

WIND DATA REPORT

Mt. Tom

December 1, 2003 – February 29, 2004

Prepared for

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by

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April 15, 2004

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EXECUTIVE SUMMARY

This wind measurement station is installed on the FAA tower at Mt. Tom in Holyoke, MA. Installed in December of 1999, the station is in continuous operation to this day. The two sets of two anemometers and one wind vane are mounted at 24 m (78.7 ft) and 37 m (121.4 ft) respectively.

During the period covered by this report, December 2003 – February 2004, the mean recorded wind speed at 37 meters was 7.50 m/s (16.8 mph); the prevailing wind direction was from the WNW. The gross data recovery percentage (the actual percentage of expected data received) was 99.992% and the net data recovery percentage (the percentage of expected data which passed all of the quality assurance tests) was 85.685%. The net data recovery value is low is because of multiple sensor failures occurring during this data quarter and icing events.

- Station Location

The Mt. Tom site is located at an existing FAA tower on top of Mt. Tom in Holyoke, MA. Some trees are located in the vicinity, as is an ESI-80 wind turbine. The location of the tower base is at 42°-14-59.2' North, 72°-38-42.2' West.

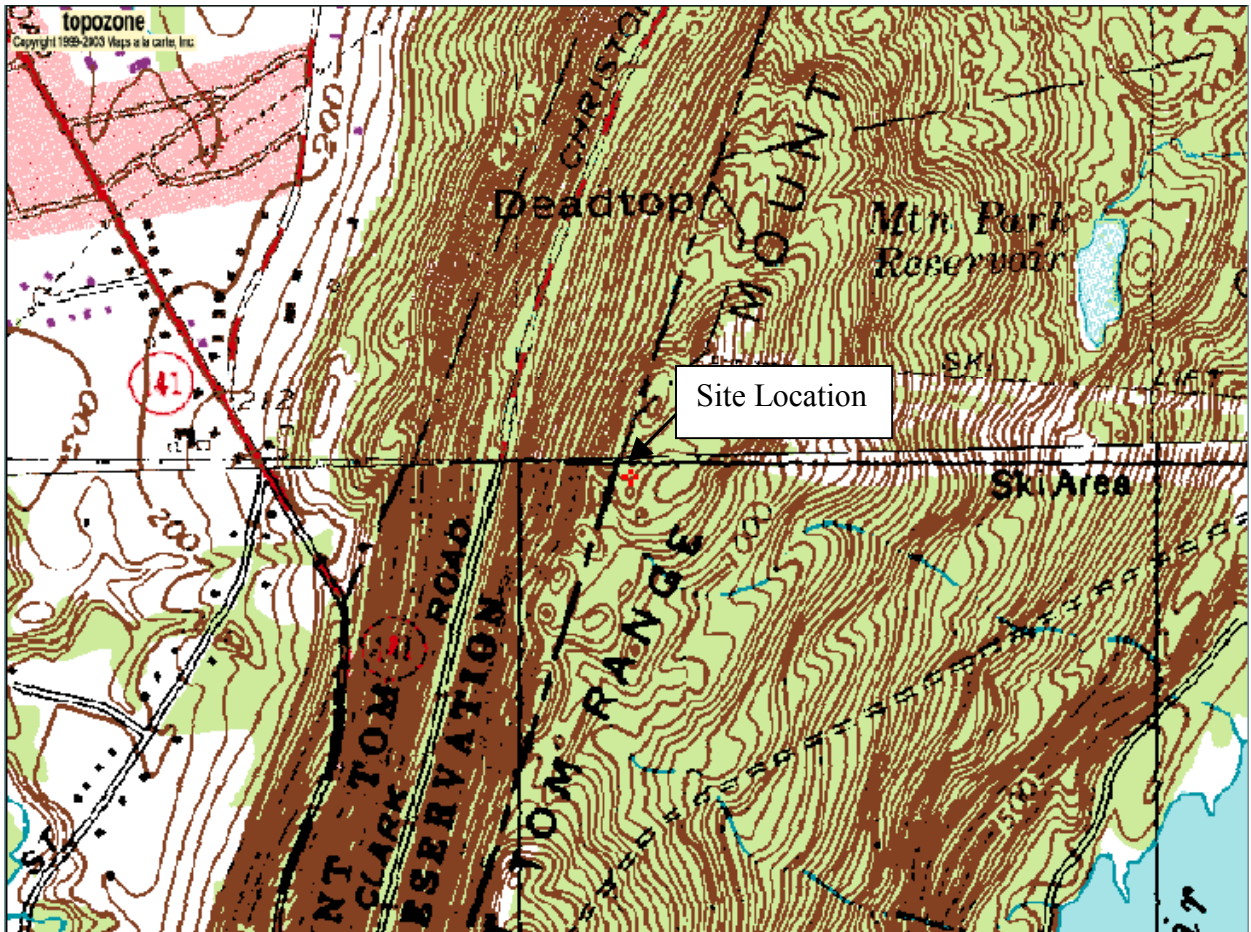


Figure 1 - Site location at Mt. Tom site.

Source: www.topozone.com.

SECTION 1 - Instrumentation and Equipment

The wind monitoring equipment is mounted on a 160 ft lattice tower. All the remaining monitoring equipment comes from NRG Systems, and consists of the following items:

- Model 9302 Cellogger®, serial # 0656
- Electrical enclosure box
- Yagi directional antenna and mount
- 4 – #40 Anemometers, standard calibration (Slope - 0.765 m/s, Offset – 0.350 m/s)
- 2 - #200P Wind direction vanes
- 4 – Sensor booms, 43” length
- Lightning rod and grounding cable
- Shielded sensor wire

The NRG 9302 system logger is equipped with a built-in cell phone so that the data can be transmitted weekly to a PC, located at the University of Massachusetts/ Amherst. The logger samples wind speed and direction once every second. 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 2 - Data Collection and Maintenance

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

- December 10 16:10: Replaced Primary and Secondary Anemometer at 37 meters. Replaced Vane at 37 meters.
- December 19 13:00: Replaced Primary Anemometer at 24 meters. Replaced Vane at 24 meters.

Data Statistics Summary

Date	Mean Wind Speed 37 m,[m/s]	Max Wind Speed 37 m,[m/s]	Turbulence Intensity 37 m,[]	Prevailing Wind Direction 37 m,[]
December 2003	Not enough data	Not enough data	Not enough data	Not enough data
