

Assessing Spatial Variability in Wind Patterns and the Effect on Power Prediction in New Jersey Offshore Wind Energy Area

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ABSTRACT

Wind energy is a rapidly expanding renewable energy source, with the potential to generate large amounts of electricity both on land and offshore. New Jersey has taken initiative in expanding renewable energy through the planned development of wind farms offshore. Simulation models currently exist for predicting the power output of turbines with changing meteorological environments. Weather models such as Weather Research and Forecasting (WRF) can predict wind speed and potential power output; however this data is imperfect and must be validated for accurate predictions. For this reason, it is desired to determine the spatial variability across the wind energy area (WEA). This analysis is achieved by comparing turbine hub-height wind speeds from several hundred points within the WEA. Empirical orthogonal functions are used to compare time and spatial variability for wind speed and predicted power output. Results indicate that there is a strong correlation between offshore distance and wind speed, which will have a significant impact on the power prediction for wind developers. Accurate modeling is imperative to the feasibility of the planned wind farm, and continuing research needs to be done to support this and future offshore wind projects.

INTRODUCTION

- New Jersey is currently planning to develop an 1100 MW offshore wind farm and is committed to expanding renewable energy in the next decade.
- The wind energy sector relies on weather modeling data and simulation tools to support design of wind farms, assess environmental impacts, and develop an efficient model for predicting power output.

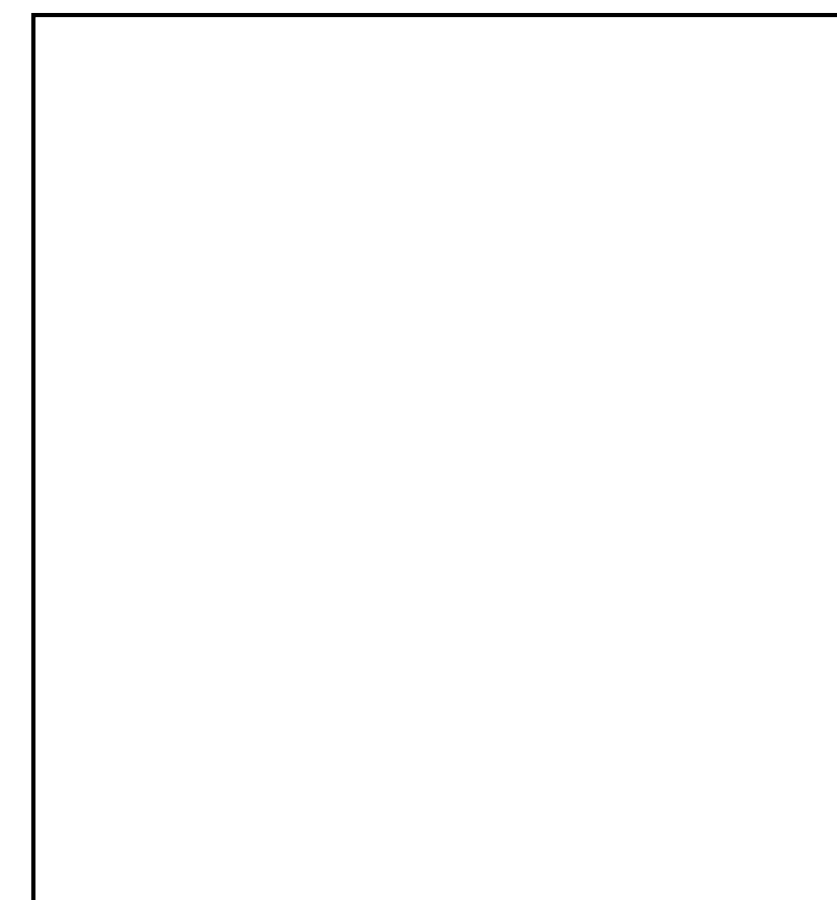


Figure 1. Offshore wind turbine in Block Island, RI. This is the only offshore wind farm currently in the US.

