CONCENTRATION MEASUREMENT AND DISPERSION MODELING OF PM-10 FROM A COTTON GIN

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Abstract

State Air Pollution Regulatory Agencies (SAPRAs) are continually faced with challenges associated with implementation of the Federal Clean Air Act. SAPRAs often resort to modeling and/or onsite measurement to assist with resolving permitting issues. This study combines the two methods to show the difficulty associated with source regulation.

Introduction

This research effort was proceeded by several projects involved with developing a more accurate model for predicting concentrations of particulate downwind of point sources due to atmospheric dispersion of the particulate. In the course of these projects the Fritz-Zwicke Dispersion Model (FZM) was developed. The major advance in this modeling routine was to incorporate the use of two-minute meteorological data versus one-hour averaged meteorological data. Validation studies of this model showed that the FZM did perform better than the present Environmental Protection Agency (EPA) approved model, Industrial Source Complex – Short Term Version 3 (ISC-ST3), while still being conservative with respect to measured data. It was also found that ISC-ST3 over-predicted downwind concentrations as much as 3 to 10 times that of measured.

The importance associated with permitting and regulation of sources due to inaccurate models became apparent as a cotton gin in New Mexico attempts to obtain an operating permit. The National Ambient Air Quality Standards (NAAQS) set a 24-hour concentration limit of 150 $\mu g/m^3$, and an annual average of 50 $\mu g/m^3$ for PM_{10} (particulate matter with an aerodynamic equivalent diameter of 10 micrometers or less) and no limit for TSP (Total Suspended Solid). All states air pollution regulatory agencies (SAPRAS) are required to regulate based on these levels, but are allowed to set more stringent levels.

The New Mexico Ambient Air Quality Standards (NMAAQS) are the same as the NAAQS for PM_{10}, but are 150 $\mu g/m^3$, 24-hour average, and 60 $\mu g/m^3$, annual average for TSP. The New Mexico SAPRA (The State of New Mexico Environmental Department) also uses a statewide background concentration of 47 $\mu g/m^3$ TSP, and 35 $\mu g/m^3$ PM_{10}. New Mexico also bases permitting on the property line concentrations levels. For example, the cotton gin we are working with in the permitting process must demonstrate that it does not exceed the NMNAAQS at its property lines. The incorporation of the background levels means that this gin must have property line concentrations, due to its emissions, of less than 103 $\mu g/m^3$ TSP, and 115 $\mu g/m^3$ PM_{10} based on 24-hour concentrations. Past research projects dealing with particle sizing of different types of pollutants has shown that for a cotton gin the TSP sample consists of approximately 25% PM_{10}. This means that if the gin were to meet the TSP 24-hour standard of 103 $\mu g/m^3$, the PM_{10} concentrations would be 26 $\mu g/m^3$. The TSP level is extremely difficult to meet with modeling results.

Modeling of the gin was performed using 1991 meteorological data and source and sampler input parameters as provided by the State of New Mexico Environmental Department. The seasonal cycle of the gin is to operate in October, November, December, and the following January. ISC-ST3 allows seasonal variation of the emission rate through the input of monthly emission factors. The maximum predicted TSP 24-hour property line concentration was 377 $\mu g/m^3$, and the maximum predicted PM_{10} 24-hour property line concentration was 260 ug/m^3. Neither TSP nor PM10 meets the NMAAQS. The modeling incorporated factors for building downwash effects as determined using BPIP (Building Profile Input Program).

In an effort to demonstrate the extreme conservative nature of the models, on-site sampling was performed at the cotton gin in New Mexico to determine actual downwind PM-10 concentrations. Approximately 20 sample tests were performed. These were primarily 8 hour tests, with one 24 hour test. Using meteorological data collected on-site and input data provided by the New Mexico Department of Environmental Quality, both ISC-ST3 and FZM Dispersion models were used to predict PM-10 concentrations at the four sampling locations used in the site measurement study. Four sampling locations were used in order to isolate upwind and downwind concentrations. The four stations were at the property lines north (Station 3), south (Station 1), east (Station 2), and west (Station 4) of the gin (See Figure 1). Comparisons were made between the measured and predicted concentrations at the four stations to demonstrate the difficulty in regulating a source.

Discussion

Once the measured concentrations were determined, an attempt was made to assign an upwind and downwind direction (based on wind variation during the sample period)

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and average concentration. Assigning the upwind and downwind stations was relatively easy for most tests, but there were several instances were the concentrations indicated a higher upwind concentration than downwind. One of the major reasons for this incongruity was the nearness of a Dairy to the west, and its corresponding feeding area to the north. This means that wind directions from north to south and from east to west are actually carrying particulate from these outside sources to stations 3 and 2 respectively. This results in a higher upwind than downwind. These extra sources were the major difficulty in this study.

The next step in this process was predicting the concentrations at each station using ISC-ST3 and FZM and comparing the predicted concentrations to the measured. Due to some problems with the weather station, the on-site meteorological data is missing data for tests 1, 15, and 19. ISC-ST3 modeling used the one hour averaged weather data, while the FZM used the two-minute weather data. NOTE: building downwash effects as determined by BPIP were incorporated into the modeling runs. Tables 1 (Test 1) through 20 (Test 20) show the summary results of the measured concentrations and the ISC-ST3 and FZM predicted concentrations. Both the TSP and PM_{10} measured and predicted concentrations are shown in the tables. Tests 1, 15 and 19 contain NA under the model predicted concentration columns, as the meteorological data needed for modeling was corrupt. For the ease of the discussions to follow, only the PM_{10} concentrations are discussed explicitly although the concepts discussed also apply to TSP. The notation NA under the measured concentration column denotes sampler or generator failure or other difficulties. Figures 2 (Test 2) through 35 (Test 20) are the one-hour and two-minute windrose for each test. The wind roses are grouped in pairs by test. For example, Figures 2 and 3 are the one-hour and two-minute (respectively) windroses for Test 2 (Table 2). The petals of the windroses are in the direction from which the wind blows. For example, if the petal is in the north, the wind blows from north to south.

Looking at Test 2 (Table 2 and Figures 2 and 3), there were measured concentrations for both TSP and PM_{10}, to the north and the west, while the model predicted 0 concentrations. Looking at the windrose, we see that the wind is primarily out of the west with some out of the north and the south. The highest predicted concentrations are to the east with values of 278.2 and 134.5 $\mu g/m^3$ for ISC-ST3 and FZM respectively. While the only other predicted concentrations are 13.6 and 22.3 $\mu g/m^3$ for ISC-ST3 and FZM respectively. The general trend for predicted versus measured for this test is over prediction in the east and under prediction in the south. The concentrations 9.5 and 19.7 $\mu g/m^3$ can be attributed to release from the dairy and the feedlot close to the north and west sampling stations. This test illustrates the problem associated with setting up samplers and taking the highest concentration as the downwind and the lowest as the upwind. The remainder of the tests have similar results due to similar circumstances. In these test the models predict 0 concentrations at the north and west stations while the measured data indicates some concentration present.

The general trend for all of the samples is for the northern and western sampling stations to be considered the upwind samplers, but they are sampling emissions from the dairy and the dairy feeding area. If we use **the southern and eastern stations as downwind** of the gin without correcting for ambient or upwind influence, and use the highest sequential 3 8-hour test average from the measured, ISC-ST3 predicted, and FZM predicted concentrations, we can estimate the potential maximum 24-hour concentrations for the three different methods.

