# Appendix P. Expanded Analyses of Wind Speeds and Temperature/Seasonality Influences on Measured Air Contaminant Concentrations

## Analyses of Average Wind Speed Influences on Measured Air Contaminant Concentrations

To investigate the relationship between average wind speed and concentration, the monitored concentration data was separated into the highest and lowest 20% average daily wind speed days. The top and bottom 20% were used instead of the top and bottom 10% to ensure that the daily variability in the meteorological conditions was smoothed out and so the wind direction patterns became closer to the overall prevailing wind patterns. This allows the wind directionality patterns for the highest and lowest average wind speed days to more closely resemble one another, thus removing the influences of wind direction to a greater extent. The wind roses for the highest and lowest 20% average wind speed days are included which indicate that both the overall wind direction percentages spread and the resultant vector are similar (Figure P.1). The differences in the resultant vector towards the 225° direction and the additional wind from the west, southwest observed with the highest 20% wind speed day's wind rose would be expected to result in an increase of the industrial area influences. However, it is the lowest average wind speed days that have the higher mean concentration, as compared to that of the highest average wind speed days, for the majority of the contaminants. With benzene, however, increased influences from the industrial area and the largest study area benzene source (due to these wind directionality differences) could be masking any effects due to variations in the average wind speeds because the increased wind from the direction of the industrial area during the highest average wind speed days would result in more influences on the measured concentrations at both the GIBI and BTRS monitors. For this analysis, the concentrations over all four monitoring locations were averaged together, allowing any differences in wind direction patterns to be smoothed out because the various monitors are orientated so that they capture winds moving over the industrial area in different directions. The percentage differences for the contaminants investigated from the highest 20% wind speed days (average = 9.18 mph) to the lowest 20% wind speed days (average = 3.15 mph) are as follows: Benzene -7%, Formaldehyde +240%, Acetaldehyde +76%, Acrolein +51%, Carbon Tetrachloride +3%, Toluene +260%, Benzene/Toluene Ratio -49%, 1,3-Butadiene and Carbon Disulfide +69% (Figure P.2).

Another method to analyze the relationship between wind speed and concentration was to organize the data by the concentration and then determine what the average wind speed was for the top 10 and 20% and the bottom 10 and 20% concentration days. The average wind speeds for the highest versus lowest concentration days was observed for each monitoring site individually and with all the monitoring sites combined for each contaminant investigated. Acrolein, toluene, and 1,3-butadiene all show substantially lower wind speeds for the highest 10 and 20% concentration days consistently at all four monitoring sites (Figures P.3-5). Formaldehyde and acetaldehyde show this same relationship but the differences observed for the top and bottom 10% at the BTRS site are not nearly as substantial as those seen with acrolein, toluene, and 1,3-butadiene (Figures P.6-7). Benzene also indicates this same relationship for both the top and bottom 10% and the top and bottom 20% at all four monitoring sites (with the one exception of the top and bottom 20% at BISP), although to a much smaller degree than was the case with acrolein, toluene, and 1,3-butadiene (Figure P.8). Because of the small differences with benzene and the large differences with toluene, the benzene/toluene ratio shows the opposite trend with substantially higher wind speeds for the highest 10 and 20% concentration days consistently at all four monitoring sites (Figure P.9). Carbon tetrachloride also shows only small differences in average wind speed with the highest and lowest concentration days and does not show any consistency between the monitoring sites and different percentages (Figure P.10). Finally, carbon disulfide shows the same overall trend as did most of the other contaminants with lower wind speeds for the highest 10 and 20% concentration days at all four monitoring sites, again with the one exception of the top and bottom 20% at BISP (Figure P.11). The most substantial differences were seen at the GIBI site, then at the BTRS site, but only small differences were seen at the BISP and SPWT sites.

**Analyses of Seasonality and Average Temperature Influences on Measured Air Contaminant Concentrations.**

The seasons were segmented by temperature rather than by calendar dates which was verified by looking at the temperature trends at the BISP monitoring site over the study period on the sampling days (Figure P.12). Therefore, summer included June, July, and August, autumn included September, October, and November, winter included December, January, and February, and spring included March, April, and May. The analysis of seasonality indicates that the majority of the contaminants analyzed had the lowest concentrations measured in the winter and the highest concentrations measured in the summer and autumn (Figure P.13). The average temperatures (on the sampling days only) calculated for the seasons were 70°F for summer, 57°F for autumn, 30°F for winter, and 45°F for spring so the autumn temperature was substantially that of the winter and almost as close to the summer average as it was to the spring average. The contaminants that followed the general trend described above and their percentage increase from the winter to the summer were: Formaldehyde (300%), Acrolein (58%), Acetaldehyde (39%), Toluene (50%), and 1,3-Butadiene (67%). Benzene had very similar concentrations in the summer, winter, and spring with a percentage increase of only 7% from winter to summer but the autumn average concentration was more than double than that of any of the other three seasons. Because the benzene concentrations changed very little while the toluene concentrations were substantially lower in the winter as compared to the summer, the benzene/toluene ratio was slightly lower in the summer than in the winter (12%). Carbon tetrachloride showed very little difference in concentration between any of the four seasons and the percentage increase from winter to summer was only 6%. Carbon disulfide concentrations had a percent increase of 88% from winter to summer, but the average concentrations were even higher in the autumn and spring as compared to the summer.

It is important again to look at the differences in the wind patterns for each season to investigate the potential contributions to the concentration differences noted (Figure P.14). While the wind roses and the resultant vectors shown are similar, there are certain differences that may have contributed to some of the concentration differences measured. The summer winds were out of the south, southwest almost 30% of the time and directly out of the southwest just over 18% of the time. The winter winds were out of the south, southwest just over 16% of the time and directly out of the southwest 10% of the time, but overall, the winds were more variable with additional winds from the west, southwest (15%) and the west (12%). The autumn winds were out of the south, southwest almost 20% of the time and directly out of the southwest almost 16%

of the time, but again, were more variable than in the summer with additional winds from the south (14%). The spring winds were the most variable with winds out of the south, southwest 13% of the time, the southwest 11% of the time, the south 12% of the time, and the west, southwest and north, northeast 9% of the time. What makes the wind variations somewhat less influential in this analysis is the fact that the concentrations of all four sites, which are in different directions with respects to the industrial area and the local sources, again have all been pooled together to look at the seasonal variability.

