

Comparison of NWP prognosis and local monitoring data from NPPs

P. ASTRUP¹, T.K. MIKKELSEN¹

ABSTRACT For four German nuclear power plant sites and for Risø, the site of the Danish nuclear research reactors now being decommissioned, Numerical Weather Predictions (NWP) of wind speed and direction have been compared to 10 minute averaged local measurements. For the German sites the comparison covers data for approximately three month, January to March 2009, for the Risø site for approximately two thirds of the year October 1998 to September 1999. For each site the comparison has been made for all measurement levels and both for the NWP analysis time and for the maximum available forecast time. Means and standard deviations of NWP minus measured data are given as tables for all measurement levels while scatter plots are presented for only a single measurement level at analysis time at each site. For Risø and for the site close to the North Sea plus for the inland site Philippsburg the predictions of wind speed are on average rather close to the measured, but for sites not far from the latter two, Krümmel respectively Obrigheim, the discrepancies are substantial.

Introduction

The purpose of this study was to investigate the difference between on-site measured wind speed and direction and numerical predictions of these data as delivered by the weather services. Having compiled a data base it might then be possible to characterise sites with a “deviation” factor or function that could be used for local correction of NWP data.

The results published here are a subset of those reported in Astrup and Mikkelsen (2010), where NWP to local measurement comparisons are given for seven German NPP sites and for the Danish Risø research reactor site. The NWP data covering the seven German NPP sites Neckarwestheim, Obrigheim, Philippsburg, Isar, Brokdorf, Brunsbüttel, and Krümmel and produced by the Austrian Meteorological and Geophysical Office, AMGO, consists of two daily sets of analysis plus hourly forecasts of up to 48 hours. The spatial resolution is approximately 10 km. Together with ten minute averaged measured wind speeds and directions, temperatures and other meteorological parameters at the sites, the AMGO forecasts have been made available by Bundesamt für Strahlenschutz

¹ Wind Energy Department, Risø – DTU, Frederiksborgvej 399, 4000 Roskilde, Denmark.

(BfS), the German Federal Office for Radiation Protection. For the Risø site the NWP results are produced by the Danish Meteorological Institute (DMI) and consist of 4 daily sets of analysis and hourly forecasts up to 5 hours. The spatial resolution is here approximately 5.5 km. Also here forecasts for up to 48 hours were originally received, but due to the 4 daily updates only forecasts up to 5 hours have been saved.

The NWP results are referred to the measurement sites by so called r^{-2} interpolation between the 4 nearest NWP points and to the measurement heights by vertical interpolation following similarity theory, van Ulden and Holtslag (1995), *i.e.* the differences between the NWP wind speed at the NWP levels and the similarity wind speeds at the same level heights – based on Monin-Obukhov length and friction velocity – are linearly interpolated to the measurement heights and the so obtained values are added to the similarity wind speeds calculated for these heights. Speed and direction differences are taken as NWP results minus measurements, the direction differences normalized to stay within plus minus 180 degrees.

Risø

The Risø site has the geographical coordinates 55.694° N, 12.088° E and is situated on a small peninsula in the Roskilde Fjord. The comparison NWP to mast data has been done for the analysis time and for the 5 hour forecast, for wind speed for three heights: 44.2 m, 76.6 m, and 125.2 m above ground, and for wind direction at 76.6 m and 125.2 m. Wind direction is not measured at 44.2 m. The wind direction comparison is further split into measured wind speed at 44.2 m being above or below 5 m/s. [Figure 1](#) shows plots for 76.6 m for the analysis hours while means and standard deviations for speed and direction differences for all heights are listed in [Table I](#).

The NWP data for wind speed are as an average slightly under predicted but the difference to measured speed is increasing with height. The mean direction difference NWP minus measured is pretty low, below 5° at analysis time, but with a standard deviation of approximately 25° which however reduces to 15° if only times with wind speeds above 5 m/s at 44.2 m is taken into account. The 5 hour forecasts behave expectedly, both speed and direction standard deviations increase, although very little, and the 5 hour forecasts compare to data almost as well as the analysis time NWP results.

