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Evaluating the Accuracy of WRF Simulations for Vertical Wind Profiles at Coastal Locations: A Comparison of Measurement Data and PBL Schemes.

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SUMMARY:
This study investigates the accuracy of vertical wind profile simulations using the Weather Research and Forecasting (WRF) model for ocean and estuary coast locations. The study compares wind measurement data from towers at various heights with numerical simulations using different planetary boundary layer (PBL) schemes and mesoscale grid resolutions. The simulations use a nested domain of 12 km, 3 km and 1 km. A comparison is made based on real data obtained from three meteorological stations and satellite data in the two coastal regions, two towers on the oceanic coast and one on the estuary of the Rio de la Plata. The towers are equipped with cup anemometers, wind vanes and three-dimensional 32-Hz ultrasonic anemometers. The study focuses on analyzing a low wind and a high wind scenarios. The results show the performance of the WRF model in simulating the wind profiles during. The study also analyzes the impact of different model configurations on the accuracy of the simulations. The partial results show that the model underestimates lower level winds and the inverse over higher levels.

Keywords: offshore, wind profiles, WRF

1. INTRODUCTION

Mesoscale models such as WRF Skamarock et al., 2019 are particularly relevant in the case of offshore wind resources. Li et al., 2021 performed WRF simulations over the Baltic Sea, a study of model sensitivity to multiple model configurations, including domain setup, grid resolution, sea surface temperature, land surface data, and atmosphere-wave coupling. The simulated offshore wind was evaluated against LiDAR observations under different wind directions, atmospheric stability, and sea status. The study shows that increasing the vertical resolution, and updating the sea surface temperature and the land surface information only had a slight impact, mainly visible during very stable conditions. Increasing the horizontal resolution also had a slight impact, most visible during unstable conditions. Hasager et al., 2016 have analyzed long-term variability of wind regimes in the North Sea and South China Sea, with WRF and satellite-based wind data comparison.

In Gutiérrez and Fovell, 2018 is described diurnal cycles of atmospheric stability regimes, for the analyzed region in the present work. In Ignacio Franco, 2021 it was analyzed velocity integral scale at one of the analyzed location of the present work, La Paloma, a coastal location in Uruguay, using measurements from three three-dimensional 32-Hz ultrasonic anemometers.

In the present study, we analyze the performance of different Planetary Boundary Layer (PBL) configurations on WRF simulations during a high wind scenario (day 1) and a low wind scenario (day 2), both blowing from the SE quadrant. The real data is obtained from three meteorological stations near the coast side and from satellite. The wind profiles are evaluated at six simulation nodes, three on the ground and three on the sea.

2. OBSERVATIONAL WIND DATA, TOWER LOCATION AND WRF DOMAIN

The analyzed wind data represent the mesoscale wind of two sea coast regions, the first region is close to the La Plata River, including an estuary composed of seawater and freshwater from the Paraná River and the Uruguay River, and is the site of the Mc Meekan tower (MC2) over the coordinates 34.64S, 56.7W. The second region is close to the Atlantic Ocean, its tower being called Jose Ignacio (JI) and La Paloma port (LP). They are located over the coordinates 34.85S, 54.74W, and 34.65S, 54.14W respectively.

On the one hand, MC2 and JI towers are equipped with two anemometers mounted orthogonally to filter the effect of the tower wake. On the other hand, the LP tower has a single anemometer per level, each of them installed at 3.5 m from the tower to reduce the effect of the tower wake. The installation adhered to standard IEC-61400-12, 1998 on both cases.

JI and MC2 wind measurements were performed with cup anemometers (NRG Systems 40, with a distance constant of 3 m) and wind vanes (NRG Systems 200P) mounted at 12.4 m, 40 m, 60.8 m and 98.4 m for the JI tower and 10.4 m, 30 m, 64 m, and 101.5 m for the MC2 tower. LP wind measurements were done with three-dimensional 32-Hz ultrasonic anemometers mounted at 12 m, and 66 m.