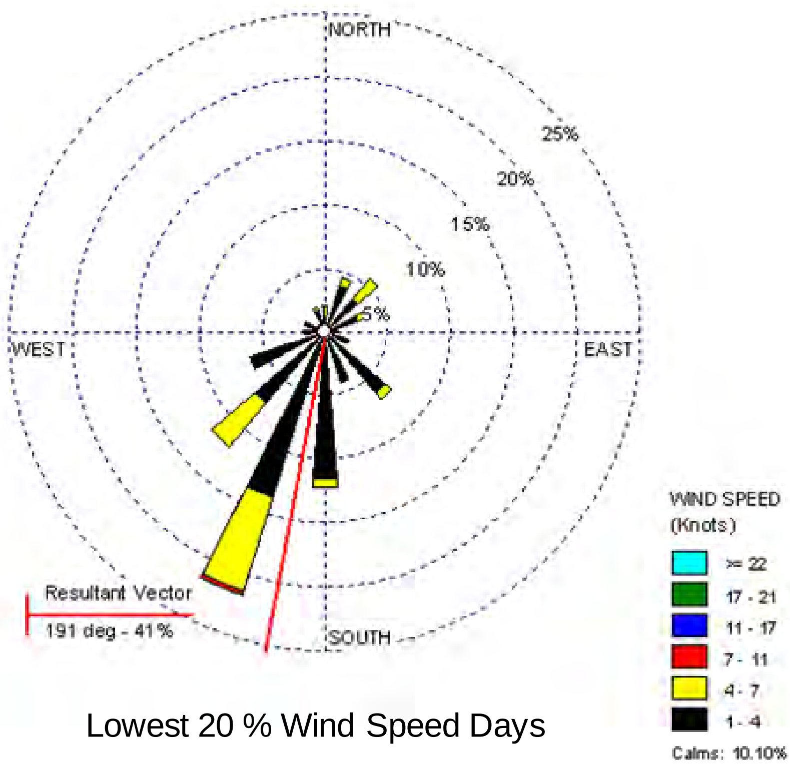
Whether or not any monthly trends were apparent was then investigated. The average monthly concentrations for only the monitoring days were: 70°F for July, 72°F for August, 63°F for September, 61°F for October, 57°F for November, 32°F for December, 31°F for January, 30°F for February, 35°F for March, 48°F for April, 45°F for May, and 70°F for June. The benzene concentration in October was substantially higher than for any other month, so the monthly trends graph for benzene is in log scale (Figure P.15). However, this causes the difference between the benzene concentration in October and the other months less strikingly visible. There were no meaningful monthly trends apparent over the year for the monitored benzene concentrations. Note that the concentrations at the GIBI and BTRS monitors followed the same monthly trends, indicating that their similar directionality with respect to the largest study area benzene source/industrial area resulted in the different wind patterns over the year leading to similar changes in relative benzene concentrations. Additionally, the monthly trends for 1,3-butadiene over the study year track closely with benzene and also do not appear to have meaningful annual temporal differences (Figure P.16). The monthly acrolein concentrations clearly indicate a consistent increase at all four monitors during the warmer months as opposed to the colder months (Figure P.17). With few exceptions, the monthly formaldehyde and, to a slightly lesser extent, acetaldehyde concentrations also indicate increased levels at all four monitors during the warmer months as opposed to the colder months (Figures P.18-19). This trend can be seen more clearly when the four monitoring sites are combined to lessen the overall influence of the wind directionality. The monthly trends over the year for formaldehyde and acetaldehyde are similar to one another but at different relative scales. The concentration scale for carbon tetrachloride exhibits very little variability and the monthly concentrations vary only slightly (Figure P.20). With several exceptions, the monthly toluene concentrations also indicate increased levels during the warmer months as opposed to the colder months (Figure P.21). The benzene/toluene ratio seems apparently to be dominated by the benzene concentrations, resulting again in both no meaningful monthly trends being observed over the study year and the large spike in October causing the need to use a log scale for the ratio levels in our graph (Figure P.22). Although the carbon disulfide concentrations for the coldest months are among the lowest when all four monitoring sites were combined, individually there do not appear to be any meaningful trends and there is little indication that the differences in carbon disulfide concentrations can be attributed to variations in temperature or sun intensity/insolation over the course of a year (Figure P.23).

Once again, combined monthly wind roses, for only the monitoring days of each month, were reviewed to determine if the differences in wind directionality could have contributed to the concentration differences observed (Figure P.24). The previously summarized analyses indicated that benzene, 1,3-butadiene, and carbon disulfide are the three contaminants which most clearly show indications that their measured concentrations were primarily driven by differences in wind direction and the relative orientation relationships between the locations of the large local point sources and the monitoring sites. Therefore, this review of the monthly patterns as compared to the wind directionality during that time period will be limited to those contaminants and, due to the monthly trend similarities between benzene and 1,3-butadiene, only benzene will be discussed to avoid redundancy.

The highest monthly benzene concentration at both the GIBI and the BTRS monitor in October can be explained by wind directionality. The wind rose for October indicates that roughly 60% of the time the winds were either directly out of the southwest or from the south, southwest (the direction of the monitor with respect to the largest study area benzene source). The resultant vector for the October wind rose was at 217° with a percentage of 66% and this month had a relatively large amount of calms (8.33%) during that time period (Figure P.24). The combined percentage of winds from these two directions was greater than for all other months except for June which was also among the highest benzene concentration months at the GIBI and BTRS monitors. In contrast, the lowest percentage of winds from these two wind directions combined was during the month of December and the resulting concentration at the GIBI and BTRS monitors was also among the lowest. Even though the winds directly from the southwest were seldom during January, the two wind sectors adjacent to this wind direction on either side had the highest percentages of winds blowing from them and the monthly benzene concentration was among the highest at the GIBI and BTRS monitors. The one month at the GIBI and BTRS monitors that seems to be an anomaly of sorts is November where the benzene concentration is the second highest but the percentage of winds from the southwest and south, southwest combined is only in the middle of the range. The highest benzene concentration month at both the SPWT and BISP monitors (April) has a wind rose that indicates some wind from the east northeast (but not the highest amount) and no winds from the northwest quadrant. It appears that the elevated concentrations are the result of the amount of calm winds which was the second highest in April as compared to any other month (6.72%). The next two highest concentration months at SPWT (December and January) do have the second and third highest percentage of winds coming from the east, northeast, respectively (the direction of the monitor with respect to the largest study area benzene source). At the BISP monitor, the next highest benzene concentration month is September which has the highest overall percentage of winds from the three wind sectors in the northeast quadrant (the direction of the monitor with respect to the largest study area benzene source).

The monthly carbon disulfide concentrations at the SPWT monitor also indicate that both wind direction and wind speed are influencing factors (Figure P.24). While the second highest concentration month at the SPWT monitor, April, has the second highest percentage of wind from the west, southwest, the highest month at this site, October, is only in the middle of the range as far as the percentage of wind from that direction (the direction of the monitor with respect to the largest source). However, these two months have the highest percentage of calm winds out of all months (6.72% and 8.33%, respectively). In addition, the month with the highest percentage of winds from the west, southwest at the SPWT monitor, January, is only in the middle of the range in terms of carbon disulfide concentration, but this month is also the one with the lowest percentage of calm winds (0.00%). The lowest carbon disulfide concentration month at the SPWT monitor, December, is in the middle of the range for percentage of wind from the west, southwest but has the second lowest percentage of calm winds (0.83%). The second lowest concentration month at the SPWT monitor, August, does have one of the lowest percentages of wind from the west, southwest. The highest carbon disulfide concentration months at the GIBI monitor, March and May, have the highest percentages of wind directly from the south and the lowest two months, January and February, indicate no winds from this direction (the direction of the monitor with respect to the largest source). The highest three carbon disulfide concentration months at the BTRS monitor, July, June, and October, have the highest percentages of wind from the southwest/south, southwest and the lowest concentration month, December, has the lowest percentage of winds from this direction (the direction of the monitor with respect to the largest source). Finally, the highest two carbon disulfide concentration months at the BISP monitor, September and July, have the highest percentages of wind from the east, northeast and five out of the six months with the lowest percentages of winds from this direction (the direction of the monitor with respect to the largest source) are also the lowest 5 concentration months.

