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Meteorological Measurements OWEZ

Half year report 01-01-2006 - 30-06-2006

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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 first semester of 2006; the period between 01-01-2006 and 30-06-2006.

The project is carried out under assignment of NoordzeeWind BV.

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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. 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 first semester of 2006; the period between 01-01-2006 and 30-06-2006.

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.

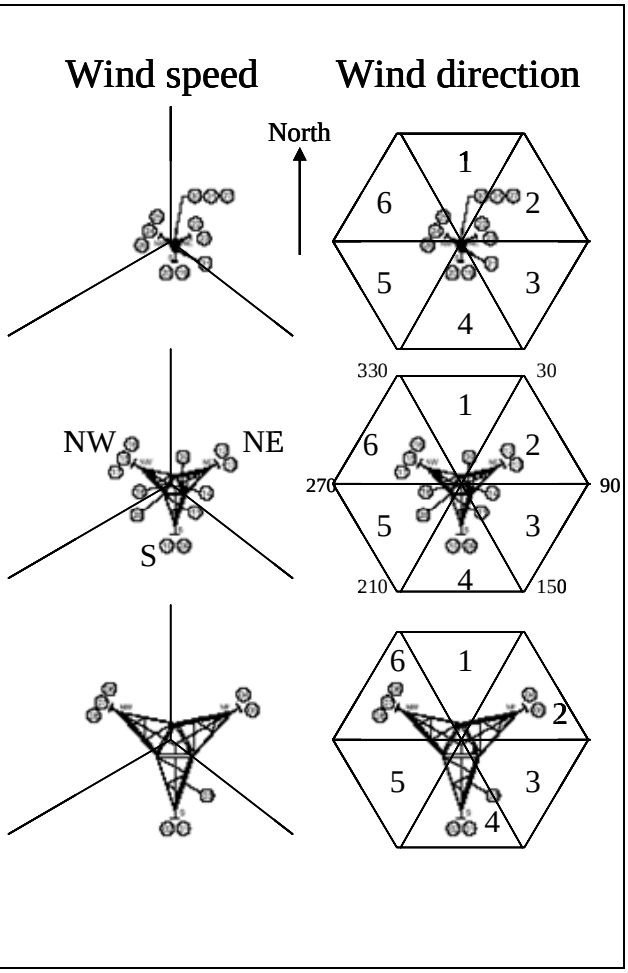
For the selection of the wind speed sensor it is important that at the direction where the wind speed sensor is changed from one sensor to the other, the ratio of the wind speeds is close to one. Furthermore, the wind speed may not be measured in the wake of the mast or a neighbouring sensor. Averaging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



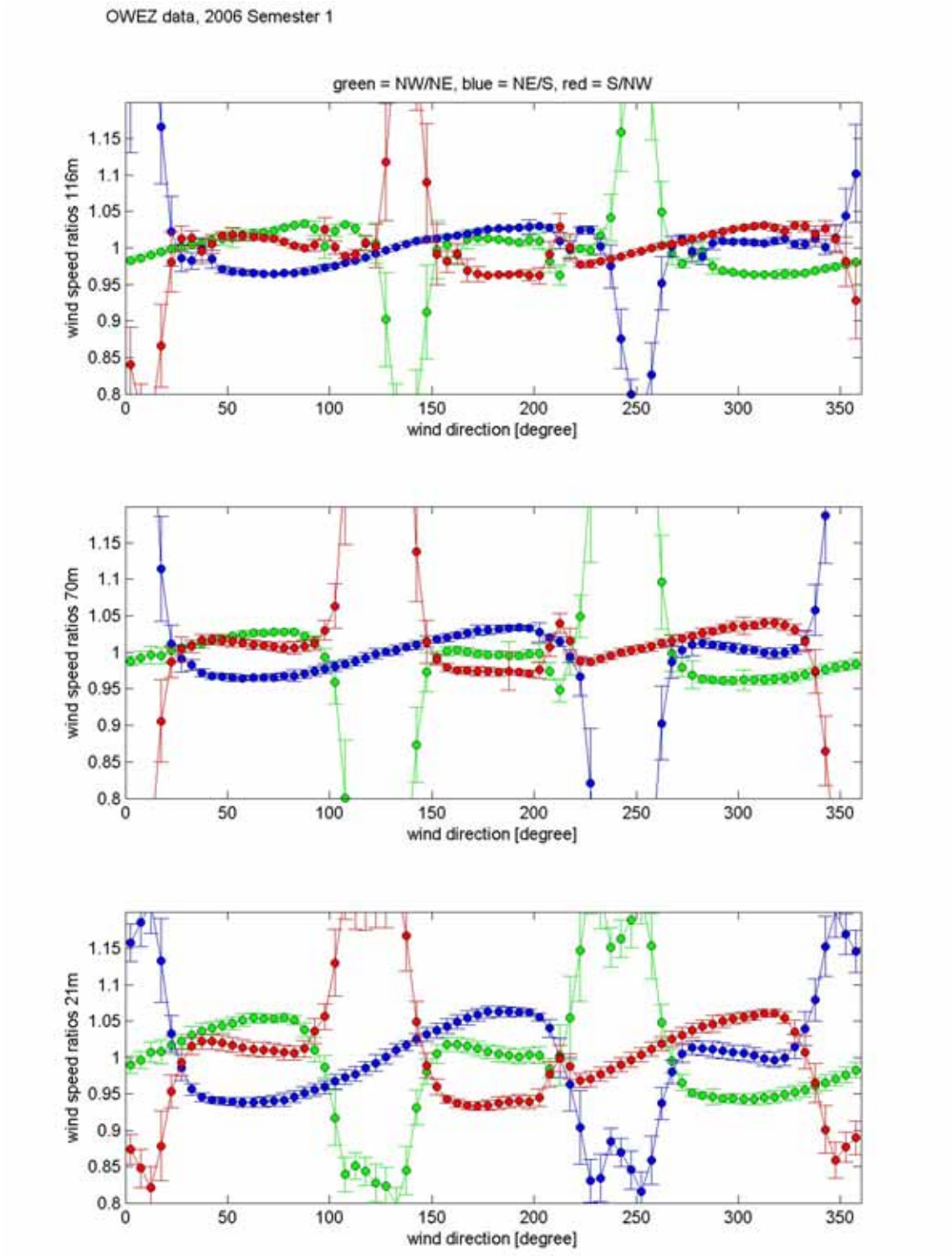


Figure 2.1 *Ratios between anemometer readings mounted on the South (S), North-West (NW) and North-East (NE) booms of the meteorological mast. The wind speed ratios NW/NE are indicated in green, the ratios NE/S are indicated in blue and the ratios S/NW are indicated in red. The indicated wind direction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

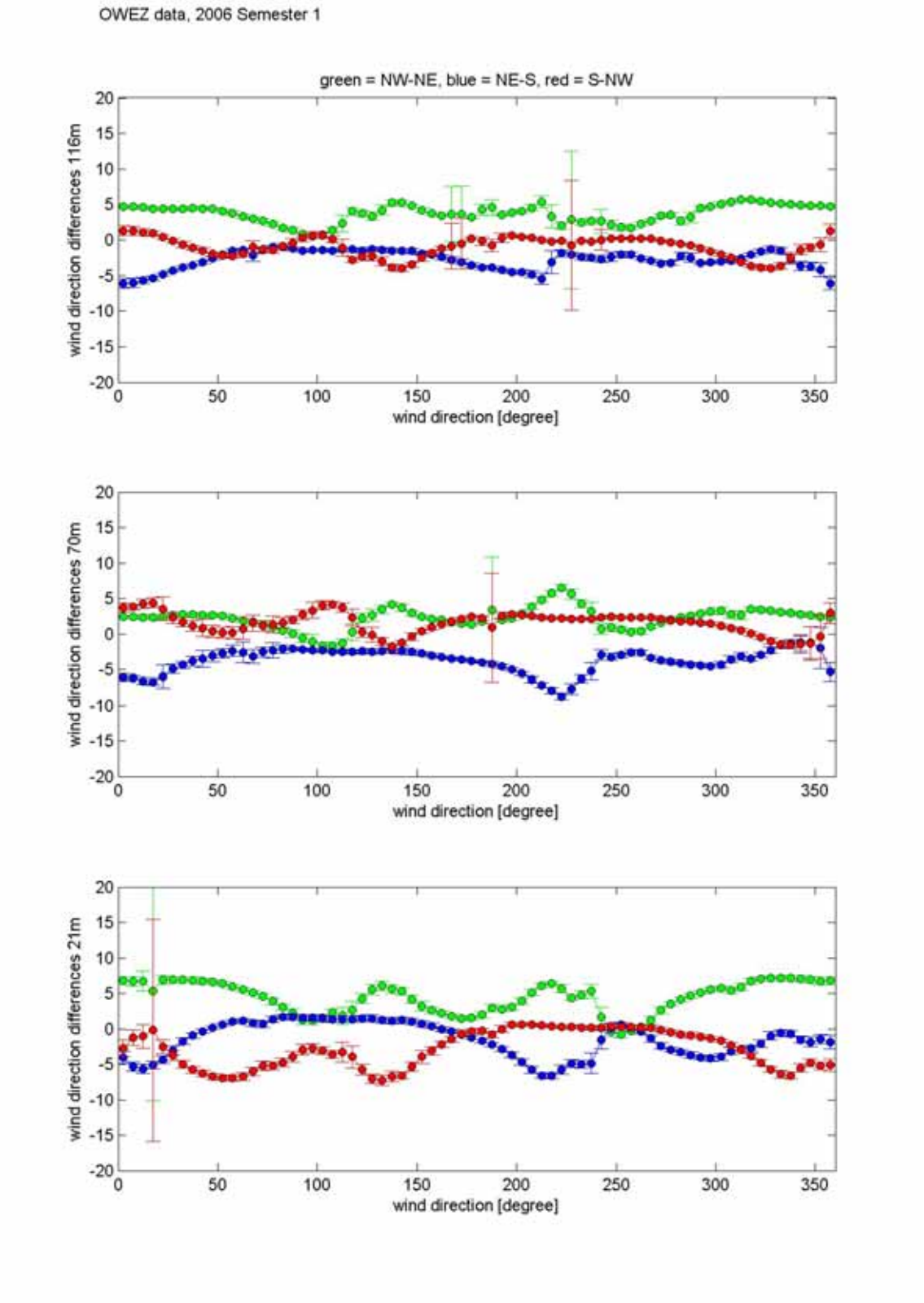


Figure 2.2 *Differences between wind vane readings mounted on the South (S), North-West (NW) and North-East (NE) booms of the meteorological mast. The wind direction differences NW/NE are indicated in green, the differences NE/S are indicated in blue and the differences S/NW are indicated in red. The 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 January 2006 - June 2006	
		number of valid 10-minute averages	availability [%]
wind direction [°]	3D WM4/NW/116	18228	69.9
horizontal wind speed [m/s]	3D WM4/NW/116	18228	69.9
vertical wind speed [m/s]	3D WM4/NW/116	18221	69.9
wind speed [m/s]	WS 018/NW/116	25040	96.1
wind speed [m/s]	WS 018/NE/116	25040	96.1
wind speed [m/s]	WS 018/S/116	25664	98.5
wind speed [m/s]	WS 018/NW/70	25666	98.5
wind speed [m/s]	WS 018/NE/70	25660	98.4
ambient temp. [°C]	RHTT 261/S/116	25665	98.5
ambient temp. [°C]	RHTT 261/S/70	21274	81.6
relative humidity [%]	RHTT 261/S/116	25665	98.5
ambient air pressure [mbar]	DP910	25666	98.5
precipitation [yes/no]	PD 205/NW/70	25666	98.5
sea water temperature [°C]	ST 808/NW/-3.8	24478	93.9
X (north – south) acceleration [m/s^2]	AC SB2i/T/116	25659	98.4
Y (west – east) acceleration [m/s^2]	AC SB2i/T/116	25655	98.4
wind direction [°]	WD 524/NW/116	21268	81.6
wind direction [°]	WD 524/NE/116	16524	63.4
wind direction [°]	WD 524/S/116	21268	81.6
wind direction [°]	WD 524/NW/70	25659	98.4
wind direction [°]	WD 524/NE/70	25659	98.4
wind direction [°]	3D WM4/NW/21	23411	89.8
horizontal wind speed [m/s]	3D WM4/NW/21	23411	89.8
vertical wind speed [m/s]	3D WM4/NW/21	23411	89.8
wind direction [°]	3D WM4/NW/70	23305	89.4
horizontal wind speed [m/s]	3D WM4/NW/70	23305	89.4
vertical wind speed [m/s]	3D WM4/NW/70	23305	89.4
wind speed [m/s]	WS 018/S/70	23425	89.9
wind speed [m/s]	WS 018/NW/21	23514	90.2
wind speed [m/s]	WS 018/NE/21	23514	90.2
wind speed [m/s]	WS 018/S/21	23514	90.2
ambient temp. [°C]	RHTT 261/S/21	23512	90.2
relative humidity [%]	RHTT 261/S/70	21272	81.6
relative humidity [%]	RHTT 261/S/21	23512	90.2
precipitation [yes/no]	PD 205/NE/70	23515	90.2
wind direction [°]	WD 524/S/70	23513	90.2
wind direction [°]	WD 524/NW/21	18714	71.8
wind direction [°]	WD 524/NE/21	23513	90.2
wind direction [°]	WD 524/S/21	23511	90.2
derived wind direction	21m	23513	90.2
derived wind direction	70m	25666	98.5
derived wind direction	116m	21268	81.6
derived wind speed	21m	23511	90.2
derived wind speed	70m	24870	95.4
derived wind speed	116m	21268	81.6

