WIND DATA REPORT

Vinalhaven

January 1, 2004 – December 31, 2004

Prepared for

Fox Islands Electric Cooperative

By

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June 22, 2005

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EXECUTIVE SUMMARY

All the work presented in this Wind Data Report including installation and decommissioning of the meteorological tower and instrumentation, and the data analysis and reporting was performed by the Renewable Energy Research Laboratory (RERL) at the University of Massachusetts, Amherst.

This report covers wind data measured at a meteorological tower installed on Vinalhaven, an island off the coast of Maine. Installed in August 2002, the RERL has collected wind resource data under the support of the US Department of Energy and with the cooperation of the local utility, Fox Islands Electric Cooperative. Mounted at 40 m (131.2 ft), one anemometer and one wind vane measure the wind speed and direction.

The year covered by this report is January 1, 2004 – December 31, 2004. The mean recorded wind speed for this entire year was 5.27 m/s (11.80 mph)* and the prevailing wind direction was from the southwest. Winds were found to be lowest in the summer and highest in the winter. The gross data recovery percentage (the actual percentage of expected data received) was 99.96 % and the net data recovery percentage (the percentage of expected data which passed all of the quality assurance tests) was 99.88 %. Both of these percentages are very high, indicating that the sensors and data logger were performing well.

Additional information about interpreting the data presented in this report can be found in the Fact Sheet, "Interpreting Your Wind Resource Data", produced by RERL and the Massachusetts Technology Collaborative (MTC). This document is found through the RERL website:

http://www.ceere.org/rerl/about_wind/RERL_Fact_Sheet_6_Wind_resource_interpretation.pdf.

*1 m/s = 2.24 mph

SECTION 1- Station Location

The Island of Vinalhaven is 15 miles off the coast of Maine in Penobscot Bay and is occupied year-round; lobstering is the major industry. The island is powered via a cable to the mainland and Fox Islands Electric Cooperative serves both Vinalhaven and the smaller island of North Haven.

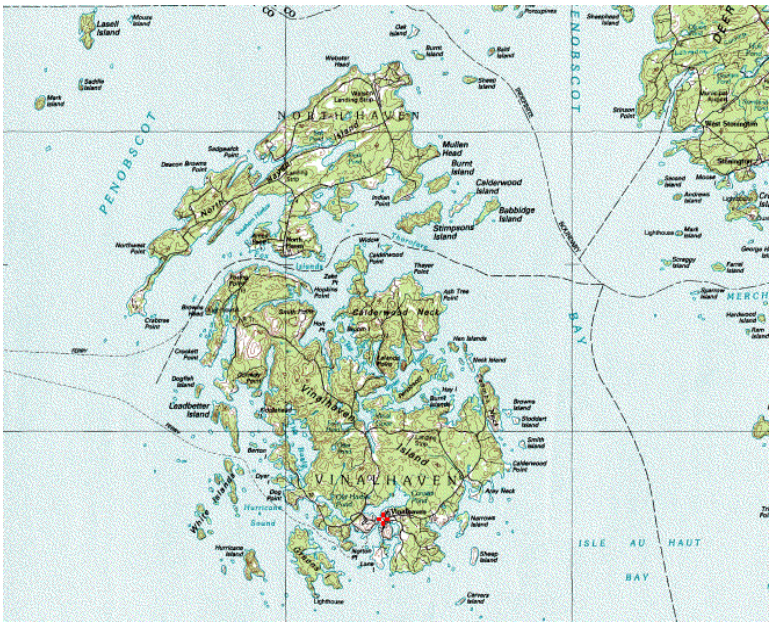

Figure 1: Map of Vinalhaven

In 2002, RERL placed a meteorological tower in the west-central section of the island with the support of the US Department of Energy, Region 1, and with the cooperation of Fox Islands Electric Cooperative. The tower base is located at NAD 27, 44°- 5'- 34.1" North, 68°- 51'- 55.4" West (Figure 2). The site elevation is 55 m (180.5 ft) above sea level. The time zone is Eastern Standard Time (daylight savings time is not used in data collection or recording).

