Wind Institute Fellows' Research Project Abstracts (2022-2023 Cohort)

More information on the Wind Institute Fellows' research projects can be found by clicking on each Fellow's name at www.njeda.com/wind-institute-fellowship/

Design & Innovation

Stephen Conte, Optimal Energy Extraction Conditions for SWIND VAWT Design

Montclair University, Undergraduate Student, Mathematics

Advisor: Dr. Ashwin Vaidya

This project explores the performance of small-scale vertical-axis wind turbines in lab and realistic settings. Specifically, we examine the optimal design of a new turbine (SWIND), a combination of the well-known Darrius and Savonius turbine. Thus far the study has involved doing experiments in and outside a wind tunnel in the Complex Fluids Lab at Montclair State University. The tunnel was built specifically for this purpose and allows us to study the turbine performance under ideal conditions. Our experimental tests have studied: a) optimal blade configurations such as: number, placement, size; b) wind speed impact on the turbine's rotational capacity; and c) power generation as a function of wind speed. We also want to compare the turbine to more standard models such as the H-Rotor. Experimental studies will lead to identifying optimal designs as functions of external conditions. This will be used to scale and study larger models. An extension of this work will involve numerical simulations to confirm experimental observations and compute significant physical quantities such as: drag force, lift, and torque. This work is still preliminary, and I propose to continue it as a part of my master's thesis during the 2023-2024 academic year, during which time I will also experimentally and numerically examine optimal configurations of an array of the SWIND VAWTs.

James Fera, How Smart Grid Technologies and Energy Storage Can Help Offshore Wind in PJM Markets

Rowan University, Graduate Student, Electrical & Computer Engineering

Advisor: Dr. Jie Li

This project aims to investigate advanced strategies to make New Jersey offshore wind marketable in the PJM markets, to embrace the maximum capacity of offshore wind, and to support the sustainable development of NJ offshore wind. To achieve these goals, smart grid technologies and energy storage (ES), which are commonly deployed with renewable projects, are investigated. Recognizing the wide deployment of system/market monitoring tools, and availability of artificial intelligence (AI) and machine learning (ML) tools along with smart grid development, this project specifically investigates market participation tools which can provide offshore wind power producers (WPPs) with data-assisted decision making in PJM's markets. The tool, built upon model-free single-agent reinforcement learning, is under development and the results will be compared to current practices of most WPPs via power purchase agreements with the system operators, or treating themselves as negative loads, to illustrate its effectiveness. Furthermore, conventional mathematical optimization will be used to justify the performance of the data-assisted tool in both solution optimality and computation efficiency to show the advancement of AI/ML on system/market data. Finally, the optimal use of ES in enhancing WPPs' participation in PJM markets along with potential use in ancillary services will be explored.

Nathaniel Greengart, Verification of Framework for Wind Turbine Design
Rutgers University, Undergraduate Student, Applied Physics
Advisor: Dr. Onur Bilgen
As wind power becomes increasingly prominent in the clean energy industry, it is important to optimize wind turbine design to maximize power output from each turbine. In this project, we helped develop OpenTurbineCoDe, an open-source computer program for wind turbine design optimization. Using OpenTurbineCoDe's geometry, aerodynamics, structures, and controls modules, we ran many simulations on its DTU 10MW reference wind turbine. These simulations included analyses of control parameters, the bending moment on the turbine shaft, and the power output against different wind speeds and blade pitch angles. Certain physical experiments were also run on a commercial wind turbine, and these results were compared to the OpenTurbineCoDe simulations. Such experiments included observing power output against different values of rotor speed, load value, and wind speed. Results from both the simulations and experiments were found to broadly accord with analytical theories for aerodynamics, electronics, and structures.

Mohammad Katibeh, Control Co-Design Optimization of Floating Offshore Wind Turbine Blade Using a Multi-Objective Genetic Algorithm
Rutgers University, Graduate Student, Mechanical Engineering
Advisor: Dr. Onur Bilgen
Offshore wind power has great potential for generating electricity due to its high speed and steady wind flow. Approximately 60% of the total resource potential for offshore wind energy in the United States is located in deep waters that require floating wind turbines. The design and implementation of floating offshore wind turbines present numerous challenges due to the added complexity of setup, maintenance, and control. Therefore, this study focuses on conducting a robust design optimization to obtain an optimal turbine design to achieve a feasible levelized cost of electricity and power generation. To achieve this, the study aims to optimize a wind turbine's structural and control parameters to improve power output while reducing aeroelastic loads. As a wind turbine includes multiple sub-systems that affect the overall performance of the turbine, studying these sub-systems and their interactions with each other plays a vital role in the development of the turbines. In many cases, a sequential design optimization process is used to obtain the optimal design of different components and sub-systems of the floating offshore wind turbines separately. However, this research presents a control co-design optimization approach that integrates different domains into the design optimization process. The blade twist and chord distribution are selected as the geometric design parameters. Also, a controller is designed and optimized simultaneously to control the blade pitch angle.

