WIND DATA REPORT

Savoy

September 1, 2003 – November 30, 2003

Prepared for

Massachusetts Technology Collaborative
75 North Drive
Westborough, MA 01581

by

James F. Manwell
Anthony F. Ellis
Chris Henderson

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Renewable **E**nergy **R**esearch **L**aboratory
University of Massachusetts, Amherst
160 Governors Drive, Amherst, MA 01003
www.ceere.org/rerl • (413) 545-4359 • rerl@ecs.umass.edu

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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 20m, 39m, and 50m above the tower base. Data are transmitted to RERL via modem on a weekly schedule.

This is the first quarterly report since the tower installation and only a few weeks of data were collected during this period. The mean recorded wind speed was 7.32m/s (16.37mph) at 50m and the prevailing wind direction was from the WNW. The average wind shear factor of 0.26 is well above the rule-of-thumb value 0.14 (the shear factor is calculated from data from the 50m and 39m 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 99.891% and the net data recovery percentage (the percentage of expected data which passed all of the quality assurance tests) was 67.856%. 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 also problems with the 39m and 20m vanes, but it appears that these problems have been resolved for the time being.

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).

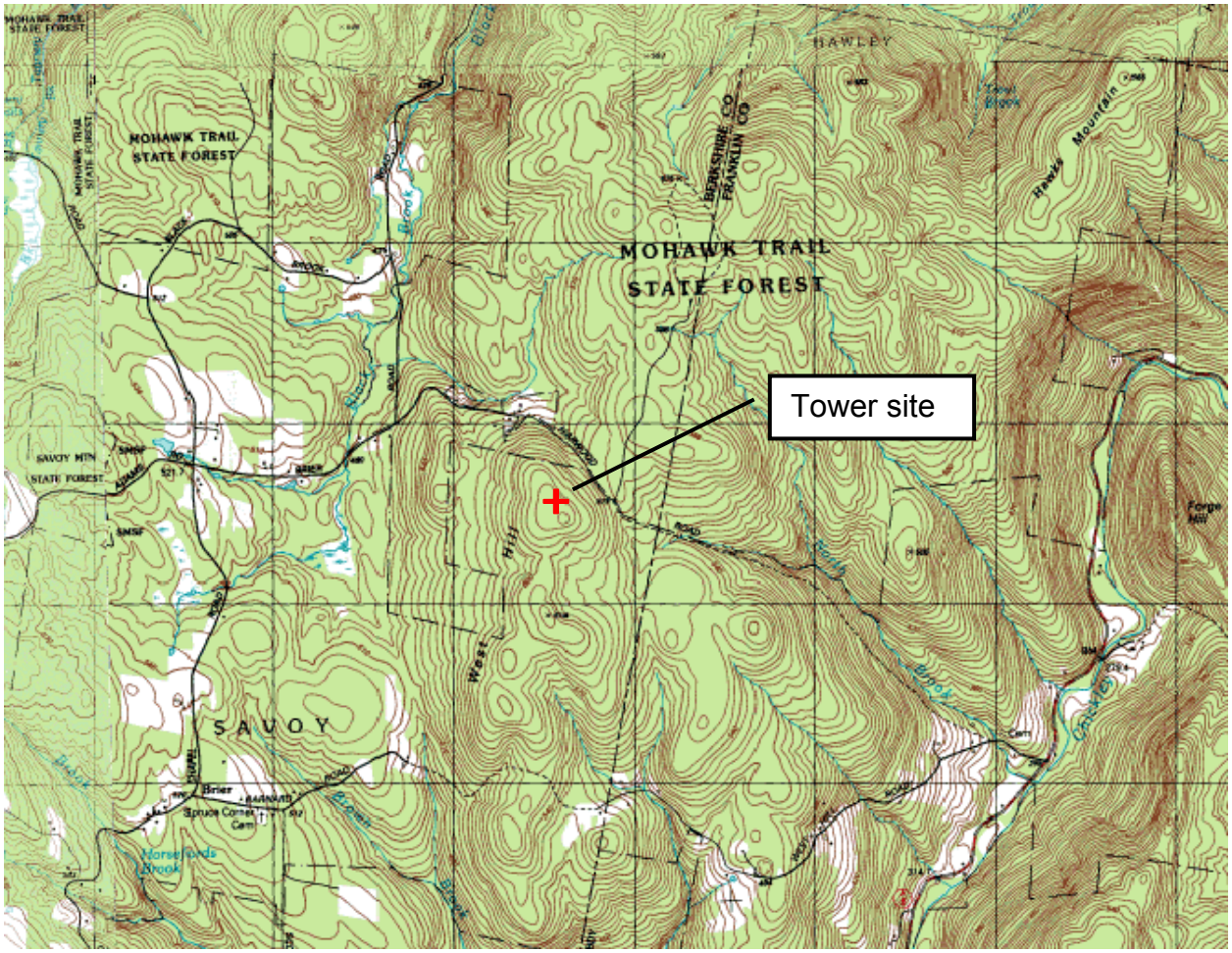

Figure 1 – Map of Savoy site.