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]	7.0	8.0	8.9	7.9	7.4	8.2	9.2	12.2	10.7	8.6	8.3	7.9	8.9
Weibull	A [m/s]	7.9	9.0	9.9	8.8	8.3	9.1	10.3	13.6	12.0	9.6	9.3	8.9	10.1
	k [-]	2.6	2.6	3.0	3.1	2.8	3.3	2.5	3.3	2.7	2.6	2.2	2.1	2.4
	[%]	8.4	6.2	10.9	8.2	4.6	6.3	6.2	12.9	11.1	8.6	8.4	8.2	
Wind speed [m/s]	0-1	6	8	9	4	10	7	2	3	5	10	12	11	7
	1-2	24	22	19	24	22	14	12	7	20	29	40	47	23
	2-3	42	37	19	33	58	33	54	11	23	49	60	69	38
	3-4	91	59	35	39	45	27	53	22	29	41	69	76	47
	4-5	118	77	46	74	58	46	50	31	49	58	60	74	60
	5-6	114	81	59	78	104	91	48	32	52	56	110	74	71
	6-7	101	95	72	74	129	91	65	29	42	62	66	84	70
	7-8	119	127	113	139	164	131	86	24	35	99	56	96	92
	8-9	146	120	152	182	124	165	115	36	59	111	60	80	107
	9-10	100	100	132	113	93	135	110	77	106	106	92	90	104
	10-11	55	68	82	99	51	122	109	87	78	119	103	83	88
	11-12	27	78	64	70	94	59	64	84	69	84	88	56	69
	12-13	27	61	72	46	31	53	42	106	106	71	54	56	65
	13-14	16	30	72	25	13	18	68	89	106	61	43	40	54
	14-15	8	18	39		3	8	53	71	71	22	40	17	33
	15-16	4	18	14				32	73	47	10	24	13	23
	16-17	1	3	1				12	90	34	9	12	12	19
	17-18		1					8	57	29	3	7	13	13
	18-19							12	45	22		3	7	9
	19-20							5	18	13		1	1	4
	20-21								5	5				1
	21-22								2					
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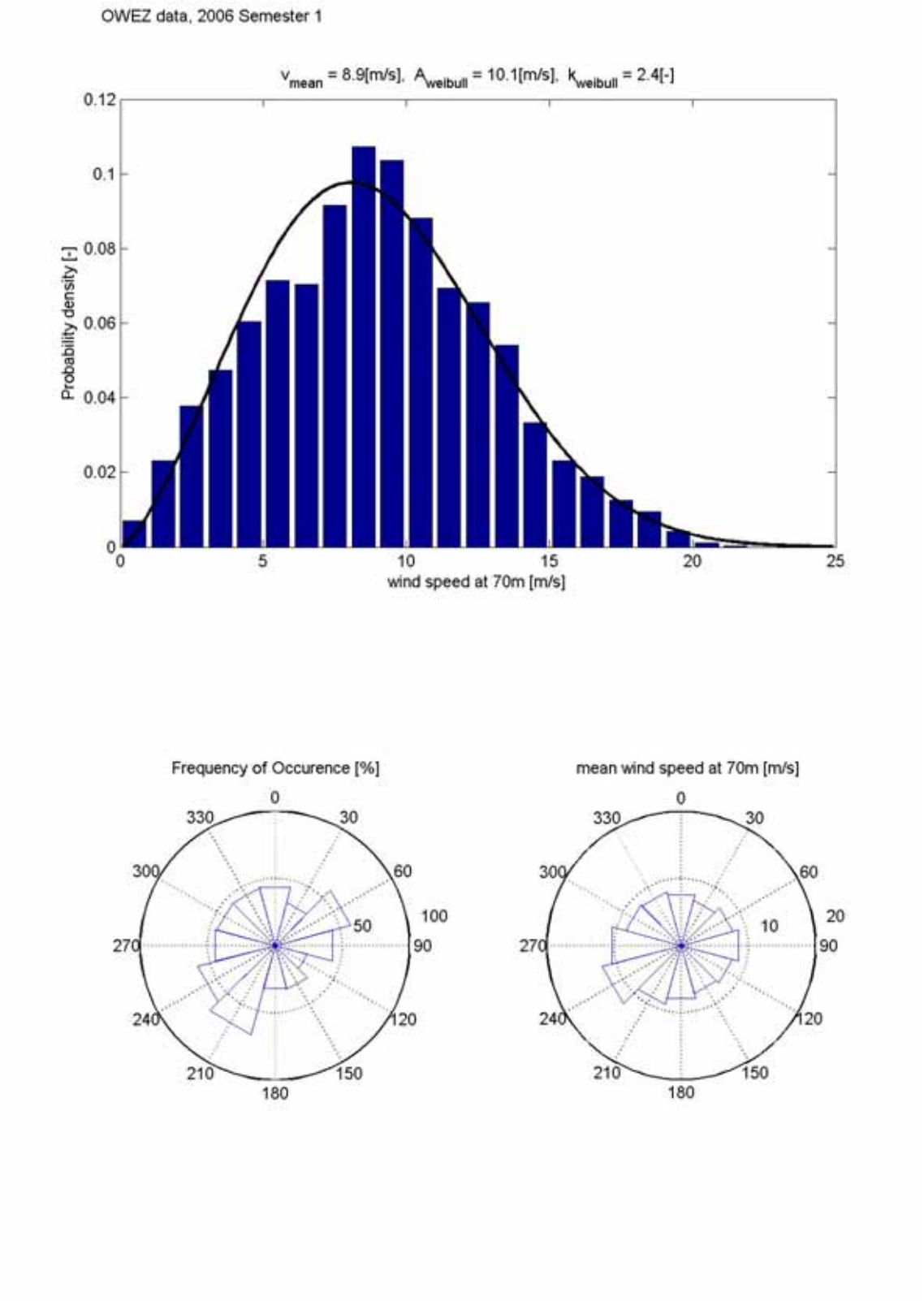


Figure 4.1 *Overall wind speed frequency distribution measured at 70 m above MSL during the reporting period (histogram) and the fitted Weibull distribution. Wind roses for the frequency of wind direction occurrence and the mean wind speed measured at 70 m above MSL during the reporting period. The corresponding 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	7.5	7.6	8.6	8.7	8.8	7.7	7.6	6.7	6.9	6.8	9.6	8.6	8.2
	5	7.3	6.6	7.3	8.4	8.1	6.0	5.7	5.4	5.7	6.8	7.2	7.0	6.9
	6	6.8	6.3	6.2	6.2	7.0	5.1	4.5	5.2	5.5	5.9	6.4	6.2	6.1
	7	6.5	5.0	5.9	5.5	5.9	5.9	5.4	4.9	5.4	5.2	6.0	6.0	5.7
	8	5.9	4.8	5.7	5.3	5.4	5.2	5.8	5.3	5.1	5.3	6.0	6.0	5.5
	9	5.9	4.9	6.0	4.9	5.4	5.0	5.3	5.0	5.2	5.6	6.3	6.1	5.5
	10	6.0	5.6	6.2	5.5	3.9	4.6	5.3	5.0	5.1	5.6	6.2	6.3	5.5
	11	6.2	5.8	6.2	6.1	4.0	4.1	4.8	4.8	5.5	5.9	6.2	6.9	5.6
	12	6.9	6.1	6.4	3.9	3.5	4.1	4.7	4.8	5.3	6.1	6.8	6.9	5.5
	13	6.9	6.4	6.8	3.7	5.2	3.6	5.2	5.0	5.1	5.3	6.7	6.9	5.6
	14	7.8	7.1	6.7	4.7	6.8	4.2	5.5	5.2	5.2	5.7	6.6	7.3	5.9
	15	6.5	7.2	6.4		7.5	4.7	5.2	5.4	5.5	6.5	6.8	7.6	5.9
	16	6.8	7.0	4.9				5.0	5.5	5.7	7.1	7.6	7.9	5.9
	17		6.4					5.6	5.8	5.5	6.8	8.3	7.3	6.0
	18		6.1					5.2	5.9	5.6	6.3	8.2	7.9	6.0
	19							5.9	5.7	6.5		6.6	7.6	6.1
	20							7.4	5.9	6.7			8.0	6.3
	21								6.8	6.1				6.6
	22													
	23													
	24													
	25													
	26													
	27													
	28													
	29													
	30													
	TI IEC I_{ref}	7.2	6.7	6.3	6.0	5.7	5.0	6.3	6.3	6.3	6.6	7.9	8.1	6.8

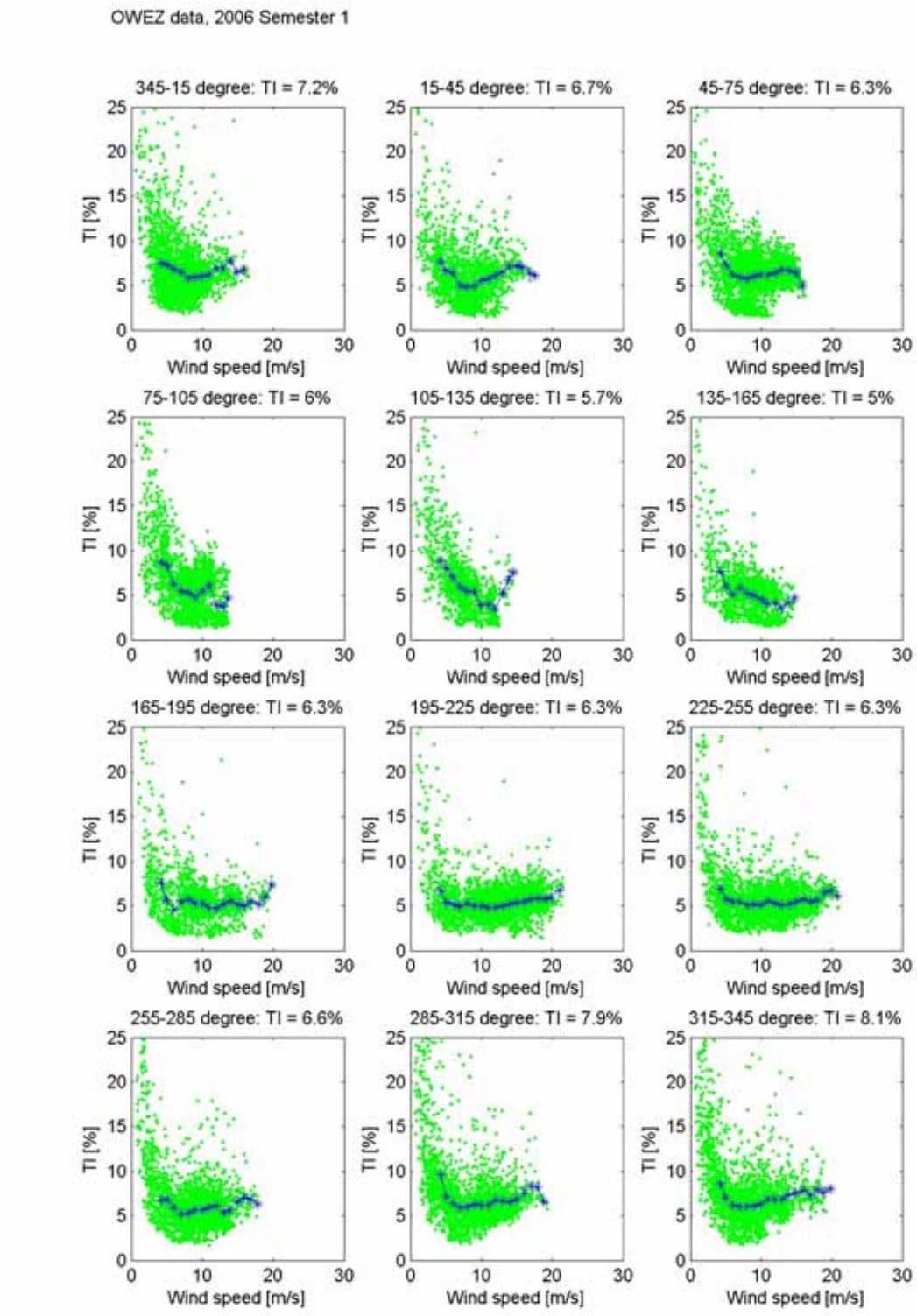


Figure 4.2 *Turbulence intensities per wind direction sector, measured at 70m above MSL during the reporting period. The blue stars indicate the average turbulence intensities in the wind speed bins. For each wind direction sector the turbulence intensity determined according IEC 61400-1 Ed. 3 [5] is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

4.2.2 Turbulence intensity

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.

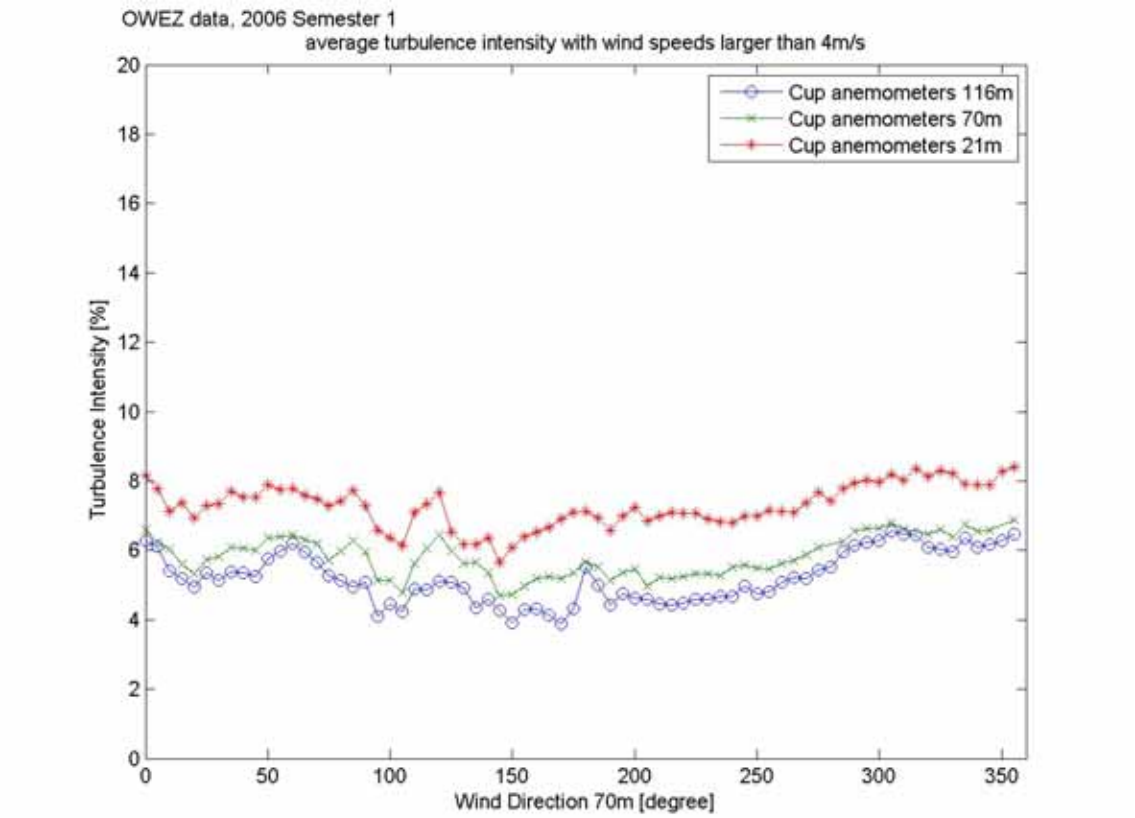


Figure 4.3 *Average turbulence intensities at measuring heights 21, 70 and 116m depending on wind direction (bin width 5º) measured during the reporting period. Only data are included with wind speeds above 4m/s.*

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:

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

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	0.06	0.07	0.07	0.14	0.14	0.15	0.16	0.17	0.15	0.12	0.08	0.07	0.12
standard deviation	0.09	0.08	0.06	0.13	0.16	0.13	0.09	0.10	0.09	0.09	0.07	0.08	0.10

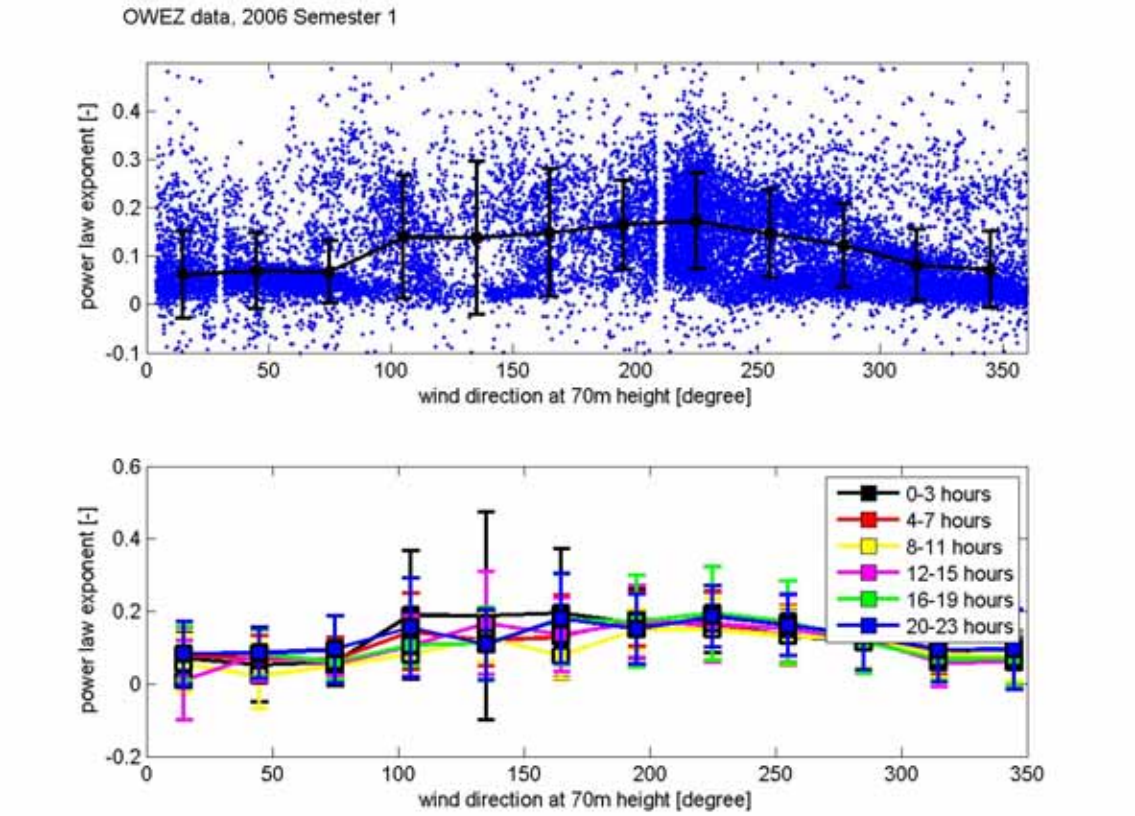


Figure 4.4 *Upper plot: Exponents for each 10-minute average together with the average exponent for the vertical wind speed and standard deviation depending on wind direction (bin width 2º) as measured during the reporting period Only data are included that meet the requirement V_{70} > 4 m/s. Lower 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 June 2006.

