

Comparison of OWEZ Wind Speed and Wind Direction Measurements with Meetpost Noordwijk, IJmuiden and K13

Linear Regression and Long Term Wind Climate

S. Barth

ECN-E-08-024

OWEZ_R_181_long_term_wind



NoordzeeWind



Abstract

NoordzeeWind carries out an extensive measurement and evaluation program as part of the Offshore Wind Farm Egmond aan Zee (OWEZ) project.

The technical part of the measurement and evaluation program considers topics as climate statistics, wind and wave loading, detailed performance monitoring of the wind turbines, etc.

The datasets are available in the public domain. The data that are analyzed in this report have been measured on a $116m$ height meteorological mast, located $15.5km$ offshore for the coast of Egmond aan Zee, the Netherlands. The data that are used in this report have been measured from 1.7.2005 to 30.06.2006, representing one year of measurements before the turbines are in operation, thus representing the undisturbed situation.

Wind speeds and wind direction measured at $21m$ height have been compared to the simultaneous potential wind velocities at the stations Meetpost Noordwijk, IJmuiden and K13. Those datasets were available in the public domain of the Royal Netherlands Meteorological Institute. The relationship between the OWEZ measurements and the stations Meetpost Noordwijk, IJmuiden and K13 has been investigated by means of linear regressions. The found regression coefficients are then used to correct the long-term datasets of Meetpost Noordwijk, IJmuiden and K13 in order to estimate long-term Weibull distributions and wind roses for the OWEZ location.

Acknowledgement

The Offshore wind Farm Egmond aan Zee has a subsidy of the Ministry of Economic Affairs under the CO₂ Reduction Scheme of the Netherlands

Principal

NoordzeeWind
2e Havenstraat 5b
1976 CE IJmuiden

Project Information

Contract number: NZW-16-C-C-R01
ECN project number: 7.9433

Contents

1	Introduction	6
2	Measured data	7
2.1	Measured signals	7
2.2	Measurement sectors	8
2.2.1	Meteorological mast	8
2.2.2	Derived wind data	8
3	Measurements database KNMI	10
4	Linear Regression of Wind Directions	12
5	Linear Regression of Wind Speeds	14
6	Quasi-long-term wind climate	22
6.1	Procedure to obtain quasi-long-term wind climate	22
6.2	Weibull distributions	22
7	Summary	26

List of Figures

1	Location of the OWEZ meteorological mast and the KNMI stations.	10
2	Probabilistic weighted linear regression of wind directions. The background color indicates the frequency of measurements, with red representing a low frequency of observations and green representing a high frequency of observations. At each top side and right side the histograms of the signal are shown indicating the distribution over the wind directions.	13
3	Probabilistic weighted linear regression of wind speeds measured at the OWEZ location and Meetpost Noordwijk for the 30° sectors from 0°...180°. The background color indicates the frequency of measurements, with red representing a low frequency of observations and green representing a high frequency of observations. At each top side and right side the histogram of the signal is shown.	15
4	Probabilistic weighted linear regression of wind speeds measured at the OWEZ location and Meetpost Noordwijk for the 30° sectors from 180°...360°. The background color indicates the frequency of measurements, with red representing a low frequency of observations and green representing a high frequency of observations. At each top side and right side the histogram of the signal is shown.	16
5	Probabilistic weighted linear regression of wind speeds measured at the OWEZ location and Meetpost IJmuiden for the 30° sectors from 0°...180°. The background color indicates the frequency of measurements, with red representing a low frequency of observations and green representing a high frequency of observations. At each top side and right side the histogram of the signal is shown.	17
6	Probabilistic weighted linear regression of wind speeds measured at the OWEZ location and Meetpost IJmuiden for the 30° sectors from 180°...360°. The background color indicates the frequency of measurements, with red representing a low frequency of observations and green representing a high frequency of observations. At each top side and right side the histogram of the signal is shown.	18
7	Probabilistic weighted linear regression of wind speeds measured at the OWEZ location and Meetpost K13 for the 30° sectors from 0°...180°. The background color indicates the frequency of measurements, with red representing a low frequency of observations and green representing a high frequency of observations. At each top side and right side the histogram of the signal is shown.	19
8	Probabilistic weighted linear regression of wind speeds measured at the OWEZ location and Meetpost K13 for the 30° sectors from 180°...360°. The background color indicates the frequency of measurements, with red representing a low frequency of observations and green representing a high frequency of observations. At each top side and right side the histogram of the signal is shown.	20

- 9 Polar plots of the regression parameters m and $|c|$. The largest deviations of m from unity (note that unity is indicated in the figures in grey) can be found in the eastern sectors, which is due to influence of the landmass. With increasing distance from the coast easterly winds speed up. That is why for these sectors m_{K13} is above unity, while $m_{Noordwijk}$ and $m_{IJmuiden}$ are below unity. Numbers can be found in Table 1. 21
- 10 Flow diagram indicating the procedure that has been followed to obtain the quasi-long-term wind climate. 22
- 11 Polar plots of the Weibull parameters A and k . While the scale parameters for the stations Meetpost Noordwijk and IJmuiden are rather similar, those of the K13 station show larger deviations from Meetpost Noordwijk and IJmuiden. Also the scale parameters show the largest volatility for K13. Numbers can be found in Table 2 and 3. 25
- 12 Quasi-long-term Weibull distribution and quasi-long-term wind rose for the OWEZ location at 21m height, based on the long-term data base of the KNMI station Meetpost Noordwijk. 26

1 Introduction

NoordzeeWind carries out an extensive measurement and evaluation program (NSW-MEP) as part of the OWEZ project. NoordzeeWind contracted Bouwcombinatie Egmond (BCE) to build and operate an offshore meteorological mast at the location of the OWEZ wind farm. BCE contracted Mierij Meteo to deliver and install the instrumentation in the meteorological mast. After the data have been validated, BCE delivers the measured 10 minutes statistics data to NoordzeeWind.

A 116m high meteorological mast has been installed to measure the wind conditions. This mast is in operation since the summer of 2005. The measurements at the 116m high mast are available at www.noordzeewind.nl. Only OWEZ data from that website are used within this report. The data are also available at the Senter/Novem website www.senternovem.nl

Potential wind datasets from the measurement stations at Meetpost Noordwijk, IJmuiden and K13 have been downloaded from the website of the Royal Netherlands Meteorological Institute www.knmi.nl/klimatologie/onderzoeksgegevens/potentiele_wind. These have been correlated with the OWEZ measurements in order to estimate a long-term wind climate prediction for the location of the OWEZ meteorological mast.

In section 2 the measured signals are described and the instrument codes are given. From the measurements with several anemometers and vanes at each measurement level, a wind speed and wind direction is constructed that reduces the effect of flow distortion due to the mast and neighboring sensors. The definitions of derived wind speed and derived wind direction are described.

The long-term measurement stations of the KNMI project are described in section 3.

A two-step probabilistic linear regression to estimate the correlation between the OWEZ station and the KNMI station is applied to wind direction measurements (section 4) as well as wind speed measurements (section 5).

The corrected long-term wind measurements are then used to estimate Weibull distributions, section 6.2.

Finally a summary is given in section 7.

2 Measured data

2.1 Measured signals

The instrumentation codes of the sensors in the 116m high meteorological mast at the offshore wind farm location OWEZ are indicated in the following table. The instrumentation is described in [1].

