Analysis of the Wind Resource off New Jersey for Offshore Wind Energy Development

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***Abstract*—The state of New Jersey has the goal of producing 23% of its energy from renewable sources by 2021. Offshore wind is envisioned as being part of that renewable portfolio. To meet this goal New Jersey passed the nation's first offshore wind renewable energy standard which requires that at least 1,100 megawatts (MW) by 2021. Currently NJ has 0 MW of offshore wind energy. In order to reduce the risk associated with installing these turbines, the Rutgers University Coastal Ocean Observation Laboratory has undertaken a two year study of the ocean winds and currents to provide insight to the wind farm developers to the best locations for siting the wind turbines. A 13 MHz HF radar network was installed to measure the surface currents every 2 km out to a range of 60 km from the coast. These surface current measurements were validated against surface wind measurements from available meteorological stations. The surface currents will then be used to validate the surface winds from a weather model that has been created for this program.**

***Index Terms*—HF radar, offshore wind, forecasting**

I. Introduction

The Rutgers University Coastal Ocean Observation Laboratory (RU-COOL), part of the Institute of Marine and Coastal Sciences (IMCS), is proposing to provide a detailed analysis of the wind resource and sea surface conditions over the area designated for potential wind energy development as defined by the NJ Energy Master Plan and the NJ Offshore Wind (OSW) Economic Development Act. The results of the previous offshore wind resource analysis conducted by RU-COOL for the New Jersey Board of Public Utilities (NJBPU) will be used as the basis for the proposed study. That study used the Rutgers University version of the Weather Research and Forecast model (RU-WRF). We propose to further enhance and verify the RU-WRF model, and run it over the 2-year study period, to enable further refinements in the estimates of the spatial and temporal variability of the offshore wind resource. Enhancements include nesting to resolutions better than 1 km, and use of a newly available sea surface temperature product generated at Rutgers for the Integrated Ocean Observing System (IOOS). Sea surface conditions and near surface winds for the entire study domain will be derived by Coastal Radar (CODAR) and high-resolution infrared satellite detection. Available data from coastal/offshore meteorological monitoring systems will be used to validate the vertical wind structure, and data from a surface current mapping radar network will be used to validate the complex horizontal structure. These remote sensing systems not only will provide necessary data for the wind resource assessment, they also will be used to support the coastal and offshore ecological studies being conducted under the supervision of the New Jersey Department of Environmental Protection (NJDEP). Specifically, the shore sites for each CODAR HF radar site are preferred locations for inexpensive Automatic Information System (AIS) transceivers to collect data on existing vessel traffic in the development area. Site variability and local wind resource perturbations, such as the sea breeze circulation, that affect wind power production will be resolved. Results of the proposed project can then be used to determine optimum, good, and poor locations for wind energy development. This will contribute to the risk reduction associated with achieving the objectives of the NJ Energy Master Plan and the NJ OSW Economic Development Act. The proposed wind resource and sea surface analysis program using a combination of advanced and adaptive monitoring and modeling systems that account for the dynamic interactions of the coast, sea, and atmosphere, which define the offshore wind resource, should prove to be cost-effective for assisting decision makers and other stakeholders involved in offshore wind energy development.

Additionally, the ocean monitoring systems will become part of the IOOS network thus increasing the coverage for weather forecasting, homeland security activities, water quality, fisheries, and the safety of life at sea. Furthermore, the proposed assessment program, which has both diagnostic and predictive capabilities, can support forthcoming forecasting efforts associated wind turbine installation and operational applications. At the conclusion of this 2-year study, technology that will be in place to continue supporting offshore wind development include (a) a fully validated high-resolution nested atmospheric forecast model (RU-WRF) that can be run daily, (b) a nested CODAR HF Radar network that provides hourly high resolution surface current maps in near-real time, (c) a collocated AIS transceiver network to monitor all reporting vessel traffic in the region, and (d) the satellite data analysis and model coupling routines to provide locally constructed and verified boundary conditions for area-specific wind resource and sea breeze forecasting.