The three consecutive 8-hour measured TSP concentrations resulting in the maximum 24-hour averaged concentration come from tests 11, 12, and 13. The three maximum concentrations from either the southern or the eastern stations are 128, 159, and 153.4 $\mu g/m^3$. The 24-hour averaged concentration is 146.8 $\mu g/m^3$. It should be noted that these samples are assumed to have sampled the New Mexico standard TSP ambient concentration of 47 ug/m^3, therefore the 24 hour averaged measured concentration is 146.8 $\mu g/m^3$, which is below the NMAAQS. The highest three consecutive predicted 8-hour TSP concentrations from ISC-ST3 that result in the maximum 24-hour averaged concentrations come from tests 5, 6, and 7. The three 8-hour concentrations are 113.7, 241.8, and 65.6 $\mu g/m^3$, respectively. The 24-hour averaged concentration is 140.4 $\mu g/m^3$. For modeled concentrations, we have to add the background level. This brings the maximum 24-hour ISC-ST3 predicted concentration to 187.4 $\mu g/m^3$, which exceeds the NMAAQS. The highest three consecutive predicted 8-hour TSP concentrations using FZM come from tests 5, 6, and 7. The three 8-hour concentrations are 144.3, 264.2, and 74.1 $\mu g/m^3$. The 24-hour averaged concentration is 160.9$\mu g/m^3$, TSP, or 207.9 $\mu g/m^3$, TSP, including the ambient level, which exceeds the NMAAQS.

For measured PM_{10} the three consecutive 8-hour measured concentrations resulting in the highest 24-hour averaged concentration are from test 14, 15, and 16. These concentrations are 210.6, 10.7, and 11.4 $\mu g/m^3$, respectively. The 24-hour averaged concentration is 77.6 $\mu g/m^3$. Again, the measured data is assumed to have measured the ambient level of 35 $\mu g/m^3$, PM_{10}, along with gin released particulate. Therefore the maximum 24-hour averaged concentration measured is below the NMAAQS. The three consecutive 8-hour predicted concentrations using ISC-ST3 that result in the maximum 24-hour averaged concentration come from test 5, 6, and 7. The three concentrations are 78.5, 166.8, and 45.3 $\mu g/m^3$, respectively. The 24-hour averaged concentration is

96.8 μg/m^3, PM_{10}, or 131.9 μg/m^3 with the New Mexico ambient background of 35 μg/m^3. The three highest consecutive predicted 8-hour PM_{10} concentrations using FZM that result in the maximum 24 hour averaged concentration come from test 5, 6, and 7. The three concentrations are 99.6, 182.3, and 51.1 μg/m^3, PM_{10}, respectively. The 24-hour averaged concentration is 111 μg/m^3, PM_{10}, or 146 μg/m^3, PM_{10} accounting for the ambient level. Each of the above methods demonstrates that this cotton gin meets the NMAAQS at the property line for PM_{10}.

If we look at the one 24-hour test performed (Test 17, Table 17), the maximum TSP concentrations are 111 (measured), 42.5 (ISC-ST3), and 51.1 (FZM) μg/m^3. If we adjust these concentrations for ambient levels, the 24-hour concentrations resulting from gin release are 111, 89.5, and 98.1 μg/m^3, TSP, respectively. For the PM_{10} concentrations the highest values are 10 (measured), 29.3 (ISC-ST3), and 35.3 (FZM) μg/m^3. If we adjust these concentrations for ambient conditions the 24-hour concentrations resulting from gin release are 10, 64.3, and 70.3 μg/m^3, PM_{10}, respectively.

Summary

The purpose of this paper was not validation or disproving modeling results and performance, but to illustrate the difficulties associated with source regulation. To fairly regulate a source based on property line concentrations, it is not as simple as just modeling or sampling at a few locations to determine maximum property line concentrations without considering surrounding sources and the meteorological conditions. The purpose of this paper is to provide a general overview of the steps that should be involved in the permitting and regulatory process.

Table 1: Data summary for measured and predicted data for Test 1.

Test #	**1**		
Station #	**Measured TSP / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	69.4 / 7.6	NA	NA
2 (East)	66.5 / 39.6	NA	NA
3 (North)	5.0 / 8.9	NA	NA
4 (West)	8.2 / 8.5	NA	NA

Table 2: Data summary for measured and predicted data for Test 2.

Test #	**2**		
Station #	**Measured P / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	140.2 / 12.1	13.6 / 9.4	22.3 / 15.4
2 (East)	26.2 / 15.4	278.2 / 191.9	134.5 / 92.8
3 (North)	9.5 / 17.9	0	0
4 (West)	19.7 / 23.3	0	0

Table 3: Data summary for measured and predicted data for Test 3.

Test #	**3**		
Station #	**Measured TSP / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	89.5 / 4.6	18.8 / 12.9	146.4 / 101.0
2 (East)	14.3 / 7.0	99.9 / 68.9	155.7 / 107.4
3 (North)	22.6 / 12.3	0	0
4 (West)	6.3 / 19.0	0	0

Table 4: Data summary for measured and predicted data for Test 4.

Test #	**4**		
Station #	**Measured TSP / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	111.1 / 4.0	14.8 / 10.2	15.9 / 10.9
2 (East)	10.4 / 6.6	24.1 / 16.6	28.8 / 19.9
3 (North)	14.3 / 7.7	0	0
4 (West)	16.0 / 8.3	0	0

Table 5: Data summary for measured and predicted data for Test 5.

Test #	**5**		
Station #	**Measured TSP / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	161.2 / 17.6	0.04 / 0.03	6.5 / 4.5
2 (East)	16.7 / 12.9	113.7 / 78.5	144.3 / 99.6
3 (North)	33.3 / 35.4	0	0
4 (West)	66.5 / 36.2	0	0

Table 6: Data summary for measured and predicted data for Test 6.

Test #	**6**		
Station #	**Measured TSP / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	87.2 / 3.4	0	0.5 / 0.35
2 (East)	15.9 / 0.8	241.8 / 166.8	264.2 / 182.3
3 (North)	4.8 / 7.3	0	0
4 (West)	29.3 / 10.8	0	0

Table 7: Data summary for measured and predicted data for Test 7.

Test #	**7**		
Station #	**Measured TSP / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	165.7 / 8.7	32.1 / 22.1	28.1 / 19.4
2 (East)	101.8 / 25.4	65.6 / 45.3	74.1 / 51.1
3 (North)	14.5 / 26.5	0	0
4 (West)	50.5 / 2.6	0	0

Table 8: Data summary for measured and predicted data for Test 8.

Test #	**8**		
Station #	**Measured TSP / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	NA / 12.8	0	0
2 (East)	NA / 160.2	42.7 / 29.5	48.9 / 33.7
3 (North)	NA / 0	0	0
4 (West)	NA / 45.5	0	0

Table 9: Data summary for measured and predicted data for Test 9.

Test #	**9**		
Station #	**Measured TSP / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	88.8 / 1	0	4.7 / 3.2
2 (East)	37.9 / 11.3	98.0 / 67.6	95.4 / 65.8
3 (North)	3.3 / 1	0	0
4 (West)	5.3 / 0	0	0

Table 10: Data summary for measured and predicted data for Test 10.

Test #	**10**		
Station #	**Measured TSP / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	150.1 / 3.4	3.3 / 2.3	24.0 / 16.6
2 (East)	29.6 / 9.9	67.6 / 46.6	60.2 / 41.5
3 (North)	32.3 / 18.5	0	0
4 (West)	9.8 / 2.9	0	0

Table 11: Data summary for measured and predicted data for Test 11.