January 2004	7.71	24.24	0.16	WNW
February 2004	7.03	20.17	0.17	NW
Dec 03 – Feb 04	7.5	24.24	0.16	WNW

SECTION 3 - Significant Meteorological Events

- Icing Event: December 15, 2003 00:40 – December 16, 2003 12:20
- Icing Event January 5, 2004 01:00 – January 9, 2004 08:10

A low pressure area formed over the southeastern states on December 5. At the same time, a large arctic high became established over eastern Canada. The storm tracked off the Virginia coastline on December 6, then took a track along the eastern seaboard as a classic nor'easter. The storm interacted with the strong high in eastern Canada, which caused it to move very slowly. It took over a day for the storm to move northeast of Cape Cod, which was not until late December 7. The result was the first major snowstorm of the early winter season across the Berkshires. Nine to 18 inches fell across the Berkshires with Dalton receiving 17 inches.

A low pressure area formed in the Gulf States early on December 14. This storm hugged the coast line as it tracked northward to become the second nor'easter of the winter season. This storm moved a little quicker than its predecessor. In addition, enough warm air moved in aloft to change the snow to sleet and freezing rain, thus reducing snow fall accumulations, especially in southern sections of the county. By the time the storm moved off the New England coastline, 5 to 10 inches of snow had accumulated in Berkshire County. The city of West Otis received 10.5 inches, the most reported in the county. (<http://www4.ncdc.noaa.gov>)

January began with a week of warm temperatures and rainy days. The entire Northeast was at least 2 degrees above normal from the 1st to the 7th of January, with the majority of the region between 8 and 12 degrees warmer than average during this period. Beginning on the 7th, the continental weather pattern changed drastically and January ended up the 11th coldest on record in the Northeast. Wave after wave of arctic air sank into the region from Canada setting many minimum temperature records at observation sites all over the Northeast. Cold snaps occurred from January 9-11, 13-16, and 24-26 causing pipe bursts across the region and prompting school closures even in the winter-hardy northern New England states. The entire region was more than 4 degrees below normal. Massachusetts recorded the coldest January in that state (16.4 degrees) since records began in 1895, surpassing the old record of 16.7 degrees that had stood since 1981. New York, Rhode Island, and Connecticut all fell more than 7 degrees below their respective normals setting January 2004 among the ten coldest on record in each state. The region as a whole was 5.7 degrees below normal and, at 17.3 degrees, was the coldest month since 1994 and 0.8 degrees colder than last January.

