Technical University of Denmark

Database on wind characteristics - Contents of database bank

Larsen, Gunner Chr.; Hansen, Kurt Schaldemose

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Database on Wind Characteristics

Contents of Database Bank, revision I

Gunner C. Larsen and Kurt S. Hansen

Risø National Laboratory, Roskilde
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Abstract The main objective of IEA R&D Wind Annex XVII - Database on Wind Characteristics - has been to provide wind energy planners, designers and researchers, as well as the international wind engineering community in general, with a source of actual wind field data (time series and resource data) observed in a wide range of different wind climates and terrain types. Connected to an extension of the initial Annex period, the scope for the continuation was widened to include also support to the international wind turbine standardisation efforts. The project partners are Sweden, Norway, U.S.A., The Netherlands and Denmark, with Denmark as the Operating Agent.

The reporting of the continuation of Annex XVII falls in two separate parts. Part one accounts in details for the available data in the established database bank, and part two describes various data analyses performed with the overall purpose of improving the design load cases with relevance for to wind turbine structures.

The present report constitutes the first part of the Annex XVII reporting. Basically, the database bank contains four categories of data, i.e. *i*) high sampled wind field time series; *ii*) high sampled wind turbine structural response time series; *iii*) wind resource data; and *iv*) wind farm data. The main emphasis, however, is on category *i*). The available data, within each of the four categories, are described in details. The description embraces site characteristics, terrain type, measurement set-up and the amount of available data.

IEA R&D Wind Annex XVII
Database on Wind Characteristics

http://www.winddata.com/

E-mail: winddata@mek.dtu.dk

Gunner Chr. Larsen
Wind Energy and Atmospheric
Physics Department
Risø National Laboratory
Post Office Box 49
DK-4000 Roskilde

E-mail: gunner.larsen@risoe.dk

Kurt S. Hansen
Fluid Mechanics Section
Department of Mechanical Engineering
Technical University of Denmark
Nils Koppels Allé
DTU-Building 403
DK-2800 Lyngby
E-mail: ksh@mek.dtu.dk

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Contents

1. Background

In 1996, the EU-DG XII (JOULE) project "Database on Wind Characteristics" was started. The project was concluded at the end of 1998 and resulted in a unique database of quality controlled and well-documented wind field measurements in a standardised format. The established data bank was supplemented with tools to enable access and simple analysis through an Internet connection using the World-Wide-Web. The contents and the facilities are reported in [1].

As a follow-up to the JOULE project, Annex XVII, within the auspices of the IEA R&D Wind, was formulated with Sweden, Norway, U.S.A., The Netherlands, Japan and Denmark as active participants. The Annex entered into force on 1st January 1999, and an initial annex period of two and a half year was successfully concluded on 30st June 2001. The main objective of Annex XVII was to provide wind energy planners and designers, as well as the international wind engineering community in general, with easy access to quality controlled measured wind field time series observed in a wide range of environments. From its inception Annex XVII has successfully met the purpose by ensuring that the database is always on-line and available through the Internet, and by making possible and managing the continuous development and dissemination of the database. The achievements, covering this initial annex period are reported in [2], [3] and [4].

With the purpose of continuing the ongoing maintenance and dissemination, accomplish the initiated extension of facilities and content, and further to support the international wind turbine standardisation efforts, IEA decided to run Annex XVII for an additional period of 2.5 years. The continuation of Annex XVII entered into force on 1st July 2001 and was concluded on 31st December 2003.

2. Introduction

The reporting of the 2.5 years continuation of Annex XVII falls in two separate parts. Part one accounts in details for the available data in the established database bank, and part two describes various data analyses performed with the overall purpose of improving and validating code specifications for wind turbine design on a rational basis [5].

The present report constitutes the part one of Annex XVII reporting. For each site, the description of the database bank embraces site characteristics, terrain type, experimental set-up, measurement system and the amount of available data.

3. Available data - an overview

Basically, the database bank contains four types of data:

1) High sampled wind field time series;
2) High sampled wind turbine structural response time series;
3) Wind resource data;
4) Wind farm data.

The available data, within each of these categories, are described in details in the following sections. The description embraces site characteristics, terrain type, measurement set-up and the amount of available data. This report presents the content of the database bank at the end of the IEA Annex XVII project, ultimo 2003.

3.1 High frequency sampled wind field time series

The wind field time series are characterised by being represented by high frequency sampled raw values in the database. The sampling frequency is typically between 1 and 40 Hz depending on the particular site as well on the actual channel sensor.

Presently, the database includes wind field time series from 12 different countries inside Europe and 3 countries outside (Egypt, USA and Japan) distributed on 60 sites. In total more than 172.000 hours of high sampled meteorological data are available. The present status is illustrated in Table 3-1, where the available data has been classified according to country, terrain type, type of orography and length of the data record. As seen, 8 different terrain types and 3 types of orography types are represented. For a definition of terrain classes and classes of orography refer to [1].

#	Site	Country	Terrain	Orography	Hours
1	Abisko Lake, Lappland	Sweden	ice	mountain	230
2	Acqua Spruzza	Italy	pastoral	mountain	542
3	Agia Marina, Lavrio	Greece	pastoral	mountain	759
4	Ainsworth, Nebraska, NE	US	scrub	hill	5421
5	Alsvik, Gotland, Sweden	Sweden	coastal	flat	17500
6	Andros	Greece	pastoral	mountain	625
7	Bockstigen Offshore wind park	Sweden	offshore	flat	1239
8	Burger Hill, Orkney Island, UK	UK	coastal	flat	6083
9	Calhete, S. Jorge Island, Azores	Portugal	coastal	mountain	5
10	Calwind, Tehachapi, CA	US	scrub	hill	4180
11	CIBA, Monte Torozos	Spain	pastoral	flat	426
12	ECN 25m HAWT	Netherlands	coastal	flat	49
13	ECN testveld Petten[1]	Netherlands	coastal	flat	793
14	Emden	Germany	coastal	flat	781
15	San Gorgonio Pass, CA	US	scrub	hill	1399
16	Gedser Rev, Gedser, Denmark	Denmark	offshore	flat	702
17	Equinox Mountain, Vermont	US	scrub	hill	72
18	Hanford, WA	US	pastoral	flat	1071
19	Holland, Minnesota, MN	US	scrub	hill	6525

[1] This site includes the two site codes Ecn_ems and Ecn_met, respectively.

20	HornsRev, Northsea outside port of Esbjerg	Denmark	offshore	flat	13478
21	Hurghada Wind Energy Technology Center, Egypt	Egypt	sand	flat	1380
22	Jericho, Texas, Texas, USA	US	scrub	hill	6349
23	Kaiser-Wilhem-Koog	Germany	coastal	flat	4
24	KNMI Meteo tower, Cabauw, Utrecht, NL	Netherlands	pastoral	flat	472
25	La Clape near Narbonne (France)	France	scrub	hill	242
26	Lammefjord, Sealand	Denmark	pastoral	flat	663
27	Lysekil, Sweden	Sweden	coastal	mountain	31355
28	Maglarp, Skaane	Sweden	rural	flat	41
29	Marsta, Uppsala, Sweden	Sweden	rural	flat	2975
30	Middelgrunden, Copenhagen, Denmark	Denmark	offshore	flat	2075
31	Mojave, Horned Toad Hils, CA	US	scrub	hill	5947
32	Monolith, CA	US	scrub	hill	3667
33	Mt. Tsukuba, Japan	Japan	forest	mountain	2410
34	National Wind Test Center, Denver, CO, USA	US	pastoral	flat	24
35	Norrekaer Enge, Jutland	Denmark	coastal	flat	746
36	NTK 1500 wind turbine, Tjaereborg, Denmark	Denmark	coastal	flat	151
37	Näsudden, Gotland, Sweden	Sweden	coastal	flat	3069
38	Oak Creek, Tehachapi, California	US	scrub	hill	5200
39	Roedsand, Gedser syd offshore park	Denmark	offshore	flat	619
40	Rosiere, Wisconsin	US	scrub	hill	4681
41	Skipheia, Fröya	Norway	coastal	hill	13174
42	Sky River wind farm, V27 location.	US	scrub	hill	164
43	Sky River wind farm, V39 location	US	scrub	hill	138
44	Sletringen, Fröya	Norway	coastal	flat	3756
45	Sprogoe, Island in Great Belt	Denmark	coastal	flat	527
46	Tarifa, Spain	Spain	pastoral	mountain	280
47	Tarifa, Spain with NTK turbines	Spain	coastal	hill	663
48	Tejona, Costa Rica	CostaRica	scrub	mountain	2511
49	Tjaereborg, Esbjerg	Denmark	pastoral	flat	79
50	Toboel, Mast #1, Ribe	Denmark	pastoral	flat	2071
51	Toboel, Mast #2, Ribe	Denmark	pastoral	flat	1147
52	Toplou, Crete	Greece	pastoral	mountain	172
53	Tsukuba test centre, Japan	Japan	rural	flat	1355
54	Tug Hill Plateau, New York	US	pastoral	hill	2983
55	Utlängan, Sweden	Sweden	coastal	flat	27
56	Vallersund	Norway	coastal	hill	5956
57	Vindeby, offshore, Denmark	Denmark	offshore	flat	2394
58	Wilhelmshaven,	Germany	rural	flat	344
59	Windpark Zeebrugge, port of Zeebrugge	Belgium	coastal	flat	103
60	Windy Standard	UK	pastoral	mountain	405
	60 sites	*16 countries*			*172196*

Table 3-1: High sampled wind field time series in the database bank ultimo December 2003.

3.2 Wind turbine structural response time series

For three different sites the high frequency sampled wind field time series are supplemented by high frequency sampled wind turbine structural response measurements. The structural recordings originate from measurements on i) 2 x 300 kW Nordtank wind turbines, located inside a wind farm in Noerrekaer Enge, Denmark; ii) a Vestas V39 (500 kW) wind turbine located in a wind farm in a rather complex terrain in Tehachapi, USA; and iii) a 2MW, 60m wind turbine located in Tjaereborg, Denmark. The available time series reflects different modes of operation (start, stop, idling and operation) of the wind turbine.

The main characteristics of the available structural response data are presented in Table 3-2.

#	Site	Country	Terrain	Orography	Hours
35	Norrekaer Enge, Jutland	Denmark	coastal	flat	746
43	Sky River wind farm, V39 location	US	scrub	hill	138
49	Tjaereborg, Esbjerg	Denmark	pastoral	flat	79
	3 sites	2 countries			963

Table 3-2: High frequency sampled wind turbine structural response time series in the database bank ultimo 2003.

3.3 Wind resource data

Wind resource data are statistical quantities (mean, max., min., standard deviation) typically based on a (high frequency) sampling records between 1 and 60 minutes. Due to the limited temporal resolution such data usually extend over very long time span, typically between 1 and 30 years. Presently, wind resource data are available from 33 different sites in Denmark, Greenland, Faroe Islands, Sweden, Norway, The Netherlands, UK, Greece, USA and Mexico. Furthermore the wind resource data includes 1320 hours of SODAR measurements recorded in The Netherlands. The wind resource data include as a minimum both a wind speed signal and a wind direction signal for each site. The characteristics of the available wind resource measurements are summarised in Table 3-3.

#	Site	Country	Terrain	Orography	Hours
1	Ainsworth, Nebraska, NE	US	scrub	hill	7249
2	Alsvik, Gotland, Sweden	Sweden	coastal	flat	17502
3	Borglum, Denmark	Denmark	pastoral	flat	35552
4	Burger Hill, Orkney Island, UK	UK	coastal	flat	9707
5	Calwind, Tehachapi, CA	US	scrub	hill	17303
6	Capel Cynon, Dyfed, Wales	UK	pastoral	flat	55523
7	Delabole, North Cornwall	UK	pastoral	flat	16671
8	San Gorgonio Pass, CA	US	scrub	hill	6580
9	Godhavn, Diskos, Greenland	Greenland	coastal	hill	73510
10	Green Mountain Power Corp., Equinox Mountain, Vermont	US	scrub	hill	3223
11	Hanford, WA	US	pastoral	flat	8625
12	Holland, Minnesota, MN	US	scrub	hill	3797
13	Jericho, Texas, Texas, USA	US	scrub	hill	6567
14	Kegnes, Als, Denmark	Denmark	coastal	flat	96432
15	KNMI Meteo tower, Cabauw, Utrecht, NL	Netherlands	pastoral	flat	124128
16	La Ventosa, Oaxaca, MX	Mexico	scrub	hill	12432

17	Lysekil, Sweden	Sweden	coastal	mountain	31479
18	Mojave, Horned Toad Hils, CA	US	scrub	hill	15204
19	Monolith, CA	US	scrub	hill	17090
20	NTUA Campus, Athens, Greece	Greece	scrub	hill	49587
21	Näsudden, Gotland, Sweden	Sweden	coastal	flat	27904
22	Risø Mast, Risø campus	Denmark	coastal	flat	61234
23	Rosiere, Wisconsin	US	scrub	hill	6497
24	Sarfannguit, Sisimiut, Greenland	Greenland	coastal	hill	3304
25	Skipheia, Fröya	Norway	coastal	hill	6600
26	SODAR measurements from Cabauw, NL	Netherlands	rural	flat	1320
27	Sornfelli, Faroe Island	Denmark	coastal	mountain	3221
28	Tjaereborg	Denmark	pastoral	flat	33830
29	Tjareborg Enge, NTK1500 site, Esbjerg, Denmark	Denmark	coastal	flat	11355
30	Tug Hill Plateau, New York	US	pastoral	hill	10521
31	Vindeby, offshore	Denmark	offshore	flat	48746
32	BAO, Boulder, USA[2]	US	pastoral	flat	11088
33	ECN testveld Petten[1]	Netherlands	coastal	flat	10320
	33 sites	*8 countries*			*844095*

Table 3-3: Wind resource data in the database bank ultimo December 2003.

3.4 Wind farm data

Wind farm data are statistical quantities (mean and standard deviation) representing e.g. electrical power, yaw misalignment, wind speed and wind direction for each individual wind turbine located in a wind farm. Presently, wind farm data are available from two different wind farms i) 10 x 400 kW VESTAS VD34 wind turbines located in Delabole, Cornwall, UK; and ii) 42 x 300 kW Nordtank wind turbines located in the Noerrekaer Enge wind farm, Denmark, The characteristics of the available wind farm measurements are summarised in Table 3-4.

#	Site	Country	Terrain	Orography	Hours
1	Delabole, North Cornwall	UK	pastoral	flat	6800
2	Norrekaer Enge, Jutland	Denmark	coastal	flat	12342
	2 sites	*2 countries*			*19142*

Table 3-4: Wind farm data in the database bank ultimo December 2003.

[2] 1-minute average values.

4. Available data - site presentation

All available sites were briefly categorised in the previous Chapter. The present Chapter contains a detailed description of these sites. The description accounts in details for characteristics such as site classification, number and size of instrumented meteorological masts, number of wind speed and wind direction measuring channels, number of wind turbines in the close surroundings, sampling frequency and time extend of the data. Moreover, the measuring system is described and the original motivation for conducting the measuring campaign is set out. Furthermore a detailed site description including maps, photos and measured distributions is available on the web-server as a PDF document. An example of site description for the Swedish Bockstigen site is listed in Appendix A.

The presentation is structured according to the four classes of data. For the high frequency sampled wind field data, the above specified information are supplemented with plots of the turbulence intensity versus the mean wind speed. This type of plot provides a quick visual general view of the data material. For the high frequency sampled structural response data, the general information is supplemented by a plot showing the power production as function of the mean wind speed in order to illustrate the extend of stand still and normal operation modes of the turbines during the measuring campaign. The wind resource data information includes a plot of the probability density function of the observed mean wind speeds, while all other distributions are available online.

4.1 High frequency sampled wind field time series

Site = Abisko, Lapland, Sweden

Site code **Abisko**

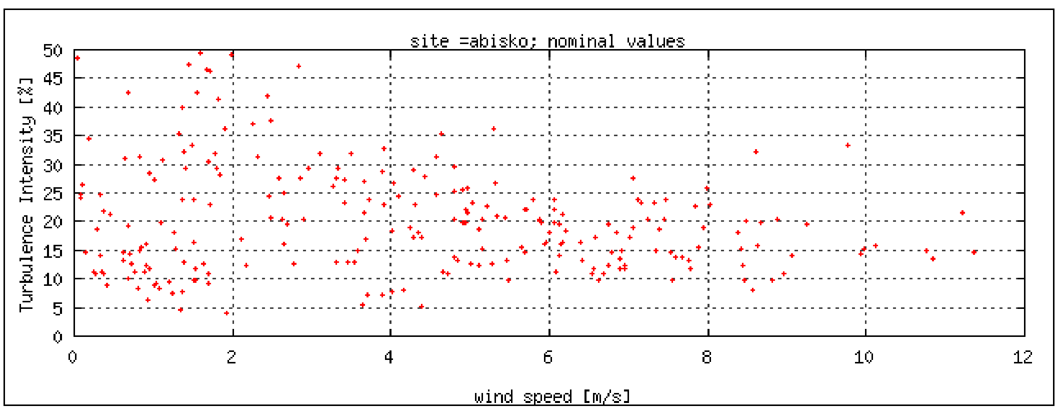
Dominating terrain/ orography	Ice	Mountain
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	2 (3)	2 (3)
Number of sonics / height of met. Mast.	0	22 m
Hours of measurements / frequencies	230	

Project motivation
Measurements from a frozen lake in a mountainous area - in Lapland.

Measurement system
The instrumentation consists only of 3-component hotwires.

Comments
All measurements are recorded with hotwires.

Acknowledgements: Mikael Magnusson & Hans Bergström, Uppsala University, Sweden.



Nominal turbulence vs. wind speed.

Site = Ainsworth, Nebraska, NE, USA

Site code	**Ainswort**	
Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	4	4
Number of sonics / height of met. Mast.	0	40 m
Hours of measurements / frequencies	230	5 Hz

Project motivation

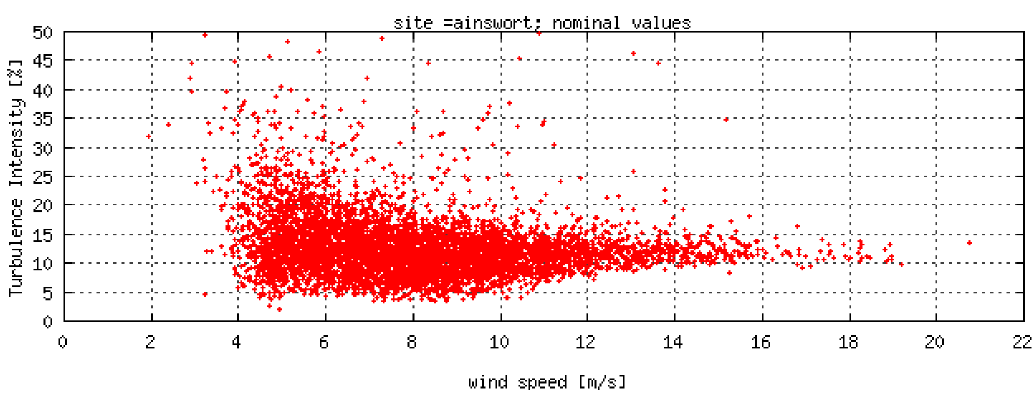
This project was initiated in 1990 to develop measurements and analysis methods that would establish representative and appropriate turbulence characteristics needed for the design and siting of costeffective wind turbines. NREL and Batelle had additional objectives that included correlating the nature of the turbulence in the inflow to upwind features, and transferring the technology developed in the project to industry for operational applications.

Measurement system

11 different sites with identical equipment (4 cups, 4 vanes and 4 vertical propellers). Measurements from three sensors on the 40-m tower (T1) provided a representation of the vertical shear of the wind velocity for wind turbines with a 20-m rotor diameter and a 30-m rotor diameter. The 30-m tower (T2) allowed a hub-height wind measurement positioned on the perimeter of the rotor disk 10m away from the centre of the rotor disc, and in direction perpendicular to the prevailing wind direction. This data configuration provided not only vertical and horizontal wind shear data at a site but also data on the effect on rotational sampling of the turbulent wind. The horizontal wind speed and direction were measured at four locations with R.M.Young Wind Monitors. The vertical component of the wind was measured by a single Gill propeller anemometer mounted directly underneath each of the propeller-vane anemometers. A single cup-vane anemometer was mounted near the propeller-vane anemometer at the top of T2 within a few feet of the propeller-vane anemometer at the same location. This was the Maximum cup and NRG vane that are commonly used in the wind industry to estimate the resource at the site.

Acknowledgements:

Sandy Butterfield & Maureen Hand, NREL.



Nominal turbulence vs. wind speed.

Site = Alsvik, Gotland, Sweden

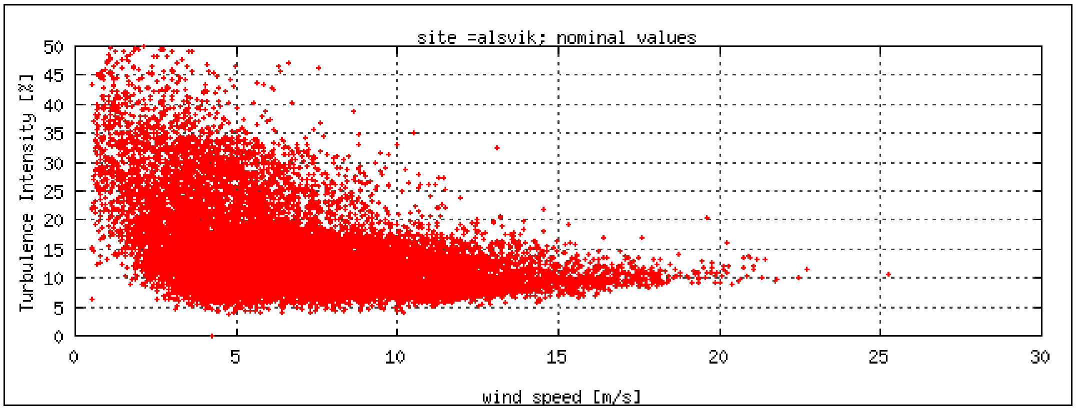
Site code **Alsvik**

Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	2	4
Number of channels with wind speed / wind direction	16	16
Number of sonics / height of met. Mast.	0	56 m
Hours of measurements / frequencies	17500	Appr. 1 Hz

Project motivation
Meteorological measurements from flat, coastal site on Gotland equipped with four wind turbines.

Measurement system
1 Hz data at eight levels on two 54 m towers during four years. 20 Hz data at three levels on one 54 m tower during one year.

Acknowledgements: Mikael Magnusson & Hans Bergström, Uppsala University, Sweden.



Nominal turbulence vs. wind speed.

Site = Andros, Greece

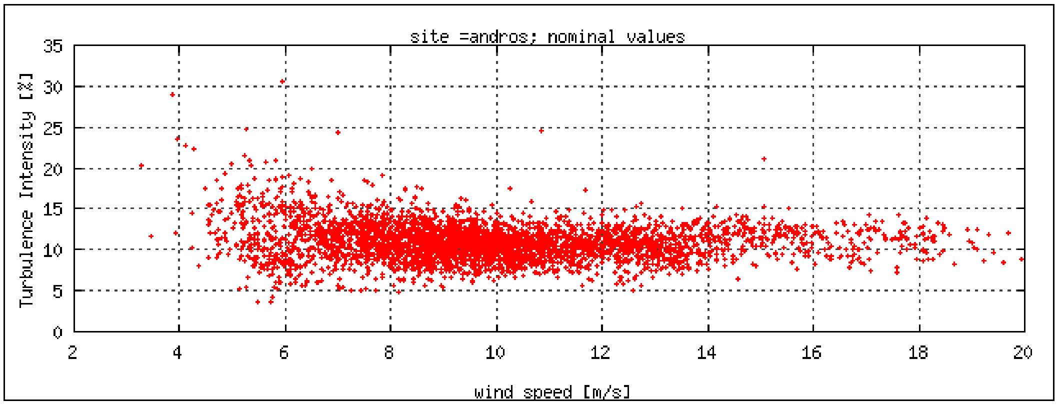
Site code **Andros**

Dominating terrain/ orography	Pastoral	Mountain
Number of masts / wind turbines	2	1
Number of channels with wind speed / wind direction	3	3
Number of sonics / height of met. Mast.	0	40 m
Hours of measurements / frequencies	625	1 Hz

Project motivation
The main objectives of the project were to a) develop draft design guidelines for wind turbines in simple terrain wind farms, b) investigate the behaviour of wind turbines in undulating and complex terrain wind farms and c) extend simple terrain design guidelines to complex terrain.

Measurement system
Full scale measurements at a wind farm sited in mountainous terrain consisting of seven V27-225kW fixed speed, variable pitch wind turbines. Measurements of wind speed and direction were carried out at three heights a.g.l. on two meteorological masts using six cup anemometers and six vanes, in order to define the operational characteristics of one of the seven wind turbines in relation to the wind regime of the site.

Acknowledgements
E.E.Morfiakakis & G.Glenou, C.R.E.S, Greece.



Nominal turbulence vs. wind speed.

Site = Acqua Spruzza, Italy

Site code **Aspruzza**

Dominating terrain/ orography	Pastoral	Mountain
Number of masts / wind turbines	1	8
Number of channels with wind speed / wind direction	3	1
Number of sonics / height of met. Mast.	0	40 m
Hours of measurements / frequencies	542	1 Hz

Project motivation

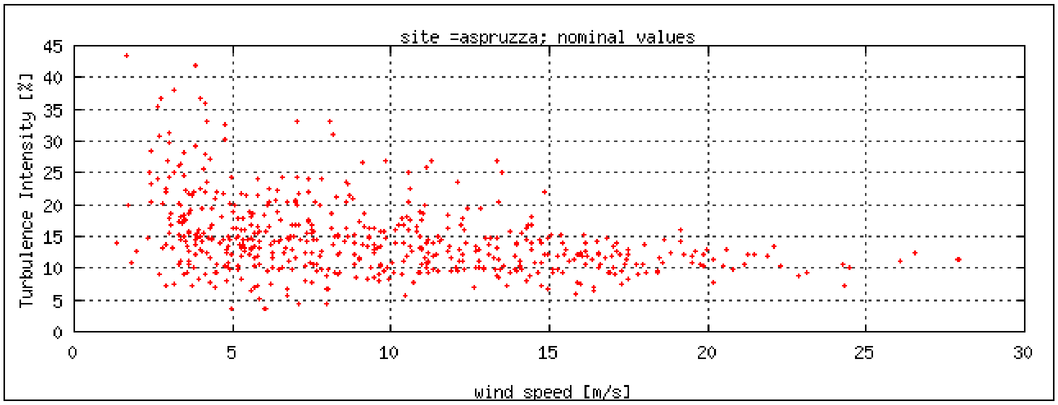
The Acqua Spruzza wind turbine test site has been built by ENEL S.p.A. within the framework of a programme aimed at evaluating the technology of commercial medium-sized machines operating in complex terrain and very hostile climate and with special regard to availability, energy output, lifetime (through the monitoring of loads), operating and maintenance costs. The objective is to assess the viability and the economic attractiveness of wind farms in hostile terrain and to understand the risk, associated with the exploitation of these kinds of sites. To this end, a suitable research programme has been outlined, comprising regular performance and load monitoring of the wind turbines and wind monitoring as well, through acquisition of both statistical and campaign series of data. The campaign wind data are available for the present Project "Database on Wind Characteristics".

Measurement system

A number of data acquisition systems are presently installed at the Acqua Spruzza test site, namely the Measurement Control and Monitoring system (MCM), the Scientific Measurement Systems (SMS) and the SQUIRREL data loggers. The MCM system allows the general monitoring of wind turbines and the wind measurements from conventional anemometers installed on two wind masts, namely M1 and M2, through the recording of 10-min main statistics. The SMSs are specifically dedicated to the performance and load monitoring of three wind turbines, through the acquisition of extensive campaign data (20 - 60 Hz). The SQUIRREL data loggers are dedicated to summary wind data acquisition, some of which from sensors specially designed for operation in cold climate, and to the collection of wind data time series at 1 Hz frequency from mast M1. The wind campaigns recorded by a SQUIRREL data logger are available for the present Project.

Acknowledgements

Massimo Cavaliere, ENEL Research, Renewable unit, Italy.



Nominal turbulence vs. wind speed.

Site = Bockstigen, Gotland, Sweden

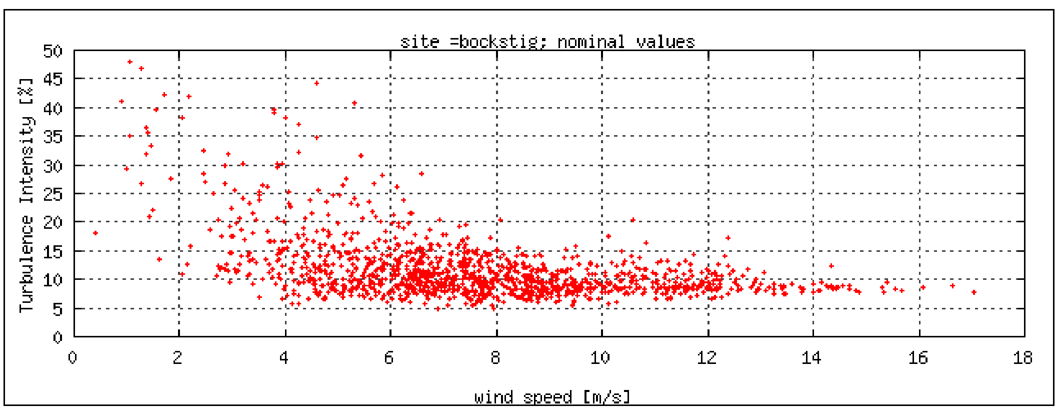
Site code **Bockstig**

Dominating terrain/ orography	Offshore	Flat
Number of masts / wind turbines	1	5
Number of channels with wind speed / wind direction	4	3
Number of sonics / height of met. Mast.	0	40 m
Hours of measurements / frequencies	1239	

Project motivation
The Bockstigen off-shore wind farm consists of five 500 kW wind turbines erected three km of the SW coast of the island of Gotland on the Baltic. The project was launched in order to gain experience from bottom mounted offshore wind turbine installation. Specifically, the method of drilling a hole for a monopile foundation, directly into the limestone rock, was in focus for the investigations.

Measurement system
Measurements are performed in one meteorological mast, and on one instrumented turbine (no measurements in the rotating system). Data are sampled by use of several loggers (DataScan 20 Hz), and the signals are transferred through an optical fibre cable (4500 m) to an onshore cabin. Data is continuously stored on video8 tapes.

Acknowledgements
Göran Ronsten, FOI (FFA), Sweden.



Nominal turbulence vs. wind speed.

Site = Cabauw, The Netherlands

Site code **Cabauw**

Dominating terrain/ orography	Pastoral	Flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	5	5
Number of sonics / height of met. Mast.	0	213 m
Hours of measurements / frequencies	472	

Project motivation

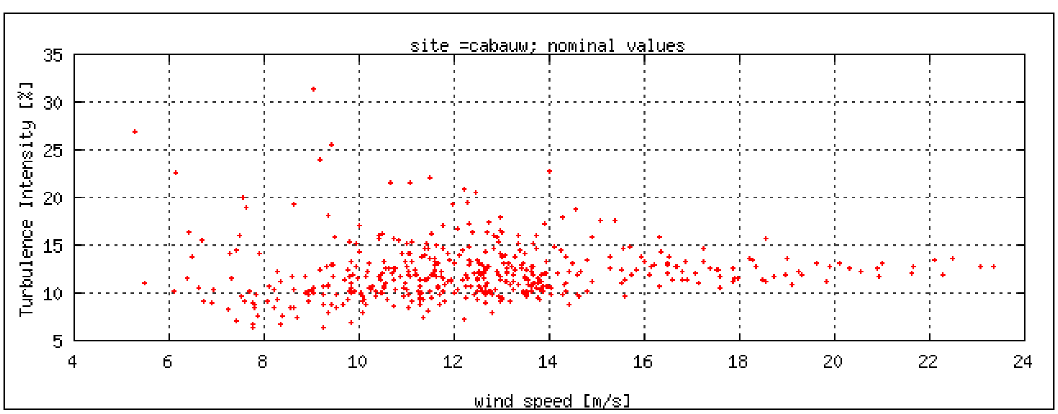
In the framework of the project "a manual of design wind data for wind turbines ", measurements from the Royal Netherlands Meteorological Institute (KNMI) were used extensively. In this project a set of wind measurements of about 800 hr, measured in 1985 and 1986, was used. An important subject in this project was the frequency of occurrence of wind gusts and of wind direction changes. Wind data files in which average values (averaging time 600s) greater than 15 m/s are present at 20 m height, were classified as wind files with strong winds. The wind data in this subset (50 hrs) are made available for the "Database on Wind Characteristics". The KNMI allows the use of these data under the following conditions: Users of the data refer to the source of the data e.g. with the following sentence: The Cabauw wind data were made available by the Royal Netherlands Meteorological Institute (KNMI). The KNMI appreciates to be informed how the data were treated and likes to get relevant reports. In general commercial use of the data is not allowed. Information about the terms for commercial use can be obtained at the KNMI, attention to W.A.A. Monna, Section atmospheric research, P.O. Box 201, 3730 AE De Bilt, NL.

Measurement system

The Cabauw meteorological mast is a tubular tower with a height of 213 m and a diameter of 2 m. Guy wires are attached at four levels. From 20m upwards horizontal trussed measurement booms are installed at intervals of 20 m. At each level there are three booms, extending 10.4 m from the centreline of the tower. These booms point to the directions 10, 130, 250 degrees relative to North. The SW and N booms are used for wind velocity and wind direction measurements. These booms carry at the end two lateral extensions with a length of 1.5 m and a diameter of about 4 cm.

Acknowledgements

J.W.M.Dekker & Terry Hegberg, ECN, The Netherlands.



Nominal turbulence vs. wind speed.

Site = Calwind, Tehachapi,CA, USA

Site code **Calwind**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	4	4
Number of sonics / height of met. Mast.	0	40 m
Hours of measurements / frequencies	4180	5 Hz

Project motivation
This project was initiated in 1990 to develop measurements and analysis methods that would establish representative and appropriate turbulence characteristics needed for the design and siting of cost-effective wind turbines. NREL and Batelle had additional objectives that included correlating the nature of the turbulence in the inflow to upwind features, and transferring the technology developed in the project to industry for operational applications.

Measurement system
11 different sites with identical equipment (4 cups, 4 vanes and 4 vertical propellers). Measurements from three sensors on the 40-m tower (T1) provided a representation of the vertical shear of the wind velocity for wind turbines with a 20-m rotor diameter and a 30-m rotor diameter. The 30-m tower (T2) allowed a hub-height wind measurement positioned on the perimeter of the rotor disk 10m away from the centre of the rotor disc, and in direction perpendicular to the prevailing wind direction. This data configuration provided not only vertical and horizontal wind shear data at a site but also data on the effect on rotational sampling of the turbulent wind. The horizontal wind speed and direction were measured at four locations with R.M.Young Wind Monitors. The vertical component of the wind was measured by a single Gill propeller anemometer mounted directly underneath each of the propeller-vane anemometers. A single cup-vane anemometer was mounted near the propeller-vane anemometer at the top of T2 within a few feet of the propeller-vane anemometer at the same location. This was the Maximum cup and NRG vane that are commonly used in the wind industry to estimate the resource at the site.

Acknowledgements:
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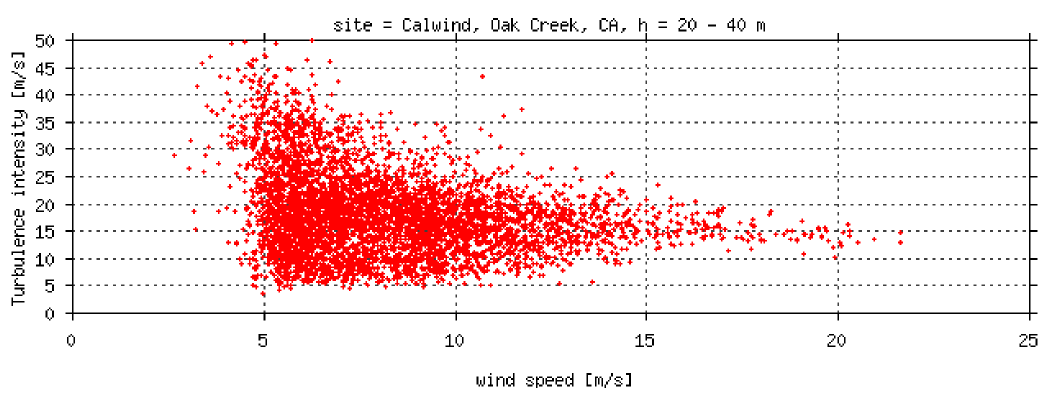


Nominal turbulence vs. wind speed.

Site = CIBA, Monte Torozos, Spain

Site code **Ciba**

Dominating terrain/ orography	pastoral	flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	4 (3,10,20,50&100m)	4 (3,10, 20,50&100m)
Number of sonics / height of met. Mast.	3 (h=6,14,32m)	100 m
Hours of measurements / frequencies	426	5 & 20 Hz

Project motivation

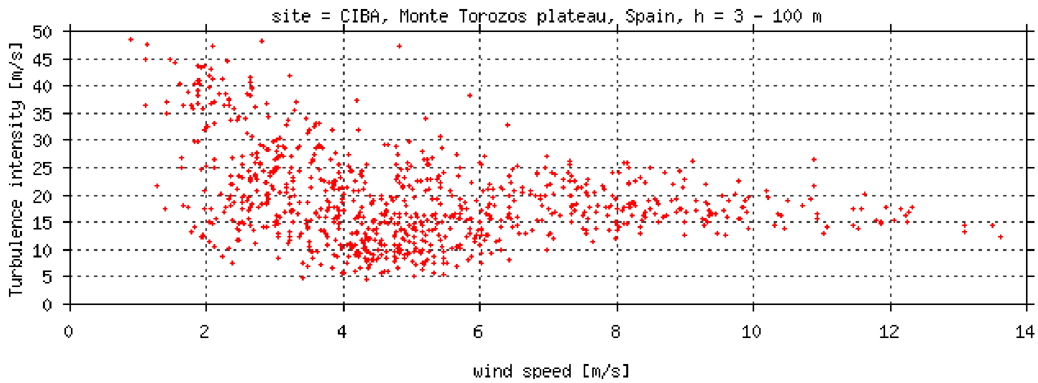
In the period 10-28 September 1998, the Stable Atmospheric Boundary Layer Experiment in Spain (henceforth) SABLES 98) took place at the Research Centre for the Lower Atmosphere (CIBA) in the northern Spanish plateau. This Centre belongs to the University of Valladolid and the Spanish Meteorological Institute (INM), and the purpose of the experiment was to study the characteristics of the Stable Atmospheric Boundary Layer in mid-latitudes. The surrounding terrain is fairly flat and homogeneous and the measurement site is located in the centre of an 800 km**2 plateau (Monte Torozos), which is 840 m above sea level and surrounded by fairly level grass plains with a surface roughness parameter, Zo, of 1.1 cm (Sam Jóse et. al. 1985). The plateau is raised about 50 m above en extensive region of homogeneous level terrain. Only the meteorological measurements (1 & 3D wind speed, direction, temperatures and atmospheric pressure) from these measurements has been made available through the wind database.

