What grid resolution do you need for offshore wind flow modeling?

Philippe Beaucage and Beanan O'Loughlin | UL Solutions | Philippe.Beaucage@UL.com & Beanan.OLoughlin@UL.com

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INTRODUCTION

There are no industry standards for offshore wind resource mapping but mesoscale numerical weather prediction models such as the Weather Research and Forecasting (WRF[1]) appear to be the common approach for offshore wind flow modeling.

For more than two decades, UL Solutions has relied on Sitewind[2], a coupled mesoscale-microscale modeling system. The current version of Sitewind is based on the mesoscale model WRF and the in-house microscale model WindMap[3]. For onshore projects, UL Solutions typically runs 1 km resolution WRF simulations which are then downscaled to 50 m resolution by the microscale model. However, the 50 m Wind Resource Grids (WRG) become too large and cumbersome when modeling large offshore areas. UL Solutions is currently examining the impact of varying WRG grid sizes on the wind flow and energy production estimates at 48 offshore wind farms in the US and the UK (see Table below).

Offshore Areas	Country	Waters	Number of wind farms	Distance to Shore
New York and New Jersey	USA	Atlantic	11*	15 to 121 km
Central Atlantic	USA	Atlantic	2*	16 to 64 km
Northern California	USA	Pacific	2*	33 to 60 km
Southern California	USA	Pacific	3*	27 to 66 km
Wales and Northwest	UK	Irish Sea	12	6 to 38 km
East of England	UK	North Sea	8	5 to 75 km
Southeast of England	UK	North Sea	9	5 to 54 km
South of England	UK	English Channel	1	13 to 20 km

* Hypothetical farms

[1] Skamarock, W. C. (2004). "Evaluating Mesoscale NWP Models Using Kinetic Energy Spectra". Mon. Wea. Rev., vol. 132, pp. 3019-3032.

[2] Brower, M. et al. (2004). "Mesoscale modeling as a tool for wind resource assessment and mapping". Proceedings from the AMS conference. Seattle, USA. 7 pp.

[3] Brower, M. (1999). "Validation of the WindMap Program and Development of MesoMap". Proceedings from the AWEA WindPower conference. Washington, USA. 10 pp.

METHODOLOGY

For each offshore areas listed in the table above, UL Solutions had access to meteorological time series from floating lidar systems or offshore met masts thanks to the UK Marine Data Exchange, NYSERDA, DOE and others. UL Solutions ran its Sitewind modeling system at different spatial resolution to study the impact of the grid spacing, i.e. 50 m, 200 m and 1 km WRGs, on the energy production estimates. Standard frequency distribution energy captures were carried by the Openwind software to calculate turbine-induced wake and induction losses. An additional plant loss of 10% was added to account for availability, electrical, turbine performance, environmental and curtailment losses and simulate the net energy production at the offshore wind farms. Based on UL Solutions' review of operational plant data, this additional plant loss value of 10% appears to be typical for offshore wind farms in Europe. Below is a list of necessary inputs for the energy capture in Openwind for this study:

- Met time series (from floating lidars or offshore met masts)
- Binary WRGs with terrain elevation and surface roughness maps
- Wind farm layouts and turbine characteristics