When the region changed from warm to cold after the first week in January, it also went from wet to extremely dry. Many observation sites, especially in the northern half of the region, measured less than a quarter inch of rain/melted snow after the first week. All six New England states were more than 2 inches below the normal amount. Maine, New Hampshire and Vermont averaged only about an inch of precipitation (rain plus the liquid

equivalent of snow) making this January one of the five driest on record in those states.. The near continuous fresh snow pack contributed to temperature departures in the 14 to 16 degree below normal range in these areas during the latter part of the month. Overall the Northeast fell more than 1 inch short of its January precipitation total but amazingly this was the wettest January since 2000. The lack of rain and snow this month puts an end to an 8-month streak of wet weather here in the Northeast.

The Northeast was very close to normal in terms of temperature this February. While southern portions of the region were at or slightly below normal this month, the New England states saw a more significant positive temperature departure. Overall, the land-area weighted regional average was 26.0 degrees, or 0.5 degrees above normal. While not a very impressive temperature departure, this month was 4.5 degrees warmer than February 2003. All six New England states were above normal, and all of these except Vermont were more than 1 degree above normal. The general weather pattern this February brought storm systems northward over the Appalachians rather than over the coast, keeping New England on the warm side of the storms. This western storm trend also prevented any deep or prolonged cold snaps from taking hold in the northern states which could potentially have dropped the average temperatures down a notch. New Jersey was the only other state above normal this month, and the remaining 5 states were all within 0.5 degrees of their respective averages. Whether warmer or colder than normal, February temperatures in all 12 states were a welcome change after a bitterly cold January. Many states in the region saw a temperature increase of over 10 degrees from last month to this month. In fact, the region as a whole was 8.7 degrees warmer in February than in January.

One trend that did continue from January was the lack of precipitation across the Northeast (rain and water equivalent of snow). The region's measure of 1.97 inches makes February 2004 the driest since 1991. Rain and snow from two storms early in the month was followed by 20 days of no significant precipitation. High pressure was dominant during this time and the majority of the region received less than 1/2 an inch of rain/melted snow. Large portions of the region didn't see even a quarter of an inch after the 8th of February. This dry period was more extreme in the region's southern states, but early rains in that area seemed to cover for the future lack. Northern states were the most dry overall. Of six states in the region falling more than an inch short of their normal amounts, five were in New England (the sixth was Delaware). New Hampshire and Vermont both totaled less than an inch and a half on the month which was enough to put 2004 among the ten driest on record for both states. West Virginia was the most wet state in the region at 2.98 inches but still failed to reach its average value (precipitation departure: -.13 inches). This February was the first month since January 2003 in which all 12 states in the Northeast were on the dry side of their respective normals. A precipitation total of 1.97 inches is the lowest of any month since November 2001. (<http://met-www.cit.cornell.edu/climate/Impacts.html>)

SECTION 4 - 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 [%]	99.992
Net Data Recovered [%]	85.685

The high Gross Data Recovery Percentage is an indication that the logger was recording and transmitting properly. The low Net Data Recovery Percentage is a result of multiple icing events and sensors failures. In the beginning of December, five sensors were not functioning. The sensors were replaced.

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 which 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.

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

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.

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

To exit an icing event, the wind direction standard deviation must be greater than Factor 4.

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.

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

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 5 - 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 6 and 7 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 Jan 2003 – Feb 2004
- 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 7 and 9 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. The turbulence intensities recorded during the winter were around 0.16.
- 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 strong prevailing WNW wind direction. The maximum average wind speed were recorded from the WNW.

