Added value of high resolution forecast models in the assessment of UK offshore wind resource

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1. Introduction

The offshore wind resource of the UK is amongst the best in the world and The Crown Estate works with industry and government to bring investable opportunities to market. In December 2014 the Met Office were awarded a contract by The Crown Estate following a competitive tender process to produce a new UK wide offshore wind dataset. The purpose of the project was to provide an updated wind resource layer for use within GIS systems by improving on the methodology used in the currently available Atlas of UK Marine Energy Resources [1].

2. Approach

The approach taken to produce the UK Offshore Wind Dataset utilised two datasets that were already available to the Met Office; a very high resolution, 1.5 km horizontal resolution, UK operational forecast model archive of length 4+ years and a high resolution 4.4 km horizontal resolution European hindcast dataset spanning 1979 to present.

The European hindcast dataset was used to generate the 4.4 km resolution dataset covering the Renewable Energy Zone (REZ) Waters. The UK 1.5 km data, through a directional dependent linear regression, were used to adjust the European hindcast to produce the 1.5 km resolution dataset covering the areas of less than 40 m of water. The work enabled the Met Office to assess the benefits of using high resolution numerical model data combined with long term hindcast data on the resultant wind fields.

3. Main body of abstract

All of the forecast data used to generate the UK Offshore Wind Dataset were generated using the Met Office Unified Model (UM). The UM is a recognised state-of-the art seamless forecast and climate modelling system used operationally for both global and limited area numerical weather prediction (NWP) as well as climate and coupled atmosphere-ocean Earth-system modelling [2].

Since December 2010 the Met Office has been running a configuration of the UM called the UKV which uses a grid where the horizontal spacing decreases smoothly from 4 km at the lateral boundaries to a fixed 1.5 km across the UK [3] (Figure 1 – orange). The UKV uses incremental 3D variational data assimilation (3D-Var), where the resolution of the data assimilation is approximately half the model resolution, at ~3 km. The UKV is run and archived 4 times a day which meant that it was possible to use data that was close to the analysis time by using all 4 forecasts per day.

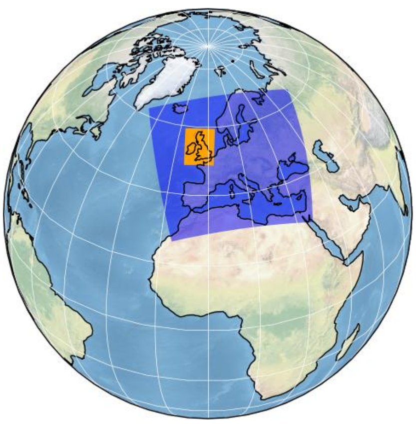

Figure 1: UKV fixed resolution inner domain (orange) and Euro4 domain (blue)

Mesoscale models are now widely used to downscale from global atmospheric reanalyses to produce hindcast datasets which can be used to provide site-specific guidance on wind resources and to produce wind maps. It has been shown that this inclusion of mesoscale models either forced by reanalyses or operational forecast models, reduces the biases substantially compared to modern reanalyses alone [4]. A 4.4 km horizontal resolution configuration of the UM covering Europe (Figure 1 – blue) was used to downscale the complete period of ERA-Interim [5] nested inside a 12 km domain slightly larger than the 4.4 km region. This set up was run every 24 hours, and all of the runs were combined producing a consistent long-term hourly dataset. The approach the Met Office has taken to producing hindcast datasets is to downscale as long a period as possible and to downscale all cases, rather than to use any statistical methods.

The UKV has 3 advantages over the European hindcast:

a. *Operational UK model*: It is the primary forecast model used at the Met Office for UK forecasts and as a result there has been significant investment in the setup resulting in an extensively verified optimal configuration.
b. *Data assimilation*: Unlike the hindcast, the UKV contains 3D-Var and as such the analyses will better reflect the observations.
c. *Resolution*: The increased resolution results in an improved land sea mask and better resolved orography. This means the UKV is able to produce finer detail around the complex coastal regions.

For 4 overlapping years the UKV forecasts and European hindcast were binned based on wind direction (twelve 30 degree bins). For each of these bins linear regression coefficients were found. These were then applied to 30 years of the European hindcast data to produce maps of average wind speed and other products. This method takes advantage of the high resolution and data assimilation of the UKV whilst utilising the long term climatological information from the hindcast.

