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NORSEWIND – Mesoscale model derived Wind Atlases for the Irish Sea, the North Sea and the Baltic Sea

by

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Summary

As a part of the EU Framework 7 R&D Program NORSEWInD, Wind Atlases for the Irish Sea, the North Sea and the Baltic Sea have been developed and made public available. In the present study the development of the offshore Wind Atlases is focused on the use of mesoscale model data since the access to measurements and satellite data have been limited. Mesoscale model runs were carried out for focus areas with high spatial model resolution (2 km) and the entire Wind Atlas domain with coarser resolution (6 km). The annual average wind speed data have been long-term adjusted. Through the NORSEWInD project we have experienced that mesoscale models are efficient and accurate tools for generating offshore Wind Atlases. Long-term annual average wind speeds are estimated to have a random uncertainty of ±4.2 % and a bias of -1.3 % which is lower than what is experienced onshore. For the Weibull k-parameter we estimate a random uncertainty of ±4.0 % and a bias of -6.4 % which is higher than for the average annual wind speed. It is emphasized that the amount of validation data is small and considerable spatial variability of the uncertainty may be expected. For example, near coastal zones model errors could be expected to be larger than far offshore.

Introduction

Offshore wind resource assessment has become increasingly important as offshore wind farm development is under rapid development. The homogeneous sea surface compared to the land surface, imply that point measurements are representative for much larger areas offshore than onshore. Also, for the same reason mesoscale models are often more accurate offshore than onshore. Still, the near surface processes such as the air-sea interactions can be difficult to describe accurately with a mesoscale model. Traditional onshore micro-scale modeling by industry standard models (WAsP, WindSIM, etc.) is of less relevance for offshore Wind Atlases due to the spatial homogeneity. One exception can be very close to shorelines where strong roughness change or terrain effects may be encountered. One dimensional vertical profile modeling in the lowest few hundred meters can however be important if measured wind profiles are not available, since the mesoscale models often gives inaccurate vertical wind shear close to the surface.

One important objective of the NORSEWInD project has been to develop public available Wind Atlases for the Irish Sea, the North Sea and the Baltic Sea. The data sets available for the Wind Atlas development have been wind measurements from Lidars and meteorological masts, satellite derived wind data, and meso-scale model data. During the project a systematic collection, validation and combination of different data sets have been carried out to generate offshore Wind Atlases, and in the present paper we show final results of the Wind Atlases together with a validation and estimation of the uncertainties of key Wind Atlas parameters.

Methods

Offshore measurements by meteorological masts or Lidars, satellite data and mesoscale model data are all sources for the development of offshore Wind Atlases. In the present study we have focused the development of the Wind Atlases on application of mesoscale model data since the access to measurements and satellite data became too limited for the Wind Atlas development. Considerable efforts have been devoted into understanding the quality of the meso-scale model data, its strengths and weakness. Different mesoscale model runs were carried out for the purpose of the NORSEWInD Wind Atlases. In particular, two focus areas with high horizontal resolution (2 km) were included. Also a mesoscale model data set with a coarser horizontal resolution (6 km) was developed for the whole Wind Atlas region. An example on a fine-scale model domain set-up is given in Figure 1. For the final Wind Atlases a combination of the finer scale runs and the coarser domain run covering the entire Wind Atlas area is applied. Long-term corrections are also applied to the annual average wind speeds. In this study we present results for the Irish Sea and the North Sea. Results for the Baltic Sea are found in [1] and [2].

