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Meteorological Measurements OWEZ

Half year report - 01-07-2008 - 31-12-2008

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ECN-E--09-018
OWEZ_R_121_20080701-20081231_WIND_RESOURCE_2008_2

NoordzeeWind

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Abstract
NoordzeeWind carries out an extensive measurement and evaluation program as part of the 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 meteorological measurements at the 116m high meteorological mast at the location of the wind farm are reported in half year reports. This report describes the measured data for the second semester of 2008; the period between 01-07-2008 and 31-12-2008.

The project is carried out under assignment of NoordzeeWind BV.

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.

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Project information
Contract number	NZW-16-C-2-R01
ECN project number:	7.9433

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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-minute statistics data to NoordzeeWind. ECN created a database under assignment of NoordzeeWind and fills the database with the delivered data. NoordzeeWind contracted ECN to report the data.

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. Before installation of the wind farm, a 116m high meteorological mast has been installed to measure the wind conditions. During this period, wind conditions are measured that are not disturbed by a nearby wind farm. This mast is in operation since the summer of 2005. After realisation of the wind farm, the mast will also be used to, among others, measure wind conditions in the wake of turbines and perform mechanical load and power performance measurements. The measurements at the 116m high mast are part of NSW-MEP tasks 1.2.1 and 1.8.1 and are reported in half-year reports. This report graphically and tabularly describes the measured data for the second semester of 2008; the period between 01-07-2008 and 31-12-2008.

In Chapter 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 neighbouring sensors. The definitions of derived wind speed and derived wind direction are described.

In Chapter 3 the measurement database is described and the availabilities of the signals in the reporting period are presented.

In Chapter 4 an overview of the meteorological data is presented over the reporting period. The overviews are made based on the content of the generated database, which is indicated in Table 3.1. The overview is presented for the hub height of the turbines in the wind farm, which is 70m. Unless otherwise noted, the derived wind speed and derived wind directions are used for the analyses, such as wind resource and turbulence analyses.

In Chapter 5 an overview of the meteorological data is presented for the cumulative period of the meteorological mast. In the present report, the cumulative period is identical to the measurement period.

In Chapter 6 the time series for all data are presented for the 6 months of the reporting period.

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 Table 2.1, together with the measured variables and instrument codes. The instrumentation is described in an earlier report [1].

Table 2.1 *Measured parameters, their units and instrumentation codes*

Instrument Code	Measured parameter and Unit
3D WM4/NW/116	wind direction [°]
3D WM4/NW/116	horizontal wind speed [m/s]
3D WM4/NW/116	vertical wind speed [m/s]
WS 018/NW/116	wind speed [m/s]
WS 018/NE/116	wind speed [m/s]
WS 018/S/116	wind speed [m/s]
WS 018/NW/70	wind speed [m/s]
WS 018/NE/70	wind speed [m/s]
RHTT 261/S/116	ambient temp. [°C]
RHTT 261/S/70	ambient temp. [°C]
RHTT 261/S/116	relative humidity [%]
DP910	ambient air pressure [mbar]
PD 205/NW/70	precipitation [yes/no]
ST 808/NW/-3.8	sea water temperature [°C]
AC SB2i/T/116	X (north – south) acceleration [m/s2]
AC SB2i/T/116	Y (west – east) acceleration [m/s2]
WD 524/NW/116	wind direction [°]
WD 524/NE/116	wind direction [°]
WD 524/S/116	wind direction [°]
WD 524/NW/70	wind direction [°]
WD 524/NE/70	wind direction [°]
3D WM4/NW/21	wind direction [°]
3D WM4/NW/21	horizontal wind speed [m/s]
3D WM4/NW/21	vertical wind speed [m/s]
3D WM4/NW/70	wind direction [°]
3D WM4/NW/70	horizontal wind speed [m/s]
3D WM4/NW/70	vertical wind speed [m/s]
WS 018/S/70	wind speed [m/s]
WS 018/NW/21	wind speed [m/s]
WS 018/NE/21	wind speed [m/s]
WS 018/S/21	wind speed [m/s]
RHTT 261/S/21	ambient temp. [°C]
RHTT 261/S/70	relative humidity [%]
RHTT 261/S/21	relative humidity [%]
PD 205/NE/70	precipitation [yes/no]
WD 524/S/70	wind direction [°]
WD 524/NW/21	wind direction [°]
WD 524/NE/21	wind direction [°]
WD 524/S/21	wind direction [°]

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) [1]. Sensors attached to the meteorological mast are described in [2]. The location of the meteorological mast is given in Table 2.2.

Table 2.2 *Coordinates of the meteorological mast at OWEZ*

	UTM31 ED50	**WGS 84**
x	594195	4º23'22,7" EL
y	5829600	52º36'22,9" NB

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 neighbouring sensors or are otherwise significantly disturbed by the mast. It is necessary to select one of the cup anemometers depending on the actual wind direction in order to establish a wind speed that minimises the distortion of the meteorological mast. The constructed wind speed and wind direction are used in this report unless it is explicitly indicated. The selection of signals is indicated in Table 2.3.

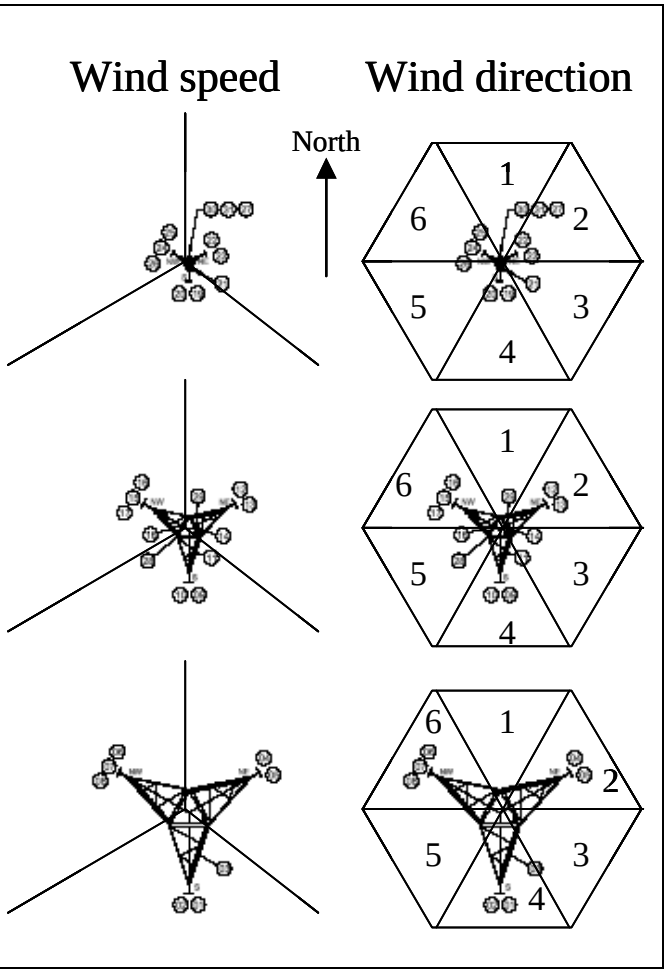
For the selection of the wind speed sensor it is important that at the direction where the wind speed sensor is changed from one sensor to the other, the ratio of the wind speeds is close to one. Furthermore, the wind speed may not be measured in the wake of the mast or a neighbouring sensor. Averaging over two vanes can reduce the effect of the distortion of the mast on the wind direction measurement.

Also the standard deviation of the wind direction has been taken into account. The standard deviation is significantly increased for wind directions directly along the booms. This is the reason that six sectors are defined instead of the three sectors in the case of wind speed.

A first assessment of the order of the distortion of the wind direction and wind speed measurements due to the mast at the three heights can be made by comparison of the sensors at the three booms. The ratios of the wind speeds at the three booms for the three heights are indicated in Figure 2.1, the differences between the three wind vanes for the three heights are indicated in Figure 2.2.

Table 2.3 *Detailed information to create the derived wind direction and wind speed based on wind direction.*

Wind direction		Selected sensors
Derived wind direction	(1) 330 to 30 degree	average of wind vanes NW and NE boom
	(2) 30 to 90 degree	average of wind vanes S and NW boom
	(3) 90 to 150 degree	average of wind vanes S and NE boom
	(4) 150 to 210 degree	average of wind vanes NW and NE boom
	(5) 210 to 270 degree	average of wind vanes NW and S boom
	(6) 270 to 330 degree	average of wind vanes NE and S boom
Derived wind speed	0 to 120 degree	cup anemometer in NE boom
	120 to 240 degree	cup anemometer in S boom
	240 to 360 degree	cup anemometer in NW boom



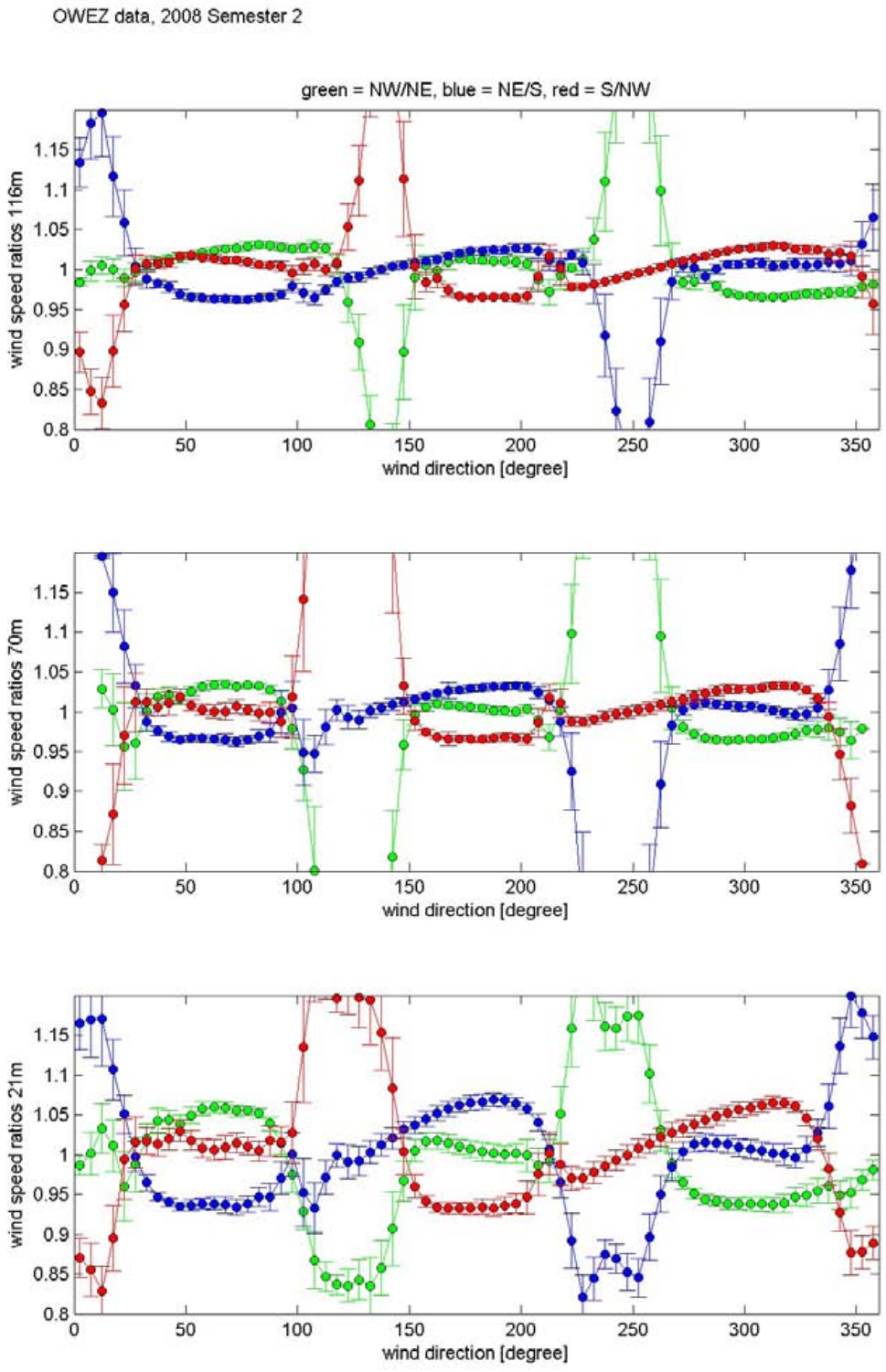


Figure 2.1 *Ratios between anemometer readings mounted on the South (S), North-West (NW) and North-East (NE) booms of the meteorological mast. The wind speed ratios NW/NE are indicated in green, the ratios NE/S are indicated in blue and the ratios S/NW are indicated in red. The indicated wind direction along the horizontal axis is the derived wind direction as described in section 2.2.2. Wind speeds above 4m/s have been selected.*

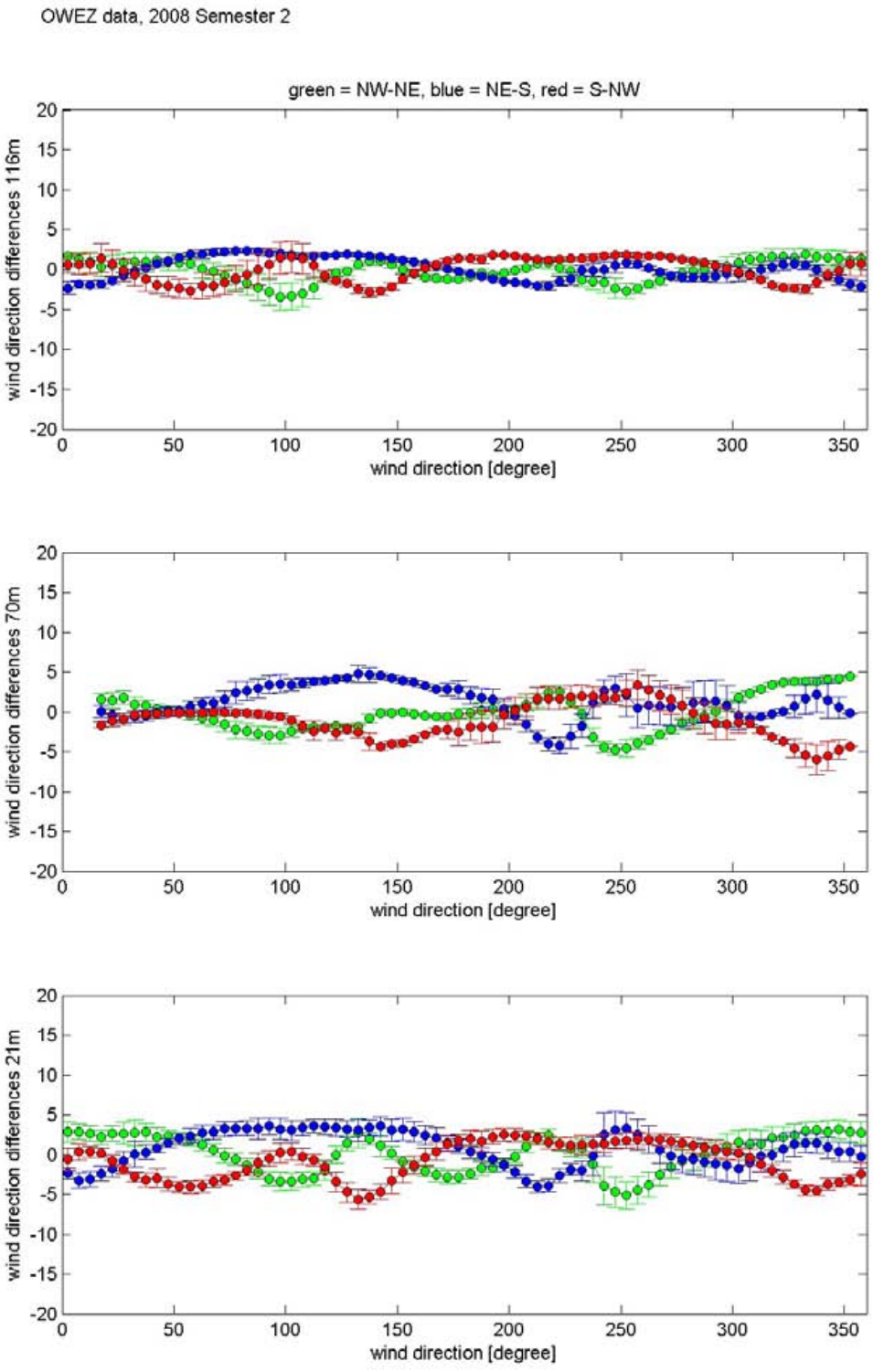


Figure 2.2 *Differences between wind vane readings mounted on the South (S), North-West (NW) and North-East (NE) booms of the meteorological mast. The wind direction differences NW/NE are indicated in green, the differences NE/S are indicated in blue and the differences S/NW are indicated in red. The indicated wind direction along the horizontal axis is the derived wind direction as described in section 2.2.2. Wind speeds above 4m/s have been selected.*

3. Measurements data base

3.1 Sensor calibration

The applied sensors in the meteorological mast are calibrated according to maintenance schedules of BCE (Mierij Meteo). The cup anemometers are calibrated at DEWI Germany. BCE (Mierij Meteo) calibrates the other sensors. The calibration constants are applied to the data during the stage of data processing at BCE (Mierij Meteo).