To attempt to reduce the wind directionality influence as much as possible, the data was then dichotomized into the highest and lowest 30% temperature days and then the four monitors were combined together to observe what the resulting mean concentrations for those days were (Figure P.25). As can be seen in the wind roses for the highest and lowest concentration days, the wind directionality patterns did differ from one another somewhat (Figure P.26). However, because the monitoring locations were combined together, the increased influence from the industrial area at the GIBI monitor and, to a lesser extent, the BTRS monitor during the highest 30% temperature days was concurrent with a decreased influence from the industrial area at the SPWT and BISP monitors. Then, the diminished influence from the industrial area at the GIBI monitor and also at the BTRS monitor (but less so than at GIBI) during the lowest 30% temperature days was concurrent with an increased influence from the industrial area at the SPWT and BISP monitors. Therefore, combining the monitoring locations together allows for less overall influence from the wind directionality and more influence from the temperature differences, but the full effect cannot be totally deciphered. Almost all the contaminants investigated had higher concentrations with the highest temperatures as compared to the lowest temperatures, with the highest percentage differences being the following: Formaldehyde at 325%, Carbon Disulfide at 220%, 1,3-Butadiene at 200%, Acrolein at 78%, and Toluene at 75% (Figure P.25). Acetaldehyde and benzene had lower percentage increased concentrations during the highest temperature versus lowest temperature days at 47% and 43%, respectively. Because the toluene concentration had a greater percentage increase than the benzene concentration with the highest temperature days as compared to the lowest, the benzene/toluene ratio was lower with the higher temperatures versus the lower temperatures. The carbon tetrachloride concentration showed almost no difference between the highest temperature days and the lowest temperature days.



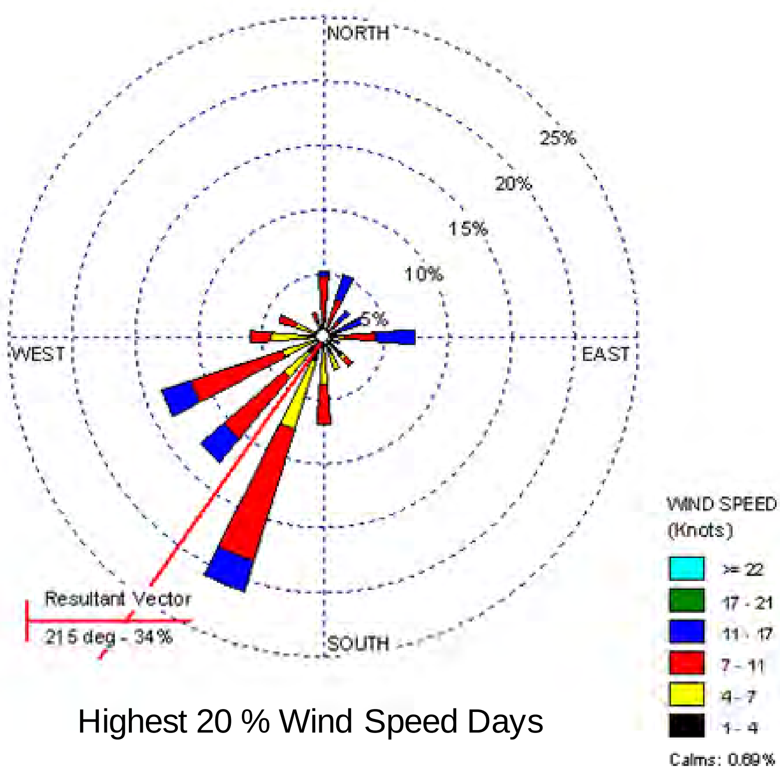
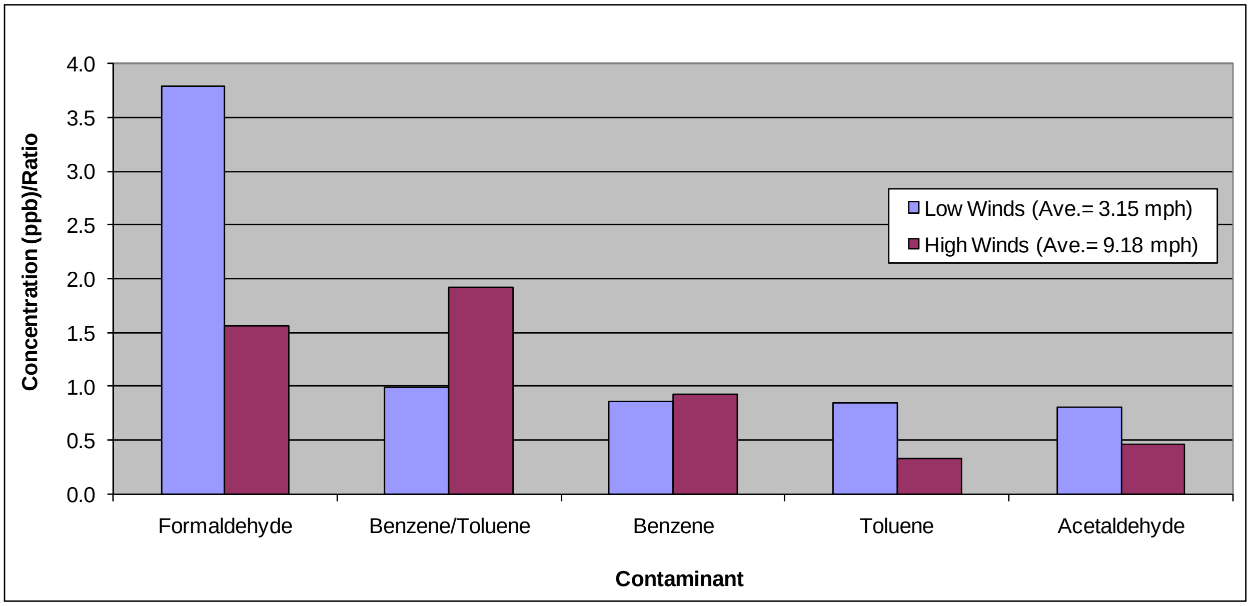




**Figure P.1.** Wind Roses for the Lowest 20% Wind Speed Days Combined and the Highest 20% Wind Speed Days Combined.



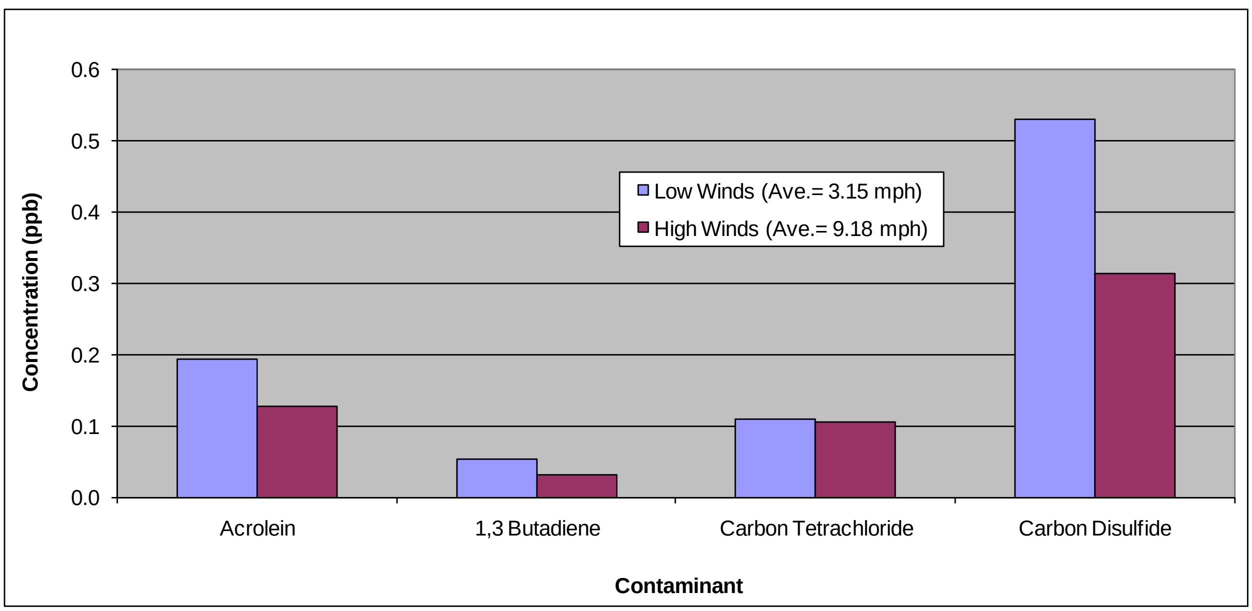




**Figure P.2.** Concentrations/Ratios during the Lowest 20% Average Wind Speed Days Combined compared to the Highest 20% Average Wind Speed Days Combined.


