Software Tools for the Mitigation of Wind Turbine Interference in the U.S. IOOS Network

Final Report
August 31, 2024

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Software Tools for the Mitigation of Wind Turbine Interference in the U.S. IOOS Network

Final Report

Submitted by:

Hugh Roarty

August 31, 2024

Introduction

The rapidly emerging U.S. offshore wind energy industry will both require new environmental data and data aggregation that IOOS is uniquely positioned to provide as well as disrupt existing sensing systems that IOOS supports. A significant adverse consequence of the likely installation of 100s of wind turbines over the outer continental shelf (OCS) within the next 3-6 years is the disruption of ocean current observations from land-based high frequency (HF) radar systems. As a core IOOS operational dataset, wind turbine interference (WTI) on the distributed surface current observations managed by the National HF Radar Network would render them blind within large areas of the coastal ocean.

Mitigating the effects of spinning turbines on HF radars is a difficult, but solvable, problem. Initial efforts have established: (1) the mechanism by which turbines can interfere with HF radars, (2) the potential effects of the interference on accurate measurements of surface currents over broad areas of the radar's coverage, and (3) the likely pathways to mitigate the interference for small numbers of turbines (Trockel et al., 2018). However, the offshore wind industry will rapidly outpace these simplified methods and thus a robust, permanent mitigation solution is needed.

The proposed work will leverage an ongoing, limited software development project funded by BOEM, and conduct a coordinated set of system integration, testing, validation, and verification activities needed to advance the technology through RL 9. The proposed work addresses the limitations of the BOEM study through planned efforts that will: (1) collect WTI data at the frequencies/ranges missing from previous efforts; (2) develop and utilize a focused dataset of simulated, hybrid, and observed WTI and conduct detailed mitigation methodological testing; (3) document operational changes of the networked IOOS-radar systems that will increase the accuracy of mitigation methods; and (4) conduct a full scale, in situ validation of mitigation methods at the first major U.S. offshore wind farm.

Both the BOEM software effort and transition work proposed here dovetail with the recommendations of an IOOS-tasked community working group. Paired together, these efforts will fully advance HF radar WTI mitigation of surface current observations from research into regular operations. The combined efforts will result in validated software operating on HF radar site computers, enabling radars to observe ocean currents in and around operating offshore wind farms. HF radar is a critical component of the IOOS mission and the only instrument capable of making both high spatial and temporal resolution observations of surface currents over the continental shelf. The plan outlined here will meet the challenges presented by offshore wind development and ensure the continued viability of this essential IOOS data product. Without efforts to prevent it, large areas of existing HF radar coverage, which are strategically important precisely because they coincide with potential offshore wind farms, will be lost as more turbines come online.

Methods

Rutgers participated in each of the Zoom meetings as part of the project. We participated in the installation of a 13 MHz radar in Point Judith, RI. The system was installed on March 11, 2021, with Rutgers providing the 13 MHz Tx/Rx antenna, transmitter, phasing cable, GPS antenna and cable. The site was operating at 13.5 MHz, 100 kHz bandwidth, 2 Hz sweep rate. On March 18 the sweep rate was increased to 4 Hz. On April 2 the reflected power jumped from 2 watts to 11 watts. There were periods of intense interference. The equipment was removed on April 30, 2021. The data for the deployment is saved on the UC Santa Barbara server.

Figure 1: Picture of the antenna deployed as part of the GAIL installation.

Range series data was recorded at the Block Island 5 MHz station and archived on the Rutgers Department of Marine Science file server. Figure 2 shows the inventory from 2016 to 2024.

