WIND DATA REPORT

Vinalhaven

January - March, 2004

Prepared for

Fox Islands Electric Cooperative

by
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EXECUTIVE SUMMARY

The Renewable Energy Research Laboratory at the University of Massachusetts has collected wind resource data on the Maine island of Vinalhaven since August of 2002, under the support of the US Department of Energy, and with the cooperation of Fox Islands Electric Cooperative, the local utility.

This report summarizes the data collected from the beginning of data collection to the end of 2002. The annual average wind speed measured in that period was 5.79 m/s (12.95 mph).

SECTION 1- Station Location

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

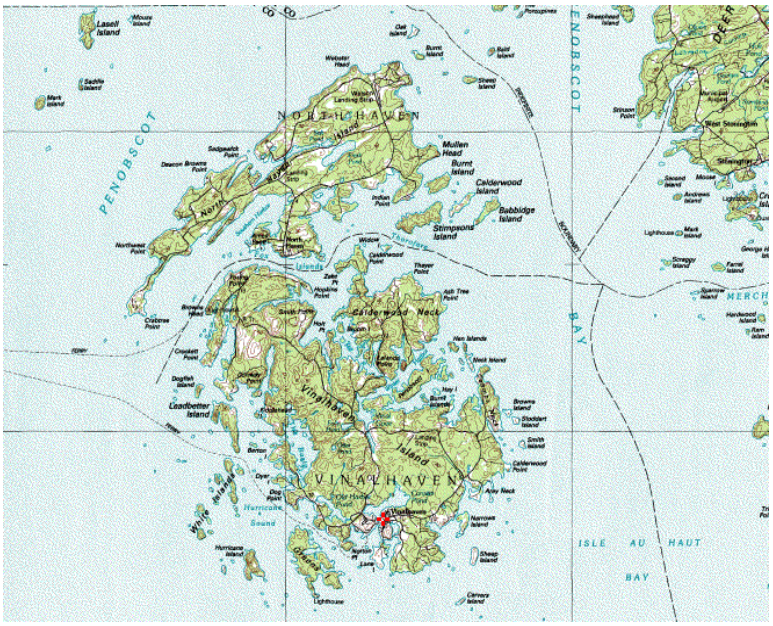

Figure 1. Map of Vinalhaven

In 2002, RERL placed a met 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.

Site data:

- Site Elevation: 55 meters
- Latitude: 44.0928, Longitude: 68.8654
- Time Zone: Eastern Standard Time (daylight savings time is not used in data collection or recording)

