WIND DATA REPORT

Savoy

December 1, 2003 – February 29, 2004

Prepared for

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by

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EXECUTIVE SUMMARY

Wind monitoring equipment was first installed in Savoy on November 8, 2003. Anemometers and wind direction vanes are installed at 20 m, 39 m, and 50 m above the tower base. Data are transmitted to RERL via modem on a weekly schedule.

This is the second quarterly report since the tower installation and the first with an entire quarter's worth of data from December 1, 2003 to February 29, 2004. The mean recorded wind speed was 7.60 m/s (17.0 mph) at 50 m and the prevailing wind direction was from the WNW. The average wind shear factor of 0.26, calculated from data from the 50 m and 39 m anemometers. The average turbulence intensity at 50m was 0.17, well within the normal values recorded at other sites in eastern MA.

The gross data recovery percentage (the actual percentage of expected data received) was 99.96% and the net data recovery percentage (the percentage of expected data which passed all of the quality assurance tests) was 81.873%. The gross data recovery is good but the net data recovered is low because of an anemometer failure that occurred within the first few days of logging. There were still problems with the 30 m vane which continues to give no signal for long periods.

SECTION 1 - Station Location

The Savoy, MA station is located on privately owned land on a cleared hilltop. 40-50ft tall trees surround the site in every direction. Several trees were removed to create a clearing for the tower approximately 250 ft in diameter. There is a 1-2ft layer of topsoil above the rock surface. Poor drainage results in the area being very wet, almost boggy. The location of the tower base is 42.6034 N, 072.9699 W (NAD 27).