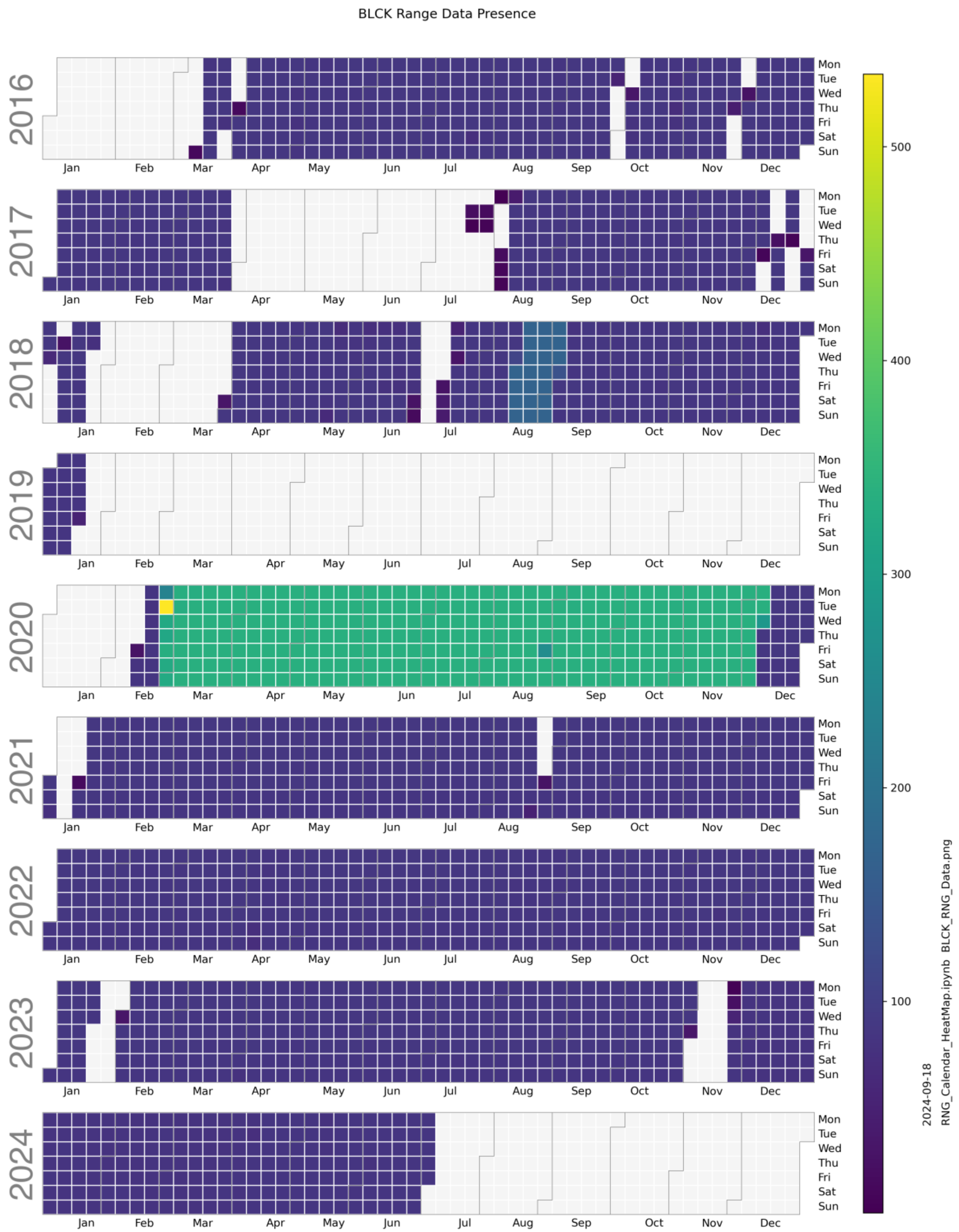


Figure 2: Inventory of range files archived on the Rutgers file server; each box represents a day from 2016 to 2024. The color of the box represents the number of range files saved. From February to December 2020 BLCK was run a 4 Hz sweep rate, otherwise the site ran at 1 Hz sweep rate.

Turbine Rotation Data

The team was able to acquire two wind turbine rotation data sets during the project. The first data set was acquired via communication between Rutgers and Orsted. The data contained wind and turbine rotation data for the five turbines south of Block Island and covered March 1, 2021, to April 30, 2021 (Figure 3).

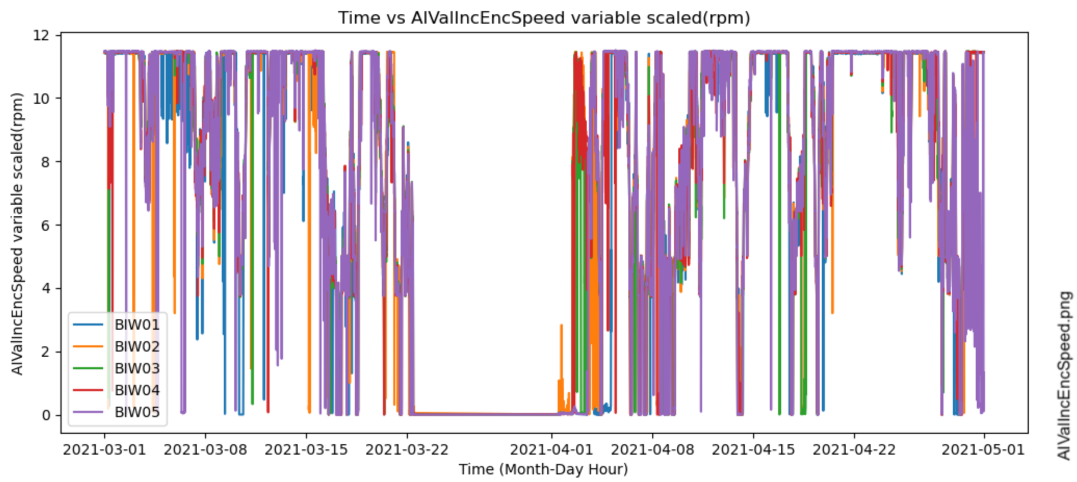


Figure 3: Turbine rotation data from the Block Island Wind Farm from March to May 2021.

The second turbine rotation data set was acquired via Brian Zelenke from NOAA IOOS. The data set covers May 2021 to April 2023 (Figure 4). The variables in the data set are found in Table 1.