Channel	Instrumentation Code	Parameter	Unit
0	3D WM4/NW/21	wind direction	°
1	3D WM4/NW/21	horizontal wind speed	ms^{-1}
2	3D WM4/NW/21	vertical wind speed	ms^{-1}
3	3D WM4/NW/116	wind direction	°
4	3D WM4/NW/116	horizontal wind speed	ms^{-1}
5	3D WM4/NW/116	vertical wind speed	ms^{-1}
6	3D WM4/NW/70	wind direction	°
7	3D WM4/NW/70	horizontal wind speed	ms^{-1}
8	3D WM4/NW/70	vertical wind speed	ms^{-1}
9	WS 018/NW/116	wind speed	ms^{-1}
10	WS 018/NE/116	wind speed	ms^{-1}
11	WS 018/S/116	wind speed	ms^{-1}
12	WS 018/NW/70	wind speed	ms^{-1}
13	WS 018/NE/70	wind speed	ms^{-1}
14	WS 018/S/70	wind speed	ms^{-1}
15	WS 018/NW/21	wind speed	ms^{-1}
16	WS 018/NE/21	wind speed	ms^{-1}
17	WS 018/S/21	wind speed	ms^{-1}
18	RHTT 261/S/116	ambient temperature	°C
19	RHTT 261/S/70	ambient temperature	°C
20	RHTT 261/S/21	ambient temperature	°C
21	RHTT 261/S/116	relative humidity	%
22	RHTT 261/S/70	relative humidity	%
23	RHTT 261/S/21	relative humidity	%
24	DP910	ambient air pressure	mbar
25	PD 205/NW/70	precipitation	boolean
26	PD 205/NE/70	precipitation	boolean
27	ST 808/NW/-3.8	sea water temperature	°C
28	AC SB2i/T/116	acceleration (north - south)	ms^{-2}
29	AC SB2i/T/116	acceleration (west - east)	ms^{-2}

30	WD 524/NW/116	wind direction	°
31	WD 524/NE/116	wind direction	°
32	WD 524/S/116	wind direction	°
33	WD 524/NW/70	wind direction	°
34	WD 524/NE/70	wind direction	°
35	WD 524/S/70	wind direction	°
36	WD 524/NW/21	wind direction	°
37	WD 524/NE/21	wind direction	°
38	WD 524/S/21	wind direction	°
50	ADCP	water level	<i>m</i>
51	ADCP	water temperature	°C
52	ADCP	wave height	<i>m</i>
53	ADCP	wave period	<i>s</i>
54	ADCP	wave direction	°
55	ADCP	current velocity 7m	ms^{-1}
56	ADCP	current velocity 11m	ms^{-1}
57	ADCP	current direction	°
58	ADCP	current direction	°
Channel	Instrumentation Code	Parameter	Unit

2.2 Measurement sectors

2.2.1 Meteorological mast

The meteorological mast is a lattice tower with booms at three heights: 21m, 70m and 116m above mean sea level (MSL). At each height, three booms are installed in the directions north-east (NE), south (S) and north-west (NW). Sensors attached to the meteorological mast are described in [1]. The location of the meteorological mast is given in the following table.

	UTM31 ED50	WGS 84
x	594195	4°23'22, 7" Longitude East
y	5829600	52°36'22, 9" Latitude North

2.2.2 Derived wind data

The wind speeds and wind directions at each height are measured with more than one sensor. For certain wind directions the wind vanes and cups are in the wake of the mast or neighboring sensors or are otherwise significantly disturbed. It is necessary to select one of the cup anemometers and wind vanes depending on the actual wind direction in order to establish a wind speed that minimizes the distortion (See [2] and [3]). The constructed wind speed and wind direction are used within this report. The selection of signals is indicated in the following table.

Wind direction	Selected sensors
330 to 30 °	average of wind vanes NW and NE boom
30 to 90 °	average of wind vanes S and NW boom
90 to 150 °	average of wind vanes S and NE boom
150 to 210 °	average of wind vanes NW and NE boom
210 to 270 °	average of wind vanes NW and S boom
270 to 330 °	average of wind vanes NE and S boom
0 to 120 °	cup anemometer in NE boom
120 to 240 °	cup anemometer in S boom
240 to 360 °	cup anemometer in NW boom

Averaging over two vanes reduces the effect of the distortion by the mast on the wind direction measurement.

For the selection of the wind speed sensor it is important that at the direction where the wind speed sensor is changed from one sensor to the other, the ratio of the wind speeds is close to one. Furthermore, the wind speed may not be measured in the wake of the mast or a neighboring sensor.

3 Measurements database KNMI

For the comparison and the determination of long-term weibull distributions and wind roses for the OWEZ location, three neighboring stations have been chosen, namely Meetpost Noordwijk (offshore), IJmuiden (nearshore) and K13 (offshore), see Figure 1.



Figure 1: Location of the OWEZ meteorological mast and the KNMI stations.

The following table gives directions and distances to these stations as seen from the OWEZ meteorological mast:

	directions	distance
Meetpost Noordwijk	189.8 °	38km
IJmuiden	144.8 °	19km
K13	311.3 °	104km

The three stations are part of a measurement program of the Royal Netherlands Meteorological Institute. For all three stations the potential wind is public available from 1.1.1991 to 31.1.2007 (IJmuiden and K13) or 5.7.2006 (Meetpost Noordwijk).

The KNMI definition of potential wind is

- wind that is corrected for the effects of shelter from buildings or vegetation.
- over land an estimate of the wind speed that could have been measured at 10 m height if the station's surroundings was free of obstacles and flat with a roughness that is equal to that of grass (roughness length = 0.03 m).
- over sea an estimate of the wind speed that could have been measured at 10 m height over water with a roughness that equals that of water in high wind speed conditions (roughness length = 0.002 m).
- more homogeneous both in wind direction, space and time as a result of the corrections compared to the measured wind speed.
- derived from hourly averaged wind speed; the wind direction is a 10-minute average which is not different from the measured wind direction.

4 Linear Regression of Wind Directions

In order to get a first order relation between wind direction measurements at Meetpost Noordwijk, IJmuiden or K13 and wind direction measurements at the OWEZ meteorological mast at 21m height a linear regression of the following form has been used:

$$WD_{KNMI} = m \times WD_{OWEZ} + c, \quad (1)$$

with WD_{KNMI} and WD_{NSW} being the the wind direction in degree at the KNMI location or the OWEZ location, respectively and m and c being fitting parameters. Only wind directions have been used where simultaneous wind speeds are $> 4ms^{-1}$.

To get a robust linear regression, which is independent of unwanted outliers a two-step probabilistic linear fit has been used.

As a first step the datasets have been binned into bins with a width of 1° , then only the values with the highest probability have been selected. In doing so outliers do not affect the analysis as it would be the case if averaging methods are used.

As a second step a linear fit has been applied to the bins of highest probability, weighted with their probability, see Figure 2

The fitting parameters are given in the following table.

	m	c
Meetpost Noordwijk	1.00	14.42
IJmuiden	1.01	-4.04
K13	0.99	10.77

From the results it can be concluded that wind directions between the various stations show a high correlation, however, a relatively large offset is observed. However, compared with the stations of Noordwijk and IJmuiden, K13 shows a relatively large scatter. Therefore it can be concluded that K13 is less appropriate than Noordwijk or IJmuiden to estimate a correct long term wind climate for the OWEZ location.

