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Wave Resource Characteristics Near Humboldt Bay – Results from a 10-year Hindcast

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Introduction

- Assessment of the spatial variation of wave characteristics is important when conducting wave characterization studies for WEC test and deployment sites
- Potential wave energy converter (WEC) test/commercial deployment site offshore of Humboldt Bay, CA was selected to investigate
  - performance of a nearshore SWAN model
  - spatial variability of wave statistics within and around the site
- Predicted significant wave heights were overbiased due to Climate Forecast System Reanalysis (CFSR) winds used to drive WAVEWATCH III
- Spatial variability of wave statistics calculated from the hindcast simulation were found to vary by season and were affected by the wind direction
- Spatial variation of significant wave height across an assumed typical test site is almost negligible; at most about 0.1 m in both winter and summer

Model Setup

- The most likely onshore connection point for a future test or deployment site is signified in Fig. 1
- This is the connection point for the former Pacific Gas & Electric's (PG&E) pilot project test bed, Humboldt WaveConnect (HWC)

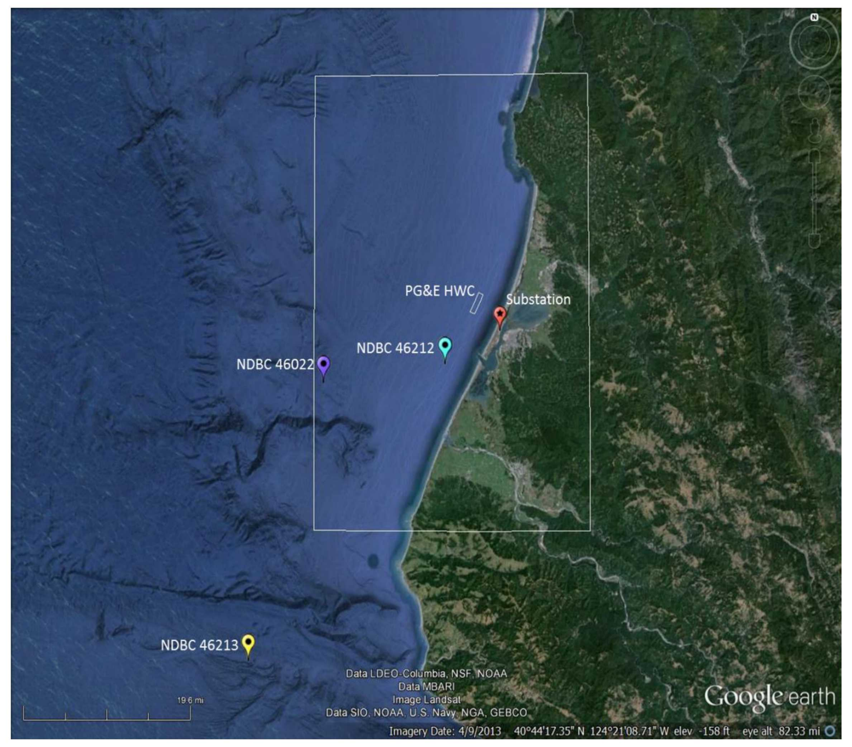

Figure 1. SWAN domain (larger white box), NDBC 46022, NDBC 46212, and NDBC 46213 buoys (purple, blue, and yellow marker), the PG&E Humboldt WaveConnect (HWC) array location (small white box), and the potential onshore substation site (red marker).

- SWAN model domain, 0.002° (~200 m) grid, in Fig. 2
- WAVEWATCH III forced with 0.5° CFSR winds every 6 hours and ~1.88° ice data every 24 hours; implemented to get boundary conditions for SWAN
- Wind input not used in SWAN because of short fetch (e.g., as found in García-Medina et al. 2013)
- Breaking, friction, triads enabled in SWAN; default parameters used
- Negligible sensitivity to variations in parameterizations for friction and whitecapping (considered depths 30 m or greater)
- 10 years (Jan. 2000 – Dec. 2009) simulated to provide statistics for site characterization (Dallman & Neary 2014)