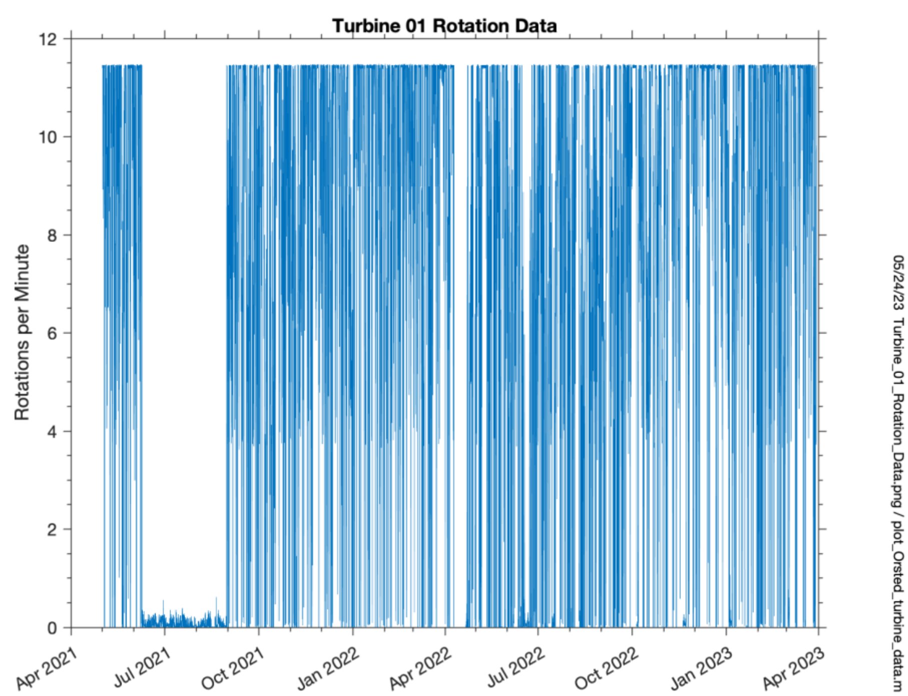


Figure 4: Turbine rotation data from the Block Island Wind Farm (Turbine 01) from May2021 to April 2023.

Table 1: Ørsted Turbine SCADA (Supervisory Control and Data Acquisition) Data Variables

Parameter	Units	Meaning
WindSpeed	m/s	Wind Speed
AI_ValWindDirection1	°	Wind direction
IncEncSpeedScaled	rpm	Wind turbine rotations per minute
NetPower	kW	Power
NorthDirection	°	Yaw angle (absolute north related to the aero)
WindDirection	°	Nacelle position
TwistAngle	°	Nacelle revolution (Yaw_RevolutionsToUntwist)

Drifter Data

Researchers from Woods Hole Oceanographic Institution deployed four drifters that were constructed by students from the Career and Academic Development Institute of Philadelphia, PA. Mr. Jeff Frank was the faculty lead at CADI directing the construction of the drifters. The drifters are part of the Student Drifter Program and was sponsored through a grant by the Toshiba STEM grant program. The drifters were deployed in the vicinity of the Massachusetts wind lease areas. Information on the drifters is given in Table 2 and the trajectories of the drifters are shown in Figure 5.

Student Drifters is as an educational program for formal and informal learning. Educators can address multiple disciplines including Science, Technology, Engineering, and Math (STEM), and customize their lesson plans with existing resources from simple concepts of latitude and longitude to complex studies of dispersion.

Table 2: Summary statistics of the four drifters released as part of this project.

Drifter	Start	End	Duration (days)	Fate
246400711	4-Jun-24	24-Sep-24	112	Recovered on Assateague Island
246400712	4-Jun-24	8-Aug-24	65	Recovered on Martha's Vineyard
246400713	4-Jun-24	21-Sep-24	109	Stopped transmitting at sea
246400714	4-Jun-24	5-Sep-24	93	Stopped transmitting at sea

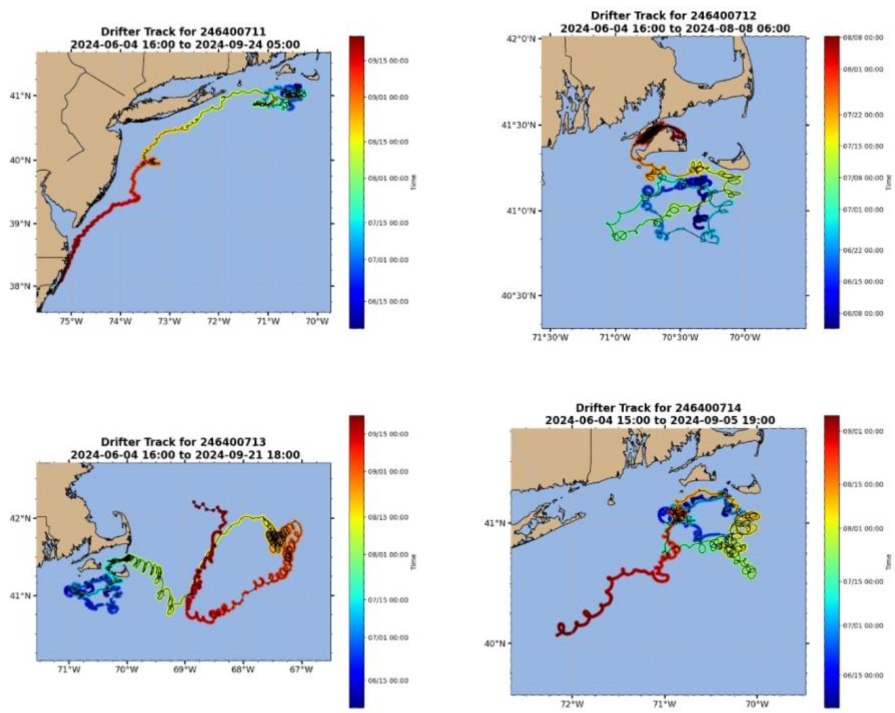


Figure 5: Maps of the four drifters deployed as part of the project.

Radial Velocity Waterfall Plots

The Rutgers team developed a radial velocity waterfall plot (Figure 6) to help identify time periods of wind turbine interference. The product is generated for each radar station within the Mid Atlantic and can be found [here](#).