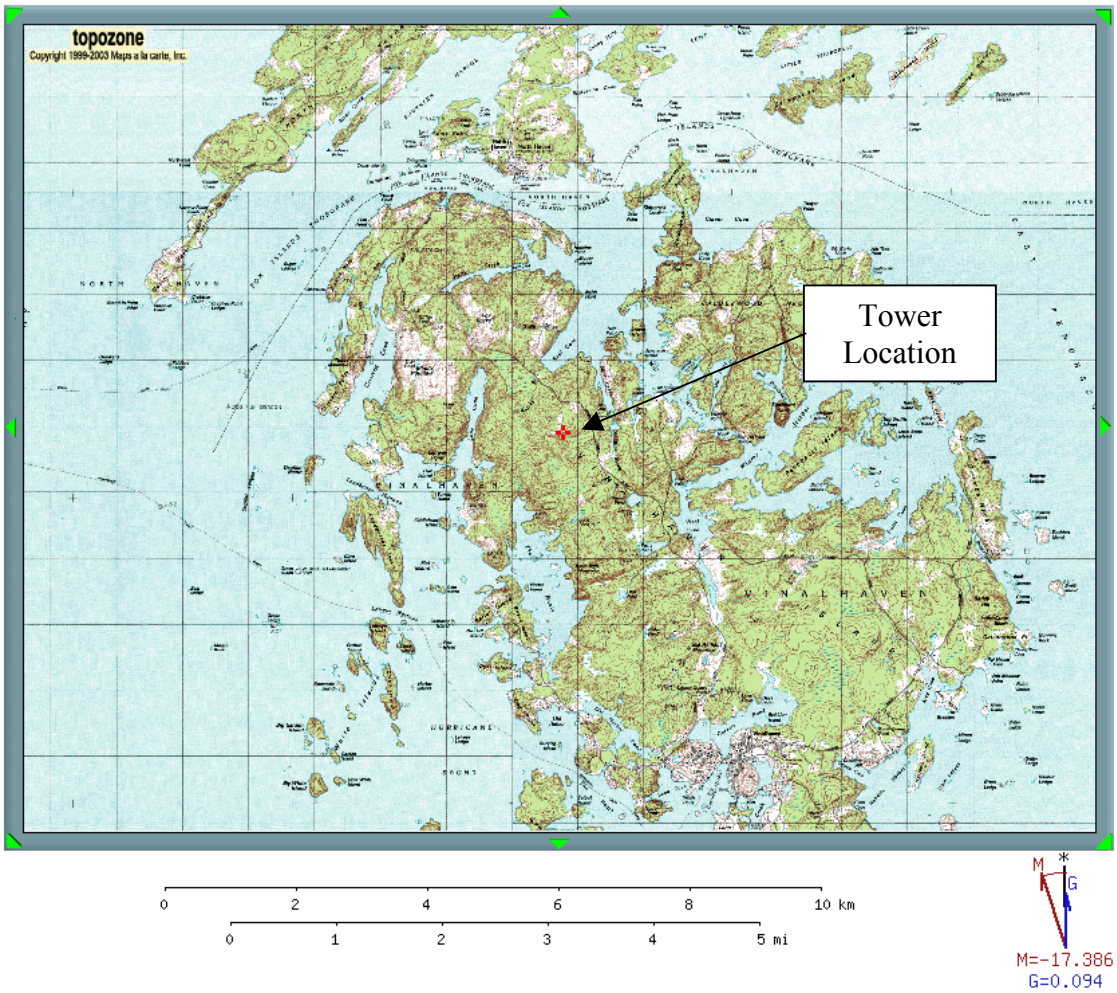

Figure 2. Location of tower on Vinalhaven

SECTION 2 - Instrumentation and Equipment

The wind monitoring equipment is mounted on a 40-meterm 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-eighth of a circle, i.e. 22.5 degrees. This produces relatively course 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. Typically this is accounted for with an offset programmed into the logger, but the Wind Explorer did not properly allow for this function; therefore the offset is taken in the data processing. Since the vanes were swapped in July 2003, this will need to be checked for the secondary vane as well, although it appears to be similar. The secondary vane may require a somewhat different offset; this analysis has not been done yet. Precision in this matter is made more difficult by the course binning of the data. Nearby wind data (from Matinicus Rock and Mount Desert Rock Island) will be useful in checking this since wind direction (as opposed to speed) does not vary substantially in that distance.

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".

A typical sample of data looks like this:

Time Stamp	Average Speed	Standard Deviation	Average Direction	Extra Channel
11/21/2002 19:20	3.4	0.86	180	-86.4
11/21/2002 19:30	4.4	1.1	158	-86.4
11/21/2002 19:40	5.3	0.98	158	-86.4
11/21/2002 19:50	4.8	1.08	158	-86.4
11/21/2002 19:20	3.4	0.86	180	-86.4
11/21/2002 19:30	4.4	1.1	158	-86.4

The "Extra Channel" is not used. These text files are then imported into a database software program where they are subjected to QA tests prior to using the data.

SECTION 3 - Data Collection and Maintenance

Dave Folce, manager of Fox Islands Electric Cooperative, collects the data plug and mails it to RERL at the University of Massachusetts every 1 to 3 months. There is typically a gap in the data of about 20 minutes when the data plug is swapped.