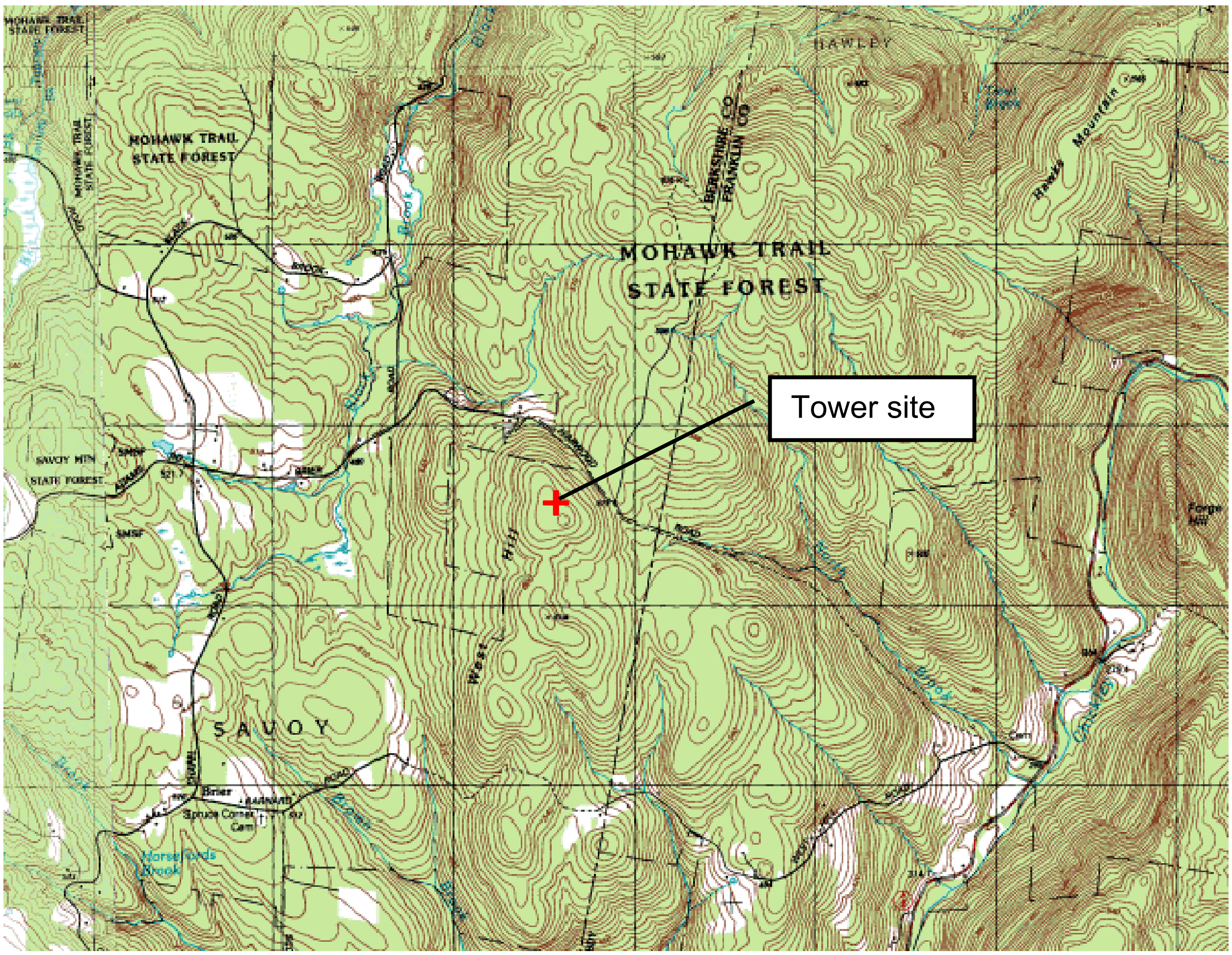

Figure 1 – Map of Savoy site.

Source: www.topozone.com.

SECTION 2 - Instrumentation and Equipment

Wind monitoring equipment is mounted on a standard WindMast™ 50-meter tall 6in diameter tilt-up guyed tower purchased from Second Wind Inc. Four rock anchors were installed and proof tested at 7,400-8,000 lbs load for 10 minutes (equal to 160mph loading without ice). Wind vanes and anemometers are located at three heights on the tower: 20m, 39m, and 50m. Redundant anemometers exist at 39m and 50m. Additional equipment and models:

- NRG model 9300 Cellogger®
- 5 – #40 Anemometers, standard calibration (Slope - 0.765 m/s, Offset – 0.350 m/s)
- 3 - #200P Wind direction vanes
- 3 – Sensor booms, 54” length
- 4 – Rock anchors
- Lightning rod and grounding cable
- Shielded sensor wire

Figure 2 – 50m data tower in Savoy during installation.

SECTION 3 - Data Collection and Maintenance

There are no data transmission problems to report for this period. Nearly 100% of data was sent from the logger via modem and successfully received at RERL.

There have been a few significant sensor issues since the commissioning of the Savoy tower. Within the first 20 minutes of logging one of the 50 m anemometers (Anem50a) failed and now reports only a zero wind speed. Occasionally in high winds this anemometer will produce a value greater than zero, but it does not correlate with the working anemometer at the same height (Anem50b). No maintenance is planned for this sensor, as the tower would have to be lowered to replace it.

In the past, the 20 m and 39 m vanes failed periodically, but then seemed to recover only to fail again later. For now the 20m anemometer seems to have corrected itself to a degree. The 39 m vane is still failing occasionally and is characterized by long periods with no signal and then dramatic changes in direction with very high standard deviations. On December 12 strong winds shifted the 3 m wind vane approximately 7 degrees to the north. The offset from these data have been changed to correct this.

The 20m vane reported values with very little change but with the same trend as the 50m vane for the first few days of logging, as if only the magnitude of the value were incorrect. Then the 20m vane miraculously corrected itself and values began to closely follow the 50m vane values. At times, however, the 20m vane will closely match the 50m vane, then suddenly shift so that the magnitude changes are similar but at very different values. The reason for this offset is unknown.

On December 23, 2003 Tony Ellis made a site visit and replaced the #4 SIM card in the logger. During this visit data no was data logged for approximately two hours. Replacing the SIM card did affect the problem sensors, but they continued to fail in a different way.

On February 18, 2004 Tony Ellis made another site visit, this time to replace the logger. With the new logger the wind vanes seem to be working much better, although the 39 m vane has still given no signal on a few occasions. Most of the time, however, the 39 m vane appears to be working correctly.

These problematic sensors will continue to be closely monitored as data arrives at RERL and appropriate actions will be planned if problems persist. At this time, data form the 20 and 39m wind vanes should be considered suspect.