**Figure P.3.** Average Wind Speeds for Highest and Lowest 10% and 20% Acrolein Concentration Days Combined.

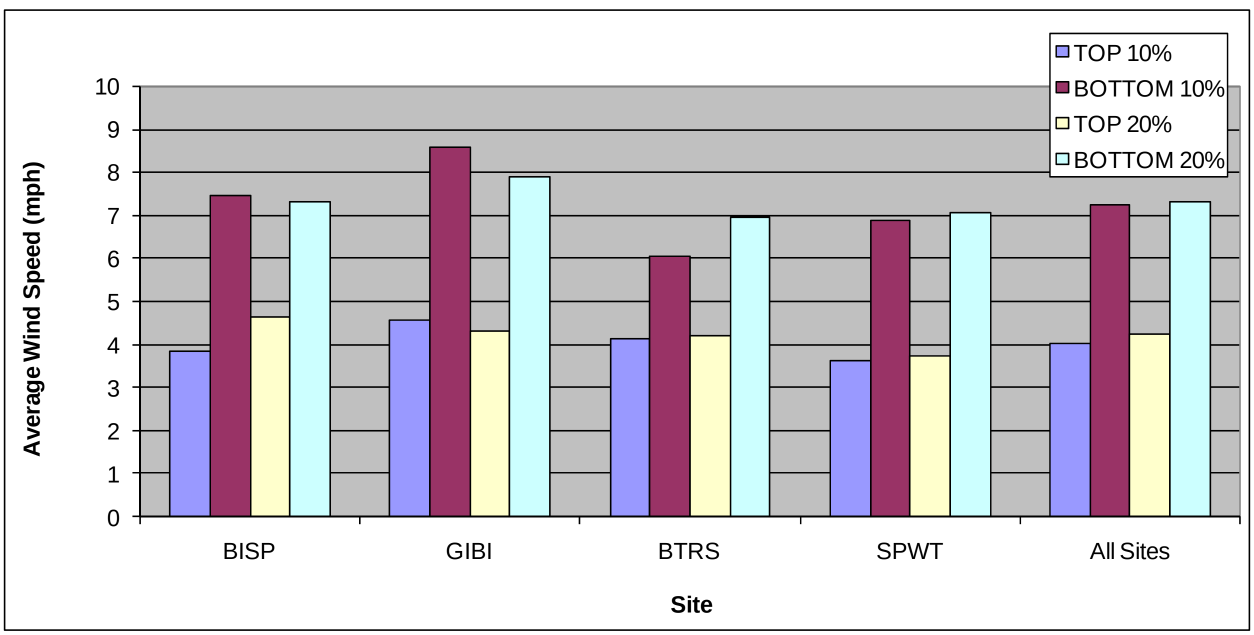



**Figure P.4.** Average Wind Speeds for Highest and Lowest 10% and 20% Toluene Concentration Days Combined.

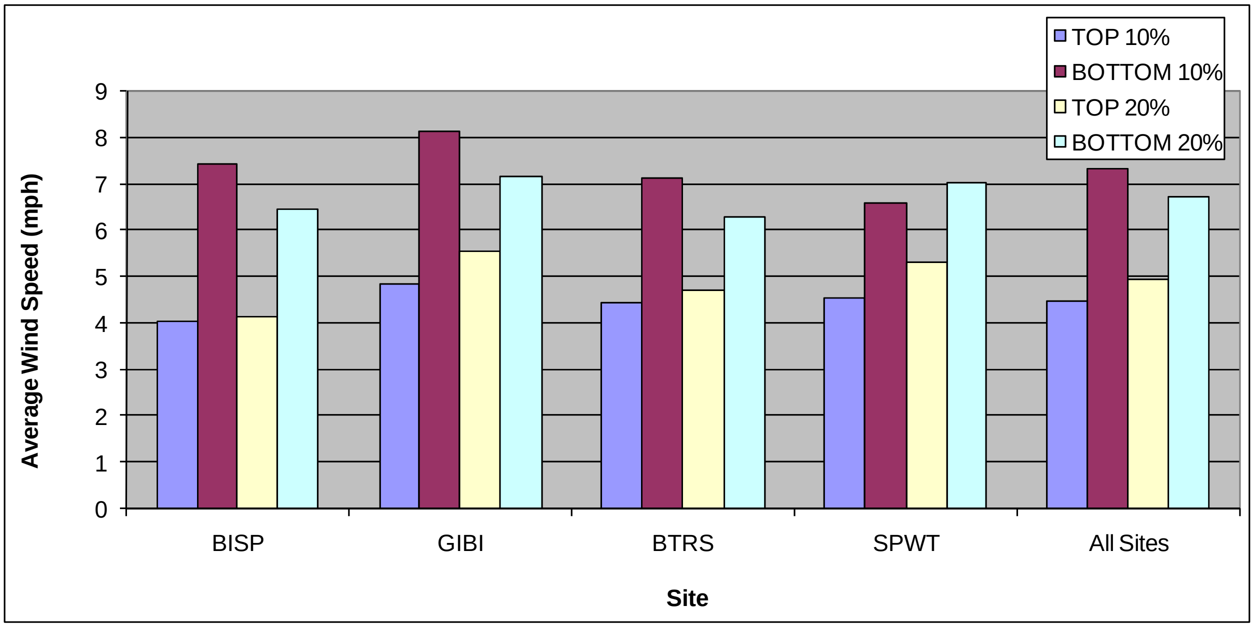



**Figure P.5.** Average Wind Speeds for Highest and Lowest 10% and 20% 1,3-Butadiene Concentration Days Combined.