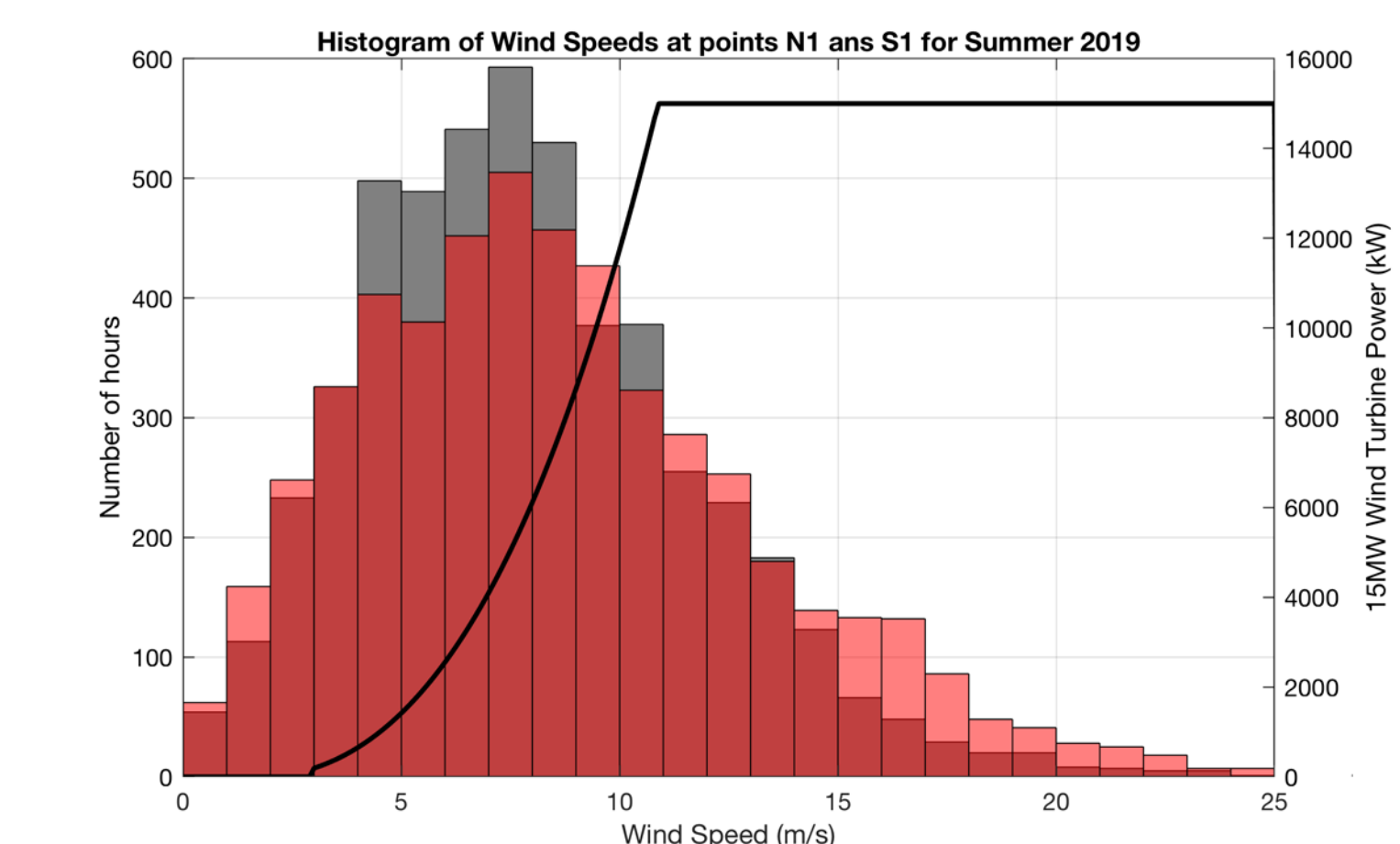


Figure 2. Histogram of wind speeds at 2 points, N1 (gray) and S1 (red) in the WEA for Summer 2019. The 15 MW turbine power curve is shown in black. Locations of the points are shown in Figure 5.

