EWTW Meteorological database

Description June 2003 - May 2005

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Abstract

The ECN Wind Turbine Test Station Wieringermeer (EWTW) is a test location for wind turbines that comprises of four prototype turbines, five research N80 turbines and three large meteorological masts. Two masts reach to 108m height and one mast to 100m. Several research projects have been carried out at the EWTW during the first two years. For each project, a database is created in order to separate confidential turbine data. As a result, the meteorological data are scattered over several databases. The set-up of the EWTW meteorology database (EWTWM) is such that all meteorological data measured during the projects at EWTW are stored in a single database. This database does not contain confidential data.

Since there is not a specific project for the definition of the EWTWM database, it must be stipulated that only data measured in operational projects are stored. If signals are not measured in these projects and the instruments are removed, the EWTWM database cannot provide for further extension of the measurements. As a result, the EWTWM database consists of a patchwork of measurements that are valuable when properly described. Storage of the meteorological data is done using the WDMS database structure. This structure has been developed by ECN and is used for the storage of the large data sets measured at wind turbine measurement projects. With this structure, the data are easily accessible. The data are stored with a sample frequency of 4 Hz together with the 10-minute statistics (average, minimum, maximum and standard deviation). This means that some data have been resampled.

The first meteorological mast at EWTW is installed in March 2003 and is operational since June 2003. In this report an overview of the data in the EWTWM database is presented. A site description is given and also the meteorological mast and the instrumentation and data acquisition system are specified. The second meteorological mast is erected in July 2004 and data are included in the EWTWM database since December 2004. In addition experiments are done with a 25m high mast next to the meteorological mast 1 in order to characterise the flow distortion around the mast. These data are also included in the EWTWM database.

Keywords: wind data; database; wind energy

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1. Introduction

Since the end of 2002 the unit Wind Energy of the Energy research Centre of the Netherlands ECN has made available the ECN Wind Turbine Test Station Wieringermeer (EWTW). This test station has been developed because the existing test site for commercial wind turbines at the Petten location is not suitable anymore for the modern Mega Watt sized machines and local expansion at Petten is not possible.

The EWTW is located in the North East of the Province of North-Holland 35 km eastwards of ECN Petten. The wind turbine test station consists of:

- Four locations for prototype wind turbines with one 100m and one 108m high meteorological mast.
- Five Nordex N80/2500 wind turbines; these wind turbines are equipped for experimental research including a third 108m high meteorological mast. The energy production of these turbines finances the station.
- A measurement pavilion with offices and computer centre for the measurements.

The first meteorological mast has been installed March 2003 and is in operation since June 2003. The meteorological mast 2 will be installed in the summer of 2005. The meteorological mast 3, as part of the long-term measurement programme at the N80 turbines, was erected in July 2004.

Several research projects have been carried out at the EWTW during the first two years. For each project, a database is created in order to separate confidential turbine data. As a result, the meteorological data are scattered over several databases. In order to store all meteorological data measured during the projects at EWTW in a single database the EWTW meteorology database (EWTWM) has been created. This database does not contain confidential data. Storage of the meteorological data is done using the WDMS database structure. This structure has been developed by ECN and is used for the storage of the large data sets measured at wind turbine measurement projects. With this structure, the data are easily accessible. The data are stored with a sample frequency of 4 Hz together with the 10-minute statistics (average, minimum, maximum and standard deviation). This means that some data have been resampled.

Future data analyses using the EWTWM database require the full description of the measurement conditions. This report describes the data and the measurement conditions for the first two years, June 2003 to May 2005. In Chapter 3, the meteorological masts 1 and 3 are technically described. The instrumentation is described in Chapter 4 for the status in summer 2005. The masts have been used for several research projects, the backgrounds of the measurements projects are presented Chapter 6. An overview of the measured data that are captured in the EWTWM database is presented in Appendix A for the period June 2003-May 2004 and Appendix B for the period June 2004-May 2005.

2. Site Description EWTW

2.1 General

The meteorological masts 1 and 3 are erected at the EWTW in the Wieringermeer, a polder in the North East of the province North Holland, 3 km North of the village of Medemblik and 35 km East of ECN Petten (Figure 2-1). The test site and its surroundings are characterised by flat terrain, consisting of mainly agricultural area, with single farmhouses and rows of trees. The lake IJsselmeer is located at a distance of 2 km East of meteorological masts 1 and 3 (Figure 2-2).

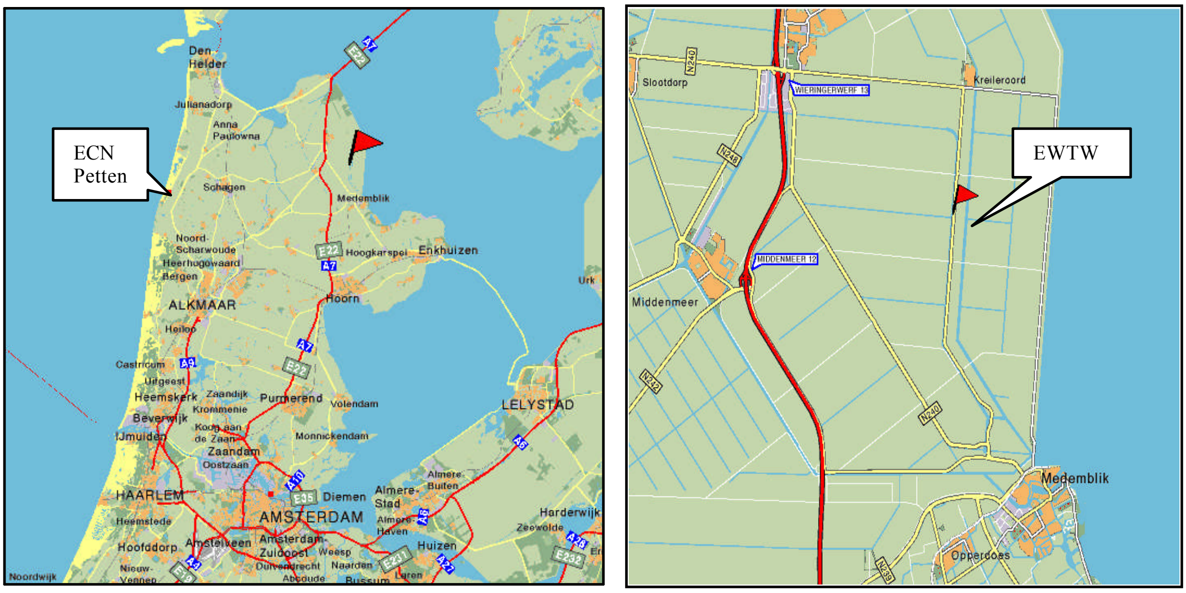


Figure 2-1 Map of the Province of North Holland and a detailed map of test site EWTW in the Polder of Wieringermeer. ECN Petten at the North Sea coast is also indicated.

2.2 Topography and obstacles

The polder Wieringermeer consists of flat agricultural land at an altitude of 5m below sea level. In this area the wind turbine test site, including meteorological masts, is positioned (Figure 2-2). The East border of the polder is a dike (or sea wall) of ± 8m height, seen from the land site, and 3m height seen from the IJsselmeer.

The relevant obstacles, as seen from **meteorological mast 1**, are a row of trees, farmhouses plus barn, and surrounding wind turbines.

1. Along the road (Zuiderkwelweg), 250m West of the meteorological mast 1, a row of trees stretches from the North to the South. It ranges from the village Kreileroord to three kilometres South of the prototypes. The height of the trees is approximately 10m. The influence of the row of trees on the operation of the wind turbines has been calculated and has been reported in [6].
2. The farm houses, in the North, with a height of approximately 5m - 8m, are at a distance of 900m from the meteorological mast 1, and do not influence the measurements. This is also true for the farmhouse plus barn in the South at 900m distance.
3. In the surrounding areas several wind turbines are operating, as indicated in Figure 2-2 and visible on the photo's in Section 2.3. Besides some scattered wind turbines three rows of turbines are distinguished: the five EWTW Nordex N80 turbines in the North, the prototype turbines and a row of NM52 turbines in the South. The distances from these wind turbines to the meteorological mast 1 is 1.5 km as shown in Figure 2-2. The distances are included in the re-

port in Table 2-1. The nearest single wind turbines are at a distance of 1 km to the North and at 1.2 and 1.6 km to the South-East.

The relevant obstacles, as seen from **meteorological mast 3**, are a row of trees, farmhouses plus barn, and surrounding wind turbines. This is shown in Figure 2-2 and presented in Table 2-1 and Table 2-2. The small village of Kreileroord is in the vicinity.

1. Along the road (Zuiderkwelweg), 250m West of the meteorological mast 3, a row of trees stretches from the North to the South. It ranges from the village Kreileroord to three kilometres South of the prototypes. The height of the trees is approximately 10m.
2. North of the meteorological mast 3, five Nordex N80 wind turbines are located as shown in Figure 2-2.
3. South of the meteorological mast 3, a single wind turbine (NM52) is located.
4. South of the meteorological mast 3, the prototype turbines are located.

The locations of the turbines and the masts that are shown on the map in Figure 2-2 have been measured with GPS. These coordinates are presented in the Dutch "Rijksdriehoek" (RD) coordinates in Table 2-1 and Table 2-2. In Table 2-1, the distances between the turbines and masts are presented, and in Table 2-2 the relative directions (with respect to North) between the turbines and masts are presented.