Test #	**11**		
Station #	**Measured TSP / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	128 / 1.8	0	0.07 / 0.05
2 (East)	16.9 / 0	88.1 / 60.8	80.6 / 55.6
3 (North)	3.3 / 8.9	0	0
4 (West)	13.7 / 5.8	0	0

Table 12: Data summary for measured and predicted data for Test 12.

Test #	**12**		
Station #	**Measured TSP / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	159 / 0	129.9 / 89.6	89.3 / 61.6
2 (East)	51.9 / 13.5	69.1 / 47.7	46.5 / 32.1
3 (North)	14.8 / 14.8	0	0
4 (West)	55.8 / NA	0	0

Table 13: Data summary for measured and predicted data for Test 13.

Test #	**13**		
Station #	**Measured TSP / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	153.4 / 10	62.8 / 43.3	61.1 / 42.2
2 (East)	80.7 / 14.7	0.9 / 0.6	22.3 / 15.4
3 (North)	55.7 /	0	0
4 (West)	63.8 / NA	0	0

Table 14: Data summary for measured and predicted data for Test 14.

Test #	**14**		
Station #	**Measured TSP / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	NA / 210.6	0	0
2 (East)	NA / 22.1	24.6 / 16.9	27.9 / 19.3
3 (North)	NA / 38.8	0	0
4 (West)	NA / 123.6	0	0

Table 15: Data summary for measured and predicted data for Test 15.

Test #	**15**		
Station #	**Measured TSP / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	137.2 / 7.4	NA	NA
2 (East)	47.4 / 10.7	NA	NA
3 (North)	30.3 . 9.6	NA	NA
4 (West)	24.3 / 23.7	NA	NA

Table 16: Data summary for measured and predicted data for Test 16.

Test #	**16**		
Station #	**Measured TSP / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	157.3 / 11.4	51.2 / 35.3	27.7 / 19.1
2 (East)	64.2 / 10	66.0 / 45.5	74.8 / 51.6
3 (North)	38.3 / 17.1	0	0
4 (West)	24.7 / NA	0	0

Table 17: Data summary for measured and predicted data for Test 17.

Test #	**17**		
Station #	**Measured TSP / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	111 / 10	42.5 / 29.3	28.2 / 19.5
2 (East)	18.1 / 6.7	38.8 / 26.8	51.1 / 35.3
3 (North)	70.1 / 14.1	0	0
4 (West)	56.5 / 15.9	0	0

Table 18: Data summary for measured and predicted data for Test 18.

Test #	**18**		
Station #	**Measured TSP / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	NA / 37.2	0	0
2 (East)	15.2 / 9	35.9 / 24.8	33.7 / 23.3
3 (North)	NA / 28.3	0	0
4 (West)	NA / 27.8	0	0

Table 19: Data summary for measured and predicted data for Test 19.

Test #	**19**		
Station #	**Measured TSP / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	220.2 / 10.4	NA	NA
2 (East)	46.9 / 9.5	NA	NA
3 (North)	123.6 / 22.2	NA	NA
4 (West)	35.6 / 10.8	NA	NA

Table 20: Data summary for measured and predicted data for Test 20.

Test #	**20**		
Station #	**Measured TSP / PM10 [ug/m^3]**	**1 Hour Modeled TSP / PM10 [ug/m^3]**	**2 Minute Modeled TSP / PM10 [ug/m^3]**
1 (South)	157.5 / 7.3	0	0
2 (East)	NA / NA	48.8 / 33.7	51.4 / 35.5
3 (North)	58.6 / 17.8	0	0
4 (West)	16.4 / 15.7	0	0

