# WIND DATA REPORT

## Orleans

27th October, 2003 – 3rd August, 2005

Prepared for

Massachusetts Technology Collaborative
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by

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# Notice and Acknowledgements

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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 wind measurement station was installed at the town watershed in Orleans, MA. Installed on October 27 of 2003, the station was in continuous operation until August 3rd, 2005, when it was taken down and dismantled. 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 of measurement, October 2003 – August 2005, the mean recorded wind speed at 50 m (164.0 ft) was 5.77 m/s (12.9 mph)*; the prevailing wind direction at 40 m (131.2 ft) was SW. The gross data recovery percentage (the actual percentage of expected data received) was 99.2 % and the net data recovery percentage (the percentage of expected data which passed all of the quality assurance tests) was 88.0%. The net data recovery percentage is low because the 50 m (164.0 ft) wind vane had failed since November 2003.

Between June 2004 and May 2005, the mean recorded wind speed at 50 m (164.0 ft) was 5.59 m/s (12.5 mph), the prevailing wind direction at 40 m (131.2 ft) was SW. This time period was chosen because it provided a continuous year's worth of data for analysis.

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 Orleans site is located on the town watershed in Orleans, MA. The tower was on a cleared hilltop, surrounded by trees. The location of the tower base was measured to be at 41.7584° North, 69.9933° West referred to the NAD83 datum.