Data Statistics Summary

	Anemometer 50m			Anemometer 39m			Anemometer 20m			10m to 39m	Vane 50m	Vane 39m	Vane 20m
Date	Mean [m/s]	Max [m/s]	Turb. Int. [ ]	Mean [m/s]	Max [m/s]	Turb. Int [ ]	Mean [m/s]	Max [m/s]	Turb. Int. [ ]	Shear [ ]	Prev. Dir	Prev. Dir	Prev. Dir
Dec 2003	8.05	30.26	0.17	7.77	29.38	0.2	5.13	17.9	0.32	0.16	WNW	NA**	N
Jan 2004*	7.44	20.22	0.19	6.83	21.39	0.19	5.33	15.43	0.3	0.17	WNW	NA**	NNE
Feb 2004	7.31	21.56	0.18	7.04	21.96	0.2	4.91	16.18	0.31	0.18	WNW	NA**	WNW
Dec 01 – Feb 31	7.60	30.26	0.18	7.21	29.38	0.20	5.12	17.9	0.31	0.18	WNW	NA**	NNW

* A long icing event in January caused more than 10% of the data to be flagged. Values are still reported for this month even though they fall below usual 90% threshold.

** The vane at the 30 m level frequently failed during this period and prevailing wind directions cannot be accurately reported.

SECTION 4- Significant Meteorological Events

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 Appalachains 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 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 [%]	99.96
Net Data Recovered [%]	81.873

The gross data recovery is good but the net data recovered is low because of the anemometer failure that occurred within the first few days of logging. This zero value drags down the overall net data recovery numbers. Due to the unusual nature of the vane failures, the standard filters did not catch all the problems and some data were incorrectly counted as recovered data. The data from these vanes is clearly corrupted and all data for this period were manually flagged. Further refinement of the filters and fixing the sensor problems should resolve this issue in the future.

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.

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

Icing Test: An icing event 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.

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

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.

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 the following types of wind data graphs:

- 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 distribution peak occurs 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 over the year. At this time only three full months of data are available.
- Diurnal – A plot of the average wind speed for each hour of the day. This site has a fairly even diurnal distribution, with a slight decrease in wind speeds in the morning hours.
- 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 average turbulence intensity was 0.18.
- 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 graph shows a clear prevailing wind direction from the West/North West.