SECTION 4 - Significant Meteorological Events

The National Climatic Data Center (NCDC) listed no significant storm events for Knox County during the first three months of 2004 (see their 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. These control filters were designed to automate the quality control process and used many of the previous hand-worked data sets made at UMass to affect a suitable emulation. 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 [%]	100
Net Data Recovered [%]	100

There were no missing data points due to card changes and 4.33 hours of flagged wind speed standard deviation values, primarily due to a known logger bug that produces a speed standard deviation value of 6.1.

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 MinMax and MinMaxT tests. These tests flag data which 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 from 1 quarter (3 months). The following graphs are included:

- Time Series – 10-minute average wind speeds are plotted against time.
- Wind Speed Distribution – A histogram plot giving the percentage of time that the wind is at a given wind speed.
- Monthly Average – A plot of the monthly average wind speed over a 12-month period, from April 1, 2003 until March 31, 2004.
- Diurnal – A plot of the average wind speed for each hour of the day. The diurnal pattern is generally flat, with lightly lower wind speeds at mid-day and higher speeds in the evening.
- Turbulence Intensity – A plot of turbulence intensity as a function of wind speed. 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.
- Wind Rose – 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. The plots show that the winds are generally more from the NW.

Data summary:

For the last four months of 2002:

- Annual Average speed: 5.79 m/s
- Peak 10-minute average speed: 15.9 m/s
- Predominant wind direction: 292.5 degrees
- Average turbulence intensity: 0.20