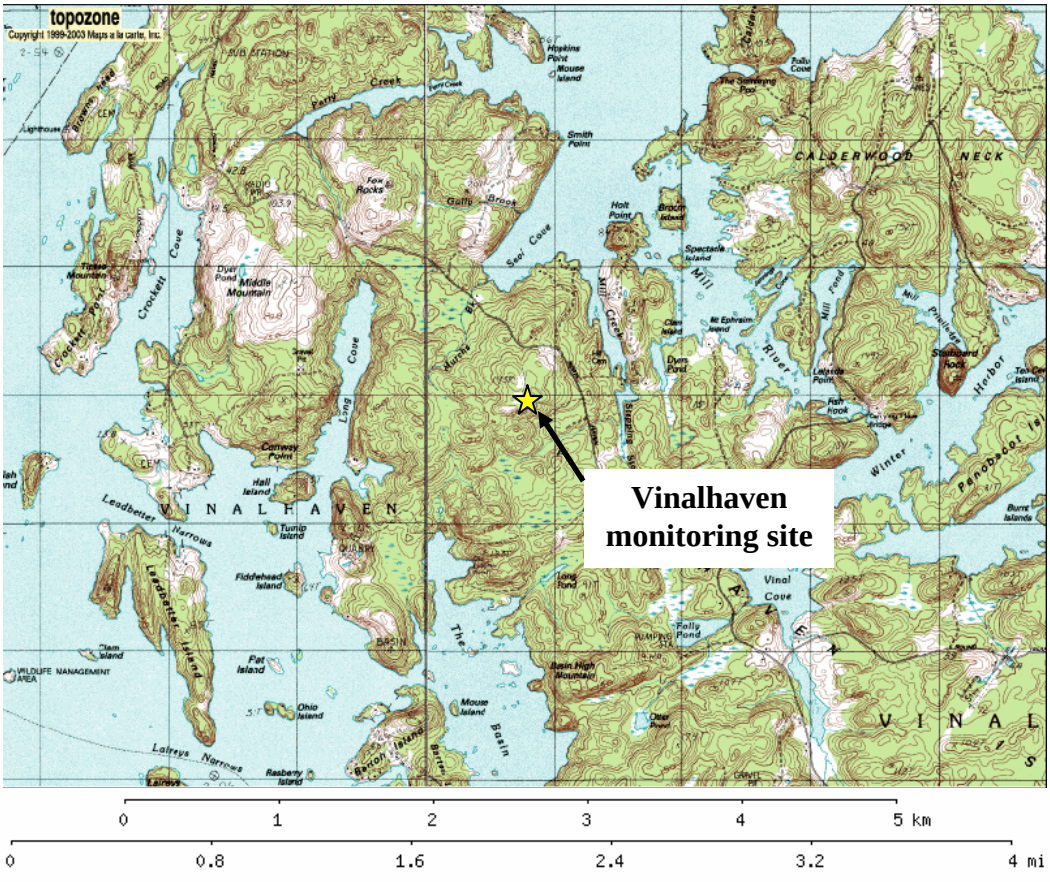

Figure 2: Location of tower on Vinalhaven

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SECTION 2 - Instrumentation and Equipment

The wind monitoring equipment is mounted on a 40-meter NRG Systems tower. The monitoring equipment is also supplied by NRG Systems, and consists of the following items:

- NRG Wind Explorer data logger; Model Number: 2333; Serial Number: 0267; Logger Firmware Version: 07.
- Electrical enclosure box
- Two #40 Anemometers, standard calibration. Height: 39.5m. (Scale Factor: 0.765; Offset: 0.35 m/s).
- Two #200P Wind direction vanes. Heights: 39.5 meters and 40.5 meters. (Scale Factor: 1; Offset: 0).
- 3 Sensors on lateral booms, 43” length. One vane on vertical stab, approximately one foot above top of tower
- Lightning rod and grounding cable
- Shielded sensor wire

Sensors notes & history:

- Only one of the anemometers and one of the vanes are connected to the logger. The others were installed for back-up purposes.
- The Wind Explorer data logger bins the vane's data into bins of one-sixteenth of a circle (22.5 degrees). This produces relatively coarse directional data.
- On the 30th of July 2003 at 2:30 pm (EDT), the primary and back-up anemometers were swapped. This was done in an attempt to determine if there was a faulty anemometer. The vanes were also swapped at that time.
- The original primary vane was aligned approximately 20 degrees west of north. This alignment is typically accounted for with offset programmed into the data logger, but the Wind Explorer does not properly allow for this function; therefore the offset is taken in the data processing. When the vanes were swapped in July 2003, the exact vane offset of the secondary vane was not recorded, although it appears to be similar to the primary. The Vinalhaven directional data from the secondary vane have been compared to directional data from Matinicus Rock, a National Data Buoy Center meteorological station 17.4 miles south of Vinalhaven. Wind direction does not vary much in this distance, so based on this comparison, it appears that the 20 degree offset in the secondary vane's data processing is approximately correct. However, it is difficult to precisely determine the exact offset because the logger bins directional data quite coarsely. The actual secondary vane offset will be measured when the tower is decommissioned and any modifications to the data can then be made if necessary.