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

Measured parameter and unit	Instrument code	reporting period July 2005 - June 2006	
		number of valid 10-minute averages	availability [%]
wind direction [°]	3D WM4/NW/116	42681	81.2
horizontal wind speed [m/s]	3D WM4/NW/116	42681	81.2
vertical wind speed [m/s]	3D WM4/NW/116	42674	81.2
wind speed [m/s]	WS 018/NW/116	48120	91.6
wind speed [m/s]	WS 018/NE/116	48120	91.6
wind speed [m/s]	WS 018/S/116	50818	96.7
wind speed [m/s]	WS 018/NW/70	50820	96.7
wind speed [m/s]	WS 018/NE/70	50814	96.7
ambient temp. [°C]	RHTT 261/S/116	50818	96.7
ambient temp. [°C]	RHTT 261/S/70	44352	84.4
relative humidity [%]	RHTT 261/S/116	50813	96.7
ambient air pressure [mbar]	DP910	50820	96.7
precipitation [yes/no]	PD 205/NW/70	50820	96.7
sea water temperature [°C]	ST 808/NW/-3.8	47963	91.3
X (north – south) acceleration [m/s^2]	AC SB2i/T/116	51376	97.7
Y (west – east) acceleration [m/s^2]	AC SB2i/T/116	51373	97.7
wind direction [°]	WD 524/NW/116	44907	85.4
wind direction [°]	WD 524/NE/116	40155	76.4
wind direction [°]	WD 524/S/116	45400	86.4
wind direction [°]	WD 524/NW/70	51341	97.7
wind direction [°]	WD 524/NE/70	51375	97.7
wind direction [°]	3D WM4/NW/21	32593	62.0
horizontal wind speed [m/s]	3D WM4/NW/21	46148	87.8
vertical wind speed [m/s]	3D WM4/NW/21	46148	87.8
wind direction [°]	3D WM4/NW/70	49258	93.7
horizontal wind speed [m/s]	3D WM4/NW/70	49258	93.7
vertical wind speed [m/s]	3D WM4/NW/70	49258	93.7
wind speed [m/s]	WS 018/S/70	49920	95.0
wind speed [m/s]	WS 018/NW/21	50009	95.1
wind speed [m/s]	WS 018/NE/21	50009	95.1
wind speed [m/s]	WS 018/S/21	50009	95.1
ambient temp. [°C]	RHTT 261/S/21	50005	95.1
relative humidity [%]	RHTT 261/S/70	44912	85.5
relative humidity [%]	RHTT 261/S/21	50005	95.1
precipitation [yes/no]	PD 205/NE/70	50010	95.2
wind direction [°]	WD 524/S/70	48565	92.4
wind direction [°]	WD 524/NW/21	45207	86.0
wind direction [°]	WD 524/NE/21	50003	95.1
wind direction [°]	WD 524/S/21	50004	95.1
derived wind direction	21m	50007	95.1
derived wind direction	70m	51384	97.8
derived wind direction	116m	45402	86.4
derived wind speed	21m	50005	95.1
derived wind speed	70m	50149	95.4
derived wind speed	116m	44396	84.5

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]	7.5	7.6	8.2	7.6	7.4	8.5	9.1	11.3	9.7	8.2	8.5	8.0	8.7
Weibull	A [m/s]	8.4	8.5	9.2	8.5	8.3	9.5	10.2	12.7	10.9	9.3	9.6	9.0	9.8
	k [-]	2.4	2.5	2.7	2.9	2.4	2.7	2.2	2.7	2.5	2.4	2.2	2.0	2.3
	[%]	8.2	5.4	8.3	6.8	4.4	6.7	6.5	12.0	12.1	9.6	10.0	8.7	
Wind speed [m/s]	0-1	6	10	8	5	13	7	5	4	5	10	7	10	7
	1-2	21	21	19	28	28	20	28	15	19	34	32	43	25
	2-3	52	46	32	39	64	55	68	24	34	49	54	71	47
	3-4	81	73	47	52	62	50	63	34	52	57	64	86	59
	4-5	101	87	75	78	79	43	58	34	58	71	56	79	66
	5-6	93	93	85	96	106	64	47	43	59	68	76	65	71
	6-7	89	98	89	98	117	68	64	42	63	70	71	80	75
	7-8	117	121	114	139	121	97	78	51	51	93	78	84	90
	8-9	138	125	142	156	99	121	80	58	70	104	110	82	103
	9-10	108	112	113	92	76	115	85	80	95	110	108	89	99
	10-11	67	67	69	81	54	128	84	89	101	104	89	87	87
	11-12	44	52	58	68	95	86	66	64	88	72	69	63	68
	12-13	29	40	56	43	53	69	69	79	85	66	53	46	60
	13-14	18	22	54	22	27	46	61	74	74	46	53	33	48
	14-15	15	18	27	3	5	16	55	63	48	21	37	20	31
	15-16	15	12	11			4	30	61	30	11	15	12	20
	16-17	6	3				2	21	67	20	5	7	12	15
	17-18	1	1				2	22	52	18	2	5	16	12
	18-19	1					4	10	39	17	1	3	11	9
	19-20	1					2	4	16	10	2	2	6	5
	20-21								5	3	2	2	3	2
	21-22								3			2	1	1
	22-23								1			1	1	
	23-24											1		
	24-25											2		1
	25-26											2		
	26-27											1		
	27-28													
	28-29													

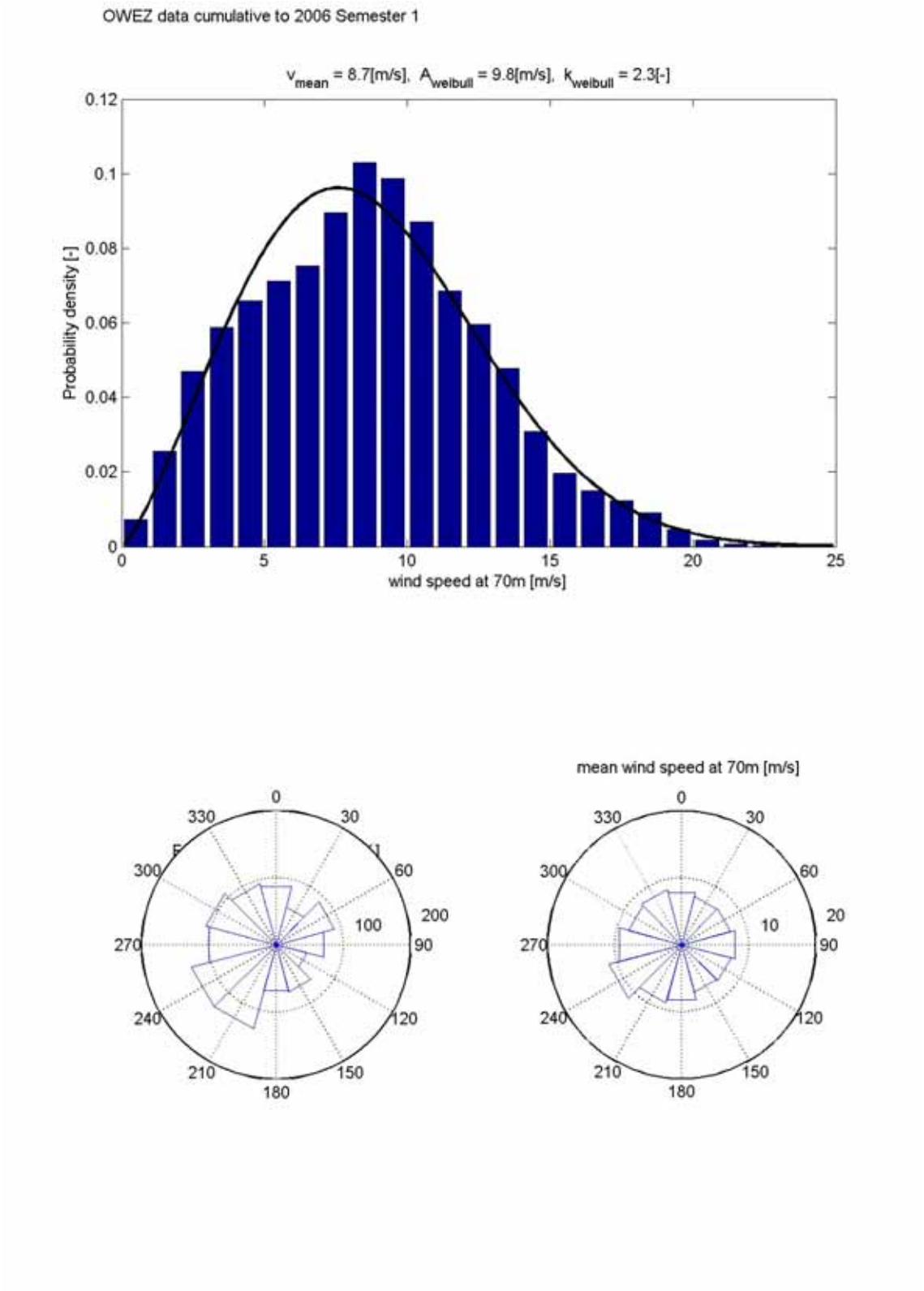


Figure 5.1 *Overall wind speed frequency distribution measured at 70 m above MSL during the period from July 2005 to June 2006 (histogram) and the fitted Weibull distribution. Wind roses for the frequency of wind direction occurrence and the mean wind speed measured at 70 m above MSL during the reporting period. The corresponding numerical values are given in Table 5.2.*

6. Time histories January-February 2006

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

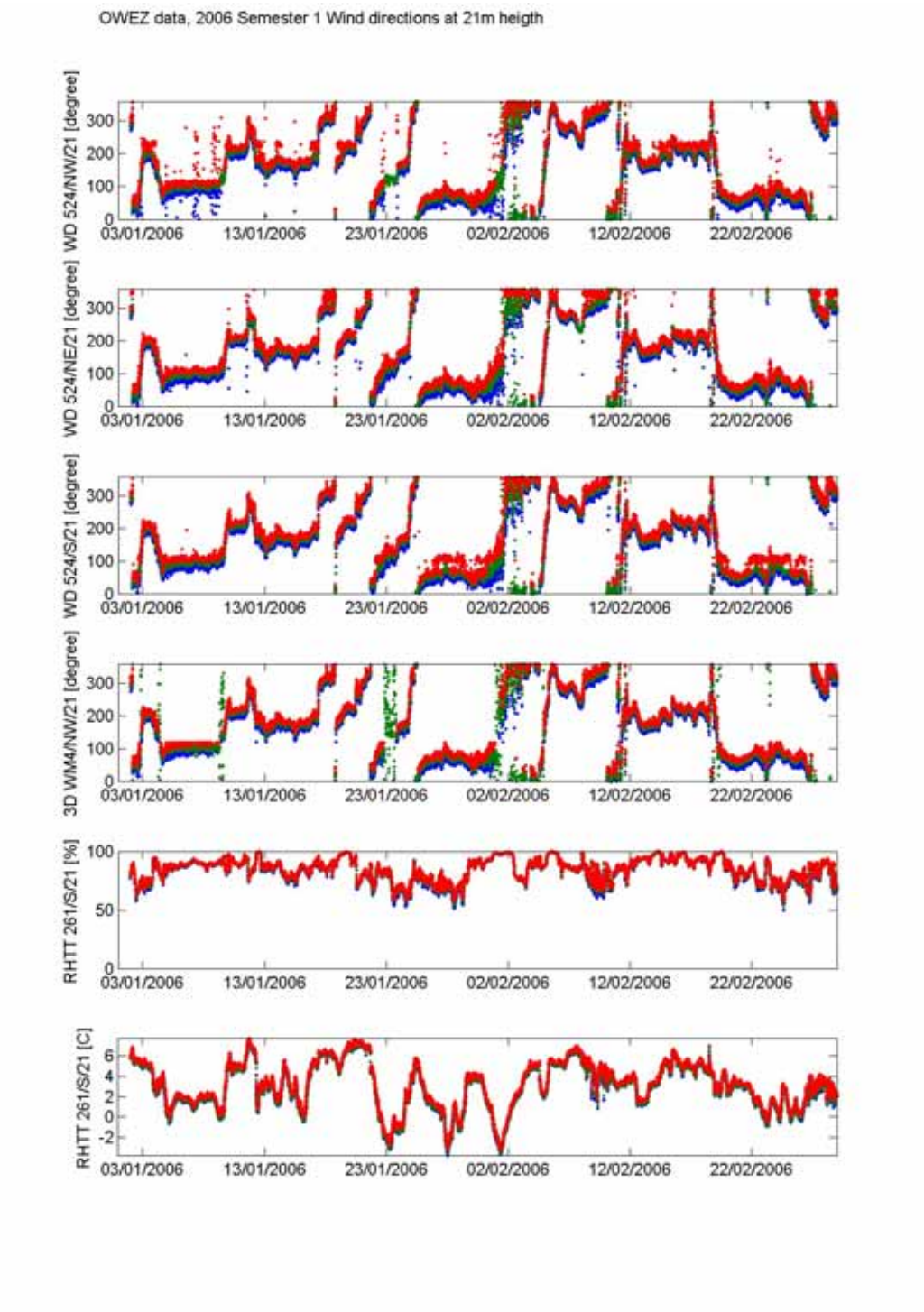


Figure 6.1 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 21 m height are shown for January and February 2006.*