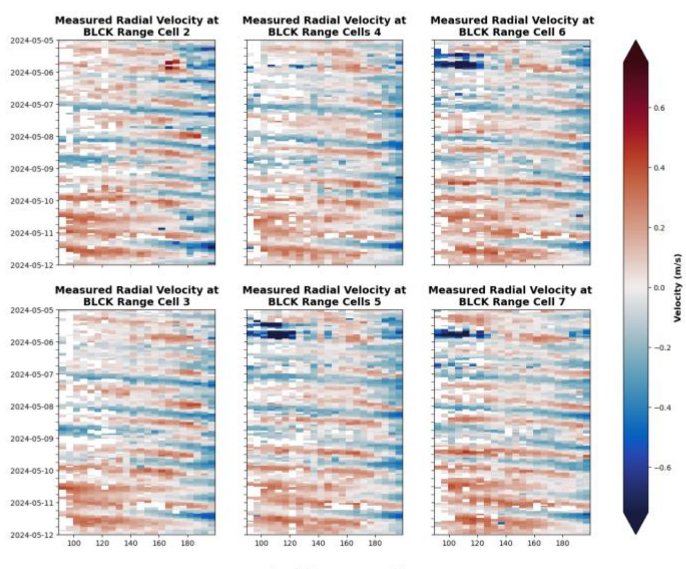


Figure 6: Waterfall plot of radial velocity from range cells 2-7 at the Block Island 5 MHz station. Potential wind turbine is identified in range cells 5-7 on May 5, 2024.

Results

Rutgers participated in several publications as part of this project. They are summarized in Table 3.

Table 3: Presentations/reports given as part of this project..

#	Presentation
1	Ford, Kuska, Roarty, Kirincich, Trockel, Trockel, Emery and Whelan (2021) “Mitigating Wind Turbine Interference in the US HF Radar Network” Offshore WINDPOWER Conference & Exhibition, October 13-15, 2021, Boston, MA
2	Trockel, Trockel, Muglia, Roarty, Taylor, Updyke, Whelan (2022) “HF Radar Wind Turbine Interference Mitigation” Offshore Windpower 2022, October 18-19, 2022, Providence, RI
3	Trockel, Kirincich, Emery, Roarty, Trockel, Whelan (2023) “Mitigating Wind Turbine Interference in the US HF Radar Network” IOOS Webinar, June 14, 2023
4	Trockel, Joshua, Brian Emery, Anthony Kirincich, Mike Muglia, Hugh Roarty, Patterson Taylor, Dale Trockel, Teresa Updyke, and Chad Whelan. "Strategies for Operating HF Radars in Field of View of Offshore Wind Turbines." In *OCEANS 2023-MTS/IEEE US Gulf Coast*, pp. 1-6. IEEE, 2023.
5	Kirincich, Emery, Roarty (2023) “Challenges and Opportunities at the Interface of Wind Energy and Radar Technology” U.S. Department of Energy, Request for Information DE-FOA-0003166

Presentation 5 is in the appendix along with a one pager that explained the state of the problem in July 2023.

References

Trockel, D., I. Rodriguez-Alegre, D. Barrick, C. Whelan, J. F. Vesesky, and H. Roarty. "Mitigation of Offshore Wind Turbines on High-Frequency Coastal Oceanographic Radar." In *OCEANS 2018 MTS/IEEE Charleston*, pp. 1-7. IEEE, 2018.

Acknowledgement

We would like to acknowledge the work of Mr. Brian Zelenke, IOOS Surface Currents Program Manager, who have advocated for the Mid Atlantic HF Radar Network these past years.

Appendix I: One pager

Mitigating Wind Turbine Interference in the US HF Radar Network

Issue, present status, and future outlook

Summary: Research partners coordinated by NOAA's Integrated Ocean Observing System (IOOS), are working with offshore wind energy groups to develop and test mitigation methods that will allow the surface current network to co-exist with, and support, the planned buildout of offshore wind energy installations.

Block Island's 5-turbine offshore array, installed in 2016, and a nearby Codar Ocean Sensors HF radar system.

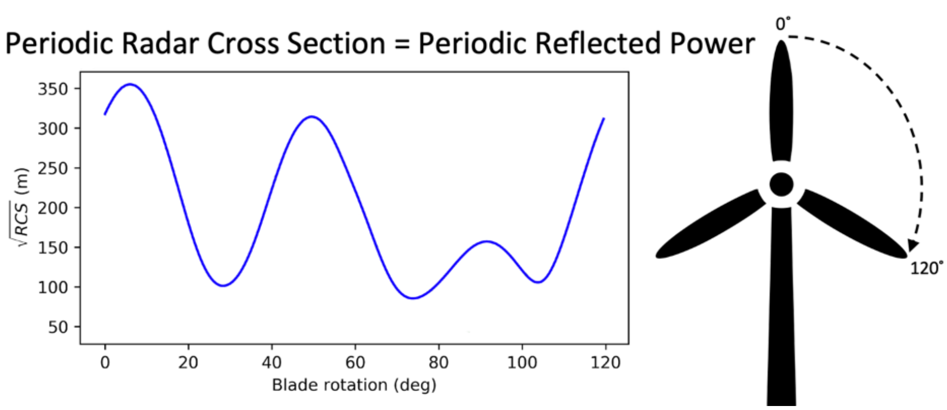
Research Partners

UC Santa Barbara | Rutgers | Woods Hole Oceanographic Institution | CODAR Ocean Sensors

Research Supporters

BOEM Bureau of Ocean Energy Management | IOOS Integrated Ocean Observing System | NOAA

Issue: The spinning blades of offshore wind turbines cause interference in the signals received by high frequency radars, and can result in spatially variable errors in ocean surface currents. Variable turbine rotation rates with changing wind speeds, or large numbers of turbines, alter the characteristics of the interference in HFR data, requiring dynamic mitigation methods.