SECTION 6 - Graphs

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

Wind Speed Time Series

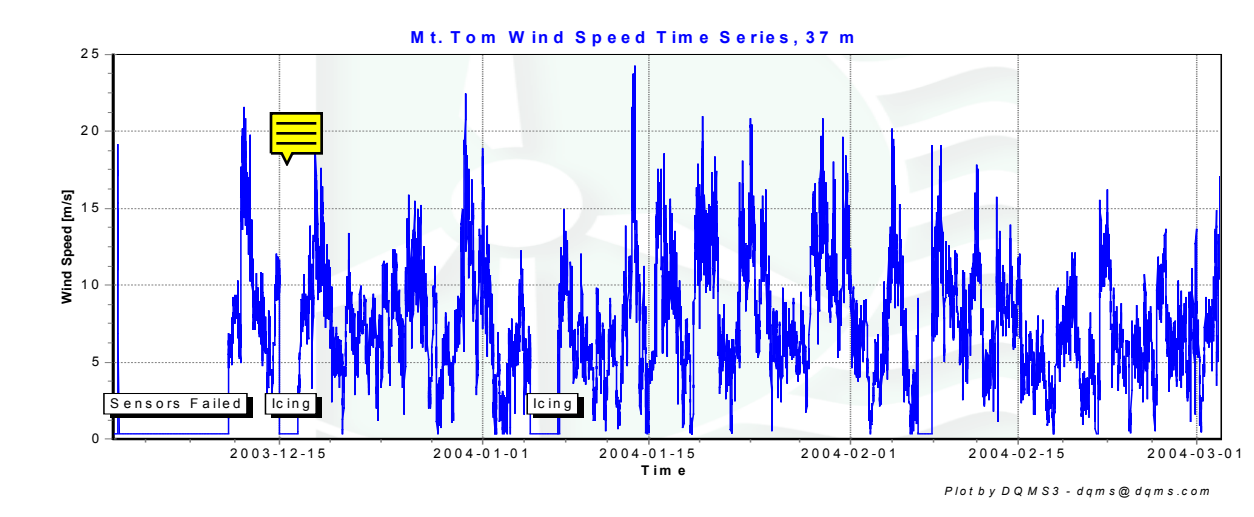


Figure 2 - Wind Speed Time Series, December 2003 – February 2004

Wind Speed Distributions

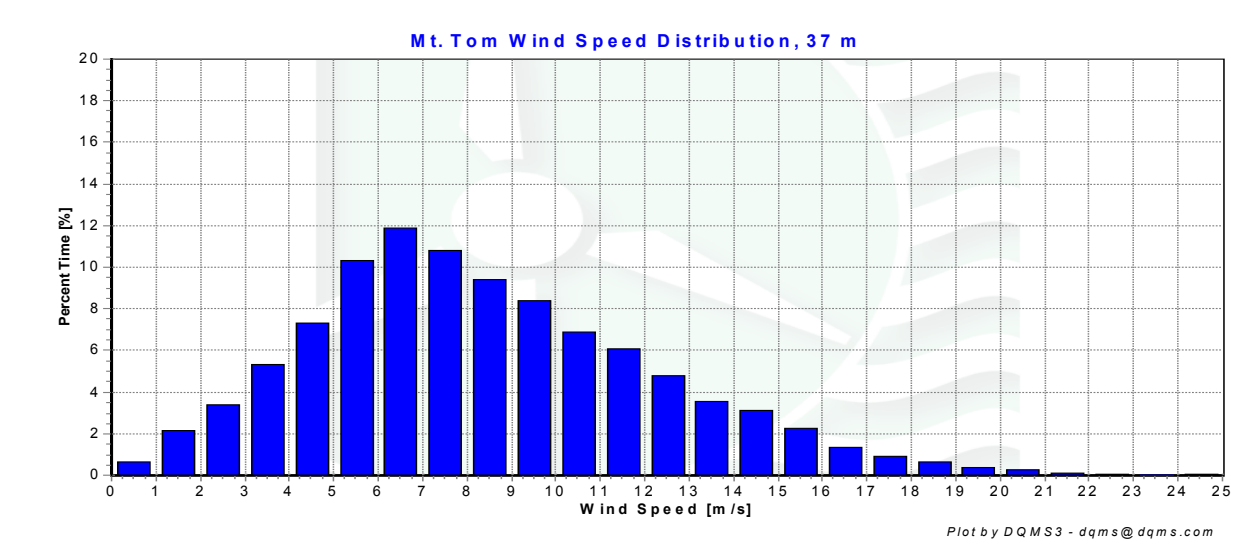


Figure 3 - Wind Speed Distribution, December 2003 – February 2004

Monthly Average Wind Speeds

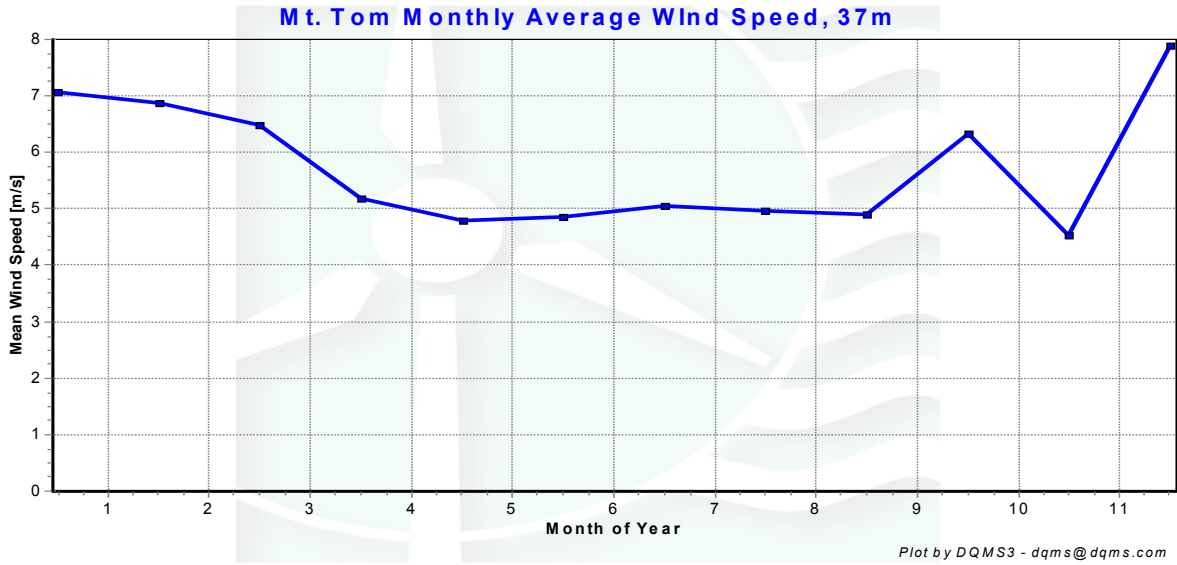


Figure 4 - Monthly average wind speed, January 2003 - February 2004

Diurnal Average Wind Speeds

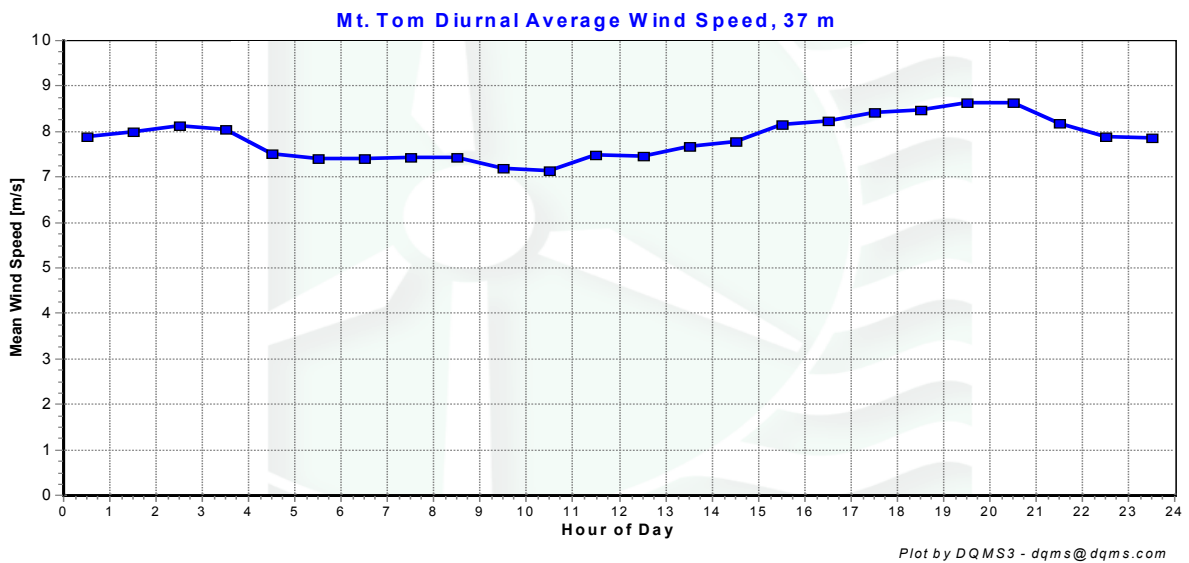


Figure 5 - Diurnal Wind Speed, December 2003 – February 2004

