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Meteorological Measurements OWEZ

Half year report 01-07-2005 - 31-12-2005

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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 2005; the period between 01-07-2005 and 31-12-2005.

The project is carried out under assignment of NoordzeeWind BV.

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Project information

Contract number	NZW-16-C-2-R01
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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. This mast is in operation since the summer of 2005. During the period before the realisation of the wind farm, wind conditions have been measured that are not disturbed by the wind farm. After realisation of the wind farm, the mast has also been 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 2005; the period between 01-07-2005 and 31-12-2005.

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*

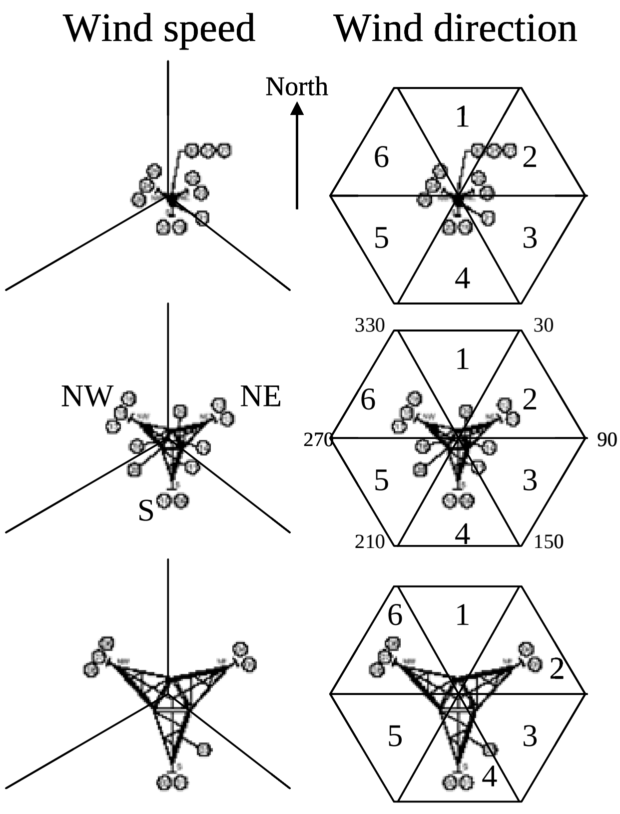
	UTM31 ED50	**WGS 84**
x	594195	4º23'22,7" EL
y	5829600	52º36'22,9" NB

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



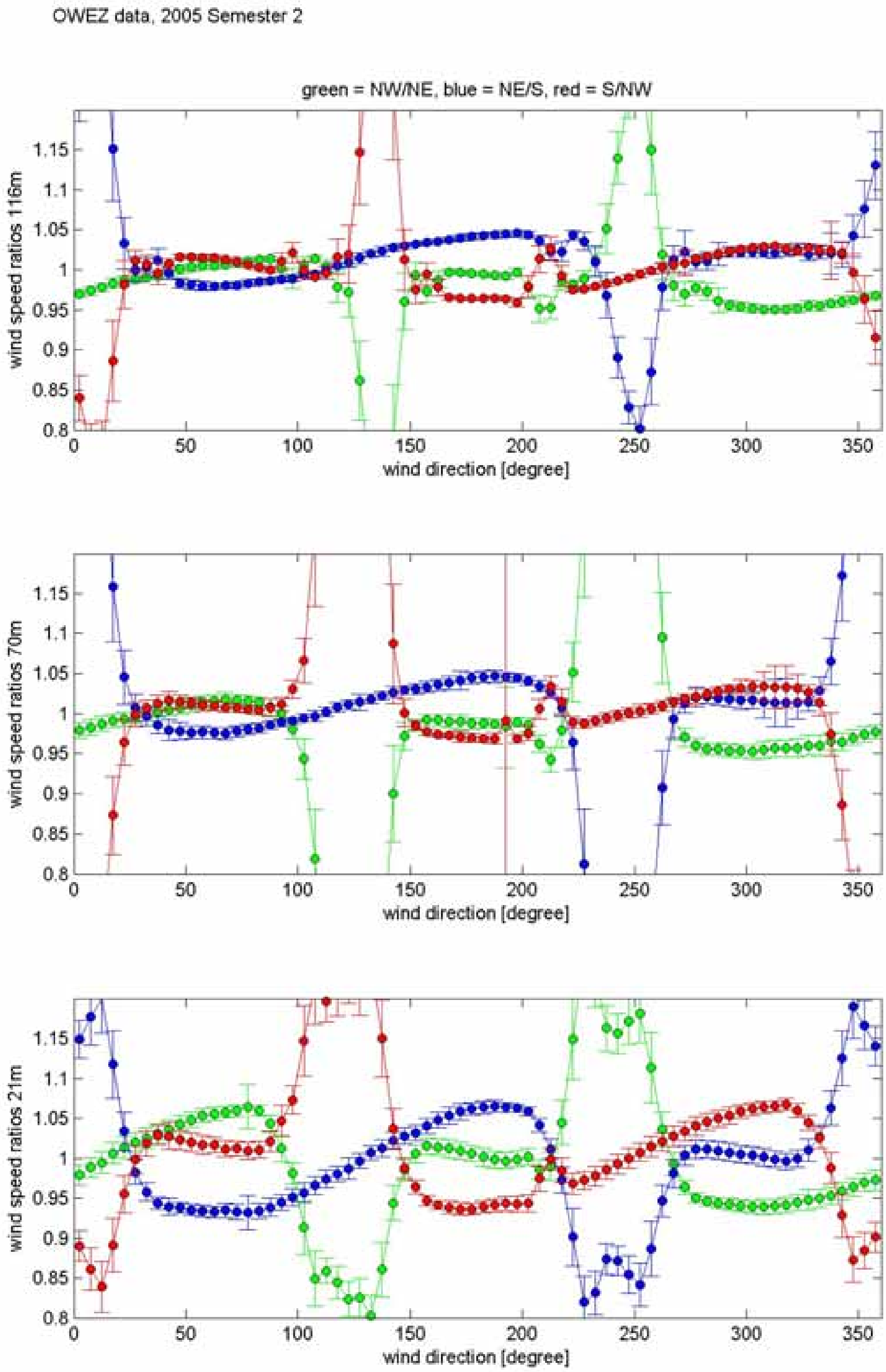


Figure 2.1 *Ratios between anemometer readings mounted on the South (S), North-West (NW) and North-East (NE) booms of the meteorological mast. The wind speed ratios NW/NE are indicated in green, the ratios NE/S are indicated in blue and the ratios S/NW are indicated in red. The indicated wind direction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

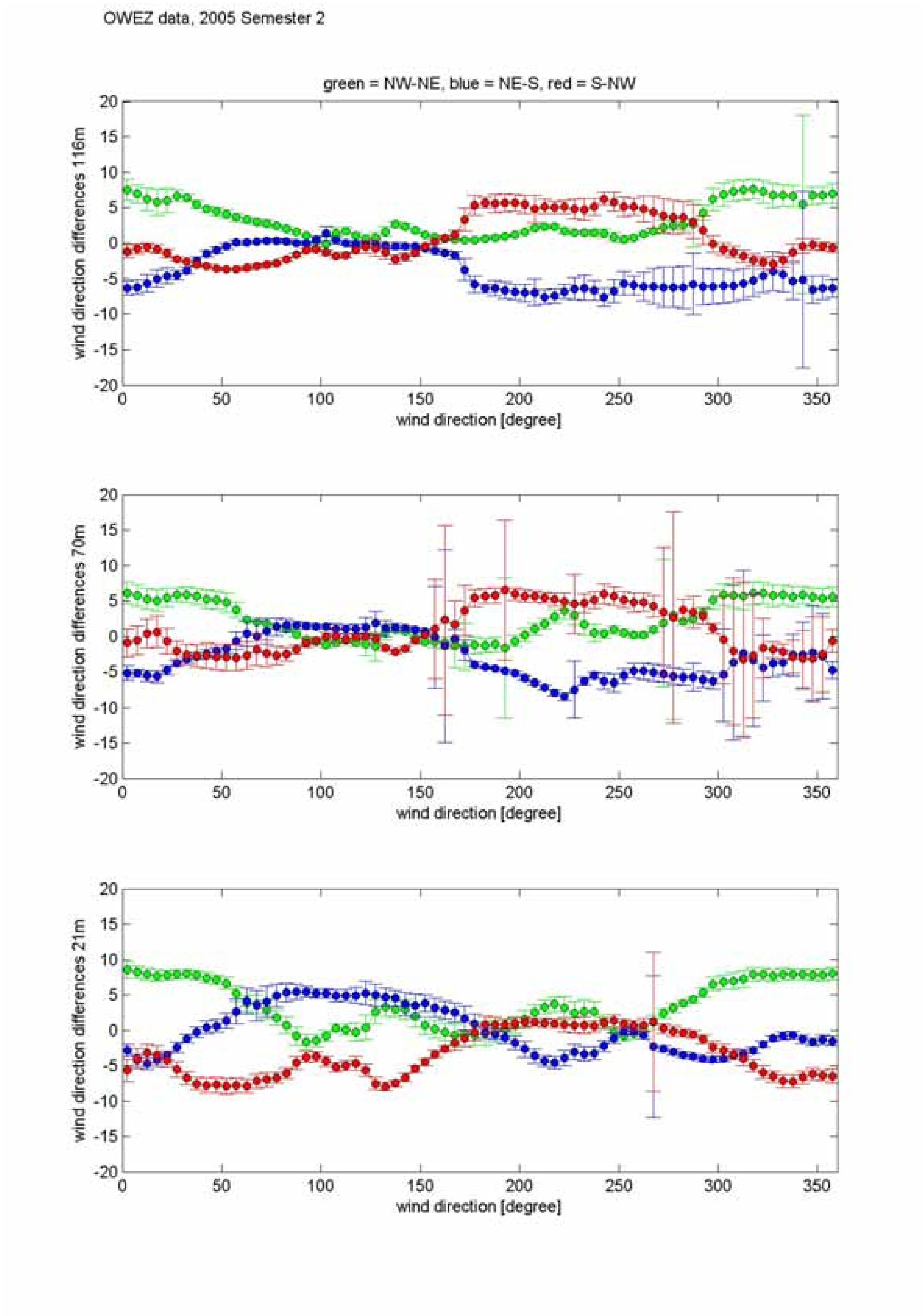


Figure 2.2 *Differences between wind vane readings mounted on the South (S), North-West (NW) and North-East (NE) booms of the meteorological mast. The wind direction differences NW/NE are indicated in green, the differences NE/S are indicated in blue and the differences S/NW are indicated in red. The 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 (-99999).

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 except for the wind directions. A large portion of the data has a validated average wind direction, however the standard deviation, minimum and maximum value were invalid. Since the wind direction is crucial for the determination of the distortion by the mast on the wind speed, it is essential to maintain these averaged wind directions in the database.

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.*

Measured parameter and unit	Instrument code	reporting period July 2005 - December 2005	
		number of valid 10-minute averages	**availability [%]**
wind direction [°]	3D WM4/NW/116	24453	92.3
horizontal wind speed [m/s]	3D WM4/NW/116	24453	92.3
vertical wind speed [m/s]	3D WM4/NW/116	24453	92.3
wind speed [m/s]	WS 018/NW/116	23080	87.1
wind speed [m/s]	WS 018/NE/116	23080	87.1
wind speed [m/s]	WS 018/S/116	25154	94.9
wind speed [m/s]	WS 018/NW/70	25154	94.9
wind speed [m/s]	WS 018/NE/70	25154	94.9
ambient temp. [°C]	RHTT 261/S/116	25153	94.9
ambient temp. [°C]	RHTT 261/S/70	23078	87.1
relative humidity [%]	RHTT 261/S/116	25148	94.9
ambient air pressure [mbar]	DP910	25154	94.9
precipitation [yes/no]	PD 205/NW/70	25154	94.9
sea water temperature [°C]	ST 808/NW/-3.8	23485	88.6
X (north – south) acceleration [m/s^2]	AC SB2i/T/116	25717	97.1
Y (west – east) acceleration [m/s^2]	AC SB2i/T/116	25718	97.1
wind direction [°]	WD 524/NW/116	23639	89.2
wind direction [°]	WD 524/NE/116	23631	89.2
wind direction [°]	WD 524/S/116	24132	91.1
wind direction [°]	WD 524/NW/70	25682	96.9
wind direction [°]	WD 524/NE/70	25716	97.1
wind direction [°]	3D WM4/NW/21	9182	34.7
horizontal wind speed [m/s]	3D WM4/NW/21	22737	85.8
vertical wind speed [m/s]	3D WM4/NW/21	22737	85.8
wind direction [°]	3D WM4/NW/70	25953	98.0
horizontal wind speed [m/s]	3D WM4/NW/70	25953	98.0
vertical wind speed [m/s]	3D WM4/NW/70	25953	98.0
wind speed [m/s]	WS 018/S/70	26495	100.0
wind speed [m/s]	WS 018/NW/21	26495	100.0
wind speed [m/s]	WS 018/NE/21	26495	100.0
wind speed [m/s]	WS 018/S/21	26495	100.0
ambient temp. [°C]	RHTT 261/S/21	26493	100.0
relative humidity [%]	RHTT 261/S/70	23640	89.2
relative humidity [%]	RHTT 261/S/21	26493	100.0
precipitation [yes/no]	PD 205/NE/70	26495	100.0
wind direction [°]	WD 524/S/70	25052	94.6
wind direction [°]	WD 524/NW/21	26493	100.0
wind direction [°]	WD 524/NE/21	26490	100.0
wind direction [°]	WD 524/S/21	26493	100.0
derived wind direction	21m	26494	100.0
derived wind direction	70m	25718	97.1
derived wind direction	116m	24134	91.1
derived wind speed	21m	26494	100.0
derived wind speed	70m	25279	95.4
derived wind speed	116m	23128	87.3

