Wind and PM_{10} Characteristics at the ODSVRA from the 2013 Assessment Monitoring Network

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1 Introduction

This document presents observations from the Temporary Baseline Monitoring Network installed at the ODSVRA in May 2013. The network operated through September 2013, but the focus of the analyses presented here is for data collected through to July 15 2013. The monitoring network consisted of three instrumented towers on each of four transects oriented to 292°. Instruments at each monitoring position consisted of anemometers and wind vanes to measure wind speed and wind direction, Sensit piezoelectric sensors to measure saltation activity, and e-BAMs at one or two positions on each of the transects to measure local concentration of PM_{10}. MetOne Aerosol Particle Profilers (APP) were also deployed at each measurement position to provide complimentary data on the particle number concentrations at a greater time resolution than provided by the e-BAMs. This report does not include a discussion of the data collected by the MetOne APPs nor the data collected as part of the PI-SWERL measurements. This will be provided in a subsequent report.

2 Wind Speed and Direction Characteristics for the Four Transects

2.1 Mean Hourly Wind Speed and Direction at 10 m

At each measurement position along the East-West transects, data on wind speed and direction (at 3 m and in four locations at 10 m above ground level) were obtained to characterize the local conditions and regional air flow patterns. When these characteristics are compared across space they provide information on the regional wind flow characteristics across the ODSVRA and the Dune Preserve. This information will be used, in part, to aid in the selection of monitoring locations that will be used to evaluate compliance with the Dust Rule.

The locations (latitude and longitude), distances of the transect monitoring positions from the shoreline and their elevation above sea level are listed in Table 1. The data used in this (draft) report encompass the time period from May 10, 2013 through July 15, 2013. These data were quality assured and quality controlled using criteria set forth in the Q/A – Q/C Document developed and subsequently administered by STI, Inc.

Transect 1 lies within the northern section of the Dune Preserve, to the east of the fore-dune complex dominated by non-native plant species. The three measurement positions span a distance of approximately 1185 m and align on 292°. Position B, it must be noted, does not fall on the straight line distance between A and C; it is shifted slightly off-line to the south. This was required to avoid topography that was unsuitable for siting the tower and platform that held the meteorological instrumentation, but this minor deviation of B off the line between positions A and C does not affect the observed general patterns of wind speed and direction.

Table 1. The positional data for the measurement locations.

Transect ID	Latitude	Longitude	Distance from Shoreline (m)	Elevation (m)
T1A	35.088257	-120.6235	700	17.95
T1B	35.087615	-120.6216	893	29.05
T1C	35.086687	-120.6186	1185	21.15
T2A	35.071805	-120.6263	409	13.09
T2B	35.070713	-120.6243	628	19.04
T2C	35.069508	-120.6193	1101	32.35
T3A	35.056977	-120.6261	500	19.64
T3B	35.052712	-120.6181	1365	34.31
T3C	35.048821	-120.6076	2420	24.31
T4A	35.023906	-120.6269	859	18.6
T4B	35.021225	-120.6218	1411	37.28
T4C	35.018632	-120.6173	1913	37.08

Transect 1, Position A is approximately 700 m from the shoreline (Table 1). Wind roses, based on wind speed and direction measurements made at 3 m above ground level (a.g.l.) for the three positions are shown in Fig. 1. As these wind roses show the winds reach position A with a dominant westerly component (270°). With increasing distance from the shoreline there is change in the dominant wind direction to the west-north-west (292.5°). This series of wind roses also indicates that 3 m mean hourly wind speeds are increasing moving from west to east. This is a likely result of compression of the airflow as the lowermost airflow streamlines encounter dune topography (Wiggs et al., 1996). Plotting the frequency of wind speed occurrence (in 1 m/s bins) (Fig. 2) shows that the frequency of winds greater than 6.5 m/s measured at 3 m a.g.l. is highest for Position C on this transect. For comparison purposes the wind rose for T1C for the wind speed and direction measured at 10 m is shown in Fig. 3, and shows essentially the same directional pattern, but higher wind speeds occur with greater frequency (Fig. 4).

Transect 2 Position A is approximately 409 m from the shoreline (Table 1). Transect 2 lies approximately 1885 m to the south of Transect 1 and has the same azimuth, i.e., 292°. Wind roses for the three positions based on measurement of wind speed and direction made at 3 m a.g.l. are shown in Fig. 5.

Transect 2 shows a similar pattern to Transect 1 in the wind roses moving west to east, but position 2A shows that west-north-west (292°) winds are of equivalent frequency to west winds, unlike at position 1A, and these winds are also of greater magnitude (Fig. 5). In the progression from west to east on Transect 2, the frequency of the 292° winds is maintained and the magnitude of the winds along this direction increases. This is illustrated in Fig. 6, which shows the histogram of wind speed at each of the three positions along this transect. The wind rose for position T2C for wind speed and direction measured at 10 m a.g.l. is shown in Fig. 7 and the directional pattern is similar except for the increased frequency of higher winds at 10 m a.g.l. (Fig. 8).

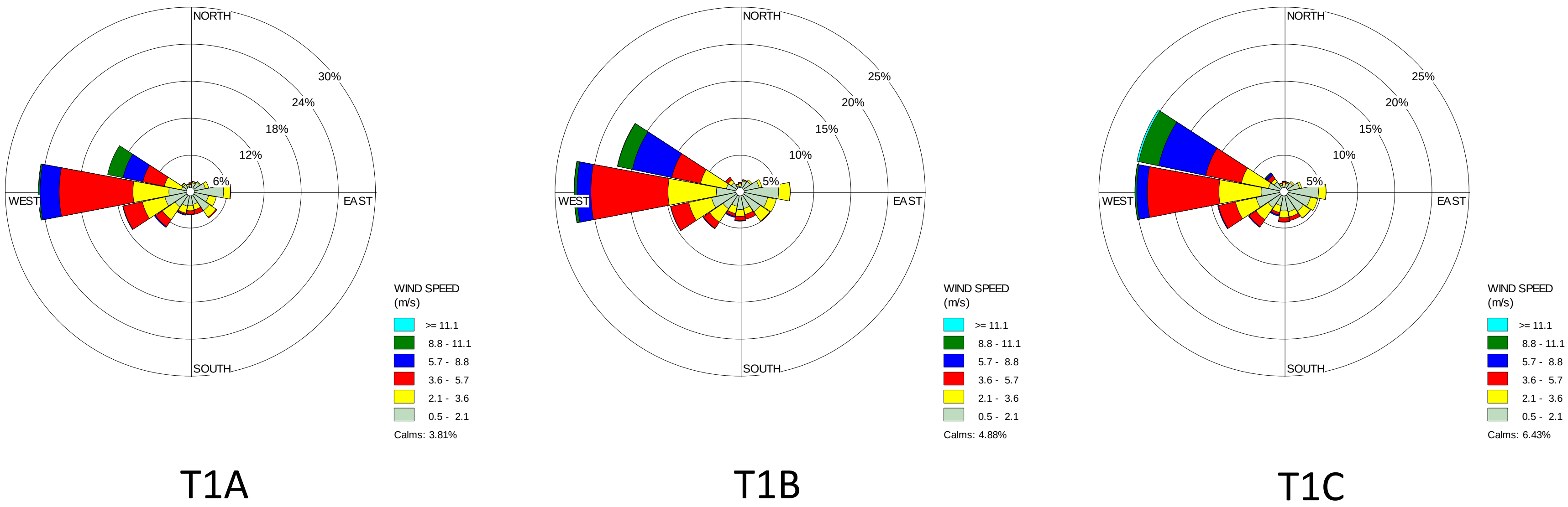


Figure 1. Wind roses for the three positions along Transect 1 for wind speed and direction measured at 3 m a.g.l.

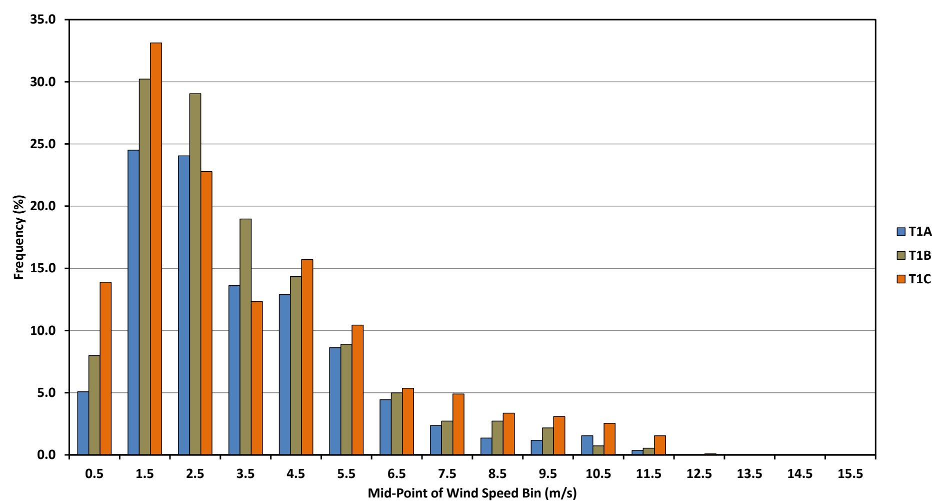


Figure 2. Wind speed frequency distribution for the three positions along Transect 1 for wind speed measured at 3 m a.g.l.

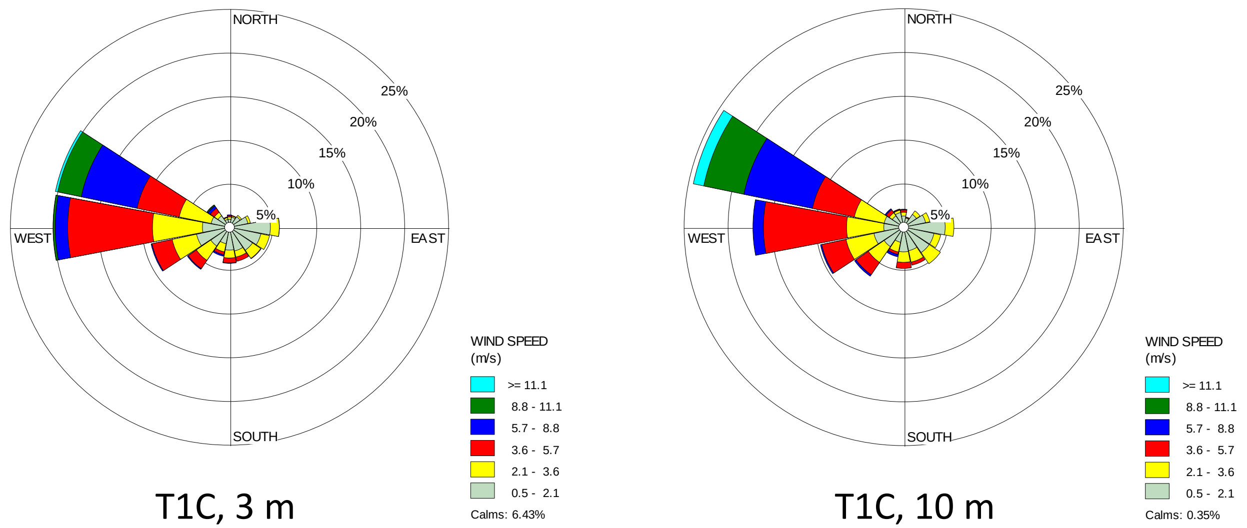


Figure 3. Wind roses for position T1C for wind speed and direction measured at 3 m and 10 m a.g.l. The wind direction pattern is essentially identical, but the frequency of higher wind speeds measured at 10 m is greater than at 3 m.

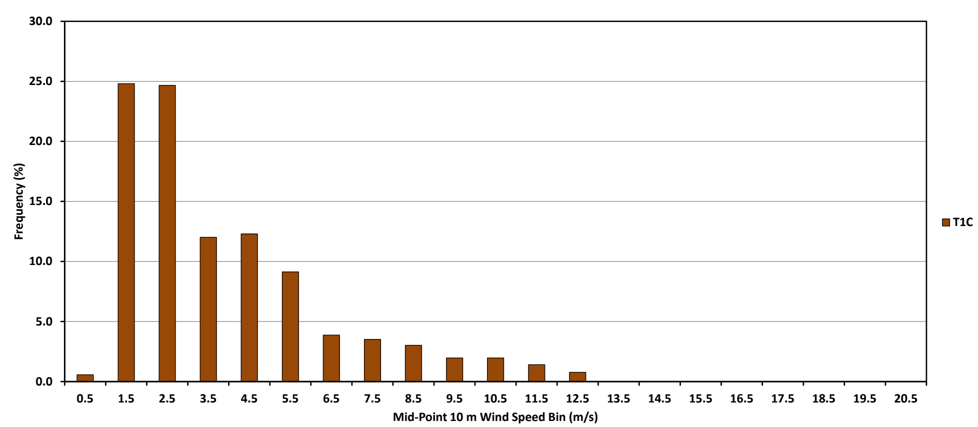


Figure 4. Wind speed frequency distribution for T1C for wind speed measured at 10 m a.g.l.

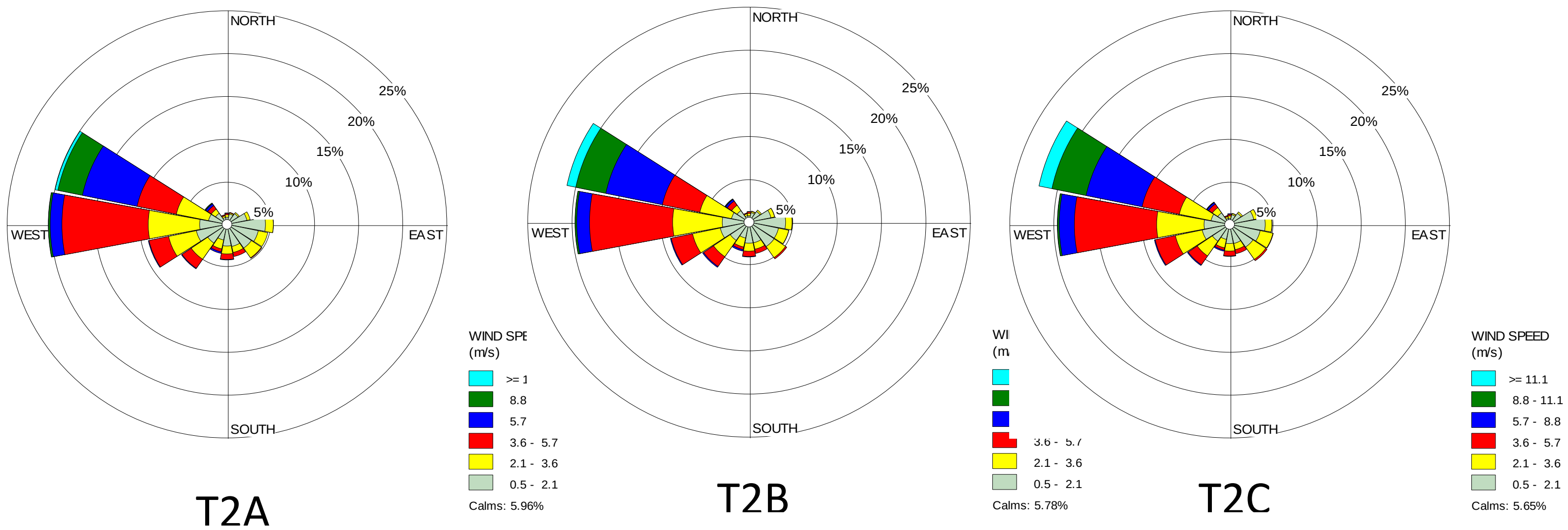


Figure 5. Wind roses for the three positions along Transect 2 for wind speed and direction measured at 3 m a.g.l.

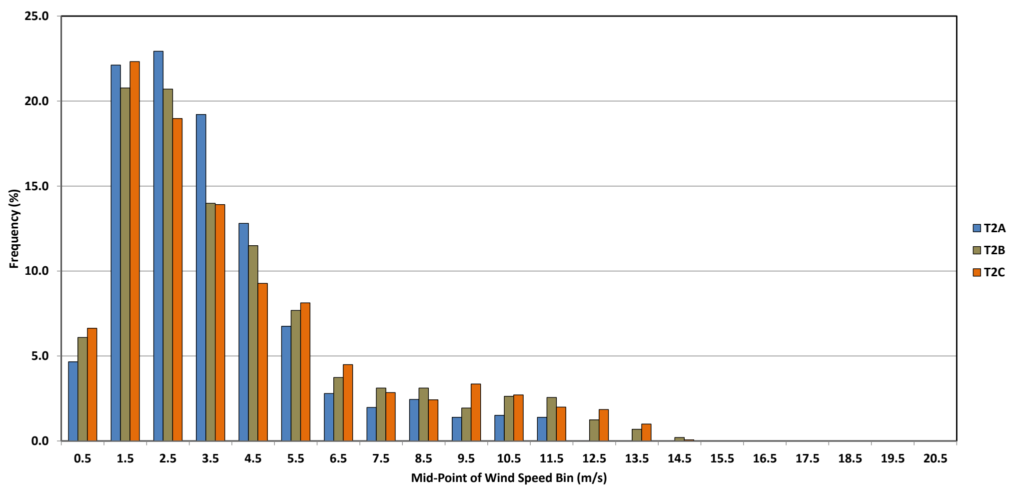


Figure 6. Wind speed frequency distribution for the three positions along Transect 2 for wind speed measured at 3 m a.g.l.

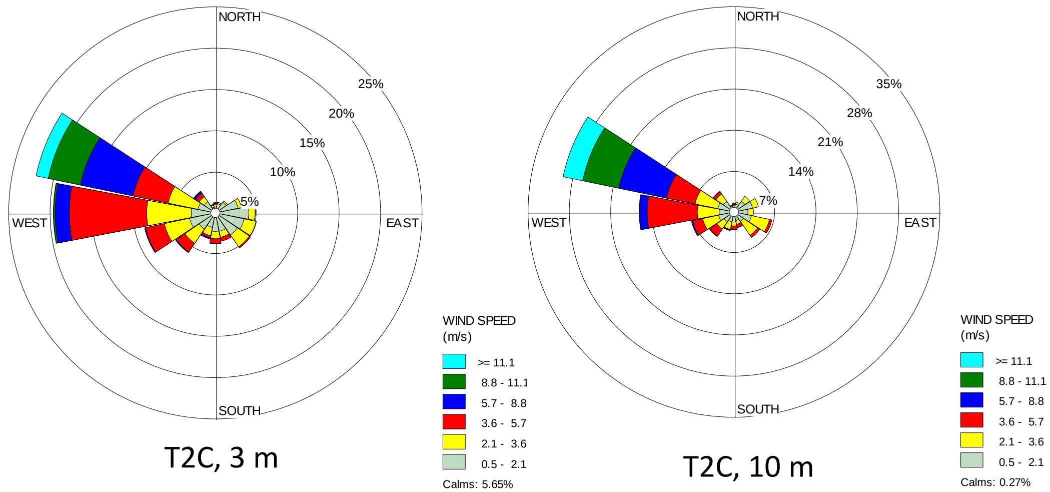


Figure 7. Wind roses for position T2C for wind speed and direction measured at 3 m and 10 m a.g.l. The wind direction pattern is essentially identical, but the frequency of higher wind speeds measured at 10 m is greater than at 3 m.

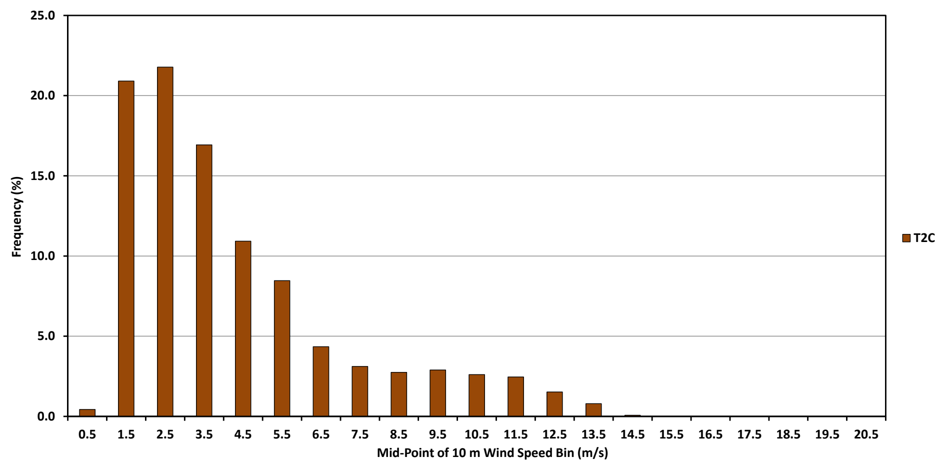


Figure 8. Wind speed frequency distribution for T2C for wind speed measured at 10 m a.g.l.

Transect 3, approximately 1760 m south of Transect 2, maintains the same pattern in the wind roses moving west to east as Transect 2, but position 3A shows that west-north-west (292°) winds are more frequent than west winds and these winds are of greater magnitude (Fig. 9). In the progression from west to east on Transect 3, the frequency of the 292° winds is maintained. The histogram of wind speed frequency (Fig. 10) shows that the highest wind speed class (14.5 m/s) is only observed at positions T3B and T3C, suggesting some increase in wind speed moving eastward along the transect, but not as much as observed for the other Transects. The wind rose for position T3C for wind speed and direction measured at 10 m a.g.l. is shown in Fig. 11 and the directional pattern is similar except for the increased frequency of higher winds at 10 m a.g.l. (Fig. 12).

Transect 4 is approximately 3600 m south of Transect 3, and lies within the southern area of ODSVRA, south of Oso Flaco Lake. At all three positions the dominant wind direction is west-north-west (292°), and the highest magnitude mean hourly 3 m a.g.l. wind speeds are associated with this direction (Fig. 13). Winds at 3 m a.g.l. from the west (270°) are the second most frequent direction but do not exceed 11 m/s. Unlike the three transects to the north of Transect 4, winds from the north-west are more frequent and can reach hourly mean 3 m wind speeds in excess of 11 m/s. The wind speed frequency distribution (Fig. 14) also shows that Transect 4, similarly to Transect 3, has the highest observed wind speeds at positions T4B and T4C with a small percentage of speeds exceeding 15 m/s. The wind rose for position T4B for wind speed and direction measured at 10 m a.g.l. is shown in Fig. 15 and the directional pattern is similar except for the increased frequency of higher winds at 10 m a.g.l. (Fig. 16).

Based on the comparisons of wind roses using wind speed and wind direction data from 3 m and 10 m a.g.l., measured at the same position for each of the Transects (i.e., T1C, T2C, T3C, and T4C), it is clear that the pattern is preserved and independent of height between 3 and 10 m. Therefore information on the characteristics of wind speed and direction at the ODSVRA can be obtained with a high degree of confidence using measurements from either height.

2.2 One Hour Maximum Wind Gust at 3 m and 10 m a.g.l.

The emission of dust is a fast process operating at time scales much less than one hour. The emission system (entrainment and transport of sand and dust) responds quickly to changes in wind shear at the scale of seconds (Baas, 2006), and the relationship between wind shear and the flux of sand and dust is non-linear (Gillies, 2013). Further understanding on how the local winds may affect the sand transport and dust emissions along the four transects can be gained from examining the range and frequency distribution of the one hour maximum wind gust data.

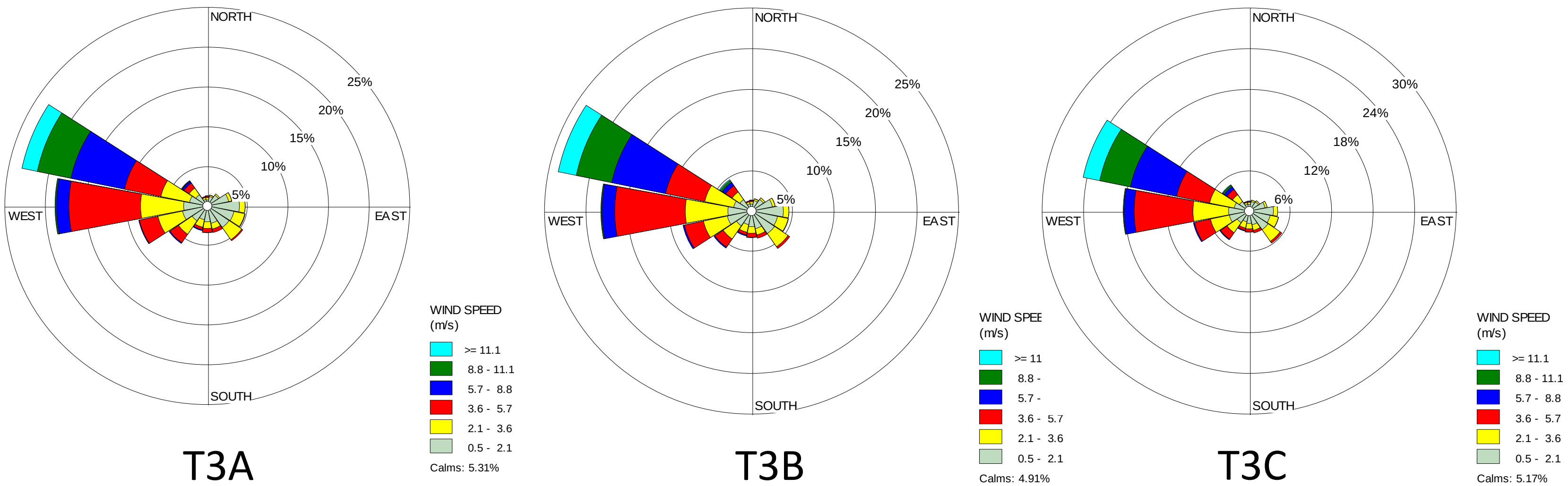


Figure 9. Wind roses for the three positions along Transect 3. for wind speed and direction measured at 3 m a.g.l.

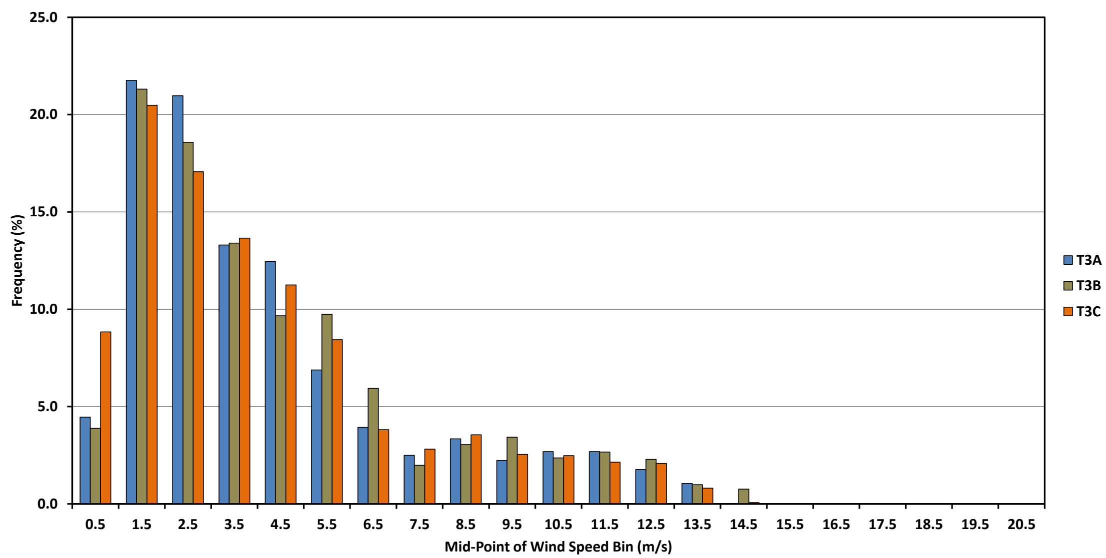
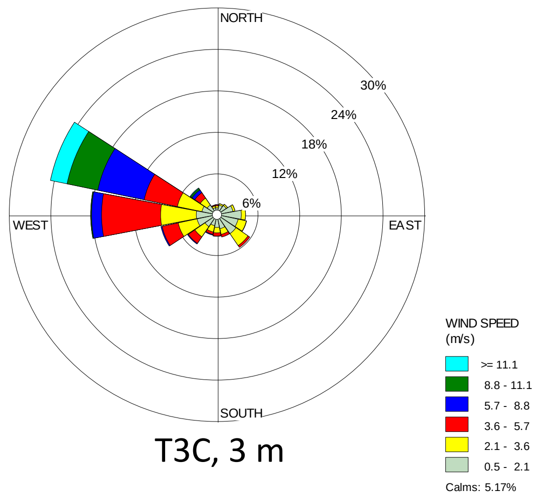


Figure 10. Wind speed frequency distribution for the three positions along Transect 3 for wind speed measured at 3 m a.g.l.



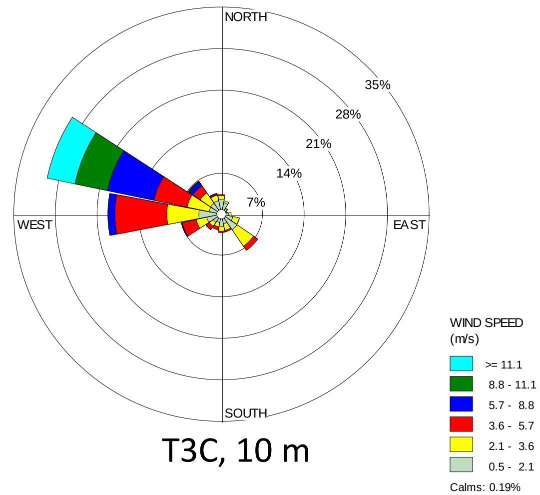


Figure 11. Wind roses for position T3C for wind speed and direction measured at 3 m and 10 m a.g.l. The wind direction pattern is essentially identical, but the frequency of higher wind speeds measured at 10 m is greater than at 3 m.