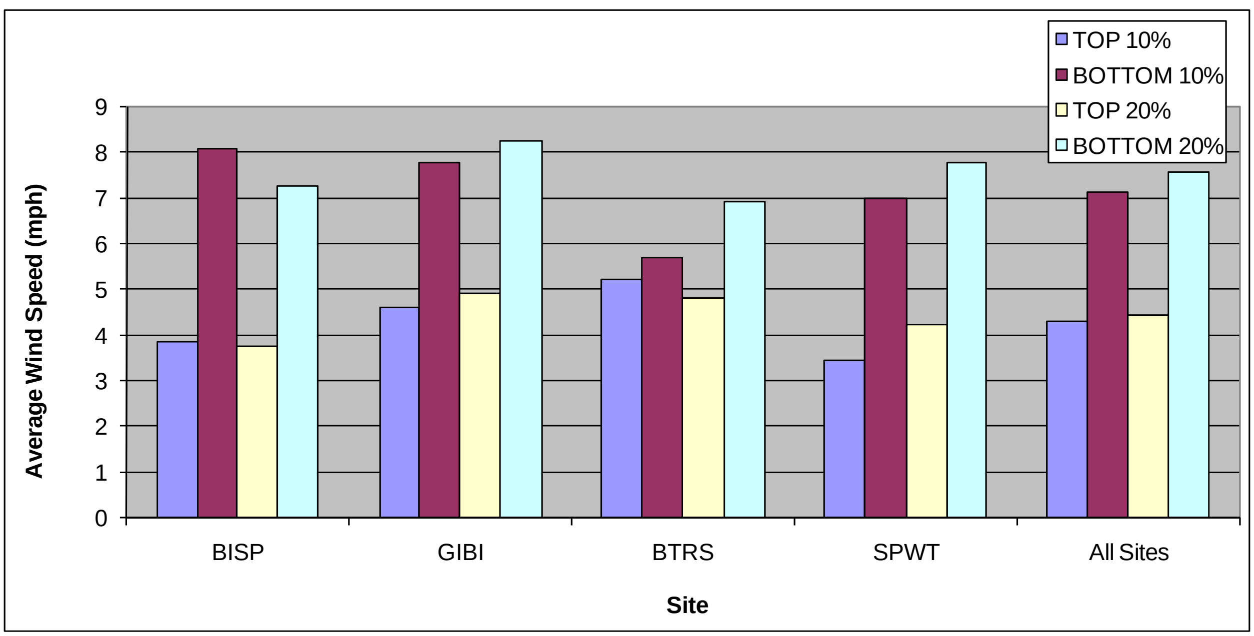



**Figure P.6.** Average Wind Speeds for Highest and Lowest 10% and 20% Formaldehyde Concentration Days Combined.

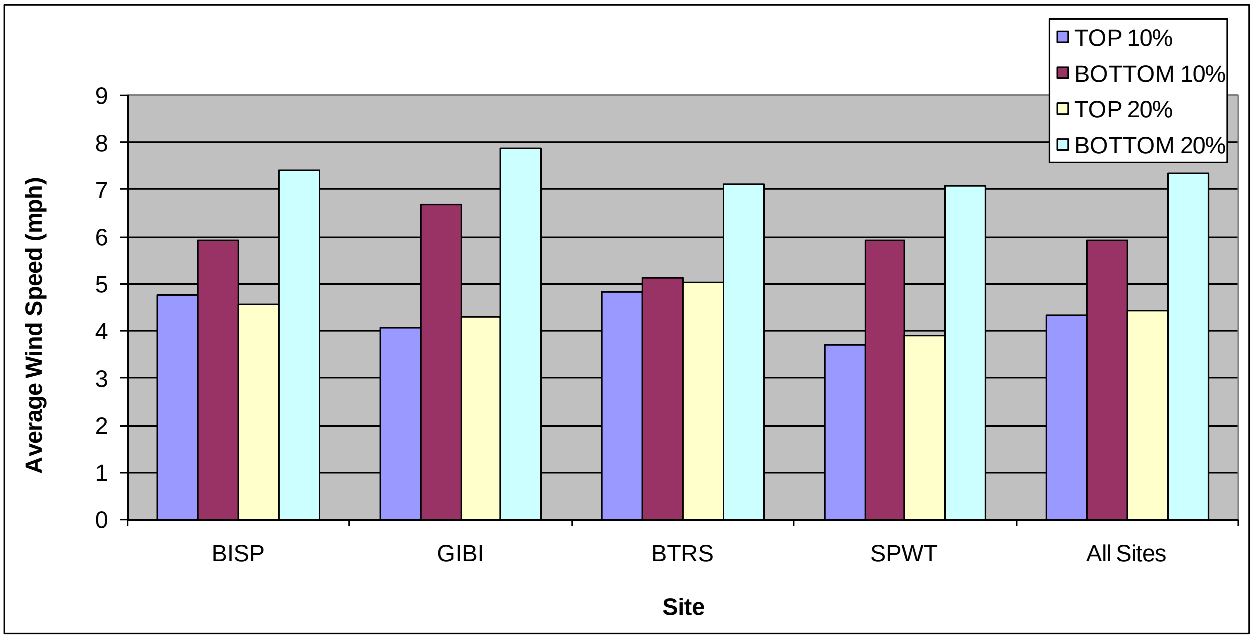



**Figure P.7.** Average Wind Speeds for Highest and Lowest 10% and 20% Acetaldehyde Concentration Days Combined.

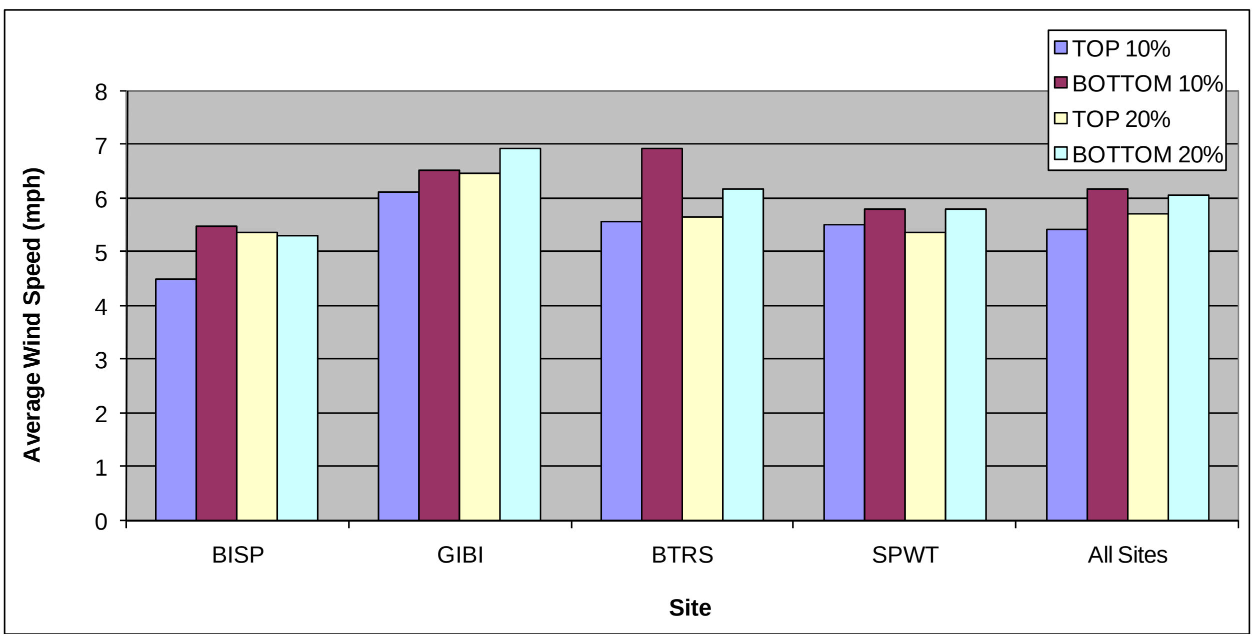



