Generation of a wind and stability atlas for the optimized utilization of offshore wind resources in the North Sea Region

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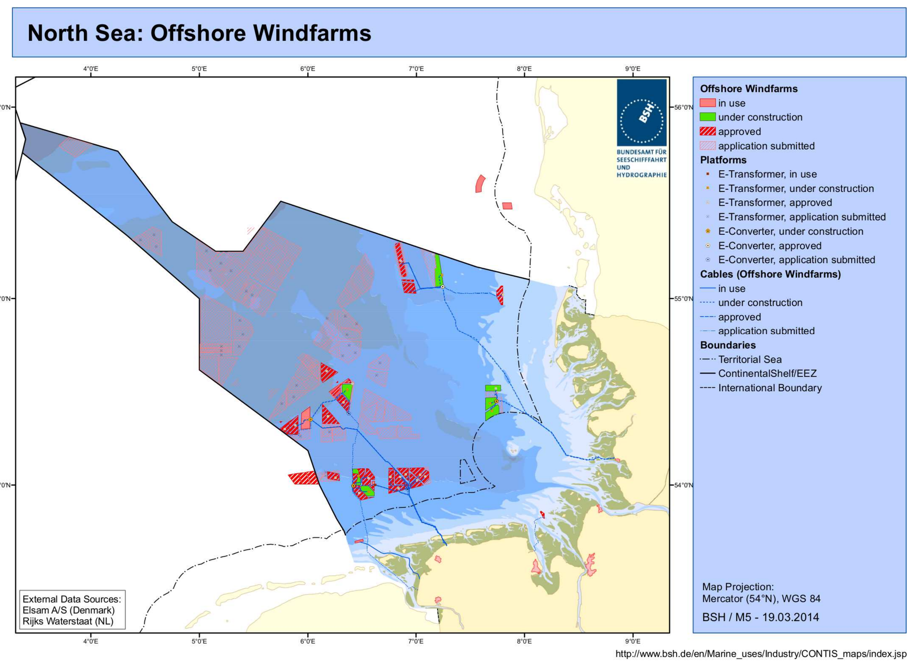
R18

MOTIVATION



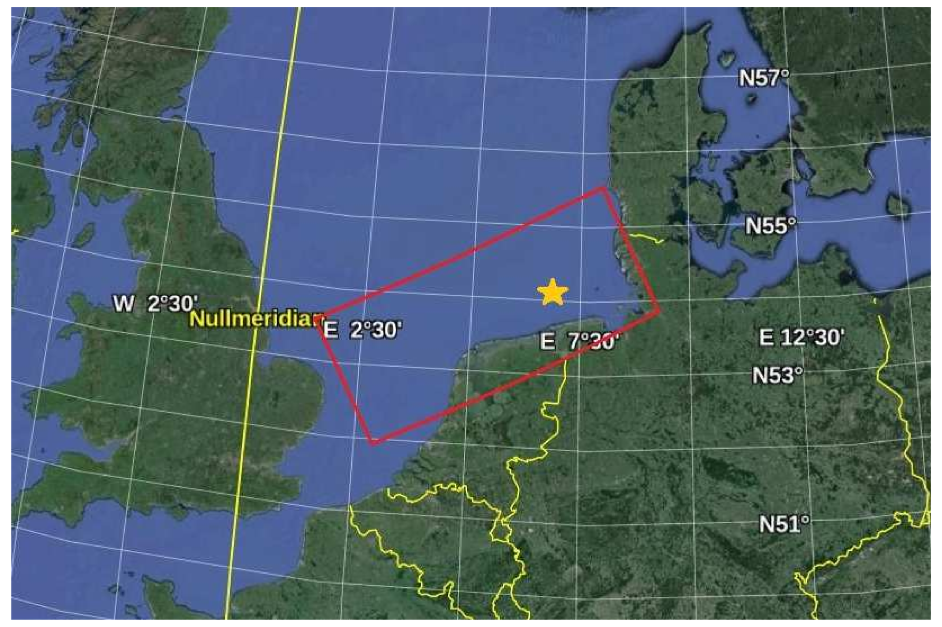
Installed and planned wind farms in the German North Sea [1]

By the year 2030 Europe's offshore wind capacity is expected to reach 150 GW [2]. However, detailed knowledge on the atmospheric conditions offshore is still lacking. Both, satellite-based observations and in-situ met mast measurements cannot provide spatially distributed long-term (climatological) information with high temporal resolution which is beneficial to plan prospective wind farms. Mesocale models can fill this gap.