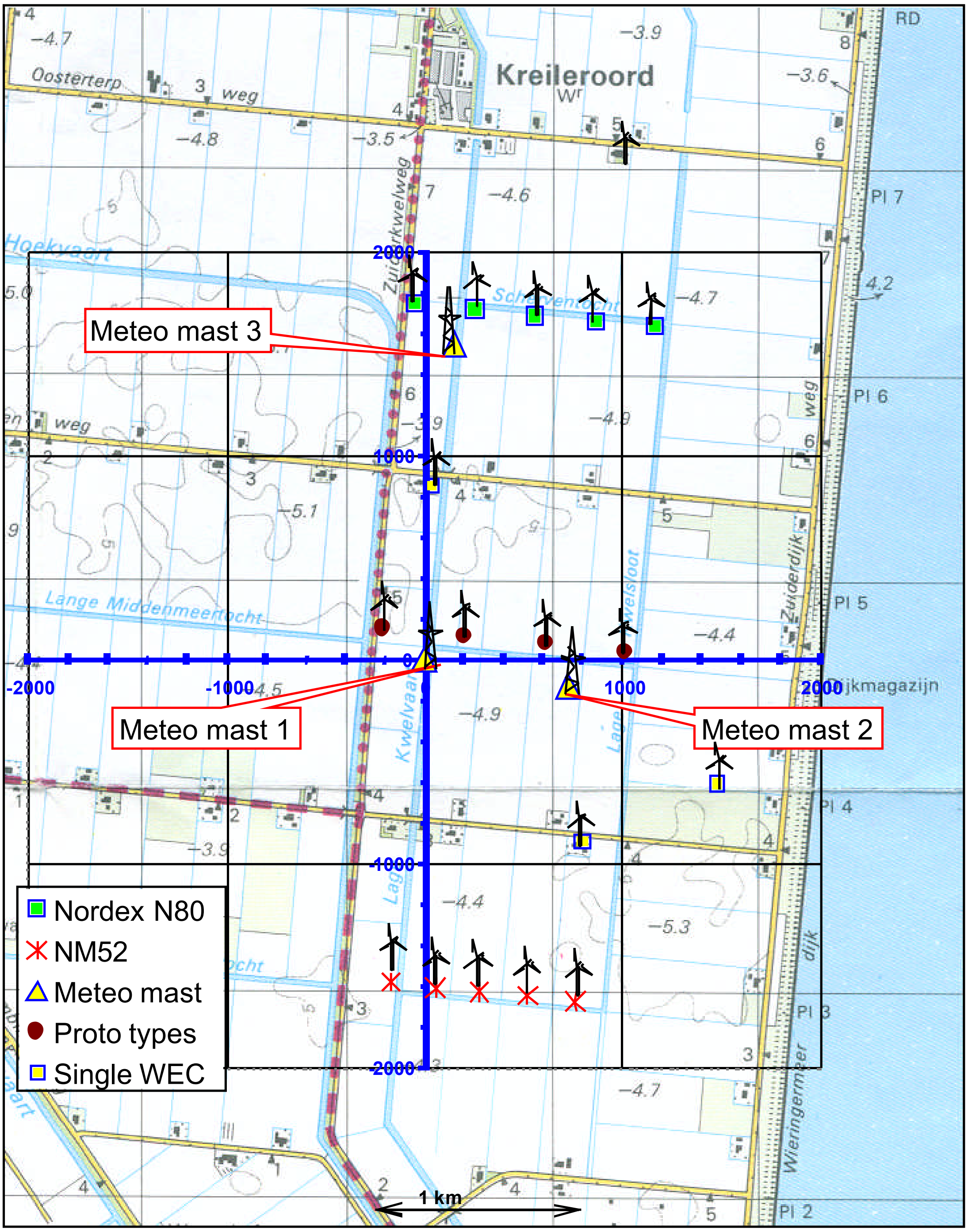


Figure 2-2 Detailed map of the ECN Wind Turbine Test Station Wieringermeer, including the location of surrounding wind turbines and meteorological masts 1, 2 and 3. Directly West of the Zuiderkwelweg the row of trees is located.

Table 2-1. Distances between the objects at EWTW in meters.

DISTANCES	RD coordinates	RD coordinates	Meteomast1	GE 2.5	NM92	N80_5	N80_6	N80_7	N80_8	N80_9	Meteomast3	NM52_900_north	Vestas_V52	LW52_750	NM52_900_south1	NM52_900_south2	NM52_900_south3	NM52_900_south4	NM52_900_south5
Meteomast1	134272	536398	0	226	264	1725	1713	1754	1844	1982	1531	1033	1667	1307	1585	1612	1670	1761	1879
GE 2.5	134466	536514	226	0	411	1629	1582	1591	1657	1778	1410	918	1550	1273	1722	1722	1753	1815	1906
NM92	134056	536549	264	411	0	1580	1611	1696	1828	2002	1418	931	1927	1567	1739	1793	1873	1984	2116
N80_5	134205	538122	1725	1629	1580	0	305	610	917	1223	282	713	2888	2831	3307	3336	3380	3441	3519
N80_6	134509	538095	1713	1582	1611	305	0	305	612	918	201	683	2709	2714	3296	3303	3328	3367	3424
N80_7	134813	538067	1754	1591	1696	610	305	0	306	612	433	781	2553	2626	3312	3298	3301	3318	3354
N80_8	135118	538037	1844	1657	1828	917	612	306	0	306	722	968	2424	2570	3354	3319	3301	3295	3309
N80_9	135423	538012	1982	1778	2002	1223	918	612	306	0	1022	1208	2333	2555	3428	3372	3335	3305	3297
Meteomast3	134405	537923	1531	1410	1418	282	201	433	722	1022	0	498	2612	2578	3116	3130	3162	3210	3277
NM52_900_north	134366	537427	1033	918	931	713	683	781	968	1208	498	0	2232	2126	2618	2635	2671	2728	2806
Vestas_V52	135790	535708	1667	1550	1927	2888	2709	2553	2424	2333	2612	2232	0	645	1836	1649	1482	1313	1180
LW52_750	135191	535468	1307	1273	1567	2831	2714	2626	2570	2555	2578	2126	645	0	1199	1026	887	778	742
NM52_900_south1	134186	534815	1585	1722	1739	3307	3296	3312	3354	3428	3116	2618	1836	1199	0	233	459	709	951
NM52_900_south2	134418	534793	1612	1722	1793	3336	3303	3298	3319	3372	3130	2635	1649	1026	233	0	226	476	718
NM52_900_south3	134643	534770	1670	1753	1873	3380	3328	3301	3301	3335	3162	2671	1482	887	459	226	0	250	492
NM52_900_south4	134892	534750	1761	1815	1984	3441	3367	3318	3295	3305	3210	2728	1313	778	709	476	250	0	242
NM52_900_south5	135133	534728	1879	1906	2116	3519	3424	3354	3309	3297	3277	2806	1180	742	951	718	492	242	0

Table 2-2. Relative directions between the objects at EWTW with respect to North.

Directions	Meteomast1	GE 2.5	NM92	N80_5	N80_6	N80_7	N80_8	N80_9	Meteomast3	NM52_900_north	Vestas_V52	LW52_750	NM52_900_south1	NM52_900_south2	NM52_900_south3	NM52_900_south4	NM52_900_south5
RD coordinates	134272	134466	134056	134205	134509	134813	135118	135423	134405	134366	135790	135191	134186	134418	134643	134892	135133
RD coordinates	536398	536514	536549	538122	538095	538067	538037	538012	537923	537427	535708	535468	534815	534793	534770	534750	534728
Meteomast1		59	305	358	8	18	27	35	5	5	114	135	183	175	167	159	153
GE 2.5	239		275	351	2	13	23	33	358	354	121	145	189	182	174	166	160
NM92	125	95		5	16	27	36	43	14	19	116	134	176	168	162	155	149
N80_5	178	171	185		95	95	95	95	135	167	147	160	180	176	173	168	165
N80_6	188	182	196	275		95	95	95	211	192	152	165	186	182	178	173	170
N80_7	198	193	207	275	275		96	95	251	215	158	172	191	187	183	179	175
N80_8	207	203	216	275	275	276		95	261	231	164	178	196	192	188	184	180
N80_9	215	213	223	275	275	275	275		265	241	171	185	201	197	194	189	185
Meteomast3	185	178	194	315	31	71	81	85		184	148	162	184	180	176	171	167
NM52_900_north	185	174	199	347	12	35	51	61	4		140	157	184	179	174	169	164
Vestas_V52	294	301	296	327	332	338	344	351	328	320		248	241	236	231	223	214
LW52_750	315	325	314	340	345	352	358	5	342	337	68		237	229	218	203	184
NM52_900_south1	3	9	356	0	6	11	16	21	4	4	61	57		95	96	95	95
NM52_900_south2	355	2	348	356	2	7	12	17	360	359	56	49	275		96	95	95
NM52_900_south3	347	354	342	353	358	3	8	14	356	354	51	38	276	276		95	95
NM52_900_south4	339	346	335	348	353	359	4	9	351	349	43	23	275	275	275		95
NM52_900_south5	333	340	329	345	350	355	360	5	347	344	34	4	275	275	275	275	

2.3 Pictures taken from the meteorological mast no1. at 70m height.

North direction
with Nordex turbines (#5&#6) in background

North-North East,
with Nordex turbines (#6-#9) in background

East-North East; foundation GE2.5 in front,
Lake IJsselmeer in background

East direction;
Lake IJsselmeer background

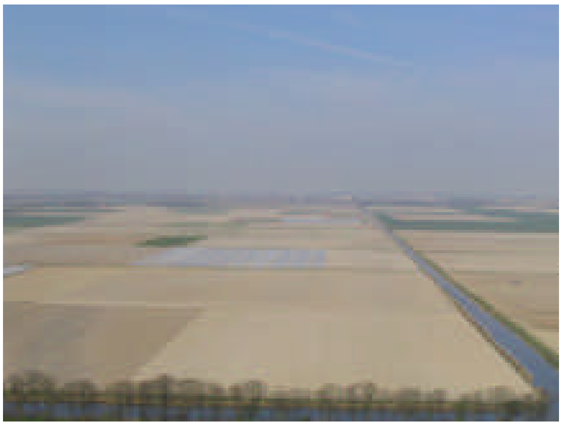
East-South East

South-South -East;
NM 52 machines in background


South direction


South-South-West


West-South-West


West direction


North-West, with the DOWEC turbine in front


North- North West

2.4 Environmental conditions of test site

2.4.1 Wind regime

The wind regime is shown for the period June 2003-May 2005. The values are calculated using WAsP 8.0 on the basis of the wind speed and direction measurements at 71.6m height. The results are summarized in Table 2-3 where for each sector are shown the frequency of occurrence, the averaged measured wind speed (*U*), the values of the Weibull fit (*A* and *k*) and the mean power density P. Note that the measurements are disturbed by the NM92 turbine (at 305º) and GE2.5 turbine (at 59º). The free wind speed will therefore be higher in these sectors. The wind rose for the all sectors is shown in Figure 2-3. This wind rose clearly shows the dominating wind direction in the southwest area.

Table 2-3 Annual average wind speed at the meteorological mast 1 location at 71.6m height. Note that the sectors 60 and 300 are disturbed by nearby turbines.

Sector	0	30	60	90	120	150	180	210	240	270	300	330	Total
A [m/s]	7.0	7.4	7.2	8.4	7.7	6.9	8.1	8.8	10.1	8.2	6.6	7.6	8.1
k	2.1	2.3	2.5	3.1	2.6	2.7	2.8	2.2	1.9	1.8	1.7	2.2	2.0
U [m/s]	6.2	6.6	6.4	7.5	6.8	6.1	7.2	7.8	8.9	7.3	5.9	6.7	7.2
P [W/m2]	269	293	256	362	304	214	330	512	875	507	286	330	438
Freq [%]	5	5	6	8	6	5	7	13	15	11	9	8	100

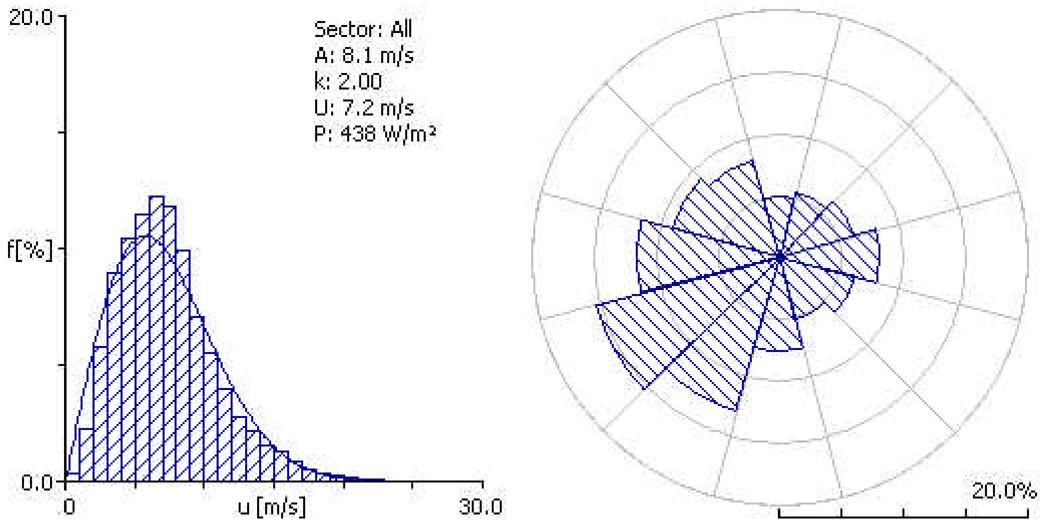


Figure 2-3 Wind rose, at 71.6m height, of the meteorological mast 1 at ECN Wind turbine Test Location Wieringermeer for the period June 2003-May 2005. Note that the sectors 60 and 300 are disturbed by nearby turbines.