3.2 Data validation

In the measuring period, defective sensors or cables or other malfunctioning of the measurement system can corrupt the measured data. For this reason, BCE (Mierij Meteo) validates all measured data [4]. The quality and consistency of the data is assessed by means of manual check of the received data on

1. Consistency
2. Out of range numbers
3. Followed by marking of incorrect and unavailable records

Corrupt or missing data fields are marked by error values (-999999).

3.3 Data transport

The validated data are sent to ECN, where the data are collected in a database [3].

3.4 Database content

The signals that are measured at the meteorological mast at OWEZ are indicated in Table 2.1. The statistics data for each of the signals are the

10-minute average value
10-minute minimum value
10-minute maximum value
10-minute standard deviation

An overview of the availability of data for each signal is included in Table 3.1. In this table the availability in the reporting period is given together with the availability in the cumulative period. Note that for each valid average 10-minute measurement, also a valid standard deviation, minimum or maximum value exists.

3.5 Data reporting

The data are reported in half-year reports.

Table 3.1 *Contents of database and availability of data in the reporting period.*

WDMS identification code	reporting period July 2008 - December 2008	
	number of valid 10-minute averages	availability [%]
3D WM4/NW/116	18167	68.57
3D WM4/NW/116	18166	68.56
3D WM4/NW/116	18167	68.57
WS 018/NW/116	24475	92.37
WS 018/NE/116	24664	93.09
WS 018/S/116	24651	93.04
WS 018/NW/70	23951	90.39
WS 018/NE/70	24247	91.51
RHTT 261/S/116	24781	93.53
RHTT 261/S/70	24738	93.37
RHTT 261/S/116	24758	93.44
DP910	24701	93.23
PD 205/NW/70	24520	92.54
ST 808/NW/-3.8	17928	67.66
AC SB2i/T/116	25197	95.10
AC SB2i/T/116	25197	95.10
WD 524/NW/116	24231	91.45
WD 524/NE/116	23880	90.13
WD 524/S/116	24326	91.81
WD 524/NW/70	22037	83.17
WD 524/NE/70	22622	85.38
3D WM4/NW/21	24466	92.34
3D WM4/NW/21	24466	92.34
3D WM4/NW/21	24466	92.34
3D WM4/NW/70	24400	92.09
3D WM4/NW/70	24400	92.09
3D WM4/NW/70	24400	92.09
WS 018/S/70	24539	92.61
WS 018/NW/21	24113	91.01
WS 018/NE/21	24449	92.27
WS 018/S/21	24113	91.01
RHTT 261/S/21	15461	58.35
RHTT 261/S/70	24724	93.31
RHTT 261/S/21	15209	57.40
PD 205/NE/70	24601	92.85
WD 524/S/70	21178	79.93
WD 524/NW/21	23512	88.74
WD 524/NE/21	22936	86.56
WD 524/S/21	22678	85.59
derived wind direction	24348	91.89
derived wind direction	24170	91.22
derived wind direction	24634	92.97
derived wind speed	23347	88.12
derived wind speed	23186	87.51
derived wind speed	24150	91.15

4. Wind climate in the reporting period

4.1 Wind speed frequency distribution

The wind speed frequency distribution is reported according the widely used Wasp 'tabfile' format. Table 4.1 gives the wind speed frequency distributions, the average wind speed and the Weibull parameters per wind direction sector measured during the reporting period. The average wind speed is the average of all wind speed measurements in the wind direction sector. The Weibull A and k values result from a Weibull fit to all wind speed measurements in the wind direction sector. The percentage of occurrence is the percentage of wind speed data in the wind direction sector over all wind speed data. The distributions per sector are presented in per mille.

Table 4.1 A*verage wind speed (V), Weibull parameters (A, k) and percentages of occurrence [%] per wind direction sector are presented. The wind speeds are measured at 70m above MSL in the reporting period. Distributions per sector are given in per mille.*

		Wind direction sector [degree]												
		-15-15	15-45	45-75	75-105	105-135	135-165	165-195	195-225	225-255	255-285	285-315	315-345	ALL
	V [m/s]	3.5	5.1	6.5	6.7	5.6	7.5	9.3	11.8	10.2	9.3	8.3	7.5	8.9
Weibull	A [m/s]	4.0	5.8	7.4	7.5	6.3	8.5	10.5	13.2	11.4	10.4	9.3	8.4	10.1
Weibull	k [-]	1.9	2.4	2.9	3.0	2.1	2.1	2.6	3.1	3.2	2.6	2.6	2.4	2.4
	[%]	2.5	2.3	5.8	10.9	4.1	3.3	5.7	18.0	18.5	12.0	8.5	4.3	
Wind speed [m/s]	0-1	39	10		2	6			1	1			4	2
	1-2	132	6	16	9	29	39	15	8	2	14	9	37	15
	2-3	380	76	56	33	96	84	25	14	20	25	29	47	35
	3-4	218	223	12	17	23	13	44	16	22	36	36	8	59
	4-5	54	22	133	15	167	80	68	20	24	57	88	96	73
	5-6	39	125	120	13	153	86	72	24	4	75	113	114	76
	6-7	62	13	126	135	80	123	70	4	46	92	135	99	84
	7-8	32	65	16	144	123	82	94	49	79	72	133	122	94
	8-9	8	74	117	100	61	51	99	64	13	96	17	93	90
	9-10	32	4	85	99	17	73	99	1	14	125	77	82	1
	10-11	8	2	5	65	5	7	79	13	124	118	58	87	86
	11-12		15	32	24	10	55	72	94	116	86	52	52	7
	12-13		2	8	5	9	53	9	81	94	49	50	40	55
	13-14		4	3	6	21	2	58	75	57	37	6	26	43
	14-15				1	2	31	6	68	5	23	20	12	31
	15-16				2		47	28	61	38	35	20	5	29
	16-17						4	25	67	27	22	15	9	24
	17-18							11	56	14	13	6	7	16
	18-19							7	29	1	16	4		1
	19-20							3	14	1	7			4
	20-21							1	4	1				1
	21-22								7					1
	22-23								2					
	23-24								2					
	24-25								1					
	25-26													
	26-27													
	27-28													
	28-29													

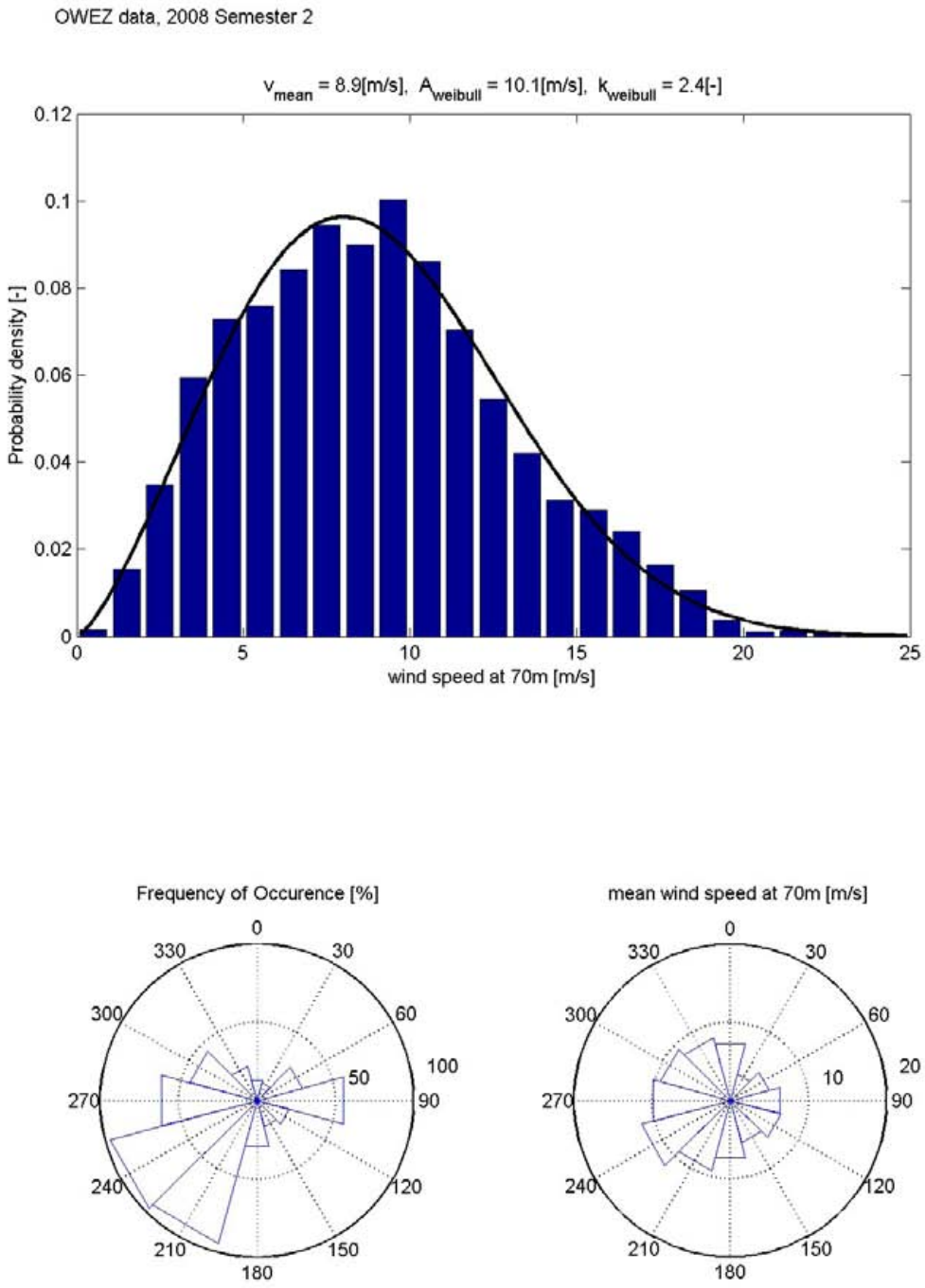


Figure 4.1 *Overall wind speed frequency distribution measured at 70 m above MSL during the reporting period (histogram) and the fitted Weibull distribution. Wind roses for the frequency of wind direction occurrence and the mean wind speed measured at 70 m above MSL during the reporting period. The corresponding numerical values are given in Table 4.1*

4.2 Turbulence intensity

4.2.1 Turbulence intensity, frequency of occurrence

The turbulence intensities are calculated for direction sectors of 30 degrees. For each sector the turbulence according IEC 61400-1 Ed.3 [5] is calculated, which is calculated as follows:

1. For all ten-minutes averages determine the average wind speed v_{mean} and the turbulence standard deviation σ_1. The turbulence standard deviation σ_1 is the standard deviation of the longitudinal component of the turbulent wind velocity at hub height. The longitudinal component of turbulence may be approximated by the horizontal component.
2. Perform a bin action on the v_{mean} using a bin width of 1m/s.
3. Consider only the bins between v_{cutin} and v_{cutout}.
4. For each bin calculate the mean wind speed from the data $v_{mean,bin}$ and the mean turbulence standard deviation σ_{1bin}.
5. Plot $v_{mean,bin}$ versus σ_{1bin}. Then the function (1) should be fitted to the data. In this equation, I_{ref} is the desired turbulence intensity at 15m/s at the site applying the normal turbulence model.

$$\sigma_1 = I_{ref}\left(0.75 v_{hub} + b\right); \qquad b = 5.6\ \text{m/s} \tag{1}$$

The numbers are presented in Table 4.2 and graphical presentations of $v_{mean,bin}$ versus the average turbulence intensity in the bin I_{bin} are given in Figure 4.2.

Table 4.2 *Average turbulence intensities (in percent) per wind speed bin and wind direction sector, measured during the reporting period. The wind speed bins are centred around integer wind speeds.*

		Wind direction sector [degree]												
		345-15	15-45	45-75	75-105	105-135	135-165	165-195	195-225	225-255	255-285	285-315	315-345	all
Wind speed [m/s]	4	21.9	12.8	8.2	11.3	9.3	7.3	7.9	7.9	7.8	8.1	7.8	1.8	9.5
	5	1.5	13.5	8.9	11.1	1.4	7.8	6.7	7.4	7.6	7.3	6.8	9.1	9.6
	6	1.7	1.6	8.6	1.5	9.5	6.7	6.7	6.7	6.9	7.4	7.6	9.2	8.1
	7	7.9	1.8	8.2	1.2	1.4	6.4	6.7	6.4	6.6	8.0	6.4	8.9	7.8
	8	9.8	9.6	7.8	9.3	9.5	6.1	5.9	6.1	6.3	6.9	6.4	8.1	7.2
	9	1.8	8.9	9.0	8.3	9.3	5.5	5.5	5.9	6.1	6.7	6.4	8.1	6.7
	10	9.6	9.5	7.6	7.9	6.9	4.6	4.9	5.5	5.9	6.7	6.0	8.6	6.3
	11		8.7	7.5	8.1	7.9	4.9	6.0	5.6	6.7	6.3	6.1	9.0	6.2
	12		8.5	7.7	7.3	8.9	5.2	5.9	5.9	6.9	6.2	5.7	8.7	6.1
	13		7.5	6.2	8.0	7.8	5.0	6.1	6.2	6.1	6.5	6.5	7.9	6.3
	14			4.4	7.6	7.8	6.7	6.2	6.3	6.2	6.2	6.8	7.8	6.4
	15				7.6	7.9	6.7	6.2	6.5	6.2	6.8	7.3	6.8	6.4
	16				6.9		6.3	6.5	6.7	6.5	6.4	6.8	7.0	6.6
	17							6.6	6.6	6.6	6.5	6.6	6.8	6.5
	18							6.7	6.5	6.2	6.8	6.7	5.7	6.5
	19							6.9	6.5	6.2	6.3	6.5		6.4
	20							7.3	6.2	6.5	5.6			6.3
	21								6.2	5.8				6.1
	22								6.2					6.2
	23								6.0					6.0
	24								6.0					6.0
	25								5.6					5.6
	26													
	27													
	28													
	29													
	30													
	TI IEC I_{ref}	9.0	8.9	6.4	7.9	8.0	6.5	6.6	6.6	6.7	6.9	7.1	7.7	6.8

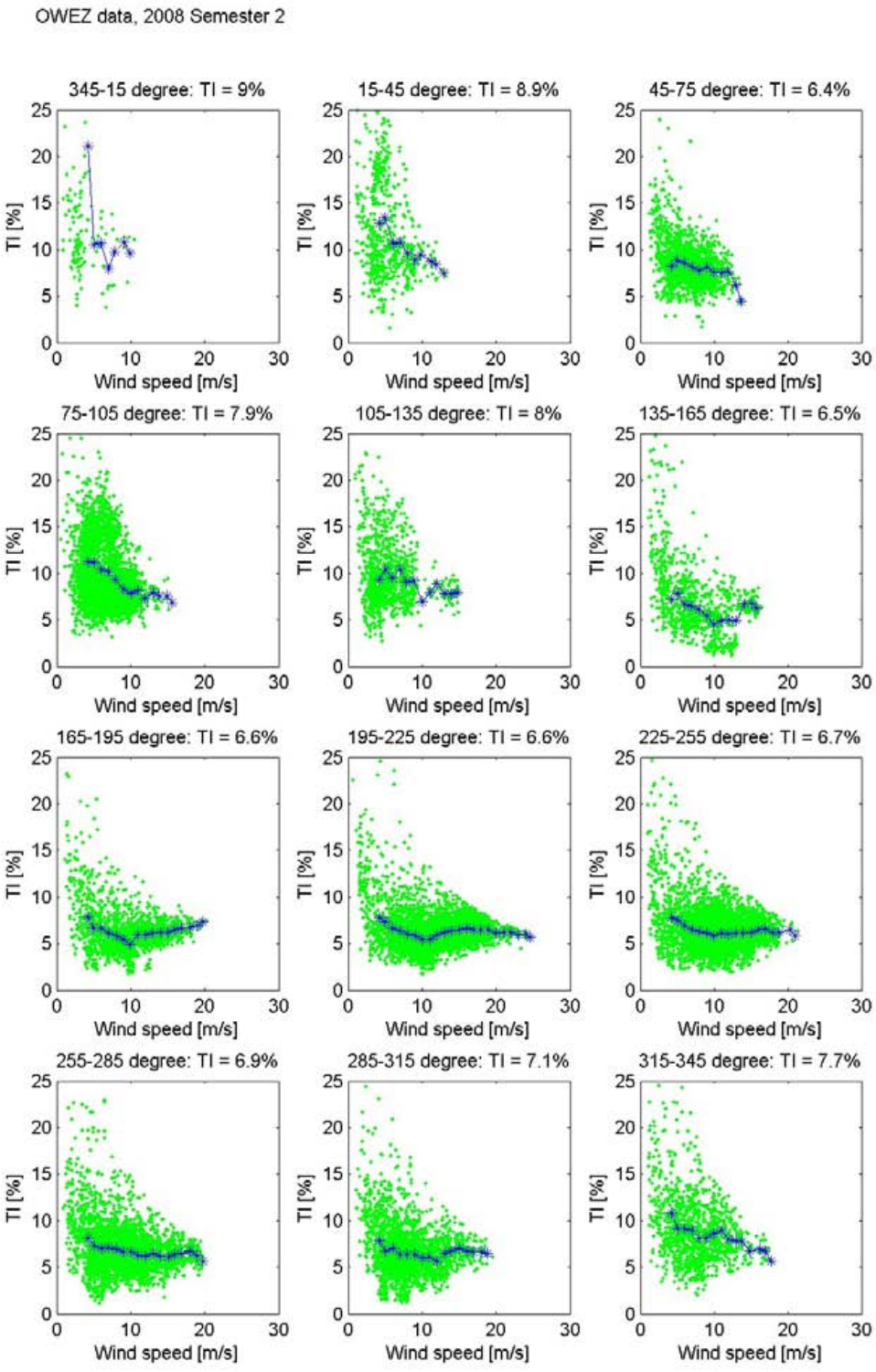


Figure 4.2 *Turbulence intensities per wind direction sector, measured at 70m above MSL during the reporting period. The blue stars indicate the average turbulence intensities in the wind speed bins. For each wind direction sector the turbulence intensity determined according IEC 61400-1 Ed. 3 [5] is indicated.*

4.2.2 Turbulence intensity, vertical profile

The average turbulence intensities at the three heights are given as function of wind direction in Figure 4.3 in 5-degree wind direction bins. The average turbulence intensities are determined at the three heights by averaging the turbulence intensities with wind speeds above 4m/s.

