

FINAL WIND DATA REPORT

Vinalhaven

August 28, 2002 – August 25, 2005

Prepared for

Fox Islands Electric Cooperative

By

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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 on August 28, 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 equipment was taken down on August 25, 2005, after completing almost three full years of wind measurements. For this time period, August 28, 2002, through August 25, 2005, the gross data recovery percentage (the actual percentage of expected data received) was 99.95 % and the net data recovery percentage (the percentage of expected data which passed all of the quality assurance tests) was 99.82 %. In the final months of measurement, January 1, 2005, through August 25, 2005, the gross data recovery percentage was 99.96% and the net data recovery percentage was 99.84%. All of these percentages are very high, indicating that the sensors and data logger performed well.

This final data report summarizes the wind data collected between August 28, 2002, and August 25, 2005. The mean speed at 40 m over this time period was 5.3 m/s (11.9 mph^{*}). The highest monthly mean wind speed during the three years at 40 m was in December 2003 at 7.1 m/s (16.0 mph) and the lowest was 3.8 m/s (8.4 mph) in July 2004. The prevailing wind direction over the three-year period was south-southwest. The 40 m mean wind speed for the time period of January 1, 2005, through August 25, 2005, was 5.0 m/s (11.3 mph) and the prevailing wind direction was southwest.

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 = 2.237 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).