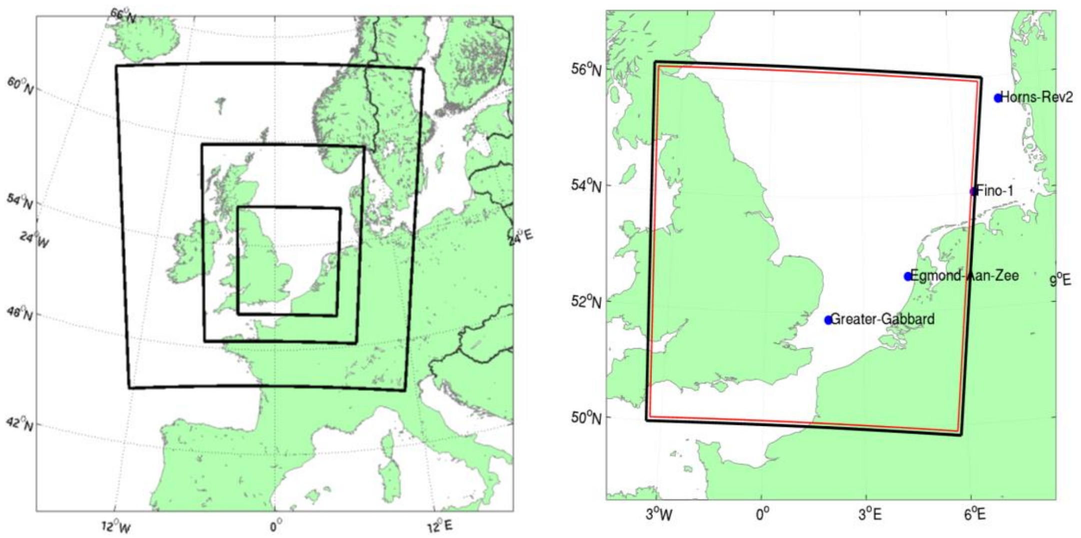

Figure 1. Example on a three domain nest for a sub-area of the Wind Atlas applying the mesoscale moldel WRF (Weather Research and Forecast model) setup. The horizontal resolution is 2 km, 6 km and 18 km for the inner, middle and outer nests, respectively. The inner nest is shown in the right panel.

Results

Results from the Wind Atlas for the Irish Sea and the North Sea are presented in Figure 2. From the figure we see that the long-term wind speed levels vary from about 9 m/s in the southern part of the North Sea to about 10 m/s in the northern part. We observe clear sheltering effects of the land masses in particular to the east of England and to the west of Norway. It is also noted that high wind speed levels can be encountered close to the coastline as for example in southwestern Norway and east of Scotland. In the Irish Sea wind speeds up to 10 m/s are encountered in the central parts between England and Ireland. The long-term average wind roses far offshore show that the dominant directions often west and southwest. However, 50-100 km from the coastlines effects on the wind direction distributions due to the land masses are clearly seen. The Weibull-k parameter varies in the range 1.7 to 2.3 in the North Sea/Irish Sea region (not shown). The lowest values are found on the west coast of Norway and England, and the highest values are encountered on the east coasts of England and Ireland.