German nuclear power plant sites

Comparisons of NWP and measured wind speed and direction data are here presented for four of the seven sites considered in the overall study. Comparison

COMPARISON OF NWP PROGNOSIS AND LOCAL MONITORING DATA FROM NPPS

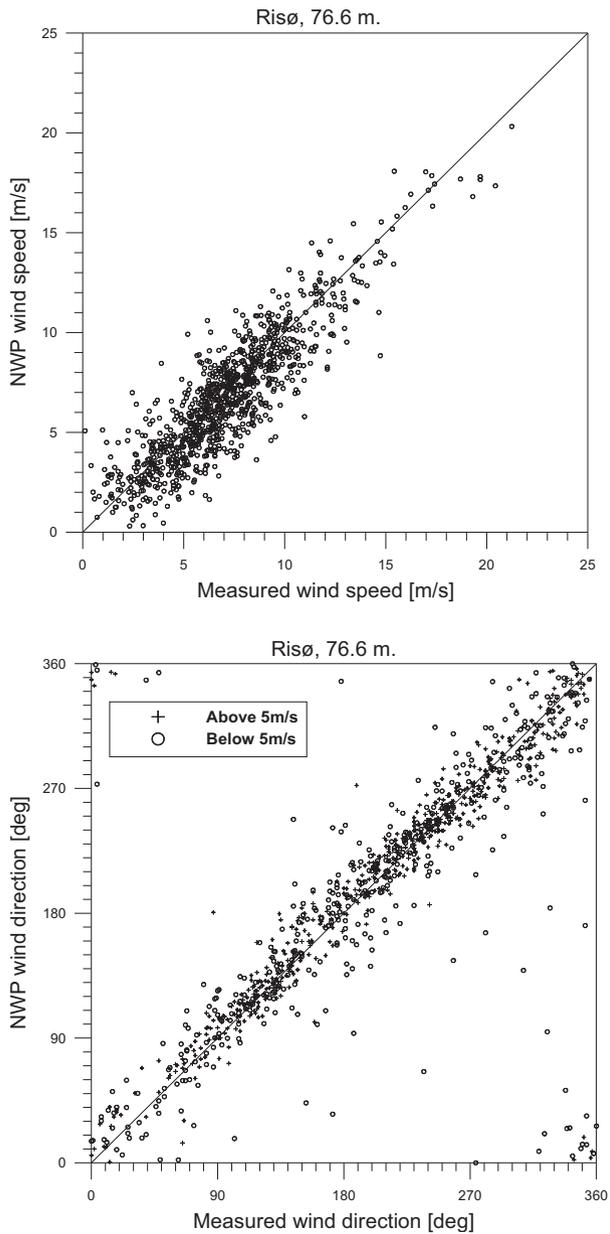


Figure 1 – 1017 sets of DMI HIRLAM results for Risø compared to measured data. Analysis time.

TABLE I
Statistics of differences between DMI HIRLAM results and Risø data.

Height [m]	Analysis time speed diff [m/s]			5 hour forecast speed diff [m/s]		
	mean	std.dev	count	mean	std.dev	count
44.2	-0.167	1.375	1017	0.568	1.755	1015
76.6	-0.223	1.456	1010	0.527	1.869	1008
125.2	-0.579	1.553	1017	0.221	1.903	1015

Height [m]	direction diff [deg]			direction diff [deg]		
	mean	std.dev	count	mean	std.dev	count
76.6	1.4	24.6	1017	6.4	27.0	1015
125.2	4.0	24.3	1017	7.9	25.4	1015

Measured wind speed at 44.2 m < 5 m/s						
Height [m]	direction diff [deg]			direction diff [deg]		
	mean	std.dev	count	mean	std.dev	count
76.6	0.3	34.8	406	6.6	38.7	375
125.2	1.4	35.1	406	6.6	37.3	375

Measured wind speed at 44.2 m > 5 m/s						
Height [m]	direction diff [deg]			direction diff [deg]		
	mean	std.dev	count	mean	std.dev	count
76.6	2.1	14.2	611	6.3	16.6	640
125.2	5.7	12.5	611	8.7	14.3	640

has been performed for the analysis time and for the 48 hour forecast. The reported site order ranges from north to south, *i.e.* Brokdorf, Krümmel, Obrigheim, and Philippsburg.

