WIND DATA REPORT

Orleans

October 27, 2003 – November 31, 2003

Prepared for

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by

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EXECUTIVE SUMMARY

This wind measurement station is installed at the town watershed in Orleans, MA. Installed on October 27 of 2003, the station is in continuous operation to this day. The two sets of two anemometers and one wind vane are mounted at 50 m (164.0 ft) and 40 m (131.2 ft), an additional vane and anemometer are mounted at 20 m (65.6 ft).

During the period covered by this report, October 27, 2003 – November 2003, the mean recorded wind speed at 50 meters was 5.83 m/s (13.0 mph); the prevailing wind direction at 40 meters was WSW. The gross data recovery percentage (the actual percentage of expected data received) was 100% and the net data recovery percentage (the percentage of expected data which passed all of the quality assurance tests) was 94.181%.

SECTION 1 - Station Location

The Orleans site is located on the town watershed in Orleans, MA. The tower is on a cleared hilltop, surrounded by trees. The location of the tower base is at 41.7584° North, 69.9933° West.

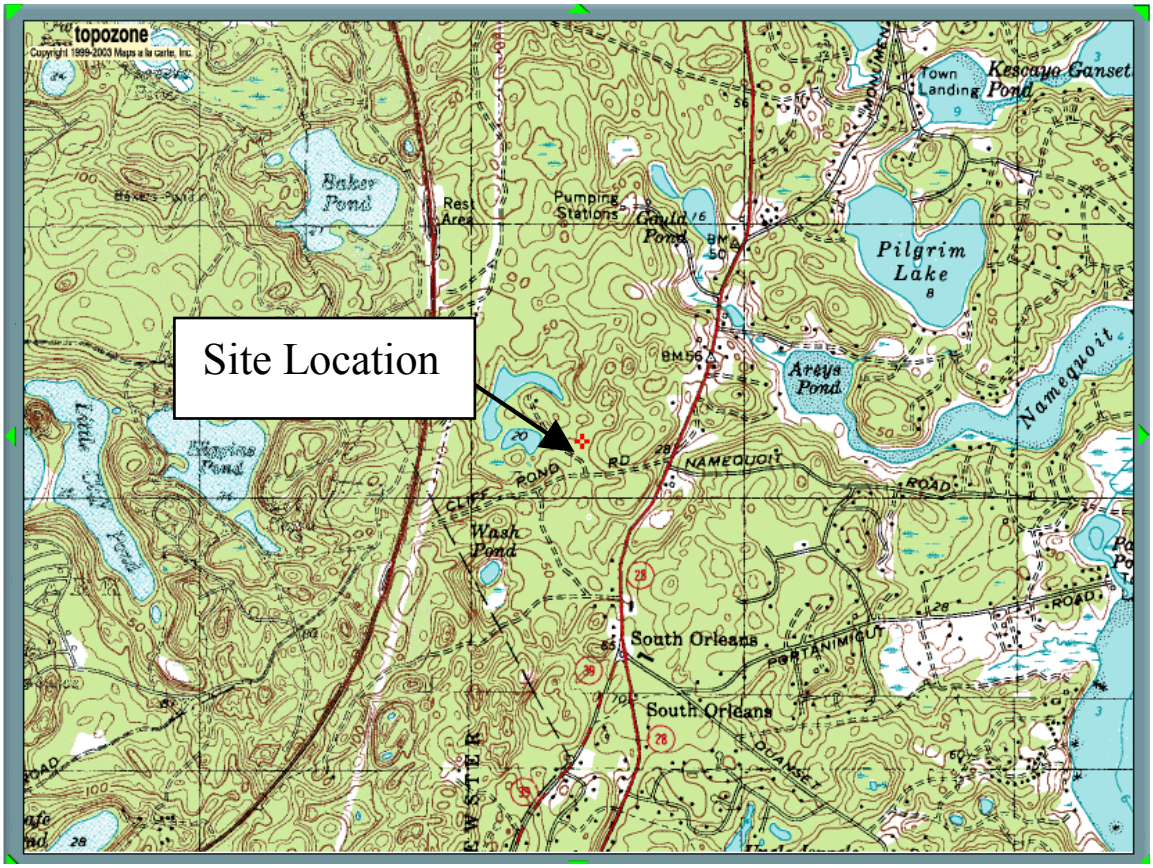

Figure 1 - Site location at Orleans site.

Source: www.topozone.com.