Turbulence Intensities

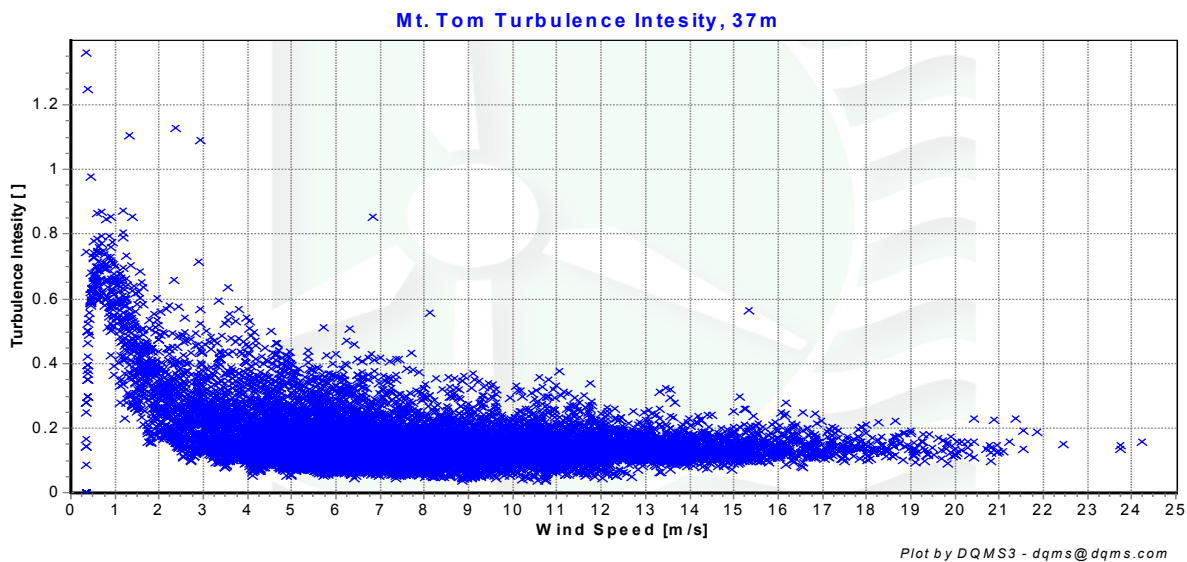


Figure 6 - Turbulence Intensity vs. Wind Speed, December 2003 – February 2004

Wind Roses

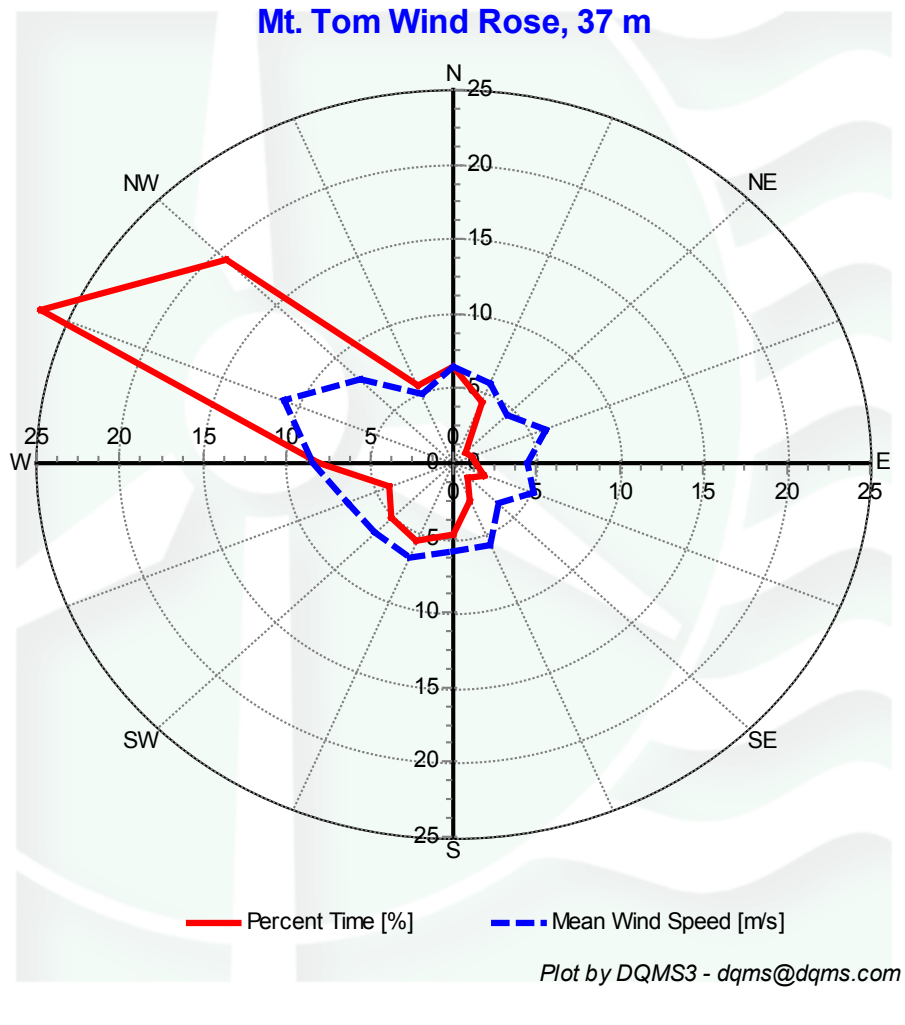


Figure 7 - Wind Rose, December 2003 – February 2004

APPENDIX A - Sensor Performance Report

Test Definitions

Test Order	TestField1	TestField2	TestField3	CalcField1	CalcField2	TestType	Factor1	Factor2	Factor3	Factor4
1						TimeTest Insert				
2	Itmp3aDEGC					MinMax	-30	60		
3	Batt3aVDC					MinMax	10.5	15		
4	Etmp3aDEGC					MinMax	-30	60		
5	EtmpSD3aDEGC					MinMax	0	4		