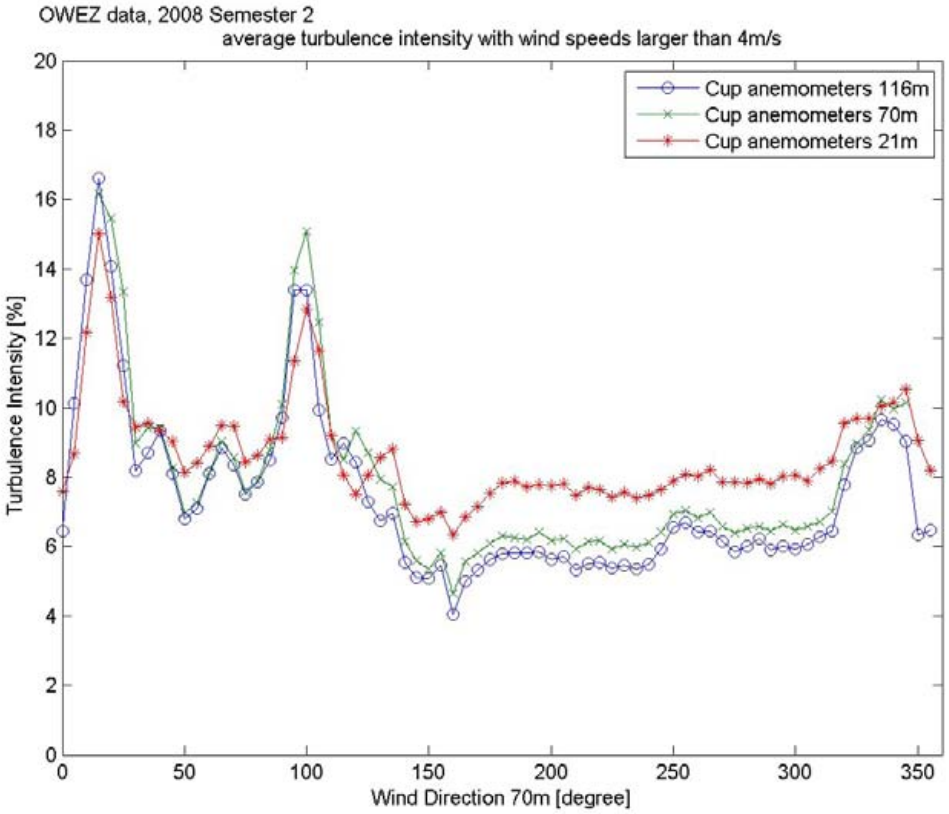


Figure 4.3 *Average turbulence intensities at measuring heights 21, 70 and 116m depending on wind direction (bin width 5º) measured during the reporting period. Only data are included with wind speeds above 4m/s.*

4.2.3 Wind speed profile

The vertical wind speed profile can be modelled using the so-called power law. This is a simple model for the profile of wind speed with height:

$$\frac{U(z)}{U(z_r)} = \left(\frac{z}{z_r}\right)^{\alpha} \qquad (2)$$

For every 10-minute record the exponent α determined from fitting to the derived wind speeds at 21, 70 and 116m height under the assumption that it crosses the 21m wind speed. Only data are included that meet the requirement $V_{70} > 4$ m/s. The numerical values are indicated in Table 4.3. In the upper plot of Figure 4.4 the power law exponents for each ten-minute measurement are presented together with the average power law exponents as a function of wind direction. In the lower plot in Figure 4.4 the power law exponents are presented as function of time of the day and wind direction sector.

Table 4.3 *Exponents α for the vertical wind speed profile per wind direction sector, measured during the reporting period. Only data are included with wind speeds at 70m exceeding 4 m/s.*

	Wind direction sector [degree]												
	345-15	15-45	45-75	75-105	105-135	135-165	165-195	195-225	225-255	255-285	285-315	315-345	all
α [-] average	0.08	0.03	0.05	0.05	0.10	0.10	0.08	0.07	0.06	0.06	0.07	0.06	0.07
standard deviation	0.05	0.07	0.03	0.06	0.09	0.09	0.06	0.04	0.05	0.05	0.07	0.04	0.06

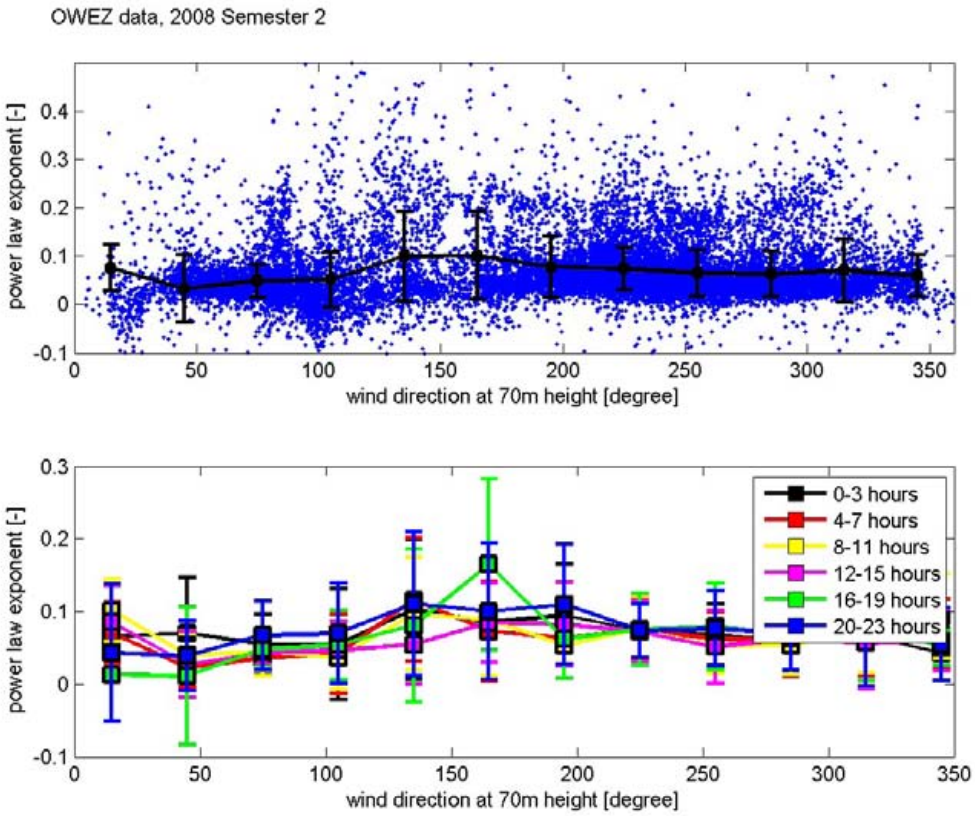


Figure 4.4 *Upper plot: Exponents for each 10-minute average together with the average exponent for the vertical wind speed and standard deviation depending on wind direction (bin width 2º) as measured during the reporting period Only data are included that meet the requirement V_{70} > 4 m/s. Lower plot: averaged exponents as function of wind direction and time of the day are plotted.*

5. Wind climate, cumulative

This Chapter presents the cumulative data from July 2005 to December 2008 measured at the mast. Since the mast is nearby the OWEZ wind farm, the wind conditions at certain wind directions (143 to 316 degrees, reference [6]) are disturbed by the wakes of the turbines. As a result, the wind climate indicated here does not represent the undisturbed wind conditions; it represents the measured wind conditions.

Table 5.1 *Contents of database and availability of data in the cumulative period.*

WDMS identification code	reporting period July 2005 - December 2008	
	number of valid 10-minute averages	availability [%]
3D WM4/NW/116	130694	70,9
3D WM4/NW/116	130733	70,9
3D WM4/NW/116	130728	70,9
WS 018/NW/116	167429	90,8
WS 018/NE/116	168117	91,2
WS 018/S/116	172379	93,5
WS 018/NW/70	166498	90,3
WS 018/NE/70	167598	90,9
RHTT 261/S/116	178173	96,7
RHTT 261/S/70	171643	93,1
RHTT 261/S/116	177506	96,3
DP910	160145	86,9
PD 205/NW/70	177474	96,3
ST 808/NW/-3.8	169044	91,7
AC SB2i/T/116	174254	94,5
AC SB2i/T/116	174250	94,5
WD 524/NW/116	163517	88,7
WD 524/NE/116	144494	78,4
WD 524/S/116	164584	89,3
WD 524/NW/70	161143	87,4
WD 524/NE/70	161430	87,6
3D WM4/NW/21	147682	80,1
3D WM4/NW/21	161964	87,9
3D WM4/NW/21	161935	87,9
3D WM4/NW/70	173762	94,3
3D WM4/NW/70	173772	94,3
3D WM4/NW/70	173779	94,3
WS 018/S/70	172144	93,4
WS 018/NW/21	170776	92,7
WS 018/NE/21	169612	92,0
WS 018/S/21	170776	92,7
RHTT 261/S/21	166152	90,1
RHTT 261/S/70	172480	93,6
RHTT 261/S/21	164562	89,3
PD 205/NE/70	178378	96,8
WD 524/S/70	151452	82,2
WD 524/NW/21	168301	91,3
WD 524/NE/21	164523	89,3
WD 524/S/21	169182	91,8
derived wind direction	169172	91,8
derived wind direction	167719	91,0
derived wind direction	161696	87,7
derived wind speed	157045	85,2
derived wind speed	153541	83,3
derived wind speed	150950	81,9

Table 5.2 A*verage wind speed (V), Weibull parameters (A, k) and percentages of occurrence [%] per wind direction sector are presented. The wind speeds are measured at 70m above MSL in the cumulative period. Distributions per sector are given in per mille.*

		Wind direction sector [degree]												
		-15-15	15-45	45-75	75-105	105-135	135-165	165-195	195-225	225-255	255-285	285-315	315-345	ALL
	V [m/s]	7,2	7,3	7,5	7,1	6,5	8,4	9,6	11,4	10,1	9,2	8,6	8,0	8,9
Weibull	A [m/s]	8,1	8,2	8,5	8,0	7,4	9,5	10,8	12,8	11,4	10,3	9,8	9,1	10,1
	k [-]	2,1	2,3	2,7	2,8	2,3	2,5	2,4	2,8	2,6	2,4	2,3	2,1	2,3
	[%]	6,3	5,0	6,4	7,2	3,8	4,5	6,1	13,6	13,7	9,7	8,5	6,9	
Wind speed [m/s]	0-1	11	7	4	5	12	6	3	2	3	5	5	6	5
	1-2	45	30	23	21	38	22	18	12	16	21	18	31	22
	2-3	84	65	40	38	69	48	41	19	25	33	38	60	40
	3-4	98	91	68	72	102	63	52	26	35	50	56	76	57
	4-5	86	99	95	96	112	55	55	31	43	60	72	82	66
	5-6	87	92	101	125	130	70	60	37	50	67	86	86	75
	6-7	87	93	101	139	125	88	66	44	64	79	89	94	83
	7-8	99	117	126	137	132	88	83	53	75	82	94	93	91
	8-9	111	105	135	118	88	95	80	68	82	96	104	86	94
	9-10	88	88	107	89	54	102	92	79	99	104	98	84	92
	10-11	53	74	70	66	37	111	85	83	97	96	81	79	82
	11-12	46	51	45	46	51	80	68	78	87	70	63	59	66
	12-13	33	32	34	27	30	69	71	87	79	60	53	48	58
	13-14	26	21	31	15	16	48	60	76	64	49	49	41	47
	14-15	21	16	14	5	5	25	52	72	49	32	36	26	36
	15-16	17	11	5	2		18	38	62	40	31	22	14	28
	16-17	7	4				6	30	58	33	25	14	11	22
	17-18	1	4				3	24	42	26	18	8	10	16
	18-19	1	1				2	10	31	17	12	6	6	10
	19-20						1	6	20	8	6	3	4	6
	20-21							3	10	4	2	2	2	3
	21-22							3	5	1	1	1	1	1
	22-23							2	2	1				1
	23-24								1					
	24-25											1		
	25-26											1		
	26-27													
	27-28													
	28-29													

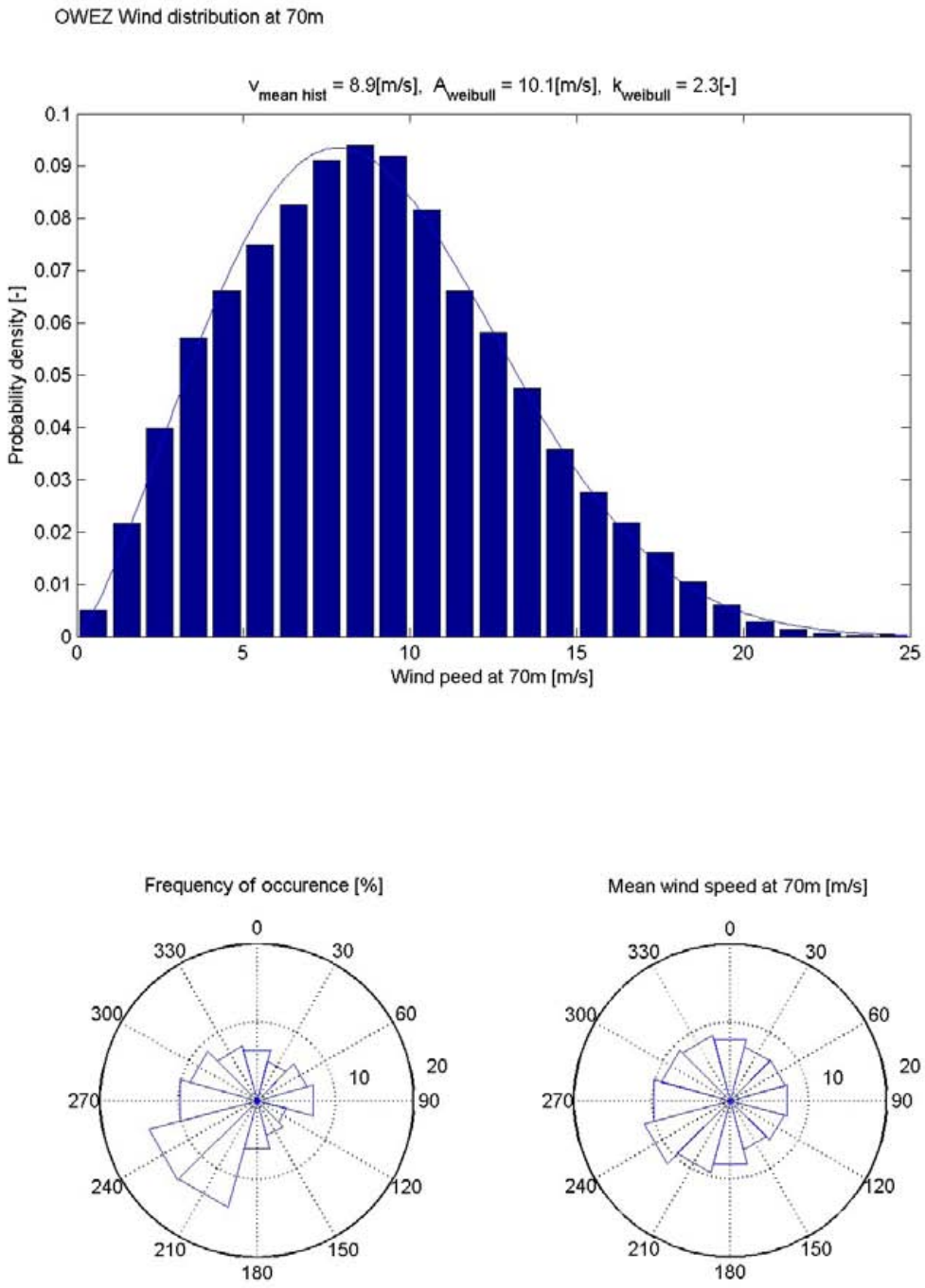


Figure 5.1 *Overall wind speed frequency distribution measured at 70 m above MSL during the period from July 2005 to December 2008 (histogram) and the fitted Weibull distribution. Wind roses for the frequency of wind direction occurrence and the mean wind speed measured at 70 m above MSL during the reporting period. The corresponding numerical values are given in Table 5.2.*