Brokdorf

The Brokdorf plant with the coordinates 53.851° N, 9.346° E is situated in flat terrain on the bank of the River Elbe approximately 25 km upstream from the rivers mouth at the North Sea coast.

There exist three measurement heights with 19 m, 60 m and 100 m. [Figure 2](#) shows the scatter plots of the numerical weather predictions *versus* the measured data at 100 m, and [Table II](#) lists means and standard deviations of the differences.

The NWP wind speeds are on average pretty close to the measured ones, both at analysis time and at 48 hours forecast, the scatter growing reasonably with time. The NWP wind speeds are slightly over predicted at the lowest height, tending towards under prediction at 60 m and are generally somewhat under predicted at 100 m. The difference is increasing with increasing measured wind speed. As

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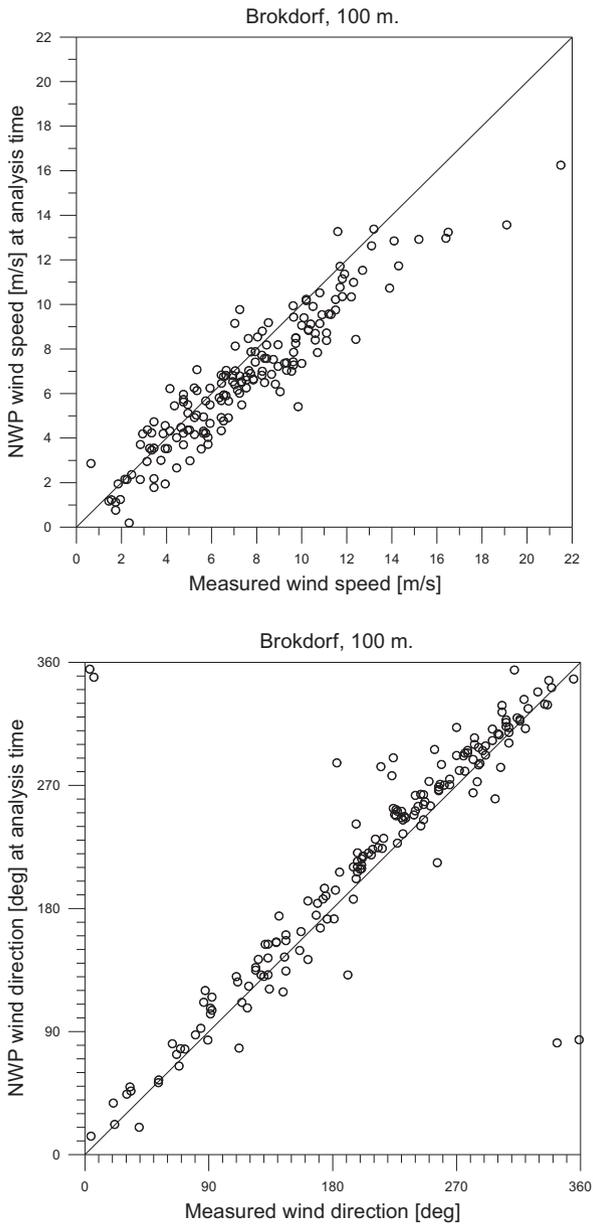


Figure 2 – NWP results for Brokdorf compared to measured data. Analysis time.

TABLE II
Statistics of differences between NWP results and Brokdorf data.

Height	Analysis time			48 hour forecast		
	speed diff [m/s]			speed diff [m/s]		
[m]	mean	std.dev	count	mean	std.dev	count
19.0	0.643	1.20	170	1.295	1.75	166
60.0	-0.274	1.34	167	0.392	1.91	163
100.0	-0.819	1.29	171	-0.099	2.14	167

Height	direction diff [deg]			direction diff [deg]		
	direction diff [deg]			direction diff [deg]		
[m]	mean	std.dev	count	mean	std.dev	count
19.0	14.299	23.67	170	13.253	36.31	166
60.0	12.321	22.77	167	13.040	34.34	163
100.0	10.848	19.67	171	10.495	34.59	167

expected, but reasonably in number, the scatter, *i.e.* standard deviation, is higher at the 48 hours forecast compared to the analysis time. Wind directions are all slightly over predicted.

