



# Mitigating Wind Turbine Interference in the US HF Radar Network

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# What is HF Radar?

Operational ocean surface currents served by NOAA via the U.S. Integrated Ocean Observing System:

*Provided to the public by:*



**IOOS**  
Integrated Ocean  
Observing System



hfradar.ndbc.noaa.gov

National Oceanic and Atmospheric Administration's  
**National Data Buoy Center**  
Center of Excellence in Marine Technology

weather.gov

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This is the **NOAA HF Radar National Server**.  
HF Radar is used to remotely measure ocean surface currents.

[Access Data via NDBC THREDDS Server](#)

☒ vectors ☒ 25 hr avg 2021-10-07 23:00:00 UTC 6k resolution ☐ time lapse ☐ sites Oceans

Map Satellite

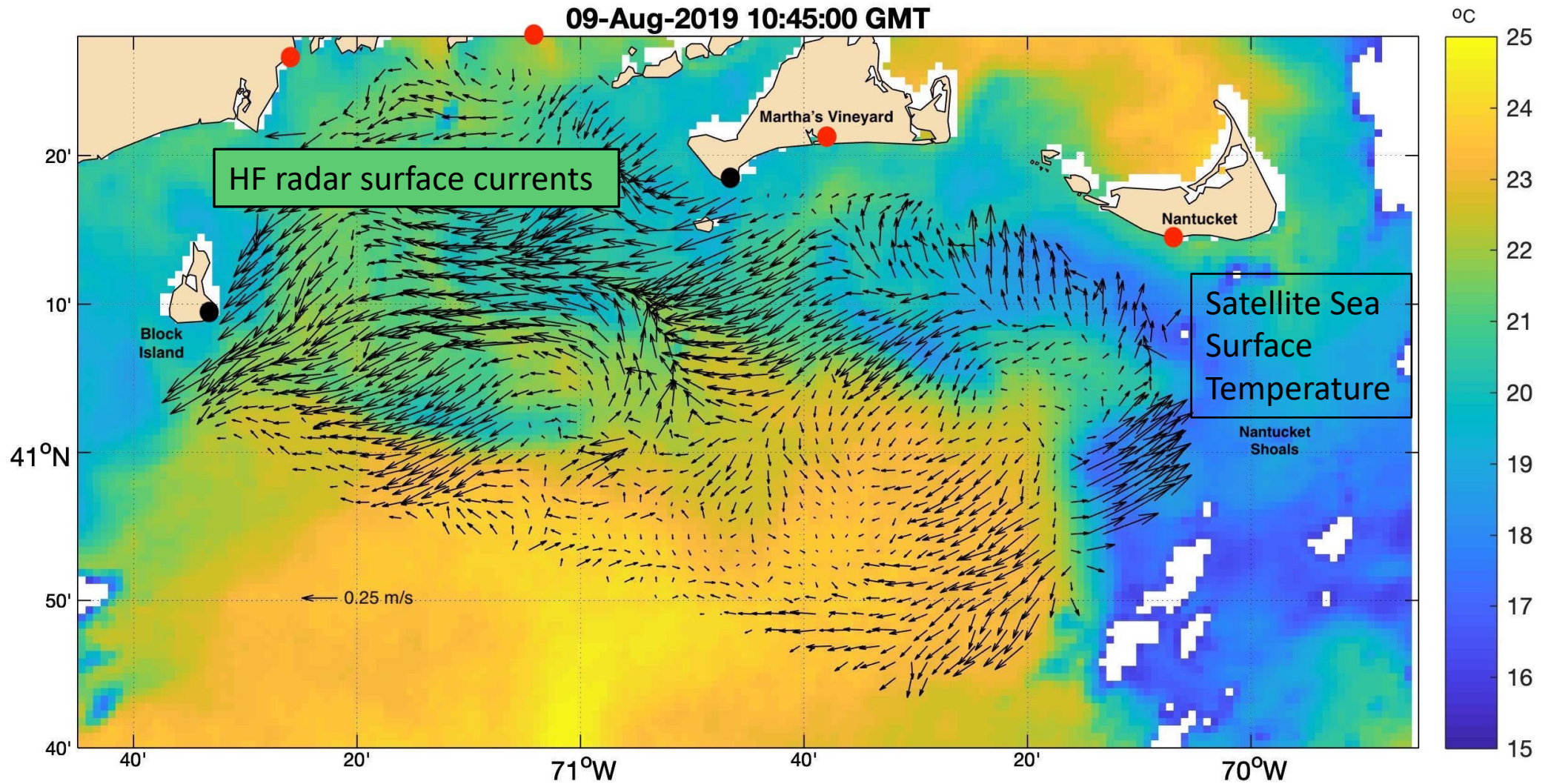
For more information, see [IOOS® High Frequency \(HF\) Radar](#).  
View HF Radar data in [Tabular Format](#).

[Disclaimer](#)



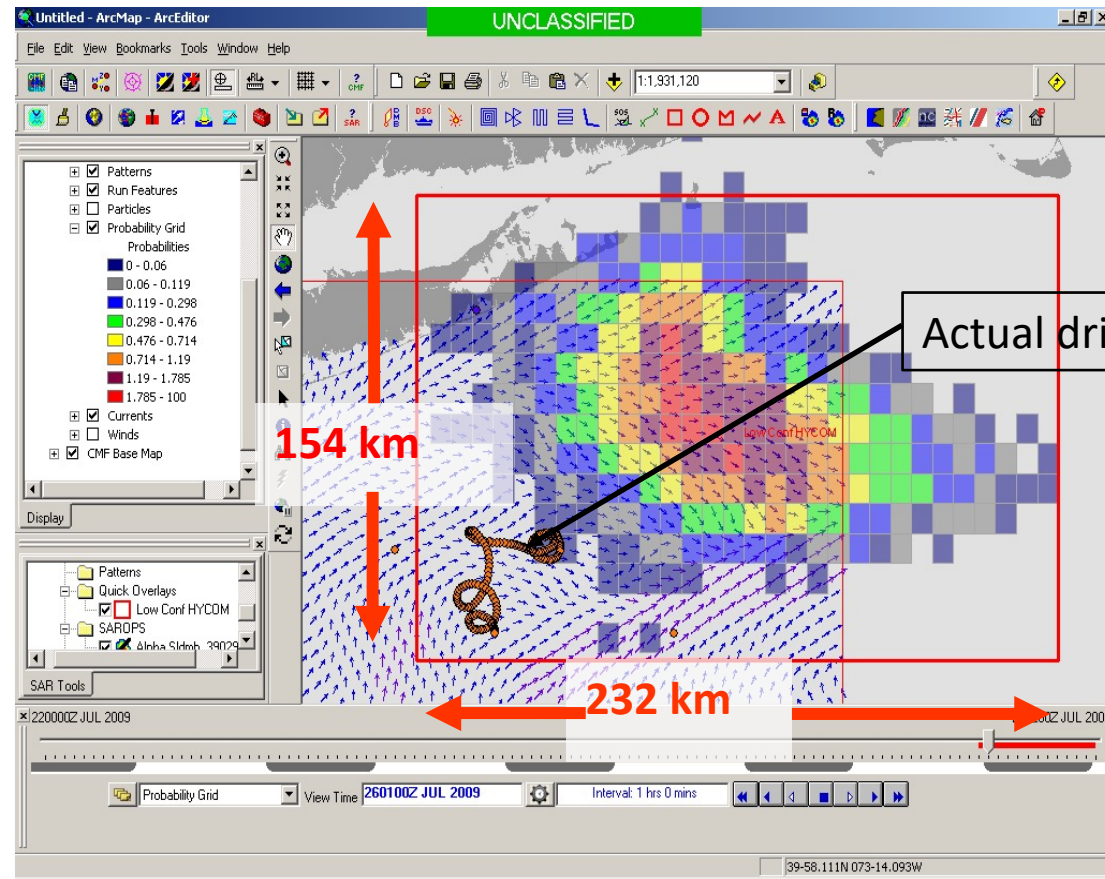
# What is HF Radar?

Realtime  
Ocean  
Observations  
that matter:

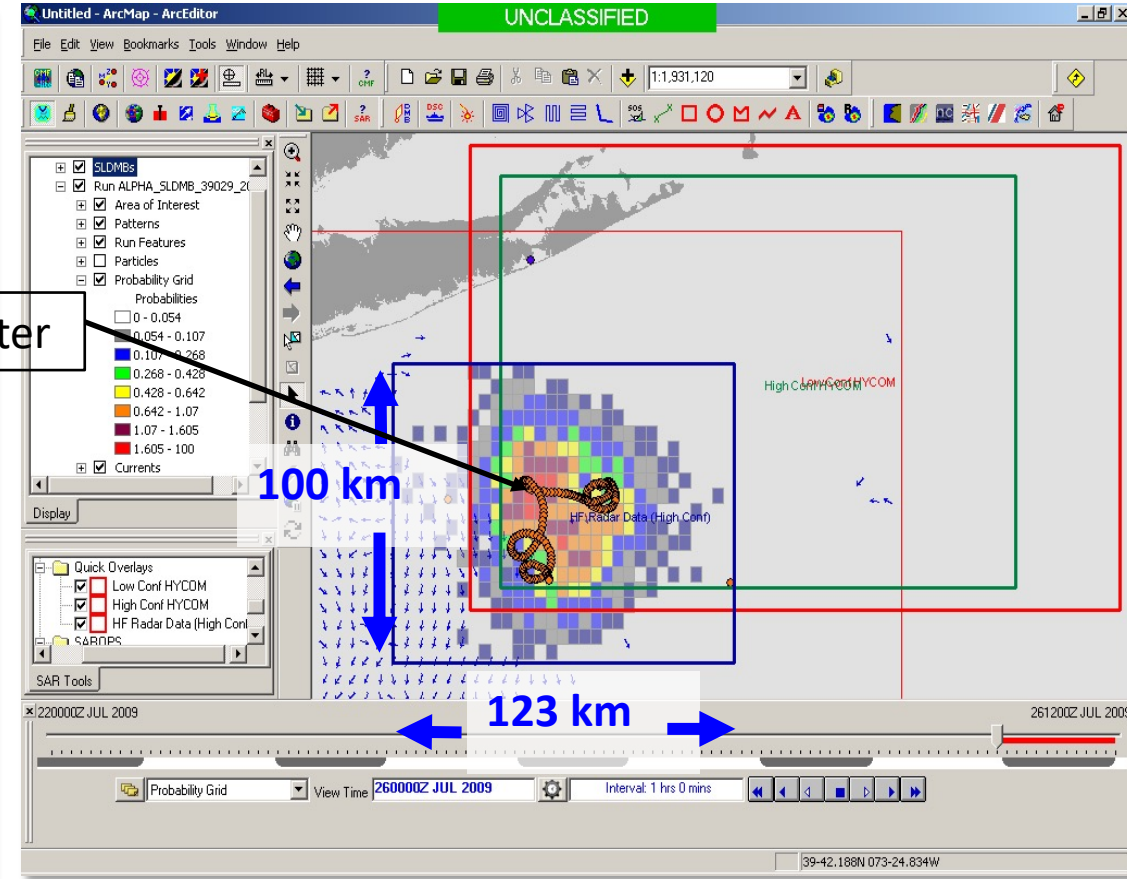




# HFR Applications: USCG Search and Rescue



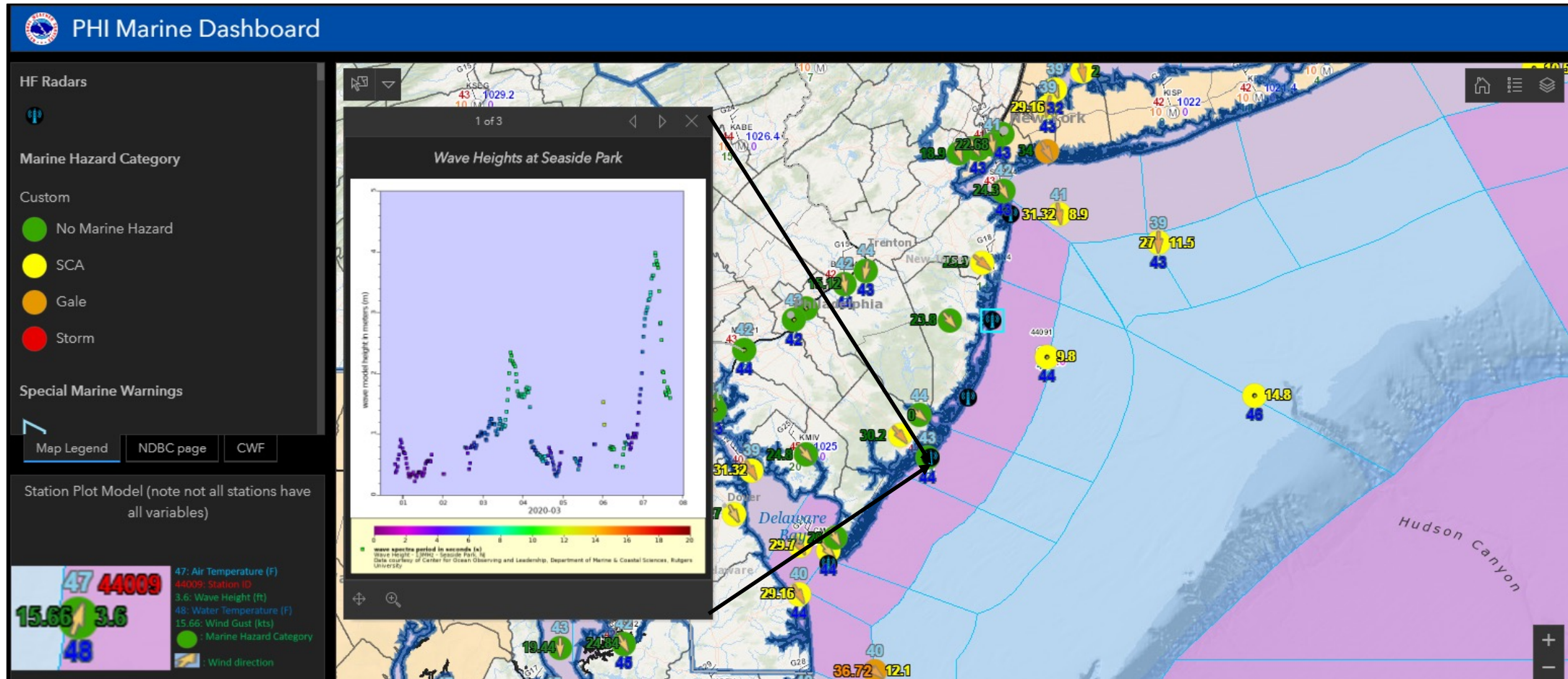
HYCOM 96 hour Search Area  
36,000 km<sup>2</sup>



HF Radar 96 hour Search Area  
12,000 km<sup>2</sup>



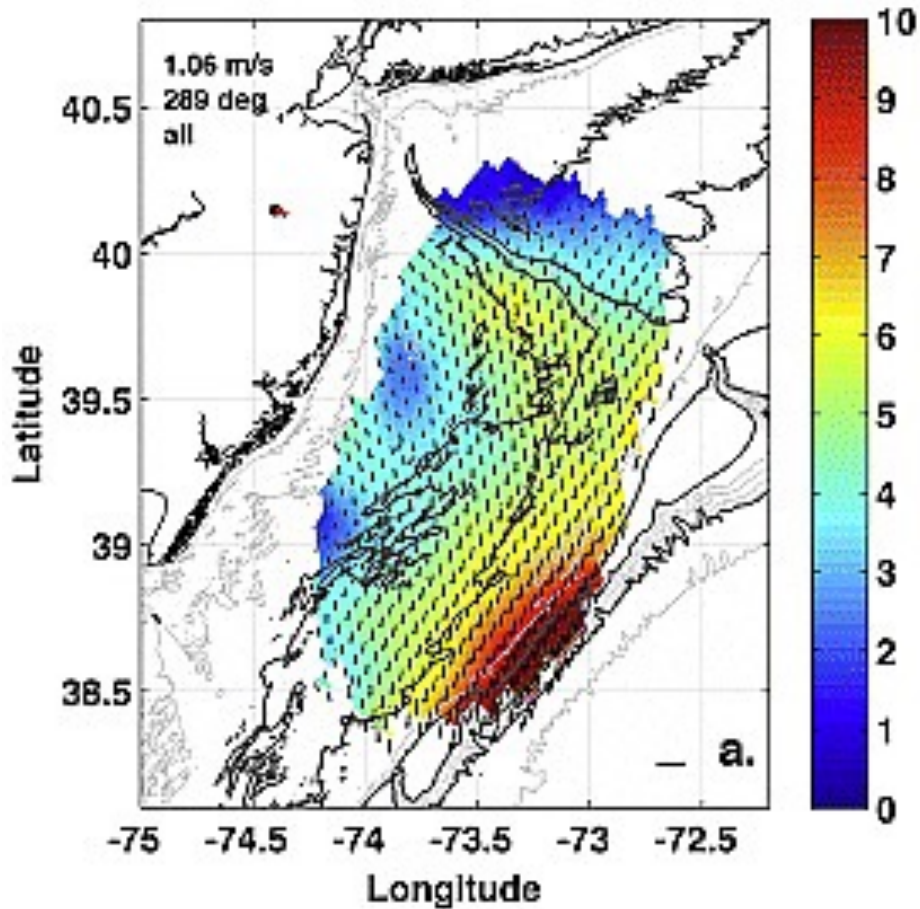
# HFR Applications: Wave Products for Forecasters



HFR wave data as displayed within the National Weather Service's Marine Dashboard

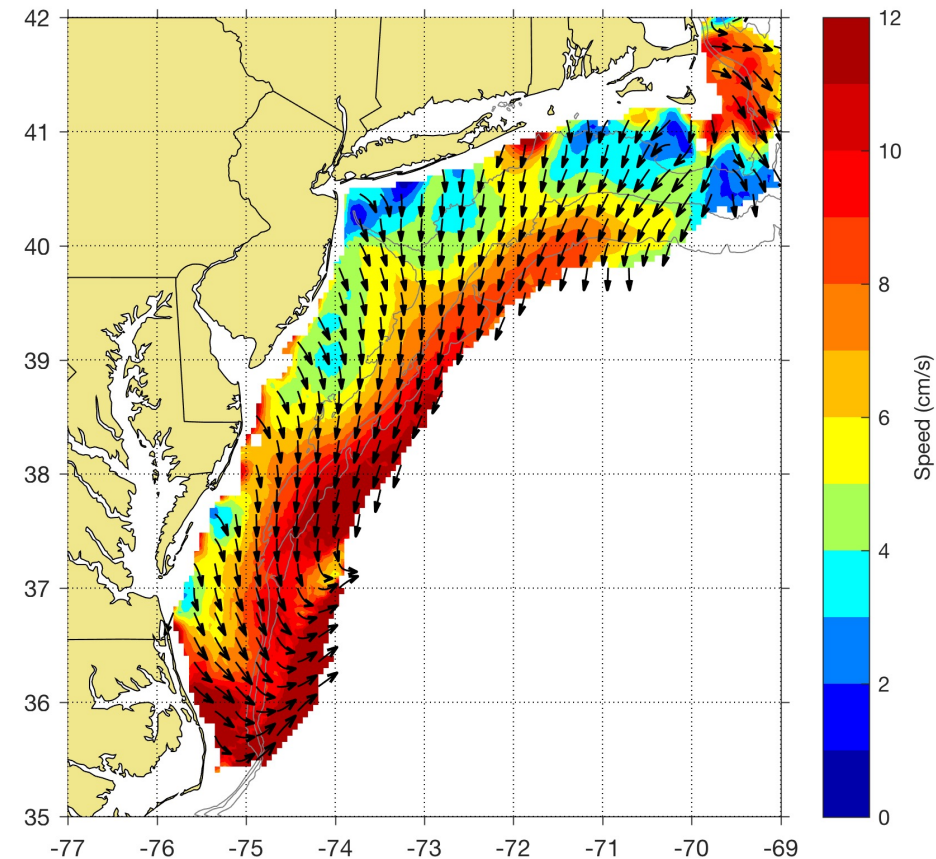
# HFR Applications: Long Term Measurements

5 years



Seasonal climatology of wind-driven circulation on the New Jersey Shelf

10 Years

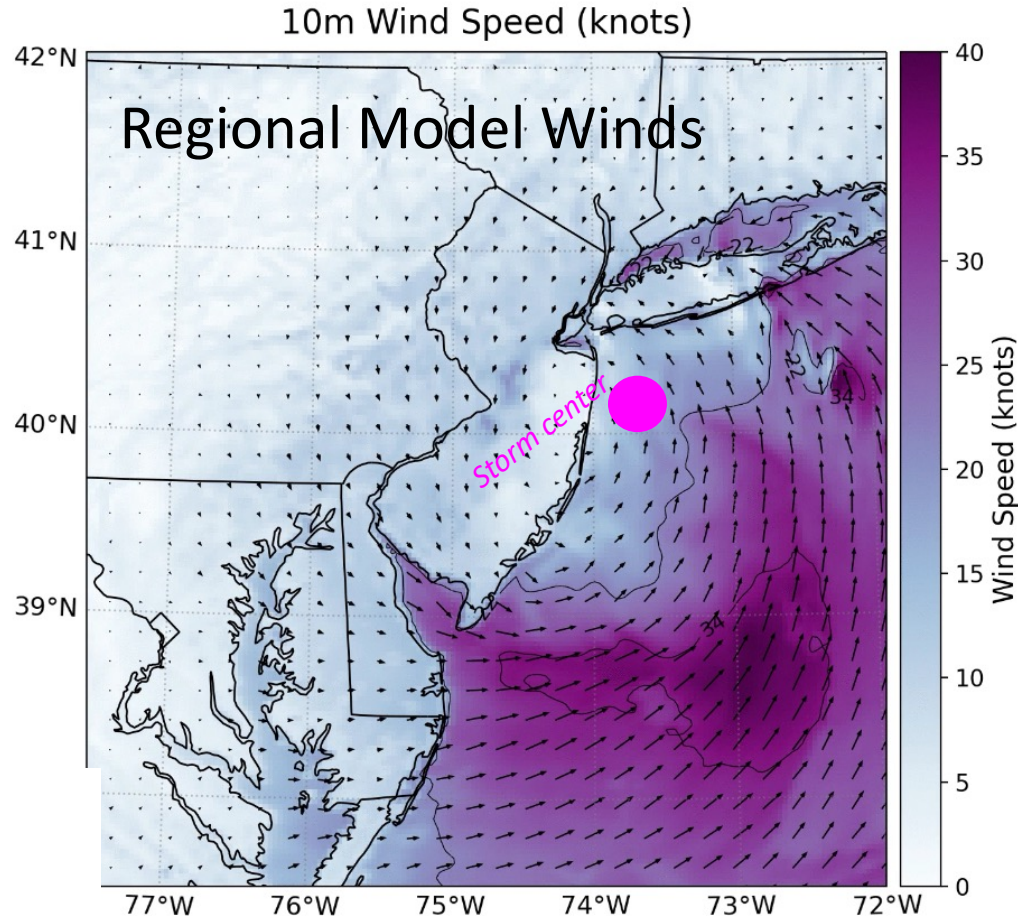


Annual and Seasonal Surface Circulation Over the Mid-Atlantic Bight Continental Shelf Derived From a Decade of High Frequency Radar Observations