6. Time histories July-August 2008

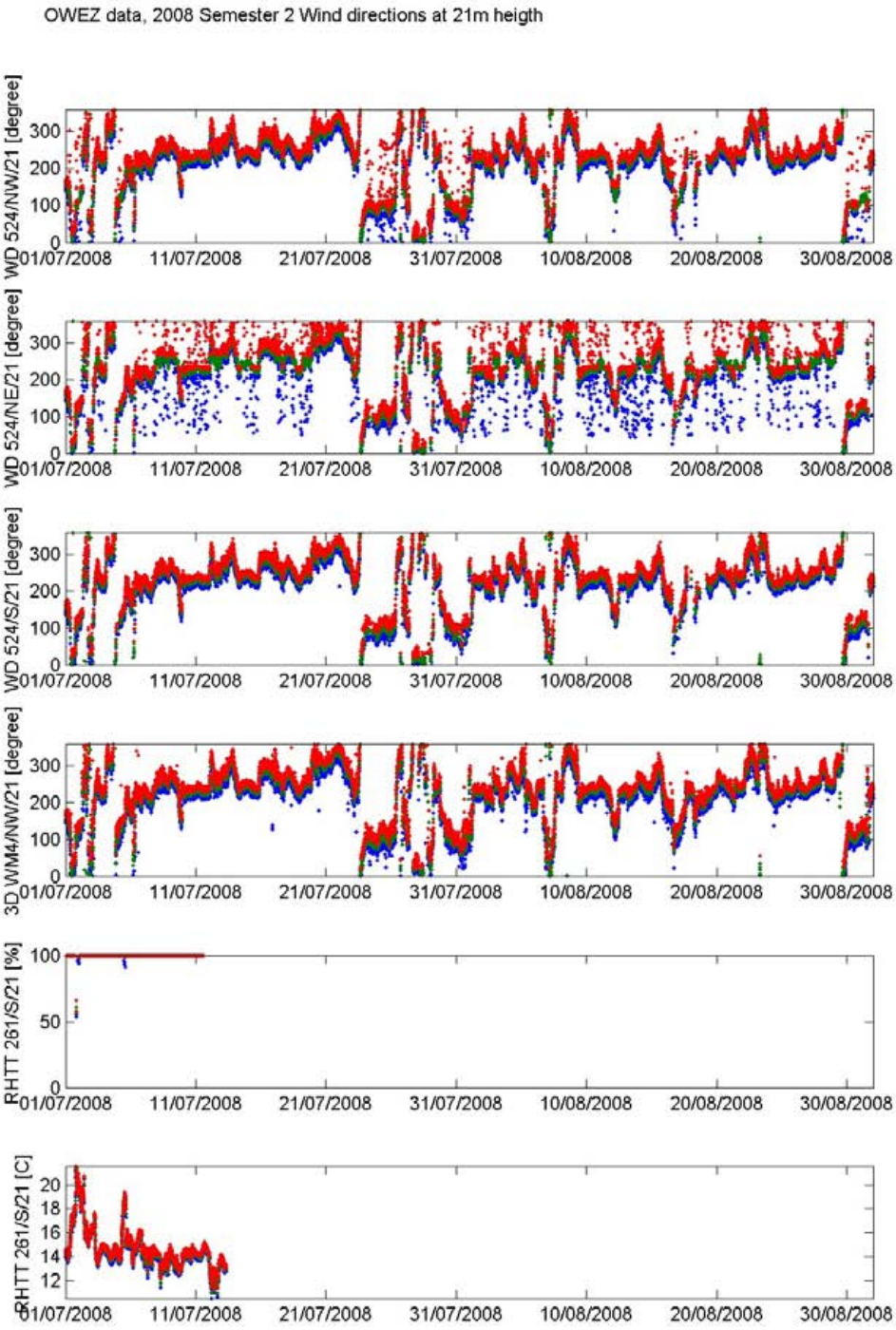


Figure 6.1 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 21 m height are shown for July and August 2008.*

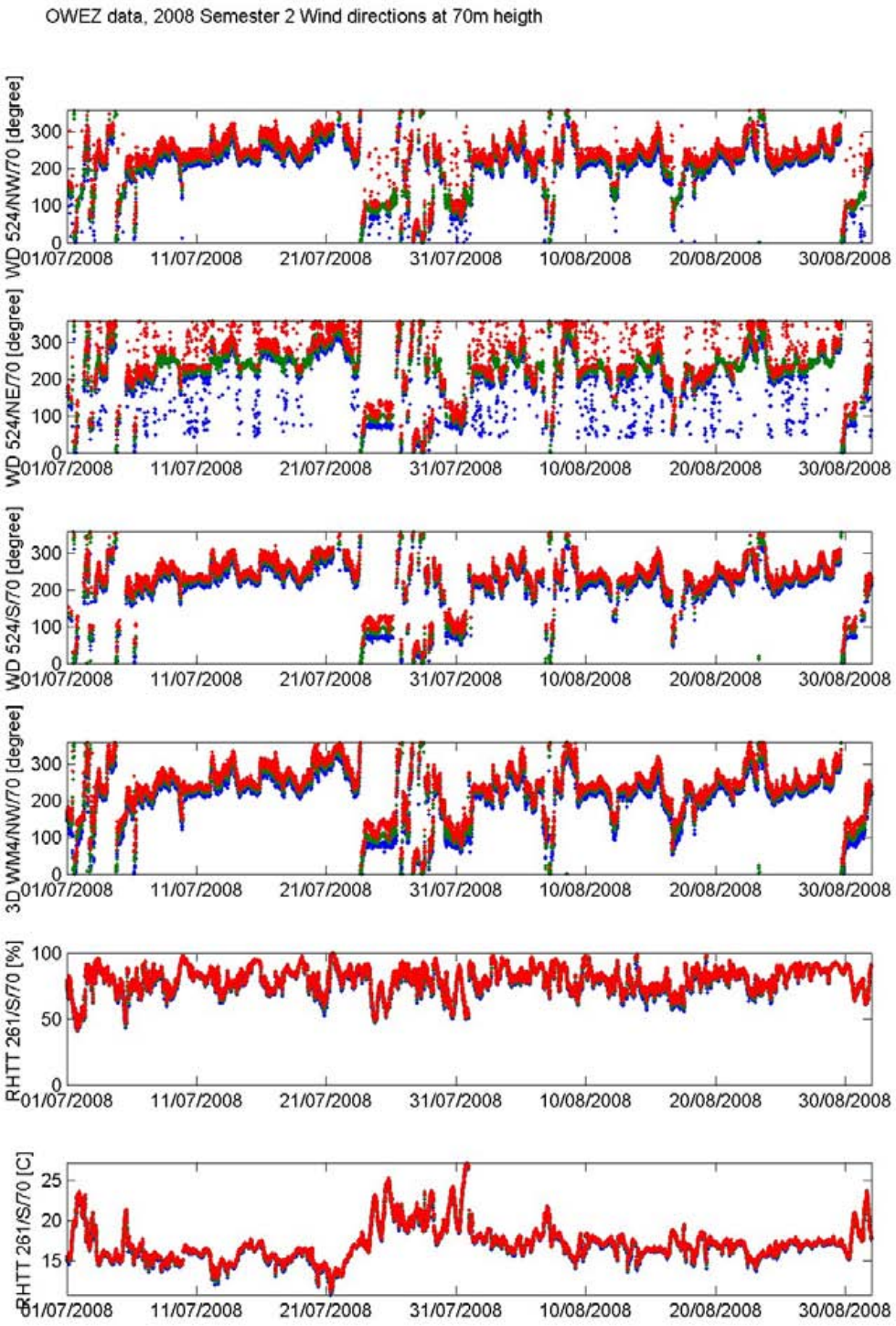


Figure 6.2 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 70 m height are shown for July and August 2008.*

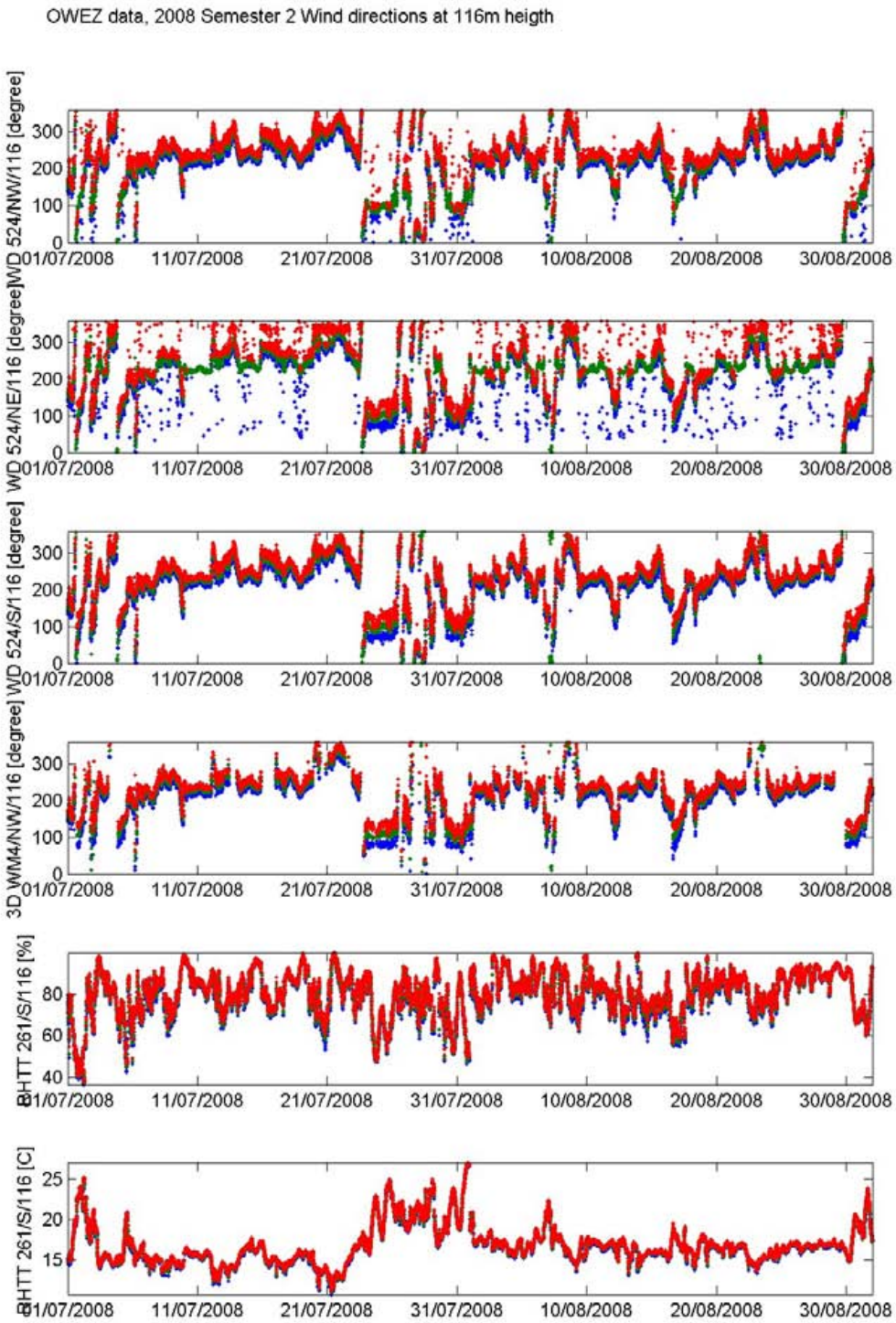


Figure 6.3 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 116 m height are shown for July and August 2008.*

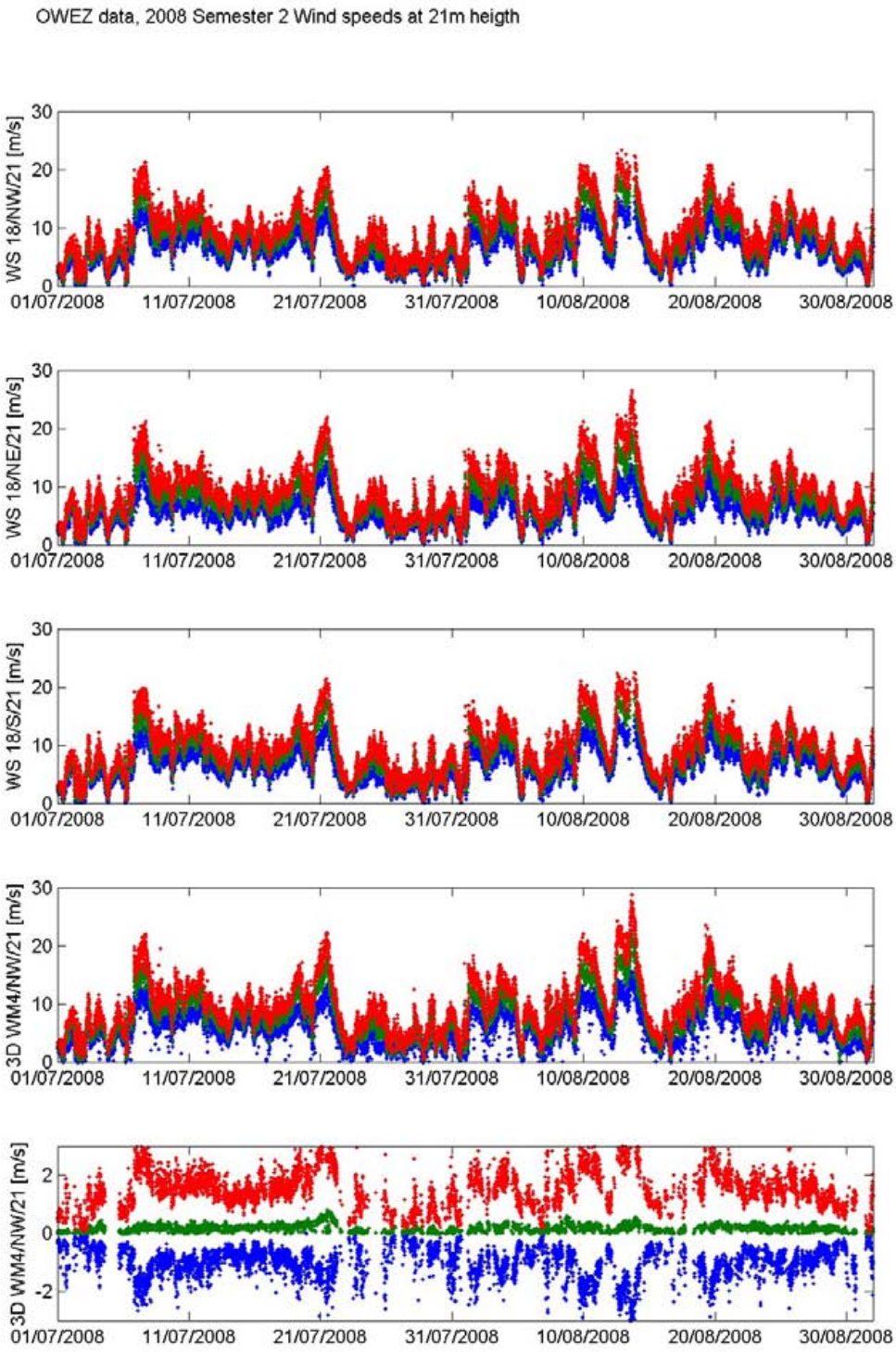


Figure 6.4 *Time histories of stored data in ten-minute averaged values. Wind speed measurements with cup anemometers and sonic anemometer are shown together with the vertical wind speed measured with the sonic anemometer at 21m height are shown for July and August 2008.*