Krümmel

The Krümmel plant with the coordinates 53.411° N, 10.410° E is situated at the River Elbe approximately 85 km southeast of the Brokdorf plant and 30 km southeast of Hamburg and thus somewhat more inland than Brokdorf.

There are three measurement heights at Krümmel: 47 m, 85 m and 148 m. [Figure 3](#) shows two scatter plots of the numerical weather predictions *versus* the measured data, and [Table III](#) lists means and standard deviations of the differences.

The NWP results for Krümmel show large over predictions for wind speeds while wind directions are pretty close to the measured. Most but not all of the worst direction outliers correspond to very low wind speeds so selecting only winds with speeds above 1 m/s results in a wind direction scatter somewhat smaller than for the whole set, most pronounced for the analysis time.

Obrigheim

The Obrigheim plant with the coordinates 49.364° N, 9.076° E is situated in the Southern part of Germany at the River Neckar, a tributary to the Rhine River. The meteorological measurements here are available at 20 m, 60 m, and 80 m above ground. [Figure 4](#) shows the scatter plots of the numerical weather predictions *versus* the measured data, [Table IV](#) provides the statistics.

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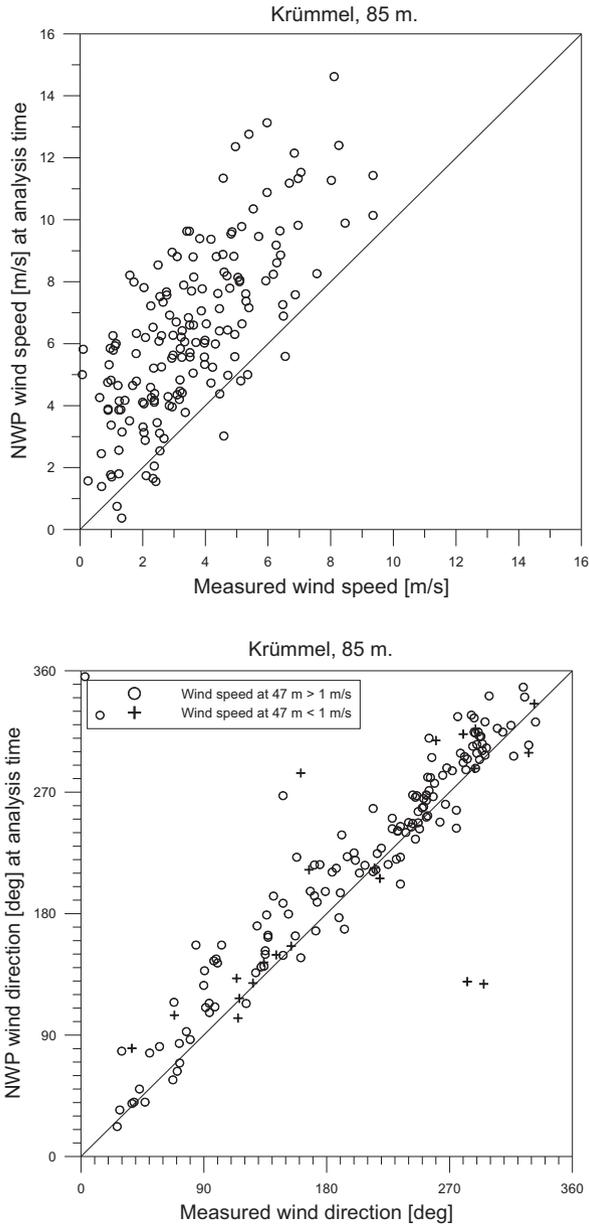


Figure 3 – NWP results for Krümmel compared to measured data. Analysis time.