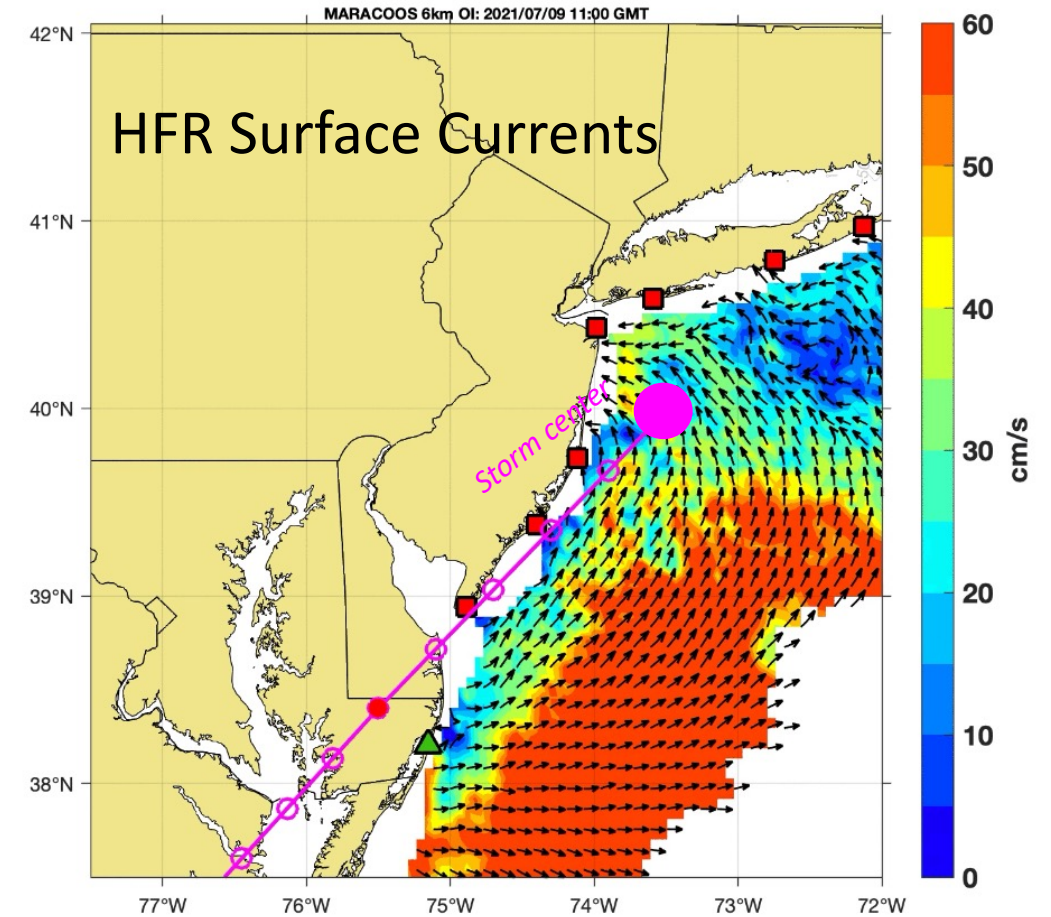
# HFR Applications: Topical Measurements

## Tropical Storm Elsa – July 2021

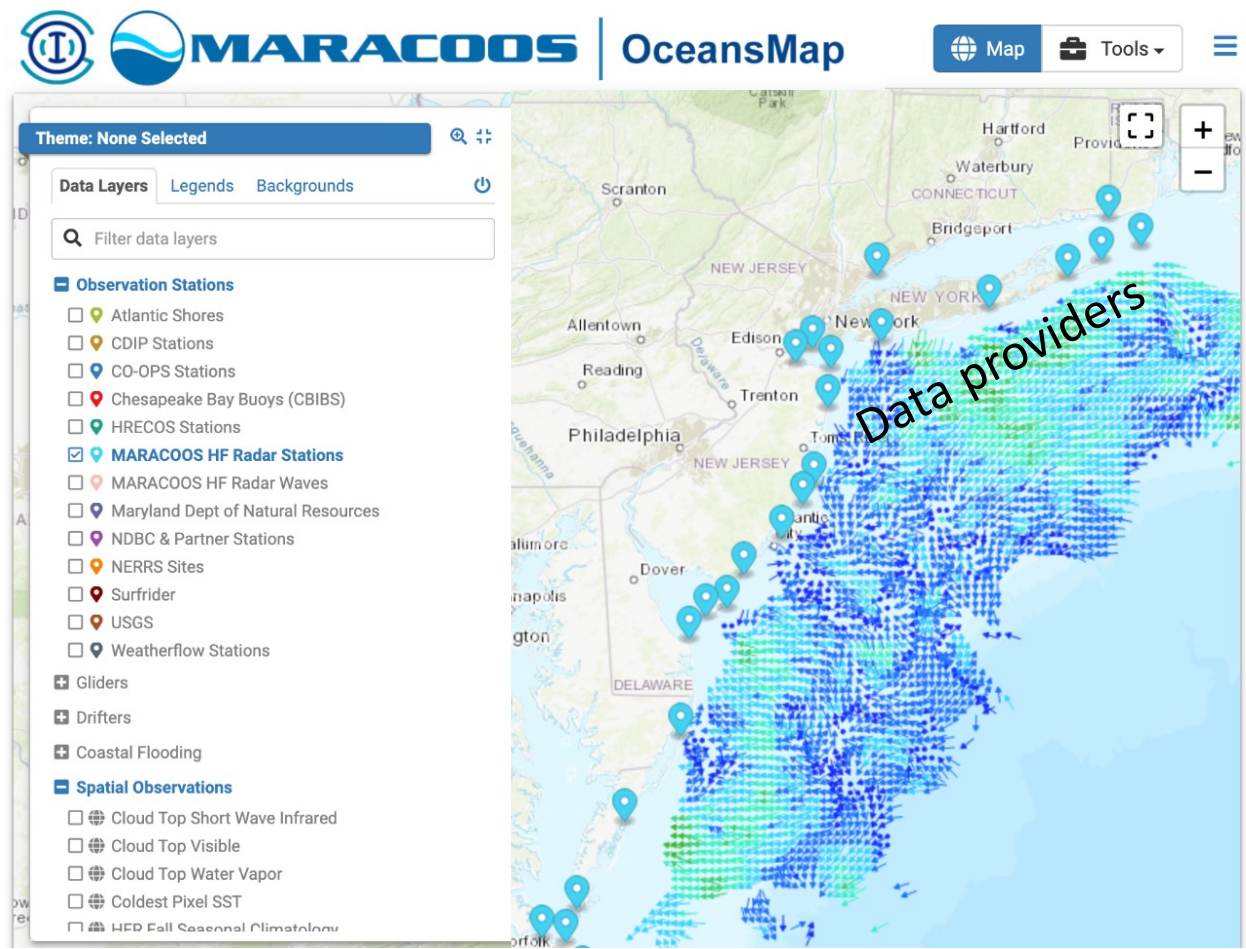


RU-WRF (v4.1) 3km Model: Initialized 00Z09Jul2021

Valid 11Z09Jul2021 (Fri 09Jul2021 07:00EDT) | Forecast Hr 11



# Aggregating Regional Data into a National Network



Data providers



One of 11  
IOOS Regional  
Associations:

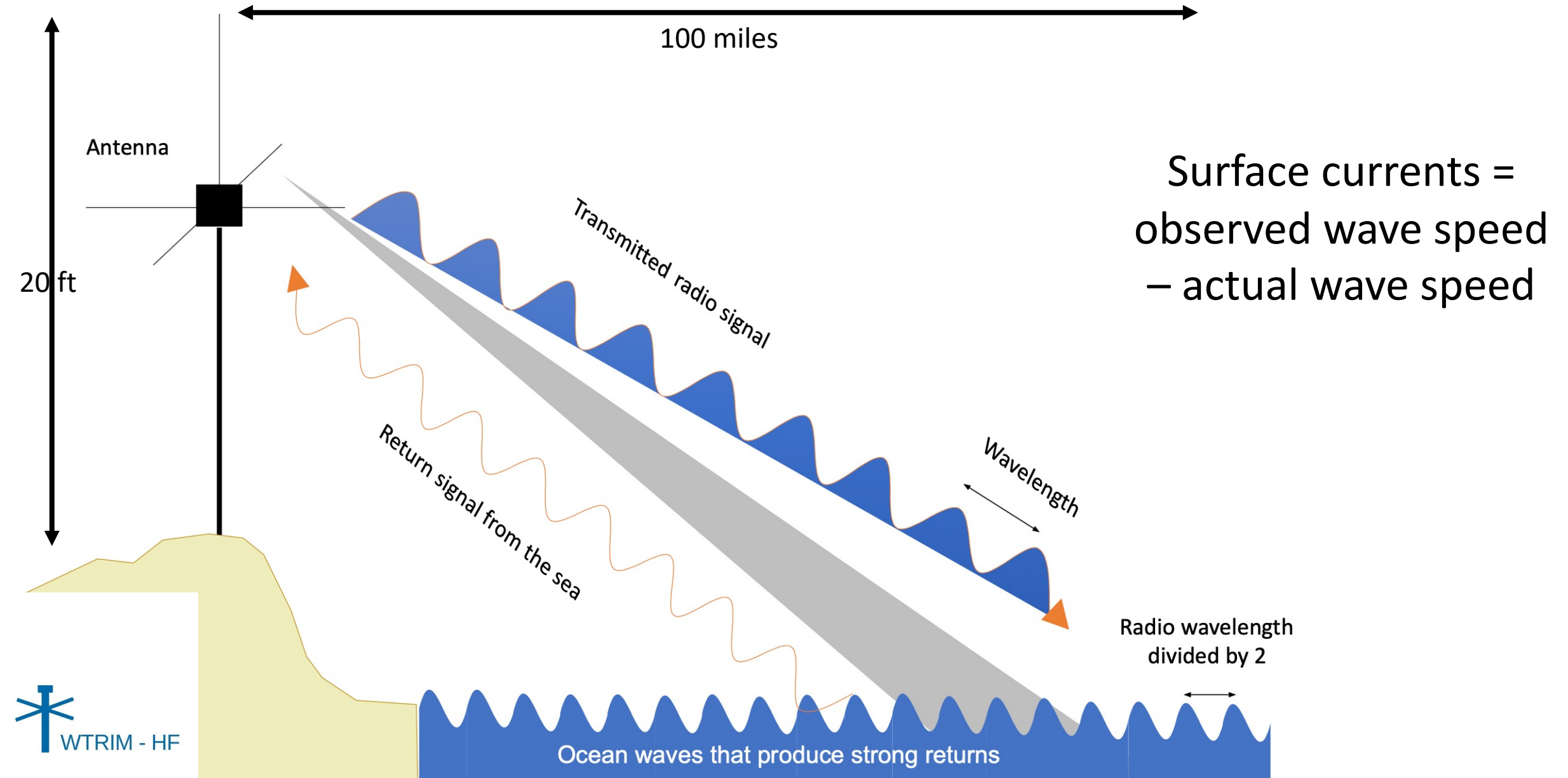


Powering Understanding and Prediction of the  
Mid-Atlantic Ocean, Coasts, and Estuaries