Dave Folce, manager of Fox Islands Electric Cooperative, collects the data plug and mails it to RERL at the University of Massachusetts, Amherst, every 1 to 3 months. There is typically a 20-minutes gap in the data when the data plugs are swapped. The logger samples wind speed and direction once every 2 seconds. These are then combined into 10-minute averages, and along with the wind speed standard deviation for those 10-minute periods, are put into a binary file. These binary files are converted to ASCII text files using the NRG software "Wind Data Retriever". These text files are then imported into a database software program where they are subjected to quality assurance (QA) tests prior to using the data.

SECTION 3- Data Collection and Maintenance

The following maintenance/equipment problems occurred during the report period, and the following corrective actions taken:

- No problems with the data were encountered.
- No maintenance operations were needed or performed.

No measurement of wind speed can be perfectly accurate. Errors occur due to anemometer manufacturing variability, anemometer calibration errors, the response of anemometers to turbulence and vertical air flow and due to air flows caused by the anemometer mounting system. Every effort is made to reduce the sources of these errors.

Nevertheless, the values reported in this report have an expected uncertainty of about +/- 2% or +/- 0.2 m/s.

Data Statistics Summary

Date	Mean Wind Speed	Max Wind Speed	Turbulence Intensity	Prevailing Wind Direction
Height, units	**40 m, [m/s]**	**40 m, [m/s]**	**40 m, [ ]**	**40 m, [ ]**
Jan 2004	6.51	15.8	0.20	WNW
Feb	5.43	15.9	0.18	NNW
Mar	5.42	12.2	0.20	SSW
Apr	5.70	14.7	0.20	SW
May	4.89	11.7	0.21	SW
Jun	4.51	11.1	0.20	WSW
Jul	3.76	11.9	0.22	SW
Aug	4.65	12.6	0.19	SW
Sep	4.96	12.3	0.19	SW
Oct	5.31	16.8	0.20	SW
Nov	6.09	16.5	0.21	N
Dec 2004	5.99	18.0	0.21	N
Jan – Dec 2004	**5.27**	**18.0**	**0.20**	**SW**

SECTION 4 - Significant Meteorological Events

The National Climatic Data Center (NCDC) listed several significant storm events for Knox County during the year of 2004. Extreme cold and wind chill events were recorded on January 8, 13, and 24. There was a winter storm on February 21, 2004. Strong wind events occurred on November 3, 5, and 28, and December 1 and 23, 2004. Further details can be found at the following website: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms.

SECTION 5- Data Recovery and Validation

All raw wind data are subjected to a series of tests and filters to weed out data that are faulty or corrupted. Definitions of these quality assurance (QA) controls are given below under Test Definitions and Sensor Statistics. The gross percentage of wind speed data recovered (ratio of the number of raw data points received to data points expected) and net percentage (ratio of raw data points which passed all QA control tests to data points expected) are shown below.

Gross Data Recovered [%]	99.96
Net Data Recovered [%]	99.88

Test Definitions

All raw data were subjected to a series of validation tests, as described below. The sensors tested and the parameters specific to each sensor are given in the Sensor Performance Report that is included in APPENDIX A. Data that were flagged as invalid were not included in the statistics presented in this report.

MinMax Test: All sensors are expected to report data values within a range specified by the sensor and logger manufacturers. If a value falls outside this range, it is flagged as invalid. A data value from the sensor listed in Test Field 1 (TF1) is flagged if it is less than Factor 1 (F1) or greater than Factor 2. This test has been applied to the following sensors (as applicable): wind speed, wind speed standard deviation, wind direction, temperature, and solar insolation.

$$F1 > TF1 > F2$$

Sensor Statistics

Expected Data Points: the total number of sample intervals between the start and end dates (inclusive).

Actual Data Points: the total number of data points recorded between the start and end dates.

% Data Recovered: the ratio of actual and expected data points (this is the *gross data recovered percentage*).

Hours Out of Range: total number of hours for which data were flagged according to the MinMax test. These tests flag data that fall outside of an expected range.

% Data Good: the filter results are subtracted from the gross data recovery percentage to yield the *net data recovered percentage*.

SECTION 6 - Data Summary

This report contains several types of wind data graphs. Unless otherwise noted, each graph represents data at a height of 40 m (131.2 ft) for the entire year of 2004, starting January 1 and ending December 31.

- Time Series – In Figure 3, 10-minute average wind speeds are plotted against time for all data starting on January 1, 2004 at midnight through December 31, 2004 at 11:50 PM.

- Wind Speed Distribution – A histogram plot giving the percentage of time that the wind is at a given wind speed is shown in Figure 4. This plot shows that the wind speeds ranged between 4 and 5 m/s (8.9 and 11.2 mph) 17.7% of the time.

- Monthly Averages – A 12-month plot of the average monthly wind speed for each month from January 2004 through December 2004 is shown in Figure 5. The average monthly speed decreases significantly in the summer compared to the winter; the highest monthly average during 2004 was in January with an average wind speed of 6.51 m/s (14.58 mph) and the lowest was the average wind speed of 3.76 m/s (8.42 mph) in July.