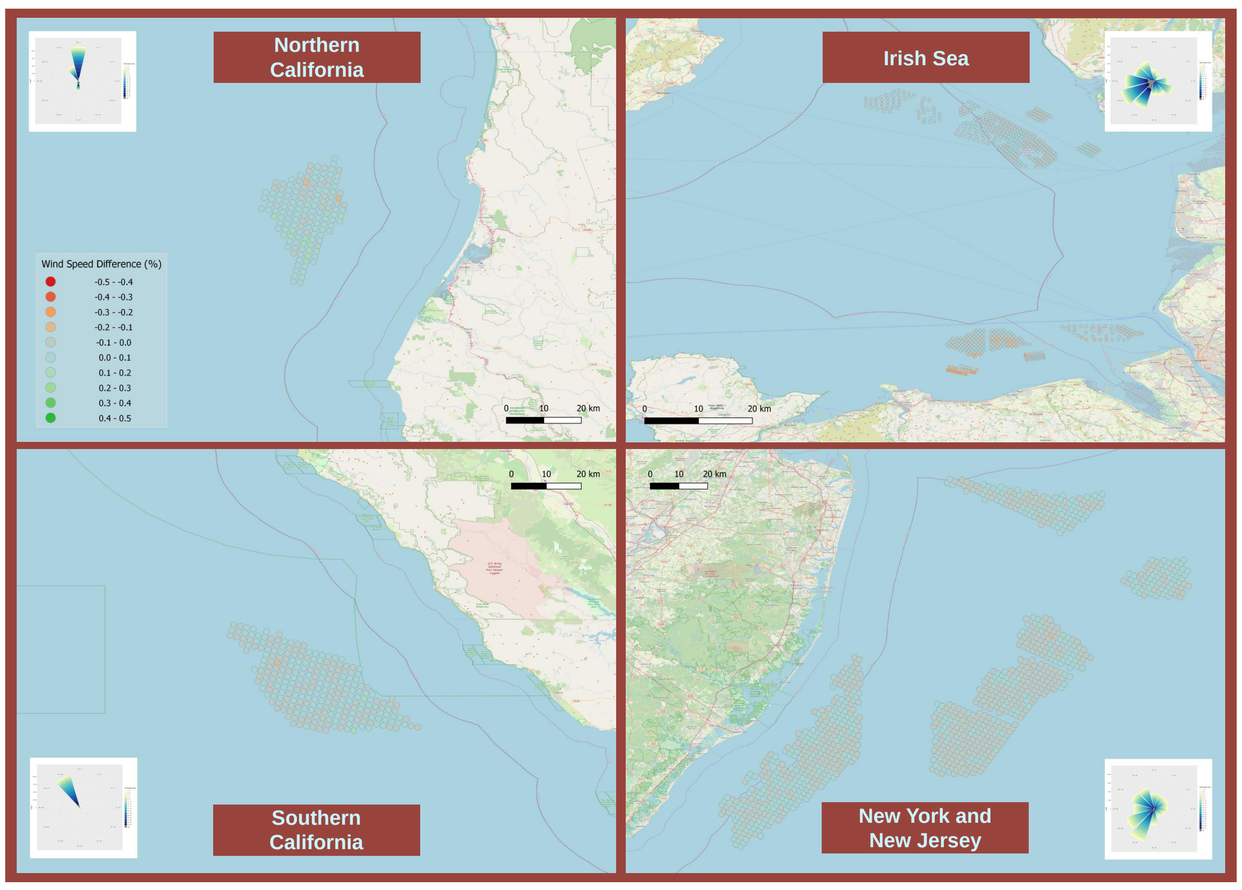
For the offshore wind plants in the US, hypothetical plant layouts were built within the BOEM lease areas[4] by placing 15 MW NREL[5] reference wind turbines every one nautical mile within the lease areas.

[4] https://www.boem.gov/sites/default/files/documents/renewable-energy/All-States-Poster_1.pdf