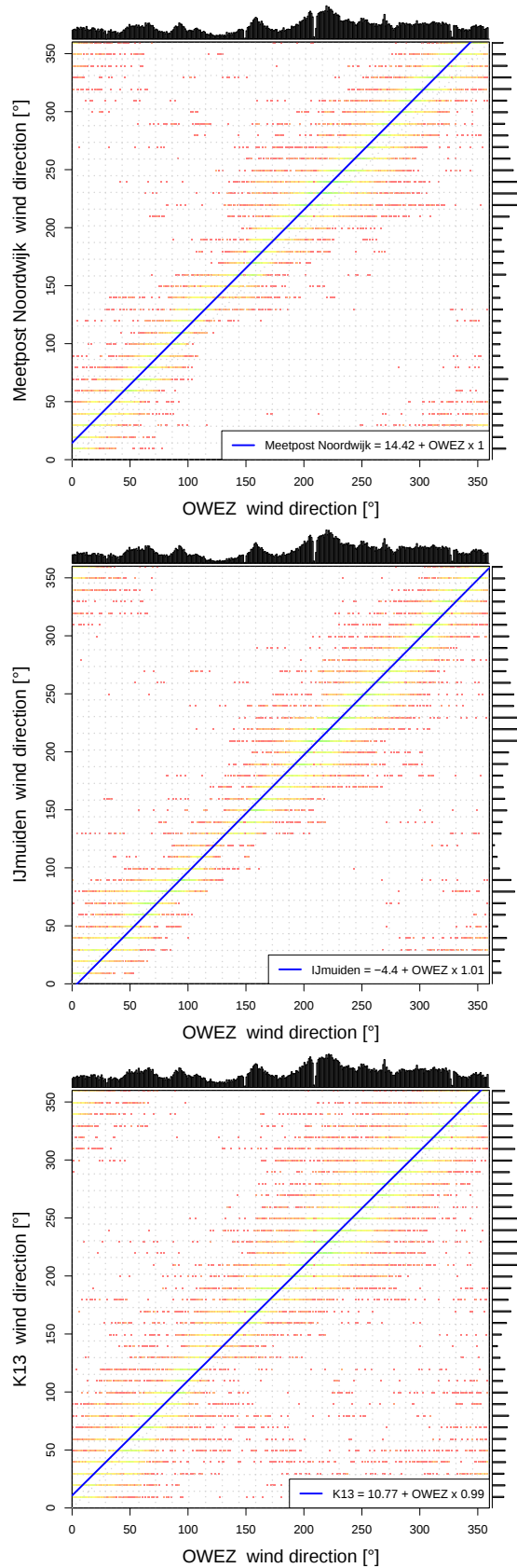


Figure 2: Probabilistic weighted linear regression of wind directions. The background color indicates the frequency of measurements, with red representing a low frequency of observations and green representing a high frequency of observations. At each top side and right side the histograms of the signal are shown indicating the distribution over the wind directions.

5 Linear Regression of Wind Speeds

In order to get a first order relation between wind speed measurements at Meetpost Noordwijk, IJmuiden or K13 and wind speed measurements at the OWEZ meteorological mast at 21m height a linear regression of the following form has been used:

$$WS_{KNMI} = m \times WS_{OWEZ} + c, \quad (2)$$

with WS_{KNMI} and WS_{OWEZ} being the the wind speed in m/s at the KNMI location or the OWEZ location, respectively and m and c being fitting parameters.

To get a robust linear regression, which is independent of unwanted outliers the same two-step probabilistic linear fit has been used, which has already been applied to the wind directions.

The fitting parameters have been estimated for wind direction sectors of 30° . This means that wind speed measurements at the KNMI stations, the corrected wind direction of which lies within the wanted sector, are compared with simultaneous wind speed measurements at the OWEZ location.

wind direction in $^\circ$	$m_{Noordwijk}$	$c_{Noordwijk}$	$m_{IJmuiden}$	$c_{IJmuiden}$	m_{K13}	c_{K13}
$0 < \dots \leq 30$	0.94	-0.39	0.86	-0.17	1.14	-2.10
$30 < \dots \leq 60$	1.02	-1.17	0.81	-0.30	1.38	-4.22
$60 < \dots \leq 90$	0.84	-0.19	0.95	-0.38	1.28	-2.01
$90 < \dots \leq 120$	0.89	-0.64	0.74	-0.29	1.31	-2.15
$120 < \dots \leq 150$	0.83	0.20	0.63	-0.08	1.28	-1.55
$150 < \dots \leq 180$	0.77	0.39	0.64	0.16	1.12	-0.11
$180 < \dots \leq 210$	0.95	-0.41	0.76	0.03	1.04	0.81
$210 < \dots \leq 240$	1.15	-1.95	0.96	-0.55	1.04	0.09
$240 < \dots \leq 270$	1.08	-1.50	0.89	0.10	1.00	-0.55
$270 < \dots \leq 300$	1.04	-1.02	0.98	-0.57	1.03	-0.48
$300 < \dots \leq 330$	0.98	-0.40	0.92	-0.29	0.97	-0.20
$330 < \dots \leq 360$	0.98	-0.44	0.86	0.41	0.98	-0.40

Table 1: Fitting parameters of the two-step probabilistic linear regression.

The largest deviations of m from unity can be found in the eastern sectors, which is due to influence of the landmass. With increasing distance from the coast easterly winds speed up. That is why for these sectors m_{K13} is above unity, while $m_{Noordwijk}$ and $m_{IJmuiden}$ are below unity. A graphical illustration of the regression parameters can be found in Figure 9.

As for the wind directions, the sectorwise wind speed regressions show the largest scatter for the K13 station. The fewest scatter can be observed for the station Meetpost Noordwijk. Therefore that station will be favored to estimate the long-term wind climate for the OWEZ location.