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 *Average 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]	7.9	6.9	6.8	7.1	7.3	8.7	9.0	10.3	8.9	8.0	8.7	8.2	8.4
Weibull	A [m/s]	8.9	7.8	7.7	8.0	8.2	9.8	10.1	11.6	10.0	9.0	9.8	9.2	9.5
	k [-]	2.4	2.5	2.6	2.6	2.2	2.5	2.0	2.3	2.4	2.2	2.2	1.9	2.2
	[%]	8.1	4.6	5.8	5.4	4.1	7.1	6.8	11.1	13.0	10.5	11.5	9.1	
Wind speed [m/s]	0-1	7	11	6	6	17	7	8	4	6	10	4	10	7
	1-2	17	20	20	34	35	24	41	24	18	38	27	39	28
	2-3	63	59	58	48	70	71	79	38	43	49	49	73	56
	3-4	70	92	70	70	79	68	72	48	70	70	60	95	70
	4-5	83	100	136	85	101	41	64	37	65	81	54	83	72
	5-6	71	110	138	123	107	44	47	54	64	78	51	56	71
	6-7	76	104	124	134	106	51	64	56	81	77	74	76	80
	7-8	115	114	117	139	76	71	72	79	63	87	94	73	88
	8-9	130	132	121	117	73	88	51	81	78	98	145	84	99
	9-10	115	130	75	60	59	99	66	84	87	113	120	88	94
	10-11	78	65	41	53	56	133	64	91	119	92	78	90	86
	11-12	62	16	47	65	96	107	68	44	103	62	55	69	68
	12-13	30	10	24	38	76	82	91	51	69	62	52	36	54
	13-14	19	10	17	17	40	67	56	60	48	34	60	27	42
	14-15	22	18	3	9	8	22	57	55	31	21	35	23	28
	15-16	25	4	4			6	29	48	17	12	9	11	16
	16-17	11	2				4	28	42	8	2	3	13	11
	17-18	2	1				3	33	48	9	2	3	19	12
	18-19	1					6	8	33	13	3	2	14	9
	19-20	1					4	3	13	7	4	2	11	5
	20-21							1	5	1	3	4	5	2
	21-22								3	1	1	3	2	1
	22-23								2			2	1	1
	23-24											1		
	24-25											4		1
	25-26											4	1	
	26-27											2		
	27-28													
	28-29											1		

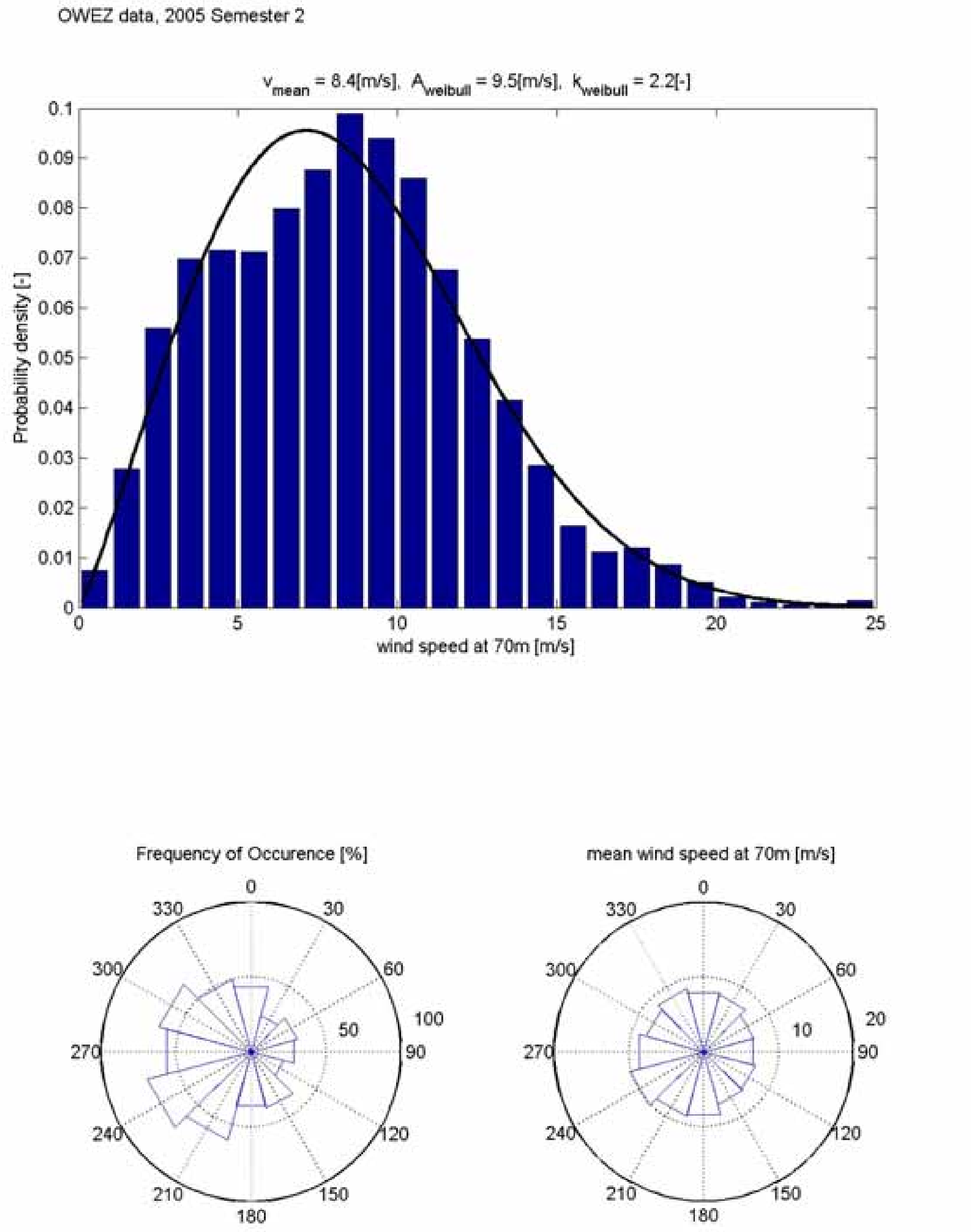


Figure 4.1 *Overall wind speed frequency distribution measured at 70 m above MSL during the reporting period (histogram) and the fitted Weibull distribution. Wind roses for the frequency of wind direction occurrence and the mean wind speed measured at 70 m above MSL during the reporting period. The corresponding 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]												
Wind speed [m/s]	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
4	9.3	9.1	7.5	6.3	7.0	7.4	7.8	8.2	8.5	8.5	9.2	9.2	8.8
5	8.2	7.9	7.1	6.3	6.5	7.7	7.7	7.1	8.0	8.3	8.9	8.7	7.8
6	7.9	7.2	6.2	6.0	5.1	5.5	7.2	6.2	6.5	7.0	8.5	8.7	6.8
7	7.8	7.0	6.0	5.4	5.0	5.0	5.8	5.7	6.5	6.8	7.8	7.8	6.5
8	6.6	5.7	5.9	4.9	4.2	5.0	4.7	5.8	6.3	6.5	7.3	7.6	6.2
9	6.9	6.4	6.3	4.6	4.3	4.6	5.4	5.5	6.3	6.4	6.8	7.6	6.2
10	6.8	6.2	6.5	5.4	4.9	4.8	4.7	5.4	6.2	6.0	6.9	7.7	6.1
11	6.7	6.6	7.2	6.0	6.1	4.5	5.5	5.4	5.8	5.9	6.8	7.2	6.0
12	8.1	7.3	7.4	6.8	6.9	4.4	5.0	5.9	6.1	6.2	7.0	7.8	6.3
13	8.4	9.4	7.3	6.9	7.1	4.0	5.1	6.3	6.5	6.7	7.1	8.7	6.4
14	8.1	7.6	6.6	7.1	6.8	3.7	5.7	6.5	6.4	6.9	7.2	8.5	6.5
15	7.4	7.2	5.9	6.7	6.0	5.9	6.1	6.6	7.1	6.4	7.3	9.9	7.0
16	7.0	6.6	6.7			7.1	6.9	7.1	6.1	7.5	10.3	8.5	7.3
17	8.5	7.0				7.7	7.1	6.8	7.0	7.9	9.1	9.2	7.3
18	9.5					7.5	6.9	7.1	7.6	6.8	8.1	8.8	7.5
19	8.6					6.9	7.0	6.8	7.4	7.5	11.9	8.4	7.5
20	12.0					6.6	7.7	7.1	7.8	7.0	9.0	8.3	7.8
21								7.4	12.6	7.4	7.8	9.8	8.2
22								7.2	8.9		8.5	7.8	7.8
23	10.8							9.2	7.7		7.8	13.9	9.1
24											10.1	14.2	11.0
25											8.5	6.8	8.4
26											8.1	8.6	8.1
27											8.2		8.2
28											7.2		7.2
29											8.0		8.0
30													
TI IEC I_{ref}	9.9	8.0	6.4	5.9	5.9	6.4	6.8	7.3	8.0	7.4	11.0	11.0	9.3

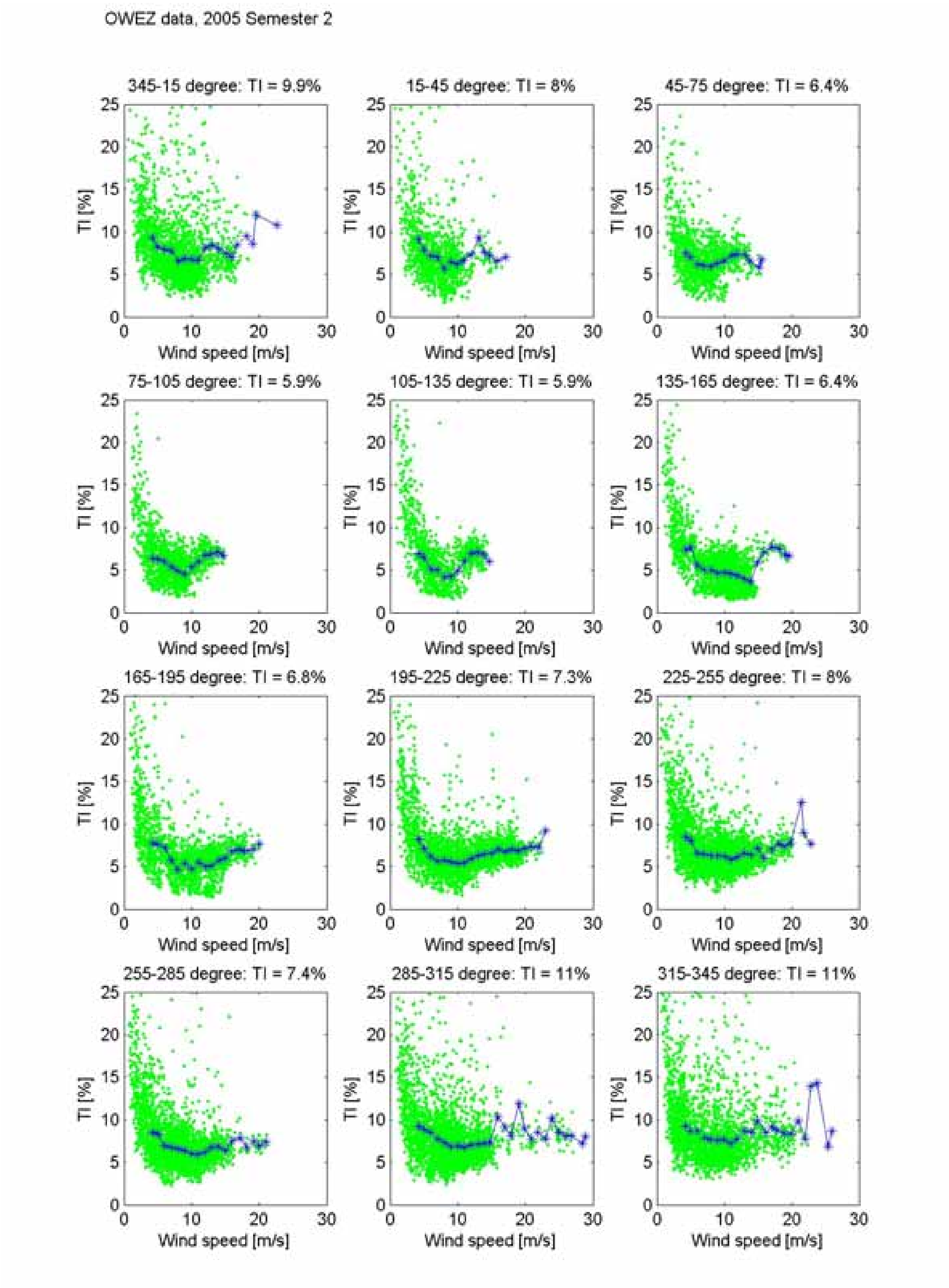


Figure 4.2 *Turbulence intensities per wind direction sector, measured at 70m above MSL during the reporting period. The blue stars indicate the average turbulence intensities in the wind speed bins. For each wind direction sector the turbulence intensity determined according IEC 61400-1 Ed. 3 [5] is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

4.2.2 Turbulence intensity

The average turbulence intensities, defined by the standard deviation divided by the mean wind speed in the 10-minute period, at the three heights are presented 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.

Since in the reporting period the turbines were not yet installed, the ambient turbulence is presented in Figure 4.3.