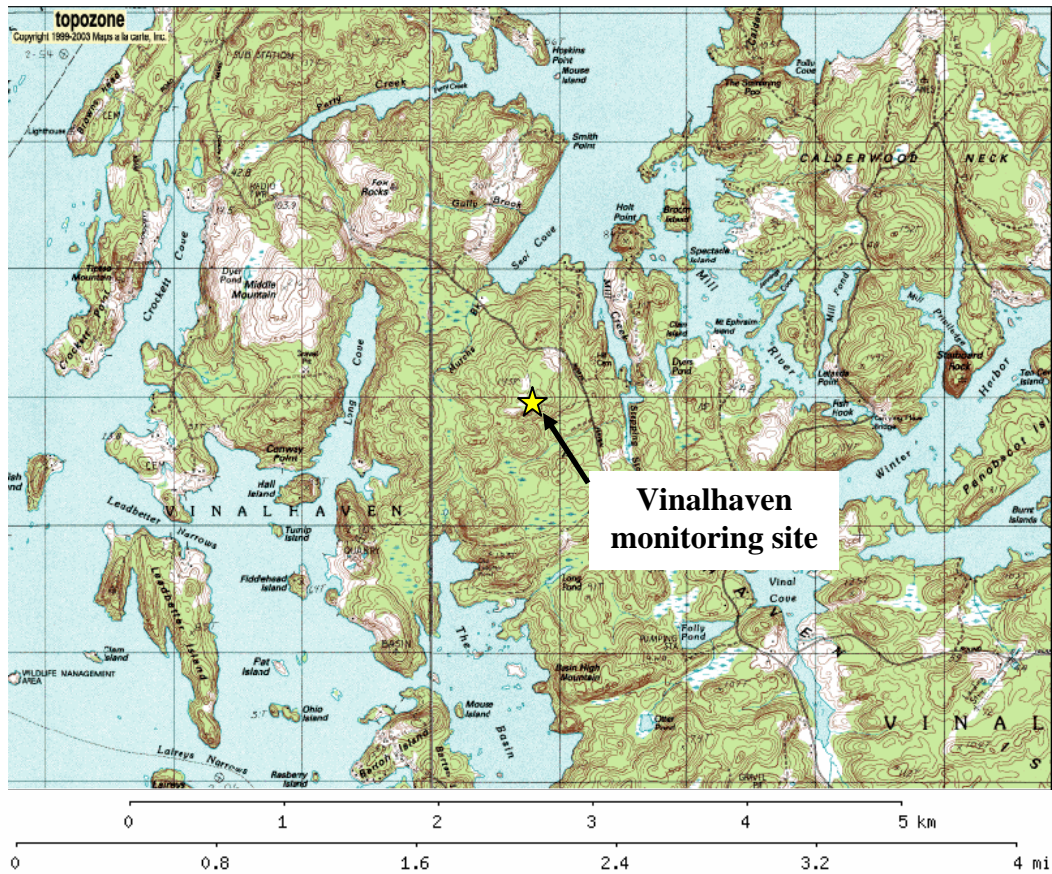


Figure 2: Location of tower on Vinalhaven

www.topozone.com

SECTION 2 - Instrumentation and Equipment

The wind monitoring equipment was mounted on a 40-meter NRG Systems tower. The monitoring equipment was 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 were connected to the logger. The others were installed for back-up purposes.
- The Wind Explorer data logger binned the vane's data into bins of one-sixteenth of a circle (22.5 degrees). This produces relatively coarse directional data.

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

Dave Folce, manager of Fox Islands Electric Cooperative, collected the data plugs and mailed them to RERL at the University of Massachusetts, Amherst, about every 1 to 3 months. RERL staff collected the last 3 months of data when the tower was decommissioned. When the data plugs are swapped there is typically a 20-minute gap in the data. The following maintenance/equipment problems occurred during the measurement period, and the following corrective actions taken:

- 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. While this alignment is typically accounted for with the offset programmed into the data logger, the Wind Explorer does not properly allow for this function. Therefore, the offset is taken into account during the data processing. When the vanes were swapped in July 2003, the exact vane offset of the secondary vane was not recorded, although it appeared 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. 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 tower was taken down on August 25, 2005, so more than 10% of the data are missing for the month of August 2005, and therefore no statistics are reported for that month. During the period from January 2005 through August 25, 2005, no other problems with the data were encountered and no maintenance operations were needed or performed on the equipment.

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, []
Sep 2002 – Aug 2003	5.4	18.0	0.18	SSW
Sep 2003 – Aug 2004	5.3	19.7	0.20	SSW
Sep 2004 – Aug 2005	5.2	18.0	0.20	N
Aug 2002 – Aug 2005	5.3	19.7	0.19	SSW

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 2005	6.3	17.5	0.19	N
Feb	5.0	14.9	0.18	ENE
Mar	5.3	13.2	0.18	N
Apr	5.6	15.5	0.20	SSW
May	5.0	16.6	0.21	E
Jun	4.5	12.3	0.21	WSW
Jul	4.2	13.4	0.20	SW
Aug	---	---	---	---
Sep 2004 – Aug 2005	5.0	17.5	0.20	SW

SECTION 4 - Significant Meteorological Events

The National Climatic Data Center (NCDC) listed two significant windstorm events for Knox County during 2005:

- January 21 & 27, 2005 – Extreme cold/ wind chill.

The wind conditions were close to average for the rest of the year. Further details can be found at the following websites:

<<http://www.erh.noaa.gov/box/MonthlyClimate2.shtml>>,
 <<http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms>>

SECTION 5- Data Recovery and Validation

All 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 data points received to data points expected) and net percentage (ratio of data points which passed all QA control tests to data points expected) are shown below.

August 28, 2002 – August 25, 2005

Gross Data Recovered [%]	99.95
Net Data Recovered [%]	99.82

January 1, 2005 – August 25, 2005

Gross Data Recovered [%]	99.96
Net Data Recovered [%]	99.84

Once the tower was taken down, the slope and offset of the anemometer were compared to a calibrated anemometer in the UMass, Amherst, wind tunnel. These tests verified that the performance of the anemometer did not degrade during the measurement period and that it were accurately calibrated when it were first installed on the tower.

Test Definitions

All 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 three-year measurement period of August 28, 2002, through August 25, 2005.