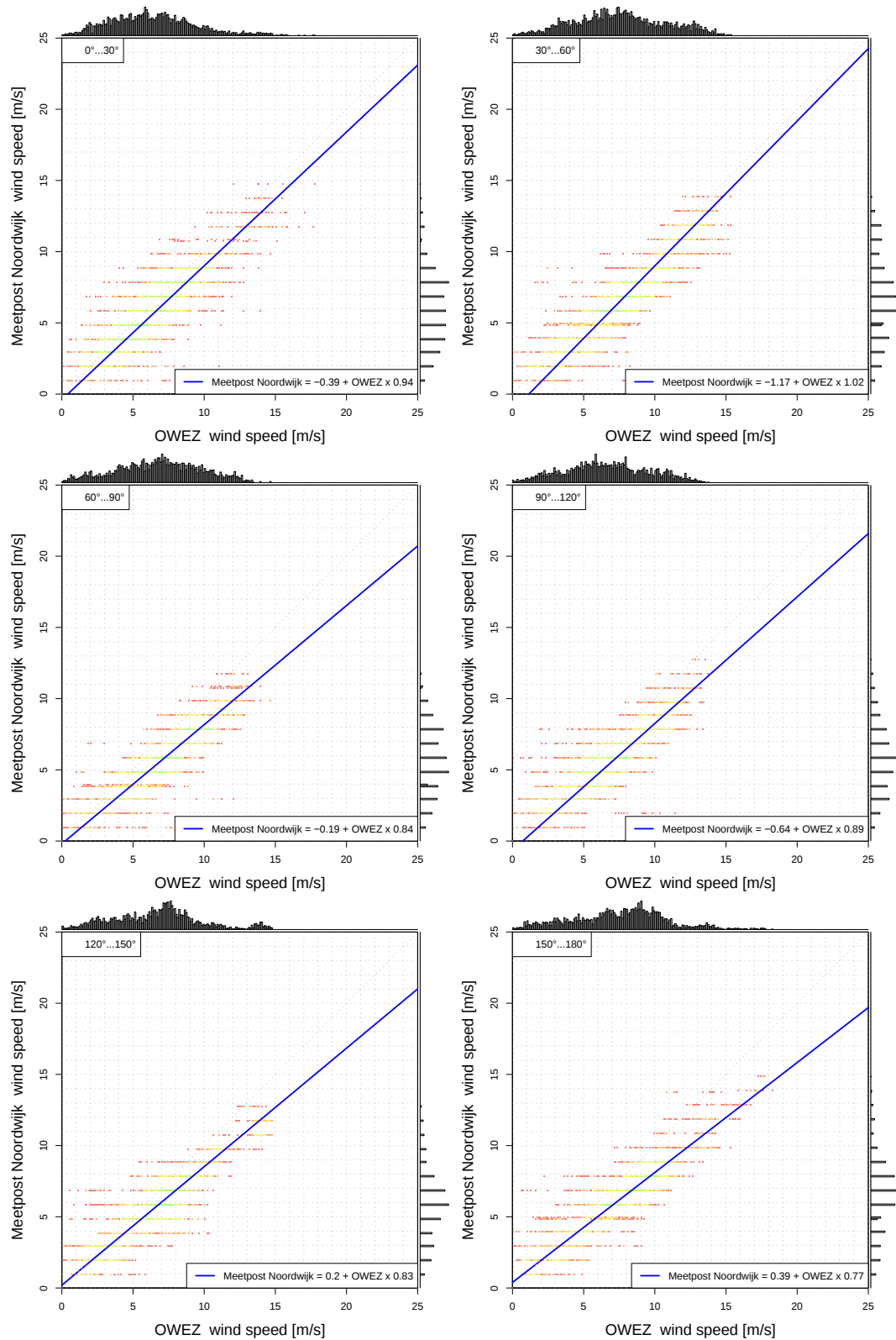


Figure 3: Probabilistic weighted linear regression of wind speeds measured at the OWEZ location and **Meetpost Noordwijk** for the 30° sectors from 0°...180°. The background color indicates the frequency of measurements, with red representing a low frequency of observations and green representing a high frequency of observations. At each top side and right side the histogram of the signal is shown.

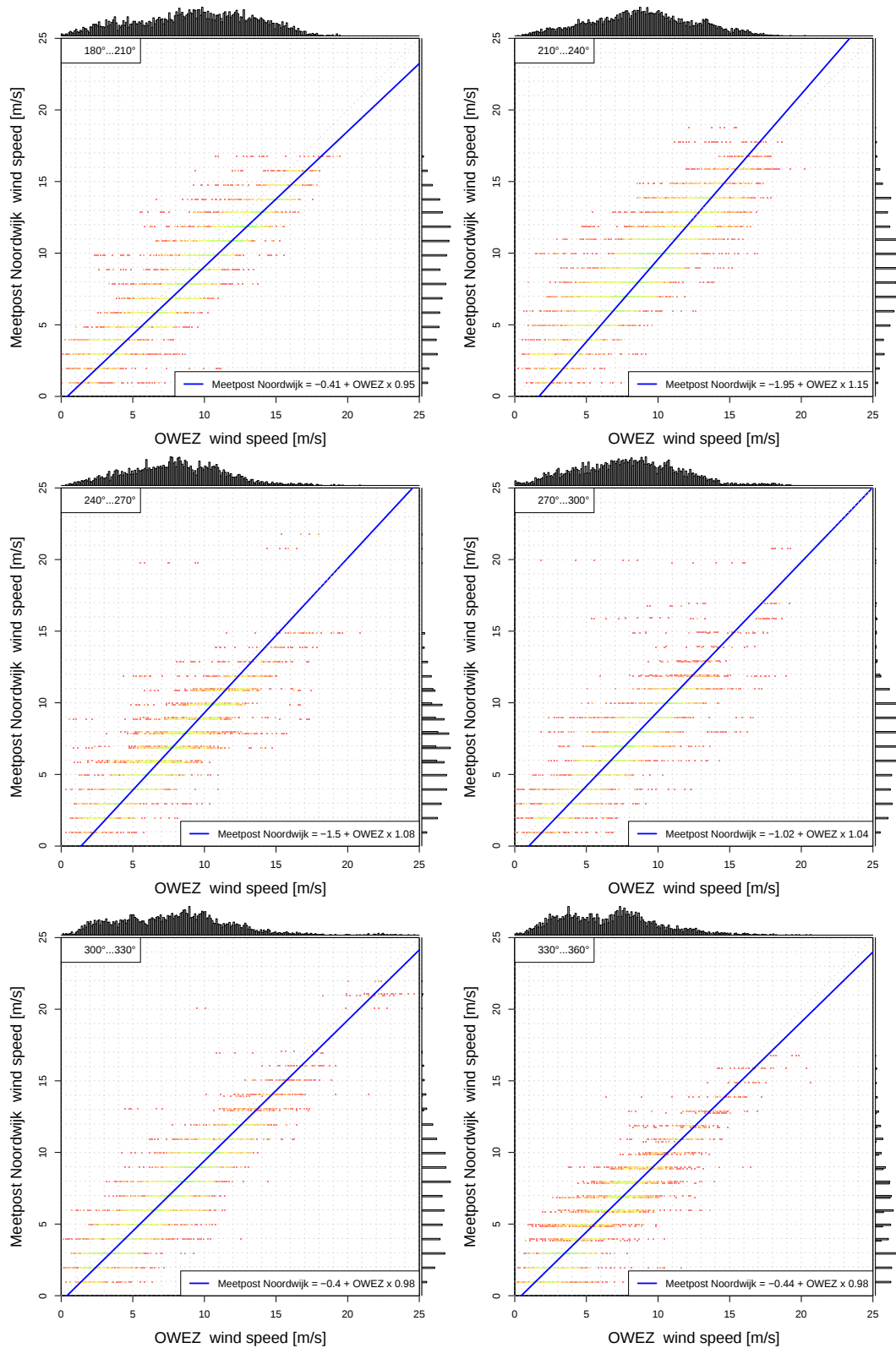


Figure 4: Probabilistic weighted linear regression of wind speeds measured at the OWEZ location and **Meetpost Noordwijk** for the 30° sectors from 180°...360°. The background color indicates the frequency of measurements, with red representing a low frequency of observations and green representing a high frequency of observations. At each top side and right side the histogram of the signal is shown.

