HF Radar Wind Turbine Interference Mitigation

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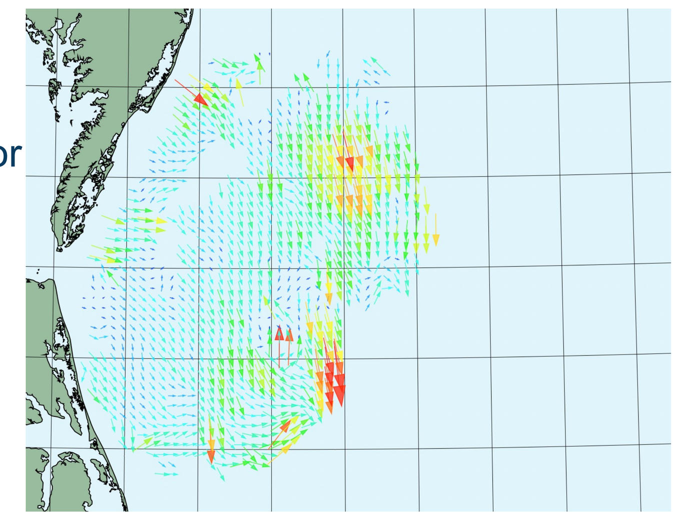
BACKGROUND

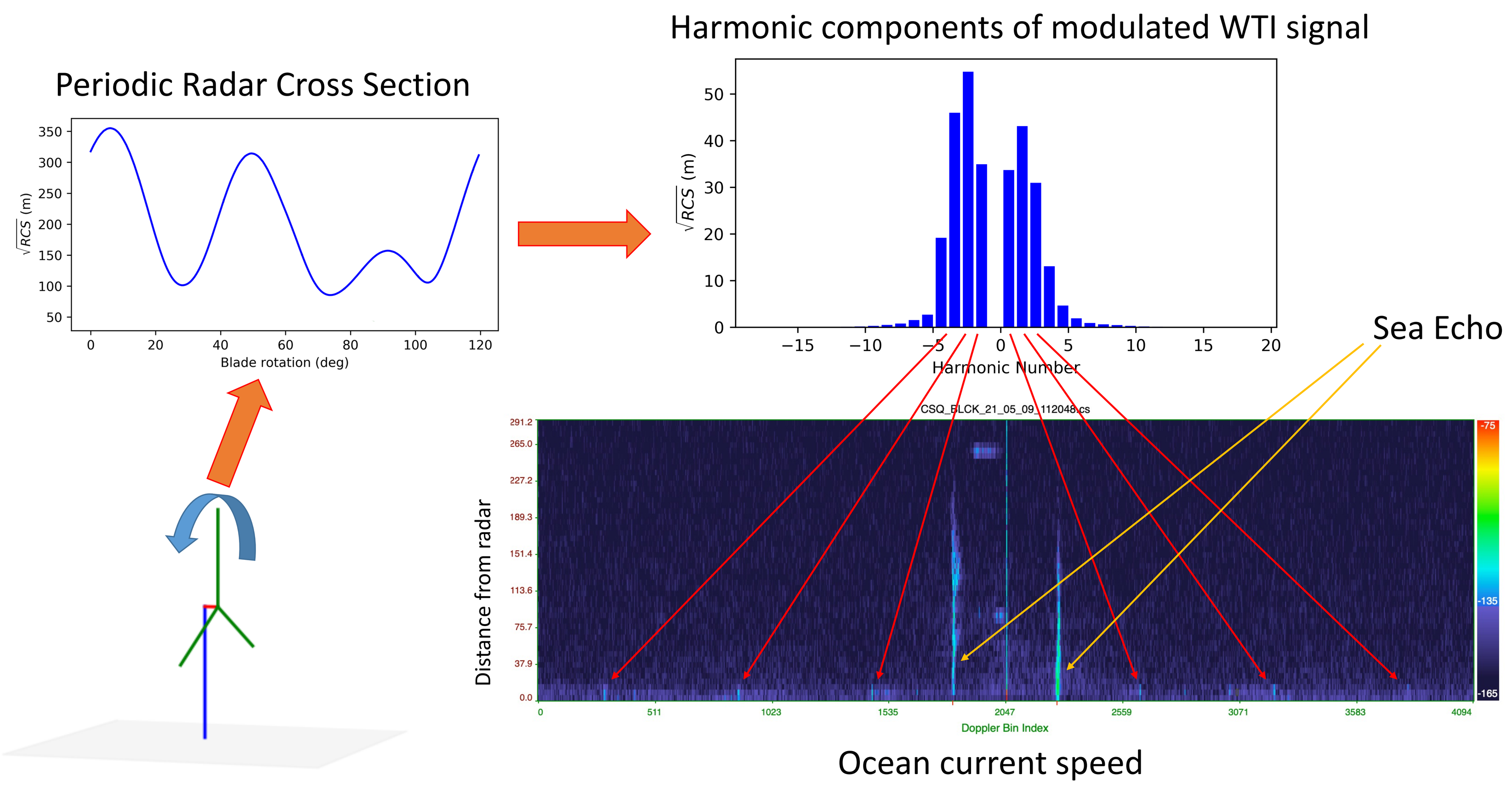
High-frequency radars provide oceanographic observations for maritime operations such as

- High temporal and spatial resolution surface current maps for search and rescue, spill response, harmful algal bloom forecasting and many other applications
- Wave Measurements for vessel operations and storm modelling
- Under development: Wind measurements for resource characterization



Offshore wind turbines interfere with ocean observations.