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 several significant sensor issues since the commissioning of the Savoy tower. Within the first 20 minutes of logging one of the 50m 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 (Anem50b). No maintenance is planned for this sensor, as the tower would have to be lowered to replace it.

Periodically the 20m and 39m vanes failed, but then seemed to recover only to fail again later. The 39m vane failures are characterized by long periods with no signal and then dramatic changes in direction with very high standard deviations.

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.

Another oddity is that the pyronometer channel is reporting values without a sensor attached to it. This logger was previously used at another site had a pyronometer connected at that time. This is not really a problem, but may signify a logger malfunction.

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. Two days before his visit the problems with the vanes ceased to exist and have not returned since. After the SIM card replacement the pattern of the pyronometer values changed significantly, but it continues to report.

These problematic sensors will be closely monitored as data arrives at RERL and another site visit to replace the logger will be planned if problems persist. At this time the values from the wind vanes at the 20 and 39m vane should be considered suspect.

Data Statistics Summary

	Anemometer 50m			Anemometer 39m			Anemometer 20m			39m to 50m	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
Nov 08 – Nov 30	7.32	25.1	0.17	6.97	26.4	0.22	4.62	16.18	0.34	0.26	WNW	NA*	NA*

* The vanes at these levels failed and prevailing wind directions cannot be accurately reported.

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 wind storm is visible in the wind time series plot during this period.

Aside from the windstorm there were no significant meteorological events that occurred between November 8, 2003 and November 30, 2003 in Savoy.

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 [%]	99.891
Net Data Recovered [%]	67.856

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 and the vane failures at 20m and 30m. 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.

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

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.

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. Savoy was commissioned with only a few weeks left in the quarter and a complete month's worth of data were not collected. For this reason there are not yet any monthly averages and this graph is omitted from this report. Future quarterly reports will have this graph of monthly averages.
- 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 0.17.
- 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