SECTION 2 - Instrumentation and Equipment

The wind monitoring equipment is mounted on a 50 m 2nd Wind tower. All the remaining monitoring equipment comes from NRG Systems, and consists of the following items:

- Symphonie Data Logger
- Electrical enclosure box
- 5 – #40 Anemometers, standard calibration (Slope - 0.765 m/s, Offset – 0.350 m/s)
- 3 - #200P Wind direction vanes
- 5 – Sensor booms, 54" length
- Lightning rod and grounding cable
- Shielded sensor wire

The data from the Symphonie logger is mailed to the University of Massachusetts, Amherst on a regular basis. The logger samples wind speed and direction once every two seconds. These are then combined into 10-minute averages, and along with the 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 BaseStation®. 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

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

- 2003-11-13, 4:30 AM: 50 m. vane fails. Data from the 40 m vane is used to characterize the wind direction for the site. A plot showing the wind direction at 40 m compared to the wind direction at 50 m while the 50 m vane was still functioning is given in section 7.

Data Statistics Summary

Date	Mean Wind Speed 50 m, [m/s]	Max Wind Speed 50 m, [m/s]	Turbulence Intensity 50 m, [ ]	Prevailing Wind Direction 40 m, [ ]
October 2003	Not Enough Data	Not Enough Data	Not Enough Data	Not Enough Data
November 2003	5.84	16.2	0.21	NW
Oct 27, 2003 – Nov 03	**5.83**	**16.2**	**0.20**	**WSW**

SECTION 4 - Significant Meteorological Events

On Thursday November 13 strong winds hit much of the northeast. The winds gusted to more than 70 mph in places on Thursday and gusts as high as 45 mph swept over some areas Friday. This windstorm is visible in the wind time series plot during this period.

On November 11, 2003 and November 26, 2003 multiple icing events were recorded.

The northeast region as a whole experienced a slightly wet fall. According to the National Weather Service, Worcester, MA experienced above average precipitation (12.65 in, 0.25 in above average) and about average temperatures (54.02°F) during the fall of 2003. Boston, MA experienced above average precipitation (11.48 in, 0.23 in above average) and about average temperatures (54.25°F) during the fall of 2003. (www.erh.noaa.gov/box/MonthlyClimate2.shtml).

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 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 [%]	100.0
Net Data Recovered [%]	94.181

The high Gross Data Recovery Percentage is an indication that the logger was recording and transmitting properly. The lower Net Data Recovery Percentage is a result of the 50 m vane failing.

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, which 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.

$$F1 > TF1 > F2$$

MinMaxT Test: This is a MinMax test for wind direction standard deviation with different ranges applied for high and low wind speeds. A wind direction standard deviation data value (TF1) is flagged either if it is less than Factor 1, if the wind speed (TF2) is less than Factor 4 and the wind direction standard deviation is greater than Factor 2, or if the wind speed is greater than or equal to Factor 4 and the wind direction standard deviation is greater than Factor 3.

$$(TF1 < F1)$$
$$\text{or } (TF2 < F4 \text{ and } TF1 > F2)$$
$$\text{or } (TF2 \geq F4 \text{ and } TF1 > F3)$$

Icing Test: An icing event is characterized by the simultaneous measurements of near-zero standard deviation of wind direction, non-zero wind speed, and near- or below-freezing temperatures. Wind speed, wind speed standard deviation, wind direction, and wind direction standard deviation data values are flagged if the wind direction standard deviation (CF1) is less than or equal to Factor 1, the wind speed (TF1) is greater than Factor 2, and the temperature (CF2) is less than Factor 3.

$$CF1 \leq F1 \text{ and } TF1 > F2 \text{ and } CF2 < F3$$

CompareSensors Test: Where primary and redundant sensors are used, it is possible to determine when one of the sensors is not performing properly. For anemometers, poor performance is characterized by low data values. Therefore, if one sensor of the pair reports values significantly below the other, the low values are flagged. At low wind speeds (Test Fields 1 and 2 less than or equal to Factor 3) wind speed data are flagged if the absolute difference between the two wind speeds is greater than Factor 1. At high wind speeds (Test Fields 1 or 2 greater than Factor 3) wind speed data are flagged if the absolute value of the ratio of the two wind speeds is greater is greater than Factor 2.

$$[\ TF1 \leq F3 \text{ and } TF2 \leq F3 \text{ and } abs(TF1 - TF2) > F1\ ]$$
$$\text{or } [\ (TF1 > F3 \text{ or } TF2 > F3) \text{ and } (abs(1 - TF1 / TF2) > F2 \text{ or } abs(1 - TF2 / TF1) > F2)\ ]$$

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.

Hours of Icing: total number of hours for which data were flagged according to Icing tests. This test uses the standard deviation of wind direction, air temperature, and wind speed to determine when sensor icing has occurred. It should be noted that, while this test is tuned to detect sensor icing events, it is possible for the conditions that are representative of icing to occur at other times. The error due to this possibility is considered to be insignificant.