II. METHODS

A thirteen MHZ HF radar network was installed as part of this project. The CODAR SeaSonde type HF radars were installed in Brant Beach (BRNT), Brigantine (BRMR), Strathmere (RATH) and North Wildwood (WOOD) New Jersey. The average spacing between the systems was 29 km. The first system was installed in December 2011 and the last system was installed in January 2012. The radial data from three other thirteen MHz systems at Sea Bright [1], Belmar and Seaside Park, NJ was also used in this study. The radial data from these seven stations was combined on the 2km National grid [2] to produce surface current measurements once an hour.

The HF radar data collected for this study spanned from January to June 2012. A representative temporal and spatial coverage for the HF radar data is shown in Figure 1. The surface current data was compared with the wind measurements at six other locations. Three of the locations were National Data Buoy Center (NDBC) station 44025 Long Island 33 nautical miles south of Islip, NY, station 44065 entrance to New York Harbor and station 44009 Delaware Bay 26 nmi southeast of Cape May, NJ. The other three wind measurements were from MARACOOS partner WeatherFlow. Their stations were located in Tuckerton (station 37558), Barnegat Inlet (station 45247) and Atlantic City (station 1103) New Jersey. The wind data was binned to every hour to match the HF radar data.

The closest surface current grid point with at least 70% temporal coverage over the study period was used to compare with the wind measurements. The surface current data was first detided using a least squares technique that accounted for the 5 major constituents in the region (M2, S2, N2, K1 and O1). The currents were then passed through a 30-hour low pass filter. An example of this analysis is shown in Figure 2 for the east/west velocity u and Figure 3 shows the analysis for the north/south velocity v.

Then the complex correlation between the surface currents and surface wind were computed on a monthly basis (Figure 4). The complex correlation outputs a magnitude and bearing of the surface current most correlated with the wind. If the bearing is positive, it indicates that the surface currents are shifted to the right of the wind as should be the case in the northern hemisphere [3]. Then the currents were rotated based on the bearing to match the angle of the wind data (Figure 5). This methodology follows the work of previous research on the comparison between surface currents and winds [4]. The correlation between the rotated surface currents and one of the wind measurements for the entire study period is shown in Figure 6.

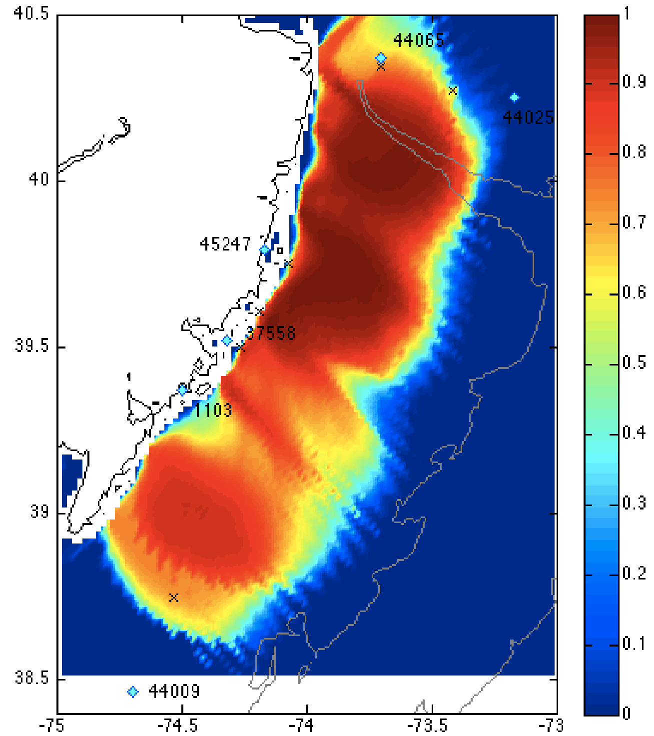

Figure 1: Spatial data coverage of the HF radar network from January 23 to May 7, 2012. The location of other data sampling locations are also depicted: NDBC buoys 44009 and 44025 and WeatherFlow wind stations 1103, 37558 and 45247. The x's mark the closest point to the wind measurements where there was HF radar surface current data for 70% of the study period. Bathymetry contours are shown as the gray lines.