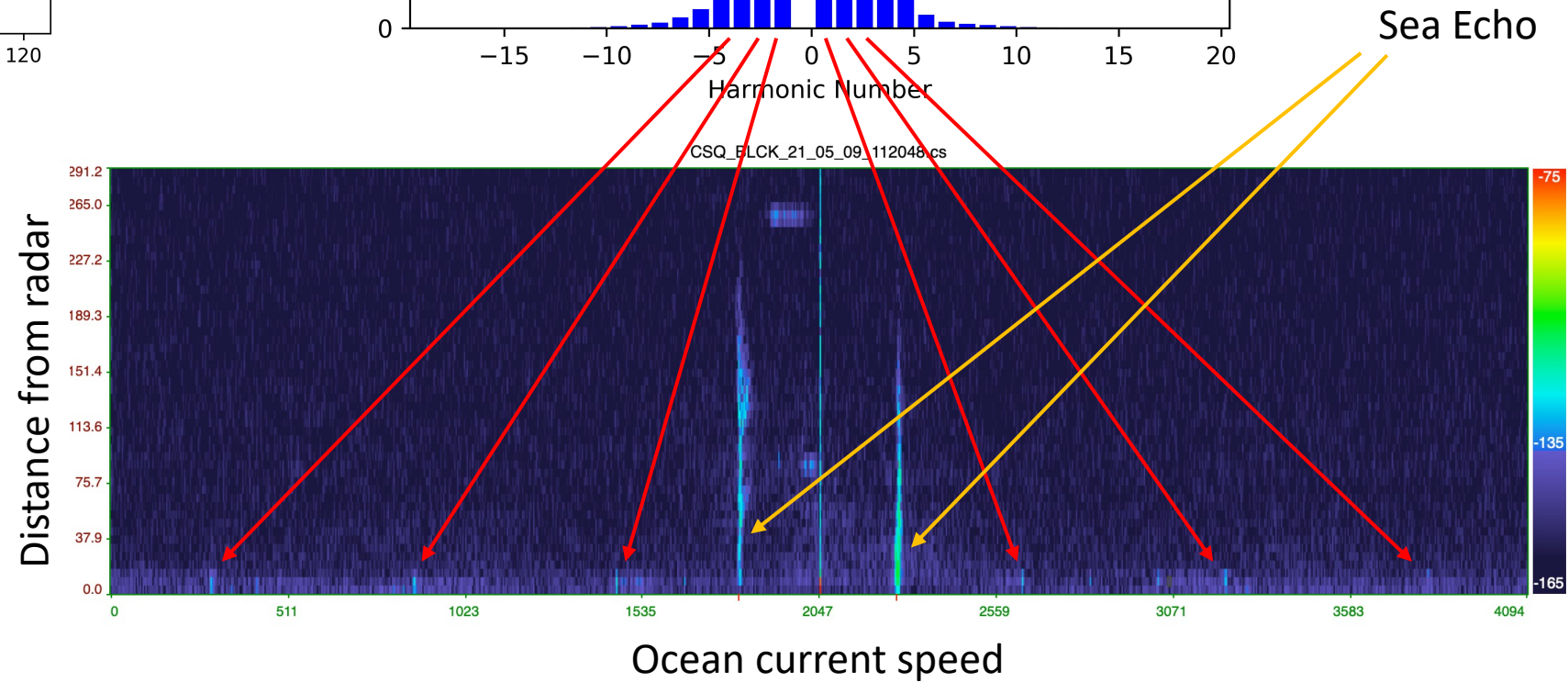
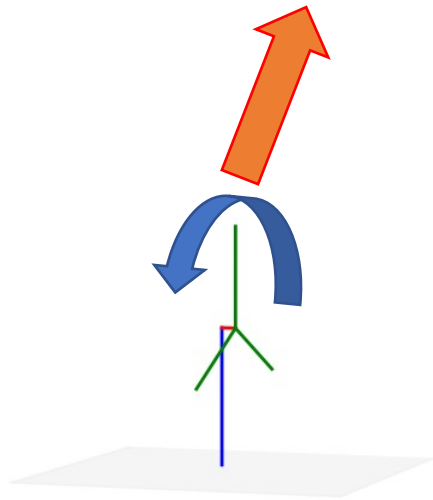
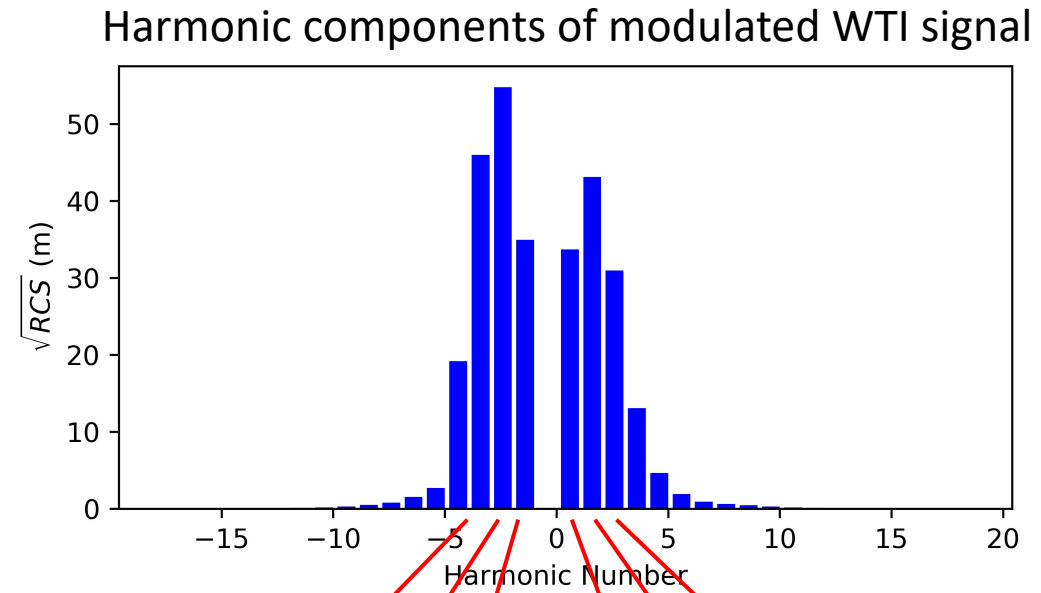
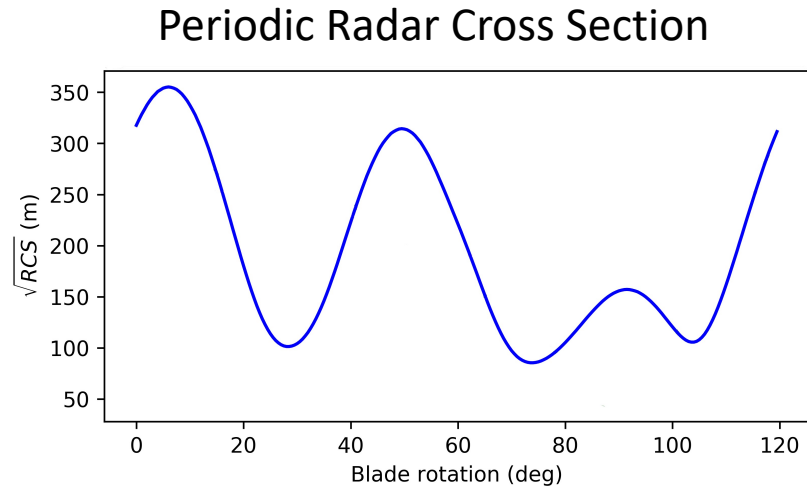




# How do small land-based antennas observe the ocean remotely?



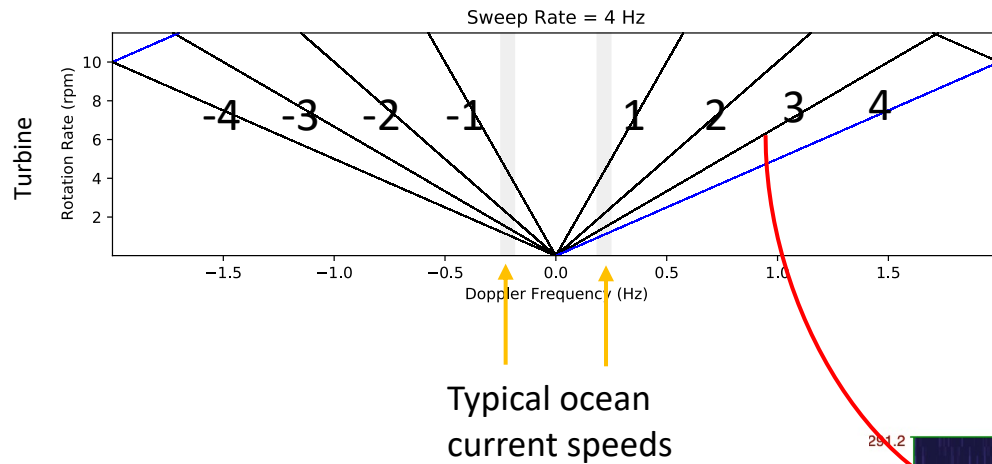
# Wind Turbine Interference in HFR signals: Block Island Example





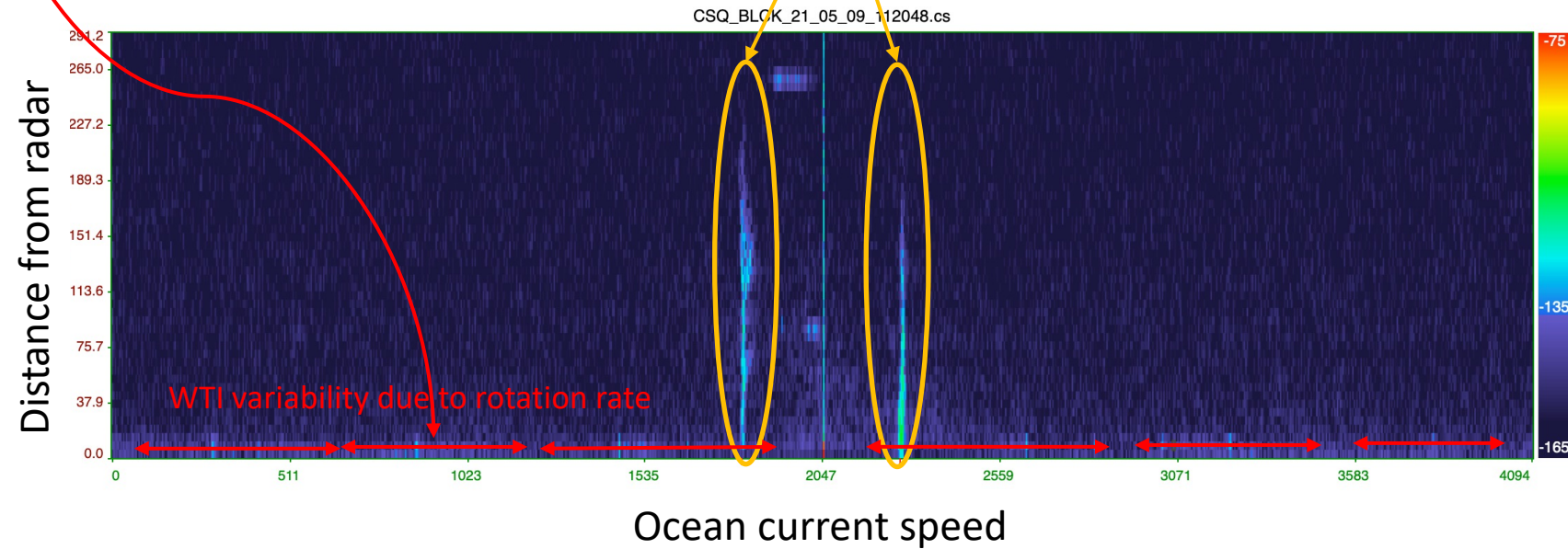
# Wind Turbine Interference in HFR signals: Block Island Example

Relationship between RPM and Doppler frequency of WTI harmonic components



*Key Point:* As the rotation rate of the turbine changes, the location of the interference in the HFR signal changes.