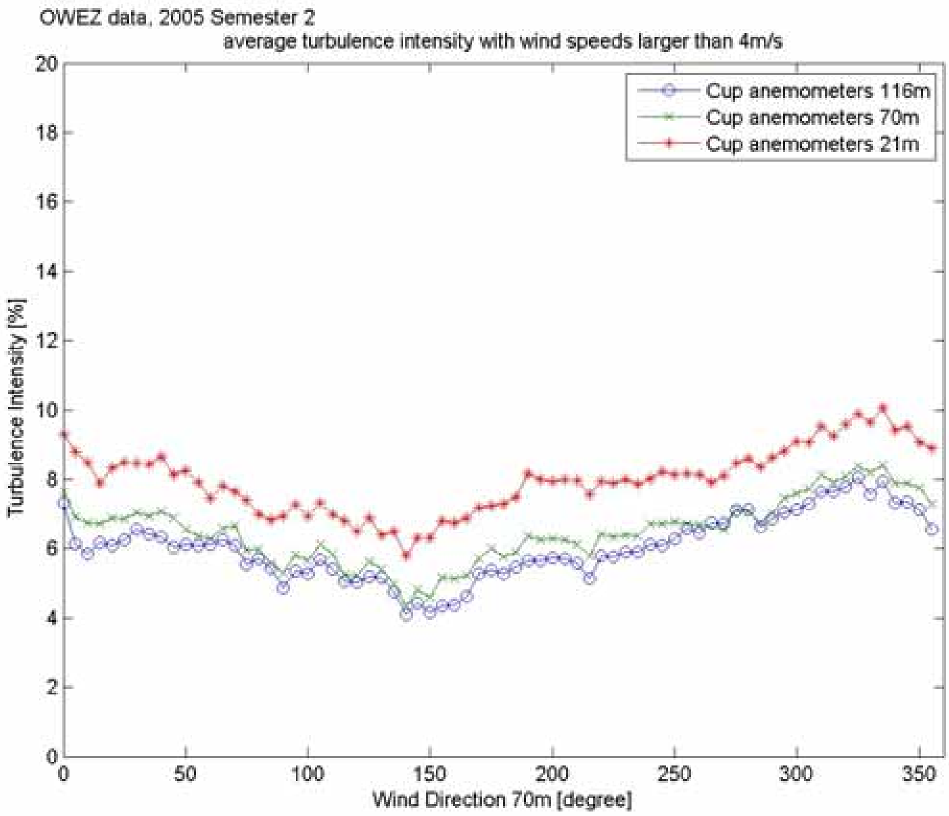


Figure 4.3 *Average turbulence intensities at measuring heights 21, 70 and 116m depending on wind direction (bin width 5º) measured during the reporting period. Only data are included with wind speeds above 4m/s.*

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:

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

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 the wind speed profile 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	0.05	0.07	0.07	0.12	0.11	0.15	0.12	0.10	0.06	0.05	0.05	0.05	0.08
standard deviation	0.04	0.07	0.07	0.09	0.10	0.09	0.09	0.07	0.04	0.03	0.02	0.03	0.07

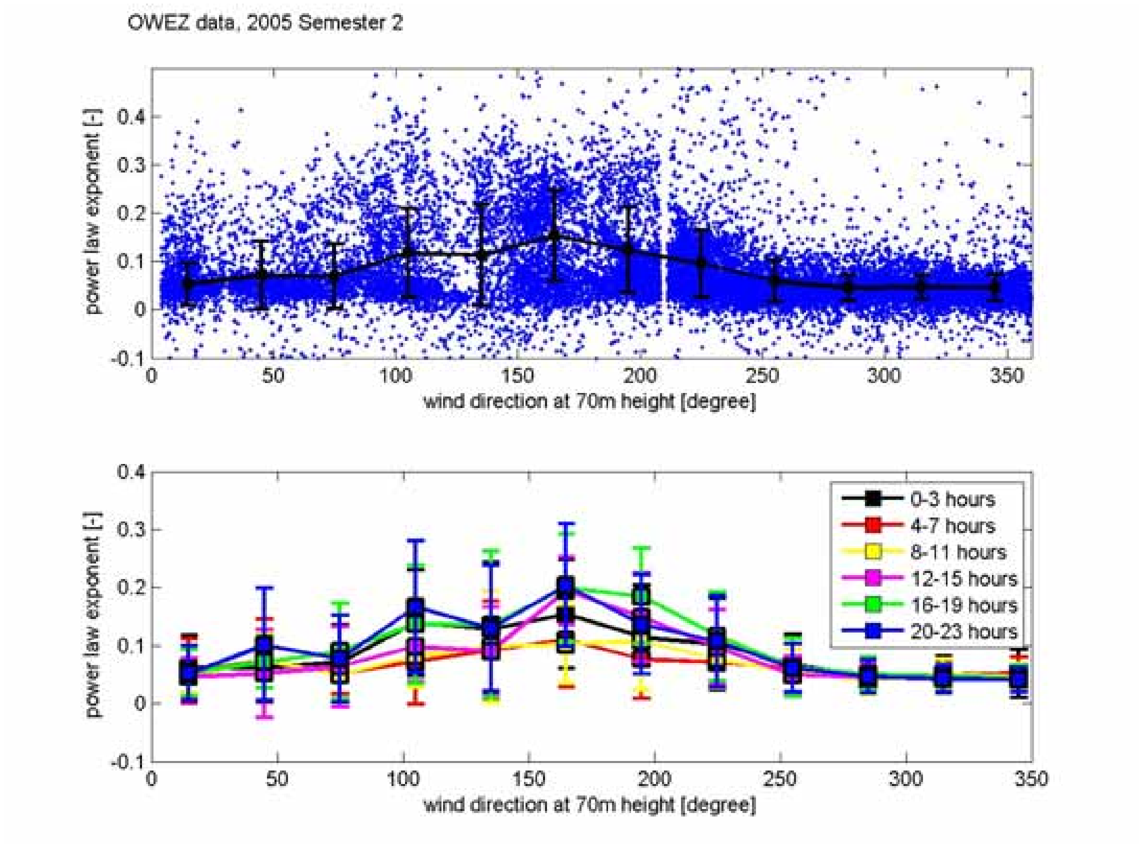


Figure 4.4 *Upper plot: Exponents for each 10-minute average together with the average exponent for the vertical wind speed and standard deviation depending on wind direction (bin width 2º) as measured during the reporting period Only data are included that meet the requirement V_{70} > 4 m/s. Lower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

5. Wind climate, cumulative

The second semester 2005 is the first reporting period of the measurements at the meteorological mast at OWEZ. Therefore the cumulative report is identical to the above report.

6. Time histories July-August 2005

In the following Chapters, the 10-minute averaged data are indicated by averages (green), maxima (red) and minima (blue).

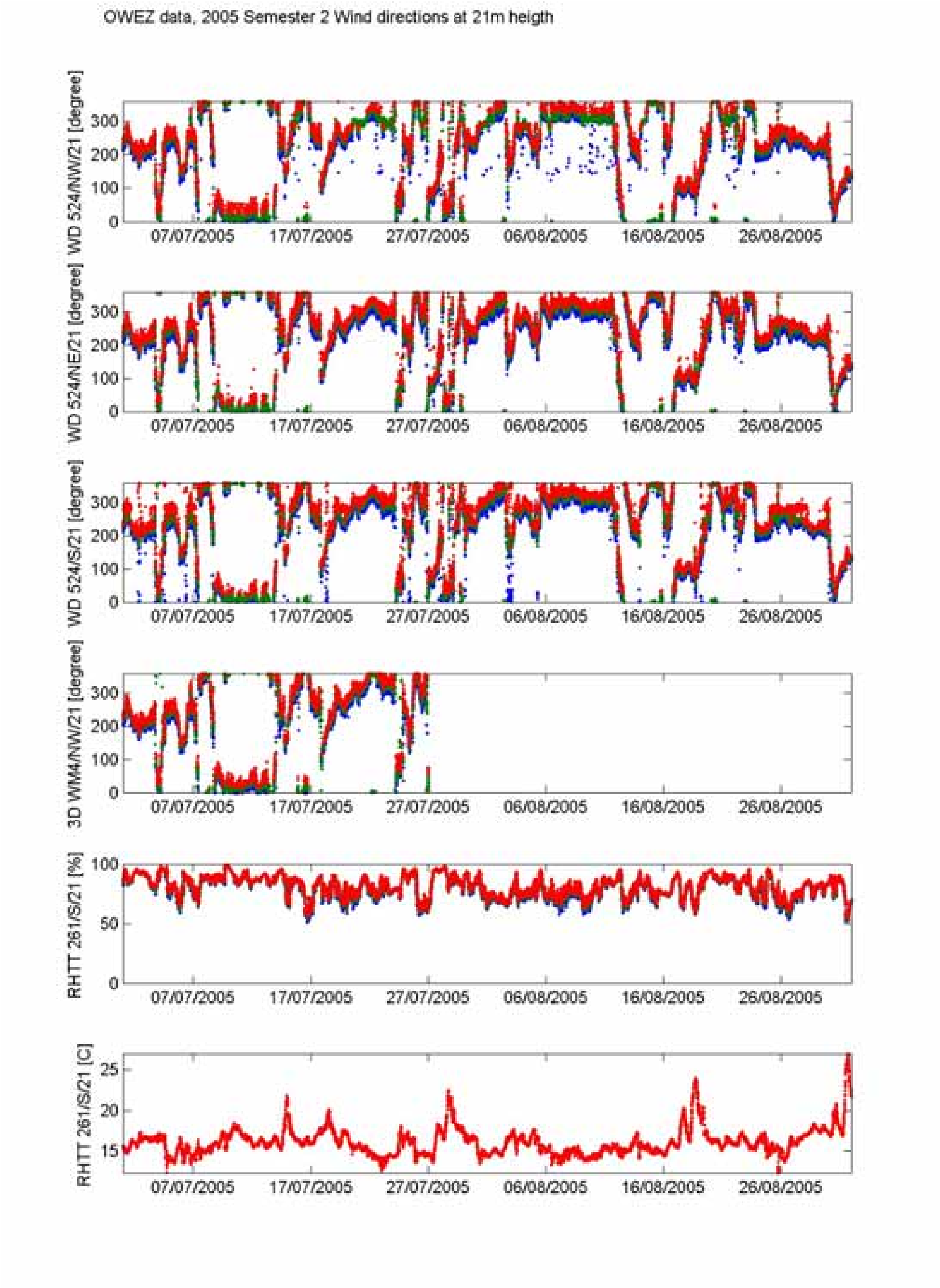


Figure 6.1 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 21 m height are shown for July and August 2005.*

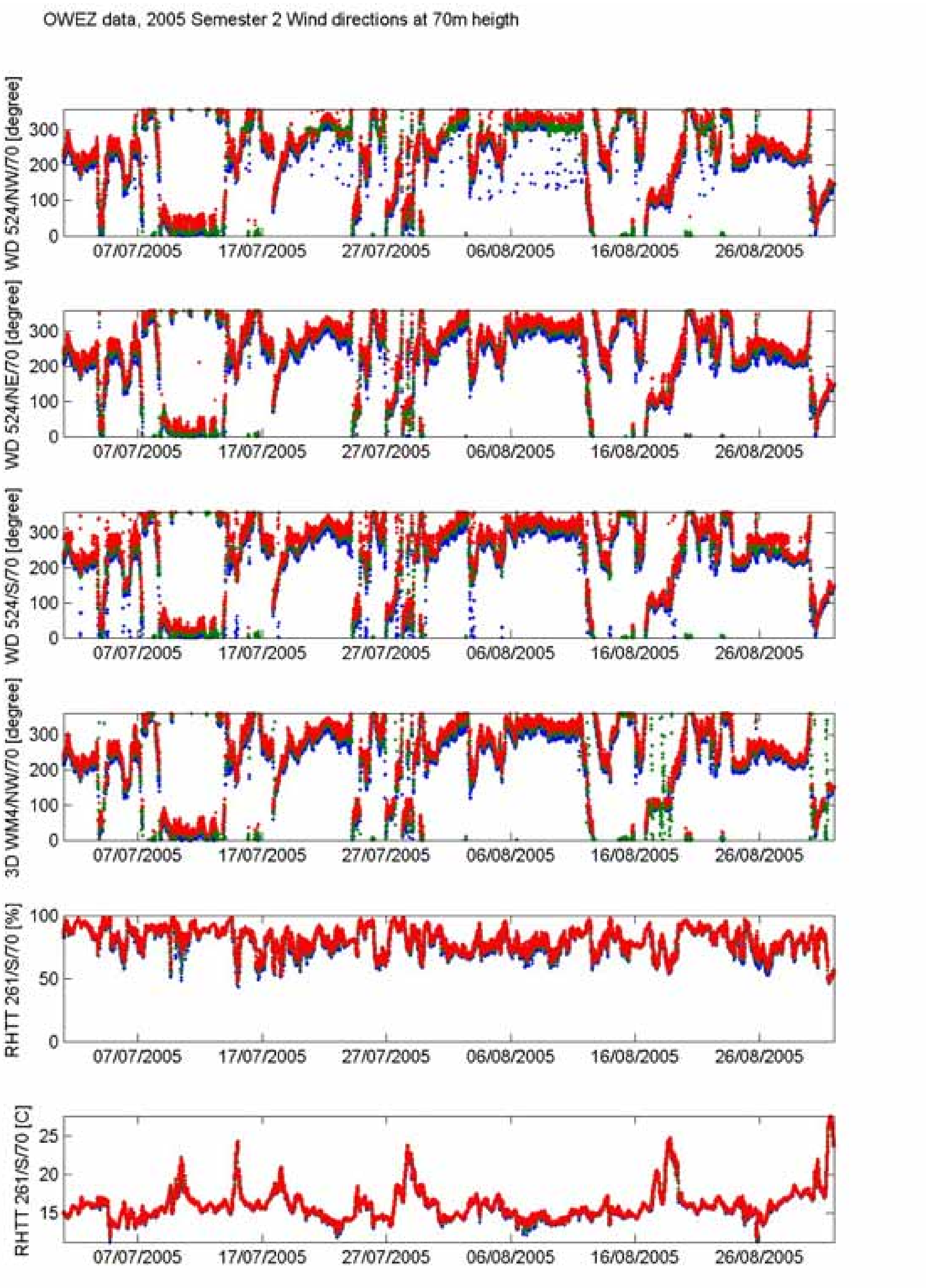


Figure 6.2 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 70 m height are shown for July and August 2005.*

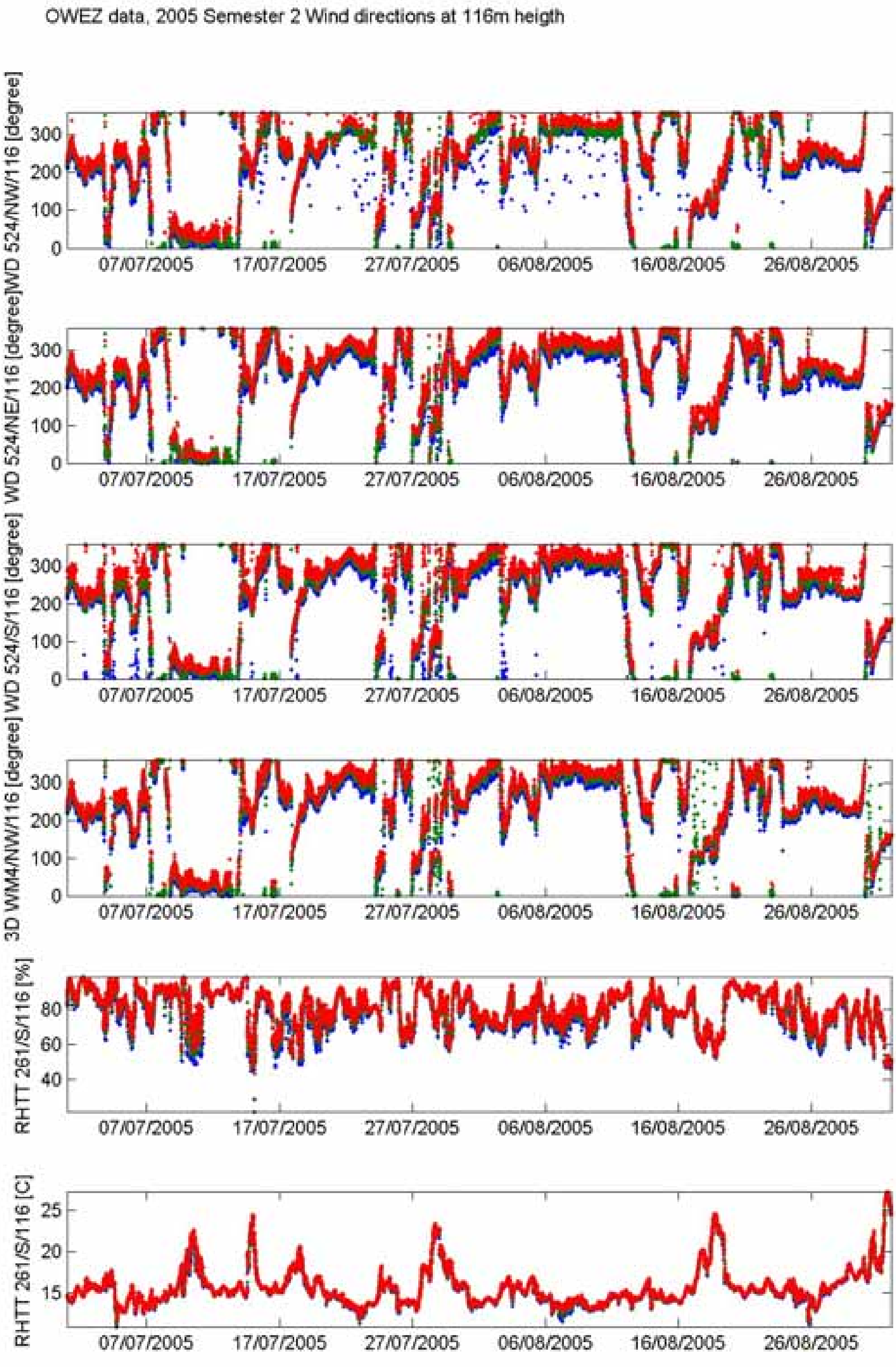


Figure 6.3 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 116 m height are shown for July and August 2005.*