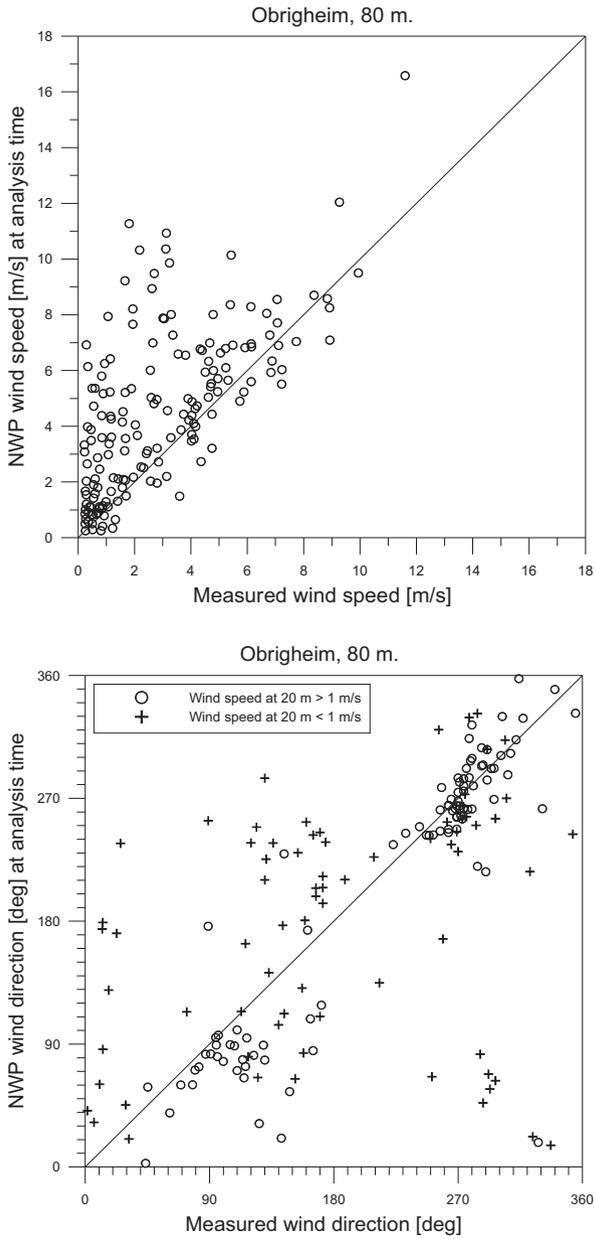


Figure 4 – NWP results for Obrigheim compared to measured data. Analysis time.

TABLE III
Statistics of differences between NWP results and Krümmel data.

Height [m]	Analysis time speed diff [m/s]			48 hour forecast speed diff [m/s]		
	mean	std.dev	count	mean	std.dev	count
47.0	3.091	1.72	169	3.913	2.24	165
85.0	2.824	1.90	169	3.686	2.43	165
148.0	0.875	2.25	169	1.689	2.62	165
Height [m]	direction diff [deg]			direction diff [deg]		
	mean	std.dev	count	mean	std.dev	count
47.0	11.359	31.54	169	12.228	35.05	165
85.0	13.136	30.06	165	13.543	34.80	161
148.0	13.011	25.86	169	12.266	35.13	165
Measured wind speed at 47 m > 1 m/s						
Height [m]	direction diff [deg]			direction diff [deg]		
	mean	std.dev	count	mean	std.dev	count
47.0	14.117	21.68	144	12.864	31.71	142
85.0	14.881	21.72	144	14.335	31.78	142
148.0	13.957	19.78	144	13.873	30.83	142

TABLE IV
Statistics of differences between NWP results and Obrigheim data.

Height [m]	Analysis time speed diff [m/s]			48 hour forecast speed diff [m/s]		
	mean	std.dev	count	mean	std.dev	count
20.0	1.543	1.72	170	2.053	2.13	166
60.0	1.467	2.11	169	2.022	2.63	165
80.0	1.660	2.24	170	2.223	2.76	166
Height [m]	direction diff [deg]			direction diff [deg]		
	mean	std.dev	count	mean	std.dev	count
20.0	-3.492	69.04	170	-8.538	68.60	166
60.0	31.256	86.79	169	24.783	84.84	165
80.0	8.002	57.90	170	-4.714	61.75	166
Measured wind speed at 20 m > 1 m/s						
Height [m]	direction diff [deg]			direction diff [deg]		
	mean	std.dev	count	mean	std.dev	count
20.0	-5.041	34.65	97	-13.737	40.27	93
60.0	37.408	65.69	97	29.468	71.26	93
80.0	-9.368	32.00	97	-17.343	37.60	93

TABLE V
Statistics of differences between NWP results and Philippsburg data.

