ECN
Energy research Centre of the Netherlands

EWTW Meteorological database

Description June 2003 - May 2007

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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 three 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. Meteorological data needs not to be treated as confidential; therefore, this database does not contain any 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 reduced in sample rate compared to the data acquisition in the projects, which might be higher.

The first meteorological mast at EWTW (MM1) is installed in March 2003 and is operational since June 2003. The second meteorological mast (MM3) 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. In 2005, the second mast near the prototype locations is erected (MM2). Data from this mast are measured since October 2005. 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.

Contents

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) [1]. This test station has been developed because the existing test site for commercial wind turbines at the Petten location was 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 Noord-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.
- A measurement pavilion with offices and computer centre for the measurements.

The first meteorological mast (MM1) has been installed March 2003 and is in operation since June 2003. The collected data are used for the evaluation of two prototype wind turbines: NM92 (DOWEC) and the GE 2.5. The second meteorological mast (MM2) has been installed in the summer of 2005 and is in operation since October 2005. The collected data are used for the evaluation of two prototype wind turbines: GE 2.3 and the Siemens 3.6. The third meteorological mast (MM3), 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 since that time. 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 non-confidential 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 [1]. 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 primarily 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 sampled down.

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 four years, June 2003 to May 2007. Earlier reports describe the first two years [2a] or the first three years [2b].

The report is organised as follows:

- Chapter 2. The site EWTW is described. Locations of turbines and masts are presented. A climatologically description of the site is given.
- Chapter 3. The meteorological masts 1, 2 and 3 are technically described.
- Chapter 4. The instrumentation is described for the status in summer 2006.
- Chapter 6. The masts have been used for several research projects, the backgrounds of the measurements projects are presented here.

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, Appendix B for the period June 2004-May 2005, Appendix C for the period June 2005-May 2006 and Appendix D for the period June 2006-May 2007.

2. Site Description EWTW

2.1 General

The meteorological masts 1, 2 and 3 are erected at the EWTW in the Wieringermeer, a polder in the North East of the Province Noord-Holland, 3 km North of the town 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).

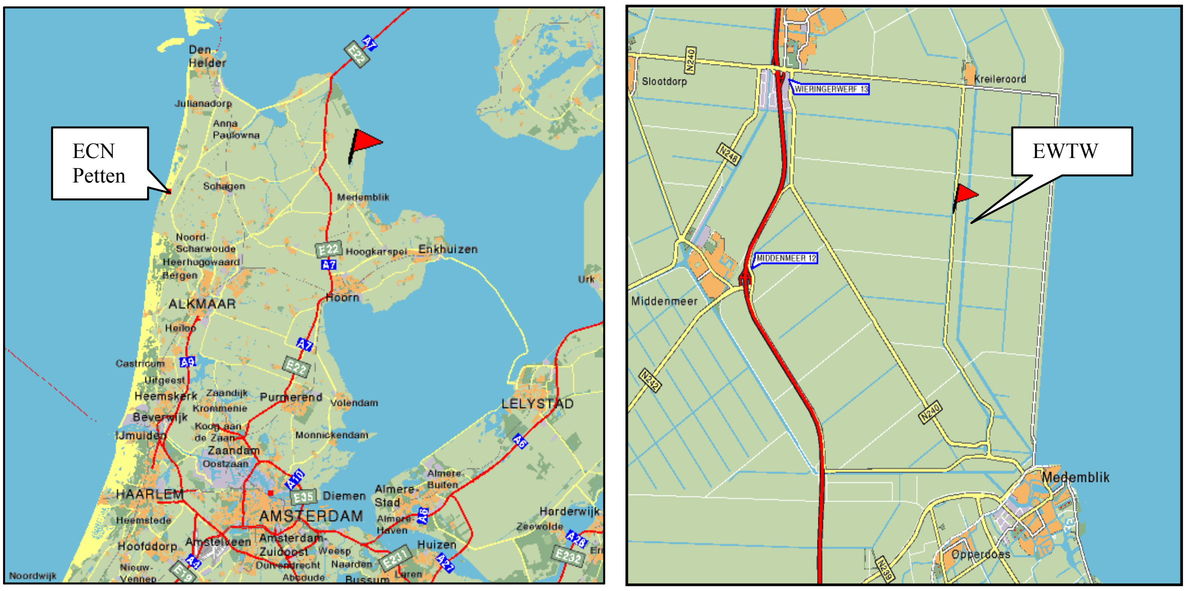

Figure 2.1 Map of the Province Noord-Holland and a detailed map of test site EWTW in the polder of Wieringermeer. ECN Petten at the North Sea coast is also indicated.

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 [3].
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 Appendix E. 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 report 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 2** are farmhouses plus barns, and several surrounding wind turbines. This is shown in Figure 2.2 and presented in Table 2-1 and Table 2-2.

1. The farm houses, in the north, with a height of approximately 5m - 8m, are at a distance of 900m from the meteorological mast 2, and do not influence the measurements. This also counts for the farmhouse plus barn in the south at 800m distance.
2. In the surrounding areas several wind turbines are operating, as indicated in Figure 2.2. Besides some solitary wind turbines three rows of machines can be distinguished: the EWTW Nordex N80 machines 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 2 is 1.5 km as shown in Figure 2.2. The nearest wind turbines (except for the proto-types) are located at a distance of 862m at 167° with respect to North (Lagerwey 52/750) and at a distance of 993m at 127° (Vestas V52).

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.

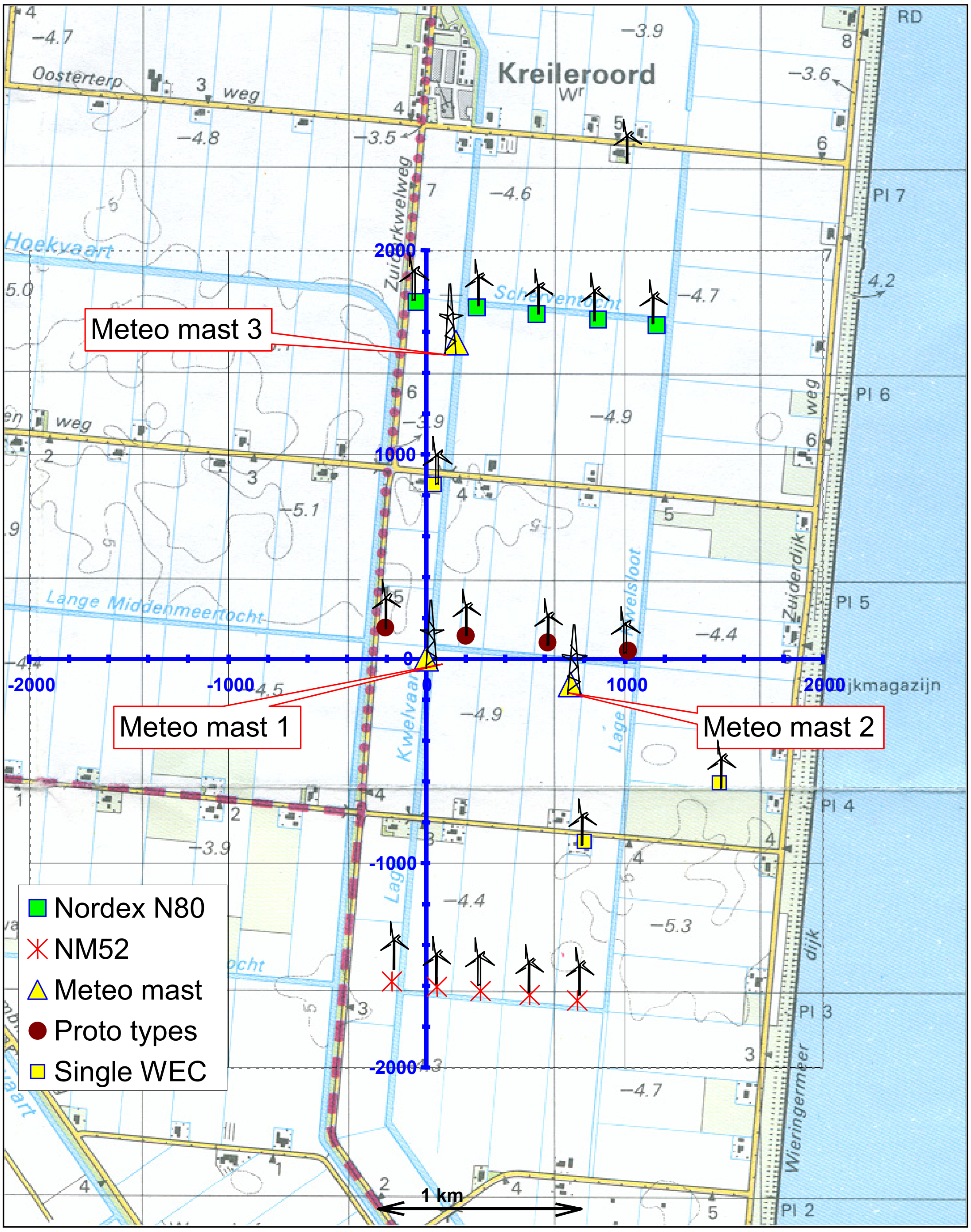

Figure 2.2 Detailed map of the ECN Wind Turbine Test Station Wieringermeer, including the location of surrounding wind turbines and meteorological masts 1, 2 and 3. Directly West of the Zuiderkwelweg the row of trees is located.

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

Distances [m]	Meteomast 1	Meteomast 2	Meteomast 3	NM 2750	GE 2.5	GE 2.3	Siemens	N80_5	N80_6	N80_7	N80_8	N80_9	NM52 900 Schervenweg	NM52 900 W	Vestas V52	LW52 750	NM52 900 South 1	NM52 900 South 2	NM52 900 South 3	NM52 900 South 4	NM52 900 South 5	Vestas V66 1	Vestas V66 2	Vestas V66 3	Vestas V66 4	Vestas V66 5	Vestas V66 6	Vestas V66 7	Vestas V66 8	NM52 900 NW	NM52 900 N
RD coordinates X	134272	135019	134405	134056	134466	134876	135286	134205	134509	134813	135118	135423	134270	132906	135790	135191	134186	134418	134643	134892	135133	132760	132497	132329	132158	131616	131449	131278	131109	133241	135230
RD coordinates Y	536398	536308	537923	536549	536514	536479	536444	538122	538095	538067	538037	538012	537213	537565	535748	535468	534815	534793	534770	534750	534728	541042	541547	541880	542215	543261	543565	543944	544277	539013	538753
Meteomast 1	0	752	1531	264	226	609	1015	1725	1713	1754	1844	1982	815	1797	1651	1307	1585	1612	1670	1761	1879	4884	5446	5816	6189	7359	7703	8118	8490	2811	2543
Meteomast 2	752	0	1728	993	590	223	300	1988	1858	1771	1732	1751	1175	2459	953	857	1710	1630	1583	1563	1584	5245	5814	6187	6563	7741	8088	8503	8877	3237	2454
Meteomast 3	1531	1728	0	1418	1410	1519	1722	282	201	433	722	1022	723	1541	2579	2578	3116	3130	3162	3210	3277	3526	4096	4469	4845	6023	6369	6785	7158	1595	1171
NM 2750	264	993	1418	0	411	823	1234	1580	1611	1696	1828	2002	698	1535	1910	1567	1739	1793	1873	1984	2116	4676	5236	5604	5975	7142	7485	7900	8271	2595	2498
GE 2.5	226	590	1410	411	0	411	823	1629	1582	1591	1657	1778	726	1881	1530	1273	1722	1722	1753	1815	1906	4839	5404	5776	6150	7324	7669	8085	8458	2783	2366
GE 2.3	609	223	1519	823	411	0	411	1775	1657	1589	1577	1628	952	2250	1170	1059	1801	1747	1725	1729	1770	5030	5599	5971	6347	7525	7871	8287	8660	3016	2302
Siemens	1015	300	1722	1234	823	411	0	1996	1825	1691	1602	1574	1274	2631	859	981	1966	1865	1793	1739	1723	5246	5815	6188	6564	7742	8089	8504	8877	3284	2310
N80_5	1725	1988	282	1580	1629	1775	1996	0	305	610	917	1223	911	1413	2854	2831	3307	3336	3380	3441	3519	3258	3827	4200	4576	5754	6101	6516	6890	1313	1204
N80_6	1713	1858	201	1611	1582	1657	1825	305	0	305	612	918	914	1688	2674	2714	3296	3303	3328	3367	3424	3427	3996	4368	4744	5921	6268	6682	7055	1565	976
N80_7	1754	1771	433	1696	1591	1589	1691	610	305	0	306	612	1012	1972	2516	2626	3312	3298	3301	3318	3354	3615	4180	4551	4925	6099	6446	6858	7231	1835	803
N80_8	1844	1732	722	1828	1657	1577	1602	917	612	306	0	306	1182	2262	2386	2570	3354	3319	3301	3295	3309	3820	4381	4748	5120	6289	6635	7045	7417	2116	725
N80_9	1982	1751	1022	2002	1778	1628	1574	1223	918	612	306	0	1403	2556	2294	2555	3428	3372	3335	3305	3297	4034	4589	4953	5322	6484	6829	7237	7607	2401	766
NM52 900 Schervenweg	815	1175	723	698	726	952	1274	911	914	1012	1182	1403	0	1409	2111	1973	2399	2425	2471	2540	2631	4116	4683	5055	5430	6605	6950	7366	7739	2073	1815
NM52 900 W	1797	2459	1541	1535	1881	2250	2631	1413	1688	1972	2262	2556	1409	0	3409	3101	3033	3158	3291	3445	3607	3480	4003	4353	4710	5840	6174	6583	6948	1486	2610
Vestas V52	1651	953	2579	1910	1530	1170	859	2854	2674	2516	2386	2294	2111	3409	0	661	1856	1672	1507	1343	1213	6100	6669	7041	7417	8595	8941	9356	9729	4142	3057
LW52 750	1307	857	2578	1567	1273	1059	981	2831	2714	2626	2570	2555	1973	3101	661	0	1199	1026	887	778	742	6081	6649	7022	7397	8574	8920	9336	9709	4046	3286
NM52 900 South 1	1585	1710	3116	1739	1722	1801	1966	3307	3296	3312	3354	3428	2399	3033	1856	1199	0	233	459	709	951	6388	6941	7305	7673	8828	9168	9581	9950	4303	4074
NM52 900 South 2	1612	1630	3130	1793	1722	1747	1865	3336	3303	3298	3319	3372	2425	3158	1672	1026	233	0	226	476	718	6465	7022	7388	7758	8920	9261	9675	10045	4381	4043
NM52 900 South 3	1670	1583	3162	1873	1753	1725	1793	3380	3328	3301	3301	3335	2471	3291	1507	887	459	226	0	250	492	6549	7109	7477	7849	9014	9357	9772	10143	4468	4026
NM52 900 South 4	1761	1563	3210	1984	1815	1729	1739	3441	3367	3318	3295	3305	2540	3445	1343	778	709	476	250	0	242	6643	7207	7577	7950	9120	9464	9879	10251	4571	4018
NM52 900 South 5	1879	1584	3277	2116	1906	1770	1723	3519	3424	3354	3309	3297	2631	3607	1213	742	951	718	492	242	0	6745	7311	7682	8056	9229	9574	9990	10362	4684	4027
Vestas V66 1	4884	5245	3526	4676	4839	5030	5246	3258	3427	3615	3820	4034	4116	3480	6100	6081	6388	6465	6549	6643	6745	0	569	942	1318	2497	2843	3259	3632	2085	3367
Vestas V66 2	5446	5814	4096	5236	5404	5599	5815	3827	3996	4180	4381	4589	4683	4003	6669	6649	6941	7022	7109	7207	7311	569	0	373	749	1927	2274	2689	3063	2641	3908
Vestas V66 3	5816	6187	4469	5604	5776	5971	6188	4200	4368	4551	4748	4953	5055	4353	7041	7022	7305	7388	7477	7577	7682	942	373	0	376	1554	1901	2316	2690	3009	4265
Vestas V66 4	6189	6563	4845	5975	6150	6347	6564	4576	4744	4925	5120	5322	5430	4710	7417	7397	7673	7758	7849	7950	8056	1318	749	376	0	1178	1525	1940	2313	3380	4628
Vestas V66 5	7359	7741	6023	7142	7324	7525	7742	5754	5921	6099	6289	6484	6605	5840	8595	8574	8828	8920	9014	9120	9229	2497	1927	1554	1178	0	347	762	1135	4548	5778
Vestas V66 6	7703	8088	6369	7485	7669	7871	8089	6101	6268	6446	6635	6829	6950	6174	8941	8920	9168	9261	9357	9464	9574	2843	2274	1901	1525	347	0	416	789	4892	6120
Vestas V66 7	8118	8503	6785	7900	8085	8287	8504	6516	6682	6858	7045	7237	7366	6583	9356	9336	9581	9675	9772	9879	9990	3259	2689	2316	1940	762	416	0	373	5307	6524
Vestas V66 8	8490	8877	7158	8271	8458	8660	8877	6890	7055	7231	7417	7607	7739	6948	9729	9709	9950	10045	10143	10251	10362	3632	3063	2690	2313	1135	789	373	0	5679	6892
NM52 900 NW	2811	3237	1595	2595	2783	3016	3284	1313	1565	1835	2116	2401	2073	1486	4142	4046	4303	4381	4468	4571	4684	2085	2641	3009	3380	4548	4892	5307	5679	0	2006
NM52 900 N	2543	2454	1171	2498	2366	2302	2310	1204	976	803	725	766	1815	2610	3057	3286	4074	4043	4026	4018	4027	3367	3908	4265	4628	5778	6120	6524	6892	2006	0

