Abstract content

Abstract Title:

STUDY OF THE OFFSHORE WIND SPEED RELATIVE TO THE SHORE DISTANCE: PRELIMINARY RESULTS

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1. Introduction:

In the UK, there is an interest in the expected offshore wind resource given ambitious national plans to expand offshore capacity. At the end of 2014, the UK had the largest capacity of offshore wind generation worldwide. There is also an increasing interest in alternative datasets to minimise the requirement for offshore masts. These alternatives include global reanalysis datasets.

State-of-the-art meteorological models solve the equations describing the atmospheric processes and changes in time on a three-dimensional grid (unlike wind measurements taken at particular levels at irregular surface locations). Multiple meteorological models are run at different spatial scales providing long-term homogeneous time series for an entire simulation domain. Therefore, reanalysis datasets as a source of meteorological information derived from numerical weather prediction (NWP) models are more appropriate for large area offshore resource studies than using solely historical weather observations from ships, buoys, satellites, aircraft, balloons, and surface stations.

In particular, ERA-40 is a second generation reanalysis of the global atmospheric data over 45-years period from 1st September 1957 to 31st August 2002, created from a European Centre for Medium-Range Weather Forecasts (ECMWF) Integrated Forecast Model. The model has observations recorded every 6-hourly through a 3D variational analysis and has been used in a variety of research projects to evaluate wind seasonal and inter-annual cycles which can be very useful in the initial stages of the design of wind farms in order to identify prospective areas where local measurements can then be applied to determine small-scale variations in the marine wind climate.

2. Approach:

The ERA-40 reanalysis dataset is used in this paper as source of 21 years of meteorological information to study the offshore wind patterns around the UK relative to shore distance, comprising the period from 1st January 1968 to 31st December 1989.

The wind data used in this study are on a geographical grid with a horizontal resolution of 1º x 1º every 6 hours at 10 metres height. The approximate centre points of the original nine offshore regions defined by the Crown Estate Round 3 were selected as the study sites. Due to the fact that the study sites were not located exactly on the grid points of the ERA-40 database, values were bi-linearly interpolated from the 1º x 1º grid.

The statistical analysis undertaken in this research comprised: a study of the offshore wind speed and direction patterns and an analysis of the wind speed as a function of the distance to the coast. Trends are discussed and the main findings of the analysis are summarised.

3. Main body of abstract:

As was stated above, this paper used reanalysis data in order to study nine offshore UK sites. The study sites were selected as the approximate centre of each of the nine development sites that comprise the original UK Crown Estate Round 3 offshore wind programme. As can be seen in the following Figure:

Figure 1. UK map with the geographical locations of the Round 3 study sites.

The mean wind speed as a function of distance to the coast for the nine Round 3 sites is shown by the points plotted in Figure 2 and 3Figure for the long term period and by season, respectively. It can be seen that there is a relationship between mean wind speed and distance. There is evidence of the wind speed reaching an asymptotic values at large distances. Although all the sites considered are offshore, clearly, the wind speed at the coast would be expected to be non-zero. With this in mind, an empirical expression for the mean long term offshore wind speed as a function of distance from the coast was proposed of the form:

$$\mathbf{u} = \mathbf{u_0} * \left(\mathbf{a} - \sqrt{\frac{\mathbf{x_0}}{x + \mathbf{x_0}}}\right) \quad (1)$$

where $\mathbf{u}$ represents the mean wind speed at a distance $\mathbf{x}$ from the nearest coast line, $\mathbf{a}$ is a dimensionless constant equal to 2. The empirical parameter $\mathbf{x_0}$ is a distance scale which reflects how quickly the wind speed adjusts to the offshore conditions. The value of $\mathbf{u_0}$ and $\mathbf{x_0}$ were fitted for the long term period and by season using a least squared fit in the Mathematica programming evironment. The fits are shown as dotted lines in Figure 2 and 3; and the values of $\mathbf{u_0}$ and $\mathbf{x_0}$ are given in Table 1 along with the coefficient of determination R^2 and the estimated bias for each fitted value.

Table 1. Values of $\mathbf{u_0}$ and $\mathbf{x_0}$ used to fit Eq. 1 to the mean 10m wind speeds showed in Figure 2 and 3.

	$\mathbf{u_0}$ [m/s]	$\mathbf{x_0}$ [km]	R^2	Estimated bias
Whole period	4.4	17.2	0.9970	0.146
Winter	5.3	18.9	0.9965	0.252
Spring	4.0	11.3	0.9979	0.047
Summer	3.3	11.9	0.9985	0.029
Autumn	5.0	24.8	0.9944	0.703

The wind speed would equal $\mathbf{u_0}$ at the coast and would asymptote at large distances to $2\mathbf{u_0}$, however, it should be stressed that the fit has only been made between the closest site at 22km and the furthest at 223km, so would only strictly be valid in this range. Although it can be seen that there is some degree of scatter for the values at each site around the trend lines, the empirical expression in Eq. 1 does provide a reasonable fit to the data over a range of distances between ~20km and ~250km from the coast.