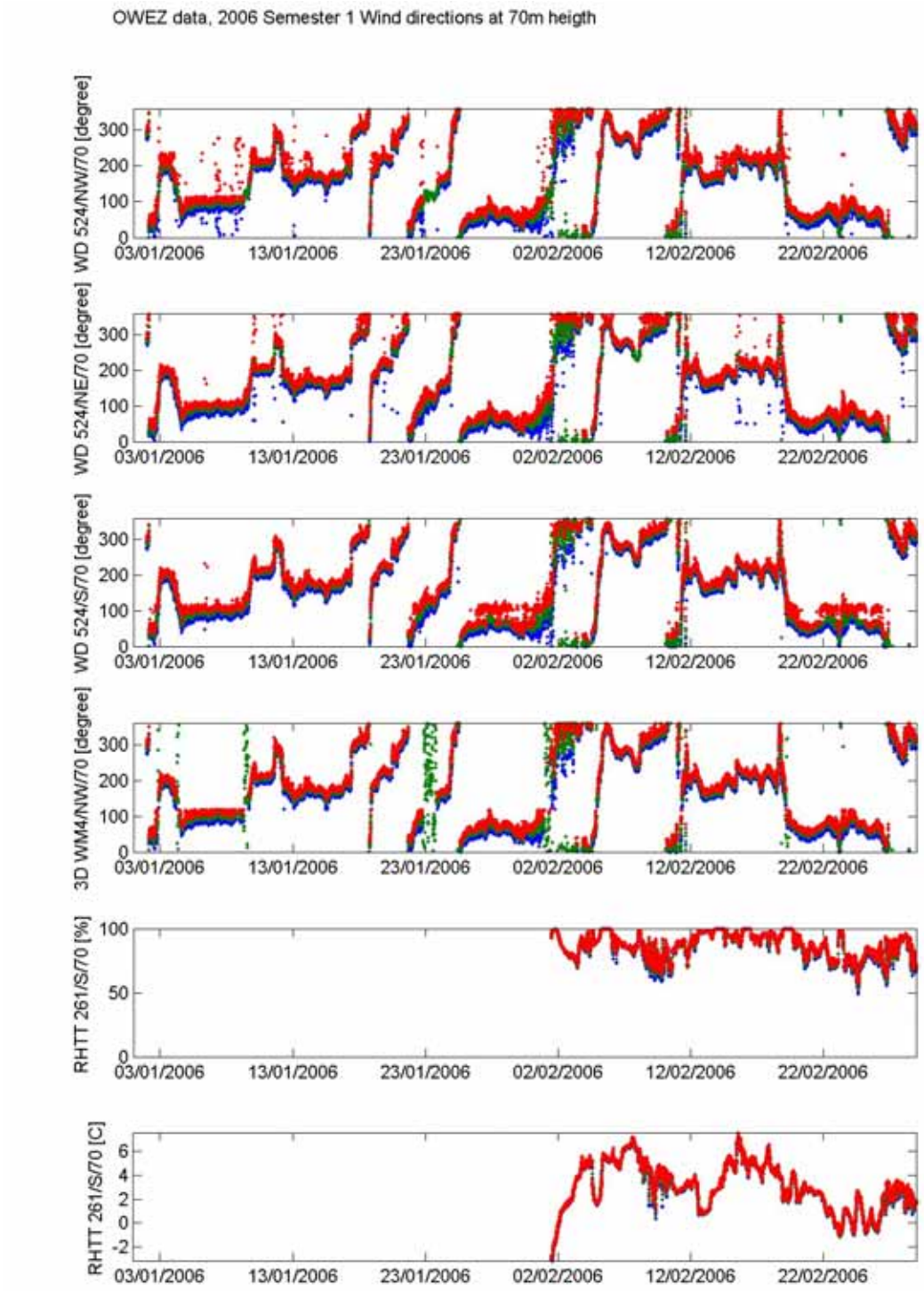


Figure 6.2 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 70 m height are shown for January and February 2006.*

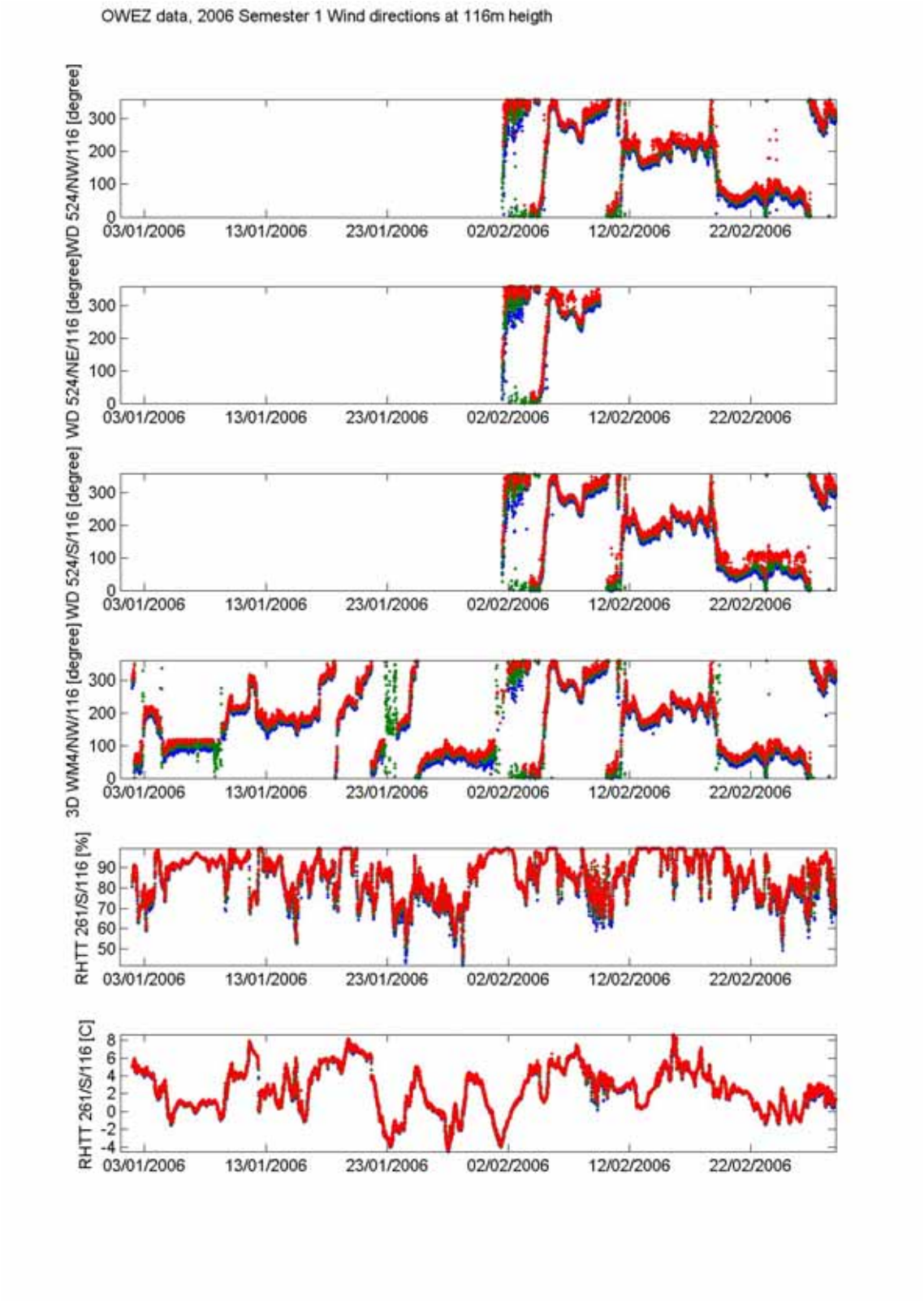


Figure 6.3 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 116 m height are shown for January and February 2006.*

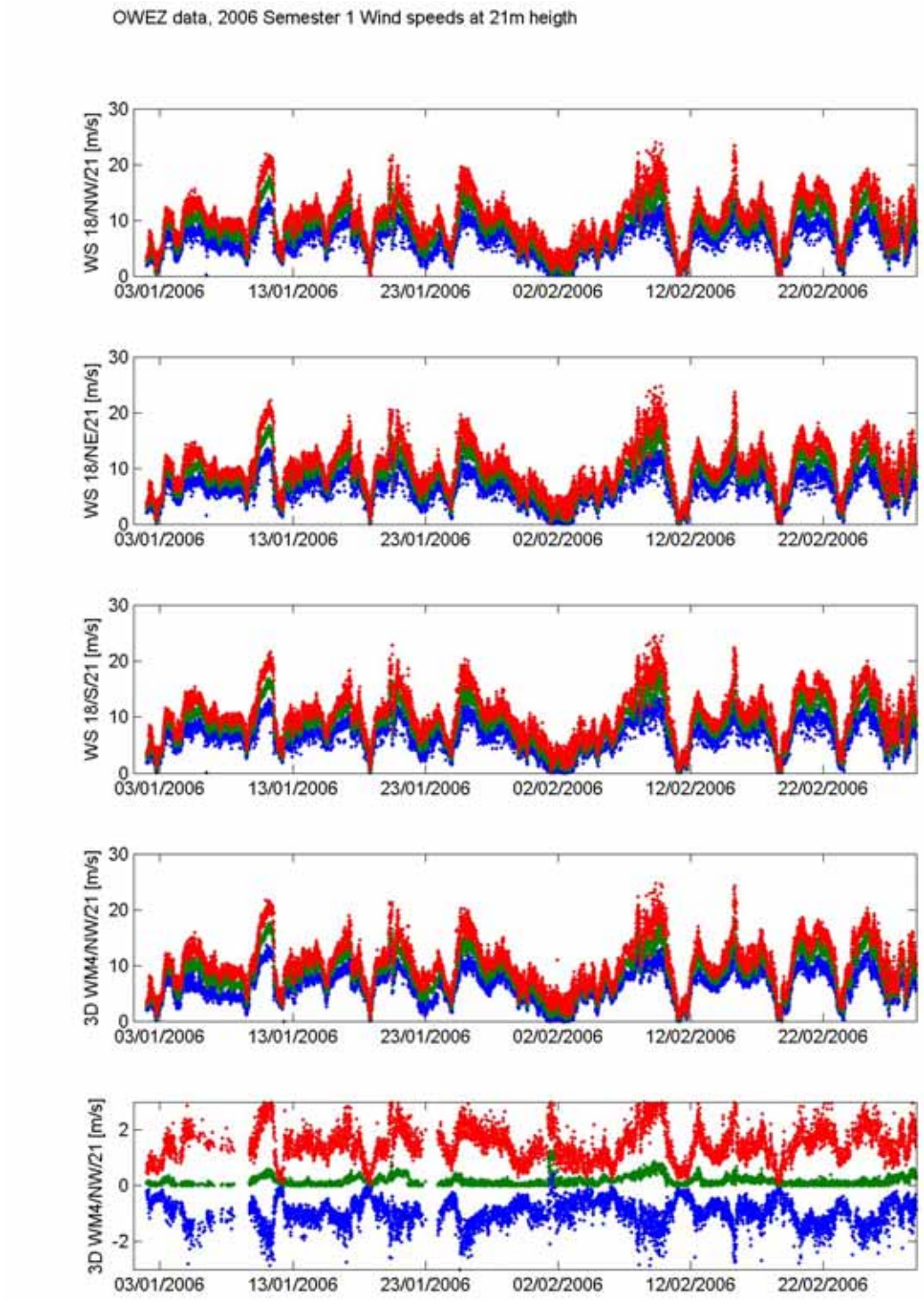


Figure 6.4 *Time histories of stored data in ten-minute averaged values. Wind speed measurements with cup anemometers and sonic anemometer are shown together with the vertical wind speed measured with the sonic anemometer at 21m height are shown for January and February 2006.*

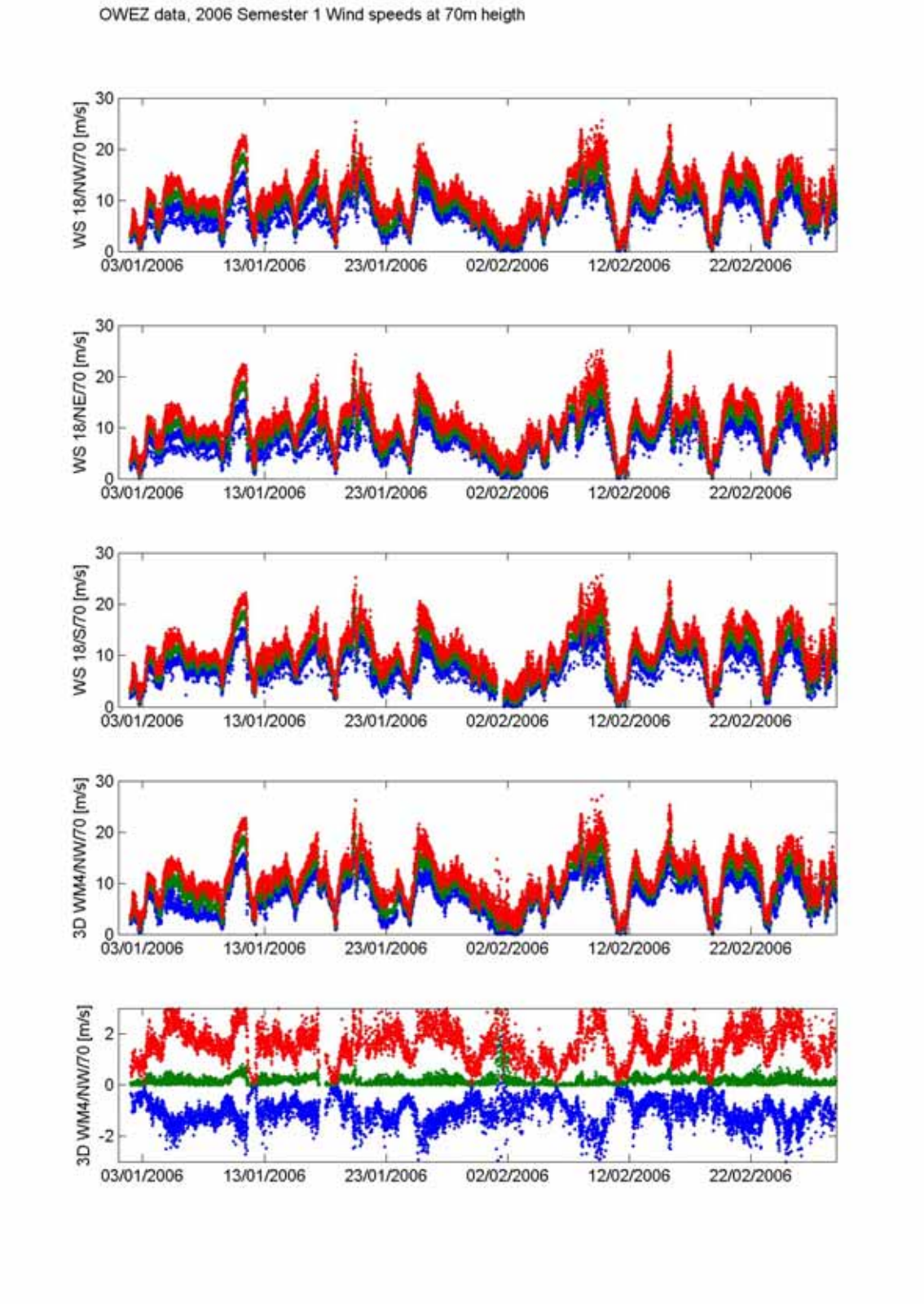


Figure 6.5 *Time histories of stored data in ten-minute averaged values. Wind speed measurements with cup anemometers and sonic anemometer are shown together with the vertical wind speed measured with the sonic anemometer at 70m height are shown for January and February 2006.*