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

	Meteomast 1	Meteomast 2	Meteomast 3	NM 2750	GE 2.5	GE 2.3	Siemens	N80_5	N80_6	N80_7	N80_8	N80_9	NM52 900 Schervenweg	NM52 900 W	Vestas V52	LW52 750	NM52 900 South 1	NM52 900 South 2	NM52 900 South 3	NM52 900 South 4	NM52 900 South 5	Vestas V66 1	Vestas V66 2	Vestas V66 3	Vestas V66 4	Vestas V66 5	Vestas V66 6	Vestas V66 7	Vestas V66 8	NM52 900 NW	NM52 900 N
RD coordinates X	134272	135019	134405	134056	134466	134876	135286	134205	134509	134813	135118	135423	134270	132906	135790	135191	134186	134418	134643	134892	135133	132760	132497	132329	132158	131616	131449	131278	131109	133241	135230
RD coordinates Y	536398	536308	537923	536549	536514	536479	536444	538122	538095	538067	538037	538012	537213	537565	535748	535468	534815	534793	534770	534750	534728	541042	541547	541880	542215	543261	543565	543944	544277	539013	538753
Meteomast 1		97	5	305	59	82	87	358	8	18	27	35	360	311	113	135	183	175	167	159	153	342	341	340	340	339	339	338	338	338	22
Meteomast 2	277		339	284	290	320	63	336	344	353	3	13	320	301	126	168	209	202	194	185	176	334	334	334	334	334	334	334	334	327	5
Meteomast 3	185	159		194	178	162	149	315	31	71	81	85	191	257	148	162	184	180	176	171	167	332	332	332	332	332	332	333	333	313	45
NM 2750	125	104	14		95	95	95	5	16	27	36	43	18	311	115	134	176	168	162	155	149	344	343	342	341	340	340	339	339	342	28
GE 2.5	239	110	358	275		95	95	351	2	13	23	33	344	304	120	145	189	182	174	166	160	339	339	338	338	337	337	337	337	334	19
GE 2.3	262	140	342	275	275		95	338	347	358	9	20	320	299	129	163	203	195	188	179	172	335	335	335	335	334	334	334	334	327	9
Siemens	267	243	329	275	275	275		327	335	344	354	5	307	295	144	186	214	208	201	193	185	331	331	331	332	332	332	332	332	321	359
N80_5	178	156	135	185	171	158	147		95	95	95	95	176	247	146	160	180	176	173	168	165	334	333	333	333	333	333	333	333	313	58
N80_6	188	164	211	196	182	167	155	275		95	95	95	195	252	151	165	186	182	178	173	170	329	330	330	330	331	331	331	331	306	48
N80_7	198	173	251	207	193	178	164	275	275		96	95	212	255	157	172	191	187	183	179	175	325	326	327	327	328	329	329	329	301	31
N80_8	207	183	261	216	203	189	174	275	275	276		95	226	258	164	178	196	192	188	184	180	322	323	324	325	326	326	327	327	297	9
N80_9	215	193	265	223	213	200	185	275	275	275	275		235	260	171	185	201	197	194	189	185	319	320	321	322	324	324	325	325	295	345
NM52 900 Schervenweg	180	140	11	198	164	140	127	356	15	32	46	55		284	134	152	182	177	171	166	161	338	338	337	337	336	336	336	336	330	32
NM52 900 W	131	121	77	131	124	119	115	67	72	75	78	80	104		122	133	155	151	148	145	142	358	354	352	351	347	346	346	345	13	63
Vestas V52	293	306	328	295	300	309	324	326	331	337	344	351	314	302		245	240	235	230	222	213	330	330	331	331	331	331	331	331	322	349
LW52 750	315	348	342	314	325	343	6	340	345	352	358	5	332	313	65		237	229	218	203	184	336	336	336	336	335	335	335	335	331	1
NM52 900 South 1	3	29	4	356	9	23	34	0	6	11	16	21	2	335	60	57		95	96	95	95	347	346	345	345	343	343	342	342	347	15
NM52 900 South 2	355	22	360	348	2	15	28	356	2	7	12	17	357	331	55	49	275		96	95	95	345	344	344	343	342	341	341	341	344	12
NM52 900 South 3	347	14	356	342	354	8	21	353	358	3	8	14	351	328	50	38	276	276		95	95	343	342	342	342	340	340	340	340	342	8
NM52 900 South 4	339	5	351	335	346	359	13	348	353	359	4	9	346	325	42	23	275	275	275		95	341	341	340	340	339	339	339	338	339	5
NM52 900 South 5	333	356	347	329	340	352	5	345	350	355	360	5	341	322	33	4	275	275	275	275		339	339	339	338	338	337	337	337	336	1
Vestas V66 1	162	154	152	164	159	155	151	154	149	145	142	139	158	178	150	156	167	165	163	161	159		332	333	333	333	333	333	333	167	133
Vestas V66 2	161	154	152	163	159	155	151	153	150	146	143	140	158	174	150	156	166	164	162	161	159	152		333	333	333	333	333	333	164	136
Vestas V66 3	160	154	152	162	158	155	151	153	150	147	144	141	157	172	151	156	165	164	162	160	159	153	153		333	333	332	333	333	162	137
Vestas V66 4	160	154	152	161	158	155	152	153	150	147	145	142	157	171	151	156	165	163	162	160	158	153	153	153		333	332	333	333	161	138
Vestas V66 5	159	154	152	160	157	154	152	153	151	148	146	144	156	167	151	155	163	162	160	159	158	153	153	153	153		331	334	333	159	141
Vestas V66 6	159	154	152	160	157	154	152	153	151	149	146	144	156	166	151	155	163	161	160	159	157	153	153	152	152	151		336	334	159	142
Vestas V66 7	158	154	153	159	157	154	152	153	151	149	147	145	156	166	151	155	162	161	160	159	157	153	153	153	153	154	156		333	158	143
Vestas V66 8	158	154	153	159	157	154	152	153	151	149	147	145	156	165	151	155	162	161	160	158	157	153	153	153	153	153	154	153		158	143
NM52 900 NW	158	147	133	162	154	147	141	133	126	121	117	115	150	193	142	151	167	164	162	159	156	347	344	342	341	339	339	338	338		97
NM52 900 N	202	185	225	208	199	189	179	238	228	211	189	165	212	243	169	181	195	192	188	185	181	313	316	317	318	321	322	323	323	277	

2.3 Environmental conditions of test site

2.3.1 Wind regime

The wind regime is shown for the period June 2003-May 2007. The values are calculated using WAsP 8.0 on the basis of the wind speed and direction measurements at 71.6m height. Note that the data are extended using data of 85m height when the equipment was removed from 70m 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]	6.9	7.3	6.8	7.8	7.6	7.4	8.3	9.0	9.7	8.3	6.7	7.3	8.1
k	2.1	2.3	2.1	2.5	2.4	2.7	2.8	2.1	1.9	1.9	1.8	2.0	2.0
U [m/s]	6.1	6.4	6.0	6.9	6.7	6.6	7.4	8.0	8.6	7.4	5.9	6.4	7.2
P [W/m^2]	256	277	243	319	301	264	367	573	769	515	283	305	423
Freq [%]	6	6	6	7	6	5	9	13	14	11	9	8	100

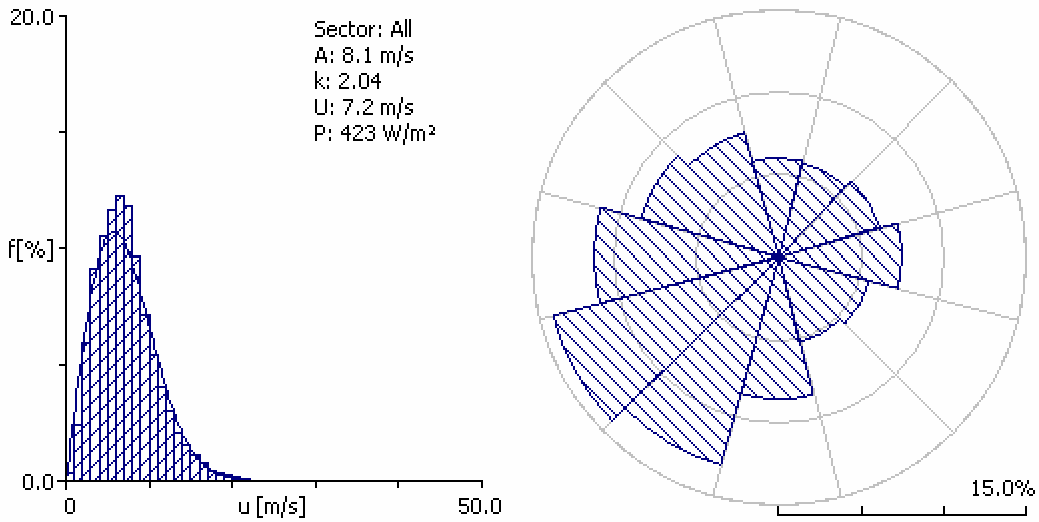

Figure 2.3 Wind rose, at 71.6m height (extended with data of 85m height), of meteorological mast 1 at ECN Wind turbine Test Location Wieringermeer for the period June 2003-May 2007. Note that the sectors 60 and 300 are disturbed by nearby turbines.

2.3.2 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 North-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.