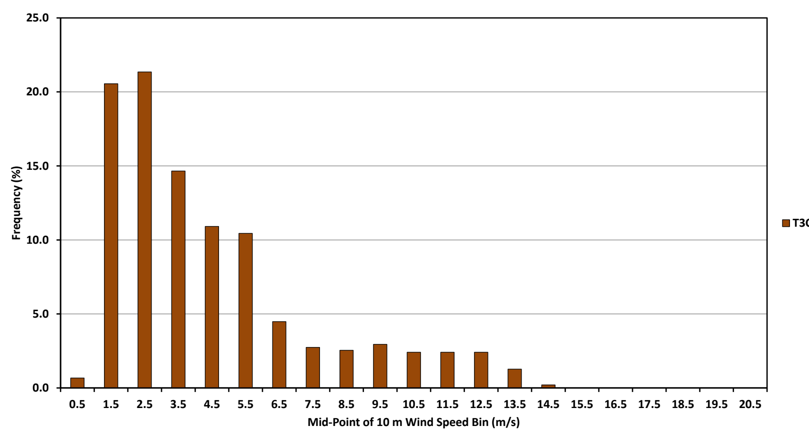


Figure 12. Wind speed frequency distribution for T3C for wind speed measured at 10 m a.g.l.

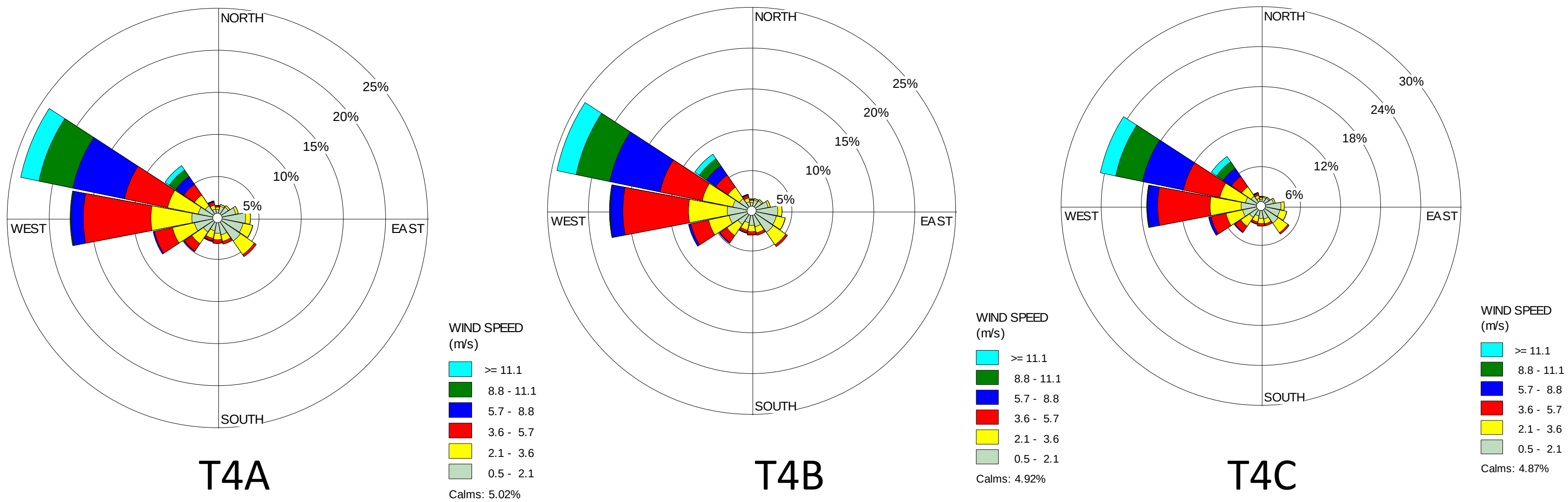


Figure 13. Wind roses for the three positions along Transect 4 for wind speed and direction measured at 3 m a.g.l.

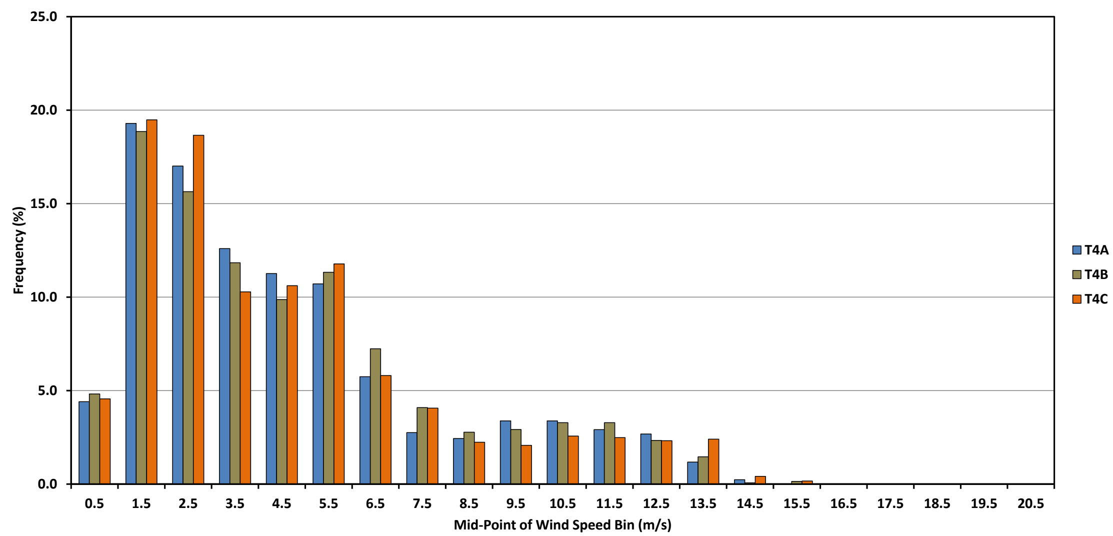


Figure 14. Wind speed frequency distribution for the three positions along Transect 4 for wind speed at 3 m a.g.l.

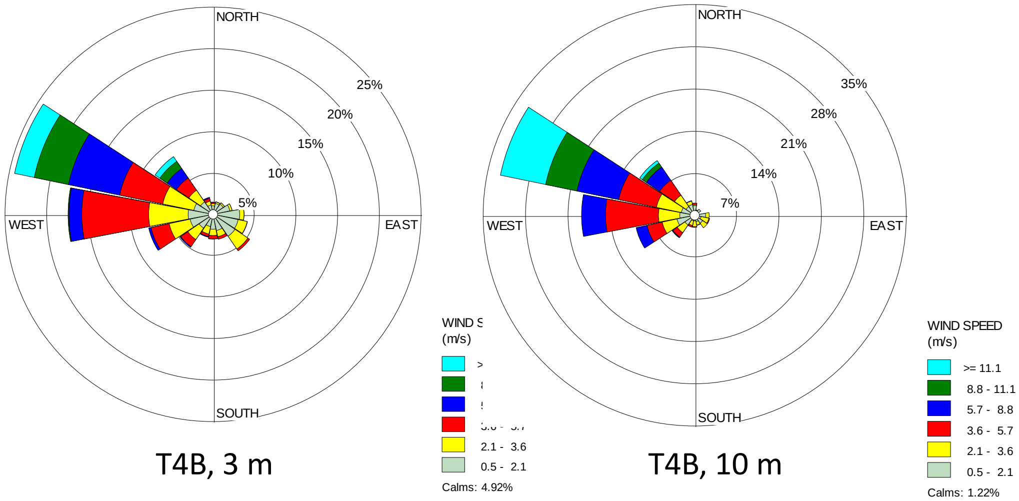


Figure 15. Wind roses for position T4B for wind speed and direction measured at 3 m and 10 m a.g.l. The wind direction pattern is essentially identical, but the frequency of higher wind speeds measured at 10 m is greater than at 3 m.

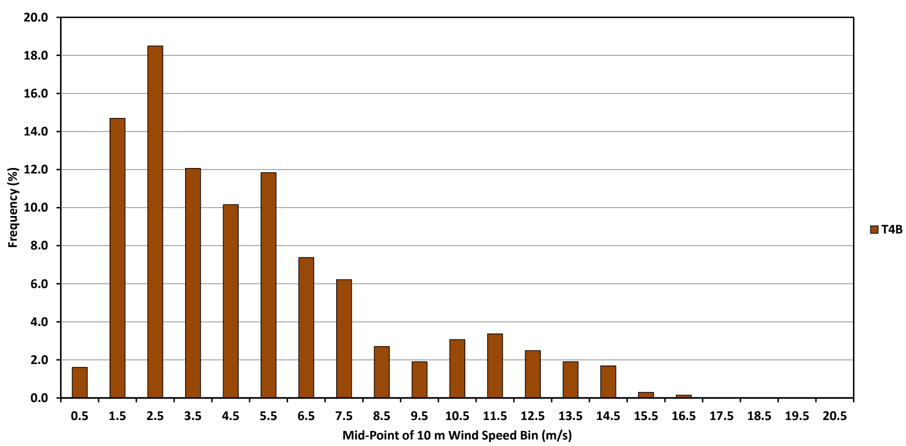


Figure 16. Wind speed frequency distribution for T4B for wind speed measured at 10 m a.g.l.

Histograms of the percent frequency of occurrence of one hour maximum wind gusts at each of the measurement positions along the four transect are shown in Fig. 17 for the 3 m measurement height a.g.l. These histograms show that the magnitude of wind gusts in all cases increase in frequency and magnitude from west to east. These histograms also show that Transects 3 and 4 experience higher magnitude wind gusts than Transects 1 and 2, with values in excess of 20 m/s. These higher magnitude wind gusts will produce large transient increases in the instantaneous sand and dust flux. Once entrained by these high speed gust events the dust is available for longer transport distances unlike the sand in motion that will quickly respond to rapidly decreasing wind speeds.

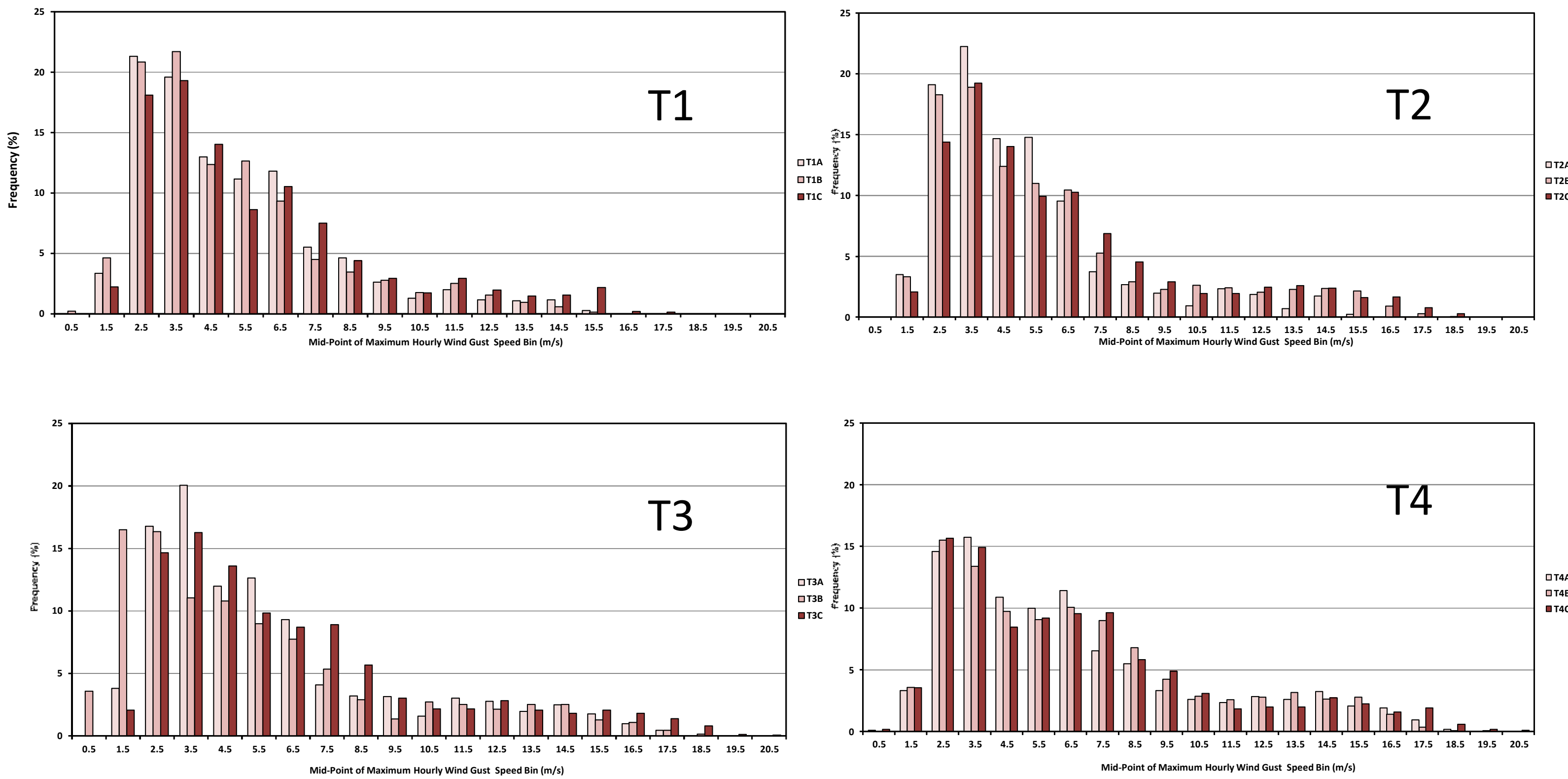


Figure 17. Wind gust speed frequency distributions for the three positions along each transect for wind speed and direction measured at 3 m a.g.l.

The three stations with measurements at 10 m also show that there is a shift to higher magnitude gusts of greater frequency moving from north to south along the positions T1C, T2C, T3C, and T4B, which follows the same pattern as the mean wind speed data at these positions (Fig. 18). This, in part, will be why the mean wind speed data increase with increasing westerly position as the gust data are within the mean wind speed data.

3 Average Threshold Wind Speeds for Saltation

Estimating the threshold wind speed for particle entrainment from ambient measurements with a low degree of uncertainty requires measurement of the wind speed (or wind shear) and the presence or absence of saltating sand or elevated levels of dust (i.e., PM_{10}) at a frequency of at least 1 Hz (Stout, 2004). This frequency of measurement was not possible for logistical reasons for this project phase, so an alternative method was used that utilizes the acquired Sensit count and the mean 10 m wind speed data. As threshold of motion is achieved on the scale of seconds, in an hour where Sensits indicate that saltation has occurred it is not possible to define the exact time and wind speed that initiated the motion. Threshold is defined here by the mean of all wind speed values that indicate saltation has been registered by the Sensit in the hour immediately following an hour for which no Sensit counts were registered, and all wind speeds that show zero counts immediately following an hour with counts. This takes into account the critical hour-long intervals where saltation begins and then ceases. Sensit counts of one were treated as zero in this analysis. The mean threshold 3 m wind speed for each transect and each position along the four transects and the standard deviation of the mean threshold wind speed value are shown in Table 2. The range of estimated threshold 3 m wind speed is 4.01 m/s (±0.86 m/s) to 6.28 (±2.38 m/s). The mean threshold for the study area is 4.97 m/s (±0.70 m/s). Given the standard deviations of the mean values, a mean minimum wind speed threshold should be around 3.6 m/s, measured at 3 m a.g.l.

At the three positions where wind speed is measured at 10 m a.g.l. (i.e., T1C, T2C, T3C, and T4B) the same analysis can be performed to define the threshold wind speed for this standard wind measurement height. At these positions the 10 m a.g.l. threshold wind speed ranges from 5.81 m/s (±1.34 m/s) at T1C to 6.21 m/s (±1.50 m/s) at T4B. The 10 m threshold wind speed can be estimated for the other locations on the same transect by using the 3 m to 10 m threshold wind speed ratio. These 10 m threshold wind speed estimates for T1A, T1B, T2A, T2B, T2C, T3A, T3B, T4A, and T4C are provided in Table 2.

Based on the threshold wind speed data, saltation and dust emissions should begin to commence within the ODSVRA and the Dune Preserve areas at any time that 3 m mean hourly wind speed exceeds 3.6 m/s, or the 10 m wind speed exceeds 3.8 m/s. These estimates represent the lowest values based on the standard deviations of the mean threshold value for the position with the lowest estimated threshold wind speed. This does not mean that saltation will begin everywhere at these wind speeds, but only at the most susceptible areas.

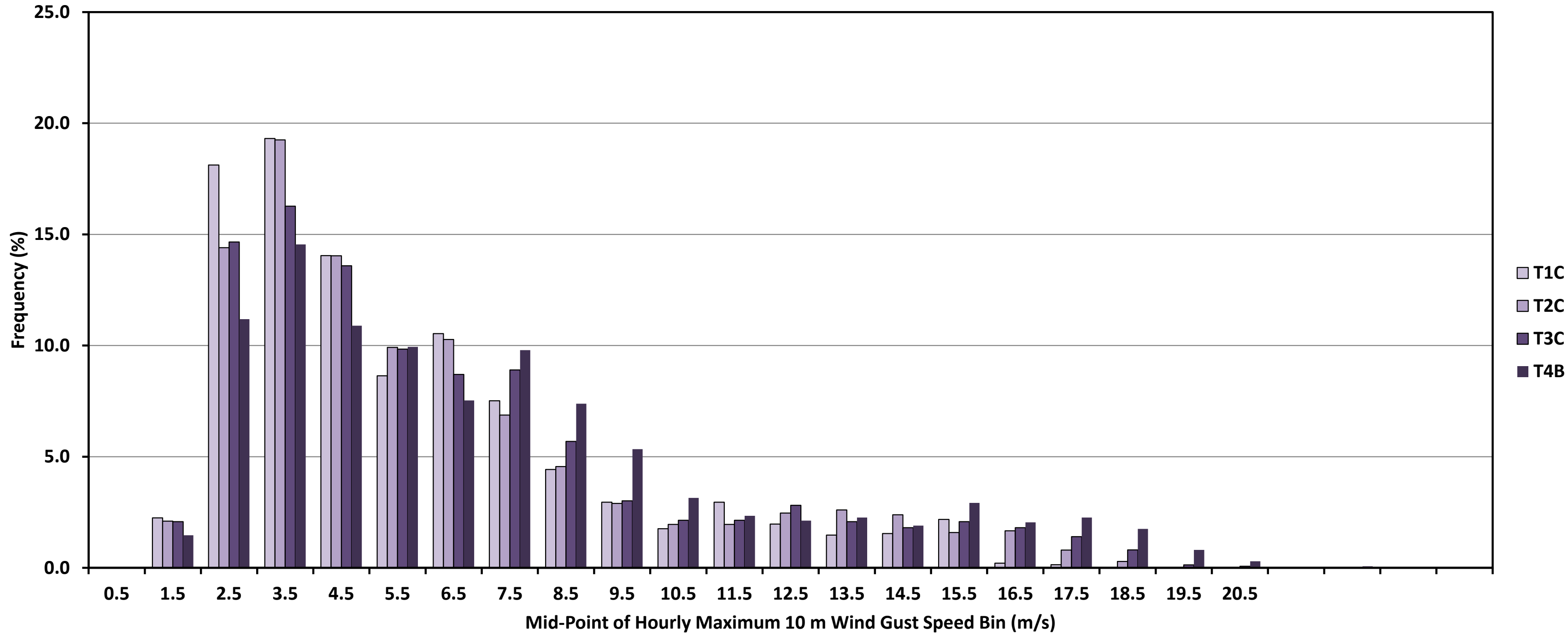


Figure 18. Wind gust speed frequency distributions for the 4 measurement positions with wind speed measurements at 10 m a.g.l.

The threshold wind speed data presented in Table 2, show several patterns based on location and position of measurement along the transects. In general, there seems to be no relationships between elevation and 3 m mean threshold wind speed. Transect 1 shows a linear increase in threshold mean wind speed for saltation with increasing distance from the shoreline. Transects 2 and 3 show a decrease in threshold wind speed with increasing distance from the shoreline and Transect 4 does not show any appreciable change in threshold wind speed as a function of distance from the shoreline. In all these cases however, the small sample size and the overlap of the associated standard deviations of the mean values makes the certainty of these relationships ambiguous.

Table 2. Mean Hourly 3 m and 10 m Wind Speed Threshold for Saltation.

Transect ID	Distance from Shoreline (m)	Elevation (m)	Mean Threshold 3 m Wind Speed (m/s)	Std. Dev. Threshold 3 m Wind Speed (m/s)	Mean Threshold 10 m Wind Speed (m/s)	Std. Dev. Threshold 10 m Wind Speed (m/s)
T1A	700	17.95	4.01	0.86	4.43	
T1B	893	29.05	4.20	0.84	4.65	
T1C	1185	21.15	5.63	1.33	5.81	1.34
T2A	409	13.09	5.02	1.34	5.42	
T2B	628	19.04	5.09	1.66	5.50	
T2C	1101	32.35	4.40	1.21	4.34	1.20
T3A	500	19.64	6.28	2.38	6.96	
T3B	1365	34.31	5.06	1.30	5.61	
T3C	2420	24.31	4.27	0.98	4.52	0.970
T4A	859	18.6	5.07	1.43	5.72	
T4B	1411	37.28	5.85	1.51	6.21	1.50
T4C	1913	37.08	4.77	1.16	5.38	

Shaded grey cells represent estimated wind speed based on the ratio of 3 m wind speed to 10 m wind speed for positions with wind speed measurements at both heights along the same transect and wind speed at 3 m ≥ 1 m s^{-1} (i.e., T1C, T2C, T3C, T4B).

Mean threshold wind speed at 3 m and 10 m can also be examined for patterns of change in the north-south direction. A least squares, best fit regression to these data suggest the mean transect threshold wind speed increases linearly with increasing distance south from Transect 1 to 4 (Fig. 19). The reasons for this could be two-fold. The most likely is that there is an increase in size of the sand particles (e.g., mean grain size) from north to south. Larger particles require higher wind shear to entrain them. A second effect could be due to increased shear stress partitioning caused by the presence of increasing roughness of the surface from north to south. More roughness will require that higher wind speeds be attained to create the necessary shear stress to mobilize the sand among those elements. Both of these affects may be, in part, responsible for this trend. The most likely explanation is a particle size increase and this can be examined when the particle size analyses is completed.

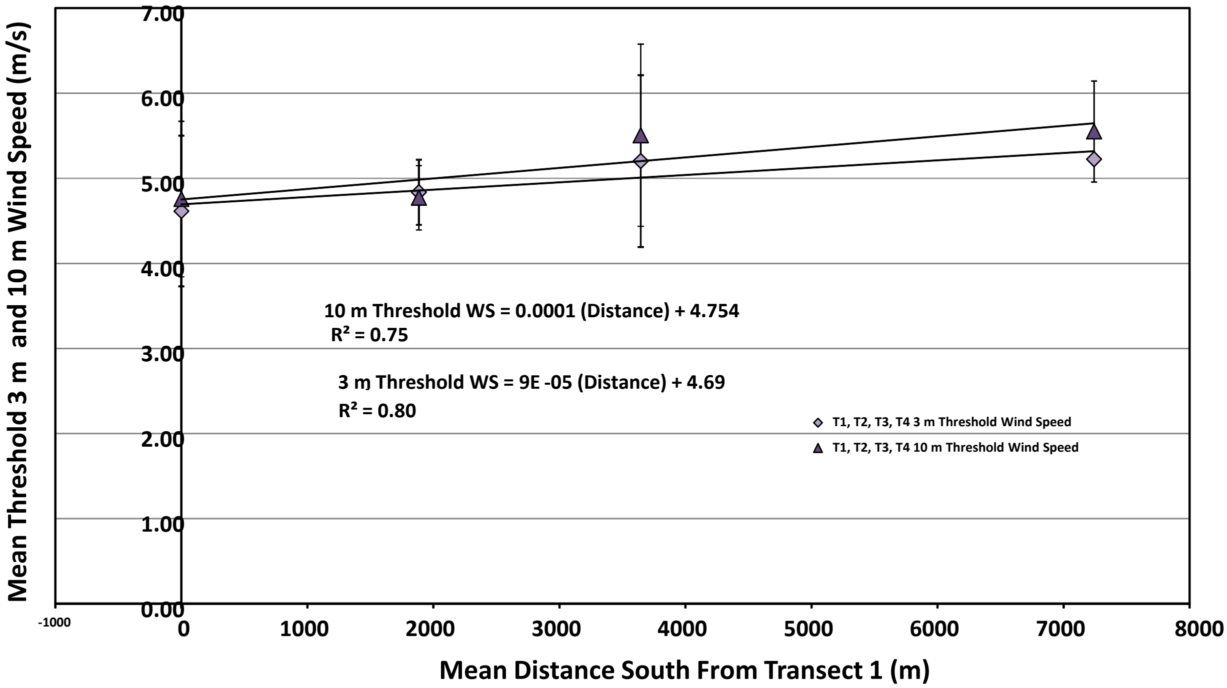


Figure 19. Mean saltation threshold 3 m and 10 m wind speed for each transect as a function of mean distance south of Transect 1.

The Sensit data can also be used to evaluate the percent of time that the saltation system is active at each of the measurement locations (approximately May 10 – July 15). A simple metric is defined by the percentage of hours in which Sensits record saltation activity (counts) for the total number of hours monitored (Table 3). Count must be >1 to be a valid measurement.

Table 3. Saltation activity as a function of measurement duration and hours recorded with saltation counts. Threshold wind speed data from Table 2 are listed as well.

Site	Hours of Observation	% Missing Observations	Hours that Recorded Saltation Counts (>1)	% of Hours with Saltation Activity	Threshold 3 m Wind Speed (m/s)	Mean Threshold 10 m Wind
T1A	1102	2	222	20	4.01	4.13
T1B	1359	2	138	10	4.20	4.33
T1C	1423	0.2	87	6	5.63	5.81
T2A	859	0	57	7	5.02	4.95
T2B	1444	0	89	6	5.09	5.02
T2C	1402	6	226	16	4.40	4.34
T3A	1526	0	33	2	6.28	6.65
T3B	1314	17	140	11	5.06	5.35
T3C	1480	3	206	14	4.27	4.52
T4A	1270	0	130	10	5.07	5.38
T4B	1368	7	126	9	5.85	6.21
T4C	1206	0	226	19	4.77	5.06

The most active locations for saltation are T1A, T2C, T3C and T4C. Except for Transect 1 the trend is for increasing saltation activity moving from west to east, which fits with the general pattern of increasing wind speed from west to east.

4 Relationships Between Hourly 3 m Mean Wind Speed and Hourly Mean e-BAM Measured PM_{10}

To investigate the relationship between wind speed and dust emissions within the ODSVRA and the Dune Preserve areas e-BAM PM_{10} monitors were deployed on each of the four west-east transects. e-BAMs were located at T1C, T2C, T3B, T3C, and T4B.

The available wind speed, wind direction, and PM_{10} data were filtered using two criteria: 1) periods when the e-BAM hourly PM_{10} was ≥50 µg/m^3, and 2) periods when the e-BAM hourly PM_{10} was ≥50 µg/m^3 and 3 m hourly mean wind speed was ≥4.0 m/s (i.e., just above the minimum threshold of 3.6 m/s). The first criteria selects all periods where e-BAM measurements indicate that the PM_{10} is elevated to levels that could potentially impact air quality standards external to the ODSVRA and Dune Preserves. The second criterion selects data for the time periods when PM_{10} is elevated to levels that could potentially impact air quality standards external to the ODSVRA and Dune Preserves when the saltation system is activated, i.e., mean wind speed is above saltation threshold.

These data are presented as a series of wind roses for each position (using 3 m wind speed and direction data) on the transects where e-BAM instruments were located. Figure 20 represents Transect 1 (T1C), Fig. 21 Transect 2 (T2C), Fig. 22 Transect 3 (T3B), Fig. 23 Transect 3 (T3C), and Fig. 24 Transect 4 (T4B).

PM_{10} ≥50 µg/m^3 for the Transect 1 e-BAM location (Fig. 20) is associated, for the most part, with winds that originate from south (180°) through to north-west (315°), but the frequency of occurrence for this condition is dominated by winds from the west-north-west (292°). There are infrequent occurrences of low wind speed (0.5 – 4.0 m/s) from the south-east that can raise the PM_{10} levels to ≥50 µg/m^3 at this location, which when included in the application of Rule 1001 for days when this occurs could affect the calculation for attribution of an exceedence. When the second criterion of mean hourly wind speed ≥4.0 m/s is used to filter these data, the wind direction with the highest frequency (73%) that results in PM_{10} ≥50 µg/m^3 is overwhelmingly from the west-north-west (292°). The next most frequent direction when this filtering criterion is applied is north-west (315°) accounting for just 7% of occurrences.