Measurement system

A 100 m tower with booms oriented such that optimum measurements would be taken for easterly winds. The tower has been equipped with instruments provided and calibrated by Risø National Laboratories which was operated by Ph. D., M. Sc. Hans E. Jørgensen, Department Wind Energy and Atmosphere Physics, Risø National Laboratory, 4000 Roskilde, Denmark.

Acknowledgements:

Ph. D., M. Sc. Hans E. Jørgensen, Department Wind Energy and Atmosphere Physics, Risø National Laboratory.



Nominal turbulence vs. wind speed.

Site = La Clape, Narbonne, France

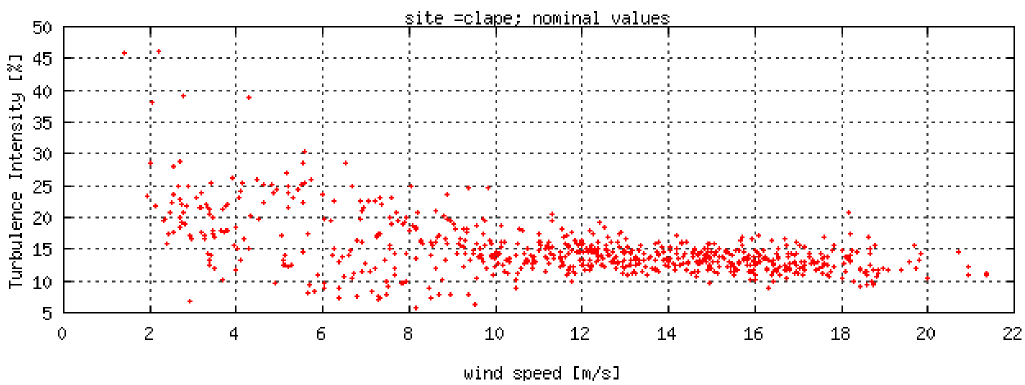
Site code **Clape**

Dominating terrain/ orography	Scrub	Hill
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	2	2
Number of sonics / height of met. Mast.	1	41 m
Hours of measurements / frequencies	242	2 & 8 Hz

Project motivation
In the frame of the European Joule Program: concerning wind resource assessment over complex terrain, the purpose of this study is to provide a set of wind speed data for a hill in the South of France, a validation test for the software WASP and to improve the knowledge of turbulence over complex terrain.

Measurement system
On the summit, a 40 m high mast had been erected and equipped at three levels: at 10 m a vane propeller, at 24 m a three directional gill propeller and at 40 m a sonic anemometer. At the reference point, the data acquisition system was a “micro-Mac” from Analog Device that allows a scan rate of 2 Hz. At the hill top, the data acquisition system was built around a portable Compaq 286 with a data acquisition workstation Keithley system 570 as interface, and two optical disk units Ricoh RO 5030E for data storage. Optical disks are 5’1/4 cartridge with a capacity of 2x293 MB each one.

Acknowledgements
Christian Sacre, CSTB, Nantes, France.



Nominal turbulence vs. wind speed.

Site = Ecn, Petten, The Netherlands

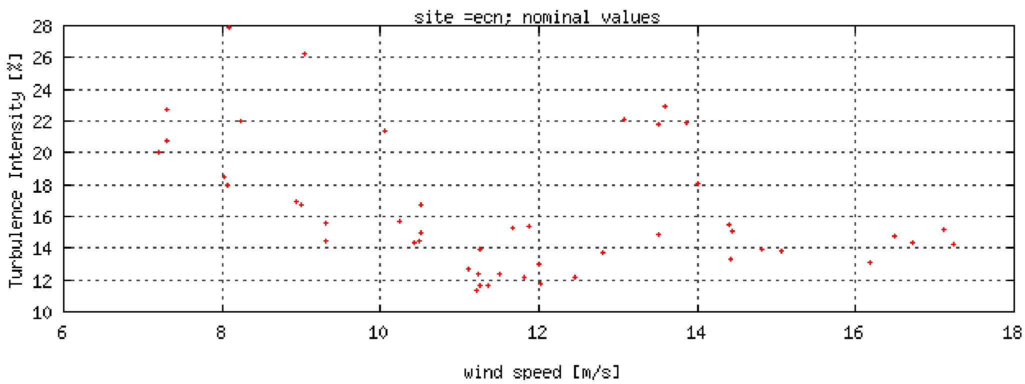
Site code **Ecn**

Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	4	1
Number of channels with wind speed / wind direction	9	3
Number of sonics / height of met. Mast.	0	41, 41, 41 & 41m
Hours of measurements / frequencies	49	4 Hz

Project motivation
The primary goal was to design and build and test a flexible rotor (two blades, diameter 21.6 m) with passive tip-pitch control and a teetered hub with an elastomeric bearing. The FLEXTEETER rotor was tested at the 25m HAWT test facility of ECN. During the project the wind input was measured with a set of four meteorological masts. The wind data obtained as part of the test of FLEXTEETER are available for the "Database on Wind Characteristics".

Measurement system
The measurement system consists of 4 meteorological mast, mast no. 1, 2, 3 were placed West of the turbine and mast 4 at the East side. The measurements system was based on a PDP data logger and the data were transferred to a DIGITAL VAX system (VAX VMS operating system with data handling routines and programs developed at ECN). The data to be measured were divided in two groups: group 1, wind data with a recording frequency of 4 Hz; group 2, turbine operational data and mechanical load data with a recording frequency of 32 Hz. The maximum duration of a consecutive measurement with 32 channels in both groups was about 18 hrs.

Acknowledgements
J.W.M. Dekker, ECN, The Netherlands.



Nominal turbulence vs. wind speed.

Site = ECN Testveld, Petten, The Netherlands

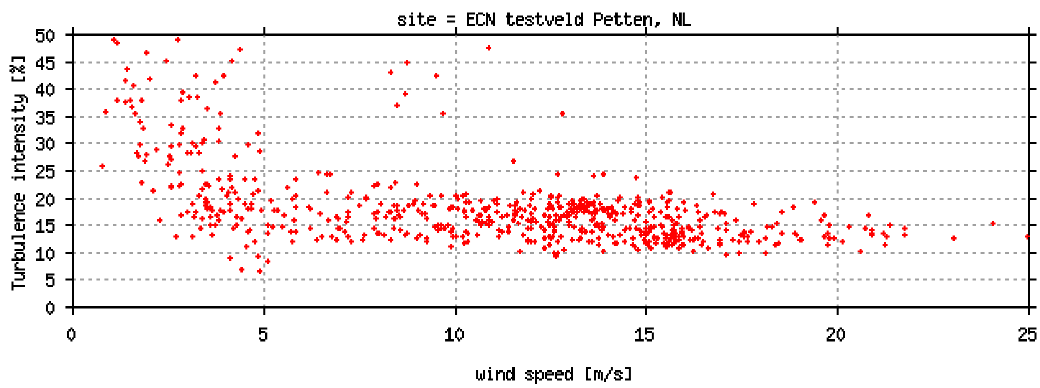
Site code **Ecn_ems**

Dominating terrain/ orography	coastal	flat
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	3 (h=10,32&50m)	3 (h=10,32&50m)
Number of sonics / height of met. Mast.	0	50 m
Hours of measurements / frequencies	651	1 Hz

Project motivation
Winter 2000 a meteorological measuring station is realised on the ECN test-site. Purpose of this station is to gather data of high quality. The data are used for direct use as well as for interpretation later on and are therefore stored in a database. The data is available for both internal as external users.

Measurement system
The measuring station consists of two masts, a group of meteorological sensors, a data log system and is connect to the ECN local area network.

Acknowledgements:
Hans Verhoef, Energy research Centre of the Netherlands (ECN).



Nominal turbulence vs. wind speed.

Site = ECN Testveld, Petten, The Netherlands

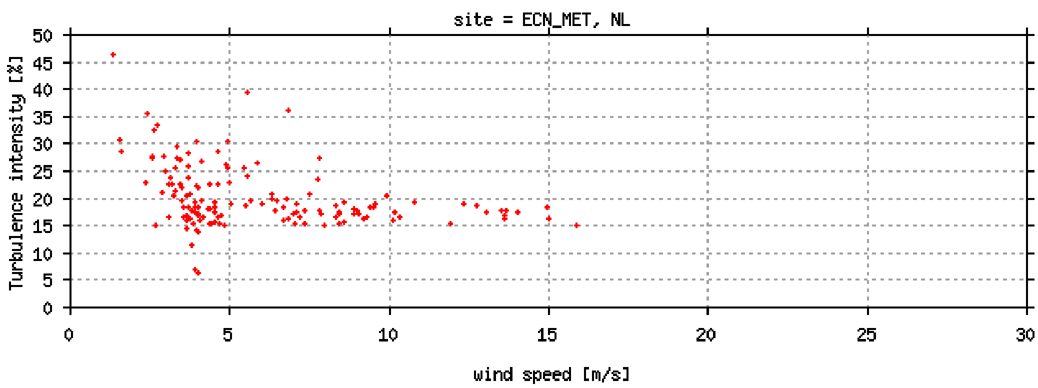
Site code **Ecn_met**

Dominating terrain/ orography	coastal	flat
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	0	0
Number of sonics / height of met. Mast.	1	12 m
Hours of measurements / frequencies	142	4 Hz

Project motivation
Power performance measurements on the LW 5/2.5. These measurements are never carried out due to problems with the turbine. The wind data that were available are included in the international wind database.

Measurement system
Small guyed mast of 12m length with ECN/Miery meteorological boom setup in top. One cup anemometer, one wind vane and a sonic anemometer are used. Note that the time used in the data for this mast is two hours behind GMT.

Acknowledgements:
Sam Barhorst & Dr. Peter Eecen, Energy research Centre of the Netherlands (ECN).



Nominal turbulence vs. wind speed.

Site = Emden, Germany

Site code **Emden**

Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	2	1
Number of sonics / height of met. Mast.	0	68 m
Hours of measurements / frequencies	781	20 Hz

Project motivation

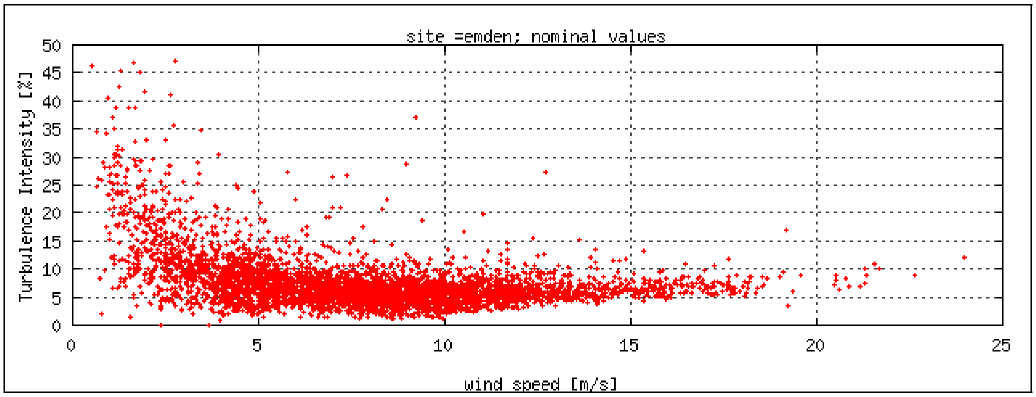
Due to the increase in size of today's series production wind turbines into the MW-range optimised tower designs and minimised use of material are necessary for augmentation of these turbines' economics. Exact knowledge of the loads is of vital importance in the design and certification process. To arrive at a dependable prediction of fatigue loads they are either calculated using elaborate computer simulations of the turbine's dynamic behaviour or estimated by means of simplified fatigue load spectra. Lately, the use of load measurements becomes more and more important in that issue. In Germany both, calculation and estimation are used. Recent measurements have given rise to a discussion about the adequacy of the use of simplified load assumptions. As a contribution to settle this discussion "real life"-measurements are carried out by DEWI within a research project which is co-ordinated by VDMA (the German machinery and plant manufacturers' association) and partly funded by the German Research Ministry (BMBF) and AVIF (Research society of the working alliance between the iron, steel and metal working industries).

Measurement system

A 68 m high mast served as bases for the meteorological measurements. The meteorological data were collected by two independent data loggers. An Ammonit data logger was used for the long term recording of 5 minute averages of all data relevant for the power curve evaluation of a 1.5 MW WEC. In Addition a modular processor-controlled data acquisition system (MOPS) served for investigations of the structural loads and dynamic behaviour of the turbine. Only the data gained from this system are relevant for the Database on Wind Characteristics. The sample rate was 20 Hz and time series with duration of 600 seconds have been stored.

Acknowledgements

Christian Hinch, DEWI, Germany.



Nominal turbulence vs. wind speed.

Site = Equinox Mountain, Vermont, USA

Site code **Equinox**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	4	4
Number of sonics / height of met. Mast.	0	40 m
Hours of measurements / frequencies	72	5 Hz

Project motivation

This project was initiated in 1990 to develop measurements and analysis methods that would establish representative and appropriate turbulence characteristics needed for the design and siting of cost-effective wind turbines. NREL and Batelle had additional objectives that included correlating the nature of the turbulence in the inflow to upwind features, and transferring the technology developed in the project to industry for operational applications.

Measurement system

11 different sites with identical equipment (4 cups, 4 vanes and 4 vertical propellers). Measurements from three sensors on the 40-m tower (T1) provided a representation of the vertical shear of the wind velocity for wind turbines with a 20-m rotor diameter and a 30-m rotor diameter. The 30-m tower (T2) allowed a hub-height wind measurement positioned on the perimeter of the rotor disk 10m away from the centre of the rotor disc, and in direction perpendicular to the prevailing wind direction. This data configuration provided not only vertical and horizontal wind shear data at a site but also data on the effect on rotational sampling of the turbulent wind. The horizontal wind speed and direction were measured at four locations with R.M.Young Wind Monitors. The vertical component of the wind was measured by a single Gill propeller anemometer mounted directly underneath each of the propeller-vane anemometers. A single cup-vane anemometer was mounted near the propeller-vane anemometer at the top of T2 within a few feet of the propeller-vane anemometer at the same location. This was the Maximum cup and NRG vane that are commonly used in the wind industry to estimate the resource at the site.

Acknowledgements:

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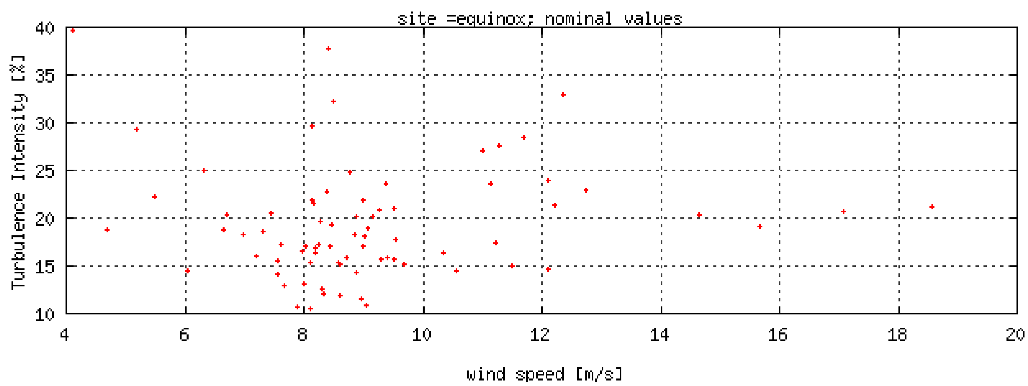

Nominal turbulence vs. wind speed.

Site = Mojave Horned Toad hills, CA, USA

Site code **Flowind**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	3	3
Number of sonics / height of met. Mast.	0	40 m
Hours of measurements / frequencies	5947	5 Hz

Project motivation

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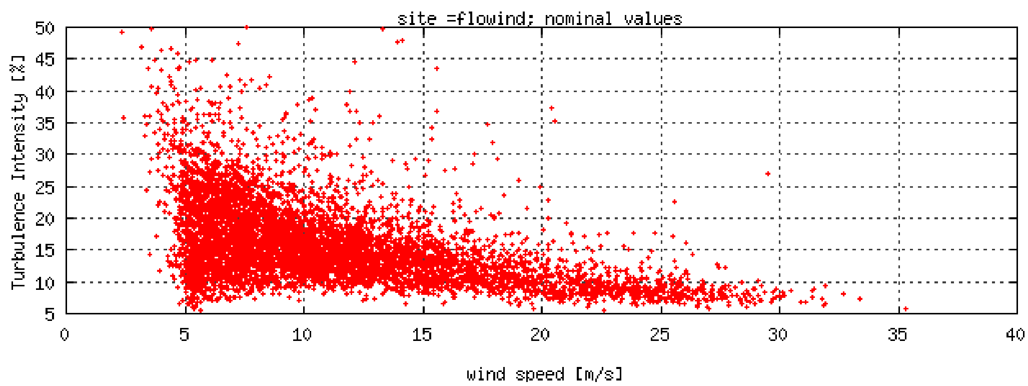


Nominal turbulence vs. wind speed.

Site = Gedser Rev, Gedser, Denmark

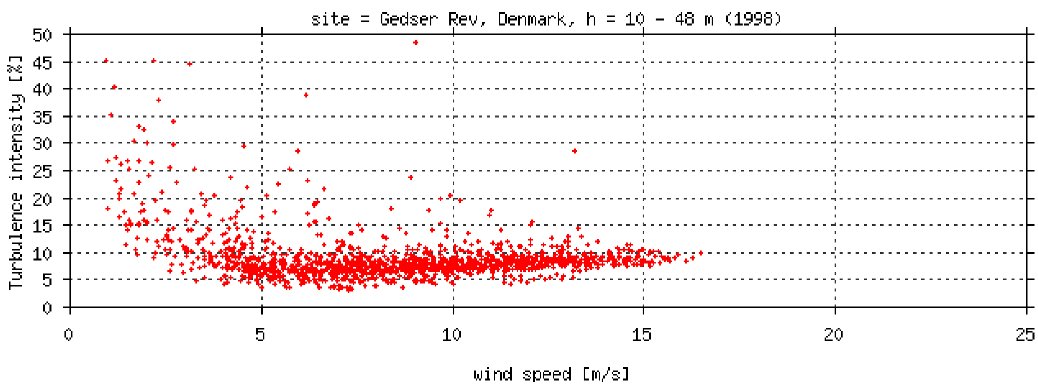
Site code **Gedsrev**

Dominating terrain/ orography	offshore	flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	3 (h=8,28 & 45m)	1 (h=27m)
Number of sonics / height of met. Mast.	0	45 m
Hours of measurements / frequencies	702	5 Hz

Project motivation
Characterising wind and turbulence for offshore wind energy development.

Measurement system
The met.mast near Gedser Rev has been instrumented with 3 cup anemometers, one vane and 3 thermometers.
The data acquisition system DAQ has used for data recording (5 and 20 Hz) and was operated by Rebecca Barthelmie and Peter Zanderhoff, Risø National Laboratories.
The measured time series from Roedsand / Gedser Syd has been collected, validated and provided by: Senior Scientist, Rebecca Barthelmie Ph.D, Email: r.barthelmie@risoe.dk Department Wind Energy and Atmosphere Physics, Risø National Laboratory, 4000 Roskilde, Denmark.
SEAS Distribution A.m.b.A funds instrumentation, operation and maintenance at Roedsand.

Acknowledgements:
Senior Scientist, Rebecca Barthelmie Ph.D, Department Wind Energy and Atmosphere Physics, Risø National Laboratory & SEAS Distribution A.m.b.A.



Nominal turbulence vs. wind speed.

Site = San Gorgonio Pass, CA, USA

Site code **Gorgonio**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	3	3
Number of sonics / height of met. Mast.	0	40 m
Hours of measurements / frequencies	1399	5 Hz

Project motivation
This project was initiated in 1990 to develop measurements and analysis methods that would establish representative and appropriate turbulence characteristics needed for the design and siting of cost-effective wind turbines. NREL and Batelle had additional objectives that included correlating the nature of the turbulence in the inflow to upwind features, and transferring the technology developed in the project to industry for operational applications.

Measurement system
11 different sites with identical equipment (4 cups, 4 vanes and 4 vertical propellers). Measurements from three sensors on the 40-m tower (T1) provided a representation of the vertical shear of the wind velocity for wind turbines with a 20-m rotor diameter and a 30-m rotor diameter. The 30-m tower (T2) allowed a hub-height wind measurement positioned on the perimeter of the rotor disk 10m away from the centre of the rotor disc, and in direction perpendicular to the prevailing wind direction. This data configuration provided not only vertical and horizontal wind shear data at a site but also data on the effect on rotational sampling of the turbulent wind. The horizontal wind speed and direction were measured at four locations with R.M.Young Wind Monitors. The vertical component of the wind was measured by a single Gill propeller anemometer mounted directly underneath each of the propeller-vane anemometers. A single cup-vane anemometer was mounted near the propeller-vane anemometer at the top of T2 within a few feet of the propeller-vane anemometer at the same location. This was the Maximum cup and NRG vane that are commonly used in the wind industry to estimate the resource at the site.

Acknowledgements:
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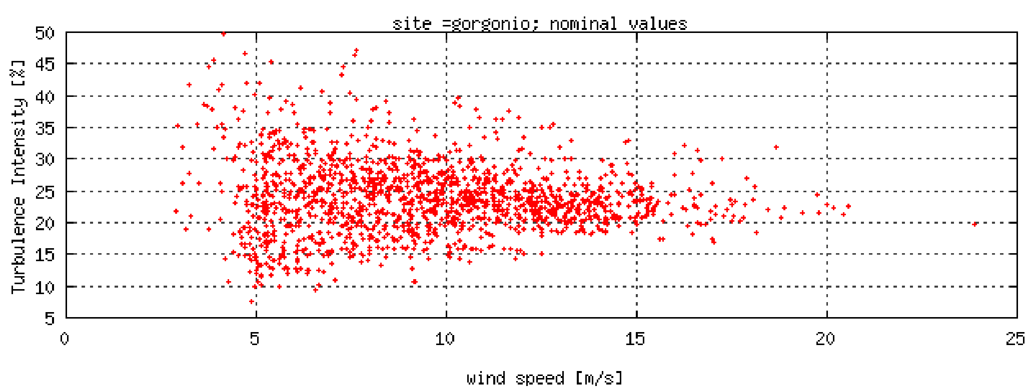

Nominal turbulence vs. wind speed.

Site = Hanford, WA, USA

Site code **Hanford**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	3	3
Number of sonics / height of met. Mast.	0	40 m
Hours of measurements / frequencies	1071	5 Hz

Project motivation

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Measurement system

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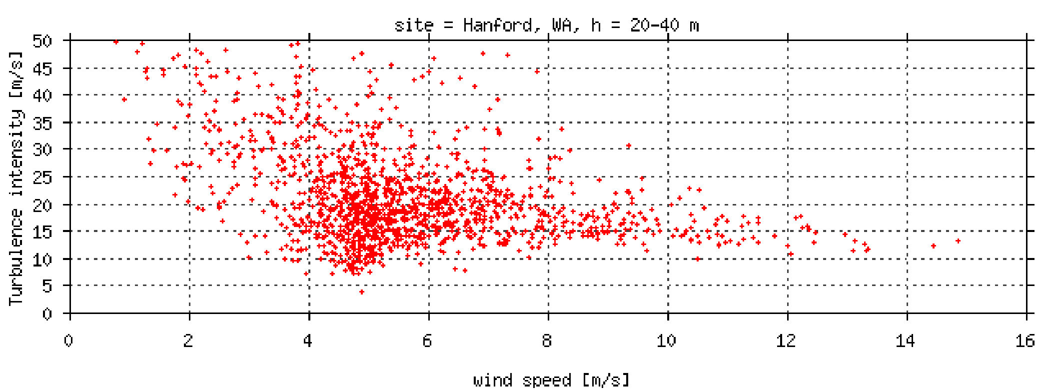

Nominal turbulence vs. wind speed.

Site = Holland, Minnesota, MN, USA

Site code **Holland**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	3	3
Number of sonics / height of met. Mast.	0	40 m
Hours of measurements / frequencies	6525	5 Hz

Project motivation

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Measurement system

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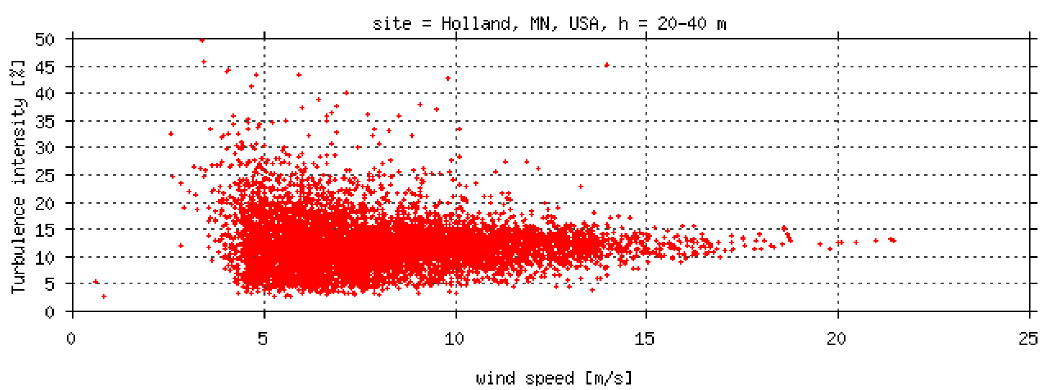


Nominal turbulence vs. wind speed.

Site = Horns Rev, Esbjerg, Denmark

Site code **Hornsrev**

Dominating terrain/ orography	Offshore	Flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1	1
Number of sonics / height of met. Mast.	1	50 m
Hours of measurements / frequencies	13478	20 Hz

Project motivation

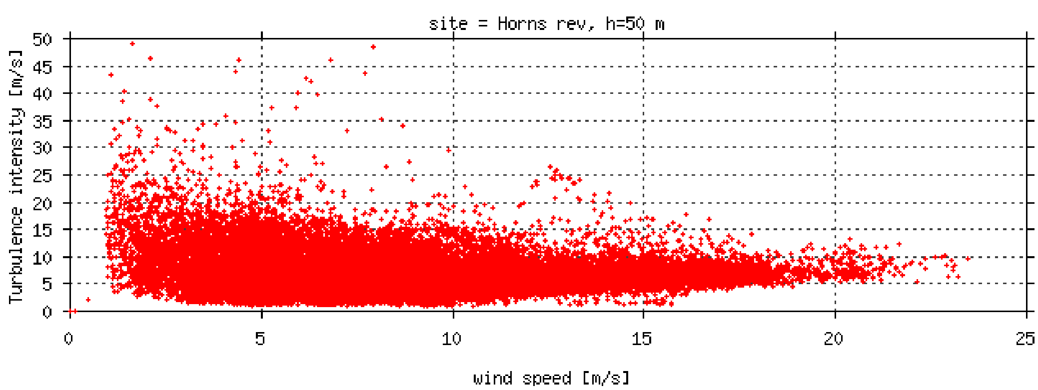
The purpose of the work are to investigate the wind and sea climates for the first of the two offshore wind farms in the Elsam area, i.e. the 150 MW Horns Rev wind farm to be built and commissioned by the end of year 2002. The Horns Rev site is located at a reef approx.14 km off Jutland in the North Sea in a very harsh environment. The water depths at the site vary between 6 and 12 m. In-depth knowledge of the environment at the offshore site was crucial to enable the evaluation of vital information, such as wind farm energy production prognoses, assessment of structural loads and the prediction of global long-term sea bed changes and local scouring around the foundation.

Measurement system

A square lattice mast was erected on a mono pile close to the wind farm site at Horns Rev and mid May 1999 the meteorological measurement programme was initiated and later in June 1999 the marine measurement programme started. Cup anemometers are located at 15, 30, 45 and 62 m above sea level. Vanes are located 28, 43 and 60 above sea level. The 3-D sonic measurements are recorded at 40 m above sea level. Cup and vane signals are stored as 10-minute statistics while only 3-D sonic measurements are stored as time series.

Acknowledgements

ELSAM, Søren Neckelmann, Anders Sommer, ELSAM Engineering, Denmark.



Nominal turbulence vs. wind speed.

Site = Hurghada, Egypt

Site code **Hurghada**

Dominating terrain/ orography	Sand	Flat
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	4	2
Number of sonics / height of met. Mast.	0	
Hours of measurements / frequencies	1386	8 Hz

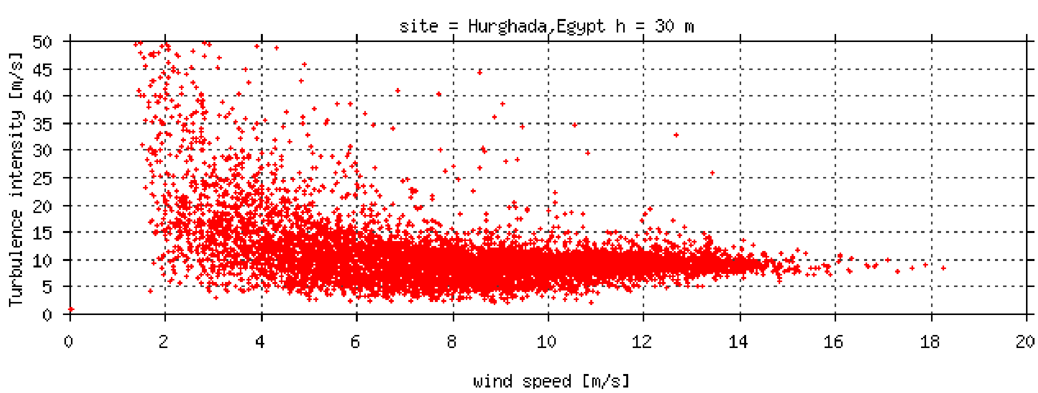
Project motivation
Characterizing wind and turbulence for a desert location equipped with wind turbines during stable conditions. The measurements were ordered for a 2 month period.

Measurement system
Two standard meteorological masts with a height of 30 m, each equipped with 2 cups and one vane has been used. Signals has been recorded continuously with 8 Hz. The stability measurements are recorded on a third mast equipped with Anderaa meteorological instrumentation.

Instrumentation and measurement setup has been done in cooperation between Risø National Laboratories and Hurghada Wind Technology Center and the equipment used are identical to standard Risø measurement setup. Monitoring of the measurement program has been done by the staff at the Hurghada Wind Energy Technology Center.

Note: Each met. mast has its own measurement computer and it is been necessary to merge all the time series, and this caused some errors due to errors in the synchronization.

Acknowledgements
Staff at the Hughhada Wind Energy Technology Center, Hurghada, Egypt.



Nominal turbulence vs. wind speed.

Site = Jericho, Texas, TX, USA

Site code **Jericho**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	3	3
Number of sonics / height of met. Mast.	0	40 m
Hours of measurements / frequencies	6349	5 Hz

Project motivation
This project was initiated in 1990 to develop measurements and analysis methods that would establish representative and appropriate turbulence characteristics needed for the design and siting of cost-effective wind turbines. NREL and Batelle had additional objectives that included correlating the nature of the turbulence in the inflow to upwind features, and transferring the technology developed in the project to industry for operational applications.

Measurement system
11 different sites with identical equipment (4 cups, 4 vanes and 4 vertical propellers). Measurements from three sensors on the 40-m tower (T1) provided a representation of the vertical shear of the wind velocity for wind turbines with a 20-m rotor diameter and a 30-m rotor diameter. The 30-m tower (T2) allowed a hub-height wind measurement positioned on the perimeter of the rotor disk 10m away from the centre of the rotor disc, and in direction perpendicular to the prevailing wind direction. This data configuration provided not only vertical and horizontal wind shear data at a site but also data on the effect on rotational sampling of the turbulent wind. The horizontal wind speed and direction were measured at four locations with R.M.Young Wind Monitors. The vertical component of the wind was measured by a single Gill propeller anemometer mounted directly underneath each of the propeller-vane anemometers. A single cup-vane anemometer was mounted near the propeller-vane anemometer at the top of T2 within a few feet of the propeller-vane anemometer at the same location. This was the Maximum cup and NRG vane that are commonly used in the wind industry to estimate the resource at the site.

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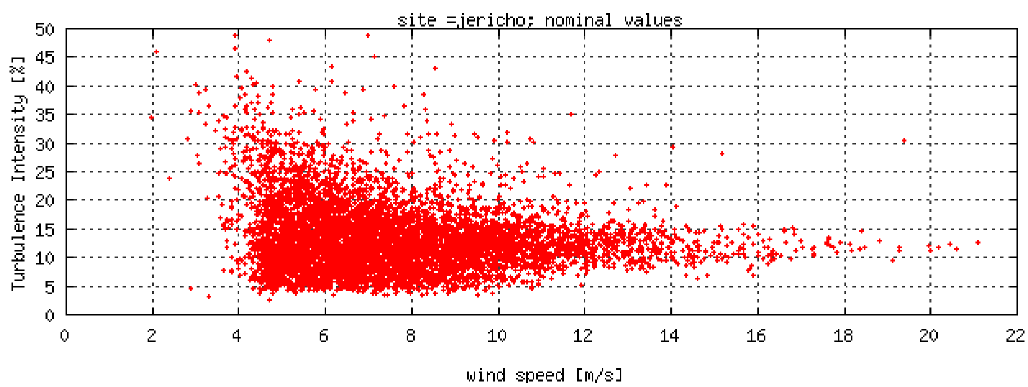


Nominal turbulence vs. wind speed.

Site = Jade Wind Park, Wilhelmshafen, Germany

Site code **Jwe**

Dominating terrain/ orography	Rural	Flat
Number of masts / wind turbines	1	4
Number of channels with wind speed / wind direction	3	1
Number of sonics / height of met. Mast.	0	130 m
Hours of measurements / frequencies	344	20 Hz

Project motivation

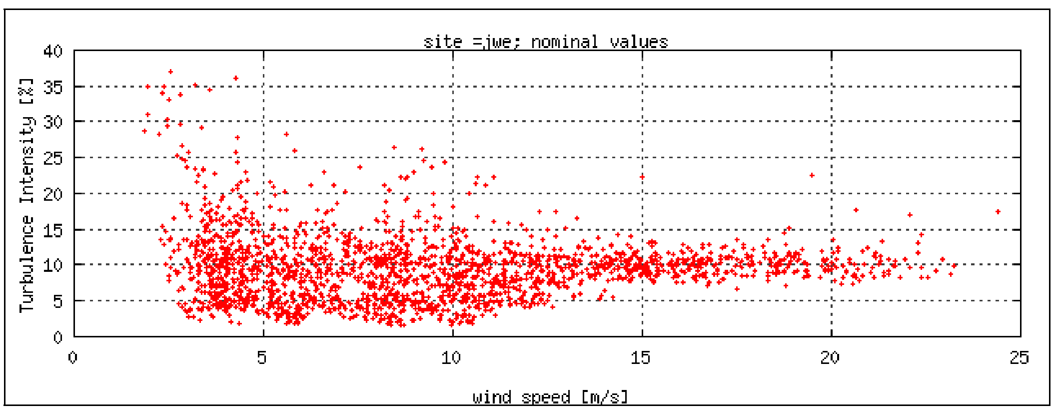
In the framework of the EU funded program “WEGA II Large Wind Turbine Scientific Evaluation Project” (Jou2-CT93-0349) a subproject CAN - Comparison of Aeolus II (located in Germany) and Naesudden II (located in Sweden) - was carried out to investigate the behaviour of two sister wind turbines with 3 MW rated power, but with different control mechanism and tower design. High resolution wind data recorded within this project at the Aeolus II to evaluate the mechanical loads also measured at the turbine are available for the “Database on Wind Characteristics”.

Measurement system

A 130 m high mast served as bases for the meteorological measurements. The meteorological data were collected by two independent data loggers. An Ammonit data logger was used for the long term recording of 5 minute averages of all data relevant for the power curve evaluation at the Aeolus II. In Addition a modular processor-controlled data acquisition system (MOPS) served for investigations of the structural loads and dynamic behaviour of the Aeolus II. Only the data gained from this system are relevant for the Database on Wind Characteristics. The sample rate was 20 Hz and time series with a duration of 600 seconds have been stored.

Acknowledgements

Christian Hinch, DEWI, Germany.



Nominal turbulence vs. wind speed.

Site = Kaiser Wilhelms Koog, Hamburg, Germany

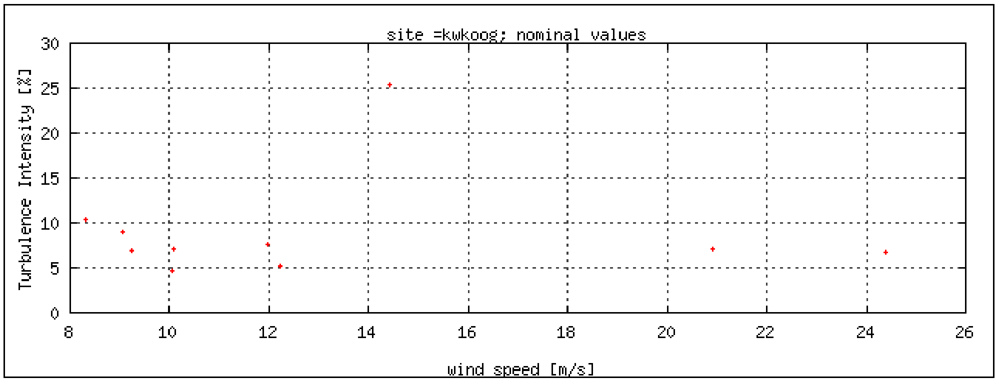
Site code **Kwkoog**

Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	3	1
Number of channels with wind speed / wind direction	20	18
Number of sonics / height of met. Mast.	0	150 m
Hours of measurements / frequencies	4	2 Hz

Project motivation
The main goal is to archive the wind data, which were measured during the test programme of the 3 MW wind turbine GROWIAN at Kaiser-Wilhelm-Koog at the North Sea coast of Germany from 1983 to 1987.

Measurement system
Two masts of 150 m height are placed 65 m east-south-east of the 3 MW wind turbine, their lateral distance is 52 m. 20 propellers and vanes are installed at pairs of booms of 12 m length to the right and to the left of the two masts so that an area of 75m x 100m is covered. The measuring frequency is 2.5 Hz and the duration of one measuring run is approximately 25 min. 300 runs are sampled between April 1984 and February 1987 at different inflow conditions. 10 data sets are available in this database, 9 for undisturbed inflow conditions at various wind speeds and stability conditions and one for flow from the wind turbine. The other data sets are available from the German Weather Service, Hamburg.

Acknowledgements
Horst Günther, Deutcher Wetterdienst Hamburg, Germany.