2.4.2 Other conditions

The temperature at the site can be characterised as mild: in average between 1.2 ºC (average minimum in winter) and 19.1 ºC (average maximum during summer). Rainfall is on average (30 years) 740 mm a year, during 7% of the time. In Figure 2-4 and Figure 2-5 information about the climate at Den Helder (24 km West of EWTW) is presented. In these figures monthly averages are presented of hours of sun, minimum temperature, maximum temperature, number of days with rain, precipitation and relative humidity.

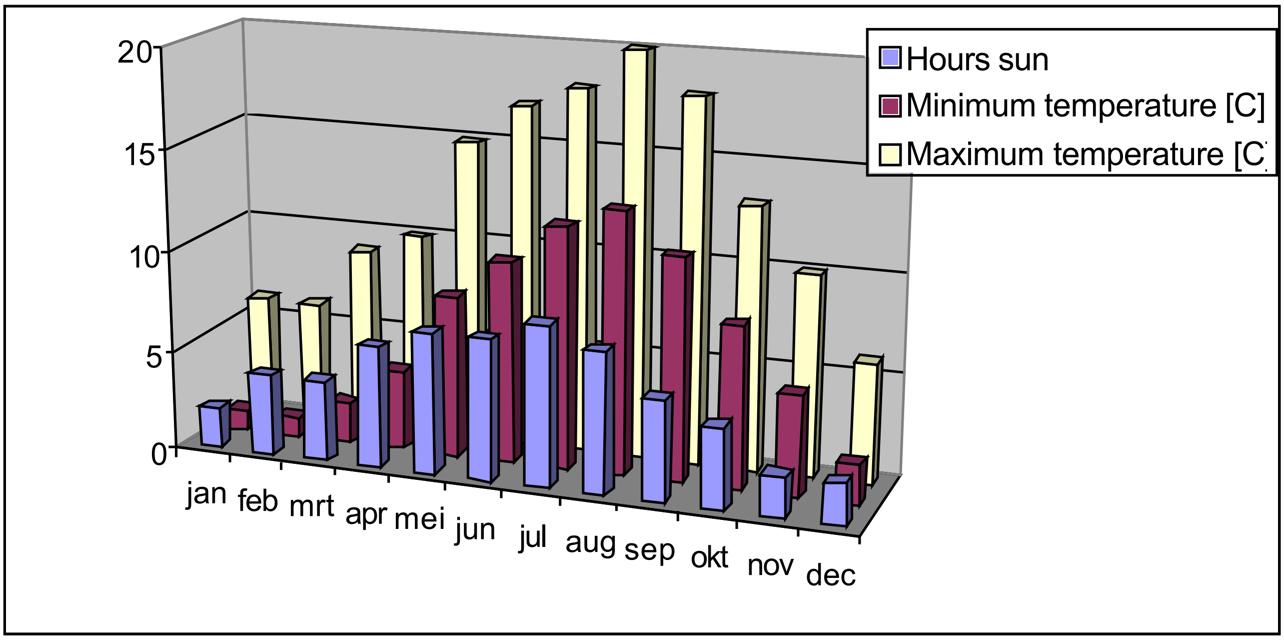


Figure 2-4. Averaged monthly minimum and maximum temperatures and hours sun (Den Helder)

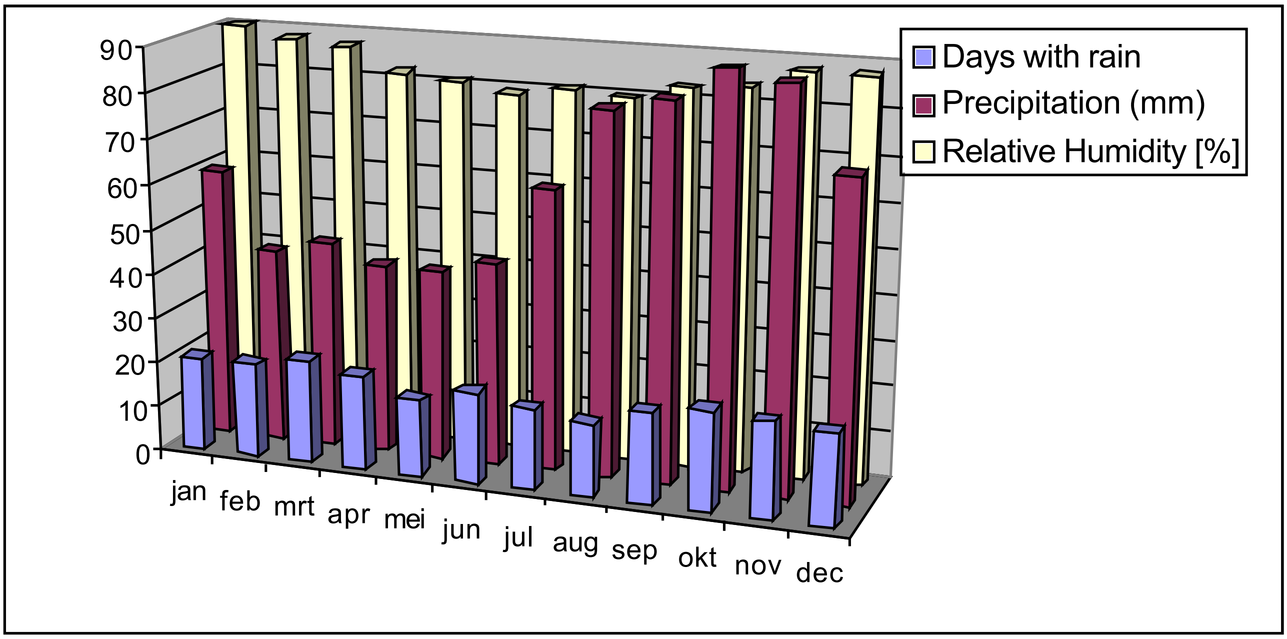


Figure 2-5. Averaged monthly days with rain, precipitation and relative humidity (Den Helder)

3. The Meteorological masts

The ECN Wind Turbine Test Station Wieringermeer (EWTW) is equipped with meteorological masts to support experimental activities at both the prototype wind turbines and the experimental turbines.

The meteorological masts have similar construction: they have lattice towers with a height of 108m. Mast 2 will be installed in summer 2005 and differs from the other masts by height only. The top mounted anemometers will be at 100m in order to perform the measurements on the GE 2.3 turbine. The tri-angular cross sections of the masts (side length is 1.6m) are equal at all levels; see Figure 3-1 and Figure 3-2. The masts are constructed with tubular components. The three pillars of each mast have a diameter of 133mm; the bracers are 60.3mm thick. The masts are placed on concrete foundations and are positioned with guy wires in three directions at two levels: 90m and 50m. The guy wires are fixed to concrete blocks at a radius of 60m from the tower base. The masts are equipped with internal platforms at different levels to be able to work at the booms and top mounted instruments. This construction ensures a stable tower with only small and slow movements at the top.

Booms to support measurement instruments are located at different levels. Due to the construction of the mast, the booms can have three directions. One boom is pointing to North: 0º, a second one to East-South-East: 120º and a third one to West-South-West: 240º. These 6.5m long tri-angular booms (Figure 3-2) are collapsible for maintenance of the boom-mounted sensors. Winches are present to lift and drop the booms. The stiffness of the boom construction is achieved with cables. At the mast top special arrangements are installed to hoist the booms from one height to the other. In summer 2004 the following booms are installed in meteorological mast 1. Three booms are installed at 83.4m, three booms at 70m, and single booms are installed at 25m and 45m levels, pointing in East-South-East direction; see Figure 3-1. In autumn 2004, meteorological mast 3 has been erected. This mast includes instrumentation at 52m, 80m and 108m heights. Three booms are installed at both 50.4m and 78.4m heights. The directions of the booms are similar to the booms in mast 1.

Because of its height the masts are sensitive to lightning. Lighting conductors are connected at the mast top and at the tip end of all booms. Furthermore, aviation-warning lights are installed in the mast: one in the top and two at 45m level.

Figure 3-1 View of the meteorological mast 1 with attached booms at different levels. The booms at the lowest levels are positioned at 25m and 45m heights and are directed to East-South-East.

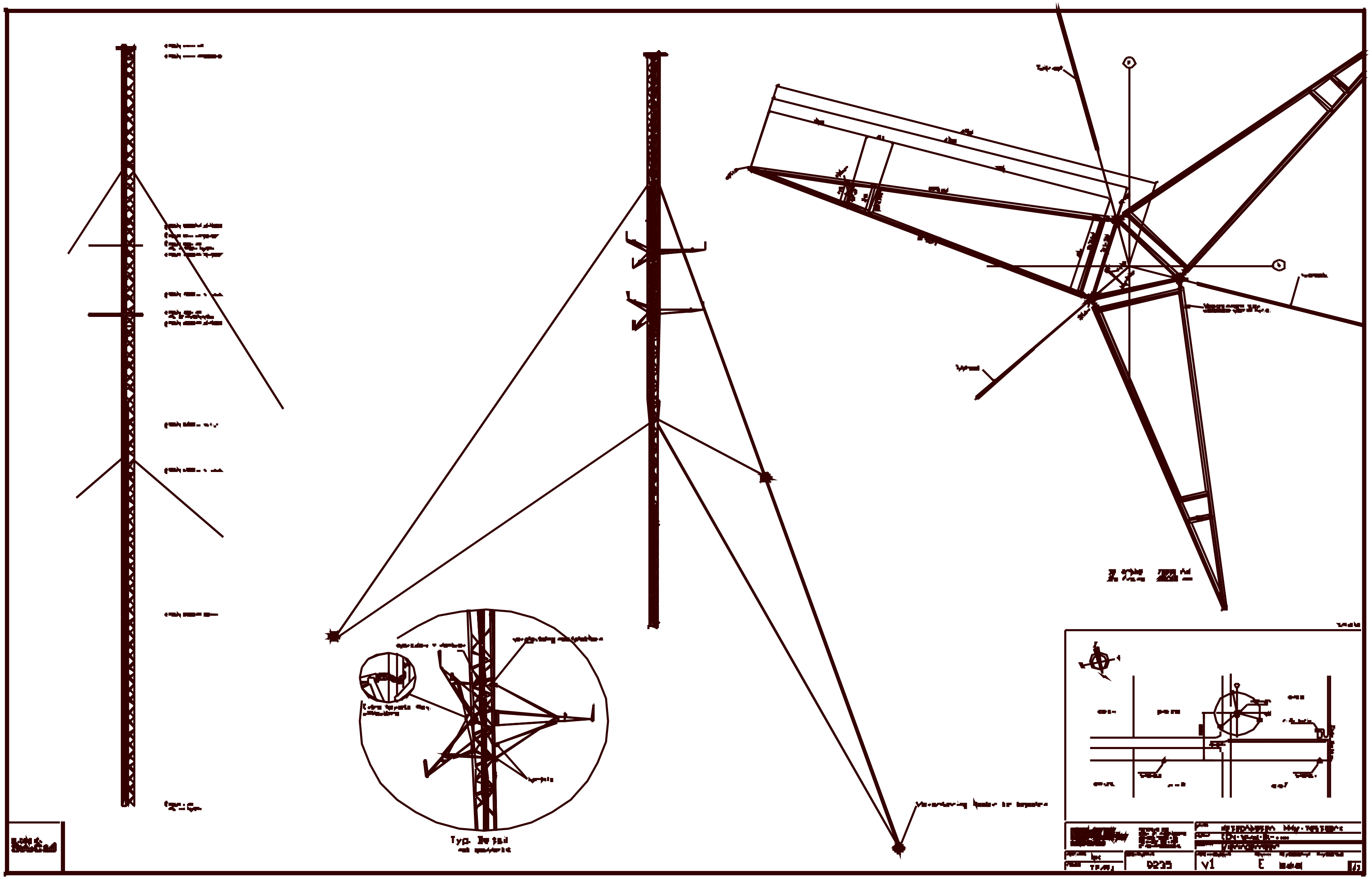


Figure 3-2 Drawing of the 108m tall meteorological masts at EWTW, showing cross section and guy wires lay out. The booms are depicted at arbitrary heights and have lengths of 6.5 m.