- **Time Series** – In Figure 3, 10-minute average wind speeds are plotted against time for all data starting on August 28, 2002, at 2:40 PM through August 25, 2005, 10:00 AM. This time series demonstrates the seasonal oscillations of the wind speed, where it is generally higher in the winter months than in the summer.
- **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) 17.3% of the time.
- **Monthly Averages** – A 35-month plot of the average monthly wind speed for each month from September 2002 through July 2005 is shown in Figure 5. August 2005 is not shown because data was collected for less than 90% of the month. The average monthly speeds decreases significantly in the summer compared to the winter; the highest monthly average during the measurement period was in December 2003 with an average wind speed of 7.1 m/s (16.0 mph) and the lowest was the average wind speed of 3.8 m/s (8.4 mph) in July 2004.
- **Diurnal** – Figure 6 is a plot of the average wind speed for each hour of the day. The hourly average varied between 5.0 and 5.5 m/s (11.2 and 12.3 mph), with the lowest averages speeds between 6 and 8 in the morning and the highest between 7 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 January 1 through August 25, 2005, 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 south-southwest. Wind blew from this direction 10.9% of the time with a mean wind speed of 5.3 m/s (11.8 mph). Wind blew from the west 7.5% of the time and had the highest average wind speed by compass direction at 6.36 m/s (14.2 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