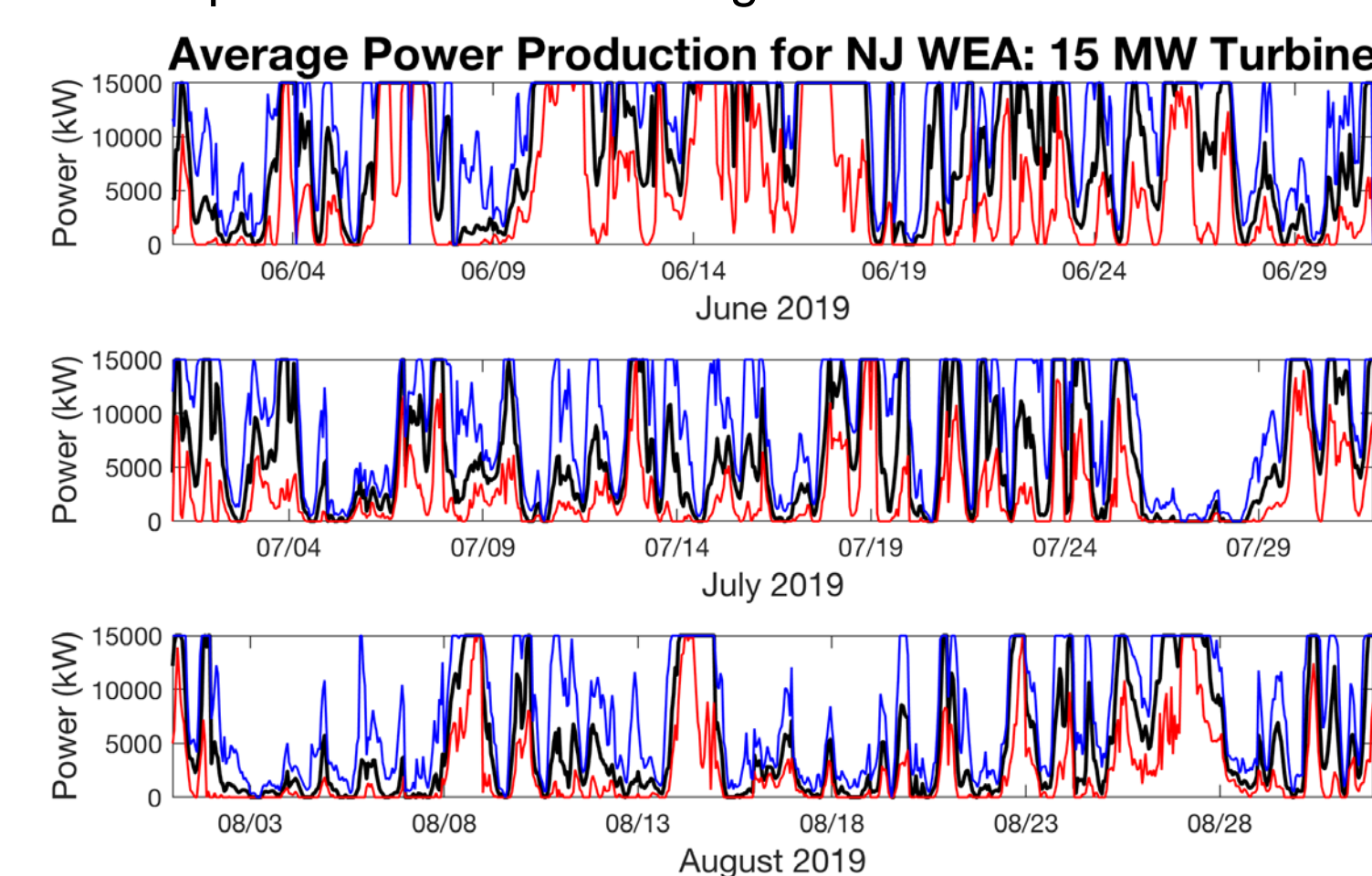


Figure 3. Hourly time series of power output in WEA. Average power is shown in black. Wind speeds at two different points are shown in blue and red to indicate the magnitude of spatial variability.