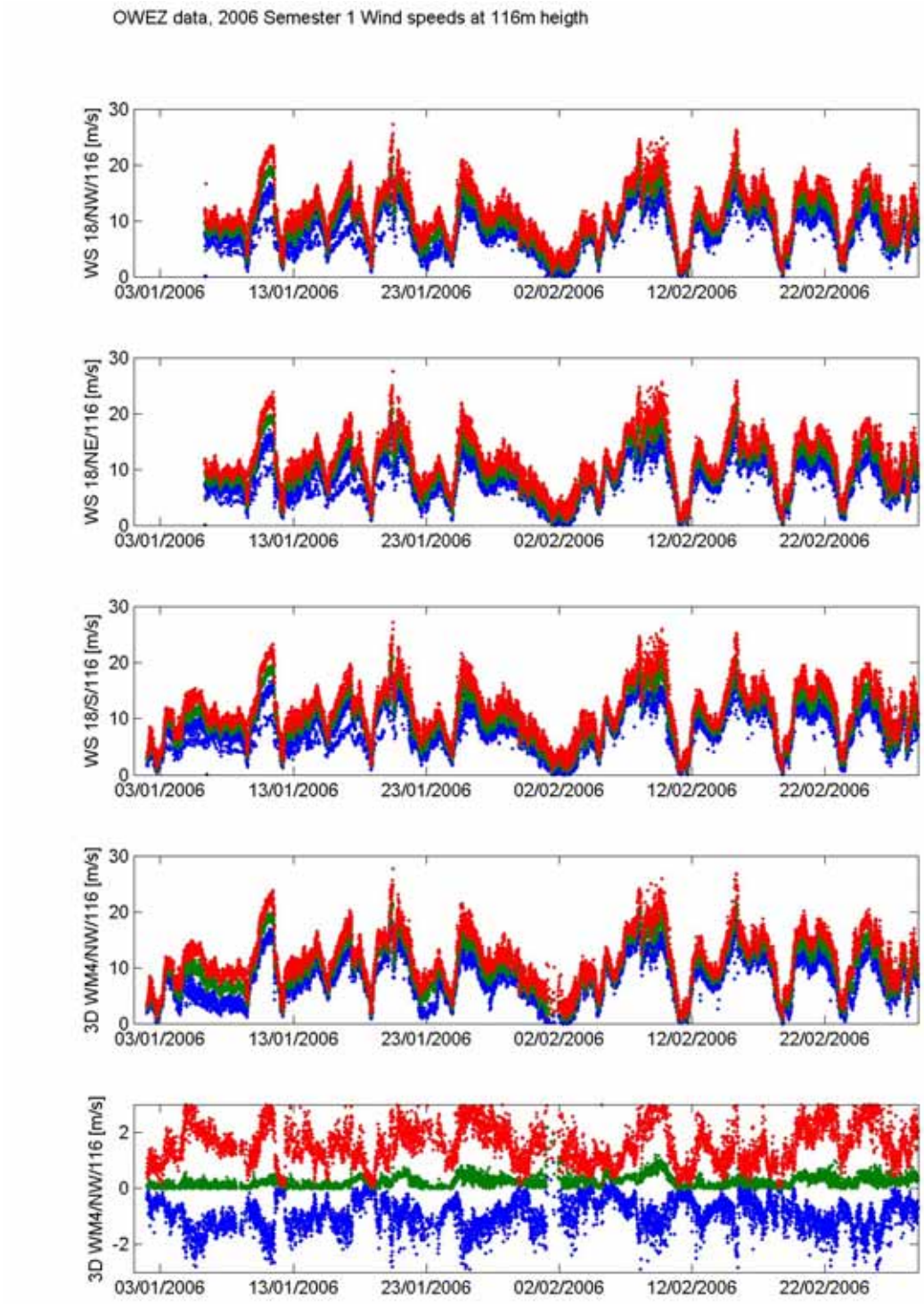


Figure 6.6 *Time histories of stored data in ten-minute averaged values. Wind speed measurements with cup anemometers and sonic anemometer are shown together with the vertical wind speed measured with the sonic anemometer at 116m height are shown for January and February 2006.*

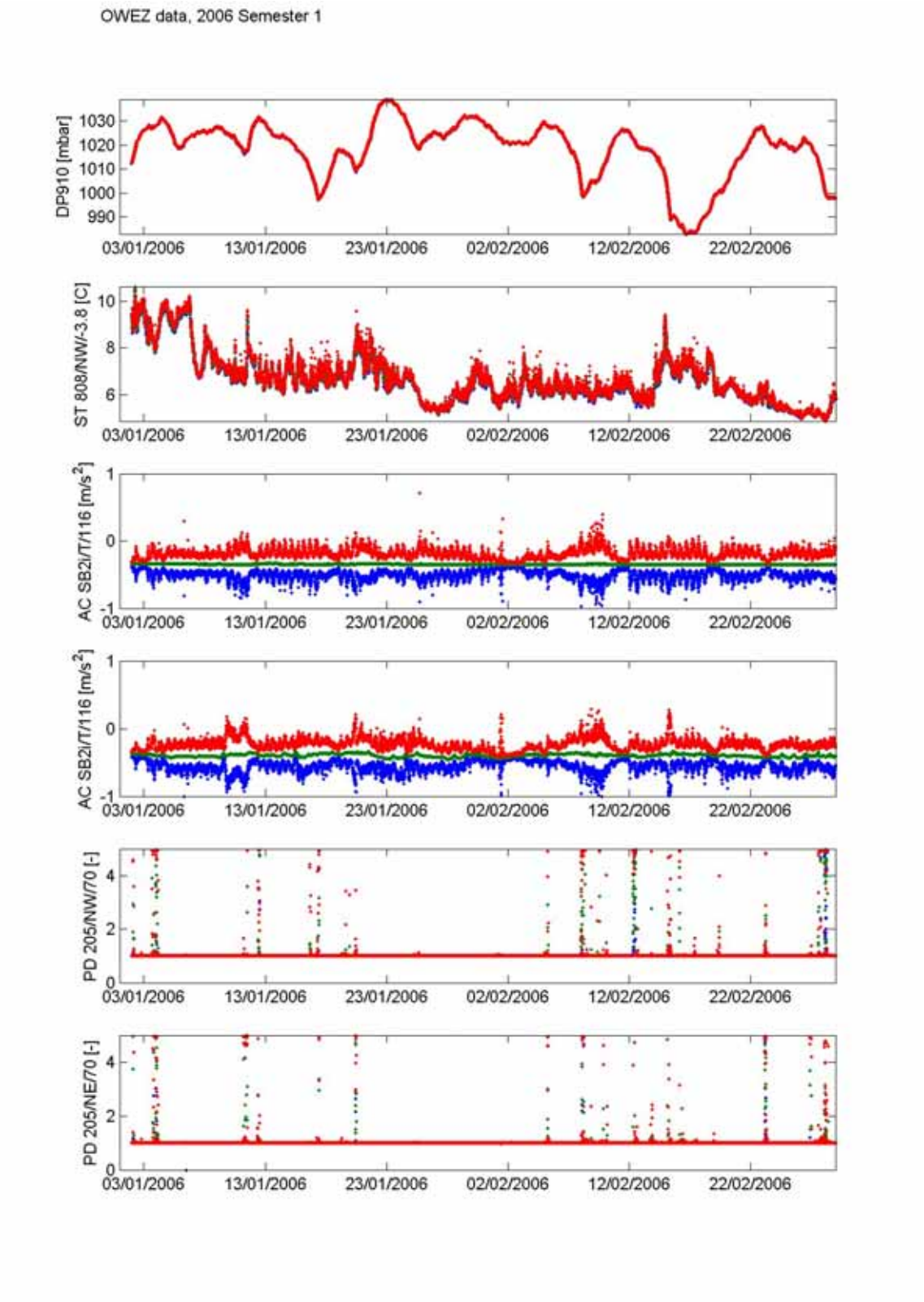


Figure 6.7 *Time histories of stored data in ten-minute averaged values. Air pressure at 21m above MSL, seawater temperature, mast top accelerations in N-S and W-E directions at 116.6 m above MSL and precipitation (70 m) are shown for January and February 2006. The precipitation is measured with sensors in the NE and NW boom.*

7. Time histories March-April 2006

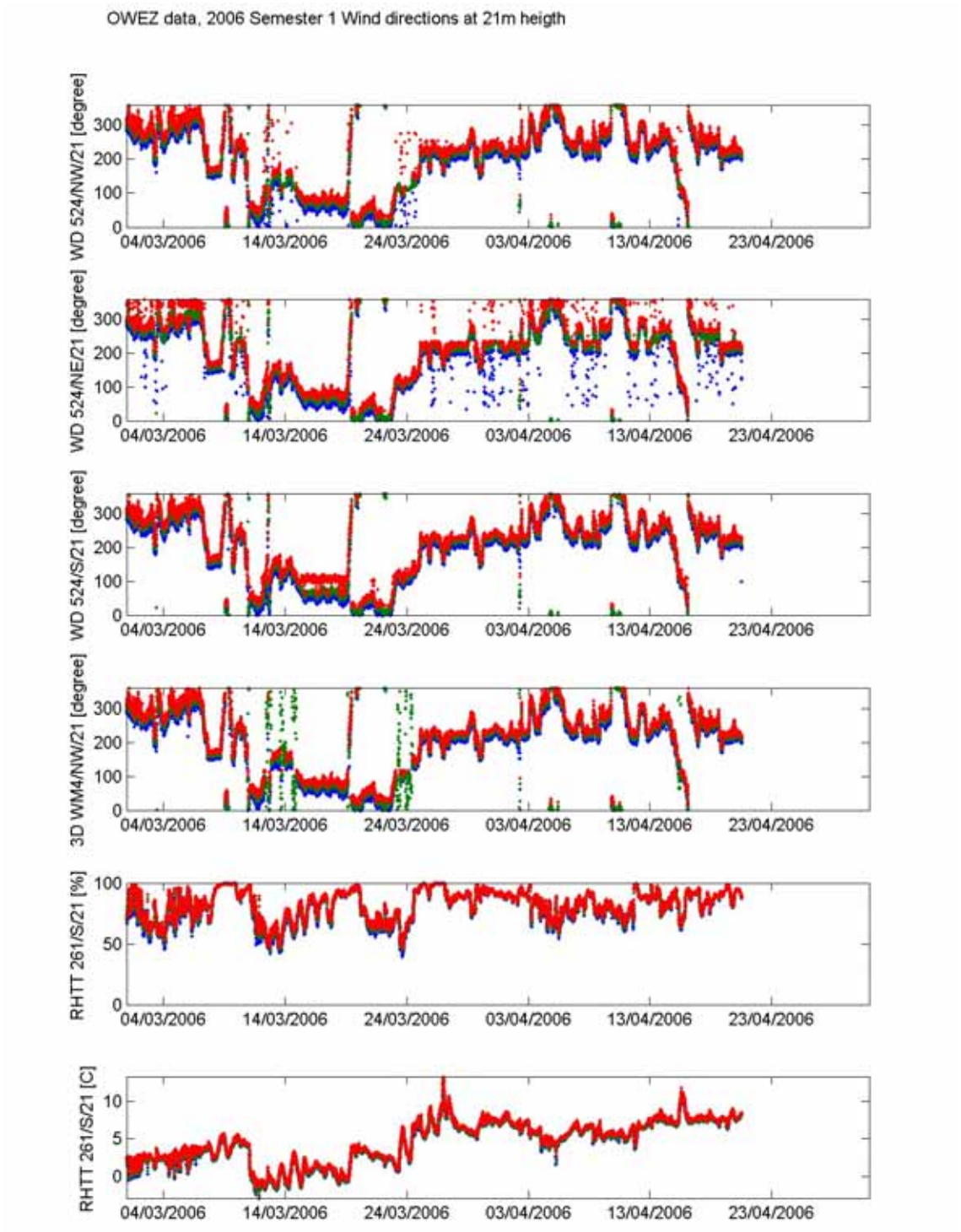


Figure 7.1 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 21 m height are shown for March and April 2006.*

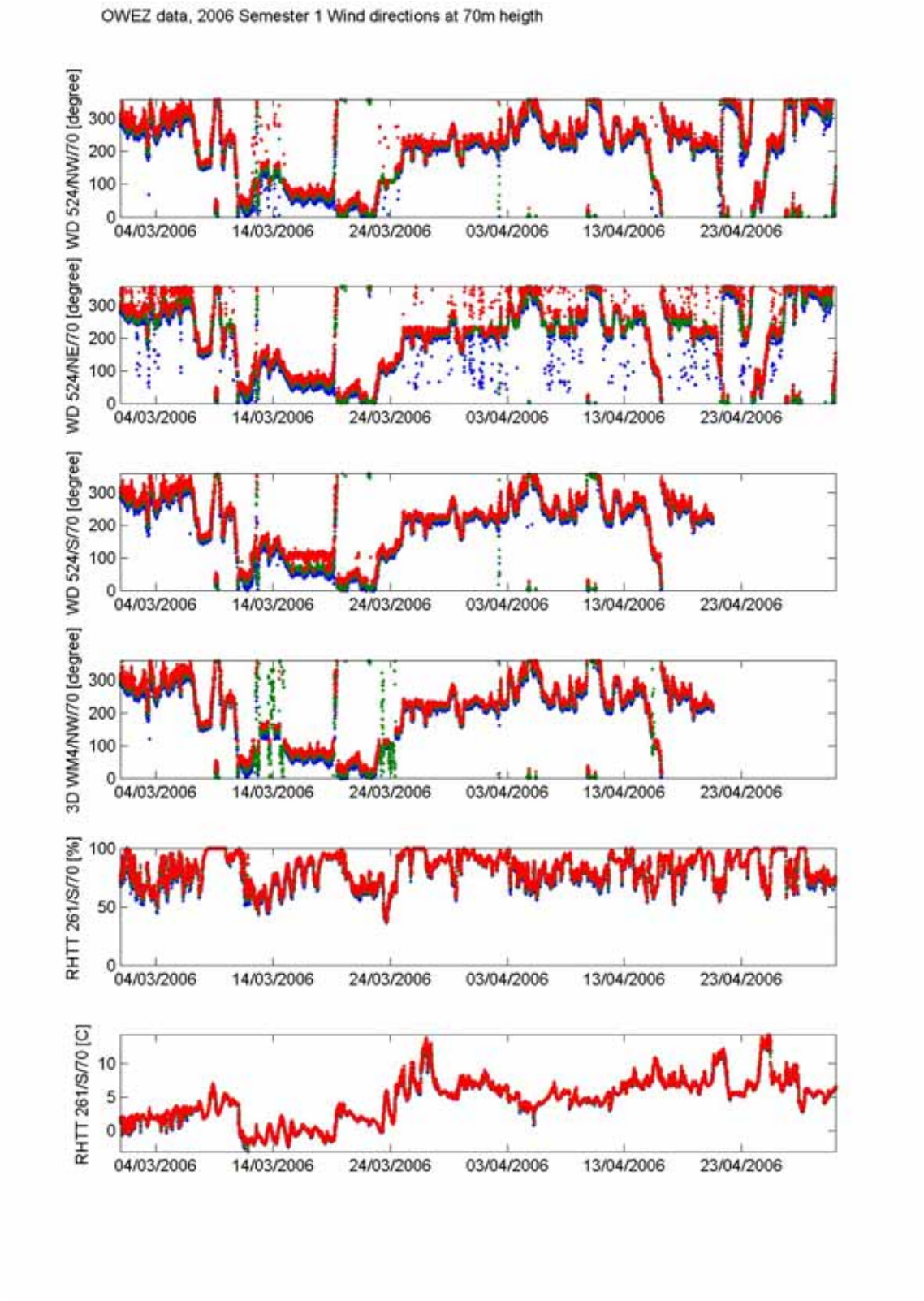


Figure 7.2 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 70 m height are shown for March and April 2006.*