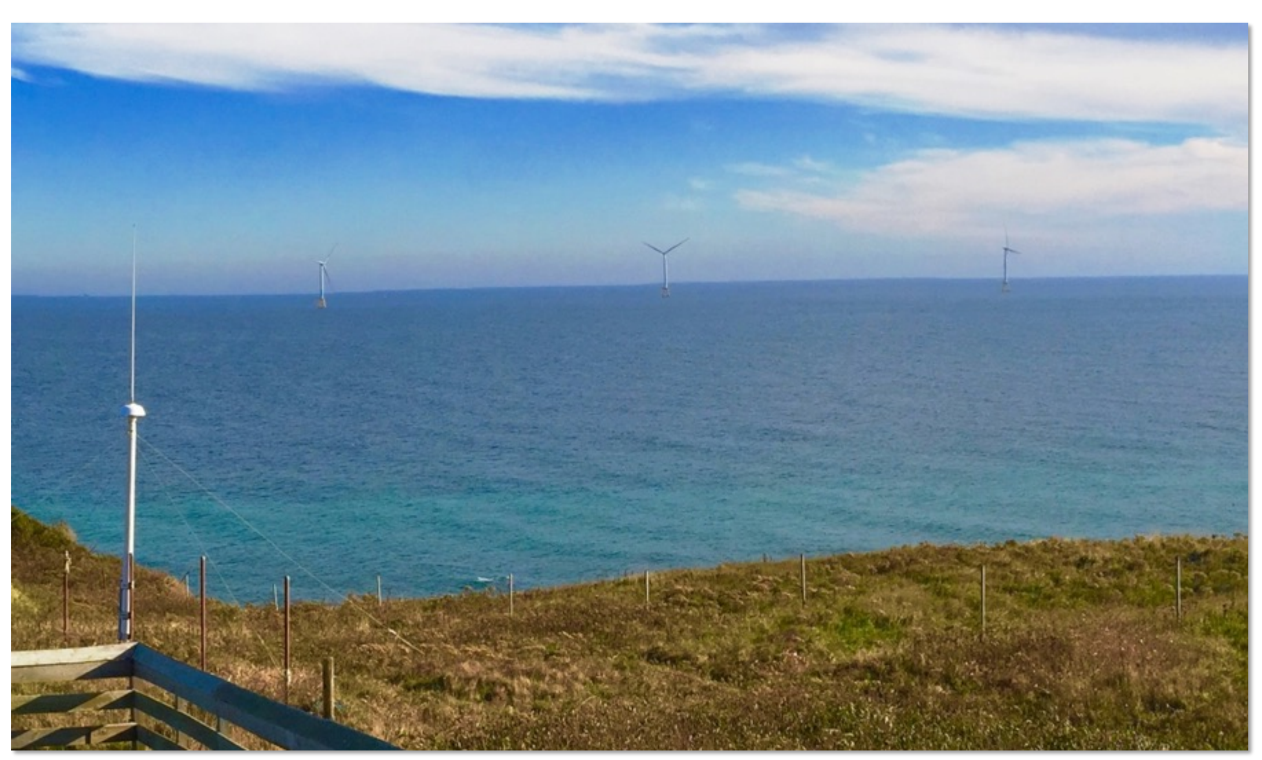
- Offshore wind turbines reflect an amplitude-modulated signal.
- The harmonic components of the reflected signal introduce interference at distinct Doppler.



Mitigation relies on flagging and removing observations containing wind turbine interference.