From multiannual mesocale simulations spatially distributed climatological information on the atmospheric conditions offshore can be derived. Such multiannual simulations with the Weather Research and Forecasting (WRF) Model have been carried out to derive a wind and stability atlas (WASA). The WASA can easily be used to weight wake simulations with different atmospheric input data. The aim is to improve the energy yields estimated by the wake models by improving the quality and complexity of the atmospheric input data used.

DESCRIPTION OF WASA

21 years (1992 to 2012) of CFSR data [3] and OSTIA sea surface temperature data [4] have been downscaled to reach a final spatial resolution of 2 km for the German Bight and Southern North Sea.



Domain of WASA (red box) and FINO1 (yellow star)

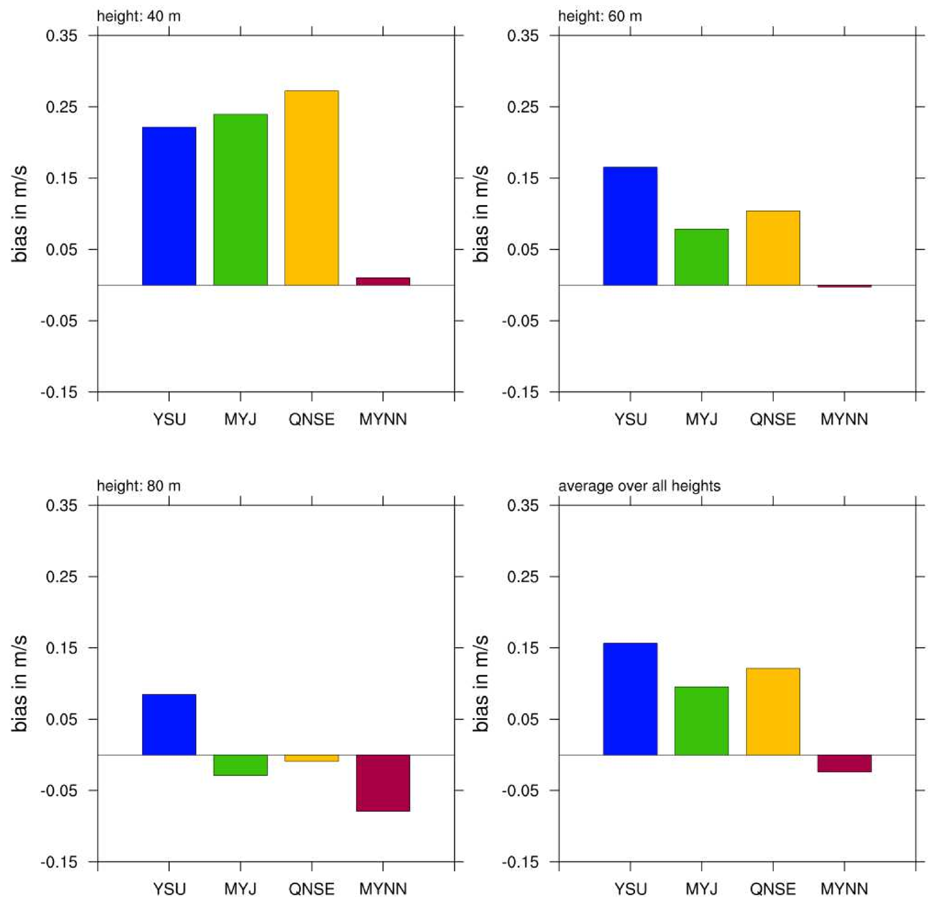
The WASA is a NetCDF-file that provides information on how often a combination of a certain

- wind speed
- wind direction
- air density
- stability parameter
- turbulence intensity

occurred at a specific location and a specific height within the 10 minute data during the period from 1992 to 2012. To find the Setup of WRF that yields the best agreement with measurements, different setups (e.g. PBL schemes – YSU, MYJ, QNSE and MYNN) have been tested and the results obtained were assessed by comparison of simulated wind speed, wind directions, stability parameters and turbulence intensities with data from the FINO1 met mast for the year 2007.