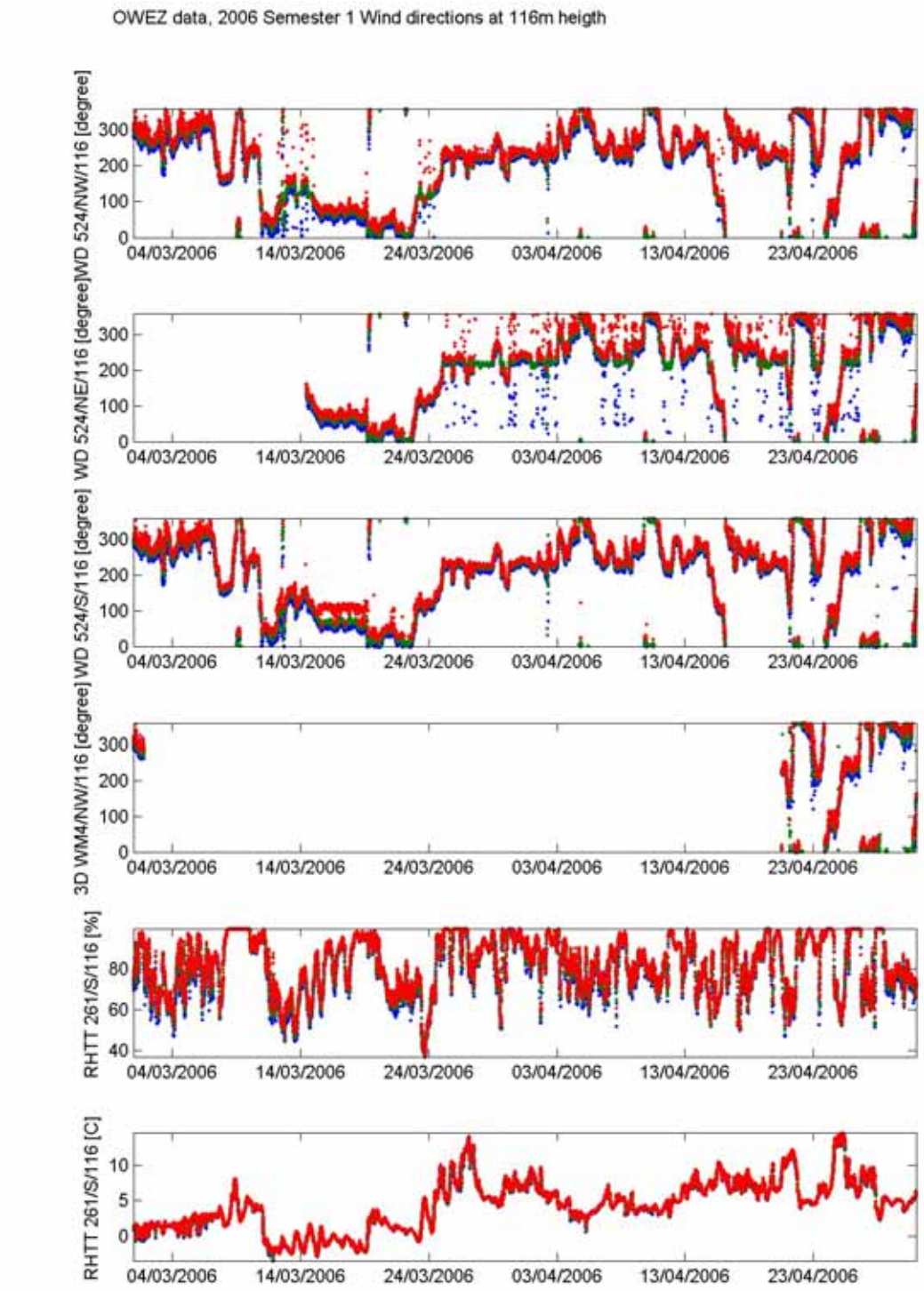


Figure 7.3 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 116 m height are shown for March and April 2006.*

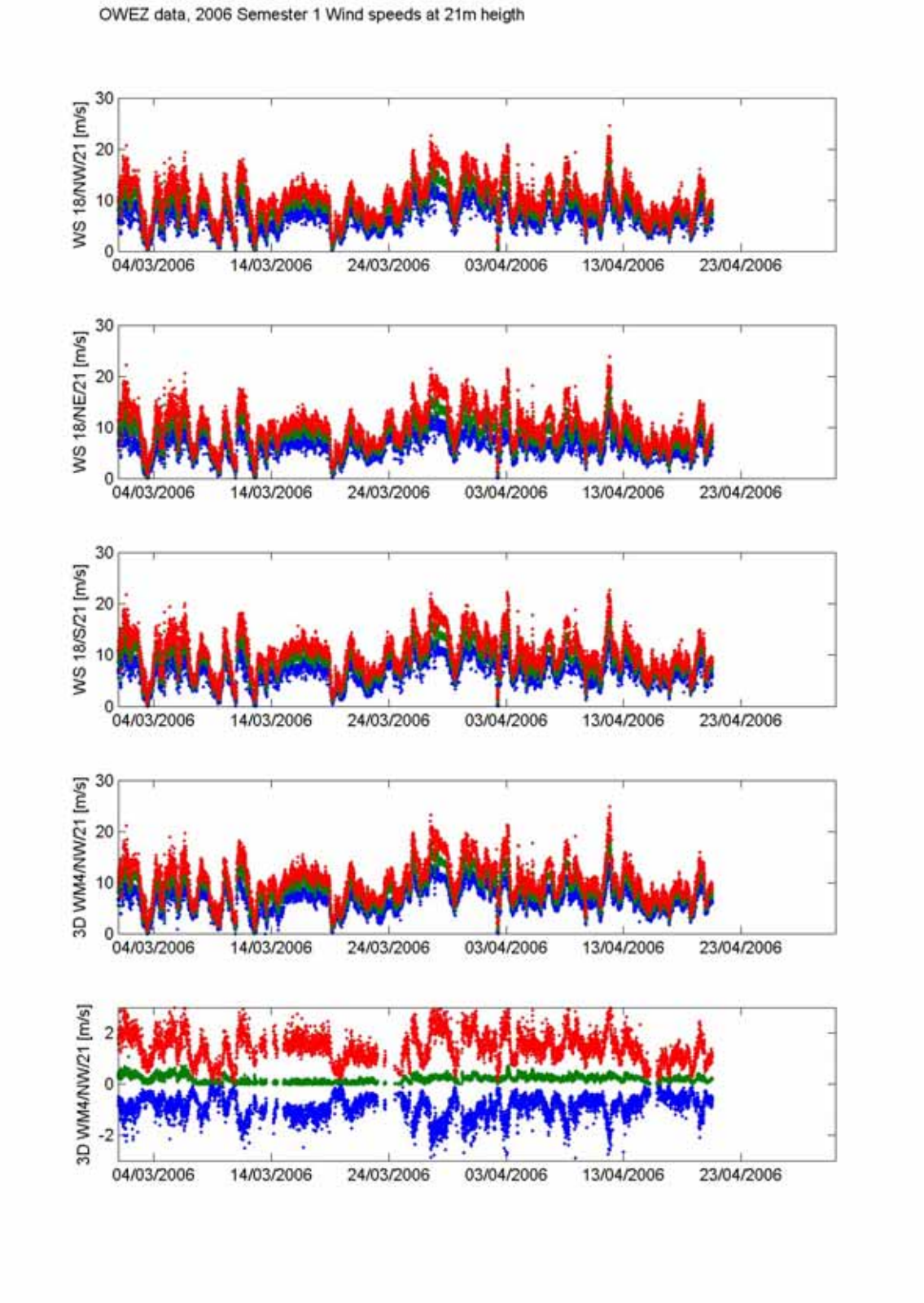


Figure 7.4 *Time histories of stored data in ten-minute averaged values. Wind speed measurements with cup anemometers and sonic anemometer are shown together with the vertical wind speed measured with the sonic anemometer at 21m height are shown for March and April 2006.*

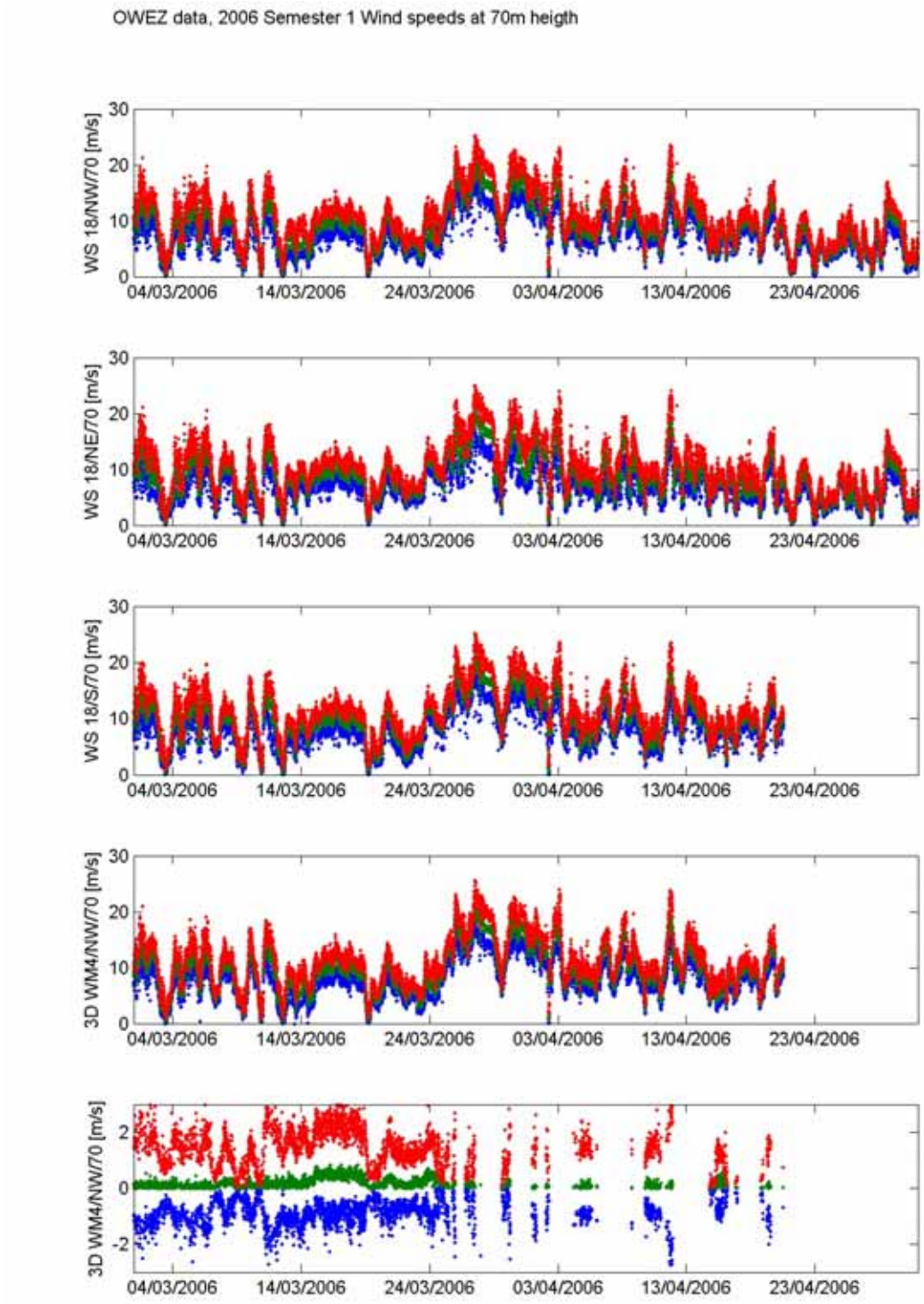


Figure 7.5 *Time histories of stored data in ten-minute averaged values. Wind speed measurements with cup anemometers and sonic anemometer are shown together with the vertical wind speed measured with the sonic anemometer at 70m height are shown for March and April 2006.*

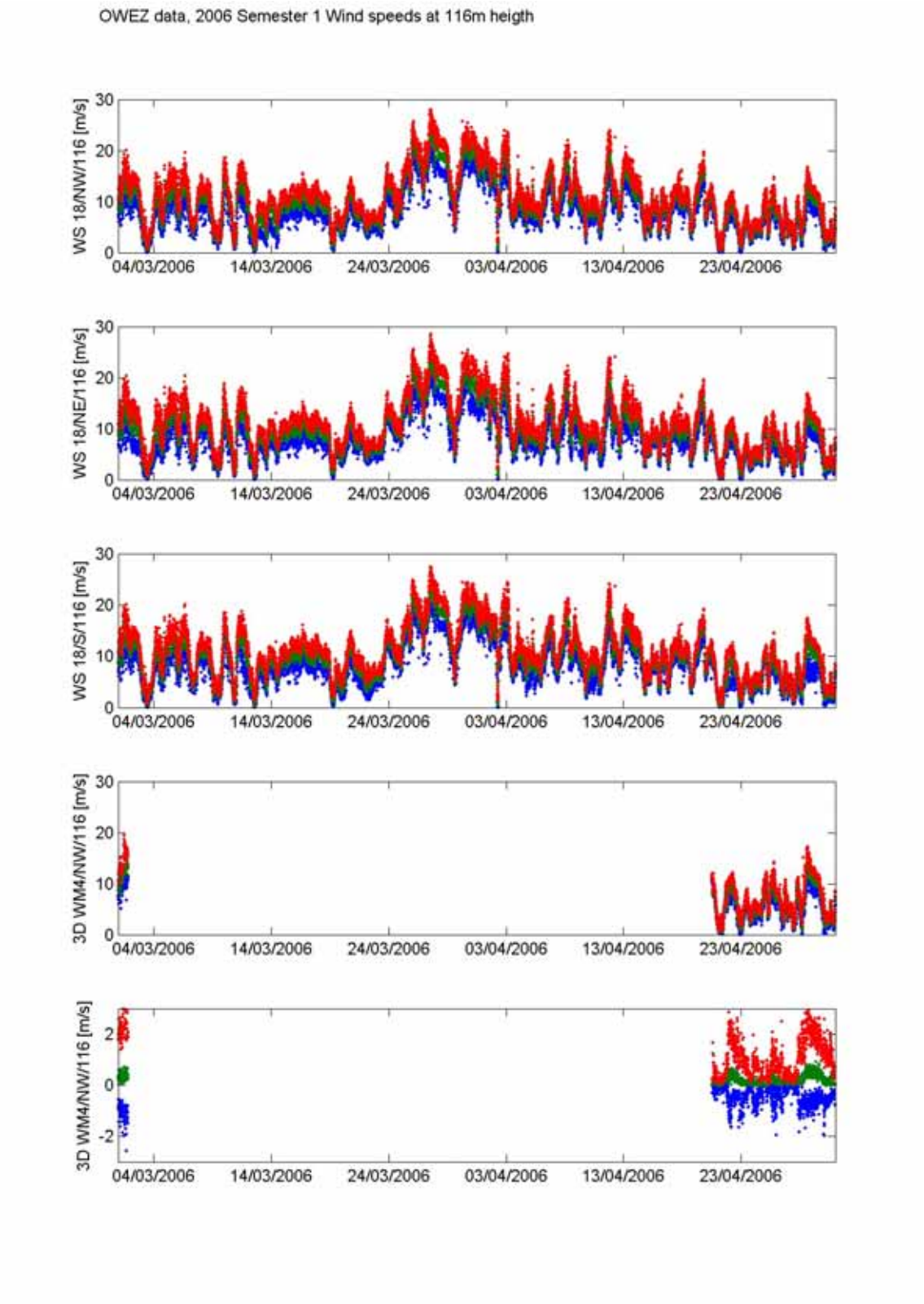


Figure 7.6 *Time histories of stored data in ten-minute averaged values. Wind speed measurements with cup anemometers and sonic anemometer are shown together with the vertical wind speed measured with the sonic anemometer at 116m height are shown for March and April 2006.*

