Assimilation of Wind Retrievals from a Network of Coastal High-Frequency Radars with Bistatic Configuration

U.S. NAVAL RESEARCH LABORATORY

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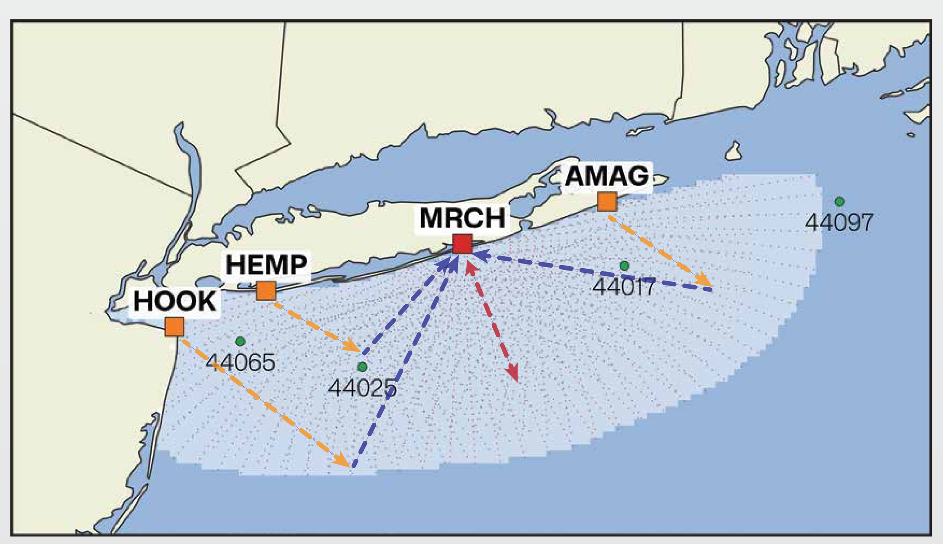
Objective

Coastal high-frequency (HF) radar networks are traditionally used for monitoring waves and ocean currents. Previous studies have shown their potential in retrieving **near-surface winds** and their use in numerical weather prediction (Muscarella et al. 2021, Blaylock et al. 2022, 2023). This study demonstrates the retrieval of near-surface wind vectors from 5 MHz HF radar Doppler spectra for a **bistatic** configuration and their assimilation in the Navy's Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS).

Wind retrievals were collected from May 1-22, 2022, using a single HF radar receiver at Moriches, NY (MRCH), with Doppler spectra transmitted from itself (monostatic) and three other transmitters (bistatic). The retrieval process utilizes an HF radar forward and adjoint model along with the Simulating WAves Nearshore (SWAN) model to correct background winds based on the observed Doppler spectra.



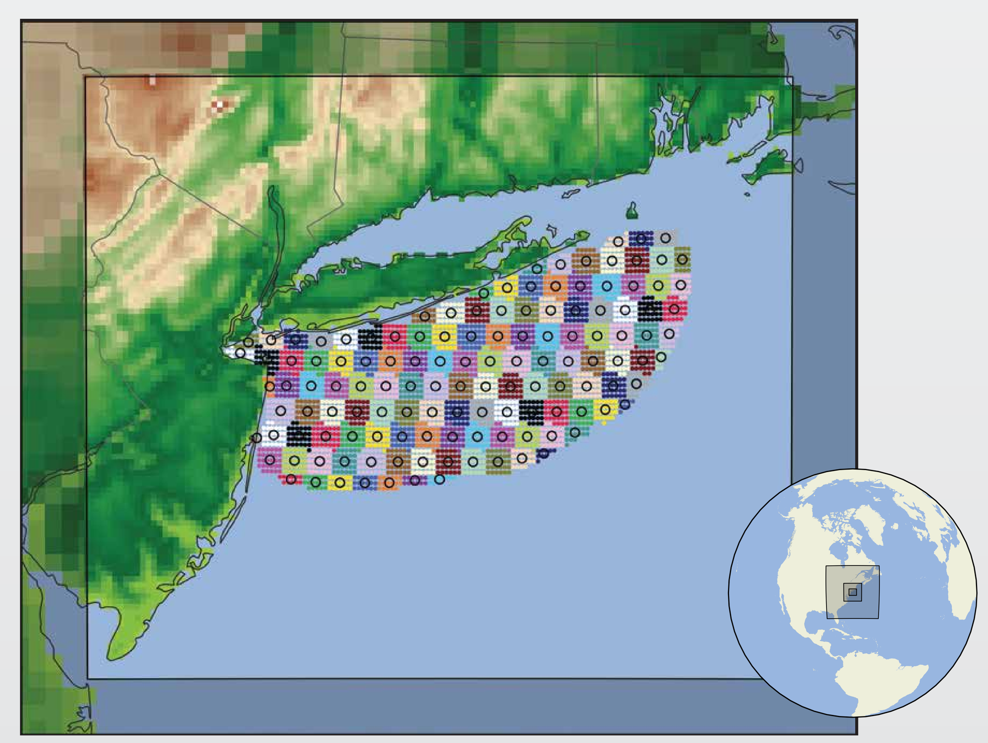
Long Island HF radar locations (squares) with example bistatic and monostatic transmission paths. NDBC buoys also shown (green).