WIND SPEED

Wind speed measurements with sonic anemometers are available at three different heights (40, 60 and 80 m) at FINO1. To evaluate the best agreement between WRF simulations with different setup and measurements for the wind speed, the bias, rmse and correlation coefficient are calculated. Wind direction which are disturbed by the met mast were filtered.

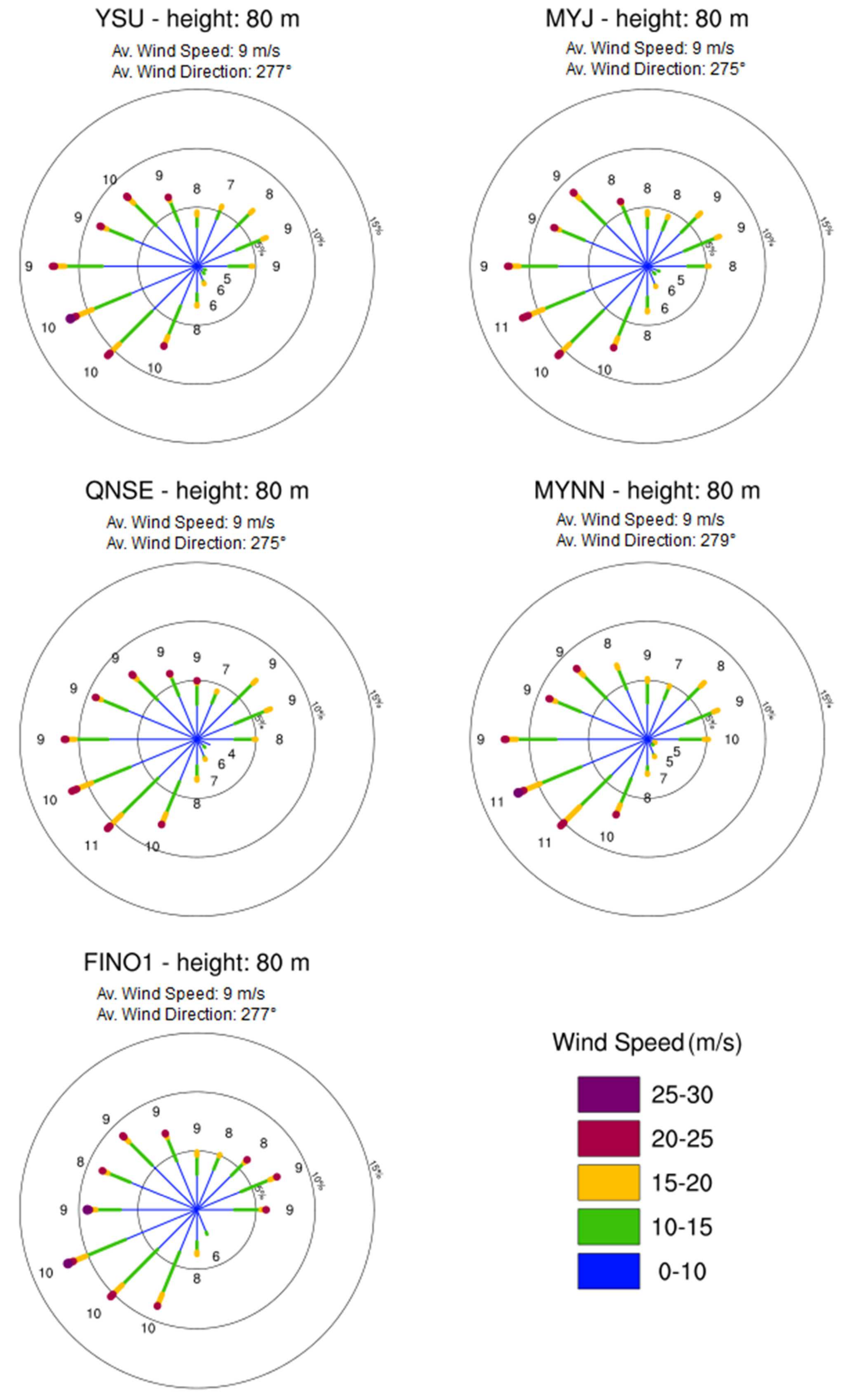


Height	YSU	MYJ	QNSE	MYNN
rmse				
40 m	1.62 m/s	1.63 m/s	1.39 m/s	1.37 m/s
60 m	1.66 m/s	1.66 m/s	1.39 m/s	1.38 m/s
80 m	1.69 m/s	1.69 m/s	1.44 m/s	1.44 m/s
Average	1.66 m/s	1.66 m/s	1.41 m/s	1.40 m/s
correlation coefficient				
40 m	0.975	0.911	0.937	0.979
60 m	0.925	0.890	0.915	0.958
80 m	0.934	0.901	0.905	0.968

Analysis of vertical profiles, histograms, scatter plots and other methods (not shown here) yield the results shown above.

WIND DIRECTION

For the analysis of the wind direction wind roses for simulations and measurements for all heights were calculated and for 80 m they are displayed. The south-easterly wind directions have been filtered in both simulations and measurements due to the mast shadow. Additionally, the averaged wind speed per wind direction bin and the overall averaged wind speed and wind direction have been plotted.