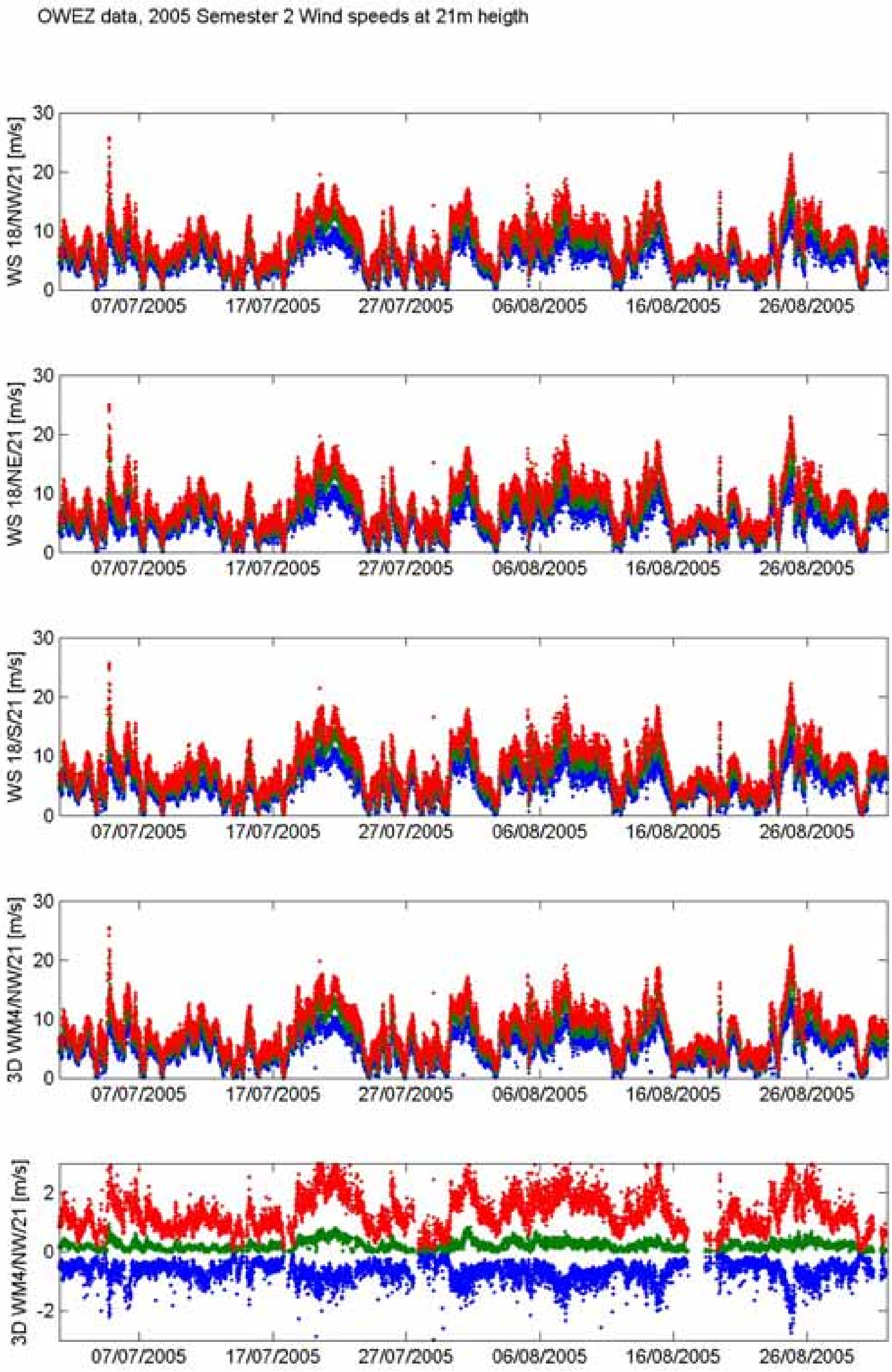


Figure 6.4 *Time histories of stored data in ten-minute averaged values. Wind speed measurements with cup anemometers and sonic anemometer are shown together with the vertical wind speed measured with the sonic anemometer at 21m height are shown for July and August 2005.*

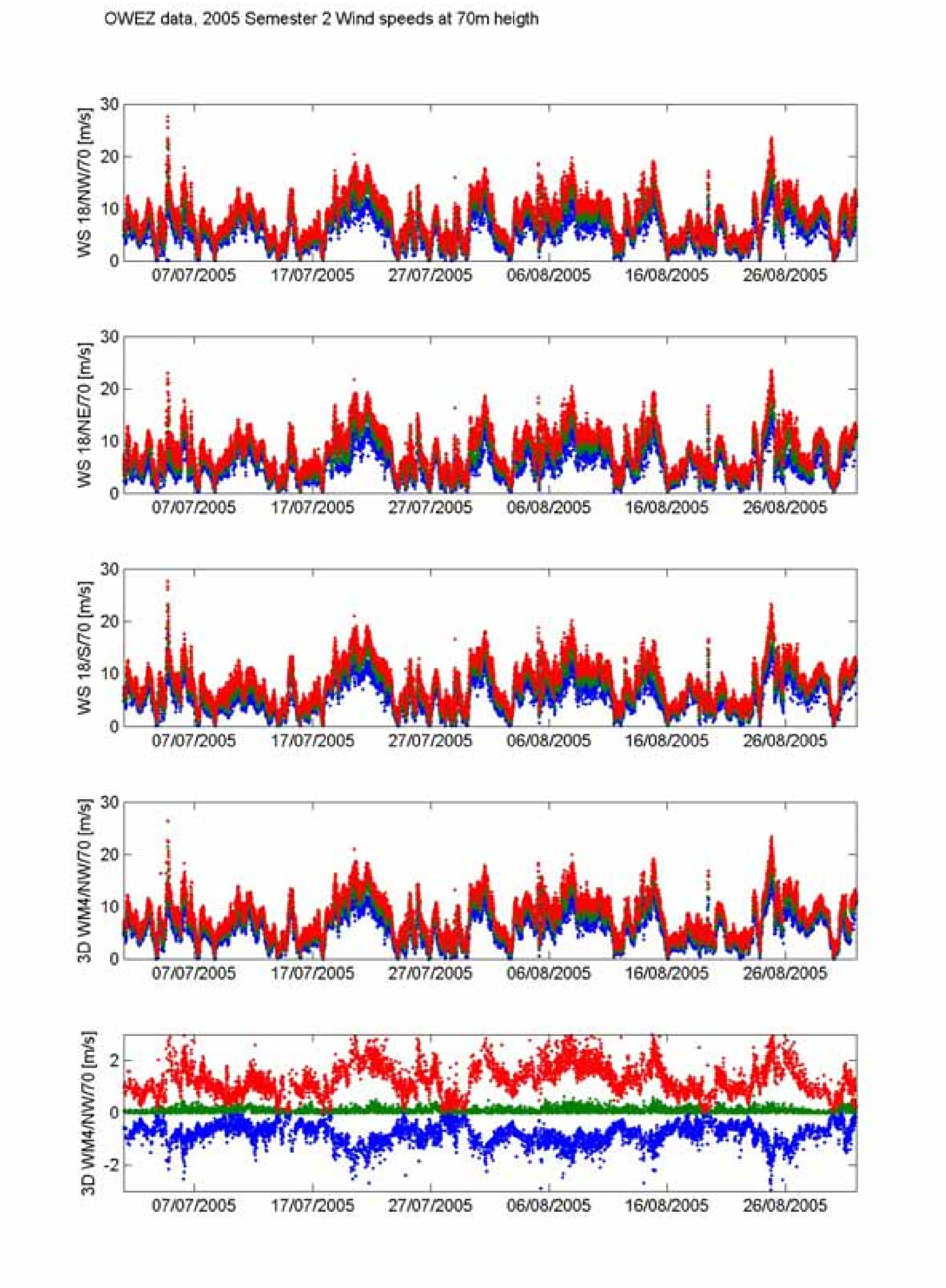


Figure 6.5 *Time histories of stored data in ten-minute averaged values. Wind speed measurements with cup anemometers and sonic anemometer are shown together with the vertical wind speed measured with the sonic anemometer at 70m height are shown for July and August 2005.*

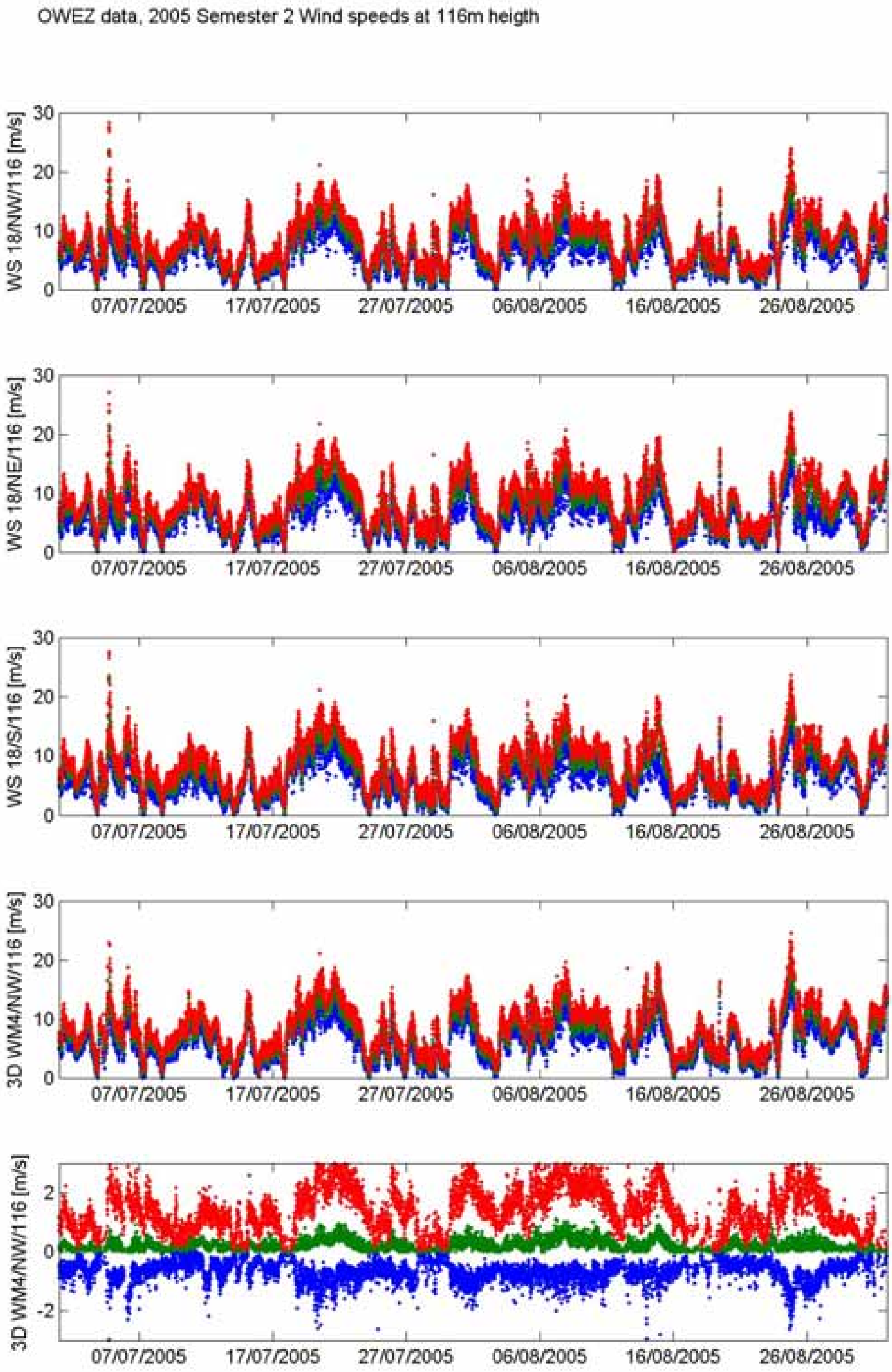


Figure 6.6 *Time histories of stored data in ten-minute averaged values. Wind speed measurements with cup anemometers and sonic anemometer are shown together with the vertical wind speed measured with the sonic anemometer at 116m height are shown for July and August 2005.*