SECTION 7 - Graphs

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

Wind Speed Time Series

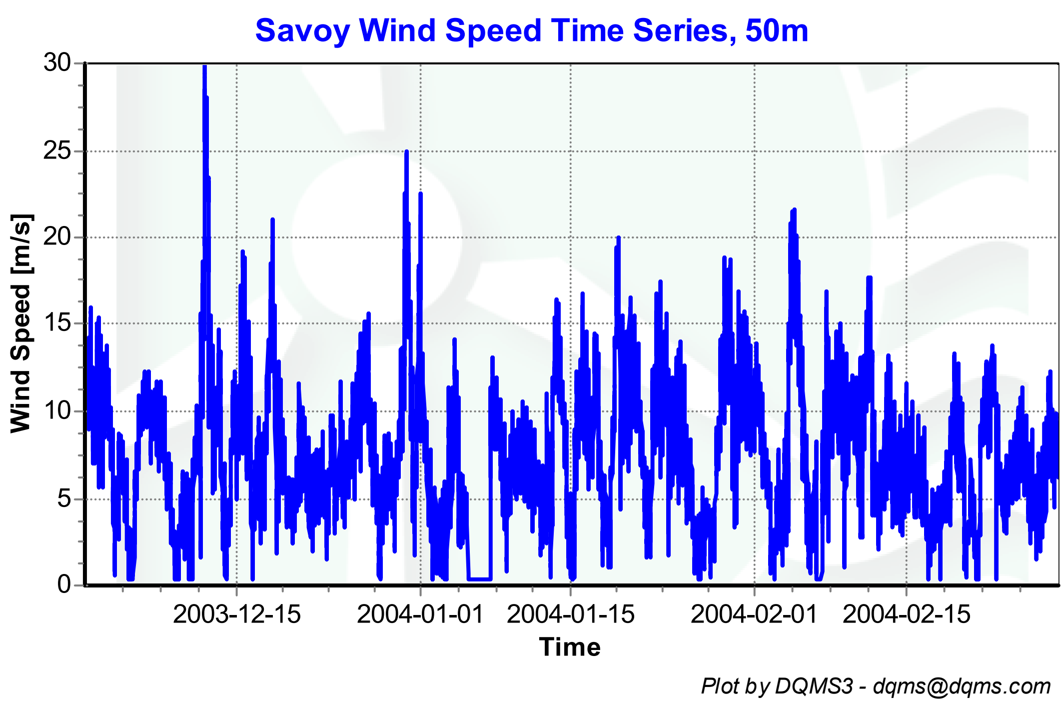

Figure 3 – Wind Speed Time Series, December 1, 2003 – February 29, 2004

Wind Speed Distributions