**Figure P.8.** Average Wind Speeds for Highest and Lowest 10% and 20% Benzene Concentration Days Combined.

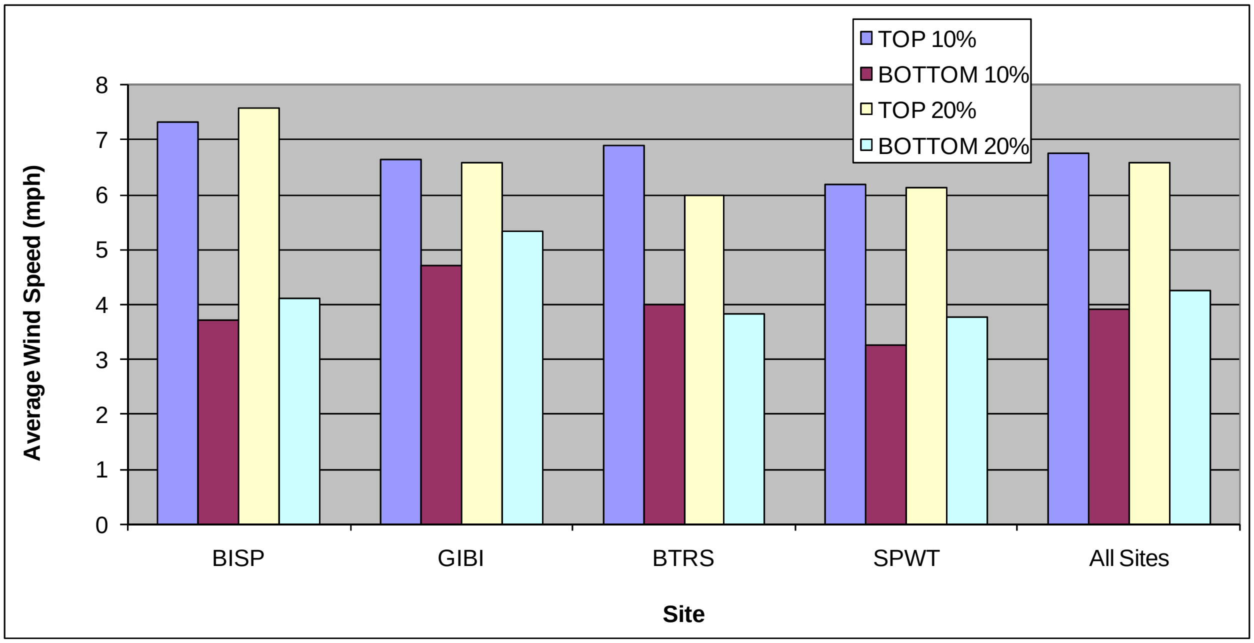



**Figure P.9.** Average Wind Speeds for Highest and Lowest 10% and 20% Benzene/Toluene Ratio Days Combined.

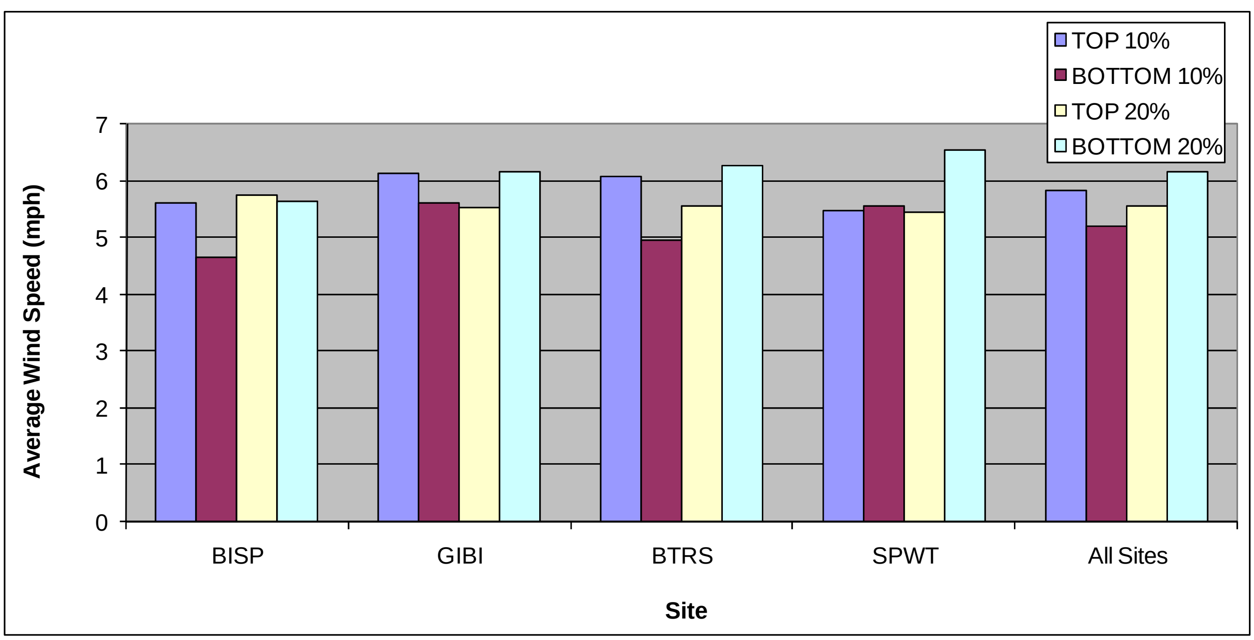



**Figure P.10.** Average Wind Speeds for Highest and Lowest 10% and 20% Carbon Tetrachloride Concentration Days Combined.