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

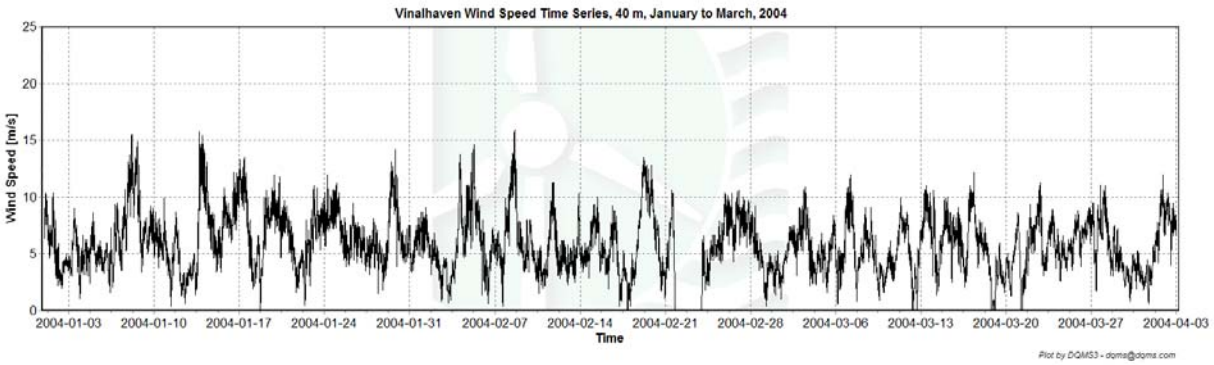

Figure 3. Wind speed time series, January to March, 2004

Wind Speed Distributions

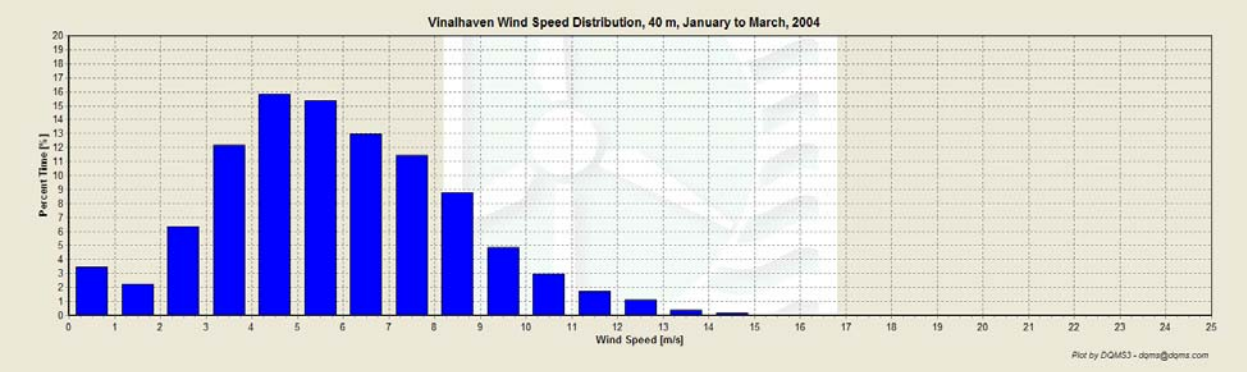

Figure 4. Wind speed distribution, January to March, 2004

Monthly Average Wind Speeds

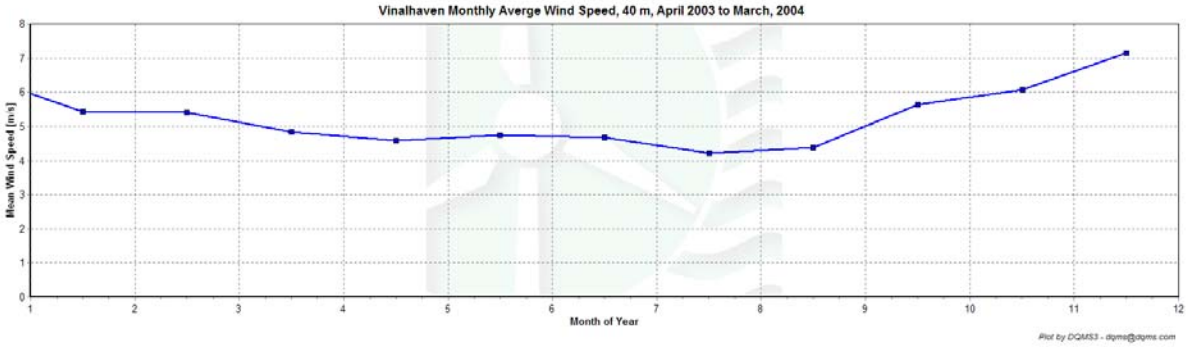

Figure 5. Average monthly wind speeds, April 2003 to March 2004

Diurnal Average Wind Speeds

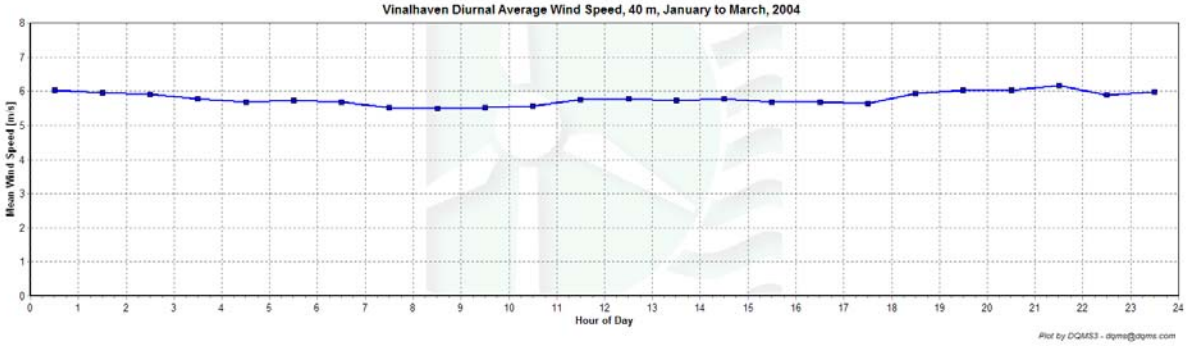

Figure 6. Diurnal average wind speeds, January to March, 2004

Turbulence Intensities

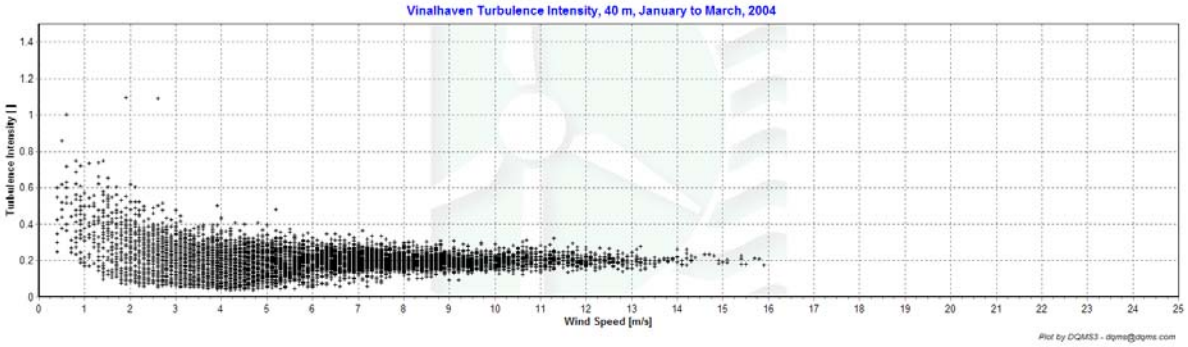

Figure 7. Turbulence intensity, January to March, 2004

Wind Roses

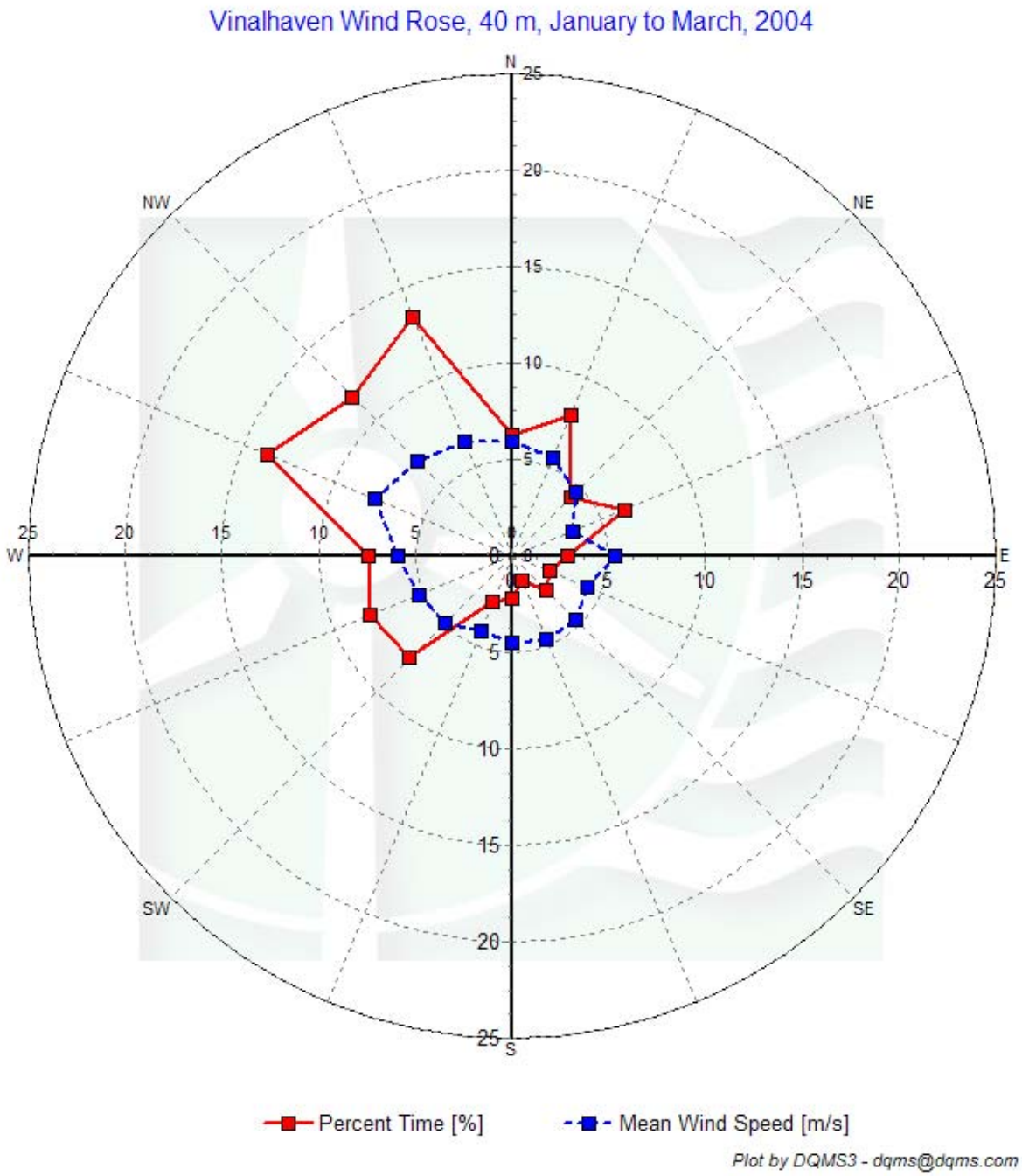

Figure 8. Wind rose, January to March, 2004

APPENDIX A - Sensor Performance Report