The estimated change in the power reflected by a wind turbine, known as the radar cross section, as the turbine blades rotate 1/3 of a revolution or 120º causes a signal similar to ocean currents.

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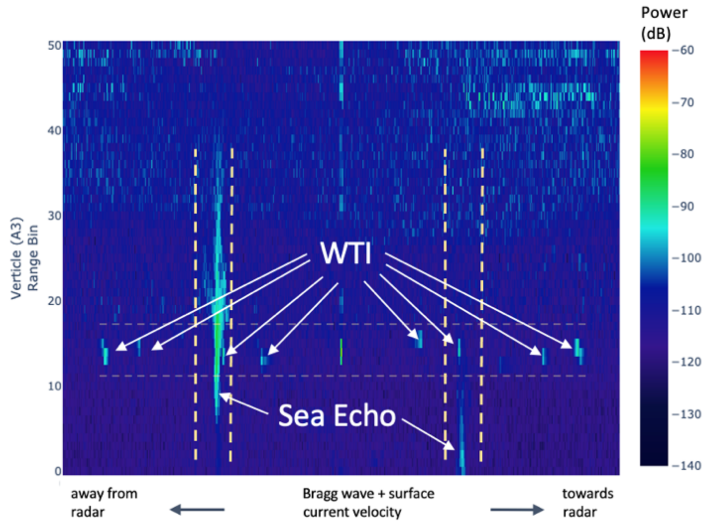
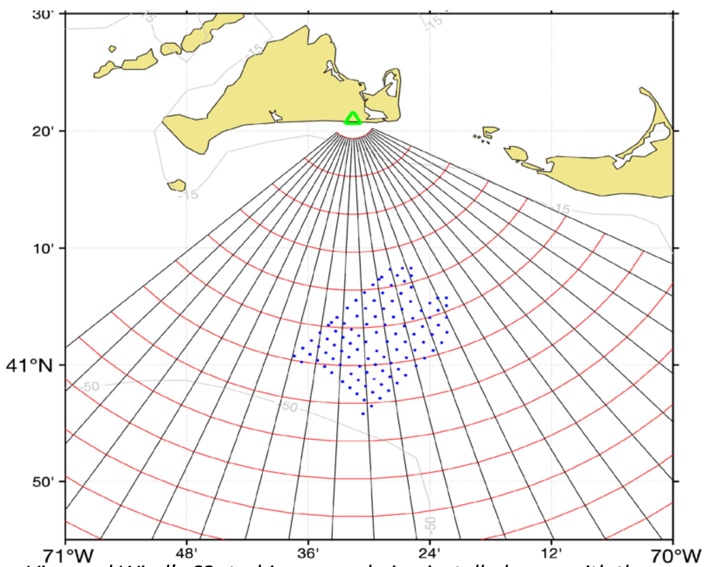
Funded WTRIM R&D has:

- Observed WTI in HFR data and **documented impacts** on ocean current observations.
- **Provided a clear theoretical understanding** of WTI in HFR data
- **Enabled robust simulations** of real-world situations.
- **Developed mitigation methods**: radar optimization strategies, software to detect and flag WTI, and effective network design strategies in WTI areas.



Example radar cross-section with both the 'sea echo', caused by surface currents, and wind turbine interference (WTI) shown.



Vineyard Wind's 62- turbine array, being installed now, with the measurement areas of a HF radar located on Martha's Vineyard, MA

Current status:

Software effectively estimates the location of the WTI based on yaw angle, rotation rate and variation.

Separating WTI from currents is challenging due to the sensitivity of WTI characteristics on rotation rate.

2023-2024 efforts will constrain WTI amplitude estimates, quantify impact on currents, and validate software and network mitigation methods from large numbers of turbines.

Takeaways

- Wind Turbine Interference can lead to surface current errors that are not confined to the location of the turbines.
- A combination of mitigation methods - including software and hardware changes - minimizes the impact of small numbers of turbines (<10) on surface current observations.
- Assessing the impact of larger numbers of turbines will start in fall 2023, through both simulation and observational (in situ and HFR) efforts as US-based turbine arrays are installed.
- Additional studies of the impacts of turbines on HFR-based wave products as well as holistic network design for regional co-existence of HFR and wind energy are required.

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Appendix II: Department of Energy Request for Information

RFI response: Challenges and Opportunities at the Interface of Wind Energy and Radar Technology

Anthony Kirincich[1], Brian Emery[2], and Hugh Roarty[3]

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[3]Rutgers University, P: 908-208-2970, E: hroarty@marine.rutgers.edu

This letter responds to the November 7, 2023 request for information *Challenges and Opportunities at the Interface of Wind Energy and Radar Technology* DE-FOA-0003166, providing our perspective on the challenges of mitigating wind turbine interference in ***oceanographic high frequency (HF) radar***.

Oceanographic high frequency (HF) radars are used to observe coastal ocean currents and waves, providing operational data to NOAA, the National Weather Service and the U.S. Coast Guard, research datasets on ocean circulation, as well as other users. These systems operate in the International Telecommunication Union (ITU) frequency bands near 5 MHz, 13 MHz and 25 MHz, with coverage areas extending from ~1 km to 180 km offshore depending on the transmit frequency. Our response is based on experience conducting research to mitigate wind turbine interference (WTI) as part of a project funded through the NOAA Ocean Technology Transition (NOAA OTT), *Software Tools for the Mitigation of Wind Turbine Interference in the U.S. IOOS Network* as well as robust, oceanographic radar community-wide discussions.