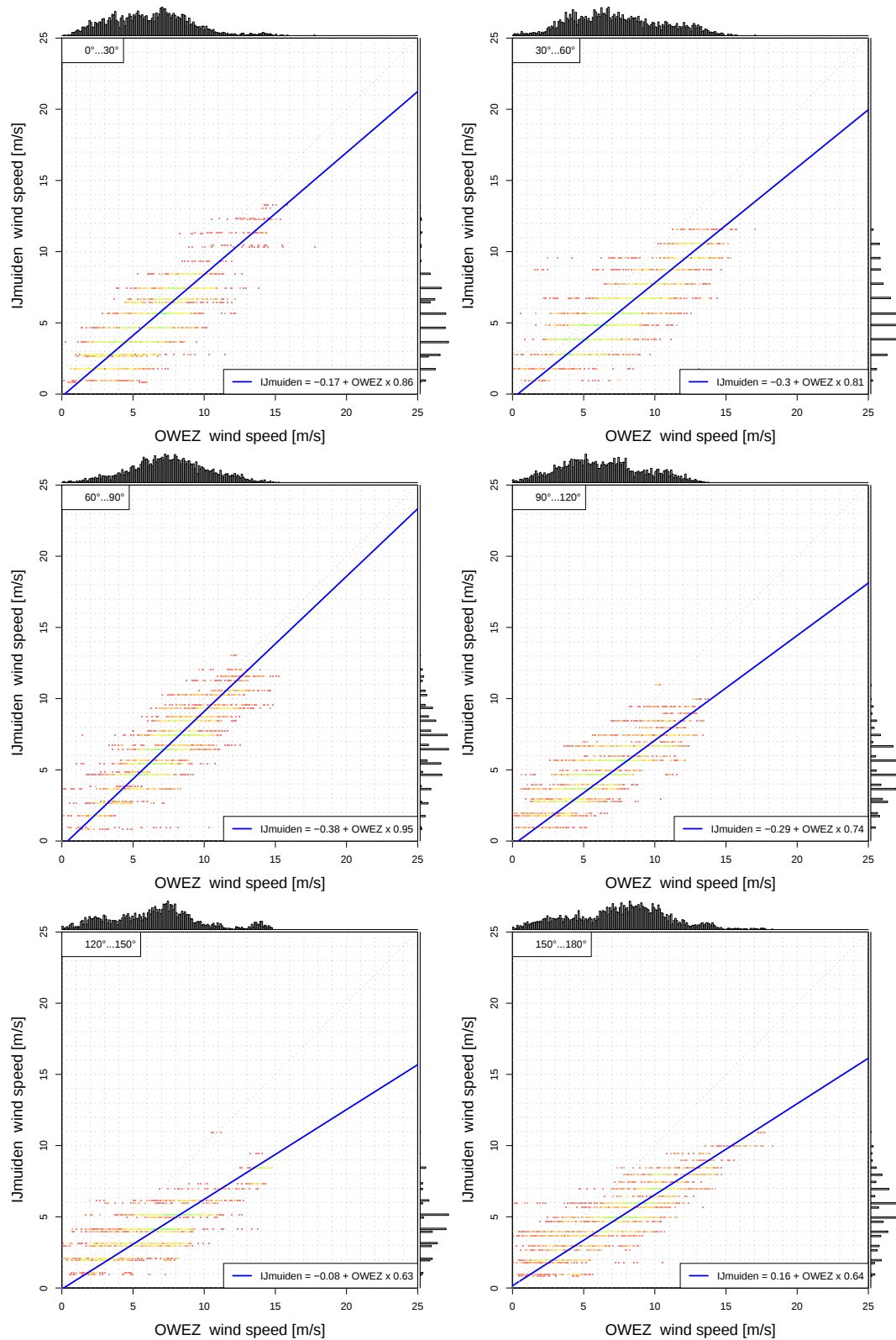


Figure 5: Probabilistic weighted linear regression of wind speeds measured at the OWEZ location and Meetpost IJmuiden for the 30° sectors from 0°...180°. The background color indicates the frequency of measurements, with red representing a low frequency of observations and green representing a high frequency of observations. At each top side and right side the histogram of the signal is shown.

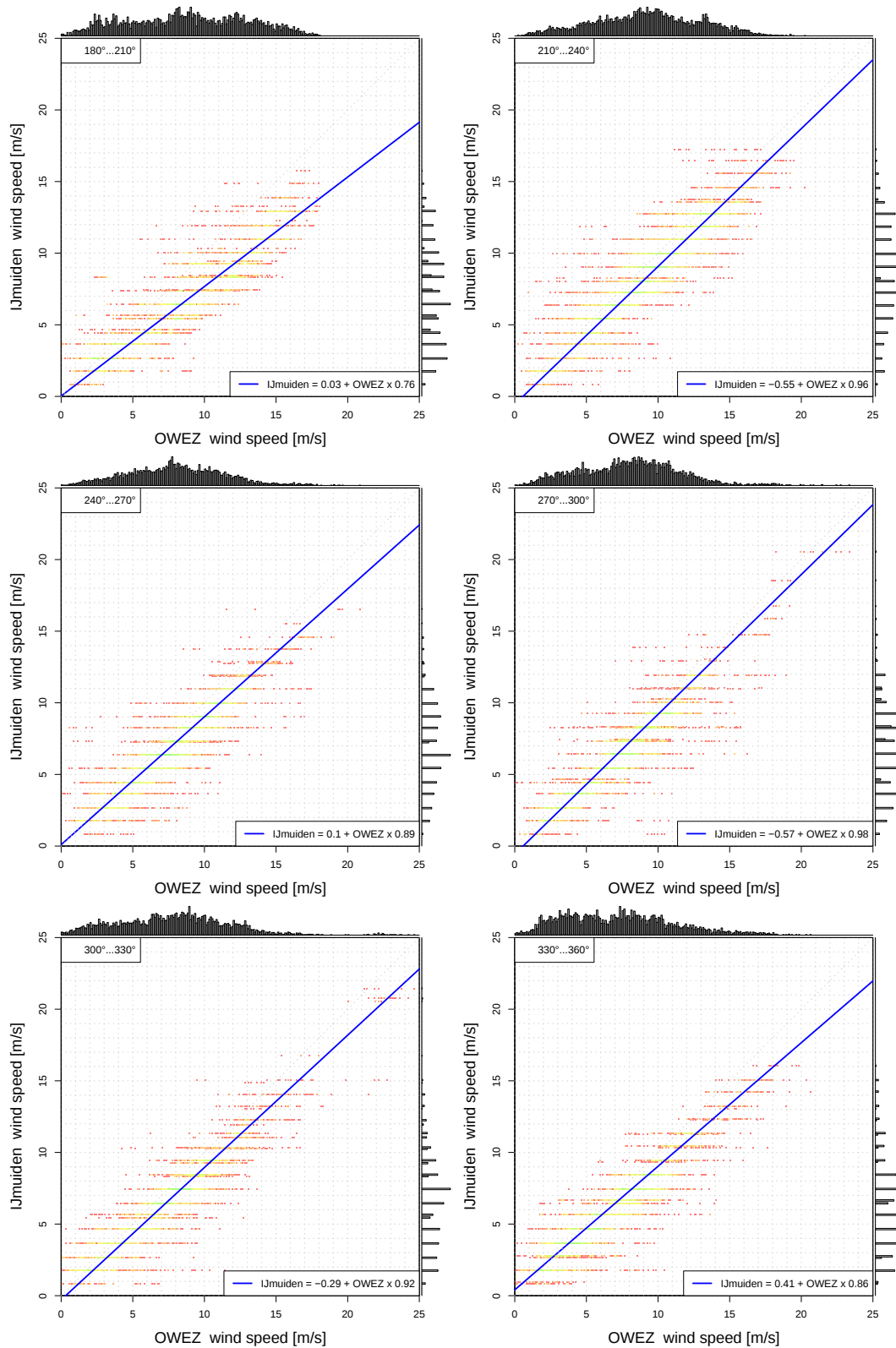


Figure 6: Probabilistic weighted linear regression of wind speeds measured at the OWEZ location and Meetpost IJmuiden for the 30° sectors from 180°...360°. The background color indicates the frequency of measurements, with red representing a low frequency of observations and green representing a high frequency of observations. At each top side and right side the histogram of the signal is shown.