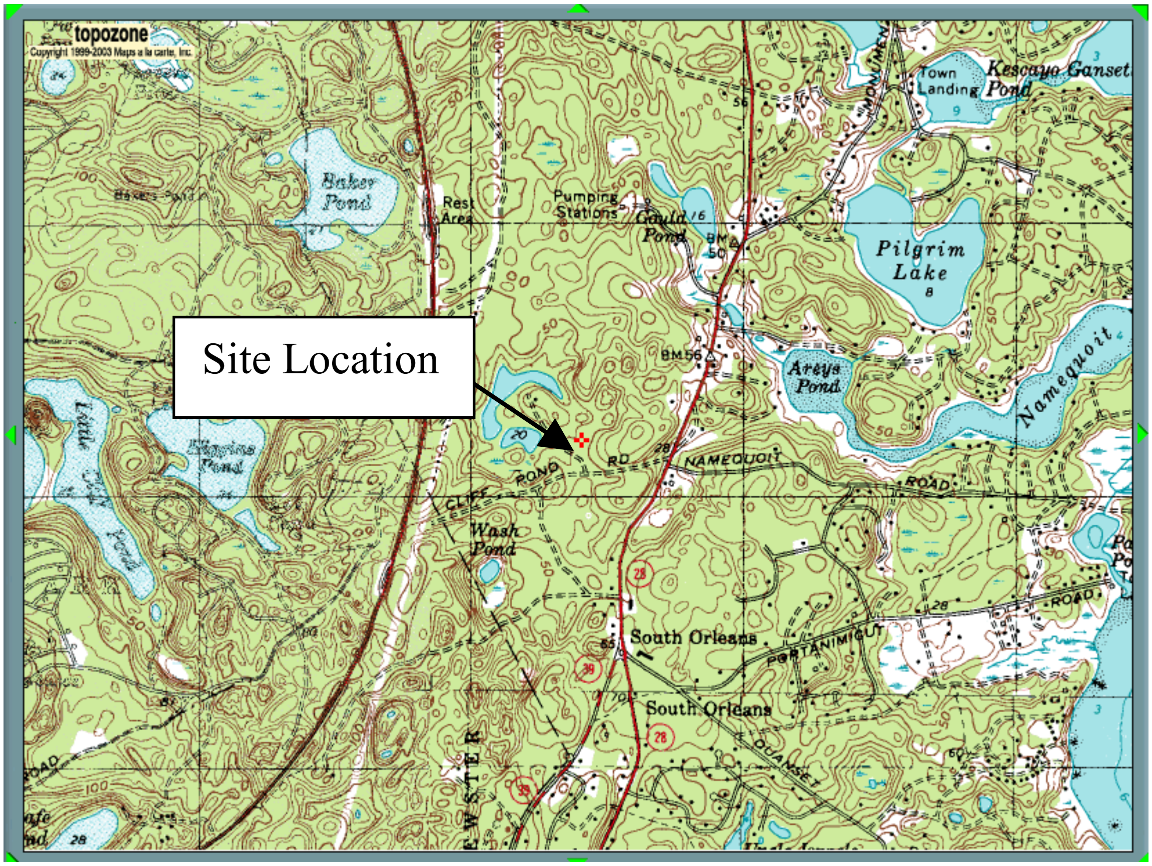


**Figure 1 - Site location at Orleans site.**
**Source: www.topozone.com.**

## SECTION 2 - Instrumentation and Equipment

The wind monitoring equipment was mounted on a 50 m (164.0 ft) Second 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). Two anemometers were located at 50 m (164.0 ft), two at 40 m and one at a height of 20 m (65.6 ft).
- 3 - #200P Wind direction vanes. They were located at heights of 50, 40 and 20 m (164.0, 131.2 and 65.6 ft) each.
- 5 – Sensor booms, 54” length
- Lightning rod and grounding cable
- Shielded sensor wire

The data from the Symphonie logger was 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 were converted to ASCII text files using the NRG software BaseStation®. These text files were then imported into a database software program where they were subjected to QA tests prior to using the data.

## SECTION 3 - Data Collection and Maintenance

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 | Mean Wind Speed | Max Wind Speed | Turbulence Intensity | Prevailing Wind Direction | Mean Wind Speed | Max Wind Speed |
|---|---|---|---|---|---|---|---|---|---|---|
| **Heights, units** | **50 m, [m/s]** | **50 m, [m/s]** | **50 m, [ ]** | **40 m, [ ]** | **40 m, [m/s]** | **40 m, [m/s]** | **40 m, [ ]** | **20 m, [ ]** | **20 m, [m/s]** | **20 m, [m/s]** |
| **November 2003** | 5.84 | 16.2 | 0.21 | NW | 5.28 | 15.1 | 0.23 | NW | 3.88 | 12.2 |
| **December 2003** | 7.47 | 17.3 | 0.2 | NW | 6.79 | 15.6 | 0.22 | WSW | 5.21 | 12.4 |
| **January 2004** | 6.94 | 14.4 | 0.21 | WNW | 6.2 | 12.9 | 0.24 | WNW | 4.85 | 10.2 |
| **February 2004** | 6.02 | 14.5 | 0.19 | NW | 5.43 | 13.4 | 0.21 | NW | 4.13 | 10.8 |
| **March 2004** | 6.46 | 13.8 | 0.21 | NE | 5.88 | 13.1 | 0.23 | NE | 4.44 | 10 |
| **April 2004** | 6.12 | 14.4 | 0.21 | SW | 5.59 | 13.5 | 0.23 | SW | 4.19 | 10.8 |
| **May 2004** | - | - | - | - | - | - | - | - | - | - |
| **June 2004** | 5.15 | 11.6 | 0.19 | SW | 4.71 | 10.9 | 0.21 | SW | 3.48 | 8.9 |
| **July 2004** | 4.48 | 10.9 | 0.2 | SSW | 4.1 | 10.2 | 0.22 | SSW | 2.98 | 8 |
| **August 2004** | 5.01 | 12.7 | 0.19 | SW | 4.59 | 11.7 | 0.22 | SW | 3.34 | 9.1 |
| **September 2004** | 5.08 | 14.8 | 0.18 | S | 4.6 | 13.2 | 0.2 | S | 3.24 | 9.6 |
| **October 2004** | 5.57 | 12.9 | 0.19 | NW | 5 | 11.3 | 0.21 | NNE | 3.49 | 9 |
| **November 2004** | 6 | 15.1 | 0.19 | NNW | 5.42 | 14.8 | 0.21 | NNW | 4.05 | 11.8 |
| **December 2004** | 6.37 | 17.8 | 0.19 | NW | 5.75 | 16.6 | 0.21 | NW | 4.09 | 13.5 |
| **January 2005** | 6.47 | 19.6 | 0.21 | NNW | 5.81 | 17.9 | 0.24 | NNW | 4.23 | 13.4 |
| **February 2005** | 5.86 | 13.2 | 0.2 | NW | 5.15 | 11.8 | 0.23 | NW | 3.84 | 9.5 |
| **March 2005** | 6.02 | 17.6 | 0.2 | WNW | 5.47 | 17.4 | 0.22 | WNW | 4.35 | 13.7 |
| **April 2005** | 5.72 | 13.9 | 0.21 | SSW | 5.25 | 13 | 0.22 | SW | 3.95 | 10.5 |
| **May 2005** | 5.41 | 15.8 | 0.22 | NW | 4.92 | 14.5 | 0.25 | N | 3.64 | 10.9 |
| **June 2005** | 5.19 | 11 | 0.2 | SW | 4.83 | 10.2 | 0.23 | SW | 3.66 | 8.4 |
| **July 2005** | 4.8 | 14 | 0.2 | SW | 4.4 | 12.9 | 0.22 | SW | 3.21 | 9.9 |
| **Oct 03 – Aug 05** | **5.77** | **19.6** | **0.2** | **SW** | **5.23** | **17.9** | **0.22** | **SW** | **3.88** | **13.7** |