Existing, planned and proposed offshore wind energy lease areas overlap with the coverage of land-based oceanographic HF radars. HF radar signals backscatter from the spinning blades of these turbines resulting in harmonic returns with amplitudes and frequencies that can be comparable to the intended returns, the reflections of ocean waves via Bragg scattering, that are used to obtain the speed and direction of ocean currents. Thus, WTI manifests as peaks in the raw signal used to observe the ocean, the Doppler spectrum, at ranges and frequencies that are critical to the functioning of these radars [Wyatt et al., 2011; Ling 2013; Trockel et al., 2018]. A community-driven process defined the scope of the issue and offered a roadmap to achieve mitigation success (https://hdl.handle.net/1912/25127). Subsequent efforts have offered updates to the potential best practices for mitigation (Trockel et al 2023; doi: 10.23919/OCEANS52994.2023.10337105). The NOAA OTT project, in its final year, has undertaken a comprehensive strategy to observe WTI in HFRs near the Vineyard Wind area as it is constructed and collect in situ data that can be used to validate mitigation strategies.

References:

Wyatt, L. R., Green, J. J., & Middleditch, A. (2011). HF radar data quality requirements for wave measurement. *58*, *Coast Eng.*, 327-36.

Ling, H., Hamilton, M. F., Bhalla, R., Brown, W. E., Hay, T. A., Whitelonis, N. J., Yang, S.-T., & Naqvi, A. R. (2013). *Assessment of Offshore Wind Farm Effects on Sea Surface , Subsurface and Airborne Electronic Systems*.

Trockel, D., Rodriguez-Alegre, I., Barrick, D., Whelan, C., Vesesky, J. F., & Roarty, H. (2019). Mitigation of Offshore Wind Turbines on High-Frequency Coastal Oceanographic Radar. *OCEANS 2018 MTS/IEEE Charleston, OCEAN 2018*. https://doi.org/10.1109/OCEANS.2018.8604609

Our responses are organized by the relevant categories below.

Category 2: Mitigation Solutions to Reduce or Eliminate the Effect of Wind Turbine Interference on Radar Systems – Radar Perspective

C2.12. What radar technologies are available or in development at the respondent's organization to mitigate wind turbine interference on radar systems?

A number of potential mitigation methods in various stages of readiness have been developed via a multi-pronged process (private company efforts; public-private collaborative efforts funded by BOEM, NOAA, and others; and community-driven, unfunded efforts). The current proposed solutions include modifying radar operational parameters, identifying and flagging contaminated data, and adding coverage redundancy to fill gaps caused by WTI, as shown in the table below. Each solution is described in more detail in the responses that follow.

Mitigation Solution	example/notes	Viability
Radar operational parameters	e.g. change the sweep rate	Limited to use with sparsely operated radars
Flagging Bad data	methods have been developed and operational software is nearly complete	Effective with small numbers of turbines within a radar range cell
Redundancy	e.g. more radars, bistatic operation	Limitations due to the radar siting requirements but has potential to fill data gaps caused by WTI

Both public and private efforts have indicated that –at present –no single mitigation method will be successful alone, and a combination of methods is likely to be required. Additionally, validation of the mitigation effectiveness is also required.

C2.13. What type of radar system and what frequency does the respondent's technology target, e.g., terminal, long-range, high-frequency, weather, etc.?

As stated above, the technology we have developed applies to Oceanographic High Frequency (HF) radars for use in observing coastal ocean currents and waves. These operate in the ITU bands near 5 MHz, 13 MHz and 25 MHz, with coverage areas extending from the coastal HF radar installations onshore up to 180 km offshore (depending on the transmit frequency).

C2.14. What is the Technology Readiness Level of the respondent's solution? Describe any testing that has been conducted with the technology and its performance in and around wind turbines. Include, as applicable, any test reports.

The approximate Technology Readiness Levels (TRL) of solutions specified above are currently:

1. Modifying radar operational parameters; TRL-8
2. Identifying and flagging contaminated data; TRL-6

3. Adding coverage redundancy to fill gaps caused by WTI. TRL-5

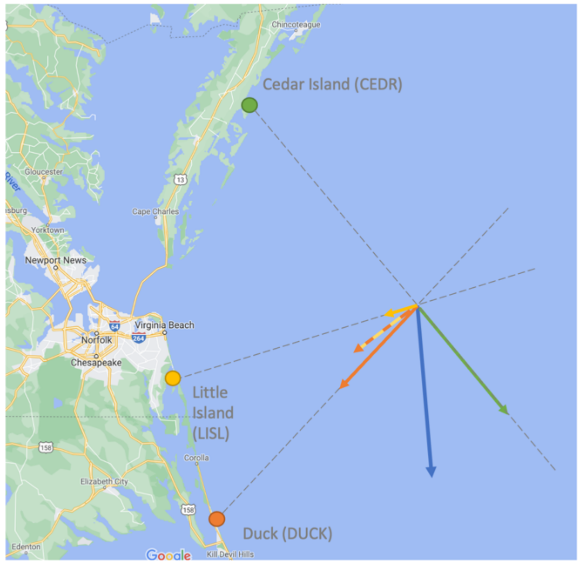
Regarding 1): radar operational parameter changes can be an effective mitigation technique when operating radars independently. For example, changing the sweep rate dramatically reduces the likelihood of WTI interfering with oceanographic data. However, operating a *network* of radars at a higher sweep rate is not currently a viable solution as the higher sweep rate causes too much site-to-site interference when operating within the allocated bands, which are shared by multiple, GPS synchronized radars. Obtaining additional bandwidth from the ITU would increase the viability of this mitigation strategy.