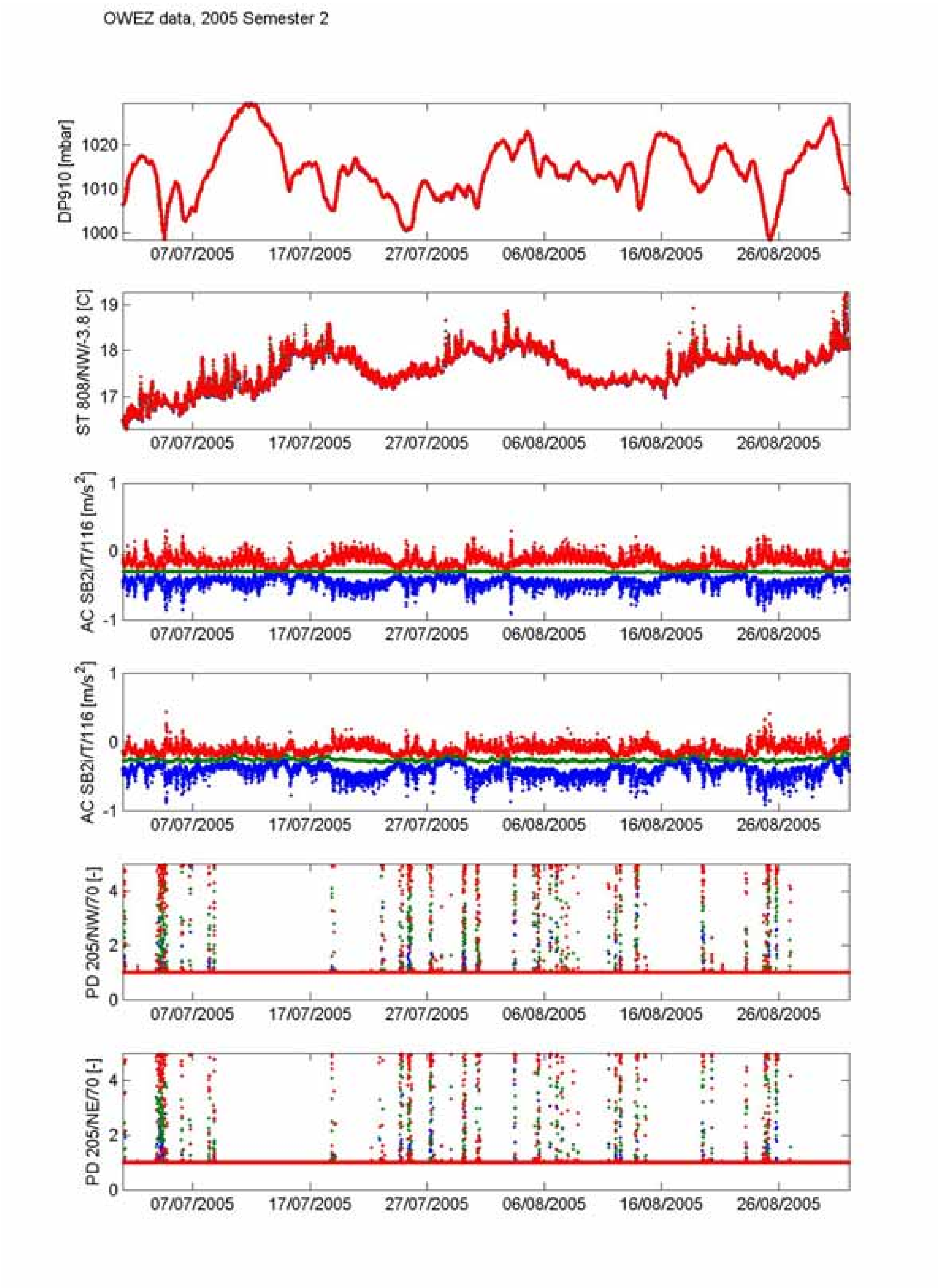


Figure 6.7 *Time histories of stored data in ten-minute averaged values. Air pressure at 21m above MSL, seawater temperature, mast top accelerations in N-S and W-E directions at 116.6 m above MSL and precipitation (70 m) are shown for July and August 2005. The precipitation is measured with sensors in the NE and NW boom.*

7. Time histories September-October 2005

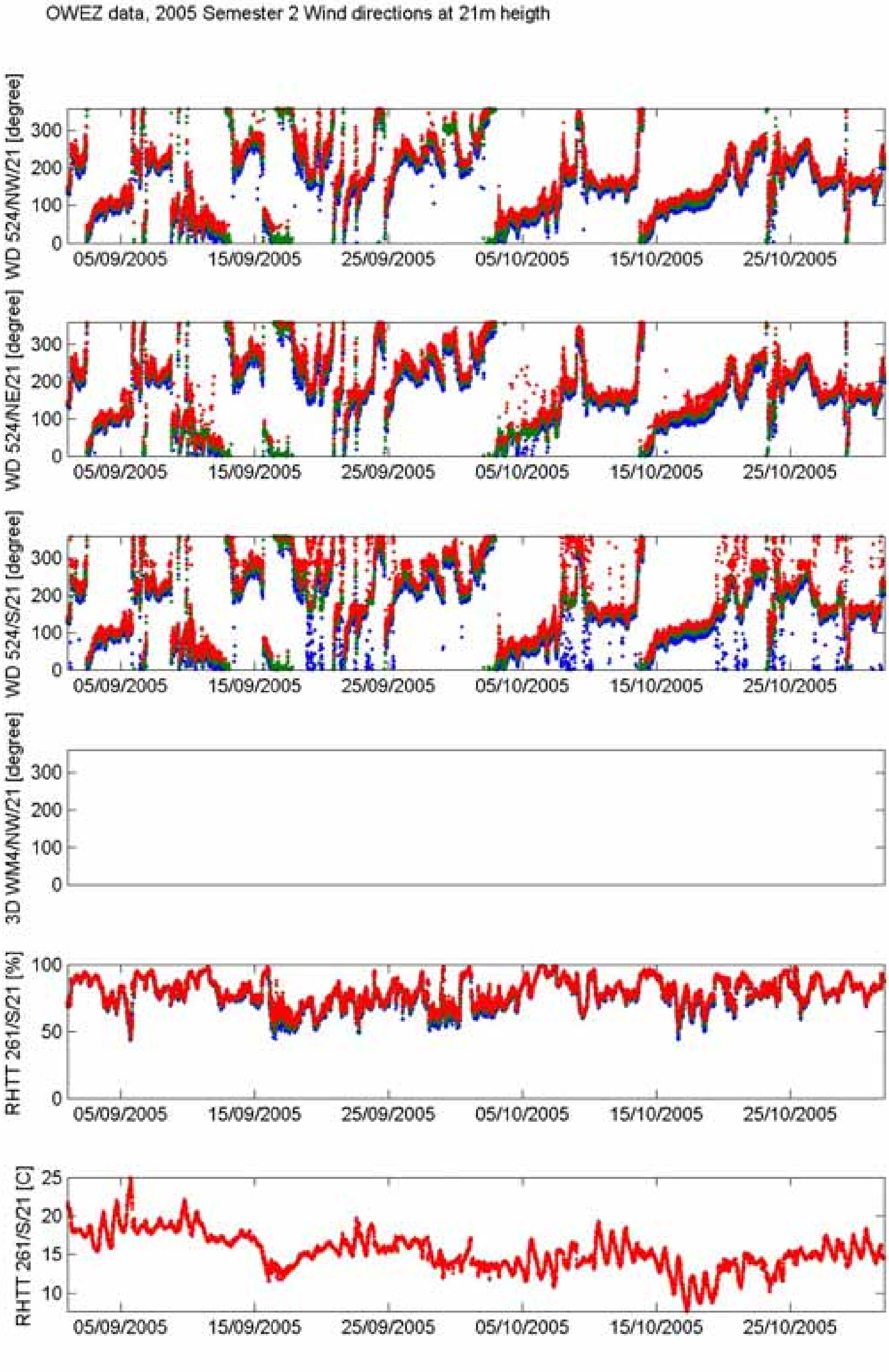


Figure 7.1 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 21 m height are shown for September and October 2005.*

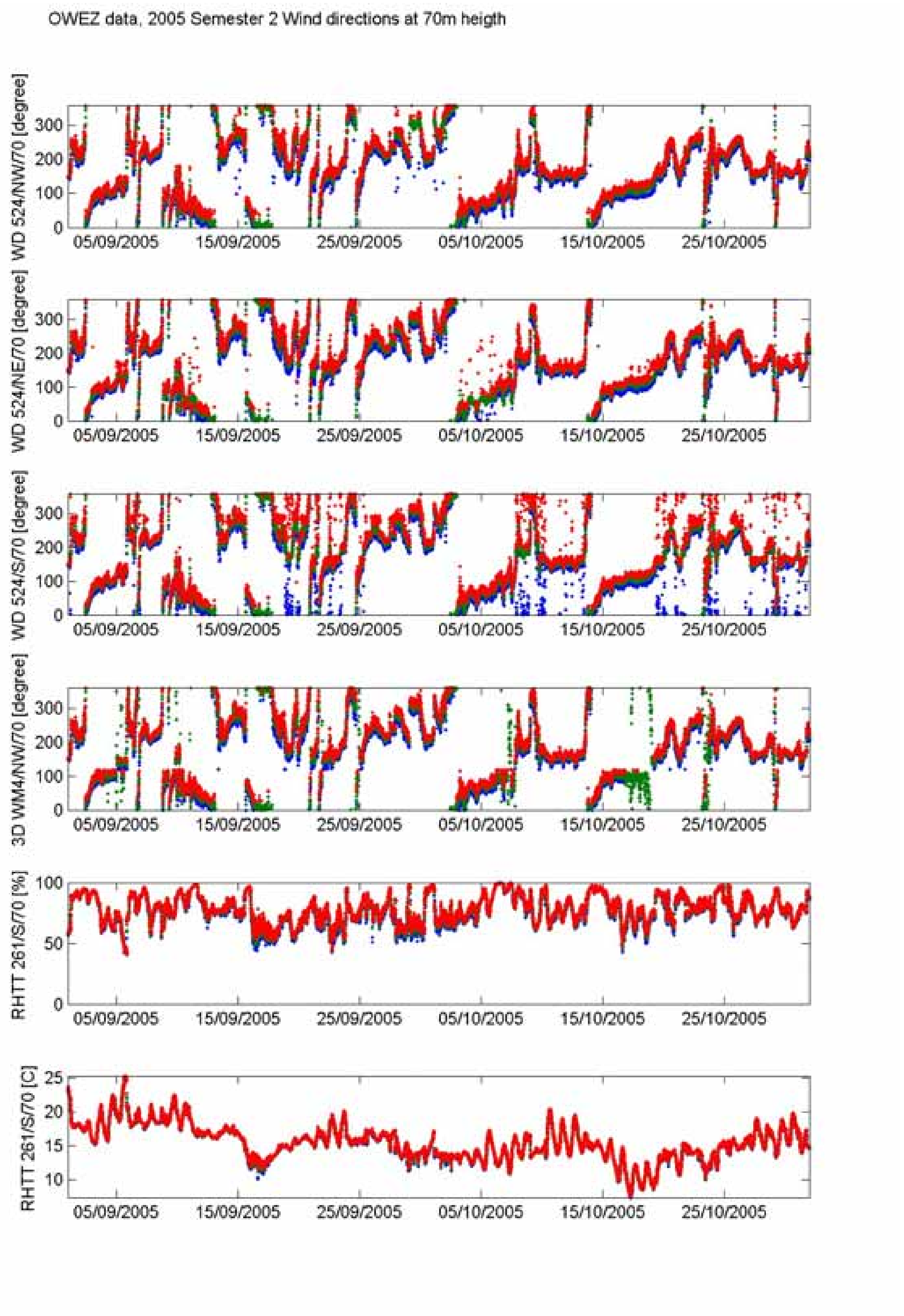


Figure 7.2 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 70 m height are shown for September and October 2005.*

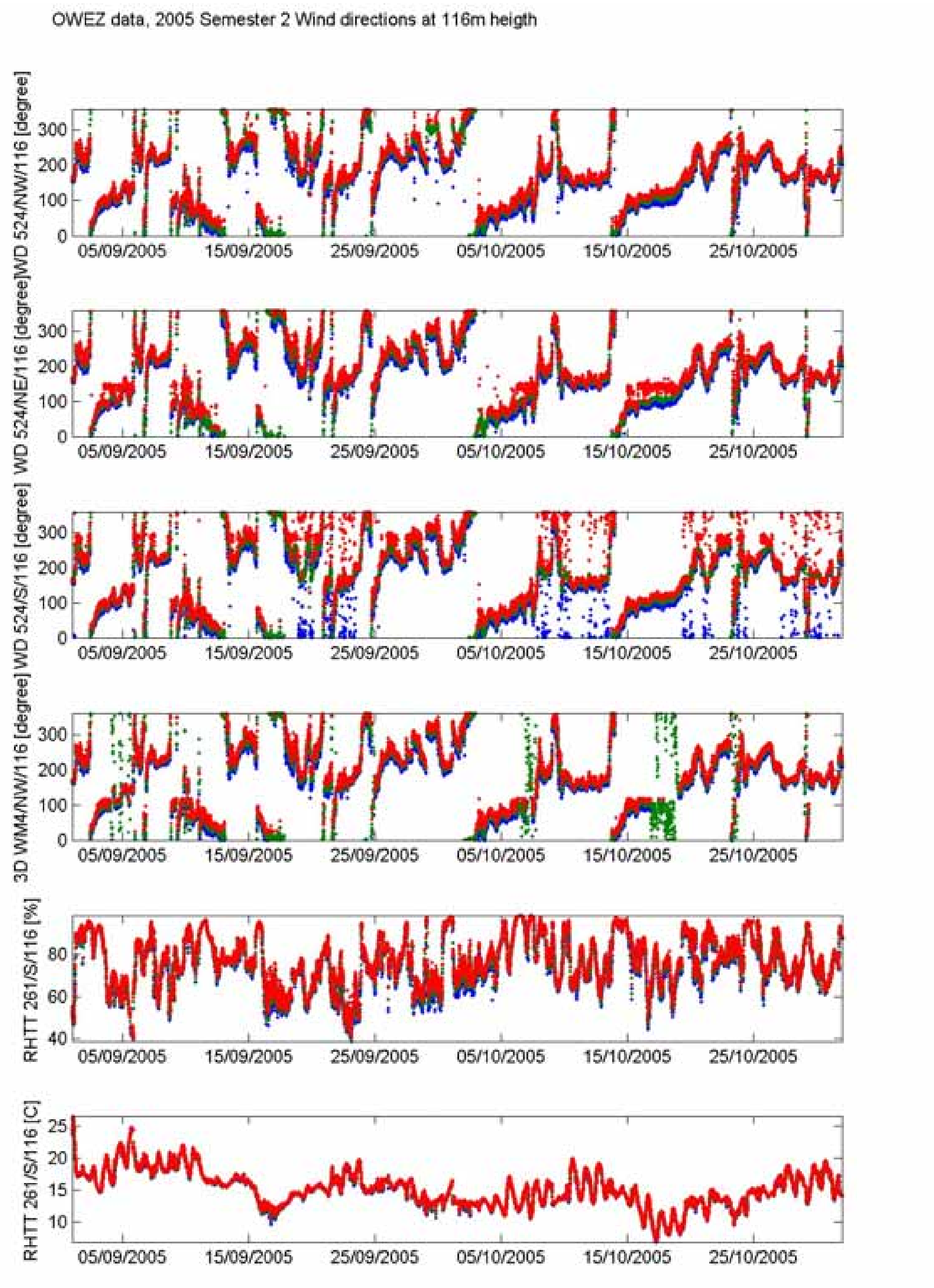


Figure 7.3 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 116 m height are shown for September and October 2005.*