Height [m]	Analysis time speed diff [m/s]			48 hour forecast speed diff [m/s]		
	mean	std.dev	count	mean	std.dev	count
15.0	0.334	1.00	170	0.854	1.37	166
40.0	0.256	1.32	170	0.862	1.69	166
120.0	-0.357	1.42	170	0.210	1.95	166
Height [m]	direction diff [deg]			direction diff [deg]		
	mean	std.dev	count	mean	std.dev	count
15.0	20.124	45.46	170	12.269	49.63	166
40.0	7.450	38.76	170	5.154	46.97	166
120.0	7.076	33.79	170	1.361	43.97	166
Height [m]	Measured wind speed at 15 m > 2 m/s					
	direction diff [deg]			direction diff [deg]		
mean	std.dev	count	mean	std.dev	count	
15.0	17.702	22.77	101	7.775	28.17	97
40.0	6.481	20.08	101	-2.357	26.07	97
120.0	6.794	17.47	101	-0.343	24.34	97

The wind speeds are generally very low at Obrigheim, 45% of the measurements at 20 m are below 1 m/s. The NWP wind speeds are over predicted at all heights, and the standard deviation of the direction difference is very high, ranging from 55° to 85°. When looking only at sets where the 20 m wind speed exceeds 1 m/s, the standard deviation of the direction difference is reduced to values between 30° and 65°.

The average difference in wind direction at 60 m is 30°, but at 20 and 80 m only 3° and 8°. Figure 5 shows scatter plots of the measured directions at 60 and 80 m against those measured at 20 m, plus the equivalent figure for the NWP results. Although with great scatter, the 60 m measured directions seem to some extent to cluster approximately 30° below the 20 and 80 m directions.

Philippsburg

Philippsburg at 49.2520° N, 8.4350° E, is situated at the Rhine River approximately midway between Karlsruhe and Mannheim. Wind speeds and directions are measured at three heights: 15 m, 40 m, and 120 m. Figure 6 shows the scatter plots of the numerical weather predictions *versus* the measured data, and Table V lists means and standard deviations of their differences.

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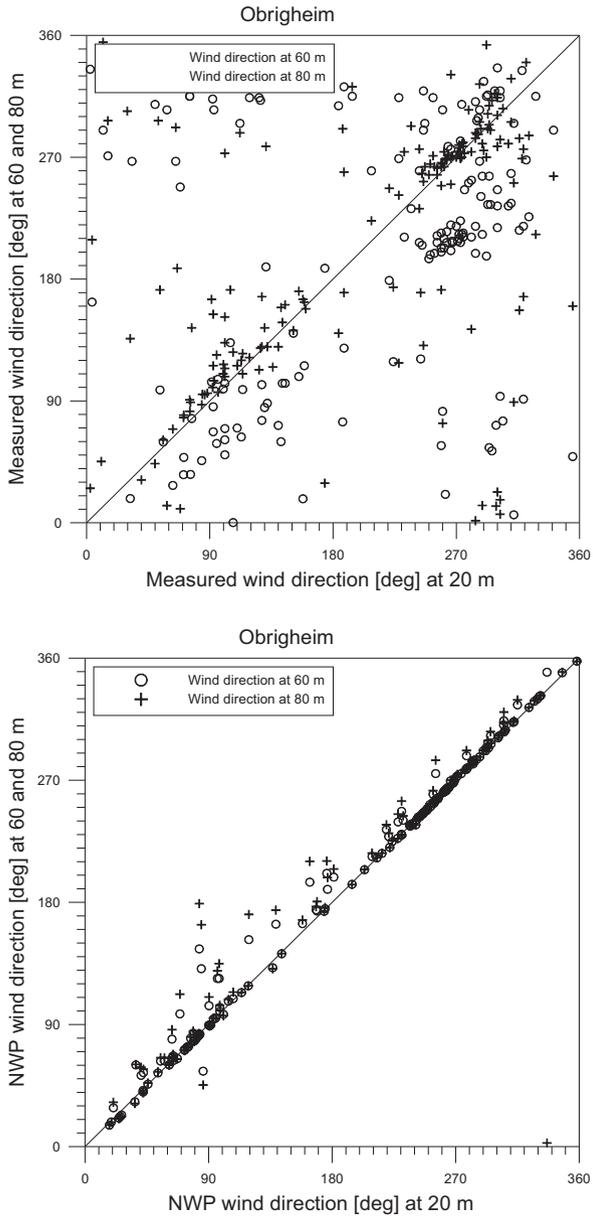