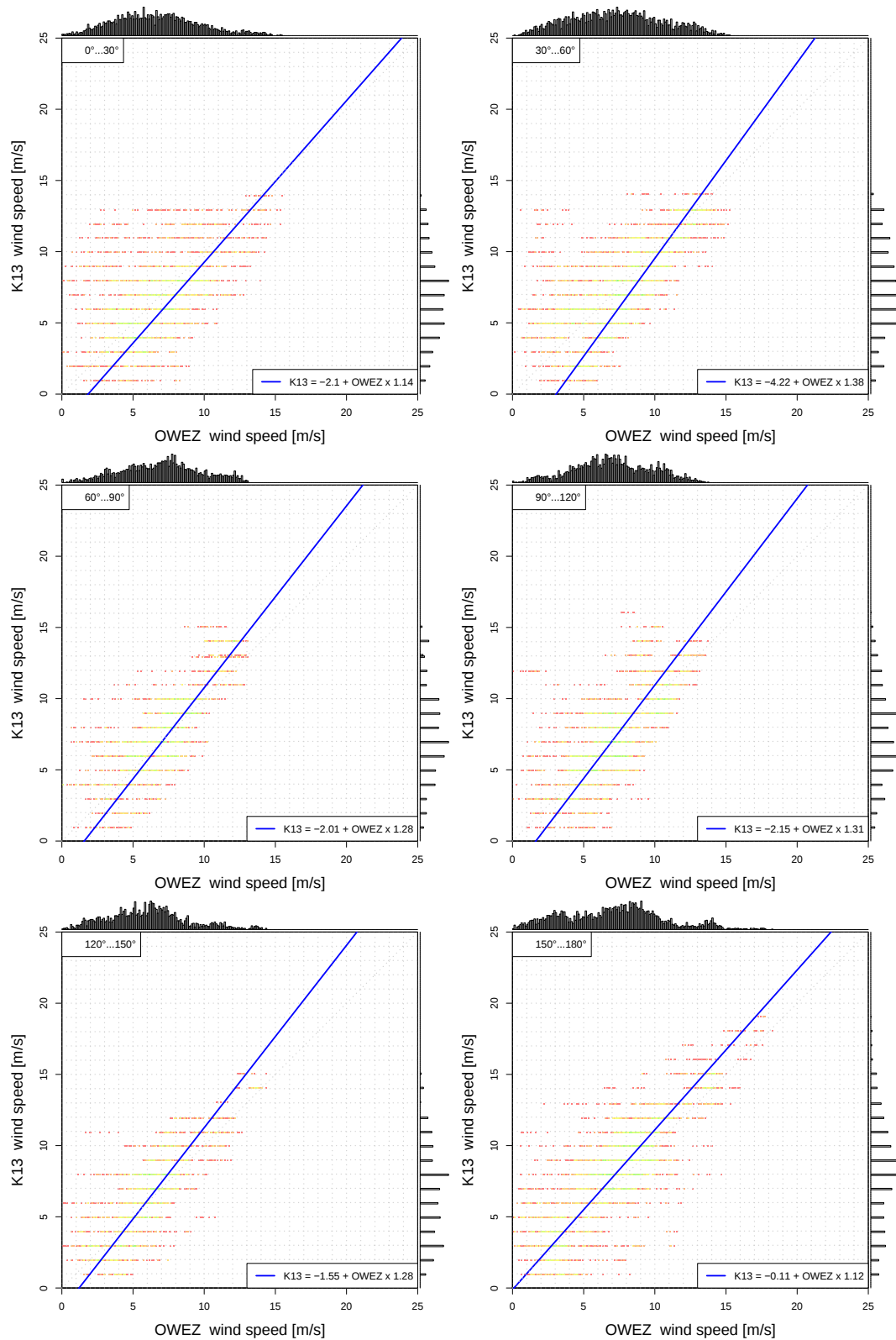


Figure 7: Probabilistic weighted linear regression of wind speeds measured at the OWEZ location and **Meetpost K13** for the 30° sectors from 0°...180°. The background color indicates the frequency of measurements, with red representing a low frequency of observations and green representing a high frequency of observations. At each top side and right side the histogram of the signal is shown.

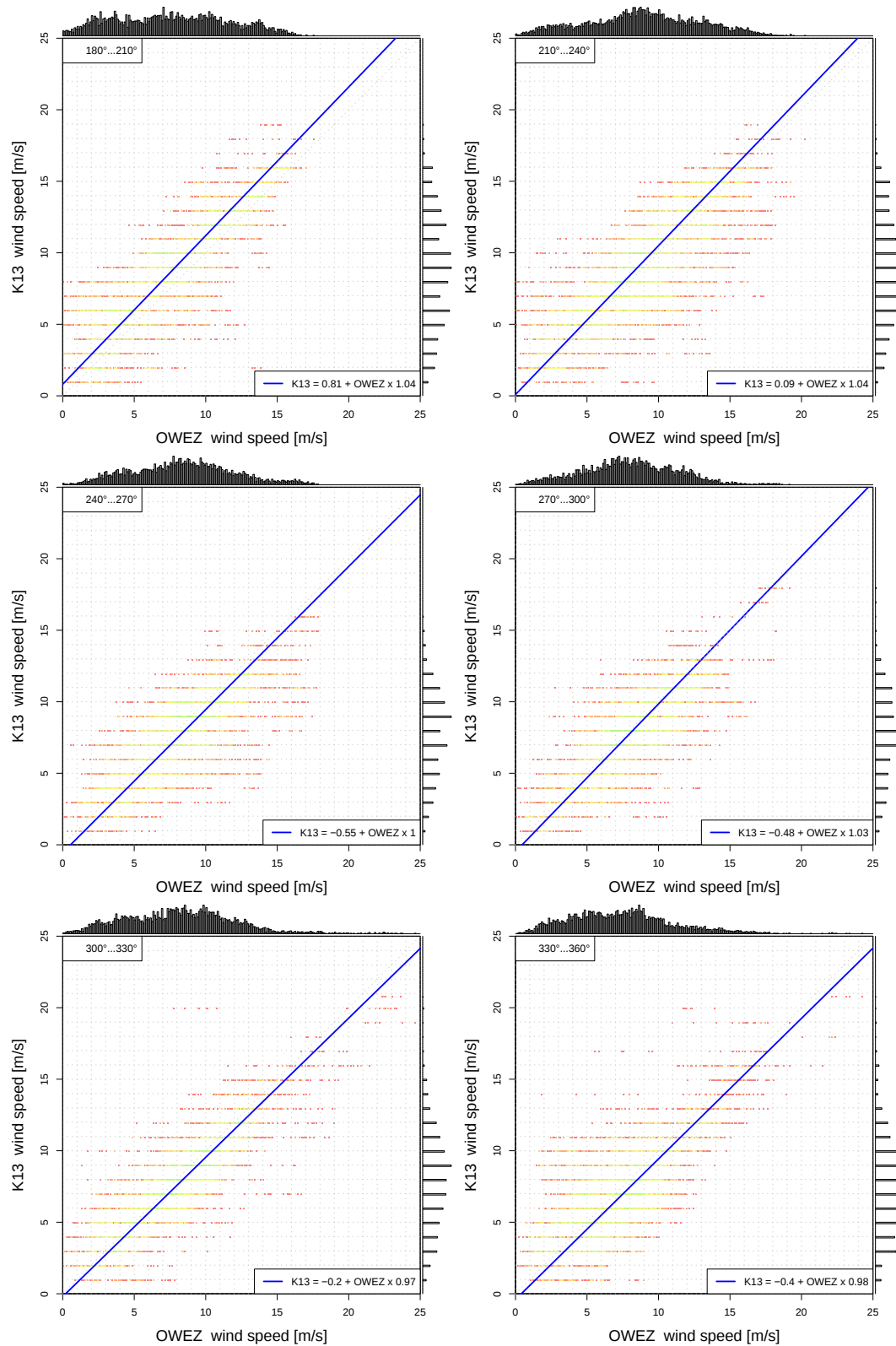


Figure 8: Probabilistic weighted linear regression of wind speeds measured at the OWEZ location and Meetpost K13 for the 30° sectors from 180°...360°. The background color indicates the frequency of measurements, with red representing a low frequency of observations and green representing a high frequency of observations. At each top side and right side the histogram of the signal is shown.