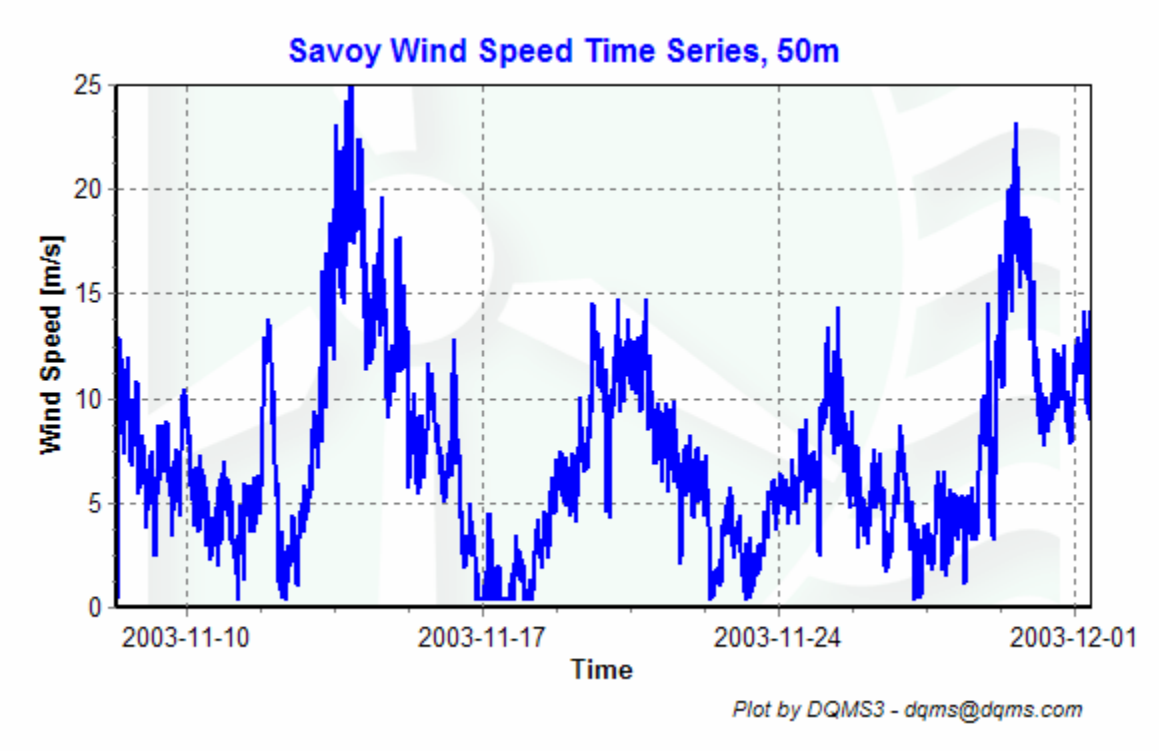

Figure 3 – Wind Speed Time Series, November 8, 2003 – November 30, 2003

Wind Speed Distributions

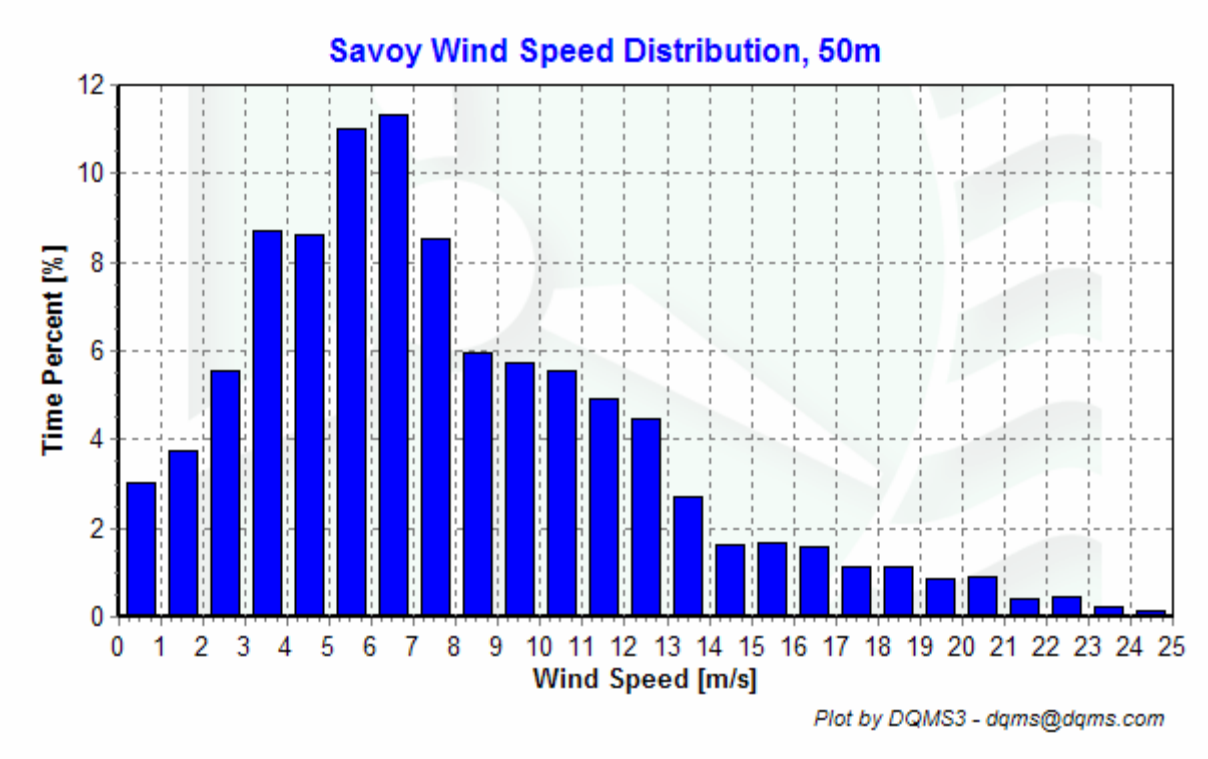