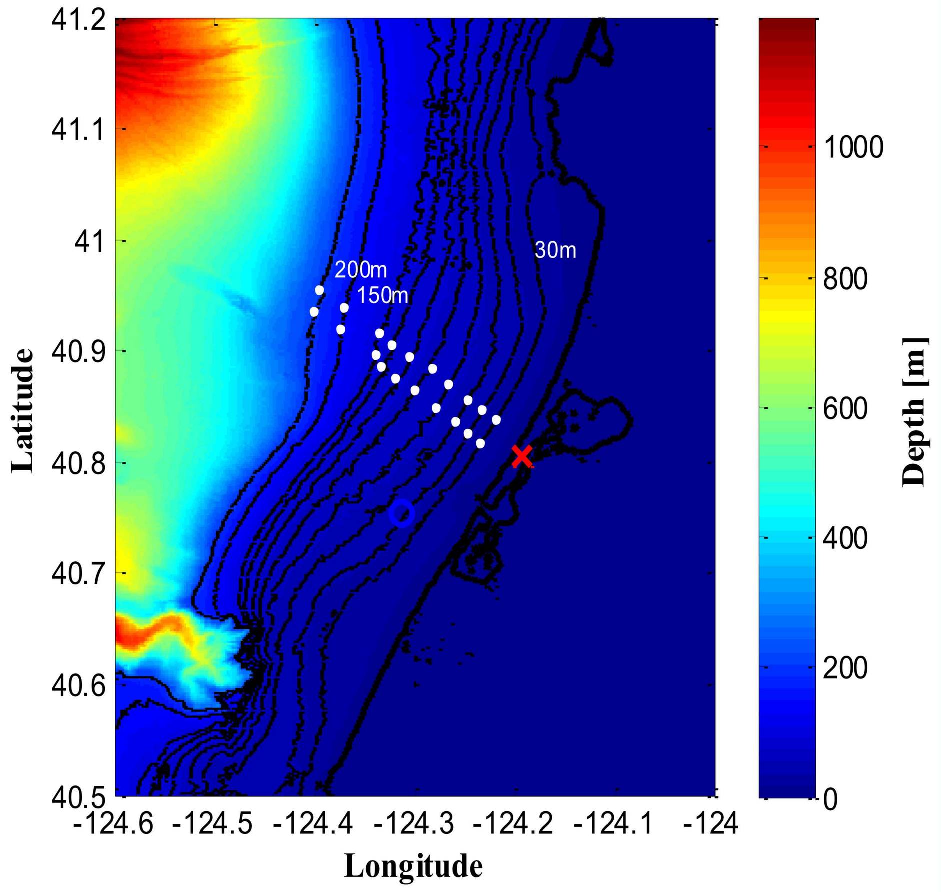

Figure 2. Depth over the SWAN domain. The white dots are spectral output locations, the onshore connection point is marked as a red x, and the location of NDBC 46212 buoy is marked as an open circle. Depth contours are shown every 10 m from 30-100 m, along with the 100 m and 150 m contours.

Spatial Variation

- Spring is defined as March – May, summer as June – August, fall as September – November, and winter as December – February
- In the winter the contours of significant wave height align well with the depth contours as they approach the shore (Fig. 3)
- The size of an example WEC test site might be 1 square nautical mile (~1.85 km²), about the distance between the 40 m and 50 m contours
- Spatial variation of H_{m0} would then be at most about 0.1 m in the direction perpendicular to contours (with very little variation along contours)