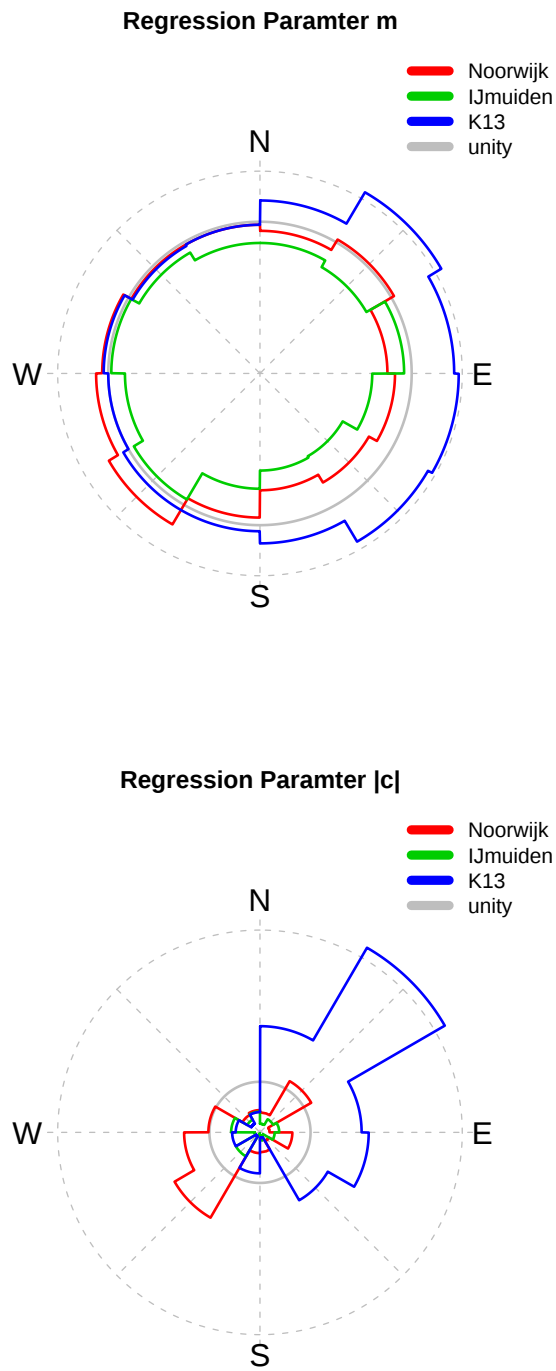


Figure 9: Polar plots of the regression parameters m and $|c|$. The largest deviations of m from unity (note that unity is indicated in the figures in grey) can be found in the eastern sectors, which is due to influence of the landmass. With increasing distance from the coast easterly winds speed up. That is why for these sectors m_{K13} is above unity, while $m_{Noordwijk}$ and $m_{IJmuiden}$ are below unity. Numbers can be found in Table 1.

6 Quasi-long-term wind climate

6.1 Procedure to obtain quasi-long-term wind climate

In order to obtain the quasi-long-term wind climate from the measurements at the mast, the following procedure is followed.

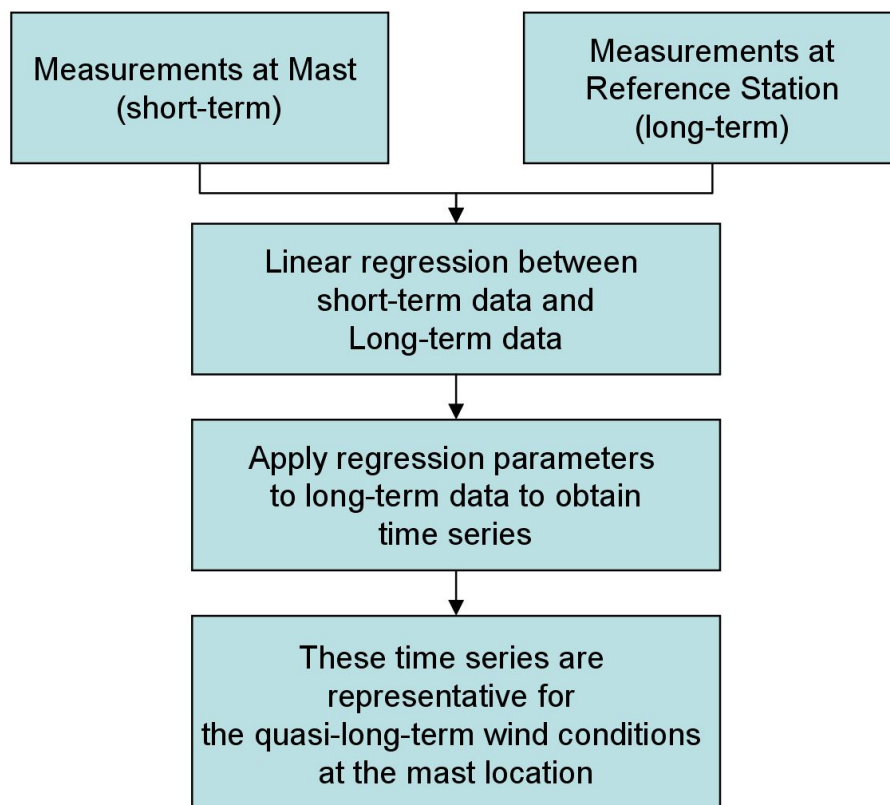


Figure 10: Flow diagram indicating the procedure that has been followed to obtain the quasi-long-term wind climate.

6.2 Weibull distributions

The previous estimated correction factors for wind directions and sector wise wind speeds have been applied to the long-term wind speed and wind direction measurements of the KNMI stations Meetpost Noordwijk, IJmuiden and K13. For those stations hourly measurements are available for the periods:

station	from	to
Meetpost Noordwijk	07/01/1996	07/05/2006
IJmuiden	10/01/1991	01/31/2007
K13	07/01/1996	01/31/2007

In doing so those long-term measurements have been transformed into quasi-long-term measurements at the OWEZ location. For each station and each 30° sector the wind speed measurements

have been binned and fitted by a Weibull distribution

$$p(u) = \frac{k}{A} \left(\frac{u}{A}\right)^{k-1} \exp\left(-\left(\frac{u}{A}\right)^k\right). \quad (3)$$

For each sector the quasi-long-term scale parameter A and the quasi-long-term shape parameter k for the OWEZ location has been estimated. Dependent on which KNMI station has been used as long-term data base a slightly different shape and scale parameter can be found in the following two tables.

wind direction in °	$A_{OWEZ_{Noordwijk}}$	$A_{OWEZ_{IJmuiden}}$	$A_{OWEZ_{K13}}$
$0 < \dots \leq 30$	7.456	7.568	8.425
$30 < \dots \leq 60$	8.073	8.415	8.940
$60 < \dots \leq 90$	8.149	8.399	8.412
$90 < \dots \leq 120$	7.858	8.398	7.971
$120 < \dots \leq 150$	7.211	7.873	7.300
$150 < \dots \leq 180$	9.466	9.055	7.632
$180 < \dots \leq 210$	11.345	10.798	8.943
$210 < \dots \leq 240$	10.292	11.031	9.984
$240 < \dots \leq 270$	9.748	9.972	10.358
$270 < \dots \leq 300$	9.470	9.806	9.404
$300 < \dots \leq 330$	9.031	9.223	9.503
$330 < \dots \leq 360$	8.252	8.389	9.019

Table 2: Quasi-long-term Weibull scale parameters (A) for the OWEZ location, based on long-term measurements at Meetpost Noordwijk, IJmuiden and K13.