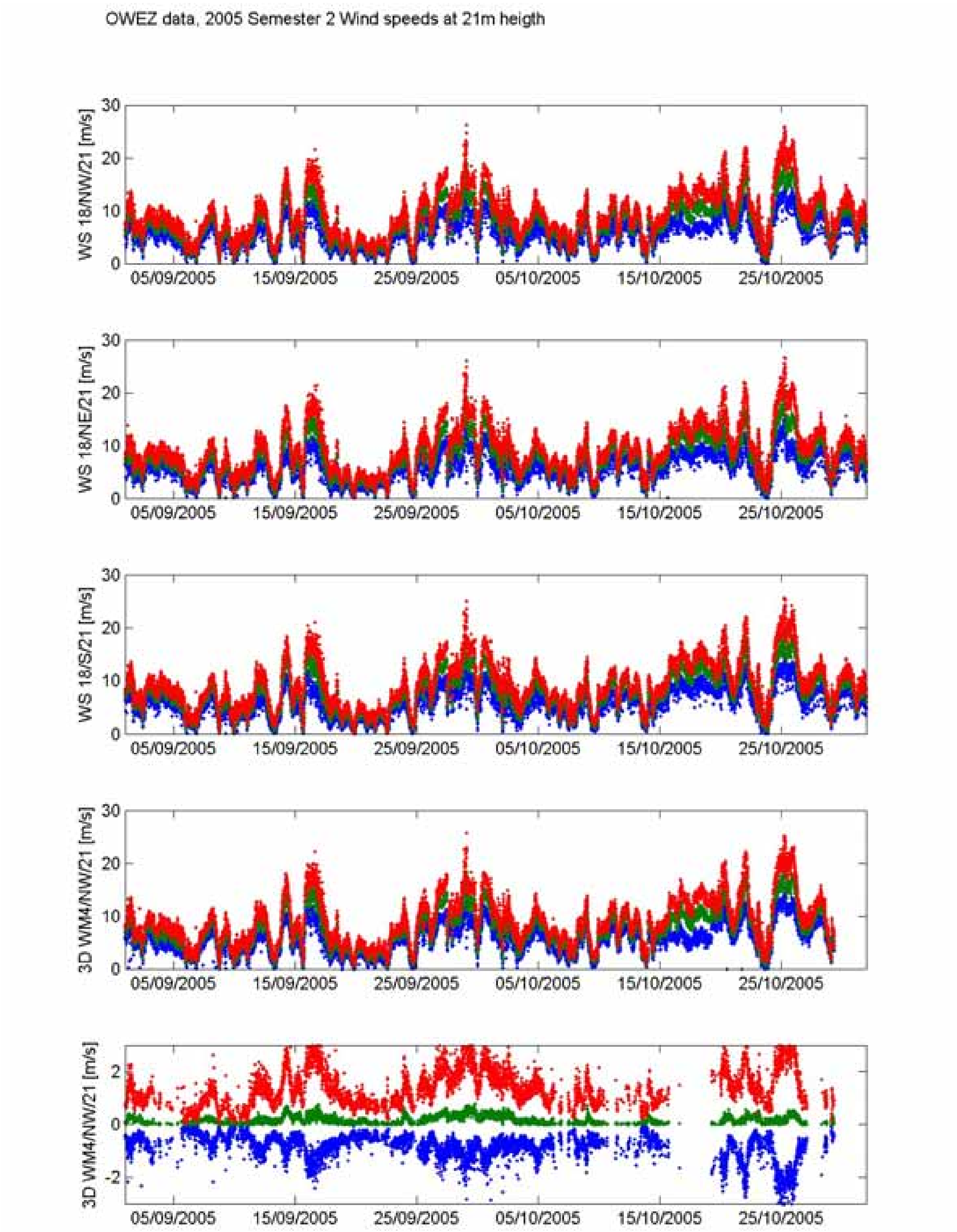
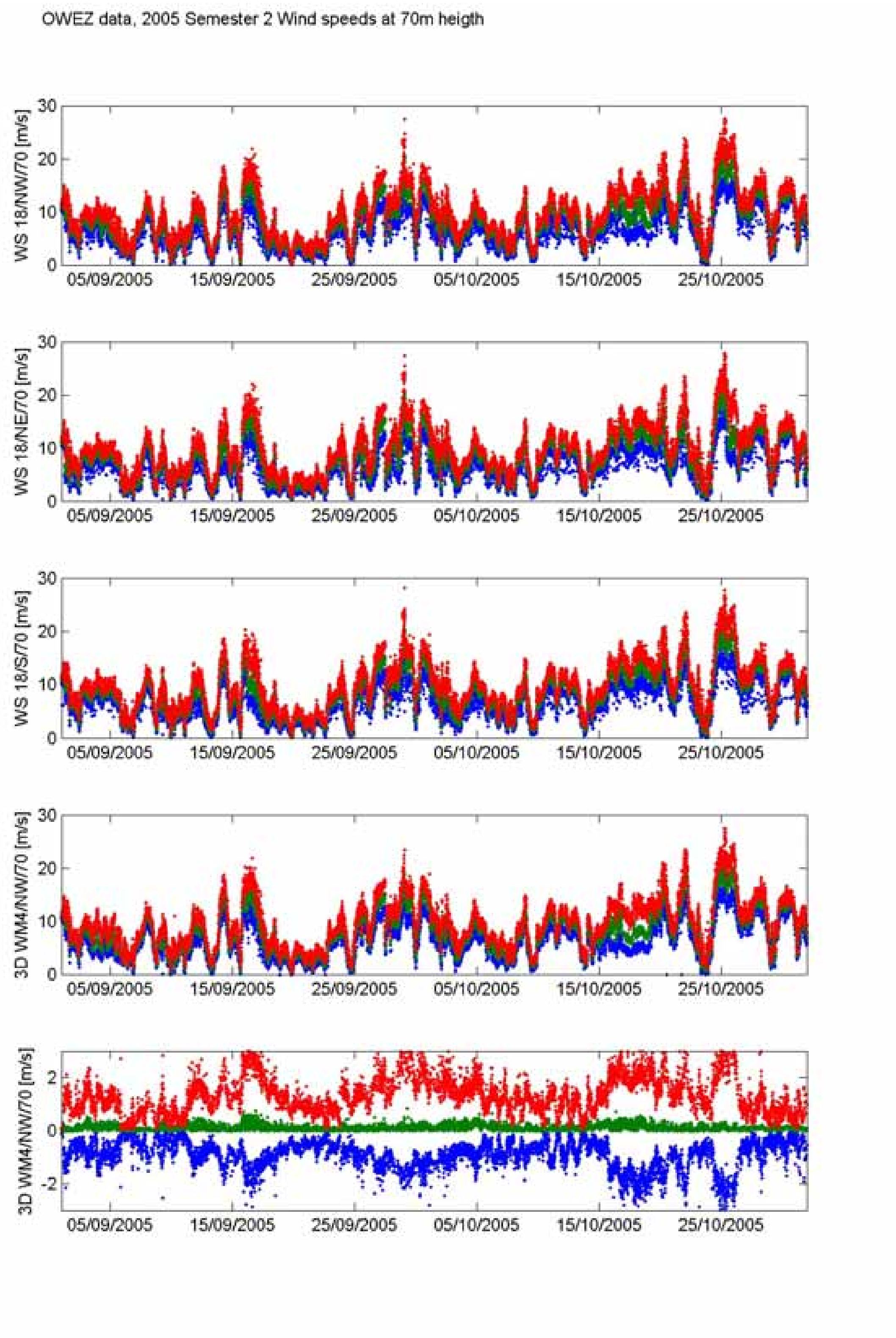


Figure 7.4 *Time histories of stored data in ten-minute averaged values. Wind speed measurements with cup anemometers and sonic anemometer are shown together with the vertical wind speed measured with the sonic anemometer at 21m height are shown for September and October 2005.*



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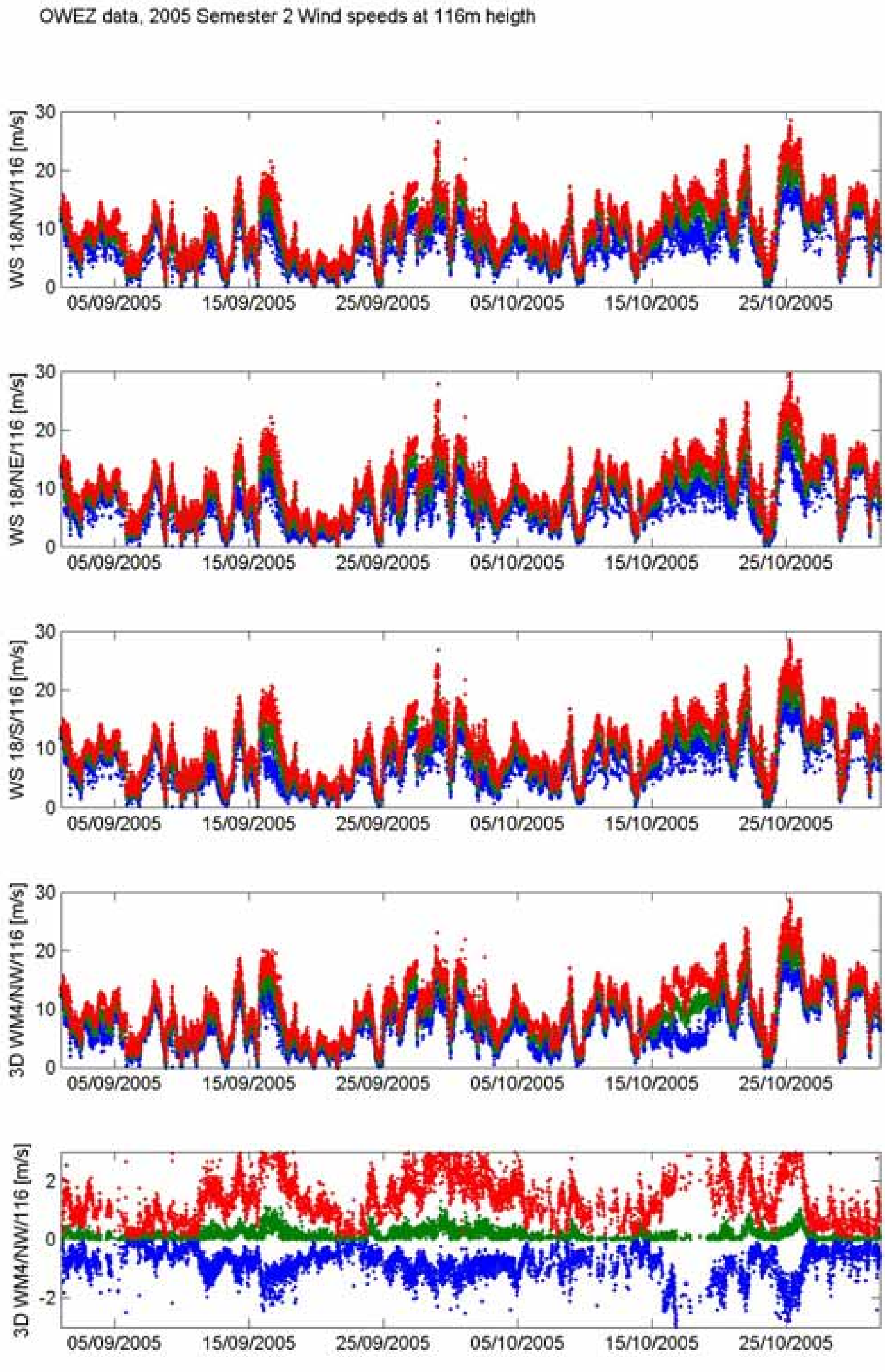


Figure 7.6 *Time histories of stored data in ten-minute averaged values. Wind speed measurements with cup anemometers and sonic anemometer are shown together with the vertical wind speed measured with the sonic anemometer at 116m height are shown for September and October 2005.*

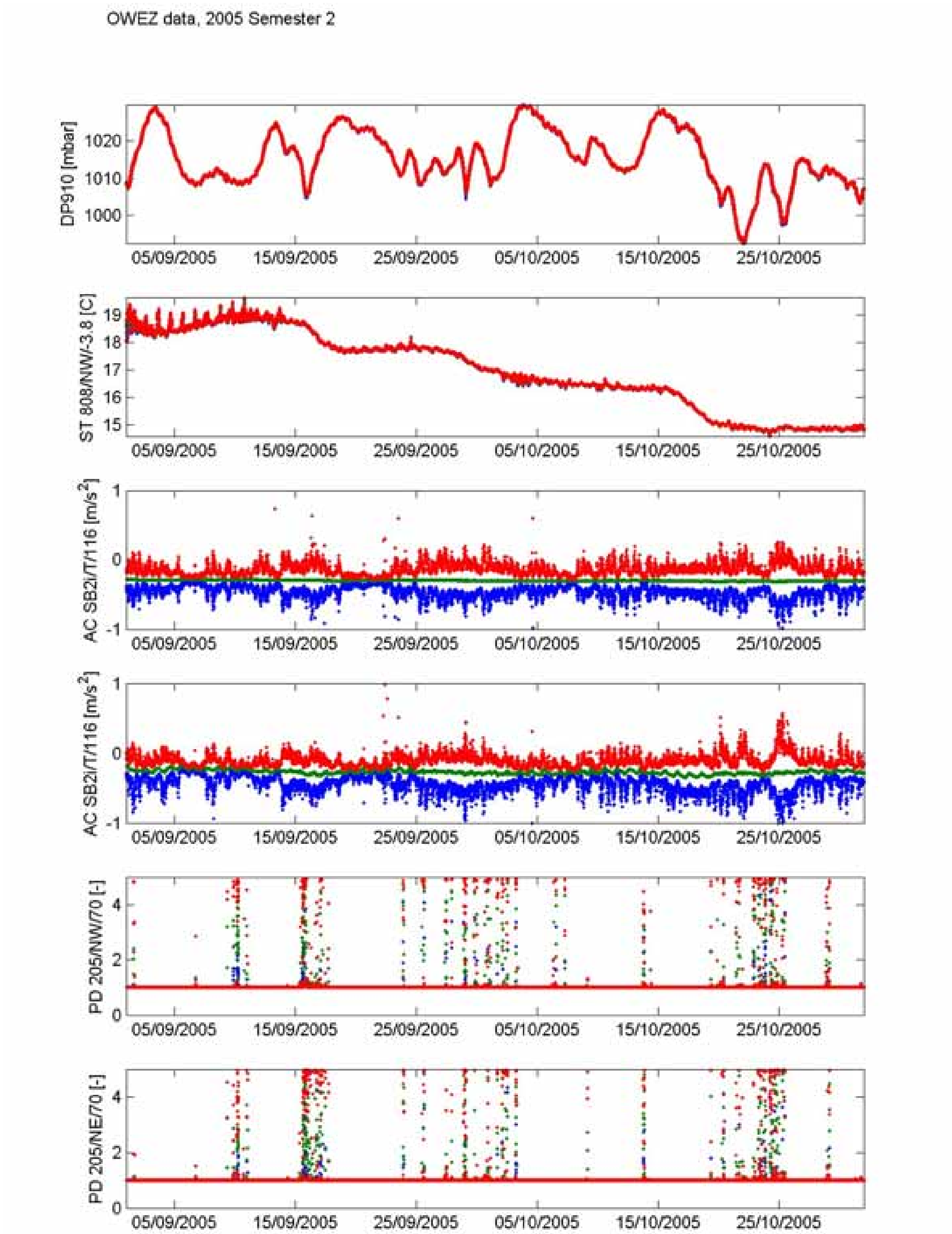


Figure 7.7 *Time histories of stored data in ten-minute averaged values. Air pressure at 21m above MSL, seawater temperature, mast top accelerations in N-S and W-E directions at 116.6 m above MSL and precipitation (70 m) are shown for September and October 2005. The precipitation is measured with sensors in the NE and NW boom.*