Hours of Fault: total number of hours for which data were flagged according to CompareSensors tests. These tests compare two sensors (e.g. primary and redundant anemometers installed at the same height) and flag data points where one sensor differs significantly from the other.

% 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. The maximum percentage is between 4 and 5 m/s.
- Monthly Average – A plot of the monthly average wind speed over a 12-month period. This graph shows the trends in the wind speed from October 27, 2003 – December 15, 2003. Only calendar months with more that 90% good data are reported.
- Diurnal – A plot of the average wind speed for each hour of the day. This graph shows a pattern of greater wind speeds in the evening, peaking at between 10 AM and 12 PM.

- 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. This wind rose shows a prevailing WSW wind direction at the 40 m height. The highest average wind speed at the 50 m height was recorded from the W.

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

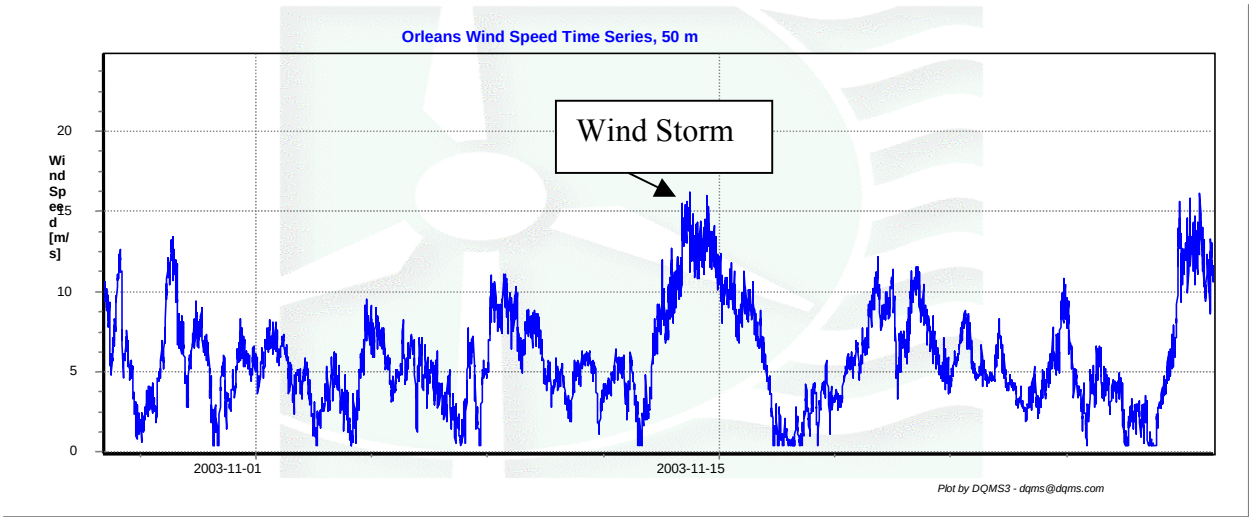

Figure 2 - Wind Speed Time Series, October 27, 2003 – November 2003

Wind Speed Distributions

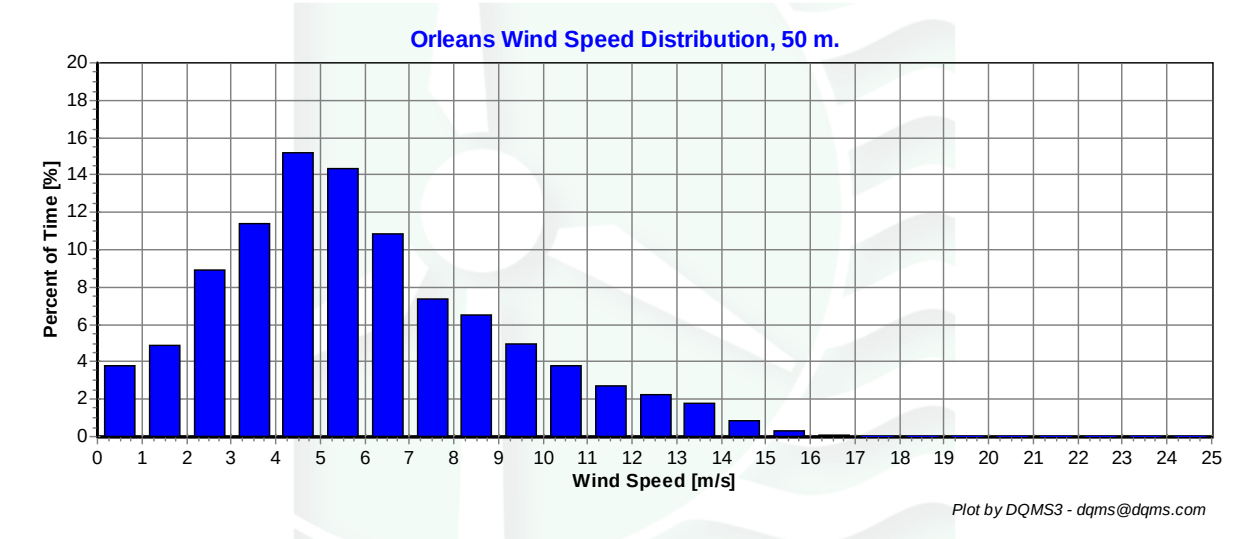

Figure 3 - Wind Speed Distribution, October 27, 2003 – November 2003

Monthly Average Wind Speeds

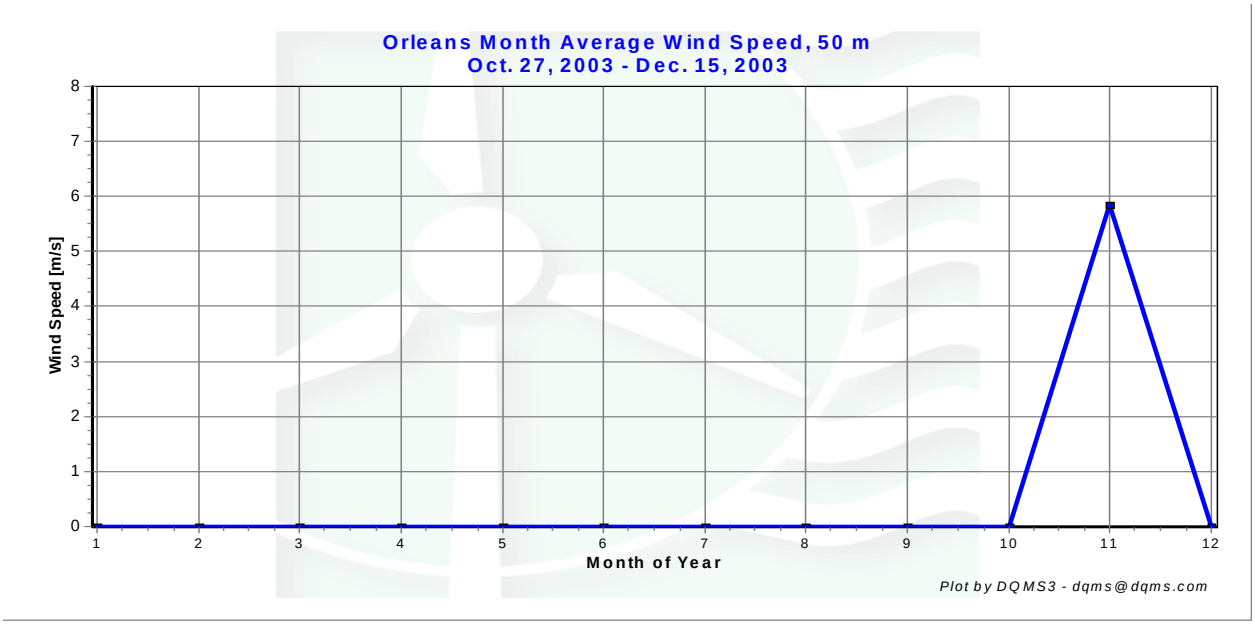

Figure 4 - Monthly average wind speed

Diurnal Average Wind Speeds

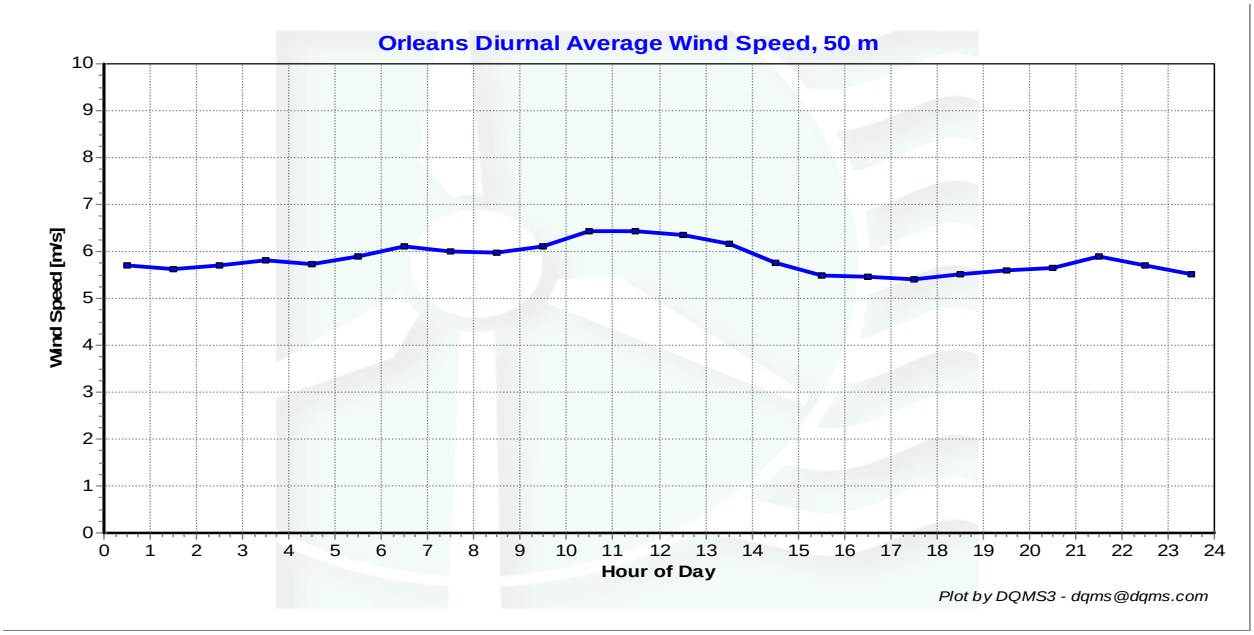

Figure 5 - Diurnal Wind Speed, October 27, 2003 – November 2003

Turbulence Intensities

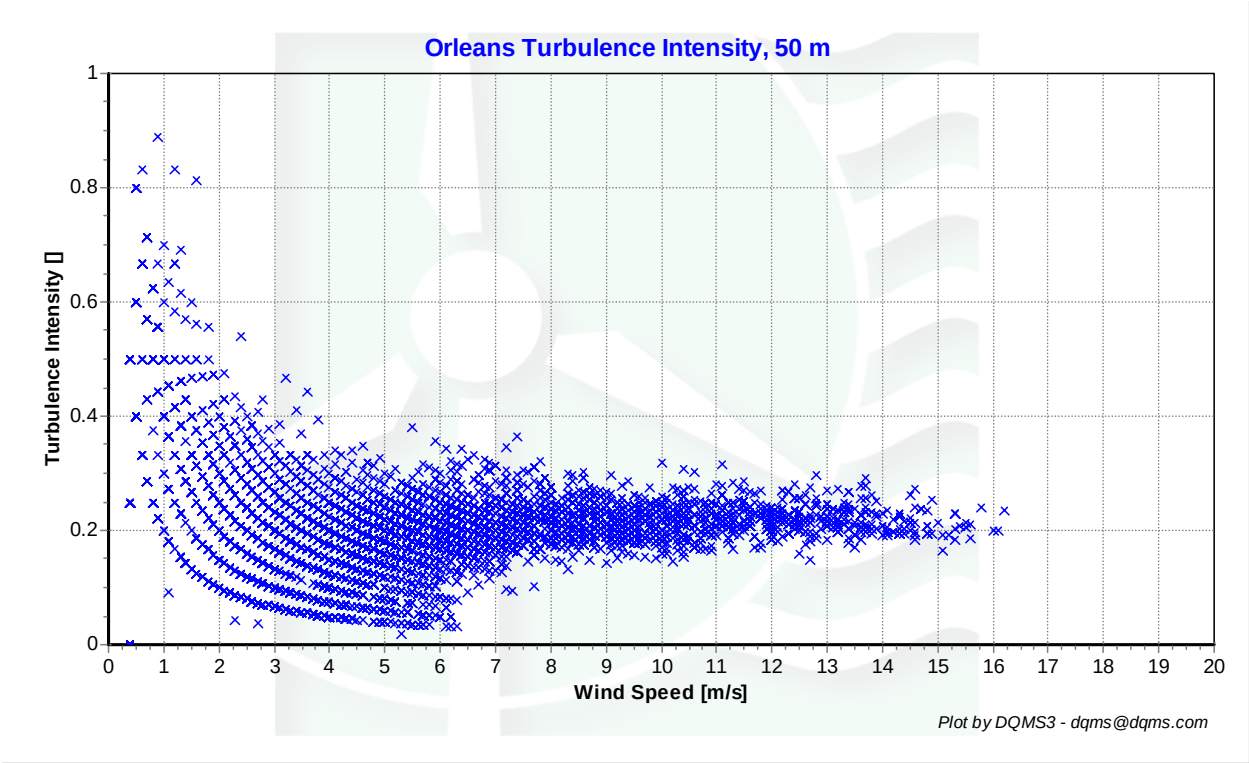

Figure 6 - Turbulence Intensity vs. Wind Speed, October 27, 2003 – November 2003