Figure 5 – Comparison of measured and predicted Obrigheim wind directions at 60 and 80 m to those at 20 m.

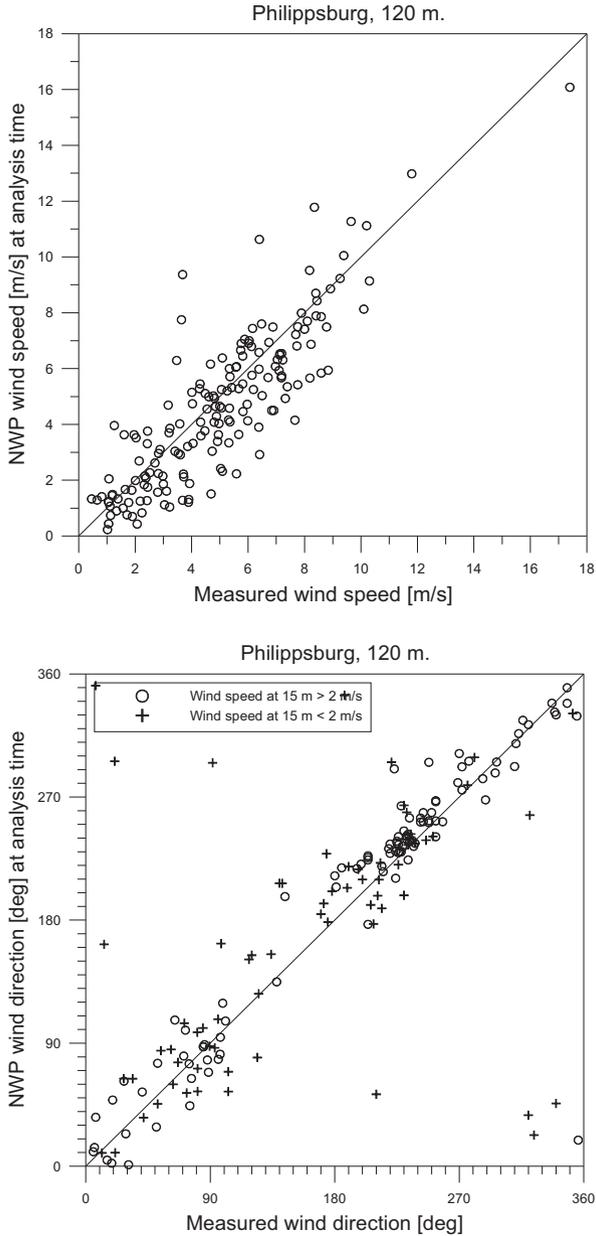


Figure 6 – NWP results for Philippsburg compared to measured data. Analysis time.

The NWP wind speeds compare pretty well with the measurements although the lowest speeds are slightly under predicted. The mean wind direction differences are small, around 7°, except at 15 m where the difference is 12°. However, the standard deviations of the wind direction differences are large with values up to 45°. For a wind speed above 2 m/s at 15 m this standard deviation of the direction however reduces to just around 20°.

Brokdorf-Krümmel, Obrigheim-Philippsburg

The NWP wind speeds at Brokdorf are very much the same as those at Krümmel, whereas those at Obrigheim are close to those of Philippsburg (see Fig. 7). This favours the assumption that the main reason for discrepancies between measured and predicted values are caused by local circumstances not resolved by the numerical models producing the NWP data.

Conclusion

Three month of data with wind speed and directions from twice per day delivered numerical weather predictions representing the analysis time and the 48 hours forecast time have been compared to measurements at four German nuclear power plant sites. In addition data from eight months were used in the comparison for the Danish Risø site for nuclear research reactors.