- Diurnal – Figure 6 is a plot of the average wind speed for each hour of the day. The hourly average varied between 4.99 and 5.51 m/s (11.18 and 12.34 mph), with the lowest average speeds between 6 and 10 in the morning and the highest between 9 and 10 at night.

- Turbulence Intensity – A plot of turbulence intensity as a function of wind speed is shown in Figure 7. Turbulence Intensity is calculated as the standard deviation of the wind speed divided by the wind speed and is a measure of the gustiness of a wind resource. Lower turbulence results in lower mechanical loads on a wind turbine. In general, turbulence intensities range from 0.1 to 0.4; for Vinalhaven, the average turbulence intensity for the year was 0.20. It is clear from the graph that turbulence intensities are higher at lower wind speeds.

- Wind Rose – Figure 8 is a plot, by compass direction, showing the percentage of time that the wind comes from a given direction and the average wind speed in that direction. This wind rose shows the prevailing direction from the southwest. Wind blew from this direction 13.36% of the time with a mean wind speed of 5.15 m/s (11.54 mph). Wind blew from west-northwest 6.71% of the time and had the highest average wind speed by compass direction at 6.49 m/s (14.54 mph).

SECTION 7 - Graphs

Data for the wind speed histograms, monthly and diurnal average plots, and wind roses are included in Appendix B.