## SECTION 4 - Significant Meteorological Events

The following significant meteorological events occurred during the measurement period:

- 13 November 2003 – High wind
- 5, 6 & 7 December 2003 – Winter storm
- 18 February 2004 – Winter Storm
- 1 December 2004 – High Wind
- 26 December 2004 – Winter Storm
- 22 January 2005 – Winter Storm
- 24 February 2005 – Heavy Snow
- 1 March 2005 – Winter Storm
- 8 March 2005 – High Wind
- 7 – May 2005 – High Wind
- 24 May 2005 – High Wind

Source: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms

## SECTION 5 - Data Recovery and Validation

All raw wind data were 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 data recovered (ratio of raw data points which passed all QA control tests to data points expected) are shown below.

| | |
|---|---|
| Gross Data Recovered [%] | 99.2 |
| Net Data Recovered [%] | 88.0 |

The gross data recovered is low at 88.0 % because of the failed 50 m (164.0 ft) wind vane. Disregarding the 50 m (164.0 ft) wind vane data, the gross data recovered is 98.9%.

**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.

$$F1 > TF1 > F2$$

**MinMax T 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.

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

**Icing Test:** An icing event occurs when ice collects on a sensor and degrades its performance. Icing events are 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 (F1), the wind speed (TF1) is greater than Factor 2 (F2), and the temperature (CF2) is less than Factor 3 (F3). To exit an icing event, the wind direction standard deviation must be greater than Factor 4.

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

**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.

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

### 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 in Figure 2. The graph shows that the winds in the summer months are generally lower. Most 10-minute averages above 15 m/s (33 mph) occcur during the winter months

- Wind Speed Distribution – A histogram plot giving the percentage of time that the wind is at a given wind speed. Figure 3 shows that the maximum percentage is between 4 and 5 m/s (8.76 and 11.18 mph).

- Monthly Average – A plot of the monthly average wind speed over a 18-month period is given in Figure 4. This graph shows the trends in the wind speed from November 2003 - July 2005. Data for the month of May 2004 is missing because the data card arrived at the lab containing missing data.

- Diurnal – A plot of the average wind speed for each hour of the day is given in Figure 5. This graph shows a peak wind speed between 12 PM and 1 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. This graph is given in Figure 6.

- Wind Rose – A plot, by compass directions showing the percentage of time that the wind comes from a given direction and the average wind speed in that direction. The spring wind rose, in Figure 7, shows that the wind tends to be predominantly from the SW and the NW at the 40 m height and that the mean wind speed is relatively equal from all directions with no dominant direction. (The 50 m (164.0 ft) wind data was used for the plot but 40 m wind direction data was used due to the failure of the vane at 50m.)