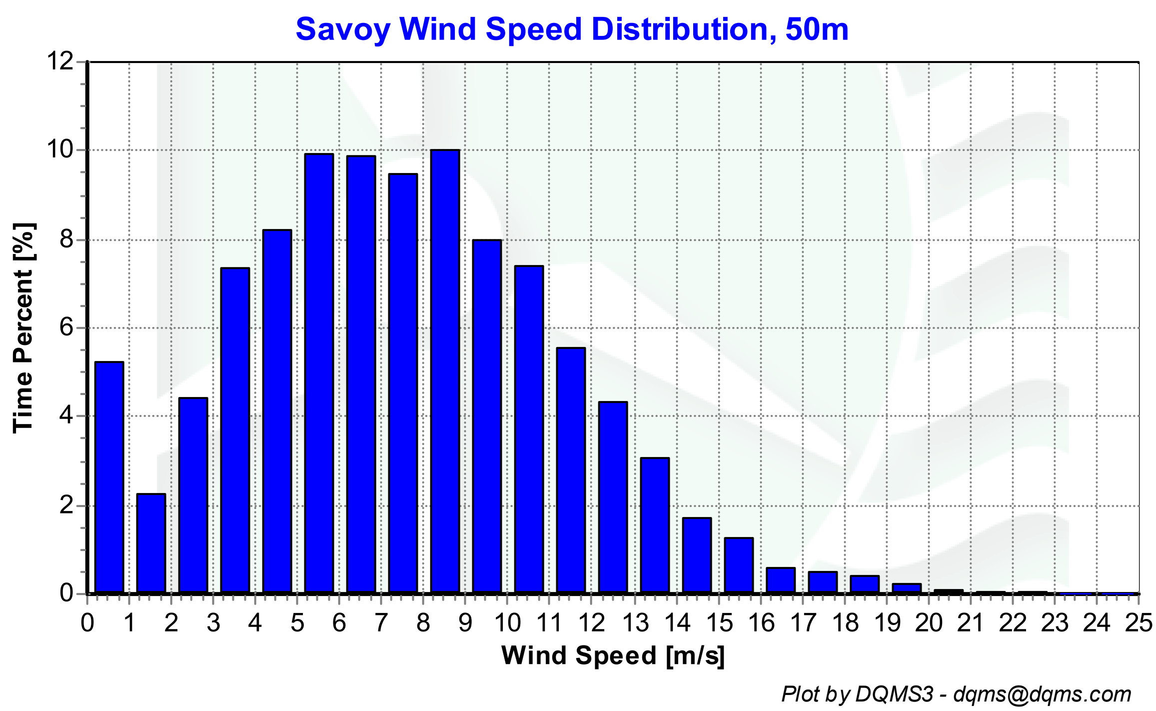

Figure 4 – Wind Speed Distribution, December 1, 2003 – February 29, 2004

Diurnal Average Wind Speeds

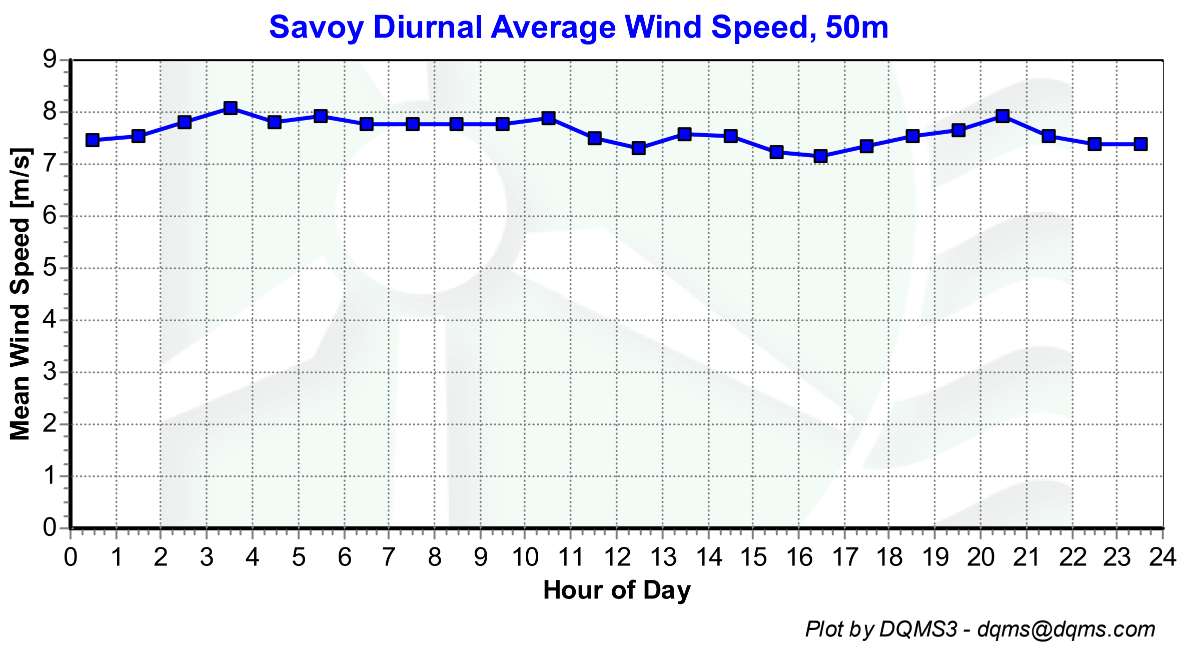

Figure 5 – Diurnal Wind Speed, December 1, 2003 – February 29, 2004