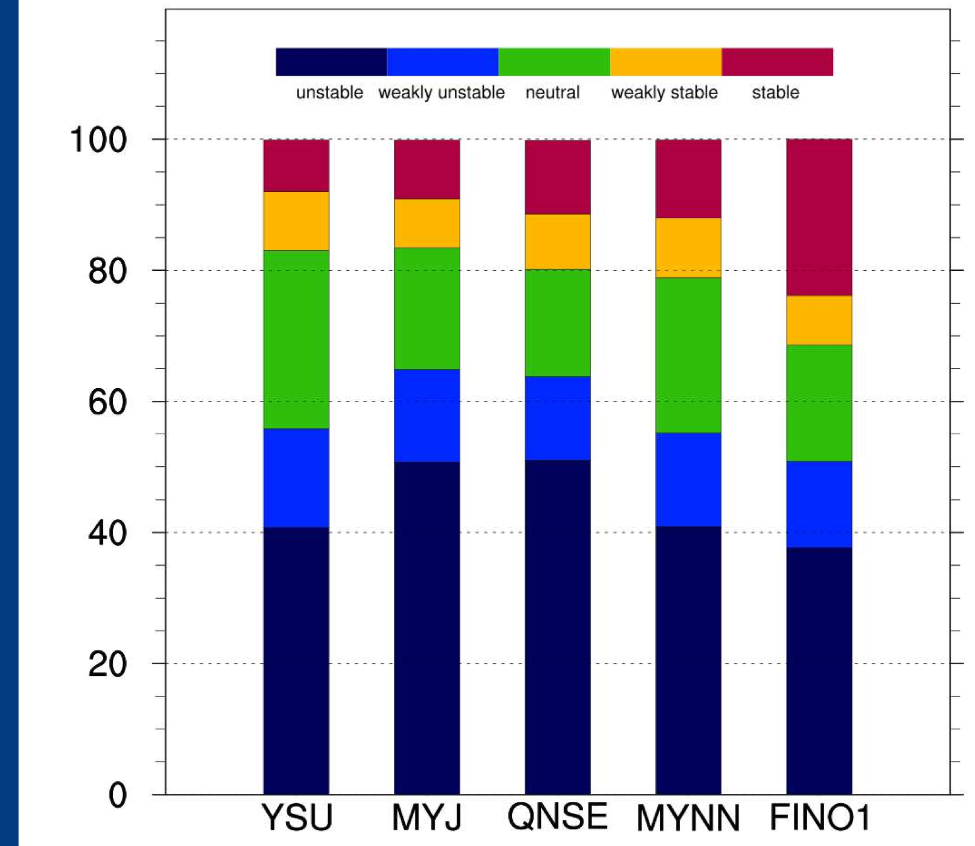
ATMOSPHERIC STABILITY

To determine the atmospheric stability, the Monin-Obukhov length (L) has been calculated using the sonic measurements (friction velocity u_*, temperature T and vertical wind speed w) at FINO1:

$$L = \frac{-u_*^3\, T}{\kappa\, g\, \overline{w'T'}} \; .$$

The in WRF pre-calculated inverse Monin-Obukhov length has been used directly. Five stability classes are defined:

Unstable [1/m]	Weakly un-stable [1/m]	Neutral [1/m]	Weakly stable [1/m]	Stable [1/m]
1/L < -0.005	-0.005 ≤ 1/L < -0.002	|1/L| ≤ 0.002	0.002 < 1/L ≤ 0.005	1/L > 0.005