MATERIALS AND METHODS

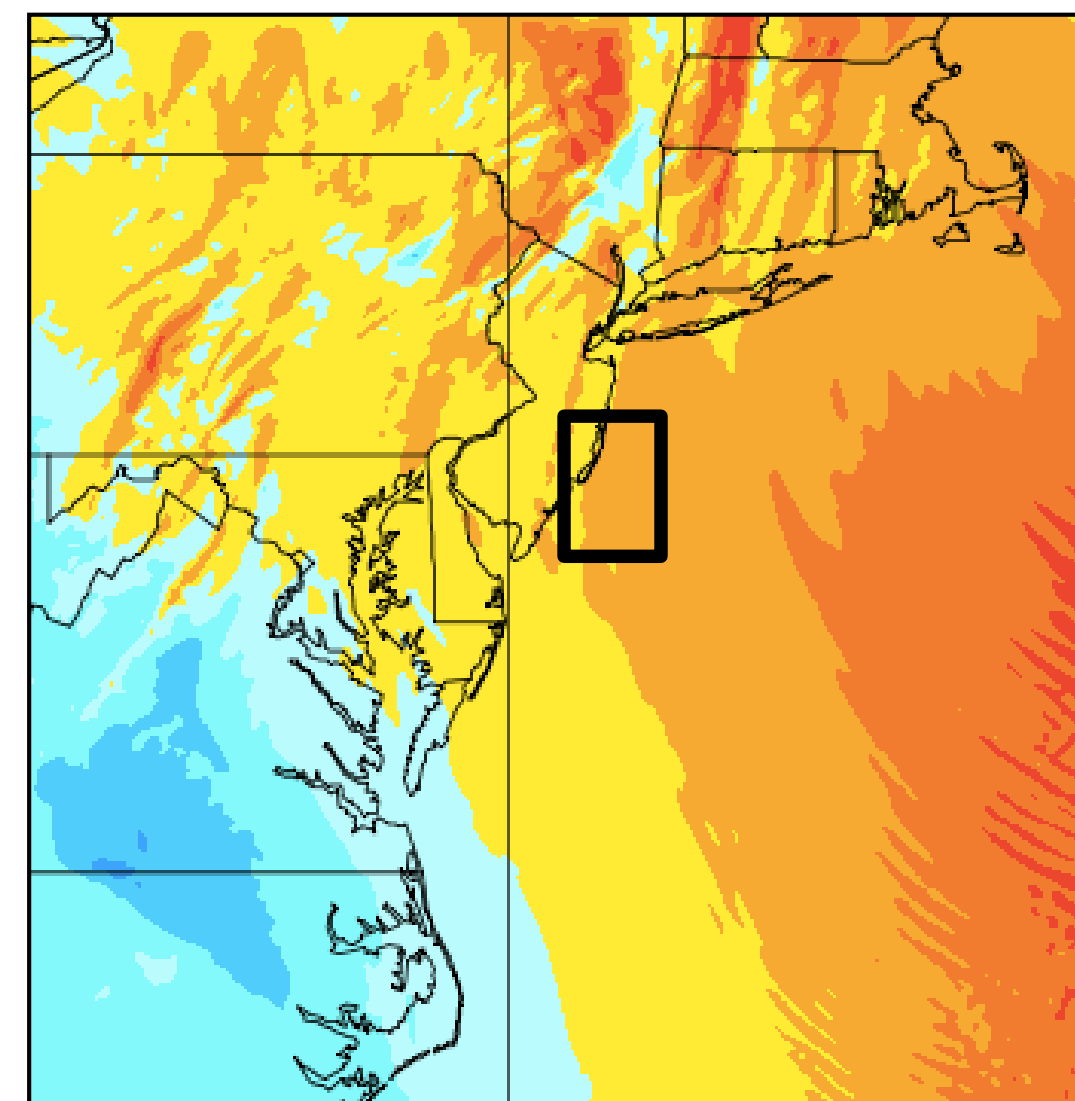


Figure 4. Hourly wind speeds for July 20, 2019 within the entire domain of the RU-WRF model. The black rectangle represents the area of interest in this study

- Time and spatial variability was analyzed for wind speeds using empirical orthogonal functions (EOF) in Matlab v. 2019a
- The results were plotted on a spatial map and compared to buoy locations
- Wind data was interpolated using a cubic power function for a 15 MW wind turbine. A similar EOF analysis was performed with power.