For the German site Brokdorf close to the North Sea and for the inland site Philippsburg the predictions of wind speed are on average rather close to the measured ones, but for sites not far from these, Krümmel respectively Obrigheim, the discrepancies are much larger. Concerning the wind directions the predicted values are on average almost everywhere larger than the measured, typically 15° to 20°. Obrigheim is the only place with wind directions that were predicted with smaller values than measured. The scatter of the direction difference is pretty large at all sites, but taking into account only data sets for which the wind speed exceeds some limit, this scatter is reduced whereas the average discrepancies are not changing significantly. The relative large wind speed discrepancies at Krümmel and Obrigheim seem to be the result of local circumstances not resolved by the simulation models calculating the NWP data.

The 125 m meteorology mast at the Danish Risø site is placed on relative flat terrain just east of a reasonable large body of water and thus the terrain is comparable in complexity with that of Brokdorf. The differences between measurements and NWP data are also for Risø at the lower end thus making them comparable to the results for Brockdorf, even if the underlying data base is different.

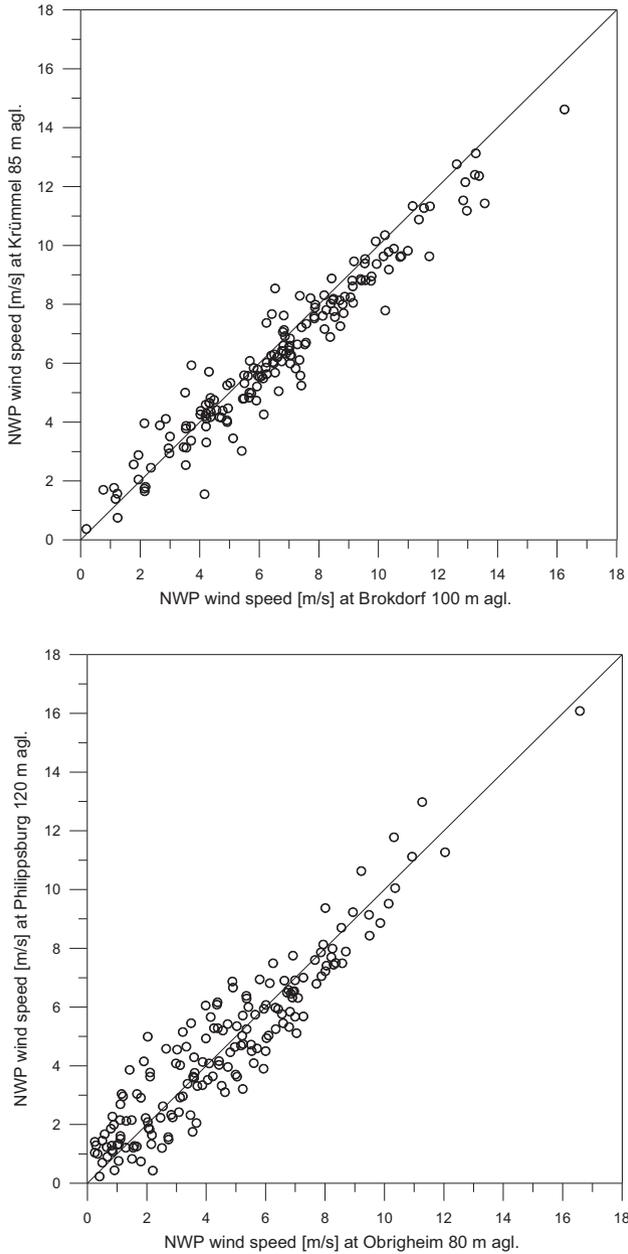


Figure 7 – Brokdorf to Krümmel and Obrigheim to Philippsburg NWP wind speed comparison.

With this study it is in principle possible to derive an average “scaling factor” representing the deviation of on-site monitoring data to NWP data. Such a factor depends on the location of the site, *e.g.* if it is close to the coast or inland, but also on more local circumstances which cannot be substantiated just from a comparative study like this. For this reason each site of interest needs its own investigation. The wind speed also plays a role, and functions rather than factors may be needed to characterise the average deviation at the individual sites.

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