Monthly Average Wind Speeds

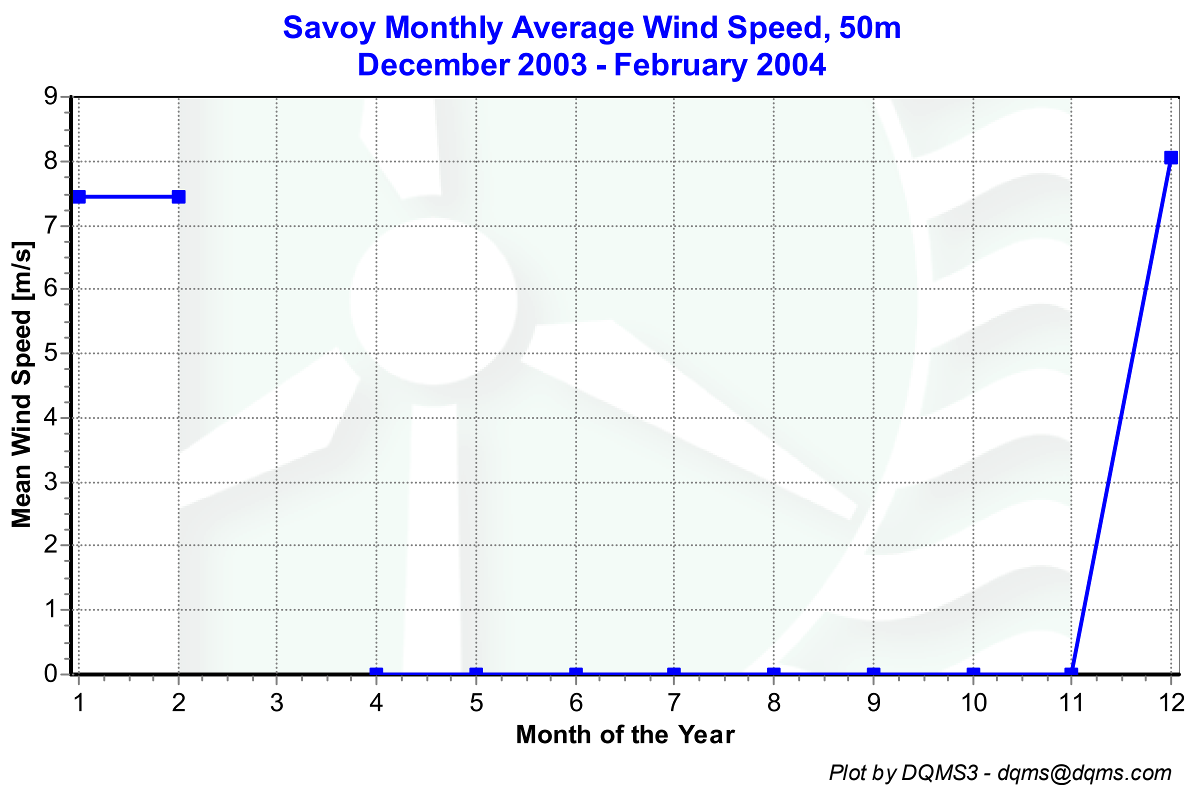

Figure 5 – Monthly Ave Wind Speed

Turbulence Intensities

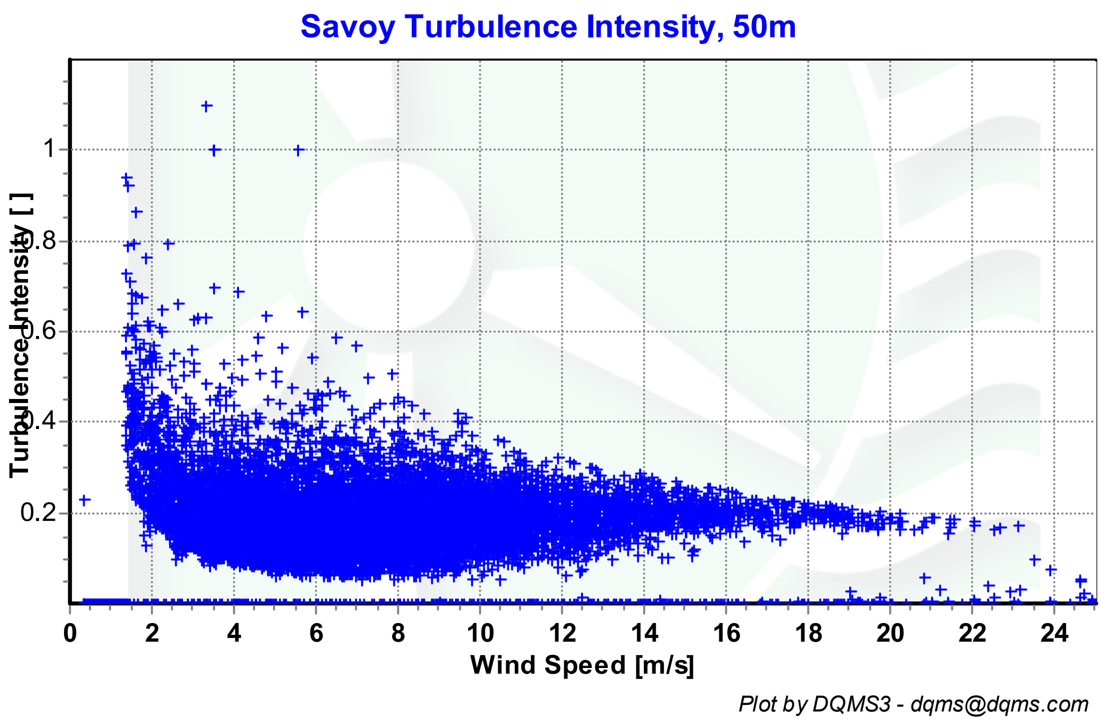

Figure 6 – Turbulence Intensity vs Wind Speed, December 1, 2003 – February 29, 2004