8. Time histories November-December 2005

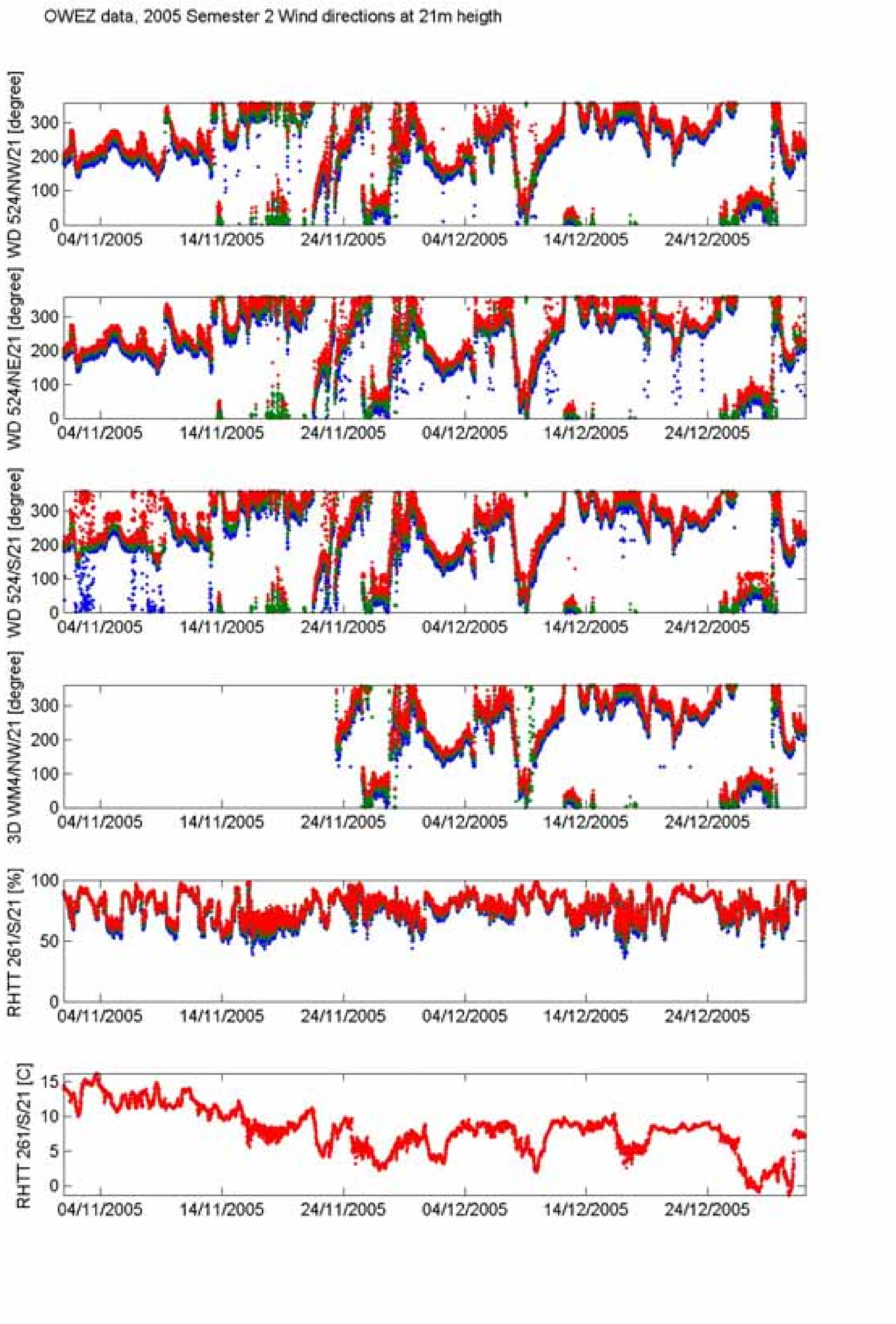


Figure 8.1 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 21 m height are shown for November and December 2005.*

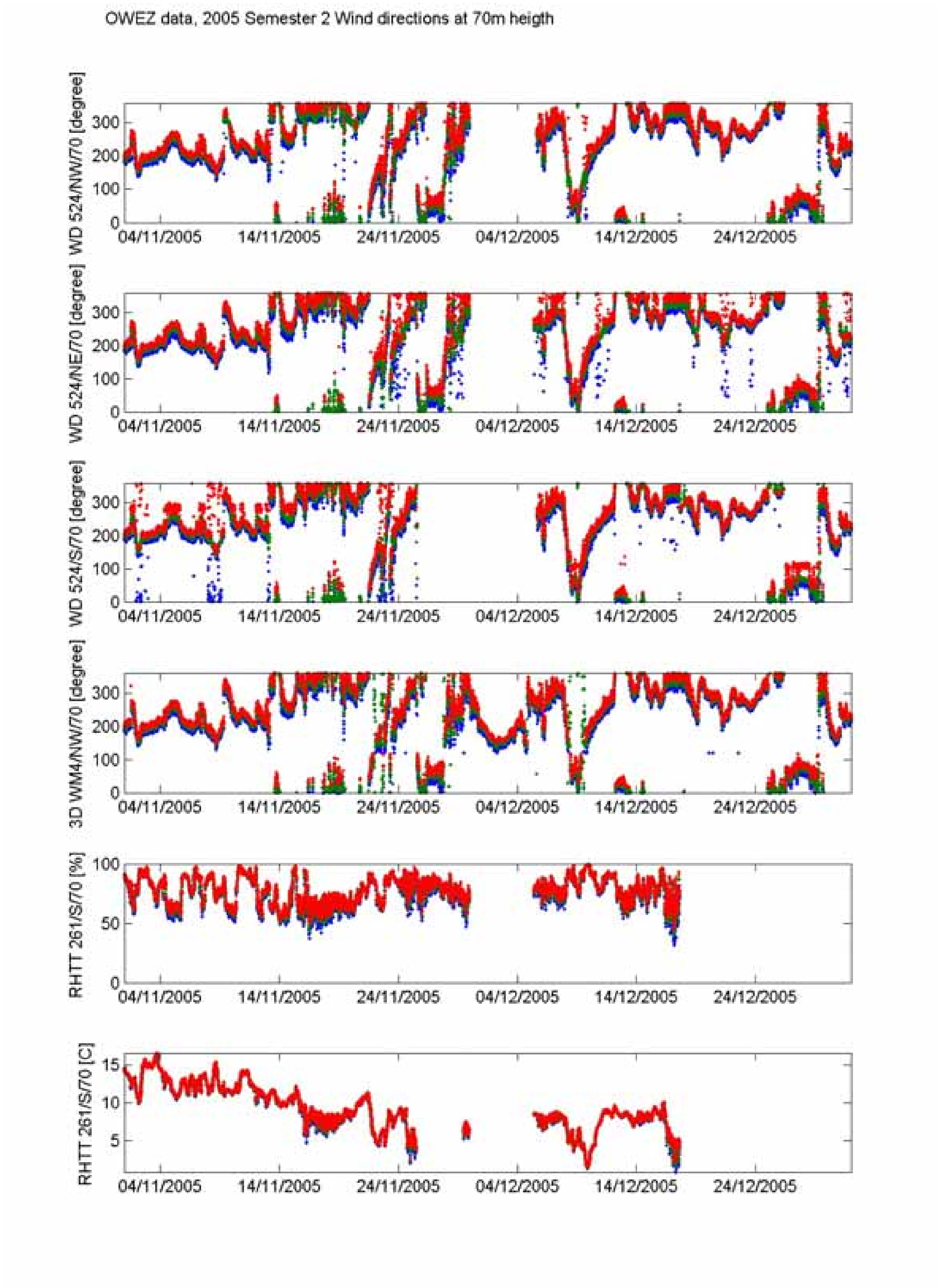


Figure 8.2 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 70 m height are shown for November and December 2005.*

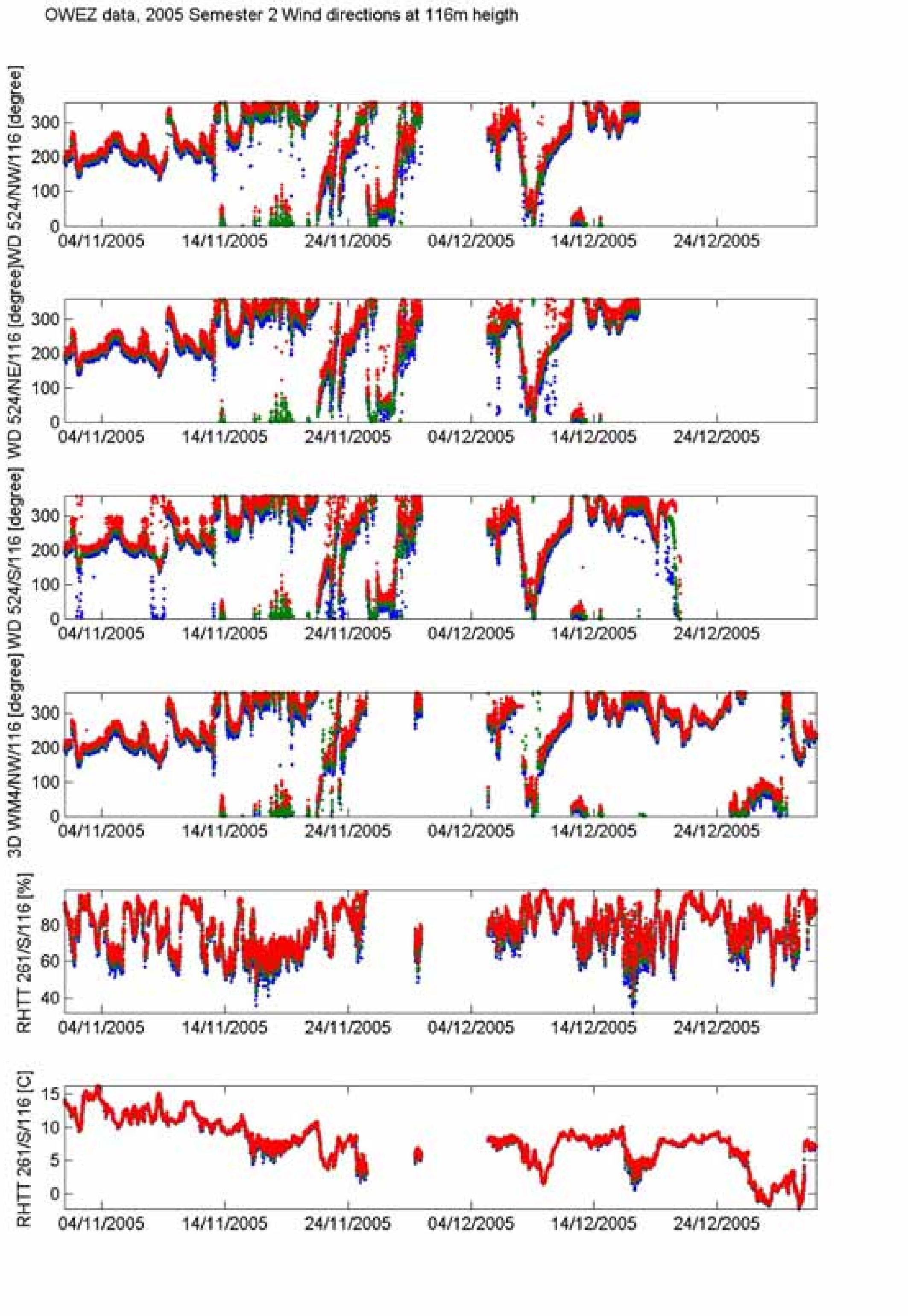


Figure 8.3 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 116 m height are shown for November and December 2005.*