Shreya Srikanth, Floating Offshore Wind Turbine Platform Design, Modelling and Control
Rutgers University, Undergraduate Student, Aerospace Engineering
Advisor: Dr. Laurent Burlion
A floating offshore wind turbine (FOWT) takes advantage of higher speeds and consistent directions of offshore winds, which require fewer turbines to produce the same amount of energy. Water perturbations around floating platforms add a layer of complexity, hence requiring an optimized FOWT. This study aims to optimally conceive, model, and control a FOWT that can withstand structural design loads and mechanical stresses with minimal cost and weight. The design involves a cross-shaped semi-submersible platform with four cylindrical columns for buoyancy, along with a thinner central column that holds the turbine. Wind and wave data from sensors on the turbine nacelle and platform respectively are collected to run simulations based on hydrodynamics, aerodynamics, and physical interactions of the entire FOWT system. These simulations enable us to identify design parameters for optimal control such as: passive damping components, actuators, and active dynamic vibration

absorbers for platform stabilization. By incorporating our ongoing real-world testing and simulations, the platform design and control system can be fine-tuned to mitigate unwanted oscillations in turbulent wind and wave conditions - ensuring a stable, optimized base for the FOWT. The resulting solution offers a reliable renewable energy source that can meet the demands of sustainable power generation.

Alexandra Reyes: The Offshore Power Portal: A Web-Based Repository to Improve Offshore Wind Knowledge Dissemination

Montclair State University, Undergraduate Student, Computer Science
Advisor: Dr. Vaibhav Anu

The purpose of this project was to create an easily accessible and simple to understand resource to provide information regarding offshore wind to the general public. In addition, a public perception survey is to be conducted to gauge the public's opinion about offshore wind projects in the US. During the development of the Offshore Power Portal website, a user interface (UI) survey was administered to students at Montclair State University to evaluate the effectiveness of the website's design and concept. Results of this survey showed positive feedback regarding the layout/design of the user interface and opinions on how to improve the site were taken into account resulting in changes to certain design elements. In addition, data from this survey showed that most respondents had minimal to no knowledge about offshore wind and found that the website would be a beneficial tool for the dissemination of offshore wind knowledge. It is evident that the usability survey aided in the overall improvement of this project and overall the Offshore Power Portal will serve as a valuable resource for offshore wind education for the general public.

Environmental Monitoring & Sustainability

Samantha Alaimo, Understanding Long-Term Trends of Commercial Fish with Planned Offshore Wind Development in the Mid-Atlantic Bight

Rutgers University, Ph.D. Student, Oceanography
Advisor: Dr. Travis Miles

The coastal ocean off New Jersey, known as the Mid Atlantic Bight (MAB), is a dynamic environment that serves as habitat for many fish species, including the summer flounder (Paralichthys dentatus), spiny dogfish (Squalus acanthias), smooth dogfish (Mustelus canis), and striped bass (Morone saxatilis), all of which serve an important role commercially, recreationally, and ecologically. With a goal of 11 gigawatts by 2040, New Jersey is at the forefront of offshore wind development in the coming years. To better assess the impact of offshore wind facilities on commercial fish species, we must first quantify long term oceanographic and fisheries trends before construction begins. The New Jersey Department of Environmental Protection's Ocean Bottom Trawl Survey contains fisheries and oceanographic data sampled across all seasons for ~30 years (1990 to 2019). Decadal trends of bottom temperature are currently being analyzed relative to species abundance and biomass. The goal of this research is to assess critical ocean habitats that overlap with offshore wind lease areas and to quantify long term trends of these commercial species.