Wind Roses

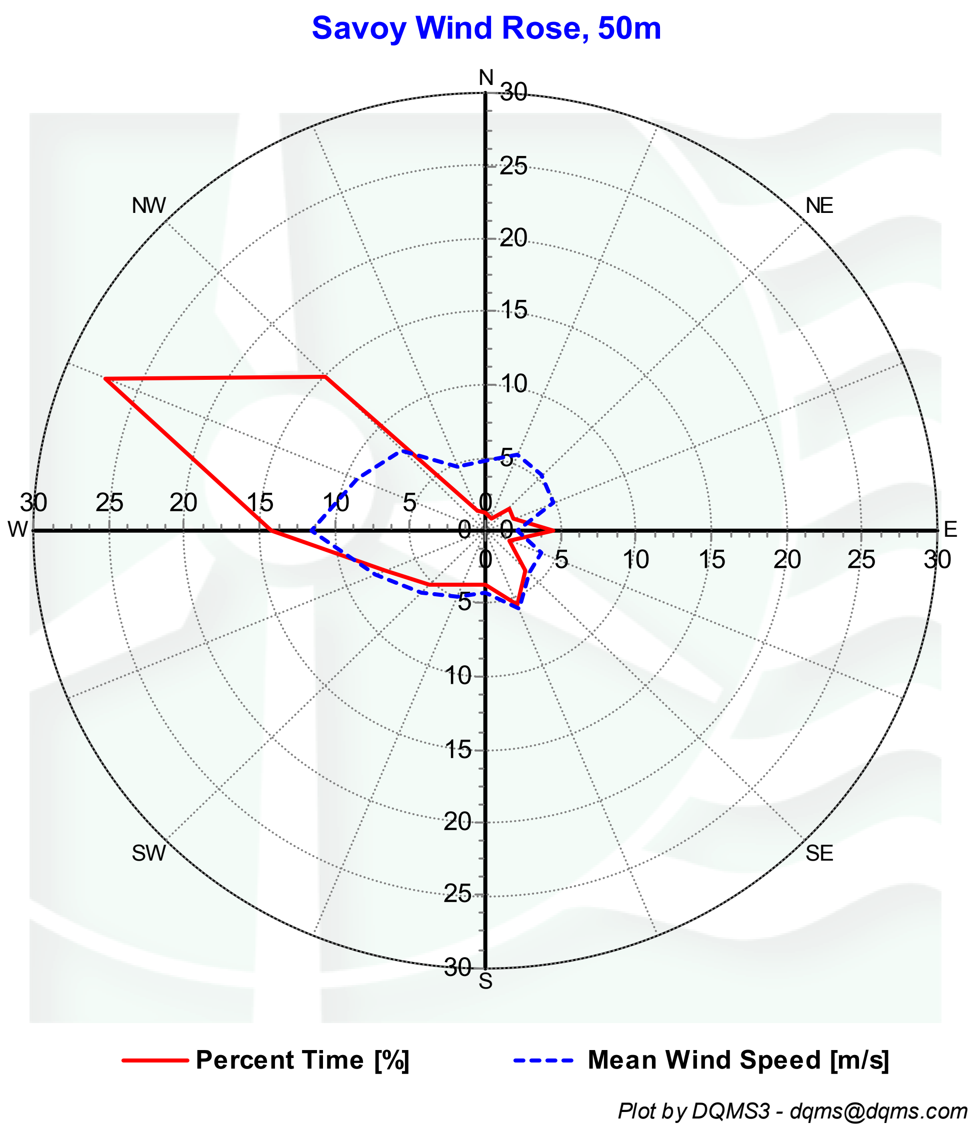

Figure 7 – Wind Rose, December 1, 2003 – February 29, 2004

APPENDIX A - Sensor Performance Report

Test Definitions

Test Order	Test Field1	Test Field2	Test Field3	Calc Field1	Calc Field2	Calc Field3	Test Type	Factor 1	Factor 2	Factor 3	Factor 4
1							TimeTest Insert				
2	Itemp2aDEGC						MinMax	-30	60	0	0
3	Batt2aVDC						MinMax	10.5	15	0	0
4	Etmp2aDEGC						MinMax	-30	60		
5	EtmpSD2aDEGC						MinMax	-30	60		
10	Anem50aMS						MinMax	0	90	0	0
11	Anem50bMS						MinMax	0	90	0	0
12	Anem39aMS						MinMax	0	90	0	0
13	Anem39bMS						MinMax	0	90	0	0
14	Anem20aMS						MinMax	0	90		
15	Anem50yMS						MinMax	0	90		
16	Anem39yMS						MinMax	0	90		
20	AnemSD50aMS						MinMax	0	4		
21	AnemSD50bMS						MinMax	0	4		
22	AnemSD39aMS						MinMax	0	4		
23	AnemSD39bMS						MinMax	0	4		
24	AnemSD20aMS						MinMax	0	4		
25	AnemSD50yMS						MinMax	0	4		
26	AnemSD39yMS						MinMax	0	4		
30	Vane50aDEG						MinMax	0	359.9		
31	Vane39aDEG						MinMax	0	359.9		
32	Vane20aDEG						MinMax	0	359.9		
50	Turb50zNONE						MinMax	0	2		
51	Turb39zNONE						MinMax	0	2		
52	Turb20zNONE						MinMax	0	2		
60	Wshr0zNone						MinMax	-100	100		
200	VaneSD50aDEG	Anem50yMS					MinMaxT	0	100	100	10
201	VaneSD39aDEG	Anem39yMS					MinMaxT	0	100	100	10
202	VaneSD20aDEG	Anem20aMS					MinMaxT	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	Anem39aMS	AnemSD39aMS	Vane39aDEG	VaneSD39aDEG	Etmp2aDEGC		Icing	0.5	1	2	
303	Anem39bMS	AnemSD39bMS	Vane39aDEG	VaneSD39aDEG	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	Anem39aMS	Anem39bMS					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
Itemp2aDEGC	13103	13097	99.954	0	0	0	99.954
Batt2aVDC	13103	13097	99.954	0	0	0	99.954
Anem50aMS	13103	13103	100	0	0	2183.833	0
AnemSD50aMS	13103	13103	100	0	0	2183.833	0
Anem50bMS	13103	13097	99.954	21.167	59	0	96.283