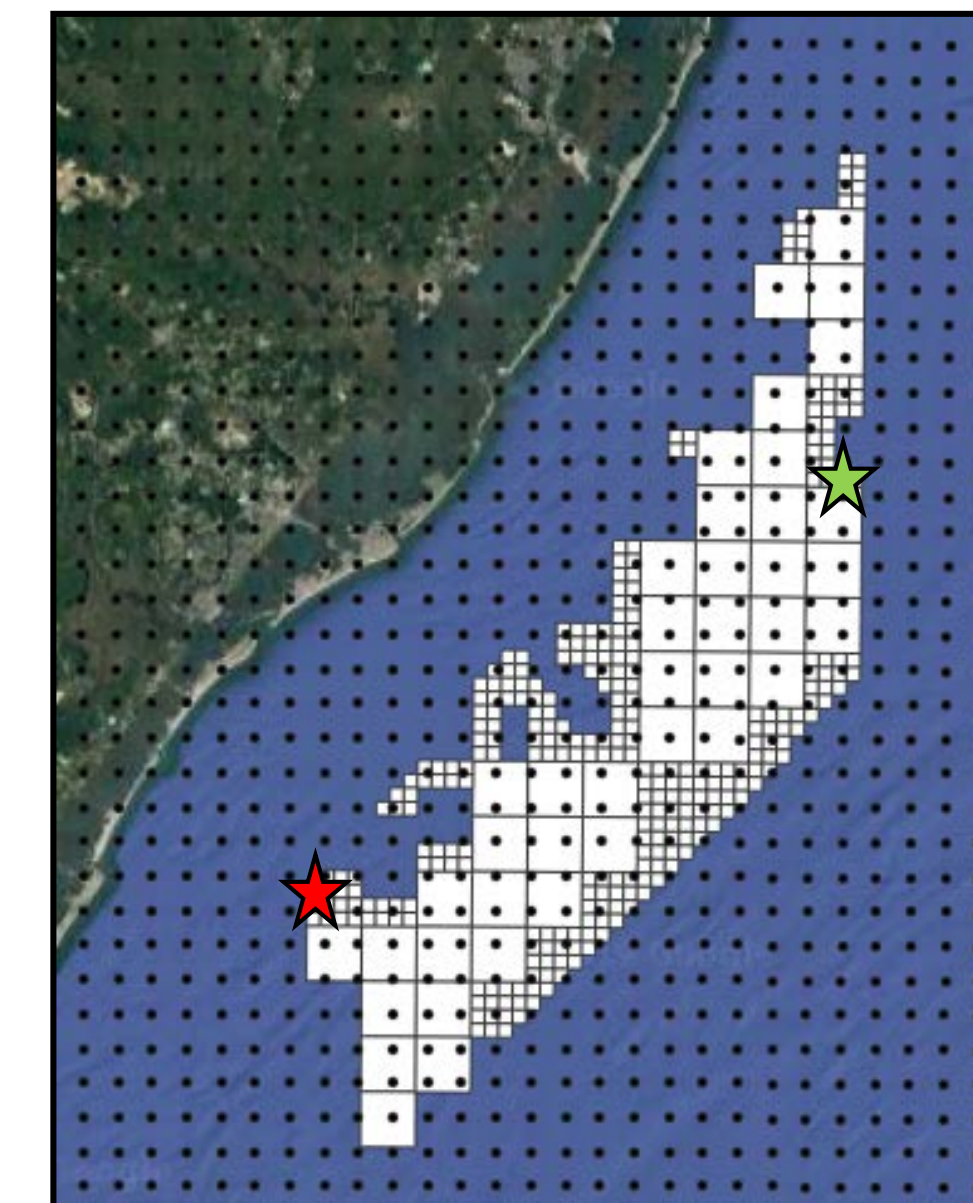


Figure 5. NJ Offshore Wind Energy Area is shown in white. Black dots represent the 3 km WRF grid where data was used in this study. Points N1 (green star) and S1 (red star) are also shown.

RESULTS

- The wind speed EOF is found to have a strong offshore/onshore variability in Mode 1, which accounts for 90% of the total variability in wind speeds. (Fig. 6A)
- In Mode 2, there is a bimodal distribution present, with an out of phase North/South relationship. This accounts for 4% of wind speed variability. (Fig. 6B) The principle component for this mode shows the wind speed variability over time. (Fig. 8)
- The wind power EOF analysis exhibits a similar pattern as the wind speeds, with higher power production further offshore. However, there is more variability, resulting in a high-power area in the north east section of the WEA. (Fig. 7)