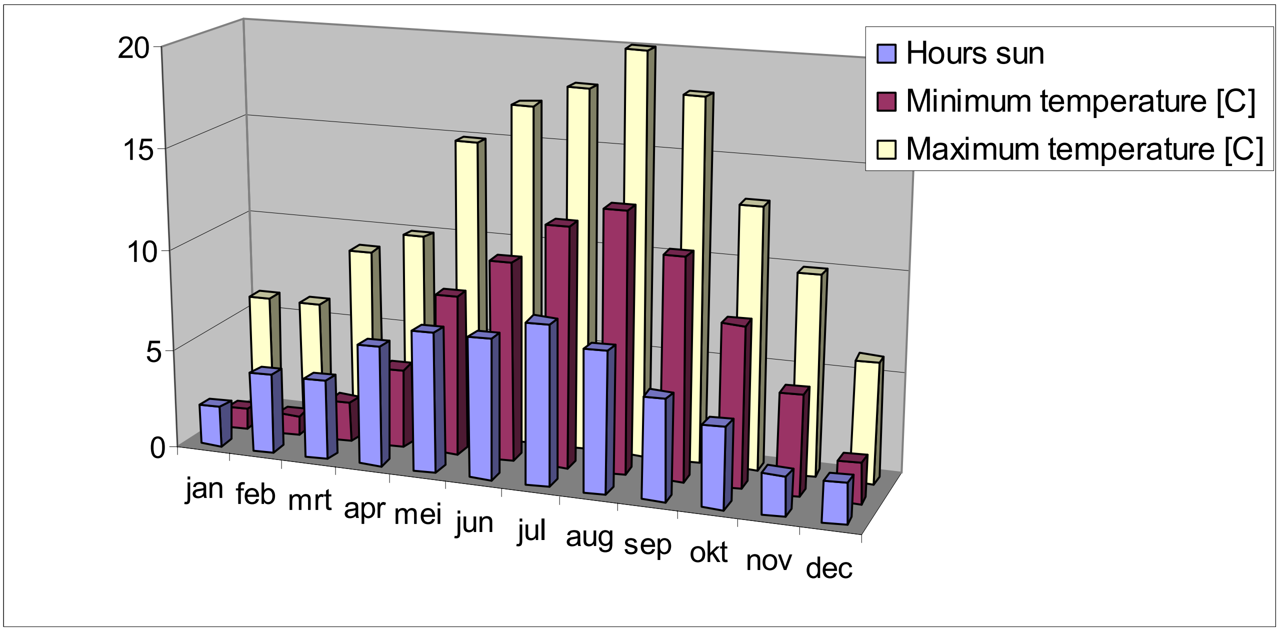

Figure 2.4. Averaged monthly minimum and maximum temperatures and hours sun (Den Helder)

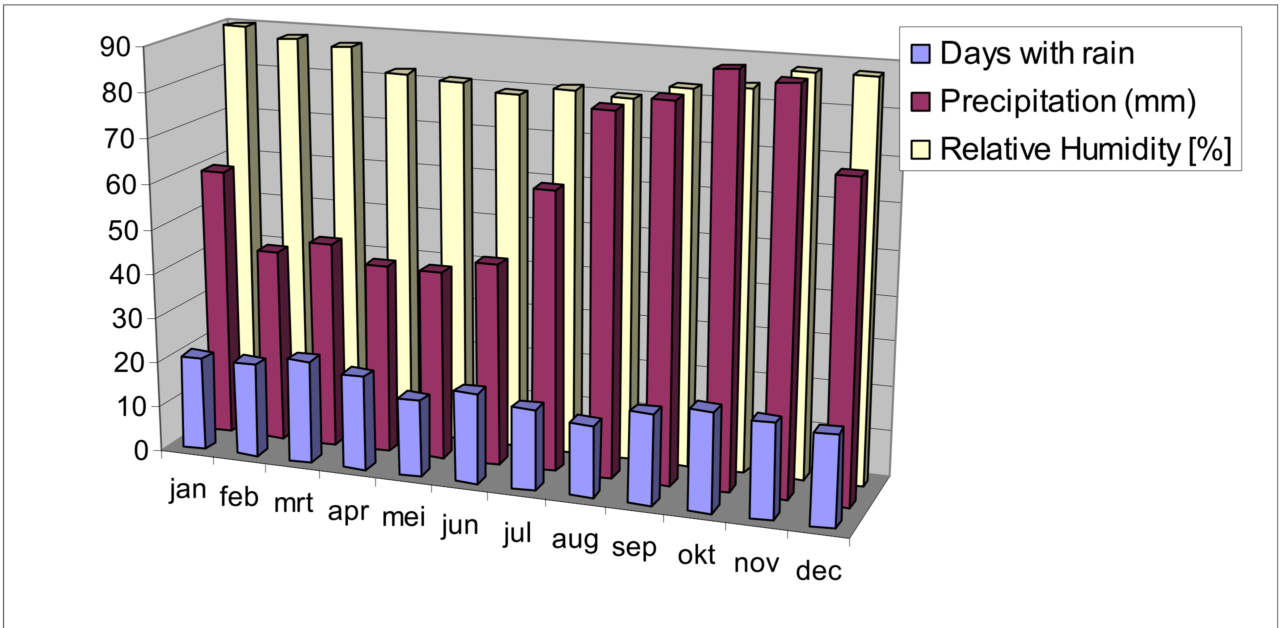

Figure 2.5. Averaged monthly days with rain, precipitation and relative humidity (Den Helder)

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 large meteorological masts at the site have similar construction: they have lattice towers and guy wires. Mast 2 is installed in summer 2005 and differs from the other two masts by height and orientation only. The top mounted anemometers in mast 1 and mast 3 are at 109m height, while the top mounted anemometers in mast 2 are at 100m height, which is the hub height of 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 3.4. 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 at 60°, 180° and 270° with respect to North for MM1 and MM3 and at 35°, 155° and 275° with respect to North for MM2. 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. For MM1 and MM3 one boom is pointing to North: 0º, a second one to East-South-East: 120º and a third one to West-South-West: 240º. For MM2 the directions are 95°, 215° and 335° respectively. These 6.5m long tri-angular booms (Figure 3.4) 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 2006 the following booms are installed in **meteorological mast 1** (see Figure 3.1).
- A single boom is installed at 25m at 240º for measurements at 26.6m height
- A single boom is installed at 45m at 240º for measurements at 46.6m height
- Three booms are mounted at 70m at 0º, 120º and 240º for measurements at 71.6m height
- Three booms are mounted at 83.4m at 0º, 120º and 240º for measurements at 85m height

In summer 2006 the following booms are installed in **meteorological mast 2** (see Figure 3.2**)**
- A single boom is mounted at 24.2m at 215° for measurements at 26m height.
- Three booms are mounted at 58.5m at 95°, 215° and 335° for measurements at 60m height.
- A single boom is mounted at 78.5m at 215° for measurement at 80m height.

In summer 2006 the following booms are installed in **meteorological mast 3** (see Figure 3.3)
- Three booms are mounted at 50.4m at 0º, 120º and 240º for measurements at 52m height.
- Three booms are mounted at 78.4m at 0º, 120º and 240º for measurements at 80m height.

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.

The meteorological mast is accessible with a ladder. Climbing the ladder is only allowed using the safety equipment (harness attached to ladder). Platforms can be used to rest. In total 6 platforms are installed at different levels, including the top platform. The sideboards of the top platforms are at 1.19m below the top of the mast, so this is 4.99m below the actual measuring level. The vertical pillars of the ladder are used as cable ducts. The tower base is screened with a 2m high fence.

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 View of the meteorological mast 2 with attached booms at different levels. The booms at the upper and lower levels are positioned at 78.5m and 24.2m heights and are directed to 215° with respect to North.

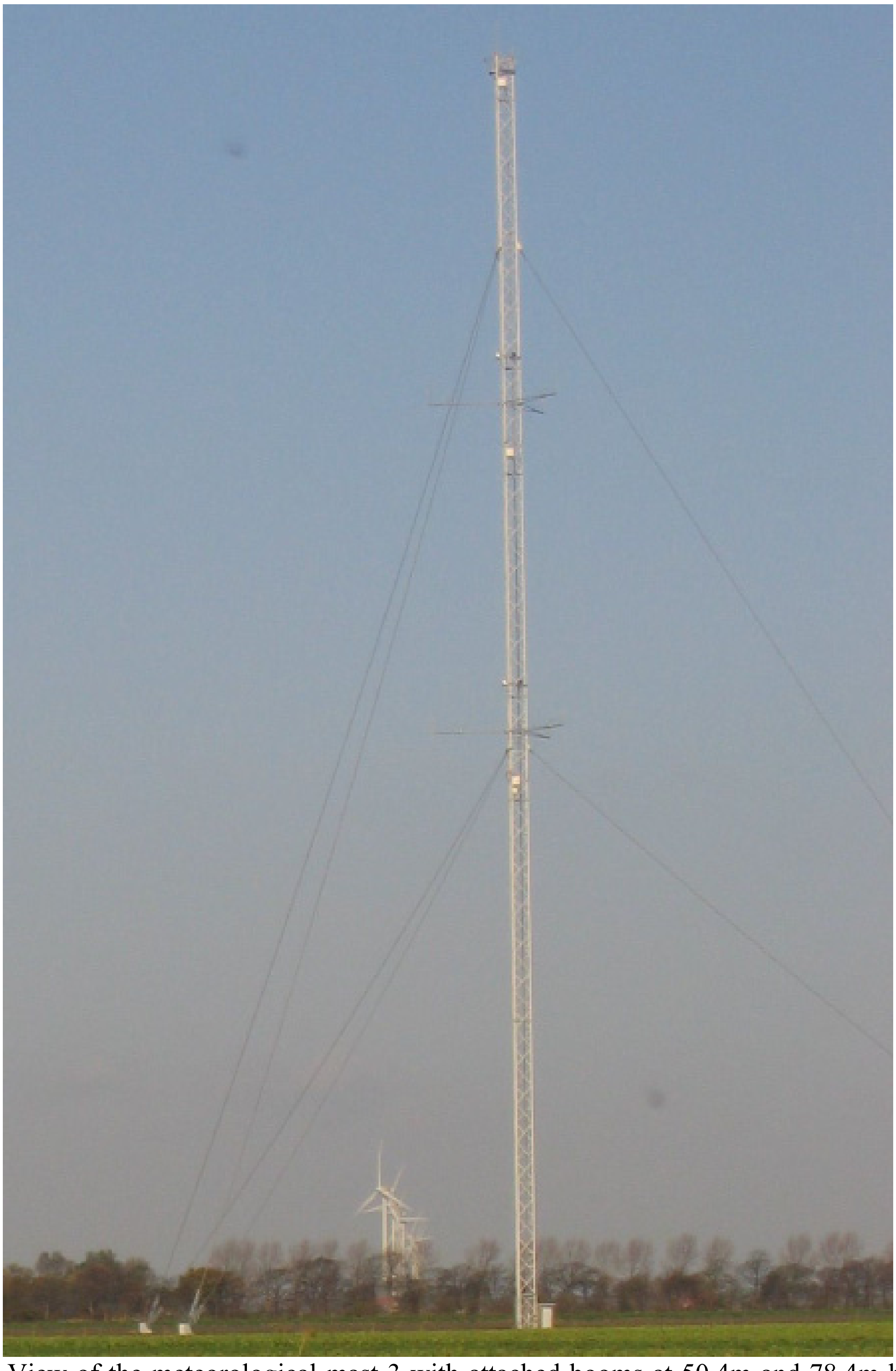

Figure 3.3 View of the meteorological mast 3 with attached booms at 50.4m and 78.4m heights and are directed to 0°, 120° and 240° with respect to North.

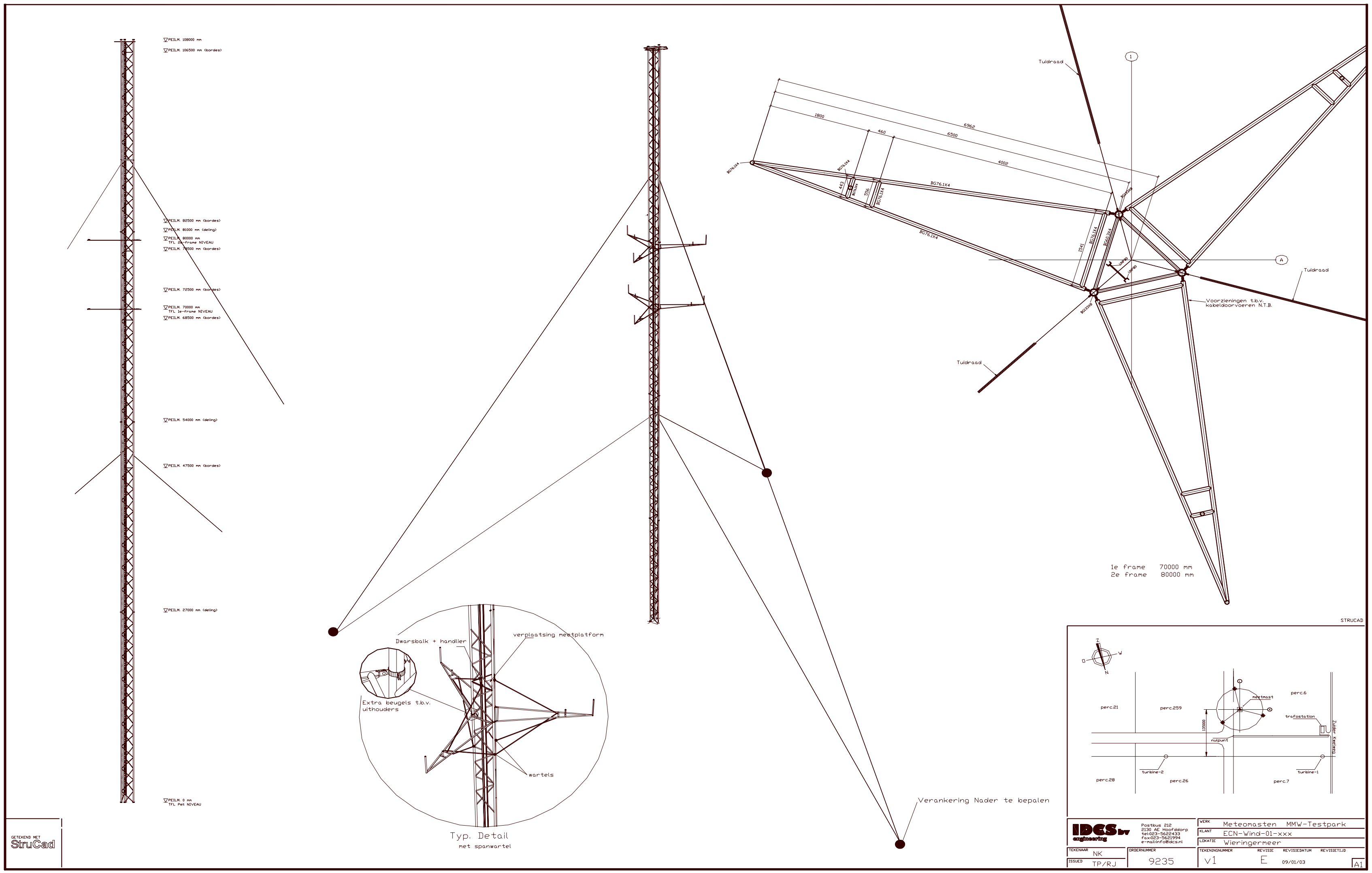

Figure 3.4 Drawing of the 108m tall meteorological masts at EWTW, showing cross section and guy wires lay out. The booms are depicted at arbitrary heights and have lengths of 6.5m.