WRF simulations used version 4.3 and employed a nested domain with a horizontal grid spacing of 12 km (D1), 3 km (D2) and 1 km (D3) and 150×150, 98×98, 119×119 grid point respectively. The domain is centered over each station's coordinates, with an initial and boundary layer condition from GFS. All simulations employed 51 vertical layers, where the resolution near the surface is very fine and decreases gradually with altitude. Common model physics selections include the RRTM longwave Mlawer et al., 1997 and Dudhia shortwave Lacis and Hansen, 1974; Stephens, 1978 radiation schemes, Lin microphysics Yuh-Lang Lin, 1983, and the Noah land surface model Chen and Dudhia, 2001. The Kain–Fritsch Kain, 2004; Kain and Fritsch, 1990 cumulus scheme, and PBL planetary boundary layers scheme Mellor-Yamada-Janjic (Eta) TKE scheme, Mellor and Yamada, 1974, 1982.

3. ANALYSIS OF VERTICAL WIND PROFILES

Figure 2 depicts a comparison between day 1 (left) and day 2 (right) scenarios of measurements taken over the LP tower at the two different heights, 66 m (top) and 12 m (bottom). The analysis is made using both anemometers and six WRF nodes close to the exact tower's coordinates, three on the ground and three on the sea.

The simulation shows a larger difference between nodes on the lower levels as expected and almost negligible on higher levels. The nodes that best represents the real data for day 1 is sea#2 for lower

Figure 1. Towers locations

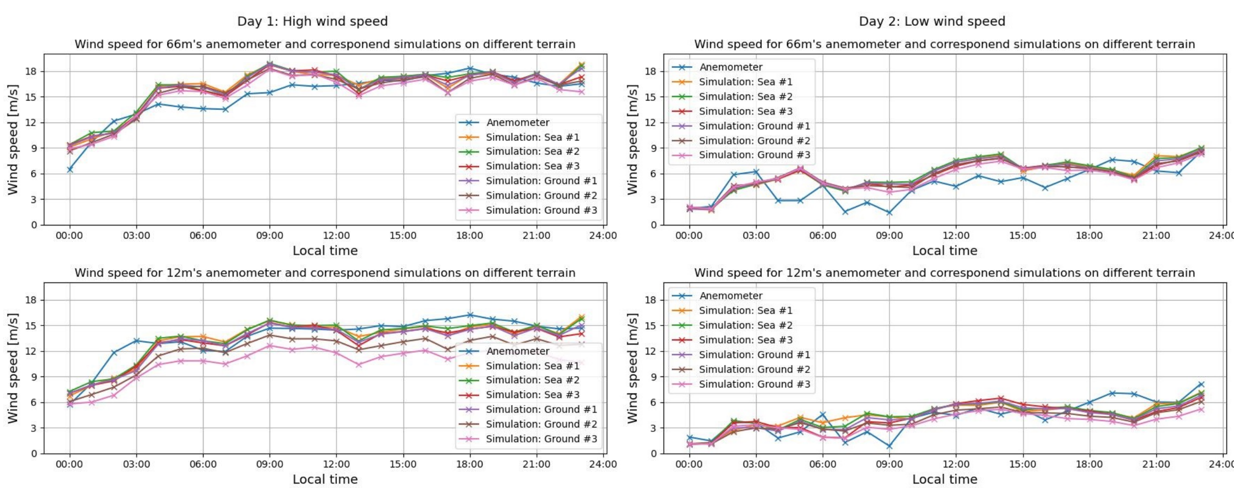

Figure 2. Vertical wind profiles comparison

heights and ground#3 for higher heights, with a bias of 0.176 m/s and -0.186 m/s, and a rmse of 3.331 m/s and 3.667 m/s, respectively. The same way for day 2 are ground#2 for lower heights and ground#3 for higher heights, with a bias of 0.382 m/s and -0.771 m/s, and a rmse of 2.335 m/s and 2.624 m/s, respectively, figure 1.

On both cases it can be seen that on lower levels the simulation underestimates real data and the opposite behavior on higher levels.

4. CONCLUSIONS

WRF simulations were analyzed using real data from three-dimensional ultrasonic anemometers from a tower near the Atlantic coast of Uruguay (LP). A comparison was made between the WRF simulations and the wind measurements taken at different heights from the tower for two wind scenarios. The results showed that the WRF model had better performance in simulating offshore wind conditions for the first scenario and onshore wind conditions for the second scenario.

Further work will include different PBL parametrization and different grid resolutions, as well as data from the JI and MC2 towers and satellite wind measurements.

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