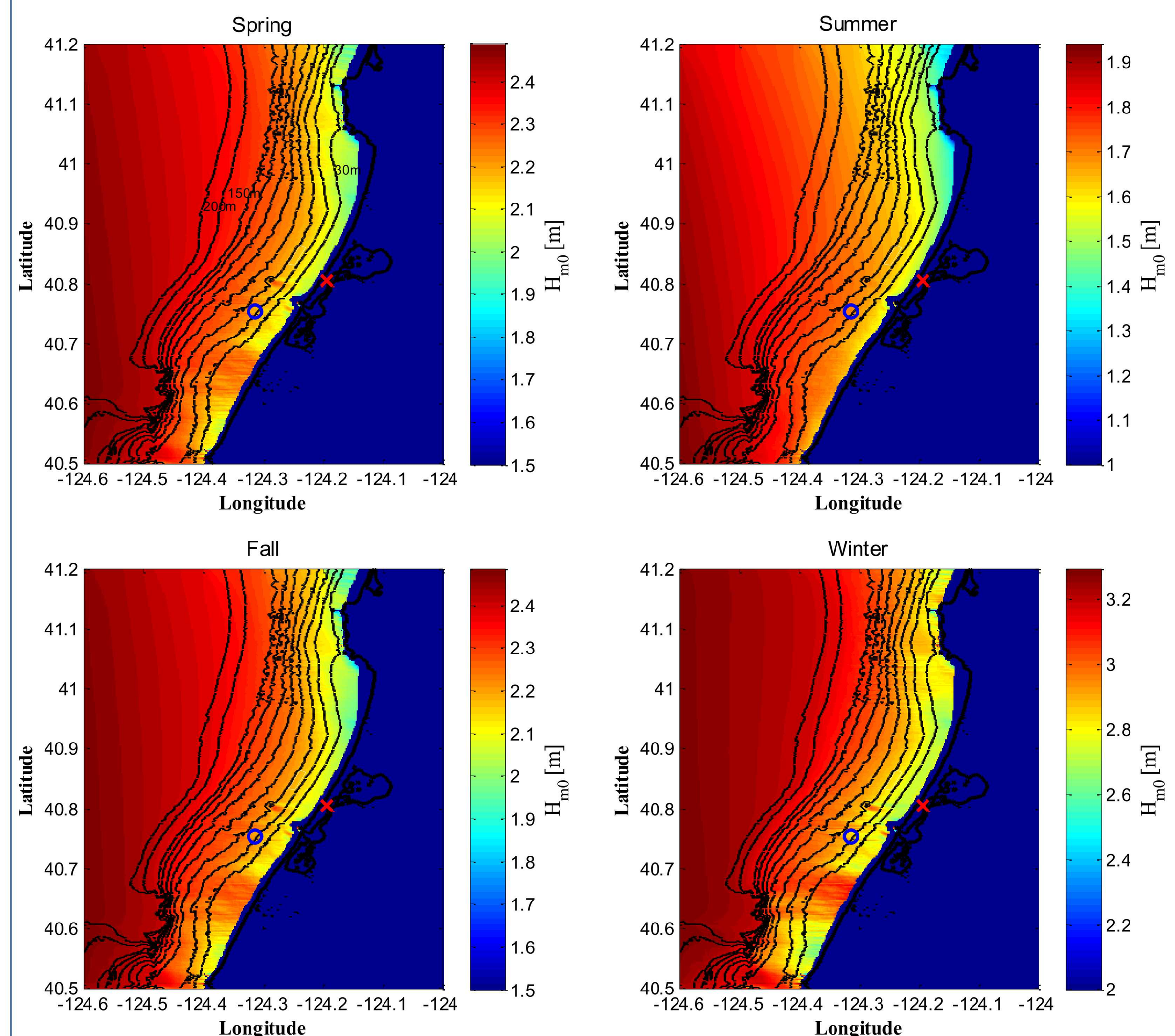

Figure 3. Average significant wave height over the domain for each season. Each season has a different color bar to emphasize the variability over the domain. The onshore connection point is marked as a red x, the location of the NDBC 46212 buoy is marked as an open blue circle, and the HWC location is outlined in white. Several depth contours are shown, and are labeled in the Spring (top left) figure.

- Summer waves are dominated by winds from the north/northwest
- Summer peak wave direction is from northwest (around 300°, Fig. 4)