Assimilation Experiment

Data Hourly HF radar wind retrievals were produced at ~3 km spacing. Quality control ensured we only considered winds with realistic wind speeds at valid model ocean points and winds with a vector difference of less than 6 m/s from the model background. In past studies, a "Doppler spectra error" was also used for quality control but was not available for this case study. Quality-controlled HF radar winds were ***superobbed*** to approximately 15 km spacing to reduce the number of observations and correlated error. An average of 650 HF radar wind vectors were assimilated each cycle.

Model COAMPS is the Navy's regional model. Configured with 60 vertical levels and 27-, 9-, 3-km nested domains, COAMPS was cycled every 6 hours with NAVGEM boundary conditions. We assimilated HF radar wind retrievals in COAMPS for 21 days (after a 10-day model spin-up) with all operationally available observations using the COAMPS-AR 4D-Var assimilation system.

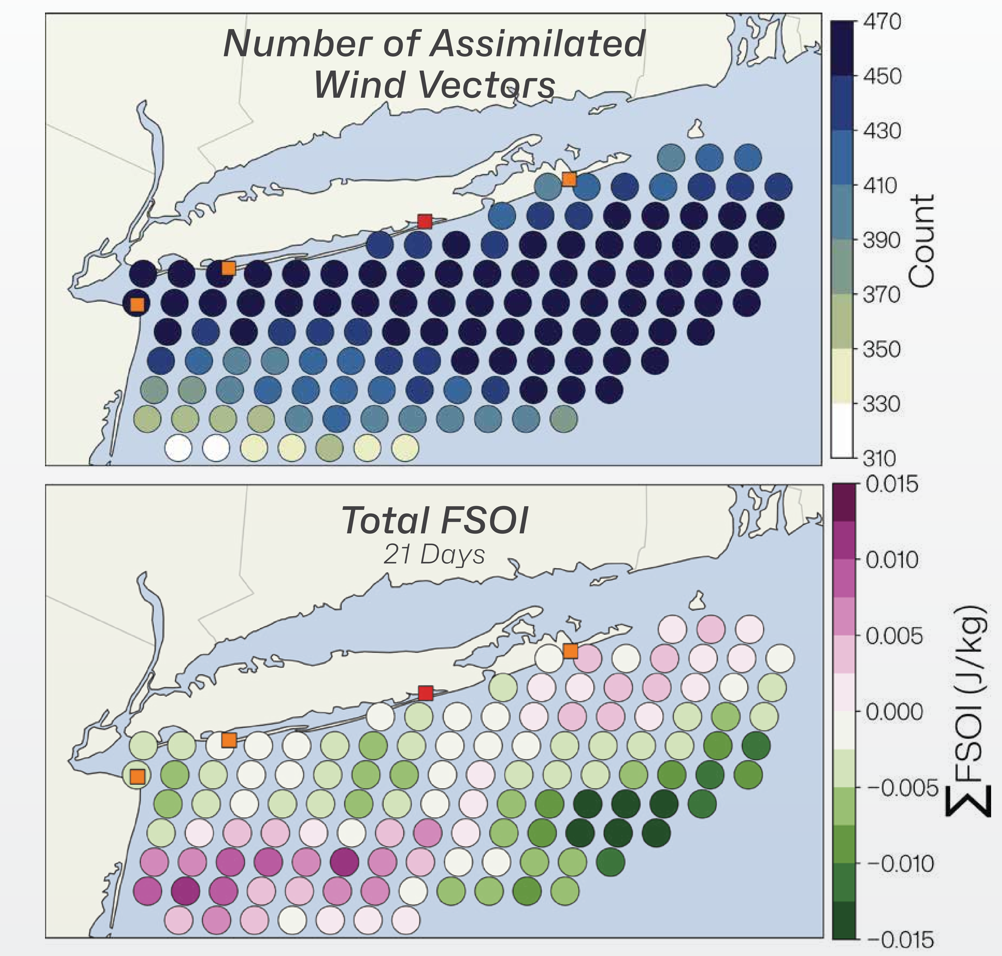
COAMPS inner domain (3 km) and HF radar wind retrieval footprint colored by superob bin. Open circles represent assimilated observation location if all observations in the superob bin pass quality control.