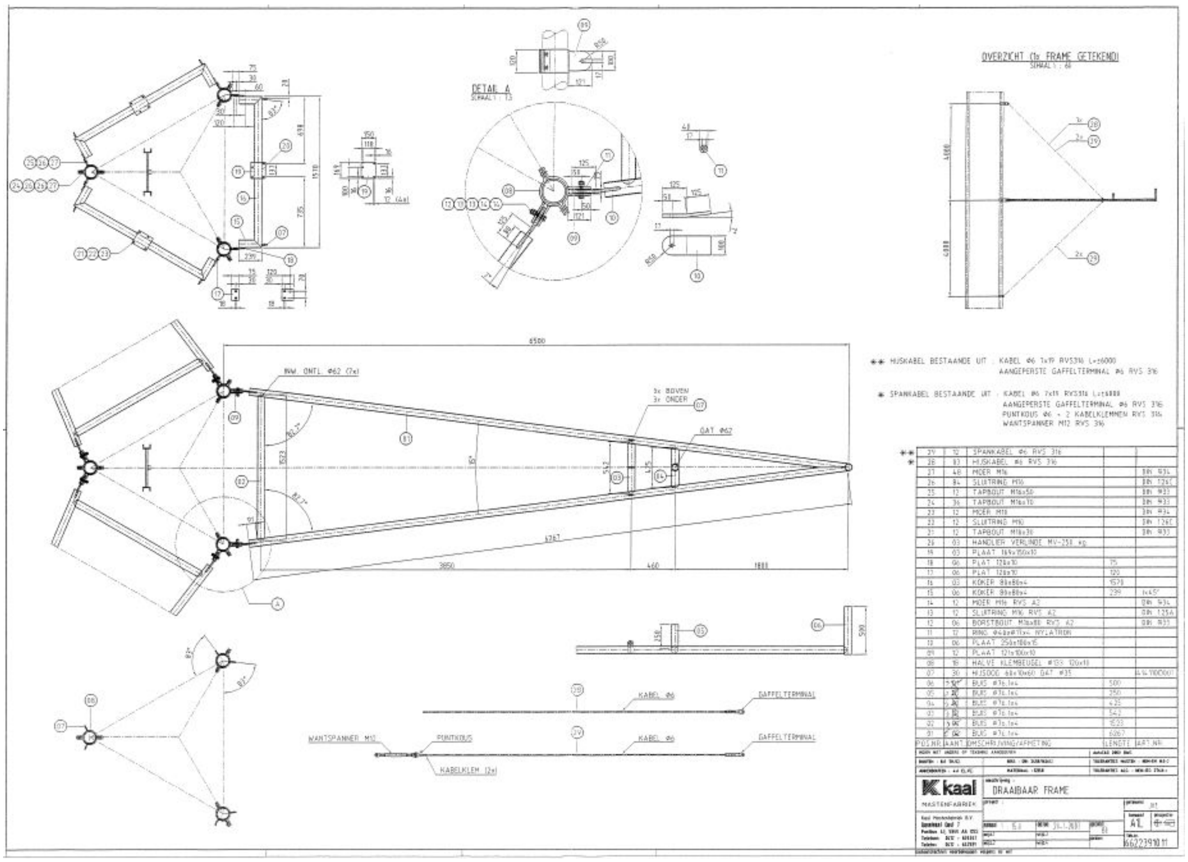

Figure 3.5 Cross section of meteorological masts (tri-angular with side length of 1.6 m) and layout plus photo of the boom, being 6.5m in length. Beside anemometer and vane, the air pressure and temperature sensor are shown. The boom in the picture is pointing in East-South-East direction and is located in meteorological mast 1.

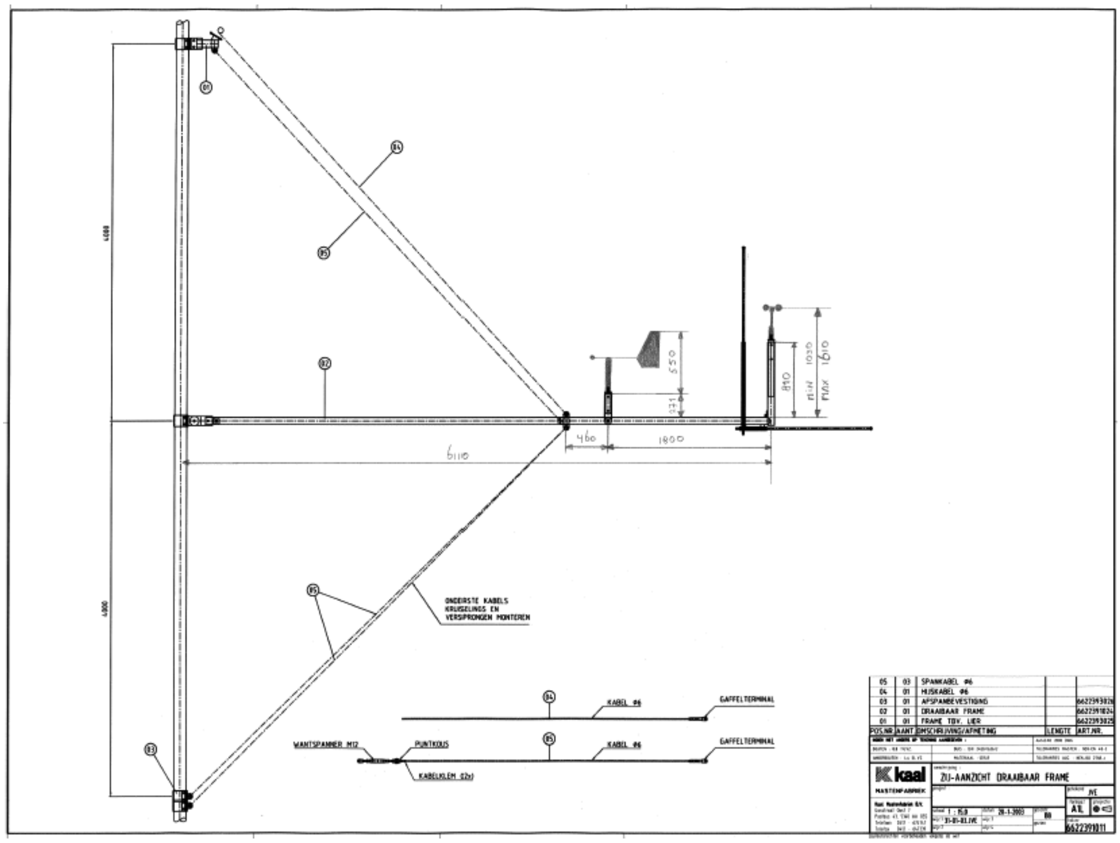

Figure 3.6 Side view of meteorological mast boom including wind sensors. Cables are used to hoist the boom towards the mast and ensure stability during operation.

Figure 3.7 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. The instrumentation and data acquisition

The EWTWM database consists of only 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 four years, June 2003 to May 2007. In this Chapter, the meteorological masts 1, 2 and 3 are described. The masts have been used for several projects, that are described in Chapter 6 and Chapter 7.

4.1 Meteorological mast 1

The set up of meteorological masts 1 is such that the wind conditions can be measured at hub height of the prototype installed at locations 1 and 2 of EWTW, according to the recommendations in the standard IEC 61400-12 [4, 6].

In meteorological masts 1 booms are installed at 25m, 45m, 70m and 83.4m heights. Instrumentation was installed in 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, Appendix B for the period June 2004-May 2005, Appendix C for the period June 2005-May 2006 and Appendix D for the period June 2006-May 2007. The sensors are connected to the DANTE data-acquisition systems [5]. 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.

Figure 4.1 Top of the meteorological mast 1 with 3D sonic sensor, wind vane, aviation warning light and lightning conductor. The boxes lower in the mast contain the signal connection and high voltage protection.

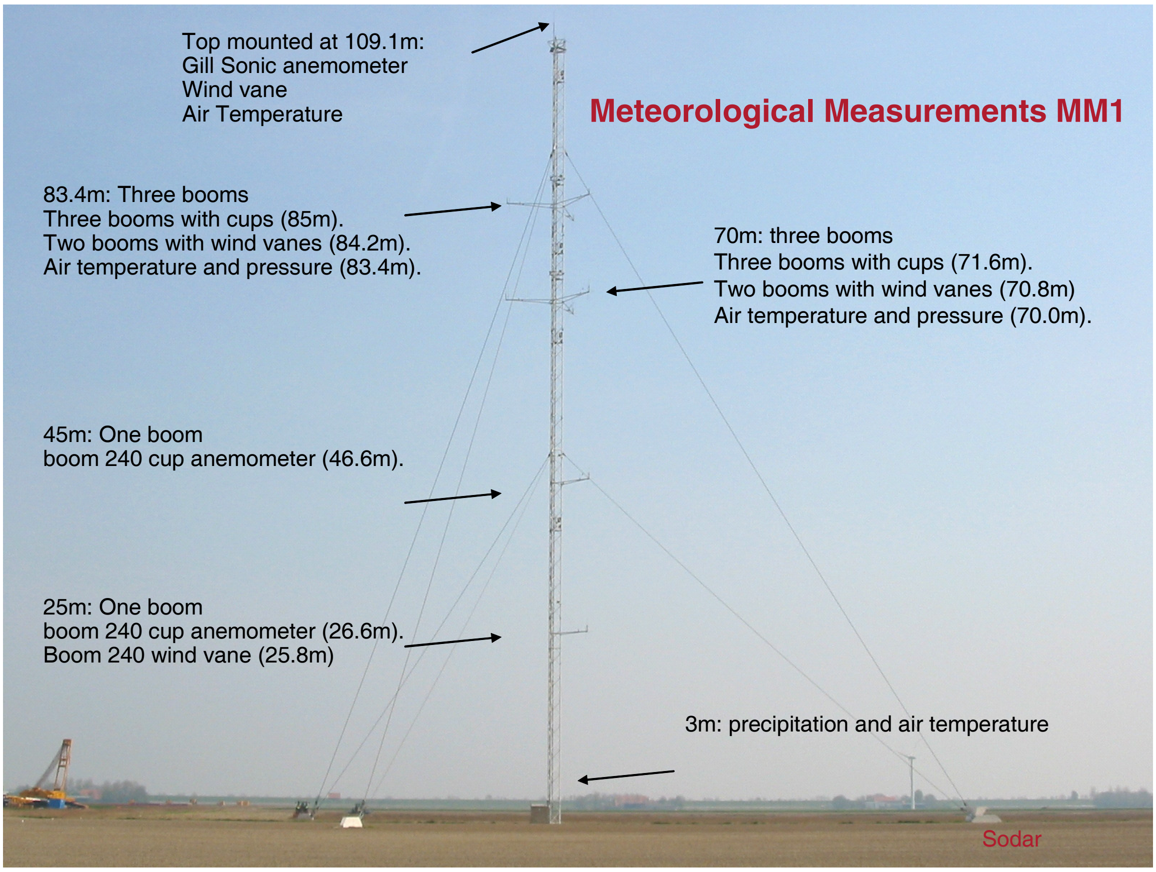

Figure 4.2. Graphical representation of the instrumentation in meteorological mast 1 at EWTW.

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 direction 108 m	MM1_WD108	deg		Mierij	508
Air temperature 108 m	MM1_Tair108	ºC	108m	Rense	XT-730-01
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

4.1.1 Specification instrumentation in meteorological mast 1

3D sonic anemometer at 109.1m

Signals:	MM1_S108_U, MM1_S108_V, MM1_S108_W
Dimension:	m/s
Signals	MM1_S108_St (status)
Dimensions	-

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.

Risø cup anemometers at 85m

Signal	MM1_WS85_0, MM1_WS85_120, MM1_WS85_240
Dimension	m/s

Risø-type cup-anemometers are located at the tip ends of the tri-angular booms (see Figure 3.5). The distance between mast and sensor is 6.5m. 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 3.6.

Risø cup anemometers at 71.6m

Signal	MM1_WS70_0, MM1_WS70_120, MM1_WS70_240
Dimension	m/s

Risø-type cup-anemometers are located at the tip ends of the tri-angular booms (see Figure 3.5). The distance between mast and sensor is 6.5m. 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 3.6.

Risø cup anemometer at 45m

Signal	MM1_WS45_240
Dimension	m/s

A Risø-type cup-anemometer is located at the tip end of the tri-angular boom (see Figure 3.5) pointing at 240 degrees w.r.t. North. The distance between mast and sensor is 6.5m. The signals from the cup-anemometer are identified with the direction of the boom. 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 3.6.

Risø cup anemometer at 26.6m

Signal	MM1_WS25_240
Dimension	m/s

A Risø-type cup-anemometer is located at the tip end of the tri-angular boom (see Figure 3.5) pointing at 240 degrees w.r.t. North. The distance between mast and sensor is 6.5m. The signals from the cup-anemometer are identified with the direction of the boom. 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 3.6.

Wind vane at 108 m

Signals:	MM1_WD108
Dimensions	° (degrees)

A Mierij wind vanes is installed on top of the meteorological mast. A small (1.5m) boom is attached to the top of the South pillar of the mast. The sensor is installed at the tip of this boom. The measurement height is 108m.

Wind vanes at 84.2 m

Signals:	MM1_WD85_120, MM1_WD85_240
Dimensions	° (degrees)

At 83.4m, three booms are mounted pointing at 0°, 120°and 240°. The Mierij wind vanes are in-stalled on the 120° and 240° booms. 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 3.6. 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 wind vanes are 84.2m above ground level.

Wind vanes at 70.8 m

Signals:	MM1_WD70_120, MM1_WD70_240
Dimensions	° (degrees)

At 70m, three booms are mounted pointing at 0°, 120°and 240°. The Mierij wind vanes are in-stalled on the 120° and 240° booms. 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 3.6. 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 wind vanes are 70.8m above ground level.

Wind vanes at 25.8 m

Signals:	MM1_WD25_240
Dimensions	° (degrees)

At 25m, one boom is mounted pointing 240°. The Mierij wind vane is installed in this 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 3.6. The heights of the wind vane is 25.8m above ground level.

Temperature sensors

Signals:	MM1_Tair108, MM1_Tair85, MM1_Tair70, MM1_Tair3
Dimensions	°C

Four temperature sensors are mounted in meteorological mast 1. The highest temperature sensor is mounted at the mast at 108m height. One temperature sensor is located at 83.4m, and is mounted on a boom, the second temperature sensor is mounted on a boom at 70m and the third is mounted on the roof of the mast base measurement cabin, at a height of 3m. The temperature sensors are PT100 instruments equipped with a radiation shield.

