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Offshore Wind Resource Characterization over California Wind Energy Areas

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GRAND CHALLENGES IN OFFSHORE WIND ENERGY

The offshore metocean environment differs significantly from that on land, and one coastal area differs from another. The offshore environment is in need of greater definition and physical understanding to optimize offshore wind plants to suit their local environments (Veers et al., 2019, Shaw et al., 2022). Lack of hub-height observations offshore in the U.S. is identified as a critical gap in numerous public forums.

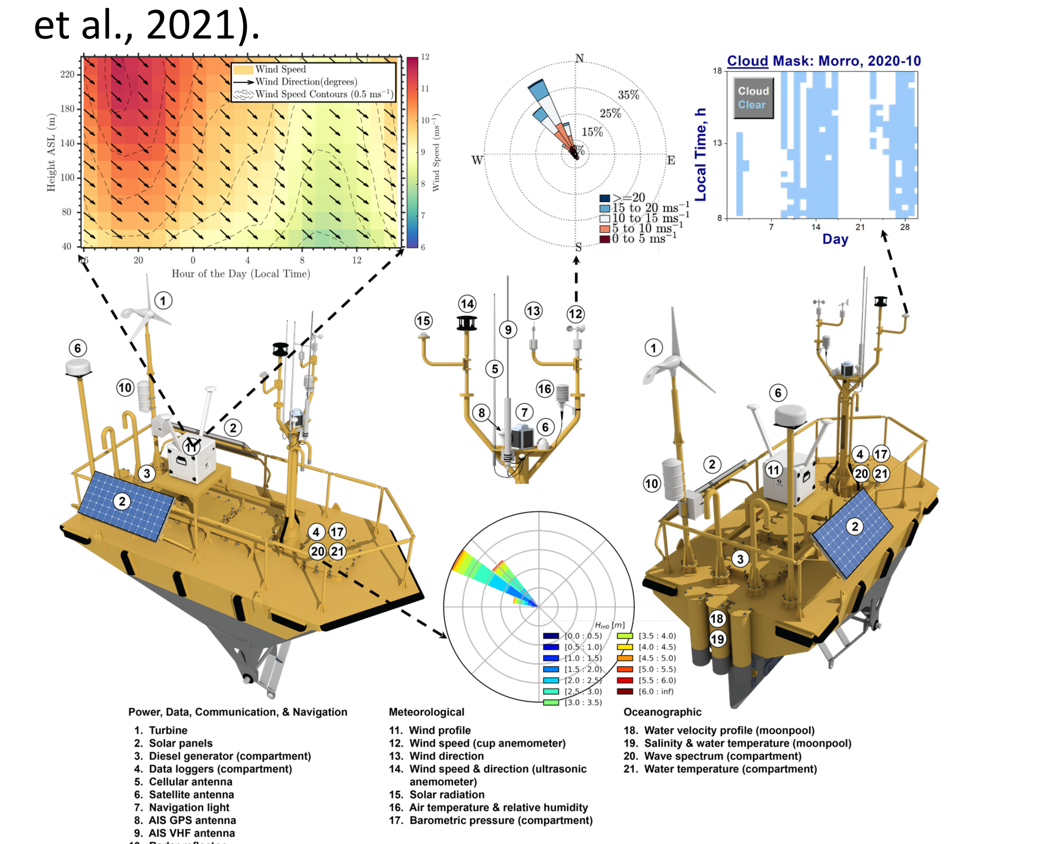
OBJECTIVE

The overall goal for this project is to use the DOE buoy data to improve our ability to characterize the wind energy resource offshore. Within this overall goal, there are four specific objectives for this work:

- Climatology of U.S. West Coast wind energy areas
- Develop and evaluate techniques to maximize the wind information available from the buoys (such as turbulence intensity [TI])
- Do the first full-year evaluation of the ability of current reanalysis models to represent the hub-height winds offshore
- Evaluate the impact of wind-wave coupled models on hub-height winds

DOE BUOYS

The DOE buoys have state-of-the-art instrumentation to measure the offshore wind resource (Krishnamurthy et al., 2021).



OBSERVATIONS AND MODELING SUMMARY

Marine and Ocean Boundary Layer Measurements

1-year measurements of winds from a Doppler lidar revealed roughly steady northerly wind speeds at each altitude at Humboldt (right), while at Morro Bay (left), winds were parallel to the coast at all hours in the mean with significant daily wind speed variability, especially in the upper part of the rotor layer and stronger shear in the evening (Fig 1). Turbulence profiles show low TI offshore with impacts from clouds and surface waves (Fig 2). The ocean currents from ADCPs also show evidence of strong vertical shear, which have been shown to impact the marine boundary layer winds (Fig 3, see coupled modeling section below).