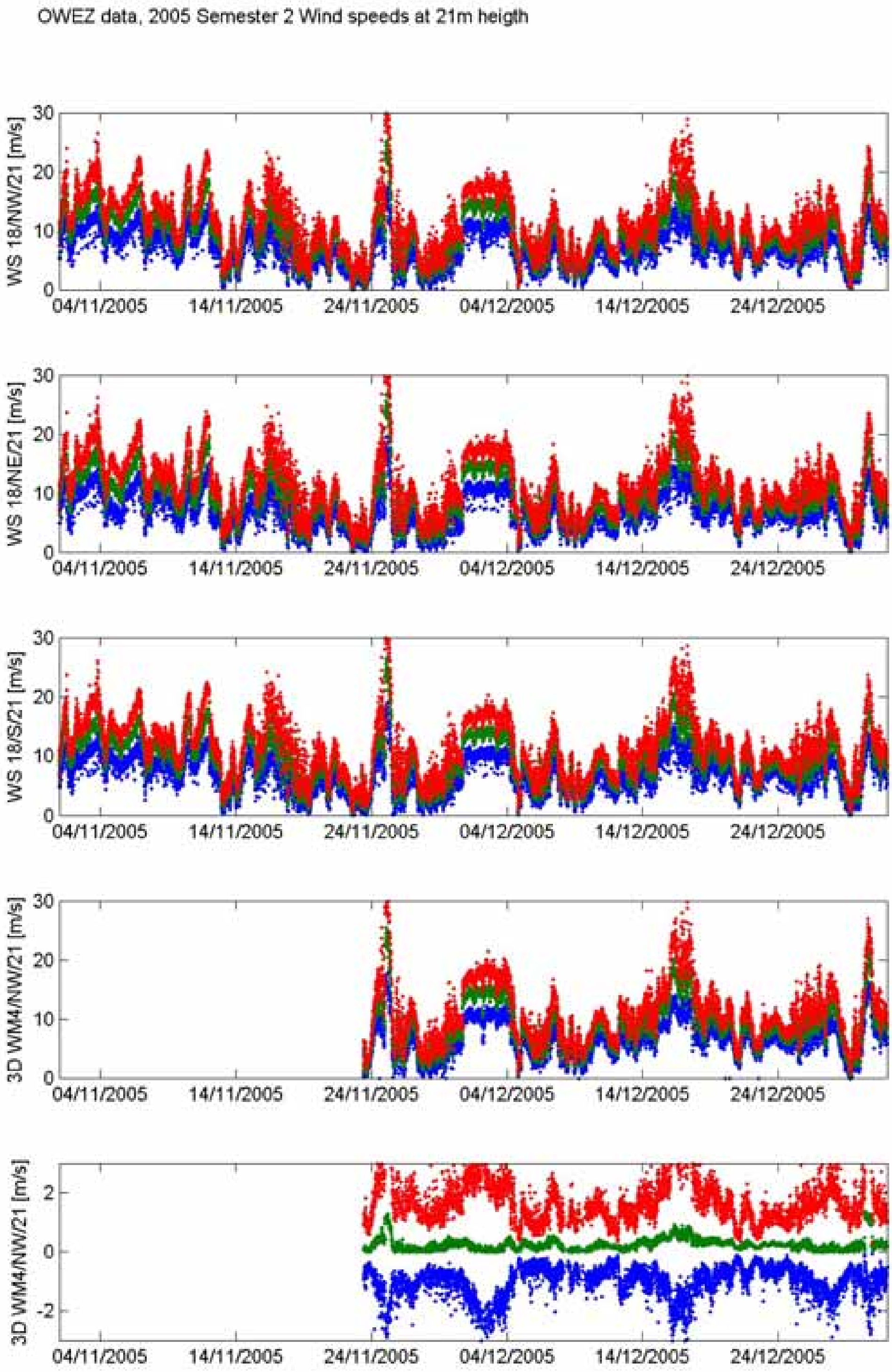
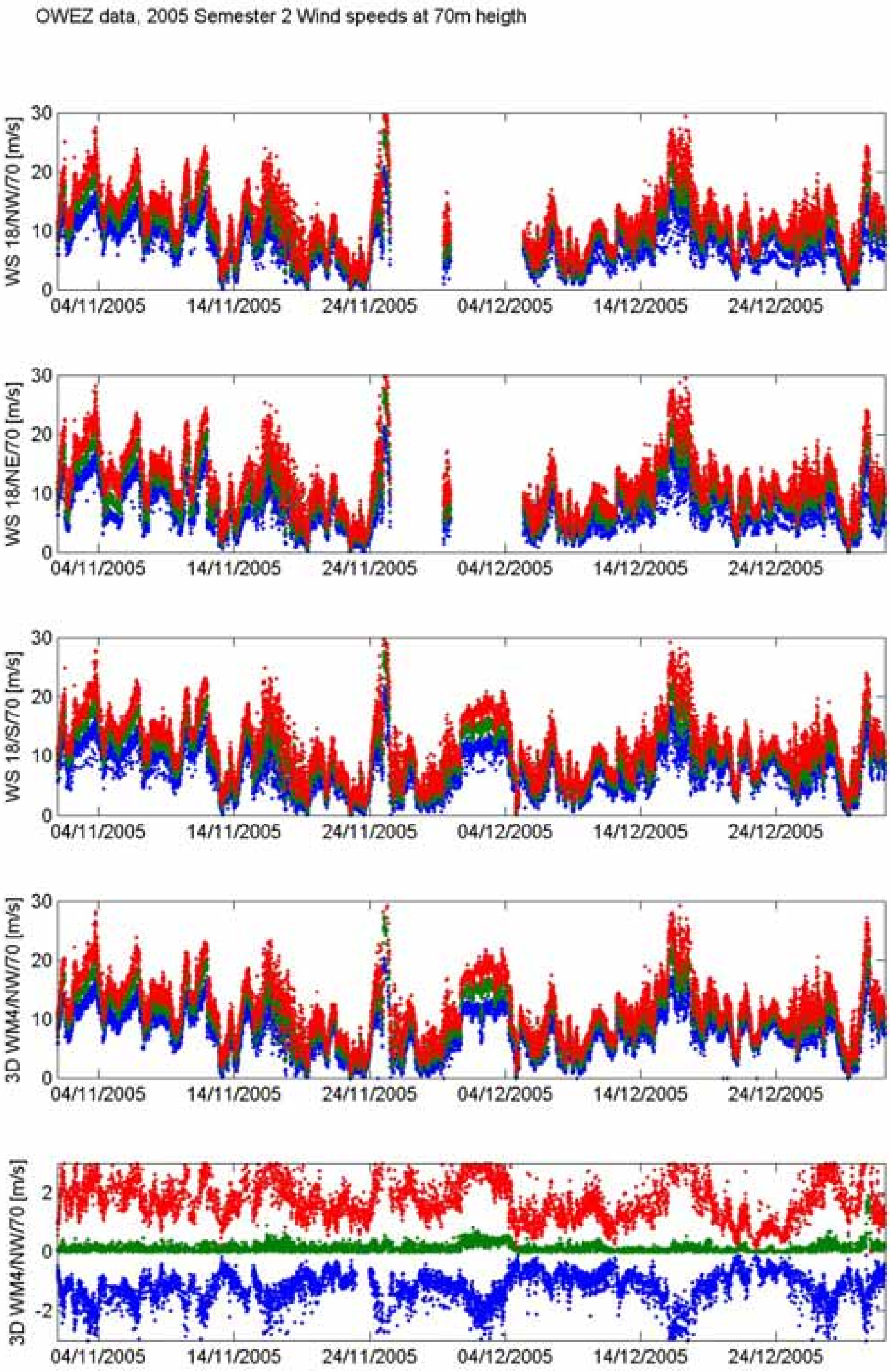


Figure 8.4 *Time histories of stored data in ten-minute averaged values. Wind speed measurements with cup anemometers and sonic anemometer are shown together with the vertical wind speed measured with the sonic anemometer at 21m height are shown for November and December 2005.*



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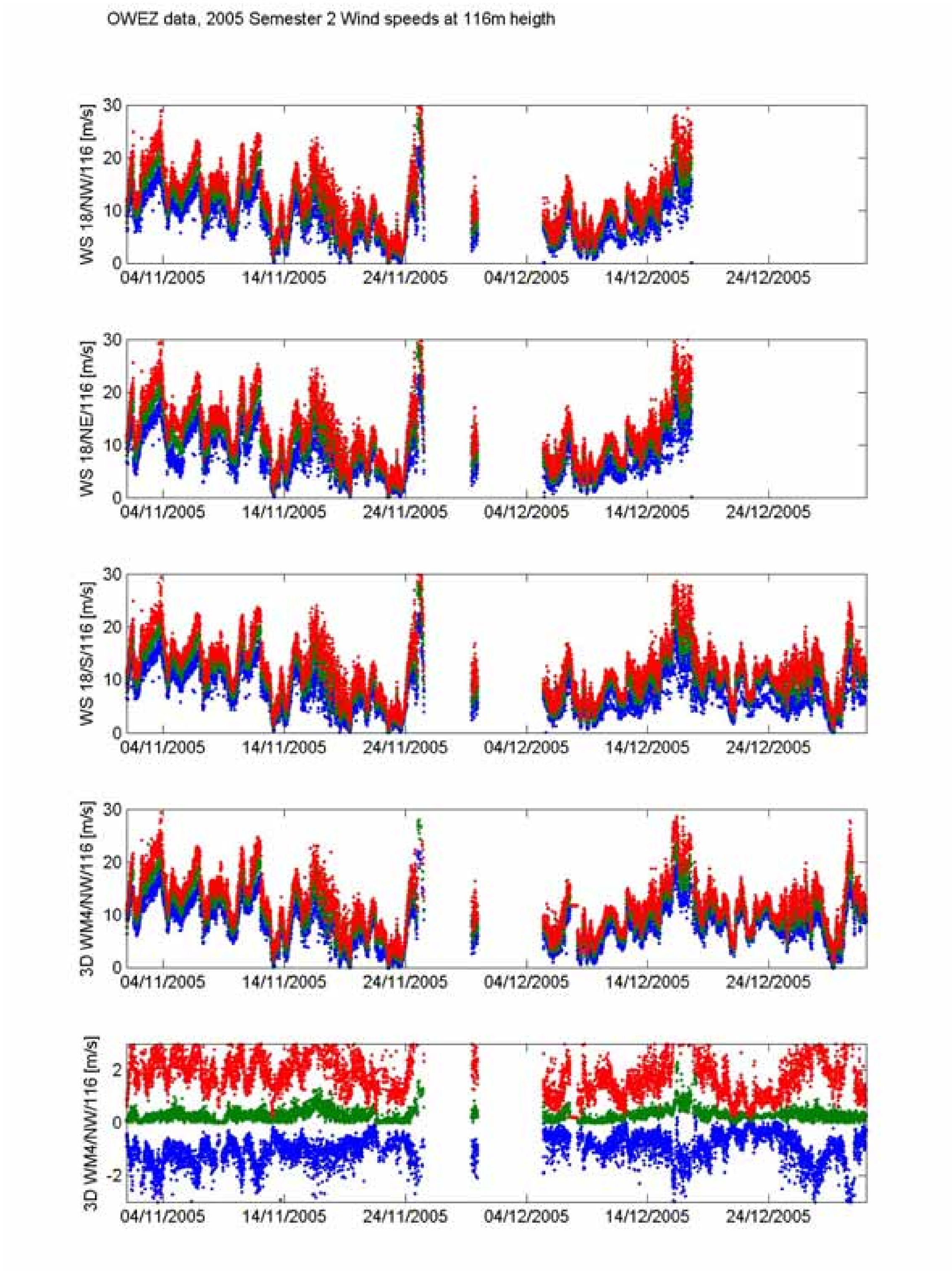

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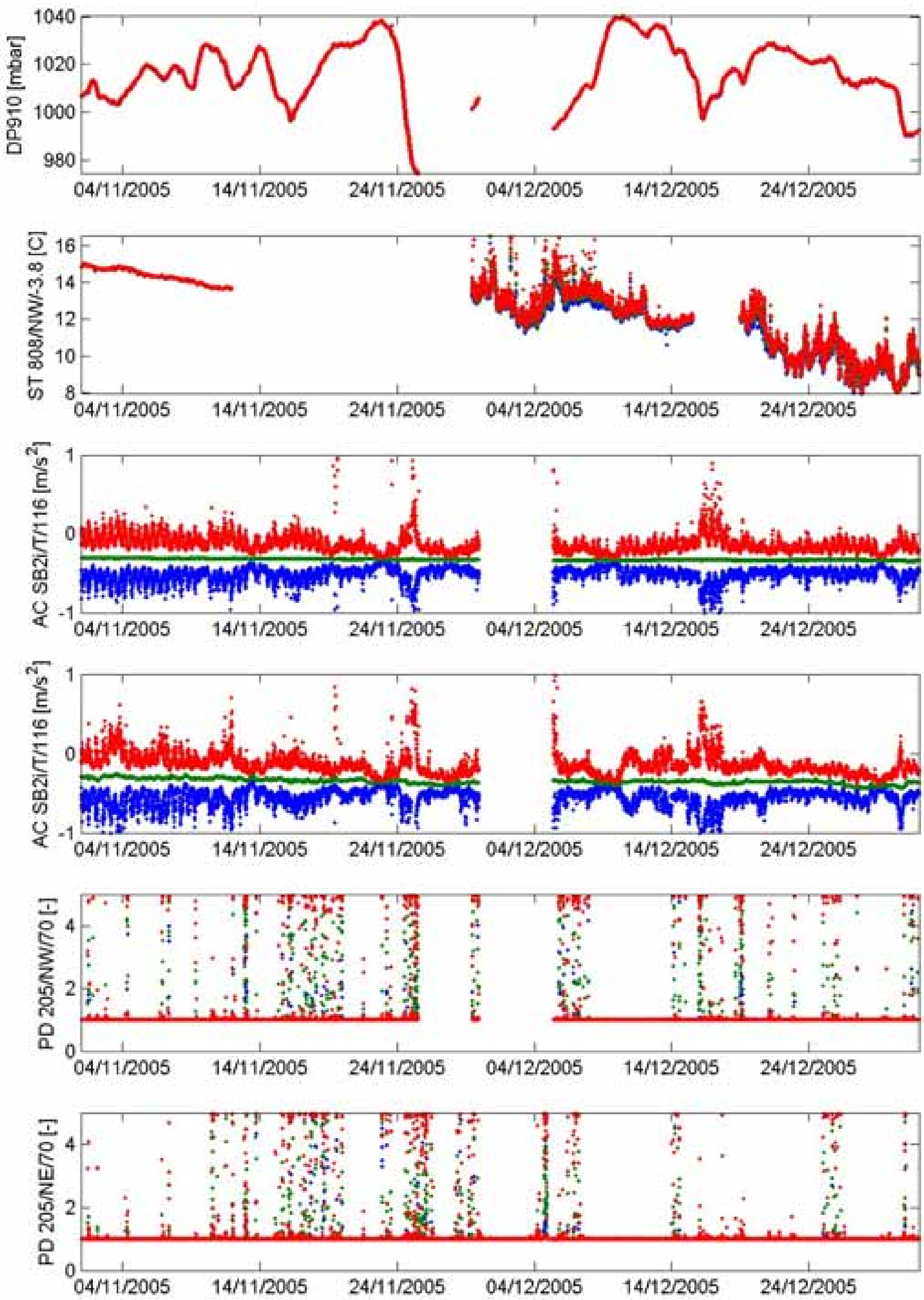

Figure 8.7 *Time histories of stored data in ten-minute averaged values. Air pressure at 21m above MSL, seawater temperature, mast top accelerations in N-S and W-E directions at 116.6 m above MSL and precipitation (70 m) are shown for November and December 2005. The precipitation is measured with sensors in the NE and NW boom.*

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