Air pressure sensors

Signals:	MM1_Pair85, MM1_Pair70
Dimensions	hPa

The air pressure sensor at 85m is mounted on one of the booms at 83.4m, the same type of air pressure sensor is also mounted on one of the booms at 70m. The air pressure is measured with silicon capacitive absolute pressure sensors of Vaisala.

Precipitation sensor

Signals:	MM1_Prec
Dimensions	%

The precipitation sensor is mounted on top of the roof of the mast base measurement cabin. The height of this sensor is 3m.

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 3.7.

4.2 Meteorological mast 2

The set up of meteorological masts 1 is such that the wind conditions can be measured at hub height of the prototype installed at locations 3 and 4 of the EWTW, according to the recommendations in the standard IEC 61400-12 [4, 6].

The instrumentation is described in Table 4-2. The data acquisition in meteorological mast 2 is in operation since October 11th 2005, except for the sonic anemometer at the top and the Risø cup anemometer at 80m. These sensors are in operation since November 15th 2005. The centre folding mast on top level for the Sonic anemometer was not in the upward position between October 11th 2005 and November 15th 2005. An overview of (validated) data collected in the EWTWM database is included in the Appendices. The sensors are connected to the DANTE data-acquisition systems [5]. 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.

Figure 4.3 Top of the meteorological mast 2 with 3D sonic sensor, 2 cup anemometers, 2 wind vanes aviation warning light and lightning conductor. The boxes lower in the mast contain the signal connection and high voltage protection.

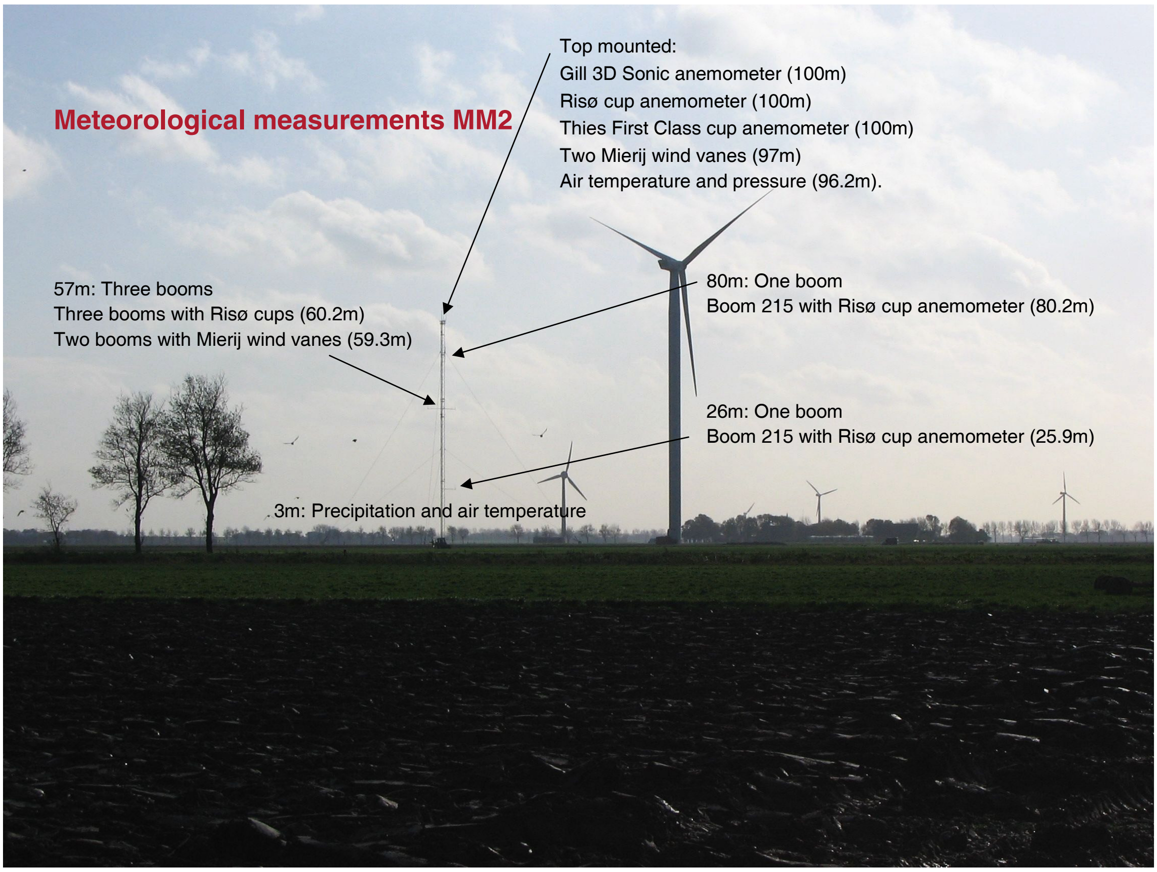

Figure 4.4. Graphical representation of the instrumentation in meteorological mast 2 at EWTW.

Table 4-2. Instrumentation in meteorological mast 2

Signal Name	**label in EWTWM**	**units**	**height**	**brand**	**Sensor type**
Gill wind speed U, V, W	MM2_S100	m/s	100m	GILL	1086 M
Wind direction 108 m	MM2_S100	deg	100m	GILL	1086 M
Wind speed 100 125º	MM2_WS100_125	m/s	100m	Thies	
Wind speed 100 305º	MM2_WS100_305	m/s	100m	Risø	P2456a
Wind direction 100 SE	MM2_WD96_215	deg	96.2m	Mierij	508
Air temperature 97 m	MM2_Tair96	ºC	96.2m	Thies	2.1280.00.141
Air pressure 97 m	MM2_Pair96	hPa	96.2m	Vaisela	PTB 210 Class B
Wind speed 80 215º	MM2_WS80_215	m/s	80.2m	Risø	P2456a
Wind speed 60 95º	MM2_WS60_95	m/s	60.2m	Risø	P2456a
Wind speed 60 215º	MM2_WS60_215	m/s	60.2m	Risø	P2456a
Wind speed 60 335º	MM2_WS60_335	m/s	60.2m	Risø	P2456a
Wind direction 60 215º	MM2_WD60_215	deg	59.3m	Mierij	508
Wind direction 60 335º	MM2_WD60_335	deg	59.3m	Mierij	508
Wind speed 26m SW	MM2_WS26_215	m/s	25.9m	Risø	P2456a
Air temperature 3 m	MM2_Tair3	ºC	3m	Thies	2.1280.00.141
Precipitation	MM2_Prec		3m	Thies	5.4103.10.00

4.2.1 Specification Instrumentation in meteorological mast 2

3 D sonic anemometer at 100m

Signals:	MM2_S100_U, MM2_S100_V, MM2_S100_W
Dimension:	m/s
Signals	MM2_S100_St (status)
Dimensions	-

The Gill sonic anemometer is located on top of the meteorological mast mounted on top of the centre folding mast. The centre of the measuring head of the sonic anemometer is located at a height of 3.8m above the mast top, giving it an actual measuring height of 100m above ground level.
The North indication of the sonic anemometer points towards 35°. In the direction of 53° behind the sonic anemometer is the top lightning conductor. This rod will influence the wind from this direction. This conductor is a cylindrical rod with an outer diameter of Ø 88.9 mm. The distance between the centre of the conductor and the centre of the measuring head of the sonic anemometer is approximately 95 cm. A top view of the top structure of the mast is in Chapter 3.

Thies First Class anemometer at 100 m

Signal:	MM2_WS100_125
Dimension:	m/s

The Thies First Class cup anemometer is mounted on the folding mast at the 125° direction. The measuring height of this cup anemometer is 100m. At this level, also a Risø cup anemometer and a Gill sonic anemometer are installed. The distance between the centre of the Risø cup and the centre of the Thies cup anemometer is 3.15m (direct line). In between the two cup anemometers the Gill sonic anemometer is located. The Thies First Class cup anemometer and the Risø cup anemometer have an opposite rotational direction.

Risø cup anemometer at 100m

Signal	MM2_WS100_305
Dimension	m/s

The Risø cup anemometer is mounted on the folding mast at the 305° direction. The measuring height of this cup anemometer is 100m. Additional information as given for the Thies cup anemometer above is also applicable here.

Risø cup anemometer at 80.2m

Signal	MM2_WS80_215
Dimension	m/s

At 78.5m mast level a boom is mounted pointing at 215°. The Risø cup is mounted at the tip end of the tri-angular boom. The distance between mast and sensor is 6.5m. The cup rotor of the anemometer is mounted 1.7m above the boom end, which is 22 times the boom thickness (Ø76 mm). The actual measuring height is 80.2m. Next to the cup-anemometer a lightning conductor (Ø22 mm) is located to protect the senor from lightning strikes. The distance between sensor and conductor is 263 mm.

Risø cup anemometers at 60.2m

Signal	MM2_WS60_95, MM2_WS60_215, MM2_WS60_335
Dimensions	m/s

At 58.5m mast level, three booms are mounted pointing at 95°, 215°and 335°. The Risø cup anemometers are located at the tip ends of the tri-angular booms. The distances between mast and sensors are 6.5m. The distance between the anemometers, in a straight line at the horizontal level, is 12.4m. The cup rotors of the anemometers are mounted 1.7m above the boom end, which is 22 times the boom thickness (Ø76mm). The actual measuring height is 60.2m. Next to the cup-anemometers a lightning conductor (Ø22 mm) is located to protect the sensors from lightning strikes. The distance between sensor and conductor is 263 mm.

Risø cup anemometer at 25.9m

Signal:	MM2_WS26_215
Dimension	m/s

At 24.2m mast level, one boom is mounted pointing at 215 °. The Risø cup anemometer is mounted at the tip end of the tri-angular boom. The distance between mast and sensor is 6.5m. The cup rotor of the anemometer is mounted 1.7m above the boom end, which is 22 times the boom thickness (Ø76 mm). The actual measuring height is 25.9m. Next to the cup-anemometer a lightning conductor (Ø22 mm) is located to protect the senor from lightning strikes. The distance between sensor and conductor is 263 mm.

Wind vanes at 97m

Signals:	MM2_WD96_215, MM2_WD96_335
Dimensions	° (degrees)

Two Mierij wind vanes are fixed at the hoisting frames at 215° and 335°. The height of the hoisting frames near the mast top level is 96.2m; the vertical distance between the hoisting frame and the wind vane is 0.8m, which gives an actual measuring height of 97m. The horizontal distance between the meteorological mast and the wind vane is 1m.

Wind vanes at 59.3m

Signals:	MM2_WD60_215, MM2_WD60_335
Dimensions	° (degrees)

At 58.5m, three booms are mounted pointing at 95°, 215°and 335°. The Mierij wind vanes are installed on the 215° and 335° booms. 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 at 59.3m above ground level.

Temperature sensors

Signals:	MM2_Tair3, MM2_Tair96
Dimensions	°C

Two temperature sensors are mounted in meteorological mast 2. One temperature sensor is located at 96.2m, and is mounted on the hoisting frame pointing at 215°, the second temperature sensor is mounted on the roof of the mast base measurement cabin, at a height of 3m.

Air pressure sensors

Signals:	MM2_Pair96
Dimensions	hPa

The air pressure sensor is mounted at the hoisting frame pointing at 215°. The height of this sensor is 96.2m.

Precipitation sensor

Signals:	MM2_Prec
Dimensions	%

The precipitation sensor is mounted on top of the roof of the mast base measurement cabin. The height of this sensor is 3m.

4.3 Meteorological mast 3

The set up of the third meteorological masts (MM3) is such that the wind conditions are measured at hub height of the research turbines 5 and 6 at EWTW, according to the recommendations in the standard IEC 61400-12 [4, 6]. Furthermore, the mast is equipped to measure accurately wake conditions and support the various research projects on the research turbines. 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. The data acquisition in meteorological mast 3 is in operation since October 2004. An overview of (validated) data collected in the EWTWM database is included in the Appendices. The sensors are connected to the DANTE data-acquisition systems [5]. 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.

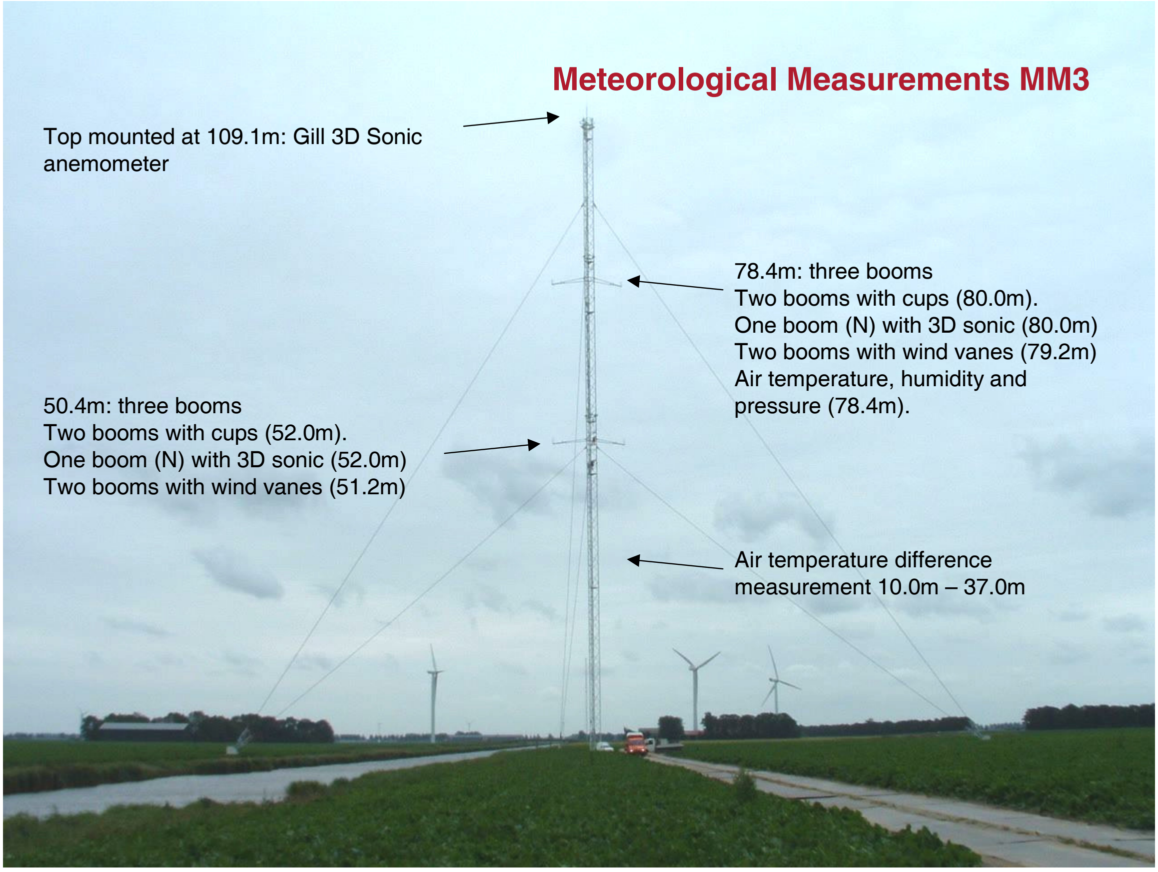

Figure 4.5. Graphical representation of the instrumentation in meteorological mast 3 at EWTW.