Nominal turbulence vs. wind speed.

Site = Lammefjorden, Hornsherred, Denmark.

Site code **Lamme**

Dominating terrain/ orography	Pastoral	Flat
Number of masts / wind turbines	4	0
Number of channels with wind speed / wind direction	10	9
Number of sonics / height of met. Mast.	1	10, 30, 30 & 45 m
Hours of measurements / frequencies	663	8 & 16 Hz

Project motivation

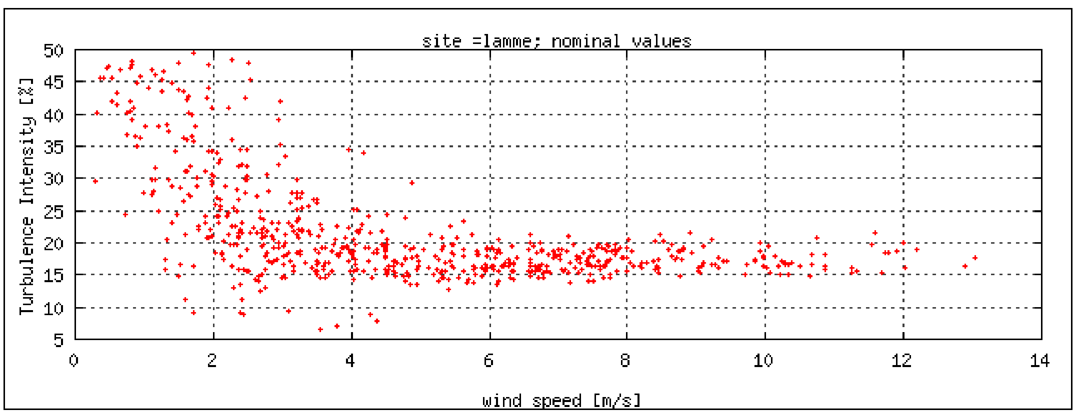
An attempt to gather data continuously for one year with sufficient spatial and temporal resolution for wind turbine design studies. Completed with around 90% availability with a longest uninterrupted series of 103 days. The Measuring Site: The current project built upon a previous field experiment conducted to collect data for lateral coherence research (Courtney 1987). For this purpose, a site was required possessing homogeneous flow, preferably when the wind was from the prevailing south-westerly direction. A site was located at Lammefjord, a reclaimed fjord on the Danish island of Zealand. Lammefjord is amongst the flattest terrain in Denmark. Much of the land lies slightly below sea-level and because of difficulties with drainage, most of the buildings are grouped together on areas that were above water level prior to reclamation. The remainder of the land is used for agriculture, predominantly with root crops such as carrots and potatoes. The location of the measuring masts is indicated in Figure 1. To the south-east and north-west lie the towns of Fårevejle Stationby and Faarvejle respectively. To the south-east (Fårevejle Stationby) the nearest buildings are about 1 km from the measuring masts whilst in the opposite direction (Fårevejle) the distance is about 0.5 km. A road connects the two towns and this passes about 150 m to the north-east of the masts. Apart from the road, the terrain to the north-east is open with the nearest buildings about 800 m away. To the south and south-west, the terrain is flat and completely unobstructed for a distance of between 2.5 and 3.0 km. Between the south-west and north-west the terrain is identical but the fetch reduces sharply to a little over 1 km. The old sea bed is bounded by a drainage canal, beyond which the terrain rises steeply, especially between west and north-west. Acknowledgements: The Lammefjord measurements were partly funded by the CEC, Directorate- General for Science, Research and Development under contract number EN-3W-002-DK(B). Preparation of the CD-ROMs has been partially supported by the EU funded JOULE project “Measuring and modelling in complex terrain”, contract number JOUR-0067-C(MB).

Measurement system

An array of cups, vanes and one sonic anemometer were sampled by a PC. Data were stored on a magneto-optic WORM drive. Data were recorded at 16 Hz for the sonic and 8 Hz for the cups and vanes. Measuring Masts: Since the data are primarily intended for wind turbine research, the aim was to instrument a vertical plane corresponding to that formed by the rotor of a medium sized wind turbine. This was accomplished by using three measuring masts erected so as to form a vertical plane 30 x 30m, perpendicular to the prevailing wind. An array of cup anemometers and wind direction vanes were distributed over this area as shown in Figure 2. A sonic anemometer was mounted at a height of 46m. In relation to the vertical plane formed by the three masts, a 10m mast was erected 15m upstream (in the prevailing wind direction). This was instrumented with a cup anemometer and a wind vane at 10m height. The masts are referred to as masts 1-4, with the mast to the left in Figure 2 as number 1, the mast in the centre as 2 and that to the right as mast 3.The upstream 10m mast is mast 4. The following table gives the (x,y) co-ordinates of the instruments mounted on each mast (including boom offset) in a co-ordinate system with x in the plane of the masts pointing towards north-west (319 deg) and y pointing perpendicular to the mast plane towards the south-west (229 deg). Dimensions are in meters. Mast x y Instrumentation 1 0.0 0.0 cups(3), vanes(3), sonic, climatology 2 20.0 0.0 cups(2), vanes(2) 3 30.0 0.0 cups(3), vanes(3) 4 22.7 15.3 cup, vane (“upstream” mast) Instrument station numbers have been assigned according to the following table.

Station Mast Height Instrumentation sonic 1 46 Sonic (X, Y, Z, T) 1 1 10 Cup and vane (cos, sin) 2 1 20 Cup and vane (cos, sin) 3 1 30 Cup and vane (cos, sin) 4 2 10 Cup and vane (cos, sin) 5 2 30 Cup and vane (cos, sin) 6 3 10 Cup and vane (cos, sin) 7 3 20 Cup and vane (cos, sin) 8 3 30 Cup and vane (cos, sin) 9 4 10 Cup and vane (cos, sin) 10 1 various Cup Climatological Measuring System: An independent climatological measuring system was also installed, with all the relevant sensors mounted on mast 1. This instrumentation comprised: cup anemometers at 3, 10 and 45m wind direction vane at 10m global radiation relative humidity (horse-hair hygrometer) absolute temperature at 10m difference temperature 10m - 2m difference temperature 40m - 10m barometric pressure Observations were recorded every 10 minutes using an Aanderaa battery powered data logging system. Note that with the exception of the cup anemometer speed, all recorded observations are instantaneous values once per 10 minutes. Cup mean speed is derived by counting pulses over the 10-minute period. Cup Anemometer: The cup anemometers used were the Risø model 70, fitted with carbon fibre cups. This instrument has a length constant of 1.7m. A two-pole magnet driven by the cup shaft is used to open and close a reed-contact switch, producing two pulses per revolution. Wind speed was derived using the Risø P1225 Wind Speed Transmitter. This device is a microprocessor controlled frequency to voltage converter. The output voltage is updated on each incoming pulse such that the signal is proportional to the frequency derived from the preceding two pulses. Before installation, but following a two month “run-in” period, the cup anemometers were calibrated in a wind tunnel. Re-calibration of the cup anemometers after the completion of the experiment showed that the instrument characteristics had remained essentially constant. Individual calibrations have been used for each of the cup anemometers. Wind speed signals were sampled at 16 Hz through a first order RC filter with a -3db frequency of 35 Hz. Each two consecutive 16 Hz scans were averaged so that the data are stored at 8 Hz.

Acknowledgements
Michael Courtney, Risø National Laboratories, Denmark.



Nominal turbulence vs. wind speed.

Site = Lavrio, CRES, Greece

Site code **Lavrio**

Dominating terrain/ orography	Pastoral	Mountain
Number of masts / wind turbines	2	1
Number of channels with wind speed / wind direction	6	4
Number of sonics / height of met. Mast.	1	40 & 40 m
Hours of measurements / frequencies	759	1 & 8 Hz

Project motivation

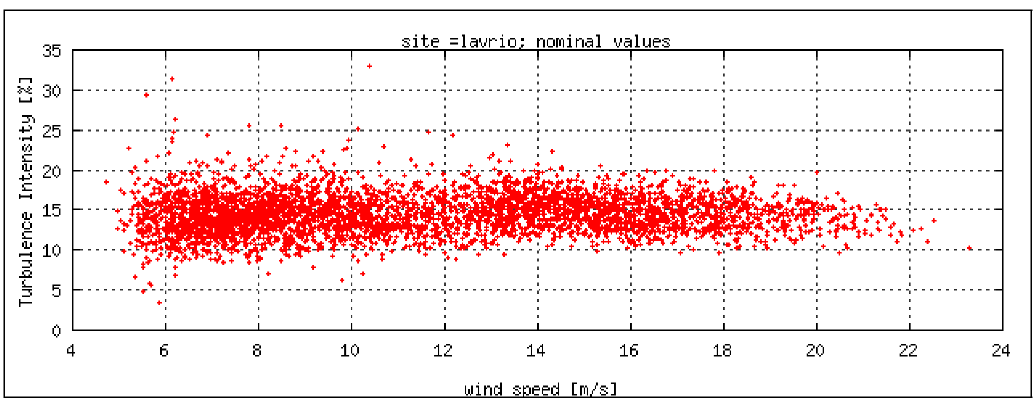
The main objective of the project was to identify the mountainous terrain effects in the operation, safety and reliability of wind turbines. The methodology designed for the project included site wind and wt on site characterisations and complex terrain parameter (of importance to wind turbine operation) identification through experimental and analytical work**.**

Measurement system

Wind structure measurements on mountainous terrain: the 3D wind inflow to a wind turbine rotor was measured by CRES with a number of standard cups and fast sonic anemometers installed on a system of masts at CRES' complex terrain wind turbine Test Station. The wind structure measurements were coupled to the response of a 110kW stall regulated wt (W110XT) through load and power measurements.

Acknowledgements

A.N.Fragoulis, C.R.E.S, Greece.



Nominal turbulence vs. wind speed.

Site = Lysekil, Sweden

Site code **Lyse**

Dominating terrain/ orography	Coastal	Mountain
Number of masts / wind turbines	1	2
Number of channels with wind speed / wind direction	12	12
Number of sonics / height of met. Mast.	0	66 m
Hours of measurements / frequencies	3355	Appr. 1 Hz

Project motivation

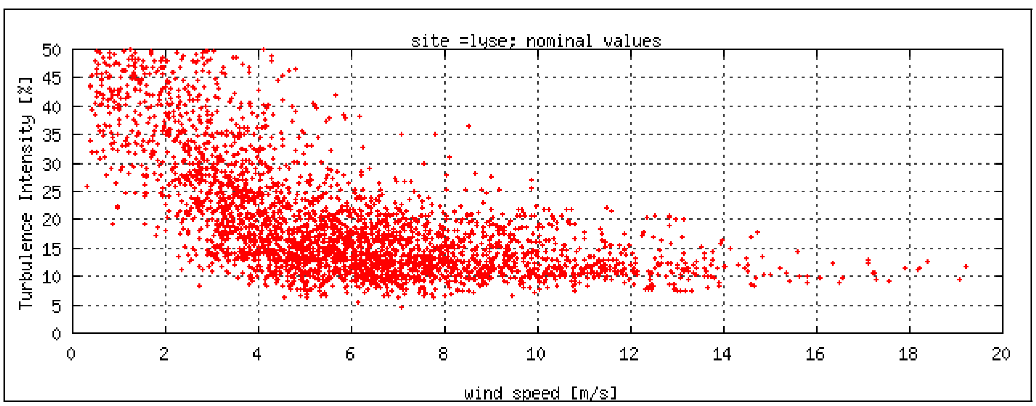
At Lyse Wind Power Station the NWP400 wind turbine was erected in 1992. The wind turbine is a two-bladed, upwind machine with a hub height of 40 m, and a rotor diameter of 35 m.

Measurement system

Lyse wind power station is situated at an artificial island created around two islets. On each of the rocky islets wind turbines are erected. The above mentioned NWP400 to the north and a Bonus 400 kW MkII to the south. Between the two turbines a 66 m high meteorological tower is situated, which is equipped with wind speed and direction sensors of the MIUU type (Lundin et al., 1990) at 7 levels. At the uppermost 5 levels two anemometers are placed at each level. Temperature profile is also recorded. All measurements are sampled with 1 Hz and stored on 1 GB streamer tape.

Acknowledgements

Mikael Magnusson & Hans Bergström, Uppsala University, Sweden.



Nominal turbulence vs. wind speed.

Site = Maglarp, Sweden

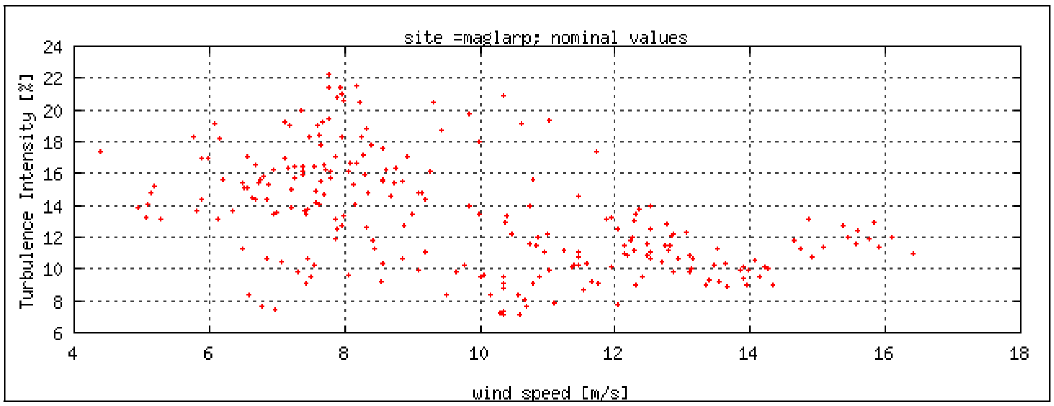
Site code **Maglarp**

Dominating terrain/ orography	Rural	Flat
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	3	3
Number of sonics / height of met. Mast.	0	84 m
Hours of measurements / frequencies	41	20 Hz

Project motivation
The project has been initiated as part of a larger measurement program on the WTS-3 wind turbine. The site is located on a low sloping hill in slightly rolling farmland.

Measurement system
20 Hz data are recorded at 2 levels (13 & 84 m) on a 120 m mast during one month. The instrumentation consists only of 3-component hotwires.

Acknowledgements
Mikael Magnusson & Hans Bergström, Uppsala University, Sweden.



Nominal turbulence vs. wind speed.

Site = Marsta, Uppsala, Sweden

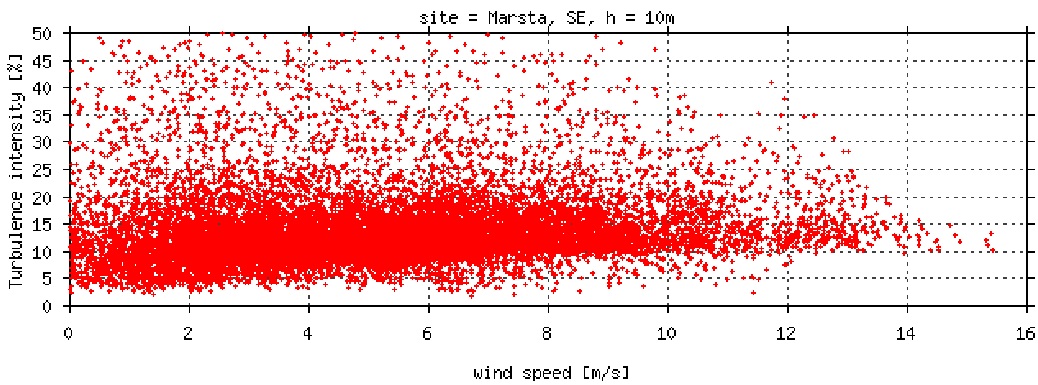
Site code **Marsta**

Dominating terrain/ orography	rural	flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	0	0
Number of sonics / height of met. Mast.	1	10 m
Hours of measurements / frequencies	2975	21 Hz

Project motivation
Meteorological measurements from a farmland site in the centre of Sweden.

Measurement system
21 Hz data from a 10m level on a 24 m tower for ½ year. Note: NOTE! Each raw file is usually about 55-56 min long, but in some cases the measurements are not continuous during the hour. Each time series has been divided into 5 different parts: 1) 0 - 10 min, 2) 10 - 20 min, 3) 20 - 30 min, 4) 30 - 40 min, 5) 40 - 50 min. which are included in the database.

Acknowledgements:
Mikael Magnusson & Ann-Sofi Smedmann, Dept. of Meteorology, Uppsala University.



Nominal turbulence vs. wind speed.

Site = Middelgrunden, Denmark

Site code **Midgrund**

Dominating terrain/ orography	Offshore	Flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	3	1
Number of sonics / height of met. Mast.	0	45 m
Hours of measurements / frequencies	2075	5 Hz

Project motivation

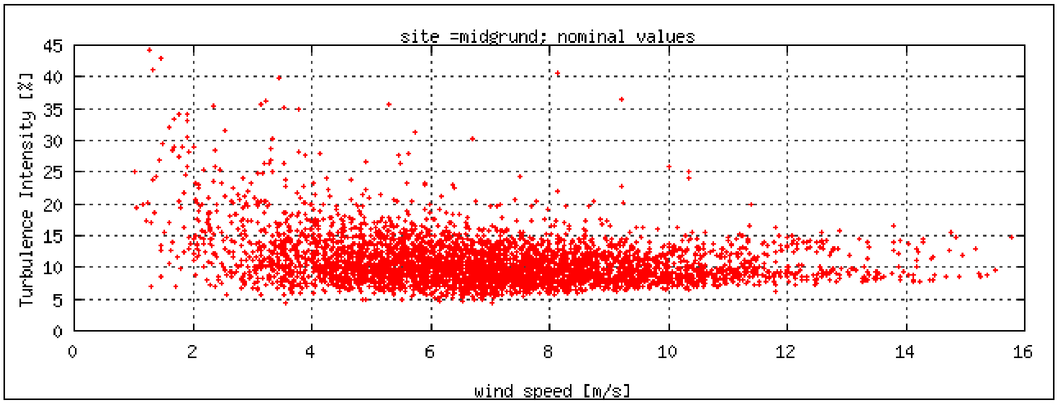
The meteorological mast at Middelgrunden was established in 1997 in order to provide wind and turbulence characteristics for the wind farm which was constructed in the autumn 2000. Middelgrunden is an atypical Danish offshore wind energy site in two respects: 1. It is east of the island of Zealand in the Øresund and has a relatively short sea fetch in most directions (from 2.1 km at 210° to a maximum of approximately 20 km across the Øresund and in north-south directions). 2. It is east of the city of Copenhagen which introduces large roughness elements which are expected to significantly influence particularly turbulence characteristics at the site. The Middelgrunden meteorological mast (55° 42.1 N 12° 39.45 E) was installed in October 1997 and ran until January 2000 when it was destroyed by a ship. At the time of writing (Autumn 2000) plans were underway to re-instrument the mast and to install mains electricity and a fibre optic link from the nearby offshore wind farm.

Measurement system

The mast is a triangular tapered structure in 7.5 m sections. Booms are oriented 94° and 274° with all cup anemometers installed on the westerly booms. Wind speeds are measured at 7.9, 27.7 and 48 m from the base of the mast at Middelgrunden but because of the foundations the actual height above mean sea level is approximately 2.5 m higher. Therefore the wind speed reference levels are 10, 30 and 50 m above mean sea level. Data acquisition is via Risø's DAQ system collected by mobile phone link. The system is powered by a wind turbine/battery system.

Acknowledgements

Rebecca Barthelmie, Risø National Laboratories, Denmark.



Nominal turbulence vs. wind speed.

Site = Mt. Tsukuba, Japan

Site code **Mttsukub**

Dominating terrain/ orography	Forest	Mountain
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1	0
Number of sonics / height of met. Mast.	0	30m
Hours of measurements / frequencies	2410	4 Hz

Project motivation

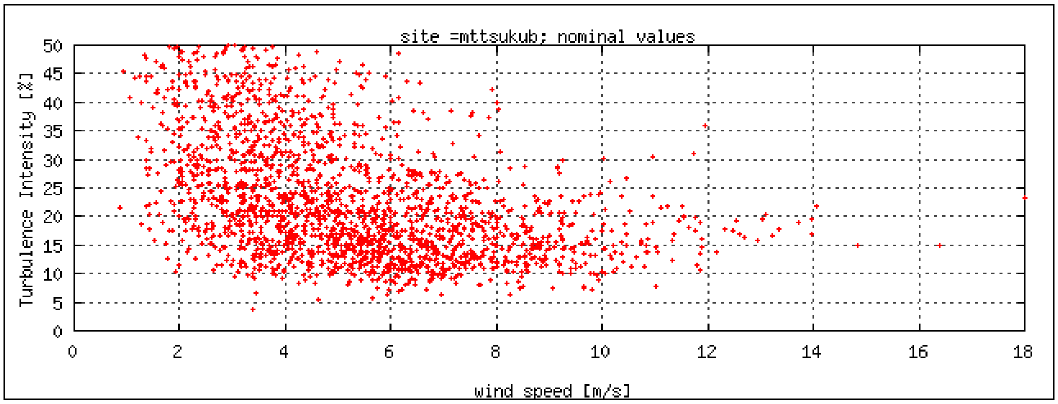
The Tsukuba city office have plan to construct a 750kw wind turbine in Mt. Tsukuba. In the region of Mt. Tsukuba, the famous strong wind called ”Tsukuba-Oroshi” blows in winter. In order to estimate the wind energy potential in this region, they started to measure wind velocities with the aid of NEDO’s Field Test Project of Wind Turbine Generation.

Measurement system

The measurement system consists of one meteorological mast. Wind measurements are carried out using a ultrasonic anemometer, two cup anemometers and two wind vanes. The height of the mast was 30 m. Only the wind data obtained by the ultrasonic anemometer is available because other data were sampled with lower sampling frequencies than that required in the database.
Measurements by the ultrasonic anemometer were sampled with 4 Hz. There is no commercial power supply near the site. Two pairs of twelve batteries for large trucks were used to operate the ultrasonic anemometer and a notebook computer used as a data logger.

Acknowledgements

Tetsuya Kogaki, AIST, Japan.



Nominal turbulence vs. wind speed.

Site = Näsudden, Gotland, Sweden

Site code **Nasudden**

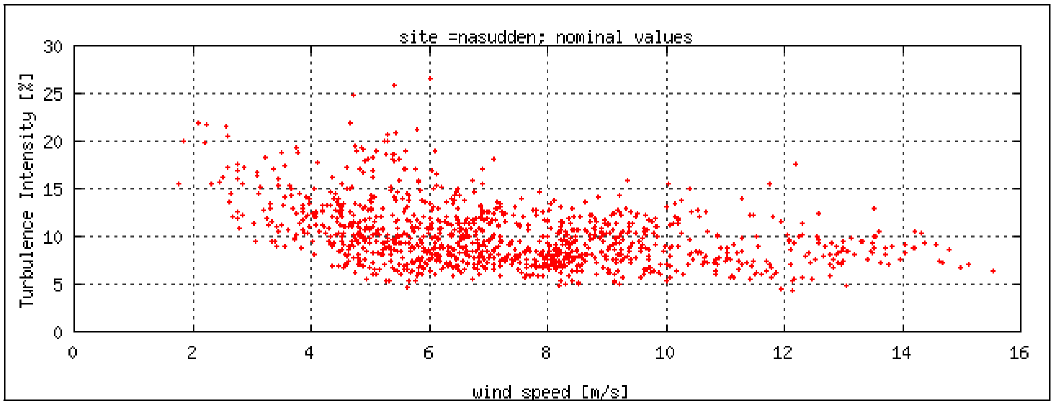
Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	3 & 5	3 & 5
Number of sonics / height of met. Mast.	0	135 m
Hours of measurements / frequencies	140 & 2870	20 & 1 Hz

Project motivation
Meteorological measurements from Nasudden site at Gotland, Sweden.

Measurement system
20 Hz data at two or three levels on a 145 m tower during several campaigns of 2-4 weeks.

Comments
Preliminary measurements are recorded with hotwires (140 hours). Sh1, sh2, sh3 are derived speeds and dh1, dh2, dh3 are derived directions from preliminary measurements.

Acknowledgements
Mikael Magnusson & Hans Bergström, Uppsala University and Ingemar Carlén, Teknikgruppen AB, Sweden.



Nominal turbulence vs. wind speed- cup signals only.

Site = Noerrekaer Enge, Jutland, Denmark.

Site code **norre**

Dominating terrain/ orography	coastal	flat
Number of masts / wind turbines	2	42(2)
Number of channels with wind speed / wind direction	15 (h=3,10,16,23,31,44 og 58 m)	3 (h=10,31 & 34 m)
Number of sonics / height of met. mast	2	31 m
Hours of measurements / frequencies	746	20 Hz

Project motivation

The Norrekaer Enge wind farm measurement campaign is part of the Risø programme for obtaining more knowledge on turbulence in wind farms and on loads on wind turbines placed in farms and arrays in different types of terrain. The main goal of this programme is to obtain information on loads on wind turbines situated in arrays, in order to enable the turbine designers to create more optimal designs.

The Norrekaer Enge measurements have been supported by the CEC under the JOULE programme, and by the Danish Ministry of Energy under the EFP programme. The good cooperation of Nordtank and Nordkraft has been very helpful in the performance of these measurements.

The Norrekaer Enge II Windfarm, containing 42 x 300 kW Nordtank turbines, is located in the North Jutland, on the south bank of the Limfjord, about 36 km west of Alborg and 8 km north east of Loegstoer. The terrain is old seabed and extremely flat, about 1 m above sea. The local terrain is however surrounded by small villages and significant terrain, with features up to 40 m in height, immediately to the south of the site. West of the site are farm buildings, rows of trees and the other windfarm: the Noerrekaer Enge I Windfarm, with 36 x 150 kW Nordtank turbines. Immediately north of the site there is water - the Limfjord.

Measurement system

Two turbines (A1 and F6) have been instrumented for obtaining structural measurements e.g. root bending moment, power, rotor-speed and yaw misalignment.

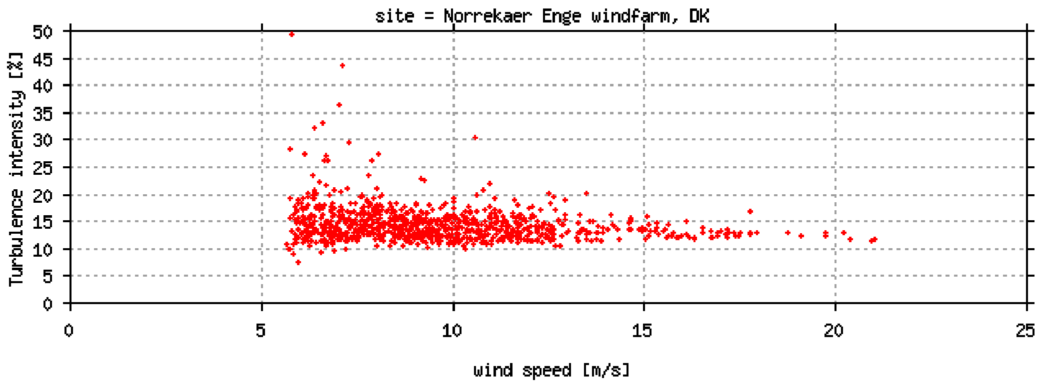
Mast 1 at A1 is placed on the row of turbines A1 - A7, 55 m south of turbine Al.

The Mast 2 at F6 is placed on the line between F6 and ES (orientation 35.83°), 55 m from F6 and the booms on both masts are perpendicular to the line F6 - E5.

Please note that the nominal turbulence intensity includes wind turbine wake turbulence.

Acknowledgements

Jørgen Højstrup and Peter Sanderhoff, Risø National Laboratories, Denmark.



Nominal turbulence vs. wind speed.

Site = NTK1500, Tjæreborg, Denmark

Site code **Ntk1500**

Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	2	1
Number of sonics / height of met. Mast.	0	60 m
Hours of measurements / frequencies	151	40 Hz

Project motivation

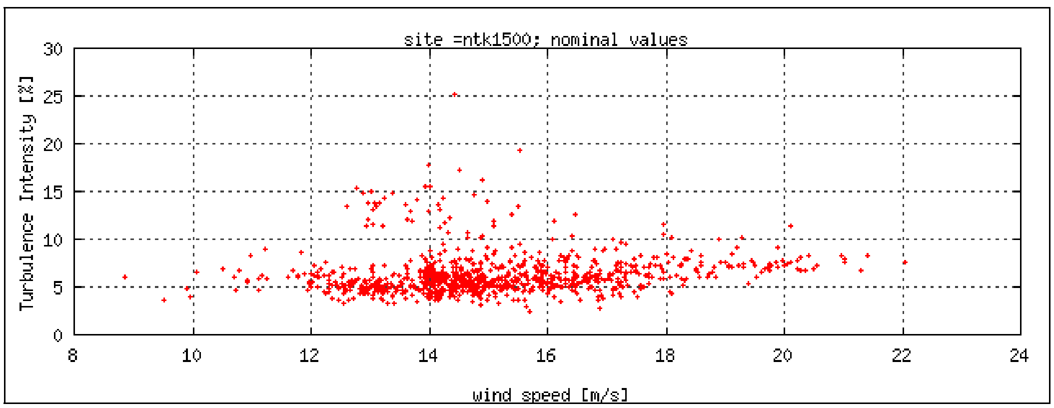
The aim of the measurement project has been to verify the characteristics of the NEG-Micon NM1500 prototype wind turbine. The terrain around the wind turbine is flat and in the measurement sector there no roughness elements of importance. The terrain south-west of the test site (the measurement sector) is a march area with a roughness length less than 0.1 m out to a distance 3 km in the measurement sector. The wind turbine NTK1500 manufactured by Nordtank A/S are located together with 3 other prototype turbines 2MW owned by Vestkraft, 1.5 MW Vestas and 1.0 MW Bonus. Note:Time series recorded as part of the 2MW measurement programme are available for the site_code=tjare.

Measurement system

The height of the meteorological mast is 60m, which contains a standard measurement setup necessary for making a standard load measuring program. The instrumentation includes 2 cup anemometers and one vane together with temperature, pressure and rain detection system. The DAQ recording software has been used for recording and storing time series at a frequency of 40 Hz.

Acknowledgements

Søren O.Lind, Risø National Laboratories, Denmark.



Nominal turbulence vs. wind speed.

Site = National Wind Test Center, Denver, CO, USA

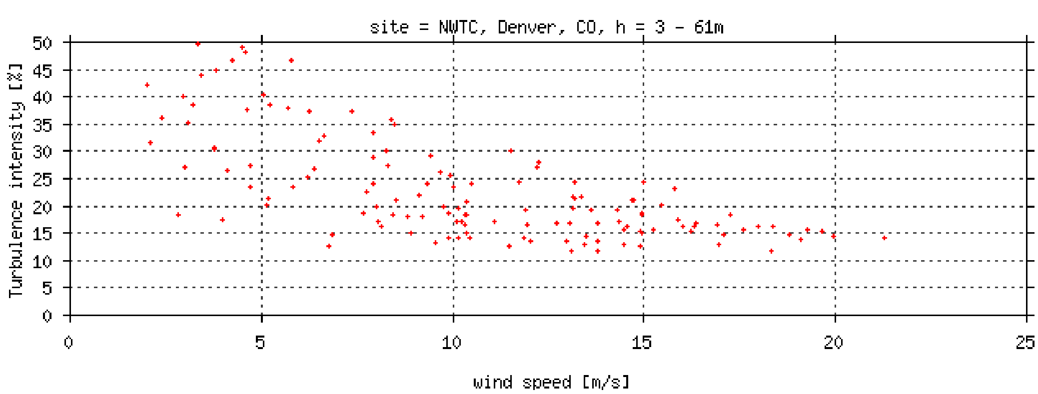
Site code **Nwtc**

Dominating terrain/ orography	pastoral	flat
Number of masts / wind turbines	3	1
Number of channels with wind speed / wind direction	3 (h=3,39 & 61 m)	3 (h=3,39 & 61 m)
Number of sonics / height of met. Mast.	5 (h=15,37 & 58m)	61 m
Hours of measurements / frequencies	24	1 & 40 Hz

Project motivation
The accurate numerical dynamic simulation of new large-scale wind turbine designs operating over a wide range of inflow environments is critical because it is usually impractical to test prototypes in a variety of locations. Large turbines operate in a region of the atmospheric boundary layer that currently may not be adequately simulated by present turbulence codes.
The objective of this experiment is to obtain simultaneously collected turbulence information from the inflow array and the corresponding structural response of the turbine. The turbulence information will be used for comparison with that predicted by currently available codes and establish any systematic differences. These results will be used to improve the performance of the turbulence simulations. The sensitivities of key elements of the turbine aeroelastic and structural response to a range of turbulence-scaling parameters will be established for comparisons with other turbines and operating environments. In this paper, we present an overview of the experiment, and offer examples of two observed cases of inflow characteristics and turbine response collected under daytime and night time conditions, and compare their turbulence properties with predictions.

Measurement system
The inflow instrumentation was mounted on three towers located 1.5-rotor diameters upstream of the turbine rotor. A total of five high-resolution Kaijo Model DA-600 ultrasonic anemometers/thermometers, which have a 10-Hz data bandwidth and a minimum resolution of 0.005 m/s or less, were deployed. In addition, cup anemometers and wind vanes were installed on the 61-m central tower at three levels, along with air temperature, fast response temperature, temperature difference between 3 and 61 m, and dew point temperature sensors. Barometric pressure was measured at a height of 3 m. GPS-based time was recorded to a resolution of 1 millisecond. The raw data was collected at rate of 40 samples per second.

Acknowledgements:
Sandy Butterfield & Maureen Hand, NREL.



Nominal turbulence vs. wind speed.

Site = Oak Creek wind farm, Tehachapi, USA

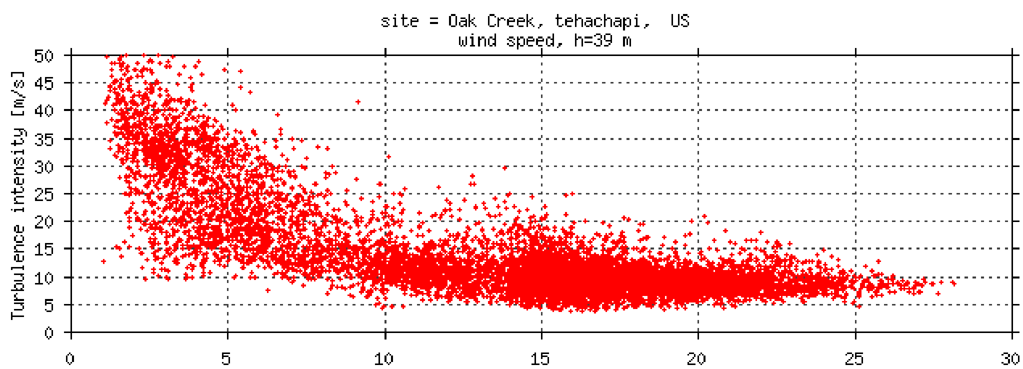
Site code **Oakcreek**

Dominating terrain/ orography	Scrub	Hill
Number of masts / wind turbines	2	2
Number of channels with wind speed / wind direction	8 (h=10,50,65 & 79 m)	6 (h=10, 50 & 79 m)
Number of sonics / height of met. Mast.	2 (h=80 m)	80 m
Hours of measurements / frequencies	5200	8 & 16 Hz

Project motivation
The objective of the Oak Creek project is to conduct a combined experimental and theoretical investigation of blade-, rotor- and tower loads caused by extreme wind load conditions occurring during normal operation as well as in stand still situations (where mean wind speeds exceeds the cut-out wind speed), with the purpose of establishing an improved description of the ultimate loading of three bladed pitch- and stall controlled wind turbines.

Measurement system
The measurements are performed in a wind farm situated at a high wind site in Oak Creek, near Tehachapi in California. The wind farm consists of wind turbines erected on a ridge in a very complex terrain. The prevailing wind direction is 320 degrees and thus perpendicular to the ridge. The wind field is measured from two 80 m high meteorological towers erected less than one rotor diameter in front of one of the wind turbines (in the direction of the prevailing wind direction), and the distance between the two meteorological towers is 25.5 m, corresponding to 0.58 rotor diameters. Thus, detailed information of the inflow field to the particular turbine rotor is provided. The instrumentation of the meteorological towers included sensors at multiple levels. In general, all specified instrument heights are given relative to the base of the relevant meteorological tower.

Acknowledgements
Søren M. Petersen, Risø National Laboratories, Denmark.



Nominal turbulence vs. wind speed.

Site = Burger Hill, Orkney Island, UK

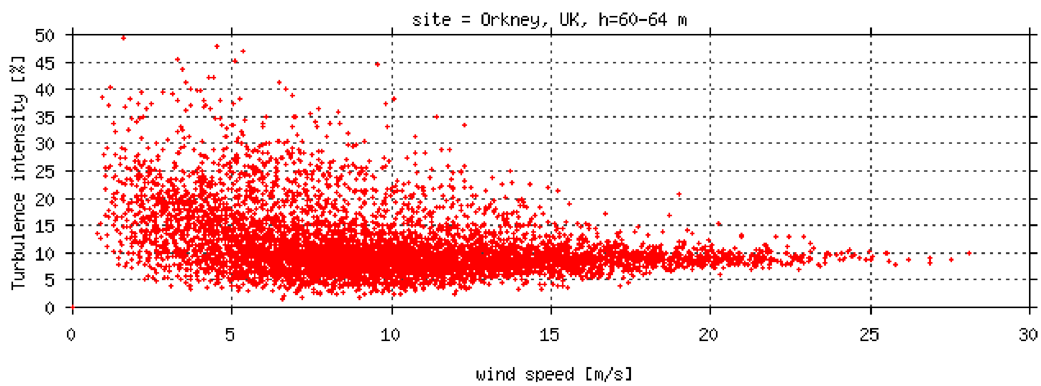
Site code **Orkney**

Dominating terrain/ orography	coastal	flat
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	2 (h=60 & 64m)	1 (h=61m)
Number of sonics / height of met. Mast.	0	64 m
Hours of measurements / frequencies	6083	1 Hz

Project motivation
N.A.

Measurement system
N.A.

Acknowledgements:
Lene Hellstern, NEG-Micon, Denmark.



Nominal turbulence vs. wind speed.