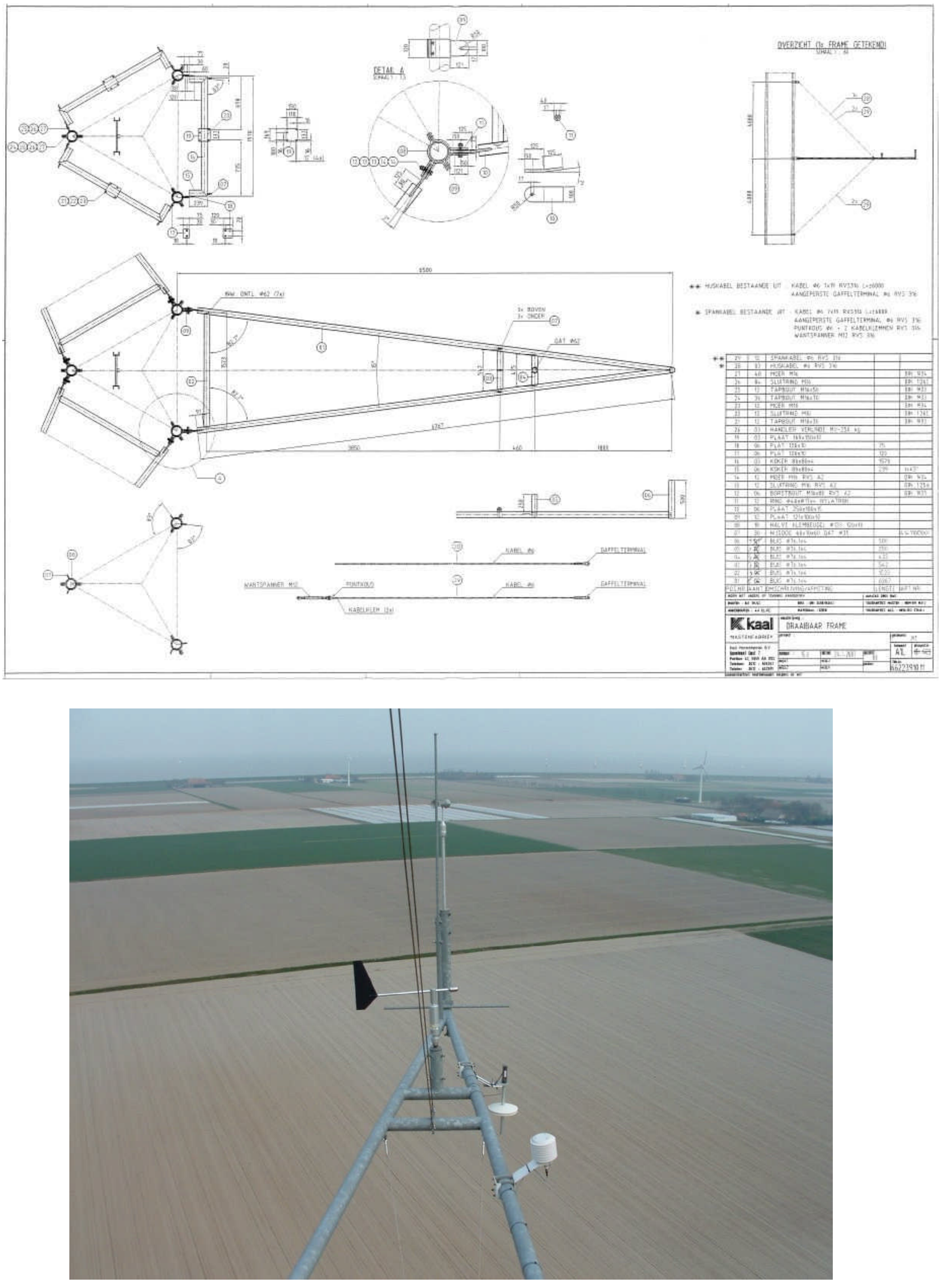


Figure 3-3 Cross section of meteorological masts (tri-angular with side length of 1.6 m) and layout plus photo of the boom, being 6.5m in length. Beside anemometer and vane, the air pressure and temperature sensor are shown. The boom in the picture is pointing in East-South-East direction and is located in meteorological mast 1.

4. The instrumentation and data acquisition

The EWTWM database consists of meteorological data. Analyses using the data require the full description of the measurement conditions. This report describes the data and the measurement conditions for the first two years, June 2003 to May 2005. In this Chapter, the meteorological masts 1 and 3 are described for their status in summer 2005. The masts have been used for several projects, that are described in Chapter 6.

4.1 Meteorological mast 1

Summer 2005, booms are installed in mast 1 at 25m, 45m, 70m and 83.4m heights. Instrumentation was installed these booms and at 3m height. The instrumentation is described in Table 4-1. An overview of (validated) data collected in the EWTWM database is included in Appendix A for the period June 2003-May 2004 and Appendix B for the period June 2004-May 2005. The sensors are connected to the DANTE data-acquisition systems [1]. In the DANTE system the signals are filtered, digitised and converted. Via an Ethernet connection the data are transported to the host computer in the measurement pavilion and stored. The names of the wind speed signals at 85m have changed in December 2004 (added '_p'), because of parallel measurements with pulse count modules. The latter are not included in this database.

Table 4-1. Instrumentation in meteorological mast 1

Signal Name	label in EWTWM	units	height	brand	Sensor type
Gill wind speed U, V, W	MM1_S108	m/s	109.1m	GILL	1086 M
Wind direction 108 m	MM1_S108	deg	109.1m	GILL	1086 M
Wind speed 85 N	MM1_WS85_0(_P)	m/s	85m	Risø	P2456a
Wind speed 85 SE	MM1_WS85_120(_P)	m/s	85m	Risø	P2456a
Wind speed 85 SW	MM1_WS85_240(_P)	m/s	85m	Risø	P2456a
Wind direction 85 SE	MM1_WD85_120	deg	84.2m	Mierij	508
Wind direction 85 SW	MM1_WD85_240	deg	84.2m	Mierij	508
Air temperature 85 m	MM1_Tair85	ºC	83.4m	Rense	XT-730-01
Air pressure 85 m	MM1_Pair85	hPa	83.4m	Vaisela	PTB 210 Class B
Wind speed 70 N	MM1_WS70_0(_P)	m/s	71.6m	Risø	P2456a
Wind speed 70 SE	MM1_WS70_120(_P)	m/s	71.6m	Risø	P2456a
Wind speed 70 SW	MM1_WS70_240(_P)	m/s	71.6m	Risø	P2456a
Wind direction 70 SE	MM1_WD70_120	deg	70.8m	Mierij	508
Wind direction 70 SW	MM1_WD70_240	deg	70.8m	Mierij	508
Air temperature 70 m	MM1_Tair70	ºC	70m	Rense	XT-730-01
Air pressure 70 m	MM1_Pair70	hPa	70m	Vaisela	PTB 210 Class B
Wind speed 45m SW	MM1_WS45_240	m/s	46.6m	Risø	P2456a
Wind speed 25m SW	MM1_WS25_240	m/s	26.6m	Risø	P2456a
Wind direction 25m SW	MM1_WD25_120	deg	25.8m	Mierij	508
Air temperature 3 m	MM1_Tair3	ºC	3m	Rense	XT-730-01
Precipitation	MM1_Prec		2m	Thies	5.4103.10.00

Table 4-2. Instrumentation in 25m mast next to meteorological mast 1

Signal Name	label in EWTWM	units	location	brand	Sensor type
Sonic wind speed	m25_vais_ws	m/s	26.6m	Vaisala	
Sonic wind direction	m25_vais_wd	deg	26.6m	Vaisala	
Wind speed M	m25_ws25_m	m/s	26.6m	Risø	P2456a
Wind speed S	m25_ws25_s	m/s	26.6m	Risø	P2456a

4.2 Sensors in meteorological mast 1

3D sonic anemometer
The Gill anemometer is located on top of the meteorological mast. It is mounted on top of the South mast pillar. The sensor itself is 1.1m above the mast top at 109.1m height. On the North-East pillar a 5m long lightning conductor is fixed. This rod influences the measurements with wind from North-North East (around 30º direction). On the northwest pillar an air-traffic warning light is positioned. See also the mast top picture in Figure 4-1.

Cup anemometers
Risø-type cup-anemometers are located at the tip ends of the tri-angular booms (see Figure 3-3). The distance between mast and sensor is 6.5 m. The signals from the cup-anemometers are identified with the directions the booms are pointed at: 0, 120 and 240 degrees. The distance, in a straight line at the horizontal level, between the anemometers is 12.4m. The cup rotors of the anemometers are mounted 1.61m above the boom end, which is 21 times the boom thickness (Ø76mm). Beside the cup-anemometers a lightning conductor (Ø22 mm) is located. The distance between sensor and conductor is 263 mm; see Figure 4-2. The heights of the cup anemometers are 26.6m, 46.6m, 71.6m and 85m above ground level.

Wind vanes
Mierij wind direction sensors (vanes) are attached to the booms at a distance of 4.7m from the mast and 1.8m from the boom tip end (cup anemometer). The top of the vane is 0.83m above the boom; see Figure 4-2. At 70m and 85m, only two booms are equipped with vanes. Due to the positioning of the meteorological mast with respect to the prototype locations, wind coming from North is not expected to be relevant for these measurement campaigns. The heights of the cup anemometers are 25.8m, 70.8m and 83.4m above ground level.

Other instruments
Both the temperature and air pressure sensor are mounted on the SE boom at the 70m and 83.4m level booms. The temperature sensor is a PT100 instrument equipped with a radiation shield. The air pressure is measured with a silicon capacitive absolute pressure sensor of Vaisala [2]. The precipitation sensor, indicating wet periods is mounted on the roof of the measurement cabin at the base of the meteorological mast.

All sensor cables are guided inside the tubes of the boom to the signal connection boxes inside the mast. The cables through the mast towards the measurement cabin have over voltage protection. The protection system is located inside the signal connection boxes up in the mast and down in the measurement cabin; see Figure 4-3.