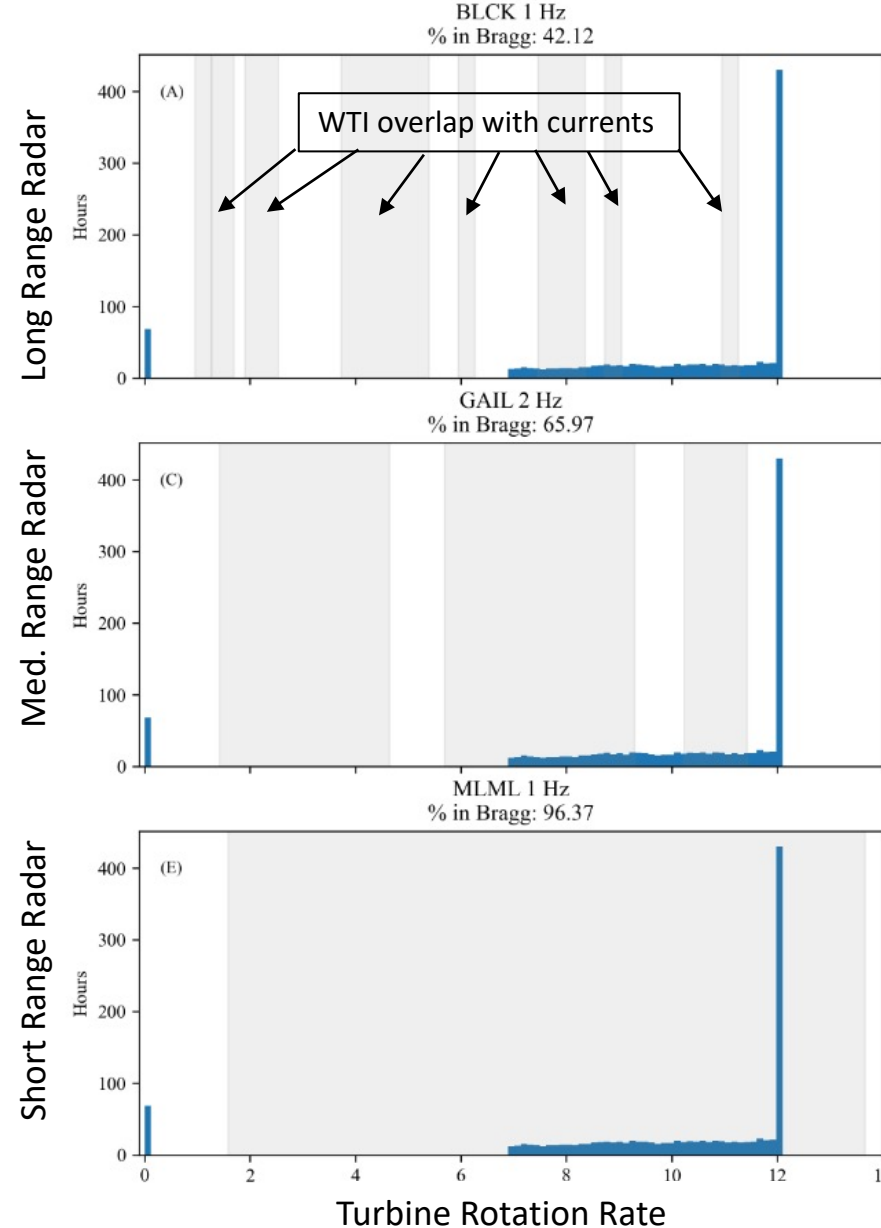
Signals used for surface currents



# Wind Turbine Interference in HFR signals: Block Island Example

As turbine rotation rates change, the location of the WTI, and potential for direct impact on currents varies.

WTI depends on turbine and on radar

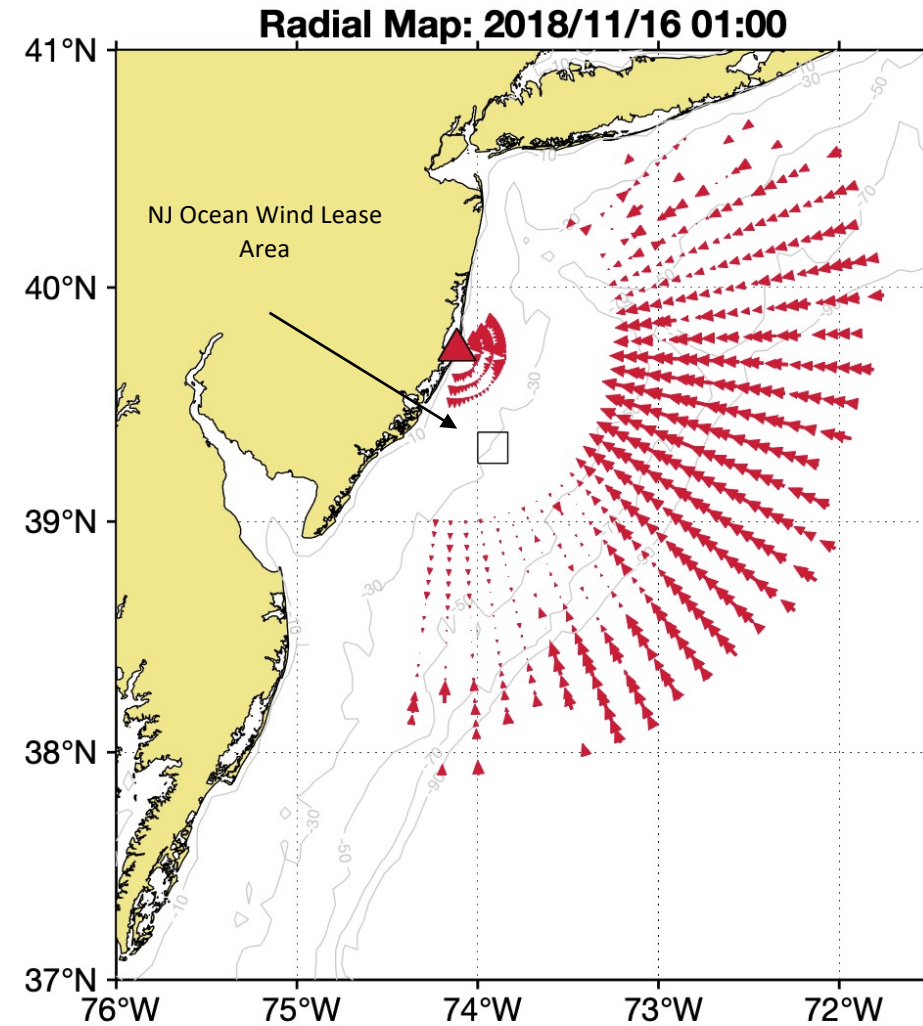
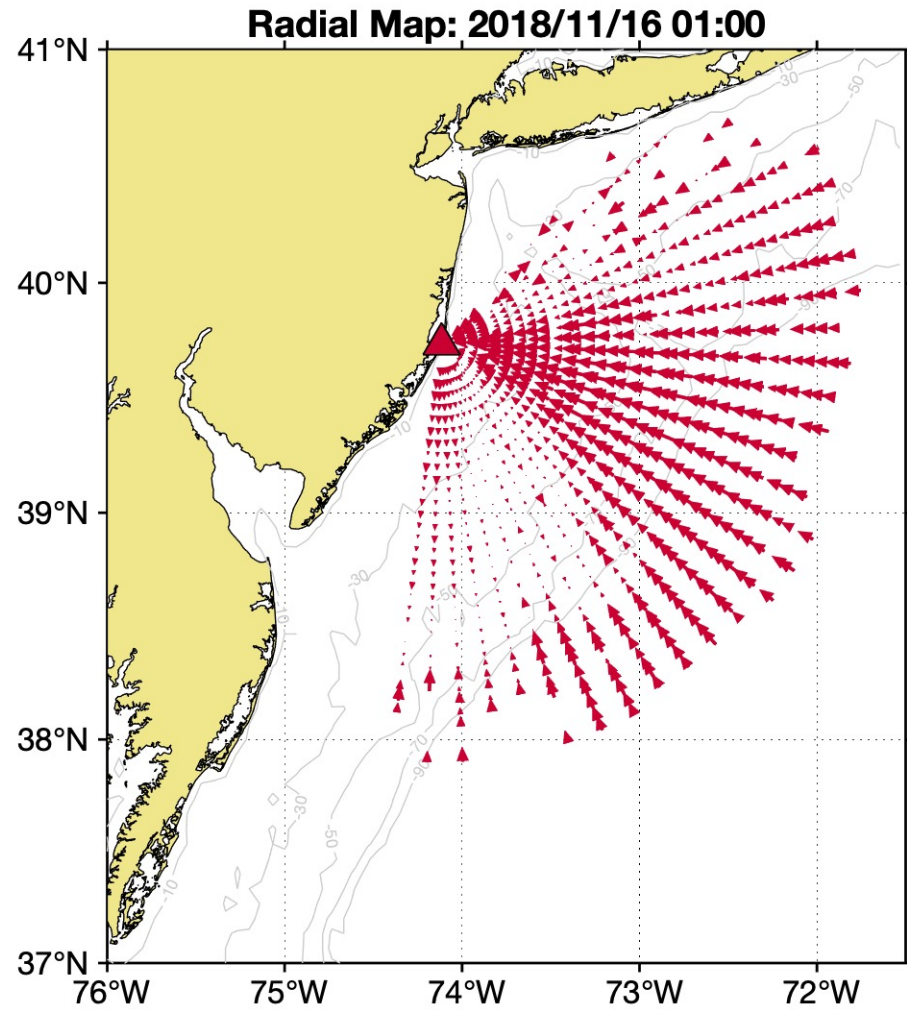


Simulation using:

- NREL 5MW turbine rotation rates
- Block Island measured winds

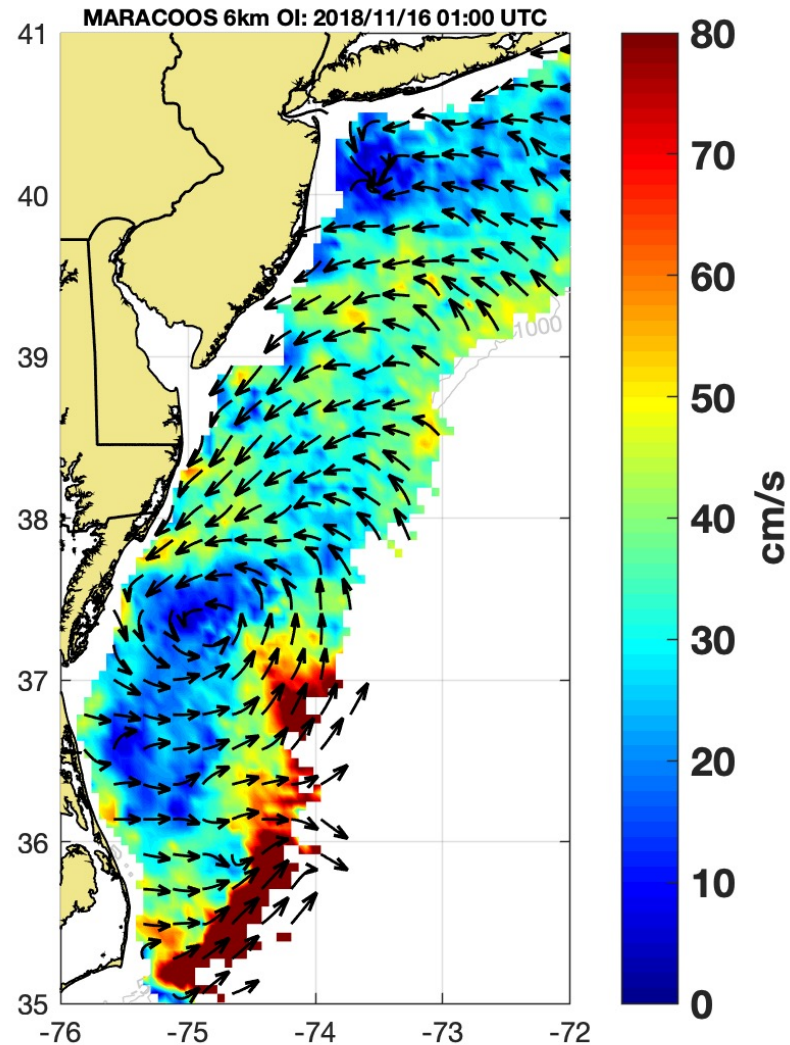


# Mitigation via Data Exclusion:

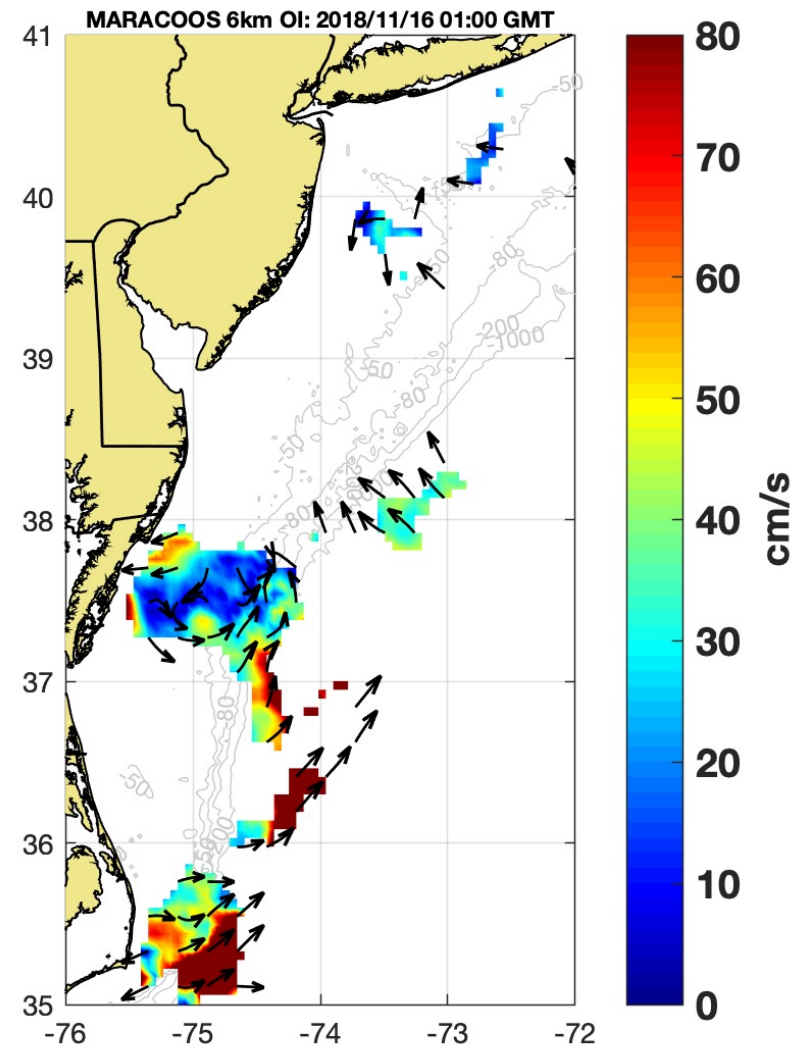


# Mitigation via Data Exclusion:

Total Map **With No** Interference



Total Map **With** Interference



Both maps filtered by 0.6 normalized uncertainty



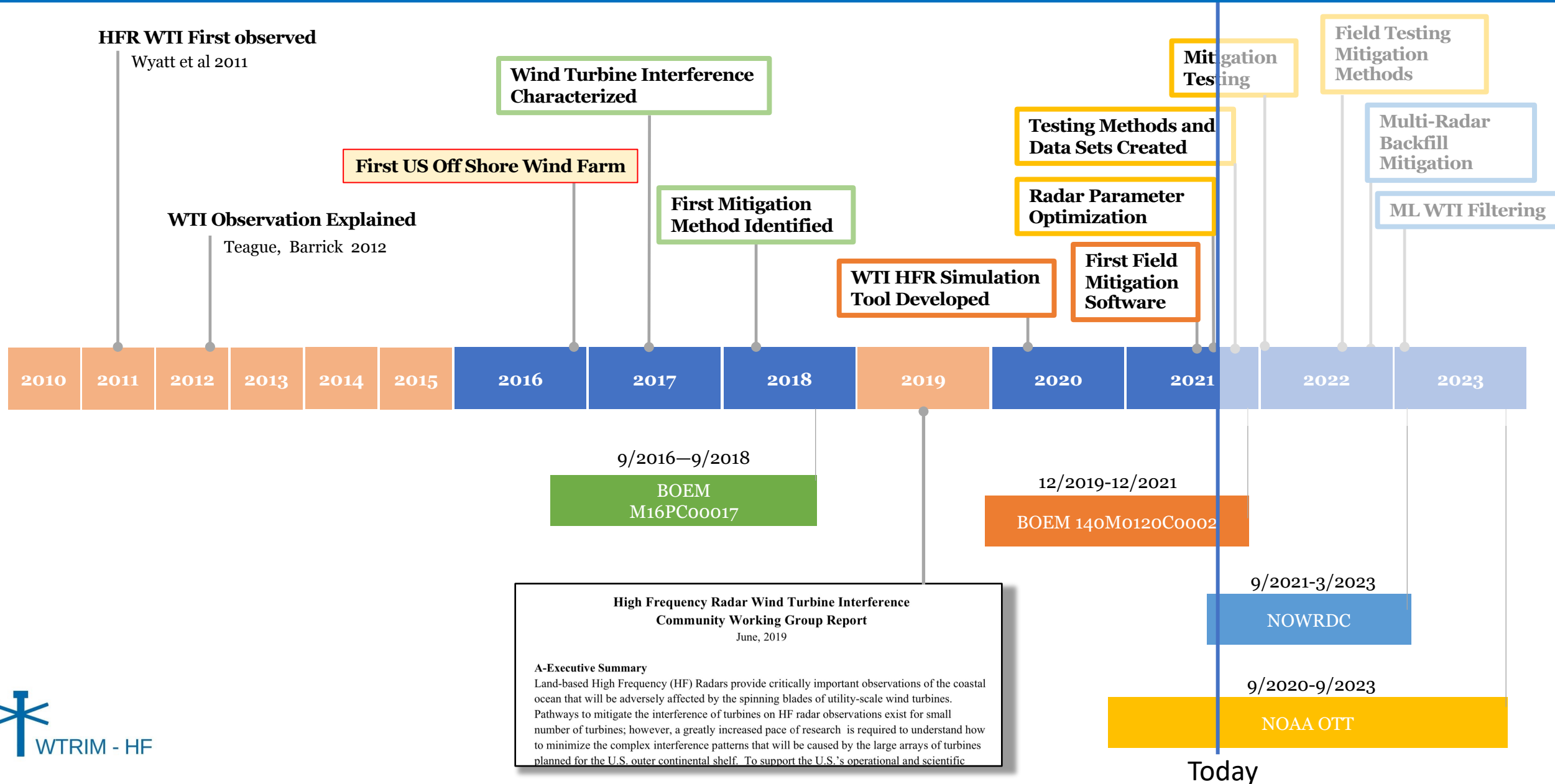
# Status of WTRIM-HF Work

HF radar plays a key role in providing environmental intelligence.

WTI within HF radar observations is a critical issue.

It is a solvable problem, but not a solved problem...

# Time Line of HFR WTI Mitigation Efforts





# IOOS-funded Effort: Status

Funded by US IOOS Ocean Technology Transfer Project  
9/2021 – 8/2023.

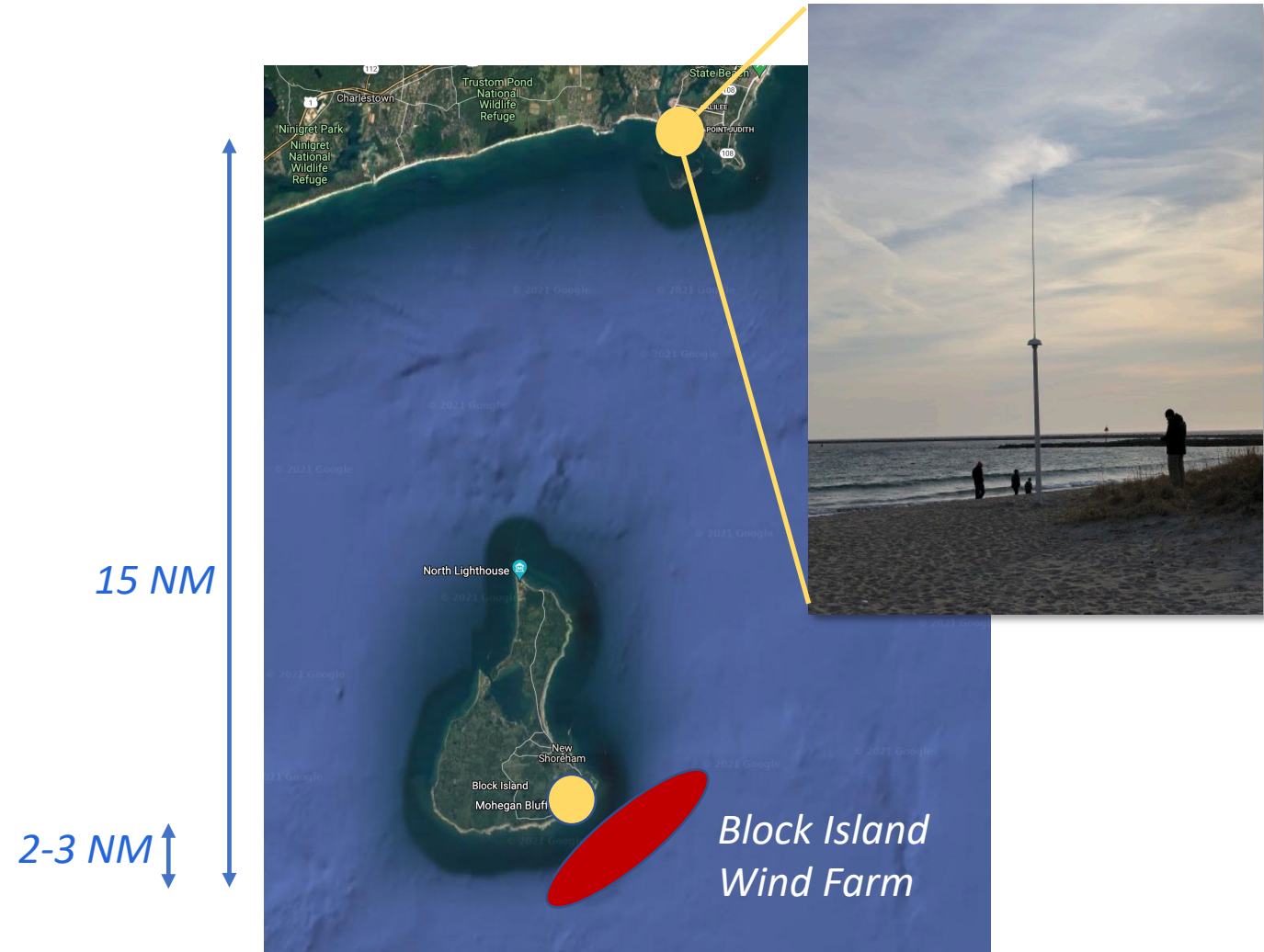
## Goal:

Advance HF radar WTI mitigation from research into regular operations via a coordinated set of system integration, calibration, testing, validation, and verification.