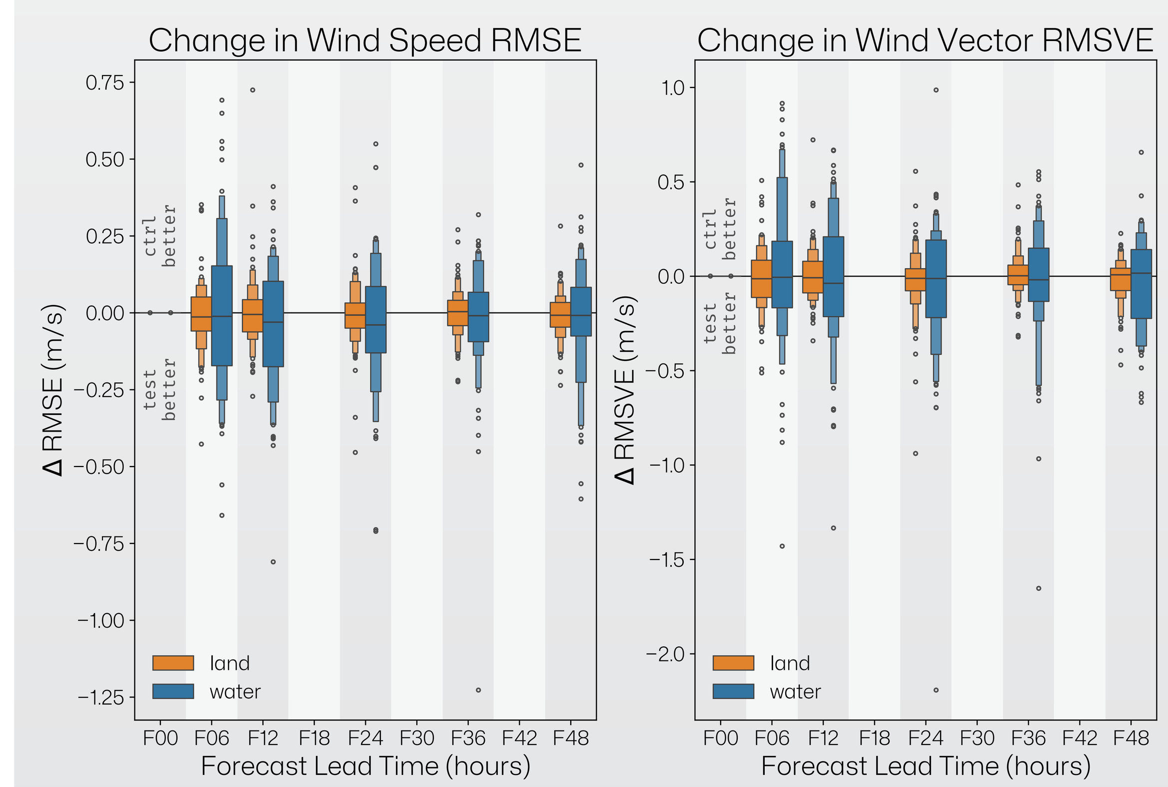


Impact on Forecasts

Observations most often fail quality control in the southern extent of the HF radar footprint–the same area where wind vector difference is greatest relative to URMA (see below).

Forecast sensitivity to observations (FSOI) was evaluated for the two lowest model levels. Negative FSOI indicates observation had beneficial impact on the 12h forecast. **Total FSOI of HF radar winds was negligible**, however, beneficial impact is gained in the eastern portion of the footprint and roughly the areas where vector difference relative to URMA is low. One possible explanation is that the area of greatest beneficial impact is far from other observing sources (i.e., rawinsondes and aircraft).