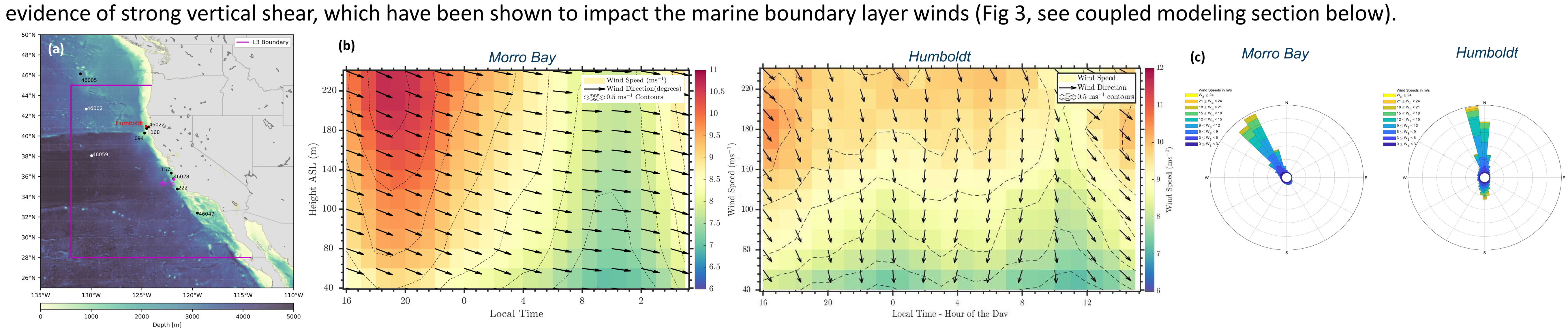


Figure 1: (a) Bathymetry along CA coast with the location of the buoys, b) hourly averaged wind profiles and c) wind roses at 100 m at Morro Bay and Humboldt lease areas.

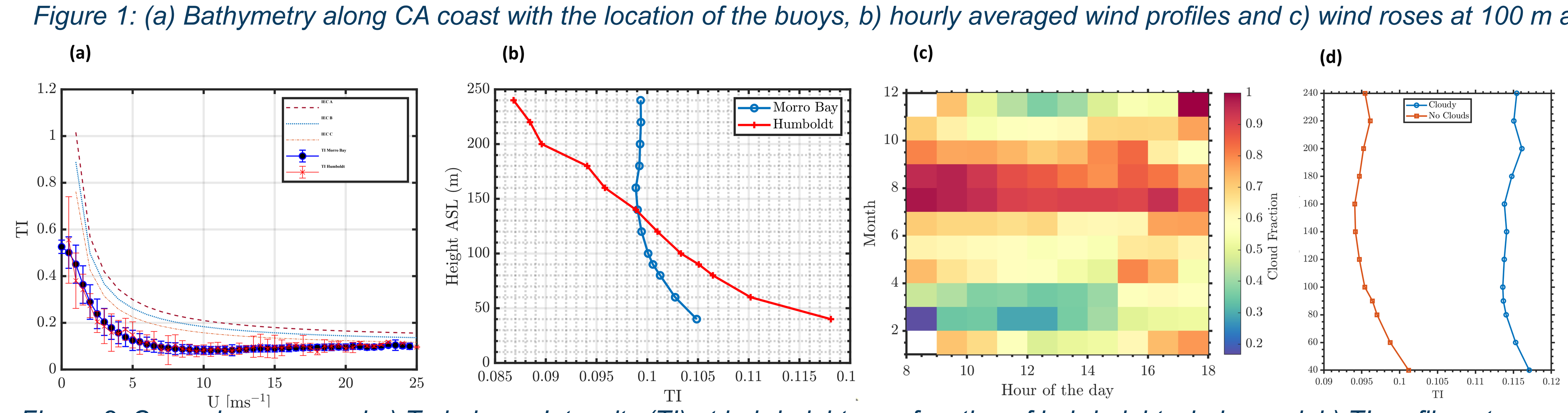


Figure 2: Campaign averaged a) Turbulence Intensity (TI) at hub-height as a function of hub-height wind speed, b) TI profiles at Morro Bay and Humboldt, c) cloud fraction at Morro Bay and d) TI during cloudy and non-cloudy conditions at Morro Bay.