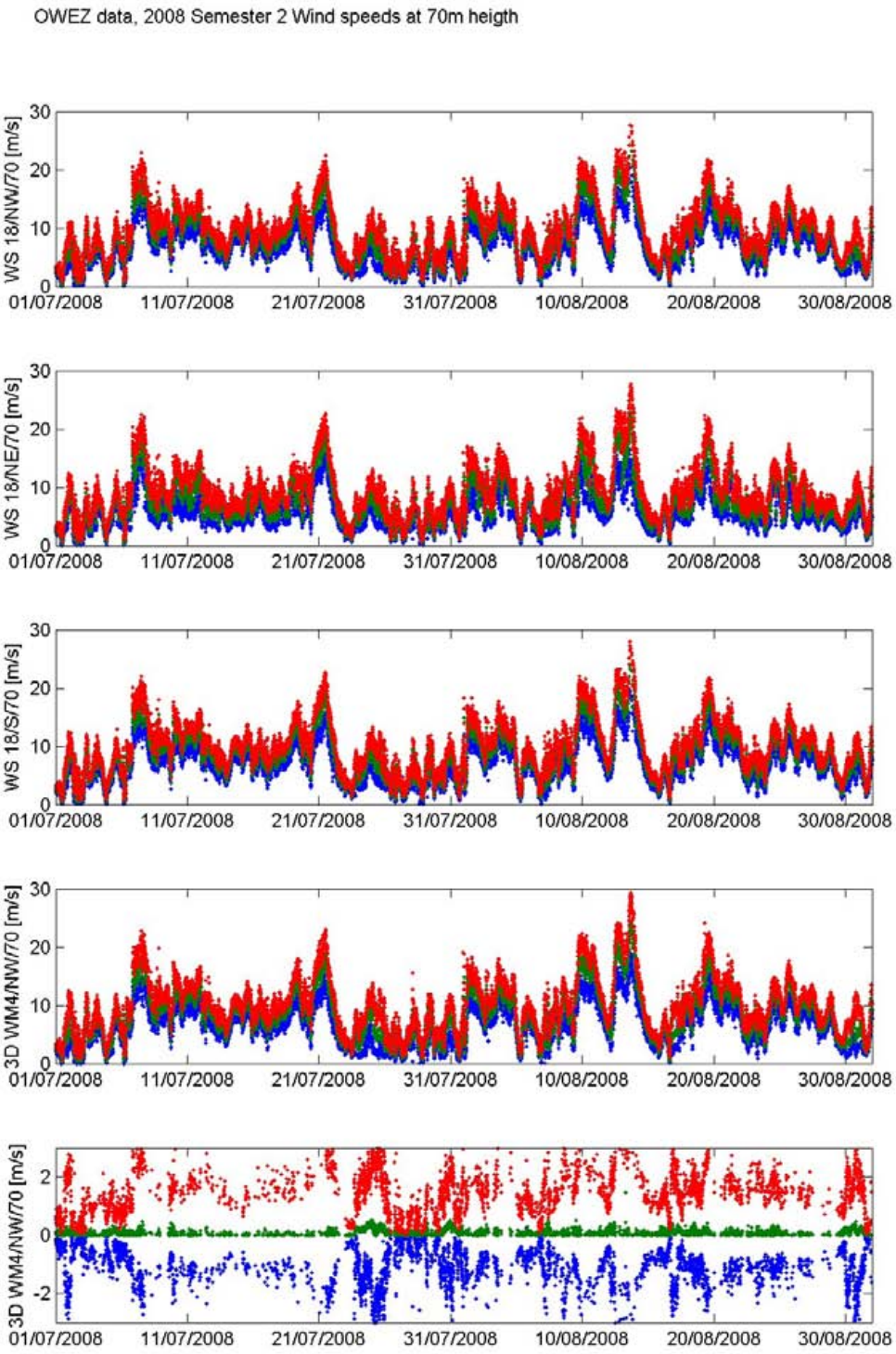


Figure 6.5 *Time histories of stored data in ten-minute averaged values. Wind speed measurements with cup anemometers and sonic anemometer are shown together with the vertical wind speed measured with the sonic anemometer at 70m height are shown for July and August 2008.*

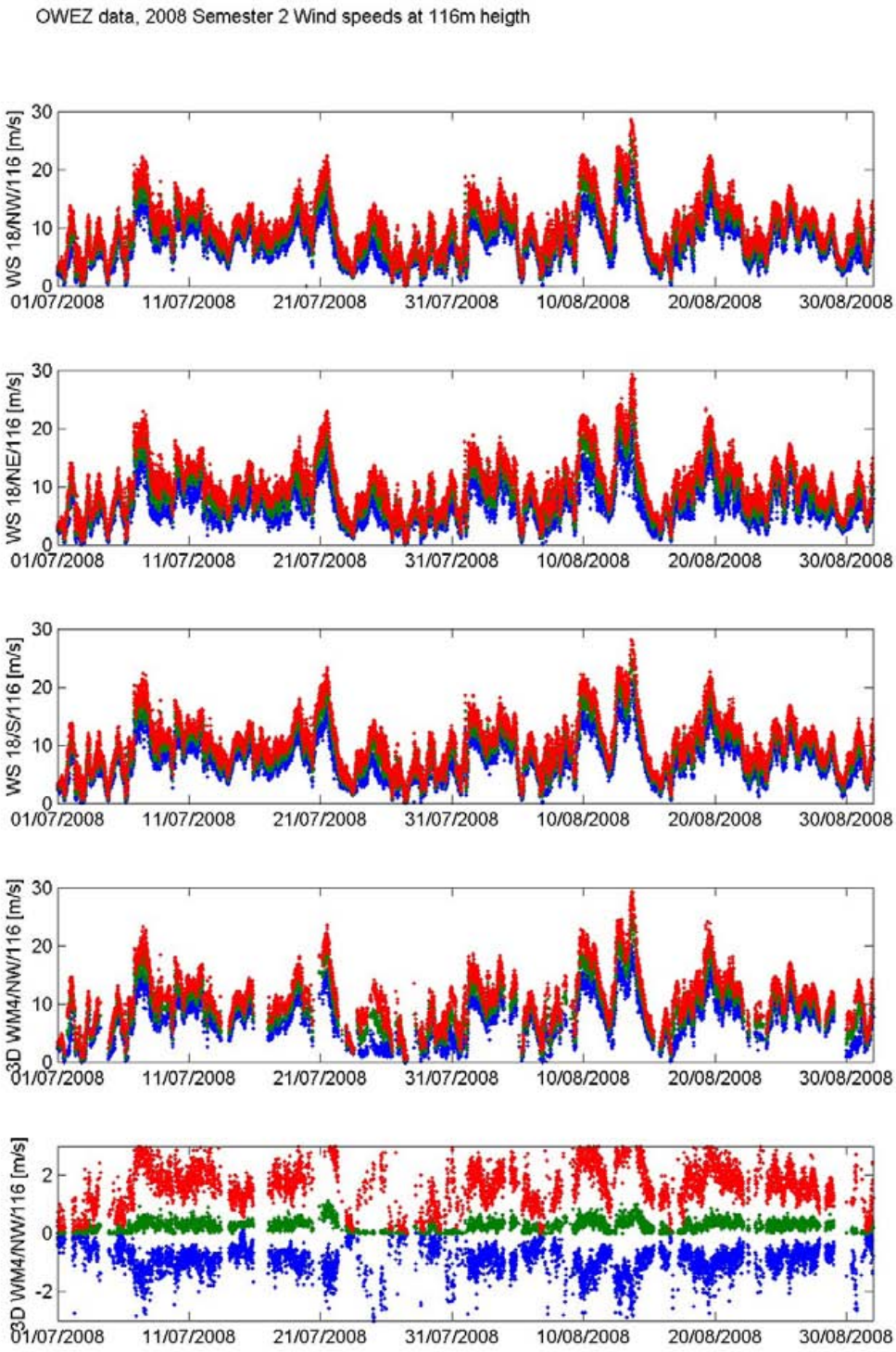


Figure 6.6 *Time histories of stored data in ten-minute averaged values. Wind speed measurements with cup anemometers and sonic anemometer are shown together with the vertical wind speed measured with the sonic anemometer at 116m height are shown for July and August 2008.*

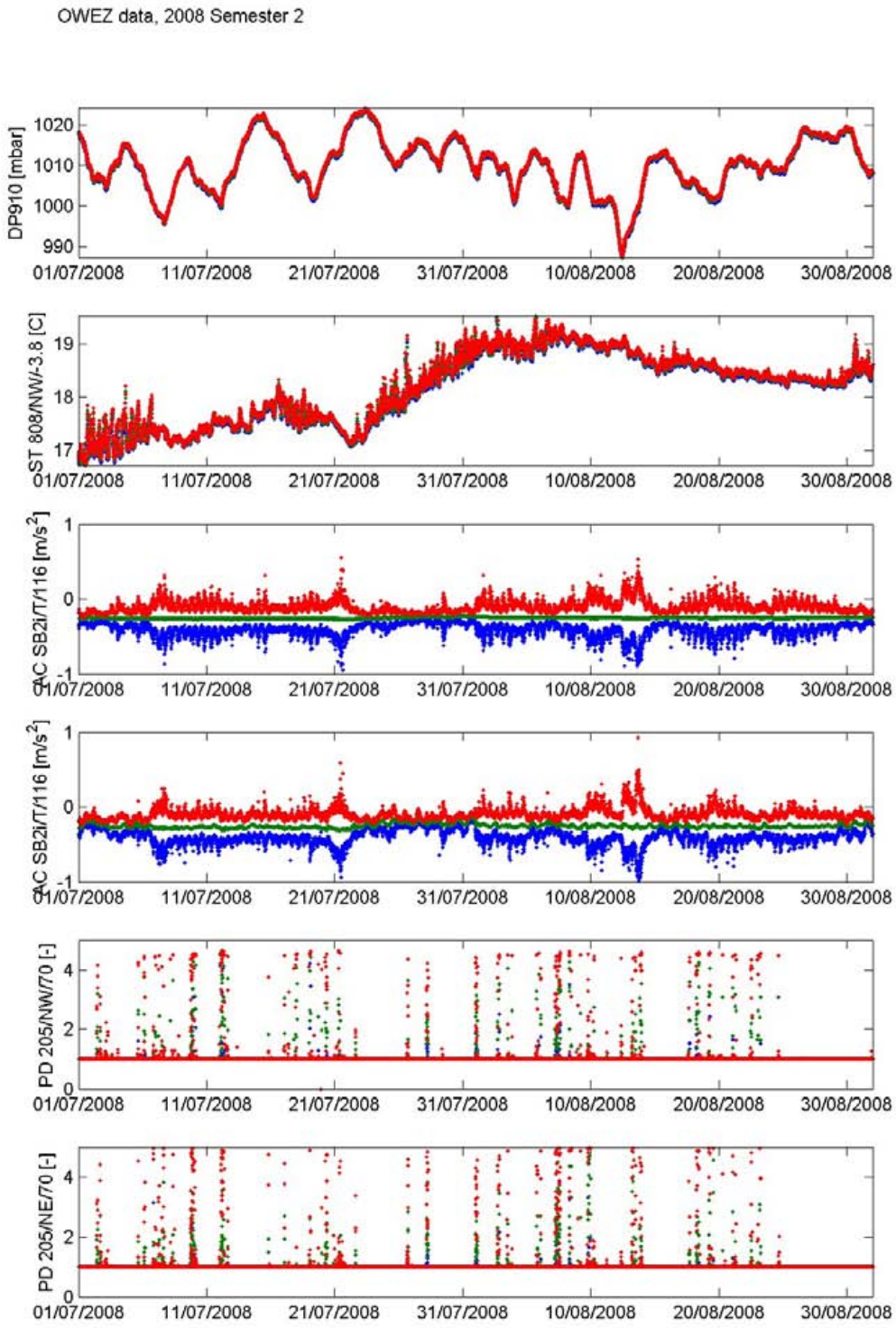


Figure 6.7 *Time histories of stored data in ten-minute averaged values. Air pressure at 21m above MSL, seawater temperature, mast top accelerations in N-S and W-E directions at 116.6 m above MSL and precipitation (70 m) are shown for July and August 2008. The precipitation is measured with sensors in the NE and NW boom*

7. Time histories September-October 2008

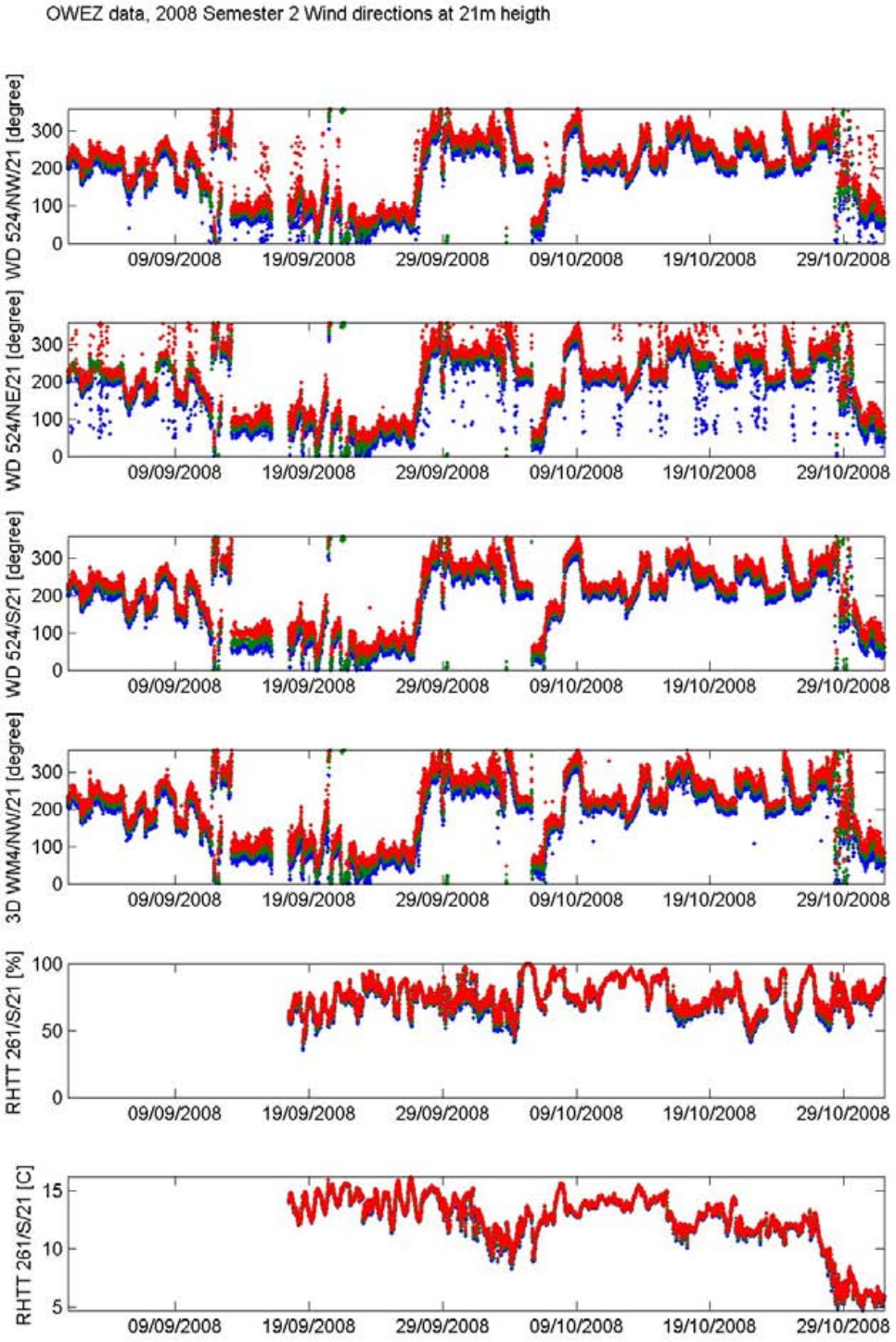


Figure 7.1 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 21 m height are shown for September and October 2008.*