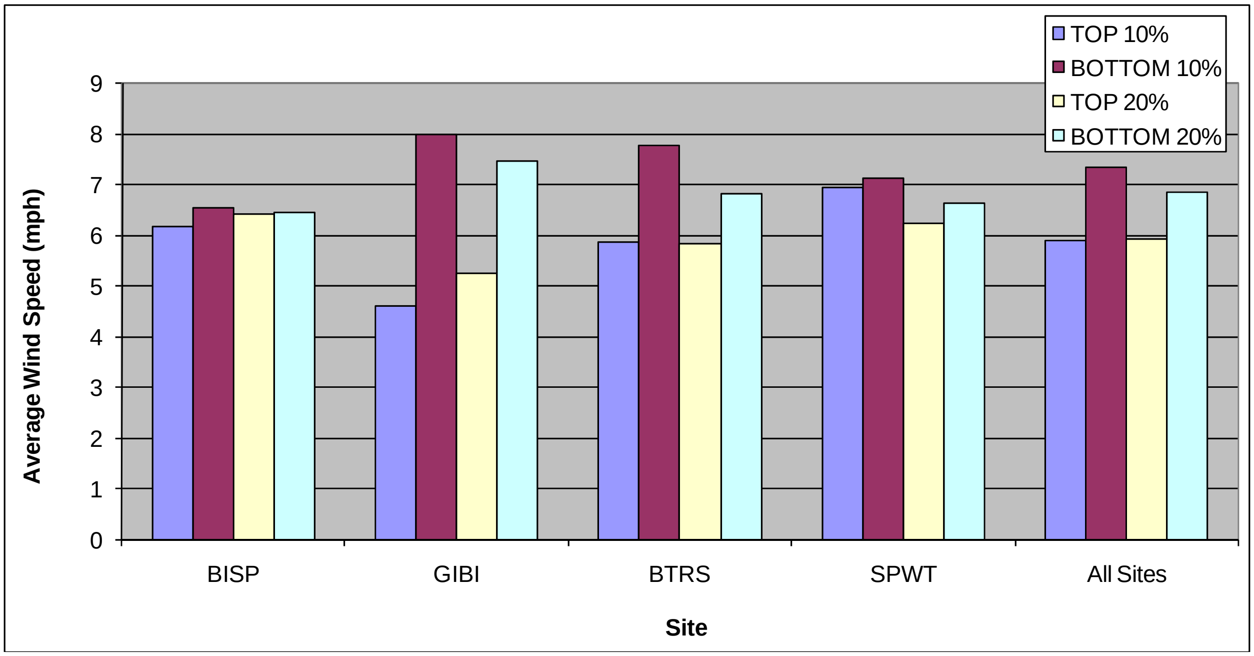



**Figure P.11.** Average Wind Speeds for Highest and Lowest 10% and 20% Carbon Disulfide Concentration Days Combined.

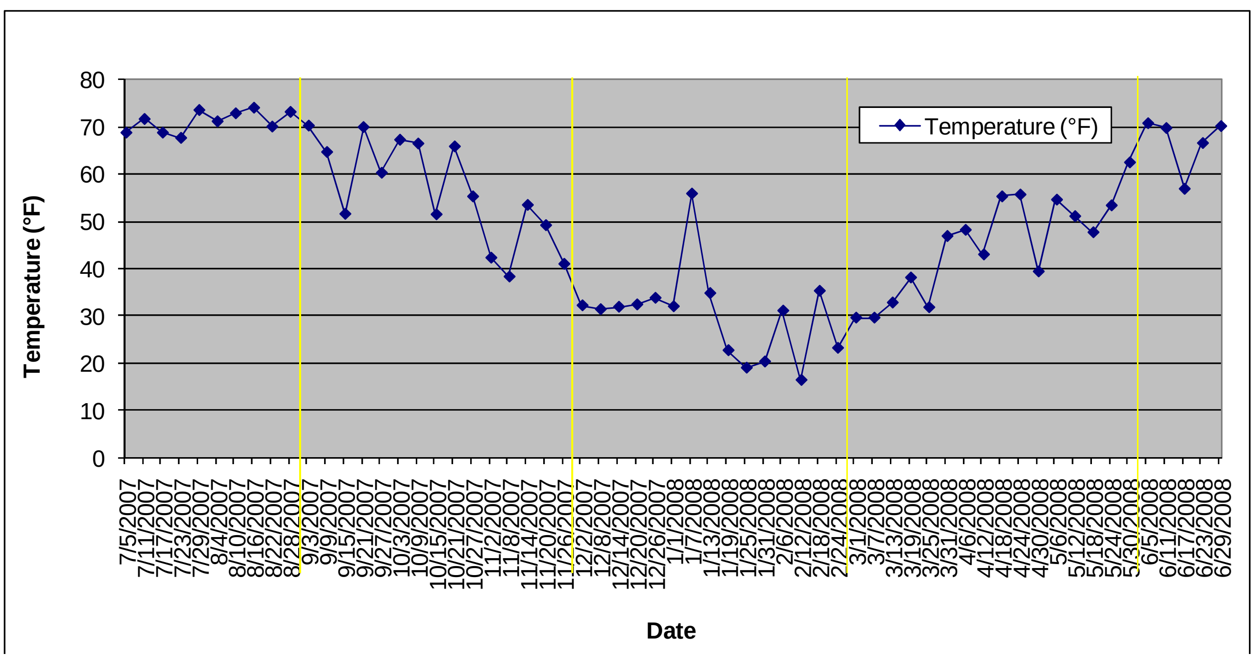



**Figure P.12.** BISP Monitor Meteorological Station Average Temperatures (°F) for the Study Dates.

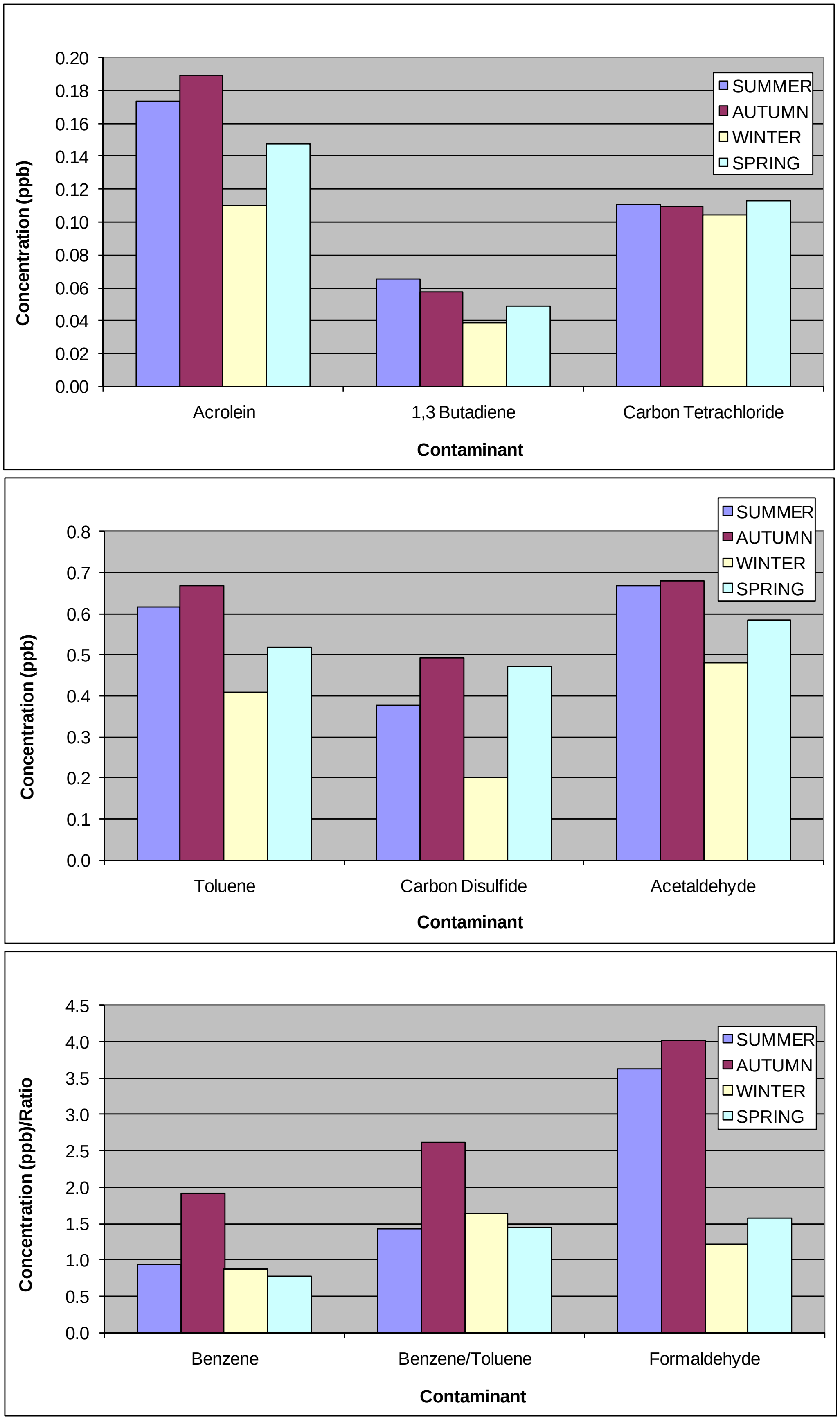



**Figure P.13.** Average Air Contaminant Concentrations during the Different Seasons.

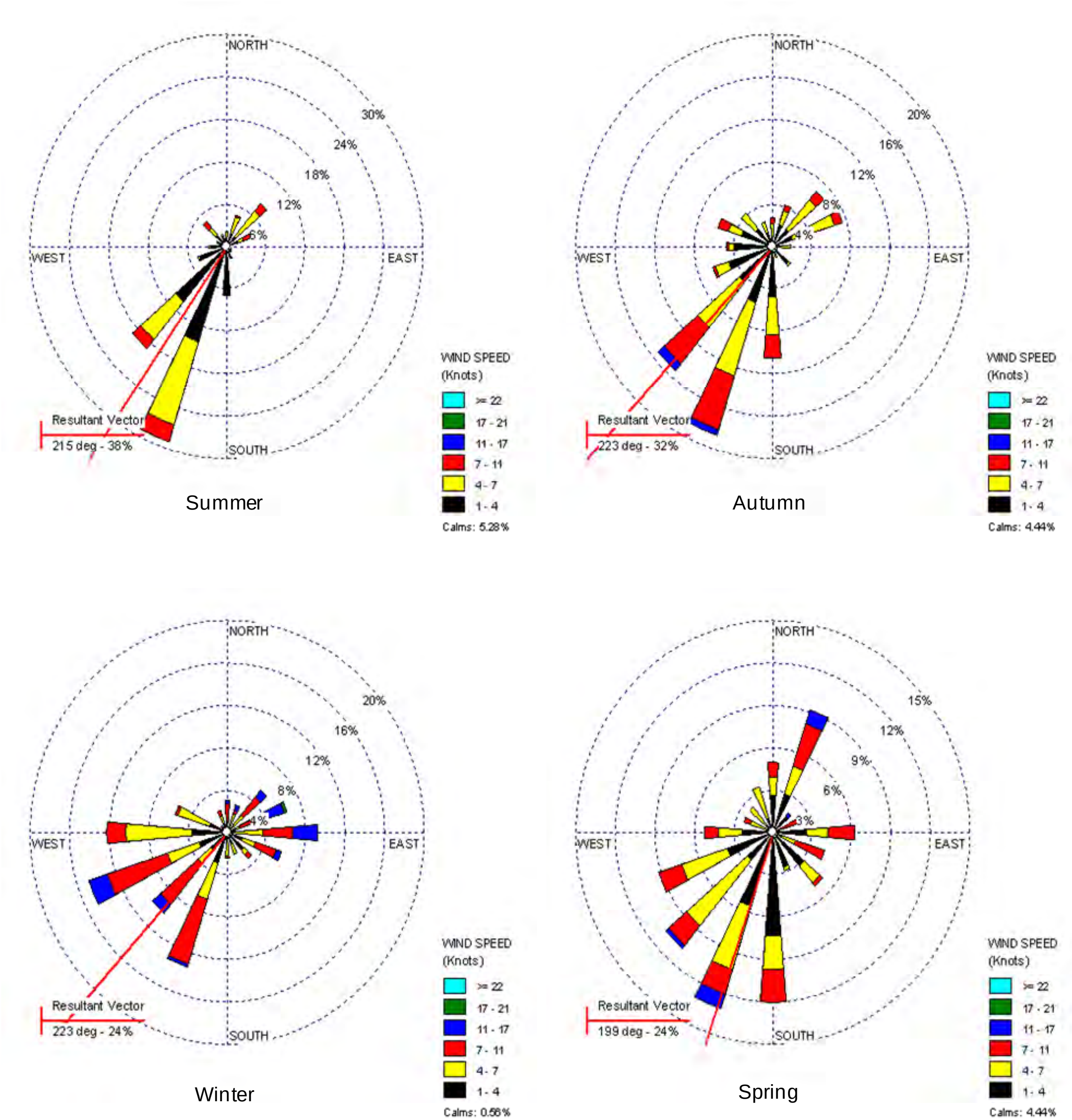