At position T2C (Fig. 21), the wind direction most frequently associated with PM_{10} ≥50 µg/m^3 is also from the west-north-west (292°), accounting for 58% of all occurrences. Similar to position T1C there are a few instances (≈4%) where low winds from the east-south-east (112°) and south-east (135°) transport PM_{10} to T2C resulting in hourly mean values ≥50 µg/m^3. When winds are ≥4.0 m/s and PM_{10} ≥50 µg/m^3, a similar pattern as was observed at 1C is repeated at T2C. The dominant PM_{10} bearing winds come from the west-north-west (292°) for 76% of the occurrences. Compared to 1C, the wind

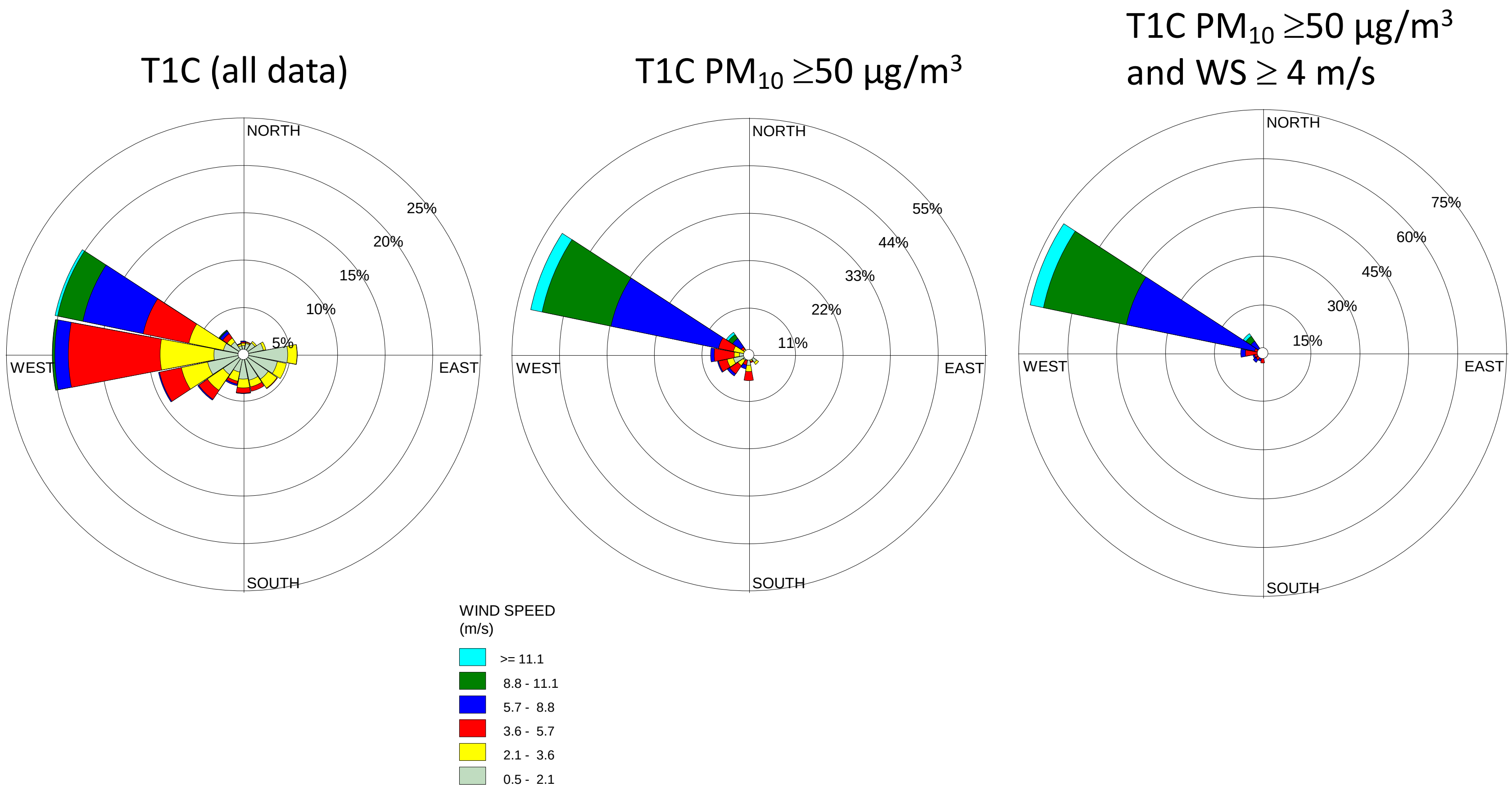


Figure 20. Wind roses for all available 3 m a.g.l. wind speed and wind direction data and the wind roses from the data filtered by the PM_{10} and wind speed (WS) criteria for Transect 1.

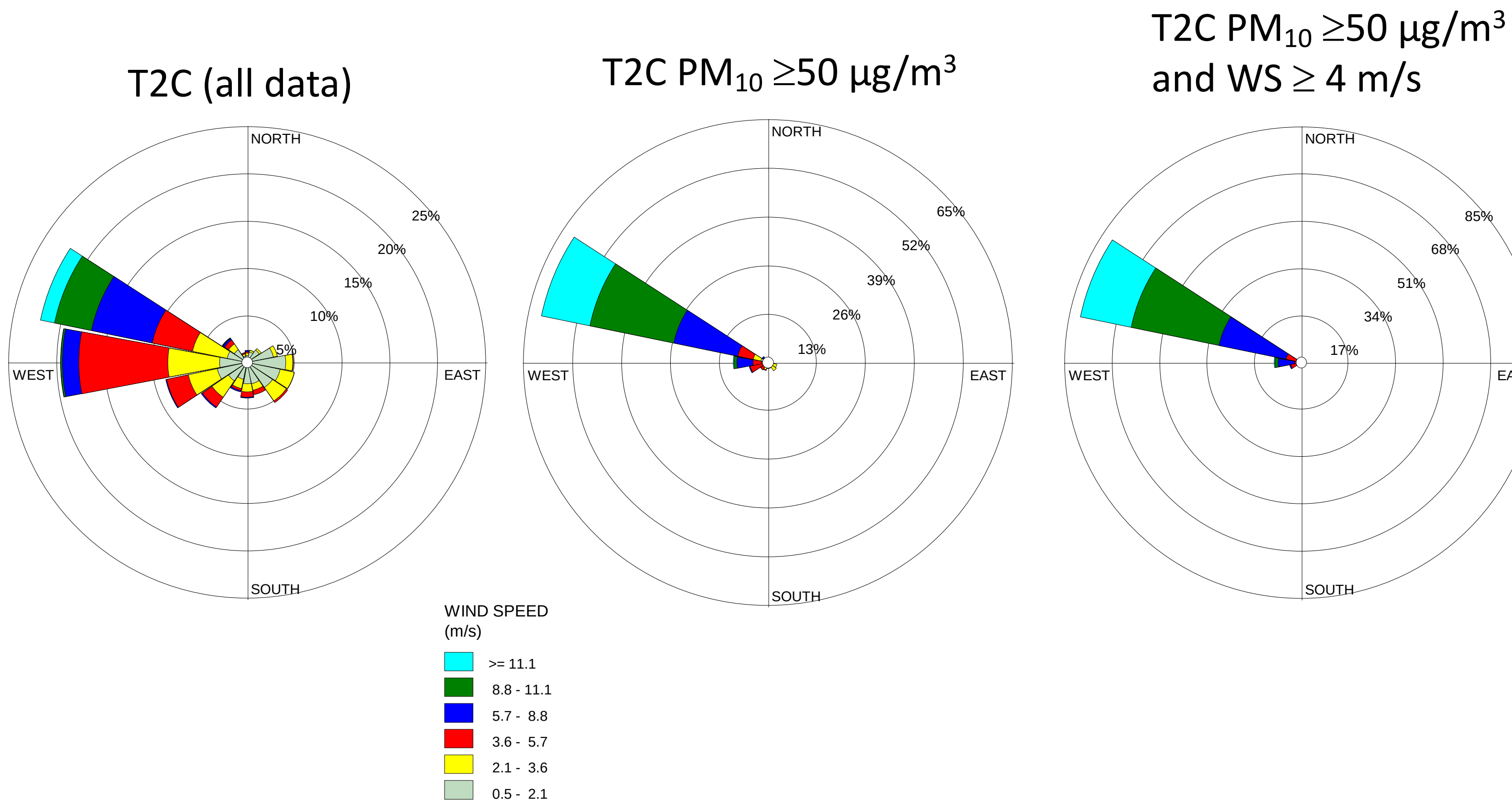


Figure 21. Wind roses for all available 3 m a.g.l. wind speed and wind direction data and the wind roses from the data filtered by the PM_{10} and wind speed (WS) criteria for Transect 2.

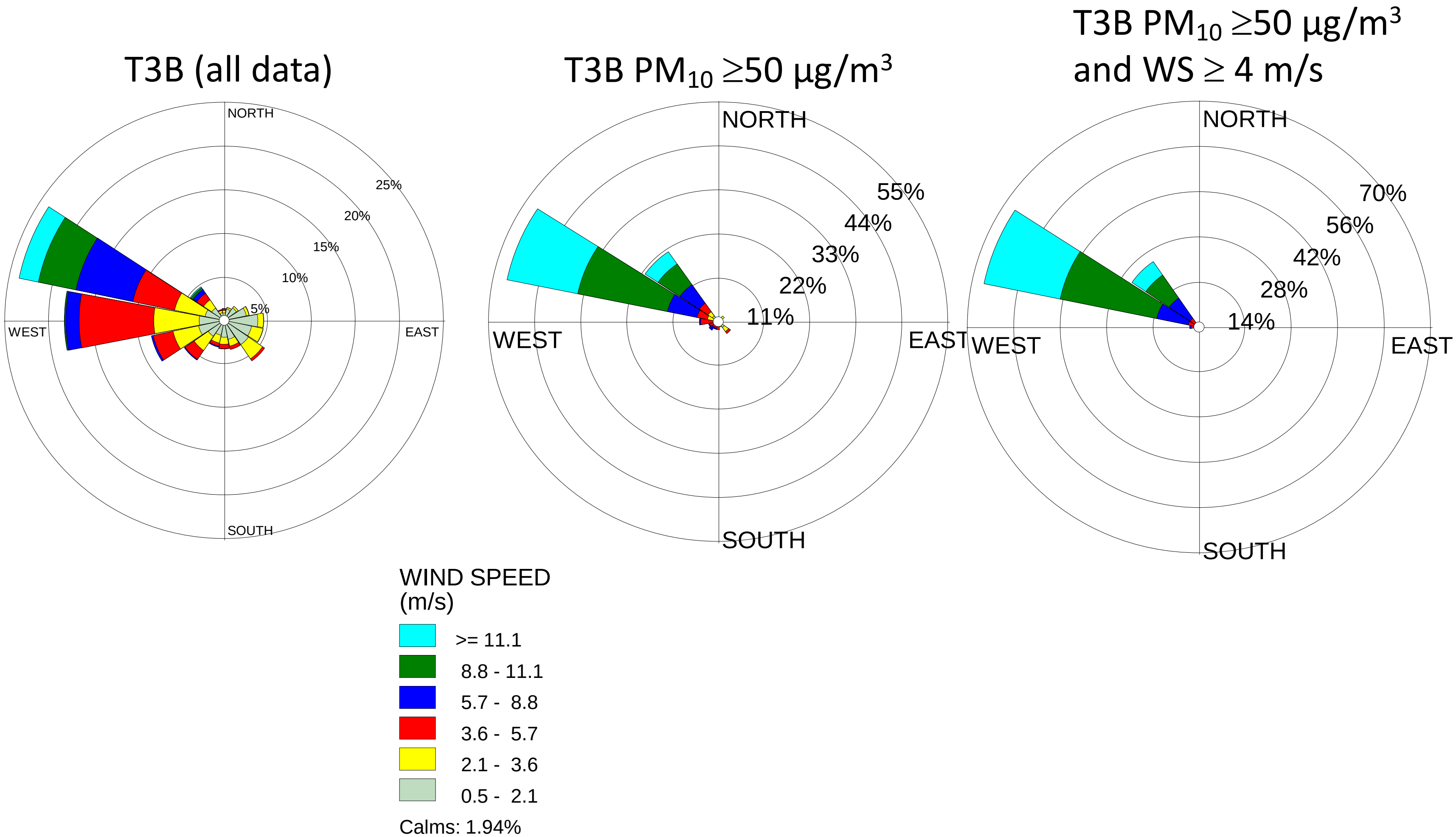


Figure 22. Wind roses for all available 3 m a.g.l. wind speed and wind direction data and the wind roses from the data filtered by the PM_{10} and wind speed (WS) criteria for Transect 3 Position B.

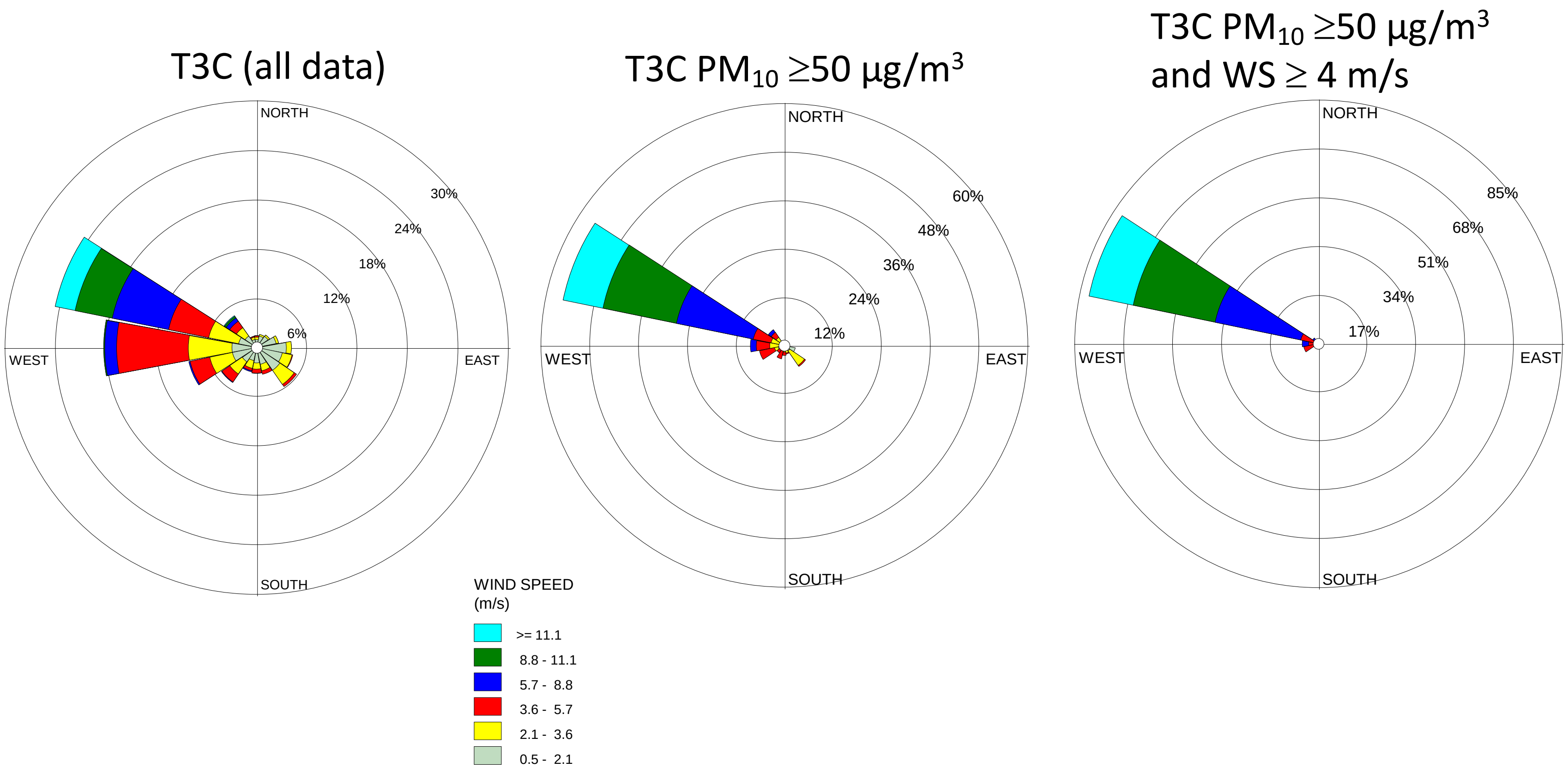


Figure 23. Wind roses for all available 3 m a.g.l. wind speed and wind direction data and the wind roses from the data filtered by the PM_{10} and wind speed (WS) criteria for Transect 3, Position C.

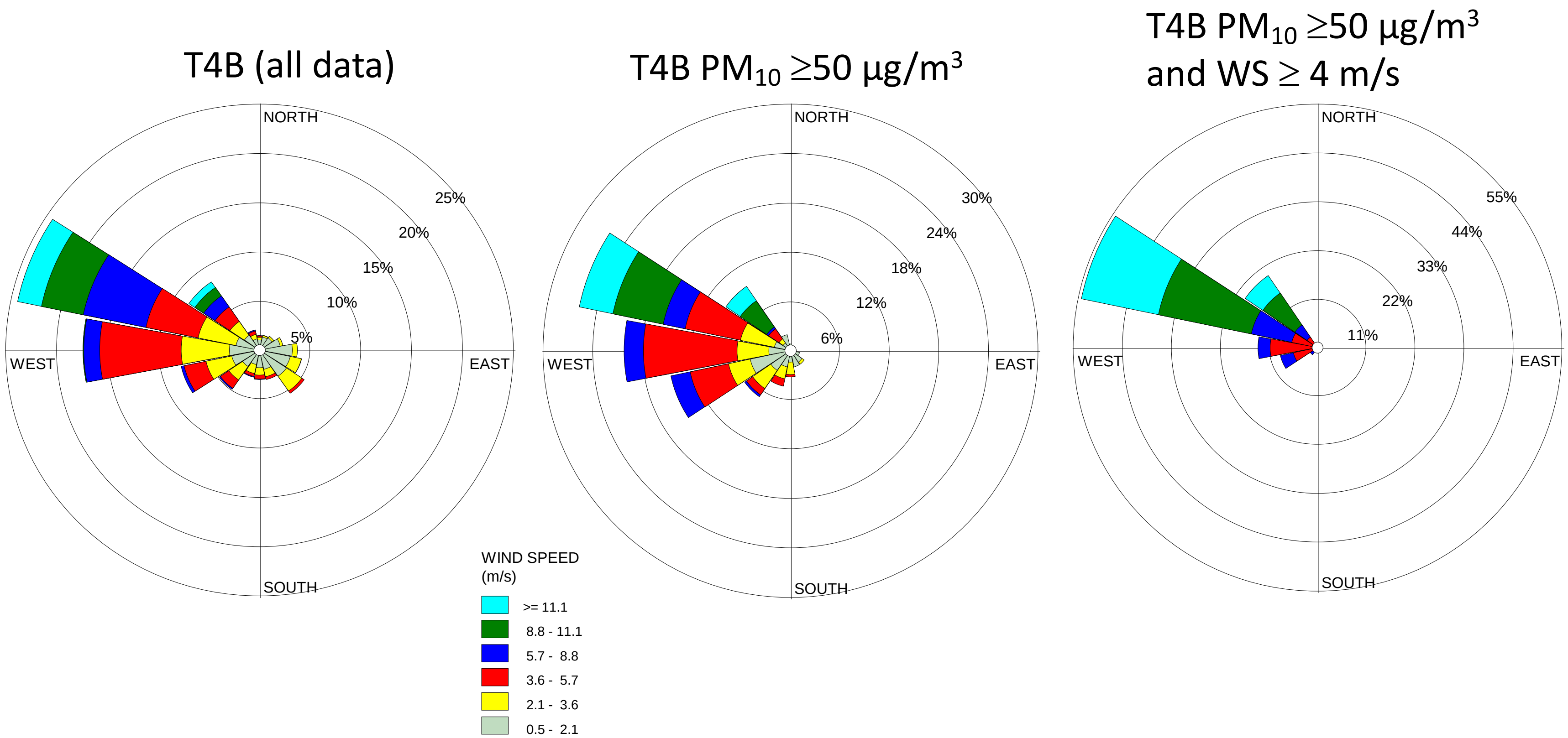


Figure 24. Wind roses for all available 3 m a.g.l. wind speed and wind direction data and the wind roses from the data filtered by the PM_{10} and wind speed (WS) criteria for Transect 4.

direction range is more restricted atT 2C, and is between west-south-west (247°) and west-north-west (292°).

The pattern of wind direction and magnitude that correspond to elevated PM_{10} at T3C (Fig. 23) is very similar to T2C. The dominant direction for elevated PM_{10} levels is associated with west-north-west (292°), and except for an infrequent occurrence of elevated PM_{10} associated with transport from the south-east (6%), this condition occurs with winds from the north-west to south. Under conditions of above threshold winds, elevated PM_{10} levels are confined to a much narrower wind direction, west-south-west (247°) and north-west (315°), with west-north-west (292°) dominating with a frequency of occurrence of 82%. At position T3B (Fig. 22), which is west of position T3C, for elevated PM_{10} levels and winds ≥4.0 m/s the dominant PM-bearing winds are from the west-north-west (292°) for 46% of occurrences, but there are winds from the north-west (315°) that frequently (19%) bring elevated PM_{10} levels to this monitoring location.

At the e-BAM position on Transect 4 (position 4B) (Fig. 24), a very different pattern is observed between elevated levels of PM_{10} and wind direction. For periods where PM_{10} is ≥50 µg/m^3 there is a much greater frequency of occurrence for each of the wind direction bins between south (180°) and north-north-west (337°) than observed for the other measurement positions. At this location elevated PM_{10} is most associated with winds from the west-north-west (292°), but these account for only 21% of the occurrences. Adding the filtering criterion of wind ≥4.0 m/s reduces the directional range for elevated PM_{10} to 225°-315°, as at the other locations winds from the west-north-west account for the majority of the occurrences at 54%.

The data presented in Figs. 20-24 indicate strongly that the majority of events that give rise to elevated PM_{10} due to saltation and dust emissions within the ODSVRA and Dune preserve are associated with winds from the west-north-west (292°) for all four of the transects. To evaluate how these data relate to the regional PM_{10} monitoring stations at CDF and Mesa, the wind speed, wind direction, and hourly PM_{10} BAM-derived data were acquired and subjected to the same data filtering criteria for the same period of time that was used for the transect data analysis. The Mesa 2 data are compared with the data from T2C (Fig. 25), T3B (Fig. 26), T3C (Fig. 27) and T4B (Fig. 28). The CDF data are compared with same transect positions (Figs. 29, 39, 31). The pairings represent the closest transect monitoring positions to the west of the regional monitoring sites.

Comparing Mesa 2 and T2C, T3B, T3C, and T4B the obvious similarity is that elevated PM_{10} conditions at both locations are associated with wind from the west-north-west (292°). For winds ≥4.0 m/s at both locations this accounts for 68% of the occurrences at Mesa 2, and 76%, 66%, and 82% of the occurrences at T2C, T3B and T3C, respectively. The most obvious difference between these sites is that at Mesa 2, 32% of the occurrences of PM_{10} ≥50 µg/m^3 occurred for winds from the north-west (315°) and associated primarily for winds in excess of 5.7 m/s. This direction is represented at the T3B (Fig. 26) location for 25% of occurrence and the T4B for 20% (Fig. 28), but absent from the T2C and T3C (Figs. 25 and 27) distributions. This suggests that the inland site of Mesa 2 may be receiving PM that is for some

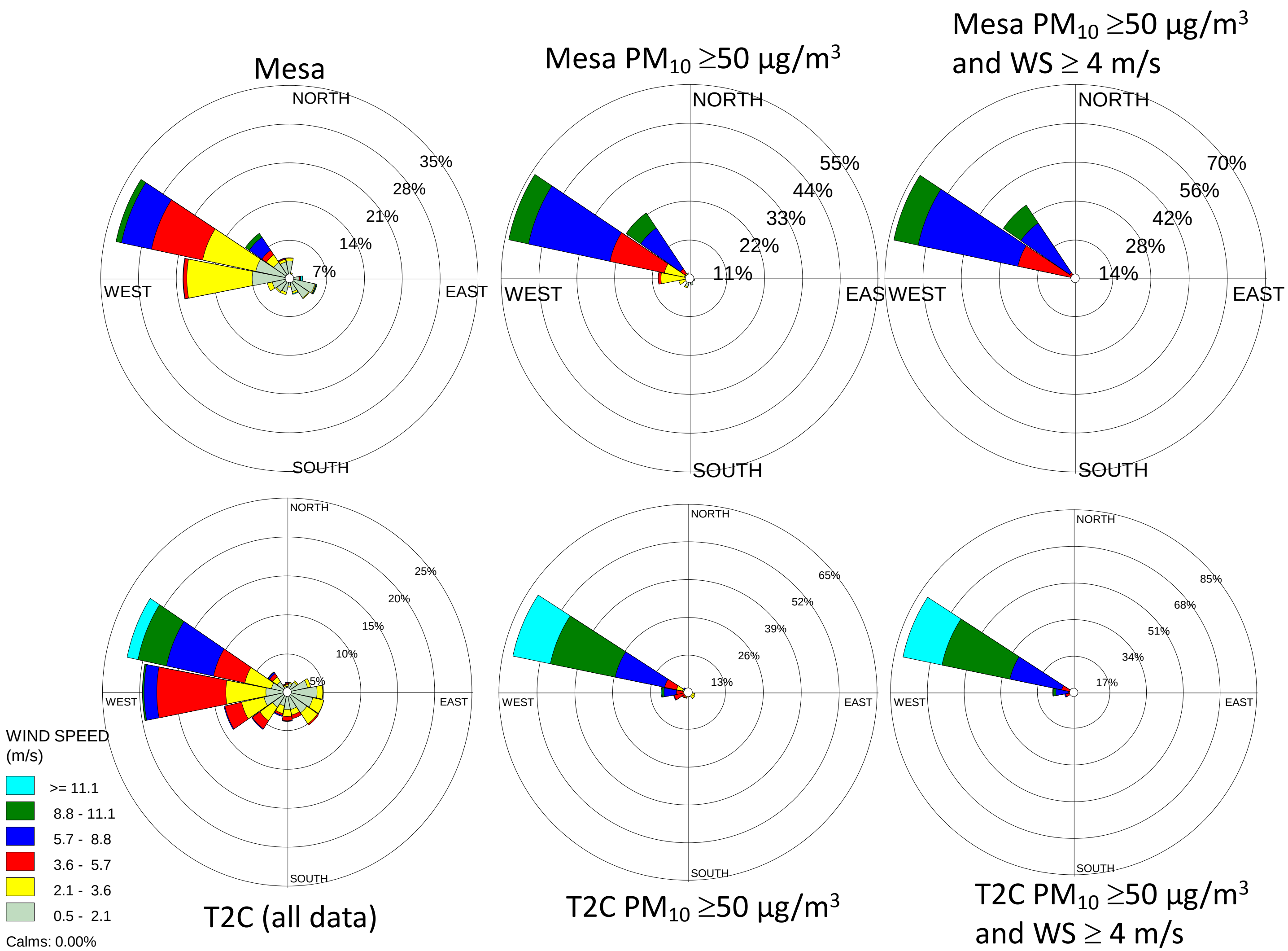


Figure 25. Wind roses for all available 10 m a.g.l. (both locations) wind speed and wind direction data and the wind roses from the data filtered by the PM_{10} and wind speed (WS) criteria for Mesa and T2C.

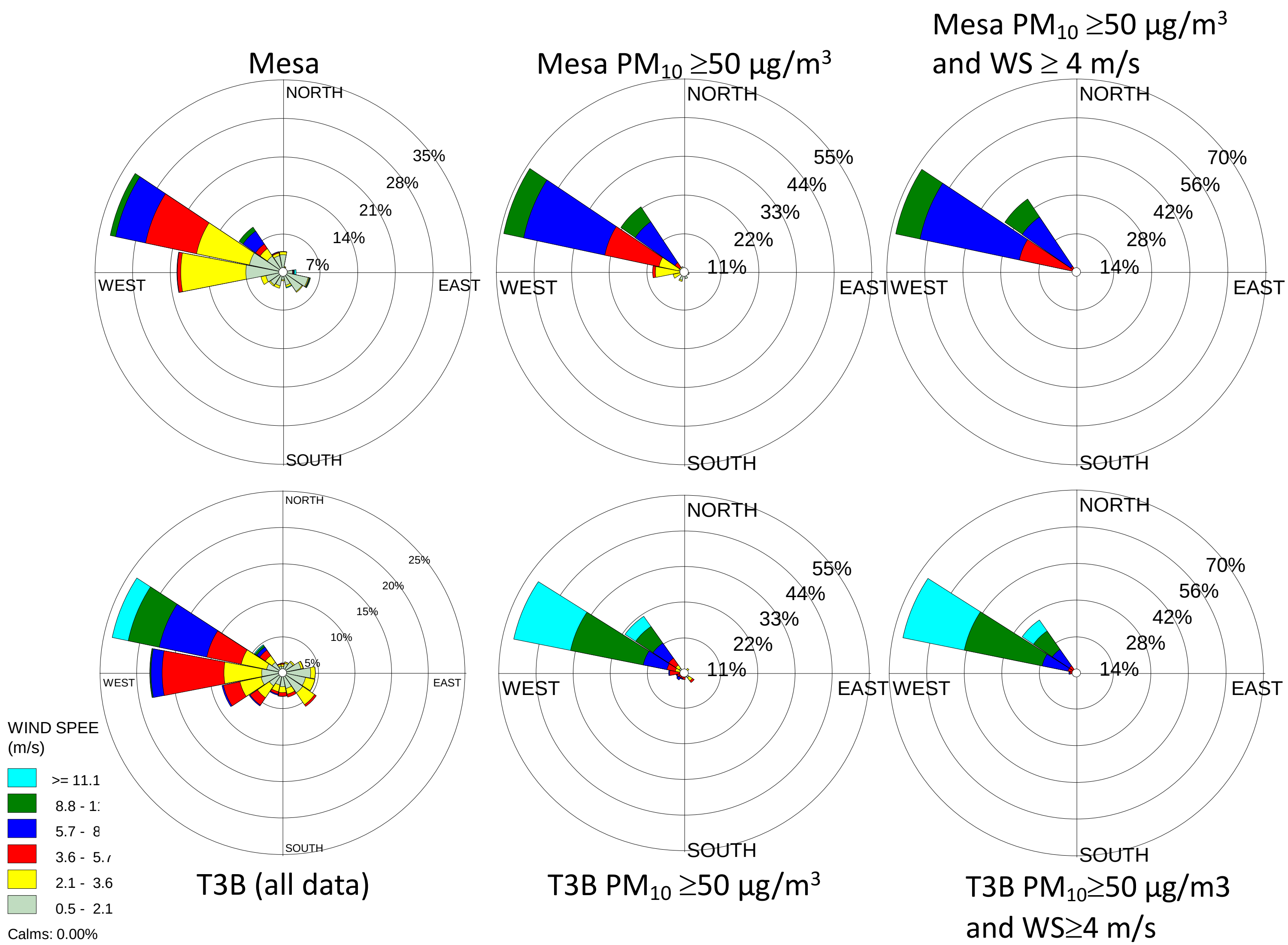


Figure 26. Wind roses for all available 10 m a.g.l. (both locations) wind speed and wind direction data and the wind roses from the data filtered by the PM_{10} and wind speed (WS) criteria for Mesa and T3B.