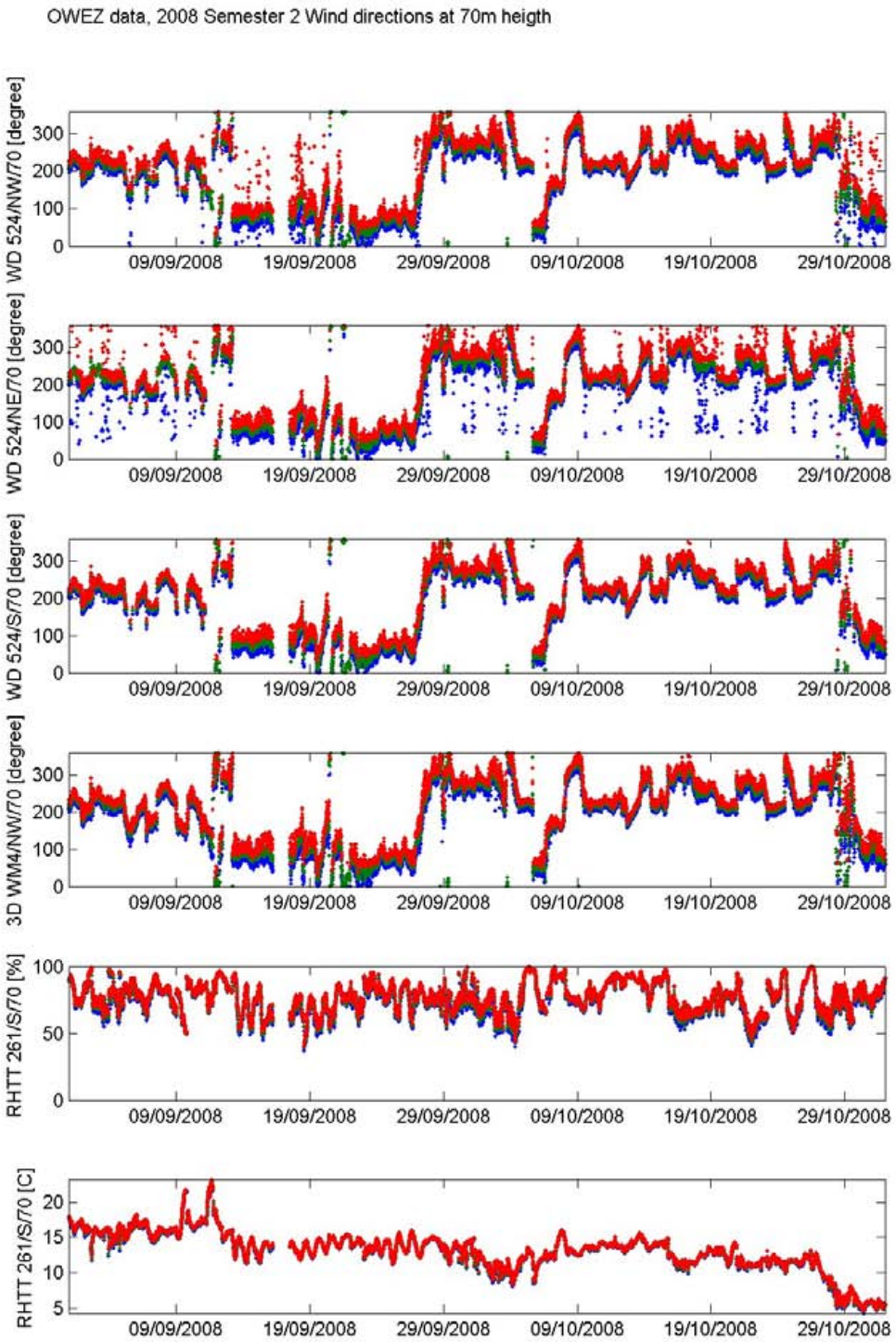


Figure 7.2 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 70 m height are shown for September and October 2008.*

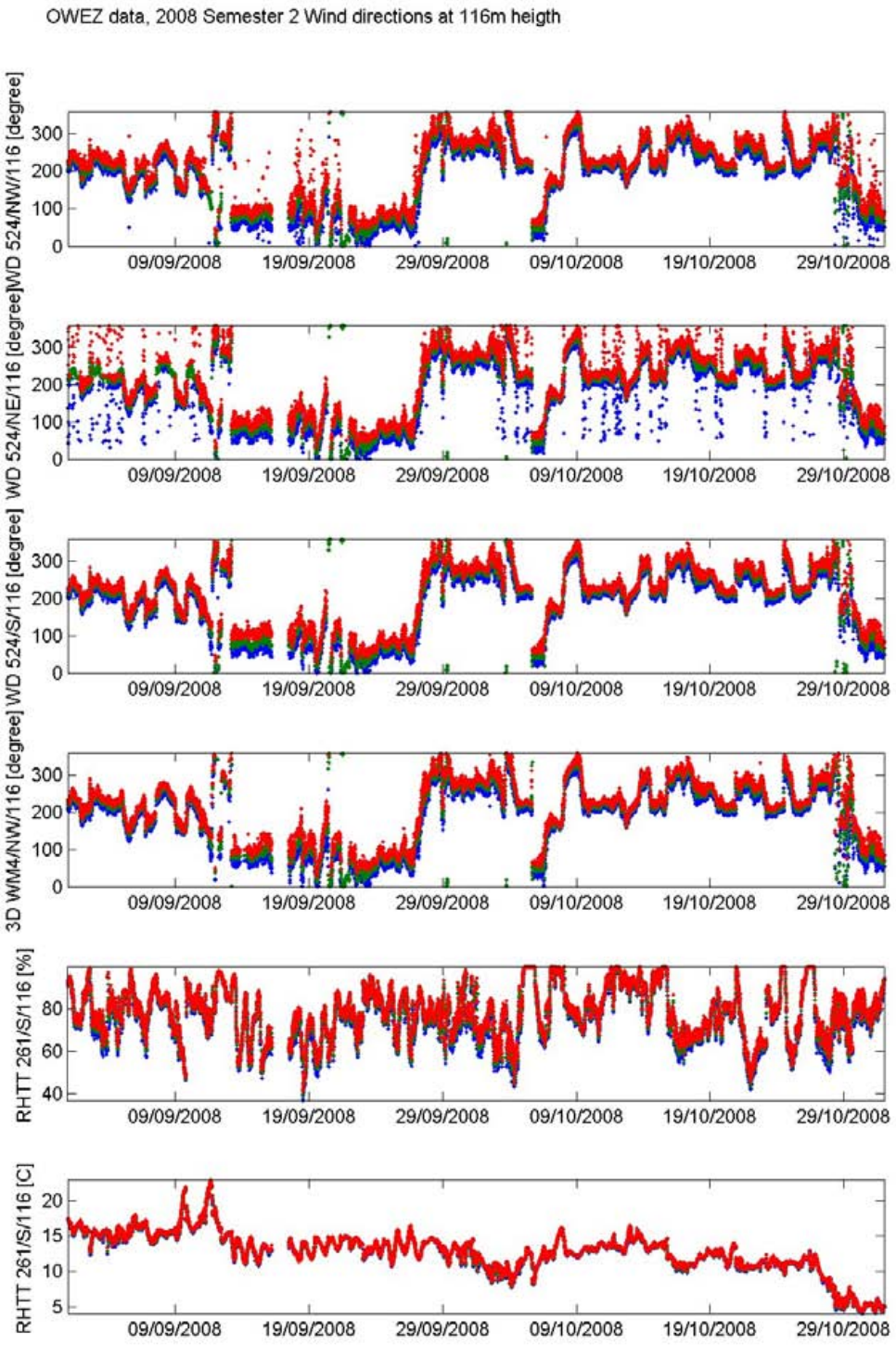


Figure 7.3 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 116 m height are shown for September and October 2008.*

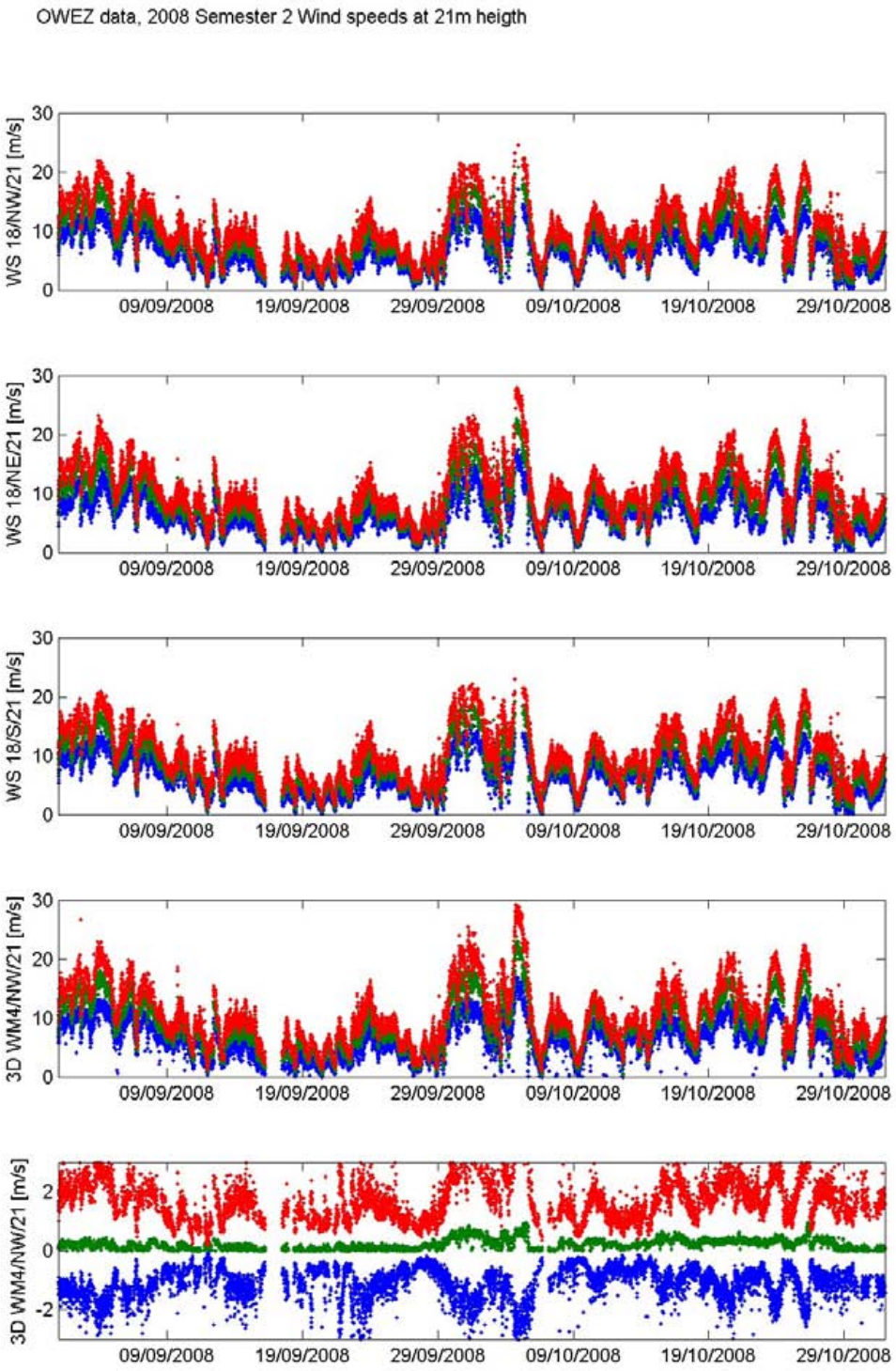


Figure 7.4 *Time histories of stored data in ten-minute averaged values. Wind speed measurements with cup anemometers and sonic anemometer are shown together with the vertical wind speed measured with the sonic anemometer at 21m height are shown for September and October 2008.*

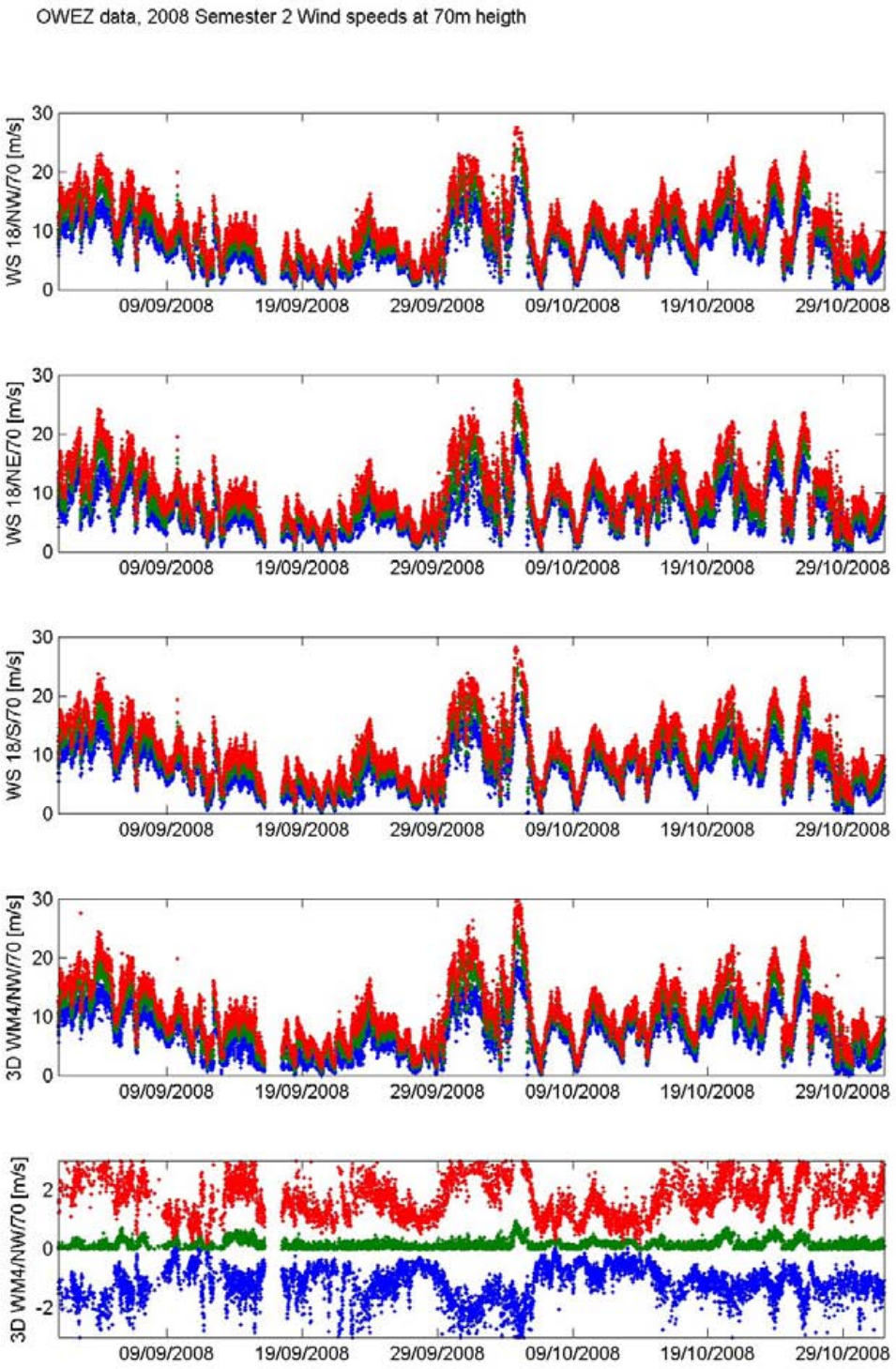
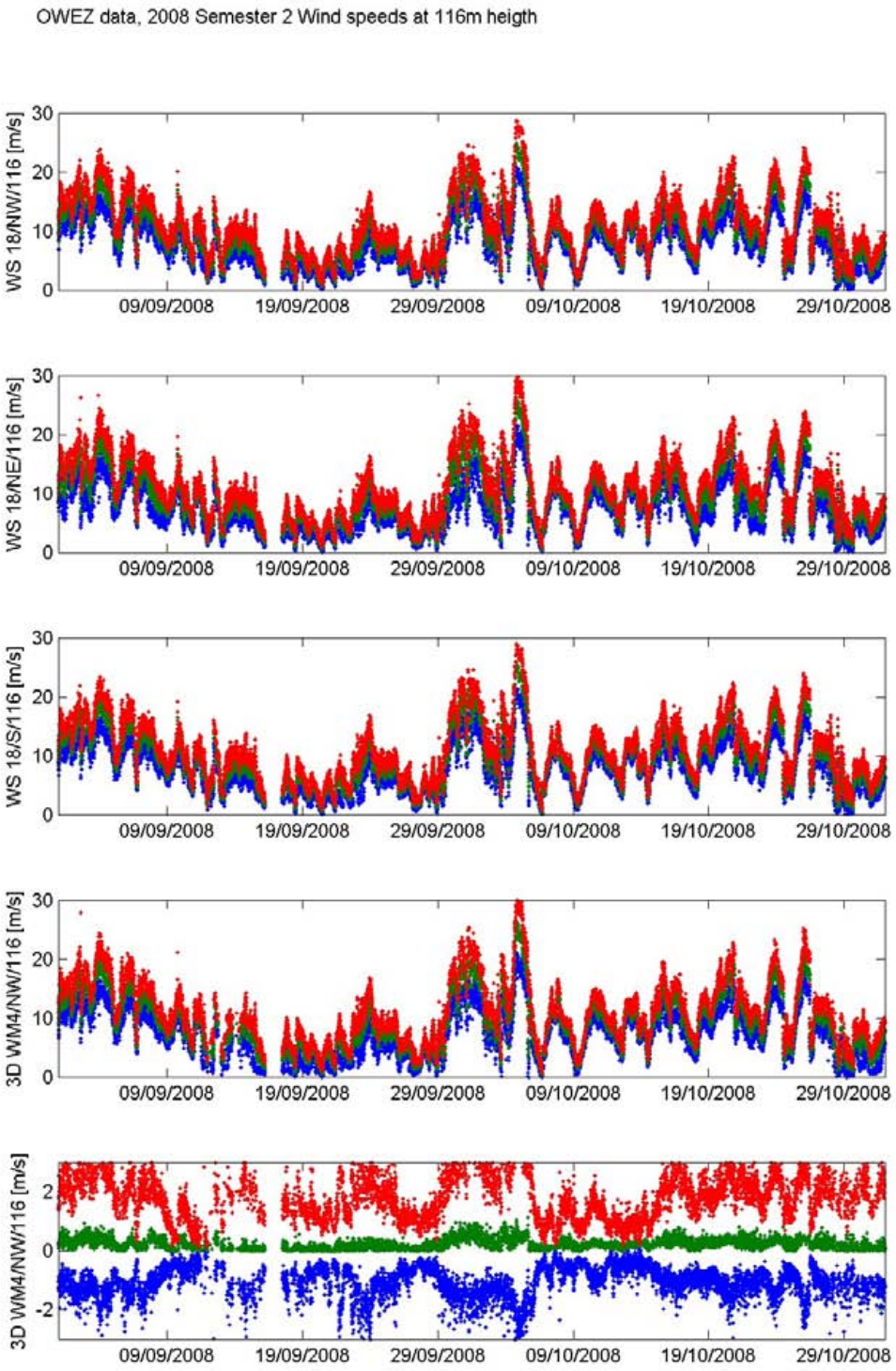