Site = Rødsand, Gedser Vest, Denmark

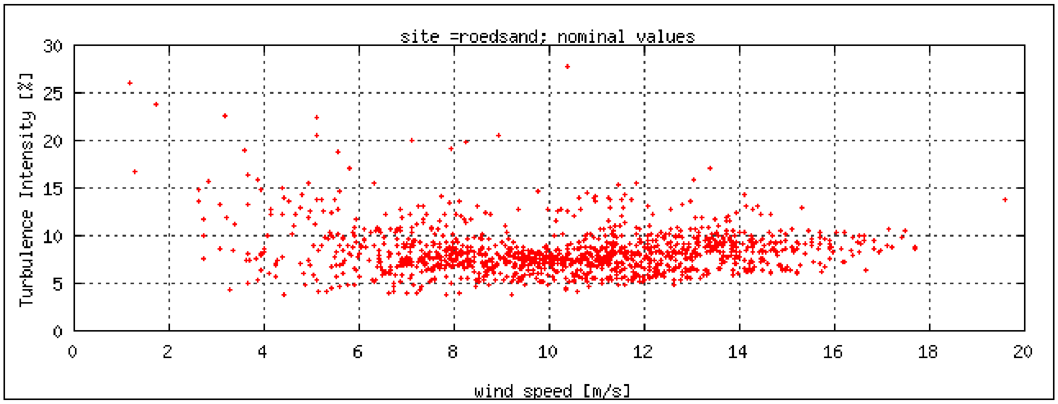
Site code **Roedsand**

Dominating terrain/ orography	Offshore	Flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	3	1
Number of sonics / height of met. Mast.	1	45 m
Hours of measurements / frequencies	41	5 & 20 Hz

Project motivation
Characterising wind and turbulence for offshore wind energy development.

Measurement system
A 48 m high lattice mast was erected at Rødsand (off-shore), Gedser Syd, Denmark. This mast has been instrumented with 3 cup anemometers, 1 vane and 1 sonic anemometer together with several thermometers.

Acknowledgements
Rebecca Barthelmie, Risø National Laboratories and SEAS, Denmark.



Nominal turbulence vs. wind speed.

Site = Rosiere, Wisconsin, USA

Site code **Rosiere**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	3	3
Number of sonics / height of met. Mast.	0	40 m
Hours of measurements / frequencies	4681	5 Hz

Project motivation

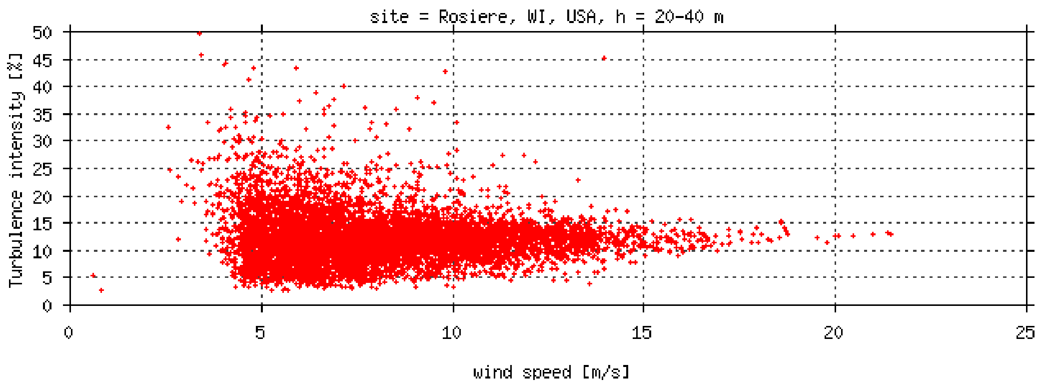
This project was initiated in 1990 to develop measurements and analysis methods that would establish representative and appropriate turbulence characteristics needed for the design and siting of cost-effective wind turbines. NREL and Batelle had additional objectives that included correlating the nature of the turbulence in the inflow to upwind features, and transferring the technology developed in the project to industry for operational applications.

Measurement system

11 different sites with identical equipment (4 cups, 4 vanes and 4 vertical propellers). Measurements from three sensors on the 40-m tower (T1) provided a representation of the vertical shear of the wind velocity for wind turbines with a 20-m rotor diameter and a 30-m rotor diameter. The 30-m tower (T2) allowed a hub-height wind measurement positioned on the perimeter of the rotor disk 10m away from the centre of the rotor disc, and in direction perpendicular to the prevailing wind direction. This data configuration provided not only vertical and horizontal wind shear data at a site but also data on the effect on rotational sampling of the turbulent wind. The horizontal wind speed and direction were measured at four locations with R.M.Young Wind Monitors. The vertical component of the wind was measured by a single Gill propeller anemometer mounted directly underneath each of the propeller-vane anemometers. A single cup-vane anemometer was mounted near the propeller-vane anemometer at the top of T2 within a few feet of the propeller-vane anemometer at the same location. This was the Maximum cup and NRG vane that are commonly used in the wind industry to estimate the resource at the site.

Acknowledgements:

Sandy Butterfield & Maureen Hand, NREL.



Nominal turbulence vs. wind speed.

Site = San Jose, Azores, Portugal

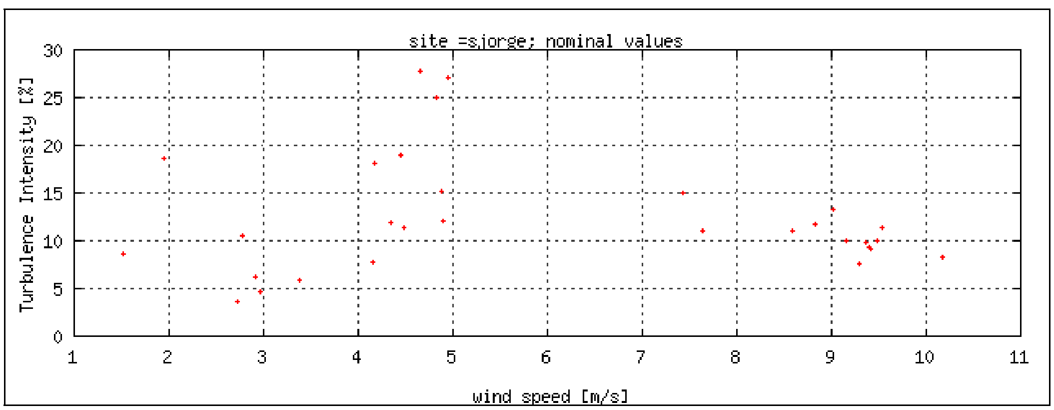
Site code **Sjorge**

Dominating terrain/ orography	Coastal	Mountain
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	3	1
Number of sonics / height of met. Mast.	1	27 m
Hours of measurements / frequencies	5	40 Hz

Project motivation
Development and validation of wind park and local grid detailed dynamic models (INPark).

Measurement system
The measurement system was based on one 9200 PLUS NRG data logger with NRG#40 cup anemometers and NRG#200P wind vane as transducers, and the 3D wind components were obtained through a Solent research symmetric head sonic anemometer, being the data acquisition system a GH-Garrad Hassan T-DAS operated by the GH-MON software.

Acknowledgements
Ana Estanqueiro, INETI, Portugal.



Nominal turbulence vs. wind speed.

Site = Skipheya, Frøya, Norway

Site code **Ski**

Dominating terrain/ orography	Coastal	Hill
Number of masts / wind turbines	3	2
Number of channels with wind speed / wind direction	17 (11,21,41,72 & 101 m)	1 (h=101 m)
Number of sonics / height of met. Mast.	0	101 m
Hours of measurements / frequencies	13174	0.85 Hz

Project motivation

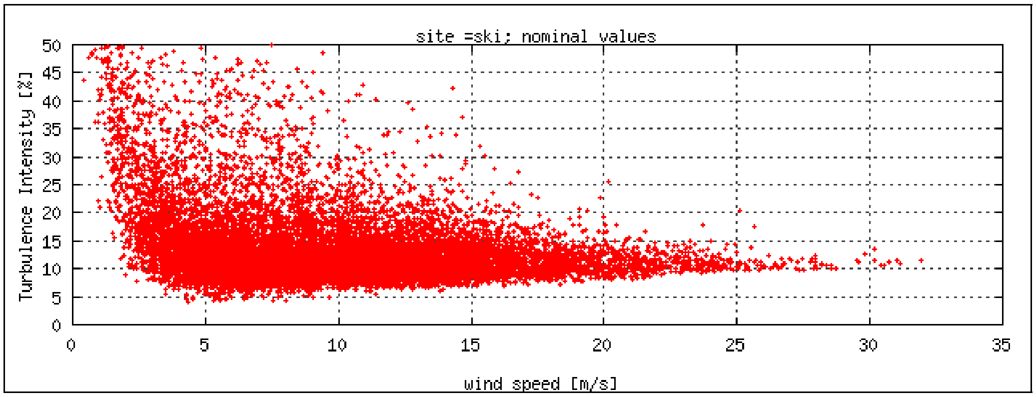
The station was build as a part of the Norwegian Wind Energy Programme in 1980. The purpose was to study the wind structure in details. Particularly, a database for high wind speed condition was desired. Data were originally intended for wind energy production; the dimension of the masts corresponds to a large WECS. The station should also serve as a reference station for other measurement stations in the region. Together with a fourth mast 4 km further west (Sletringen) the station has provided data for calculation of dynamic wind loads on off-shore constructions.

Measurement system

The measurement system consists of 3 meteorological masts (100, 100 and 45 m) placed in a triangle 80-180 metres apart. Ten-minute average of wind speed and direction have been recorded since 1982. From 1988, the logging frequency has been 0.85 Hz. 40-60 channels have been recorded continuously. In a 45 m mast at Sletringen, data has been recorded for some periods since 1988.

Acknowledgements

Jørgen Løvseth, NTNU, Norway.



Nominal turbulence vs. wind speed.

Site = Sky River wind farm (location V27) in Tehachapi, USA

Site code **Skyv27**

Dominating terrain/ orography	Scrub	Hill
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	2 (h=11 & 31 m)	2 (h=11 & 31 m)
Number of sonics / height of met. Mast.	2 (h=19 & 43 m)	43 m
Hours of measurements / frequencies	164	8 & 32 Hz

Project motivation

Verification of the structural integrity of a wind turbine involves analysis of fatigue loading as well as ultimate loading. With the trend of persistently growing turbines, the ultimate loading seems to become relatively more important. For wind turbines designed according to the wind conditions prescribed in the IEC-61400 code, the ultimate load is often identified as the leading load parameter.

The objective of the Oak Creek project is to conduct a combined experimental and theoretical investigation of blade-, rotor- and tower loads caused by extreme wind load conditions occurring during normal operation as well as in stand still situations (where mean wind speeds exceeds the cut-out wind speed), with the purpose of establishing an improved description of the ultimate loading of three bladed pitch- and stall controlled wind turbines.

Measurement system

The measurements are performed in a wind farm situated at a high wind site in Oak Creek, near Tehachapi in California. The wind farm consists of wind turbines erected on a ridge in a very complex terrain. The prevailing wind direction is 320 degrees and thus perpendicular to the ridge. The turbines are closely spaced - the inter turbine spacing is 53 m, corresponding to approximately 1.2 rotor diameters. The wind turbines are tree bladed NEG-Micon 650 kW stall regulated turbines with hub heights and rotor diameters equal to 55 m and 44 m, respectively.

The wind field is measured from two 80 m high meteorological towers erected less than one rotor diameter in front of one of the wind turbines (in the direction of the prevailing wind direction), and the distance between the two meteorological towers is 25.5 m, corresponding to 0.58 rotor diameters. Thus, detailed information of the inflow field to the particular turbine rotor is provided.

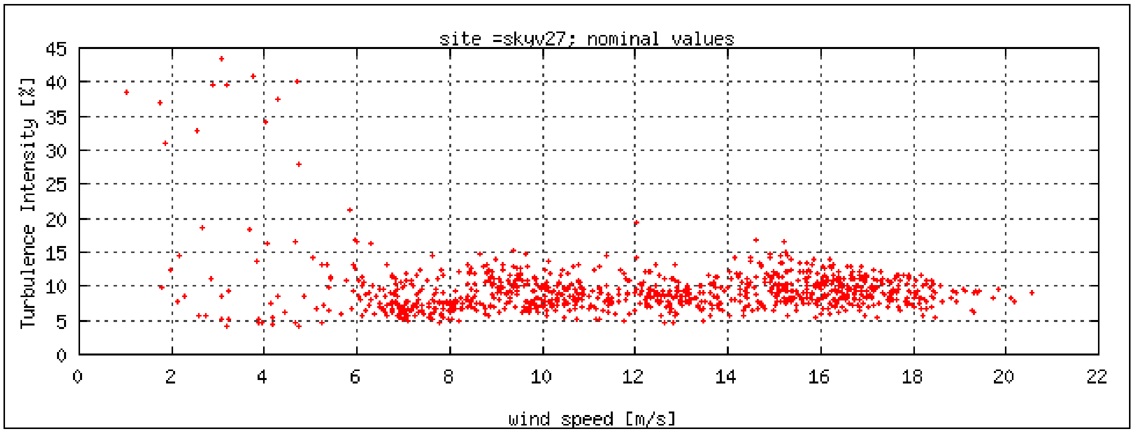
The instrumentation of the meteorological towers included sensors at multiple levels. Basically, similar instruments on each of the two masts have been installed in roughly the same level relative to the terrain level.

The monitoring system is running continuously, and the data are reduced and stored as 10-minutes statistics supplemented with intensive time series recordings covering periods where the mean wind speed exceeds a specified threshold (15 m/s). Consequently, there are time gaps in the time series. The monitoring sample rate is 32 Hz.

Detailed information on the individual sensors is provided from the Master Sensor List. In general, all specified instrument heights are given relative to the base of the relevant meteorological tower.

Acknowledgements

Søren Markkilde Petersen, Risø National Laboratories, Denmark.



Nominal turbulence vs. wind speed.

Site = Sky River wind farm (location V39) in Tehachapi, USA

Site code **Skyv39**

Dominating terrain/ orography	Scrub	Hill
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	2 (h=11 & 41 m)	2 (h=11 & 41 m)
Number of sonics / height of met. Mast.	2 (h=19 & 43 m)	43 m
Hours of measurements / frequencies	138	8 & 32 Hz

Project motivation
Verification of the structural integrity of a wind turbine involves analysis of fatigue loading as well as ultimate loading. With the trend of persistently growing turbines, the ultimate loading seems to become relatively more important. For wind turbines designed according to the wind conditions prescribed in the IEC-61400 code, the ultimate load is often identified as the leading load parameter.

The objective of the Oak Creek project is to conduct a combined experimental and theoretical investigation of blade-, rotor- and tower loads caused by extreme wind load conditions occurring during normal operation as well as in stand still situations (where mean wind speeds exceeds the cut-out wind speed), with the purpose of establishing an improved description of the ultimate loading of three bladed pitch- and stall controlled wind turbines.

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Acknowledgements
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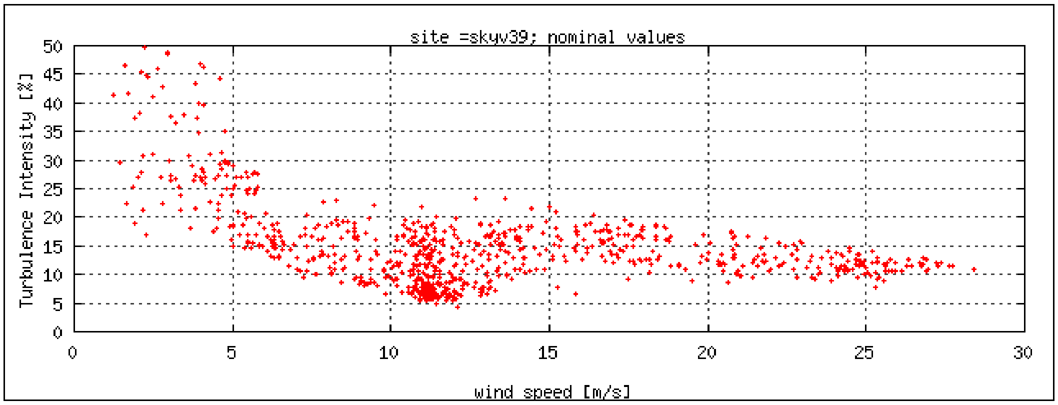


Nominal turbulence vs. wind speed.

Site = Sletringen, Norway

Site code **Sle**

Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	5	1
Number of sonics / height of met. Mast.	0	45 m
Hours of measurements / frequencies	3756	Appr. 0.85 Hz

Project motivation

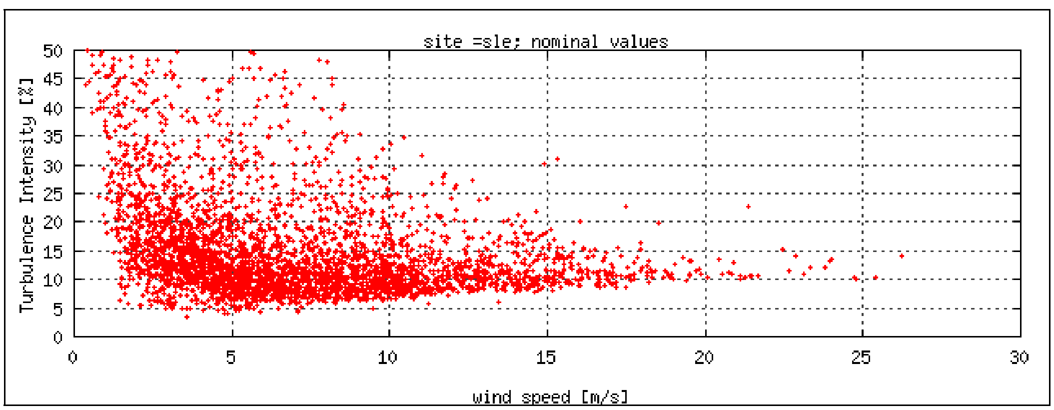
The station was build as a part of the Norwegian Wind Energy Programme in 1980. The purpose was to study the wind structure in details. Particularly, a database for high wind speed condition was desired. Data were originally intended for wind energy production; the dimension of the masts corresponds to a large WECS. The station should also serve as a reference station for other measurement stations in the region. Together with a fourth mast 4 km further west (Sletringen) the station has provided data for calculation of dynamic wind loads on off-shore constructions.

Measurement system

Lattice tower, 45 m. Booms at heights: 46, 42, 20, 10 and 5 m. Cup anemometers at all heights. Vane at 46 m. Temperature measurements at 45m, 5m, and sea.

Acknowledgements

Jørgen Løvseth, NTNU, Norway.



Nominal turbulence vs. wind speed.

Site = Sprogø, Storebælt, Denmark

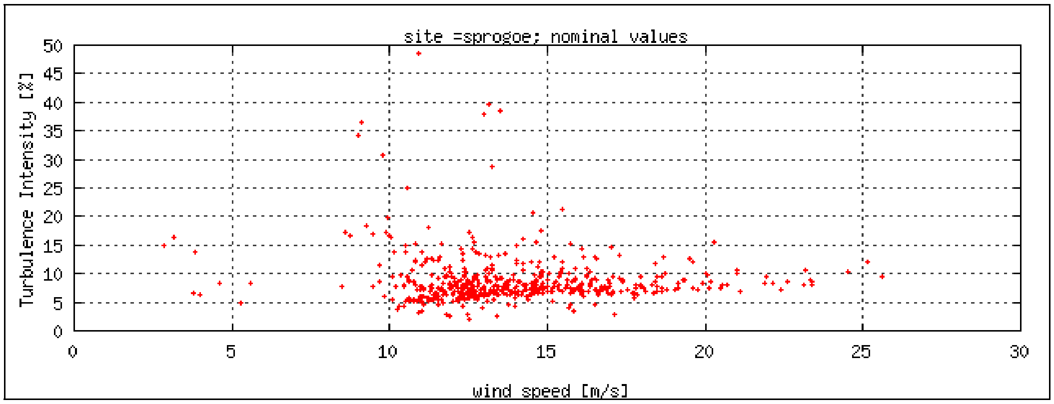
Site code **Sprogoe**

Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	3	1
Number of sonics / height of met. Mast.	3	70 m
Hours of measurements / frequencies	527	2 & 10 Hz

Project motivation
With the purpose of supporting determination of the design wind loads on the East Bridge of The Great Belt Link, Risø National Laboratory has made an investigation of the structure of the turbulence at the height of the suspended span on the suspension bridge. The experiment: In the period extending from June 1990 to the middle of June 1991 omni-directional anemometers, mounted on 70 m high meteorological towers at Sprogø, have measured the wind velocity vectors at three horizontally displaced points. The Measuring Site: The measurements were recorded on a small island, Sprogø, located in the middle of The Great Belt between Funen and Zealand. The meteorological masts were erected on the eastern side of some flow obstacles present on the island (hill and buildings), which enables free access for northern, eastern and southerly wind directions.

Measurement system
Measuring mast: The measuring setup consists of 2 meteorological masts each with a height of 70 m and 40 m horizontal separation. A 15 m horizontal boom is mounted symmetrically on top of the second mast in such a way that the whole construction has the form of the letter “T”. Instrumentation: The basis for the coherence measurements consists of an array of 3 sonic anemometers - mounted at a height of 70 m. Close to each sonic anemometer is installed a cup anemometer, and furthermore a single wind vane is mounted in the centre of the “T” boom. The data acquisition system: The data acquisition system is based upon a personal computer (PC) running the Risø DAQ data acquisition software. Signals are sampled continuously with time series data being logged to disk when certain wind speed and wind direction criteria are satisfied. Data scanning and recording: All data are sampled with 40 Hz. For sonic anemometer channels the stored data is reduced to 10 Hz by block averaging. Similarly, wind vane and cup anemometer signals are reduced to 2 Hz.

Acknowledgements
Søren Larsen, Risø National Laboratories and A/S Storebæltsforbindelsen, Denmark.



Nominal turbulence vs. wind speed.

Site = Tarifa, Spain

Site code **Tarifa**

Dominating terrain/ orography	Pastoral	Mountain
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	5 (h=10,19 & 40 m)	2 (h=40 m)
Number of sonics / height of met. Mast.	3 (h=10 & 40 m)	40 m
Hours of measurements / frequencies	280	4 Hz

Project motivation

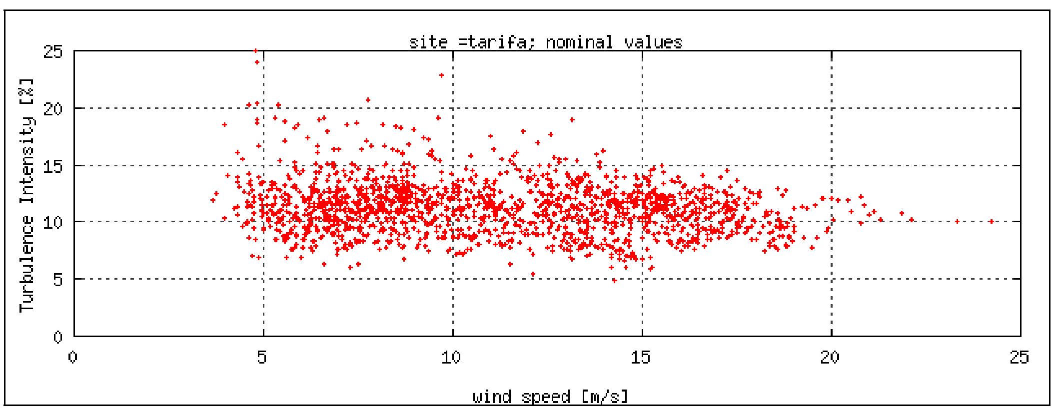
The primary goal was to investigate of design aspects and design options for wind turbines operating in complex terrain environments within COMTERID project.

Measurement system

The measurements system consist of two meteorological masts, mast n§1 located towards NNW direction and 15 degrees from the north, mast n§2 located towards South direction and 190 degrees from the north The measurements system was based on Garrad Hassan acquisition system. The system operation was primary focusing on recording structural loads including a number of meteorological channels. Data recording frequency was 40 Hz and duration of 600 seconds.

Acknowledgements

Jorge Navarro, Dept. of Renewable Energy, Ciemat, Madrid, Spain.



Nominal turbulence vs. wind speed.

Site = Tarifa, Spain; near the Nordtank wind farm

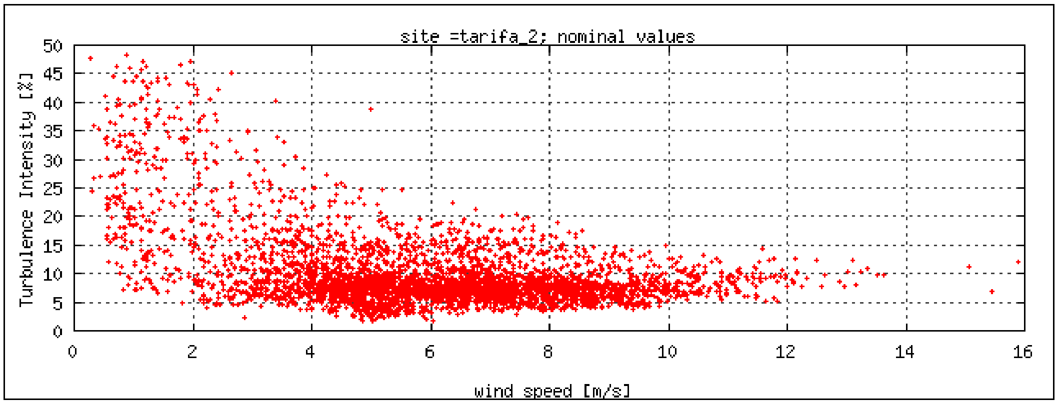
Site code **Tarifa_2**

Dominating terrain/ orography	Pastoral	Hill
Number of masts / wind turbines	1	12
Number of channels with wind speed / wind direction	0	0
Number of sonics / height of met. Mast.	2 (h=20 & 30 m)	30 m
Hours of measurements / frequencies	663	20 Hz

Project motivation
It has been known for many years that under certain climates stall-regulated wind turbines will stall at a lower level than expected - this is known as double-stall. In this project the wind climate was investigated at Tarifa in south Spain near Gibraltar where double-stall has often been observed. The object was to investigate the parameters that are believed to cause double-stall. The three turbulence components u, v and w are measured with sonic anemometer and stored as time-series. Furthermore, weather parameters like temperature, pressure, humidity and precipitation are stored as 10-minute average values.

Measurement system
The measurement system consists of 2 sonic METEK USA-1 anemometers located on a mast in 20 and 30 m height. Weather parameters are collected 3 m above ground level. The prevailing wind directions are east and west. 12 wind turbines and the mast are located on a north south going rim. Consequently, the flow at the mast will not be disturbed by the turbines. Data recording frequency was 20 Hz with the sonics and all data are stored in 600 sec files. File name indicates beginning of 10 minutes sampling period: MMDDHHMM. E.g. 01091610 means 9 January, 600 seconds sampled from 4.10 p.m.

Acknowledgements
Torkild Christensen, Tech-wise A/S (former Elsamprojekt A/S), Denmark.



Nominal turbulence vs. wind speed.

Site = Tejona, Costa Rica

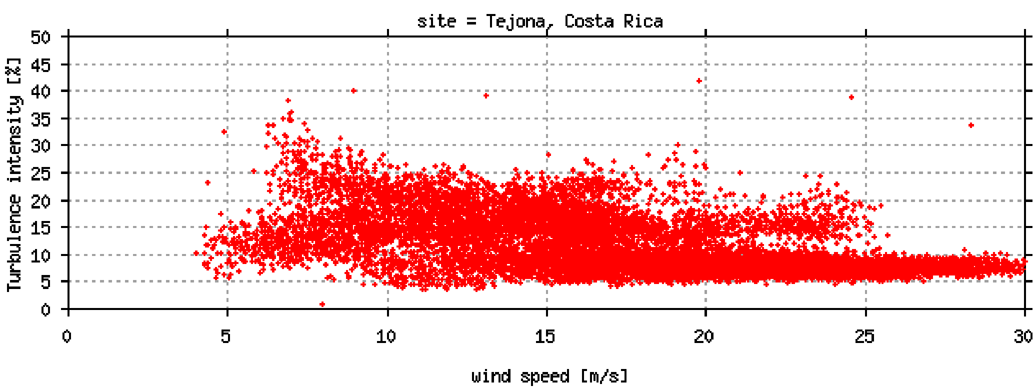
Site code **tejona**

Dominating terrain/ orography	scrub	mountain
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	2 (h=19 & 29 m)	1 (h=19 m)
Number of sonics / height of met. Mast.	1 (h=31 m)	31 m
Hours of measurements / frequencies	2511	4 & 25 Hz

Project motivation
In view of the final lay out of a 20 MW wind farm in Tejona ECN has carried out the micrositing for the wind power plant. The 20 MW is built up by 30 wind turbines of 660 kW. The process involved determination of the wind climate, the terrain orography and roughness, the wind turbine characteristics and the wind turbine positions. For this purpose the ECN Wind Energy Experiments group has installed a measuring mast for short-term measurements at the site.

Measurement system
The measurement system consists of a 30.9m mast with four guy wires. There are two sonics at the top, a cup anemometer 1m below the top and a vane and cup anemometer at 18m height. The meteorological measurements include rain, pressure and temperature.

Acknowledgements:
Sam Barhorst & Dr. P. Eecen, ECN.



Nominal turbulence vs. wind speed.

Site = Tjæreborg, 2MW, 60 m wind turbine, Denmark

Site code **Tjare**

Dominating terrain/ orography	Pastoral	Flat
Number of masts / wind turbines	2	1
Number of channels with wind speed / wind direction	12 (h=10, 30, 45, 60, 75 & 90 m)	6 (h=10, 60 & 75 m)
Number of sonics / height of met. Mast.	0	90 m
Hours of measurements / frequencies	64	25 Hz

Project motivation

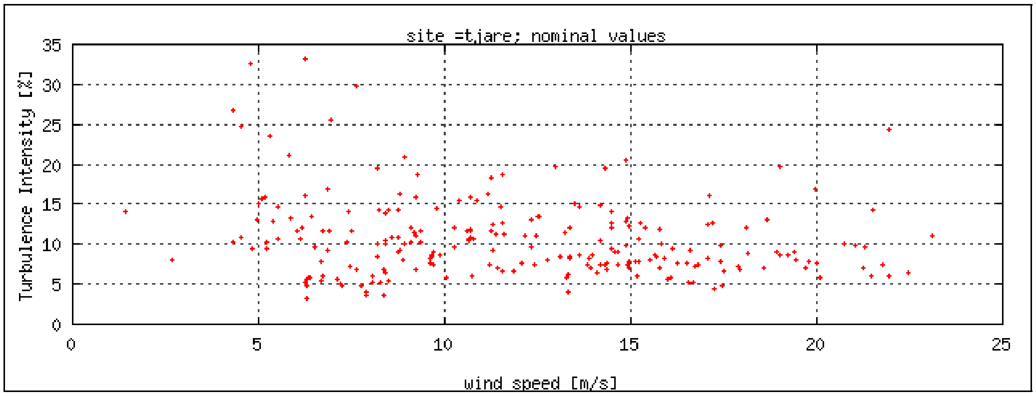
The primary goal was to design and build a 2MW wind turbine at Tjaereborg, Esbjerg. This project was accomplished with an intensive measuring programme where both mechanical loads and the wind climate on the site was measured - and analysed. The wind data were recorded as part of this measurement programme.

Measurement system

The measurement system consists of 2 meteorological mast, mast no.1 was placed in front and mast no.2 behind the wind turbine - referring to the dominant wind sector. The measurements system was based on two HP data loggers and the data was transferred to a central computer (HP operating HP-Basic with home developed data handling routines and programs). The system operation was primarily focusing on recording structural loads included a number of meteorological channels. Data recording frequency 25 Hz and duration = 184, 600 or 3600 seconds. Only data with a duration of 600 seconds or more are used.

Acknowledgements

Peter Christiansen, Tech-wise A/S (former Elsamprojekt A/S), Denmark.



Nominal turbulence vs. wind speed.

Site = Toboel, Ribe, Denmark

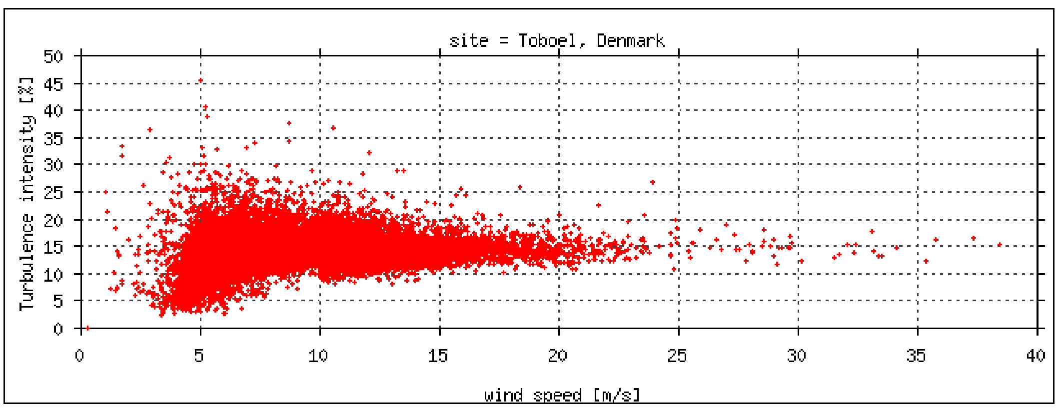
Site code **Toboel_1 & Toboel_2**

Dominating terrain/ orography	Pastoral	Flat
Number of masts / wind turbines	2	2
Number of channels with wind speed / wind direction	7 (h=15,30,48 & 65 m)	4 (h=30, 48 & 62 m)
Number of sonics / height of met. Mast.	0	65 m
Hours of measurements / frequencies	2071 + 1147	8 & 32 Hz

Project motivation
The aim of the measurement project has been to verify the characteristics of the two NEG-Micon prototype wind turbines during various tests. The terrain around the wind turbine is flat and in the measurement sector there are no roughness elements of importance.

Measurement system
The height of the meteorological mast is 49m, which contains a standard measurement setup necessary for making a standard load measuring program. The instrumentation includes five cup anemometers, one sonic anemometer and one vane together with temperature, pressure and rain detection system. The DAQ recording software has been used for recording and storing time series at a frequency of 32 Hz.

Acknowledgements
Søren Markkilde Petersen, Risø National Laboratories, Denmark.



Nominal turbulence vs. wind speed.

Site = Toplou, Crete, Greece

Site code **Toplou**

Dominating terrain/ orography	Pastoral	Mountain
Number of masts / wind turbines	1	2
Number of channels with wind speed / wind direction	1 (h=35 m)	1 (h=35 m)
Number of sonics / height of met. Mast.	1 (h=35 m)	40 m
Hours of measurements / frequencies	172	1 & 8 Hz

Project motivation

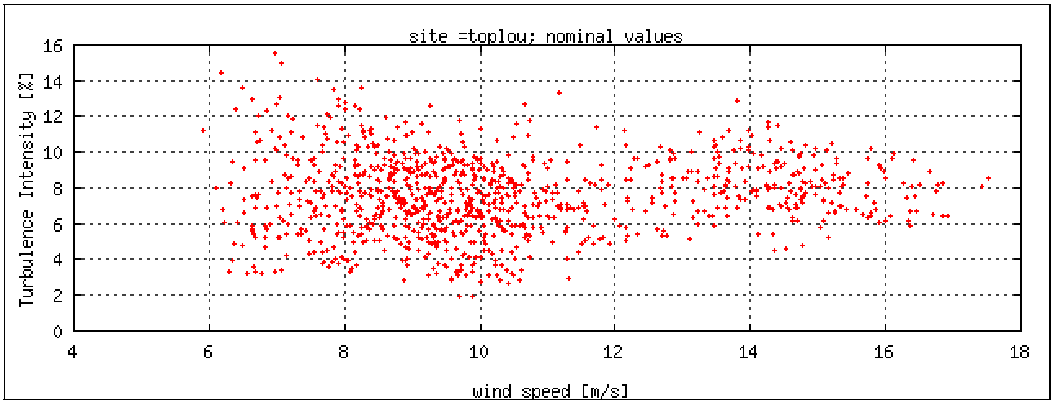
The main objective of the project is to develop a cost effective and easy to apply method for further assessment of fatigue loading effects through measurements. Its simplicity and robustness will enable easy application by industries. Obtained fatigue load "footprints" will be able to back up findings as derived from theoretical research work and will contribute to improved specifications on wind farm and mountainous terrain operation in international guidelines.

Measurement system

Wind and wind turbine power and loads measurements on mountainous terrain at Toplou site, in Crete. Wind measurements are carried out using cups and vanes and a sonic anemometer for determining the 3D characteristics of the wind and these measurements are coupled to the response of a 500kW stall regulated wt (TW-500) through load and power measurements.

Acknowledgements

E.F.Morfiadakis, C.R.E.S, Greece.



Nominal turbulence vs. wind speed.

Site = Tsukuba, Japan

Site code **Tsukuba**

Dominating terrain/ orography	Rural	Flat
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	1	1
Number of sonics / height of met. Mast.	0	15 m
Hours of measurements / frequencies	1355	1 Hz

Project motivation

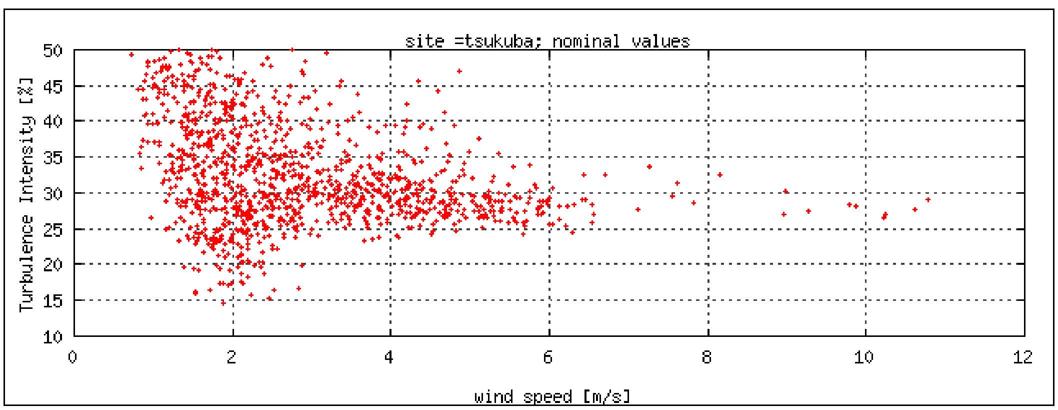
The wind turbine WINDMEL-II (WIND turbine at Mechanical Engineering Laboratory) has been erected by MEL in 1994 within the framework of the New Sunshine (NSS) project aiming at researching and developing various renewable energy technologies. The objective is to evaluating a flexible design concept of wind turbines. The WINDMEL-II (Two blades, diameter 15m) was designed based on a flexible wind turbine technology such as variable speed operation, teetered hub, soft-designed tower, and AC-DC-AC link.

Measurement system

The WINDEMEL-II has been elected in the Tsukuba Research Centre No.2, Agency of Industrial Science and Technology (AIST). The measurement system consists of 1 meteorological mast, which lies 37.5 m to the north-east of the WINDMEL-III. The height of the mast was 15.14 m, which is same as the hub height of the WINDMEL-II. Wind measurements are carried out using a propeller anemometer to evaluate the performance of the WINDMEL-II. The measurement data are transmitted from the sensors to the data logger by an optical fibre cable. All measurements are sampled with 1 Hz.

Acknowledgements

Tetsuyo Kogaki, MEL, Japan.