## Results so far:

- Additional field data at the BIWF, with help from Orsted
- Modeling effects of large turbine numbers
- Mitigation test dataset
- Best practices documentation

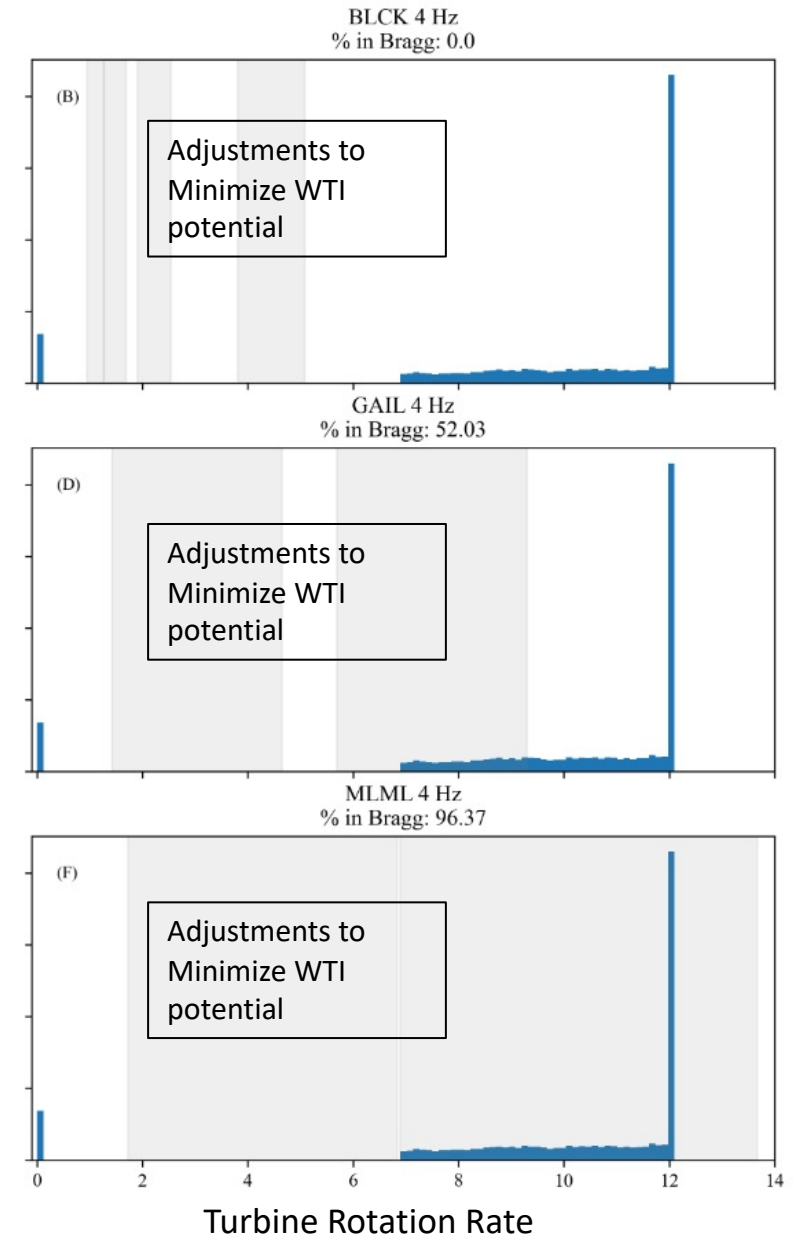
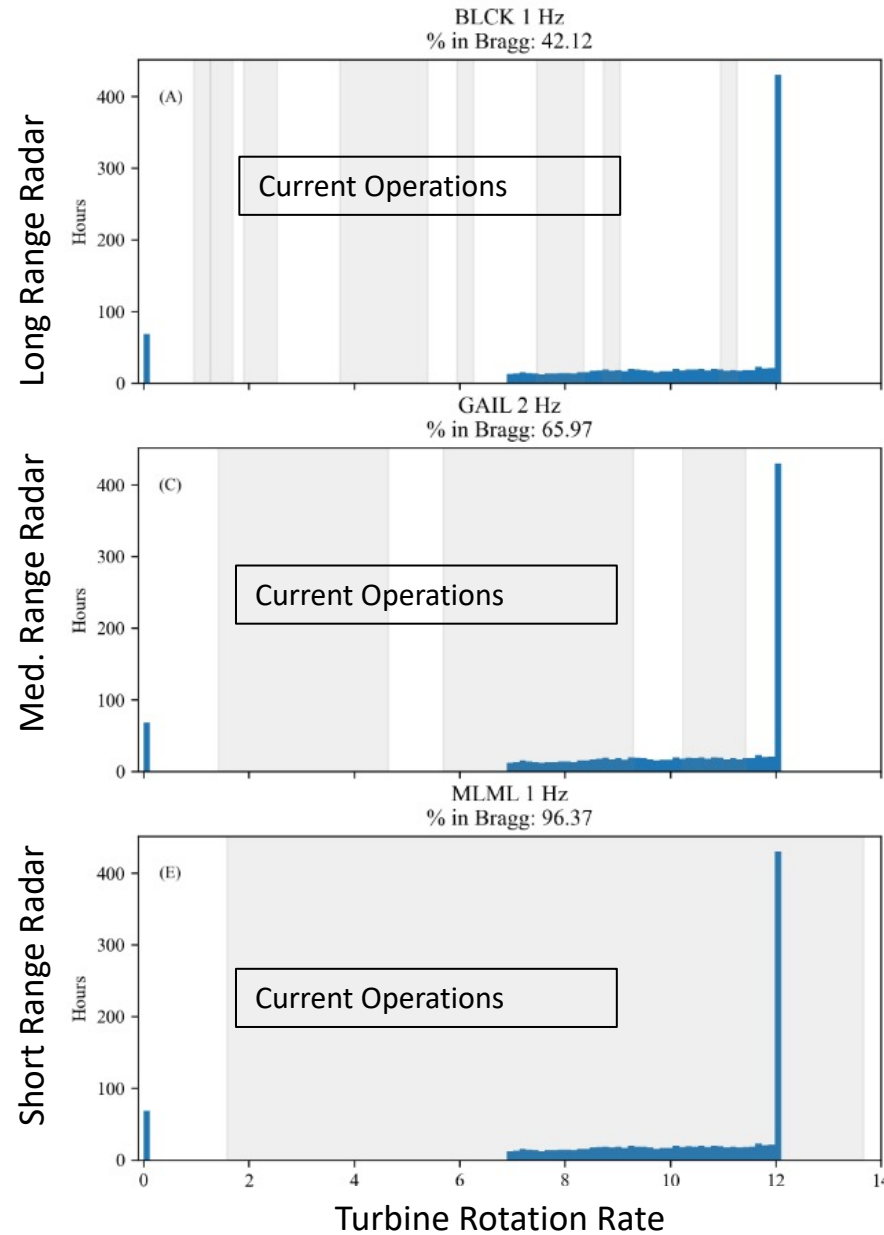
## *WTI data collection at the BIWF*



# Tools for WTI Minimization

Simulation using:

- **NREL 5MW turbine** rotation rates
- Block Island measured winds





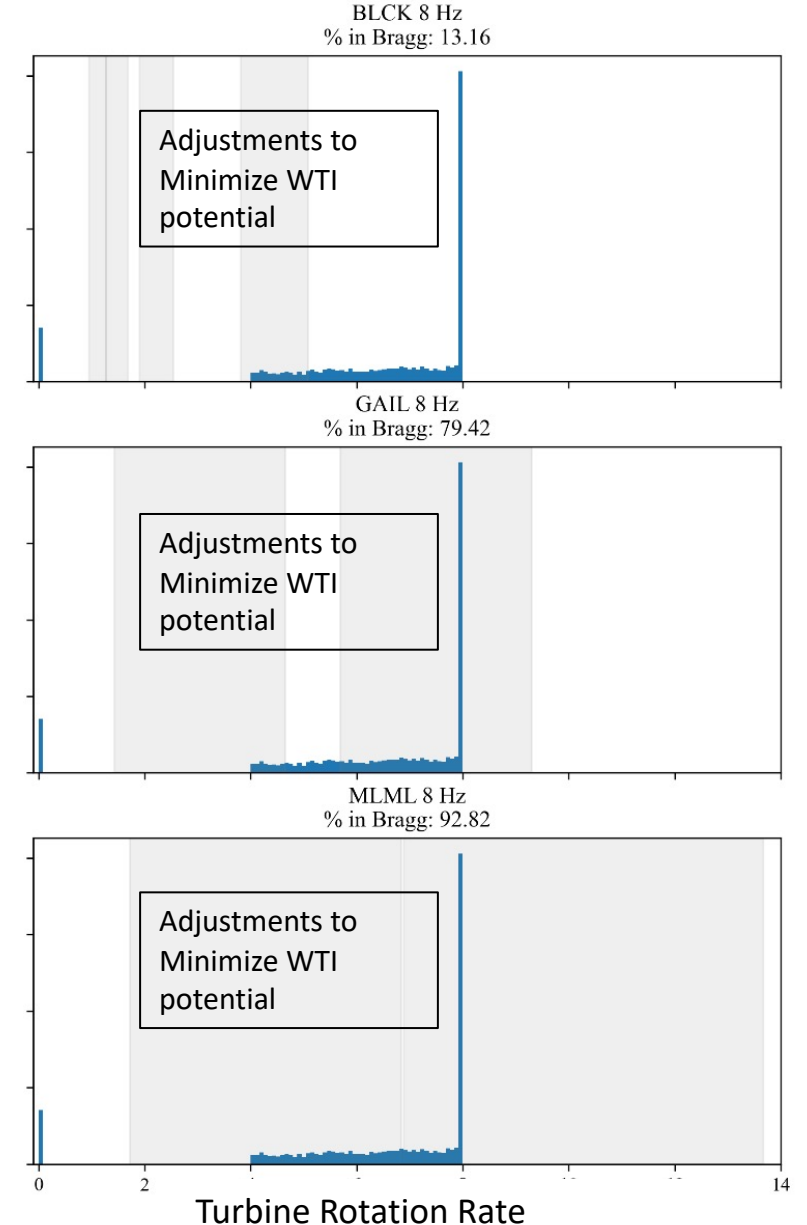
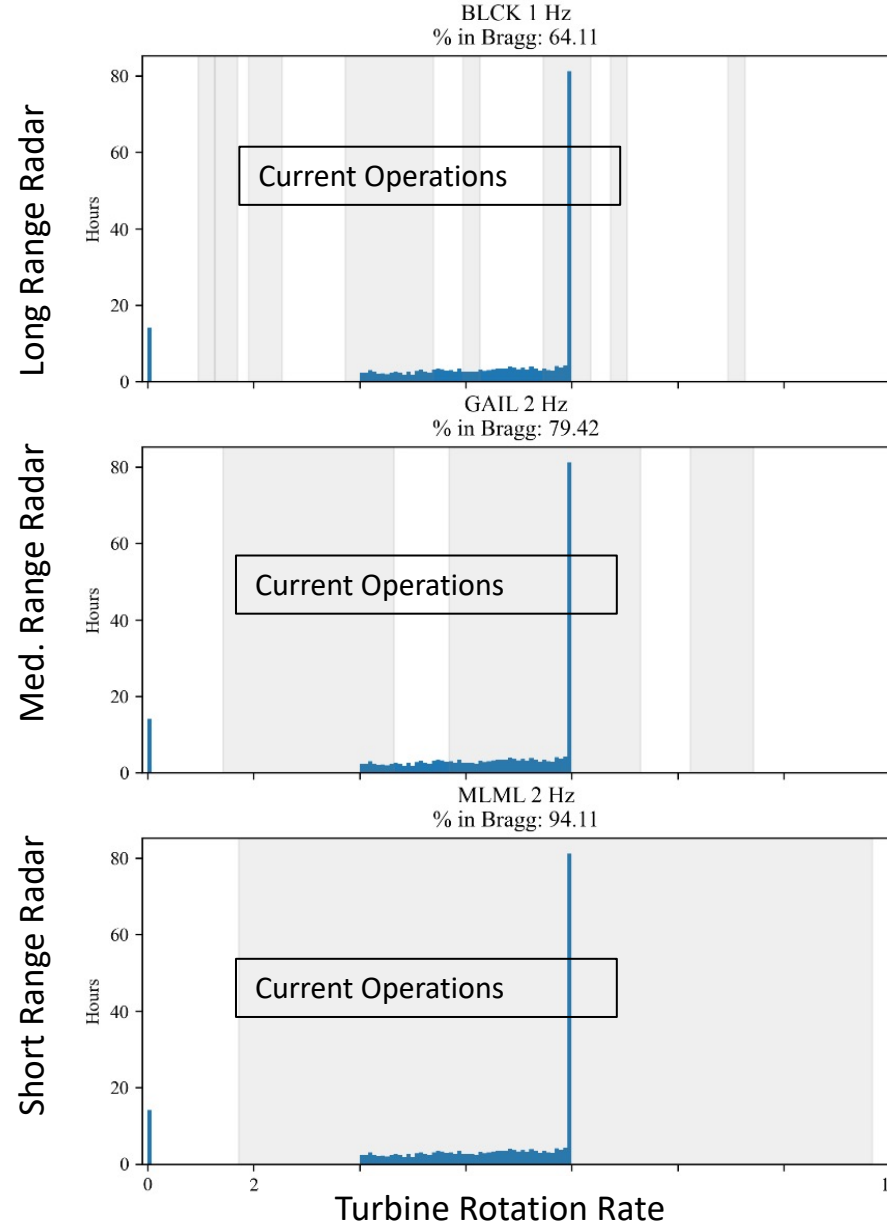
# Tools for WTI Minimization