# SECTION 7 - Graphs

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

**<u>Wind Speed Time Series</u>**

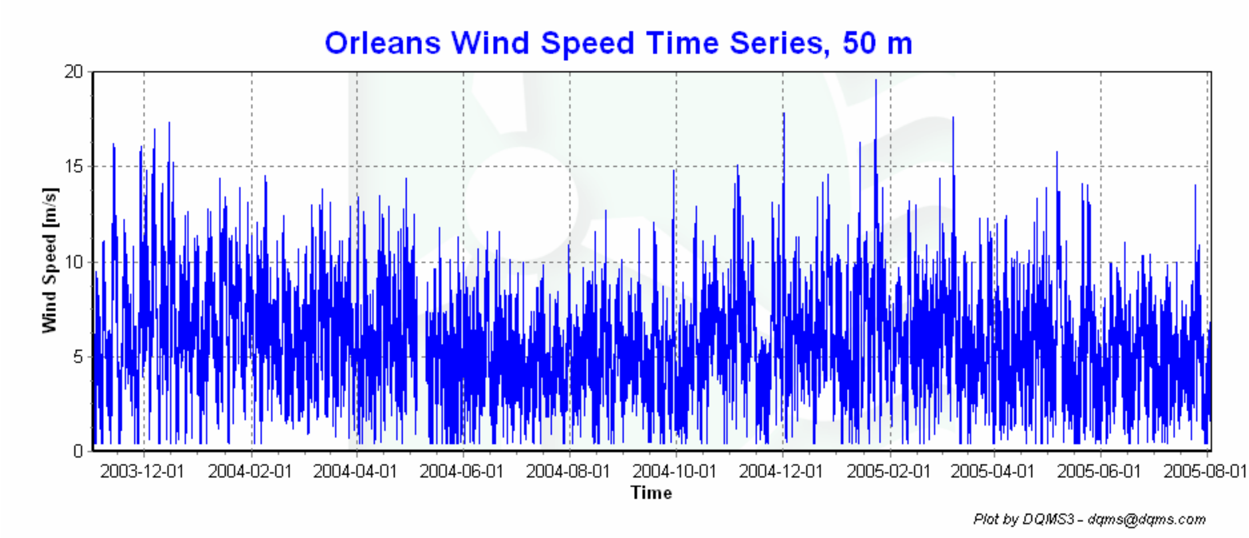


**Figure 2 - Wind Speed Time Series, October 2003 - August 2005**

**<u>Wind Speed Distributions</u>**

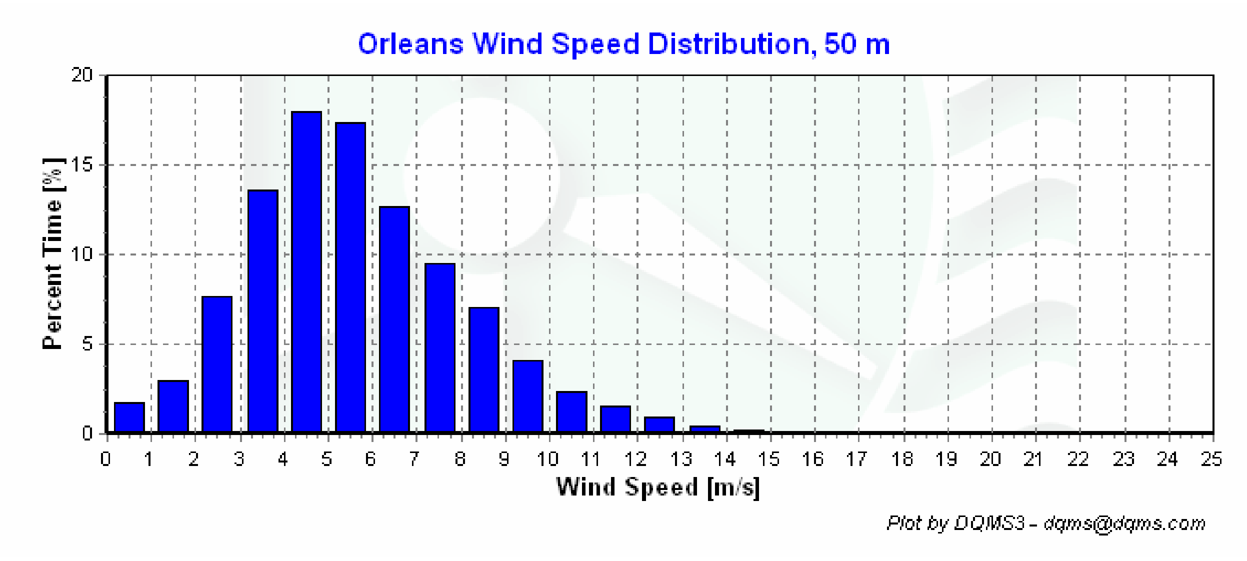


**Figure 3 - Wind Speed Distribution, June 2004 - May 2005**

## Monthly Average Wind Speeds

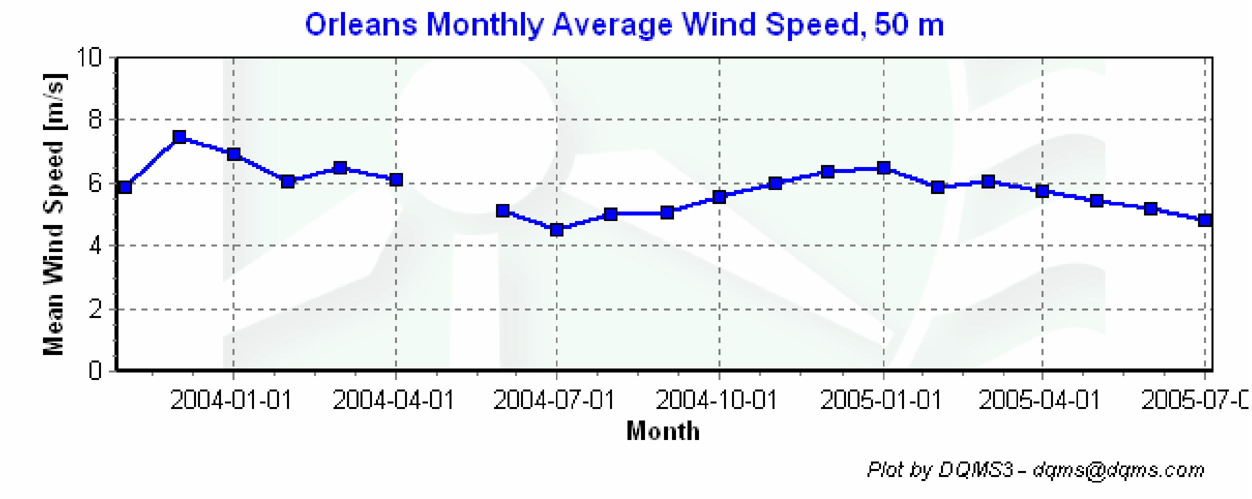


**Figure 4 - Monthly average wind speed**

## Diurnal Average Wind Speeds

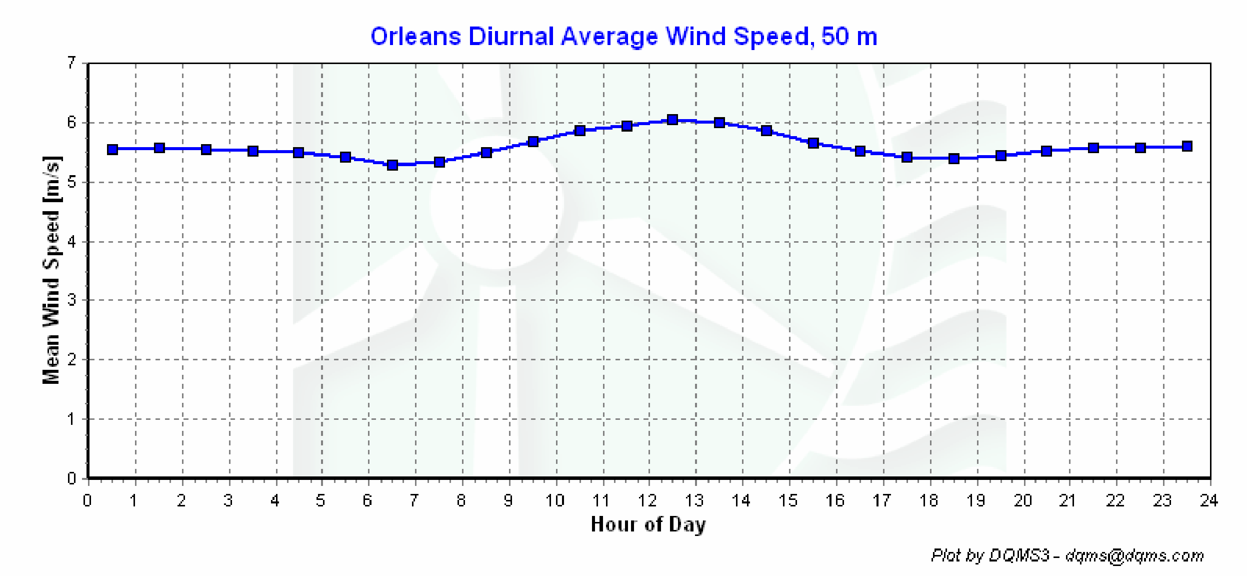


**Figure 5 - Diurnal Wind Speed, June 2004 - May 2005**

## Turbulence Intensities

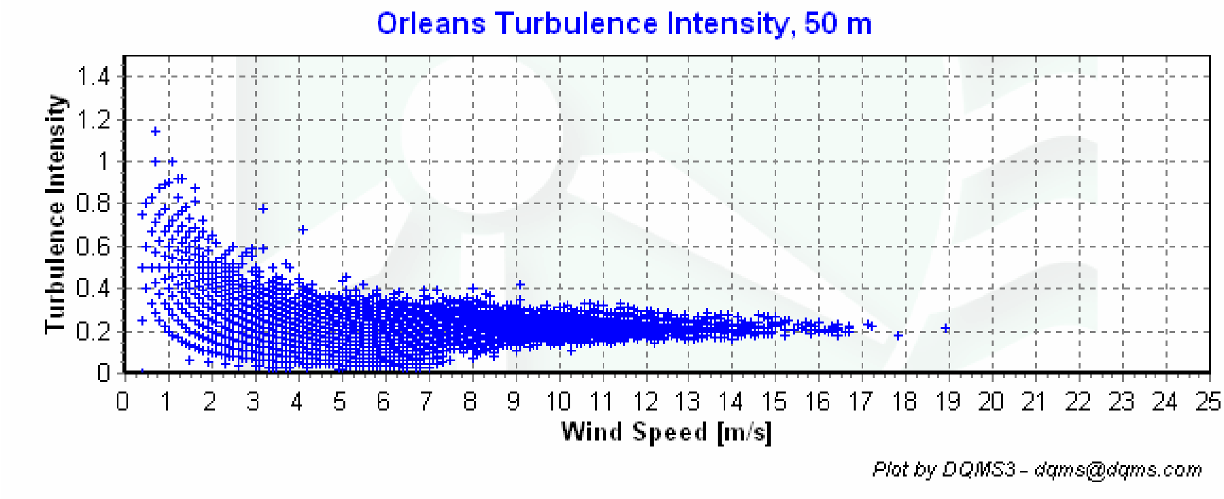


**Figure 6 - Turbulence Intensity vs. Wind Speed, June 2004 - May 2005**

## Wind Roses

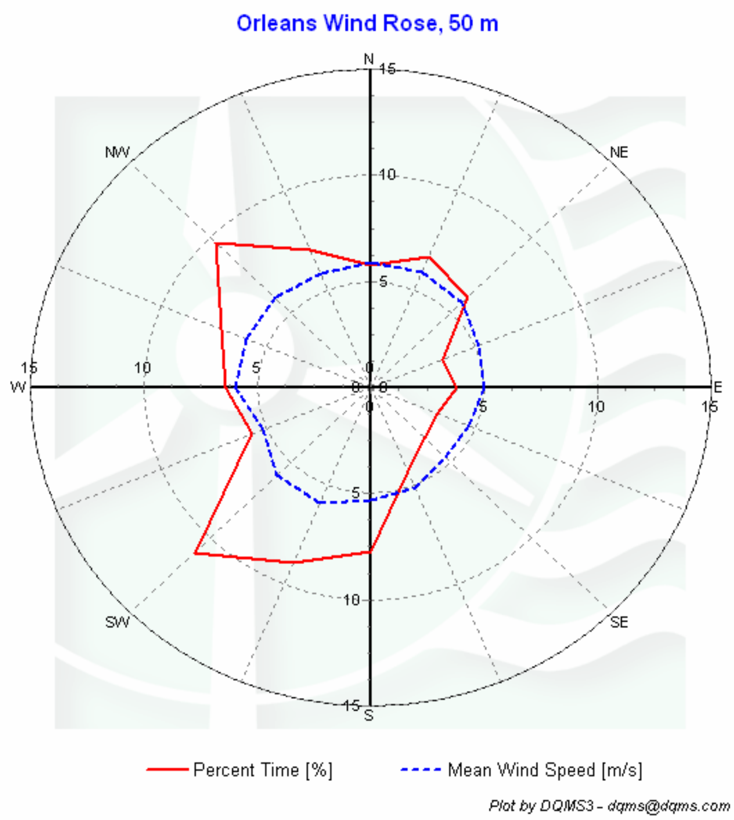


**Figure 7 - Wind Rose, June 2004 - May 2005**

# APPENDIX A - Sensor Performance Report

## Test Definitions

| TestOrder | 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 | VaneSD40aDEG | Etmp2aDEGC | Icing | 0.5 | 1 | 2 | 10 |