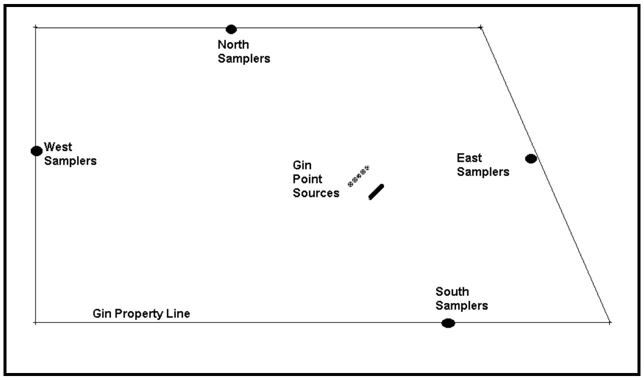

Figure 1. New Mexico Cotton Gin Property Line and Sampling Station Layout

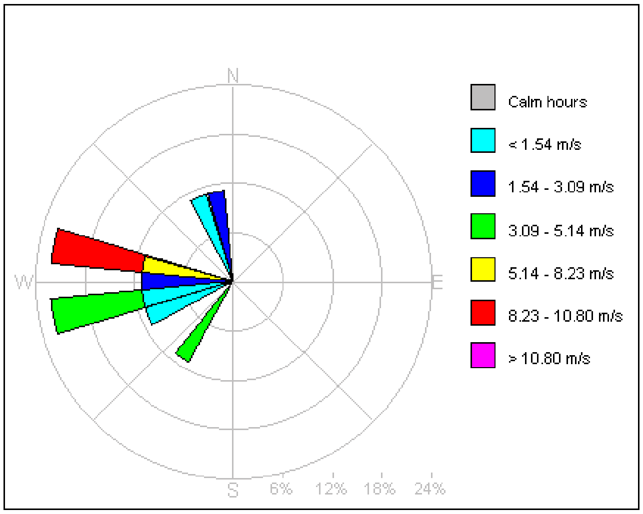

Figure 2. Test 2 – One Hour Averaged Windrose

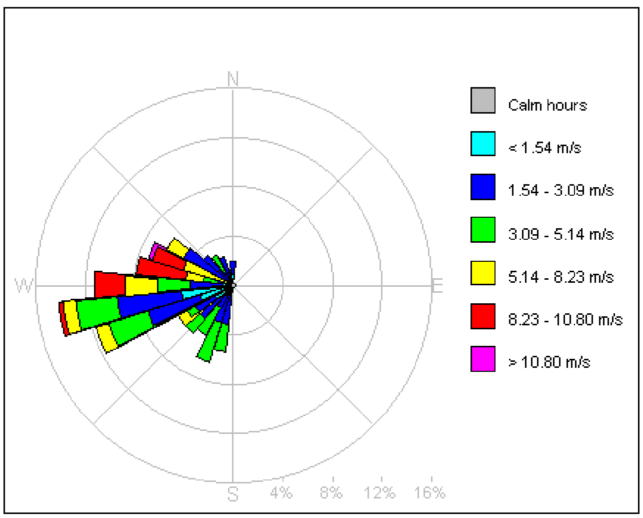

Figure 3. Test 2 – Two Minute Averaged Windrose

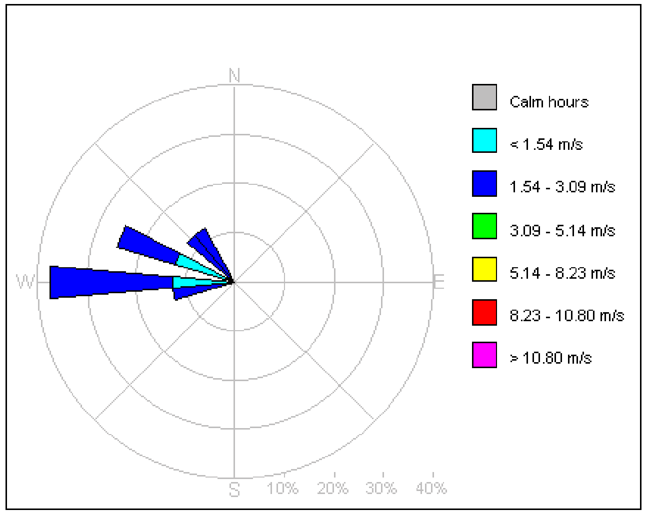

Figure 4. Test 3 – One Hour Averaged Windrose

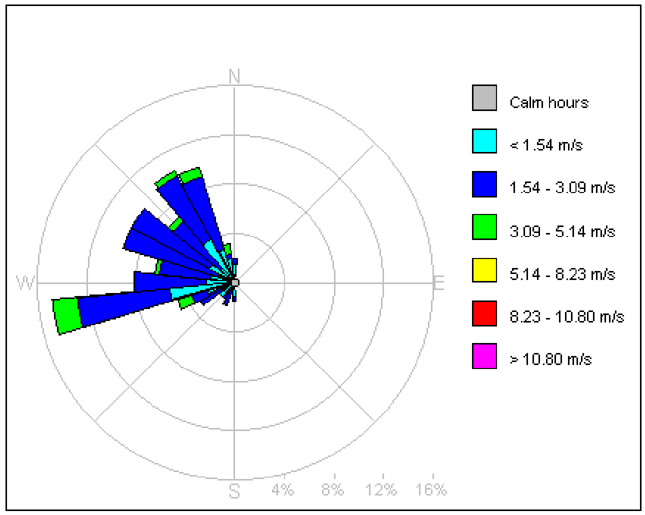

Figure 5. Test 3 – Two Minute Averaged Windrose

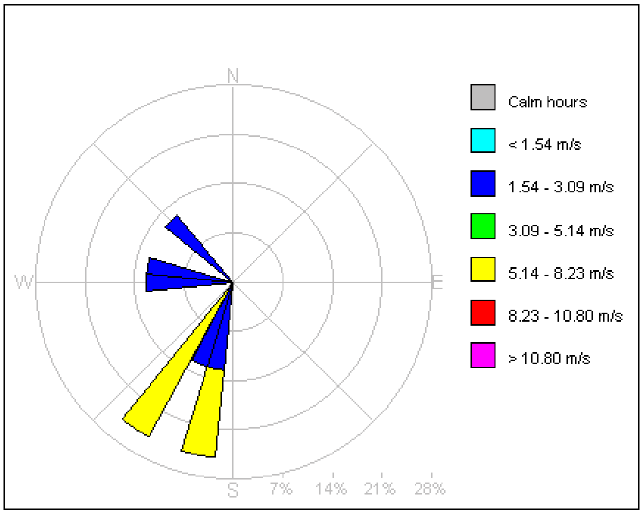

Figure 6. Test 4 – One Hour Averaged Windrose

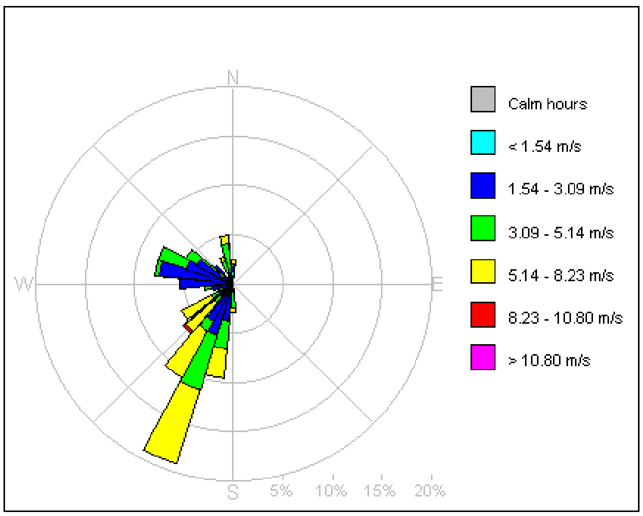

Figure 7. Test 4 – Two Minute Averaged Windrose