Simulation using:

- ***Estimated GE Haliade-X 12-14MW turbine rotation rates***
- Block Island measured winds

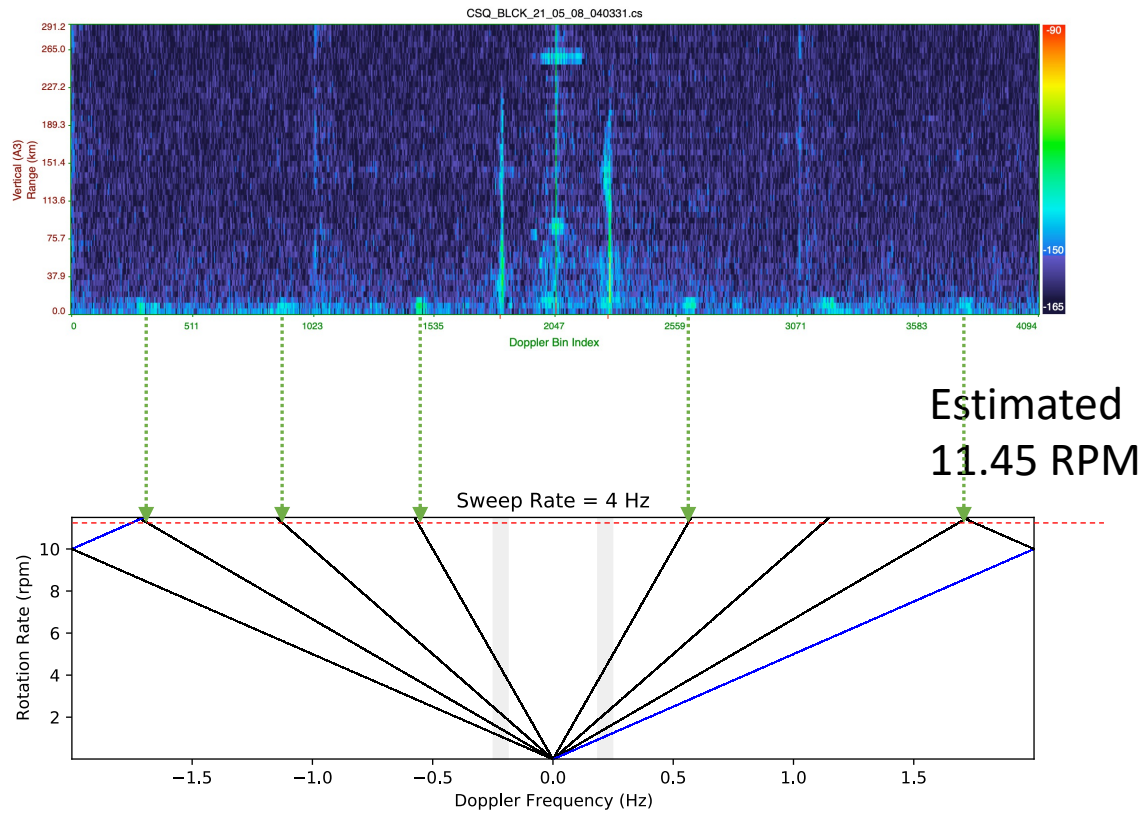
Minimization will not solve WTI for HFRs

Mitigation requires testing post-Vineyard Wind construction.

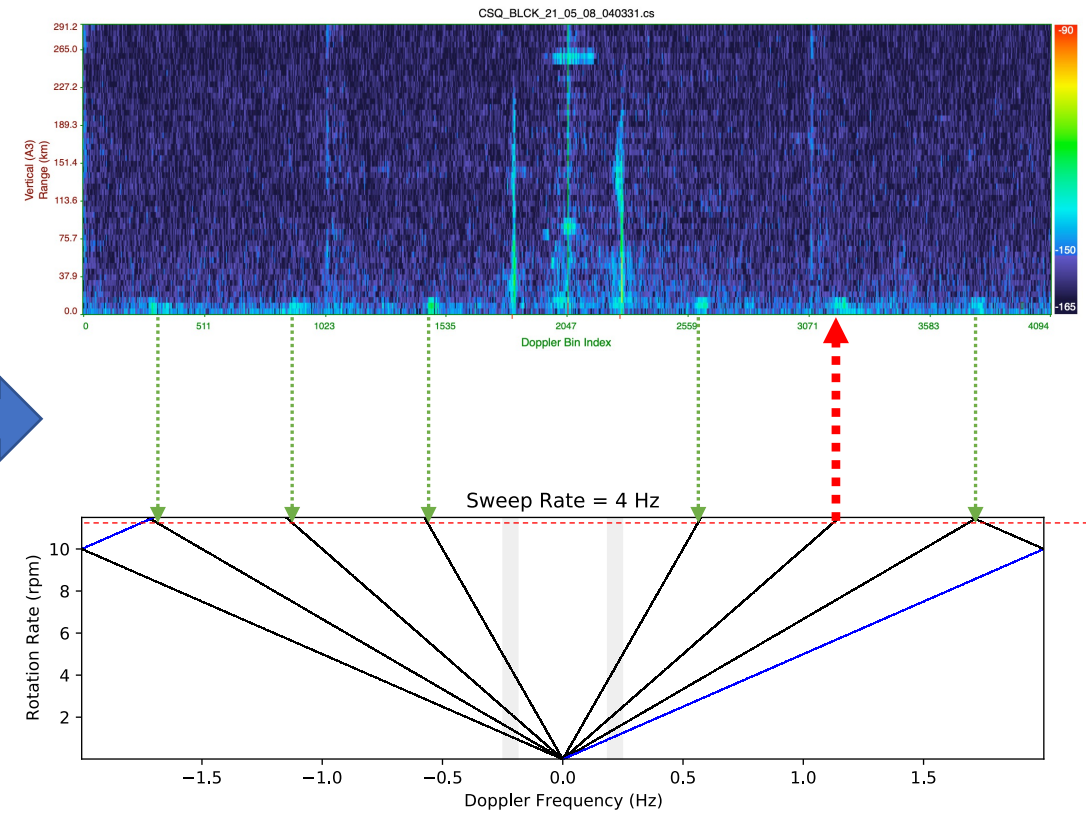


# Tools for WFI Mitigation

Inverse: Estimate RPM From Identifiable WTI Locations



Forward: Flag remaining locations of WTI





# WTRIM-HF is a National Problem

## National HF Radar Network



Coverage for 29 NOV 2018  
150 HF Radars Registered  
121 HF Radars Reporting



# Summary

## **Results:**

Community effort is making progress toward minimizing WTI on HF radar systems

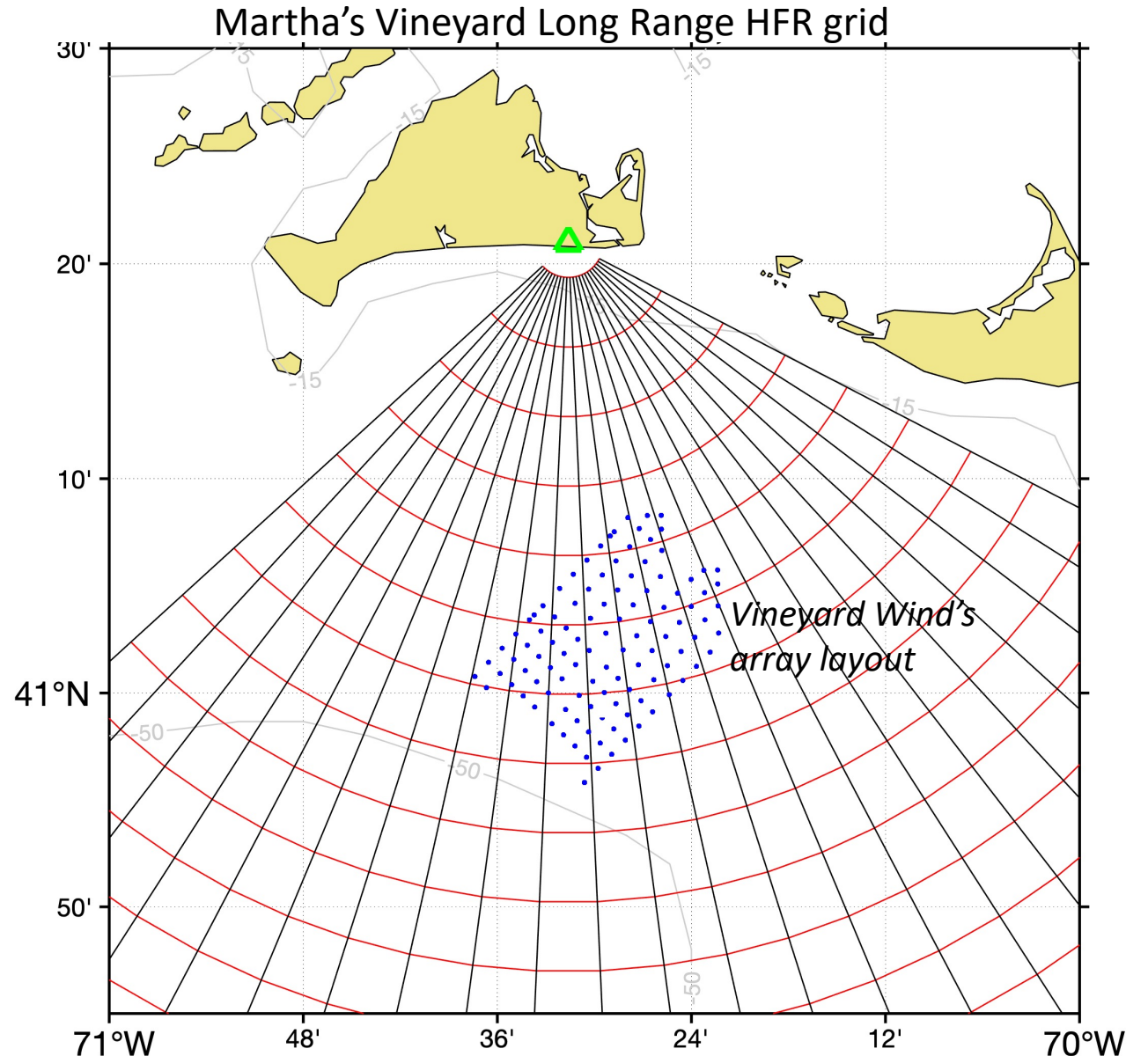
The current OTT-funded effort is one part of a multi-step process

Use the data for your environmental intelligence needs!

## **Ask:**

We need more information to help develop and test mitigation strategies.

Help us understand the potential for interference before turbines are installed at a wind farm.



# Currently Funded HFR WTI Mitigation Efforts: tasks and goals

## **BOEM:**

(CODAR)

- Implement a real-time software solution to WTI mitigation
- Optimize sweep rate and Doppler Length to minimize WTI
- Develop a simulation tool to simulate offshore wind turbine interference on coastal HF radars

## **NOAA OTT:**

(Woods Hole Oceanographic Institution, University of California Santa Barbara, CODAR, Rutgers University)

- Document the best practices for radar setup that minimize interference
- Set up robust WTI mitigation testing and testing standards
- Generate a three-tier testing data set including
  - Fully simulated data
  - Simulated WTI added to SeaSonde Spectra
  - SeaSonde data collected from sites near wind farms paired with rotation rates from the wind turbines
- Fully test the mitigation software developed under BOEM
- Field study of the impacts from WTI and WTI mitigation

## **NOWRDC:**

(CODAR, Old Dominion University, Rutgers University, East Carolina University)

- Use Multiple radar's operating bistatically to fill in gaps from WTI mitigation
- Use empirical machine learning methods, aided by the physics of WTI, to estimate WTI signals to a degree of accuracy such it can be separated and removed from the oceanographic echoes.