OBJECTIVE

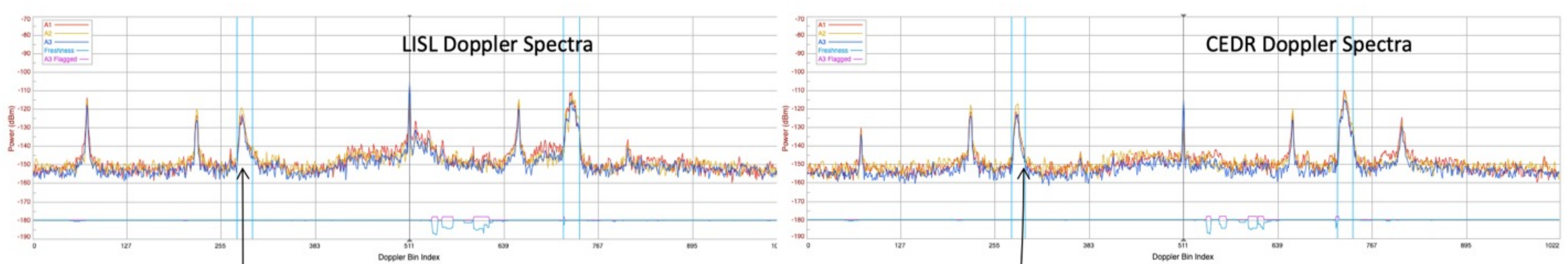
- Use of multiple radars with over-lapping coverage and multi-static operation to limit data loss caused by wind turbine interference mitigation.

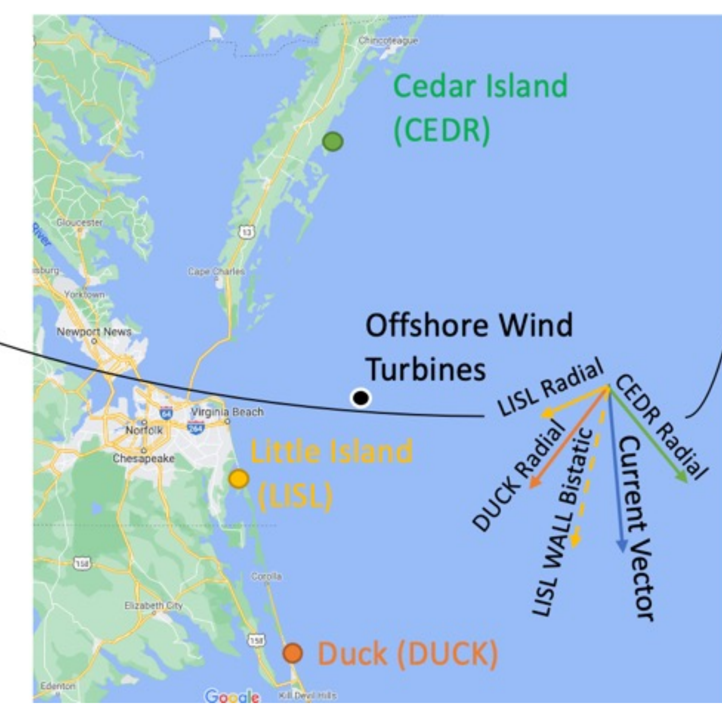


Wind Turbines In coverage area of high–frequency radar at Block Island

METHODS

- Three radars with overlapping coverage were configured to operate multistatically.
- Surface current observations were removed from each site to simulate the data loss due to wind turbine interference mitigation.
- Changes in the sea surface current observations were estimated using data from different combinations of radars.





- WTI Peaks are mapped to the same Doppler bins.
- The current vectors are mapped to different range-Doppler bins at each site.
- Mitigation will remove the observation from one of the three sites at a time.
- Using multiple radar sites fills in any data removed during mitigation.

RESULTS

DATA LOSS MITIGATION

- The inclusion of multiple radars reduces the loss and corruption of data caused by data removal.
- The more sites available, the greater the improvement, as shown in table below.
  - The percent of data lost from the system improved with the addition of each additional site from two monostatic sites, to three monostatic sites, and finally three monostatic sites and one bistatic site.
  - The percent of data changed increased with each additional site.
  - The root mean squared difference (RMSD) as well as the standard deviation of the error across the vectors that changed both improved as well with additional coverage.
- The more redundant information available, the less the impact of the missing data.

Data loss comparison of multiple radars with overlapping coverage. Redundancy mitigates the loss and corruption of data from flagging.

Sites	# Measurements Lost	RMSD (cm/s)	Sigma
CEDR, DUCK	1621	5.28	4.19
CEDR, LISL, DUCK	189	3.77	3.00
CEDR, LISL, DUCK, LISL-DUCK	151	3.45	2.76

CONCLUSIONS

DATA LOSS MITIGATION

- The impact of **flagging and removing data** from high-frequency radars with wind turbine interference **can be reduced** by using multiple radars
- Where adding new radars is not feasible, operating existing radar networks in **multi-static mode can also reduce the error** introduced by wind turbine interference mitigation.
- **Increasing redundancy** in a high-frequency radar network by either increasing the number of radars or operating them in a multistatic mode will decrease the impact of removing some of the data.

Challenges With Wind Turbine Interference Removal

- **Blade rotation rate variations have a significant impact** on the characteristics of the interference peaks in high-frequency radar data.
- More granular **SCADA data is needed** to investigate further, understand, and ultimately mitigate the effect of turbines with variable rotation rates.

ACKNOWLEDGMENTS

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