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	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	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_240	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	

4.3.1 Specification instrumentation in meteorological mast 3

3D sonic anemometer at 109.1m

Signals:	MM3_S108_U, MM3_S108_V, MM3_S108_W
Dimension:	m/s
Signals	MM3_S108_St (status)
Dimensions	-

The 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. Note that the sonic anemometer is installed at a different pillar as the setup in meteorological mast 1.

3D sonic anemometer at 80m

Signals:	MM3_S80N_U, MM3_S80N_V, MM3_S80N_W
Dimension:	m/s
Signals	MM3_S80N_St (status)
Dimensions	-

The Gill sonic anemometer is located at the tip end of the tri-angular boom directed to North. The distance between mast and sensor is 6.5m. The sensor is identified with the direction of the boom: North. The distance, in a straight line at the horizontal level, between the anemometer and cup anemometers is 12.4m. The sonic anemometer measures 1.61m above the boom end, which is 21 times the boom thickness (Ø76mm). Next to the sonic anemometer a lightning conductor (Ø22 mm) is located. The distance between sensor and conductor is 263 mm; see Figure 3.6. The sonic anemometers in the North of the mast is required to measure wake conditions with sonic anemometers.

3D sonic anemometer at 52m

Signals:	MM3_S52N_U, MM3_S52N_V, MM3_S52N_W
Dimension:	m/s
Signals	MM3_S52N_St (status)
Dimensions	-

The Gill sonic anemometer is located at the tip end of the tri-angular boom directed to North. The distance between mast and sensor is 6.5m. The sensor is identified with the direction of the boom: North. The distance, in a straight line at the horizontal level, between the anemometer and cup anemometers is 12.4m. The sonic anemometer measures 1.61m above the boom end, which is 21 times the boom thickness (Ø76mm). Next to the sonic anemometer a lightning conductor (Ø22 mm) is located. The distance between sensor and conductor is 263 mm; see Figure 3.6. The choice of the sonic anemometers in the North of the mast is driven by the desire to measure wake conditions with sonic anemometers.

Risø cup anemometers at 80m

Signal	MM3_WS80_120, MM3_WS80_240
Dimension	m/s

Risø-type cup-anemometers are located at the tip ends of the tri-angular booms (see Figure 3.5). The distance between mast and sensor is 6.5m. The signals from the cup-anemometers are identified with the directions the booms are pointed at: 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 263mm; see Figure 3.6.

Risø cup anemometers at 52m

Signal	MM3_WS52_120, MM3_WS52_240
Dimension	m/s

Risø-type cup-anemometers are located at the tip ends of the tri-angular booms (see Figure 3.5). The distance between mast and sensor is 6.5m. The signals from the cup-anemometers are identified with the directions the booms are pointed at: 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 3.6.

Wind vanes at 79.2 m

Signals:	MM3_WD80_120, MM3_WD80_240
Dimensions	° (degrees)

At 78.4m, three booms are mounted pointing at 0°, 120°and 240°. The Friedrichs wind vanes are installed on the 120° and 240° booms. 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 3.6. The heights of the wind vanes are 79.2m above ground level. The type of wind vane differs from meteorological mast 1, the locations on the booms are identical.

Wind vanes at 51.2 m

Signals:	MM3_WD52_120, MM3_WD52_240
Dimensions	° (degrees)

At 50.4m, three booms are mounted pointing at 0°, 120°and 240°. The Friedrichs wind vanes are installed on the 120° and 240° booms. 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 3.6. The heights of the wind vanes are 51.2m above ground level. The type of wind vane differs from meteorological mast 1, the locations on the booms are identical.

Temperature sensor at 78.4m

Signals:	MM3_Tair80
Dimensions	°C

One temperature sensor is mounted in meteorological mast 3. It is located at 78.4 m, and is mounted on a boom. The temperature sensor is a Vaisala HMP45A instrument equipped with a radiation shield.

Humidity sensor at 78.4m

Signals:	MM3_RH80
Dimensions	%

The relative humidity is measured with a Vaisala HMP45A instrument mounted on a boom at 78.4m. Note that the temperature and relative humidity sensor are combined in a single Vaisala sensor.

Air pressure sensor at 78.4m

Signals:	MM3_Pair80
Dimensions	hPa

One air pressure sensor is mounted on one of the booms at 78.4m height. The air pressure is measured with silicon capacitive absolute pressure sensors of Vaisala.

Temperature difference sensor

Signals:	MM3_dT
Dimensions	°C

The temperature difference between 37m height and 10m height is measured.

4.4 25 meteorological mast near MM1

Next to the meteorological mast 1 a 25m mast is 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. The two cup-anemometers in top of the 25m mast are at the same height as the cup anemometer in the 108m mast at the 25m boom. This way, the flow disturbance of the mast could be assessed. The mast did not survive a storm front on July 17th, after which a new mast was erected. Therefore, two periods are described below.

4.4.1 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 4.6). 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 4.6, 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.

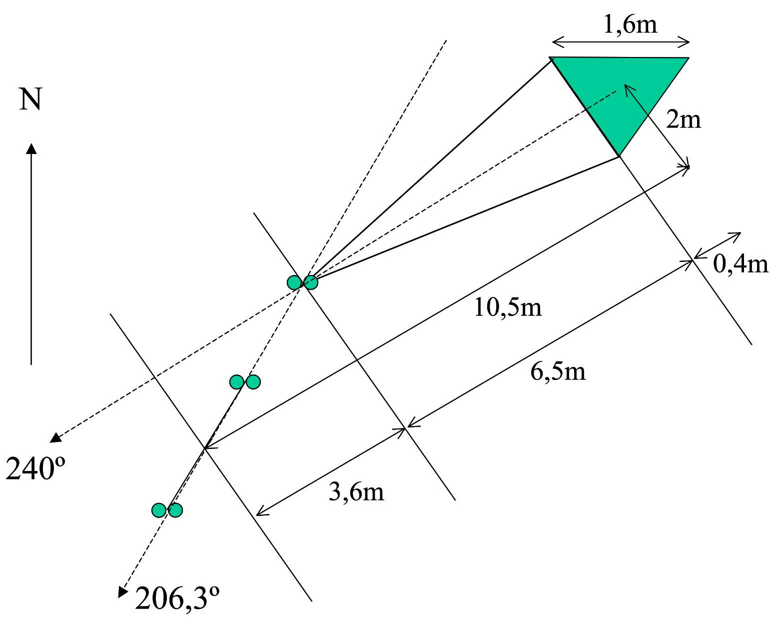

Figure 4.6. Left picture: The 25m high mast was installed next to the 108m high meteorological mast 1 in order to assess the influence of the mast on the wind speed measurements. The set-up in June/July 2004 is depicted. Right figure: Overview of experimental set-up (top view) with corresponding distances and angles with respect to North.

4.4.2 The 25m mast – experimental set-up from October 2004 to March 2006

In October 2004 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 4.7). In the top of the 25m mast, a boom is installed in which two Risø cup anemometers are placed (see Figure 4.7). 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 4.7, 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 4.7). 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. In March 2006 the mast has been removed from the site.

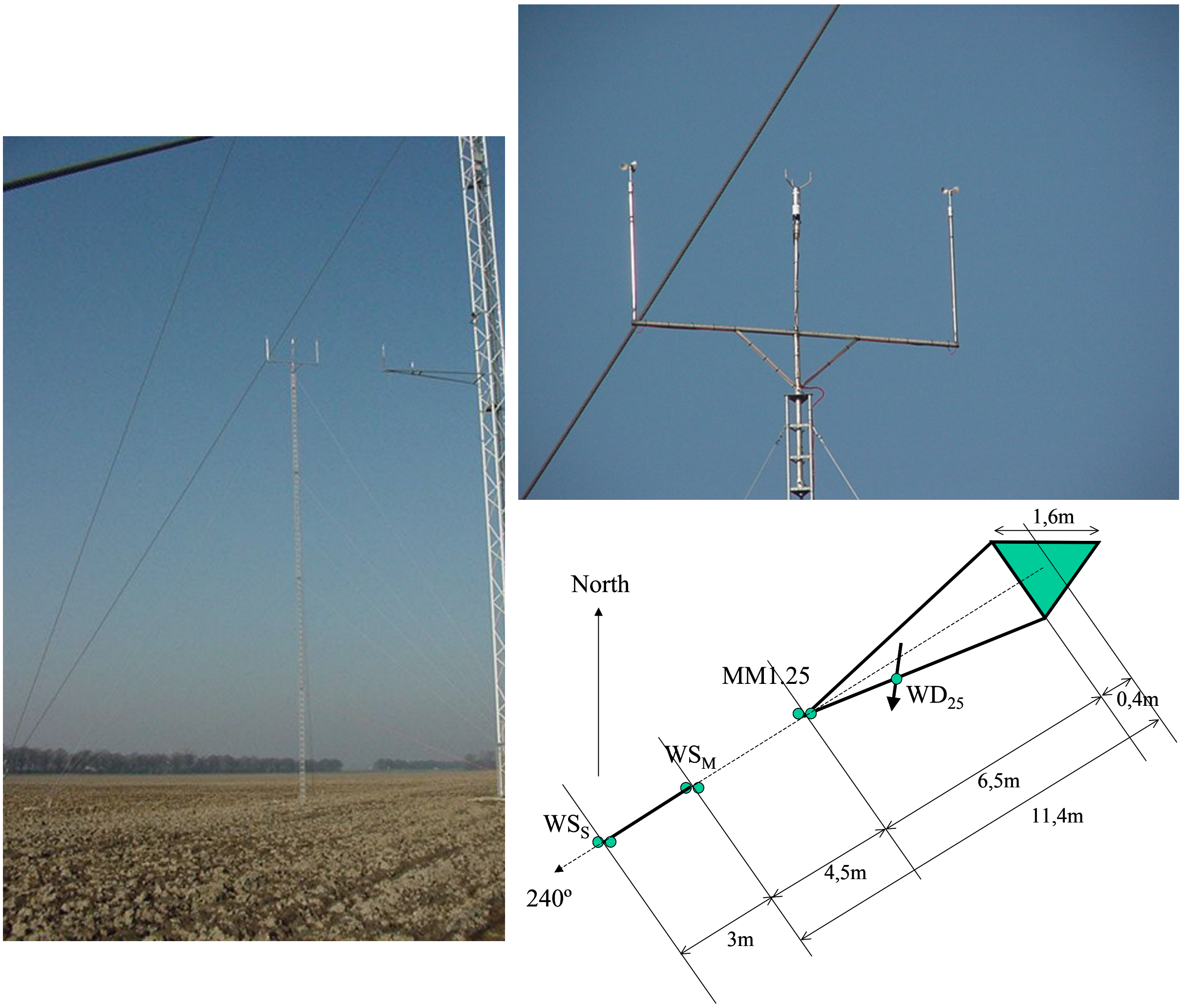

Figure 4.7. A 25m high mast installed next to meteorological mast 1 at EWTW.

Table 4-4. 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

4.4.3 Specification instrumentation in 25m mast

Risø cup anemometers at 26.6m

Signal	M25_WS25_M, M25_WS25_S
Dimension	m/s

Risø-type cup-anemometers are located at the tip ends of a dedicated boom in top of the 25m mast (see Figure 4.7). The distance between mast and sensors is specified in the previous sections. The signals from the cup-anemometers are identified with 'M', which is closest to the mast and 'S', which is more to the South. The distance, in a straight line at the horizontal level, between these anemometers is 3m. The cup rotors of the anemometers are mounted 1.5m above the boom end. In between the cup-anemometers a sonic anemometer is located at a distance of 1.5m.

2D sonic anemometers at 26.6m

Signal	M25_Vais_ws
Dimension	m/s
Signal	M25_Vais_wr
Dimension	degree

A Vaisala 2D sonic anemometer is located at the centre of a dedicated boom in top of the 25m mast (see Figure 4.7). The distance between mast and sensor is specified in the previous sections. The signals from the Vaisala sonic anemometers are identified with 'ws', the wind speed and 'wr', which is the wind direction. The sample frequency of the sonic anemometer is 2Hz.

5. Uncertainties

Uncertainties are calculated following international standards and regulations [4] and [6].

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 1.6m. 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 7m. 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 on prototype turbines

Prototype location 1: NM 92 Wind Turbine (DOWEC)

Within the framework of the DOWEC (Dutch Offshore Wind Energy Converter) project ECN carried out the following measurements on the NEG MICON NM92 at the EWTW:

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

The meteorological mast 1 is used for these measurements.

Prototype location 2: GE2.5 Wind Turbine

The GE 2.5 MW prototype turbine has been erected at prototype location 2 at EWTW. In 2006, the rotor has been replaced to test an alternative configuration. The following measurements are performed:

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

The meteorological mast 1 is used for these measurements.

Prototype location 3: GE2.3 Wind Turbine

The GE 2.3 MW prototype turbine has been erected at prototype location 3 at EWTW. The following measurements are performed:

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

The meteorological mast 2 is used for these measurements.

Prototype location 4: Siemens 3.6 Wind Turbine

The Siemens 3.6 MW prototype turbine has been erected at prototype location 4 at EWTW. The following measurements are performed:

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

The meteorological mast 2 is used for these measurements.