The effects of using 30 or 15 years were looked at along with the seasonality of the datasets. In addition comparisons were done between the two datasets, for example Figures 2-4.

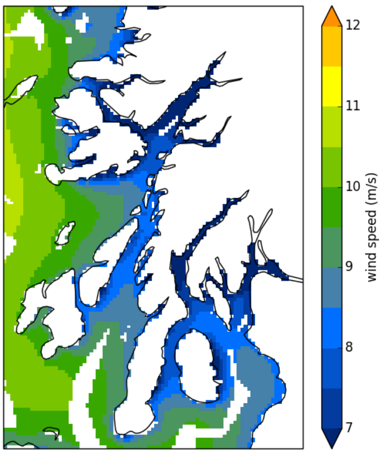

Figure 2: 1.5 km average wind speed over 30 years at 110 m

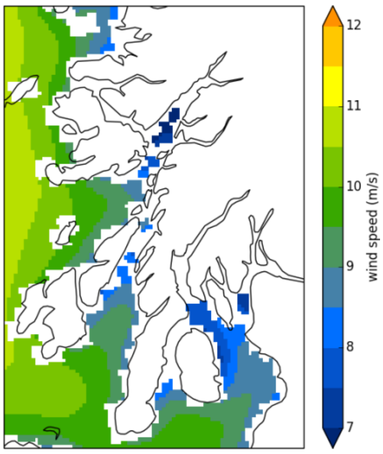

Figure 3: 4.4 km (regridded onto 1.5 km grid) average wind speed over 30 years at 110 m

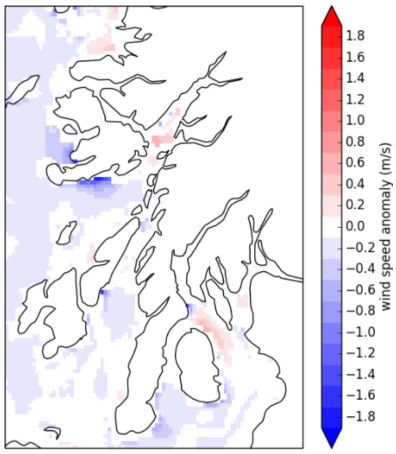

Figure 4: 1.5 km - 4.4 km, difference in average wind speed over 30 years at 110 m

The Crown Estate provided high quality cleaned met mast data at 8 sites and a variety of heights (24 site/height pairs) which were used in the validation of the datasets. These were used to both verify the method and give estimates of uncertainty. These showed the benefits of using the regression corrected winds over using the raw 4.4 km resolution winds, the mean wind speed bias across all the sites and heights was reduced from 0.102 m/s for the 4.4 km winds to 0.035 m/s for the regression corrected winds. There was an improvement at 71% of the site/heights in the bias and 100% improvement when looking at the absolute bias. Analysis of the results showed that there is significant wind resource offshore of the UK, particularly away from the coast. The north of the REZ Waters generally experiences higher winds than the south. Producing these gridded datasets enables the spatial variability of this resource to be mapped, showing where the potential is greatest and allowing comparisons between areas, such as between different near-shore locations; this near-shore comparison is only possible due to the high horizontal resolution of the data.

4. Conclusion

A 30 year UK Offshore Wind Dataset has been produced at 110 m above sea level based on numerical modelling of the meteorological conditions from December 1984 to November 2014. The dataset was produced at a 4.4 km resolution over the REZ Waters and at 1.5 km resolution over the coastal areas. The 1.5 km dataset used a directional dependent linear regression to combine 4 years of 1.5 km resolution operational wind data and 30 years of 4.4 km hindcast data.

Using very high resolution limited area models means that there is significantly increased resolution to this dataset compared to the Atlas of UK Marine Energy Resources, which was based on 12 km models. This is particularly key over coastal areas.

The dataset has been verified against 8 met masts at varying heights and it has been shown that the mean biases for these are small, 0.102 m/s for the 4.4 km data and 0.035 m/s for the 1.5 km data.

5. Learning objectives

The objective of this work was to see the benefit of using operational high resolution numerical model data to adjust a long term hindcast dataset on the resultant wind speed and wind direction fields. This was done by verifying against as many observations as possible to assess the performance and to estimate uncertainty levels.

References

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