| 301 | Anem50bMS | AnemSD50bMS | Vane50aDEG | VaneSD40aDEG | Etmp2aDEGC | Icing | 0.5 | 1 | 2 | 10 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 302 | Anem40aMS | AnemSD40aMS | Vane40aDEG | VaneSD40aDEG | Etmp2aDEGC | Icing | 0.5 | 1 | 2 | 10 |
| 303 | Anem40bMS | AnemSD40bMS | Vane40aDEG | VaneSD40aDEG | Etmp2aDEGC | Icing | 0.5 | 1 | 2 | 10 |
| 304 | Anem20aMS | AnemSD20aMS | Vane20aDEG | VaneSD20aDEG | Etmp2aDEGC | Icing | 0.5 | 1 | 2 | 10 |
| 400 | Anem50aMS | Anem50bMS | | | | CompareSensors | 1 | 0.25 | 3 | 0 |
| 401 | Anem40aMS | Anem40bMS | | | CompareSensors | 1 | 0.25 | 3 | 0 | 401 |
| 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 | 93096 | 92252 | 99.093 | 6 | 327.667 | 4.667 | 96.913 |
| AnemSD50aMS | 93096 | 92252 | 99.093 | 6 | 327.667 | 4.667 | 96.913 |
| Amax50aMS | 93096 | 92252 | 99.093 | 0 | 0 | 0 | 99.093 |
| Amin50aMS | 93096 | 92252 | 99.093 | 0 | 0 | 0 | 99.093 |
| Anem50bMS | 93096 | 92252 | 99.093 | 6.667 | 320.333 | 9.333 | 96.926 |