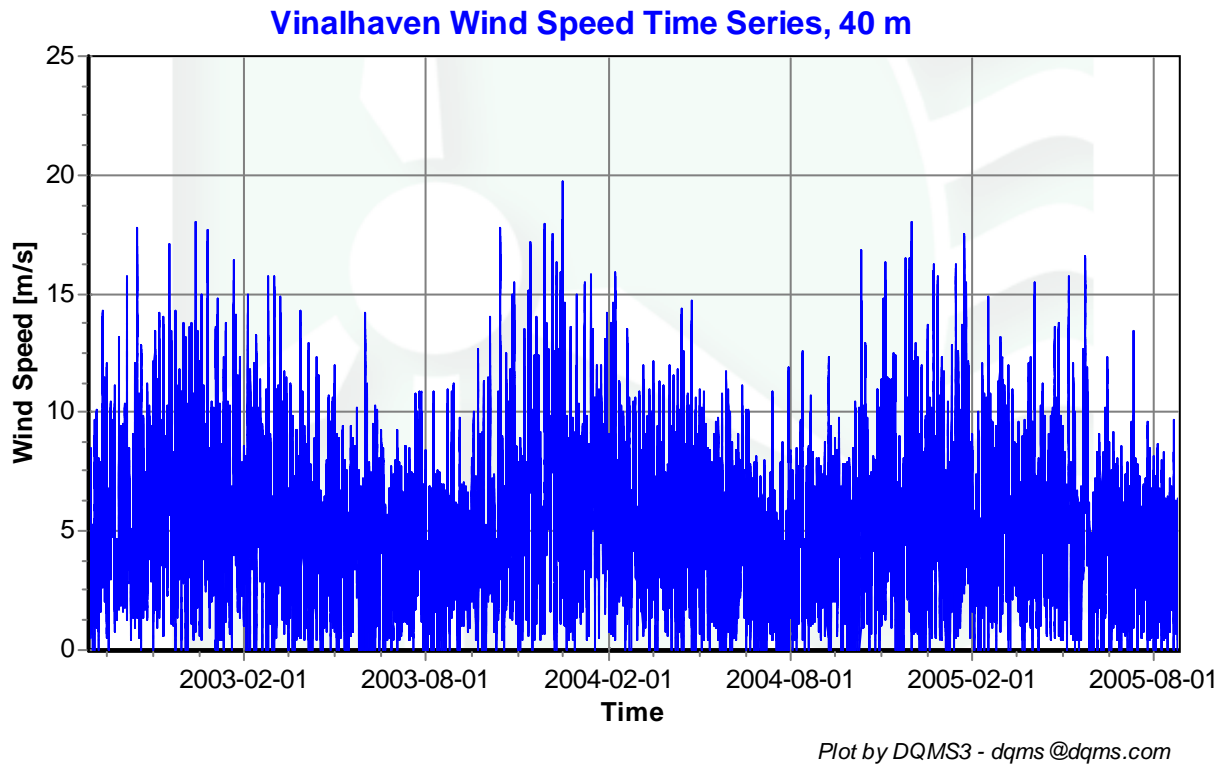


Figure 3: Wind speed time series, August 28, 2002 – August 25, 2005