Daniel Bindas, Wave Impacts on Offshore Power Generation
Rowan University, Undergraduate Student, Electrical and Computer Engineering
Advisor: Dr. John Schmalzel
Offshore wind power is a growing renewable energy enterprise within the US. Little is known about the impacts of wave motion (wave height, wave period, temperatures, pressure, etc.) on wind turbine power generation. To better understand the problem, a neural network (statistical analysis tool) is being worked on to see if wave motion inputs could predict the power generation of an offshore turbine. The analysis will help determine how wave motion parameters influence offshore wind power generation to find optimal areas where offshore wind turbines can generate the most power or methods for minimizing the impacts on net power production. Wave motion and wind speed data are collected from public resources. Only data from roughly estimated leased/proposed offshore wind turbine sites are being used in this study. This data is being used in the neural network to learn if offshore turbine power generation can be predicted based on wave motion metrics. Preliminary neural network results are pending. These results can lead to a better understanding of where to locate turbines in the future based on wave motion.

Elizabeth Fuchs, Uncertain impacts of NJ offshore wind farms on migratory birds
Rowan University, Undergraduate Student, Environmental Science
Advisor: Dr. Beth Christensen
This research addresses the possible impacts of NJ offshore wind farms, including lateral translation of traditional flyways of migratory birds, vertical turbulence impacts, and bird strikes. First, flyway records were reviewed from the National Audubon Society. Second, migratory species data was collected from Bird Cast which included estimated numbers of migrating birds and elevation of flight. Finally, we relate with European research, anticipating possible interactions between birds and turbines. European data shows birds choose to avoid turbines by going around them or over them, but this imposes extra flight costs. Brand new studies from Europe show little to no evidence of bird strikes and as our technology improves, we can expect a growth in understanding of the relationship between offshore wind and birds. The 2022 State of the Birds Report shows NJ birds face multiple pressures. This research seeks to assess pressures placed on bird migration from offshore wind farms.

Sophia Piper, The Soft Sediment Community in the Offshore Wind Lease Areas
Rutgers University, Graduate Student, Ecology & Evolution
Advisor: Dr. Daphne Munroe
Despite being among the most extensive marine habitats on earth, soft sediments and the services they provide are poorly understood and frequently overlooked. The imminent construction of offshore wind farms on the U.S. Atlantic continental shelf makes it pertinent to investigate potential impacts the turbines and associated scour protection may have on soft sediment ecosystems. The aim of this project is to develop a baseline of the infaunal community in the offshore wind lease areas whereby we can compare changes to the benthos resulting from the construction of the wind farm. To do this, we used a Peterson grab to collect sediment samples at 36 stations throughout the lease areas. We then sorted the animals by bivalves and "other" animals. The next steps are to accurately identify the bivalves and soft-bodied animals to determine species richness in each sample, which would be an estimate of the species richness at the stations.

Brianna Reynolds, Ocean Multi-Use: Can Seaweed Farms be Co-Located with Offshore Wind in New Jersey?

Montclair State University, Graduate Student, Marine Biology and Coastal Sciences
Advisor: Dr. Colette Feehan

New Jersey's wind energy sector provides an opportunity to advance the blue economy through ocean multi-use. With its low carbon footprint, seaweed farming could provide various ecosystem services, including climate mitigation, food production, and water quality improvement, when co-located within offshore wind. Yet, constraints to implementing offshore wind multi-use in NJ remain uninvestigated. In this study, a multifaceted socioecological approach was used to investigate the potential for co-locating seaweed farms with NJ offshore wind. Firstly, biological/physicochemical data were mined from published literature and databases, confirming that two native seaweed species, Saccharina latissima (sugar kelp) and Fucus vesiculosus (bladderwrack), are potentially culturable in NJ offshore waters. Secondly, a quick scoping review (QSR) quantified the state of research surrounding offshore wind–seaweed farming multi-use, globally, including identifying knowledge gaps. Main areas of research included: location, species, ecosystem services, negative effects, and policy limitations. Finally, a survey of regional stakeholders is underway to identify the strengths/weaknesses/benefits/risks of offshore wind–seaweed farming multi-use in NJ. In combination, the findings should be of interest to policy makers and aquaculturists looking to forward the NJ blue economy, and next steps may include piloting seaweed farms offshore to assess production capacity and environmental/social effects.