Wind Direction Comparison

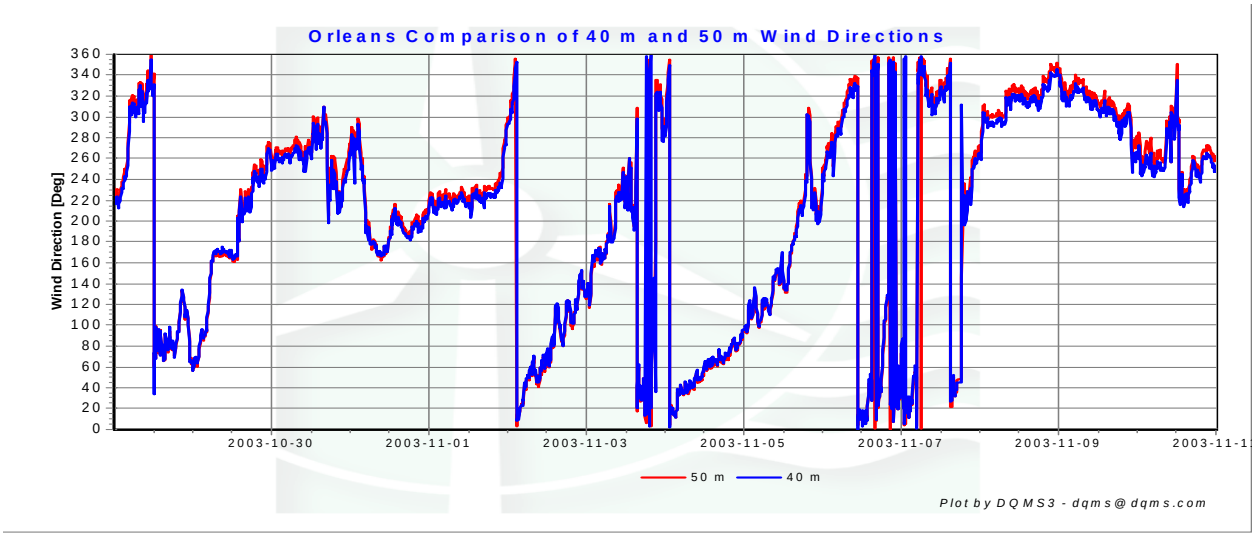

Figure 7- Comparison of Wind Direction at Different Heights

Wind Roses

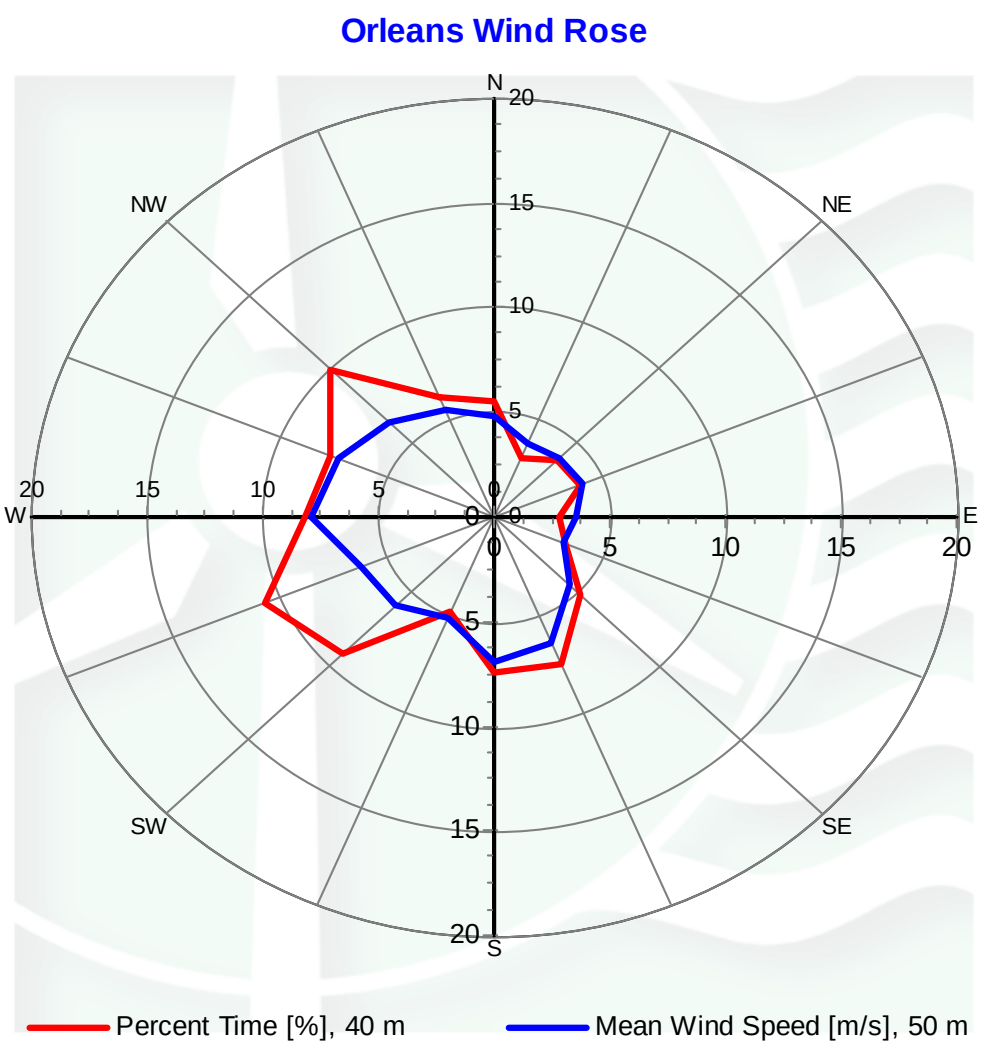

Figure 8 - Wind Rose, October 27, 2003 – November 2003

APPENDIX A - Sensor Performance Report

Test Definitions

Test Order	TestField1	TestField2	TestField3	CalcField1	CalcField2	TestType	Factor1	Factor2	Factor3	Factor4
1						TimeTest Insert				
2	Etmp2aDEGC					MinMax	-30	60		
3	Etmx2aDEGC					MinMax	-30	60		
4	Etmn2aDEGC					MinMax	-30	60		
5	EtmpSD2aDEGC					MinMax	-30	60		
10	Anem50aMS					MinMax	0	90		
11	Anem50bMS					MinMax	0	90		
12	Anem40aMS					MinMax	0	90		
13	Anem40bMS					MinMax	0	90		
14	Anem20aMS					MinMax	0	90		
15	Anem50yMS					MinMax	0	90		
16	Anem40yMS					MinMax	0	90		