AnemSD50bMS	13103	13097	99.954	21.167	59	0	96.283
Anem39aMS	13103	13097	99.954	7.333	140.667	36.667	91.498
AnemSD39aMS	13103	13097	99.954	7.333	140.667	36.667	91.498
Anem39bMS	13103	13097	99.954	15.667	150.833	1.833	92.246
AnemSD39bMS	13103	13097	99.954	15.667	150.833	1.833	92.246
Anem20aMS	13103	13097	99.954	15.167	53.333	0	96.818
AnemSD20aMS	13103	13097	99.954	15.167	53.333	0	96.818
Vane50aDEG	13103	13097	99.954	0.333	59	0	97.237
VaneSD50aDEG	13103	13097	99.954	0.333	59	0	97.237
Vane39aDEG	13103	13098	99.962	2.333	79	541.5	71.442
VaneSD39aDEG	13103	13098	99.962	2.333	79	541.5	71.442
Vane20aDEG	13103	13098	99.962	1.167	39.333	541.5	73.311
VaneSD20aDEG	13103	13098	99.962	1.167	39.333	541.5	73.311
Etmp2aDEGC	13103	13097	99.954	0.667	0	0	99.924
EtmpSD2aDEGC	13103	13097	99.954	0	0	0	99.954
Total	262060	261956	99.96	127	1162.333	6610.667	81.873

APPENDIX B - Plot Data

Wind Speed Distribution Data

Bin Center Wind Speed [m/s]	Percent
0.5	5.23
1.5	2.25
2.5	4.4
3.5	7.37
4.5	8.23
5.5	9.92
6.5	9.88
7.5	9.46
8.5	10
9.5	7.97
10.5	7.41
11.5	5.57
12.5	4.35
13.5	3.05
14.5	1.72
15.5	1.28
16.5	0.61
17.5	0.48
18.5	0.42
19.5	0.24
20.5	0.09
21.5	0.05
22.5	0.03
23.5	0.01
24.5	0

Table B1: Wind Speed Distribution

Diurnal Average Wind Speed Data

Hour of Day	Wind Speed [m/s]
0	7.48
1	7.55
2	7.82
3	8.06
4	7.83
5	7.91
6	7.75
7	7.77
8	7.77
9	7.76
10	7.87
11	7.48
12	7.32
13	7.58
14	7.53
15	7.24
16	7.15
17	7.35
18	7.54
19	7.66
20	7.94
21	7.54
22	7.37
23	7.38

Table B3: Diurnal Wind Speed

Wind Rose Data

Direction	Percent Time [%]	Mean Wind Speed [m/s]
N	1.32	5.17
NNE	0.94	5.54
NE	2.03	5.36
ENE	2.02	4.8
E	4.47	2.56
ESE	1.92	3.44
SE	2.15	2.97
SSE	3.13	4.4
S	3.08	4.31
SSW	3.28	5.11
SW	4.51	6.19
WSW	5.56	7.43
W	15.47	11.26
WNW	29.5	8.99
NW	18.87	7.44
NNW	1.73	4.64

Table B4: Wind Rose Time Percentage and Mean Wind Speed