Tolulope Omodara, Leadership Development and Institutional Capabilities in an Emerging Offshore Wind Energy Industry

Rutgers University, Graduate Student, Public Affairs/Community Development
Advisor: Dr. Stephen Danley

This "Leadership Development and Institutional Capabilities in an Emerging Offshore Wind (OSW) Energy Industry" study investigates the relationship between strategic leadership development-cum-pipelining in the Offshore Wind Energy Industry in a country like Denmark that has led in OSW, and the Institutional capabilities Denmark later developed for her OSW Industry. There is need to identify Leadership Development imperatives for building and strengthening Institutional Competencies that are a sine-qua-non for the Offshore Wind Industry in a country like the United States, especially now that it is in an emerging phase. Although studies have reviewed leadership development and institutional competencies, this unearths the association between institutional capacity and leadership development in the OSW industry, specifically, and the subsequent ability of Denmark to establish and consolidate their place in the global Offshore Wind Industry space. The study is being done through broad and deep interviews of people involved in the creation of institutions in the Offshore Wind Energy Industry in Denmark when it was at the emerging stage. It is similarly engaging with those who were part of creating and implementing the leadership development framework for the Danish Offshore Wind Energy Industry, particularly in its nascent phase.

Operations & Maintenance

Ibnaj Anamika Anni, A Hybrid Experimental-Numerical Framework to Improve the Repair Quality of Wind Turbine Blades by Cold Spray

Rowan University, Graduate Student, Mechanical Engineering
Advisor: Dr. Behrad Koohbor

Off-shore wind energy is rapidly expanding as a major source of renewable energy in the state of New Jersey. However, a significant challenge in the industry is the maintenance and repair of wind turbine blades. To address this issue, our study aims to explore the use of polymer cold spray technology as an innovative and effective alternative for repairing composite turbine blades. The project involves intentional and controlled imposition of damage to fiber reinforced polymer (FRP) composites to replicate wind turbine damage, followed by a repair protocol that is based on the cold spraying of thermoplastic and thermoset polymeric powders. The recovery of the lost structural properties (due to damage) is evaluated experimentally using quasi-static three-point bending tests. Our experimental studies, supplemented by multiscale finite element analyses, suggest that the cold sprayed particles undergo severe plastic deformation due to high-speed impact on a stiff substrate, resulting in the development of effective adhesion. The results also indicate that the polymer cold spray has the ability to substantially recover the mechanical properties of the repaired product at a significantly reduced time, cost, and energy compared with traditional repair methods. Furthermore, the investigated "repair by cold spray" process can be used for on-site damage repair, leading to the development of high adhesion strengths and stiffer coatings, while requiring less surface preparation and imposing negligible thermal, chemical, or mechanical degradation of the blade material.

Akhyurna Swain, Finite Element Modeling and Nondestructive Magnetic Field Evaluation Of Wind Turbine Drive Trains

New Jersey Institute of Technology, Graduate Student, Electrical Engineering
Advisor: Dr. Philip Pong

A typical wind turbine drive train is composed of multiple dynamic components such as the electric generator, the gearbox with bearings and the rotating shaft that are electromagnetically and electromechanically coupled with each other. However, the current finite element analysis techniques model each of these components individually and thus fail to calculate various multi-criteria constraints dependent on these coupling effects, leading to incorrect or incomplete evaluations. This work attempts to address this issue by modeling the entire wind turbine drive train to utilize the coupling effects for efficient finite element analysis. The work further takes advantage of these coupling effects to achieve the magnetic field evaluation of the entire drivetrain. From this work it can be observed that the magnetic field of the electric generator is dependent on the electrical as well as the mechanical characteristics of the all the components of the drive train. Therefore, this nondestructive magnetic field evaluation has the potential to replace the existing destructive fault sensing techniques to achieve structural health monitoring while reducing the total operations and maintenance cost of the entire wind turbine drive train.

Sindhu Sai Sree Parimi, Condition Monitoring of Renewable Energy with IoT Sensing Platform for Fault Detection and Diagnostics

New Jersey Institute of Technology, Graduate Student, Electrical Engineering
Advisor: Dr. Philip Pong
Data monitoring and communication infrastructure are the cornerstones of power system projects such as offshore wind farms. In offshore wind farm areas, data monitoring systems are usually provided by wind turbine manufacturers; however, when different brands of wind turbines are used, data information cannot be shared for autonomous survey operations. Generally, two ranges of communication should be considered: i) local communication of the wind turbine with the control centers for active and reactive power control, energy management, and the safe operation of the wind turbines; and ii) communication between onshore and offshore substations for multiple subsystem interconnection, electric energy acquisition, fault detection and protection information, predictive maintenance, and wind power prediction. The main objective of this work is to create an Internet of Things (IoT) platform for sensing, data collection, analysis, and storage using a wireless sensor network. The platform would monitor the operating conditions of offshore wind turbines, such as current, voltage, wind speed, and vibration, in remote areas when the sensing nodes are isolated from the existing communication networks. The proposed control and data acquisition (SCADA) system should be able to gather data with a high timestep resolution. A prototype is developed by integrating a set of sensors (e.g., current, voltage, temperature, irradiance, humidity) to collect data from the real system, while the data is stored on a remote ThingSpeak platform using wireless communication. The collected data is analyzed and compared to a virtual system developed in MATLAB/Simulink, forming a real-time IoT/big data platform. The system is under investigation for fault detection and diagnostics of offshore wind turbines.