Wind Speed Time Series

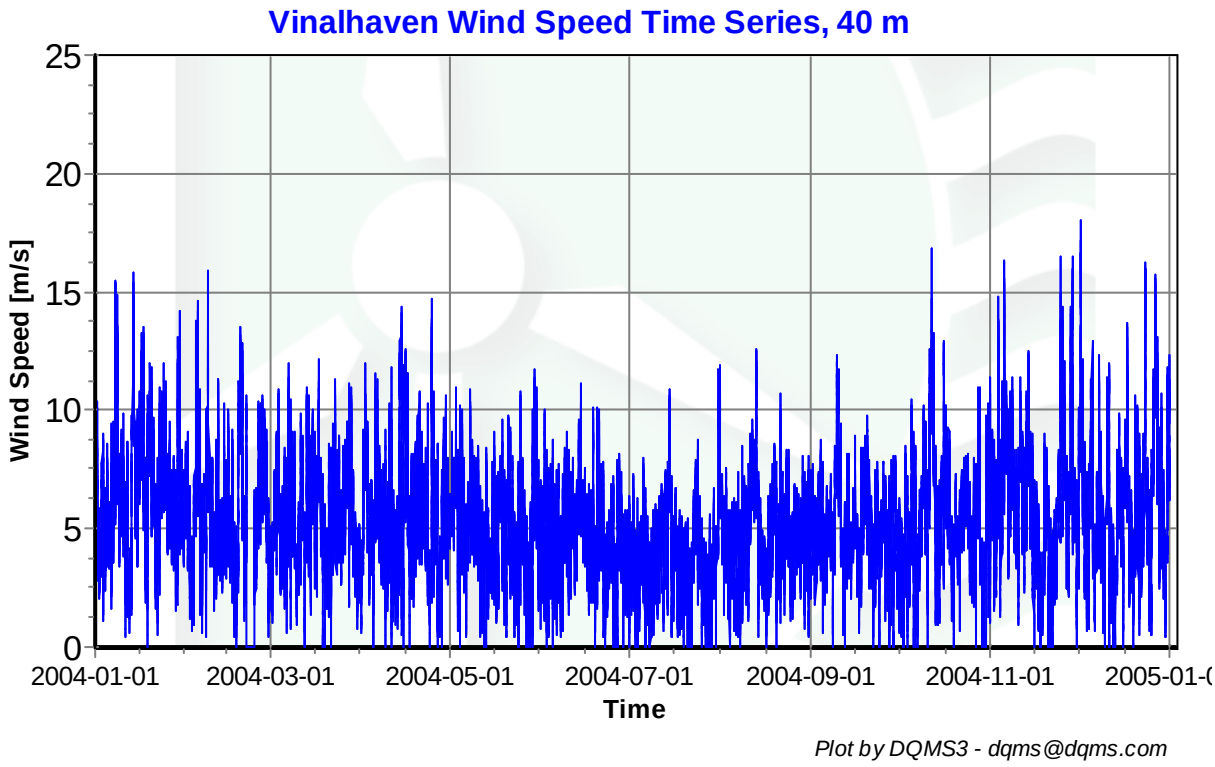

Figure 3: Wind speed time series, January 2004 – December 2004

Wind Speed Distributions

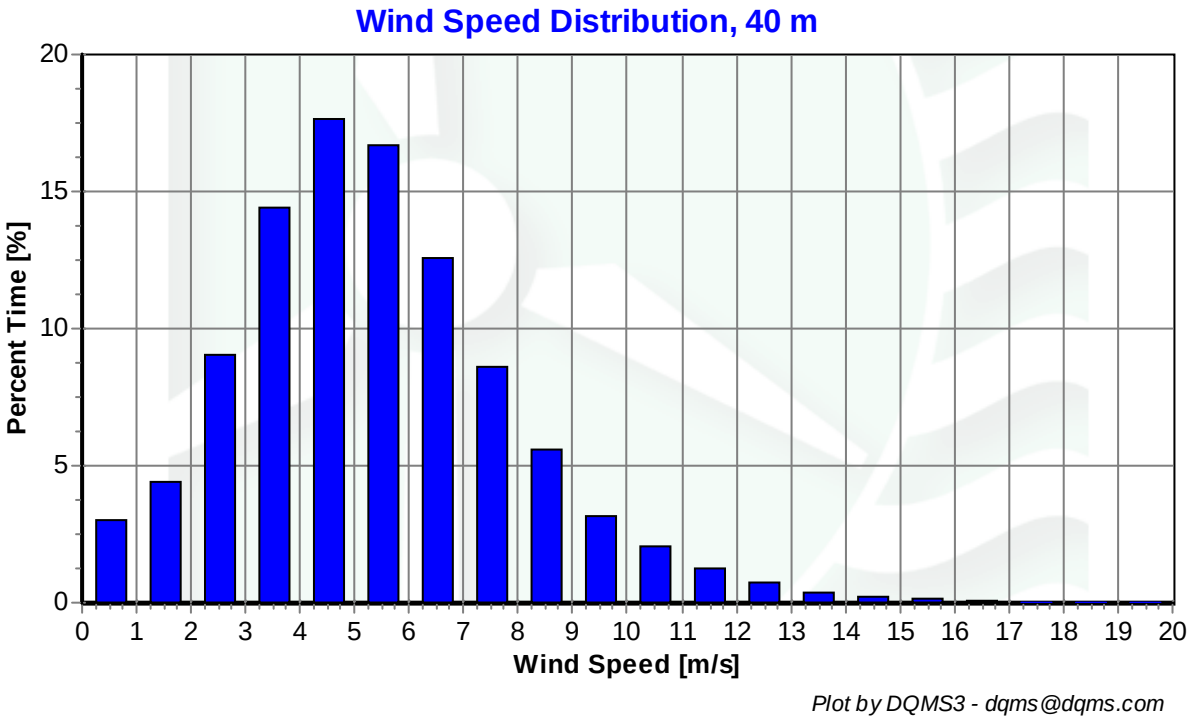

Figure 4: Wind speed distribution, January 2004 – December 2004

Monthly Average Wind Speeds

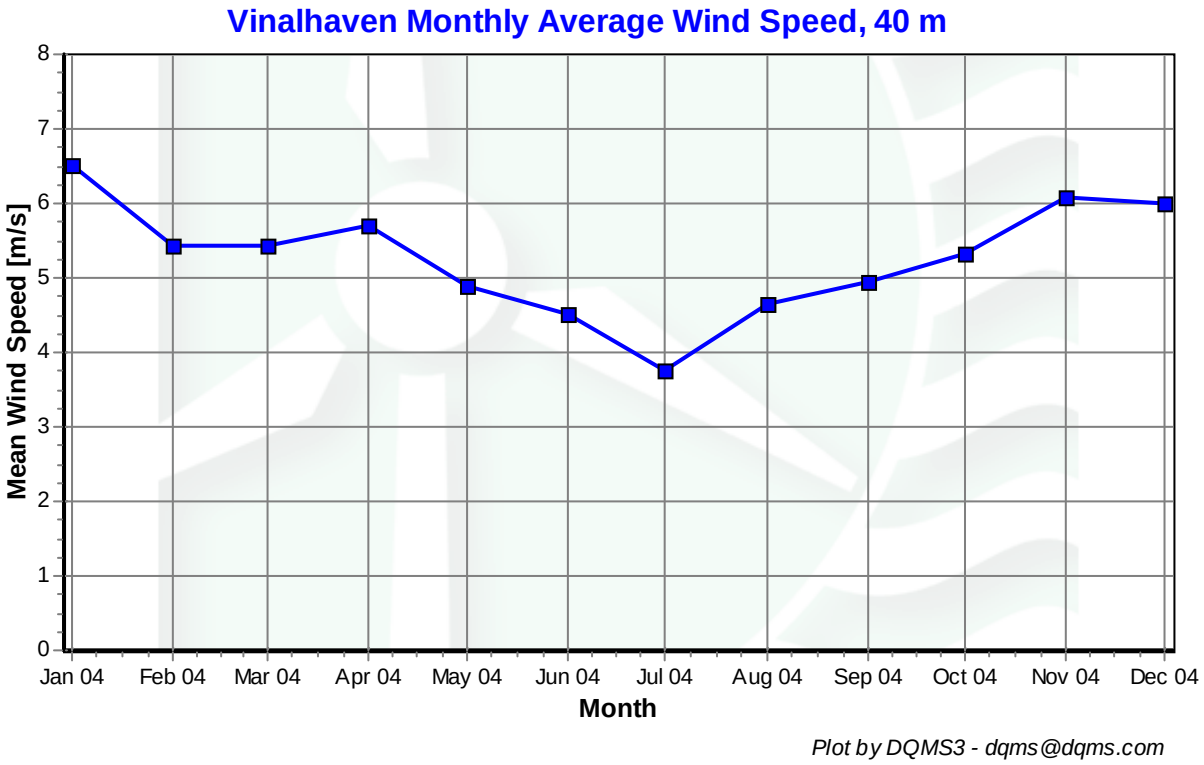

Figure 5: Average monthly wind speeds, January 2004 – December 2004

Diurnal Average Wind Speeds

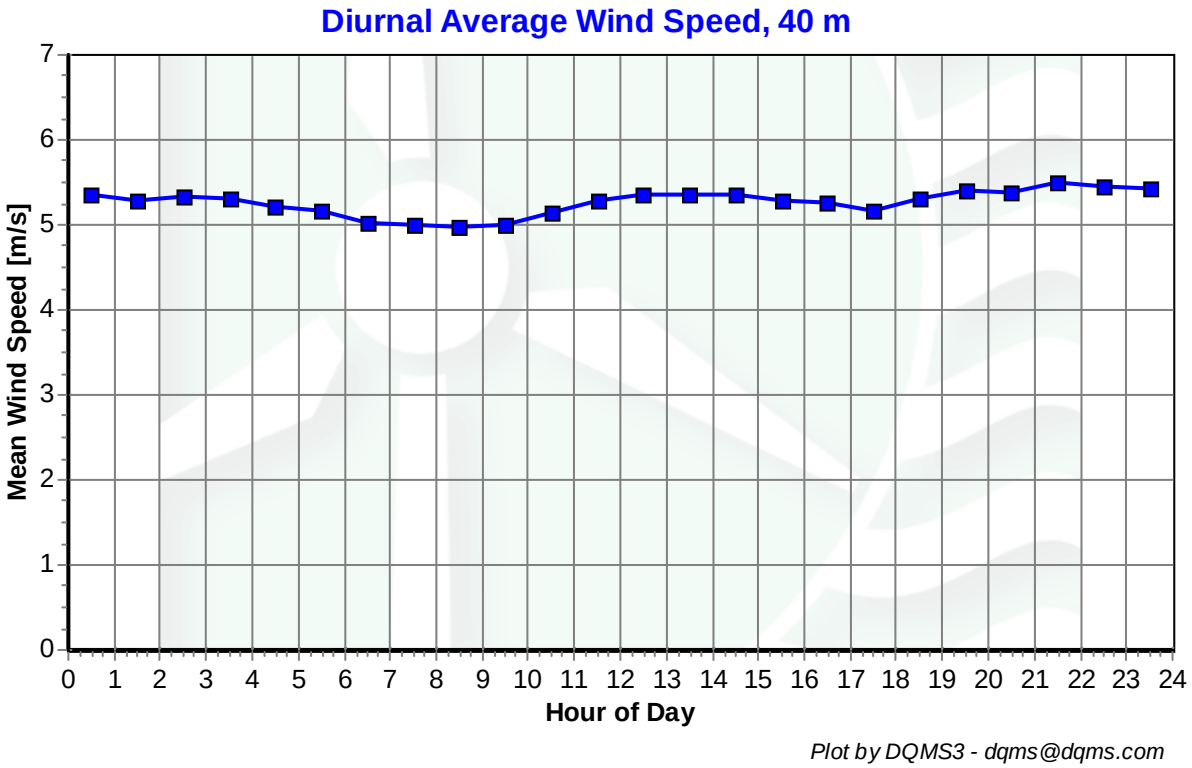

Figure 6: Diurnal average wind speeds, January 2004 – December 2004

Turbulence Intensities

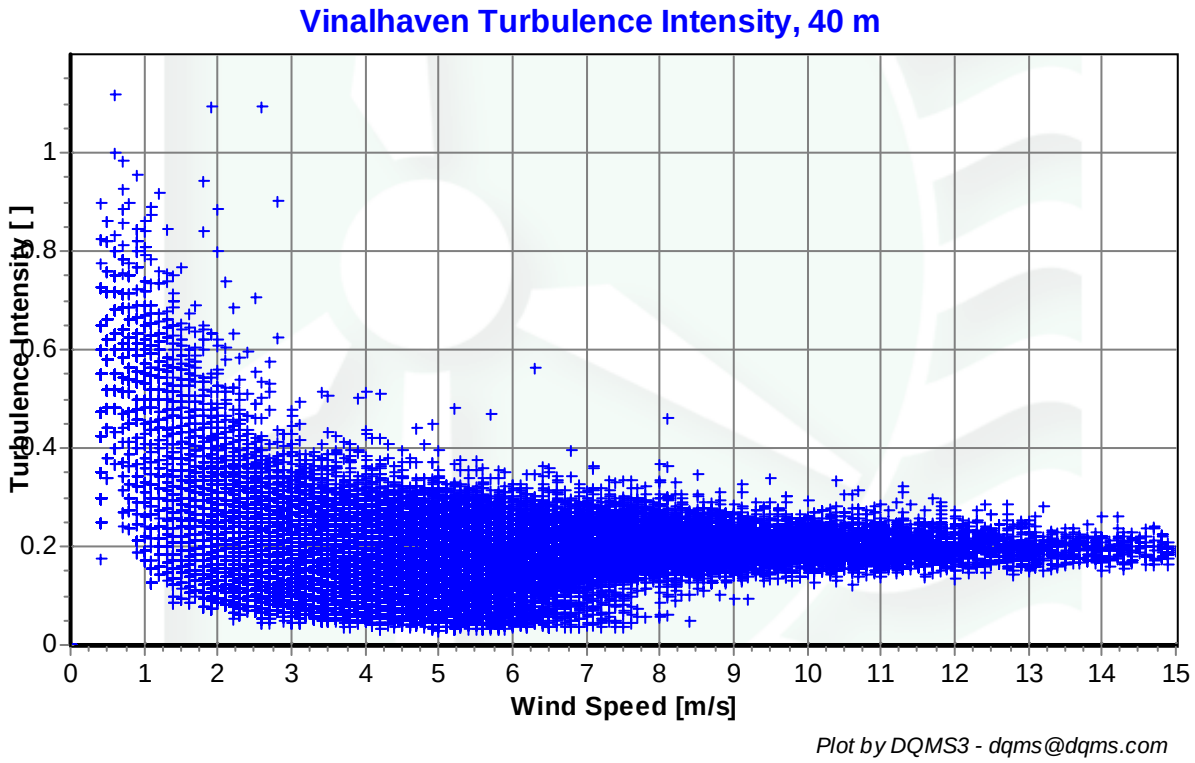

Figure 7: Turbulence Intensity vs. Wind Speed, January 2004 – December 2004