| AnemSD50bMS | 93096 | 92252 | 99.093 | 6.667 | 320.333 | 9.333 | 96.926 |
| Amax50bMS | 93096 | 92252 | 99.093 | 0 | 0 | 0 | 99.093 |
| Amin50bMS | 93096 | 92252 | 99.093 | 0 | 0 | 0 | 99.093 |
| Anem40aMS | 93096 | 92252 | 99.093 | 5.333 | 319.5 | 12.833 | 96.917 |
| AnemSD40aMS | 93096 | 92252 | 99.093 | 5.333 | 319.5 | 12.833 | 96.917 |
| Amax40aMS | 93096 | 92252 | 99.093 | 0 | 0 | 0 | 99.093 |
| Amin40aMS | 93096 | 92252 | 99.093 | 0 | 0 | 0 | 99.093 |
| Anem40bMS | 93096 | 92252 | 99.093 | 6.667 | 316 | 38.167 | 96.768 |
| AnemSD40bMS | 93096 | 92252 | 99.093 | 6.667 | 316 | 38.167 | 96.768 |
| Amax40bMS | 93096 | 92252 | 99.093 | 0 | 0 | 0 | 99.093 |
| Amin40bMS | 93096 | 92252 | 99.093 | 0 | 0 | 0 | 99.093 |
| Anem20aMS | 93096 | 92252 | 99.093 | 0 | 244 | 0 | 97.521 |
| AnemSD20aMS | 93096 | 92252 | 99.093 | 2.5 | 244 | 0 | 97.505 |
| Amax20aMS | 93096 | 92252 | 99.093 | 0 | 0 | 0 | 99.093 |
| Amin20aMS | 93096 | 92252 | 99.093 | 0 | 0 | 0 | 99.093 |
| Vane50aDEG | 93096 | 93036 | 99.936 | 0 | 0 | 14067.17 | 6.678 |