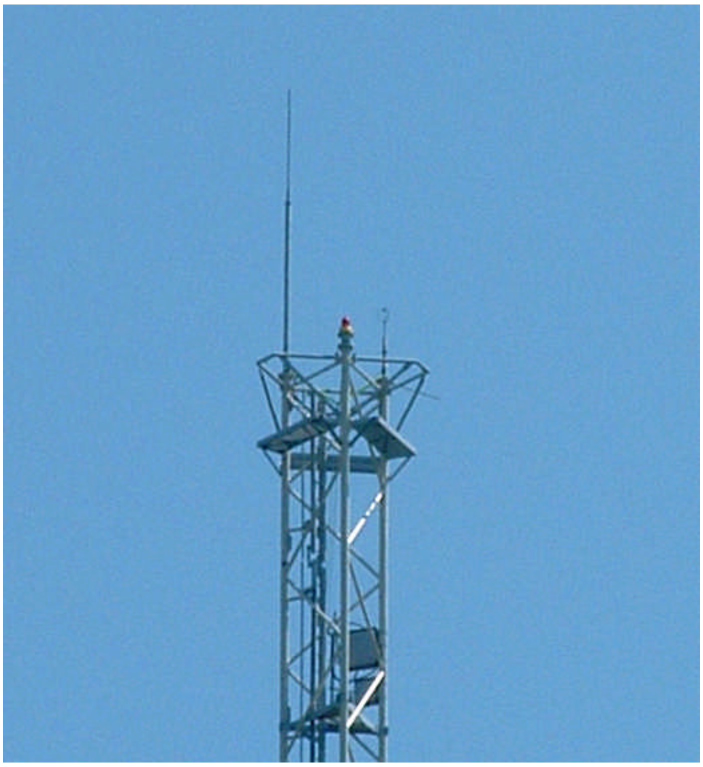


Figure 4-1 Top of the meteorological mast 1 with 3D sonic sensor, aviation warning light and lightning conductor. The boxes lower in the mast contain the signal connection and high voltage protection.

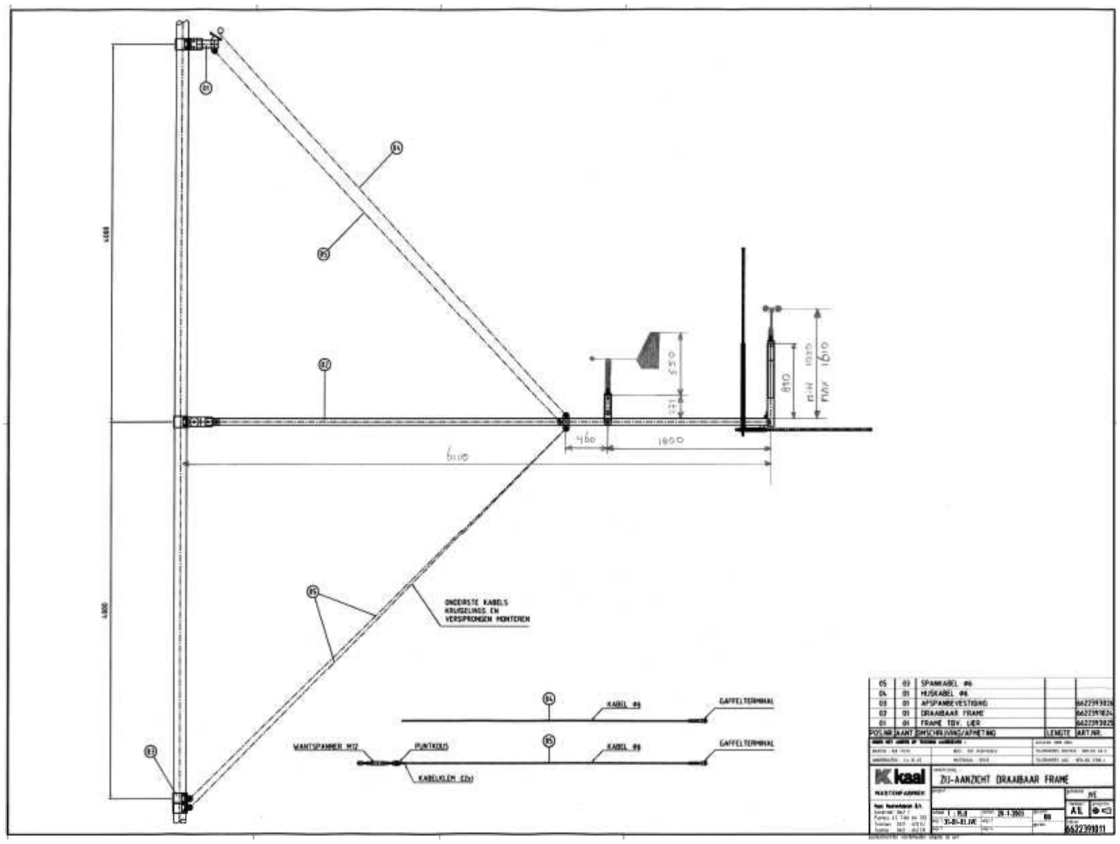


Figure 4-2 Side view of meteorological mast boom including wind sensors. Cables are used to hoist the boom towards the mast and ensure stability during operation.

Figure 4-3 Measurement cabin on the meteorological mast 1 foundation. The signal reception and front-end of the DANTE data-acquisition system are inside. On top the precipitation sensor is located.

4.3 Sensors in meteorological mast 3

The second meteorological mast became operational in October 2004 and data have been collected starting December 2004. Booms are installed in the mast at 50.4m and 78.4m heights. Instrumentation was installed in these booms and in the top at 108m height. The instrumentation is described in Table 4-3. An overview of (validated) data collected in the EWTWM database is included in Appendix A for the period June 2003-May 2004 and Appendix B for the period June 2004-May 2005. The sensors are connected to the DANTE data-acquisition systems [1]. In the DANTE system the signals are filtered, digitised and converted. Via an Ethernet connection the data are transported to the host computer in the measurement pavilion and stored.

Table 4-3. Signals measured in meteorological mast 3

Signal Name	label in EWTWM	units	location	brand	Sensor type
Wind speed SE 52 m	MM3_WS52_120	m/s	52m	Risø	P2456a
Wind speed SW 52 m	MM3_WS52_240	m/s	52m	Risø	P2456a
Wind speed N-U 52 m	MM3_S52N_U	m/s	52m	Gill	1086 M
Wind speed N-V 52 m	MM3_S52N_V	m/s	52m	"	"
Wind speed N-W 52 m	MM3_S52N_W	ms/	52m	"	"
Status Gill 52 m N	MM3_S52N_St	-	52m	"	"
Wind direction SE 52 m	MM3_WD52_120	deg	51.2m	Friedrichs	4123.0000X
Wind direction SW 52 m	MM3_WD52_240	deg	51.2m	Friedrichs	4123.0000X
Wind speed SE 80 m	MM3_WS80_120	m/s	80m	Risø	P2456a
Wind speed SW 80 m	MM3_WS80_240	m/s	80m	Risø	P2456a
Wind speed N-U 80 m	MM3_S80N_U	m/s	80m	Gill	1086 M
Wind speed N-V 80 m	MM3_S80N_V	m/s	80m	"	"
Wind speed N-W 80 m	MM3_S80N_W	m/s	80m	"	"
Status Gill 80 m N	MM3_S80N_St	-	80m	"	"
Air temperature 80 m	MM3_Tair80	ºC	78.4m	Vaisala	HMP45A
Air humidity 80 m	MM3_RH80	%	78.4m	Vaisala	HMP45A
Air pressure 80 m	MM3_Pair80	hPa	78.4m	Vaisala	PTB 210 Class B
Wind direction SE 80 m	MM3_WD80_120	deg	79.2m	Friedrichs	4123.0000X
Wind direction SW 80 m	MM3_WD80_120	deg	79.2m	Friedrichs	4123.0000X
Wind speed U 108 m	MM3_S108_U	m/s	109.1m	Gill	1086 M
Wind speed V 108 m	MM3_S108_V	m/s	109.1m	"	"
Wind speed W 108 m	MM3_S108_W	m/s	109.1m	"	"
Status Gill 108 m	MM3_S108_St	-	109.1m	"	"
Temperature difference	MM3_dT	ºC	--	Rense	

3D sonic anemometers
One Gill anemometer is located on top of the meteorological mast. It is mounted on top of the East mast pillar. The sensor itself is 1.15m above the mast top at 109.1m height. On the South pillar a 5m long lightning conductor is fixed. The wind, coming from the South-West (around 240º direction), will be influenced by this rod. On the West pillar an air-traffic warning light is positioned. See also the mast top picture in Figure 4-1. Other Gill anemometers are located on the North booms at 52m and 80m heights at the tip ends of the tri-angular booms. The distances between mast and sensors are 6.5m. The choice of the sonic anemometers in the North of the mast is driven by the desire to measure wake conditions with sonic anemometers.

Cup anemometers
Risø cup-anemometers are located at the tip ends of the tri-angular booms directed to East-South-East and West-South-West. These sensors are installed at 52m and 80m height. The distance between mast and sensor is 6.5 m. The sensors are identified with the directions the booms are pointed at: 120 and 240. The distance, in a straight line at the horizontal level, between the anemometers is 12.4m. The cup rotors of the anemometers are mounted 1.61m above the boom end, which is 21 times the boom thickness (Ø76mm). Beside the cup-anemometers a lightning conductor (Ø22 mm) is located. The distance between sensor and conductor is 263 mm; see Figure 4-2. The set-up is similar to the meteorological mast 1.

Wind vanes
Friedrichs wind direction sensors (vanes) are fixed on the SE and SW booms at 51.2m and 79.2m heights. They are attached to the boom at a distance of 4.7m from the mast and 1.8m from the boom tip end (cup anemometer). The top of the vane is 0.83m above the boom; see Figure 4-2. The type of wind vane differs from meteorological mast 1, the locations on the booms are identical.

Other instruments
The temperature and relative humidity sensor are combined in the Vaisala sensor. This sensor is mounted on the SE boom at the 78.4m level. The temperature sensor is equipped with a radiation shield. The air pressure is measured with a silicon capacitive absolute pressure sensor of Vaisala [2] and is also mounted on the SE boom at the 78.4m level. The precipitation sensor, indicating wet periods is mounted on the roof of the measurement cabin at the base of the meteorological mast 1.
The temperature difference sensor will become operational in summer 2005.

5. Uncertainties

Uncertainties are calculated following international standards and regulations [3] and [4].

5.1 Cup anemometer

The uncertainty of the cup anemometer is constructed from the following components:

- Anemometer calibration uncertainty: The average value over a large number of calibration values is calculated and is used in the uncertainty analysis. ECN calibrates its anemometers in the DEWI wind tunnel. The average anemometer calibration uncertainty is 0.062m/s for Risø cup-anemometers [9].
- Anemometer operational characteristics: The uncertainty due to the operational characteristics (sensitivity to temperature and air pressure, over-speeding, cosine response) is estimated to be smaller than 0.5%.
- Anemometer mounting effects: All anemometers are mounted identical and the uncertainty is due to two mounting effects. The first is the influence of the mast. The mast is triangular with C_T value of 0.51 and a leg distance of 1.6 m. The cup anemometer is mounted in a distance of 6.5m from the side of the mast. From the hart of the mast this is more than 7 m. The influence of the mast is smaller than 1%.
- The second anemometer mounting effect is the influence of the boom. The rotor of the cup is mounted at 1620 mm above the boom. The influence of the boom is estimated to be smaller than 0.5%. The total uncertainty due to mounting effects is estimated (quadratic summation) to be smaller than 1.12%. This has been confirmed by the experiment with the 25m mast [7].
- Anemometer data acquisition system: The uncertainty of the data acquisition module in the measuring system is 0.049% of the measuring range of the Risø anemometer, which is 70 m/s. The uncertainty is estimated as 0.034m/s

The uncertainty of the cup anemometer is 0.016v + 0.071 m/s, where v is the wind speed.

5.2 Wind vane

The uncertainties of the wind vanes are 2º for 10-minute averaged wind directions. The resolution of the wind vanes is

Friedrichs:	2.5 degrees
Mierij:	1.4 degrees

The flow distortion due to the mast is below 1.5 degrees.