Figure 7.5 *Time histories of stored data in ten-minute averaged values. Wind speed measurements with cup anemometers and sonic anemometer are shown together with the vertical wind speed measured with the sonic anemometer at 70m height are shown for September and October 2008.*



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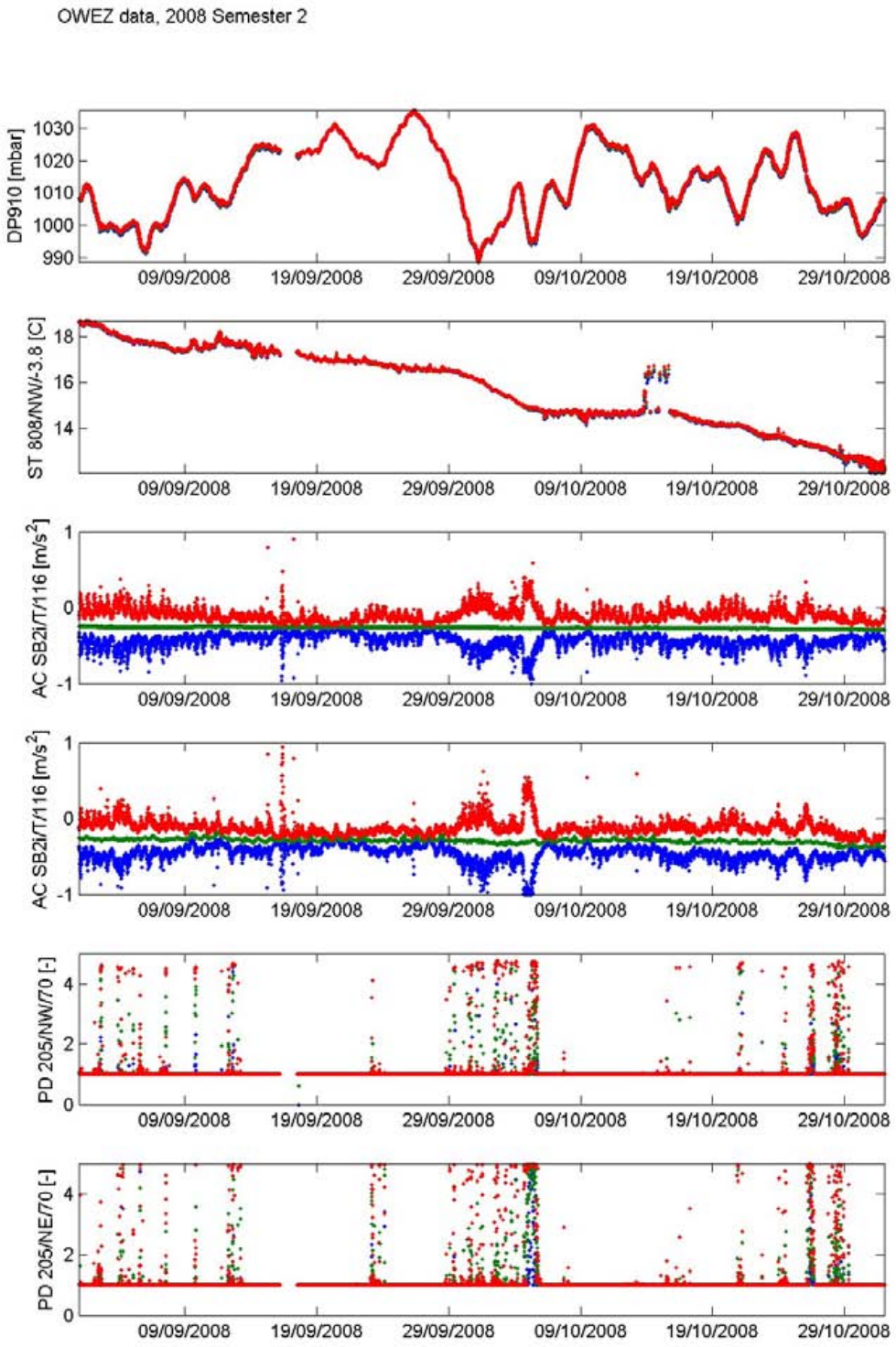

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8. Time histories November-December 2008

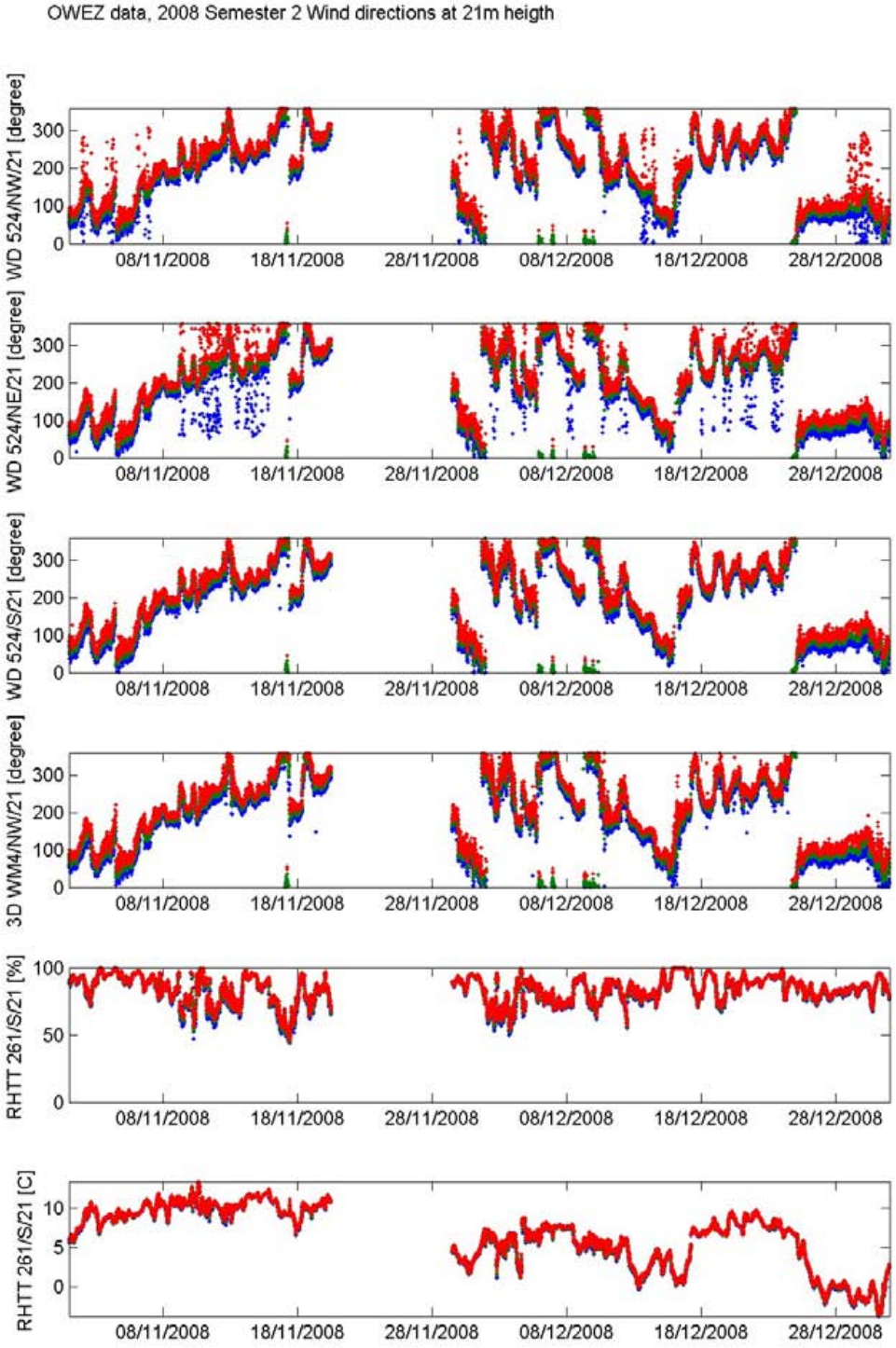


Figure 8.1 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 21 m height are shown for November and December 2008.*

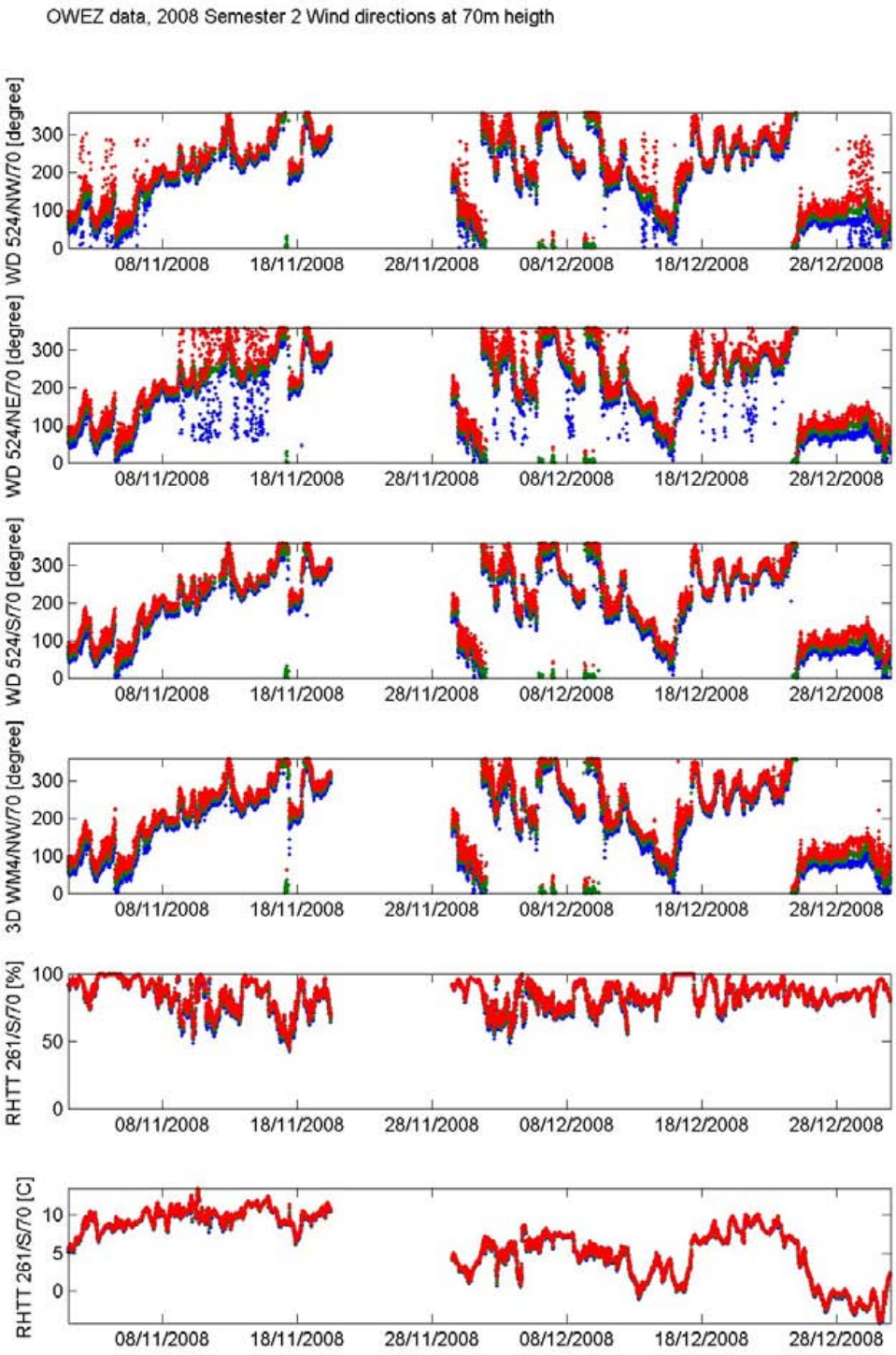


Figure 8.2 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 70 m height are shown for November and December 2008.*