Nominal turbulence vs. wind speed.

Site = Tug Hill Plateau, New York, USA

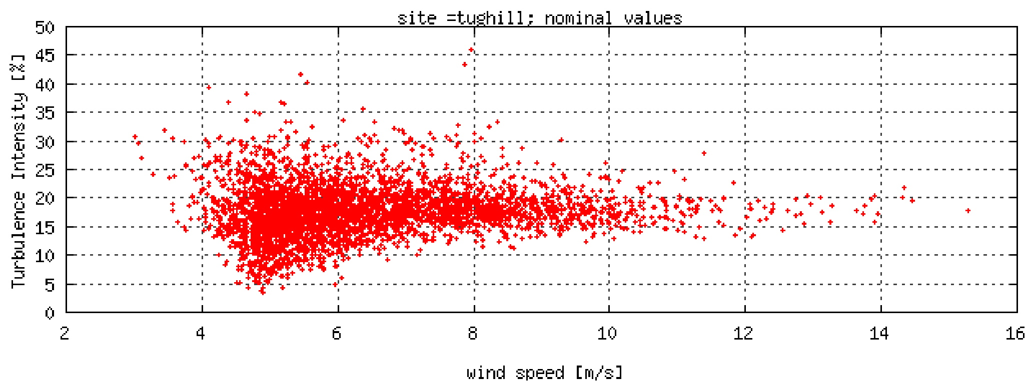
Site code **tughill**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	3	3
Number of sonics / mast height	0	40 m
Hours of measurements / frequencies	2983	5 Hz

Project motivation
This project was initiated in 1990 to develop measurements and analysis methods that would establish representative and appropriate turbulence characteristics needed for the design and siting of cost-effective wind turbines. NREL and Batelle had additional objectives that included correlating the nature of the turbulence in the inflow to upwind features, and transferring the technology developed in the project to industry for operational applications.

Measurement system
11 different sites with identical equipment (4 cups, 4 vanes and 4 vertical propellers). Measurements from three sensors on the 40-m tower (T1) provided a representation of the vertical shear of the wind velocity for wind turbines with a 20-m rotor diameter and a 30-m rotor diameter. The 30-m tower (T2) allowed a hub-height wind measurement positioned on the perimeter of the rotor disk 10m away from the centre of the rotor disc, and in direction perpendicular to the prevailing wind direction. This data configuration provided not only vertical and horizontal wind shear data at a site but also data on the effect on rotational sampling of the turbulent wind. The horizontal wind speed and direction were measured at four locations with R.M.Young Wind Monitors. The vertical component of the wind was measured by a single Gill propeller anemometer mounted directly underneath each of the propeller-vane anemometers. A single cup-vane anemometer was mounted near the propeller-vane anemometer at the top of T2 within a few feet of the propeller-vane anemometer at the same location. This was the Maximum cup and NRG vane that are commonly used in the wind industry to estimate the resource at the site.

Acknowledgements
Sandy Butterfield and Maureen Hand, NREL, USA.



Nominal turbulence vs. wind speed

Site = Ütlängan, Sweden

Site code **Utlangan**

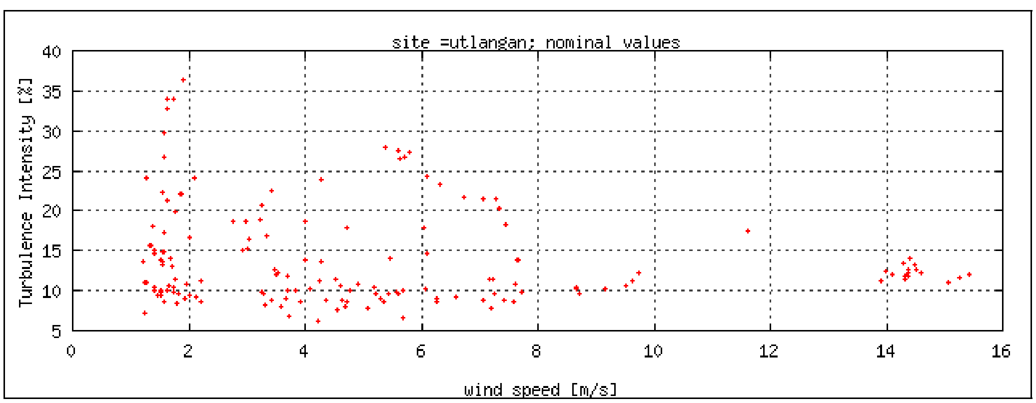
Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	3	3
Number of sonics / height of met. Mast.	0	22.5 m
Hours of measurements / frequencies	90	20 Hz

Project motivation
This site is a small island in an archipelago.

Measurement system
20 Hz data at two levels on a 20 m tower for one month.

Comments
All measurements are recorded with hotwires. Sh1, sh2 are derived speeds and dh1, dh2 are derived directions.

Acknowledgements
Mikael Magnusson and Hans Bergström, Uppsala University, Sweden.



Nominal turbulence vs. wind speed.

Site = Vindeby off-shore wind farm, Denmark

Site code **Vindeby**

Dominating terrain/ orography	Offshore	Flat
Number of masts / wind turbines	3	13
Number of channels with wind speed / wind direction	21 (h=4 –48m)	6 (h=6 – 41 m)
Number of sonics / height of met. Mast.	6 (h=6 – 45 m)	48 m
Hours of measurements / frequencies	2063	5 & 20 Hz

Project motivation

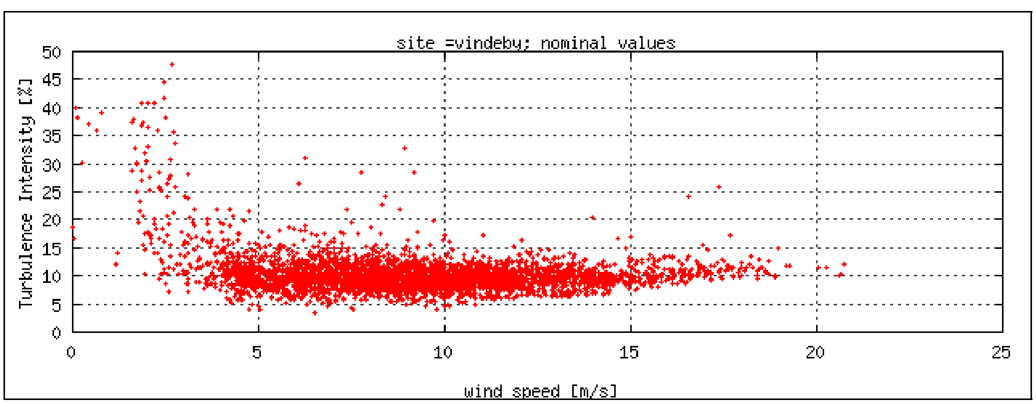
The primary goals of the Risø Air Sea Experiment (acronym: RASEX) experiment were: 1) To carry out a "Kansas experiment over the sea"; that is, examine the validity of Monin Obukhov similarity theory over the sea using profiles and eddy correlation data. 2) To provide detailed information on off-shore wind climate characteristics of relevance for wind turbine design.

Measurement system

The world's first offshore wind farm is located on a shallow water area off the north-western coast of the island of Lolland, close to Vindeby in Denmark. The wind farm consists of 11 wind turbines positioned in two rows oriented approximately in a NW-SE direction. The wind turbines are Bonus 450 kW machines with a rotor diameter of 35 m and a hub height of 37 m above average sea level. The distance between the wind turbine rows are 300 m, and so is the distance between the turbines in each of the rows. The most southerly placed wind turbine is closest to the coast, and the distance is approximately 1.5 km. In order to investigate the offshore- and coastal wind climate three 45 m high meteorological towers were erected at the site. Two of these were located offshore and denoted by SMW (sea mast west) and SMS (sea mast south), respectively.

Acknowledgements

Rebecca Barthelmie, Risø National Laboratories and SEAS, Denmark.



Nominal turbulence vs. wind speed.

Site = Vallersund, Norway

Site code **Vls**

Dominating terrain/ orography	Coastal	Hill
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	4	1
Number of sonics / height of met. Mast.	0	30 m
Hours of measurements / frequencies	3756	0.85 Hz

Project motivation

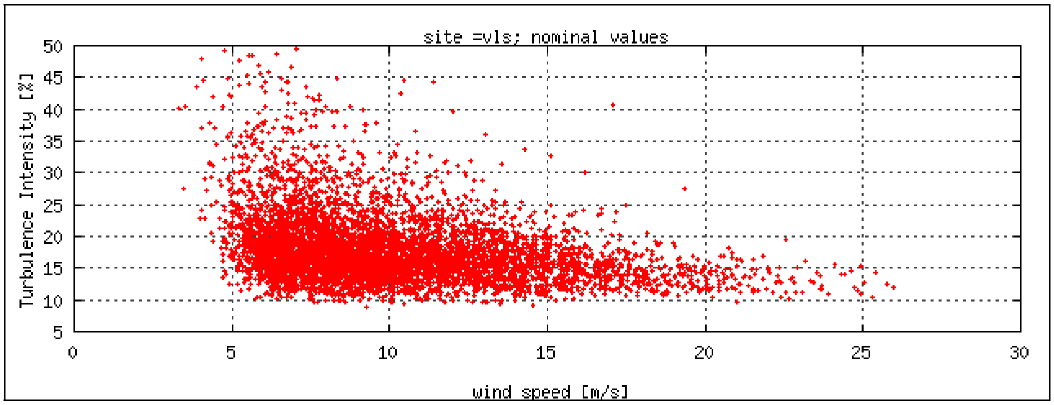
The project started in 1990, and the purpose was to study the wind structure, and to compare wind measurements to energy production from a neighbouring WECS.

Measurement system

The measurement station consists of 30 m mast with wind speed sensors at 30, 18, 10, and 5 m, and direction sensor at 12 m. Temperature has been measured at 30 and 10 m heights. The logging frequency has been 0.85 Hz.

Acknowledgements

Jørgen Løvseth, NTNU, Norway.



Nominal turbulence vs. wind speed.

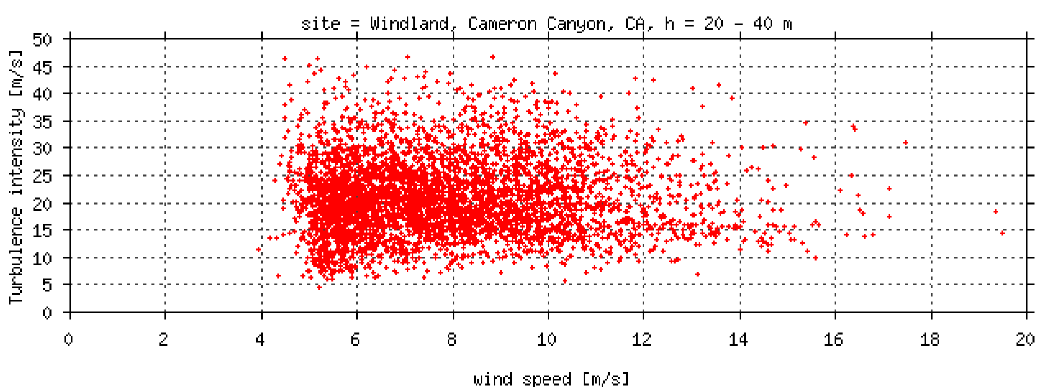
Site = Monolith, (windland), CA, USA

Site code	**Windland**	
Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	3	3
Number of sonics / height of met. Mast.	0	40 m
Hours of measurements / frequencies	3667	5 Hz

Project motivation
This project was initiated in 1990 to develop measurements and analysis methods that would establish representative and appropriate turbulence characteristics needed for the design and siting of cost-effective wind turbines. NREL and Batelle had additional objectives that included correlating the nature of the turbulence in the inflow to upwind features, and transferring the technology developed in the project to industry for operational applications.

Measurement system
11 different sites with identical equipment (4 cups, 4 vanes and 4 vertical propellers). Measurements from three sensors on the 40-m tower (T1) provided a representation of the vertical shear of the wind velocity for wind turbines with a 20-m rotor diameter and a 30-m rotor diameter. The 30-m tower (T2) allowed a hub-height wind measurement positioned on the perimeter of the rotor disk 10m away from the centre of the rotor disc, and in direction perpendicular to the prevailing wind direction. This data configuration provided not only vertical and horizontal wind shear data at a site but also data on the effect on rotational sampling of the turbulent wind. The horizontal wind speed and direction were measured at four locations with R.M.Young Wind Monitors. The vertical component of the wind was measured by a single Gill propeller anemometer mounted directly underneath each of the propeller-vane anemometers. A single cup-vane anemometer was mounted near the propeller-vane anemometer at the top of T2 within a few feet of the propeller-vane anemometer at the same location. This was the Maximum cup and NRG vane that are commonly used in the wind industry to estimate the resource at the site.

Acknowledgements:
Sandy Butterfield & Maureen Hand, NREL.



Nominal turbulence vs. wind speed.

Site = Windy Standard, Scotland

Site code **Windy**

Dominating terrain/ orography	Pastoral	Mountain
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	4(h=8,17 & 34 m)	1 (h=34 m)
Number of sonics / height of met. Mast.	0	33 m
Hours of measurements / frequencies	405	10 Hz

Project motivation

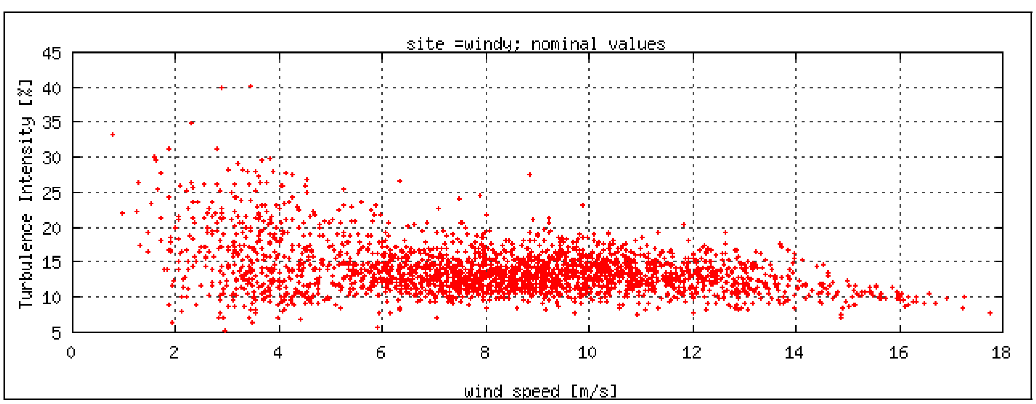
The CEC has declared that a central objective of its R&D actions in the field of wind energy is to reduce the cost of wind generated electricity to 0.04 ECU/kWh or less. It is probable that this target will be first reached on sites which offer high energy density but which also bring considerable risks due to high extreme wind speeds, severe turbulence due to highly complex terrain, and conditions of icing. It is essential that these risks are properly studied and understood in order that the full potential of such hostile sites might be safely realised. Thorough investigations have been undertaken of the meteorology, the behaviour and loading of the wind turbines at Windy Standard in the U.K. also at Acqua Spruzza in Italy. The objectives of the project have been as follows: 1) to understand, and hence reduce, the risks associated with the use of wind farm sites in hostile conditions; 2) to provide a critical appraisal of present design procedures used for hostile environments; 3) to refine the design classification of wind turbines for such sites; and 4) to disseminate the results of the project to wind turbine manufacturers, wind farm developers, Classification Societies and Standards bodies.

Measurement system

Meteorological instruments were monitored at three heights: 7.5 m, 16.5 m and 33.5 m. Cup anemometers at 7.5 m, 16.5 m and 33.5 m were heated. There was also a sonic anemometer at 7.5 m. No icing of instruments was experienced during the period of data supplied to the Danish Technical University. The meteorological mast was upwind of the turbine at which loads and other operational parameters were measured. The meteorological mast consists of a single conical steel tower which therefore causes considerable wake effects downwind.

Acknowledgements

Mark Johnston, Garrad Hassan & Partners Ltd., United Kingdom.



Nominal turbulence vs. wind speed.

Site = Zeebrugge , Belgium

Site code **Zeeb**

Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	1	23
Number of channels with wind speed / wind direction	2	1
Number of sonics / height of met. Mast.	0	64 m
Hours of measurements / frequencies	103	2 Hz

Project motivation

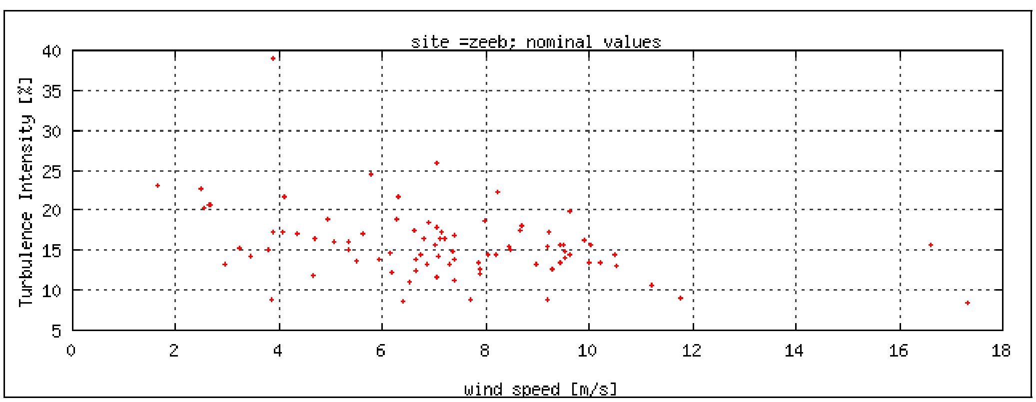
On the sea-port of Zeebrugge in Belgium, 22 turbines are installed. 20 turbines of 200 kW (1986), 1x 175 kW, 1x 400 kW (1997) and 1x 600 kW (1998) turbine. The University of Brussels does measurements on the 600 kW turbine to examine the dynamic behaviour of the blades, nacelle, and mast.

Measurement system

The University of Brussels installed a 64 m wind-measuring mast. On top and on the intermediate height of 40 m, wind-speed is measured. Data is transferred to a central computer. The wind speeds on 40 m and 64 m together with the wind direction are interpreted with LabView. Data recording frequency is 2 Hz and the duration is 3600 sec.

Acknowledgements

Luc DeWilde, University of Brussels, dept. Fluid Dynamics, Belgium.



Nominal turbulence vs. wind speed.

4.2 Wind turbine structural response time series

Site = Noerrekaer Enge, Jutland, Denmark.

Site code **Norre**

Dominating terrain/ orography	coastal	flat
Number of masts / wind turbines	2	42(2)
Number of channels with wind speed / wind direction	15 (h=3,10,16,23,31,44 og 58 m)	3 (h=10,31 & 34 m)
Number of instruments in WTGS	14	31 m
Hours of measurements / frequencies	702	20 Hz

Project motivation

The Norrekaer Enge wind farm measurement campaign is part of the Risø programme for obtaining more knowledge on turbulence in wind farms and on loads on wind turbines placed in farms and arrays in different types of terrain. The main goal of this programme is to obtain information on loads on wind turbines situated in arrays, in order to enable the turbine designers to create more optimal designs.

The Norrekaer Enge measurements have been supported by the CEC under the JOULE programme, and by the Danish Ministry of Energy under the EFP programme. The good cooperation of Nordtank and Nordkraft has been very helpful in the performance of these measurements.

The Norrekaer Enge II wind farm, containing 42 x 300 kW Nordtank turbines, is located in the North Jutland, on the south bank of the Limfjord, about 36 km west of Alborg and 8 km north east of Loegstoer. The terrain is old sea bed and extremely flat, about 1 m above sea. The local terrain is, however, surrounded by small villages and significant terrain, with features up to 40 m in height, immediately to the south of the site. West of the site are farm buildings, rows of trees and an other wind farm - the Noerrekaer Enge I wind farm, with 36 x 150 kW Nordtank turbines. Immediately north of the site there is water - the Limfjord.

Measurement system

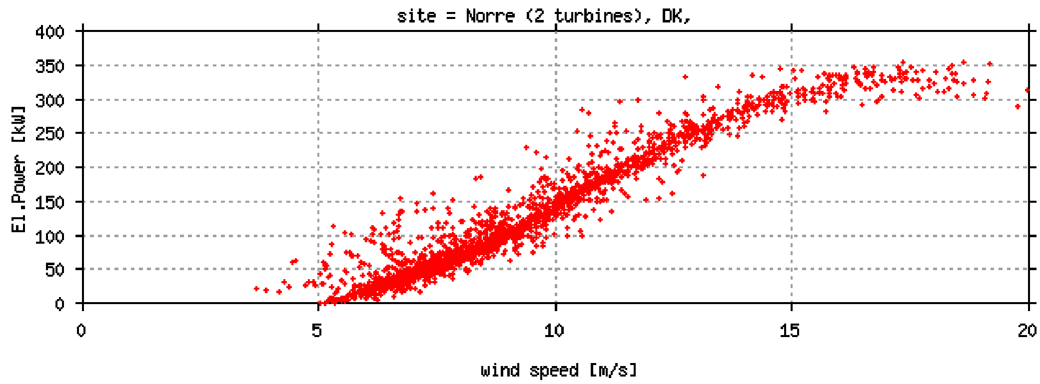
Two turbines (A1 and F6) have been instrumented for obtaining structural measurements e.g. root bending moment, power, rotor-speed and yaw misalignment.

Mast 1 at A1 is placed on the row of turbines A1 - A7, 55 m south of turbine Al.

The Mast 2 at F6 is placed on the line between F6 and ES (orientation 35.83°), 55 m from F6 and the booms on both masts are perpendicular to the line F6 - E5.

Acknowledgements

Jørgen Højstrup and Peter Sanderhoff, Risø National Laboratories, Denmark.



Nominal power vs. wind speed.

Site = Sky River wind farm, Tehachapi, USA.

Site code **Skyv39**

Dominating terrain/ orography	Scrub	Hill
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	2	2
Number of instruments in WTGS	22	41 m
Hours of measurements / frequencies	105	32 Hz

Project motivation

Verification of the structural integrity of a wind turbine involves analysis of fatigue loading as well as ultimate loading. With the trend of persistently growing turbines, the ultimate loading seems to become relatively more important. For wind turbines designed according to the wind conditions prescribed in the IEC-61400 code, the ultimate load is often identified as the leading load parameter.

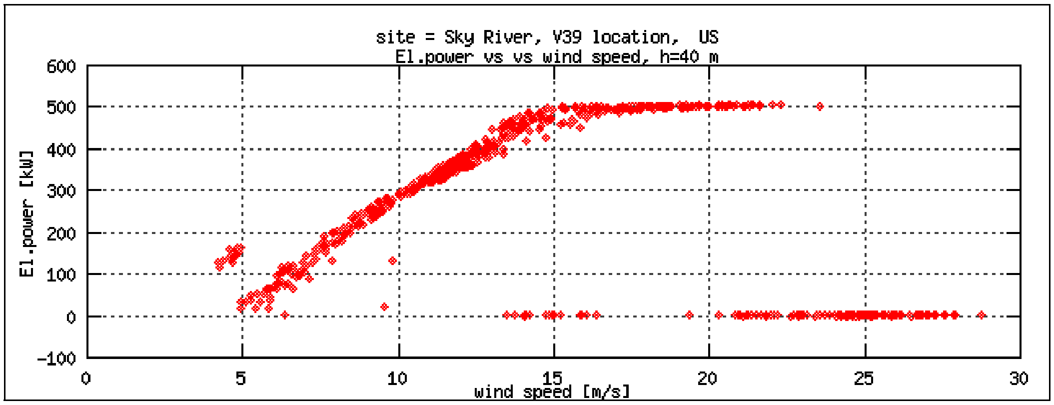
The objective of the Oak Creek project is to conduct a combined experimental and theoretical investigation of blade-, rotor- and tower loads caused by extreme wind load conditions occurring during normal operation as well as in stand still situations (where mean wind speeds exceeds the cut-out wind speed), with the purpose of establishing an improved description of the ultimate loading of three bladed pitch- and stall controlled wind turbines.

Measurement system

The main objective of the turbine specific measurements is to determine the dynamic loading of the wind turbine under different operating conditions in the wind farm in mountainous terrain.

Acknowledgements

Søren Markkilde Petersen, Risø National Laboratories, Denmark.



Nominal power vs. wind speed.

Site = Tjaereborg, Esbjerg, Denmark.

Site code **Tjare**

Dominating terrain/ orography	coastal	flat
Number of masts / wind turbines	2	1
Number of channels with wind speed / wind direction	2	2
Number of instruments in WTGS	22	41 m
Hours of measurements / frequencies	105	32 Hz

Project motivation

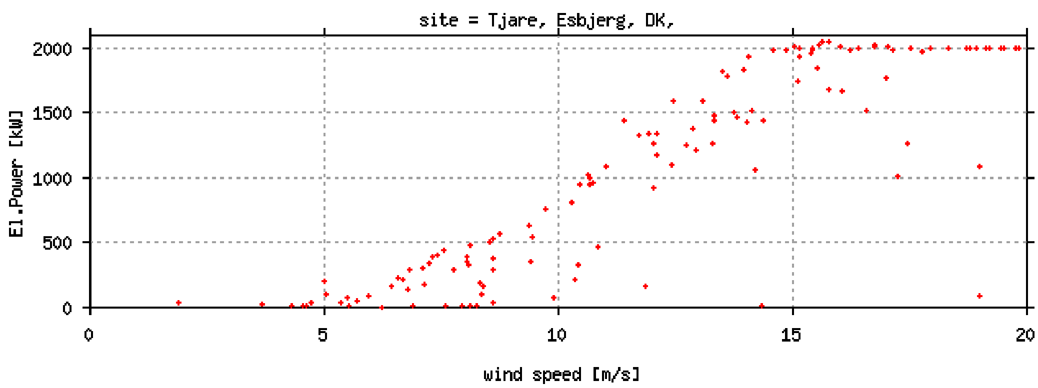
The primary goal was to design and build a 2MW wind turbine at Tjareborg, Esbjerg. This project was accomplished with an intensive measuring programme where both mechanical loads and the wind climate on the site was measured - and analysed.

Measurement system

The measurement system consists of 2 meteorological mast, mast no.1 was placed in front and mast no.2 behind the wind turbine - referring to the dominant wind sector. The measurements system was based on two HP-data loggers and the data was transferred to a central computer (HP operating HP-Basic with home developed data handling routines and programs). The system operation was primarily focusing on recording structural loads included a number of meteorological channels. A data recording frequency of 25 Hz has been used.

Acknowledgements

Peter Christiansen and Peggy Friis, ELSAM Kraft, Denmark.



Nominal power vs. wind speed.

4.3 Wind resource data

Site = Answorth, Nebraska, NE, USA

Site code **Ainswort**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1	1
Number of years / mast height	1993-1994	30 m
Hours of measurements / duration	7249	10 min.

Project motivation

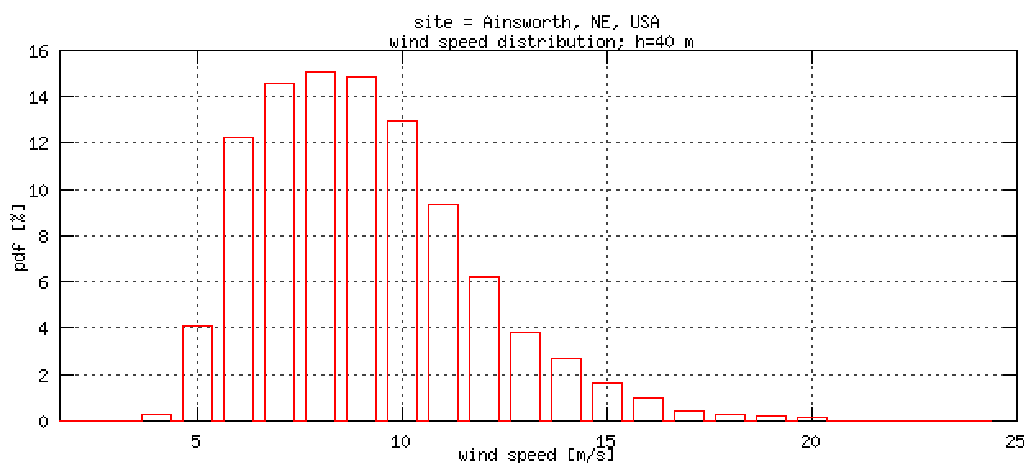
This project was initiated in 1990 to develop measurements and analysis methods that would establish representative and appropriate turbulence characteristics needed for the design and siting of cost-effective wind turbines. NREL and Batelle had additional objectives that included correlating the nature of the turbulence in the inflow to upwind features, and transferring the technology developed in the project to industry for operational applications.

Measurement system

A single cup-vane anemometer was mounted near the propeller-vane anemometer at the top of T2 within a few feet of the propeller-vane anemometer at the same location. This was the Maximum cup and NRG vane that are commonly used in the wind industry to estimate the resource at the site.

Acknowledgements

Sandy Butterfield and Maureen Hand, NREL, USA.



Distribution of wind speeds

Site = Alsvik, Gotland, Sweden

Site code **Alsvik**

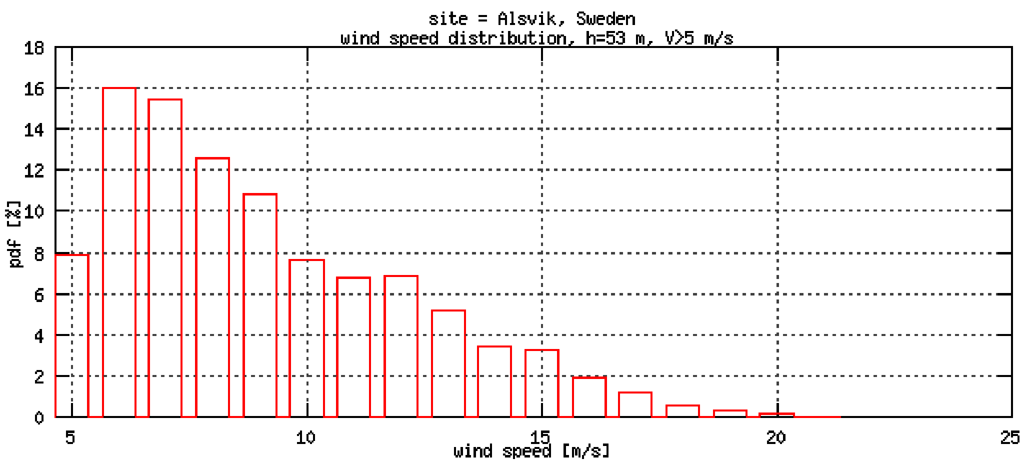
Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	2	4
Number of channels with wind speed / wind direction	6	2
Number of years / mast height	1991-1994	53 & 53 m
Hours of measurements / duration	17500	10 min.

Project motivation
Meteorological measurements from flat, coastal site on Gotland equipped with four wind turbines.

Measurement system
1 Hz data at eight levels on two 54 m towers during four years. 20 Hz data at three levels on one 54 m tower during one year.

Comment
These resource data is based on time series, which is stored as 10 minute averages including minimum, maximum, standard deviation and turbulence intensity.

Acknowledgements
Mikael Magnusson & Hans Bergström, Uppsala University, Sweden.



Distribution of wind speeds, measured at Alsvik, Sweden, 1993.

Site = Borglum, Denmark

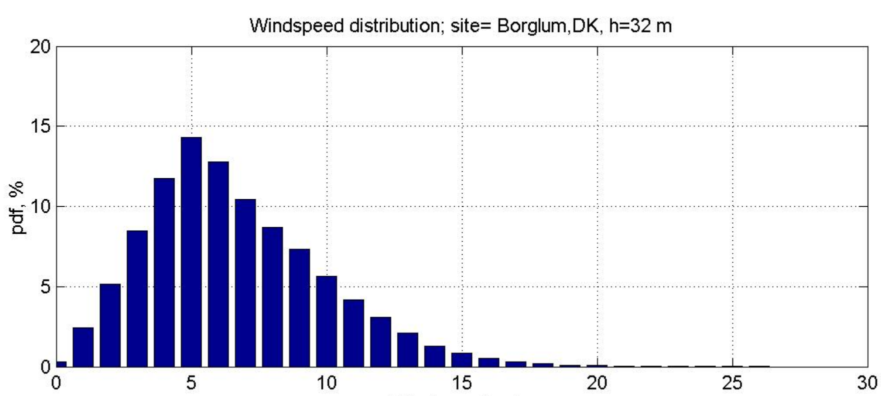
Site code **Borglum**

Dominating terrain/ orography	Pastoral	flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	3 (=h=10,20 & 32 m)	2 (h=10 & 32 m)
Number of years / mast height	1997-2001	32 m
Hours of measurements / duration	35552	10 min.

Project motivation
The meteorologists of Risø have since the start of Risø in 1956 collected climatological data from measuring masts both within Denmark and outside the country. The data have mostly been collected to obtain relevant climate statistics for the locality in question. Examples can be: Establishment of a climatology of atmospheric dispersion for a planned site for a power plant or an other production facility. Estimation of the local wind-speed distribution for evaluation of wind power resource or of the extreme wind load on structures and buildings. Description of seasonal and long-term exchange between the atmosphere and different types of vegetation. The data have also proven useful to in connection with events of various kinds, such as tracking storm surges across the country, estimating contaminated regions for transient events as different as nuclear and industrial accidents and air borne diseases.

Measurement system
Data from the Risø sites consist typically of atmospheric pressure and wind direction, wind speed in several heights, and temperature in at least two heights, such that climatology for wind speed and direction, wind variation with height and thermal stability can be established. At some stations also measurements of humidity, incoming solar radiation, and wind variability are obtained. Typically the measurements consist of ten minutes averages recorded every ten minutes.

Acknowledgements
Gunner Jensen, Risø National Lab., Roskilde, Denmark.



Distribution of wind speed.

Site =Burger Hill, Orkney Island, Scotland, UK

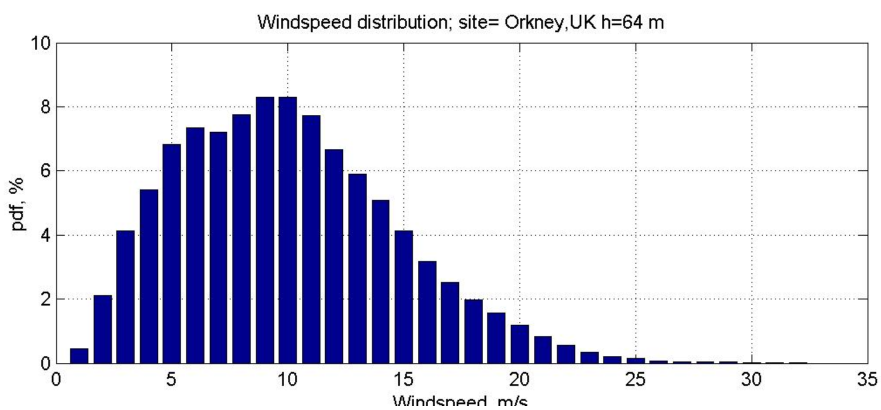
Site code **Orkney**

Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	2 (h= 60 & 64 m)	1 (h=61 m)
Number of years / mast height	2000-2001	64 m
Hours of measurements / duration	9707	10 min.

Project motivation
Test site for NEG-Micon Wind turbines.

Measurement system
One meteorological mast equipped with wind speed sensors at h=60 & 64 m, vane, temperature, atmospheric pressure sensors and rain detection.

Acknowledgements
Lene Hellstern, Vestas (former NEG-Micon), Denmark.



Distribution of wind speeds

Site = Cabauw, The Netherlands

Site code **Cabauw**

Dominating terrain/ orography	Pastoral	Flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1 (h=10m)	1 (h=10m)
Number of years / mast height	1986-2000	213m
Hours of measurements / duration	124000	1 hour

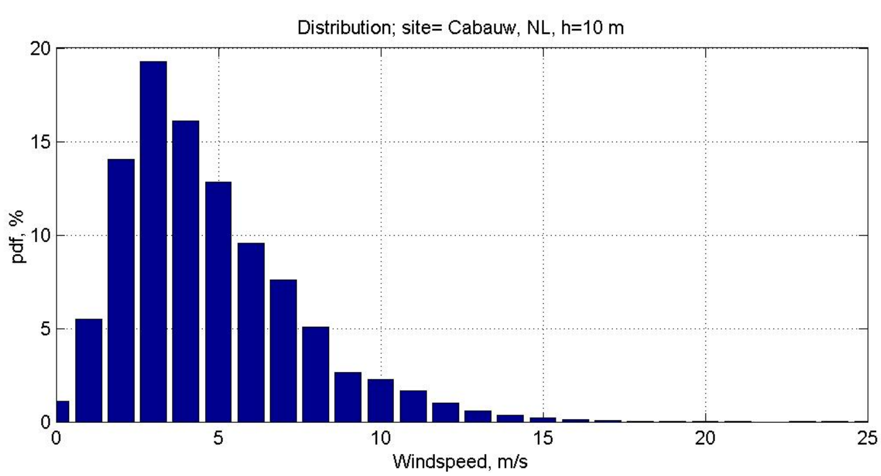
Project motivation
In the frame work of the project ”a manual of design wind data for wind turbines ”, measurements from the Royal Netherlands Meteorological Institute (KNMI) were used extensively.

The KNMI allows the use of these data under the conditions: users of the data refer to the source of the data e.g. with the sentence: The Cabauw wind data were made available by the Royal Netherlands Meteorological Institute (KNMI).

The KNMI appreciates to be informed how the data were treated. and likes to get relevant reports.
In general commercial use of the data is not allowed. Information about the terms for commercial use can be obtained at the KNMI, attention to W.A.A. Monna, Section atmospheric research, P.O. Box 201, 3730 AE De Bilt, NL.
Resource data covering the period from 1/7 1986 to 31/12 1999 has been included.

Measurement system
The Cabauw meteorological mast is a tubular tower with a height of 213 m and a diameter of 2 m. Guy wires are attached at four levels. Artificial wind speed and wind direction mean values (1 hour) with reference to 10 m agl. and based on propeller readings has been included as resource data.

Acknowledgements
Terry Hegberg, ECN and KNMI, The Netherlands.



Distribution of wind speeds, measured at Cabauw, NL 1996.

Site = Calwind, Tehachapi, CA, USA

Site code **Calwind**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1	1
Number of years / mast height	1990-1993	30 m
Hours of measurements / duration	17303	10 min.