Wind Roses

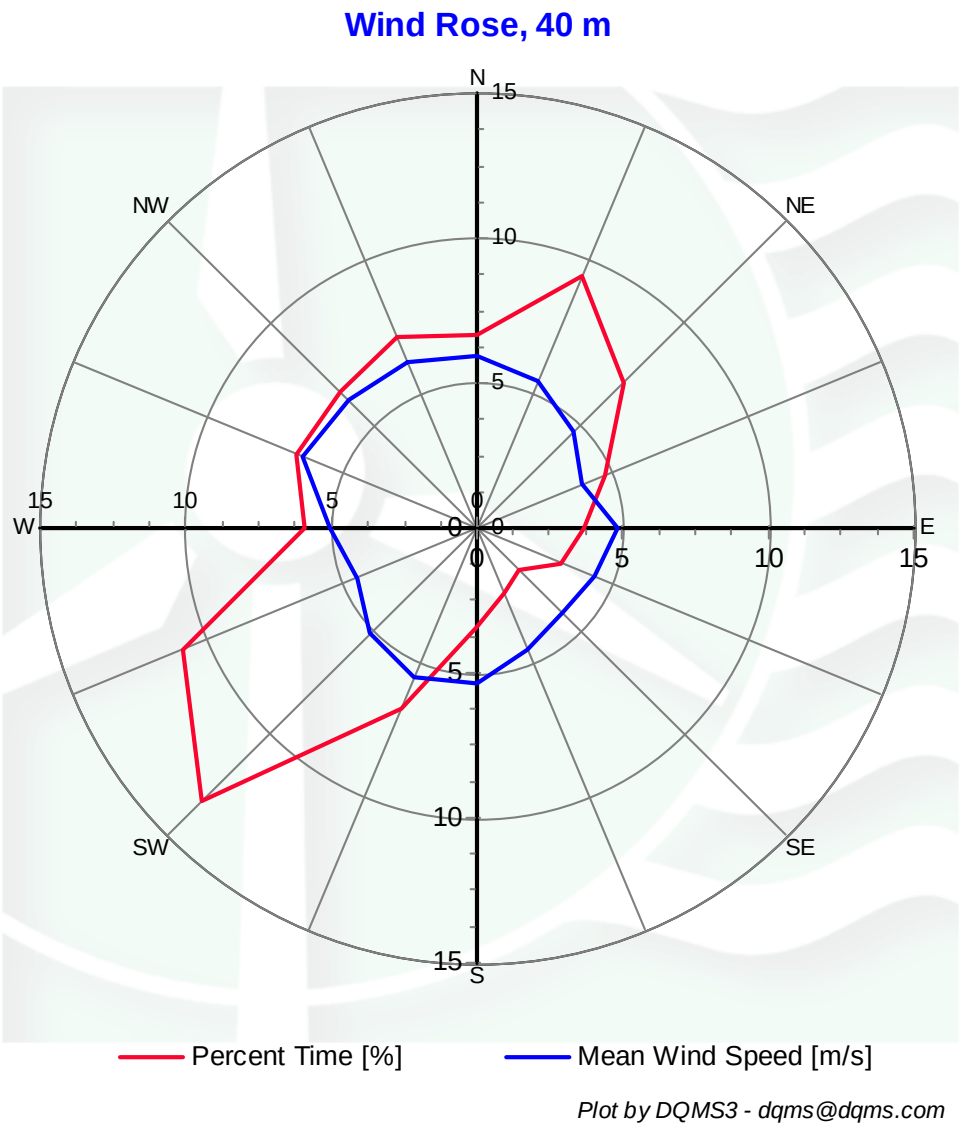

Figure 8: Wind rose, January 2004 – December 2004

APPENDIX A - Sensor Performance Report

Test Definitions

TestOrder	TestField1	TestType	Factor1	Factor2	Factor3	Factor4
1		TimeTest Insert				
2	Anem40aMS	MinMax	0	90	0	0
3	AnemSD40aMS	MinMax	0	4	0	0
4	Vane40aDEG	MinMax	0	359.9	0	0
5	Turb40zNONE	MinMax	0	2	0	0

Sensor Statistics

Sensor	Expected Data Points	Actual Data Points	% Data Recovered	Hours Out of Range	% Data Good
Anem40aMS	52704	52704	100	0	100
AnemSD40aMS	52704	52704	100	16.833	99.808
Vane40aDEG	52704	52704	100	0	100
Turb40zNONE	52704	52603	99.808	9.5	99.7