Wind Speed Distributions

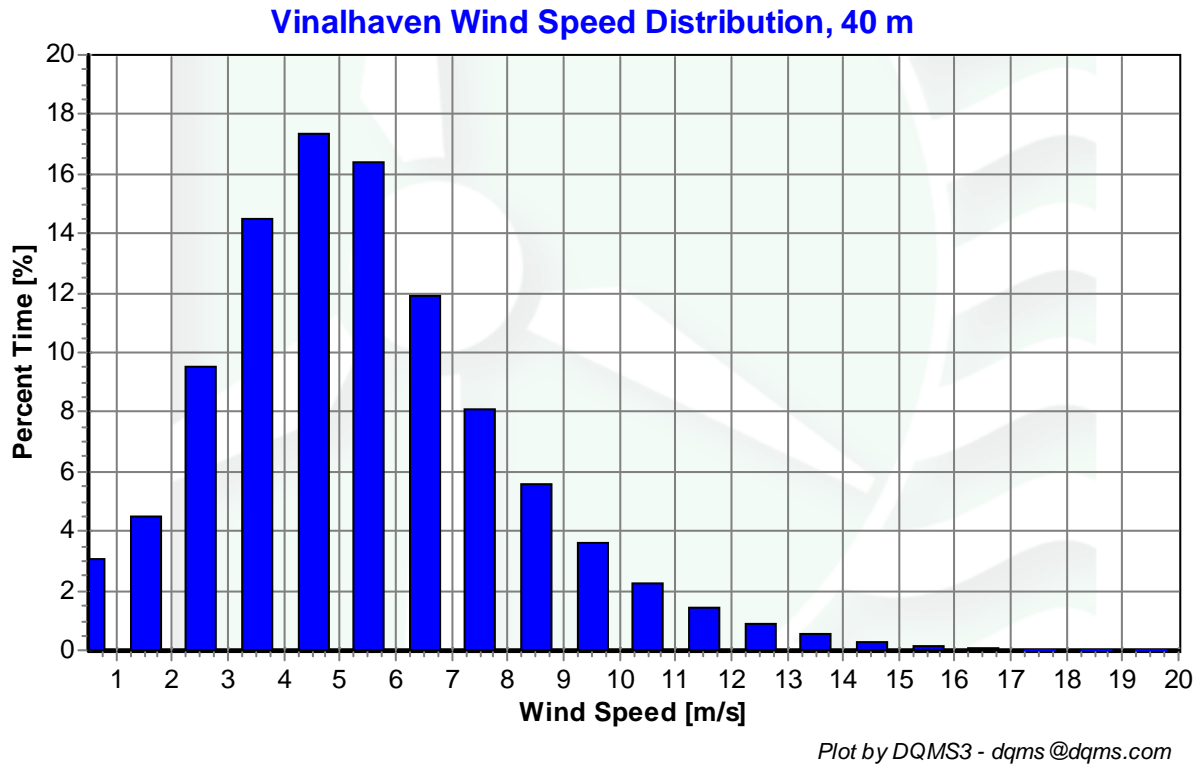
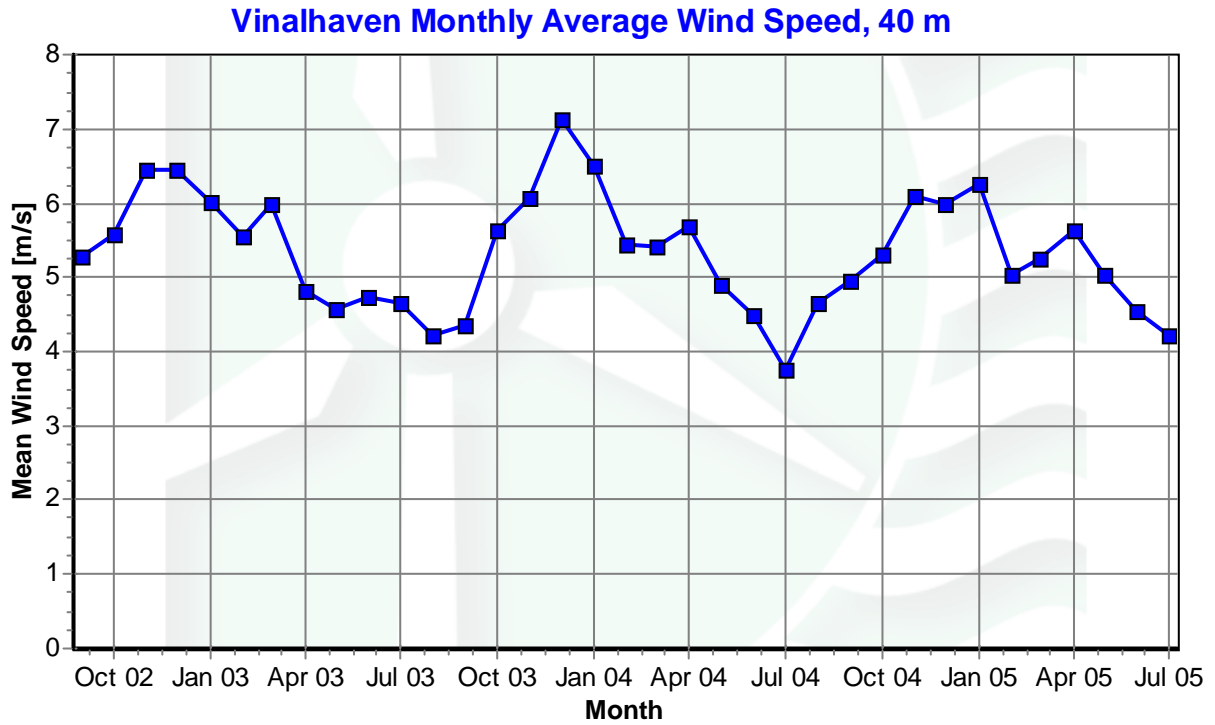