Project motivation

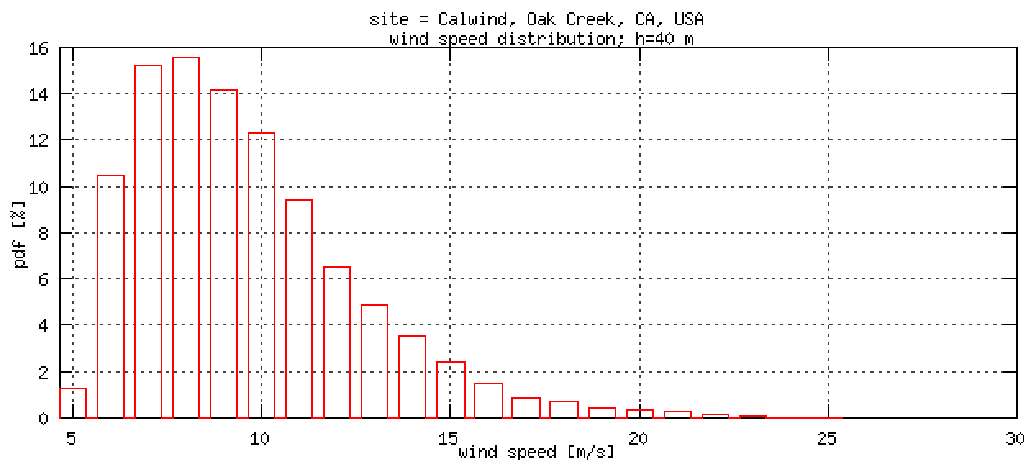
This project was initiated in 1990 to develop measurements and analysis methods that would establish representative and appropriate turbulence characteristics needed for the design and siting of cost-effective wind turbines. NREL and Batelle had additional objectives that included correlating the nature of the turbulence in the inflow to upwind features, and transferring the technology developed in the project to industry for operational applications.

Measurement system

A single cup-vane anemometer was mounted near the propeller-vane anemometer at the top of T2 within a few feet of the propeller-vane anemometer at the same location. This was the Maximum cup and NRG vane that are commonly used in the wind industry to estimate the resource at the site.

Acknowledgements

Sandy Butterfield and Maureen Hand, NREL, USA.



Distribution of wind speeds

Site =Capel Cynon, Dyfed in Wales, UK

Site code **Capel**

Dominating terrain/ orography	pastoral	flat
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	23 (h=10,15,20,25,32 & 40 m)	3 (h=10,25 & 40m)
Number of years / mast height	1989 - 1995	40 & 40 m
Hours of measurements / duration	55523	10 min.

Project motivation

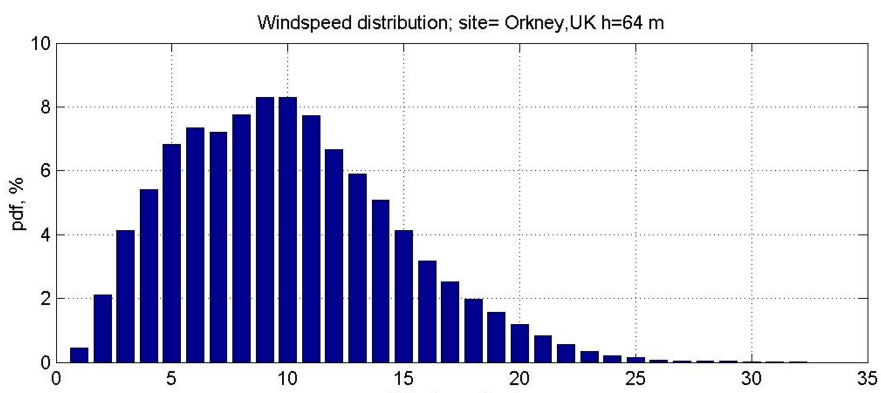
In 1989 three meteorological masts, one 50 m high and two 40m high, along with supporting data logger equipment were installed at a site near Capel Cynon, Dyfed in Wales.

Measurement system

The main loggers were Campell Scientific CR10 loggers. These collected 10 min averages on 5 seconds readings from wind speed sensors and directions sensors. They also collected ten-minute averages of two seconds readings to calculate turbulence intensity at 10m, 25m and 40m heights. The spectral loggers were IBM compatible PCs. These performed two operations: Taking sets of data at 4Hz for the 10m, 25m and 40m anemometers when the wind speed was above 10 m/s. Approximately six set of data were taken for each of the twelve directions sectors.

Acknowledgements

Mike Payne, Future Energy Solutions, AEA Technology, UK.



Distribution of wind speeds

Site =Delabole, North Cornwall, UK

Site code **Delabole**

Dominating terrain/ orography	pastoral	flat
Number of masts / wind turbines	2	0
Number of channels with wind speed / wind direction	23 (h=10,15,20,25,32 & 40 m)	3 (h=10,25 & 40m)
Number of years / mast height	1989 - 1995	40 & 40 m
Hours of measurements / duration	55523	10 min.

Project motivation

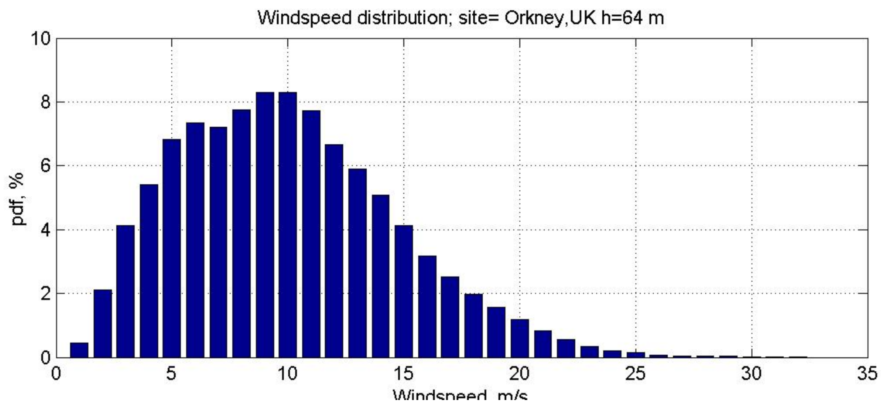
In August 1991 North Cornwall District Council granted planning permission for the UK's first wind farm at Deli Farm near Delabole in North Cornwall. The wind farm was commissioned in December 1991 and was the subject of much local and national interest. ETSU, acting for the Department of Trade and Industry (DTI), commissioned a series of studies into the impact, performance and public acceptability of the farm. The Delabole Wind Farm is situated about 2 km to the North West of Camelford in North Cornwall and is operated by Wind Electric Ltd. The site is very open with an approximate elevation of 240 m above sea level, gently sloping away towards the South-West. It is bounded to the North-East)by a minor road (B3314) and the South and East by the course of an abandoned railway. Other than the Cornish hedges (5 - 6 ft) around fields, the ground cover is low (1 - 2 ft) agricultural crops, mostly grass with some fields put to linseed. At certain periods of the year this area is ploughed or contains stubble. There are ten wind turbines installed at the Delabole Wind Farm. They are all Windane 34's manufactured by Vestas / Danish Wind Technology A/S, rated at 400 kW and were commissioned in December 1991.

Measurement system

Two meteorological masts were erected on the farm. Mast 1, located ENE from Turbine 9, was the most comprehensively equipped, with Vector Instruments A100 cup anemometers at 10 m, 20 m, 33 m and 44 m heights, a W250P wind vane also from Vector Instruments at a height of 44 m, a Unidata 6522A barometric pressure gauge, a Campbell Scientific ARG100 tipping bucket rain gauge and two Skye Instruments temperature probes mounted at 5 m and 44 m. Mast 2 was equipped with two anemometers one at 10 m, the other at 33 m. This mast was also fitted with a wind vane at a height of 33 m. The data acquisition system hardware consisted of a Dell 486 PC with 130 Mb hard disc, tape streamer and colour VGA screen running the OS/2 operating system. This PC was situated in the wind farm site office with a second similar PC connected via a network and situated in the Deli Farm office. The turbines were connected to the data acquisition computer via a Quest data concentrator supplied by Vestas. Additional sensors connected to remote data loggers passed data via radio transmitters. A receiver was installed at the wind farm office and connected to the data acquisition computer. The data from the two meteorological masts, the substation electrical data and two sites of noise monitoring equipment (required by a concurrent ETSU monitoring contract W/32/00289/00/00) were acquired by these systems.

Acknowledgements

Mike Payne, Future Energy Solutions, AEA Technology, UK.



Distribution of wind speeds

Site = San Gorgonio Pass, CA, USA

Site code **Gorgonio**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1	1
Number of years / mast height	1991-1992	30 m
Hours of measurements / duration	6580	10 min.

Project motivation
This project was initiated in 1990 to develop measurements and analysis methods that would establish representative and appropriate turbulence characteristics needed for the design and siting of cost-effective wind turbines. NREL and Batelle had additional objectives that included correlating the nature of the turbulence in the inflow to upwind features, and transferring the technology developed in the project to industry for operational applications.

Measurement system
A single cup-vane anemometer was mounted near the propeller-vane anemometer at the top of T2 within a few feet of the propeller-vane anemometer at the same location. This was the Maximum cup and NRG vane that are commonly used in the wind industry to estimate the resource at the site.

Acknowledgements
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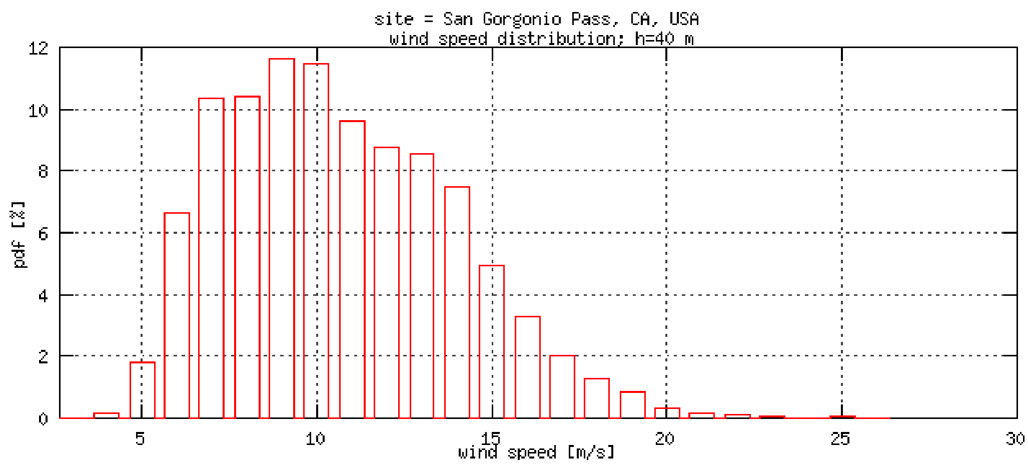


Distribution of wind speeds

Site =Godhavn, Disko Island, Greenland

Site code **Godhavn**

Dominating terrain/ orography	coastal	hill
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1 (h=10 m)	1 (h=10 m)
Number of years / mast height	1994-2002	10 m
Hours of measurements / duration	73510	30 min.

Project motivation

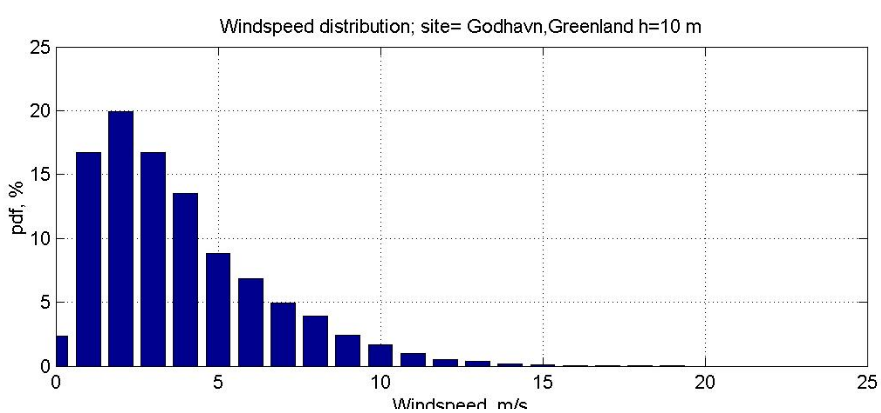
In October 1990 a new automatic meteorological station was established at the Arctic Station, Qeqertarsuaq (Godhavn), managed by the University of Copenhagen. The Arctic Station is situated at the south coast of Disko Island about one km east of the town Qeqertarsuaq (69° 15' N.lat., 53°34'W.lon.). The town stands on a small rocky promontory and due to the western position of Disko Island the area is exposed to an arctic maritime climate. From Qeqertarsuaq the bay, Disko Bugt, stretches towards south to Aasiaat (60 km) toward southeast to Qasigiannguit (105 km) and toward east to Ilulissat (90 km). Winds from west pass the Davis Strait and cross an open sea surface for about 600 km. The largest fetch is found in a SSW direction with an extension of more than 2000 km. The meteorological station is installed at one of the Arctic Station's buildings, situated about 300 m from the coast, 20 m a.s.l. Generally the terrain rises to an altitude of 200 m about 1.5 km N of the coast. Further N altitudes increase rapidly to the edge of a mountain plateau at 600 800 m above sea level. The orientation of this steep slope extends for several kilometres both E and W, only interrupted by valley mouths.

Measurement system

The meteorological data are monitored by AANDERAA scanning unit and a storage unit. The following parameters are logged - wind speed (30 minute average) - maximum gust speed (2 seconds) - wind direction (30 minute average) - air temperature (30 minute average) - relative humidity (30 minute average) All mounted 9.5 m above terrain - pluviograph - pyranometer (incoming solar radiation) - pyranometer (reflected solar radiation) all mounted on a mast, 2 m above terrain plus temperatures (5, 60, 175 & 300cm below ground surface).

Acknowledgements

Dr. Niels Nielsen, Institute of Geography, University of Copenhagen, Denmark.



Distribution of wind speeds

Site = Equinox Mountain, Vermont, USA

Site code **Equinox**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1	1
Number of years / mast height	1991	30 m
Hours of measurements / duration	3223	10 min.

Project motivation

This project was initiated in 1990 to develop measurements and analysis methods that would establish representative and appropriate turbulence characteristics needed for the design and siting of cost-effective wind turbines. NREL and Batelle had additional objectives that included correlating the nature of the turbulence in the inflow to upwind features, and transferring the technology developed in the project to industry for operational applications.

Measurement system

A single cup-vane anemometer was mounted near the propeller-vane anemometer at the top of T2 within a few feet of the propeller-vane anemometer at the same location. This was the Maximum cup and NRG vane that are commonly used in the wind industry to estimate the resource at the site.

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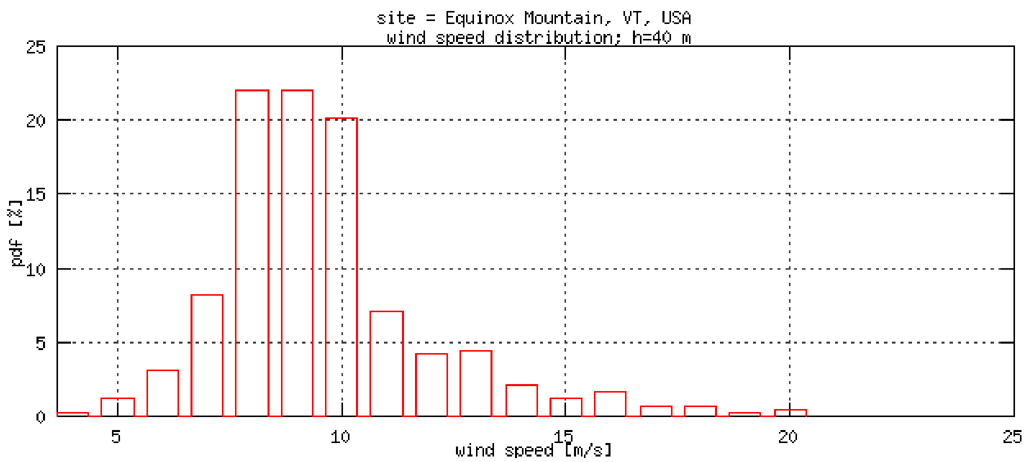

Distribution of wind speeds

Site = Hanford, WA, USA

Site code **Hanford**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1	1
Number of years / mast height	1990-1992	30 m
Hours of measurements / duration	8625	10 min.

Project motivation
This project was initiated in 1990 to develop measurements and analysis methods that would establish representative and appropriate turbulence characteristics needed for the design and siting of cost-effective wind turbines. NREL and Batelle had additional objectives that included correlating the nature of the turbulence in the inflow to upwind features, and transferring the technology developed in the project to industry for operational applications.

Measurement system
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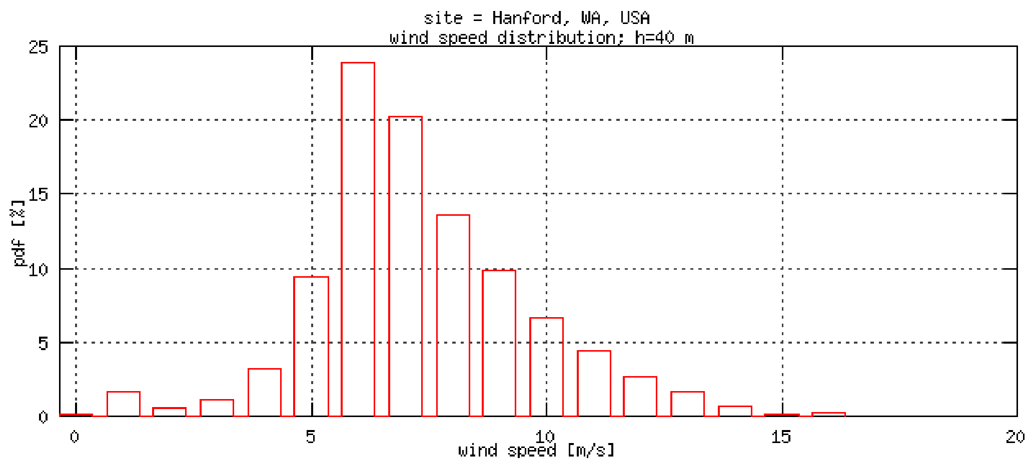

Distribution of wind speeds

Site = Holland, Minnesota, MN, USA

Site code **Holland**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1	1
Number of years / mast height	1994-1995	30 m
Hours of measurements / duration	3797	10 min.

Project motivation
This project was initiated in 1990 to develop measurements and analysis methods that would establish representative and appropriate turbulence characteristics needed for the design and siting of cost-effective wind turbines. NREL and Batelle had additional objectives that included correlating the nature of the turbulence in the inflow to upwind features, and transferring the technology developed in the project to industry for operational applications.

Measurement system
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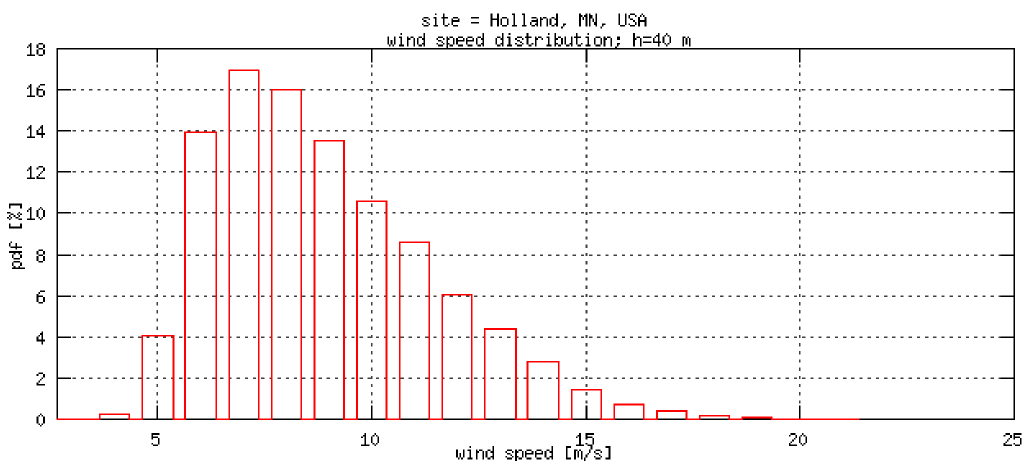

Distribution of wind speeds

Site = Jericho, Texas, TX, USA

Site code **Jericho**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1	1
Number of years / mast height	1994-1995	30 m
Hours of measurements / duration	6567	10 min.

Project motivation
This project was initiated in 1990 to develop measurements and analysis methods that would establish representative and appropriate turbulence characteristics needed for the design and siting of cost-effective wind turbines. NREL and Batelle had additional objectives that included correlating the nature of the turbulence in the inflow to upwind features, and transferring the technology developed in the project to industry for operational applications.

Measurement system
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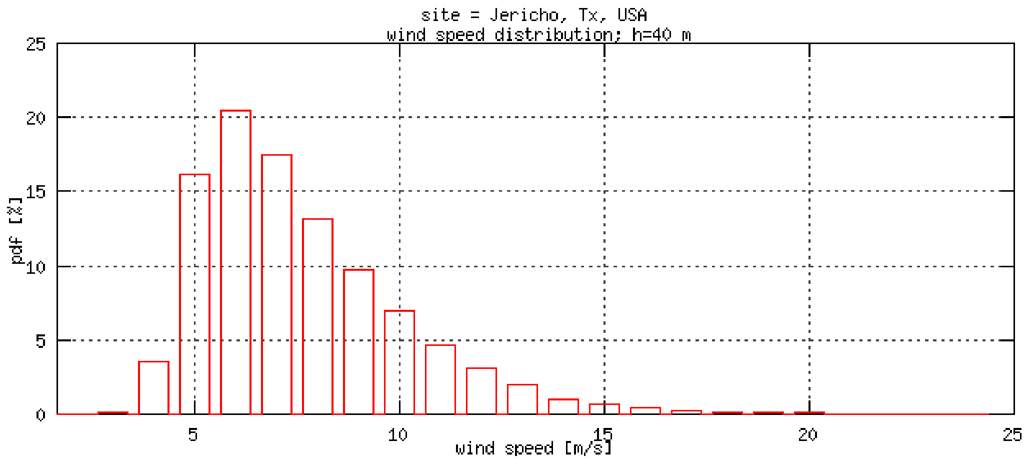


Distribution of wind speeds

Site = Kegnaes, Als, Denmark

Site code **Kegnes**

Dominating terrain/ orography	coastal	flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	3 (h=3, 11 & 23 m)	2 (h=10 & 23 m)
Number of years / mast height	1991-2001	23 m
Hours of measurements / duration	96432	10 min.

Project motivation

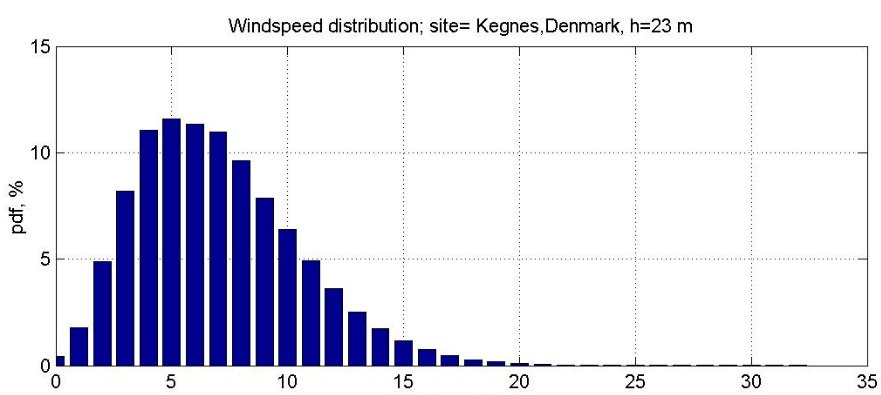
The meteorologist of Risø have since the start of Risø in 1956 collected climatological data from measuring masts both within Denmark and outside the country. The data have mostly been collected to obtain relevant climate statistics for the locality in question. Examples can be: Establishment of a climatology of atmospheric dispersion for a planned site for a power plant or an other production facility. Estimation of the local wind speed distribution for evaluation of wind power resource or of the extreme wind load on structures and buildings. Description of seasonal and long term exchange between the atmosphere and different types of vegetation. The data have also proven useful to in connection with events of various kinds, such as tracking storm surges across the country, estimating contaminated regions for transient events as different as nuclear and industrial accidents and air borne diseases.

Measurement system

Data from the Risø sites consist typically of atmospheric pressure and wind direction, wind speed in several heights, and temperature in at least two heights, such that climatology for wind speed and direction, wind variation with height and thermal stability can be established. At some stations also measurements of humidity, incoming solar radiation, and wind variability are obtained. Typically the measurements consist of ten minutes averages recorded every ten minutes.

Acknowledgements

Gunner Jensen, Risø National Labs., Roskilde, Denmark.



Distribution of wind speeds

Site =La Ventosa, Oaxaca, Mexico

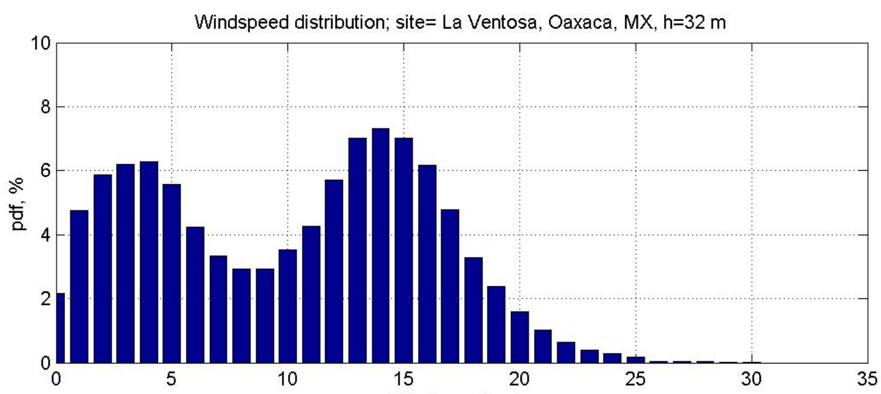
Site code **Ventosa**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	2 (h=15 & 32 m)	1 (h=32 m)
Number of years / mast height	2000-2001	32 m
Hours of measurements / duration	12432	10 min.

Project motivation
Wind resource measurements in Mexico.

Measurement system
Campell Scientific Inc. model CR10X (USA).
Cup anemometer Maximum #40.
Wind direction transducer: vane NRG 200P.

Acknowledgements
Marco Borja, Instituto de Investigaciones Eléctricas,División de Energías Alternas,
Avenida Reforma 113,Col. Palmira, Temixco, Morelos C.P., Mexico.



Distribution of wind speeds

Site = Lysekil, Götaland, Sweden

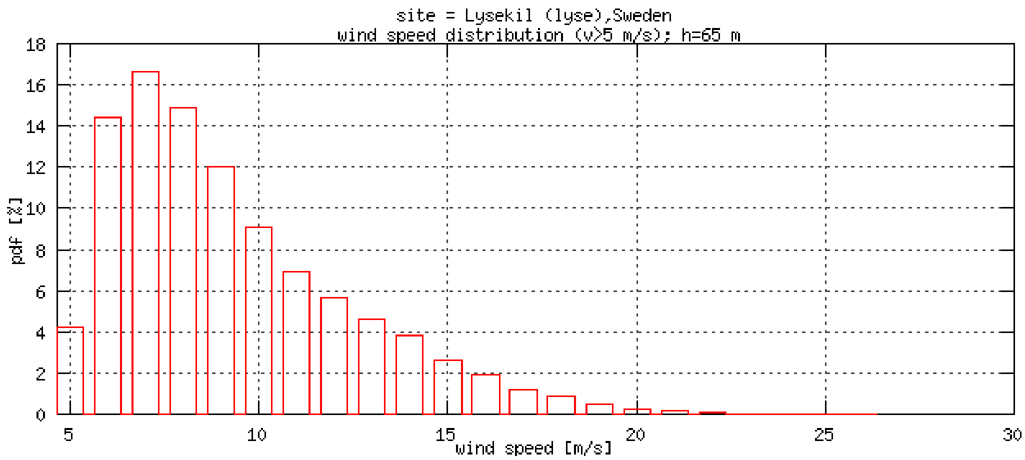
Site code **Lyse**

Dominating terrain/ orography	coastal	mountain
Number of masts / wind turbines	1	2
Number of channels with wind speed / wind direction	3 (h=10, 40 & 65 m)	1 (h=32 m)
Number of years / mast height	1993-1997	65 m
Hours of measurements / duration	31479	10 min.

Project motivation
At Lyse Wind Power Station the NWP 400 wind turbine was erected in 1992. The wind turbine is a two-bladed, upwind machine with a hub height of 40 m, and a rotor diameter of 35 m.

Measurement system
Lyse wind power station is situated at an artificial island created around two islets. On each of the rocky islets wind turbines are erected. The above mentioned NWP400 to the north and a Bonus 400 kW MkII to the south. Between the two turbines a 66 m high meteorological tower is situated, which is equipped with wind speed and direction sensors of the MIUU type (Lundin et al., 1990) at 7 levels. At the uppermost 5 levels two anemometers are placed at each level. Temperature profile is also recorded. All measurements are sampled with 1 Hz and stored on 1 GB streamer tape.

Acknowledgements
Hans Bergström, Dept. of Meteorology, Uppsala University.



Distribution of wind speeds

Site = Mojave, Horned Toad Hills, CA, USA

Site code **Flowind**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1	1
Number of years / mast height	1990-1993	30 m
Hours of measurements / duration	15204	10 min.

Project motivation

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Measurement system

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Acknowledgements

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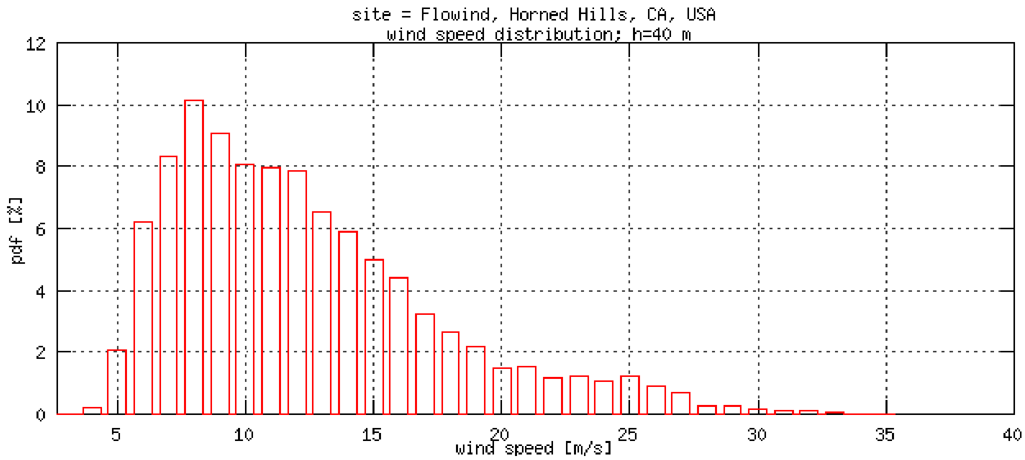

Distribution of wind speeds

Site = Monolith, CA, USA

Site code **Windland**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1	1
Number of years / mast height	1990-1993	30 m
Hours of measurements / duration	17090	10 min.

Project motivation
This project was initiated in 1990 to develop measurements and analysis methods that would establish representative and appropriate turbulence characteristics needed for the design and siting of cost-effective wind turbines. NREL and Batelle had additional objectives that included correlating the nature of the turbulence in the inflow to upwind features, and transferring the technology developed in the project to industry for operational applications.

Measurement system
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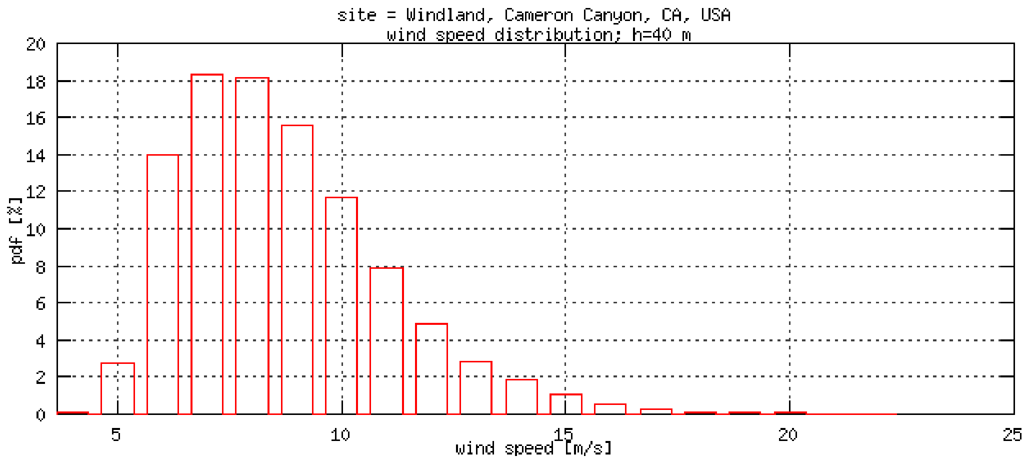


Distribution of wind speeds

Site =NTUA Campus, Athens, Greece

Site code **ntua**

Dominating terrain/ orography	Urban	hill
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1 (h=5 m)	1 (h=5 m)
Number of years / mast height	1993-1999	5 m
Hours of measurements / duration	17060	60 min.

Project motivation

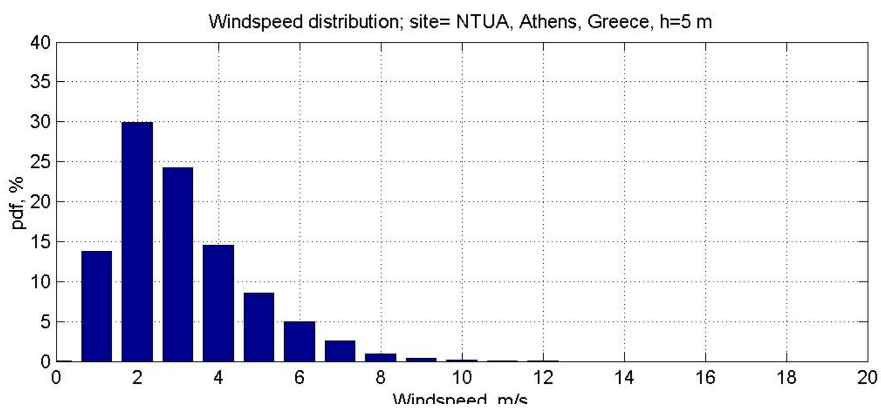
The automatic meteorological station is operated by the Department of Water Resources, NTUA, Greece. The NTUA Online Weather Data is a project of assist. prof. Demetris Koutsoyiannis. Dr. Nikos Mamassis is responsible for the supervision and maintenance of the station. Antonios Christofides is responsible for the software and the web site.

Measurement system

An Aanderaa logger and sensor scanning unit are used for the old digital sensors, with a local data storage unit. The sensors are scanned every ten minutes, after a signal produced by a timer built in the scanning unit. The measurements are sent to the radio transmitter and to the data storage unit. The data are received by a PC at the Laboratory, 1 km away, via the radio receiver.
A Delta-T logger for the new analog sensors (2000), with built-in memory for data storage, and built-in clock. The sensors are read every five minutes (sampling period) and their measurements are stored every ten minutes. The communication with the Linux PC at the Laboratory is achieved via a serial interface, modems and cable.

Acknowledgements

Nikos Mamasis, Department of Water Resources, NTUA, Athens, Greece.



Distribution of wind speeds

Site = Näsudden, Gotland, Sweden

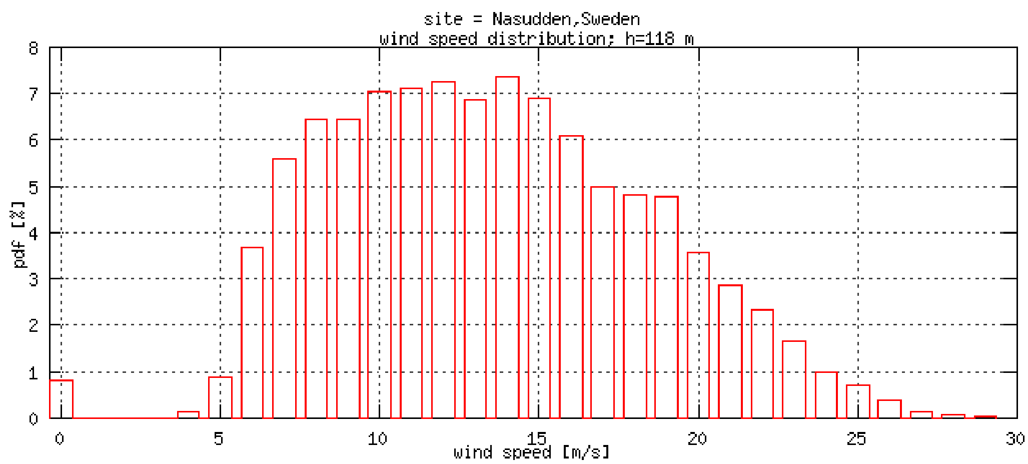
Site code **Nasudden**

Dominating terrain/ orography	coastal	flat
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	7 (h=10,38,54,75, 96,120 & 145 m)	3 (h=38, 75, 145 m)
Number of years / mast height	1992-1995	145 m
Hours of measurements / duration	27904	10 min.

Project motivation
Meteologocal mesurements from Nasudden site at Gotland, Sweden.

Measurement system
10 minute average data at 7 levels on a 145 m tower.

Acknowledgements
Ingemar Carlén, Teknikgruppen AB and Hans Bergström, Uppsala University, Sweden.



Distribution of wind speeds

Site = Skipheya, Frøya, Norway

Site code **Ski**

Dominating terrain/ orography	Coastal	Flat
Number of masts / wind turbines	3	1
Number of channels with wind speed / wind direction	9	1
Number of years / mast height	1995	100
Hours of measurements / duration	6580	10 min.

Project motivation

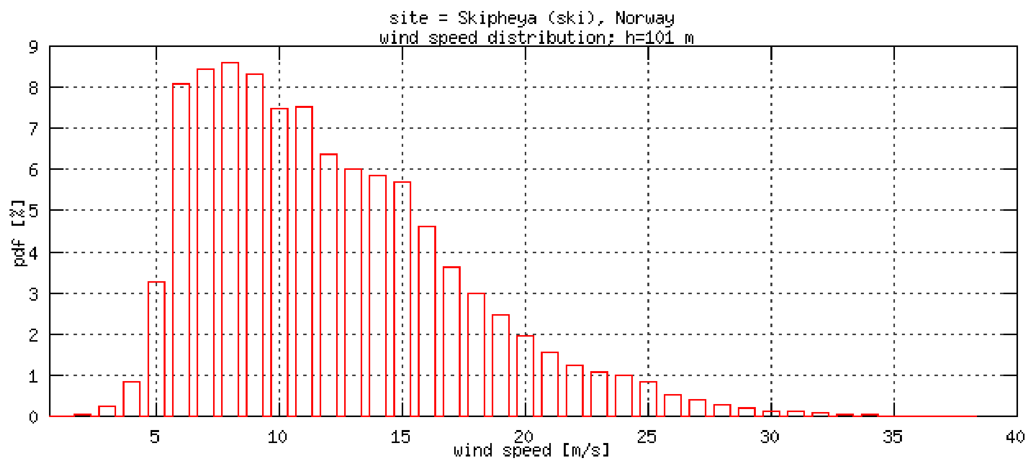
The station was build as a part of the Norwegian Wind Energy Programme in 1980. The purpose was to study the wind structure in details. Particularly, a database for high wind speed condition was desired. Data were originally intended for wind energy production; the dimension of the masts corresponds to a large WECS. The station should also serve as a reference station for other measurement stations in the region. Together with a fourth mast 4 km further west (Sletringen) the station has provided data for calculation of dynamic wind loads on off-shore constructions.