Test Definitions

VH_expRaw	Data Quality Report	2003-01-01 00:10:00 to 2004-01-01				
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		
5	Turb40zNONE	MinMax	0	2		

Sensor Statistics

Sensor	Expected Data Points	Actual Data Points	% Data Recovered	Hours Out of Range	% Data Good
Anem40aMS	13104	13104	100	0	100
AnemSD40aMS	13104	13104	100	4.333	99.802
Vane40aDEG	13104	13104	100	0	100
Turb40zNONE	13104	13078	99.802	0.667	99.771

Appendix B - Plot Data

Wind Speed Distribution Data

January to March, 2004

Bin center wind speed [m/s]	Percent of time [%]
0.5	3.44
1.5	2.26
2.5	6.36
3.5	12.19
4.5	15.8
5.5	15.35
6.5	12.97
7.5	11.45
8.5	8.76
9.5	4.88
10.5	2.97
11.5	1.76
12.5	1.14
13.5	0.41
14.5	0.18
15.5	0.08
16.5	0
17.5	0
18.5	0
19.5	0
20.5	0
21.5	0
22.5	0
23.5	0
24.5	0

Monthly Average Wind Speed Data

Begin of month	Sensor
yyyy-mm-dd hh:mm	Anem40aMSAvg
1/1/2004 0:00	6.51
2/1/2004 0:00	5.43
3/1/2004 0:00	5.42

Diurnal Average Wind Speed Data

January to March, 2004

Midpoint of Hour	Mean Wind Speed
0.5	6.03
1.5	5.96
2.5	5.91
3.5	5.78
4.5	5.68
5.5	5.73
6.5	5.68
7.5	5.53
8.5	5.51
9.5	5.53
10.5	5.57
11.5	5.76
12.5	5.78
13.5	5.74
14.5	5.78
15.5	5.68
16.5	5.69
17.5	5.64
18.5	5.93
19.5	6.03
20.5	6.02
21.5	6.16
22.5	5.89
23.5	5.98

Wind Rose Data

January to March, 2004

Wind Direction Bin Midpoint	Mean 40 m wind speed [m/s]	Percent of Time [%]
0	5.92	6.29
22.5	5.51	7.85
45	4.66	4.26
67.5	3.37	6.3
90	5.29	2.9
112.5	4.24	2.06
135	4.66	2.51
157.5	4.7	1.42
180	4.48	2.21
202.5	4.24	2.56
225	4.86	7.48
247.5	5.23	7.92
270	5.9	7.42
292.5	7.7	13.72
315	6.9	11.67
337.5	6.46	13.43