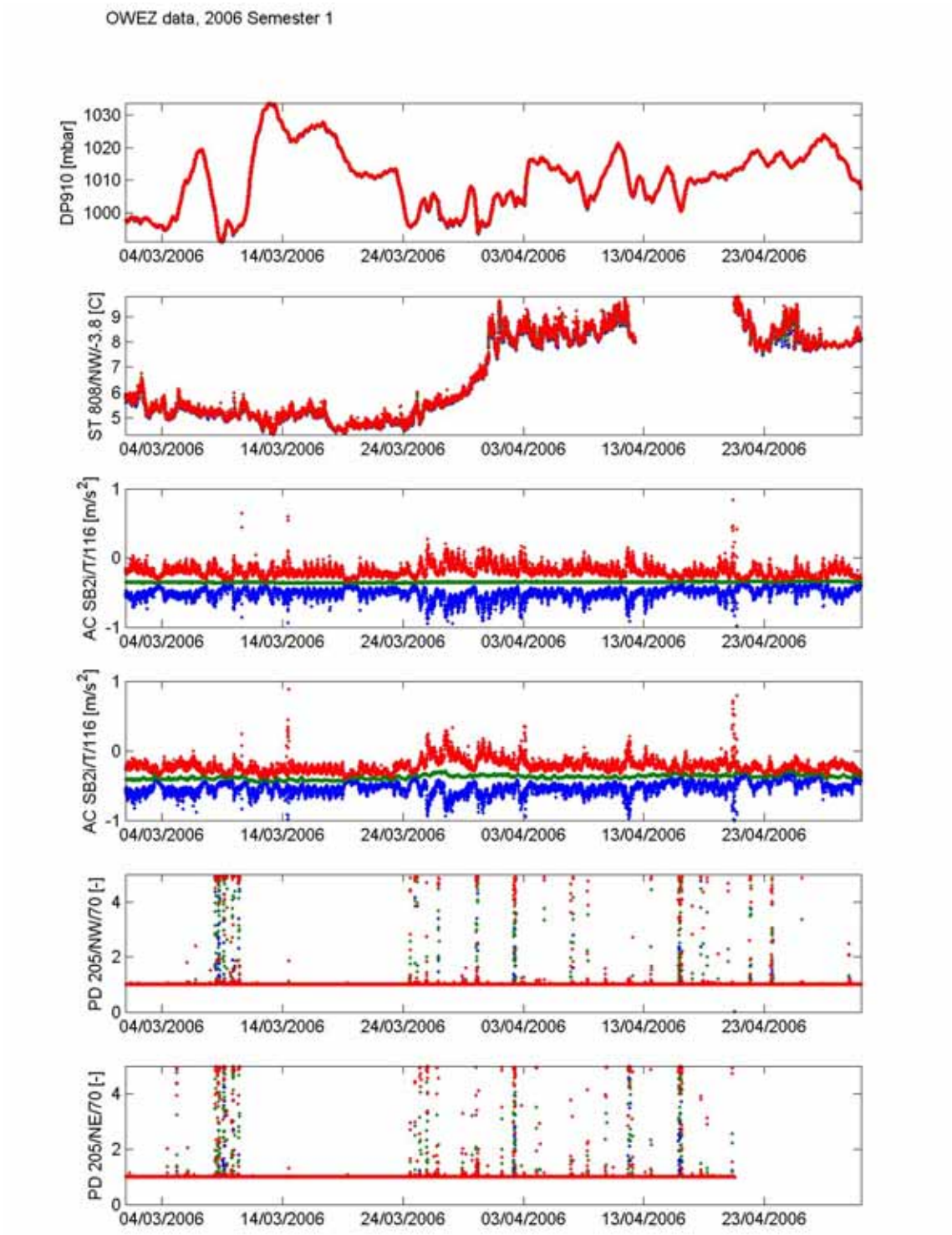


Figure 7.7 *Time histories of stored data in ten-minute averaged values. Air pressure at 21m above MSL, seawater temperature, mast top accelerations in N-S and W-E directions at 116.6 m above MSL and precipitation (70 m) are shown for March and April 2006. The precipitation is measured with sensors in the NE and NW boom.*

8. Time histories May-June 2006

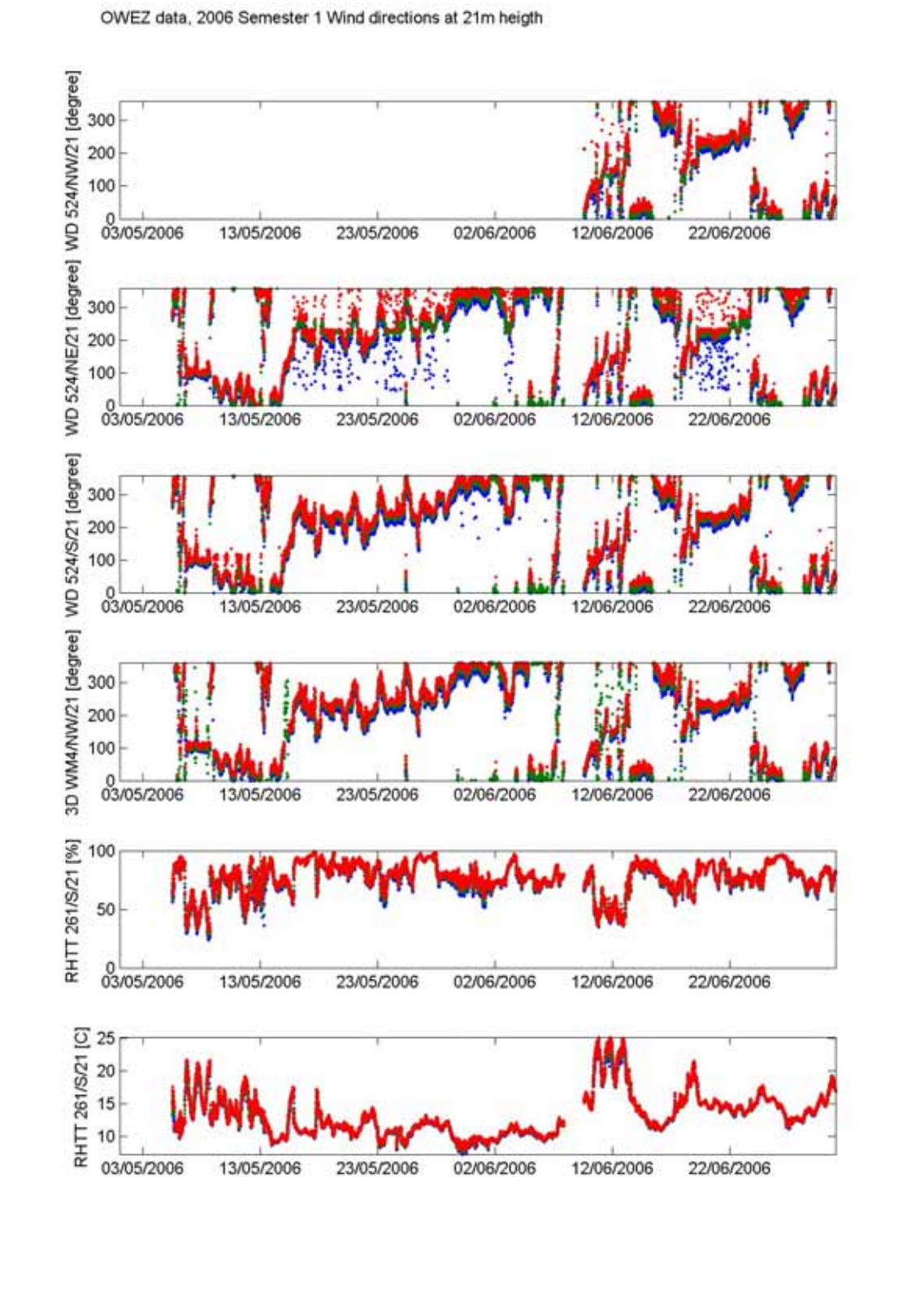


Figure 8.1 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 21 m height are shown for May and June 2006.*

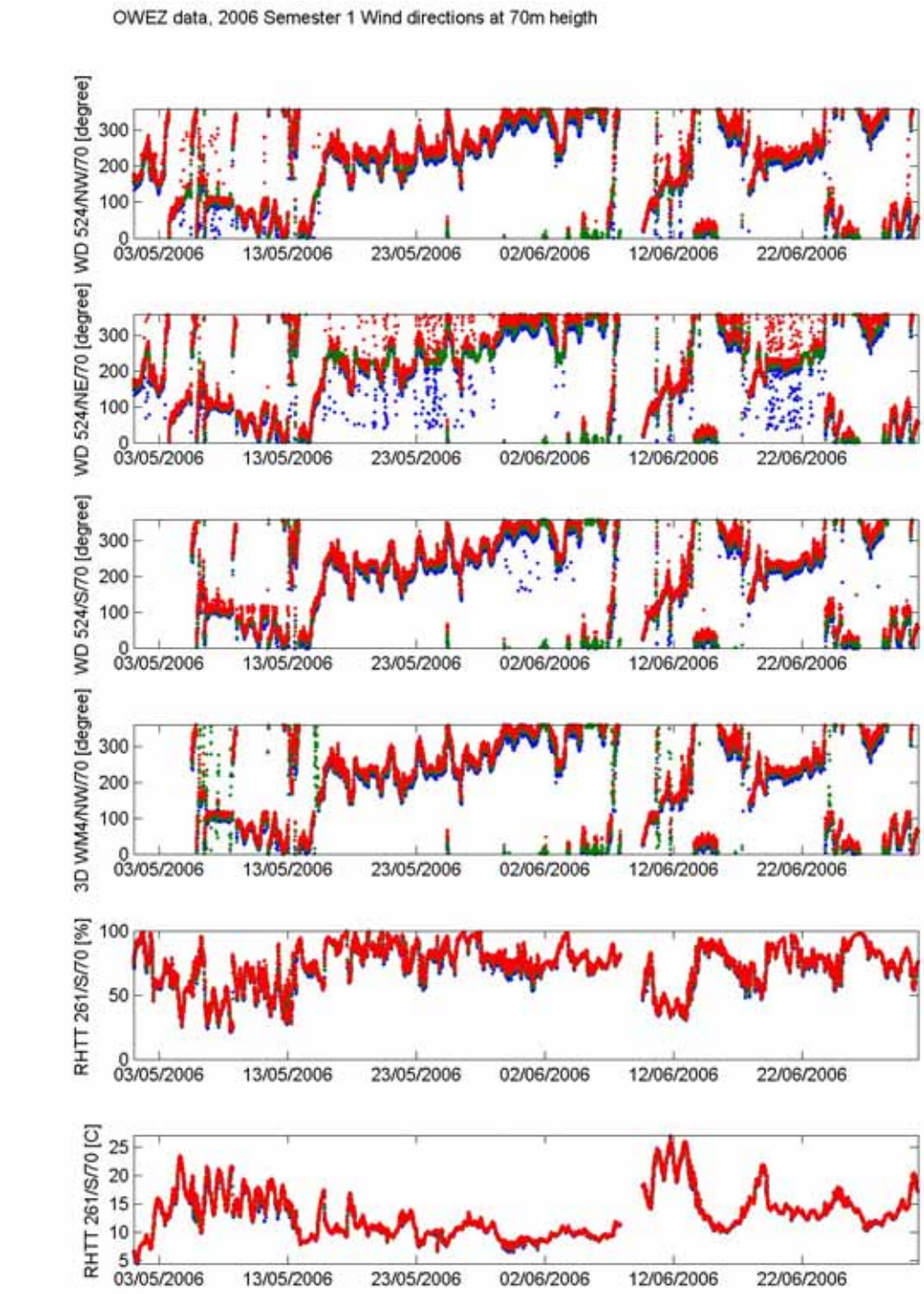


Figure 8.2 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 70 m height are shown for May and June 2006.*

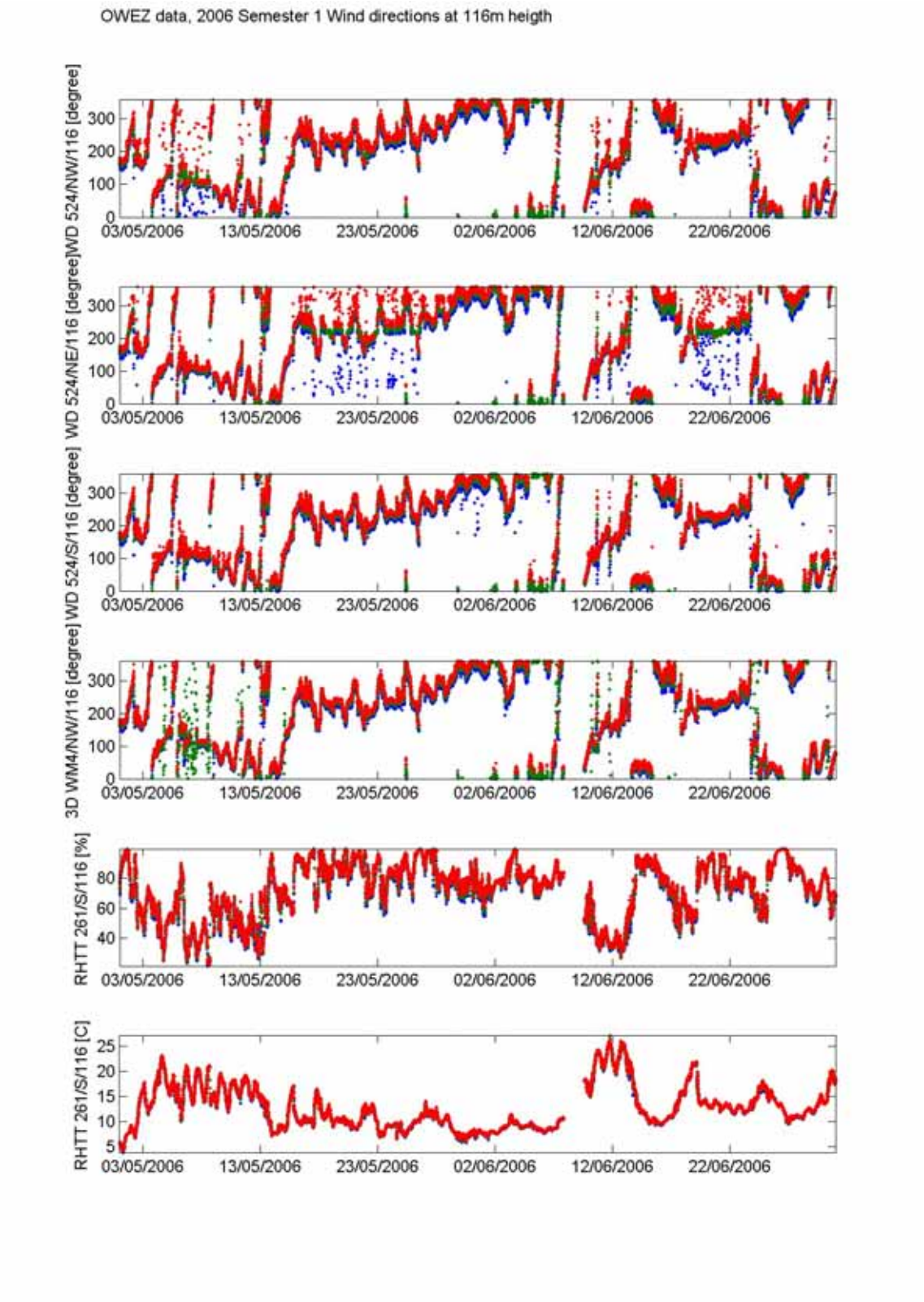


Figure 8.3 *Time histories of stored data in ten-minute averaged values. Wind directions measured with wind vanes and sonic anemometer, air temperature and relative humidity at 116 m height are shown for May and June 2006.*