| VaneSD50aDEG | 93096 | 93036 | 99.936 | 0 | 0 | 14067.17 | 6.678 |
| Vmax50aDEG | 93096 | 93036 | 99.936 | 0 | 0 | 14067.17 | 6.678 |
| Vmin50aDEG | 93096 | 93036 | 99.936 | 0 | 0 | 14067.17 | 6.678 |
| Vane40aDEG | 93096 | 92252 | 99.093 | 8 | 328.833 | 0 | 96.923 |
| VaneSD40aDEG | 93096 | 92252 | 99.093 | 8 | 328.833 | 0 | 96.923 |
| Vmax40aDEG | 93096 | 92252 | 99.093 | 2.167 | 0 | 0 | 99.079 |
| Vmin40aDEG | 93096 | 92252 | 99.093 | 0 | 0 | 0 | 99.093 |
| Vane20aDEG | 93096 | 92252 | 99.093 | 0 | 244 | 0 | 97.521 |
| VaneSD20aDEG | 93096 | 92252 | 99.093 | 3.667 | 244 | 0 | 97.497 |
| Vmax20aDEG | 93096 | 92252 | 99.093 | 0 | 0 | 0 | 99.093 |
| Vmin20aDEG | 93096 | 92252 | 99.093 | 0 | 0 | 0 | 99.093 |
| Etmp2aDEGC | 93096 | 92252 | 99.093 | 0 | 0 | 0 | 99.093 |
| EtmpSD2aDEGC | 93096 | 92252 | 99.093 | 0 | 0 | 0 | 99.093 |
| Etmx2aDEGC | 93096 | 92252 | 99.093 | 0 | 0 | 0 | 99.093 |
| Etmn2aDEGC | 93096 | 92252 | 99.093 | 0 | 0 | 0 | 99.093 |
| Total | 3351456 | 3324208 | 99.187 | 73.667 | 4200.667 | 56398.67 | 88.037 |