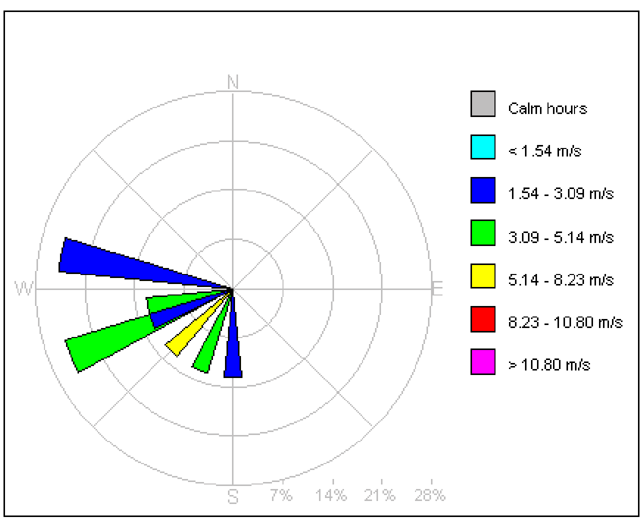

Figure 8. Test 5 – One Hour Averaged Windrose

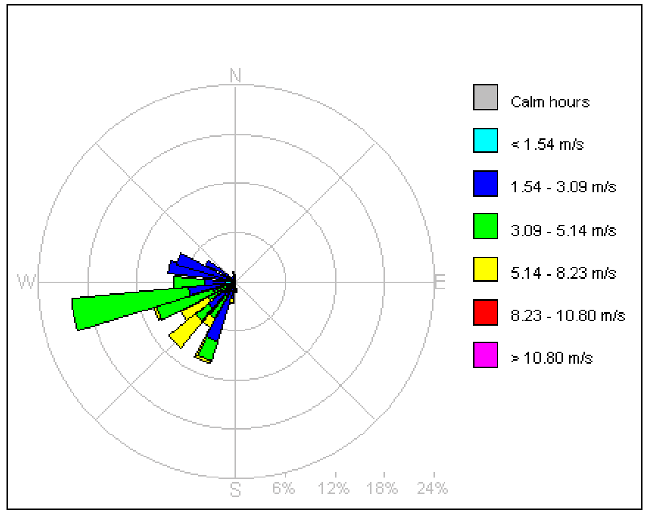

Figure 9. Test 5 – Two Minute Averaged Windrose

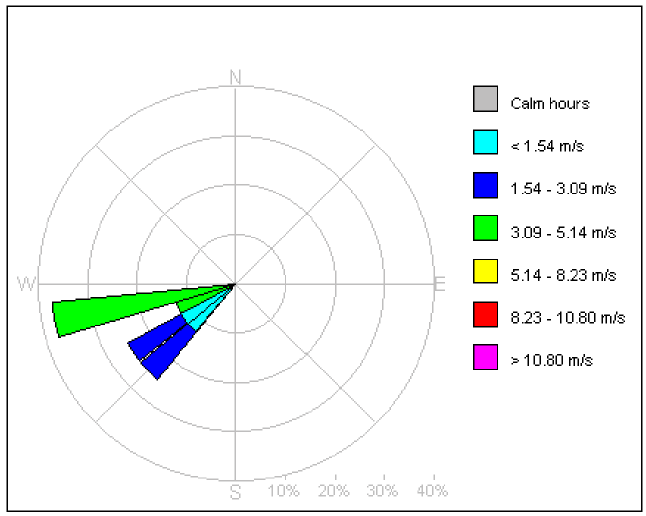

Figure 10. Test 6 – One Hour Averaged Windrose

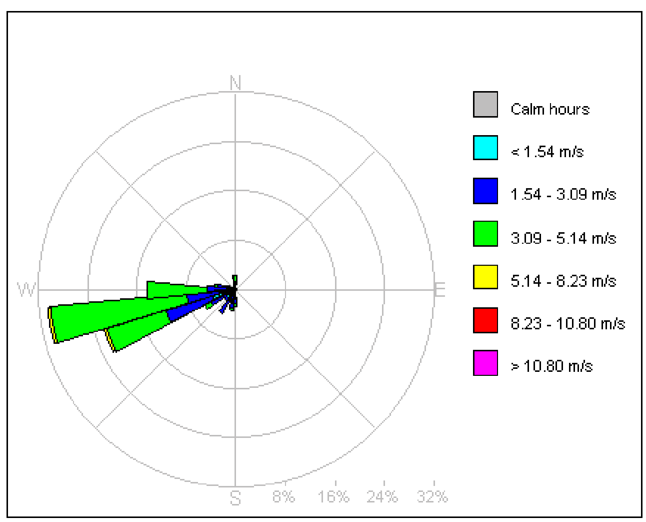

Figure 11. Test 6 – Two Minute Averaged Windrose

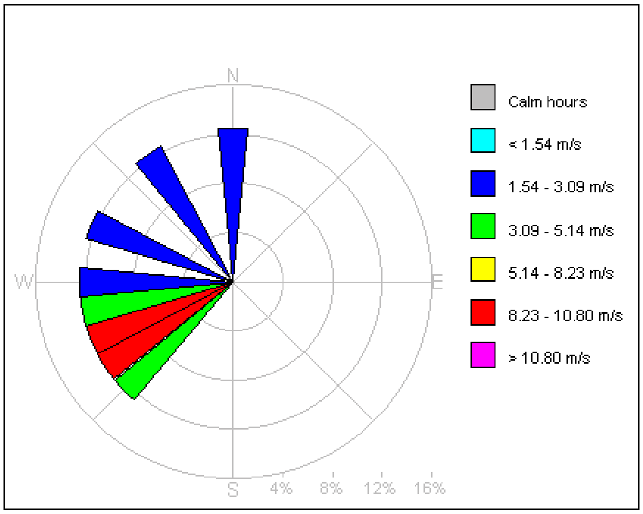

Figure 12. Test 7 – One Hour Averaged Windrose

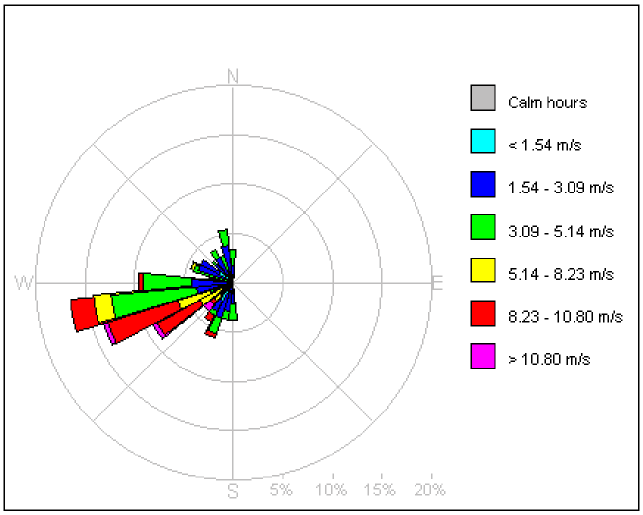

Figure 13. Test 7 – Two Minute Averaged Windrose

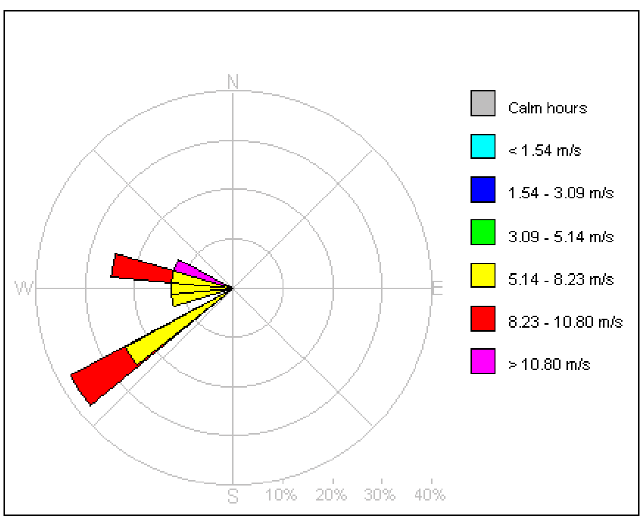

Figure 14. Test 8 – One Hour Averaged Windrose