Figure 4: Wind speed distribution, August 28, 2002 – August 25, 2005

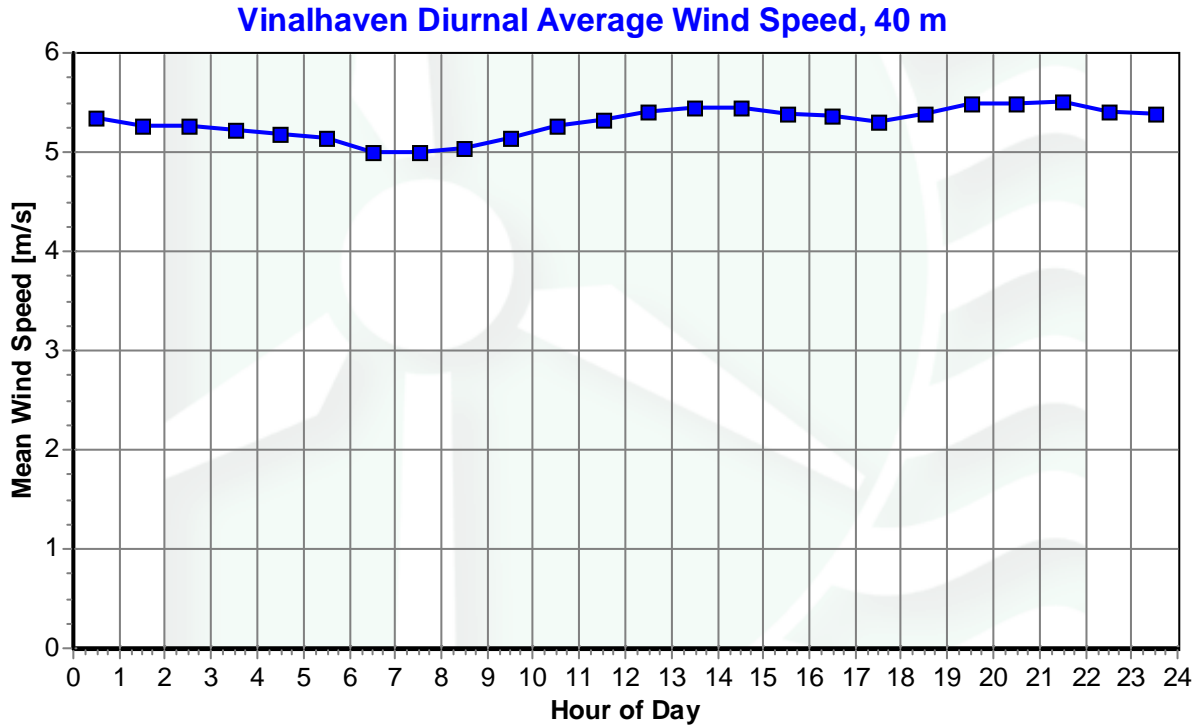
Monthly Average Wind Speeds



Plot by DQMS3 - dqms@dqms.com

Figure 5: Average monthly wind speeds, September 2002 – July 2005

Diurnal Average Wind Speeds

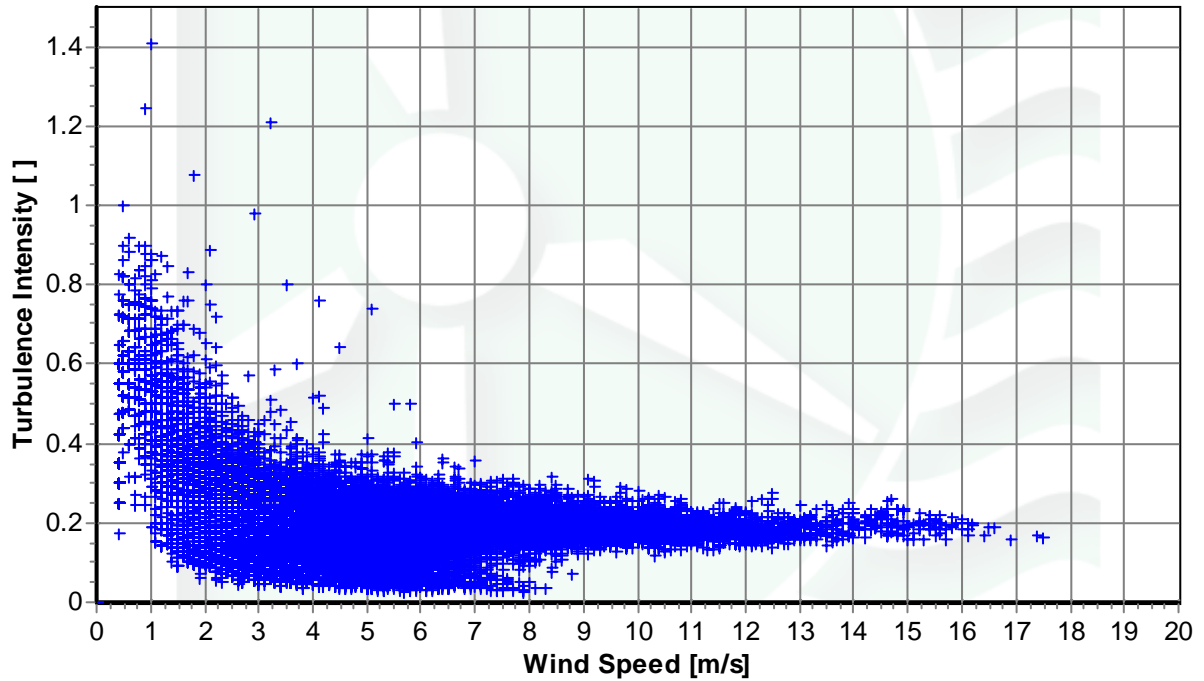


Plot by DQMS3 - dqms@dqms.com

Figure 6: Diurnal average wind speeds, August 28, 2002 – August 25, 2005

Turbulence Intensities

Vinalhaven Turbulence Intensity, 40 m

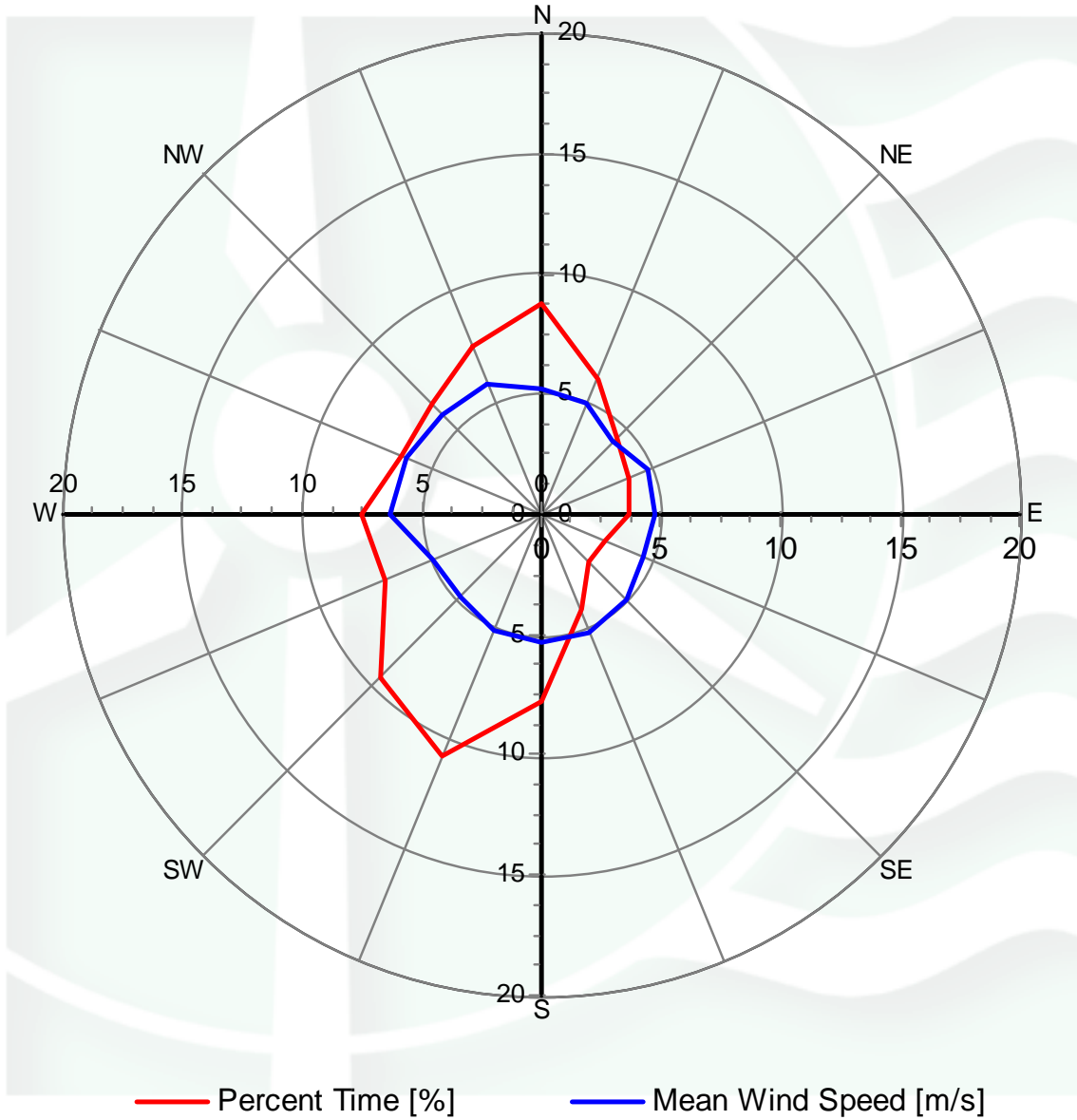


Plot by DQMS3 - dqms@dqms.com

Figure 7: Turbulence Intensity vs. Wind Speed, January 2005 – August 25, 2005

Wind Roses

Vinalhaven Wind Rose, 40 m



Plot by DQMS3 - dqms@dqms.com

Figure 8: Wind rose, August 28, 2002 – August 25, 2005

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	157355	157348	99.996	48.667	99.810