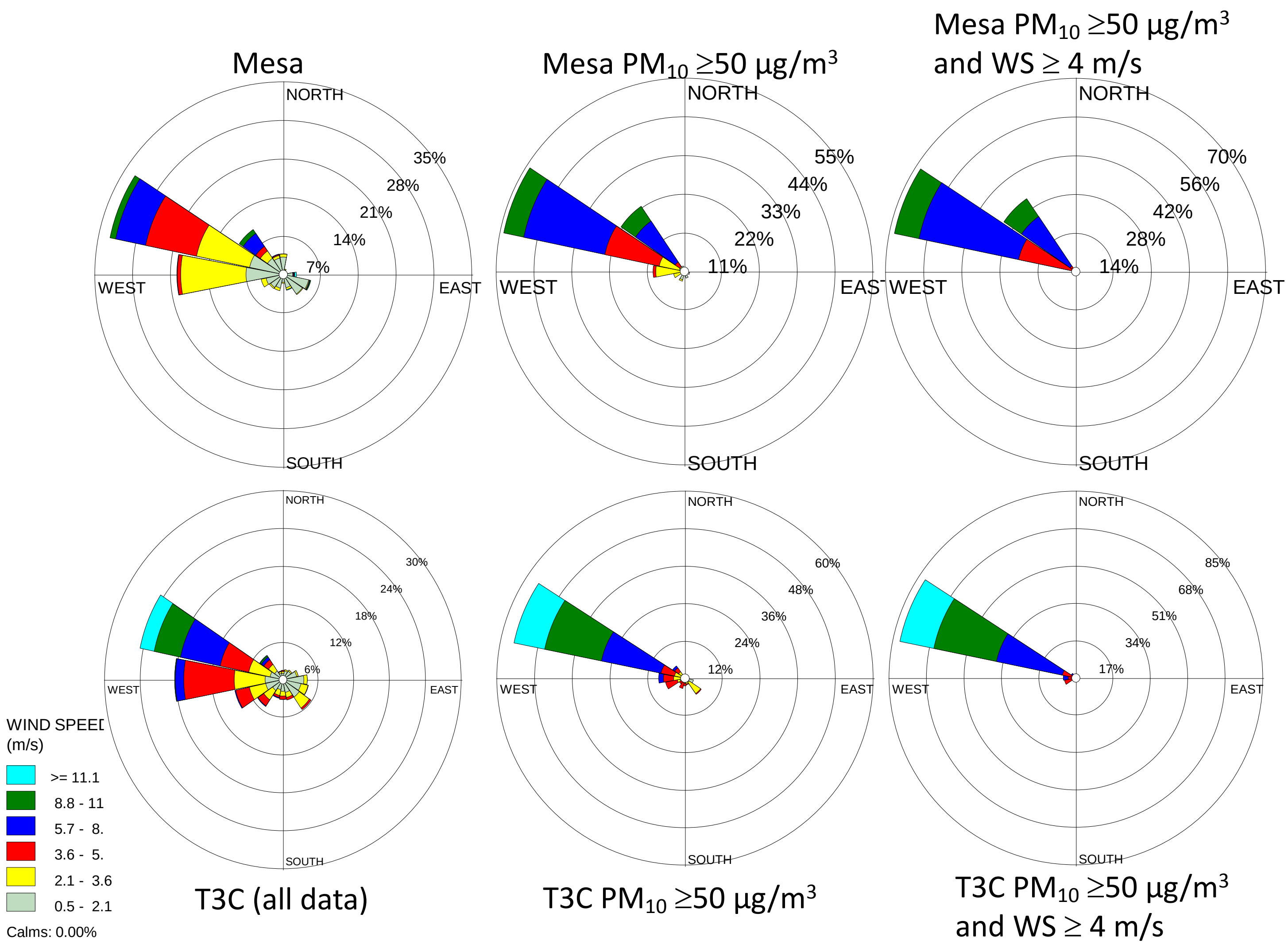


Figure 27. Wind roses for all available 10 m a.g.l. (both locations) wind speed and wind direction data and the wind roses from the data filtered by the PM_{10} and wind speed (WS) criteria for Mesa and T3C.

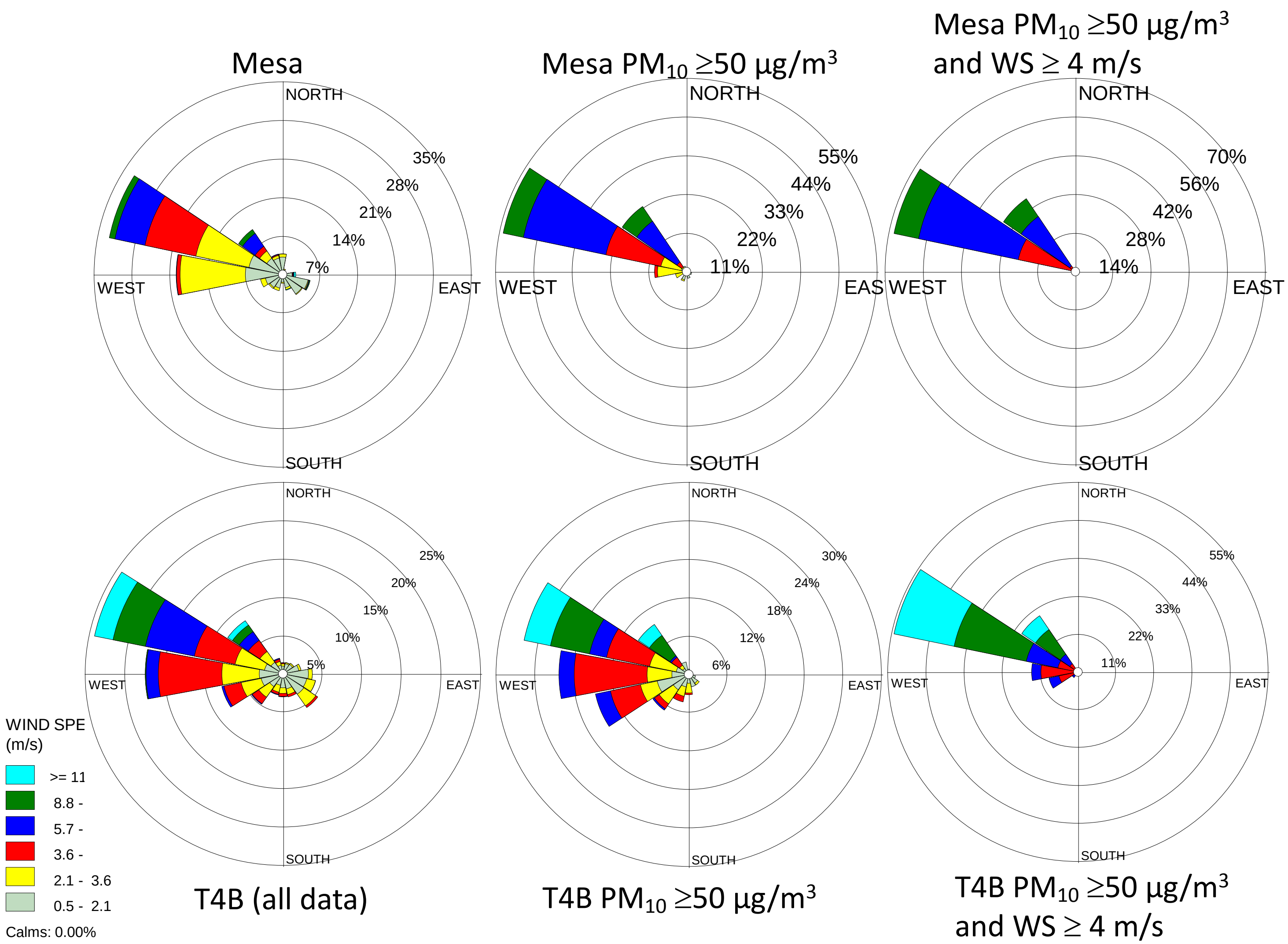


Figure 28. Wind roses for all available 10 m a.g.l. (both locations) wind speed and wind direction data and the wind roses from the data filtered by the PM_{10} and wind speed (WS) criteria for Mesa and T4B.

periods being steered southward as it exits the ODSVRA, because at the eastern borders the PM_{10} bearing winds are exiting pre-dominantly along 292°.

The comparison between CDF and T2C, T3B, and T3C data (Figs. 29, 30, 31) shows a pattern, in the wind directions that correspond to elevated PM_{10} levels and winds ≥4.0 m/s, somewhat different than the comparison between Mesa 2 and these sites. The most frequent direction associated with elevated PM_{10} at CDF is north-west (315°), with west-north-west being second in frequency of occurrence. At CDF the wind speed that this occurs for is dominated by the range 3.6 m/s to 8.8 m/s. The inland CDF site also shows a small percentage of elevated PM_{10} (≈4%) is associated with higher speed winds (8.8 m/s to 11.1 m/s) from the south-south-east (157°), suggesting this may be wind-driven mineral dust emissions from nearby agricultural areas. At CDF the PM_{10} bearing winds that are exiting the ODSVRA predominantly with an azimuth of 292° may be turned to the south over a shorter distance than is occurring at Mesa 2. The turning of the winds southwards is not yet attributed to a causal mechanism so it is not possible to say with certainty that there is a direct link between the sources of PM_{10} mineral dust within the ODSVRA and the air quality monitoring locations. To confirm that the winds and transported PM_{10} is being veered to the south upon passing by the most easterly measurement positions on the transects would require additional wind speed and direction data between the end position of the transects and the monitoring locations.

The available e-BAM data provides a means to evaluate how PM_{10} levels respond to mean 3 m and 10 m wind speed on each of the transects. To examine this relationship and reduce the inevitable scatter in the data that is inherent in most data sets of wind erosion-generated PM_{10} and wind speed (e.g., Nickling and Gillies, 1993; Alfaro et al., 2004), the data were binned into 0.5 m/s wind speed classes and average PM_{10} values calculated for the data in each wind speed class. The data can also be sorted by wind direction (16 bins, 22.5°).

From an examination of the PM_{10} and 3 m hourly mean wind speed data it became clear that strong relationships between these two environmental parameters occurs only for a limited range of wind direction, and they were non-linear in nature. The expectation is that these relationships should have the form of a power function (Gillies, 2013). For T1C this occurred for winds from the west-north-west (292°) (Fig. 32) and north-west (315°) (Fig. 33). For T2C a strong correlation between wind speed and PM_{10} was only observed for the direction west-north-west (292°) (Fig. 34). For T3B a strong correlation between wind speed and PM_{10} was observed for the direction west-north-west (292°) (Fig. 35) and a somewhat weaker relationship for north-west (315°) with fewer data points (Fig. 36). For T3C a strong correlation between wind speed and PM_{10} was only observed for the direction west-north-west (292°) (Fig. 37) and a weaker relationship for north-west (315°) with very few data points (Fig. 38) for the latter direction. For T4B, which is approximately in the north-south line from T1C, T2C, and T3B, only two directions show strong correlations between wind speed and PM_{10} (Figs. 39 and 40). These directions, west-north-west (292°) and north-west (315°) are consistent with the other measurement locations.

For purposes of comparison of PM_{10} as a function of wind speed for similar wind speeds for both the 292° and 315° wind directions the best-fit power relationships for each direction and measurement

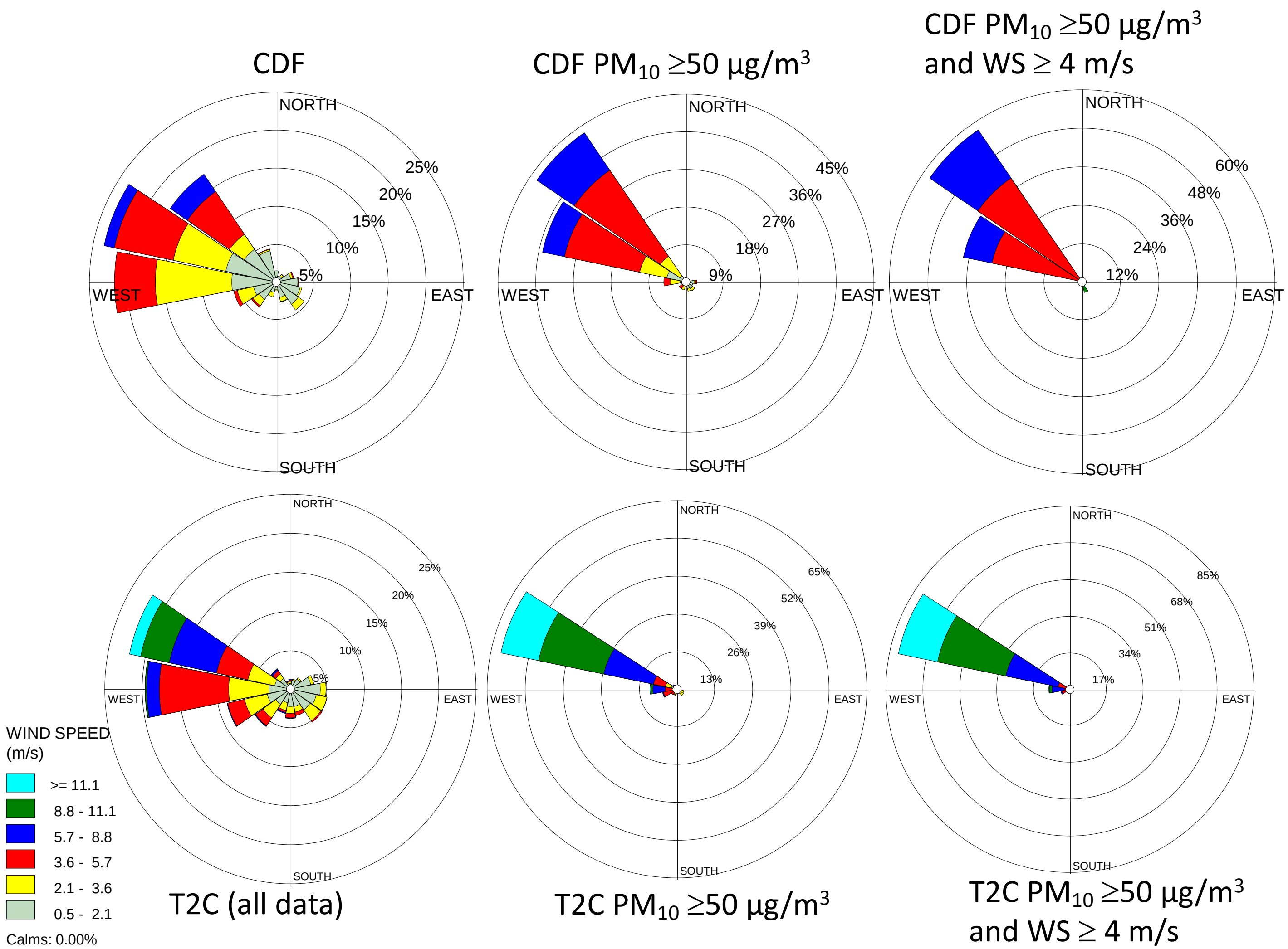


Figure 29. Wind roses for all available 3 m a.g.l. wind speed and wind direction data and the wind roses from the data filtered by the PM_{10} and wind speed (WS) criteria for CDF and T2C.

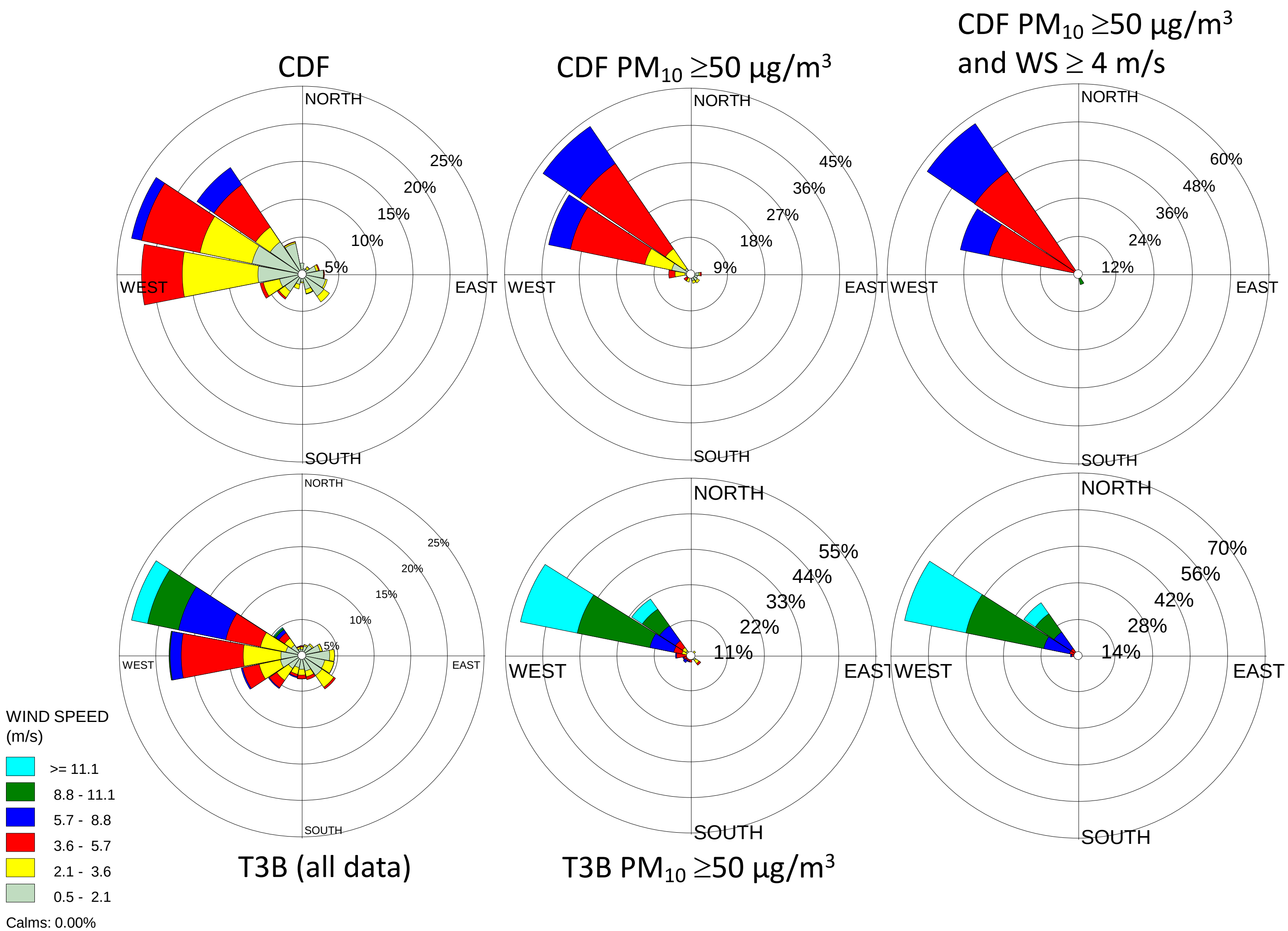


Figure 30. Wind roses for all available 3 m a.g.l. wind speed and wind direction data and the wind roses from the data filtered by the PM_{10} and wind speed (WS) criteria for CDF and T3B.

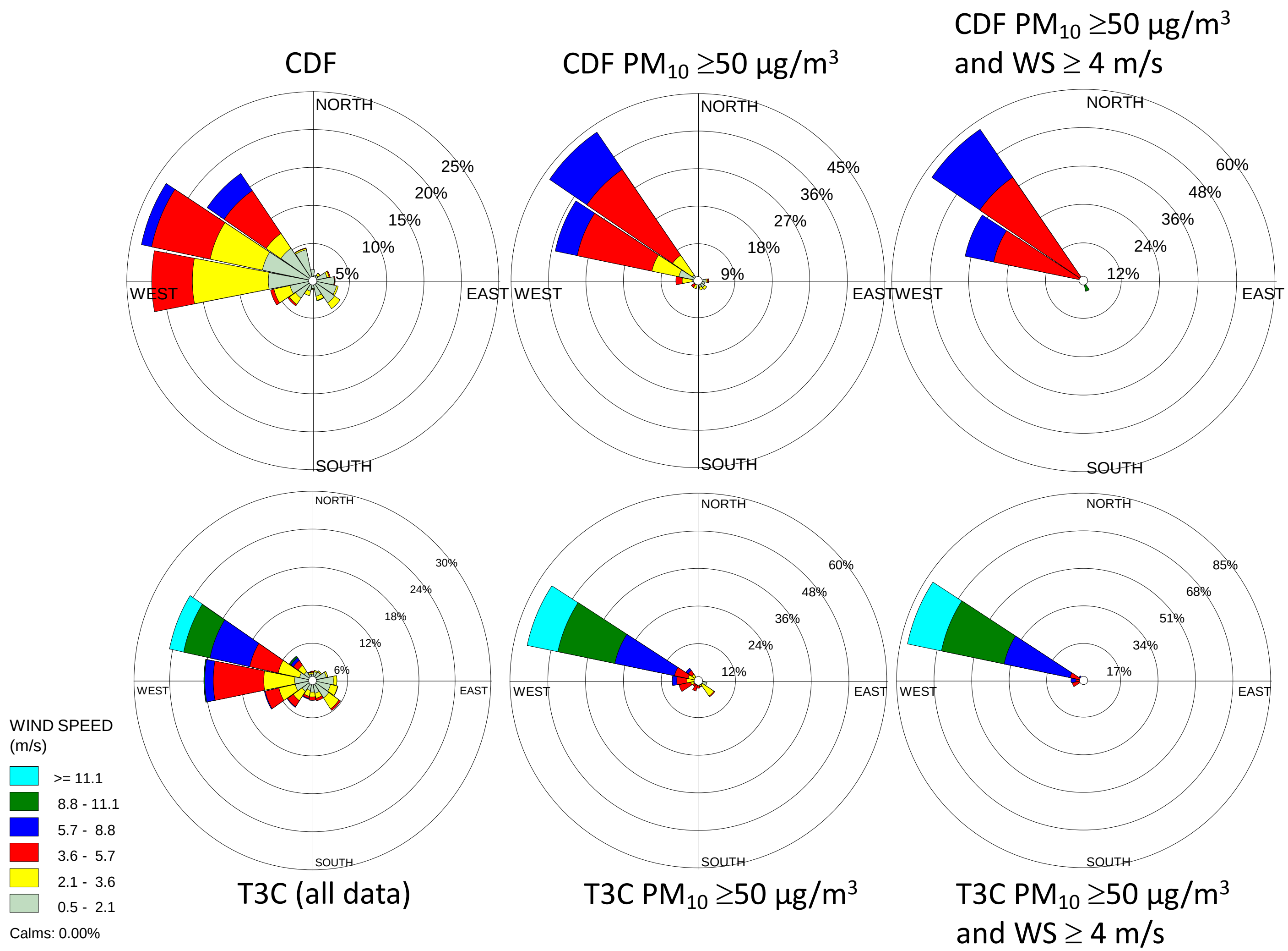


Figure 31. Wind roses for all available 3 m a.g.l. wind speed and wind direction data and the wind roses from the data filtered by the PM_{10} and wind speed (WS) criteria for CDF and T3C.

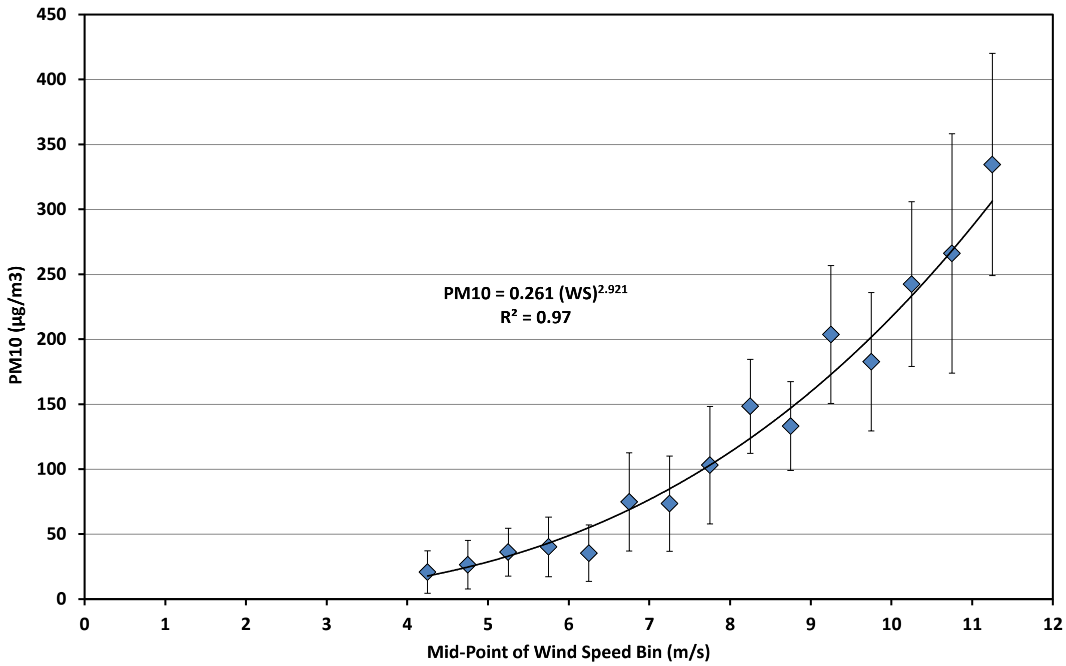


Figure 32. Relationship between mean 3 m hourly wind speed and PM_{10}, Transect 1, Position C, for the wind direction 292°. Data are truncated at 4 m/s.

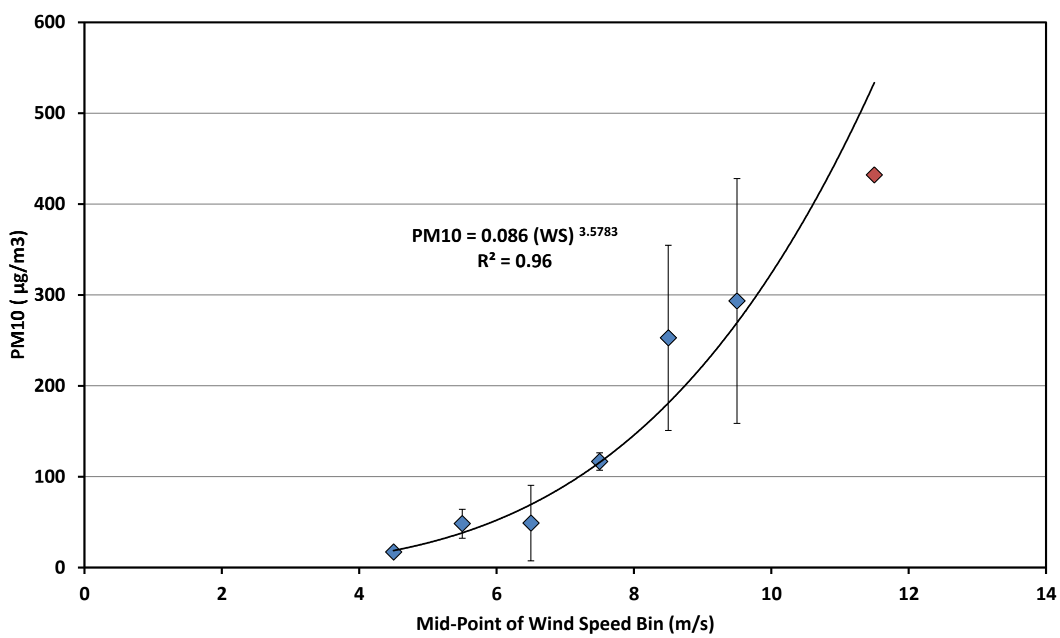


Figure 33. Relationship between mean 3 m hourly wind speed and PM_{10}, Transect 1, Position C, for the wind direction 315°. Data are truncated at 4 m/s. Red diamond symbol indicates only one data point for the wind speed bin.

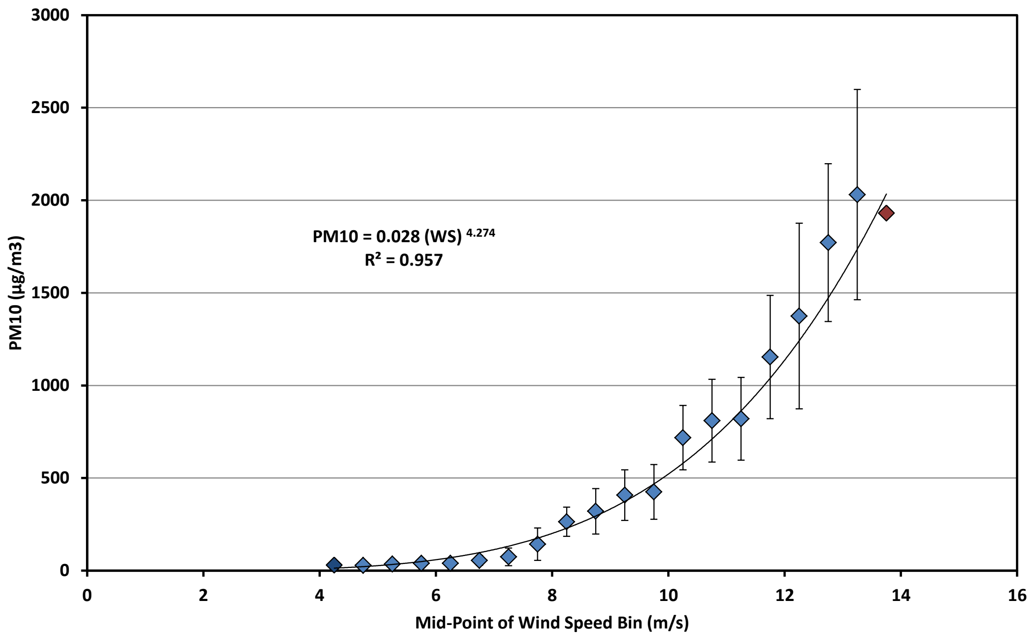


Figure 34. Relationship between mean 3 m hourly wind speed and PM_{10}, Transect 2, Position C, for the wind direction 292°. Data are truncated at 4 m/s. Red diamond symbol indicates only one data point for the wind speed bin.