Ivan Tajo, Enhancing Offshore Wind Inspection and Monitoring with Advanced Sensor-Equipped Drones

New Jersey Institute of Technology, Undergraduate Student, Electrical Engineering
Advisor: Dr. Pramod V. Abichandani
Offshore wind offers enormous potential for renewable energy in the United States, but assessing and monitoring offshore wind facilities is difficult. We want to overcome these issues by employing drones outfitted with modern sensors to identify problems and collect diagnostic data. Our project involves a thorough study of existing drone technology and sensors, specifically anemometers, for offshore wind surveys. We are developing a drone platform equipped with ultrasonic anemometers and pitot tubes that can fly in windy conditions to collect real world data through flight testing. This allows us to evaluate the effectiveness of drones as a replacement for human inspections. We currently have the drone and equipment under construction. Wind sensors and data logging components are 90% finished. Our electronics sensor suite is able to measure wind data, save the data, and append that data to create an annotated video of the flight. Finally assembly will be completed before the end of the semester and following that will be flight tests. The use of drone technology in offshore wind inspections is a promising area of study. Drones have the potential to improve the efficiency, safety, and dependability of offshore wind installations through better situational awareness. Future research could concentrate on constructing more robust drone systems that can operate in inclement weather and enhance inspection accuracy.

Walther Vera, Wind of Change, New Jersey Offshore Wind Project Anecdote
Montclair State University, Undergraduate Student, English
Advisors: Dr. Neeraj Vedwan and Dr. Pankaj Lal
This project aims to reduce the information gap between New Jersey Offshore Wind Project developers and the community. In our state, the people need to be better informed about the project stages and important details; the lack of information creates negative concepts and gossip around unclear topics like the project's economic or environmental side.

Predictions & Forecasting

Salma Alami Yadri, Univariable Machine Learning Model for Long-Term Offshore Wind Power Forecasting
New Jersey Institute of Technology, Undergraduate Student, Electrical Engineering
Advisor: Dr. Philip Pong
The increasing global population is driving up energy consumption, leading major economies and industry stakeholders to prioritize the development of renewable energy sources and move away from conventional energy. In recent years, several advances have been made. The ability to accurately forecast wind power generation has the potential to help utility companies and energy providers to schedule maintenance and repairs, increase power generation, and potentially reduce operating costs. In this work, we aim to use machine learning algorithms to forecast the power generated from offshore wind farms for the long term. Long Short-Term Memory (LSTM) and Random Forests (RF) machine learning models are used to forecast wind power generation of offshore wind farms. We compare the performance of two models to identify the best approach for forecasting offshore wind power generation. The proposed algorithms are compared using different performance metrics: mean average percentage error (MAPE), root mean square error (RMSE), sum of square error (SSE), and regression coefficient (R). The obtained results show the usefulness of the LSTM model for offshore power forecasting. Additionally, the proposed LSTM algorithm is improved by the integration of the Vanilla-LSTM model to increase its performance especially for long-term power forecasting.

Danielle Antoine, Classifying and Quantifying Uncertainty of Wind Energy Production
Rutgers University, Undergraduate Student, Environmental Engineering
Advisor: Dr. Roger (Ruo-Qian) Wang
As offshore wind energy is becoming a significant renewable energy source for the next decade, the accuracy of predicting power production for offshore wind generation under different conditions is crucial. However, our knowledge of uncertainty in using numerical models to predict power generation is limited. As the first step to understand the uncertainty, this study focuses on classifying and quantifying three types of uncertainties including sensing, modeling, and response uncertainty. We used a 15-MW offshore reference turbine model based on Openfast to demonstrate the different types and levels of uncertainty. Sensing uncertainty refers to the inaccuracy in predicting the power generation caused by biased wind condition measurements. We are quantifying this uncertainty by comparing the power generation with accurate and biased wind speed measurement. Modeling uncertainty is introduced by the inaccurate approximation of the turbine operation modeling, and we assessed it by comparing the model with perturbed incoming wind speed. Response uncertainty is the inaccuracy of power generation prediction due to the lag that a turbine responds to a wind condition change. Utilizing Matlab, statistical characteristics of these uncertainties are generated and the results will be presented in the workshop.