Total	**210816**	**210715**	**99.952**	**26.333**	**99.877**

Appendix B - Plot Data

Wind Speed Distribution Data

Bin center wind speed [m/s]	Percent of time [%]
0.5	3.05
1.5	4.44
2.5	9.03
3.5	14.4
4.5	17.67
5.5	16.67
6.5	12.58
7.5	8.63
8.5	5.57
9.5	3.19
10.5	2.08
11.5	1.27
12.5	0.7
13.5	0.34
14.5	0.22
15.5	0.11
16.5	0.04
17.5	0.01
18.5	0
19.5	0
20.5	0
21.5	0
22.5	0
23.5	0
24.5	0

Table 1 - Wind Speed Distribution

Monthly Average Wind Speed Data

Date	10 min Mean [m/s]
Jan 2004	6.51
Feb	5.43
Mar	5.42
Apr	5.7
May	4.89
Jun	4.51
Jul	3.76
Aug	4.65
Sep	4.96
Oct	5.31
Nov	6.09
Dec 2004	5.99

Table 2 - Wind Speed Averages

Diurnal Average Wind Speed Data

Midpoint of Hour	Mean Wind Speed [m/s]
0.5	5.35
1.5	5.29
2.5	5.34
3.5	5.31
4.5	5.21
5.5	5.17
6.5	5.02
7.5	5.01
8.5	4.99
9.5	5
10.5	5.13
11.5	5.29
12.5	5.36
13.5	5.36
14.5	5.36
15.5	5.28
16.5	5.26
17.5	5.17
18.5	5.3
19.5	5.4
20.5	5.39
21.5	5.51
22.5	5.44
23.5	5.44

Table 3 - Diurnal Average Wind Speeds

Wind Rose Data

Direction	Percent Time [%]	Mean Wind Speed [m/s]
N	6.66	5.95
NNE	9.44	5.47
NE	7.1	4.71
ENE	4.74	3.93
E	3.65	4.84
ESE	3.14	4.38
SE	2.08	4.15
SSE	2.4	4.53
S	3.39	5.36
SSW	6.73	5.58
SW	13.36	5.15
WSW	10.91	4.48
W	5.92	5.02
WNW	6.71	6.49
NW	6.61	6.23
NNW	7.17	6.22

Table 4 - Wind Rose, Time Percentage and Mean Wind Speed by Direction