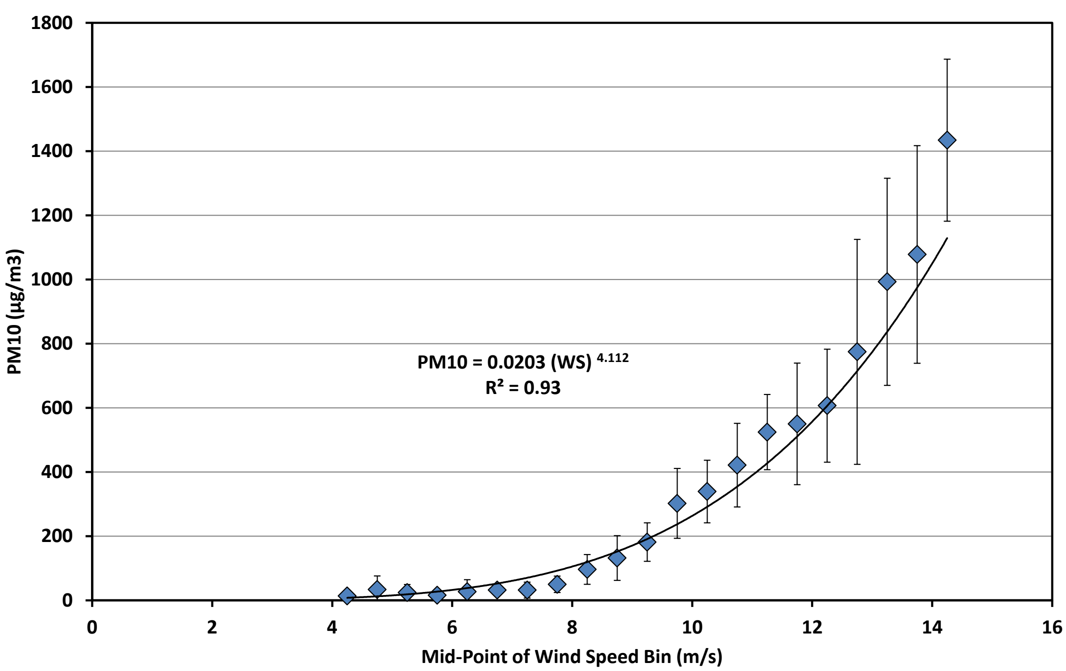


Figure 35. Relationship between mean 3 m hourly wind speed and PM_{10}, Transect 3, Position B, for the wind direction 292°. Data are truncated at 4 m/s. Red diamond symbol indicates only one data point for the wind speed bin.

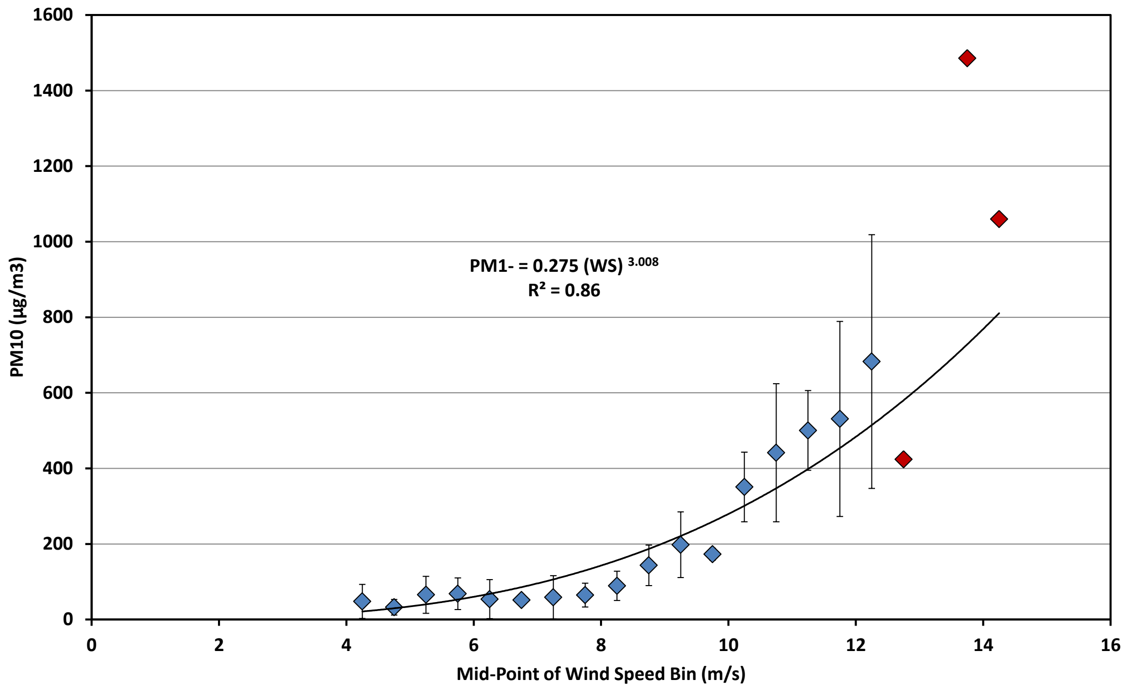


Figure 36. Relationship between mean 3 m hourly wind speed and PM_{10}, Transect 3, Position B, for the wind direction 315°. Data are truncated at 4 m/s. Red diamond symbol indicates only one data point for the wind speed bin.

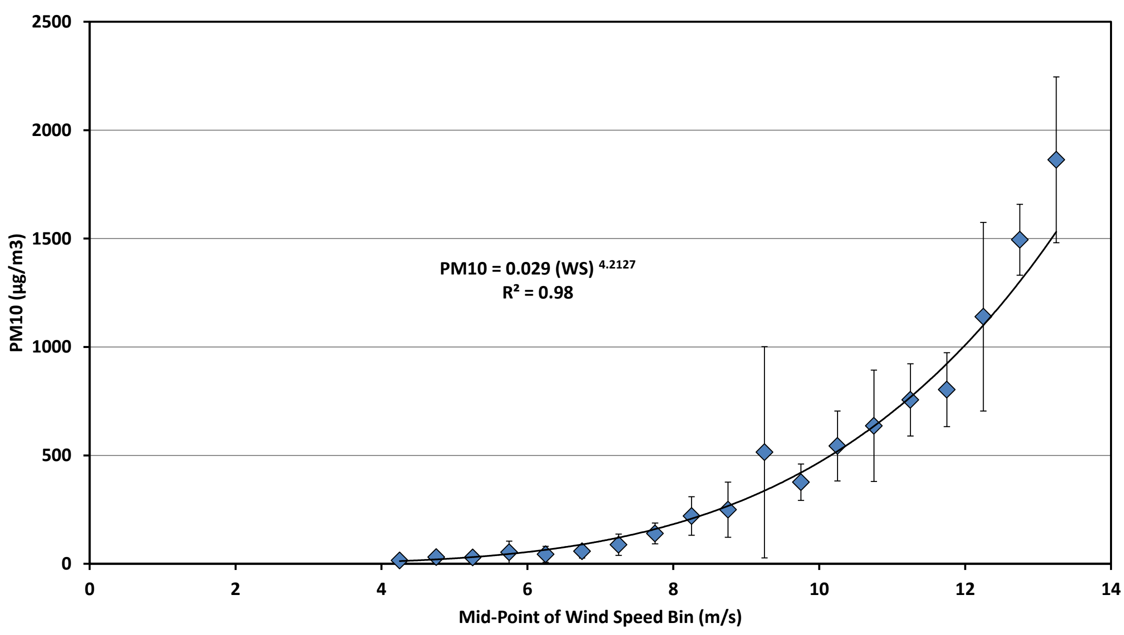


Figure 37. Relationship between mean 3 m hourly wind speed and PM_{10}, Transect 3, Position C, for the wind direction 292°. Data are truncated at 4 m/s. Red diamond symbol indicates only one data point for the wind speed bin.

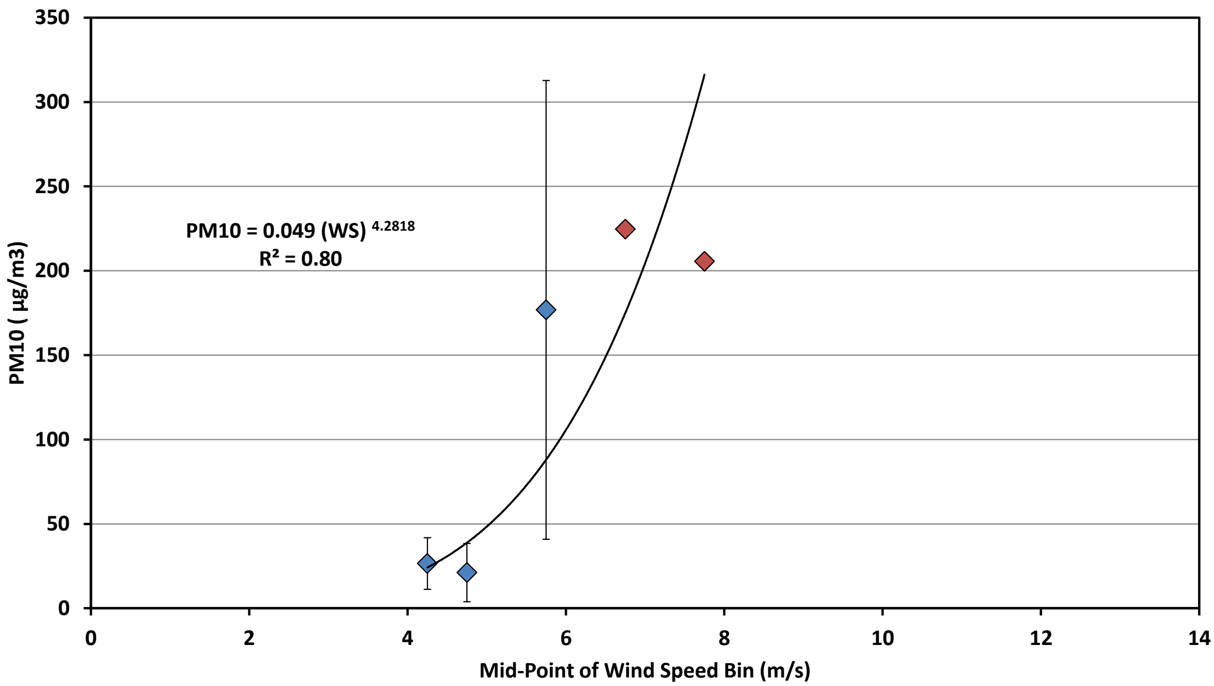


Figure 38. Relationship between mean 3 m hourly wind speed and PM_{10}, Transect 3, Position C, for the wind direction 315°. Data are truncated at 4 m/s. Red diamond symbol indicates only one data point for the wind speed bin.

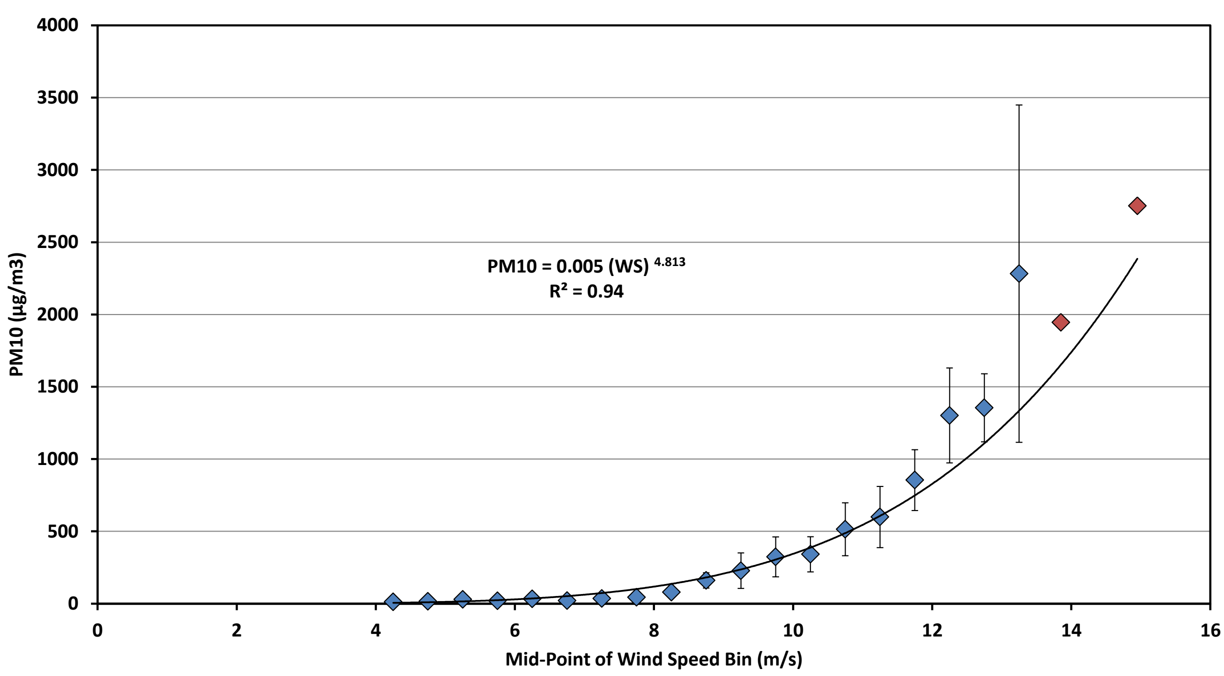


Figure 39. Relationship between mean 3 m hourly wind speed and PM_{10}, Transect 4, Position B, for the wind direction 292°. Data are truncated at 4 m/s. Red diamond symbol indicates only one data point for the wind speed bin.

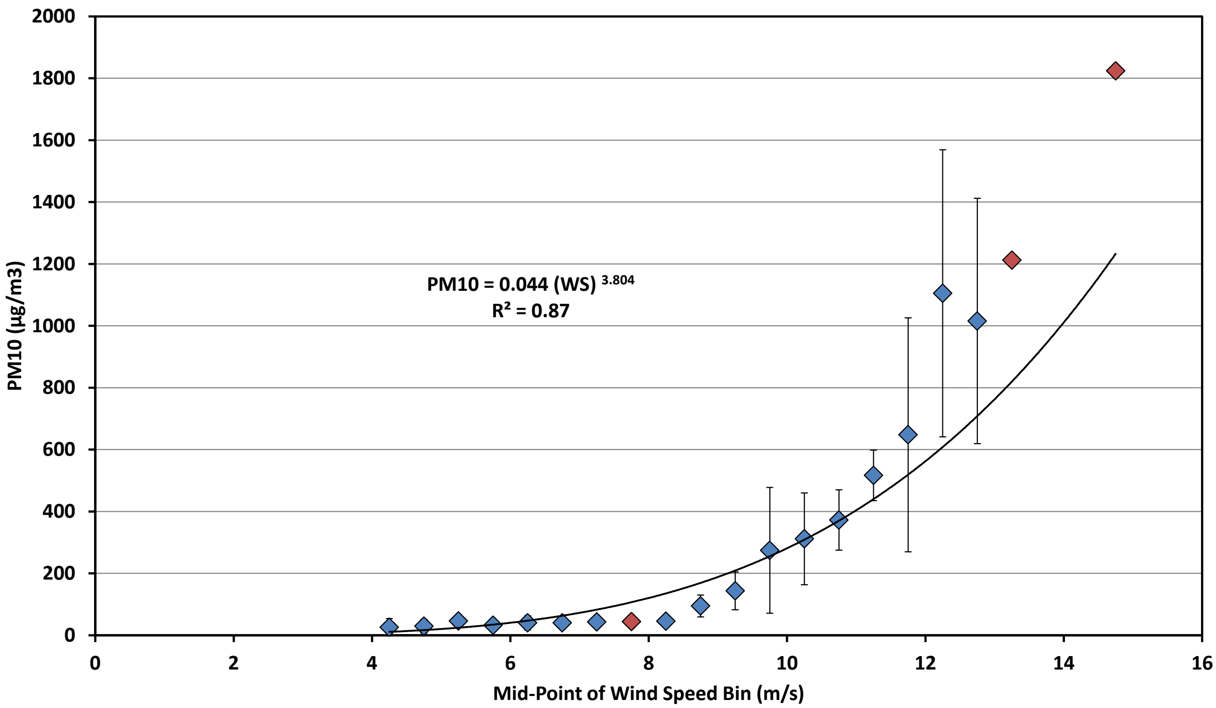


Figure 40. Relationship between mean 3 m hourly wind speed and PM_{10}, Transect 4, Position B, for the wind direction 315°. Data are truncated at 4 m/s. Red diamond symbol indicates only one data point for the wind speed bin.

position are shown in Figs. 41 and 42, respectively. As Fig. 41 shows, position T2C, produces the highest PM_{10} concentrations once 3 m mean wind speeds exceed 5.5 m/s. For equivalent wind speed, T3C produces between 7% and 12%, and T4B between 55% and 25% less PM_{10} than T2C. T4B has higher PM_{10} concentrations for equivalent wind speeds than monitors show for Transect positions 1C and 3B (Fig. 41) when wind speed at 3m exceeds 8 m/s. For 315° winds (Fig. 42), T3C shows much higher PM_{10} levels for equivalent wind speeds than all other positions where a valid relationship was obtained.

The relationship between concentration of PM_{10} and wind speed measured at 10 m a.g.l. can be examined for four of the measurement positions: T1C, T2C, T3C, and T4B (Figs. 43, 44, 45, 46). These figures also show a strong dependence on PM_{10} with 10 m a.g.l. wind speed. Using the 10 m a.g.l. wind speed data matched with the same PM_{10} data shifts the data set to the right resulting in a slight lowering of the exponent for the power relationship. The PM_{10} does not rise as quickly as a function of wind speed as the maximum values occur at the higher wind speeds experienced at 10 m versus 3 m. The best-fit relationships for wind speed and PM_{10} for T1C, T2C, T3C, and T4B are plotted together in Fig. 47. This figure shows that the order of PM_{10} production as a function of position is preserved for the 10 m wind speed and concentrations as that shown in Fig. 41.

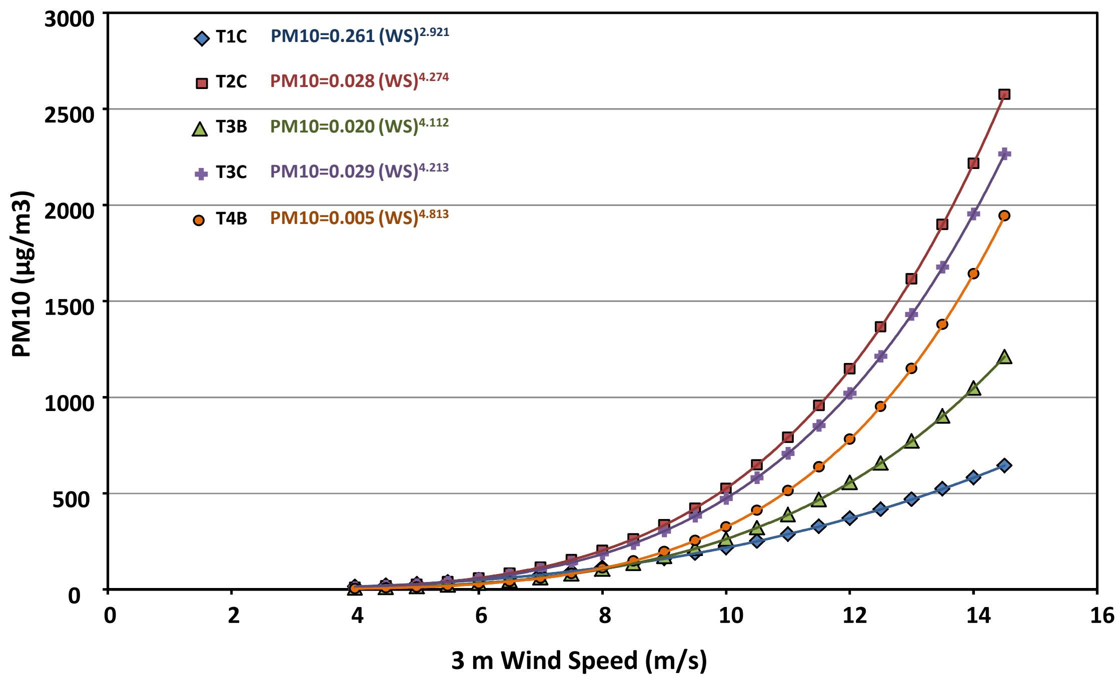


Figure 41. Relationships between mean 3 m hourly wind speed and PM_{10} for the five e-Bam measurement positions for the 292° winds.

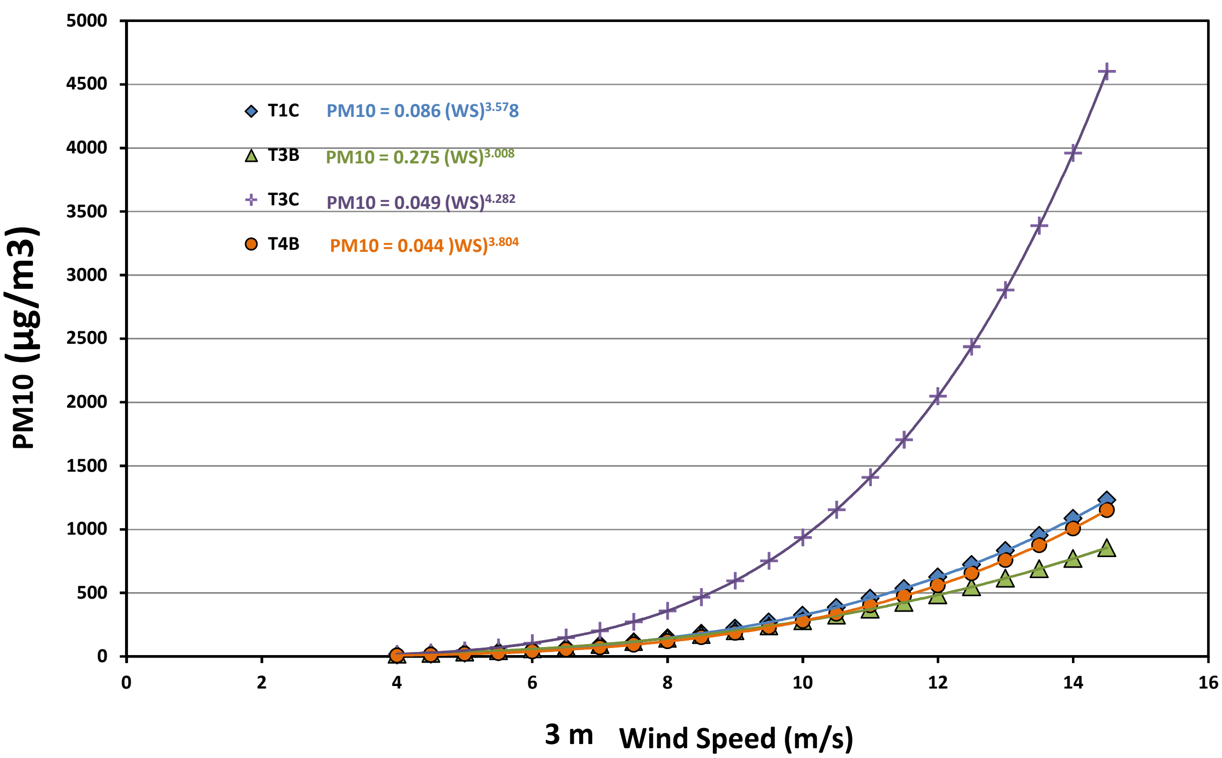
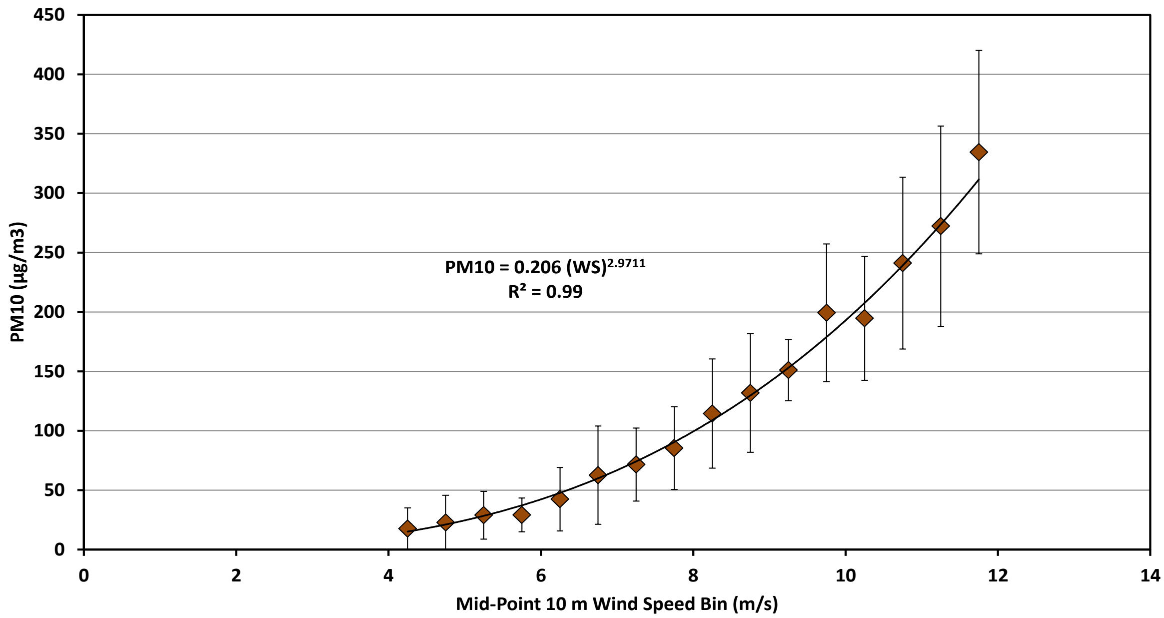


Figure 42. Relationships between mean 3 m hourly wind speed and PM_{10} for the five e-Bam measurement positions for the 315° winds.



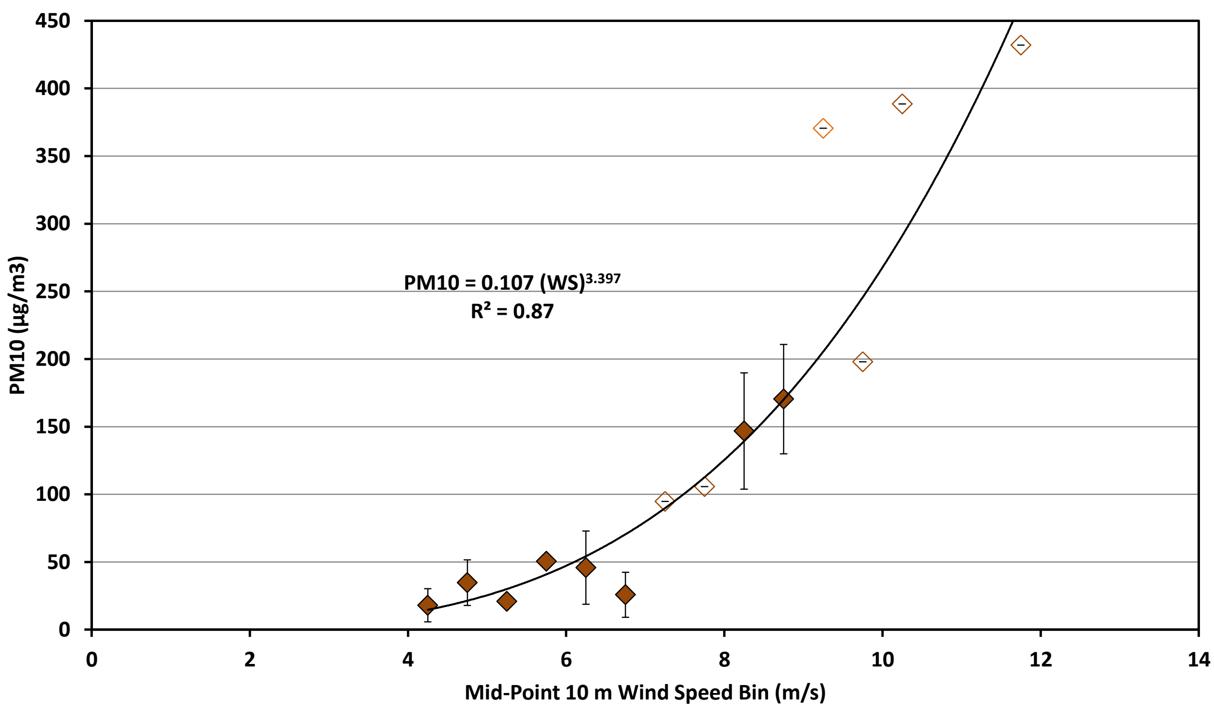
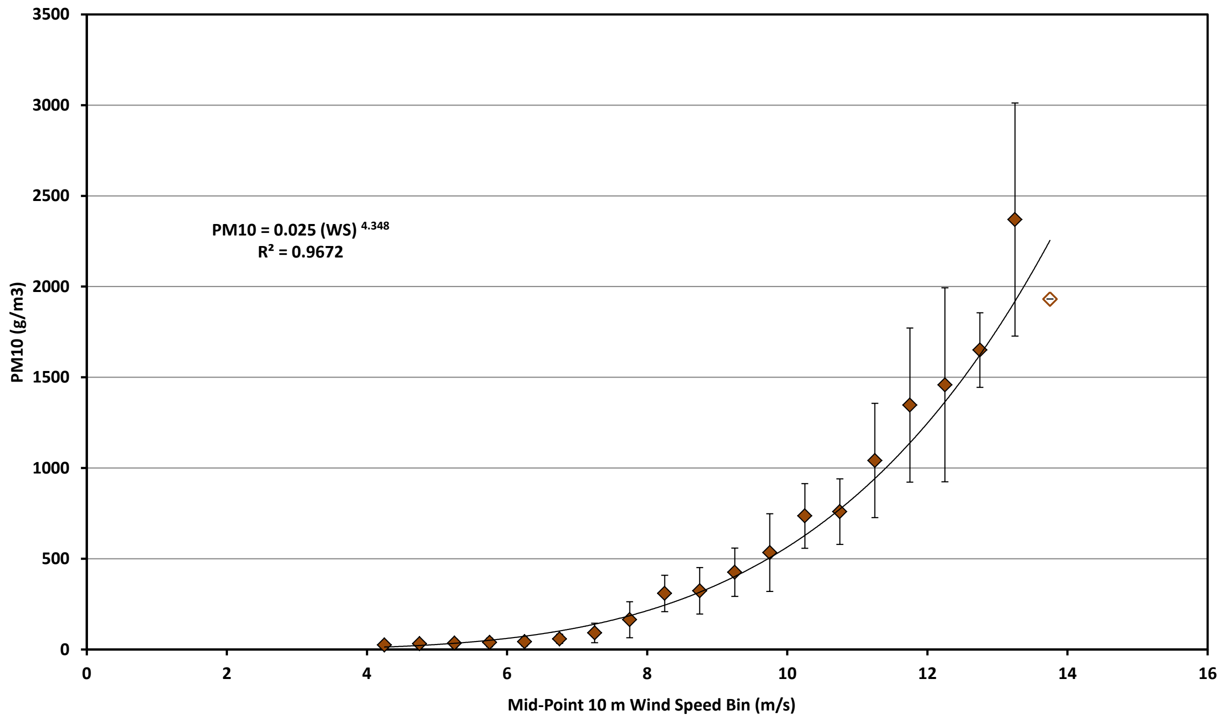


Figure 43. Relationships between mean 10 m hourly wind speed and PM_{10}, Transect 1, Position C, for the wind directions 292° (top) and 315° (bottom). Data are truncated at 4 m/s. Open symbol indicates only one data point for the wind speed bin.