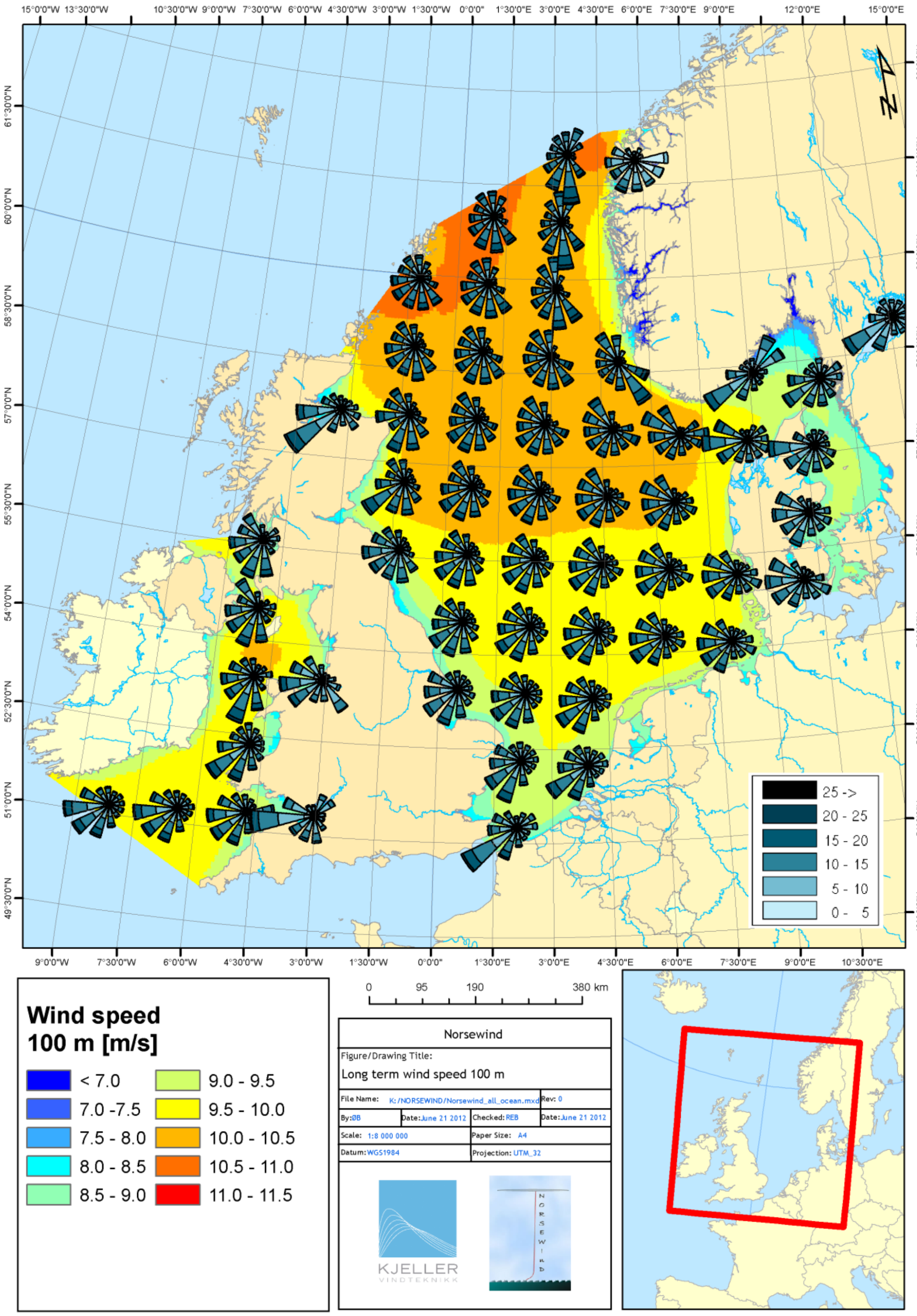

Figure 2. Long-term adjusted wind speed (100 m) and wind roses (100 m) based on the Wind Atlas for the Irish Sea and the North Sea.

In Table 1 a validation of the Wind Atlas is given. It is emphasized that the number of measurements is low and the data sample for statistical analysis is small. The random uncertainty in the annual average wind speed has been estimated to ±4.2 % based on measurements in the North Sea and the Baltic Sea, while a bias of -1.3 % is found. For the Weibull k-parameter we estimate a random uncertainty of ±4.0 % and a bias of -6.4 %. The average deviation in the annual wind direction is 3°. For annual average temperature a bias of –1.3ºC is encountered. Due to the small data samples no random uncertainty has been estimated for wind direction and temperature. The uncertainty of the mesoscale calculations are considerable lower than what is expected onshore for the annual average wind speed (see for example [3]), and the Wind Atlas data should therefore be a good basis for estimates of the AEP (Annual Energy Production).

Table 1. Comparison of annual averages of the Wind Atlas with measurements.

Annual averages at 100 m	Number of stations	Random uncertainty	Bias (model – obs)
Wind speed	7	4.2 %	- 1.3 %
Weibull k	6	4.0 %	- 6.4 %
Wind direction	3	—	3°
Temperature	1	—	- 1.3 ºC

It must also be noted that the bias in the Weibull-k parameter is as large as – 6.4 %. For the annual average wind speed regime of the North Sea, a high Weibull k factor is beneficial for the energy production, thus the k-factor of the Wind Atlas will give rise to some underestimation of the energy production.

In Figure 3 we present the standard deviations of the annual average wind speed based on 10 years of reference data. The standard deviation is important for estimating the uncertainty in the annual average wind speed and the wind energy yield of a potential wind farm. There is considerable variability in the standard deviation across the North Sea, while less variability is seen in the Irish Sea. The highest standard deviations of 4-6 % are encountered near the west coast of Norway and in the southeastern part of the North Sea. Lower values (2.5-3.5 %) are seen close to England and in the Irish Sea. Thus a longer measuring time-series would be needed close to the Norwegian coast as compared to close to England for establishing the same confidence in the annual average wind speed estimate.

Conclusions

Mesoscale model data have proven to be an efficient and accurate tool for generating offshore Wind Atlases. Long-term annual average wind speeds are estimated to have a random uncertainty of ±4.2 % and a bias of –1.3 %. This is lower than what is found in onshore studies. For the Weibull k-parameter we estimate a random uncertainty of ±4.0 % and a bias of -6.4 % which is higher than for the average annual wind speed. It is emphasized that the amount of validation data is small and considerable spatial variability of the uncertainty may be expected. For example, near coastal zones model errors could be expected to be larger than far offshore.