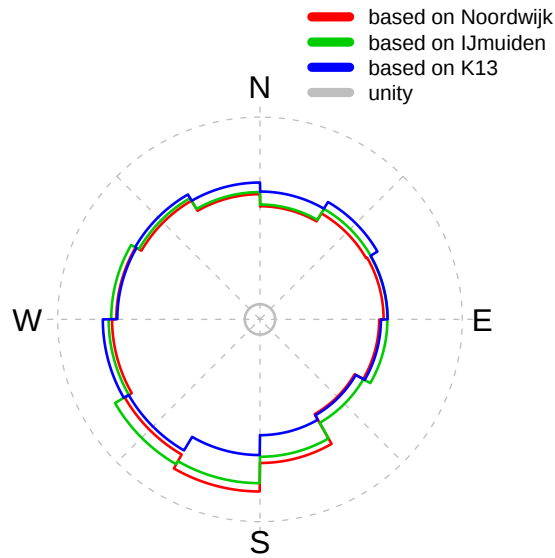
wind direction in °	$k_{OWEZ_{Noordwijk}}$	$k_{OWEZ_{IJmuiden}}$	$k_{OWEZ_{K13}}$
$0 < \dots \leq 30$	2.428	2.199	2.877
$30 < \dots \leq 60$	3.014	2.677	3.811
$60 < \dots \leq 90$	2.407	3.033	2.975
$90 < \dots \leq 120$	2.783	2.499	2.992
$120 < \dots \leq 150$	2.368	2.711	2.742
$150 < \dots \leq 180$	2.111	2.503	2.240
$180 < \dots \leq 210$	2.662	2.210	2.140
$210 < \dots \leq 240$	3.103	2.788	2.477
$240 < \dots \leq 270$	2.629	2.345	2.472
$270 < \dots \leq 300$	2.413	2.392	2.375
$300 < \dots \leq 330$	2.215	2.308	2.306
$330 < \dots \leq 360$	2.388	2.138	2.354

Table 3: Quasi-long-term Weibull shape parameters (k) for the OWEZ location, based on long-term measurements at Meetpost Noordwijk, IJmuiden and K13.

A graphical illustration of the shape and scale parameters can be found in Figure 11.

While the Weibull parameters for the stations Meetpost Noordwijk and IJmuiden are rather similar, those of the K13 station show larger deviations from Meetpost Noordwijk and IJmuiden. Together with the large scatter in wind directions and wind speeds it must be concluded that K13 is not appropriate to estimate the long-term wind climate for the OWEZ location. This is mainly due to the long distance between the OWEZ location and the K13 station.

Quasi-long-term OWEZ Weibull scale parameter A



Quasi-long-term OWEZ Weibull shape parameter k

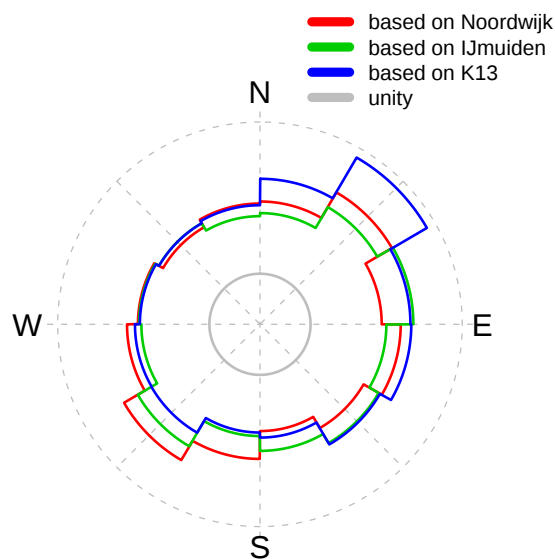


Figure 11: Polar plots of the Weibull parameters A and k . While the scale parameters for the stations Meetpost Noordwijk and IJmuiden are rather similar, those of the K13 station show larger deviations from Meetpost Noordwijk and IJmuiden. Also the scale parameters show the largest volatility for K13. Numbers can be found in Table 2 and 3.

7 Summary

By means of a two-step probabilistic linear regression the short-term measurements of wind speed and wind direction at the height of $21m$ at the OWEZ location have been correlated to the long-term potential wind speed and wind direction data sets of the KNMI stations Meetpost Noordwijk, IJmuiden and K13.

For these KNMI location the long-term data sets have been corrected with respect to the measurement location of the OWEZ measurement mast. Those corrected long-term data sets have then been used to estimate a long-term wind climate at the OWEZ location.

Scatter in wind directions, wind speeds as well as the Weibull distributions show that due to the long distance between the OWEZ location and the K13 station that long-term data set is not fully appropriate to estimate a long-term wind climate at the OWEZ location.

Although the KNMI station IJmuiden is the closest to the OWEZ location, the KNMI station Meetpost Noordwijk shows the least scatter and therefore is a better representation of the OWEZ location. This is mainly due to the fact that Meetpost Noordwijk has a similar distance to the coast, while IJmuiden is strongly influenced by onshore winds from the east, which is evident in the slopes of the linear regressions.

The quasi-long-term wind climate for the OWEZ location at $21m$ height, based on the KNMI station Meetpost Noordwijk is summarized below in Figure 12.

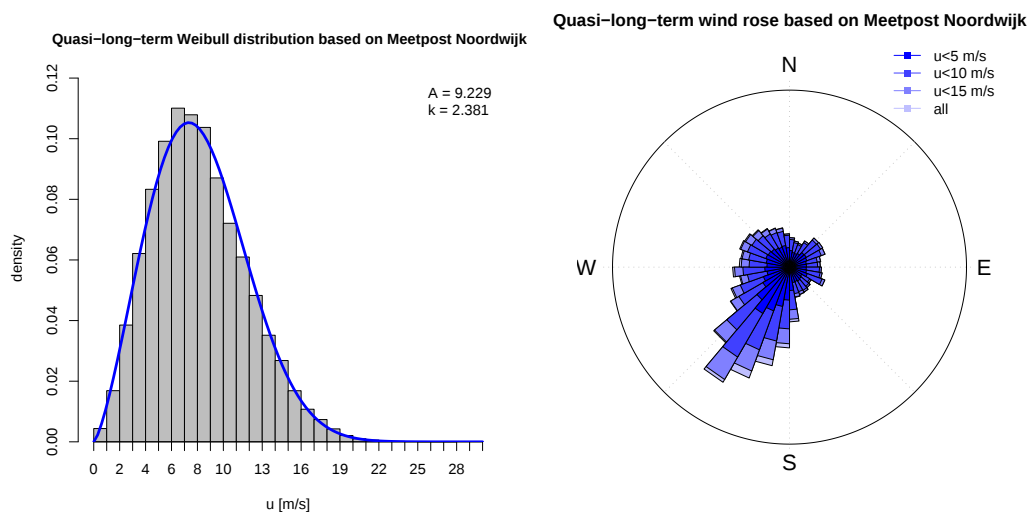


Figure 12: Quasi-long-term Weibull distribution and quasi-long-term wind rose for the OWEZ location at $21m$ height, based on the long-term data base of the KNMI station Meetpost Noordwijk.

References

- [1] H.J. KOUWENHOVEN
User manual data files meteorological mast NoordzeeWind
Document code: NZW-16-S-4-R03
www.noordzeewind.nl/files/Common/Data/

- [2] P.J. EECEN, L.A.H. MACHIELSE, A.P.W.M. CURVERS
Meteorological Measurements OWEZ; Half year report 01-07-2005 – 31-12-2005
Document code: OWEZ-R-121-20050701-20051231 wind resource 2005-2
www.noordzeewind.nl/files/Common/Data/

- [3] P.J. EECEN, L.A.H. MACHIELSE, A.P.W.M. CURVERS
Meteorological Measurements OWEZ; Half year report 01-01-2006 – 30-06-2006
Document code: OWEZ-R-121-20060101-20060630 wind resource 2006-1
www.noordzeewind.nl/files/Common/Data/