AnemSD40aMS	157355	157348	99.996	51.167	99.800
Vane40aDEG	157355	157348	99.996	0	99.996
Turb40zNONE	157355	157041	99.800	35.667	99.664
Total	629420	629085	99.947	135.5	99.818

Appendix B - Plot Data

Wind Speed Distribution Data

Bin center wind speed [m/s]	Percent of time [%]
0.5	3.04
1.5	4.48
2.5	9.52
3.5	14.49
4.5	17.34
5.5	16.4
6.5	11.93
7.5	8.09
8.5	5.57
9.5	3.60
10.5	2.28
11.5	1.40
12.5	0.87
13.5	0.51
14.5	0.26
15.5	0.13
16.5	0.06
17.5	0.02
18.5	0.00
19.5	0.00
20.5	0.00
21.5	0.00
22.5	0.00
23.5	0.00
24.5	0.00

Table 1 - Wind Speed Distribution

Monthly Average Wind Speed Data

Date	10 min Mean [m/s]	Date	10 min Mean [m/s]	Date	10 min Mean [m/s]
Sep 2002	5.28	Sep 2003	4.37	Sep 2004	4.95
Oct	5.58	Oct	5.65	Oct	5.31
Nov	6.46	Nov	6.07	Nov	6.09
Dec	6.46	Dec	7.14	Dec	5.98
Jan 2003	6.02	Jan 2004	6.5	Jan 2005	6.25
Feb	5.56	Feb	5.43	Feb	5.04
