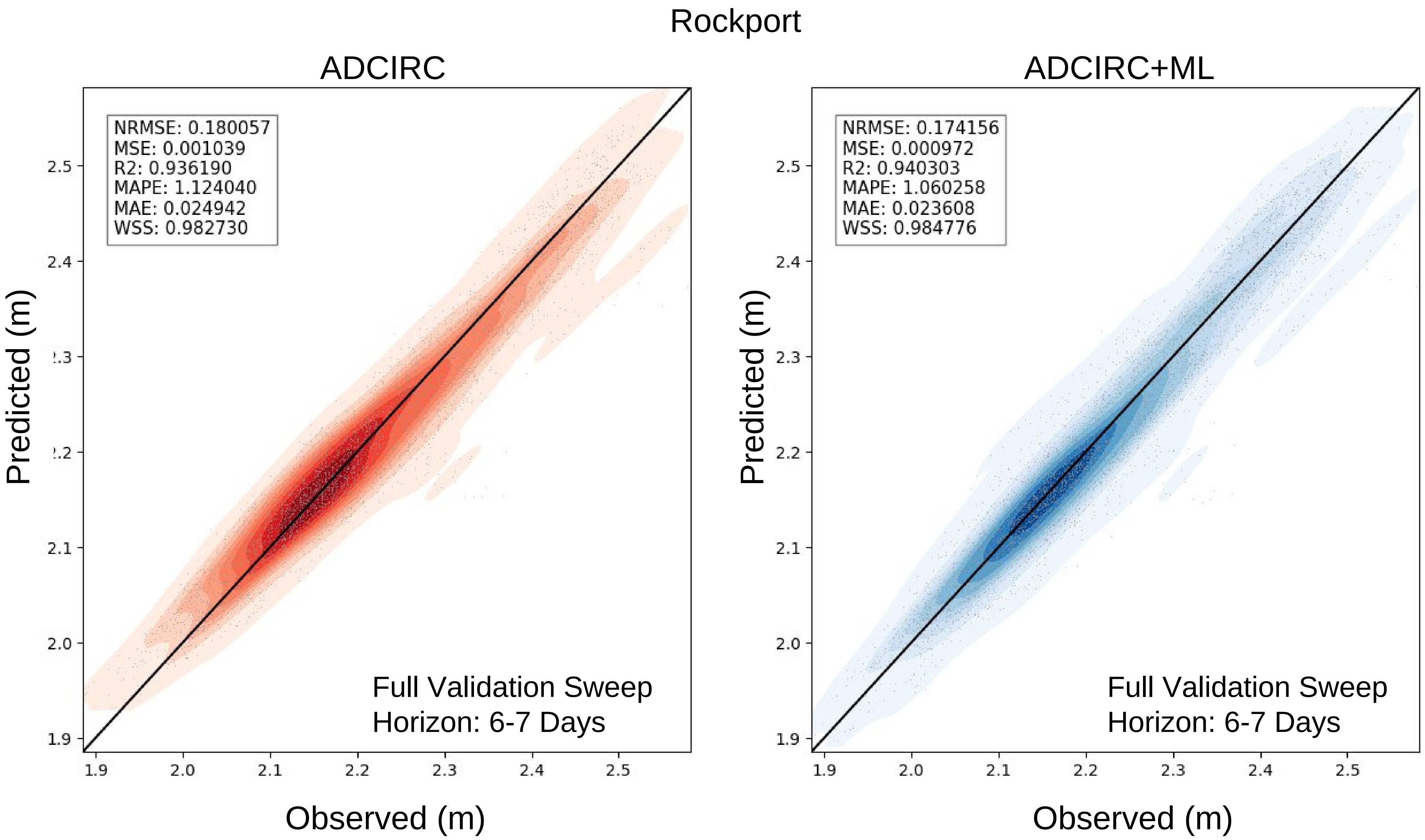


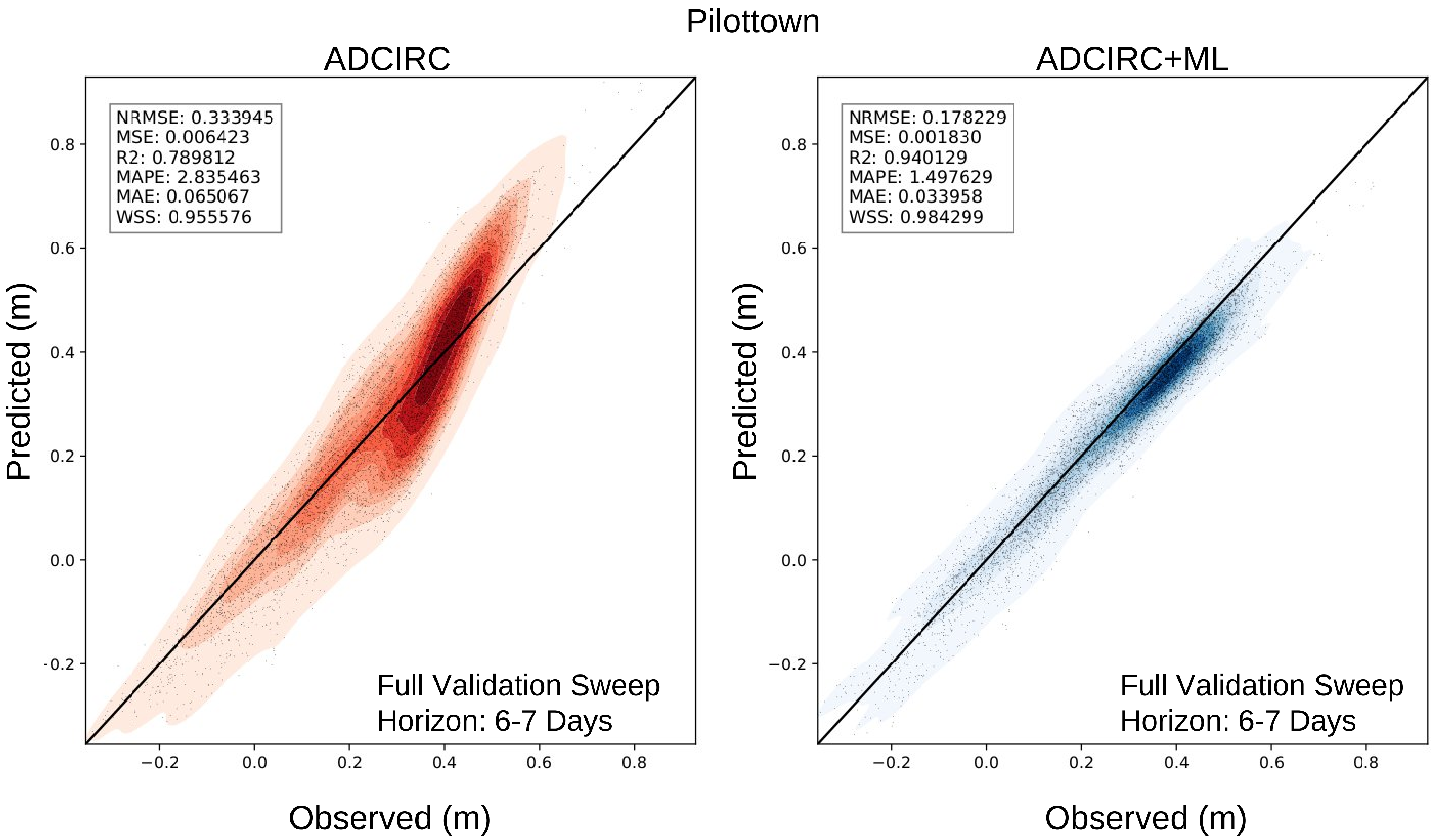
Aggressive Correction at Tidally-Dominant Station



Very Weak Correction at Wind-Driven Station



Aggressive Correction Addressing Bias



Conclusions

- The transformer is a rapid way to correct ADCIRC.
  - Highly performant for tidally-dominant stations.
  - Not as attentive to wind-driven stations, but renders corrections nevertheless.
- In the future...
  - Expose transformer to longer training period.
  - Generalize this approach to extrapolate corrections between stations.
  - Make the transformer attentive to tropical cyclones.

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