20	AnemSD50aMS					MinMax	0	4		
21	AnemSD50bMS					MinMax	0	4		
22	AnemSD40aMS					MinMax	0	4		
23	AnemSD40bMS					MinMax	0	4		
24	AnemSD20aMS					MinMax	0	4		
25	AnemSD50yMS					MinMax	0	4		
26	AnemSD40yMS					MinMax	0	4		
30	Vane50aDEG					MinMax	0	359.9		
31	Vane40aDEG					MinMax	0	359.9		
32	Vane20aDEG					MinMax	0	359.9		
50	Turb50zNONE					MinMax	0	2		
51	Turb40zNONE					MinMax	0	2		
60	Wshr0zNONE					MinMax	-100	100		
70	Pwrd50zWMS					MinMax	0	5000		
71	Pwrd40zWMS					MinMax	0	5000		
200	VaneSD50aDEG	Anem50yMS				MinMaxT	0	100	100	10
201	VaneSD40aDEG	Anem40yMS				MinMaxT	0	100	100	10
202	VaneSD20aDEG	Anem20aMS				MinMax	0	100	100	10
300	Anem50aMS	AnemSD50aMS	Vane50aDEG	VaneSD50aDEG	Etmp2aDEGC	Icing	0.5	1	2	
301	Anem50bMS	AnemSD50bMS	Vane50aDEG	VaneSD50aDEG	Etmp2aDEGC	Icing	0.5	1	2	
302	Anem40aMS	AnemSD40aMS	Vane40aDEG	VaneSD40aDEG	Etmp2aDEGC	Icing	0.5	1	2	