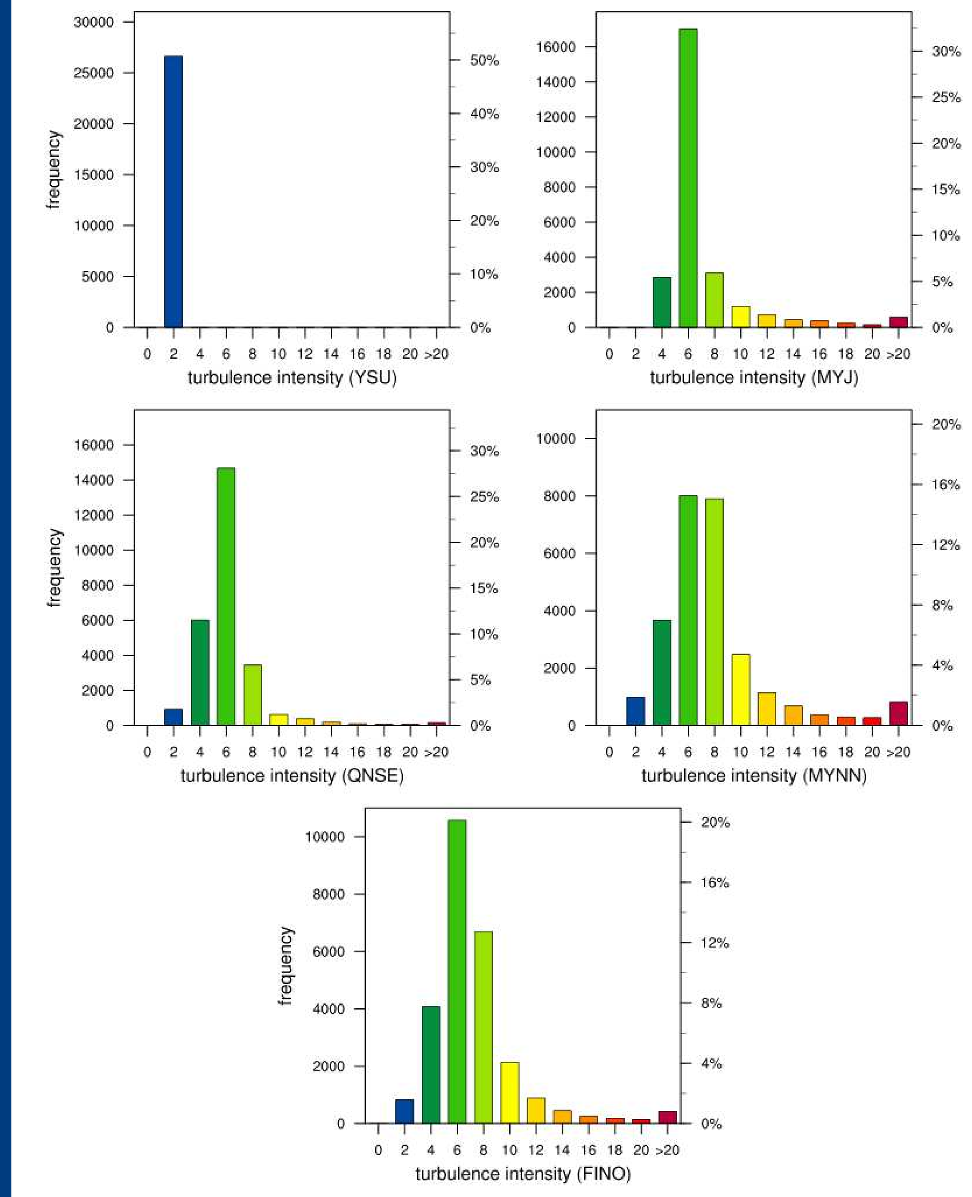


TURBULENCE INTENSITY

Three methods to calculate the turbulence intensity from WRF simulation results have been tested and compared to turbulence intensity measurements. Only results for the best-fitting approach in dependence on turbulent kinetic energy (TKE) and wind speed u

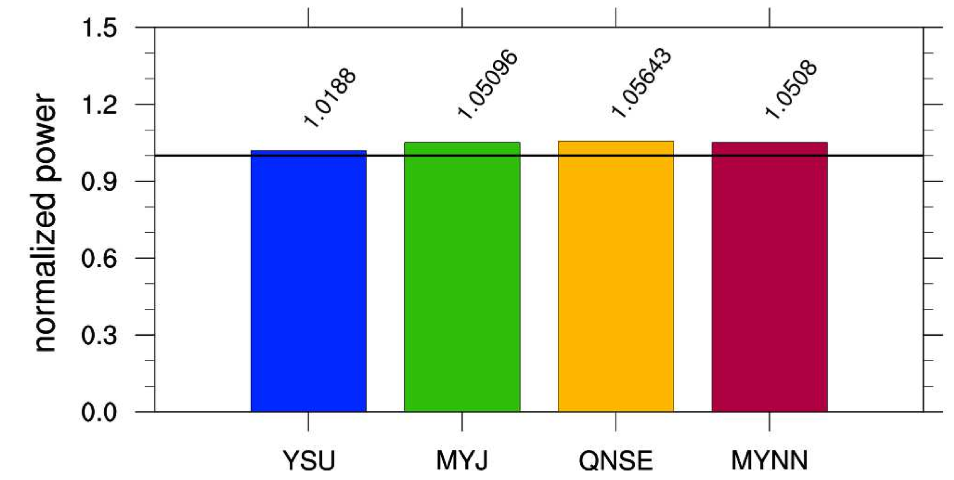
$$TI = \frac{\sqrt{\frac{1}{0.96} TKE}}{u} \quad [5]$$

are shown for 80 m height. As there is no TKE calculated while using the YSU pbl scheme and both other approaches to determine the turbulence intensity give bad results, the YSU is not an appropriate scheme for creating the WASA.



POWER

Since the WASA shall improve the energy yields estimated by the wake models, the measured and simulated atmospheric conditions have been used as input for an engineering wake model to assess the power generated at six 5 MW turbines installed in a rectangular shape.



WASA

Since the WASA provides information on how often a combination of a certain wind speed, wind direction, air density, stability parameter and turbulence intensity occurred, the simulation and measurements of 2007 were divided in the defined classes to emphasize which WRF setup reproduce the measured "WASA" best.

Number of correct divided data points in 2007 in 80 m height (of 26621)			
YSU	MYJ	QNSE	MYNN
472	8073	8087	8207

CONCLUSION

Comparisons of four different WRF setup and measurements at FINO1 emphasize that the MYNN pbl scheme is the best fit to create the WASA for the German Bight and Southern North Sea. It has to be mentioned that even the MYNN scheme describes in only approx. 30% the correct combinations of wind speed, wind direction, turbulence intensity and atmospheric stability.

REFERENCES & ACKNOWLEDGEMENT

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