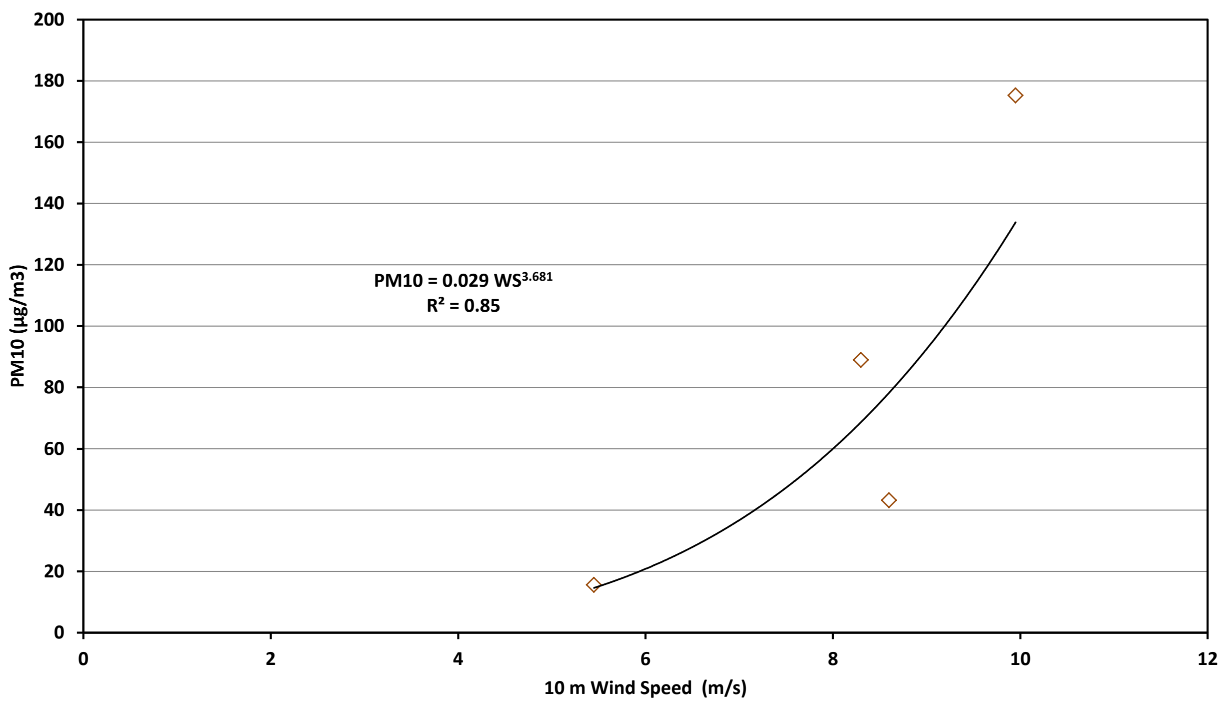
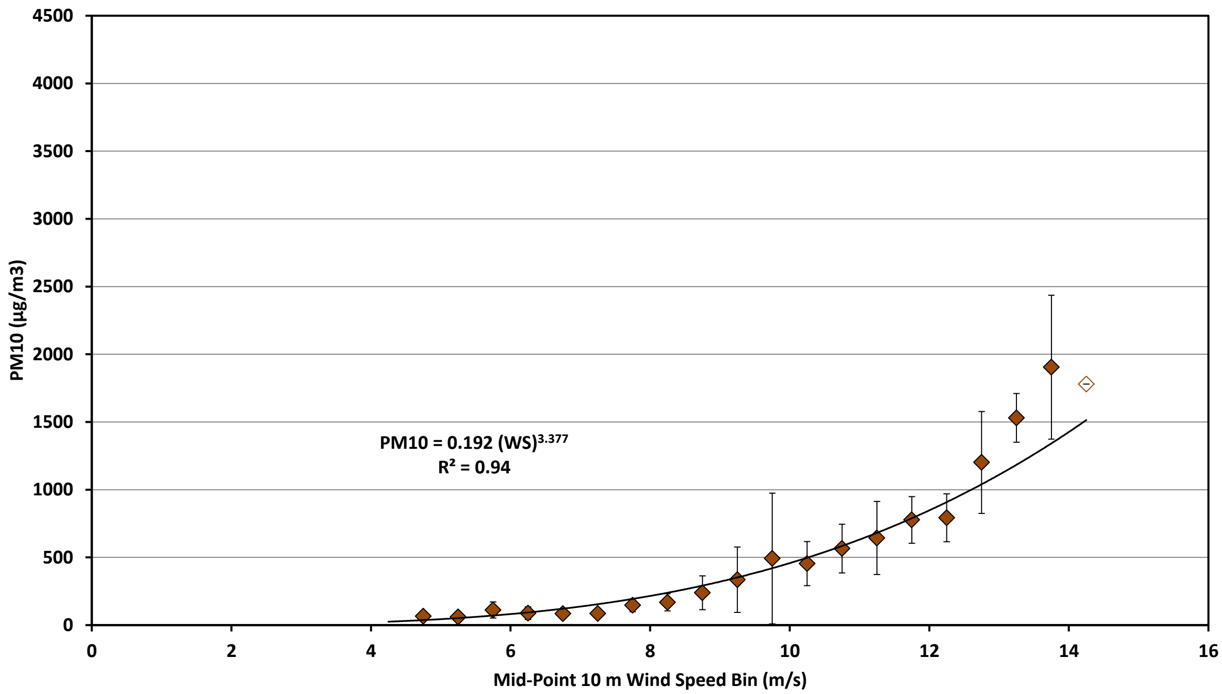


Figure 44. Relationships between mean 10 m hourly wind speed and PM_{10}, Transect 2, Position C, for the wind directions 292° (top) and 315° (bottom). Data are truncated at 4 m/s. Open symbol indicates only one data point for the wind speed bin.



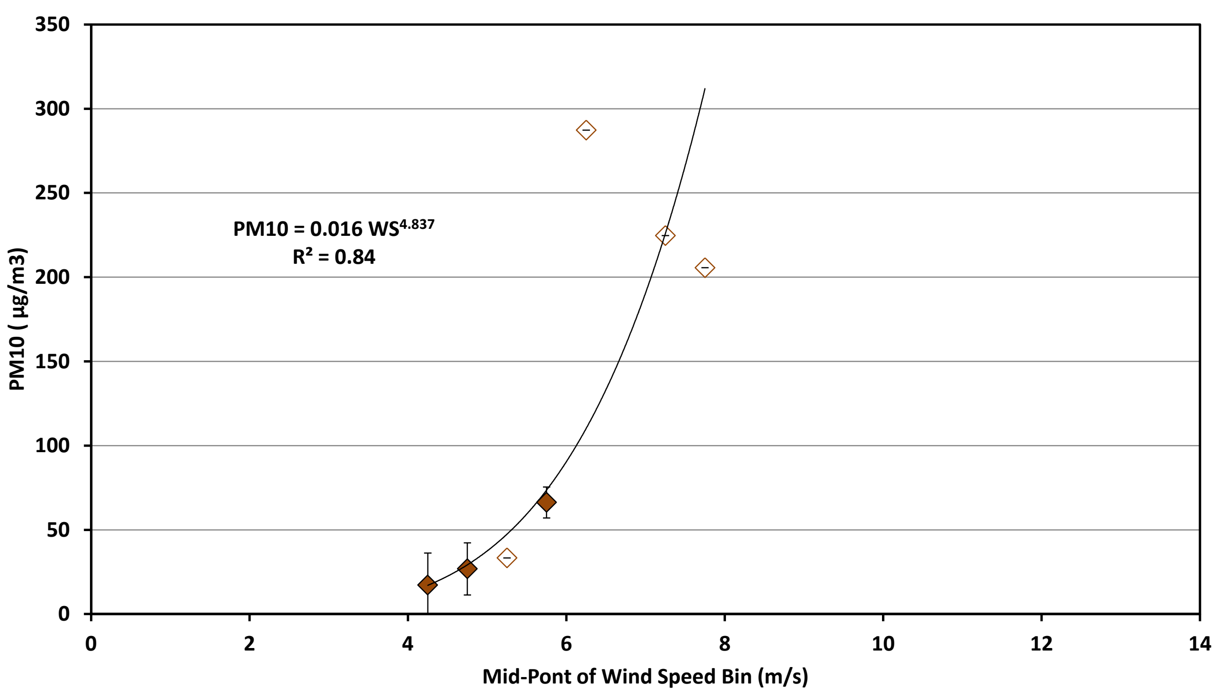
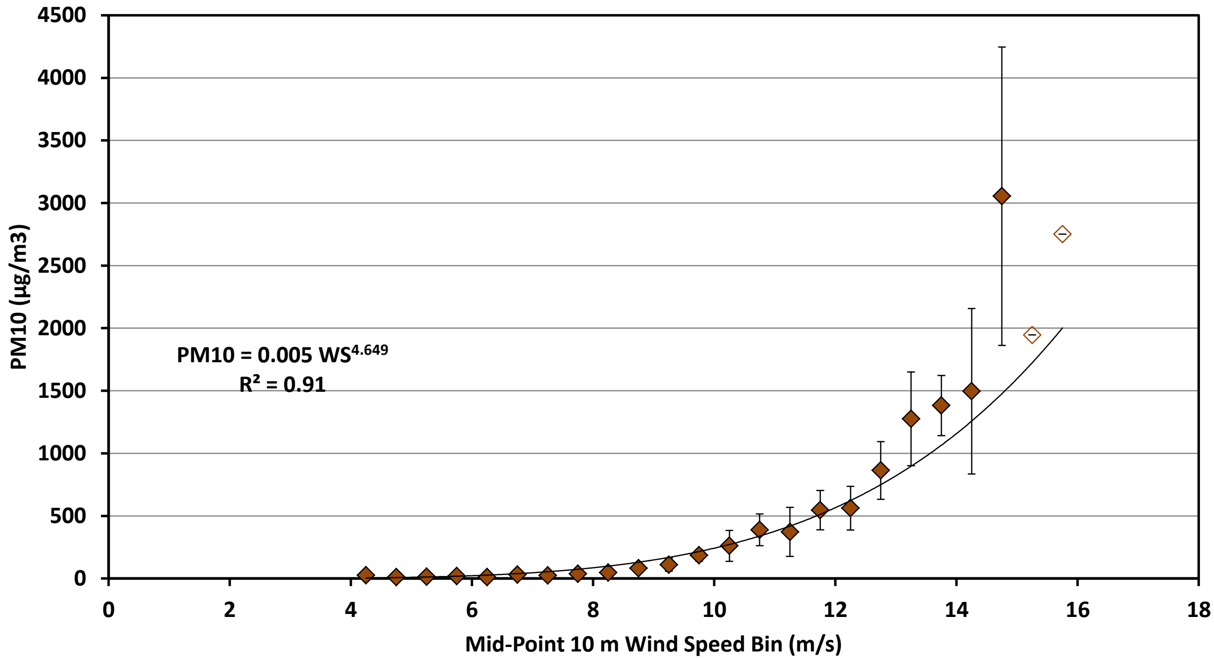


Figure 45. Relationships between mean 10 m hourly wind speed and PM_{10}, Transect 3, Position C, for the wind directions 292° (top) and 315° (bottom). Data are truncated at 4 m/s. Open symbol indicates only one data point for the wind speed bin.



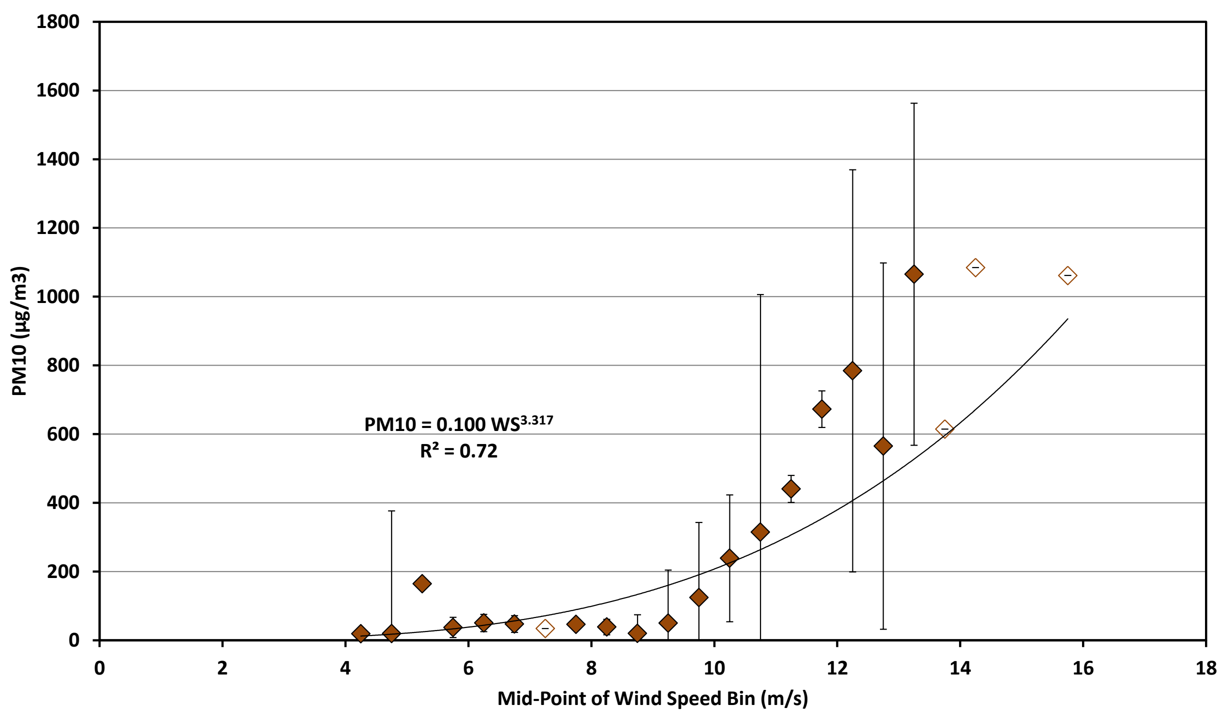


Figure 46. Relationships between mean 10 m hourly wind speed and PM_{10}, Transect 4, Position B, for the wind directions 292° (top) and 315° (bottom). Data are truncated at 4 m/s. Open symbol indicates only one data point for the wind speed bin.

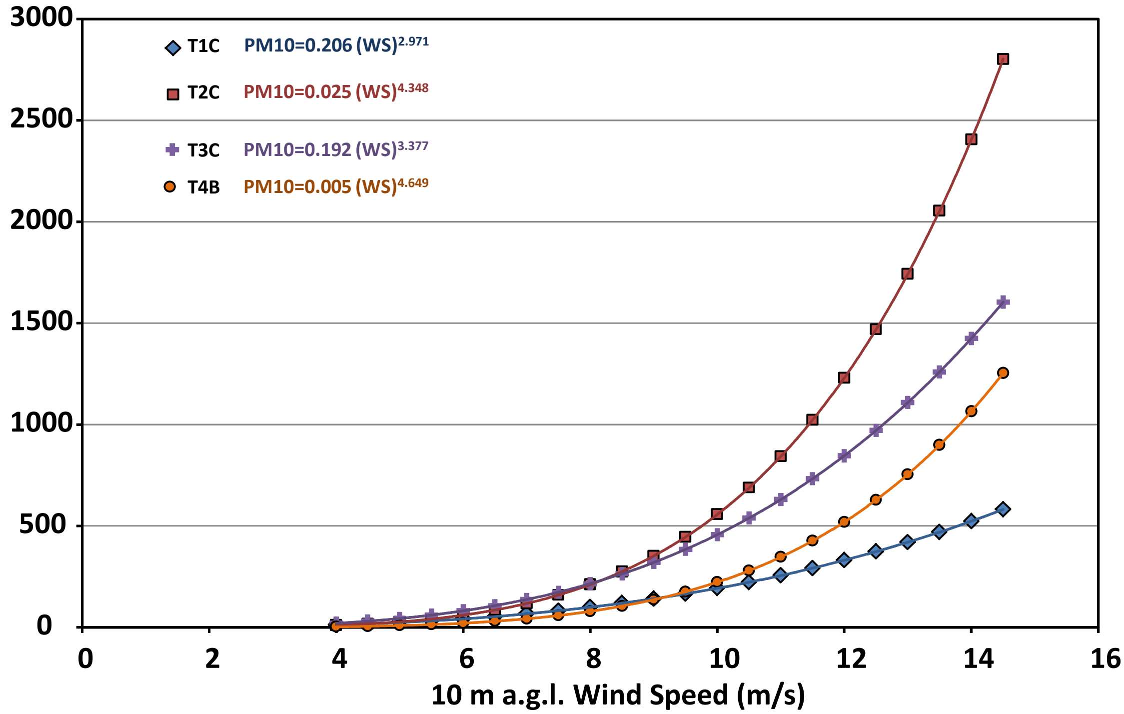


Figure 47. Relationships between mean 10 m hourly wind speed and PM_{10} for the four e-Bam measurement positions for the 292° winds (NB: no 10 m wind speed measured at position T3B).

5 Potential e-BAM Sampling Issues

A potential issue with flow rates affecting the e-BAM sampling efficiency was identified by the APCD for the period May 16 through June 6, 2013, which defines a period when the data were flagged to indicate that they may have been compromised to some degree. According to Sonoma Technologies the problem was that four of the e-BAMs were running in “Standard Mode”, while they should have been in “Actual Mode”. Because these e-BAMs were reporting in Standard Conditions, the *reported* flow rates were variable, and usually higher than 16.7 lpm. Note that the EBAM ***always samples in actual conditions***, regardless of the reporting mode. If set to Standard, the EBAM then changes the *reported* flow rate to standard conditions, dependent on temperature and pressure. This is what causes the observed variability in flow rates when reported in standard. It was not because the reference flow standard was used incorrectly. After corrections to the flows were applied, there were only two hourly periods when the flows were out of valid limits (i.e., they were between 2% and 4%). These were at T1C and T3C and the date/times are noted in the Metadata file.

To investigate if there was a difference in the PM_{10} versus wind speed measurements for the Flagged versus Non-flagged data, the data from the flagged periods were plotted with the data from the non-flagged periods (though July 15, 2013) for each e-BAM for winds from 292°, the most prevalent dust-bearing wind direction. These comparisons are shown in Figs. 48 through 52. For comparison at the same wind speed bin, data pairs had to have a non-zero standard deviation (i.e., more than one data point for the wind speed bin).

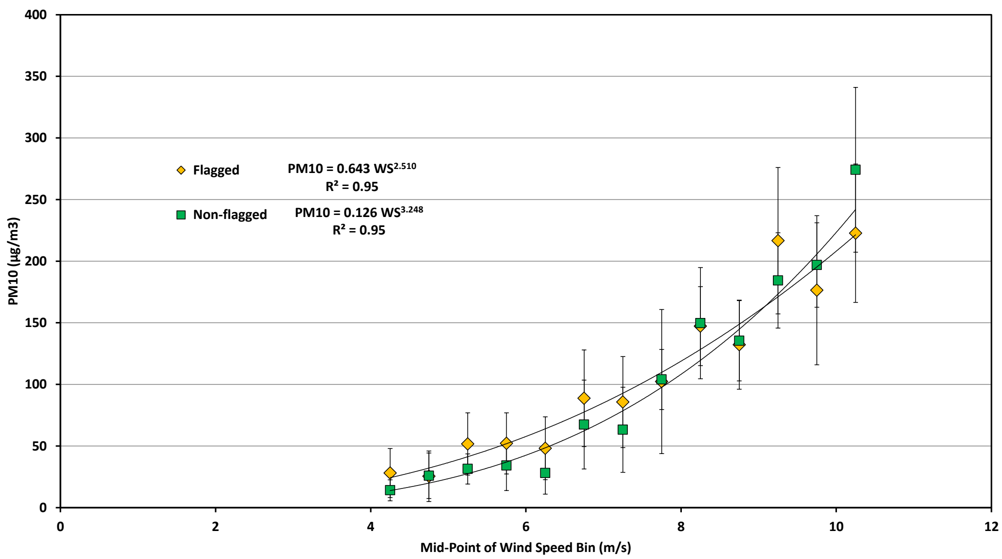


Figure 48. Comparison of the flagged and non-flagged PM_{10} data from e-BAM T1C.

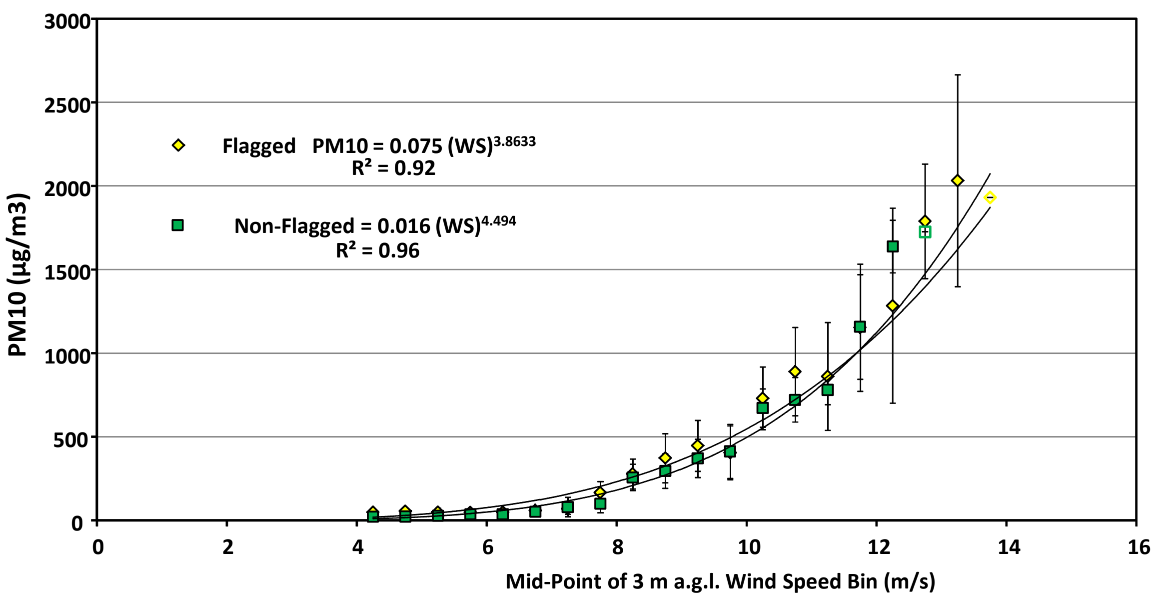


Figure 49. Comparison of the flagged and non-flagged PM_{10} data from e-BAM T2C.

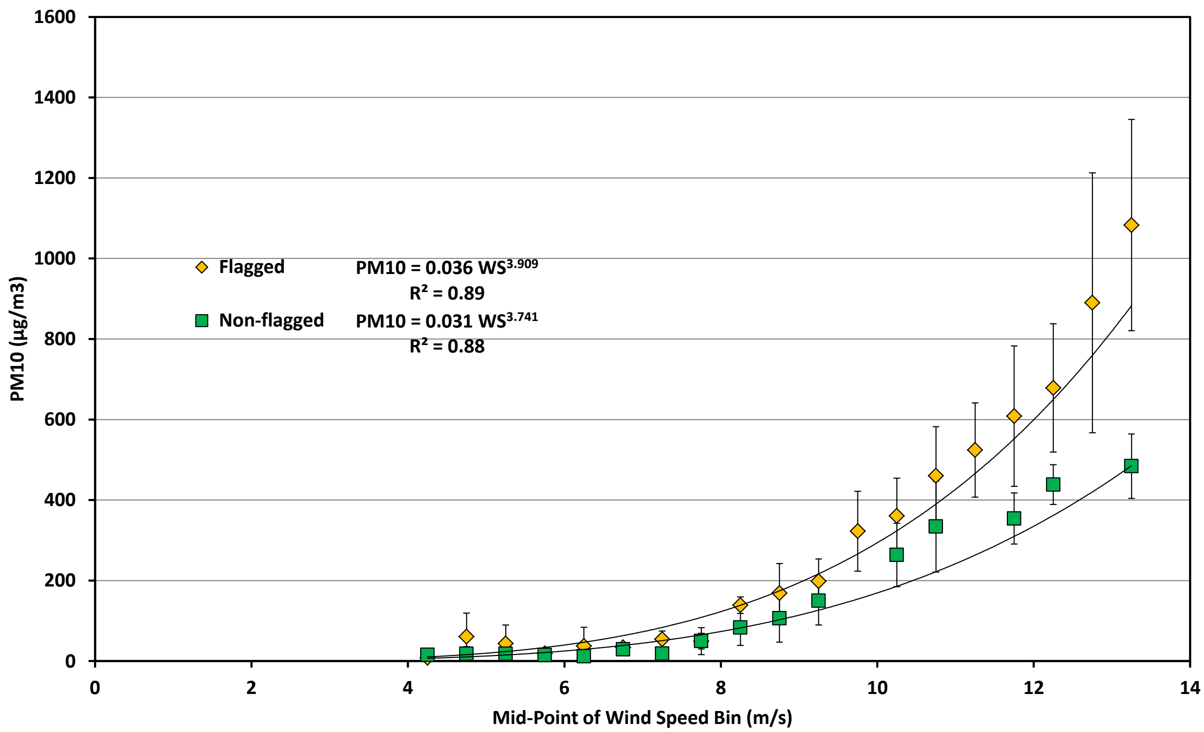


Figure 50. Comparison of the flagged and non-flagged PM_{10} data from e-BAM T3B.

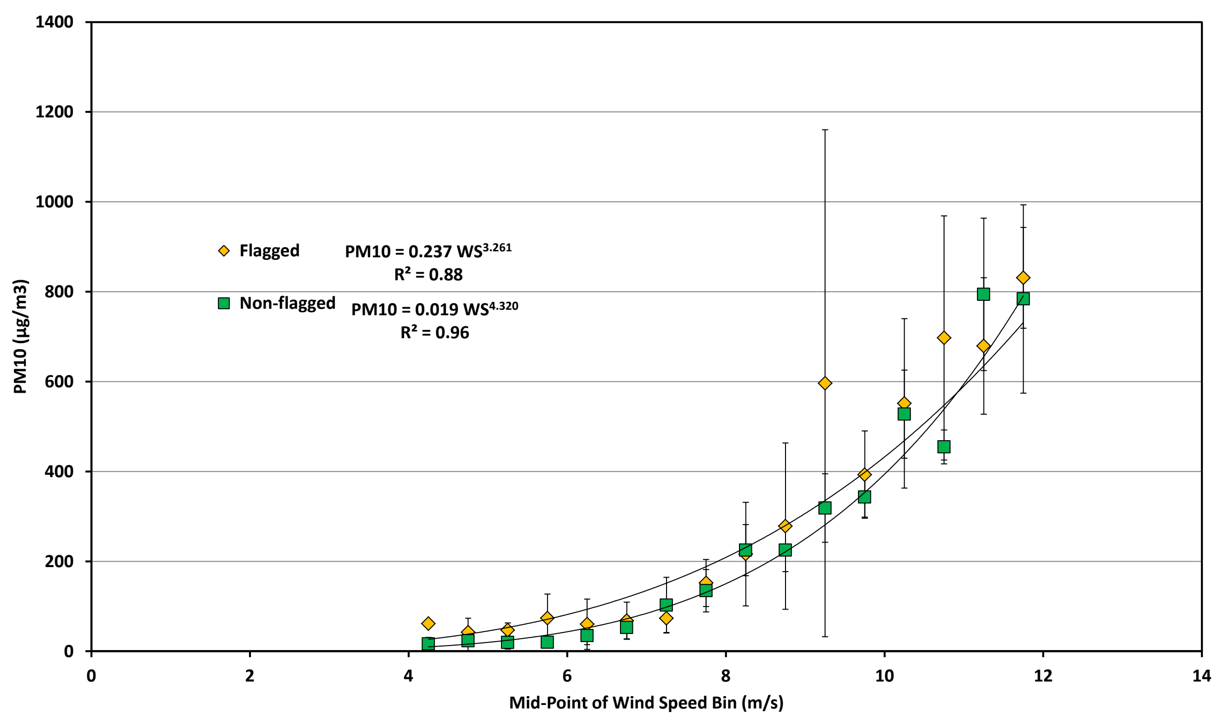


Figure 51. Comparison of the flagged and non-flagged PM_{10} data from e-BAM T3C.