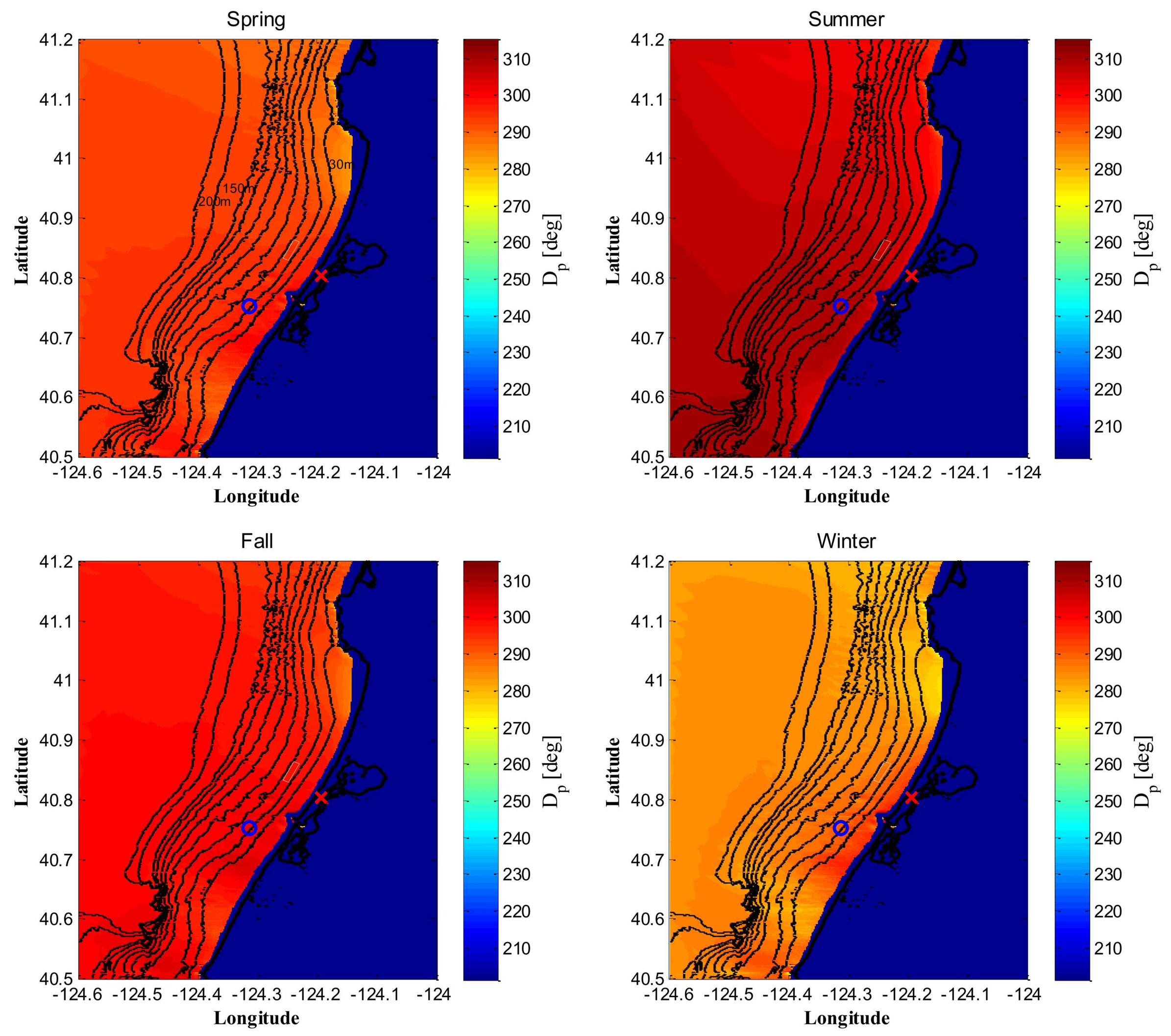

Figure 4. Average of the peak wave direction, D_p, over the domain is shown for each season. The same color bar has been used in all seasons to emphasize the seasonal variability. Depth contours are shown every 10 m from 30-100 m, along with the 100 m and 150 m contours.

- North of model domain, land protrudes out to the west, causing sheltering of north/northwesterly winds (and therefore waves) during the summer
- In the southern part of the SWAN domain (around 40.5 N), the sheltering begin to clear and the heights are larger
- H_{m0} variation is still less than 0.1 m in 1 square nautical mile in the summer

Variation of Parameters Offshore of Substation

- The six parameters from the IEC Technical Specification on Wave Energy Characterization (Folley et al. 2012, also see Dallman et al. 2014 for definitions) are compared at output points in Fig. 2
- Solid line is 40 m depth, dotted line is 80 m depth offshore of substation
- Monthly variation is similar, but higher H_{m0} and J at 80 m depth
- As found in García-Medina et al. 2014, directional spread of wave power narrows (larger d_θ) with decreasing depth