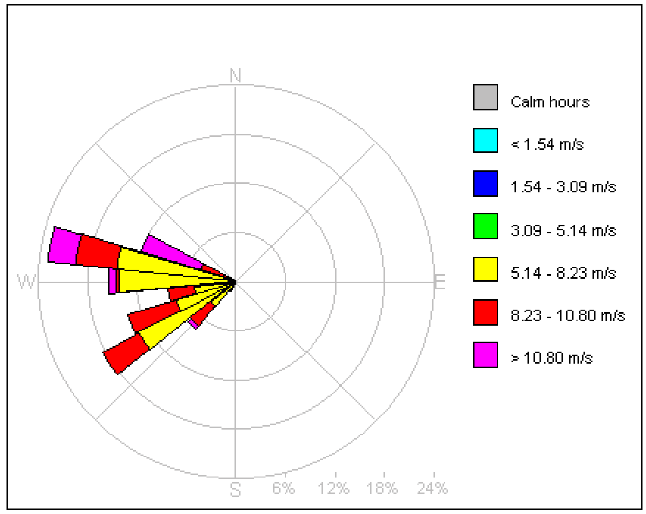

Figure 15. Test 8 – Two Minute Averaged Windrose

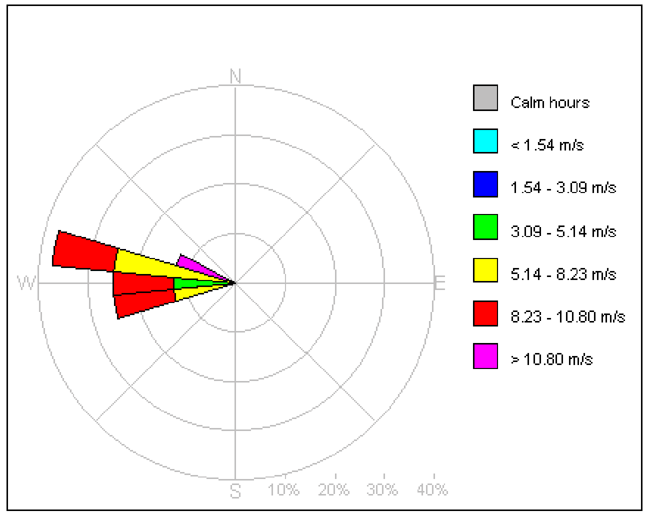

Figure 16. Test 9 – One Hour Averaged Windrose

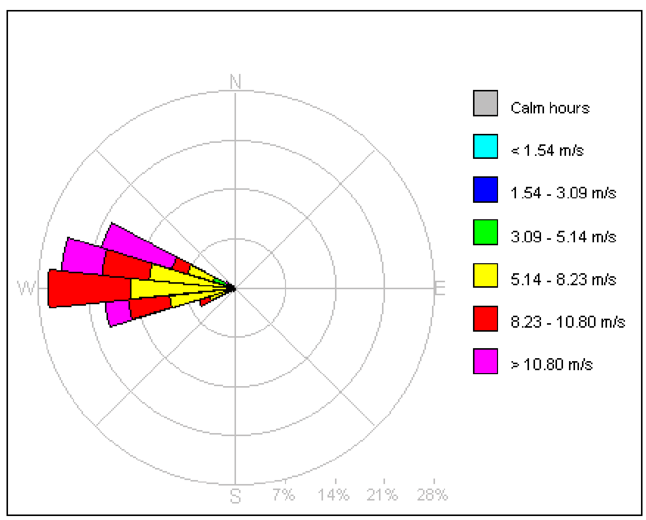

Figure 17. Test 9 – Two Minute Averaged Windrose

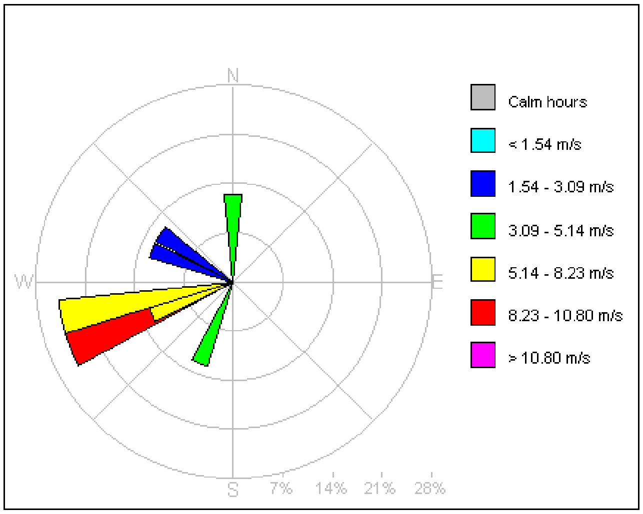

Figure 18. Test 10 – One Hour Averaged Windrose

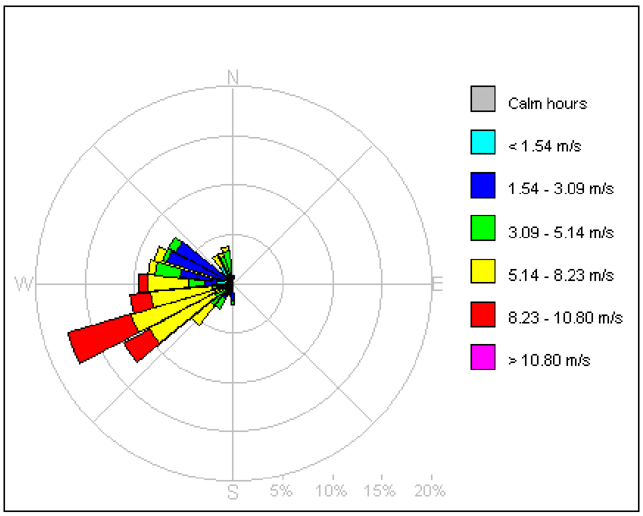

Figure 19. Test 10 – Two Minute Averaged Windrose

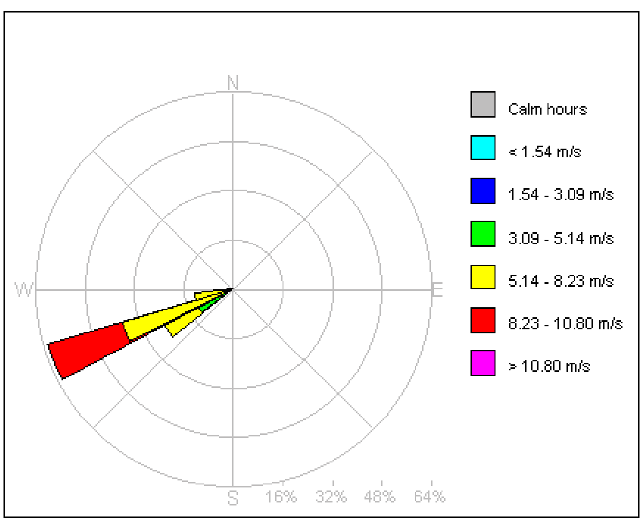

Figure 20. Test 11 – One Hour Averaged Windrose

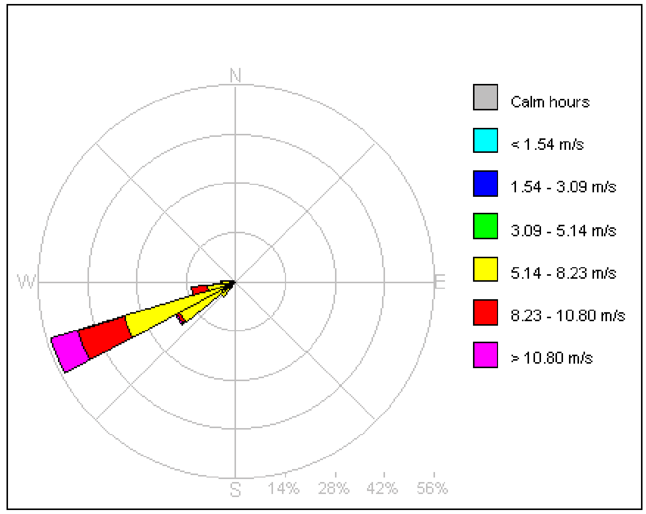

Figure 21. Test 11 – Two Minute Averaged Windrose