5.3 Air Temperature

The uncertainty of the radiation shielding of the temperature sensor is assumed to be less than 2ºC. The uncertainty of the mounting effect of the temperature sensor is assumed to be less than 1.9ºC.

The uncertainty of the air temperature sensor is 2.7ºC.

5.4 Air pressure

The uncertainty of the air pressure sensor is 0.34 hPa.

6. Campaigns

6.1 NEG MICON 92 Wind Turbine (DOWEC)

Within the framework of the DOWEC (Dutch Offshore Wind Energy Converter) project ECN carried out noise, power performance and mechanical load measurements on the NEG MICON NM92 at the EWTW. The measurements for the final power performance measurements were carried out from 27.10.2003 – 16.11.2003 according to the procedure of the IEC61400-12 standard for power performance measurement [1]. The entire measurement campaign extended from June 2003 to May 2004.

6.1.1 Instrumentation

A detailed overview of the instruments is presented in Table 4-1. All sensors and signals were calibrated according the procedure in the ECN quality system [5]. The wind speed was measured by three cup anemometers on the booms at 70m height. The distance of the anemometers from the mast is 6.5 m. The three cup anemometers have a direction of 0, 120 and 240 degrees with respect to the base of the mast and are located at 71.6m height. Two wind vanes were used at 70.8m height. The vanes were erected on the boom in the direction of 120 degrees and on the boom in the direction of 240 degrees in a distance of 4.7 m from the mast. The temperature and the air pressure sensor are mounted on the meteorological mast at a height of 70 m.

6.2 Accuwind project

The Accuwind project is a European project that is in addition partially financed by Novem under assignment of the minister of Economic Affairs under the program Renewable Energy in the Netherlands. The objective of the ACCUWIND project is to provide accurate wind speed measurements using cup and sonic anemometers. Part of the objective is to improve tools and methods to assess the accuracy of cup and sonic anemometers in wind energy measurements by development and implementation of procedures for calibration, field comparison, benchmark tests and classification. Another part of the objective is to define measured wind speed for power performance measurements in a consistent way, so that uncertainties of wind speed sensors can be reduced. The objectives of the project are organised in three work packages:

- to improve tools and methods to assess the accuracy of cup anemometers in wind energy measurements;
- to assess the accuracy of sonic anemometers in wind energy measurements;
- to define the measured wind speed for power performance measurements.

In the Accuwind project the flow distortion effects of the meteorological mast are characterised. Next to the meteorological mast 1 a 25m mast was installed in order to characterise the effects of the mast on the wind speed measurements by cup anemometers on the 6,5m long booms of the mast. In addition, at 25m a standard boom of 6,5m was installed in meteorological mast 1. The two cup-anemometers in top of the 25m mast were placed at a distance of 4.5m and 7.5m from the cup-anemometer in the boom. This way, the flow disturbance of the mast could be assessed.

6.2.1 The 25m mast – experimental set-up in June/July 2004

The 25m mast is located next to the 108m high mast at a distance of 10.7m from the heart of the mast. In the top of the 25m mast, a boom is installed in which two Risø cup anemometers are placed (see Figure 6-4, without the sonic anemometer that was added later). These anemometers are placed at a distance of 3m and 6m from the cup-anemometer in the boom of the 108m high mast. The top view is presented in Figure 6-2, where also the directions of the equipment are presented with respect to North. The cup anemometers are placed at 26.6m height, the wind vane is placed at 25.8m height. With this set-up, the influence of the mast on the wind speed measurements is characterised. During a fierce storm front on July 17th, the 25m mast collapsed. The mast was erected again in October 2004 with different location and an additional sensor. This is described in the next section.

Figure 6-1. A small 25m high mast was installed next to the 108m high meteorological mast 1 at EWTW in order to assess the influence of the mast on the wind speed measurements.

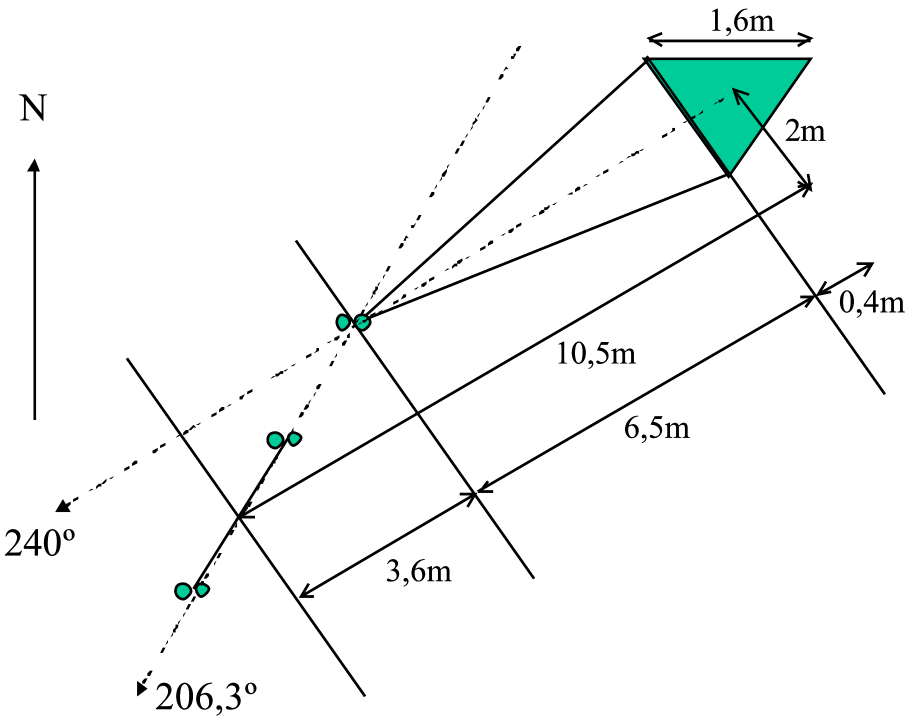


Figure 6-2. Overview of experimental set-up (top view) with corresponding distances and angles with respect to North.

6.2.2 The 25m mast – experimental set-up from October 2004

In October the 25m mast is erected again with different set-up. The 25m mast is located next to the 108m high mast at a distance of 12.9m from the heart of the mast (see Figure 6-3). In the top of the 25m mast, a boom is installed in which two Risø cup anemometers are placed (see Figure 6-4). These anemometers are placed at a distance of 4.5m and 7.5m from the cup-anemometer in the boom of the 108m high mast. The top view is presented in Figure 6-5, where also the directions of the equipment are presented with respect to North. With this set-up, the influence of the mast on the wind speed measurements is characterised. In addition to the two cup anemometers, a 2D sonic anemometer is placed on top of the 25m mast (see Figure 6-4). The measurements of this sonic anemometer are also included in the EWTWM database. The cup anemometers and sonic anemometer are placed at 26.6m height, the wind vane is placed at 25.8m height.

Figure 6-3. A 25m high mast was installed next to the 108m high meteorological mast 1 at EWTW. The objective of the experiment is to determine the flow disturbance of the mast on the wind speed measurements and to characterise the 2D sonic anemometer.

Part of the project was an investigation of the accuracy of the DANTE acquisition modules for cup anemometers. To investigate this, in parallel to the DANTE modules, pulse count modules have been installed. The pulse count module is only capable to determine the average wind speed. Other statistics cannot be determined. A more advanced module to measure the cup-anemometers is under development. The result of the exercise is that the DANTE modules are within specifications.

Figure 6-4. Side view of mounting of sensors on 25m mast.

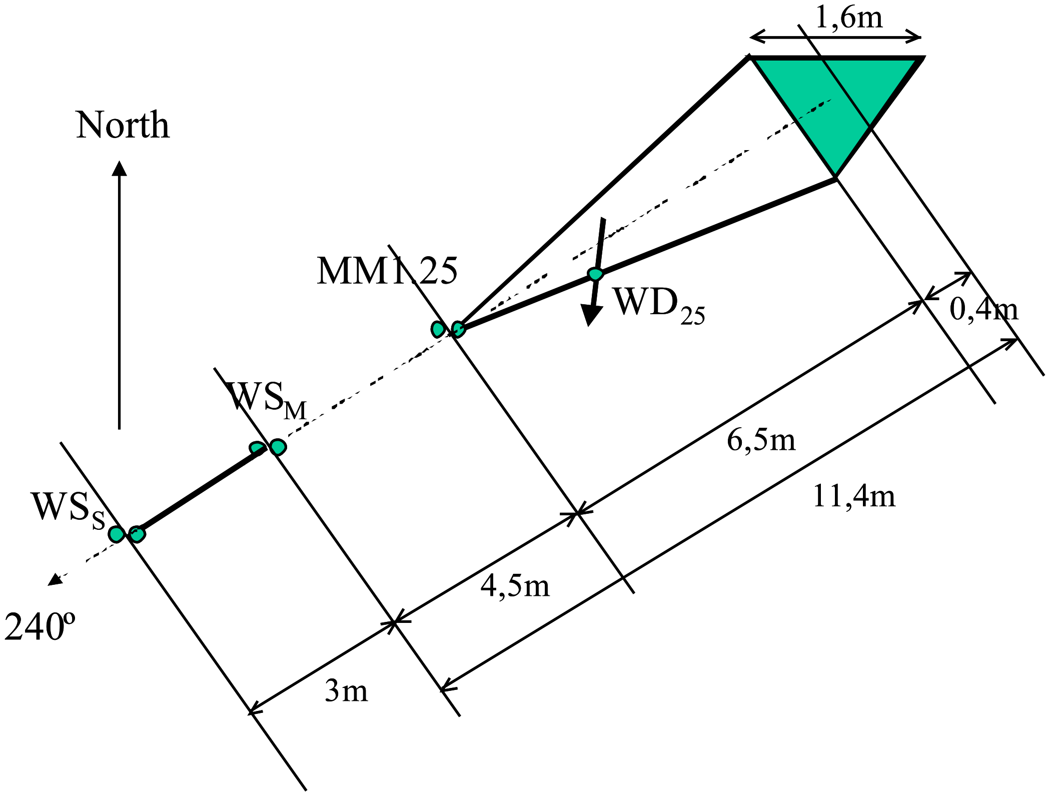


Figure 6-5. Schematic overview of the experimental set-up (top view) with corresponding distances and angles with respect to North. This anemometer determines wind speeds in the sectors 120º-180º and 300º-360º.

6.2.3 Instrumentation and data acquisition (from October 2004)

Table 6-2 presents type, number and calibration parameters of the three Risø cup-anemometers. The gain and offset determined by wind tunnel calibration are presented as well as the gains and offsets used in the data acquisition modules. Note that D indicates the Dante module and P indicates the Pulse counter module (see Table 6-1). Both the measurements with the DANTE modules as the Pulse counter are added to the EWTWM database.

Table 6-1. Type of data acquisition for the various signals.

Signal	Converter	Comment
m25_ws25_s	**D**ante 5B	Dante module – S-cup in 25m mast
m25_ws25_s_pulsecount_to_ws	**P**ulse counter	Pulse counter – S-cup in 25m mast
m25_ws25_m	Dante 5B	Dante module – M-cup in 25m mast
m25_ws25_m_pulsecount_to_ws	**P**ulse Counter	Pulse counter – M-cup in 25m mast
mm1_ws25_240	Dante 5B	Dante module – cup at 25m in MM1
mm1_ws25_240_pulsecount_to_ws	**P**ulse Counter	Pulse counter – cup at 25m in MM1

Table 6-2. Type, number and calibration parameters of the three Risø cup-anemometers under investigation.