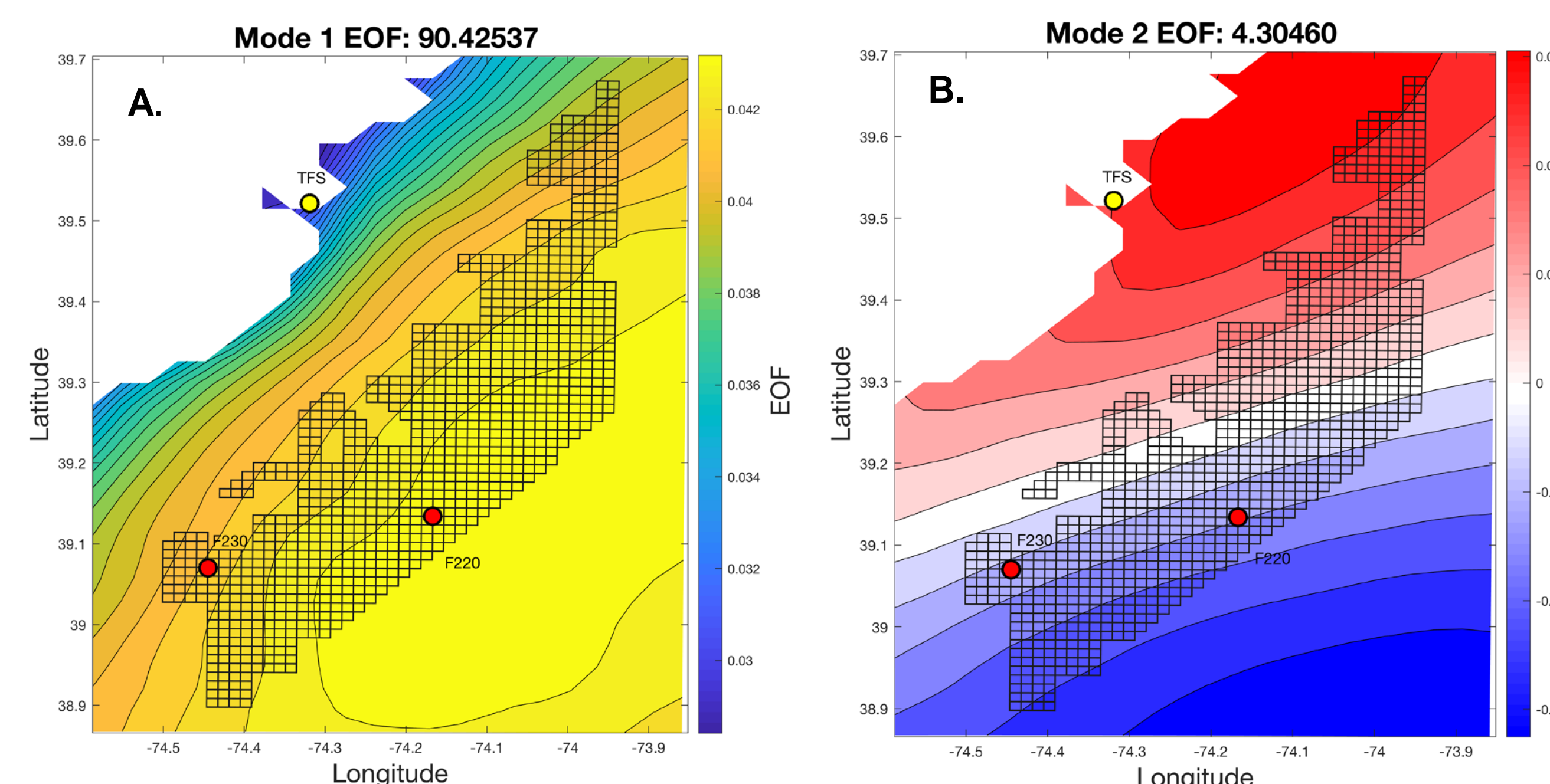


Figure 6. EOF analysis for Summer 2019 wind speeds, Mode 1 (A) and Mode 2 (B) are shown. Locations of Tuckerton Field station (yellow marker) and Orsted FLiDAR buoys F220 and F230 (red markers) are shown for comparison

DISCUSSION

- There is a history of stronger wind speeds offshore, which is consistent with the Mode 1 EOF.
- However, there is still significant variability within the WEA depending on the distance offshore.
- The North/South variability seen in the Mode 2 analysis could be a results of sea breeze circulation, which often causes uncertainty in wind and power predictions.