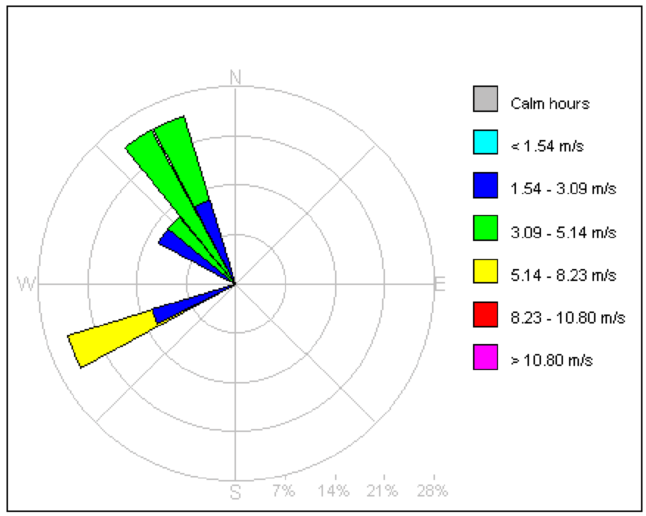

Figure 22. Test 12 – One Hour Averaged Windrose

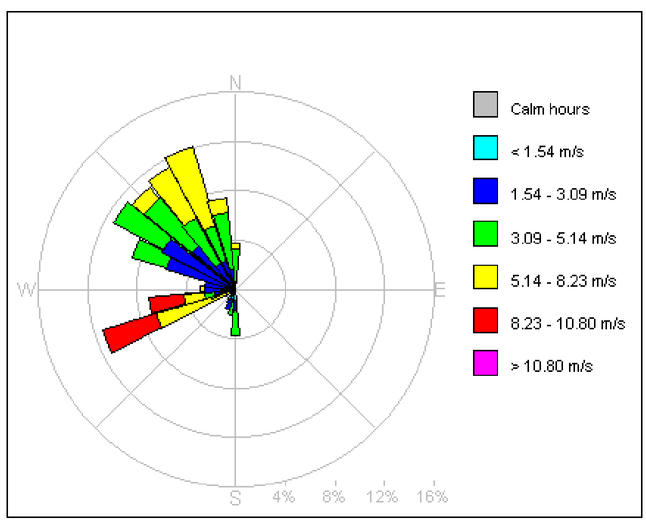

Figure 23. Test 12 – Two Minute Averaged Windrose

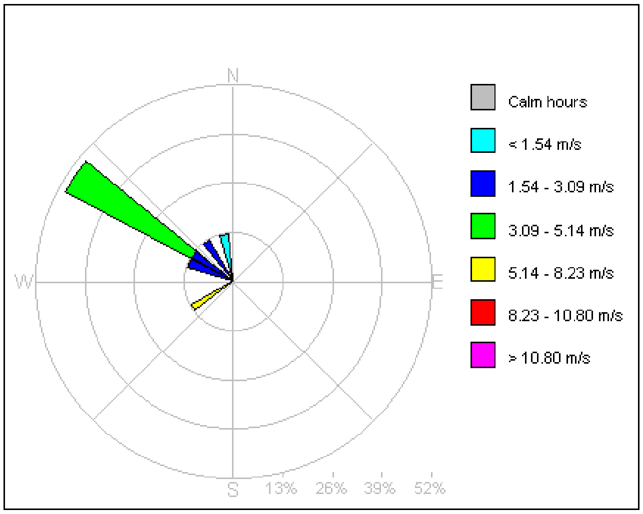

Figure 24. Test 13 – One Hour Averaged Windrose

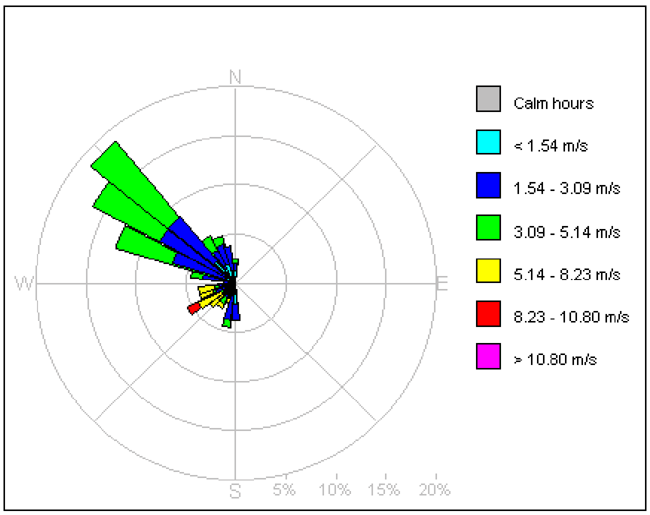

Figure 25. Test 13 – Two Minute Averaged Windrose

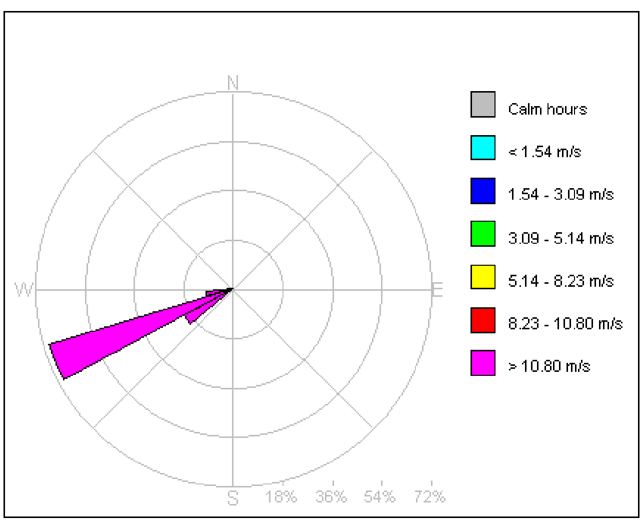

Figure 26. Test 14 – One Hour Averaged Windrose

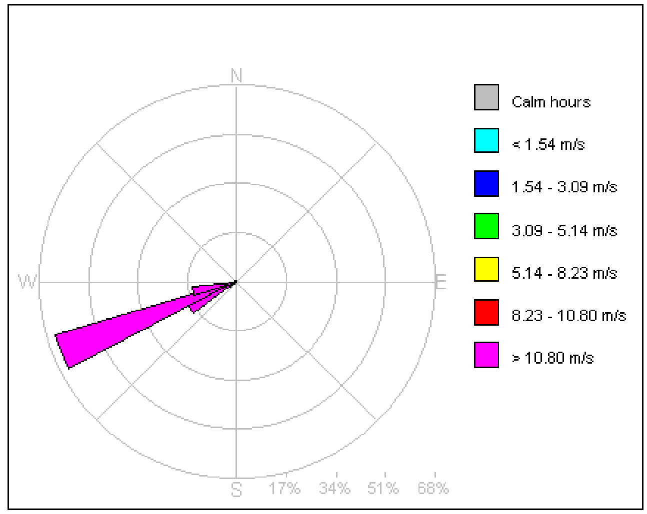

Figure 27. Test 14 – Two Minute Averaged Windrose

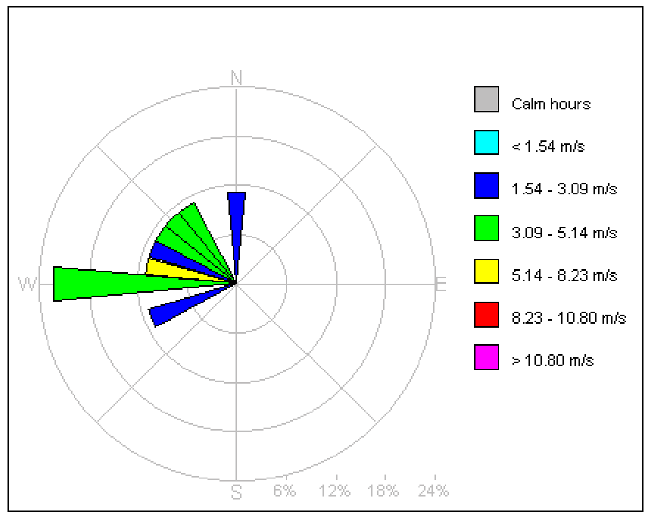

Figure 28. Test 16 – One Hour Averaged Windrose