Signal	**mm1_ws25_240**	**mm1_ws25_240_pulsecount_to_ws**
Sensor No	*725*	
Gain	0.6229	
Offset	0.254	
Module No	*751*	*971*
Type	Analogue 0..100Hz	Digital Counter
Gain	0.024413	1
Offset	0.137663	0

Signal	**m25_ws25_m**	**m25_ws25_m_pulsecount_to_ws**
Sensor No	*889*	
Gain	0.6231	
Offset	0.22	
Module No	*911*	*833*
Type	Analogue 0..100Hz	Digital Counter
Gain	0.024395	1
Offset	0.163312	0

Signal	**m25_ws25_s**	**m25_ws25_s_pulsecount_to_ws**
Sensor No	*888*	
Gain	0.62124	
Offset	0.226	
Module No	*912*	*970*
Type	Analogue 0..100Hz	Digital Counter
Gain	0.024408	1
Offset	-0.00407	0

6.3 GE2.5 project

ECN performs measurements on the GE 2.5 MW prototype turbine, erected at prototype location #2 at the EWTW. In the measuring period, roughly running from July 2004 until the end of 2005, the following measurements are performed:

- Power performance measurements
- Mechanical load measurements
- Acoustic Noise measurements
- Power Quality measurements

For this project, additional booms are applied to the meteorological mast 1 at 83.4m height. In these booms, Risø cup anemometers are placed and Mierij wind vanes.

Table 6-3. Instrumentation in meteorological mast 1 used in the GE2.5 campaign.

Signal Name	label	units	location	brand	Sensor type
Gill wind speed U, V, W	MM1_S108	m/s	109.1m	GILL	1086 M
Wind speed 85 N	MM1_WS85_0(_P)	m/s	85m	Risø	P2456a
Wind speed 85 SE	MM1_WS85_120(_P)	m/s	85m	Risø	P2456a
Wind speed 85 SW	MM1_WS85_240(_P)	m/s	85m	Risø	P2456a
Wind direction 85 SE	MM1_WD85_120	º	84.2m	Mierij	508
Wind direction 85 SW	MM1_WD85_240	º	84.2m	Mierij	508
Air temperature 85 m	MM1_Tair85	ºC	83.4m	Rense	XT-730-01
Air pressure 85 m	MM1_Pair85	hPa	83.4m	Vaisela	PTB 210 Class B
Wind speed 70 N	MM1_WS70_0(_P)	m/s	71.6m	Risø	P2456a
Wind speed 70 SE	MM1_WS70_120(_P)	m/s	71.6m	Risø	P2456a
Wind speed 70 SW	MM1_WS70_240(_P)	m/s	71.6m	Risø	P2456a
Wind direction 70 SE	MM1_WD70_120	º	70.8m	Mierij	508
Wind direction 70 SW	MM1_WD70_240	º	70.8m	Mierij	508
Air temperature 70 m	MM1_Tair70	ºC	70m	Rense	XT-730-01
Air pressure 70 m	MM1_Pair70	hPa	70m	Vaisela	PTB 210 Class B
Precipitation	MM1_Prec		2m	Thies	5.4103.10.00
Wind speed 45m SW	MM1_WS45_240	m/s	46.6m	Risø	P2456a
Wind speed 25m SW	MM1_WS25_240	m/s	26.6m	Risø	P2456a
Wind direction 25m SW	MM1_WD25_120	º	25.8m	Mierij	508
Wind direction 108 m	MM1_S108	º	109.1m	GILL	1086 M
Air temperature 3 m	MM1_Tair3	ºC	3m	Rense	XT-730-01

6.4 LTVM project

The project "Validatie metingen EWTW" is financed by Senter/Novem, and is carried out in the period from 1-10-2004 till 1-10-2006. The abbreviation LTVM originates from Long Term Validation Measurements. The main objective of the project is to perform measurements and to collect data so that the following items can be analysed later on:

- characterization of the wake of a wind turbine farm
- assessment of the effects of the wake on loads and performances
- determination of the extreme loads for fatigue analysis

The measurement plan for the ltvm project gives a detailed description of the experiment [8]. The experiment started with the erection of meteorological mast 3. At two heights, tri-angular booms have been mounted to this meteorological mast in three directions. The mounting heights of these booms are 50.4m and 78.4m. The cup anemometers are mounted at 1.6m above these booms, so the measuring heights for the wind speed are 52 an 80m. The booms have a length of 6.5m, from the centre of the cup anemometer to the middle line between the two legs of the meteorological mast.

6.4.1 Signals measured in Meteorological mast 3

The signals measured in meteorological mast 3 are presented in Table 6-4. The table includes the sensor brand and type, and the location of the sensor in the mast.

Table 6-4. Signals measured in meteorological mast 3.

Signal Name	label	units	location	brand	Sensor type
Wind speed SE 52 m	MM3_WS52_120	m/s	52m	Riso	P2456a
Wind speed SW 52 m	MM3_WS52_240	m/s	52m	Riso	P2456a
Wind speed N-U 52 m	MM3_S52N_U	m/s	52m	Gill	1086 M
Wind speed N-V 52 m	MM3_S52N_V	m/s	52m	"	"
Wind speed N-W 52 m	MM3_S52N_W	m/s	52m	"	"
Status Gill 52 m N	MM3_S52N_St	-	52m	"	"
Wind direction SE 52 m	MM3_WD52_120	deg	51.2m	Friedrichs	4123.0000X
Wind direction SW 52 m	MM3_WD52_240	deg	51.2m	Friedrichs	4123.0000X
Wind speed SE 80 m	MM3_WS80_120	m/s	80m	Riso	P2456a
Wind speed SW 80 m	MM3_WS80_240	m/s	80m	Riso	P2456a
Wind speed N-U 80 m	MM3_S80N_U	m/s	80m	Gill	1086 M
Wind speed N-V 80 m	MM3_S80N_V	m/s	80m	"	"
Wind speed N-W 80 m	MM3_S80N_W	m/s	80m	"	"
Status Gill 80 m N	MM3_S80N_St	-	80m	"	"
Air temperature 80 m	MM3_Tair80	ºC	78.4m	Vaisala	HMP45A
Air humidity 80 m	MM3_RH80	%	78.4m	Vaisala	HMP45A
Air pressure 80 m	MM3_Pair80	hPa	78.4m	Vaisala	PTB 210 Class B
Wind direction SE 80 m	MM3_WD80_120	deg	79.2m	Friedrichs	4123.0000X
Wind direction SW 80 m	MM3_WD80_120	deg	79.2m	Friedrichs	4123.0000X
Wind speed U 108 m	MM3_S108_U	m/s	109.1m	Gill	1086 M
Wind speed V 108 m	MM3_S108_V	m/s	109.1m	"	"
Wind speed W 108 m	MM3_S108_W	m/s	109.1m	"	"
Status Gill 108 m	MM3_S108_St	-	109.1m	"	"
Temperature difference	MM3_dT	ºC	--	Rense	

The **Gill sonic anemometer** mounted at the top of the mast is mounted on the East leg of the mast. On the West leg of the mast, the air-traffic warning light is mounted, and on the South leg of the mast, the lightning conductor is mounted. The middle point of the Gill sonic anemometer is at a height of 1.15 m above the mast. This means that the actual height of the sonic anemometer is 109.15m.
On the North booms at 50.5 and 78.5m **Gill sonic anemometers** are mounted. These sensors are located at the tip of the boom. The distance from the sensor to the mast is 6.5 m. At 22.6 cm from the sonic anemometer, in the direction of the mast, a lightning conductor is mounted. The lightning conductor is that long that it covers the cup for lightning with a protection angle of 60 degrees. The middle point of the Gill sonic anemometer is at a height of 1.5m above the booms, so the actual measuring heights of the boom mounted Gills are 52 and 80 m.

On the end tip of the booms pointing at 120 degrees (South-East) and 240 degrees (South-West), **Risø cup anemometers** are mounted. The distance between the cup anemometer and the mast is 6.5 m. At 22.6 cm from the centre of the cup anemometer, in the direction of the mast, a lightning rod is mounted. The lightning conductor is that long that it covers the cup for lightning with a protection angle of 60 degrees. The middle point of the Risø cup anemometers are at a height of 1.5m above the booms, so the actual measuring heights of the Risø cups are 52 and 80 degrees.

On the South-East and South-West booms at 50.5 and 78.5 m, **Friedrichs wind direction** sensors are mounted. They are attached to the boom at a distance of 4.7m from the mast and at 1.8m from the boom tip end (cup anemometer). The top of the vane is 0.83m above the boom.

In the South-East boom mounted at 78.5 m, a **Vaisala Relative Humidity and Temperature** sensor is mounted at 2m from the mast. In the same boom, a Vaisala Air pressure sensor is mounted at 4m from the mast. The Relative Humidity and Temperature sensor is a combined sensor, mounted in an appropriate sensor hut with radiation shielding. The Air pressure sensor is mounted in a so-called static pressure head, preventing the measured air pressure to be sensitive to wind speed and wind direction.

7. Sensor types and calibration information

The group 'Operation of wind farms and experiments' of ECN Wind Energy is accredited according ISO17025 and the experiments are carried out according the requirements. As a result, the sensors require regular calibration and during the measurement campaign sensors may be replaced by recently calibrated ones. This is stored in the instruments administration system, called "Aeolus". The procedures necessary for instrument calibration, use and maintenance are included in the relevant quality management system [5]. In addition, the database keeps track of the sensor types and identification. The information is stored in the metadata table.

The database contains all information regarding the instrumentation. The data is stored by DANTE in config files. These files are read in the database and stored in accessible format in the table 'metadata'. A typical query to access the metadata is

```
select * from metadata where v=219 order by t;
```

The metadata types are presented in Table 7-1.

Table 7-1. Metadata types used in the EWTWM database (select * from metadatatype;)

id	name	type	comment
1	dante_config	text	Verbatim DANTE configuration line
2	Phase	int2	Current phase of the campaign
3	Unit	text	Unit of measurement of the channel
4	LowLimit	real	Low limit of the signal
5	HighLimit	real	High limit of the signal
6	FilterType	int	Type filter applied to the signal
7	ResampleType	int	Type of resampling applied to the signal
8	AveragingType	int	Type of averaging applied to the signal
9	Sensor	int	Identification of sensor
10	SensorGain	real	Gain of sensor
11	SensorOffset	real	Offset of sensor
12	CalibrationDate	timestamptz	Time of sensor calibration
13	Technician	text	Technician changing calibration
14	ModuleType	int	Type of module (in DANTE)
15	ModuleID	int	Identification of module (in DANTE)
16	ModuleGain	real	Gain of module (in DANTE)
17	ModuleOffset	real	Offset of module (in DANTE)
18	Scanrate	int	Scan rate of signal
19	FEChannel	int	Channel number of signal in frontend
20	FrontendName	text	Name of frontend where signal is measured
21	FESignalName	text	Name of signal in frontend
22	dante_val	int4	Binary validation flags from DANTE

8. References

[1] E.J. Werkhoven, ECN Data-acquisitie systeem "DANTE"; Validatie testen, ECN-Wind Memo-03-033, Oktober 2003.

[2] PTB210 Series Digital Barometers with Serial output; User's Guide, VAISALA; U344EN-1.1, December 1999.

[3] IEA Recommended Practices for Wind Turbine Testing and Evaluation; No 11: Wind Speed Measurement and use of cup anemometry, 1. Edition 1999.

[4] Standard IEC 61400-12 and IEC 61400-121 CDV Power performance measurements of grid connected wind turbines.

[5] Gestandaardiseerde metingen aan windturbines; ECN Windenergie, documents being part of the quality system for standardised measurements at wind turbines, ECN-WIND MEMO-03-006.