Mar	5.99	Mar	5.41	Mar	5.25
Apr	4.83	Apr	5.7	Apr	5.64
May	4.57	May	4.89	May	5.04
Jun	4.74	Jun	4.5	Jun	4.53
Jul	4.66	Jul	3.75	Jul	4.23
Aug	4.21	Aug	4.65	Aug	---

Table 2 - Wind Speed Averages

Diurnal Average Wind Speed Data

Midpoint of Hour	Mean Wind Speed [m/s]
0.5	5.34
1.5	5.27
2.5	5.26
3.5	5.22
4.5	5.19
5.5	5.15
6.5	4.99
7.5	5.00
8.5	5.04
9.5	5.13
10.5	5.26
11.5	5.33
12.5	5.41
13.5	5.45
14.5	5.45
15.5	5.39
16.5	5.36
17.5	5.30
18.5	5.39
19.5	5.48
20.5	5.49
21.5	5.51
22.5	5.41
23.5	5.39

Table 3 - Diurnal Average Wind Speeds

Wind Rose Data

Direction	Percent Time [%]	Mean Wind Speed [m/s]
N	8.76	5.25
NNE	6.09	4.99
NE	4.47	4.25
ENE	3.93	4.82
E	3.62	4.76
ESE	2.84	4.66
SE	2.82	4.98
SSE	4.28	5.29
S	7.74	5.33
SSW	10.87	5.27
SW	9.57	4.81
WSW	7.10	4.96
W	7.52	6.36
WNW	6.32	6.11
NW	6.49	5.89
NNW	7.57	5.83

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