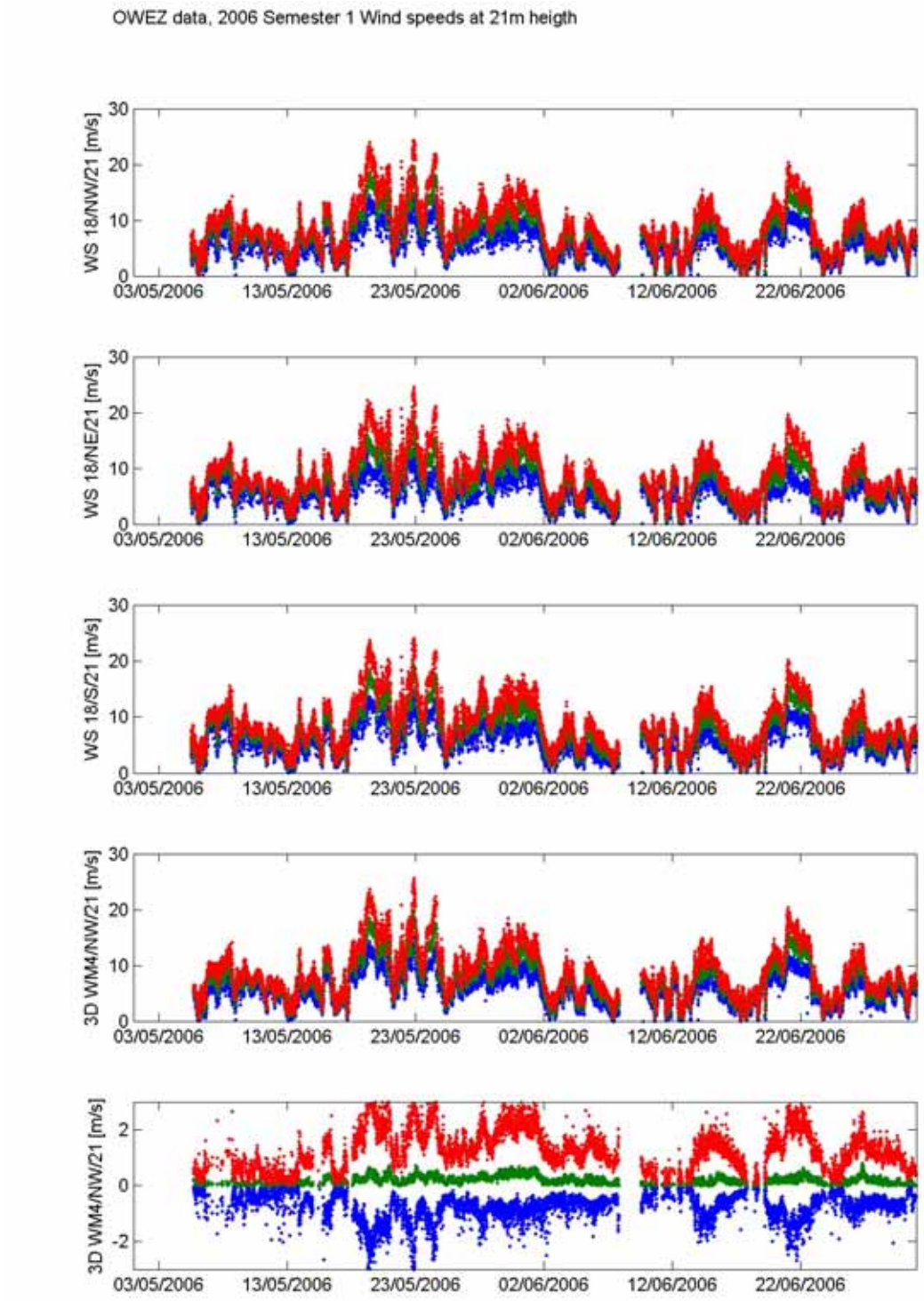


Figure 8.4 *Time histories of stored data in ten-minute averaged values. Wind speed measurements with cup anemometers and sonic anemometer are shown together with the vertical wind speed measured with the sonic anemometer at 21m height are shown for May and June 2006.*

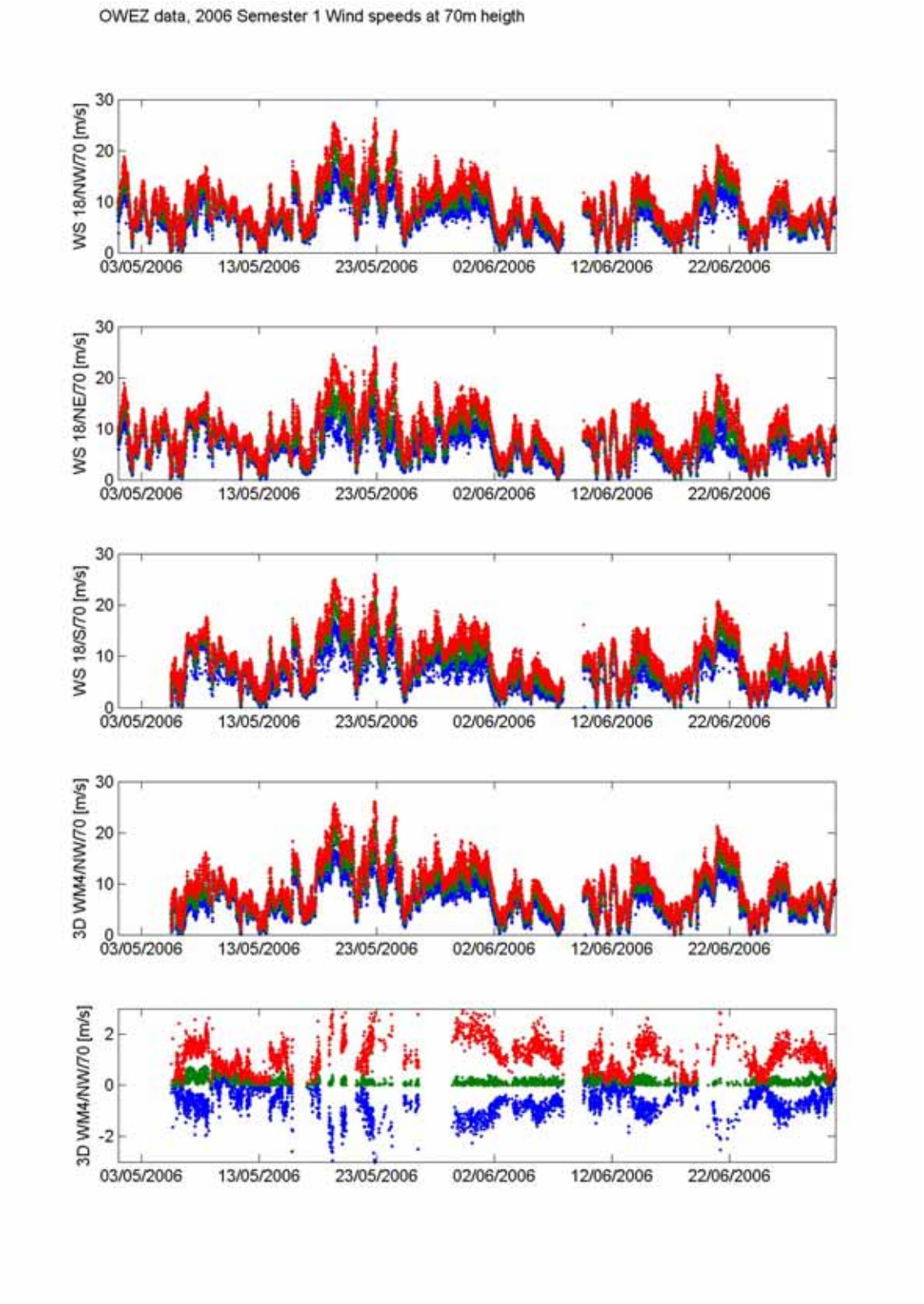
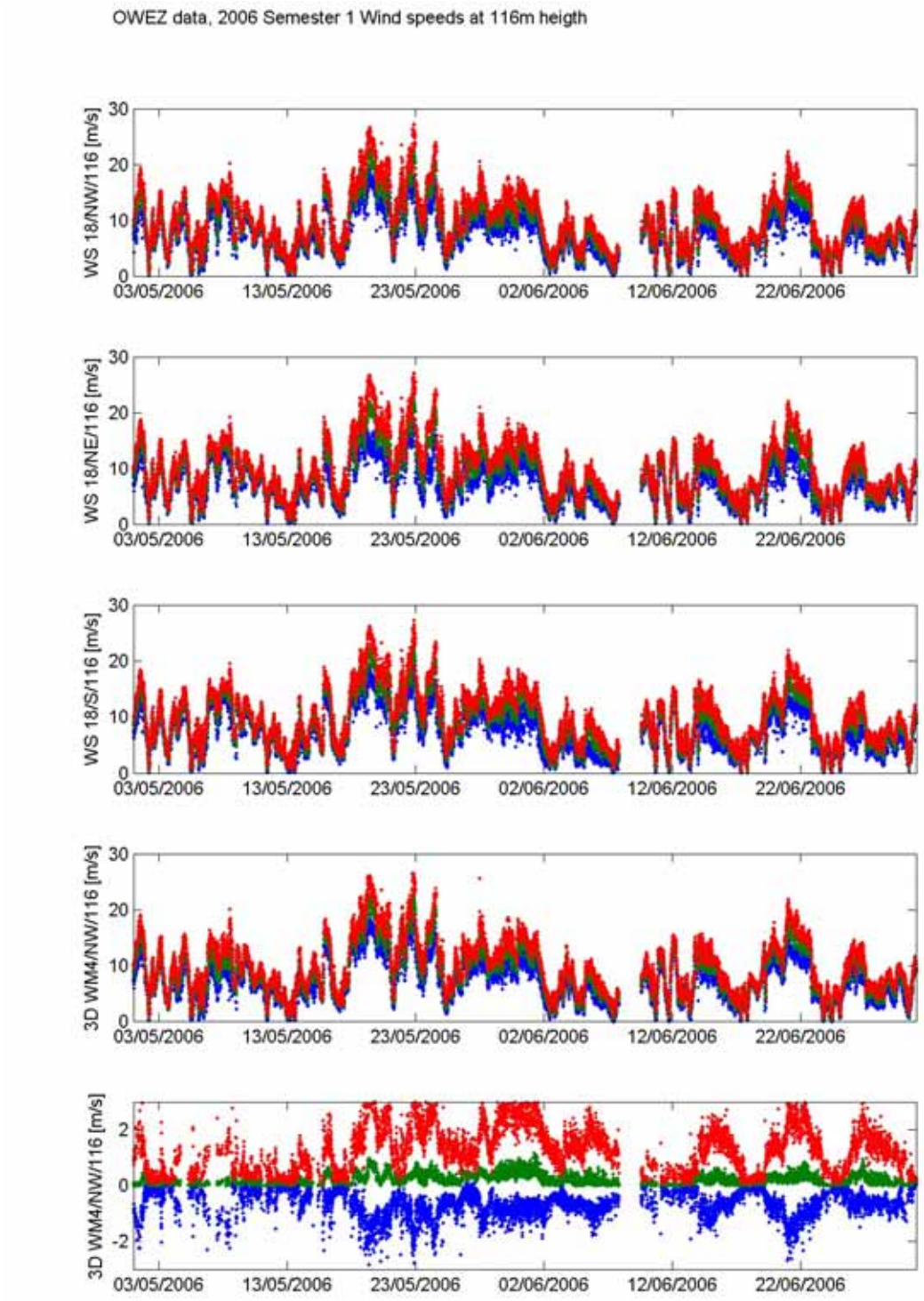


Figure 8.5 *Time histories of stored data in ten-minute averaged values. Wind speed measurements with cup anemometers and sonic anemometer are shown together with the vertical wind speed measured with the sonic anemometer at 70m height are shown for May and June 2006.*



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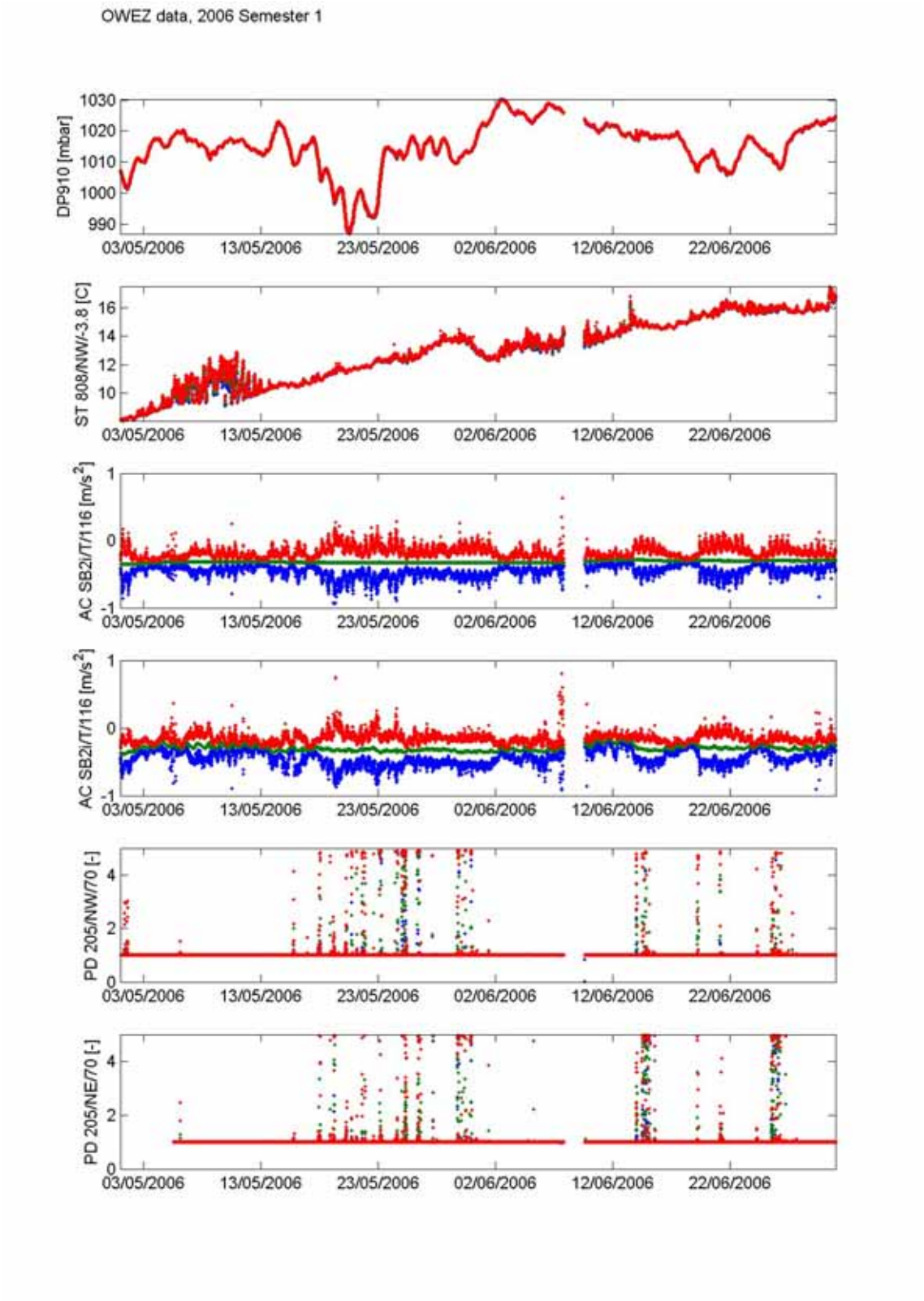

Figure 8.7 *Time histories of stored data in ten-minute averaged values. Air pressure at 21m above MSL, seawater temperature, mast top accelerations in N-S and W-E directions at 116.6 m above MSL and precipitation (70 m) are shown for May and June 2006. The precipitation is measured with sensors in the NE and NW boom.*

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