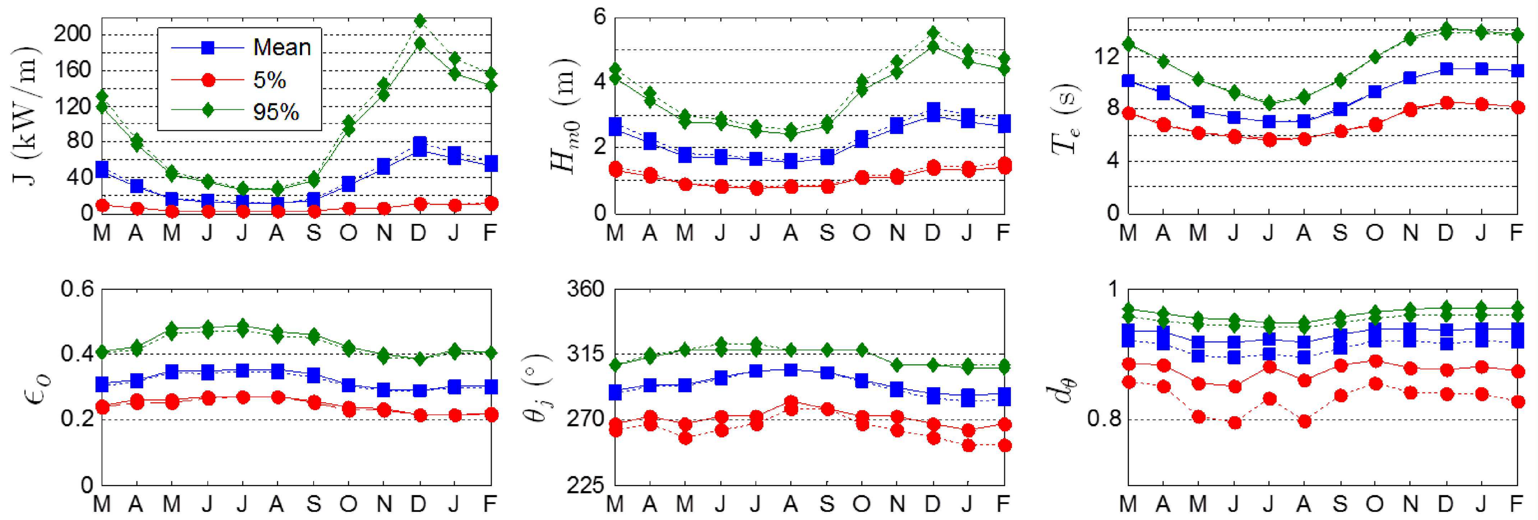

Figure 5. Monthly values of the six IEC TS parameters directly offshore of the substation at 40 m depth (solid line) and 80 m depth (dotted line).

Model Performance

- The six IEC TS parameters are compared to buoy data
- Visual comparison (see Dallman et al. 2014) showed good agreement between the model and buoy data

Table 1. SWAN performance metrics for the years 2004-2009 at NDBC 46212.

	RMSE	RMSE (%)	PE	SI	Bias	Bias (%)	R
J	17.1 kW/m	58%	52%	0.58	5.0 kW/m	17.1%	0.92
H_{m0}	0.37 m	18%	19%	0.18	0.11 m	5.5%	0.93
T_e	0.83 s	9%	9%	0.09	-0.14 s	-1.5%	0.92
ϵ_0	0.05	15%	14%	0.15	-0.01	-3.39%	0.75
θ	8.0 °	3%	3%	0.03	-2.1 °	-0.71%	0.92
d_θ	0.07	8%	14%	0.08	0.05	5.24%	0.56

Conclusions

- Model performance was similar to other SWAN models in the literature
- In general, the H_{m0} was slightly overpredicted, which led to a significant overprediction of the omnidirectional wave power (important to note for resource characterization); due to bias in CFSR wind
- Amount of variation along depth contours depends on the season; higher variation in the summer due to the wind and wave sheltering from the protruding land on the coastline north of the model domain
- Spatial variation along an assumed typical test site of 1 square nautical mile is almost negligible; at most about 0.1 m in both winter and summer
- Six wave characterization parameters varied with depth (larger wave power and height, smaller directionality coefficient at greater depths) but showed very similar trends (e.g., larger wave power, height, and period, directionality coefficient in winter; larger spectral width in summer)

References

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