[6] A.P.W.M. Curvers, P.J. Eecen, H. Korterink, M. de Noord, P.A. van der Werff, Meteorological Mast I At The ECN Wind Turbine Test Station Wieringermeer; Description and evaluation of first results, ECN-CX--04-097

[7] P.J. Eecen, P.A. van der Werff, 'EWTW – Influence of mast on wind speed measurements: Preliminary results', ECN-CX--05-025

[8] H. Korterink, Meetplan voor project 7.4347 Validatiemetingen EWTW, ECN-Wind Memo-04-021

[9] P.J. Eecen, M. de Noord, Uncertainties in Cup Anemometer Calibrations: Type A and Type B uncertainties, ECN-C--05-066

Appendix A Available data in 2003-2004 (monthly percentages)

	jun-03	jul-03	aug-03	sep-03	okt-03	nov-03	dec-03	jan-04	feb-04	mrt-04	apr-04	mei-04
m25_vais_wr												
m25_vais_ws												
m25_ws25_m												
m25_ws25_m_pulsecount_to												
m25_ws25_s												
m25_ws25_s_pulsecount_to_ws												
mm1_pair70	2	97	95	97	87	100	87	71	73	80	98	67
mm1_pair85												
mm1_prec	2	97	95	97	87	100	88	71	73	80	98	67
mm1_s108_u												
mm1_s108_v3d												
mm1_s108_v												
mm1_s108_vdir												
mm1_s108_vhor												
mm1_s108_w												
mm1_tair3												
mm1_tair70	2	97	95	97	87	100	88	71	73	33	50	67
mm1_tair85												
mm1_wd25_240												
mm1_wd70_120	2	94	92	96	87	100	88	71	73	80	98	67
mm1_wd70_240	2	94	92	96	87	100	88	71	73	80	98	67
mm1_wd85_120												
mm1_wd85_240												
mm1_ws25_240												
mm1_ws25_240_pulsecount_to_ws												
mm1_ws45_240												
mm1_ws70_0	2	97	95	97	87	100	88	71	73	80	98	67
mm1_ws70_120	2	97	95	97	87	100	88	71	73	80	98	67
mm1_ws70_240	2	97	95	97	87	100	88	71	73	80	98	67
mm1_ws85_0												
mm1_ws85_0_p												
mm1_ws85_120												
mm1_ws85_120_p												
mm1_ws85_240												
mm1_ws85_240_p												
mm3_pair80												
mm3_rh80												
mm3_s108_v3d												
mm3_s108_vdir												
mm3_s108_vhor												
mm3_s52n_v3d												
mm3_s52n_vdir												
mm3_s52n_vhor												
mm3_s80n_v3d												
mm3_s80n_vdir												
mm3_s80n_vhor												
mm3_tair80												
mm3_wd52_120												
mm3_wd52_240												
mm3_wd80_120												
mm3_wd80_240												
mm3_ws52_120												
mm3_ws52_240												
mm3_ws80_120												
mm3_ws80_240												

Appendix B Available data in 2004-2005 (monthly percentages)

	jun-04	jul-04	aug-04	sep-04	okt-04	nov-04	dec-04	jan-05	feb-05	mrt-05	apr-05	mei-05
m25_vais_wr					10	89	95	96	98	99	95	98
m25_vais_ws					11	89	95	96	70	99	95	100
m25_ws25_m	1	46			11	89	95	99	98	100	96	100
m25_ws25_m_pulsecount_to								79	98	100	96	100
m25_ws25_s	1	46			11	89	95	99	98	100	96	100
m25_ws25_s_pulsecount_to_ws								79	98	100	96	100
mm1_pair70	10	71	83	65	100	89	95	96	97	99	93	100
mm1_pair85			56	65	100	89	95	96	97	99	96	100
mm1_prec	10	45	65	65	100	89	57	99	97	99	96	100
mm1_s108_u			27	60	94	80	90	97	96	97	94	98
mm1_s108_v3d			18	60	94	77	90	97	95	97	94	98
mm1_s108_v			19	61	94	77	90	97	95	97	94	98
mm1_s108_vdir			18	60	94	77	89	97	95	97	94	98
mm1_s108_vhor			18	60	94	77	90	97	95	97	94	98
mm1_s108_w			31	61	94	82	90	98	96	98	94	99
mm1_tair3	1	54	71	91	99	89	61	99	98	100	96	100
mm1_tair70	10	71	83	65	100	89	95	94			35	100
mm1_tair85			56	65	100	68	76	99	86	99	96	100
mm1_wd25_240	1	91	98	91	81		21	53	98	100	96	100
mm1_wd70_120	10	69	83	65	100	89	95	99	97	99	95	100
mm1_wd70_240	10	90	83	65	100	89	95	99	97	99	95	100
mm1_wd85_120			52	55	98	89	95	99	90	99	96	100
mm1_wd85_240			56	65	100	89	95	99	91	99	96	100
mm1_ws25_240	1	91	98	91	99	88	95	99	98	100	93	100
mm1_ws25_240_pulsecount_to_ws								79	98	100	93	100
mm1_ws45_240	1	91	98	91	99	88	95	99	98	100	93	100
mm1_ws70_0	10	90	83	65	100	88	94	99	97	99	93	100
mm1_ws70_120	10	90	83	65	100	88	95	99	97	99	95	100
mm1_ws70_240	10	90	83	65	100	88	94	99	97	99	95	100
mm1_ws85_0			56	65	100	89	4					
mm1_ws85_0_p								66	98	100	65	63
mm1_ws85_120			56	65	100	89	4					
mm1_ws85_120_p								66	98	100	96	100
mm1_ws85_240			26	55	100	89	4					
mm1_ws85_240_p								66	98	100	96	100
mm3_pair80							72	99	98	100	96	100
mm3_rh80							72	99	98	100	96	100
mm3_s108_v3d							51	23	22	34	39	29
mm3_s108_vdir							70	98	57	98	95	98
mm3_s108_vhor							70	98	58	98	95	99
mm3_s52n_v3d							72	39	30	33	42	30
mm3_s52n_vdir							72	99	97	100	96	99
mm3_s52n_vhor							72	99	97	100	96	100
mm3_s80n_v3d							72	41	32	35	44	32
mm3_s80n_vdir							72	99	98	99	96	99
mm3_s80n_vhor							72	99	98	100	96	100
mm3_tair80							72	99	98	100	96	100
mm3_wd52_120							72	99	98	100	96	99
mm3_wd52_240							72	99	98	99	94	100
mm3_wd80_120							72	99	98	100	96	99
mm3_wd80_240							72	99	98	100	96	99
mm3_ws52_120							72	99	98	100	96	100
mm3_ws52_240							72	99	98	100	96	100
mm3_ws80_120							72	99	98	100	96	100
mm3_ws80_240							72	99	98	100	96	100

Appendix C Functions in the EWTWM database

For many purposes, the wind speed should be determined as good as possible and as often possible. For example for resource assessment, the amount of data is critical. For these purposes, a wind speed is defined that is as good as possible given the measured data. It should be noted that for purposes where the accuracy outweighs the amount of data, the measurements of the individual instruments are preferred. The definitions of overall wind speed (WS) and overall wind direction (WD) are described below.

C.1 Overall wind direction

The overall wind direction is determined by first using the wind vanes and if these are not available, the sonic anemometer. In both masts, there are two vanes at each level in directions SE and SW. In mast 3 there are additional sonic anemometers in the North boom. The direction is determined as follows: When both vanes have valid values, the average wind direction of these vanes is taken. This averages out the influence of the flow distortion (in the order of 2 degrees) of the mast. Note that the influence of the wake of the mast is small compared to the flow distortion effect. If only one of the vanes has valid output, this vane is selected. If both vanes are not valid, the valid sonic direction is taken. If there is no valid wind direction measurements, the measurement is identified as non-valid. The minimum, maximum and standard deviation of the wind direction are determined by selection of a vane in the undisturbed sector if available. Otherwise the other vane is preferred and if both vanes are not available, the values of the sonic are used. In mast 1, where no sonic anemometers are available, when both vanes are unavailable the measurement is identified as non-valid.

C.2 Overall wind speed

When the wind direction has been determined, the wind speed can be determined. When the wind direction is from the West, the cup anemometer in the SW boom is selected (if valid). When the wind direction is East, the cup anemometer in the SE boom is selected (if valid). If the preferred cup anemometer is not valid, the other is used (if valid) or the sonic anemometer (if installed). The same rule applies to average, minimum, maximum and standard deviation. If the wind direction is not available, the cup anemometer in the main wind direction (SW) is selected first, then the other cup anemometer (SE) and if these are unavailable, the sonic anemometer is selected (if installed).

C.3 Use of the function

The statistics of overall wind direction must be defined as variables by creating separate filters. These variables can then be selected via a selection query on the view *crosstable*. In this query the overall wind speed can also be obtained by functions directly applicable in the selection query.

Table 8-1. Added functions to the EWTWM database

overall_wd_wavg	to create filters for wavg	
overall_wd_stats	to create filters for wstddev,wmin,wmax	
ws_mm1_select()	to select overall windspeed for MM1 in the user	selection query
ws_mm3_select()	to select overall windspeed for MM3 in the user	selection query

Example of the creation of a filter for overall wind direction average:
select create_filter('MM1_WD70_overall_wavg,2,'overall_wd_wavg','{MM1_WD70_120, MM1_WD70_240}','1,70');

with:

'MM1_WD70_overall_wavg' 2	the name of the filter the caching policy (2 = cached)
'overall_wd'	the function to be used for wavg
'{MM1_WD70_120,MM1_WD70_240}'	the source signals[1]
'1,70'	the number of the meteo mast and the height

Example of the creation of a filter for the other overall wind direction statistics:
select create_filter('MM1_WD70_overall_wstddev,2,'overall_wd_stats', '{MM1_WD70_120, MM1_WD70_240}', '1,70,wstddev');

with:

'overall_stats'	the function to be used for wstddev, max, min
'1,70,wstddev'	the number of the meteo mast, the height and the statistics type

The user can select the overall wind speed statistics at the desired height by using the following function in the selection query on the view crosstable for meteo mast 1:
ws_mm1_select(overall_wavg, ws_0,ws_120, ws_240)

with:

overall_wavg	the overall average wind direction at desired height
ws_0	the cup wind avg,stddev,max,min from the boom at 0 degrees
ws_120	the cup wind avg,stddev,max,min from the boom at 120 degr.
ws_240	the cup wind avg,stddev,max,min from the boom at 240 degr.

For meteo mast 3 the function is defined as:
ws_mm3_select(overall_wavg, ws_120,ws_240, ws_N)

with:

overall_wavg	the overall average wind direction at desired height
ws_120	the cup wind avg,stddev,max,min from the boom at 120 degr
ws_240	the cup wind avg,stddev,max,min from the boom at 120 degr
ws_N	the sonic wind avg,stddev,max,min from the boom at 0 degr

Example for a complete selection query for overall avg wind direction and overall wavg wind speed for MM3 at height 80:
select t_0, MM3_WD80_overall_wavg, ws_mm3_select(MM3_WD80_overall_wavg, MM3_WS80_120_avg, MM3_WS80_240_avg, MM3_S80N_vhor_avg) from crosstable;

The same syntax can be used to select the other statistics, below shown for overall min wind direction and overall wavg wind speed for MM3 at height 80:

select t_0, ws_mm1_select(MM1_WD85_overall_wavg, MM1_WS85_0_min, MM1_WS85_120_min, MM1_WS85_240_min) from crosstable;

[1] Note that it is not necessary to provide the source signals, however the create_filter function requires a non-empty field as sources list.