Figure 4 – Wind Speed Distribution, November 8, 2003 – November 30, 2003

Diurnal Average Wind Speeds

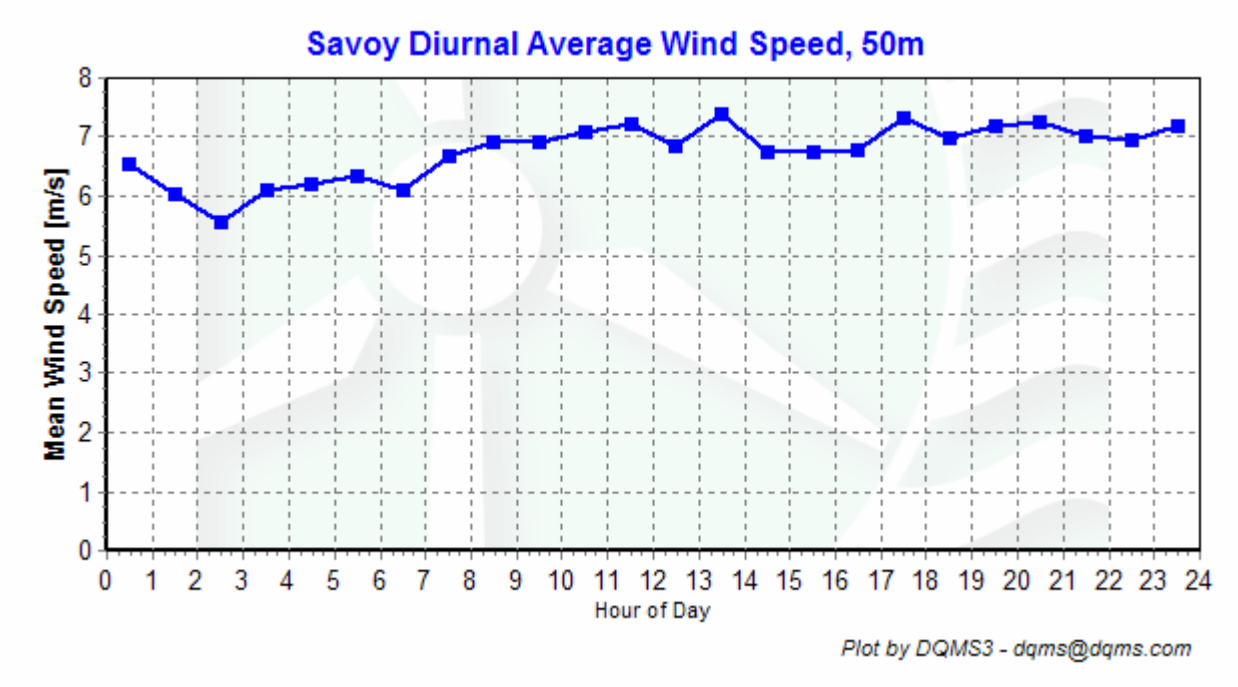

Figure 5 – Diurnal Wind Speed, November 