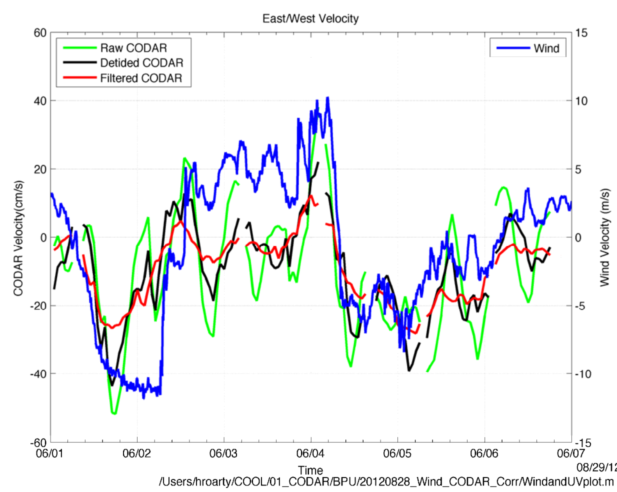

Figure 2: Time series plot from June 1-7, 2012 of the u velocity of the CODAR surface currents (green), detided surface currents (black), low pass filtered currents (red) and wind from station 44025 (blue).

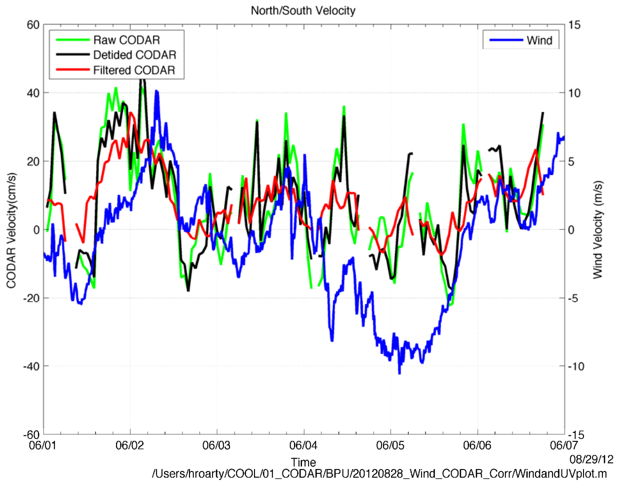

Figure 3: Time series plot from June 1-7, 2012 of the v velocity of the CODAR surface currents (green), detided surface currents (black), low pass filtered currents (red) and wind from station 44025 (blue).

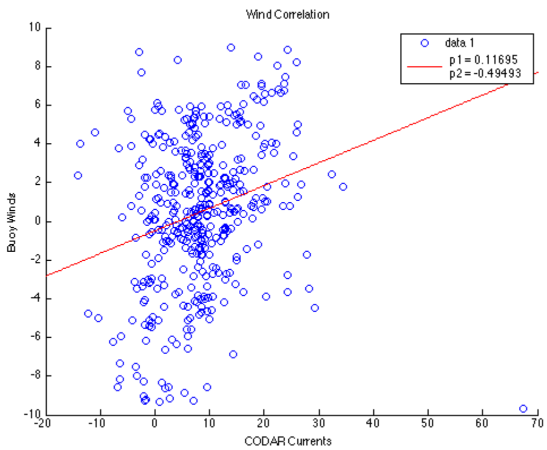

Figure 4: Scatter plot of u velocity for CODAR surface currents (cm/s) vs. u Winds from buoy 44025 (m/s) for June 2012.