303	Anem40bMS	AnemSD40bMS	Vane40aDEG	VaneSD40aDEG	Etmp2aDEGC	Icing	0.5	1	2	
304	Anem20aMS	AnemSD20aMS	Vane20aDEG	VaneSD20aDEG	Etmp2aDEGC	Icing	0.5	1	2	
400	Anem50aMS	Anem50bMS				CompareSensors	1	0.25	3	0

401	Anem40aMS	Anem40bMS				CompareSensors	1	0.25	3	0
500	Amax50aMS					MinMax	0	90		
501	Amax50bMS					MinMax	0	90		
502	Amax40aMS					MinMax	0	90		
503	Amax40bMS					MinMax	0	90		
504	Amax20aMS					MinMax	0	90		
510	Amin50aMS					MinMax	0	90		
511	Amin50bMS					MinMax	0	90		
512	Amin40aMS					MinMax	0	90		
513	Amin40bMS					MinMax	0	90		
514	Amin20aMS					MinMax	0	90		
520	Vmax50aDEG					MinMax	0	359.9		
521	Vmax40aDEG					MinMax	0	359.9		
522	Vmax20aDEG					MinMax	0	359.9		
530	Vmin50aDEG					MinMax	0	359.9		
531	Vmin40aDEG					MinMax	0	359.9		
532	Vmin20aDEG					MinMax	0	359.9		