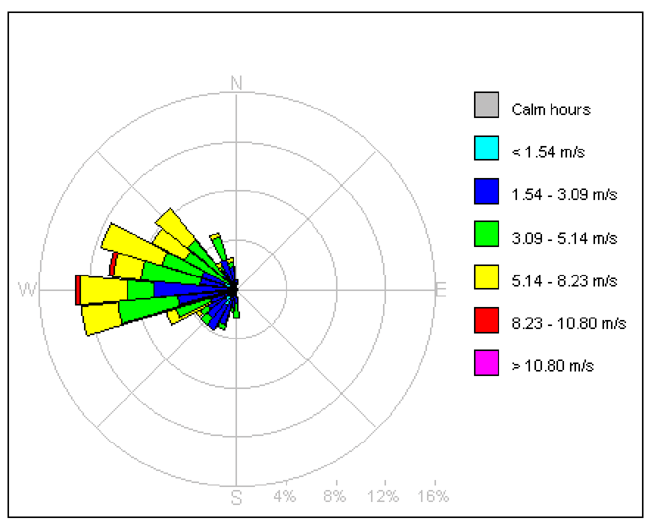

Figure 29. Test 16 – Two Minute Averaged Windrose

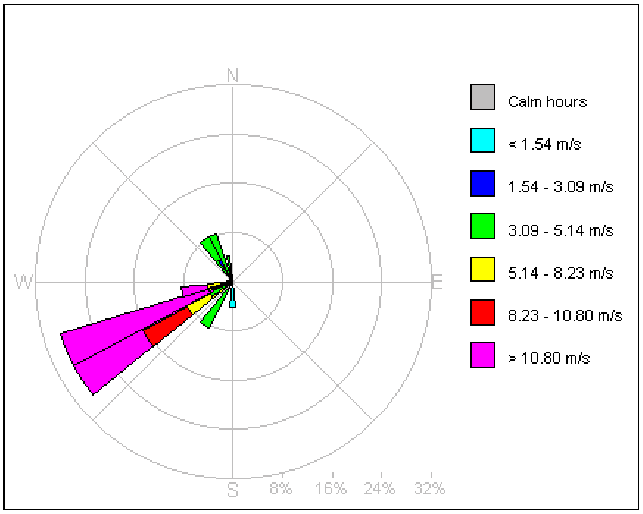

Figure 30. Test 17 – One Hour Averaged Windrose

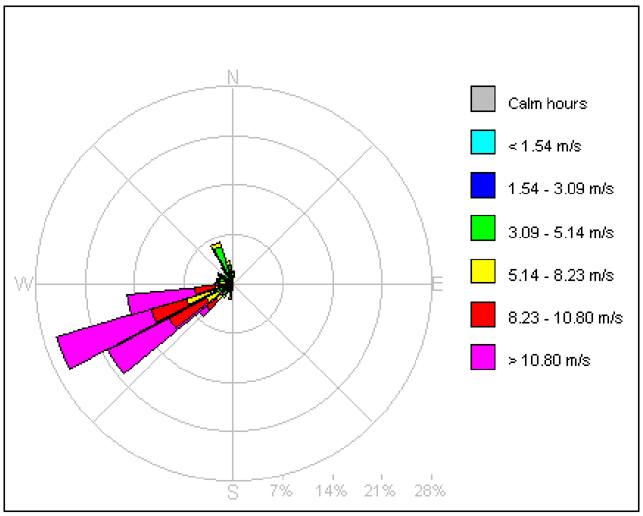

Figure 31. Test 17 – Two Minute Averaged Windrose

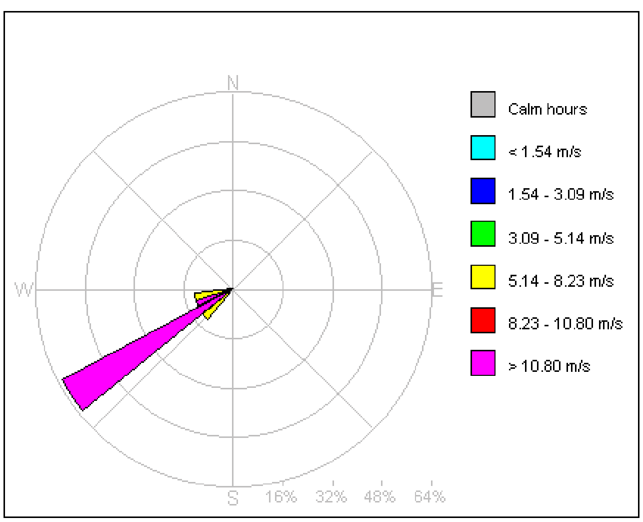

Figure 32. Test 18 – One Hour Averaged Windrose

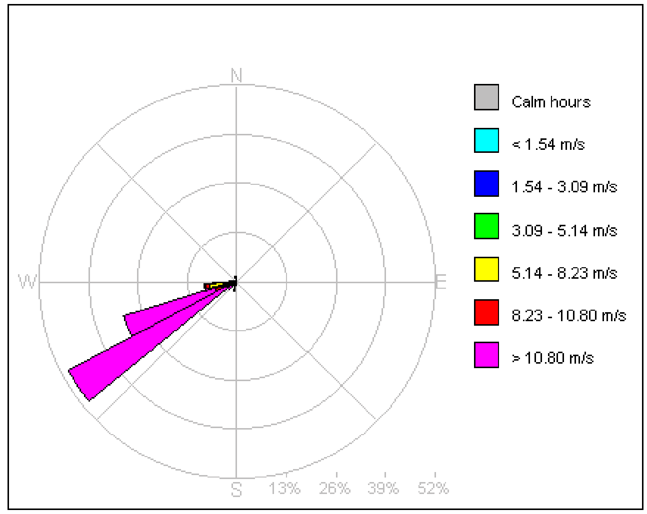

Figure 33. Test 18 – Two Minute Averaged Windrose

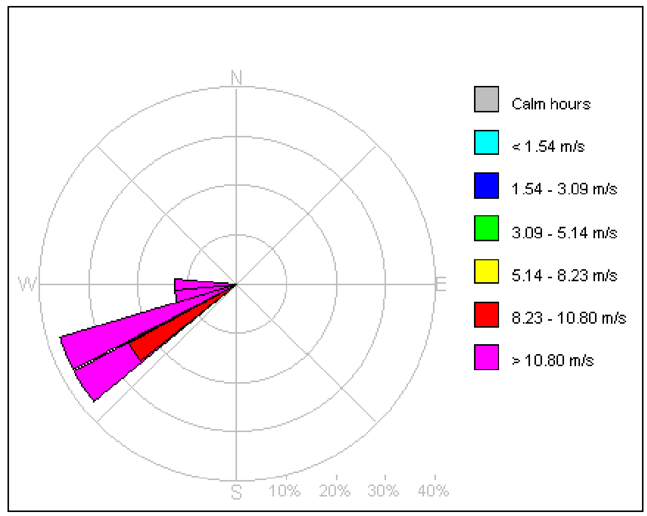

Figure 34. Test 20 – One Hour Averaged Windrose

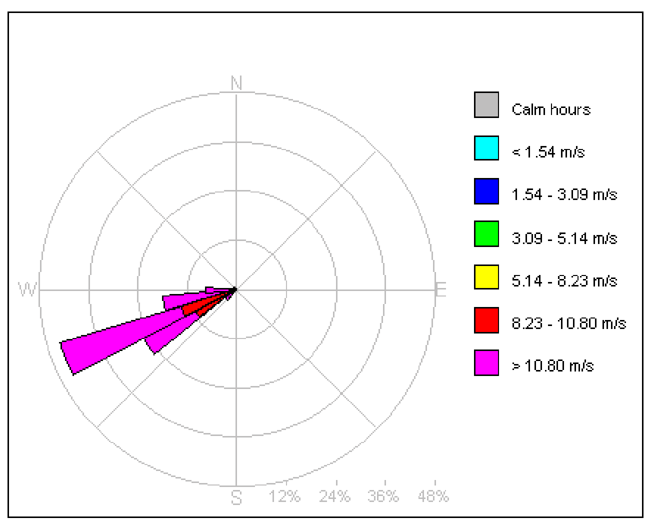

Figure 35. Test 20 – Two Minute Averaged Windrose