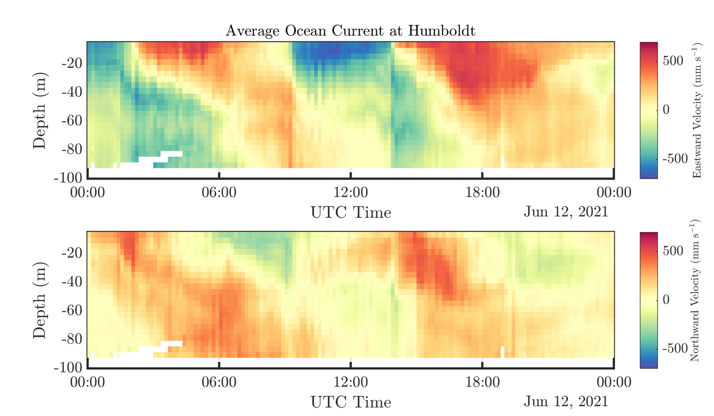


Figure 3: Current velocity component moving to the east (eastward is positive), bottom is the velocity component moving to the north (northward is positive) on June 12, 2021.

Reanalysis Model Errors

At both California coast locations, the reanalysis tends to underestimate the observed rotor-level wind resource (Sheridan et al., 2022).

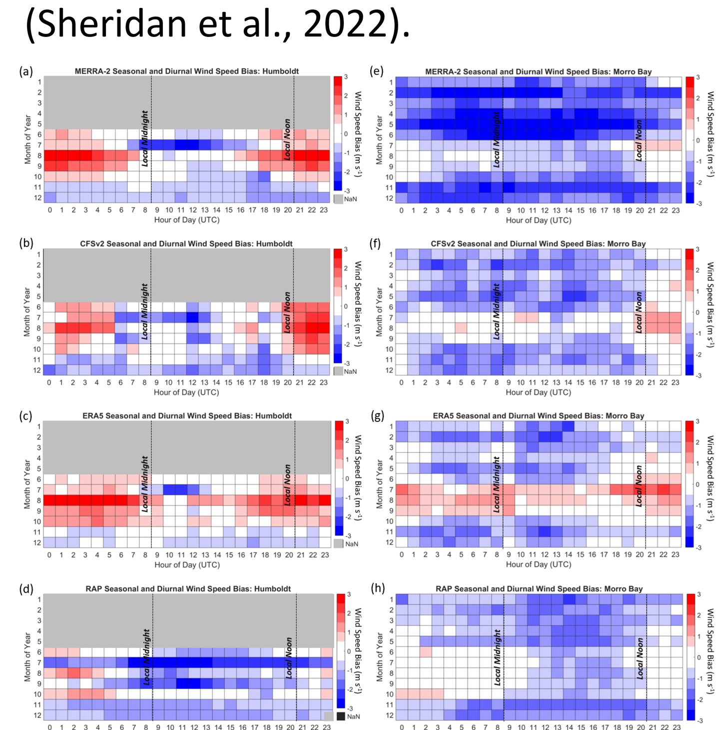


Figure 4: Seasonal and diurnal wind speed bias between obs and reanalysis

WW3 Model Calibration

A spectral wave model based on WW3 was developed and calibrated for the region offshore California. It covers the three BOEM call areas with a 3 km spatial resolution (Garcia Medina et al., 2020).