10	Anem24yMS					MinMax	0	90		
11	Anem37yMS					MinMax	0	90		
12	Anem24aMS					MinMax	0	90		
13	Anem24bMS					MinMax	0	90		
14	Anem37aMS					MinMax	0	90		
15	Anem37bMS					MinMax	0	90		
16	Anem18bMS					MinMax	0	90		
17	Anem21aMS					MinMax	0	90		
20	AnemSD24aMS					MinMax	0	7		
21	AnemSD24bMS					MinMax	0	7		
22	AnemSD37aMS					MinMax	0	7		
23	AnemSD37bMS					MinMax	0	7		
24	AnemSD18bMS					MinMax	0	7		
25	AnemSD21aMS					MinMax	0	7		
26	AnemSD24yMS					MinMax	0	7		
27	AnemSD37yMS					MinMax	0	7		
40	Pyro6aWMS					MinMax	0	1500		
41	PyroSD6aWMS					MinMax	0	1000		
50	Turb24zNONE					MinMax	0	2		
51	Turb37zNONE					MinMax	0	2		
60	Wshr0zNONE					MinMax	-100	100		
70	Pwr24zWMC					MinMax	0	10000		
71	Pwr37zWMC					MinMax	0	10000		
200	VaneSD24aDEG	Anem24yMS				MinMaxT	0	100	100	10
201	VaneSD37aDEG	Anem37yMS				MinMaxT	0	100	100	10
250	Vane24aDEG					MinMax	0	359.9		
251	Vane37aDEG					MinMax	0	359.9		
252	Vane19aDEG					MinMax	0	359.9		
300	Anem24aMS	AnemSD24aMS	Vane24aDEG	VaneSD24aDEG	Etmp3aDEGC	Icing	0.5	1	2	10
301	Anem24bMS	AnemSD24bMS	Vane24aDEG	VaneSD24aDEG	Etmp3aDEGC	Icing	0.5	1	2	10
302	Anem37aMS	AnemSD37aMS	Vane37aDEG	VaneSD37aDEG	Etmp3aDEGC	Icing	0.5	1	2	10