8, 2003 – November 30, 2003

Turbulence Intensities

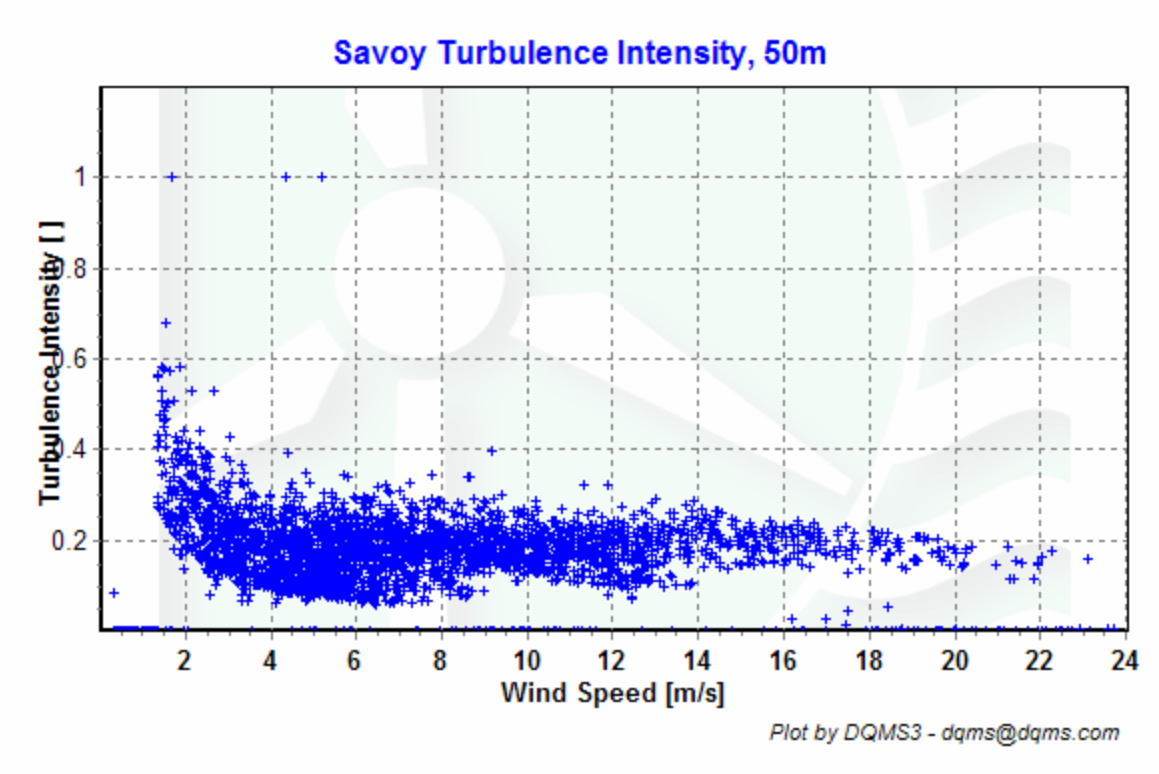

Figure 6 – Turbulence Intensity vs Wind Speed, November 8, 2003 – November 30, 2003