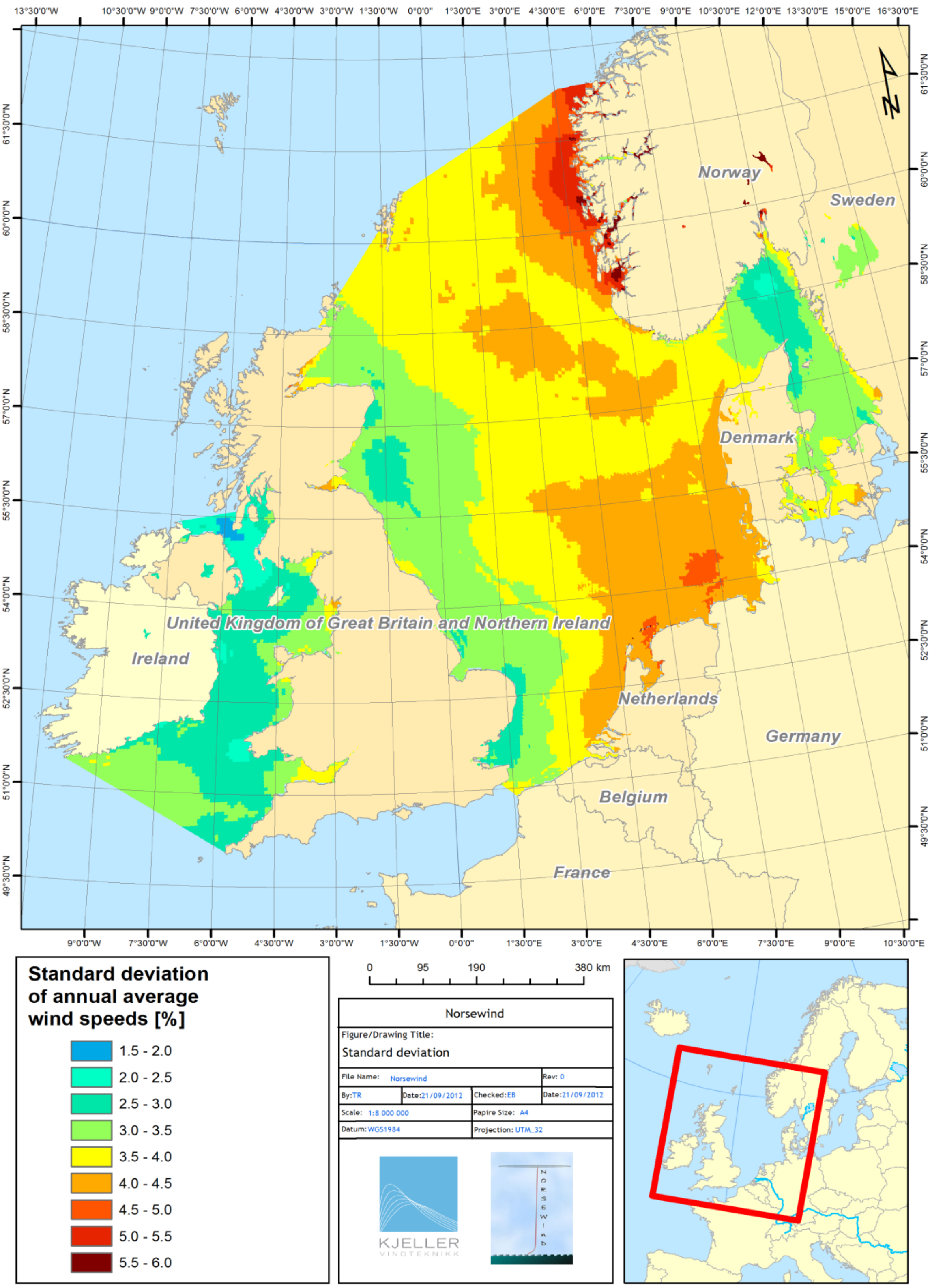

Figure 3. Standard deviations of the long-term annual wind speeds (100 m) of the Wind Atlas.

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