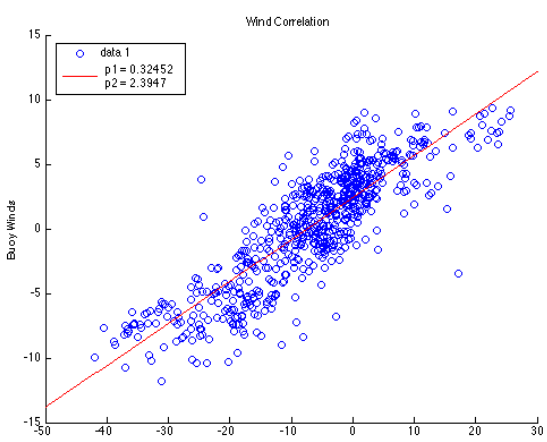

Figure 5: Scatter plot of rotated u velocity for CODAR surface currents (cm/s) vs. u Winds from buoy 44025 (m/s) for June 2012.

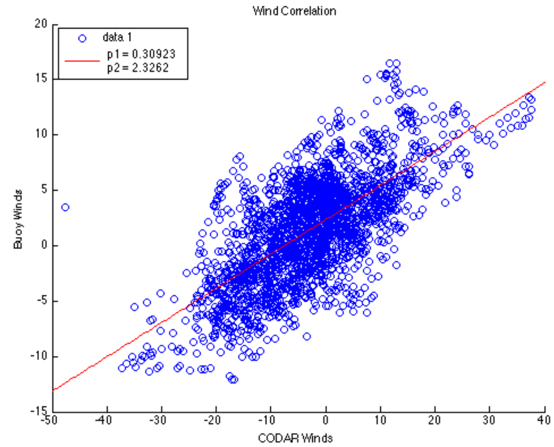

Figure 6: Scatter plot of rotated u velocity for CODAR surface currents (cm/s) vs. u Winds from buoy 44025 (m/s) for January to June 2012.

III. Results

The process, as described in the previous section, of comparing the surface current to the wind was repeated for each of the six wind sensors in the study area. The correlation between the surface currents and the wind were computed on a monthly basis. These six monthly measurements were then averaged to compute a spatial average over the study area of the surface currents with the wind as shown in Figure 7. This was done with the raw, detided and low pass filtered surface current records. The filtered product consistently produced the highest correlation of the surface currents with the wind.

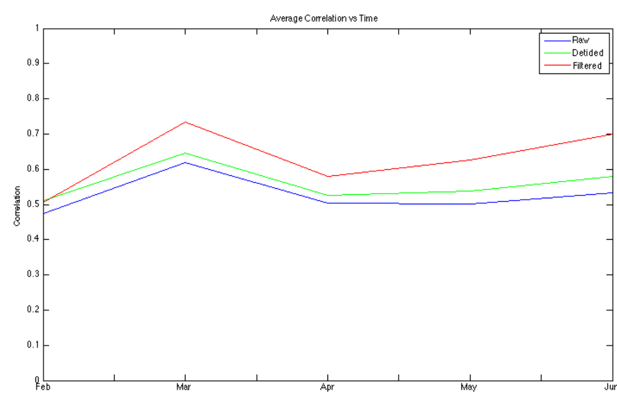

Figure 7: Average correlation between the CODAR surface currents (raw, detided and filtered) and the six wind measurements as a function of time. The x axis spans from February to June 2012.

IV. Conclusions

A weather model and 13 MHz HF radar network have been constructed to study the offshore wind resource off New Jersey for the potential construction of offshore wind turbines. The HF radar network is being utilized to assess the surface currents off New Jersey and to validate the weather model. The surface wind data from the model will be compared with the data from the HF radar network. Before this can take place the surface currents from the HF radar network were compared with point measurements of six meteorological stations in the study area. The HF radar surface currents showed moderate to strong correlation with each of the wind measurements throughout the study period. Therefore we conclude that the HF radar surface currents will be a valid method to evaluate the spatial variability of the surface winds in the weather model.

ACKNOWLEDGEMENTS

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