Measurement system

The measurement system consists of 3 meteorological masts (100, 100 and 45 m) placed in a triangle 80-180 metres apart. Ten-minute average of wind speed and direction have been recorded since 1982. From 1988, the logging frequency has been 0.85 Hz.

Acknowledgements

Jørgen Løvseth, NTNU, Norway.



Distribution of wind speeds, measured at Skipheya, Norway, h=101m, 1995.

Site = Risø Mast, Risø Campus, Roskilde, Denmark

Site code **Risoe_m**

Dominating terrain/ orography	Pastoral	Flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	3 (h=44, 77 & 125m)	2 (h=77 & 125 m)
Number of years / mast height	1995-2002	125 m
Hours of measurements / duration	61234	10 min.

Project motivation

The meteorologists of Risø have since the start of Risø in 1956 collected climatological data from measuring masts both within Denmark and outside the country. The data have mostly been collected to obtain relevant climate statistics for the locality in question.

Examples can be: Establishment of a climatology of atmospheric dispersion for a planned site for a power plant or an other production facility. Estimation of the local wind speed distribution for evaluation of wind power resource or of the extreme wind load on structures and buildings.

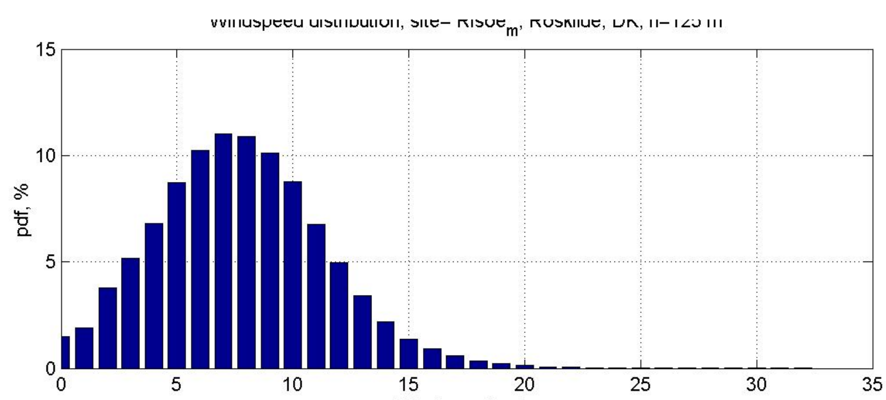
Description of seasonal and long term exchange between the atmosphere and different types of vegetation. The data have also proven useful to in connection with events of various kinds, such as tracking storm surges across the country, estimating contaminated regions for transient events as different as nuclear and industrial accidents and air borne diseases.

Measurement system

Data from the Risø sites consist typically of atmospheric pressure and wind direction, wind speed in several heights, and temperature in at least two heights, such that climatology for wind speed and direction, wind variation with height and thermal stability can be established. At some stations also measurements of humidity, incoming solar radiation, and wind variability are obtained. Typically the measurements consist of ten minutes averages recorded every ten-minutes. Details of the data are reported on the individual pages for each measuring station.

Acknowledgements

Gunner Jensen, Risø National Laboratories, Denmark.



Distribution of wind speeds.

Site = Rosiere, Wisconsin, USA

Site code **Rosiere**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1	1
Number of years / mast height	1994-1995	30 m
Hours of measurements / duration	6497	10 min.

Project motivation

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Measurement system

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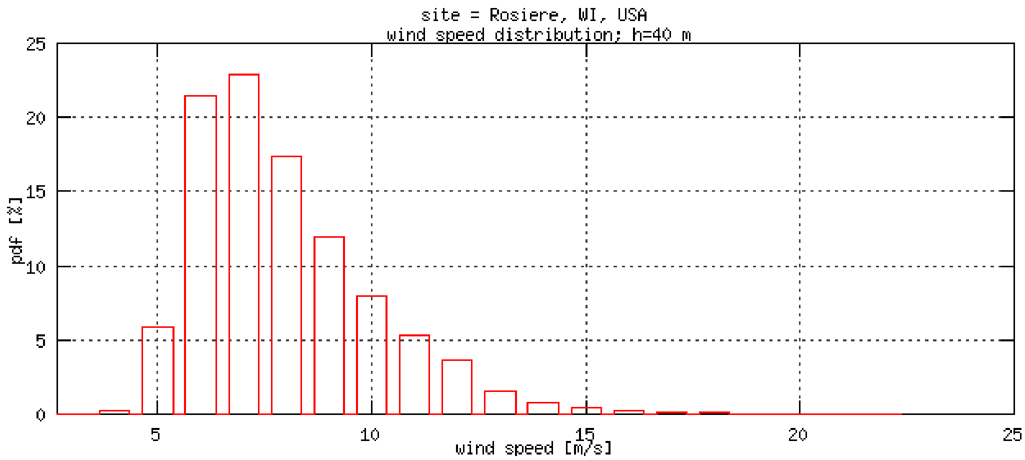


Distribution of wind speeds

Site =Sarfannguit, Sisimiut, Greenland

Site code **Sisimiut**

Dominating terrain/ orography	coastal	hill
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1 (h=10 m)	1 (h=10 m)
Number of years / mast height	2003	10 m
Hours of measurements / duration	3304	10 min.

Project motivation

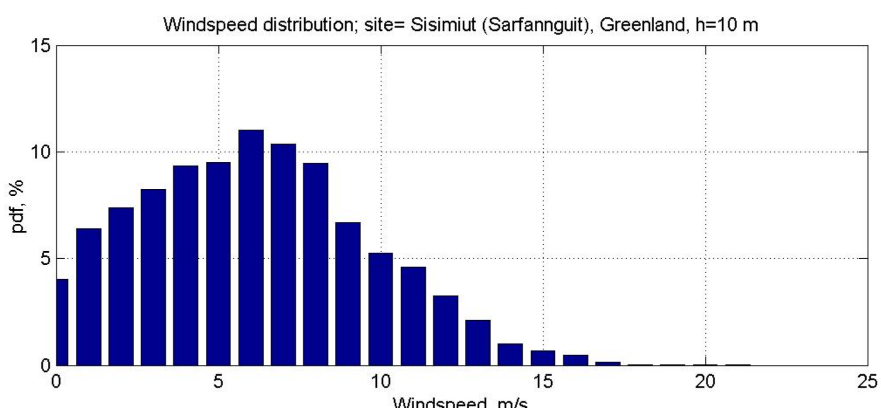
In July 2003 a meteorological mast was erected near a small village, Sarsannguit, Sisimiut in Greenland The erection and operation has been initiated as a students work in Danish Arctic Center at DTU. The main purpose is to measure the wind resource in a small remote village and determine the benefits of a combined wind diesel power system. The location of the measurement system is south west of the village, near a heli-port. The monthly maintenance, operation and data retrieval are performed by the local diesel power plant operator. The meteorological mast has been erected by Henrik Sogård Iversen & Jacob Skovgård Kristensen during the summer camp in July 2003.

Measurement system

The meteorological data in terms of wind speed and wind direction at 10 m height are recorded as 10-minute statistics with a standard NRG-system data-logger. The measurement campaign started in July 2003 and continues until summer 2004 and the database will be updated once every second month.

Acknowledgements

Kurt S. Hansen, Fluid Mechanics, MEK, Technical University of Denmark.



Distribution of wind speeds

Site = Cabauw, SODAR measurements, The Netherlands

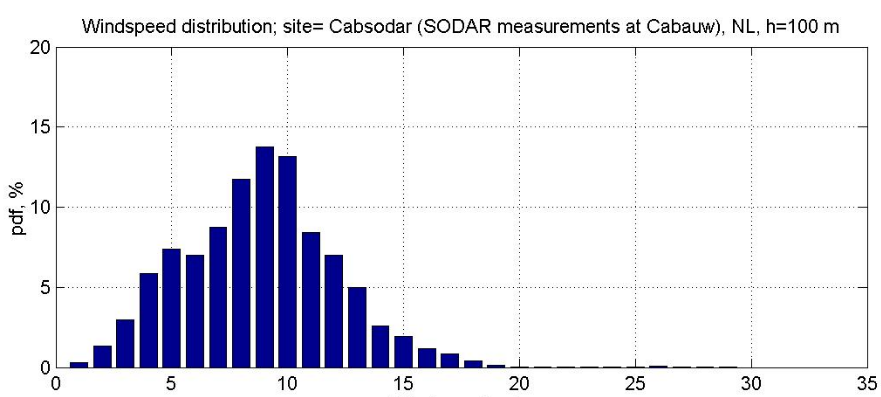
Site code **Cabsodar**

Dominating terrain/ orography	pastoral	flat
Number of masts / wind turbines	1 + sodar	0
Number of channels with wind speed / wind direction	12 (h=20,40,…,240m)	12 (h=20, 40, 60,…,240m)
Number of years / mast height	2000-2001	200 & 240 m
Hours of measurements / duration	1320	10 min.

Project motivation
ECN performed measurements to validate a MiniSODAR measurement system. A number of different measurements were done. These were hardware test, background noise and vibration measurements. The SODAR measurements are compared against the 213-metres height meteorological mast owned by the KNMI, located at Cabauw in the Netherlands. We appreciate KNMI for providing the measurement data from their meteorological mast. Comparisons are performed at different height levels and using different SODAR settings. Two different models of the MiniSODAR were used for this purpose.

Measurement system
The Cabauw meteorogical mast is a tubular tower with a height of 213 m and a diameter of 2 m. Guy wires are attached at four levels. From 20m upwards horizontal trussed measurement booms are installed at intervals of 20 m. At each level there are three booms, extending 10.4 m from the centreline of the tower. These booms point to the directions 10, 130, 250 degrees relative to North. The SW and N booms are used for wind velocity and wind direction measurements. These booms carry at the end two lateral extensions with a length of 1.5 m and a diameter of about 4 cm. Measured values from the meteorological sensors are already aggregated by the KNMI into 10-minute averaged signals. Wind speed and wind direction measurements are available at 80, 140 and 200 meter heights. Two MiniSODAR models from AeroVironment are used in this project; model 3000 and model 4000.

Acknowledgements
Peter Eecen, ECN, The Netherlands.



Distribution of wind speeds

Site =Sornfelli, Faeroe Island

Site code **Sornf**

Dominating terrain/ orography	coastal	mountain
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1	1
Number of years / mast height	1999-2000	3 m
Hours of measurements / duration	9663	2x10 min. / hour

Project motivation

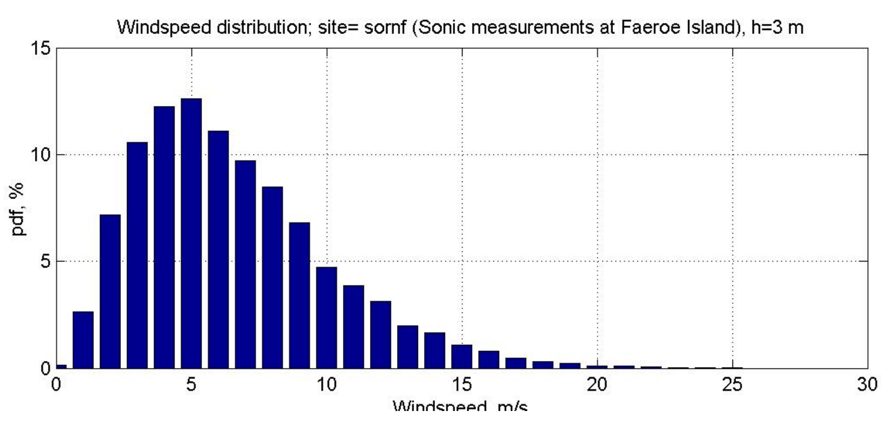
To obtain information on the mountain climate in the arctic part of the Faroese landscape, and from this analyse the vertical dimension of climate. Traditionally, most meteorological stations are located near sea level, which makes studies of vertical climate change effects difficult. The Faroe Islands are located in a key region for understanding land-atmosphere-ocean interaction in the North Atlantic region, as they are the only land area completely surrounded by the North Atlantic Drift. Sornfelli is a 749 m high mountain at the Faroe Islands in the middle of the North Atlantic Ocean, at the main island Streymoy, north west of the main city Thorshavn at 62N.

Measurement system

MetSupport have built a special heated instrument drum to solve the problem. Most of the time the instruments are inside the heated drum to prevent ice build up on the instruments. Every half an hour the instruments are lifted out of the top of the drum and exposed to the open air for 10 minutes to measure the actual weather. Then the instruments are lowered back into the "nice and warm" instrument drum for 20 minutes, before the start of the next measurement period. The instrument measuring wind speed and wind direction is a 2 axis ultrasonic anemometer of the type "Solent WindObserver", model 1172T from Gill Instruments LTD. Temperatures are measured using Pt100 sensors. The measured wind speed and wind direction are 10 minutes mean values from the minute 00 to 10 and again from the minute 30 to 40 every hour. The temperature sensor must be exposed to the actual weather for a period before it can measure the right temperature. Therefore the temperature is a one minute mean value from the minute 09 to 10 and again from the minute 39 to 40.

Acknowledgements

Institute of Geography, University of Copenhagen & MetSupport ApS, Roskilde, Denmark.



Distribution of wind speeds

Site = Tjæreborg, Esbjerg, Denmark

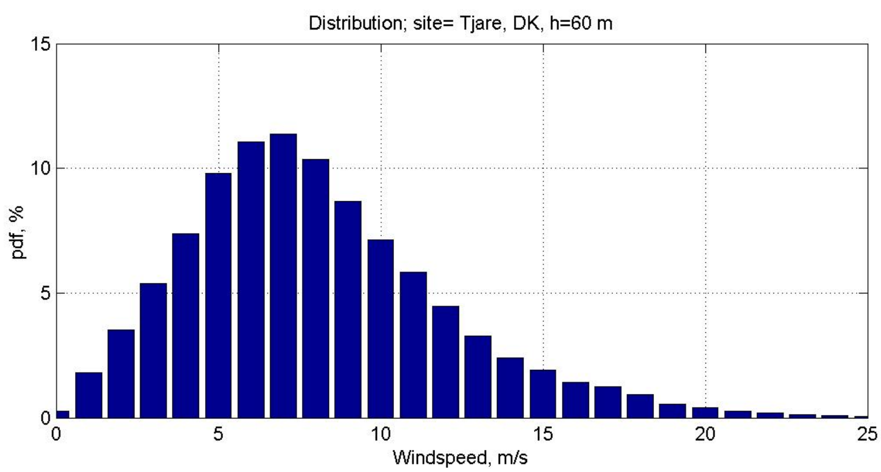
Site code **Tjare**

Dominating terrain/ orography	Pastoral	Flat
Number of masts / wind turbines	2	1
Number of channels with wind speed / wind direction	8	4
Number of years / mast height	1988-1992	90 & 90 m
Hours of measurements / duration	33500	10 min.

Project motivation
The primary goal was to design and build a 2MW wind turbine at Tjæreborg, Esbjerg. This project was accomplished with an intensive measuring programme where both mechanical loads and the wind climate on the site was measured - and analysed. The wind data were recorded as part of this measurement programme.

Measurement system
The measurement system consists of 2 meteorological masts. Mast no.1 was placed in front and mast no.2 behind the wind turbine - referring to the dominant wind sector. The measurements system was based on two HP-data loggers and the data was transferred to a central computer (HP operating HP-Basic with home developed data handling routines and programs). The system operation was primarily focusing on recording structural loads included a number of meteorological channels.

Acknowledgements
Peter Christiansen, Tech-wise A/S (former Elsamprojekt), Denmark.



Distribution of wind speeds.

Site =Tjareborg Enge, NKT 1500 site, Esbjerg, Denmark

Site code **Tjare_2**

Dominating terrain/ orography	coastal	flat
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	4 (h=10, 30, 60 & 61 m)	1 (h=60 m)
Number of years / mast height	1998-2000	61 m
Hours of measurements / duration	11355	10 min.

Project motivation

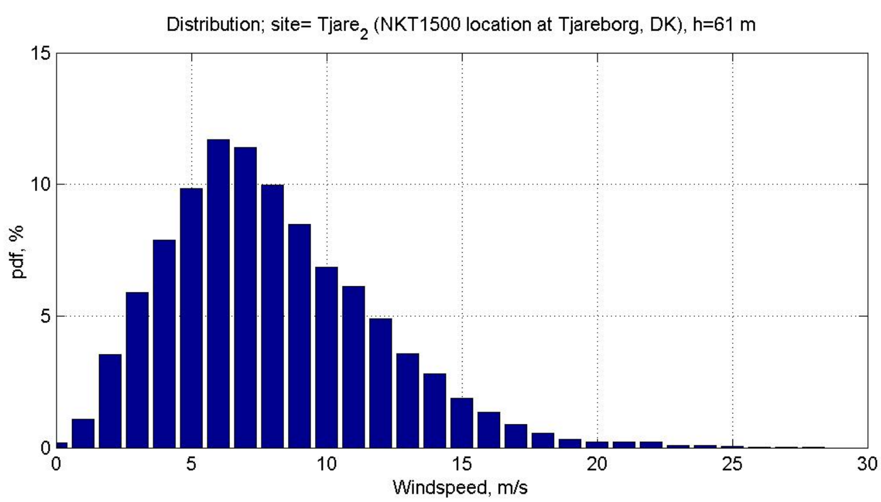
The aim of the measurement project has been to verify the characteristics of the NEG-Micon NM1500 prototype wind turbine. The terrain around the wind turbine is flat and in the measurement sector there no roughness elements of importance. The terrain South-West of the test site (the measurement sector) is a march area with a roughness length less than 0.1 m out to a distance 3 km in the measurement sector. The wind turbine NTK1500 manufactured by Nordtank A/S are located together with 3 other prototype turbines 2MW owned by Vestkraft, 1.5 MW Vestas and 1.0 MW Bonus.

Measurement system

The height of the meteorological mast is 60m and contains a standard measurement set-up necessary for making a standard load measuring program. Long term wind speed recordings for a two year period have been made available for the wind database.

Acknowledgements

Søren M. Petersen, Risø National Labotories.



Distribution of wind speeds

Site = Tug Hill Plateau, New York, USA

Site code **Tughill**

Dominating terrain/ orography	scrub	hill
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	1	1
Number of years / mast height	1992-1993	30 m
Hours of measurements / duration	10521	10 min.

Project motivation

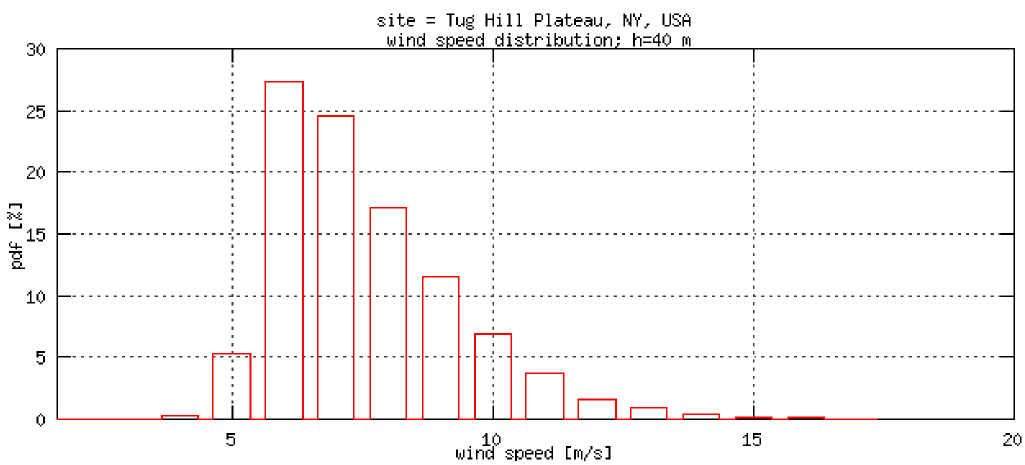
This project was initiated in 1990 to develop measurements and analysis methods that would establish representative and appropriate turbulence characteristics needed for the design and siting of cost-effective wind turbines. NREL and Batelle had additional objectives that included correlating the nature of the turbulence in the inflow to upwind features, and transferring the technology developed in the project to industry for operational applications.

Measurement system

A single cup-vane anemometer was mounted near the propeller-vane anemometer at the top of T2 within a few feet of the propeller-vane anemometer at the same location. This was the Maximum cup and NRG vane that are commonly used in the wind industry to estimate the resource at the site.

Acknowledgements

Sandy Butterfield and Maureen Hand, NREL, USA.



Distribution of wind speeds

Site = Vindeby offshore farm, Denmark

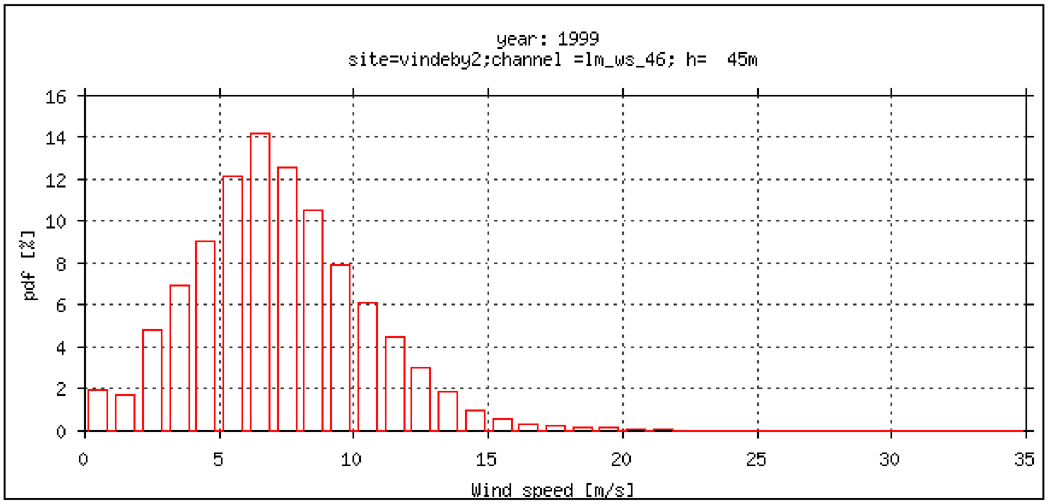
Site code **Vindeby**

Dominating terrain/ orography	Offshore	Flat
Number of masts / wind turbines	3	13
Number of channels with wind speed / wind direction	9	3
Number of years / mast height	1993-2000	45, 48 & 48 m
Hours of measurements / duration	47400	30 min.

Project motivation
Investigate long term off-shore climate and validate WasP prediction program.

Measurement system
The world's first offshore wind farm is located on a shallow water area off the north-western coast of the island of Lolland, close to Vindeby in Denmark. The wind farm consists of 11 wind turbines positioned in two rows oriented approximately in a NW-SE direction. The wind turbines are Bonus 450 kW machines with a rotor diameter of 35 m and a hub height of 37 m above average sea level. The distance between the wind turbine rows is 300 m, and so is the distance between the turbines in each of the rows. The most southerly placed wind turbine is closest to the coast, and the distance is approximately 1.5 km. In order to investigate the offshore- and coastal wind climate three 45 m high meteorological towers were erected at the site. Two of these were located offshore, denoted by SMW (sea mast west) and SMS (sea mast south), respectively.

Acknowledgements
Rebecca Barthelmie, Risø National Laboratories & SEAS, Denmark.



Distribution of wind speeds, measured at Vindeby, DK, 1999.

Site = Boulder Atmospheric Observatory Erie, CO, USA

Site code **BAO**

Dominating terrain/ orography	pastoral	flat
Number of masts / wind turbines	1	0
Number of channels with wind speed / wind direction	8 (h=10, 50, 100, 200 & 300m)	8 (h=10, 50, 100, 200 & 300m)
Number of years / mast height	2002-2003	300 m
Hours of measurements / duration	11088	1 min.

Project motivation

The Boulder Atmospheric Observatory (BAO) tower has been owned and operated by the National Oceanic and Atmospheric Administration's (NOAA) Environmental Technology Laboratory (ETL) for more than 25 years. Constructed in 1976-1977 at a cost of $1.3M, the BAO sits on State of Colorado land just west of I-25, and just east of the town of Erie, along the I-25 corridor. At a height of 300 m (with structural strength capable of supporting an additional 200 m extension), the BAO is a very unique observational platform situated on the gently rolling plains of eastern Colorado. The BAO was originally constructed to support atmospheric boundary layer probes (e.g., temperature, humidity, wind, and turbulence sensors).

Measurement system

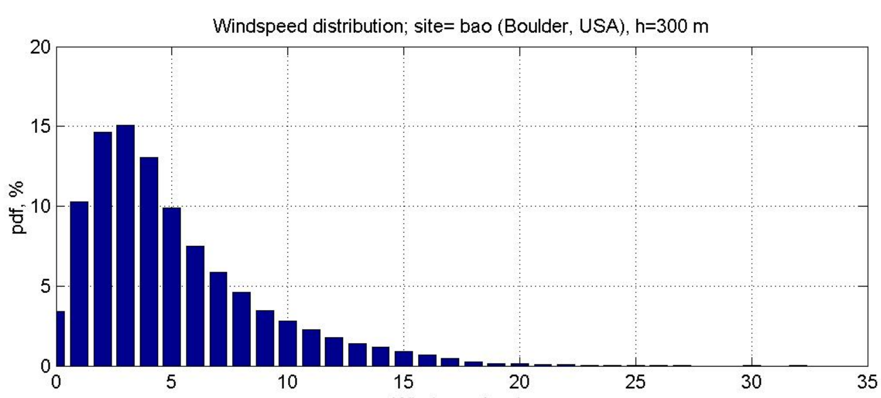
Completed in 1977, the BAO is a unique research facility for studying the planetary boundary layer and for testing and calibrating atmospheric sensors. The centrepiece of the facility is a 300-m tower instrumented at five levels with slow-response temperature and wind sensors, a variety of remote sensing systems, and a real-time processing and display capability that greatly reduces analysis time for scientists.

Comment

Note all statistics are available as 1 minute averages.

Acknowledgements

Daniel Wolfe, Boulder Atmospheric Observatory Erie, CO.



Distribution of wind speeds

Site = ECN Testveld, Petten, The Netherlands.

Site code **Ecn_met**

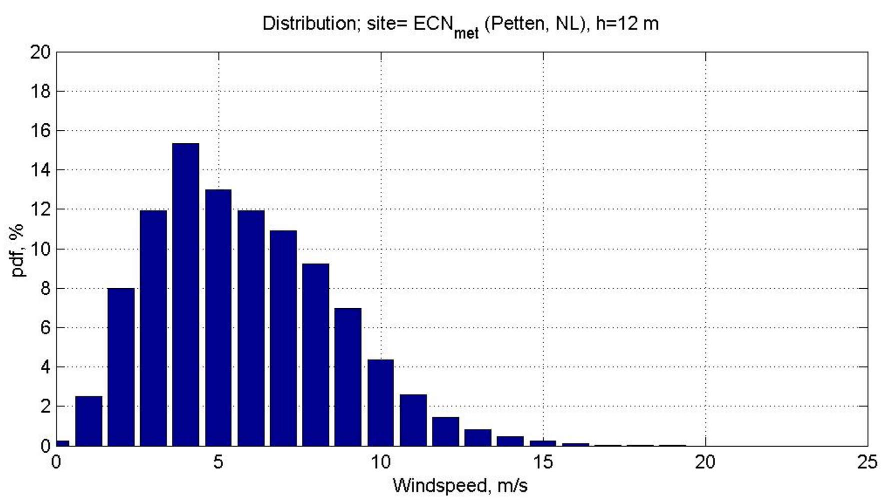
Dominating terrain/ orography	coastal	hill
Number of masts / wind turbines	1	1
Number of channels with wind speed / wind direction	1 (h=12 m)	1 (h=12 m)
Number of years / mast height	2002-2003	12 m
Hours of measurements / duration	10320	1 min.

Project motivation
Power performance measurements on the LW 5/2.5. These measurements are never carried out due to problems with the turbine. The wind data that were available are included in the international wind database.

Measurement system
Small guyed mast of 12m length with ECN/Miery meteorological boom setup in top. One cup anemometer, one wind vane and a sonic anemometer are used. Note that the time used in the data for this mast is two hours behind GMT.

Comment
Note all statistics are available as 1 minute averages.

Acknowledgements
Peter Eecen, ECN, The Netherlands.



Distribution of wind speeds

4.4 Wind farm data

Site =Delabole, North Cornwall, UK

Site code	**Delabole**	
Dominating terrain/ orography	pastoral	flat
Number of masts / wind turbines	2	10
Number of channels with wind speed / wind direction	6 (h=10,20,33&44 m)	2 (h=33 & 44 m)
No. power signals/yaw direction	10	0
Number of years / mast height	1993-1994	44 m
Hours of measurements / duration	6800	10 min.

Project motivation

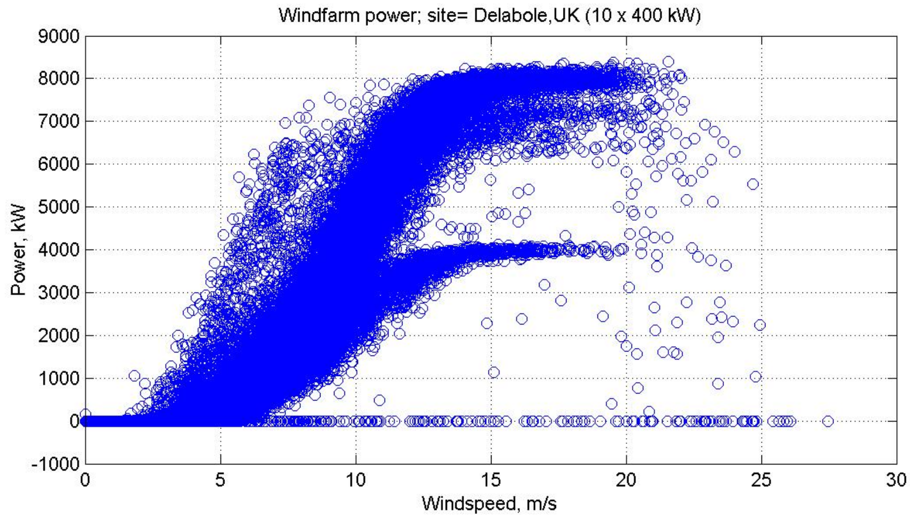
The Delabole Wind Farm is situated about 2 km to the North West of Camelford in North Cornwall and is operated by Wind Electric Ltd. The site is very open with an approximate elevation of 240 m above sea level, gently sloping away towards the South-West. It is bounded to the North-East) by a minor road (B3314) and the South and East by the course of an abandoned railway. Other than the Cornish hedges (5 - 6 ft) around fields, the ground cover is low (1 - 2 ft) agricultural crops, mostly grass with some fields put to linseed. At certain periods of the year this area is ploughed or contains stubble. There are ten wind turbines installed at the Delabole Wind Farm. They are all Windane 34's manufactured by Vestas / Danish Wind Technology A/S, rated at 400 kW and were commissioned in December 1991.

Measurement system

Two meteorological masts were erected on the farm. Mast 1, located ENE from Turbine 9, was the most comprehensively equipped, with Vector Instruments A100 cup anemometers at 10 m, 20 m, 33 m and 44 m heights, a W250P wind vane also from Vector Instruments at a height of 44 m, a Unidata 6522A barometric pressure gauge, a Campbell Scientific ARG100 tipping bucket rain gauge and two Skye Instruments temperature probes mounted at 5 m and 44 m. Mast 2 was equipped with two anemometers one at 10 m, the other at 33 m. This mast was also fitted with a wind vane at a height of 33 m. The data acquisition system hardware consisted of a Dell 486 PC with 130 Mb hard disc, tape streamer and colour VGA screen running the OS/2 operating system. This PC was situated in the wind farm site office with a second similar PC connected via a network and situated in the Deli Farm office. The turbines were connected to the data acquisition computer via a Quest data concentrator supplied by Vestas. Additional sensors connected to remote data loggers passed data via radio transmitters. A receiver was installed at the wind farm office and connected to the data acquisition computer.

Acknowledgements

Mike Payne, Future Energy Solutions, AEA Technology, UK.



wind farm power values

Site =Nørrekær Enge, Denmark

Site code	**Norre**	
Dominating terrain/ orography	coastal	flat
Number of masts / wind turbines	2	42 x 300 kW
Number of channels with wind speed / wind direction	6 (h=10,20,33&44 m)	2 (h=33 & 44 m)
No. power signals/yaw direction	42	42
Number of years / mast height	1991-1993	31 m
Hours of measurements / duration	12342	10 min.

Project motivation

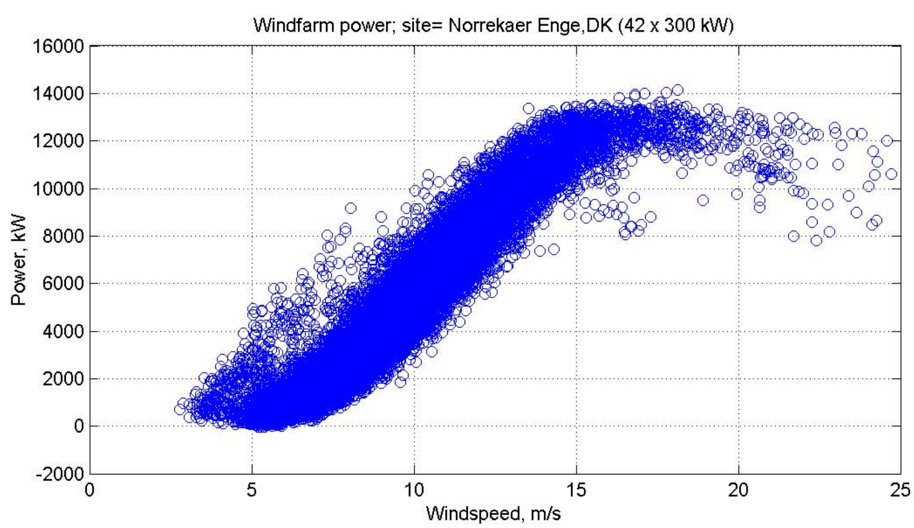
The Norrekaer Enge II wind farm, containing 42 x 300 kW Nordtank turbines, is located in the North Jutland, on the south bank of the Limfjord, about 36 km west of Alborg.

Measurement system

Mast 1 at A1 is placed on the row of turbines A1 - A7, 55 m south of turbine Al. The Mast 2 at F6 is placed on the line between F6 and ES (orientation 35.83°), 55 m from F6 and the booms on both masts are perpendicular to the line F6 - E5. Mast Instrumentation The two meteorological masts are instrumented primarily for measuring profiles of mean speed, turbulence and temperature. For the prevailing southwesterly wind direction, mast l is an upstream mast, unaffected by wakes from wind turbines.

Acknowledgements

Jørgen Højstrup, Risø National Laboratories, Roskilde, DK.



wind farm power values

5. Acknowledgements

The Ministry of Environment and Energy, Danish Energy Agency, The Netherlands Agency for Energy and the Environment (NOVEM), The Norwegian Water Resources and Energy Administration (NVE), The Swedish National Energy Administration (STEM), The Government of the United States of America and the IEA R&D Wind Agreement are all acknowledged for the support that have made the completion of this work possible.

6. References

[1] Hansen, K.S. and Courtney, M.S. (1999). Database on wind Characteristics. ET-AFM-9901, Department of Energy Engineering, DTU, Denmark.
[2] Larsen, G.C. and Hansen, K.S. (2001). Database on Wind Characteristics - Philosophy and Structure. Risø-R-1299(EN).
[3] Larsen, G.C. and Hansen, K.S. (2001). Database on Wind Characteristics - Users Manual. Risø-R-1300(EN).
[4] Larsen, G.C. and Hansen, K.S. (2001). Database on Wind Characteristics - Contents of Database Bank. Risø-R-1301(EN).
[5] Larsen, G.C. and Hansen, K.S. (2004). Database on Wind Characteristics – Analysis of Wind Turbine Design Loads. Risø-R-1473(EN).

Appendix A: Example of site documentation for Bockstigen

For each site represented in the database a "Description of Measurement Setup" - file is prepared and made available on the web-server as a PDF document. This appendix is a copy of the PDF file prepared for the measurements recorded at the Swedish Bockstigen site.

Preparing notes

The document contains background information for the measured data stored in The Database of Wind Characteristics. This PDF document is prepared by Kurt S. Hansen, Department of Mechanical Engineering, DTU, Denmark and is based on information from external sources (Ingemar Carlén, Teknikgruppen AB). It contains a copy of the project information, the site information and the master sensor list.

Content

A.1 Introduction

Motivation

The Bockstigen off-shore wind farm consists of five 500 kW wind turbines erected three km of the SW coast of the island of Gotland on the Baltic. The project was launched in order to gain experience from bottom mounted offshore wind turbine installation. Specifcally, the method of drilling a hole for a monopile foundation, directly into the limestone rock, was in focus for the investigations.

Measurement system

Measurements are performed in one meteorological mast, and on one instrumented turbine (no measurements in the rotating system). Data are sampled by use of several loggers (DataScan 20 Hz), and the signals are transferred through an optical fibre cable (4500 m) to an onshore cabin. Data is continuously stored on Video8 tapes.