Jeury Betances, Summer Sea Breeze, Upwelling and their Onshore Interaction

Rutgers University, Undergraduate Student, Meteorology
Advisor: Dr. Travis Miles

Currently research between mesoscale oceanic and atmospheric processes believe there is a connection between the oceanic processes and atmospheric processes. Wind resource estimates are typically developed using long-term wind speed averages. However, energy demand can vary significantly across hours, days, and seasons. Well-developed sea breezes will occur with weak synoptic flow and with a temperature gradient. These conditions will usually result in higher temperatures and a higher humidity inland during afternoon and early evening. Preliminary findings show that the onset and duration of sea breeze matches with the windows of peak energy load. Using NEXRAD Level-II doppler radar to conduct a historical summer sea breeze analysis of the summer months of June, July, and August from 2020 to 2022. In the summer there is usually a stable atmosphere and lower prevailing wind speeds, sea breeze circulations will most likely be their strongest during dry, stable conditions.Comparing this historical record with the Pennsylvania-New Jersey-Maryland Interconnection's (PJM), the regional transmission organization (RTO) that oversees operating the electric transmission system for NJ and neighboring states, daily metered load for the MIDATL market region will demonstrate whether the times do indeed match up on days that we have sea breezes, upwelling or a combination of both.

Andrei Dumitriu, Data Processing for Offshore Wind Energy Forecasting in New Jersey

Rutgers University, Undergraduate Student, Electrical and Computer Engineering
Advisor: Dr. Aziz Ezzat Ahmed

This research analyzes offshore wind energy regions in North and Mid-Atlantic, with a focus on New Jersey, using LIDAR technology to measure wind speed and direction. The study aims to improve the quality of data extracted from five active LIDAR buoys in the offshore leased regions by developing an algorithm to automate the process and enhance its accuracy. The research is crucial as accurate forecasting models are vital for the growth and development of the offshore wind industry, and they heavily rely on the quality of data. This study contributes to the development of accurate forecasting models, which can be used to optimize offshore wind energy production and reduce operational costs. The primary finding of this study is that there is a need for more buoys in offshore regions to train the forecasting models effectively. This study developed MATLAB scripts to perform various data processing tasks, such as handling missing data and determining periods of overlapping buoy data, to improve the quality of data. However, the lack of training data limits the accuracy of the models. In conclusion, this research identifies challenges faced in offshore wind measurement data processing and provides solutions to improve the accuracy of forecasting models. The primary contribution of this study is the development of an algorithm to automate the data extraction process and improve data quality, which can be applied to other offshore wind energy regions. This study highlights the need for continued investment in offshore wind energy research, with a focus on increasing the quantity and quality of training data.

Feng Ye, Wind Forecasting in U.S. North Atlantic Offshore Wind Energy Regions with AIRU-WRF: A Physics-guided Spatio-Temporal Model

Rutgers University, Graduate Student, Industrial and Systems Engineering
Advisor: Dr. Aziz Ezzat Ahmed

Accurate short-term wind forecasts play a critical role in the reliable integration of wind power into energy systems. We present a "physics-guided" data science approach called AIRU-WRF (short for AI-powered Rutgers University Weather Research & Forecasting) to make accurate, short-term (minutes to hours) wind speed forecasts with high spatial and temporal resolutions. In contrast to purely physics-based or black-box data-driven approaches, AIRU-WRF integrates meso-scale physics-based numerical

weather prediction (NWP) with high-resolution measurement and is designed by statistically capturing the offshore wind field's salient physical characteristics without the requirement for formal physics modeling. Extensive numerical experiments employing data from the NY/NJ Bight, a region with a number of nearby offshore wind projects that are currently under construction, suggest that AIRU-WRF not only improves prediction interpretability, but also yields better forecasts to those prevalent benchmarks in the forecasting literature and practice including physics-based, hybrid, statistical, and deep learning methods, in terms of both point and probabilistic forecasting.