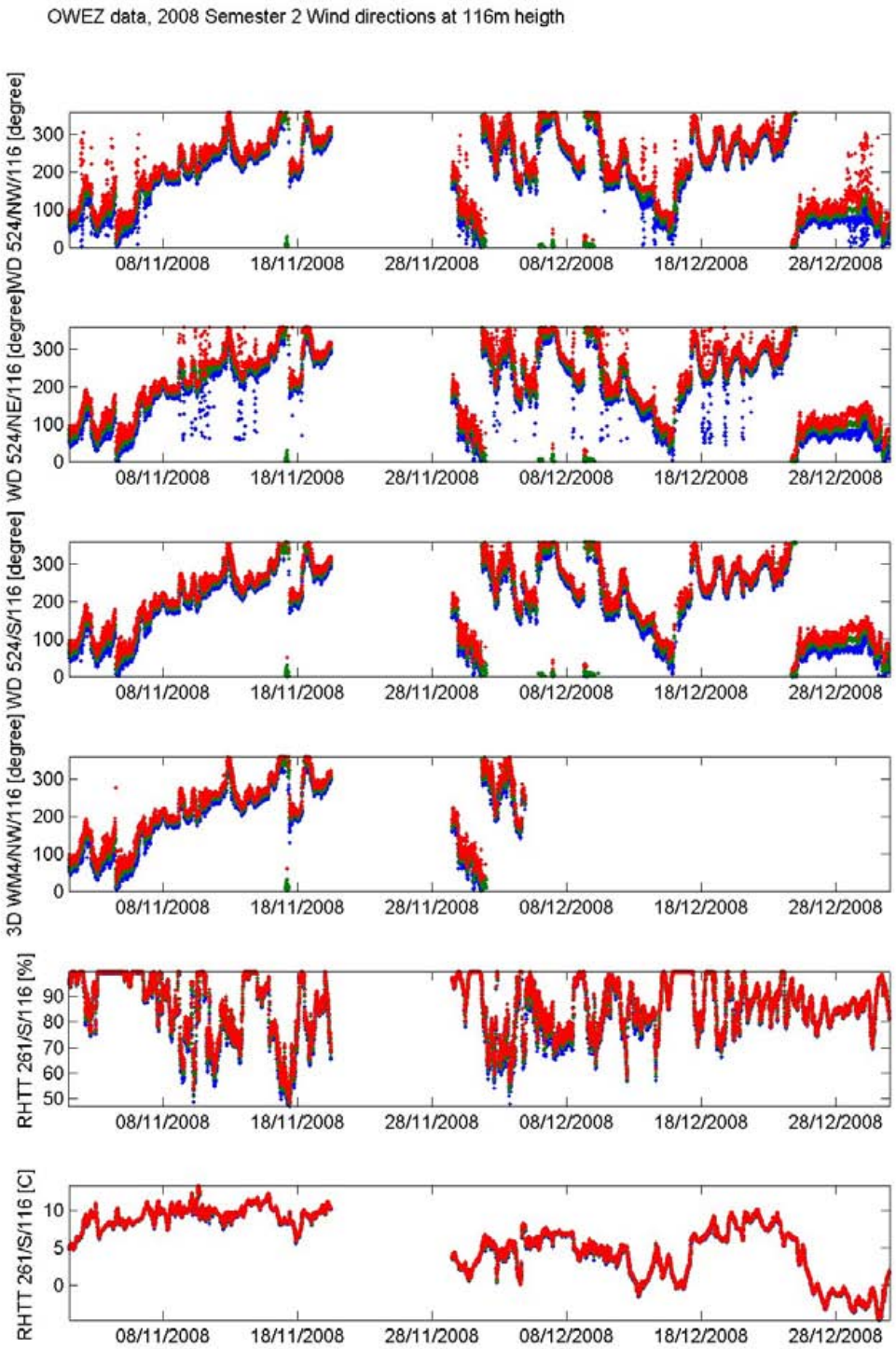
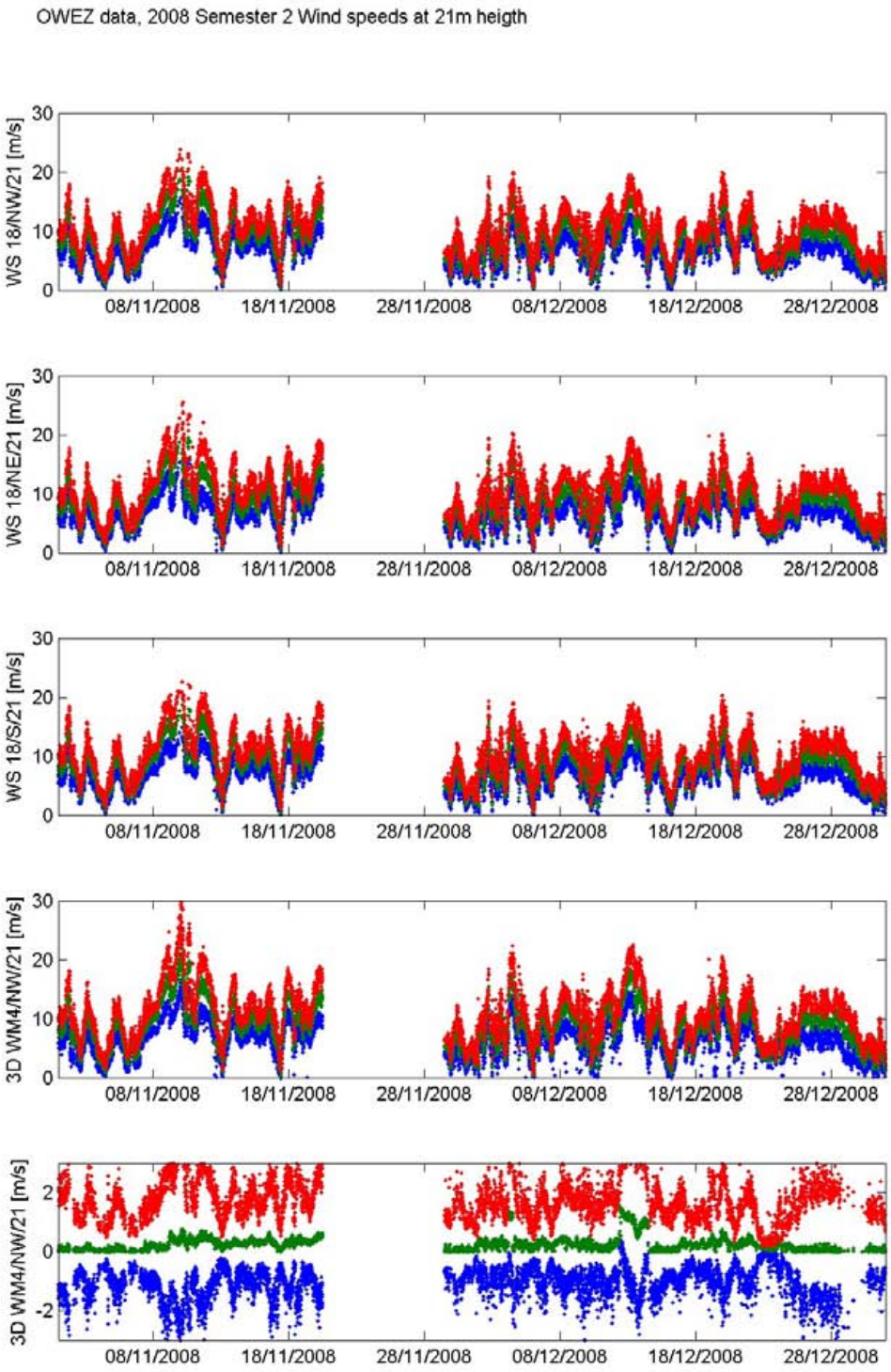


Figure 8.3 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 116 m height are shown for November and December 2008.*



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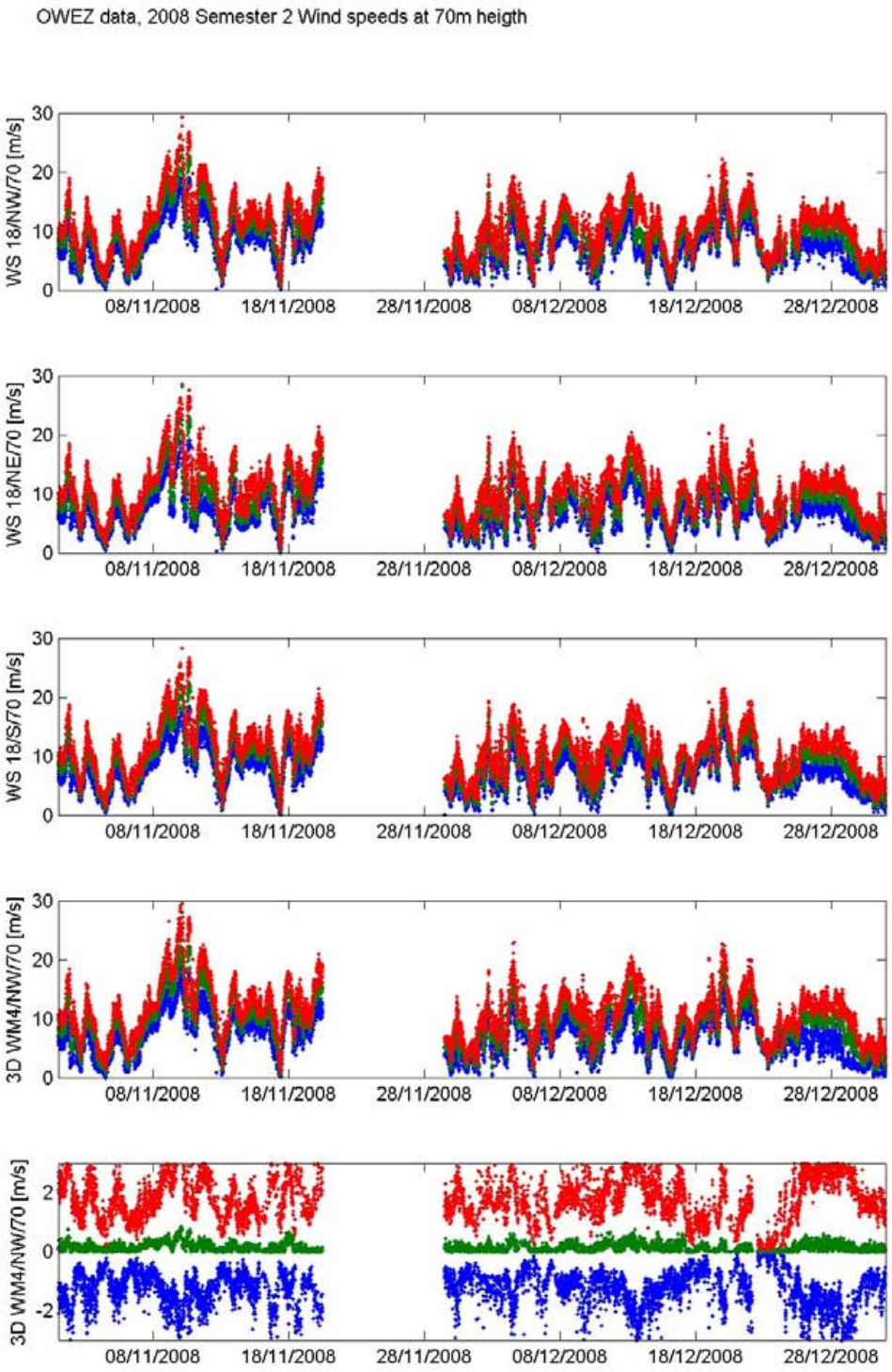

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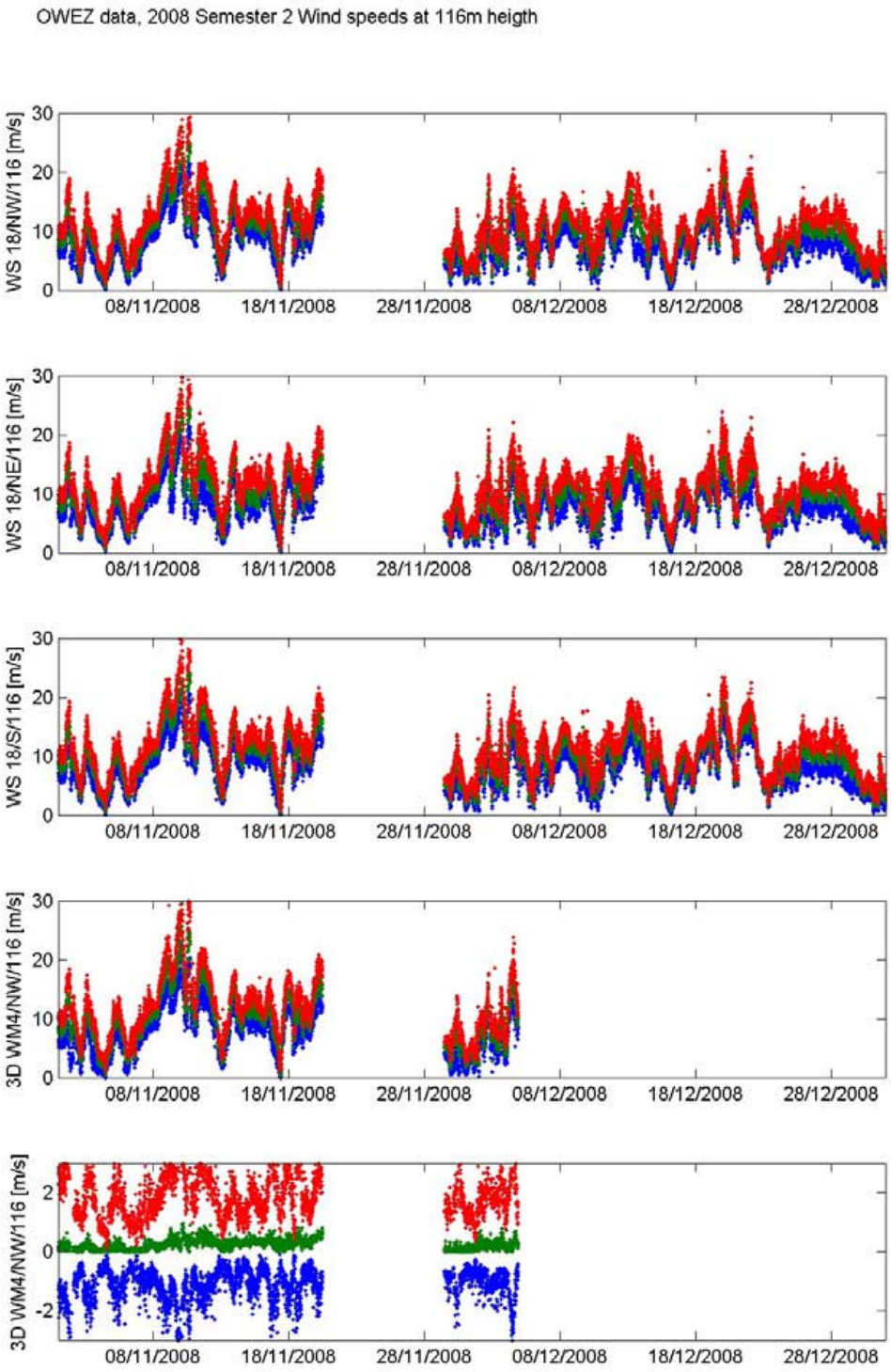

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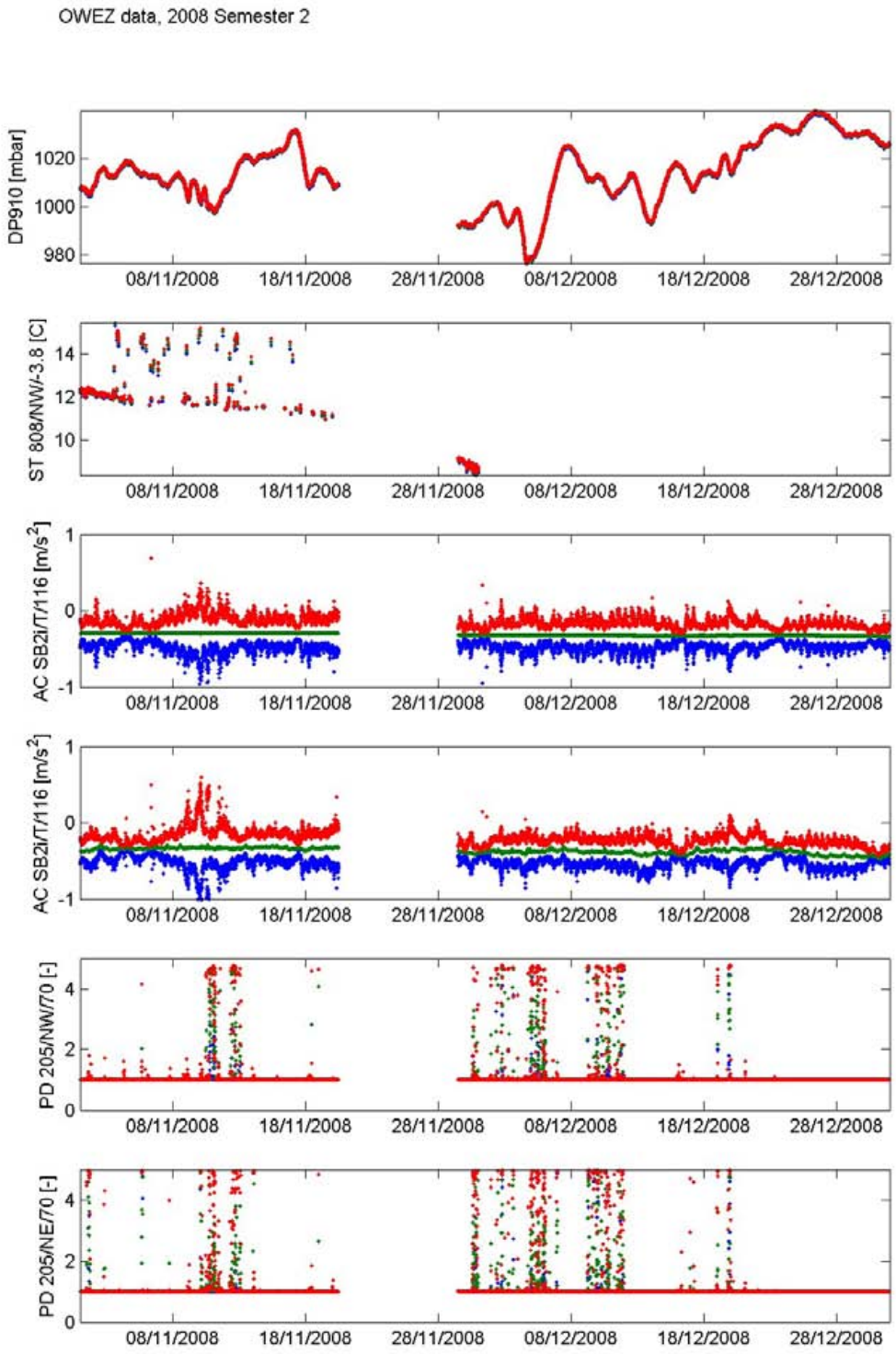

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9. References

1. H.J. Kouwenhoven, User manual data files meteorological mast NoordzeeWind, Document code: NZW-16-S-4-R03, Date: 1 October 2007,

2. BCE (Mierij Meteo), sensor overview, OWEZ document 3672-OV

3. M. de Noord, P.J. Eecen, USER MANUAL: ECN Wind Data Management System WDMS, ECN-Wind Memo-05-015
   P.J. Eecen et. al., Measurements at the ECN Wind Turbine Test Location Wieringermeer, ECN-RX--06-055

4. BCE (Mierij Meteo), NZW meteo data: Quality assessment procedure, Presentation March 21, 2005

5. International Standard IEC 61400-1 Edition 3, Wind turbine generator systems - Part 1: Design requirements

6. A. Curvers, Surrounding obstacles influencing the OWEZ meteo mast measurements, Document code: OWEZ_R_181_T0_20070821_undisturbed wind, ECN-Wind Memo-07-041, Date: August 2007