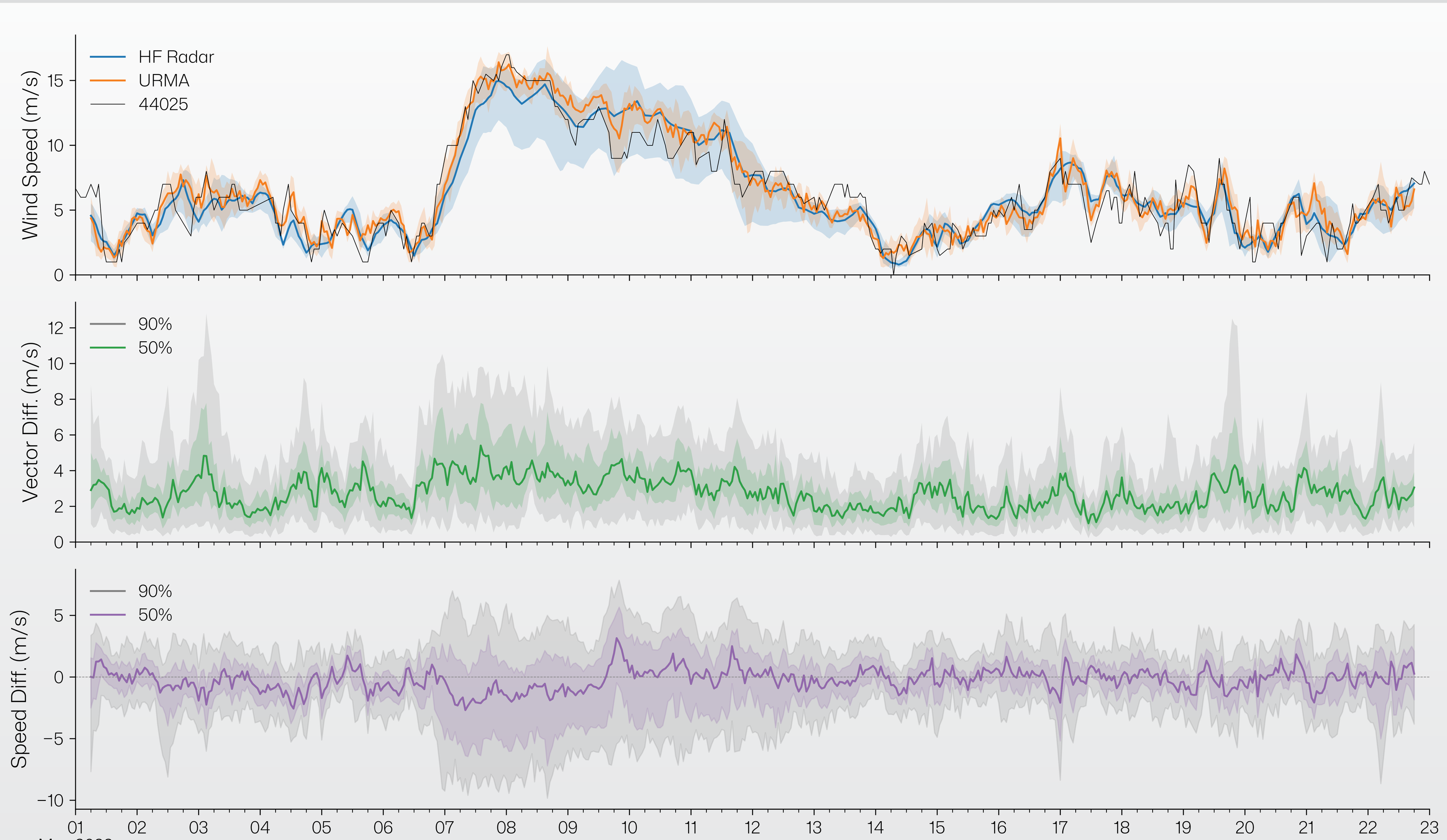
Compared to a control experiment, assimilating HF radar winds resulted in a *slight* improvement in the wind speed RMSE over water grid points at F12 and F24 relative to URMA. Similarly, there was little change in 2-m temperature and dew point forecasts (not shown).

These results are consistent with previous studies and demonstrates the potential application of HF radar for NWP. Improved QC and coordination of network owners is needed to operationalize and expand the capability.