# APPENDIX B - Plot Data

**Wind Speed Distribution Data**

| Bin Center Wind Speed [m/s] | Percent of Time [%] |
|---|---|
| 0.5 | 1.71 |
| 1.5 | 3 |
| 2.5 | 7.63 |
| 3.5 | 13.56 |
| 4.5 | 17.91 |
| 5.5 | 17.37 |
| 6.5 | 12.7 |
| 7.5 | 9.49 |
| 8.5 | 6.99 |
| 9.5 | 4.1 |
| 10.5 | 2.39 |
| 11.5 | 1.48 |
| 12.5 | 0.95 |
| 13.5 | 0.37 |
| 14.5 | 0.16 |
| 15.5 | 0.06 |
| 16.5 | 0.07 |
| 17.5 | 0.03 |
| 18.5 | 0.02 |
| 19.5 | 0.01 |
| 20.5 | 0 |
| 21.5 | 0 |
| 22.5 | 0 |
| 23.5 | 0 |
| 24.5 | 0 |

**Table 1 - Wind Speed Distribution, June 2004 - May 2005**

**Monthly Average Wind Speed Data**

| Date | 10 min Mean [m/s] |
|---|---|
| November 2003 | 5.84 |
| December 2003 | 7.47 |
| January 2004 | 6.94 |
| February 2004 | 6.02 |
| March 2004 | 6.46 |
| April 2004 | 6.12 |
| May 2004 | |
| June 2004 | 5.15 |
| July 2004 | 4.48 |
| August 2004 | 5.01 |
| September 2004 | 5.08 |
| October 2004 | 5.57 |
| November 2004 | 6 |
| December 2004 | 6.37 |
| January 2005 | 6.47 |
| February 2005 | 5.86 |
| March 2005 | 6.02 |
| April 2005 | 5.72 |
| May 2005 | 5.41 |
| June 2005 | 5.19 |
| July 2005 | 4.8 |

**Table 2 - Wind Speed Averages**

**Diurnal Average Wind Speed Data**

| Hour of Day | Average Wind Speed [m/s] |
|---|---|
| 0 | 5.56 |
| 1 | 5.57 |
| 2 | 5.53 |
| 3 | 5.52 |
| 4 | 5.49 |
| 5 | 5.42 |
| 6 | 5.28 |
| 7 | 5.33 |
| 8 | 5.49 |
| 9 | 5.68 |
| 10 | 5.87 |
| 11 | 5.96 |
| 12 | 6.04 |
| 13 | 6 |
| 14 | 5.86 |
| 15 | 5.66 |
| 16 | 5.52 |
| 17 | 5.41 |
| 18 | 5.4 |
| 19 | 5.45 |
| 20 | 5.52 |
| 21 | 5.57 |
| 22 | 5.58 |
| 23 | 5.59 |

**Table 3 - Diurnal Average Wind Speeds, June 2004 - May 2005**

## Wind Rose Data

| Direction | Percent Time [%], 40 m | Mean Wind Speed [m/s], 50 m |
|---|---|---|
| N | 5.74 | 5.91 |
| NNE | 6.67 | 5.91 |
| NE | 6.04 | 5.66 |
| ENE | 3.45 | 5.13 |
| E | 3.77 | 5.01 |
| ESE | 3.19 | 4.66 |
| SE | 3.36 | 4.62 |
| SSE | 4.28 | 5.12 |
| S | 7.75 | 5.27 |
| SSW | 8.93 | 5.89 |
| SW | 10.98 | 5.82 |
| WSW | 5.71 | 5.15 |
| W | 6.38 | 5.98 |
| WNW | 7.12 | 5.95 |
| NW | 9.64 | 5.98 |
| NNW | 7 | 5.78 |

**Table 4 - Wind Rose, Time Percentage and Mean Wind Speed by Direction, June 2004 - May 2005**