7. Campaigns of research projects

WISE project

The WISE project is a European project. In this project it has been investigated whether a Sodar (Sound Detecting and Ranging) measurement system, among the remote sensing devices, is an acceptable alternative to measure wind speeds at higher altitudes and remote areas. Especially the application to power performance measurements on wind turbines has been investigated. A measurement campaign has been performed to determine:

- A calibration procedure to improve the accuracy of Sodar measurements;
- The operational and external conditions influencing the resulting Sodar measured wind speed.

The main conclusion is that although the Sodar with the current technology has its limitations, the instrument poses an attractive alternative to expensive large meteorological masts for wind measurements with large wind turbines and measurements at offshore locations. However, improvements regarding calibration, design and software are required.

Published reports for which EWTW data has been used: ECN-RX--03-058, ECN-C--03-108, ECN-C--05-041 and ECN-C--05-044

Accuwind project

The Accuwind (**Accu**rate **Wind** measurements) project is a European project that is in addition partially financed by Senter/Novem 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.
Part of the uncertainty analysis on cup anemometer calibrations is based on measurements at EWTW.
Analysis of operational characteristics of various types of sonic anemometers is based on measurements at EWTW.

Published reports for which EWTW data has been used: ECN-C--05-066, ECN-CX--04-097, ECN-CX--05-025, ECN-CX--05-102, ECN-RX--06-061, ECN-CX--06-037, Risø-R-1563, Risø-I-2490 and UPM report

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.

Published reports for which EWTW data has been used: ECN-CX--05-084, ECN-CX--06-004 and ECN-M--07-044

O&M Cost Estimator

The WE@SEA project 'Operations and Maintenance Cost Estimator' is part of research line 5 'Installation, operations and maintenance, dismantling'. The objective of the WE@SEA project 'Operations and Maintenance Cost Estimator' (OMCE) is to develop a methodology with which owners and operators of offshore wind farms are able to estimate the future O&M costs. The methodology together with monitoring of the wind farm should give owners and operators tools to support the decisions on O&M. In order to develop a methodology with which owners and operators of offshore wind farms are able to estimate and control the future O&M costs, it will be especially relevant to determine trends that indicate if failures will occur, how many and what costs are associated to these failures on the longer term.

Published reports for which EWTW data has been used: ECN-RX--06-055, ECN-RX--06-058,
ECN-X-07-010

CONMOW

This EU funded CONMOW project mainly deals with diagnostics and condition monitoring as a means to:

- verify if the actual loads on components do agree with the design loads;
- detect faults and wear in an early stage in order to avoid consequence damage, and predict the remaining life;
- optimise and increase the maintenance intervals of certain components;
- assess the use of measured parameters as input for turbine and park control.

The CONMOW project aims at

1. adjusting currently available condition monitoring techniques to the specific wind turbine needs and make sure that they will meet the newly developed wind turbine communication standards;
2. investigating and demonstrating the benefits of condition monitoring techniques in the operation of large wind farms at remote (offshore) locations;
3. making an inventory of measurement and condition monitoring techniques that are currently under development and will have added value for the operation of wind farms on the longer term

Due to the CONMOW project condition monitoring systems have been installed in all five research turbines.

FOBM

Methods are investigated to monitor the blades of the wind turbines. Apart from the development of sensors also algorithms and tools are developed to process the measured signals of the blades. Tests of equipment, algorithms and tools are running in the research turbines, among others tests of optical strain gauges.

Published reports for which EWTW data has been used: ECN-RX--04-136

WT Bird

A new method for registration of bird collisions has been developed using video cameras and microphones combined with event triggering by acoustic vibration measurement. Remote access to the recorded images and sounds makes it possible to count the number of collisions as well as to identify the species. Currently a prototype system is being tested on one of the research turbines. Among others, test using bird dummies have been carried out.

Published reports for which EWTW data has been used: ECN-RX--03-035, ECN-RX--04-121, ECN-C--04-046, ECN-RX--06-060

CRISP

The CRISP project aims to investigate, develop and test how latest advanced intelligence by ICT technologies can be exploited in a novel way for cost-effective, fine-grained and reliable monitoring, management and control of power networks that have a high degree of Distributed Generation and RES penetration. The opportunities for interactive power networks to create new possible control mechanisms that create flexibility and self-managing networks will be shown. Normal and emergency operations are investigated covering different time scales. Insight in performance, security and architecture of highly distributed systems will be made available. Technical availability, functionality and economic cost-benefit considerations will be integrated. Results will contribute to better regional monitoring and control of local distribution in the EU-network.
The measurements at EWTW involved the power produced by the wind farm and the wind speed measurements at hub height. These measurements are compared to predictions of power production and furthermore the correlation of production of distributed wind farms is investigated.

web-page: http://www.ecn.nl/crisp/

SIROCCO

Wind turbine noise is one of the major hindrances for the widespread use of wind energy. For modern large turbines, the dominant noise source is considered to be aerodynamic noise from the blades. Therefore, the subject of the European SIROCCO project is the design, testing, and full-scale validation of quiet wind turbine blades. Among others, in this project acoustic field measurements were carried out on a three-bladed GE 2.3 MW wind turbine with a rotor diameter of 94 m, in order to characterize the noise sources and to verify whether trailing edge noise from the blades was dominant. The rotor blades were not cleaned or treated otherwise before the test campaign. A large horizontal microphone array, positioned about one rotor diameter upwind from the turbine, was used to measure the distribution of the noise sources in the rotor plane and on the individual blades.

HEAT AND FLUX

Offshore wind farms generally have a large number of wind turbines. These turbines suffer from power loss and increased mechanical loading levels because of the wake interaction. At ECN novel ways are developed of wind farm operation directed to alleviating associated loading levels and increasing electricity output. The first full scale experiment has been carried out on the N80 machines at the EWTW.

8. Sensor types and calibration information

The unit ECN Wind Energy is accredited according ISO17025 for

- noise measurements on wind turbines according IEC 61400-11 and MEASNET acoustic noise measurement procedure
- power performance measurements according IEC 61400-12 and MEASNET Power performance measurement procedure
- mechanical load measurements according IEC/TS 61400-13

The experiments are carried out according the accompanying 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". In 2007 the instruments administration is renewed with the Ultimo software package. This system has more options to store the relevant information. 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 metadata types are presented in Table 8-1.

Table 8-1. 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

9. Discussion and conclusions

At the ECN Wind Turbine Test site Wieringermeer (EWTW) a continuous stream of data is gathered from a wind farm with five Nordex N80 research turbines and a 108m high meteorological mast and from four prototype turbines and their two high meteorological masts. The data are measured by the ECN data-acquisition system. For storage and analyses of this vast amount of data, a high quality database has been developed. The database contains all the necessary information about the measurement hardware, calibrations etcetera. Storage of large quantities of data in a database requires extensive validation. The quality of the measured data is ensured by use of calibrated instruments, application of measurement procedures according ISO 17025, signal conditioning in the DANTE data acquisition system and implementation of validation filters and rules in the database structure. The database ensures good accessibility of the data and unambiguous use in subsequent analyses.

The dedicated meteorological database EWTWM has been created to collect meteorological data over a long period of time. The meteorological data are measured in the research projects that are carried out at EWTW as well as in the measurement campaigns on the prototype turbines. This means that the data are scattered over many databases that in addition are often confidential, because these contain also the turbine data. In the EWTW meteorological database the meteorological data are inserted that are measured at the three large meteorological masts at EWTW. The combined collection of data allows easy access to the validated database and offers the possibility of research to be carried out on many subjects. This report facilitates the research by a full description of the measurement conditions.

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

In the Appendices the availability of data is presented for the signals that are included in the Meteorological database (EWTWM). Note that these availabilities are not necessarily equal to the availabilities in the measurement projects. Since the EWTWM database is not connected to any project, the data are not checked on a daily basis (as is the case in ordinary measurement projects) and as a consequence, data availability can be smaller.

	June 03	July 03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	Jan-04	Feb-04	Mar-04	Apr-04	May-04
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_v												
mm1_s108_w												
mm1_s108_v3d												
mm1_s108_vdir												
mm1_s108_vhor												
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_wd108												
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												

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

	June-04	July-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04	Jan-05	Feb-05	Mar-05	Apr-05	May-05
m25_vais_ws					11	89	95	96	70	99	95	100
m25_vais_wr					10	89	95	96	98	99	95	98
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	94	99	93	82
mm1_pair85			56	65	100	89	95	96	94	99	96	82
mm1_prec	10	44	65	65	100	89	57	99	94	99	96	82
mm1_s108_St								79	94	98	96	82
mm1_s108_u			27	60	94	80	89	97	92	97	94	81
mm1_s108_v			19	61	94	77	89	97	92	97	94	81
mm1_s108_w			31	61	94	82	89	97	92	98	94	81
mm1_s108_v3d			18	60	94	77	89	97	92	97	94	81
mm1_s108_vdir			18	60	94	77	89	97	92	97	94	81
mm1_s108_vhor			18	60	94	77	89	97	92	97	94	81
mm1_tair3	1	53	71	91	99	89	61	99	94	100	96	82
mm1_tair70	10	71	83	65	100	89	95	92			35	82
mm1_tair85			56	65	100	68	76	99	83	99	96	82
mm1_tair108								79	94	100	93	82
mm1_wd25_240	1	90	98	91	81		21	53	94	100	96	82
mm1_wd70_120	10	69	83	65	100	89	95	99	94	99	95	82
mm1_wd70_240	10	90	83	65	100	89	95	99	94	99	95	82
mm1_wd70_overall	10	69	83	65	100	89	95	99	94	99	95	82
mm1_wd85_120			52	55	98	88	94	99	87	99	96	82
mm1_wd85_240			56	65	100	89	95	99	87	99	96	82
mm1_wd85_overall			52	55	98	88	94	99	87	99	96	82
mm1_wd108					11	89	95	99	98	100	96	100
mm1_ws25_240	1	90	98	91	99	88	95	99	94	100	93	82
mm1_ws25_240_pulsecount_to_ws								79	94	100	93	82
mm1_ws45_240	1	90	98	91	99	88	95	99	94	100	93	82
mm1_ws70_0	10	90	83	65	100	88	93	99	94	99	93	82
mm1_ws70_120	10	90	83	65	100	88	95	99	94	99	95	82
mm1_ws70_240	10	90	83	65	100	88	93	99	94	99	95	82
mm1_ws85_0			56	65	100	89	4					
mm1_ws85_120			56	65	100	89	4					
mm1_ws85_240			26	55	100	89	4					
mm1_ws85_0_p								42	81	100	65	45
mm1_ws85_120_p								66	94	100	96	82
mm1_ws85_240_p								66	94	100	96	82
mm1_ws85_120_d								35	50	52	50	52
mm3_pair80							72	99	98	100	96	100
mm3_rh80							72	99	98	100	96	100
mm3_s52n_St								82	98	100	97	100
mm3_s52n_u							70	99	97	100	96	100
mm3_s52n_v							70	99	98	100	96	100
mm3_s52n_w							70	99	98	100	97	100
mm3_s52n_v3d							70	99	97	100	96	100
mm3_s52n_vdir							70	99	97	100	96	99
mm3_s52n_vhor							70	99	97	100	96	100
mm3_s80n_St							0	82	98	100	97	100
mm3_s80n_u							72	99	98	100	96	100
mm3_s80n_v							72	99	98	100	96	100
mm3_s80n_w							72	100	98	100	97	100
mm3_s80n_v3d							72	99	98	100	96	100
mm3_s80n_vdir							72	99	98	99	96	99
mm3_s80n_vhor							72	99	98	100	96	100

	June-04	July-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04	Jan-05	Feb-05	Mar-05	Apr-05	May-05
mm3_s108_St							0	82	57	11	97	100
mm3_s108_u							68	99	57	11	96	99
mm3_s108_v							68	99	57	11	95	99
mm3_s108_w							69	99	57	11	97	100
mm3_s108_v3d							68	99	57	11	95	99
mm3_s108_vdir							68	98	57	11	95	98
mm3_s108_vhor							68	99	57	11	95	99
mm3_tair80							72	99	98	100	96	100
mm3_wd52_120							72	99	98	100	96	99
mm3_wd52_240							70	99	98	99	94	100
mm3_wd52_overall							70	99	98	100	96	100
mm3_wd80_120							71	99	98	100	96	99
mm3_wd80_240							72	99	98	100	96	99
mm3_wd80_overall							71	99	98	100	96	100
mm3_ws52_120							72	99	98	100	96	100
mm3_ws52_240							72	99	98	100	96	100
mm3_ws80_120							71	99	98	100	96	100
mm3_ws80_240							72	99	98	100	96	100
mm3_v_dt_37min10												

Appendix C Available data in 2005-2006 (monthly percentages)