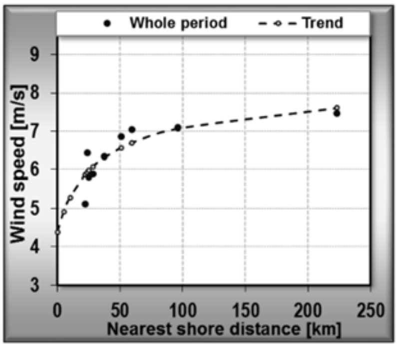

Figure 2. Distribution of the averages wind speed relative to the shore distance and the interpolation points over the whole study period.

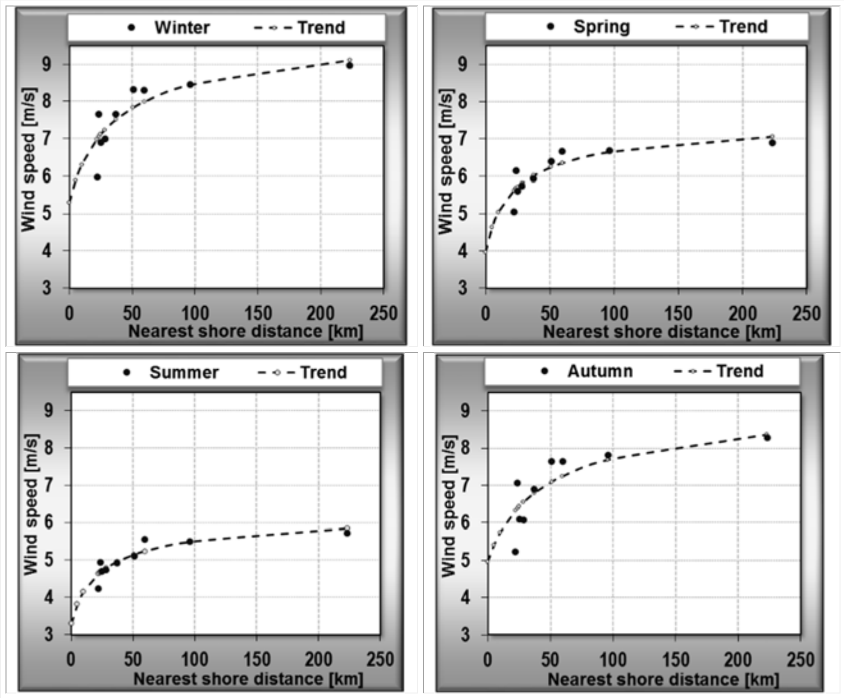

Figure 3. Distribution of the averages wind speed relative to the shore distance and the interpolation points for each season of the study period.

Table 2Table below presents the fitted values for the average wind speed of each study site over the whole study period. The corresponding standard error and the confidence interval are also listed. The confidence interval was computed with a confidence level of 95% for each average wind speed fitted.

Table 2. Wind speed fitted and relevant statistical values computed over the whole period for each study site.

Site ID	Shore distance [km]	Wind speed average [m/s]	Wind speed fitted [m/s]	Standard Error	Confidence Interval [m/s]
1	24	5.12	5.873	0.1578	{5.501, 6.245}
2	51	6.45	5.926	0.1589	{5.550, 6.302}
3	223	5.82	5.975	0.1598	{5.597, 6.352}
4	96	5.88	6.079	0.1598	{5.701, 6.457}
5	60	6.34	6.309	0.1524	{5.949, 6.669}
6	22	6.86	6.573	0.1399	{6.242, 6.904}
7	28	7.04	6.702	0.1383	{6.375, 7.029}
8	25	7.1	7.069	0.1792	{6.646, 7.493}
9	37	7.46	7.607	0.3556	{6.766, 8.448}

4. Conclusions

This paper has used 10m long term reanalysis data in order to study the spatial characteristics of the offshore wind resource at the UK's nine Round 3 development sites. It was found a relatively simple two-parameter empirical expression has been proposed to estimate wind speed based on distance from the coast giving a reasonable fit to the data, though this needs to be validated further by analysing data from a larger number of sites and a greater range of distances from shore.

It should be also noted that the analysis in this paper is based on numerical model data and needs to be validated against operational mast data to give more confidence in the results. Nonetheless, it does provide a valuable insight into potential future wind farm performance at the UK Round 3 sites.

5. Learning objectives:

- The average wind speed can be fairly described by a simple empirical equation with just two parameters to be fitted.
- The seasonal patterns of the average wind speed can be also described by the same empirical equation with coefficients fitted for each particular season.
- Even though just 9 sites were used (as sample of each of the 9 regions comprising the UK Round 3), the equation fitted provide a useful initial tool to evaluate the potential dependence of mean wind speed as function of the distance to the coast.