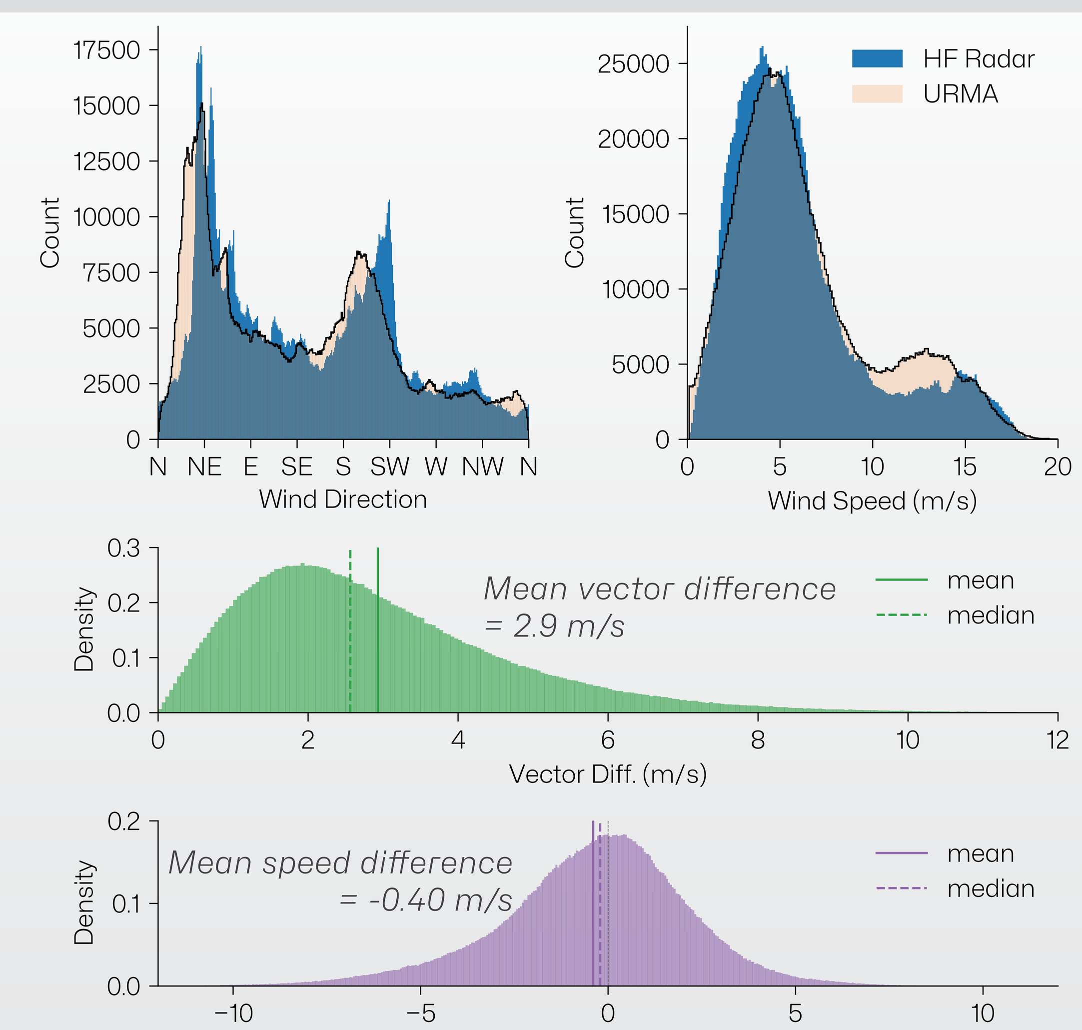
HF Radar Wind Retrievals

HF radar vector winds compared to the Un-Restricted Mesoscale Analysis (URMA) and buoys highlight times and areas of agreement and differences.

HF radar observed a frontal passage on May 7, 2022, with accurate timing. While the median HF radar wind speed agrees well with the median URMA wind speed throughout the time period, the spread in HF radar wind speed is much greater than URMA after the frontal passage. The magnitude and spread of wind vector difference and speed difference is also elevated after the frontal passage. This is possibly related to the sea state.



Top: *Median wind speed for HF radar (blue) and URMA (orange) with shading for 50% of distribution. Wind speed at buoy 44025 (black).* ***Middle:*** *Median vector difference between HF radar and URMA with shading for 50% and 90% of distribution.* ***Bottom:*** *Median speed difference with shading for 50% and 90% of distribution.*



Above: *Distribution of HF radar direction and speed bias relative to URMA.*

Spatially, the mean vector difference is largest along the eastern Long Island coastline and southern extent. The best agreement with URMA is along the center of the HF radar footprint where there is overlapping signal from many HF radar sites. Errors are slightly more elevated during nighttime hours compared to daytime, possibly due to ionosphere influences causing more noise at night (not shown).