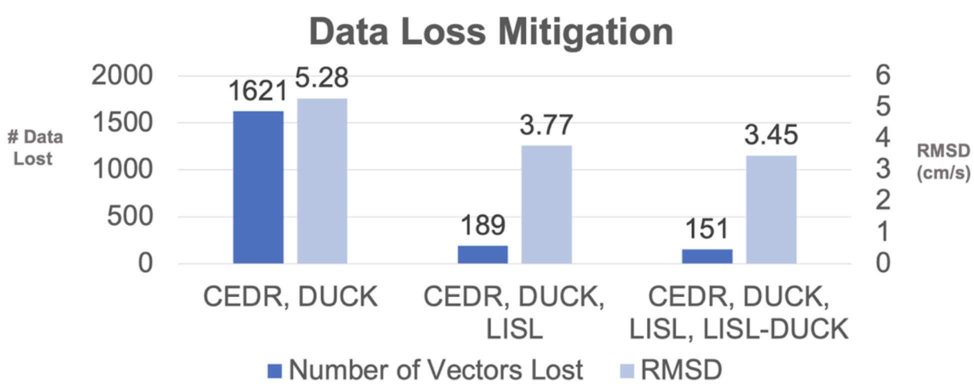
Regarding 2): Software for identifying and flagging WTI is currently TRL 6 with efforts moving this to TRL 7 and 8 by the end of 2024. As part of a joint (private-public) project led by CODAR Ocean Systems, funded by NOWRDC, offline flagging software was tested with two simulated wind turbines in the field of view of a network of three HF radars. The realtime flagging software was subsequently tested at one of the sites. Details on this study can be found in the project final report: https://nationaloffshorewind.org/projects/oceanographic-hf-radar-data-preservation-in-wind-turbine-interference-mitigation/

Flagging WTI peaks within the HFR data has been shown to be effective with small numbers of turbines. As the number of turbines increase within a location it becomes increasingly difficult to identify and separate peaks. Flagging can be effective at omitting errant vectors from processing, however, it does not recover missing data. This method is best used in conjunction with some form of redundancy (e.g. solution 3).

Regarding 3): Adding coverage redundancy to fill gaps caused by WTI has some limitations due to the siting requirements and available HF spectrum bandwidth. The use of multiple frequencies at existing sites along with bistatic operation of existing radar systems has potential to fill gaps in data caused by WTI and/or flagging as well as correct biased vectors caused by WTI. Each of these would use existing radar techniques and software packages – the technology is available now. WTI in oceanographic radar data is not colocated with the turbines, which means the patch of ocean affected by WTI from a turbine at each HFR site will be different. As additional observations are introduced into the system, they can correct the effects of WTI. Preliminary studies have shown this to be the most effective mitigation method, and additional observations are currently being collected and will be available for analysis in 2024, suggesting TRL 5.

Testing gap reduction with bistatic processing was done off the Virginia and North Carolina coast using existing HFR installations in the area of the Virginia Offshore Wind Technology Advancement Project (VOWTAP) turbines (see figures below). Using these principles on a combined dataset of real radar observations with simulated WTI, use of the bistatic datasets allowed for a greatly reduced mitigation (flagging) loss from the impact of the simulated 2 turbines.





While these tests showed that mitigation via additional radars and bistatic results is possible, and likely the method with the most potential success for impact in areas with high turbine numbers, most of U.S. network is optimized for coverage with minimal sites, and thus, significant optimization of the HFR network design would be required.

C2.15. What is the cost of the respondent's technology solution (including cost of production, total ownership, and transition). How cost effective is the solution when compared to existing state-of-the-art technologies?

It is anticipated that software will be developed for solution 2) through the funding provided by the NOAA OTT project, essentially funding the transition of the flagging/removal technology. It is anticipated that the flagging/removal software will be provided to oceanographic HF radar operators as a software update at the cost of the ongoing software licensing fee, or as an add-on software package with an additional charge. Software licensing and maintenance costs represent a fraction of the operation, maintenance and/or hardware costs of the HF radars. An estimated cost for software-based mitigation alone - if successful - would be $10-20k per year per site in software licensing fees.

Implementation of solution 3) would either require the purchase of new radars along with the cost of their installation, operation and maintenance, or additional software packages for existing radars for operation in bistatic mode. Because the use of bistatic mode would leverage existing radar infrastructure, this could be done at a lower cost than the acquisition of new hardware systems. Total cost of ownership (purchase, installation, operation, maintenance, etc.) of a single HF radar site over 10 years is approximately $1,000,000. Software to use existing HF radar sites in bistatic mode has already been developed, and costs approximately $20-30k per year per site.

C2.16. Describe the integration approach for the technology with existing infrastructure, command and control systems, and FAA automation systems. Include any testing and demonstrations as applicable.

Many of the proposed methods can be integrated into existing, deployed hardware (for software components) or utilize existing hardware to build out additional locations required to fill gaps. Recent test efforts led by CODAR Ocean Sensors and funded by the NOWRDC has shown that bistatic operations, with additional radars in the area of the turbines can be used to fill WTI-created gaps in data from traditionally operated installations (see NOWRDC final report: https://nationaloffshorewind.org/wp-content/uploads/Final_Final_Report_Deliveable_5.2.docx)

Testing and demonstration is under way now, via data collection from HFRs surrounding the Vineyard Wind lease area as the turbines are commissioned. Additional analysis of these data will be required.

C2.17. What is the overall processing approach of the respondent's radar technology to mitigate wind turbine clutter?