	June-05	July-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05	Jan-06	Feb-06	Mar-06	Apr-06	May-06
m25_vais_ws	19	32	70	93	100	97	98	99	98	16		
m25_vais_wr	18	38	96	94	99	96	98	99	97	16		
m25_ws25_m	19	40	100	98	100	97	100	55	96	75		
m25_ws25_m_pulsecount_to_ws	19	40	100	98	100	97	100	55	95	75		
m25_ws25_s	19	40	100	98	100	97	100	100	95	75		
m25_ws25_s_pulsecount_to_ws	19	40	100	98	100	97	100	100	95	75		
mm1_pair70	98	79	70	96	100	97	100	100	100	75		
mm1_pair85	100	100	100	96	100	97	100	100	100	99	100	100
mm1_prec	100	100	100	96	100	97	100	100	100	99	100	100
mm1_s108_st	99	99	99	96	99	94	97	97	94	98	99	99
mm1_s108_u	98	98	99	96	99	94	98	99	99	98	99	99
mm1_s108_v	98	98	99	96	99	94	97	99	97	97	99	99
mm1_s108_w	98	98	99	96	99	94	98	99	99	98	99	99
mm1_s108_v3d	98	98	98	96	99	94	97	98	97	97	99	99
mm1_s108_vdir	97	97	98	95	98	93	97	98	96	97	99	99
mm1_s108_vhor	98	98	98	96	99	94	97	98	97	97	99	99
mm1_tair3	100	100	100	91	100	52		82	100	99	100	100
mm1_tair70	100	100	100	93				86	42	75		
mm1_tair85	100	100	100	96	100	97	100	100	100	99	100	100
mm1_tair108	100	66	100	98	3		31	100	100	40	100	100
mm1_wd25_240	100	99	99	97	100	97	100	99	100	99	100	99
mm1_wd70_120	100	99	97	95	100	97	100	99	100	75		
mm1_wd70_240	100	99	96	95	99	97	100	99	100	75		
mm1_wd70_overall	100	99	95	94	99	97	100	99	100	75		
mm1_wd85_120	99	99	100	96	100	97	100	99	100	99	100	100
mm1_wd85_240	99	98	98	96	100	97	94	99	100	99	100	100
mm1_wd85_overall	100	98	98	96	100	97	94	99	100	99	100	100
mm1_wd108	100	99	100	98	100	97	100	100	100	99	100	100
mm1_ws25_240	100	100	100	98	100	97	99	100	95	99	100	100
mm1_ws25_240_pulsecount_to_ws	100	100	100	98	100	97	99	100	95	75		
mm1_ws45_240	100	100	100	98	100	97	100	100	95	99	100	100
mm1_ws70_0	100	100	100	96	100	97	100	100	95	75		
mm1_ws70_120	100	100	100	96	100	97	100	100	95	75		
mm1_ws70_240	100	100	100	96	100	97	99	100	95	75		
mm1_ws85_0												
mm1_ws85_120												
mm1_ws85_240												
mm1_ws85_0_p	100	100	100	98	100	97	99	100	95	99	100	100
mm1_ws85_120_p	100	100	100	98	100	97	99	100	95	99	100	100
mm1_ws85_240_p	100	100	100	98	100	97	99	100	95	99	100	100
mm1_ws85_120_d	51	51	52	50	52	50	52	52	54	51	51	52
mm2_pair96					66	97	100	98	89	99	100	100
mm2_prec					66	97	100	99	100	99	100	100
mm2_s100_st						53	100	99	100	98	100	100
mm2_s100_u						53	99	98	100	98	100	100
mm2_s100_v						53	99	97	98	98	100	100
mm2_s100_w							97	97	95	98	99	99
mm2_s100_vdir							97	97	95	98	99	99
mm2_s100_vhor							97	97	95	98	99	99
mm2_s100_v3d							97	97	95	98	99	99
mm2_tair3					66	97	100	99	100	99	100	100
mm2_tair96					66	97	100	98	100	99	100	100
mm2_wd96_215					66	96	96	98	100	99	100	100
mm2_wd96_335					66	97	100	98	100	99	100	100
mm2_wd60_215					66	97	100	99	100	99	100	100
mm2_wd60_335					66	97	100	99	100	99	100	100
mm2_ws100_125					66	97	100	97	100	99	100	100
mm2_ws100_305					66	97	98	98	96	99	100	100
mm2_ws80_215						53	100	55	100	99	100	100

mm2_ws60_215					66	97	46	99	95	99	100	100
mm2_ws60_335					66	97	46	99	95	99	100	100
mm2_ws60_95					66	97	46	99	95	99	100	100
mm2_ws26_215					66	97	100	55	100	99	100	100
mm3_pair80	99	100	100	98	100	99	100	100	100	88	100	96
mm3_rh80	99	100	100	98	100	99	100	100	100	88	100	96
mm3_s52n_st	100	100	100	98	100	99	99	100	100	88	100	96
mm3_s52n_u	99	100	100	98	100	99	100	100	99	88	100	96
mm3_s52n_v	99	100	100	98	100	99	100	100	100	88	100	96
mm3_s52n_w	99	99	100	98	99	98	100	100	97	87	100	96
mm3_s52n_v3d	99	99	100	98	99	98	100	100	97	87	100	96
mm3_s52n_vdir	99	99	100	97	100	98	99	100	98	87	100	96
mm3_s52n_vhor	99	100	100	98	100	99	100	100	99	88	100	96
mm3_s80n_st	100	100	100	98	100	99	99	96	100	86	100	96
mm3_s80n_u	99	99	100	98	100	98	99	96	99	85	100	96
mm3_s80n_v	99	100	100	98	100	98	99	96	99	86	100	96
mm3_s80n_w	99	99	99	97	100	97	99	95	97	85	100	96
mm3_s80n_v3d	99	99	99	97	100	97	99	95	97	85	100	96
mm3_s80n_vdir	98	98	99	97	99	97	99	95	97	85	100	96
mm3_s80n_vhor	99	99	100	98	100	98	99	96	99	85	100	96
mm3_s108_st	100	100	100	98	100	97	96	98	91	76	93	96
mm3_s108_u	98	99	99	97	100	94	95	98	90	76	92	96
mm3_s108_v	98	98	99	97	100	94	94	98	90	76	92	96
mm3_s108_w	98	97	97	96	99	92	94	97	88	76	92	95
mm3_s108_v3d	97	97	97	96	99	92	94	97	88	76	92	95
mm3_s108_vdir	97	97	98	96	99	93	94	97	89	75	92	95
mm3_s108_vhor	98	98	99	97	99	94	94	97	90	76	92	96
mm3_tair80	99	100	100	98	100	99	100	100	100	88	100	96
mm3_wd52_120	99	99	100	97	99	98	99	100	100	88	100	96
mm3_wd52_240	99	99	100	98	100	98	99	100	100	88	100	96
mm3_wd52_overall	99	100	100	98	100	98	99	100	100	88	100	96
mm3_wd80_120	99	99	100	97	100	98	99	100	100	88	100	96
mm3_wd80_240	99	99	100	97	99	98	99	99	100	88	100	96
mm3_wd80_overall	99	100	100	98	100	98	99	100	100	88	100	96
mm3_ws52_120	99	99	99	98	100	98	99	100	95	88	100	96
mm3_ws52_240	99	100	100	98	100	98	100	100	95	88	100	96
mm3_ws80_120	99	100	100	98	100	98	99	100	95	88	100	96
mm3_ws80_240	99	100	100	98	100	98	99	100	95	88	100	96
mm3_v_dt_37min10	5	98	96	98	100	99	99	100	100	88	100	96

Appendix D Available data in 2006-2007 (monthly percentages)

	June-06	July-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06	Jan-07	Feb-07	Mar-07	Apr-07	May-07
m25_vais_ws												
m25_vais_wr												
m25_ws25_m												
m25_ws25_m_pulsecount_to_ws												
m25_ws25_s												
m25_ws25_s_pulsecount_to_ws												
mm1_pair70												
mm1_pair85	61	98	99	97	78	93	99	78	92	100	100	100
mm1_prec	100	98	99	97	78	93	99	78	92	100	100	100
mm1_s108_st	100	98	97	97	76	91	99	78	92	100	100	100
mm1_s108_u	100	98	98	97	77	92	98	76	90	99	100	99
mm1_s108_v	100	98	98	97	77	92	98	76	91	99	100	99
mm1_s108_w	100	98	99	97	77	93	98	76	91	99	100	100
mm1_s108_v3d	100	98	98	97	77	92	98	76	90	99	100	99
mm1_s108_vdir	99	97	97	97	77	92	98	75	90	99	100	98
mm1_s108_vhor	100	98	98	97	77	92	98	76	90	99	100	99
mm1_tair3	100	98	99	97	78	93	99	78	92	100	100	100
mm1_tair70												
mm1_tair85	100	98	99	97	78	93	99	78	92	100	100	100
mm1_tair108	100	98	99	97	78	93	99	78	92	100	100	100
mm1_wd25_240	100	98	99	97	78	82	98	78	87	100	100	99
mm1_wd70_120												
mm1_wd70_240												
mm1_wd70_overall												
mm1_wd85_120	100	93	99	97	78	93	97	77	91	100	100	99
mm1_wd85_240	100	97	99	97	78	93	97	78	92	100	100	99
mm1_wd85_overall	100	93	99	97	78	93	97	77	91	100	100	99
mm1_wd108	100	98	99	97	78	93	97	78	92	100	100	99
mm1_ws25_240	100	98	99	97	78	93	99	78	92	100	100	100
mm1_ws25_240_pulsecount_to_ws												
mm1_ws45_240	100	98	99	97	78	93	99	78	92	100	100	100
mm1_ws70_0												
mm1_ws70_120												
mm1_ws70_240												
mm1_ws85_0												
mm1_ws85_120												
mm1_ws85_240												
mm1_ws85_0_p	100	98	99	97	78	93	99	77	92	100	100	100
mm1_ws85_120_p	100	98	99	97	78	93	98	77	92	100	100	100
mm1_ws85_240_p	100	98	99	97	78	93	99	77	92	100	100	95
mm1_ws85_120_d	77	77	52	50	40	48	50	40	47	51	52	52
mm2_pair96	100	100	99	96	80	93	99	77	92	99	100	100
mm2_prec	100	100	99	96	80	93	99	77	92	99	23	35
mm2_s100_st	100	100	99	96	80	93	99	77	92	98	100	100
mm2_s100_u	100	100	98	96	79	93	98	77	91	98	100	100
mm2_s100_v	100	100	98	96	79	93	98	76	91	98	100	100
mm2_s100_w	100	100	97	96	78	93	98	76	90	97	100	100
mm2_s100_vdir	100	100	97	96	78	93	98	76	90	97	100	100
mm2_s100_vhor	100	100	97	96	78	93	98	76	90	97	100	100
mm2_s100_v3d	100	100	97	96	78	93	98	76	90	97	100	100
mm2_tair3	100	100	99	96	80	93	99	77	92	99	100	100
mm2_tair96	100	100	99	96	80	93	99	77	92	99	100	100
mm2_wd96_215	100	100	99	96	80	93	99	77	92	99	100	100
mm2_wd96_335	100	100	97	96	80	93	99	77	92	99	100	100
mm2_wd60_215	100	100	99	96	80	93	99	77	92	99	100	100
mm2_wd60_335	100	100	99	96	80	93	99	77	92	99	100	100

	June-06	July-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06	Jan-07	Feb-07	Mar-07	Apr-07	May-07
mm2_ws100_125	100	100	99	96	80	93	99	77	92	99	100	100
mm2_ws100_305	100	100	99	96	80	93	99	77	92	99	100	100
mm2_ws80_215	100	100	99	96	80	93	99	77	92	99	100	100
mm2_ws60_215	100	100	99	96	80	93	99	77	92	99	100	100
mm2_ws60_335	100	100	99	96	80	93	99	77	92	99	100	100
mm2_ws60_95	100	100	99	96	80	93	99	77	92	99	100	100
mm2_ws26_215	100	100	99	96	80	93	99	77	92	99	100	100
mm3_pair80	100	100	96	96	79	93	99	78	92	100	100	99
mm3_rh80	100	100	96	96	79	93	99	78	92	100	100	99
mm3_s52n_st	100	100	96	96	79	93	98	78	92	99	100	99
mm3_s52n_u	100	100	96	96	79	93	99	77	92	99	100	99
mm3_s52n_v	100	100	96	96	79	93	99	78	92	99	100	99
mm3_s52n_w	100	100	96	96	79	93	99	77	92	99	100	99
mm3_s52n_v3d	100	100	96	96	79	93	99	77	92	99	100	99
mm3_s52n_vdir	100	99	96	96	79	93	98	77	92	99	100	98
mm3_s52n_vhor	100	100	96	96	79	93	99	77	92	99	100	99
mm3_s80n_st	98	100	96	96	79	93	98	78	92	100	100	99
mm3_s80n_u	98	100	96	96	79	93	99	77	92	99	100	99
mm3_s80n_v	98	100	96	96	79	93	99	77	92	100	100	99
mm3_s80n_w	98	100	96	96	79	93	99	77	92	99	100	99
mm3_s80n_v3d	98	100	96	96	79	93	99	77	92	99	100	99
mm3_s80n_vdir	98	99	96	96	79	93	98	77	92	99	100	98
mm3_s80n_vhor	98	100	96	96	79	93	99	77	92	99	100	99
mm3_s108_st	100	100	96	96	79	93	98	78	91	100	100	98
mm3_s108_u	100	100	94	96	77	92	97	76	90	99	100	98
mm3_s108_v	100	100	94	96	77	92	97	76	89	98	100	98
mm3_s108_w	100	100	92	96	76	92	97	75	88	98	100	98
mm3_s108_v3d	100	100	92	96	76	92	97	75	88	98	100	98
mm3_s108_vdir	99	99	93	96	77	92	97	76	89	98	100	97
mm3_s108_vhor	100	100	93	96	77	92	97	76	89	98	100	98
mm3_tair80	100	100	96	96	79	93	99	78	92	100	100	99
mm3_wd52_120	100	99	96	96	78	93	98	78	92	100	100	99
mm3_wd52_240	100	100	96	96	79	93	98	78	92	100	100	99
mm3_wd52_overall	100	100	96	96	79	93	98	78	92	100	100	99
mm3_wd80_120	100	99	96	95	78	92	98	78	91	100	100	98
mm3_wd80_240	100	99	96	96	78	93	98	77	92	100	100	99
mm3_wd80_overall	100	100	96	96	79	93	99	78	92	100	100	99
mm3_ws52_120	100	100	96	96	79	93	98	78	92	100	100	99
mm3_ws52_240	100	100	96	96	79	93	98	78	92	100	100	99
mm3_ws80_120	100	100	96	96	79	93	98	78	92	100	100	99
mm3_ws80_240	100	100	96	96	79	93	98	78	92	100	100	99
mm3_v_dt_37min10	100	100	96	96	79	93	98	78	92	100	100	99

Appendix E Pictures from meteorological mast 1 at 70m height

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

North-North-East
with Nordex turbines (6 to 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 NM92 turbine in front

North-North-West

Appendix F Pictures from meteorological mast 2 at 96.2 m height

North direction
with Nordex turbines in background
The folding mast with the sonic is down

North-North-East
with Nordex turbines in background
The folding mast with the sonic is down

East-North-East; location Siemens 3.6 in front,
IJsselmeer in background

East direction
IJsselmeer dike and lake in background

East-South-East
V52 machine in background

South-South-East
Lagerwey 52/750 machines in background

South direction
NM52 turbines in background

South-South-West
The lower part of the folding mast is visible

West-South-West

West direction
Meteo mast 1, NM92 and GE 2.5 visible

North-West
NM92, GE 2.5 and GE 2.3 visible

North-North-West
GE 2.3 and 4 Nordex turbines visible