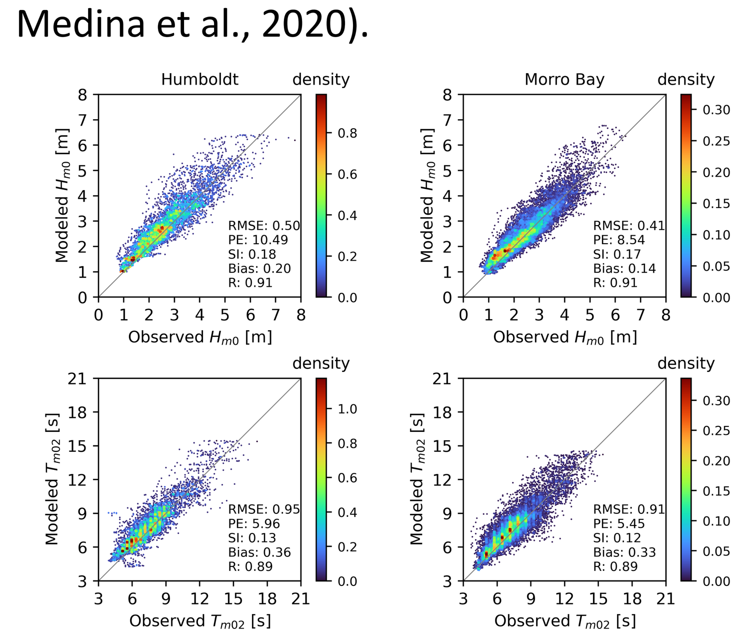


Figure 5: Error statistics on the total sea state during the hindcast period at Humboldt and Morro Bay deployments.

Wind-Wave Coupled Mesoscale Model

Under certain conditions the interactions between waves and wind at the interface can have signatures at hub-height (Gaudet et al. 2022). Wind-wave coupling can show up to 10% improvement in hub-height wind speeds during stable atmospheric conditions.

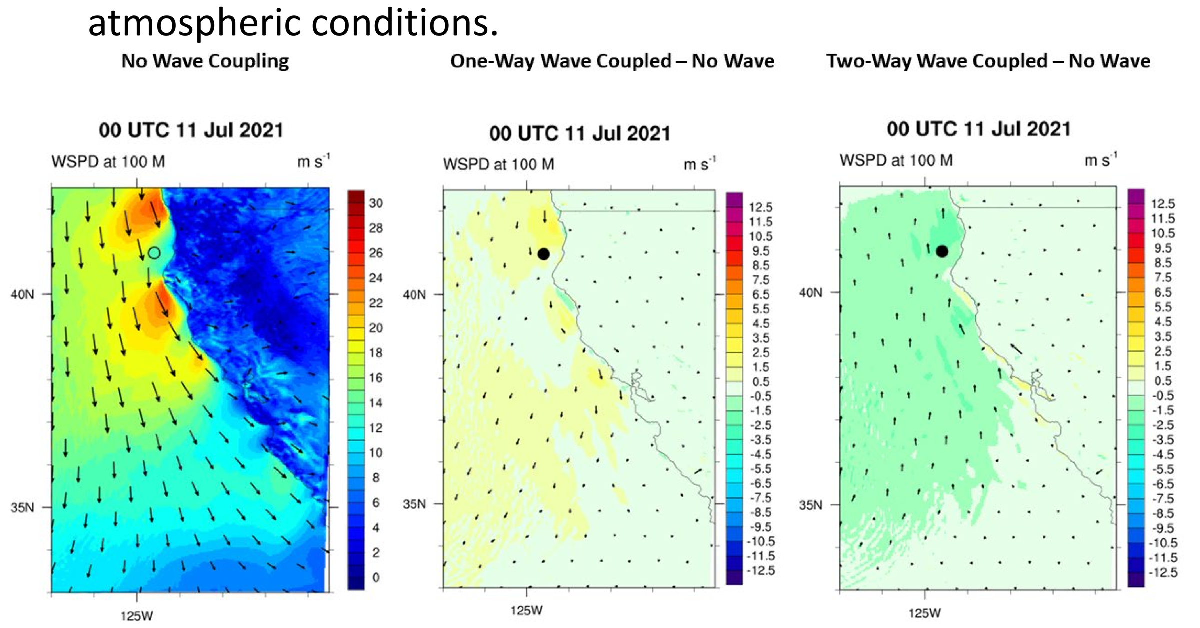


Figure 6: a) Wind speed map at 100 m without wind-wave coupling on 11 Jul 2021, b) wind speed difference between with one-way and no coupling, c) difference between two-way and no coupling.

CONCLUSIONS

- Winds blew primarily from the N-NW direction along the coast at both Morro Bay and Humboldt for majority of the year
- Boundary layer clouds increased TI within the rotor swept area. TI was higher near the surface at Humboldt likely due to possibly larger significant wave heights at Humboldt
- Reanalysis models showed that RAP had the least bias compared to other commonly used reanalysis models through the year
- The calibrated WW3 hindcast model provides a baseline surface roughness characterization for localized high-resolution wind models developed as part of this project. The provided characterization will allow investigation into complex weather phenomena in the region
- Two-way versus one-way coupling methods can lead to substantially different results, depending on parameterization

ACKNOWLEDGEMENTS

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