Sensor Statistics

Sensor	Expected Data Points	Actual Data Points	% Data Recovered	Hours Out of Range	Hours of Icing	Hours of Fault	% Data Good
Anem50aMS	4981	4981	100	0	1.833	0	99.779
AnemSD50aMS	4981	4981	100	0	1.833	0	99.779
Amax50aMS	4981	4981	100	0	0	0	100
Amin50aMS	4981	4981	100	0	0	0	100
Anem50bMS	4981	4981	100	0.5	2	0.167	99.679
AnemSD50bMS	4981	4981	100	0.5	2	0.167	99.679
Amax50bMS	4981	4981	100	0	0	0	100
Amin50bMS	4981	4981	100	0	0	0	100
Anem40aMS	4981	4981	100	0	1.5	1.167	99.679
AnemSD40aMS	4981	4981	100	0	1.5	1.167	99.679
Amax40aMS	4981	4981	100	0	0	0	100
Amin40aMS	4981	4981	100	0	0	0	100
Anem40bMS	4981	4981	100	0	1.5	0	99.819
AnemSD40bMS	4981	4981	100	0	1.5	0	99.819
Amax40bMS	4981	4981	100	0	0	0	100
Amin40bMS	4981	4981	100	0	0	0	100
Anem20aMS	4981	4981	100	0	1.167	0	99.859
AnemSD20aMS	4981	4981	100	0	1.167	0	99.859
Amax20aMS	4981	4981	100	0	0	0	100
Amin20aMS	4981	4981	100	0	0	0	100
Vane50aDEG	4981	4981	100	0.333	1.167	427.667	48.304
VaneSD50aDEG	4981	4981	100	0.333	1.167	427.667	48.304
Vmax50aDEG	4981	4981	100	0	0	427.667	48.484
Vmin50aDEG	4981	4981	100	0	0	427.667	48.484
Vane40aDEG	4981	4981	100	0.167	1.5	0	99.799
VaneSD40aDEG	4981	4981	100	0.167	1.5	0	99.799
Vmax40aDEG	4981	4981	100	0	0	0	100
Vmin40aDEG	4981	4981	100	0	0	0	100

Vane20aDEG	4981	4981	100	0	1.167	0	99.859
VaneSD20aDEG	4981	4981	100	0.167	1.167	0	99.839
Vmax20aDEG	4981	4981	100	0	0	0	100
Vmin20aDEG	4981	4981	100	0	0	0	100
Etmp2aDEGC	4981	4981	100	0	0	0	100
EtmpSD2aDEGC	4981	4981	100	0	0	0	100
Etmx2aDEGC	4981	4981	100	0	0	0	100
Etmn2aDEGC	4981	4981	100	0	0	0	100
Total	**179316**	**179316**	**100**	**2.167**	**23.667**	**1713.333**	**94.181**

APPENDIX B - Plot Data

Wind Speed Distribution Data

Bin Center Wind Speed [m/s]	Percent of Time [%]
0.5	3.83
1.5	4.88
2.5	8.91
3.5	11.4
4.5	15.16
5.5	14.31
6.5	10.86
7.5	7.37
8.5	6.54
9.5	5
10.5	3.77
11.5	2.71
12.5	2.23
13.5	1.77
14.5	0.88
15.5	0.3
16.5	0.06
17.5	0
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]
2003 Jan	0
Feb	0
Mar	0
Apr	0
May	0
Jun	0
Jul	0
Aug	0
Sept	0
Oct	5.75
Nov	5.84
Dec	7.82

Table 2 - Wind Speed Averages

Diurnal Average Wind Speed Data

Hour of Day	Average Wind Speed [m/s]
0	5.72
1	5.63
2	5.69
3	5.81
4	5.74
5	5.88
6	6.1
7	6
8	5.97
9	6.1
10	6.42
11	6.42
12	6.34
13	6.17
14	5.76
15	5.5
16	5.46
17	5.39
18	5.51
19	5.59
20	5.65
21	5.89
22	5.69
23	5.51

Table 3 - Diurnal Average Wind Speeds

Wind Rose Data

Direction	Percent Time [%], 40 m	Mean Wind Speed [m/s], 50 m
N	5.57	4.87
NNE	3.04	3.86
NE	3.84	3.95
ENE	4.06	4.15
E	2.78	3.54
ESE	3.36	3.21
SE	5.29	4.58
SSE	7.62	6.52
S	7.46	6.89
SSW	4.95	5.24
SW	9.25	6.02
WSW	10.7	6.2
W	8.19	7.92
WNW	7.7	7.28
NW	10	6.36
NNW	6.18	5.53

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