A.2 Site Description

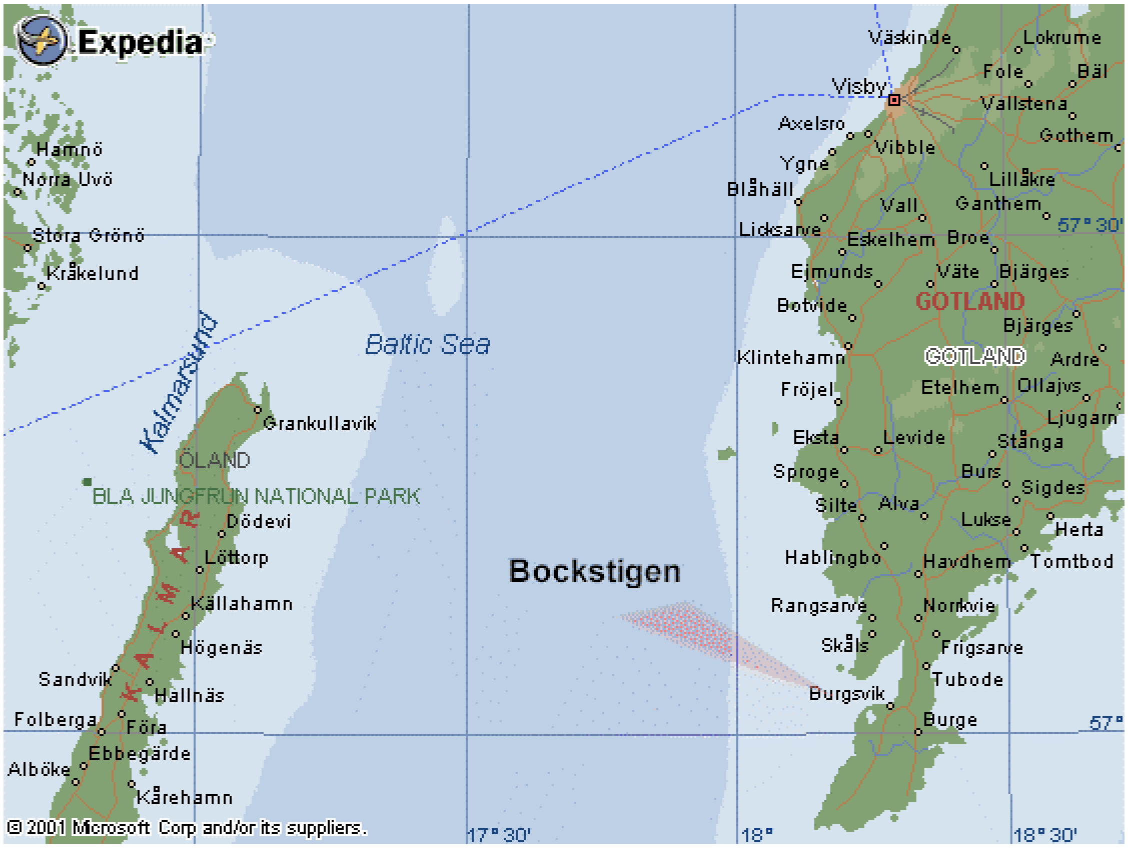


Figure A2-1: Location of the measuring site, the Bockstigen off-shore wind farm.

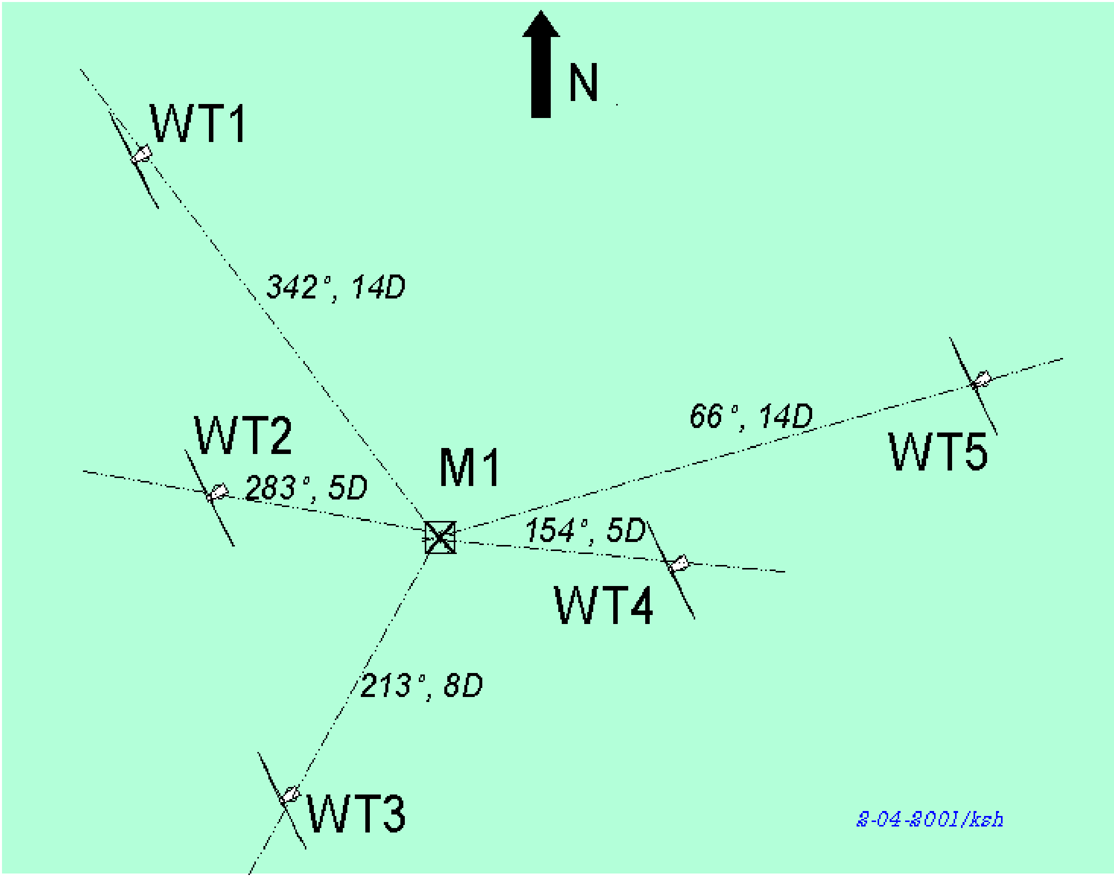


Figure A2-2: Measuring site-plan used in the Bockstigen wind farm.

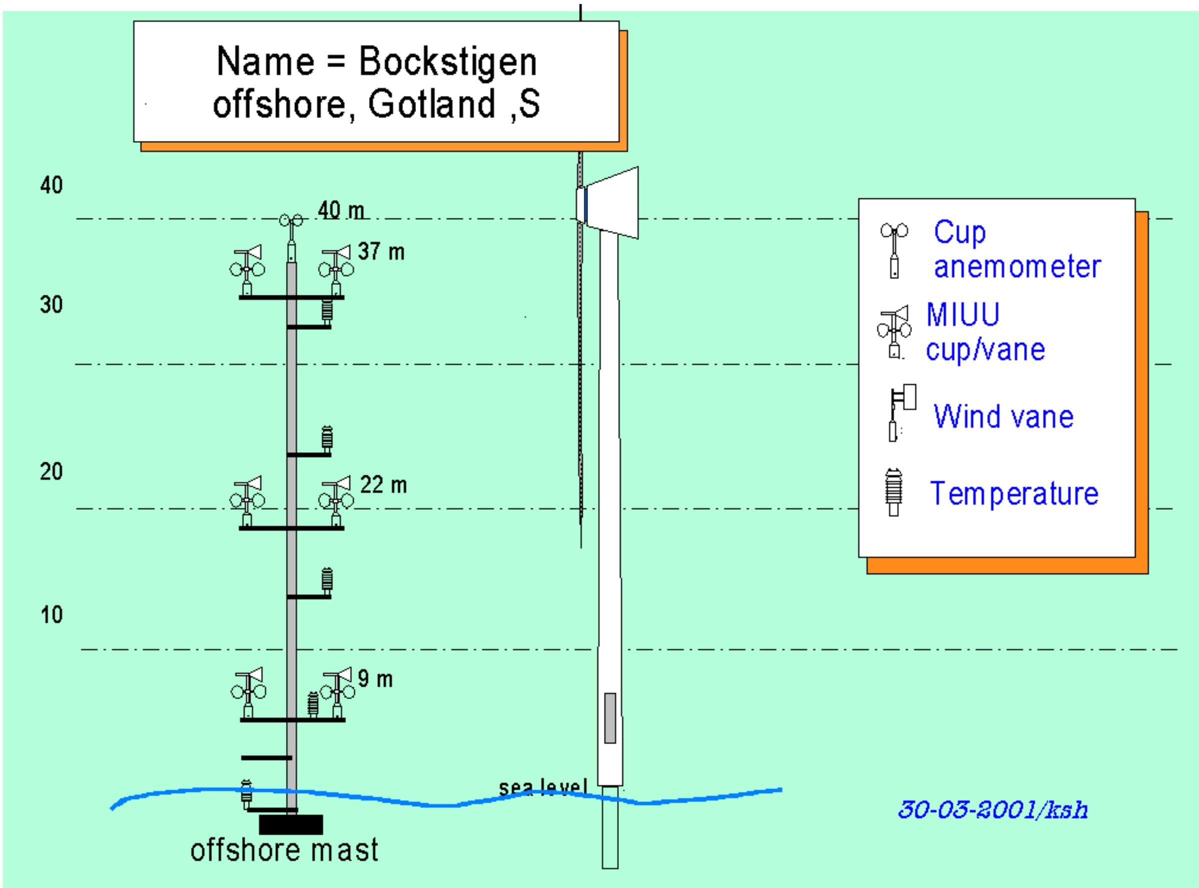


Figure A2-3: Site layout for Bockstigen measurements, 1 mast and 5 wind turbines.

A.3 Available Channels

The available channels are listed in table A3-1.

Table A3-1: Available channels from the Bockstigen measurements

Mast number	Name	height	Signal type	Instrument
1	D8s	8.4	D	CUPVANE
1	S8s	8.4	S	CUPVANE
1	D8n	9.0	D	CUPVANE
1	S8n	9.0	S	CUPVANE
1	D22n	22.4	D	CUPVANE
1	S22n	22.4	S	CUPVANE
1	D22s	22.9	D	CUPVANE
1	S22s	22.9	S	CUPVANE
1	S37s	36.8	S	CUPVANE
1	D37s	36.8	D	CUPVANE
1	D37n	37.2	S	CUPVANE
1	S37n	37.2	D	CUPVANE

1	S40	40.0	S	CUP
1	Tabs0	0.0	Tabs	Thermometer
1	Tabs6	6.0	Tabs	Thermometer
1	Tabs15	15.0	Tabs	Thermometer
1	Tabs25	25.0	Tabs	Thermometer
1	Tabs35	35.0	Tabs	Thermometer
1	Rhum6	6.1	Rhum	

A.4 Available Measurements

This Section contains a summary of the available measurements in the database.

Table A4-1: Summary of measurements

Terrain	Offshore
Orography	Flat
Number of masts	1
height[s]	40 m
wind speed measurements at 5 heights	8, 22, 37 & 40 m
wind direction measurements at 3 heights	8, 22 & 37
Frequency	1 Hz
hours of measurements	1239
number of runs	1239

At the nominal plots, each dot represents 3600 seconds.

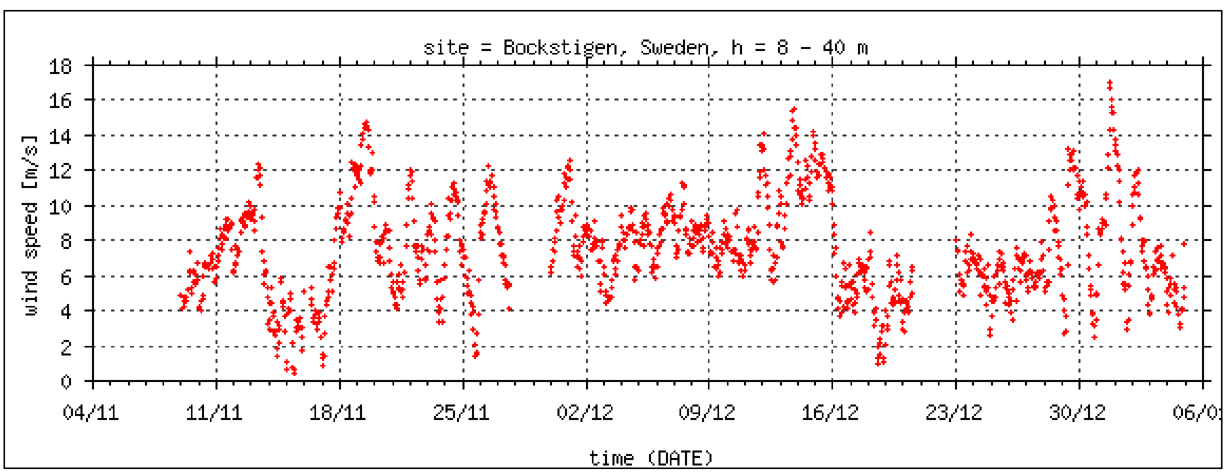


Figure A4-1: The nominal wind speed (average wind speed based on 7 cups; the reference period is 60 minutes).

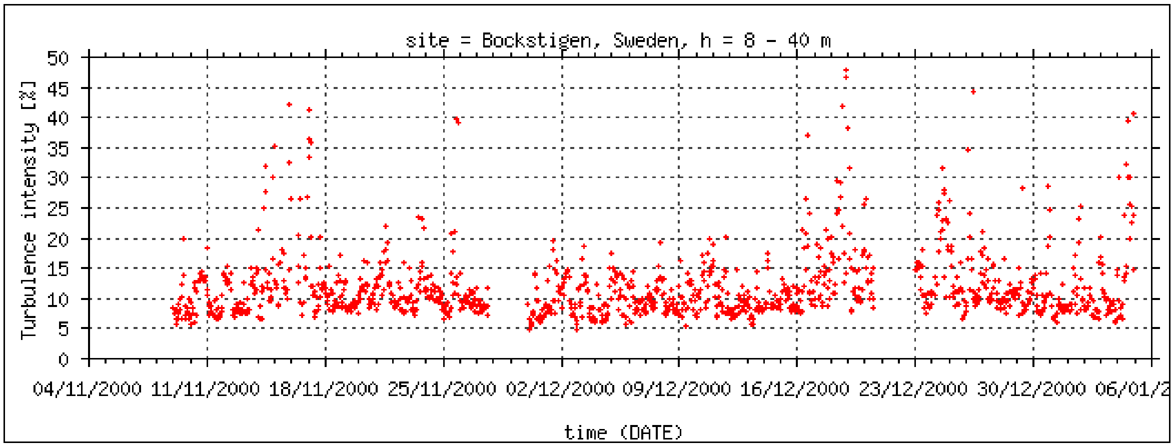


Figure A4-2: The nominal turbulence intensity (average turbulence intensity based on 7 cups; the reference period is 60 minutes).

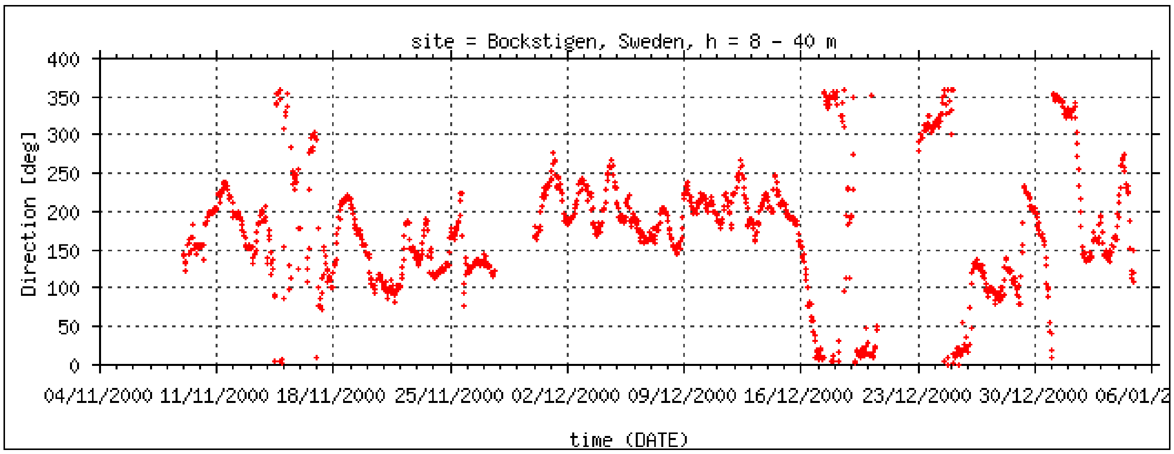


Figure A4-3: The nominal direction (based on 1-3 vanes; the reference period is 60 minutes).

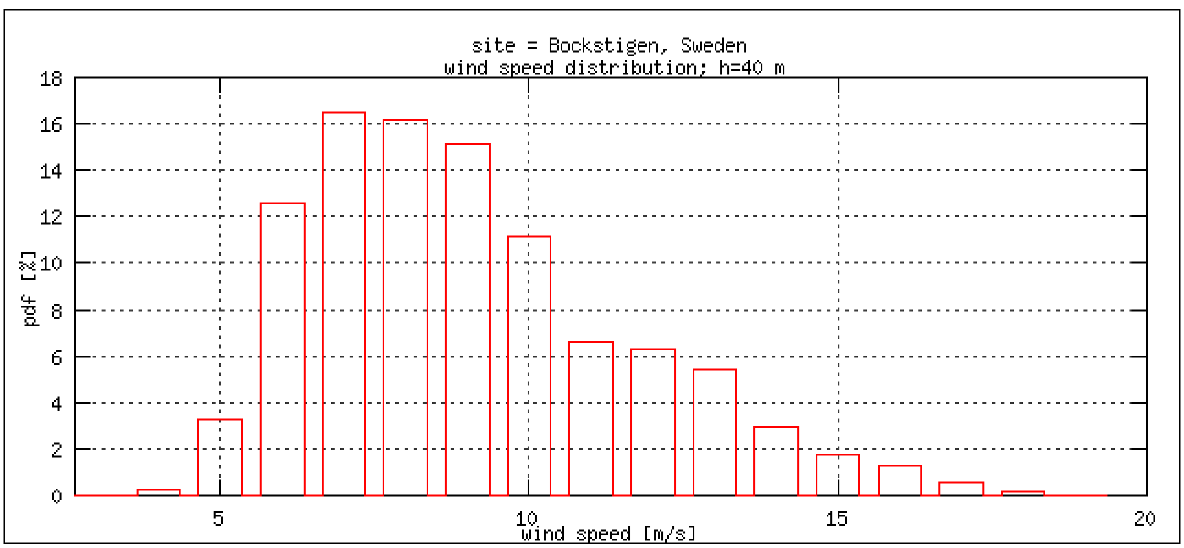


Figure A4-4: The wind speed distribution for all periods; h=40 m.

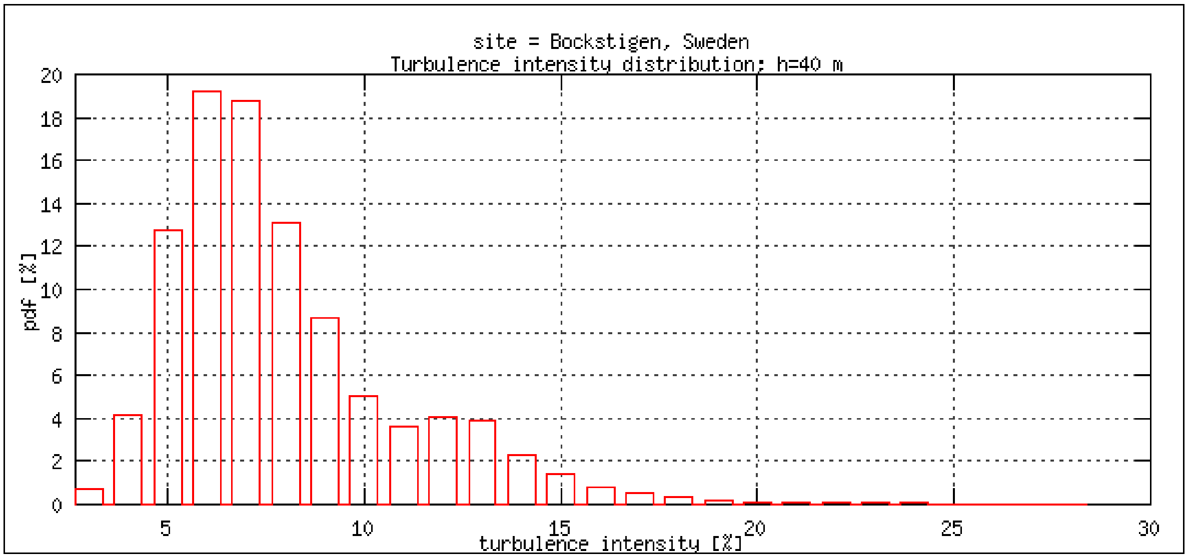


Figure A4-5: The distribution of the turbulence intensity for all periods; h=40 m.

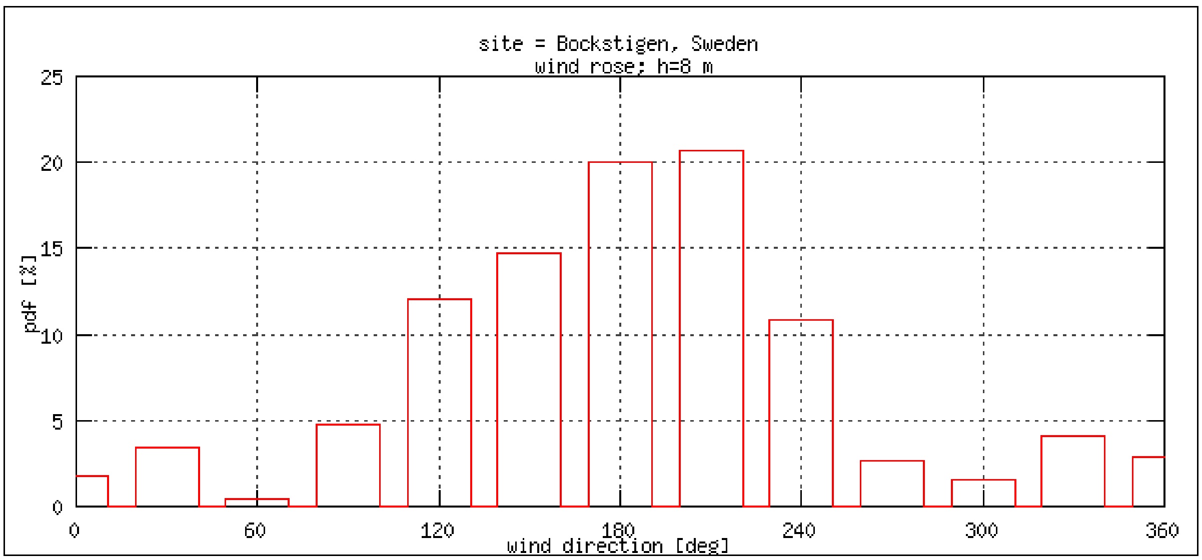


Figure A4-6: The wind rose; h=8 m.

A.5 References

1. Poppen M., Dahlberg J-Å., Thor S-E, "Proposal to a Programme for Evaluation of the Wind Turbine Units", FFAP-V-046, FFA, Stockholm (in Swedish).
2. Ronsten G. et. al. , "Instrumentation and initial evaluation of the 2.5 MW Bockstigen offshore wind farm", EWEC 99, Nice, March 1999.
3. Ronsten G. et. al. ,"Evaluation of Loads, Power Quality, Grid Interaction, Meteorological Conditions and Power Performance of the first Swedish Wind Farm at Bockstigen", OWEMS, Syracuse, Italy, April, 2000

A.6 Project Information

```
;========================================================
;  Project information
;  ==================
;  Project = Bockstigen offshore wind farm, Gotland, Sweden
;  Prepared by Ingemar Carlén, Teknikgruppen AB, Sweden
;  version : 28-3-2001
;  Modf.   : 29-3-2001 /ksh
;========================================================
[Basic_information]
project_code      = bockstigen
Institution       = FFA (FOI / Flygteknik)
Person            = Goran Ronsten
e_mail            = rng@foi.se
URL               = www.foi.se
Address           = S-172 90 Stockholm
Telephone         = +46 8 55503000
Telefax           =
Collaborators     = MIUU , Teknikgruppen AB
Funding_agencies  = NUTEK , STEM
project_start_date= Spring 1997 (met mast installed autumn 1999)
project_end_date  =

[Project Motivation]
The project was launched in order to gain experience from bottom mounted
offshore wind turbine installation. Specifically, the method of drilling a
hole for a monopile foundation, directly into the limestone rock, was in
focus for the investigations.

[Measurement_System]
Measurements are performed in one meteorological mast, and on one
instrumented turbine (no measurements in the rotating system). Data are
sampled by use of several loggers (DataScan 20 Hz), and the signals are
transferred through an optical fibre  cable (4500 m) to an onshore cabin.
Data is continuously stored on Video8 tapes.

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Number_of_maps          = 2
Number_of_graphs        = 2

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Reference               = Poppen M., Dahlberg J-Å., Thor S-E, ”Proposal to a
Programme for Evaluation of the Wind Turbine Units”, FFAP-V-046, FFA,
Stockholm (in Swedish).

[publication_2]
Description = Conference paper
Reference   = Ronsten G. et. al. , ”Instrumentation and initial evaluation
of the 2.5 MW Bockstigen offshore wind farm”, EWEC 99, Nice, March 1999

[publication_3]
Description = Conference paper
Reference   = Ronsten G. et. al. ,”Evaluation of Loads, Power Quality, Grid
Interaction, Meteorological Conditions and Power Performance of the first
Swedish Wind Farm at Bockstigen”, OWEMS, Syracuse,Italy, April, 2000

[Map_1]
Description = Location of the wind farm, southwest of the island of Gotland.
Filename    = draw_01.pdf

[Map_2]
Description = Orientation of meteorological mast, and wind turbines.
Filename    = draw_02.pdf
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[Graph_1]
Description = Temperature profiles in Land Tower, Coastal Tower, and sea
tower (see Map_1).
Filename    = graph_01.pdf

[Graph_2]
Description = Frequency of Richardson number (Sea Tower and Coastal Tower).
Filename    = graph_02.pdf
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A.7 Site Information

```
;=======================================================
;  Site information; site_code = Bockstig
;  ====================================
;  Project = Bockstigen offshore wind farm, Gotland, Sweden
;
;  Prepared by Ingemar Carlén, Teknikgruppen AB, Sweden
;  version :  1-3-2001
;  Modf.   : 29-3-2001 /ksh
;=======================================================
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site_name               = Bockstigen, Gotland, Sweden
version                 = 01-03-21
site_code               = bockstig
parent_project          = bockstigen
longitude               =  18  8’ 46.50”
latitude                =  57  2’  9.25”
altitude                = 0.0
country                       = Sweden
dominant_terrain_type         = offshore
dominant_orography            = flat
no_of_measurements_location   = 1
no_of_wind_turbines           = 5
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x     = 0.0
y     = 0.0
z     = 0.0
roughness_class   = 1,1,1,1,1,1,1,1,1,1,1,1
turbine_wakes     = f,f,t,t,f,f,t,t,f,t,t,t
desription        =  40  m  lattice  mast  located  4500  m  off-shore  from  the
island of Gotland.
[turbine_1]
x           = 490.7
y           = 159.5
z           = 0.0
description = WindWorld W-3700
diameter    = 37.0
hub_height  = 41.5
rated_power = 500
rated_wind_speed=
[turbine_2]
x           = 171.5
y           = -39.6
z           = 0.0
description = WindWorld W-3700
diameter    = 37.0
hub_height  = 41.5
rated_power = 500
rated_wind_speed=
[turbine_3]
x           =-153.6
y           =-236.5
z           = 0.0
description = WindWorld W-3700
diameter    = 37.0
hub_height  = 41.5
rated_power = 500
rated_wind_speed=
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x           =-178.0
y           =  86.8
z           = 0.0
description = WindWorld W-3700
diameter    = 37.0
hub_height  = 41.5
rated_power = 500
rated_wind_speed=
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x           =-215.2
y           = 483.3
z           = 0.0
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Filename       = photo_01.jpg

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description    = Meteorological mast seen from sea surface.
Filename       = photo_02.jpg
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A.8 Master Sensor List

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;  Master sensor list
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;  Prepared by Ingemar Carlén, Teknikgruppen AB, Sweden
;  version : 21-3-2001
;  Modf.   : 29-3-2001 /ksh
;========================================================
Master Sensor File]
Site_code            = bockstig
Version              = 21-03-01
No_of_sensors        = 13

[sensor_1]
Sensor_name          = cv8s
Sensor_type          = CUVA
Sensor_height        = 8.4
Boom_direction       = 195
Sensor_direction     =
Top_mounted          = F
Mast_number          = 1
Boom_length          = 7.0 m
Boom_shape           = circular , telescopic
Boom_dimension       = 48.3 mm (outer 1 m)
Mast_dimension       = 2.0 m
Meas_distance        =
Serial_no            =
Manufacturer         = MIUU
Model_spec.          = combined cup/vane
```

```
Last_calib.            =
No_of_signals          = 2

[Signal_1]
Signal_name            = s8s
Signal_type            = S
Time/Length Constant = 1 s
MinMeasVal             = 0.45
MaxMeasVal             = 43.0
Units                  = m/s
Accuracy               =

[Signal_2]
Signal_name            = d8s
Signal_type            = D
Time/Length Constant = 1 s
MinMeasVal             = 0
MaxMeasVal             = 360
Units                  = deg
Accuracy               =

[sensor_2]
Sensor_name            = cv8d
Sensor_type            = CUVA
Sensor_height          = 9.0
Boom_direction         = 15
Sensor_direction       =
Top_mounted            = F
Mast_number            = 1
Boom_length            = 7.0 m
Boom_shape             = circular, telescopic
Boom_dimension         = 48.3 mm (outer 1 m)
Mast_dimension         = 2.0 m
Meas_distance          =
Serial_no              =
Manufacturer           = MIUU
Model_spec.            = combined cup/vane
Last_calib.            =
No_of_signals          = 2

[Signal_1]
Signal_name            = s8n
Signal_type            = S
Time/Length Constant = 1 s
MinMeasVal             = 0.45
MaxMeasVal             = 43.0
Units                  = m/s
Accuracy               =

[Signal_2]
Signal_name            = d8n
Signal_type            = D
Time/Length Constant = 1 s
MinMeasVal             = 0
MaxMeasVal             = 360
Units                  = deg
Accuracy               =

[sensor_3]
Sensor_name            = cv22s
Sensor_type            = CUVA
Sensor_height          = 22.9
Boom_direction         = 195
Sensor_direction       =
Top_mounted            = F
Mast_number            = 1
Boom_length            = 5.25 m
Boom_shape             = circular, telescopic
Boom_dimension         = 48.3 mm (outer 1 m)
```

```
Mast_dimension        = 1.45 m
Meas_distance         =
Serial_no             =
Manufacturer          = MIUU
Model_spec.           = combined cup/vane
Last_calib.           =
No_of_signals         = 2

[Signal_1]
Signal_name           = s22s
Signal_type           = S
Time/Length Constant = 1 s
MinMeasVal            = 0.45
MaxMeasVal            = 43.0
Units                 = m/s
Accuracy              =

[Signal_2]
Signal_name           = d22s
Signal_type           = D
Time/Length Constant = 1 s
MinMeasVal            = 0
MaxMeasVal            = 360
Units                 = deg
Accuracy              =

[sensor_4]
Sensor_name           = cv22n
Sensor_type           = CUVA
Sensor_height         = 22.4
Boom_direction        = 15
Sensor_direction      =
Top_mounted           = F
Mast_number           = 1
Boom_length           = 5.25 m
Boom_shape            = circular, telescopic
Boom_dimension        = 48.3 mm (outer 1 m)
Mast_dimension        = 1.45 m
Meas_distance         =
Serial_no             =
Manufacturer          = MIUU
Model_spec.           = combined cup/vane
Last_calib.           =
No_of_signals         = 2

[Signal_1]
Signal_name           = s22n
Signal_type           = S
Time/Length Constant = 1 s
MinMeasVal            = 0.45
MaxMeasVal            = 43.0
Units                 = m/s
Accuracy              =

[Signal_2]
Signal_name           = d22n
Signal_type           = D
Time/Length Constant = 1 s
MinMeasVal            = 0
MaxMeasVal            = 360
Units                 = deg
Accuracy              =

[sensor_5]
Sensor_name           = cv37s
Sensor_type           = CUVA
Sensor_height         = 36.8
Boom_direction        = 195
Sensor_direction      =
```

```
Top_mounted          = F
Mast_number          = 1
Boom_length          = 3.5 m
Boom_shape           = circular, telescopic
Boom_dimension       = 48.3 mm (outer 1 m)
Mast_dimension       = 1.05 m
Meas_distance        =
Serial_no            =
Manufacturer         = MIUU
Model_spec.          = combined cup/vane
Last_calib.          =
No_of_signals        = 2

[Signal_1]
Signal_name          = s37s
Signal_type          = S
Time/Length Constant = 1 s
MinMeasVal           = 0.45
MaxMeasVal           = 43.0
Units                = m/s
Accuracy             =

[Signal_2]
Signal_name          = d37s
Signal_type          = D
Time/Length Constant = 1 s
MinMeasVal           = 0
MaxMeasVal           = 360
Units                = deg
Accuracy             =

[sensor_6]
Sensor_name          = cv37n
Sensor_type          = CUVA
Sensor_height        = 37.2
Boom_direction       = 15
Sensor_direction     =
Top_mounted          = F
Mast_number          = 1
Boom_length          = 3.5 m
Boom_shape           = circular, telescopic
Boom_dimension       = 48.3 mm (outer 1 m)
Mast_dimension       = 1.05 m
Meas_distance        =
Serial_no            =
Manufacturer         = MIUU
Model_spec.          = combined cup/vane
Last_calib.          =
No_of_signals        = 2

[Signal_1]
Signal_name          = s37n
Signal_type          = S
Time/Length Constant = 1 s
MinMeasVal           = 0.45
MaxMeasVal           = 43.0
Units                = m/s
Accuracy             =

[Signal_2]
Signal_name          = d37n
Signal_type          = D
Time/Length Constant = 1 s
MinMeasVal           = 0
MaxMeasVal           = 360
Units                = deg
Accuracy             =
```

```
[sensor_7]
Sensor_name            = c40
Sensor_type            = CUP
Sensor_height          = 40.0
Boom_direction         =
Sensor_direction       =
Top_mounted            = T
Mast_number            = 1
Boom_length            =
Boom_shape             =
Boom_dimension         =
Mast_dimension         = vertical top, 38 mm
Meas_distance          =
Serial_no              = T 39519
Manufacturer           = Vaisala
Model_spec.            = 151
Last_calib.            =
No_of_signals          = 1

[Signal_1]
Signal_name            = s40
Signal_type            = S
Time/Length Constant = 2.0 m
MinMeasVal             = 0.4
MaxMeasVal             = 75.0
Units                  = m/s
Accuracy               =

[sensor_8]
Sensor_name            = tabs0
Sensor_type            = Term
Sensor_height          = 0.0 (sea surface)
Boom_direction         =
Sensor_direction       =
Top_mounted            = F
Mast_number            = 1
Boom_length            =
Boom_shape             =
Boom_dimension         =
Mast_dimension         =
Meas_distance          =
Serial_no              =
Manufacturer           = Pentronic
Model_spec.            = pt100
Last_calib.            =
No_of_signals          = 1

[Signal_1]
Signal_name            = tabs0
Signal_type            = TABS
Time/Length Constant =
MinMeasVal             = -20.0
MaxMeasVal             = +50.0
Units                  = degC
Accuracy               =

[sensor_9]
Sensor_name            = tabs6
Sensor_type            = Term
Sensor_height          = 6.1
Boom_direction         =
Sensor_direction       =
Top_mounted            = F
Mast_number            = 1
Boom_length            =
Boom_shape             =
Boom_dimension         =
Mast_dimension         =
Meas_distance          =
```

```
Serial_no            =
Manufacturer         = Pentronic
Model_spec.          = pt100
Last_calib.          =
No_of_signals        = 1

[Signal_1]
Signal_name          = tabs6
Signal_type          = TABS
Time/Length Constant =
MinMeasVal           = -20.0
MaxMeasVal           = +50.0
Units                = degC
Accuracy             =

[sensor_10]
Sensor_name          = tabs15
Sensor_type          = Term
Sensor_height        = 15.0
Boom_direction       =
Sensor_direction     =
Top_mounted          = F
Mast_number          = 1
Boom_length          =
Boom_shape           =
Boom_dimension       =
Mast_dimension       =
Meas_distance        =
Serial_no            =
Manufacturer         = Pentronic
Model_spec.          = pt100
Last_calib.          =
No_of_signals        = 1

[Signal_1]
Signal_name          = tabs15
Signal_type          = TABS
Time/Length Constant =
MinMeasVal           = -20.0
MaxMeasVal           = +50.0
Units                = degC
Accuracy             =

[sensor_11]
Sensor_name          = tabs25
Sensor_type          = Term
Sensor_height        = 25.0
Boom_direction       =
Sensor_direction     =
Top_mounted          = F
Mast_number          = 1
Boom_length          =
Boom_shape           =
Boom_dimension       =
Mast_dimension       =
Meas_distance        =
Serial_no            =
Manufacturer         = Pentronic
Model_spec.          = pt100
Last_calib.          =
No_of_signals        = 1

[Signal_1]
Signal_name          = tabs25
Signal_type          = TABS
Time/Length Constant =
MinMeasVal           = -20.0
MaxMeasVal           = +50.0
Units                = degC
```

```
Accuracy             =

[sensor_12]
Sensor_name          = tabs0
Sensor_type          = Term
Sensor_height        = 35.0
Boom_direction       =
Sensor_direction     =
Top_mounted          = F
Mast_number          = 1
Manufacturer         = Pentronic
Model_spec.          = pt100
Last_calib.          =
No_of_signals        = 1

[Signal_1]
Signal_name          = tabs35
Signal_type          = TABS
Time/Length Constant =
MinMeasVal           = -20.0
MaxMeasVal           = +50.0
Units                = degC
Accuracy             =

[sensor_13]
Sensor_name          = rhum
Sensor_type          = HUM
Sensor_height        = 6.1
Boom_direction       =
Sensor_direction     =
Top_mounted          = F
Mast_number          = 1
Mast_dimension       =
Serial_no            = 1
Manufacturer         = unknown
Model_spec.          = u1
Last_calib.          =
No_of_signals        = 1

[Signal_1]
Signal_name          = rhum6
Signal_type          = RHUM
Time/Length Constant =
MinMeasVal           = 0
MaxMeasVal           = 100
Units                = %
Accuracy             =
```

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DATABASE ON WIND CHARACTERISTICS - CONTENTS OF DATABASE BANK

Gunner C. Larsen and Kurt S. Hansen

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Abstract (max. 2000 characters)

The main objective of IEA R&D Wind Annex XVII - Database on Wind Characteristics - has been to provide wind energy planners, designers and researchers, as well as the international wind engineering community in general, with a source of actual wind field data (time series and resource data) observed in a wide range of different wind climates and terrain types. Connected to an extension of the initial Annex period, the scope for the continuation was widened to include also support to the international wind turbine standardisation efforts.. The project partners are Sweden, Norway, U.S.A., The Netherlands and Denmark, with Denmark as the Operating Agent.

The reporting of the continuation of Annex XVII falls in two separate parts. Part one accounts in details for the available data in the established database bank, and part two describes various data analyses performed with the overall purpose of improving the design load cases with relevance for to wind turbine structures.

The present report constitutes the second part of the Annex XVII reporting. Both fatigue and extreme load aspects are dealt with, however, with the main emphasis on the latter.

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Descriptors INIS/EDB
DATA ANALYSIS; DATA COMPILATION; GUSTS; INFORMATION SYSTEMS; RESPONSE FUNCTIONS; RESOURCE POTENTIAL; SHEAR; SITE CHARACTERIZATION; STATISTICS; STORMS; TURBULENCE; WIND; WIND LOADS; WIND TURBINE ARRAYS; WIND TURBINES.