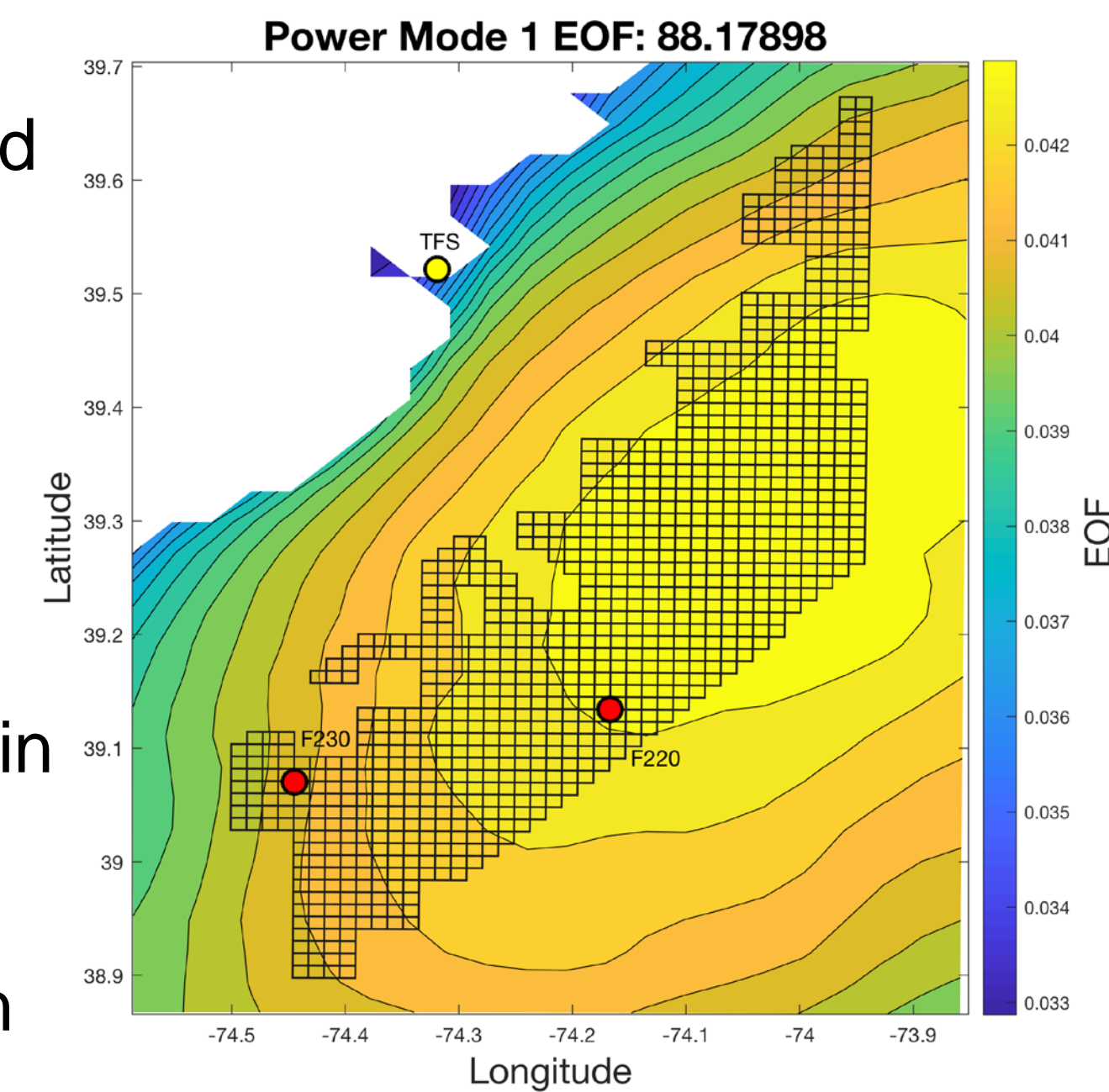


Figure 7. Mode 1 EOF Analysis for Summer 2019 predicted power output. Locations of Tuckerton Field station (yellow marker) and Orsted FLiDAR buoys F220 and F230 (red markers) are shown for comparison.