Flagging and removal of WTI contaminated data is accomplished through a two step process. First, methods to identify initial WTI signals within the HFR data are used, and from these compute the rotation rates of the turbines. The rotation rates are then used to predict the locations of other WTI signals in the range-Doppler spectrum, which are then flagged as contaminated in the data file's metadata. Software that processes the range-Doppler spectrum can then exclude these data in a later stage of the processing.

Mitigation through coverage redundancy: The use of multiple frequencies at existing sites, additional sites, along with bistatic operation of existing radar systems has potential to fill gaps in data caused by WTI and/or flagging as well as correct biased vectors caused by WTI that are identified via flagging. WTI is not colocated with the turbines, which means the patch of ocean affected by WTI from a turbine at each HFR site will be different. As additional observations are introduced into the system, they increase the system's ability to correct the effects of WTI. This occurs because each site measures a component of the ocean surface current velocity. Data from multiple sites are combined to get the total vector components of the ocean surface current.

C2.18. How does the solution address a range of desired performance parameters such as: Probability of Detection (Pd), Demonstrated Target Performance, Doppler Performance, Coverage Volume (including minimum and maximum range, azimuth extent, and altitude), Range Accuracy, Azimuth Accuracy, Azimuth Resolution, Range Resolution, Clutter Rejection, Data Latency, Update Rate, Reliability, Availability, Data Transmission, etc.?

Our primary performance parameters address the accuracy of the final data product, for example the ocean current measurements. WTI interpreted as ocean current signal by the signal processing methods results in biases in velocity and bearing. Ongoing efforts aim to assess the impact on the measurement accuracy resulting from WTI along with the effectiveness of mitigation. We have several methods for making these assessments, including the use of in situ measurements (e.g. current meters and drifters).

C2.19. When will the technology be ready to be fielded for demonstration and/or operational deployment? What are the availability, cost and infrastructure needs associated with an on-site demonstration or operational deployment of the respondent's technology?

Additional field data collection is occurring now, with funding support from NOAA. Demonstrations of the technological solutions described above are planned for this year, with operational deployment of flagging software. However, persistent efforts over the next 5-7 years will be required to analyze the data being collected now, and conduct additional validation/mitigation trials as offshore wind development progresses and many more wind turbines become operational.

C2.20. Describe market barriers or other challenges in developing radar technologies that reduce or eliminate the effect of wind turbine interference on radar systems.

The challenges presented by WTI in oceanographic HF radar data are primarily technical as we have described above. However, a network-based solution, requiring redundancy in HF radar sites, would also present other challenges, including funding capital purchases, identifying sites, obtaining required permissions and agreements, as well as funding ongoing operations.

C2.21. Is there anything else that we did not ask about this topic you would like to tell us?

Delays in development of leases have delayed collection of radar data with WTI from large numbers of turbines, hence we do not yet know the full scope of the problem. These delays have also delayed efforts to validate mitigation methods with in situ observations. While deployments of in situ sensors are in progress, funds for these efforts will end prior to the full operation of the planned lease areas. The true scope of the mitigation problem will only be clear as larger numbers of offshore wind turbines are operational within the coverage of HF radars. This is occurring now south of Martha's Vineyard and offshore of Rhode Island.

Category 6: DOE's Proposed Implementation Strategy for Challenges and Opportunities at the Interface of Wind Energy and Radar Technology

C6.43. DOE is evaluating funding mechanisms for implementation of this BIL provision. What applicable funding mechanisms are best suited to achieve the purposes of the program (e.g., Cooperative Agreements, Grants, Other Transactions Authority, Partnership Intermediary Agreements, prize competitions, technical assistance)?

Collaborative grants and contracts are best suited for the type of work that we describe in this letter. These allow for the type of basic and applied research that is still needed in the case of oceanographic radars, along with the possibility of product development required by manufacturers. Cooperation with offshore wind developers would be useful in particular for obtaining historical or real time turbine rotation rates and/or SCADA data.

C6.44. What are the key review criteria (e.g., technical merit, workplan, market transformation plan, team and resources, financial, regional economic benefits, quality jobs, environmental justice, diversity, equity, inclusion, and accessibility) that DOE should use to evaluate and select projects as well as evaluate readiness to move from one phase to the next?

Review panels of outside experts could help DOE understand the technical merit and potential of the funded activities, as well as to develop key review criteria.

C6.45. What incentives/programs exist or can be put in place to encourage and foster U.S. manufacturing of wind turbine radar interference mitigation technologies? What potential challenges or opportunities might exist to meet the new Buy America requirements in the BIL?

N/A

C6.46. What types of cross-cutting support (e.g., technical assistance) would be valuable from the DOE/national laboratories, and/or from other federal agencies, to provide in proposal development or project execution? Are there other entities that DOE could fund to provide technical assistance for individual projects or the program as a whole?

DOE national laboratories are not presently involved in HF radar operations, maintenance, or mitigation research.

C6.47. What data should DOE collect from recipients to evaluate the impact of the program? How should this data and the program outcomes be disseminated to the public?

As the WTI affected observations for the HF radar are observations of ocean surface currents and waves, the most appropriate metrics for evaluation of mitigation methods in this case would be validations against in situ sensors, or improvements in spatial or temporal radar coverage over/near wind energy lease areas. For example, it would be straightforward to report for these radars, the percent spatial coverage over time obtained on an area of ocean surface, both before and after the mitigation of WTI. This metric would clearly show the effectiveness of the mitigation strategy supported by the program. However, comparisons –or benchmarking – against independent in situ sensors is also required to full validate the mitigation strategies.