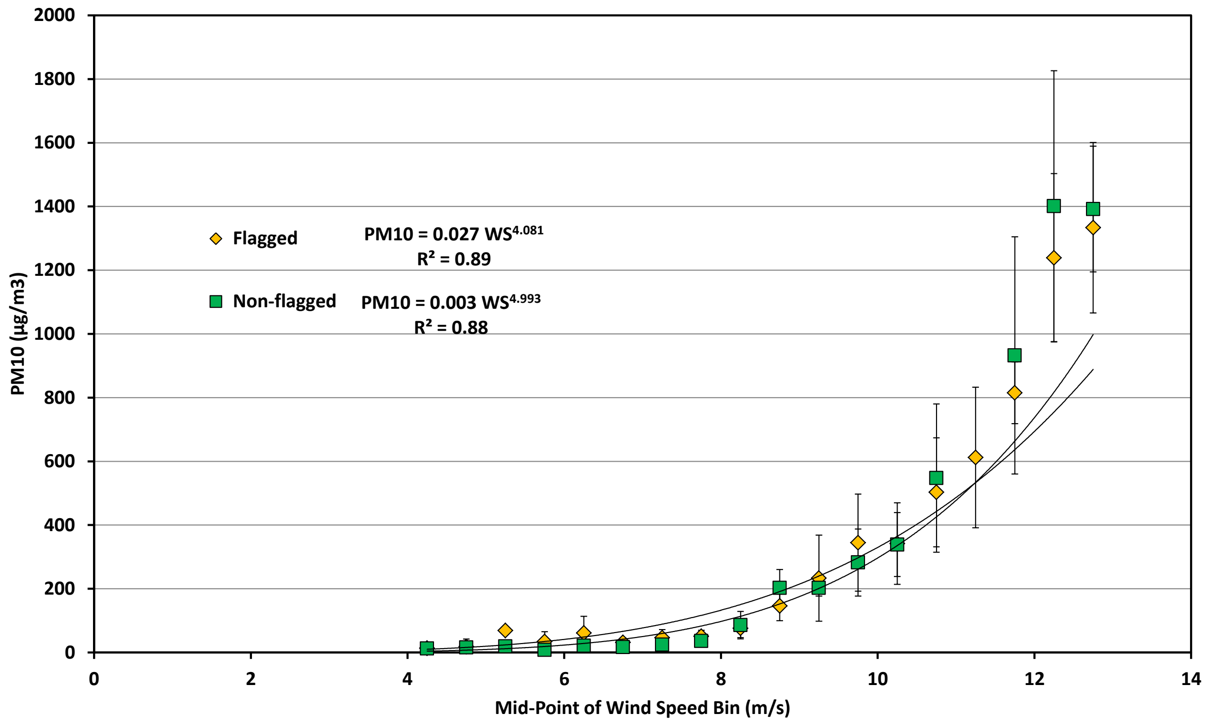


Figure 52. Comparison of the flagged and non-flagged PM_{10} data from e-BAM T4B.

As Figs. 48-52 show there appears to be no significant difference or bias in the difference in e-BAM measured PM_{10} for four of the five e-BAMs operated on the four transects. The exception is e-BAM T3B, which shows a systematic divergence of PM_{10} as wind speed increases. As the other four do not show this divergence there may have been a second operational parameter other than flow volume that can account for this discrepancy. In the four other cases, the overlap of the error bars, which represent the standard deviation of the measured PM_{10} in the wind speed class, suggests that within the uncertainty of the measurement, the flagged and non-flagged data are equivalent for the wind speed classes, and the relationships between PM_{10} and wind speed for each position on the transects well-represents the observed conditions. This supports the explanation provided by Sonoma Technologies that the data were not compromised by the flow mode setting of Standard versus Actual, once corrected. For this reason all data were used to define the relationships presented in Figs. 32-47.

6 24 Hour Mean PM_{10} vs. Wind Speed, and Frequency of Winds >6 m/s, Frequency of Saltation as Indicated by Sensits

The Dust Rule will be applied based on the measured difference between 24-hour mean PM_{10} concentrations at the Control Site Monitor (CSM) and the CDVAA monitor. To provide information on how the Dust Rule could be evaluated for different monitoring locations the 24-hour mean PM_{10} for available days (and partial days [i.e., ≥18 hours of data]) was calculated from the sites with e-BAMs (i.e., T1C, T2C, T3B, T3C, and T4B). For comparison purposes T1C and T4B are considered as CSMs as they are within the Dune Preserve areas. T2C, T3B, and T3C can be considered as CDVAA type monitors as they are located in areas that are used by park visitors for off-road vehicle driving.

To compare and contrast the environmental conditions among these locations time series plots of 24-hour mean PM_{10} and plots of the relationship between 24-hour mean PM_{10} and 24-hour mean wind speed were prepared (Figs. 53-62). In addition, an accounting of the percentage of data that are missing from each site is provided, the percentage of time that the mean hourly wind speed exceeded the threshold for transport of ≈5 m/s (measured at 10 m a.g.l., based on analysis of the Sensit data), and estimates of the percentage of hours for which Sensit data indicated saltation was active is provided.

The percentage of hours (for available data) for wind speed above threshold and for saltation activity for T1C (Figs. 53 and 54) are as follows:
% of missing WS hours for May-July: 0.14%
% of Hours for Hourly Mean 10 m WS ≥6 m/s (threshold): 14.2%
% of missing Sensit hours for May-July: 0.2%
% of Hours with Sensit counts >1: 6.11%
% of Hours with Sensit Counts >2: 5.05%

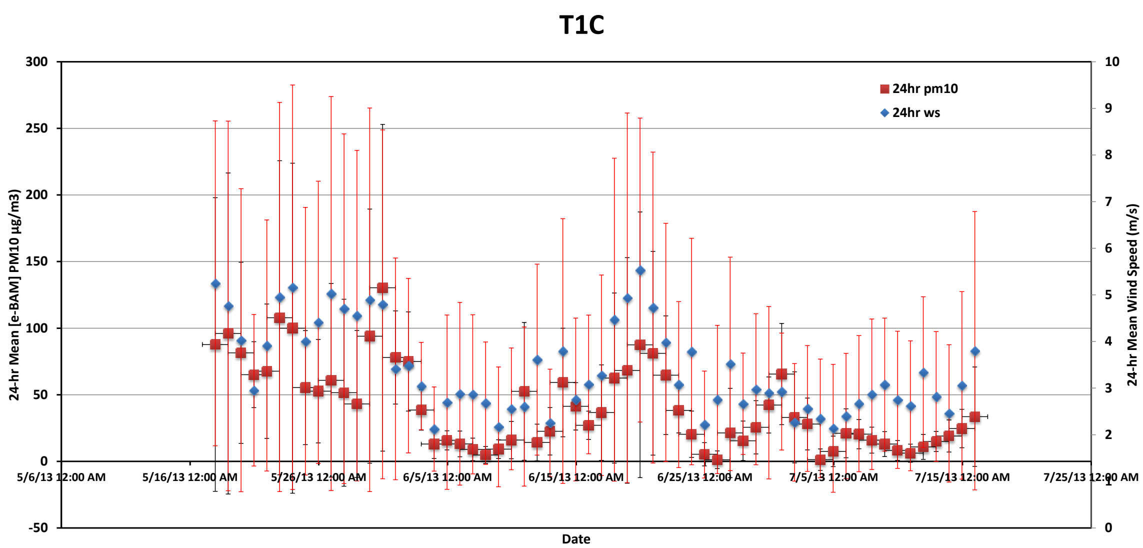


Figure 53. Time series of 24-hour mean PM_{10} concentration for the period May through July, T1C. The y-axis error bars represent the standard deviation of the 24 hour mean values (mean is calculated from 24, one hour measurements).

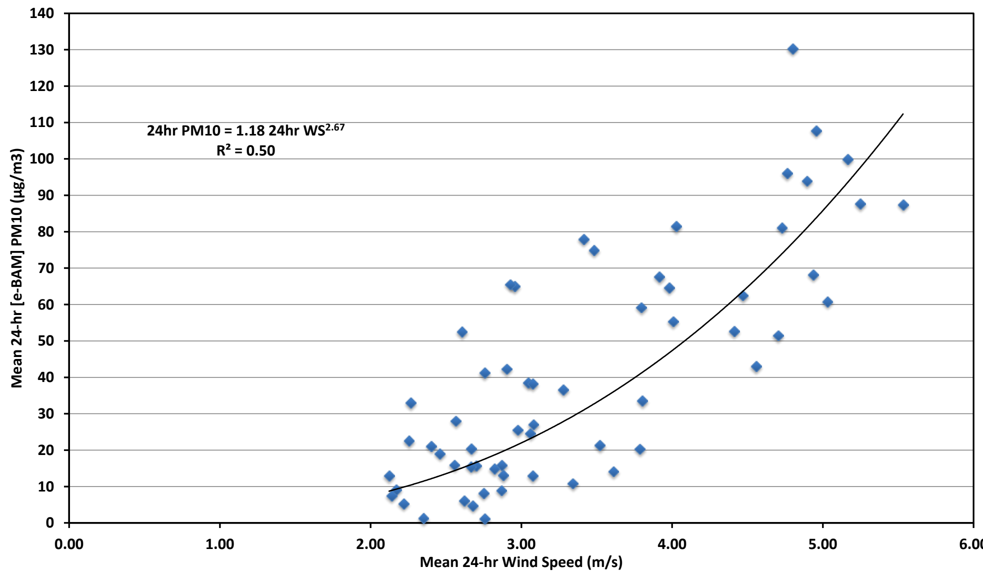


Figure 54. Relationship between 24-hour mean PM_{10} concentration and 24-hour mean wind speed (10 m a.g.l.) for the period May through July, T1C.

The percentage of hours (for available data) for wind speed above threshold and for saltation activity for T2C (Figs. 55 and 56) are as follows:

% of missing WS hours for May-July: 6.3%

% of Hours for Hourly Mean 10 m WS ≥6 m/s (threshold): 14.2%

% of missing Sensit hours for May-July: 6.3%

% of Hours with Sensit counts >1: 16.1%

% of Hours with Sensit Counts >2: 15.3%

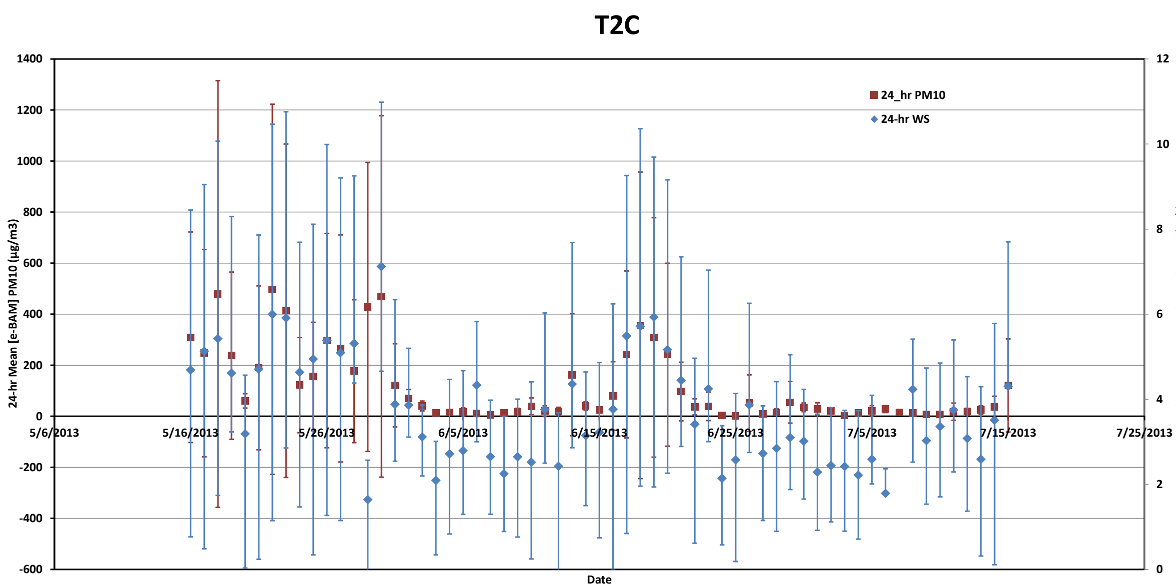


Figure 55. Time series of 24-hour mean PM_{10} concentration for the period May through July, T2C. The y-axis error bars represent the standard deviation of the 24 hour mean values (mean is calculated from 24, one hour measurements).

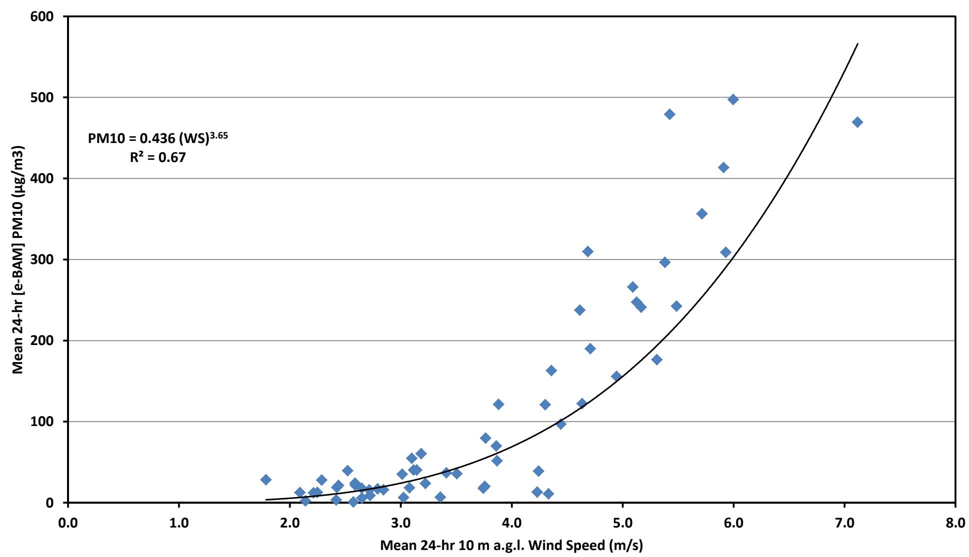


Figure 56. Relationship between 24-hour mean PM_{10} concentration and 24-hour mean wind speed (10 m a.g.l.) for the period May through July, T2C.

The percentage of hours (for available data) for wind speed above threshold and for saltation activity for T3B (Figs. 57 and 58) are as follows (Note that for T3B, Wind Speed is at 3 m a.gl):

% of missing WS hours for May-July: 18.8%

% of Hours for Hourly Mean 3 m WS ≥5 m/s (threshold): 27.4%

% of missing Sensit hours for May-July: 18.8%

% of Hours with Sensit counts >1: 10.7%

% of Hours with Sensit Counts >2: 10.2%

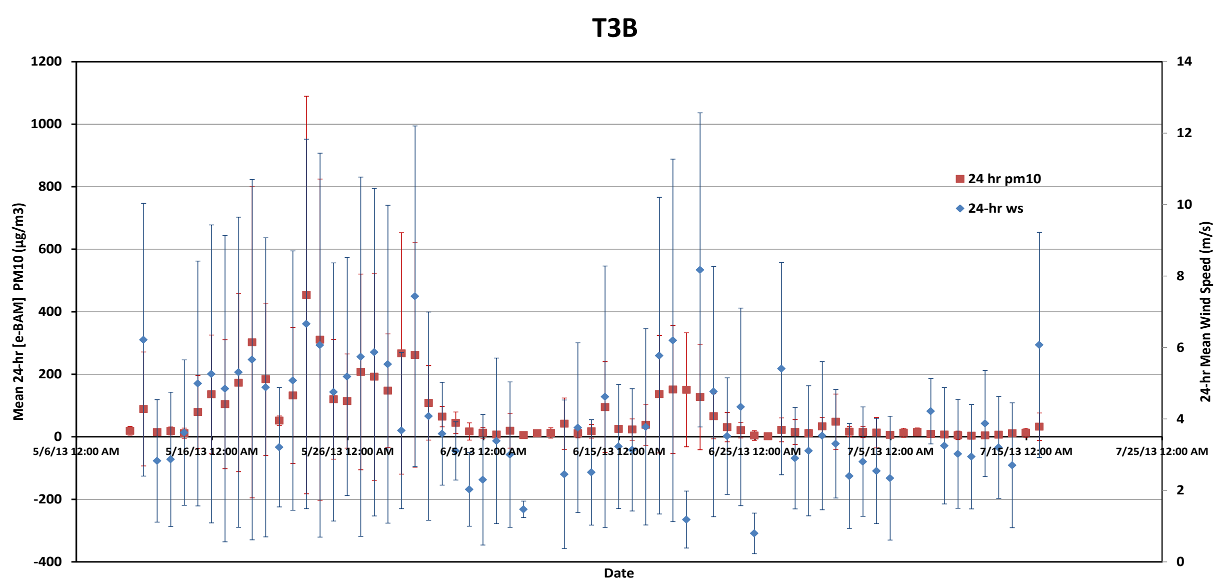


Figure 57. Time series of 24-hour mean PM_{10} concentration for the period May through July, T3B. The y-axis error bars represent the standard deviation of the 24 hour mean values (mean is calculated from 24, one hour measurements).

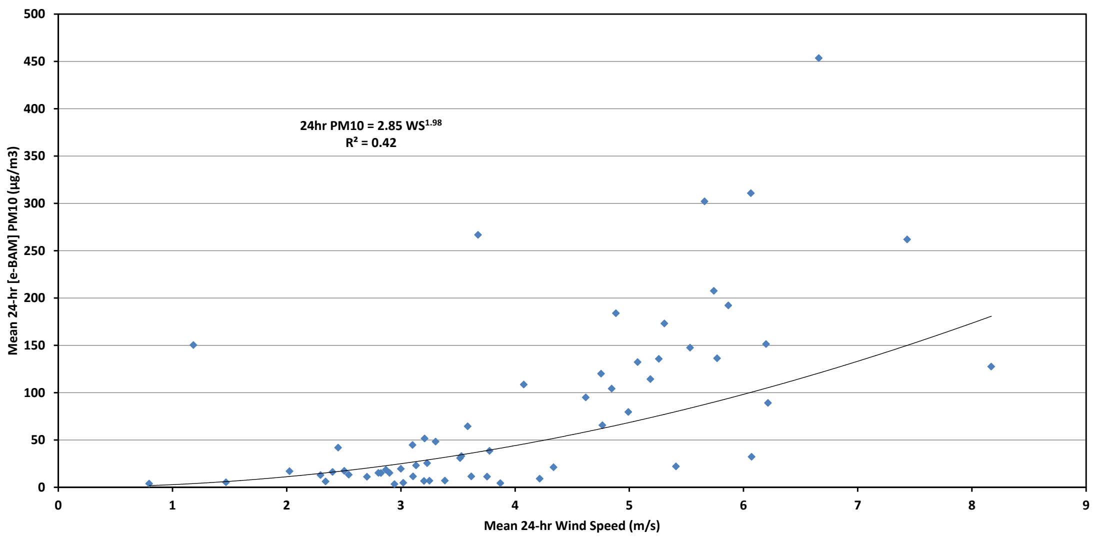


Figure 58. Relationship between 24-hour mean PM_{10} concentration and 24-hour mean wind speed (3 m a.g.l.) for the period May through July, T3B.

The percentage of hours (for available data) for wind speed above threshold and for saltation activity for T3C (Figs. 59 and 60) are as follows:

% of missing WS hours for May-July: 6.3%

% of Hours for Hourly Mean 10 m WS ≥6 m/s (threshold): 18.7%

% of missing Sensit hours for May-July: 6.3%

% of Hours with Sensit counts >1: 14.5%

% of Hours with Sensit Counts >2: 14.3%

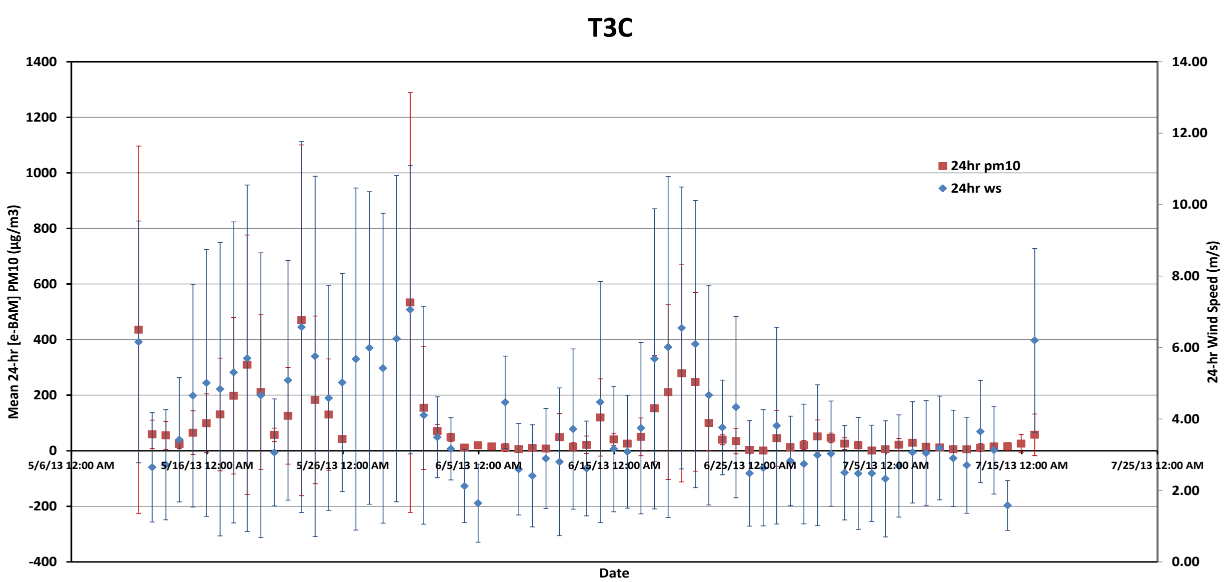


Figure 59. Time series of 24-hour mean PM_{10} concentration for the period May through July, T3C. The y-axis error bars represent the standard deviation of the 24 hour mean values (mean is calculated from 24, one hour measurements).

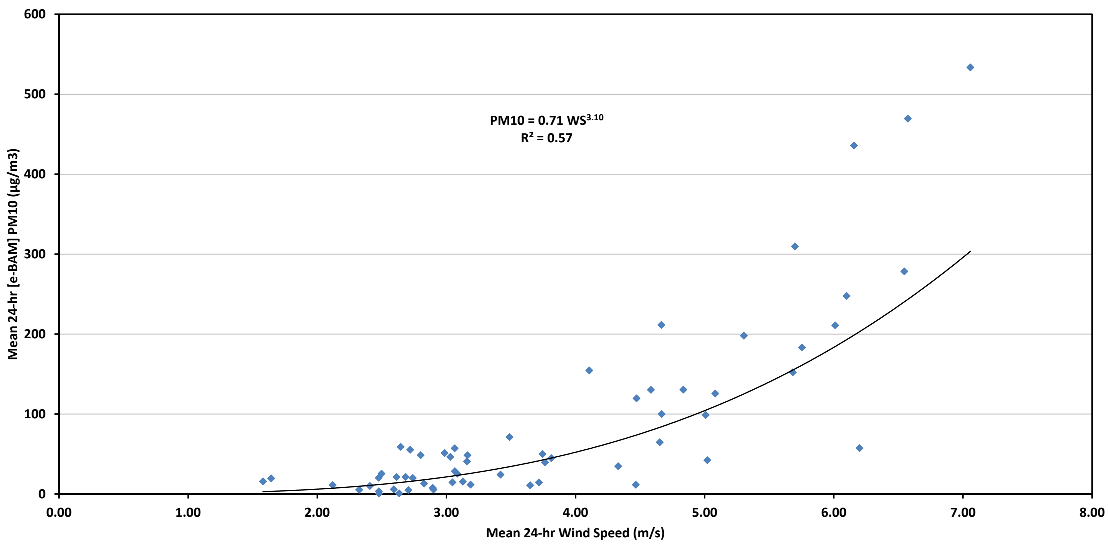


Figure 60. Relationship between 24-hour mean PM_{10} concentration and 24-hour mean wind speed (10 m a.g.l.) for the period May through July, T3C.

The percentage of hours (for available data) for wind speed above threshold and for saltation activity for T4B (Figs. 61 and 62) are as follows:

% of missing WS hours for May-July: 7.3%

% of Hours for Hourly Mean 10 m WS ≥6 m/s (threshold): 27%

% of missing Sensit hours for May-July: 7.3%

% of Hours with Sensit counts >1: 9.2%

% of Hours with Sensit Counts >2: 8.7%

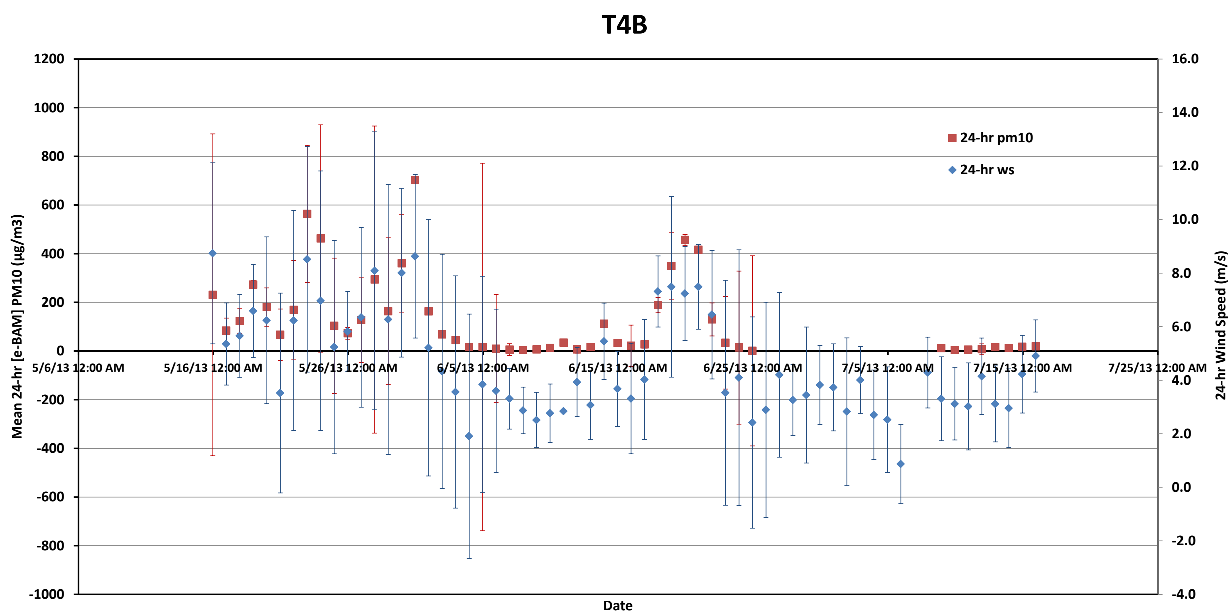


Figure 61. Time series of 24-hour mean PM_{10} concentration for the period May through July, T4B. The y-axis error bars represent the standard deviation of the 24 hour mean values (mean is calculated from 24, one hour measurements).

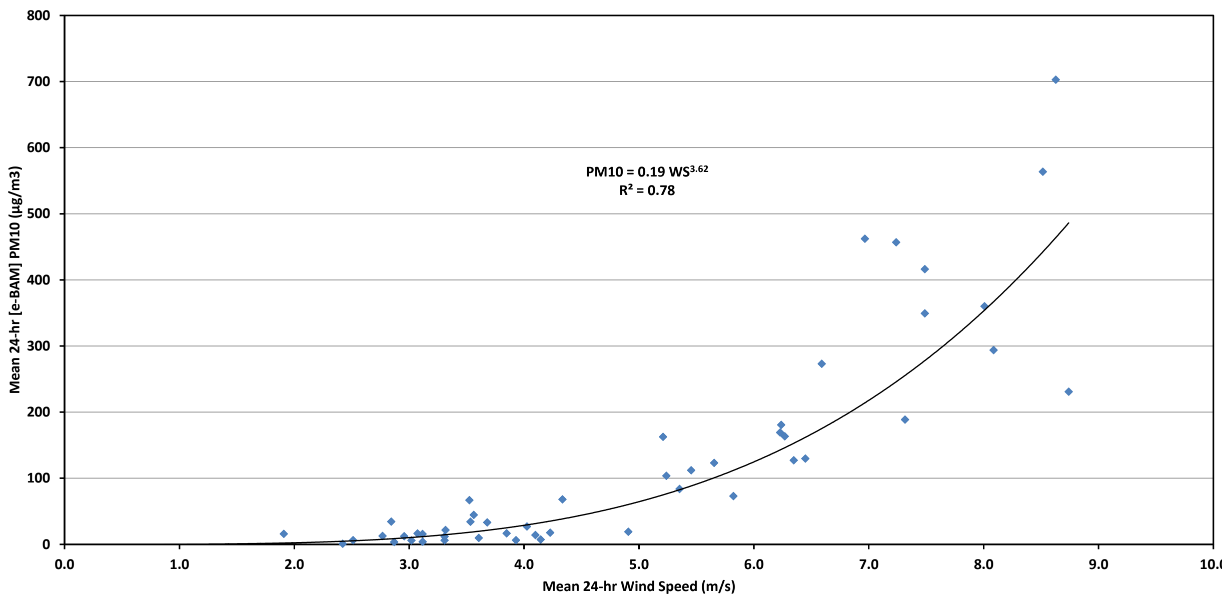


Figure 62. Relationship between 24-hour mean PM_{10} concentration and 24-hour mean wind speed (10 m a.g.l.) for the period May through July, T4B.

6.1 Application of the Dust Rule

Rule 1001 states "The CDVAA operator shall ensure that if the 24-hr average PM_{10} concentration at the CDVAA Monitor is more than 20% above the 24-hr average PM_{10} concentration at the Control Site Monitor, the 24-hr average PM_{10} concentration at the CDVAA Monitor shall not exceed 55 µg m^{-3}."