Wind Roses

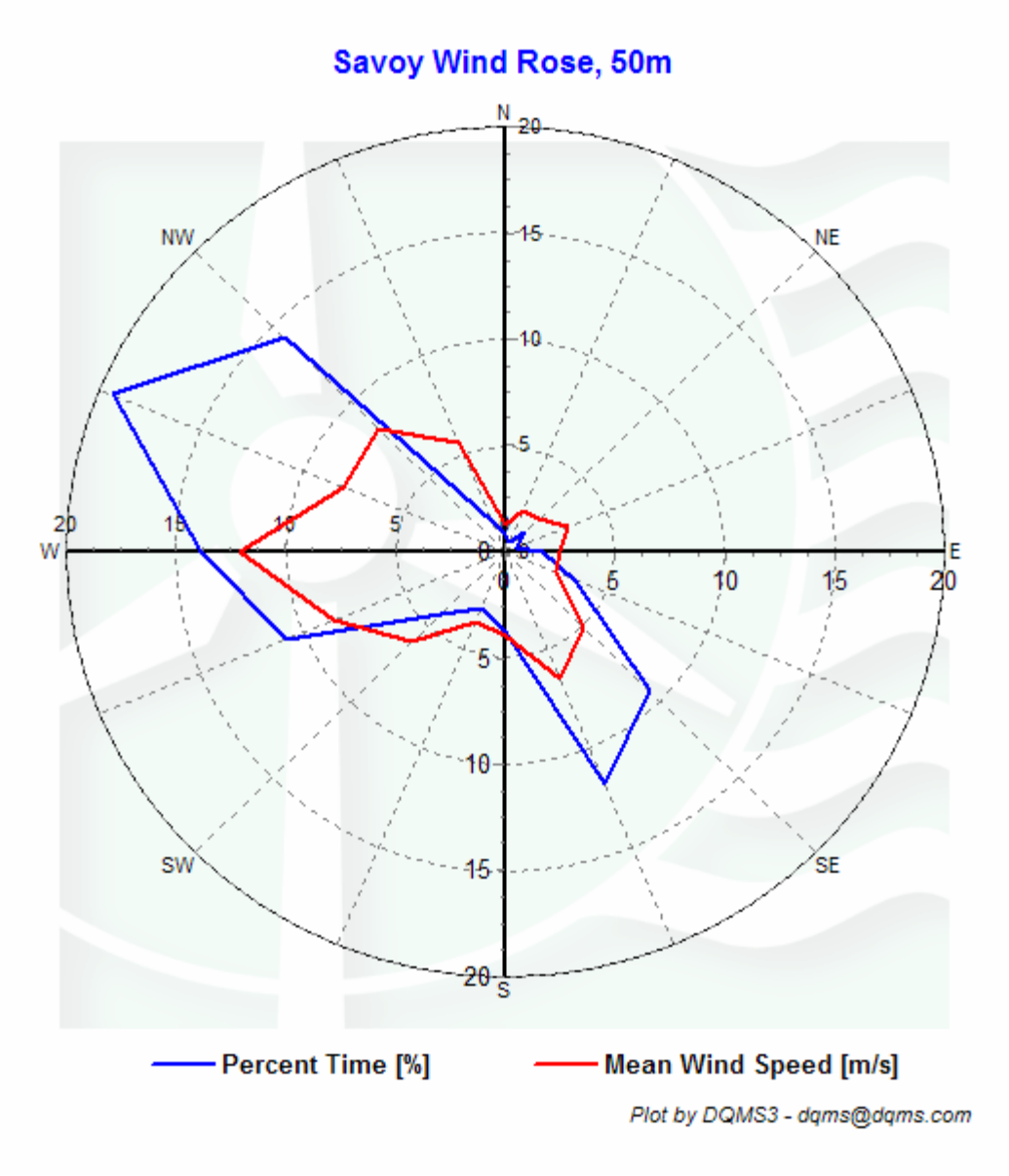

Figure 7 – Wind Rose, November 8, 2003 – November 30, 2003

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	3836	3830	99.844	0	0	0	99.844
Batt2aVDC	3836	3830	99.844	0	0	0	99.844
Anem50aMS	3836	3836	100	0	0	639.333	0
AnemSD50aMS	3836	3836	100	0	0	639.333	0
Anem50bMS	3836	3830	99.844	11.5	11	0	96.324
AnemSD50bMS	3836	3830	99.844	11.5	11	0	96.324
Anem39aMS	3836	3830	99.844	7.667	5.833	0	97.732
AnemSD39aMS	3836	3830	99.844	7.667	5.833	0	97.732
Anem39bMS	3836	3830	99.844	8.667	6.167	0.5	97.445
AnemSD39bMS	3836	3830	99.844	8.667	6.167	0.5	97.445
Anem20aMS	3836	3830	99.844	9.333	10.167	0	96.794
AnemSD20aMS	3836	3830	99.844	9.333	10.167	0	96.794
Vane50aDEG	3836	3830	99.844	0.167	11	0	98.097
VaneSD50aDEG	3836	3830	99.844	0.167	11	0	98.097
Vane39aDEG	3836	3836	100	0	0	639.333	0
VaneSD39aDEG	3836	3836	100	0	0	639.333	0
Vane20aDEG	3836	3836	100	0	0	639.333	0
VaneSD20aDEG	3836	3836	100	0	0	639.333	0
Etmp2aDEGC	3836	3830	99.844	96.167	0	0	84.802
EtmpSD2aDEGC	3836	3830	99.844	0	0	0	99.844
Total	76720	76636	99.891	170.833	88.333	3837	67.856

APPENDIX B - Plot Data

Wind Speed Distribution Data

Bin Center Wind Speed [m/s]	Percent
0.5	3.01
1.5	3.75
2.5	5.53
3.5	8.73
4.5	8.64
5.5	11
6.5	11.34
7.5	8.54
8.5	5.96
9.5	5.72
10.5	5.56
11.5	4.92
12.5	4.46
13.5	2.7
14.5	1.63
15.5	1.69
16.5	1.57
17.5	1.11
18.5	1.14
19.5	0.86
20.5	0.92
21.5	0.4
22.5	0.43
23.5	0.22
24.5	0.15

Table B1: Wind Speed Distribution

Diurnal Average Wind Speed Data

Hour of Day	Wind Speed [m/s]
0	7.34
1	7.19
2	6.93
3	7.2
4	7.15
5	6.8
6	6.64
7	6.92
8	7.04
9	6.9
10	7.1
11	7.2
12	7.07
13	7.4
14	7.3
15	7.19
16	6.91
17	7.61
18	7.54
19	8.24
20	8.26
21	8.08
22	7.74
23	7.73

Table B3: Diurnal Wind Speed

Wind Rose Data

Direction	Percent Time [%]	Mean Wind Speed [m/s]
N	0.85	1.31
NNE	0.5	2.1
NE	1.26	2.17
ENE	0.6	3.11
E	1.73	2.48
ESE	3.48	2.49
SE	9.26	5.05
SSE	11.83	6.49
S	3.77	3.96
SSW	2.86	3.54
SW	4.14	5.98
WSW	10.79	8.49
W	13.87	12.12
WNW	19.36	8
NW	14.25	8.14
NNW	1.47	5.57

Table B4: Wind Rose Time Percentage and Mean Wind Speed