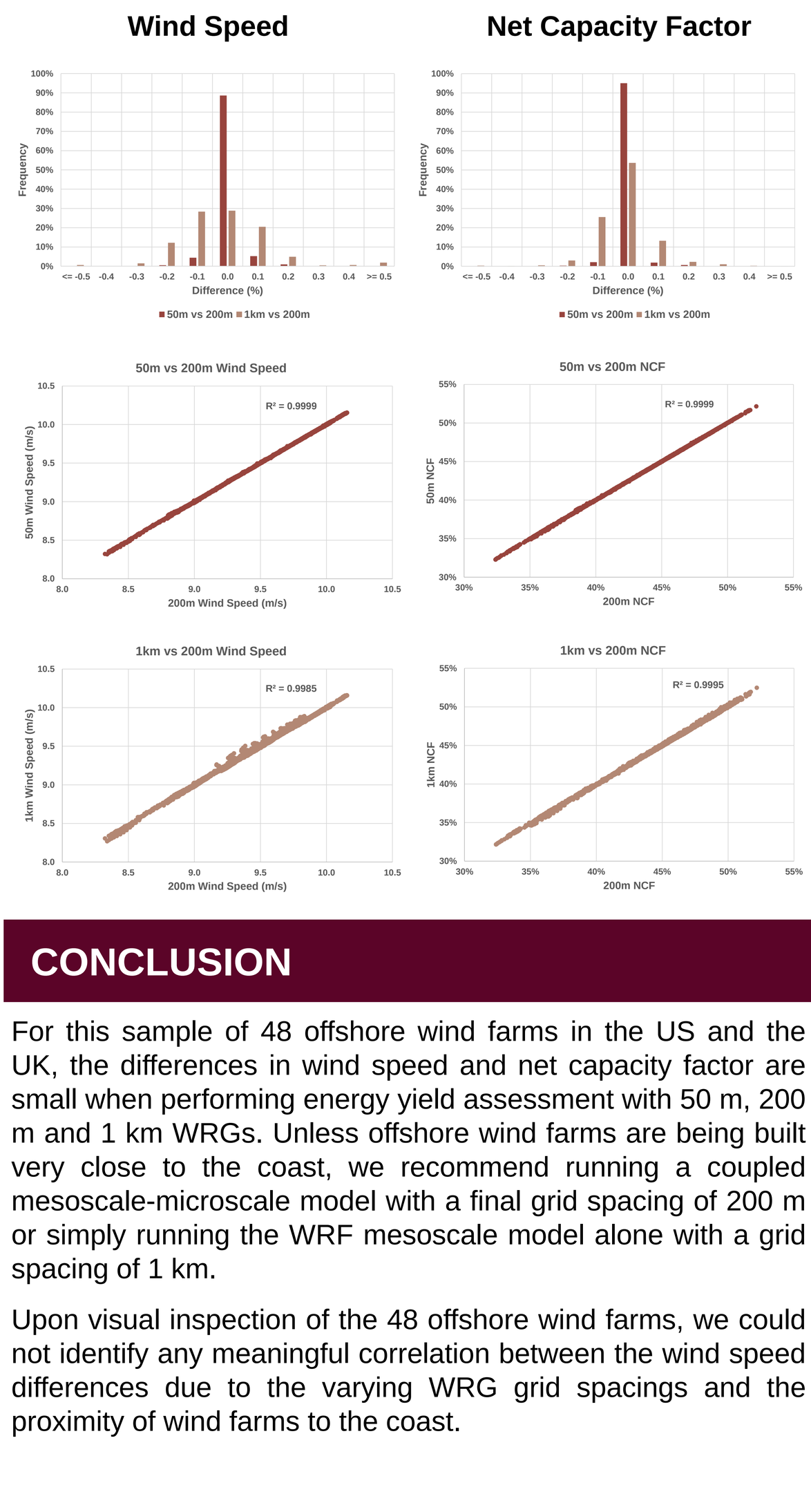
[5] Gaertner, E. et al. (2009). "Definition of the IEA 15-MW Offshore Reference Wind Turbine". Technical Report NREL/TP-5000-75698, 44 pp.

SENSITIVITY TO RESOLUTION OF WRG

Wind speed differences between 50 m and 200 m WRG for hypothetical layouts in US offshore areas, and as-built in the UK.



Wind speed and net capacity factor (NCF) differences for varying WRG grid spacings at all turbine locations of the 48 offshore farms



CONCLUSION

For this sample of 48 offshore wind farms in the US and the UK, the differences in wind speed and net capacity factor are small when performing energy yield assessment with 50 m, 200 m and 1 km WRGs. Unless offshore wind farms are being built very close to the coast, we recommend running a coupled mesoscale-microscale model with a final grid spacing of 200 m or simply running the WRF mesoscale model alone with a grid spacing of 1 km.

Upon visual inspection of the 48 offshore wind farms, we could not identify any meaningful correlation between the wind speed differences due to the varying WRG grid spacings and the proximity of wind farms to the coast.

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