303	Anem37bMS	AnemSD37bMS	Vane37aDEG	VaneSD37aDEG	Etmp3aDEGC	Icing	0.5	1	2	10
400	Anem24aMS	Anem24bMS				CompareSensors	1	0.25	3	0
401	Anem37aMS	Anem37bMS				CompareSensors	1	0.25	3	0

Sensor Statistics

Sensor	Expected Data Points	Actual Data Points	% Data Recovered	Hours Out of Range	Hours of Icing	Hours of Fault	% Data Good
Itmp3aDEGC	13104	13103	99.992	0	0	0	99.992
Batt3aVDC	13104	13103	99.992	0	0	0	99.992
Anem24aMS	13104	13103	99.992	0	122.5	416	75.336
AnemSD24aMS	13104	13103	99.992	0	122.5	416	75.336
Anem24bMS	13104	13103	99.992	0.167	180.333	2.5	91.613
AnemSD24bMS	13104	13103	99.992	0.167	180.333	2.5	91.613
Anem37aMS	13104	13103	99.992	0	213.833	234.667	79.457
AnemSD37aMS	13104	13103	99.992	0	213.833	234.667	79.457
Anem37bMS	13104	13103	99.992	0	213.167	257.667	78.434
AnemSD37bMS	13104	13103	99.992	0	213.167	257.667	78.434
Vane24aDEG	13104	13103	99.992	1	123	445	73.939
VaneSD24aDEG	13104	13103	99.992	1	123	445	73.939
Vane37aDEG	13104	13103	99.992	0	213.833	232	79.579
VaneSD37aDEG	13104	13103	99.992	0	213.833	232	79.579
Etmp3aDEGC	13104	13103	99.992	0.667	0	0	99.962
EtmpSD3aDEGC	13104	13103	99.992	0	0	0	99.992
Pyro6aWMS	13104	13103	99.992	0	0	0	99.992
Total	222768	222751	99.992	3	2133.333	3175.667	85.685

APPENDIX B - Plot Data

Wind Speed Distribution Data

Bin Center Wind Speed [m/s]	Percent of Time [%]
0.5	0.63
1.5	2.14
2.5	3.36
3.5	5.3
4.5	7.33
5.5	10.31
6.5	11.87
7.5	10.79
8.5	9.41
9.5	8.4
10.5	6.86
11.5	6.08
12.5	4.8
13.5	3.56
14.5	3.11
15.5	2.28
16.5	1.35
17.5	0.92
18.5	0.67
19.5	0.37
20.5	0.26
21.5	0.12
22.5	0.04
23.5	0
24.5	0.03

Table 1 - Wind Speed Distribution

Monthly Average Wind Speed Data

Month	10 min Mean [m/s]
Jan	7.07
Feb	6.87
Mar	6.48
Apr	5.17
May	4.78
Jun	4.86
Jul	5.05
Aug	4.97
Sept	4.89
Oct	6.32
Nov	4.53
Dec	7.89

Table 2 - Wind Speed Averages

Diurnal Average Wind Speed Data

Hour of Day	Average Wind Speed [m/s]
0	7.9
1	7.99
2	8.14
3	8.06
4	7.5
5	7.41
6	7.4
7	7.43
8	7.42
9	7.19
10	7.13
11	7.47
12	7.46
13	7.68
14	7.77
15	8.17
16	8.25
17	8.41
18	8.49
19	8.64
20	8.63
21	8.17
22	7.88
23	7.87

Table 3 - Diurnal Average Wind Speeds

Wind Rose Data

Direction	Percent Time [%]	Mean Wind Speed [m/s]
N	6.49	6.48
NNE	4.39	5.8
NE	1.07	4.55
ENE	1.14	6.02
E	1.32	4.52
ESE	2.04	5.17
SE	1.29	3.84
SSE	2.74	5.91
S	4.82	5.95
SSW	5.67	6.77
SW	5.26	6.61
WSW	4.17	6.89
W	8.02	8.41
WNW	26.76	10.92
NW	19.25	7.85
NNW	5.55	4.98

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