- The Principle Component of Mode 2 appears to have slight fluctuations during sea breeze events, indicating higher spatial variability during these times.
- Since power output is a function of wind speed, these two EOF models exhibit similar patterns, indicating stronger modes offshore.
- In the Mode 1 Power EOF, the F220 buoy lies in the highest power region on the map.
- Using observational wind data at this point would result in significant overpredictions of power for the whole WEA.
- The F230 buoy lies in an area associated with lower power production, which would also impact power prediction.

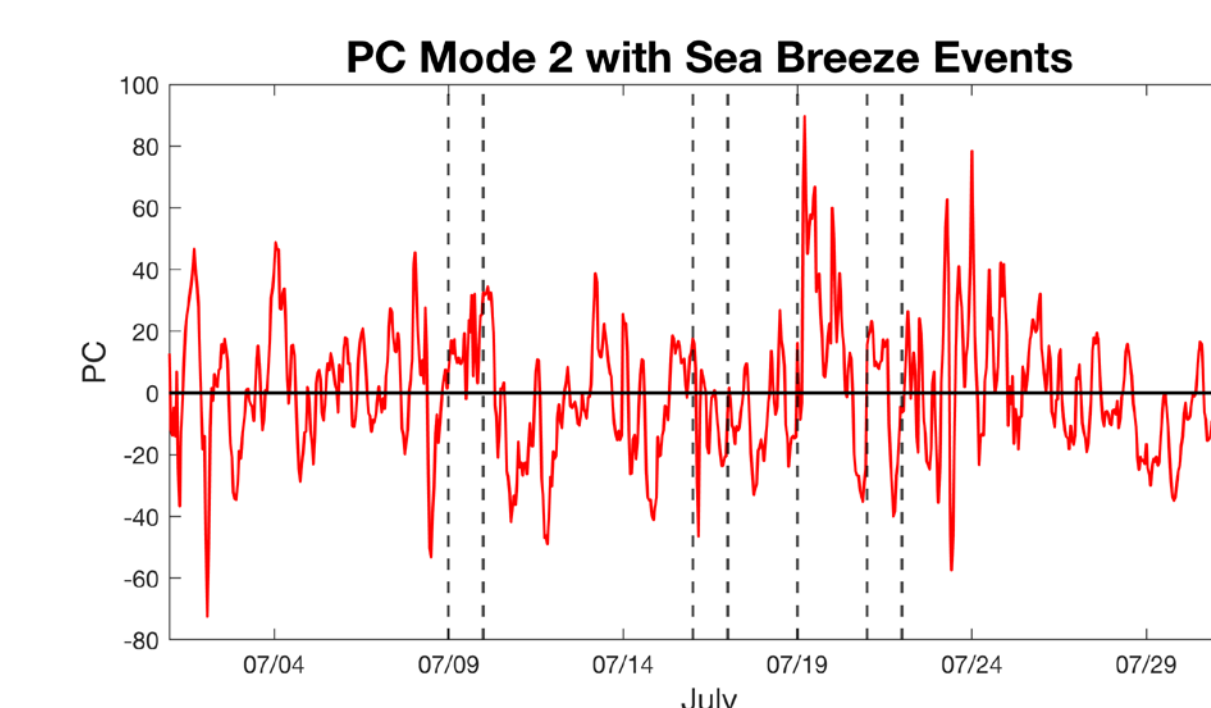


Figure 8. Principle Component of wind speed mode 2 EOF shown for July 2019 (red) and times of sea breeze events (dotted black lines).

- It is important to look at both buoy and WRF model data, along with the spatial distribution shown here, to accurately assess the wind resource to predict power output.

CONCLUSIONS AND FUTURE WORK

- The results of this study confirm that the wind speeds indeed increase at further offshore distances, and there is significant spatial variability within the WEA related to weather patterns.
- This sort of analysis is useful to wind developers, as an accurate power prediction is necessary for power bidding.
- In continuation of this research, the relationship between sea breezes and mode 2 variability will be further investigated.
- Additionally, an EOF analysis will be performed over longer time periods to gain a more accurate representation of the wind patterns.

Acknowledgements:

Thank you to the Rutgers Energy Institute Undergraduate Research Fellowship for funding this research. Thank you to Travis Miles, Joseph Brodie, Ruo-Qian Wang, and the rest of the Wind Group for your continued help and support.