The basis of Rule 1001 expressed mathematically is:

[(24-hr Mean PM_{10} riding - 24-hr Mean PM_{10} non-riding) / 24-hr Mean PM_{10} non-riding]$\times$100,

to evaluate the percent difference between the two monitors. The second component of the rule is the CDVAA monitor shall not exceed the stated 24-hour mean limit value (55 µg m^{-3}). The rule as written does not clearly state how it is applied when the 24-hour mean PM_{10} as measured at the CSM exceeds 55 µg m^{-3} and the CDVAA 24-hour mean PM_{10} is also in excess of this amount. The current wording of the rule could be interpreted to mean that the CDVAA monitor must always be below 55 µg m^{-3}.

To evaluate how the rule would be applied for the available PM_{10} data, comparisons were made between T1C and T2C, T4B and T2C, T4B and T3B, and T4B and T3C (Tables 4 – 7), to evaluate how often the 20% difference was reached for all occurrences of the CSM exceeding 55 µg m^{-3}, and noting in the absence of CSM data when the CDVAA monitor exceeded 55 µg m^{-3}.

Table 4. Application of Rule 1001 between T1C and T2C May – July 2013.

Date_Time	T1C PM10	T2C PM10	DustRule%Di
5/16/13 11:00 PM			
5/17/13 11:00 PM			
5/18/13 11:00 PM	96	479	399
5/19/13 11:00 PM	82	237	191
5/20/13 11:00 PM	65	60	-7
5/21/13 11:00 PM	68	190	181
5/22/13 11:00 PM	108	497	361
5/23/13 11:00 PM	100	413	314
5/24/13 11:00 PM	55	122	121
5/25/13 11:00 PM	53	156	195
5/26/13 11:00 PM	61	296	387
5/27/13 11:00 PM	52	266	416
5/28/13 11:00 PM	43	176	309
5/29/13 11:00 PM	94	428	356
5/30/13 11:00 PM	130	469	260
5/31/13 11:00 PM	78	121	55
6/1/13 11:00 PM	75	70	-7
6/2/13 11:00 PM	39	40	5
6/3/13 11:00 PM	13	13	-4
6/4/13 11:00 PM	16	16	-1
6/5/13 11:00 PM	13	17	29
6/6/13 11:00 PM	9	11	22
6/7/13 11:00 PM	5	6	17
6/8/13 11:00 PM	9	13	36
6/9/13 11:00 PM	16	18	11
6/10/13 11:00 PM	53	39	-25
6/11/13 11:00 PM	14	20	41
6/12/13 11:00 PM	23	19	-17
6/13/13 11:00 PM	59	163	175
6/14/13 11:00 PM	41	40	-3
6/15/13 11:00 PM	27	24	-13
6/16/13 11:00 PM	37	80	117
6/17/13 11:00 PM	63	242	288
6/18/13 11:00 PM	68	356	422
6/19/13 11:00 PM	88	309	253
6/20/13 11:00 PM	81	241	197
6/21/13 11:00 PM	65	97	50
6/22/13 11:00 PM	38	37	-4
6/23/13 11:00 PM	20	39	92
6/24/13 11:00 PM	5	2	-59
6/25/13 11:00 PM	1	1	-29
6/26/13 11:00 PM	21	52	141
6/28/13 12:00 AM	15	9	-39
6/28/13 11:00 PM	26	16	-38
6/29/13 11:00 PM	42	55	29
6/30/13 11:00 PM	66	35	-47
7/1/13 11:00 PM	33	28	-16
7/2/13 11:00 PM	28	21	-25
7/3/13 11:00 PM	1	3	166
7/4/13 11:00 PM	8	12	61
7/5/13 11:00 PM	21	22	2
7/6/13 11:00 PM	20	28	38
7/7/13 11:00 PM	16	16	0
7/8/13 11:00 PM	13	13	0
7/9/13 11:00 PM	8	6	-22
7/10/13 11:00 PM	6	7	11
7/11/13 11:00 PM	11	18	63
7/12/13 11:00 PM	15	18	23
7/13/13 11:00 PM	19	24	26
7/14/13 11:00 PM	25	36	45
7/15/13 11:00 PM	34	121	260

Yellow: 24 hour standard exceeded at CSM

Pink: Difference between CDVAA and CSM is >20%

Green: Difference between CDVAA and CSM is <20%

Orange: 24 hour standard exceeded at CDVAA but not CSM

Days with data= 59

Exceedences= 22

Rule Breaks= 18

Rule Breaks including Orange (non-riding<50 µg/m^3 or missing)= 22

Table 5. Application of Rule 1001 between T4B and T2C May – July 2013.

Date_Time	T4B PM10	T2C PM10	Dust Rule %Diff
5/16/13 11:00 PM	84	310	270
5/17/13 11:00 PM	123	247	101
5/18/13 11:00 PM	273	479	75
5/19/13 11:00 PM	181	237	31
5/20/13 11:00 PM	67	60	-10
5/21/13 11:00 PM	169	190	12
5/22/13 11:00 PM	563	497	-12
5/23/13 11:00 PM	462	413	-11
5/24/13 11:00 PM	103	122	18
5/25/13 11:00 PM	73	156	114
5/26/13 11:00 PM	127	296	133
5/27/13 11:00 PM	294	266	-9
5/28/13 11:00 PM	163	176	8
5/29/13 11:00 PM	360	428	19
5/30/13 11:00 PM	703	469	-33
5/31/13 11:00 PM	163	121	-25
6/1/13 11:00 PM	68	70	3
6/2/13 11:00 PM	44	40	-9
6/3/13 11:00 PM	16	13	-20
6/4/13 11:00 PM	17	16	-5
6/5/13 11:00 PM	10	17	75
6/6/13 11:00 PM	6	11	83
6/7/13 11:00 PM	3	6	61
6/8/13 11:00 PM	6	13	100
6/9/13 11:00 PM	13	18	41
6/10/13 11:00 PM	34	39	15
6/11/13 11:00 PM	6	20	220
6/12/13 11:00 PM	16	19	14
6/13/13 11:00 PM	112	163	45
6/14/13 11:00 PM	33	40	21
6/15/13 11:00 PM	22	24	10
6/16/13 11:00 PM	27	80	195
6/17/13 11:00 PM	189	242	28
6/18/13 11:00 PM	349	356	2
6/19/13 11:00 PM	457	309	-32
6/20/13 11:00 PM	416	241	-42
6/21/13 11:00 PM	130	97	-25
6/22/13 11:00 PM	34	37	8
6/23/13 11:00 PM	14	39	178
6/24/13 11:00 PM	1	2	181
6/25/13 11:00 PM		1	
6/26/13 11:00 PM		52	
6/27/13 11:00 PM		9	
6/28/13 11:00 PM		16	
6/29/13 11:00 PM		55	
6/30/13 11:00 PM		35	
7/1/13 11:00 PM		28	
7/2/13 11:00 PM		21	
7/3/13 11:00 PM		3	
7/4/13 11:00 PM		12	
7/5/13 11:00 PM		22	
7/6/13 11:00 PM		28	
7/7/13 11:00 PM		16	
7/8/13 11:00 PM	12	13	10
7/9/13 11:00 PM	4	6	67
7/10/13 11:00 PM	6	7	16
7/11/13 11:00 PM	7	18	144
7/12/13 11:00 PM	16	18	17
7/13/13 11:00 PM	12	24	98
7/14/13 11:00 PM	18	36	103
7/15/13 11:00 PM	19	121	534

Yellow: 24 hour standard exceeded at CSM

Pink: Difference between CDVAA and CSM is >20%

Green: Difference between CDVAA and CSM is <20%

Orange: 24 hour standard exceeded at CDVAA but not CSM

Days with data= 48

Exceedences= 23

Rule Breaks= 8

Rule Breaks including Orange (non-riding<50 μg/m^3 or missing)= 12

Table 6. Application of Rule 1001 between T4B and T3B May – July 2013.

Date_Time	T4B PM10	T3B PM10	Dust Rule %Diff
5/15/13 11:00 PM	231	136	-41
5/16/13 11:00 PM	84	104	25
5/17/13 11:00 PM	123	173	41
5/18/13 11:00 PM	273	302	11
5/19/13 11:00 PM	181	184	2
5/20/13 11:00 PM	67	52	-23
5/21/13 11:00 PM	169	132	-22
5/22/13 11:00 PM	563	454	-20
5/23/13 11:00 PM	462	311	-33
5/24/13 11:00 PM	103	120	16
5/25/13 11:00 PM	73	114	57
5/26/13 11:00 PM	127	208	63
5/27/13 11:00 PM	294	192	-35
5/28/13 11:00 PM	163	148	-10
5/29/13 11:00 PM	360	267	-26
5/30/13 11:00 PM	703	262	-63
5/31/13 11:00 PM	163	109	-33
6/1/13 11:00 PM	68	64	-5
6/2/13 11:00 PM	44	45	1
6/3/13 11:00 PM	16	17	8
6/4/13 11:00 PM	17	13	-22
6/5/13 11:00 PM	10	7	-27
6/6/13 11:00 PM	6	20	226
6/7/13 11:00 PM	3	5	54
6/8/13 11:00 PM	6	11	80
6/9/13 11:00 PM	13	12	-3
6/10/13 11:00 PM	34	42	22
6/11/13 11:00 PM	6	11	79
6/12/13 11:00 PM	16	17	6
6/13/13 11:00 PM	112	95	-15
6/14/13 11:00 PM	33	25	-23
6/15/13 11:00 PM	22	23	8
6/16/13 11:00 PM	27	39	43
6/17/13 11:00 PM	189	136	-28
6/18/13 11:00 PM	349	151	-57
6/19/13 11:00 PM	457	150	-67
6/20/13 11:00 PM	416	128	-69
6/21/13 11:00 PM	130	66	-49
6/22/13 11:00 PM	34	31	-10
6/23/13 11:00 PM	14	21	52
6/24/13 11:00 PM	1	4	398
6/25/13 11:00 PM		2	
6/26/13 11:00 PM		22	
6/27/13 11:00 PM		15	
6/28/13 11:00 PM		11	
6/29/13 11:00 PM		33	
6/30/13 11:00 PM		48	
7/1/13 11:00 PM		16	
7/2/13 11:00 PM		15	
7/3/13 11:00 PM		13	
7/4/13 11:00 PM		6	
7/5/13 11:00 PM		13	
7/6/13 11:00 PM		15	
7/7/13 11:00 PM		9	
7/8/13 11:00 PM	12	7	-41
7/9/13 11:00 PM	4	5	26
7/10/13 11:00 PM	6	3	-43
7/11/13 11:00 PM	7	4	-40
7/12/13 11:00 PM	16	7	-57
7/13/13 11:00 PM	12	11	-7
7/14/13 11:00 PM	18	13	-26
7/15/13 11:00 PM	19	32	69

Yellow: 24 hour standard exceeded at CSM

Pink: Difference between CDVAA and CSM is >20%

Green: Difference between CDVAA and CSM is <20%

Orange: 24 hour standard exceeded at CDVAA but not CSM

Days with data= 48

Exceedences= 24

Rule Breaks= 4

Rule Breaks including Orange (non-riding<50 μg/m^3 or missing)= 4

Table 7. Application of Rule 1001 between T4B and T3C May – July 2013.

Date_Time	T4B PM10	T3C PM10	Dust Rule %Diff
5/10/13 11:00 PM		436	
5/11/13 11:00 PM		59	
5/12/13 11:00 PM		55	
5/13/13 11:00 PM		24	
5/14/13 11:00 PM		65	
5/15/13 11:00 PM	231	99	-57
5/16/13 11:00 PM	84	131	56
5/17/13 11:00 PM	123	198	61
5/18/13 11:00 PM	273	310	13
5/19/13 11:00 PM	181	211	17
5/20/13 11:00 PM	67	57	-14
5/21/13 11:00 PM	169	126	-26
5/22/13 11:00 PM	563	469	-17
5/23/13 11:00 PM	462	183	-60
5/24/13 11:00 PM	103	130	26
5/25/13 11:00 PM	73	42	-42
5/26/13 11:00 PM	127		
5/27/13 11:00 PM	294		
5/28/13 11:00 PM	163		
5/29/13 11:00 PM	360		
5/30/13 11:00 PM	703	533	-24
5/31/13 11:00 PM	163	154	-5
6/1/13 11:00 PM	68	71	5
6/2/13 11:00 PM	44	48	9
6/3/13 11:00 PM	16	11	-29
6/4/13 11:00 PM	17	19	18
6/5/13 11:00 PM	10	15	55
6/6/13 11:00 PM	6	12	94
6/7/13 11:00 PM	3	6	64
6/8/13 11:00 PM	6	10	60
6/9/13 11:00 PM	13	8	-40
6/10/13 11:00 PM	34	48	41
6/11/13 11:00 PM	6	15	131
6/12/13 11:00 PM	16	21	29
6/13/13 11:00 PM	112	120	7
6/14/13 11:00 PM	33	41	23
6/15/13 11:00 PM	22	25	17
6/16/13 11:00 PM	27	50	85
6/17/13 11:00 PM	189	152	-19
6/18/13 11:00 PM	349	211	-40
6/19/13 11:00 PM	457	278	-39
6/20/13 11:00 PM	416	248	-40
6/21/13 11:00 PM	130	100	-23
6/22/13 11:00 PM	34	40	16
6/23/13 11:00 PM	14	35	148
6/24/13 11:00 PM	1	3	314
6/25/13 11:00 PM		1	
6/26/13 11:00 PM		45	
6/27/13 11:00 PM		13	
6/28/13 11:00 PM		20	
6/29/13 11:00 PM		51	
6/30/13 11:00 PM		46	
7/1/13 11:00 PM		25	
7/2/13 11:00 PM		20	
7/3/13 11:00 PM		1	
7/4/13 11:00 PM		5	
7/5/13 11:00 PM		21	
7/6/13 11:00 PM		28	
7/7/13 11:00 PM		15	
7/8/13 11:00 PM	12	12	-1
7/9/13 11:00 PM	4	6	44
7/10/13 11:00 PM	6	5	-17
7/11/13 11:00 PM	7	11	50
7/12/13 11:00 PM	16	15	-2
7/13/13 11:00 PM	12	16	30
7/14/13 11:00 PM	18	26	45
7/15/13 11:00 PM	19	57	201

Yellow: 24 hour standard exceeded at CSM

Pink: Difference between CDVAA and CSM is >20%

Green: Difference between CDVAA and CSM is <20%

Orange: 24 hour standard exceeded at CDVAA but not CSM

Days with data= 49

Exceedences= 24

Rule Breaks= 3

Rule Breaks including Orange (non-riding<50 µg/m^3 or missing)= 8

7 Summary

Based on the analysis provided in this document there are several important characteristics of the wind field pattern over the ODSVRA that can be described. In all positions the strongest most frequent winds are associated with winds from the west through west-north-west. The winds show a tendency to speed up as they move from west to east, most likely due to compression of the streamlines over the dunes that force the wind to accelerate. In addition to this acceleration there appears to be an increase in gust strength along the west to east direction, indicating an increase in turbulence intensity. Both of these will contribute to potentially greater magnitude sand and dust emission fluxes along this gradient. There is also a wind speed gradient from north to south. The data presented here indicate that mean wind speeds increase from north to south and hourly maximum wind speeds as well. This also increases the potential for sand transport and dust emissions along the north to south gradient. Because of the presence of these gradients it will be challenging to locate PM_{10} sampling monitors that experience the same wind conditions during a 24 hour period. As saltation of sand and the associated dust emissions scale as a power function of wind speed, small changes in wind speed produce significant changes in dust emission. These data also suggest that the threshold for saltation increases from north to south, which likely reflects an increase in grain size of the sand. This will be evaluated from the on-going particle size distribution analysis. Although threshold wind speed increases slightly toward the south, this is countered by the increasing wind speed gradient.

The saltation system at the ODSVRA measurement locations was, on average, active 11% of the time over the monitoring period from May 15 through July 15, 2013. The saltation count data does suggest that saltation is more frequent with increasing distance from the shoreline, which is likely due to the increase in wind speed in the same direction. The exception is Transect 1, which shows a decrease in saltation activity in the east.

The wind rose data for conditions of elevated PM_{10} and wind speed >4 m/s (Figs. 20-24), clearly demonstrate that wind generated dust at the ODSVRA is confined to a narrow range of wind directions. This is dominated at the measurement locations by winds from 292° and to a lesser extent by winds from 315°. Of note is that the inland District monitoring locations both show an increased frequency of higher PM_{10} concentrations for 315° (Figs. 25-30) than the in-park measurement positions. For CDF it is the dominant wind direction for the frequency of occurrence of elevated PM_{10}. It is not definite that the dust bearing winds passing by the measurement positions furthest east along the four transect are being turned to the south by landscape features, as the relationships between simultaneous measurements of PM_{10} at CDF and each of the transect positions T1C, T2C, T3C, and T4B show correlation (Fig. 63). That even the furthest measurement position south in the monitoring network shows correlation with CDF, suggests that the entire dust plume from north to south is responding to the wind field that is increasing and decreasing in strength in synchrony across the domain of the ODSVRA and points eastward. This feature of the dust emission system makes it very difficult to definitively ascribe a relationship between a source region (i.e., a sub-region of the whole ODSVRA) and a receptor site such as CDF.

The PM_{10} concentration as a function of wind speed relationships (Figs. 32-47) all show strong relationships as defined by their high R^2 values, for the wind direction 292° (which encompasses the

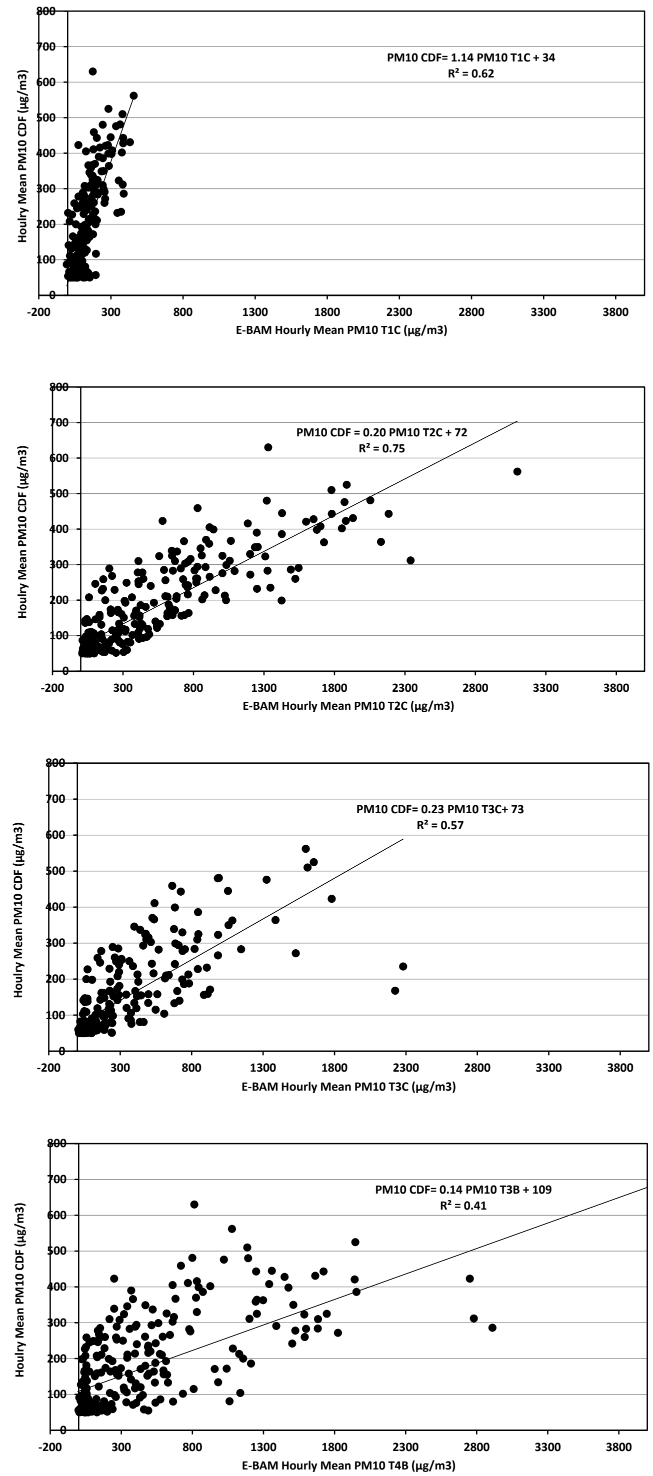


Figure 63. Relationship between PM_{10} at CDF and the four transect positions: T1C, T2C, T3C, and T4B (time is synchronized for all locations).

range of wind directions: 281° - 303°), which correlates with the wind rose data. The only other direction that shows a correlation between wind speed and PM_{10} is 315° (which encompasses the range of wind directions: 304° - 326°).

Particle size analysis of the sand samples collected as part of the PI-SWERL measurements, and analysis of the MetOne Particle Profiler data, located in the ODSVRA and Dune Preserves along the measurement transect is also on-going. These analyses will provide further insight into the sand transport and dust emission system at the ODSVRA and the Dune Preserves.

The 24-hour mean PM_{10} and wind speed data are instructional as to how the dust rule would apply for different pairs of CSM and CDVAA monitors, which are at this time being represented by monitors within the north and south dune preserves and in the riding area. The comparison between T1C and T2C in the north indicates that for 59 days of data, 22 exceedences were registered at the CSM with the CDVAA exceeding the CSM monitor by >20% 18 times.

For monitors in the south, T4B and T3B are approximately equidistant from the shoreline with T3B positioned within the riding area and T4B in the dune preserve. This comparison indicates that for the 49 days of available data there would have been 24 exceedences of the 55 $\mu g\ m^{-3}$ standard at the CSM, which results in only four instances where T3B (the designated CVAA monitor) exceeds the CSM by >20%. Comparing between T4B and T2C for 48 available days, increases the number of times the CDVAA is >20% than the CSM to 8, with CMS exceedences totaling 23. These comparisons illustrate that it will be difficult to completely define the dust emission characteristics of both the riding and dune preserves, and compare their different PM_{10} concentrations with just two measurement locations.

Responses to APCD Staff Comments

Q: Please clarify whether "particle entrainment" refers to sand particle entrainment or to fine article entrainment.

A: In this section particle entrainment refers to sand sized particles beginning to saltate.

Q: It is stated that measurement of the wind speed (or wind shear) and the presence or absence of saltating sand or elevated levels of dust (i.e., PM10) at a frequency of at least 1 Hz is needed to produce results with high confidence. The wind measurements and sensit counts were recorded continuously on a data logger, so it seems it should be possible to determine what 1-min wind gusts produce saltation. Please clarify.

A: To apply the Stout (2004) method for determining threshold requires that the saltation seconds (i.e., the number of seconds during a sampling interval that recorded the presence of saltation) be calculated. The Sensit data were recorded as a summation of counts in the averaging interval. A second-by-second (i.e., One Hz) record was not logged. It is not possible to link gust to saltation count as the time resolution is insufficient to resolve the saltation counts with the time of the maximum hourly wind gust.

Q: It is stated that sensit counts of one were treated as zero in this analysis. Please explain this.

A: A count of one within a 60 minute sampling interval especially when associated with winds <6 m/s is likely spurious.

Q: It is stated that 10 m threshold wind speeds were estimated for at the 3m wind sites on the same transect by using the 3 m to 10 m threshold wind speed ratio. Given the preliminary data we have seen and the accompanying quality assurance records, it appears some of the 3m wind data was likely out of spec and invalid, as described in our comments under section 2.2, above. Further confirmation of this is required. Given that, the 10 meter data is most appropriate to use for this analysis; estimates for the other sites are inappropriate unless/until the 3m data is validated.

A: Although the 3 m wind speed data may at some measurement intervals been out of spec, there is considerable value in looking at the larger data patterns to evaluate the performance of the measurements and what they can tell us about the larger dunes sediment transport system. The correlation between the 10 m and 3 m wind speeds at the positions where both measurements were acquired on a transect is high (Fig. 1a). In addition, the 3 m wind speeds among the transect positions are also highly correlated (Fig. 2a). Within the uncertainty associated with the measurements the effect of having some measurements fall outside the specification will not, in our opinion, adversely affect the wider results, such as the calculation of 10 m wind speed based on the 3 m to 10 m ratio derived for a transect.

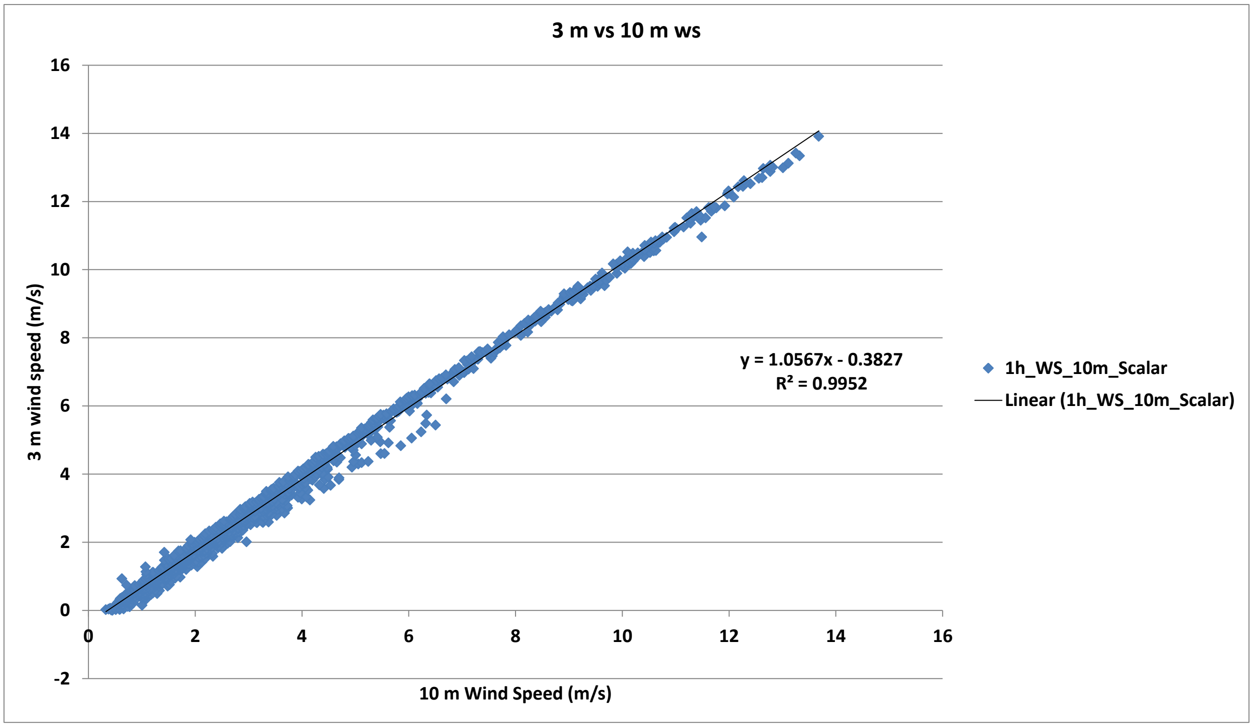


Figure 1a. 3 m vs 10 m wind speed at position T2C.

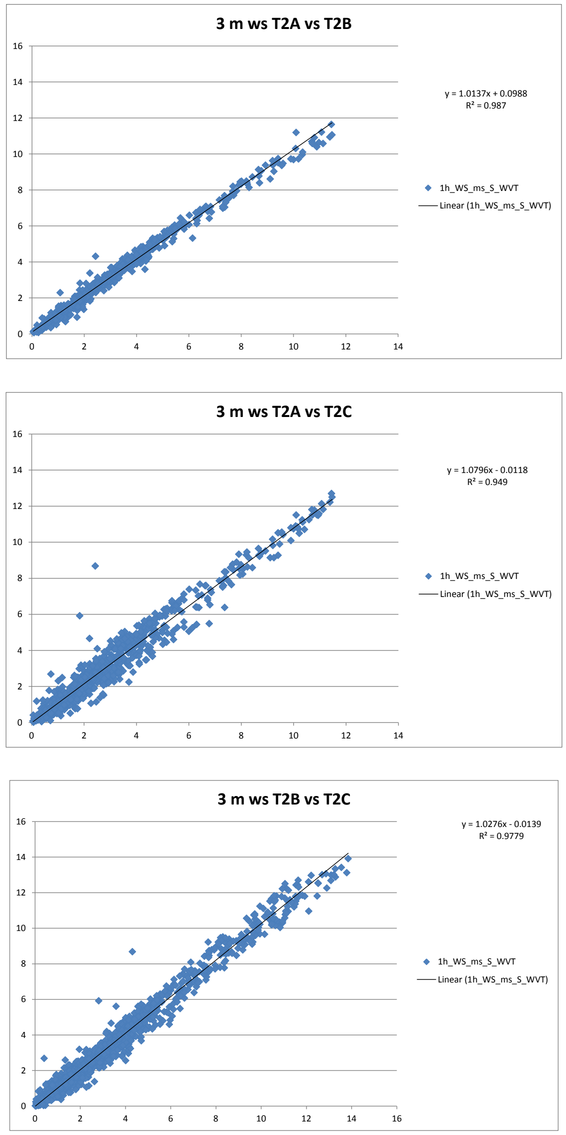


Figure 2a. Comparison of 3 m a.g.l. wind speed measurements along Transect 2.

Q: It is stated below Table 2 that 'The 10 m wind speed threshold at positions T3C and T4B are 5.5 (±1.1 m/s) and 5.6 (±0.6 m/s), which also suggests that the difference between them is too uncertain to unambiguously declare they are different." However, Table 2 shows the 10 m wind speed threshold at positions T3C and T4B to be 4.52 and 6.21, respectively; this represents a difference of nearly 40%. Please explain these differences.

A: The wind speed thresholds referred to in the identified paragraph were the mean values for all stations along the transects. The sentence:

"The 10 m wind speed threshold at positions T3C and T4B are 5.5 (±1.1 m/s) and 5.6 (±0.6 m/s), which also suggests that the difference between them is too uncertain to unambiguously declare they are different".

Should have read:

The mean 10 m wind speed threshold for transects 3 and 4 are 5.5 (±1.1 m/s) and 5.6 (±0.6 m/s), which also suggests that the difference between them is too uncertain to unambiguously declare they are different.

8 References

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