**Figure P.14.** Wind Roses for the Four Seasons of the Study Period.

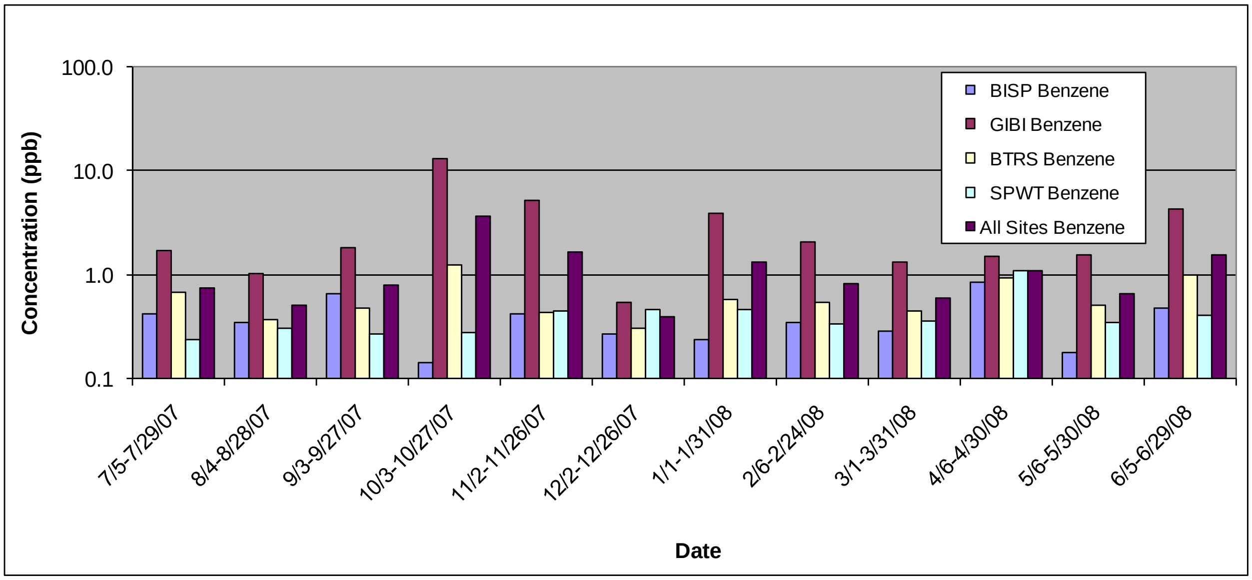



**Figure P.15.** Monthly Trends of Benzene Concentrations in Log Scale. The concentrations are presented using the logarithmic scale because the high GIBI monitor concentration in October resulted in very small bars for many of the other concentrations presented when the normal scale was used.

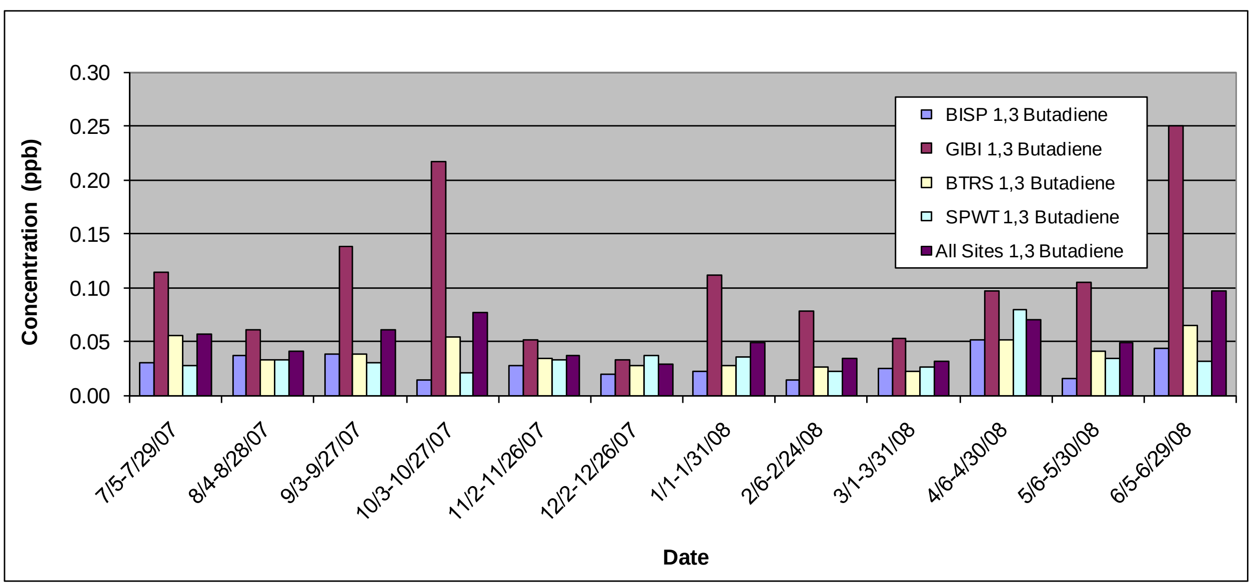



**Figure P.16.** Monthly Trends of 1,3-Butadiene Concentrations.

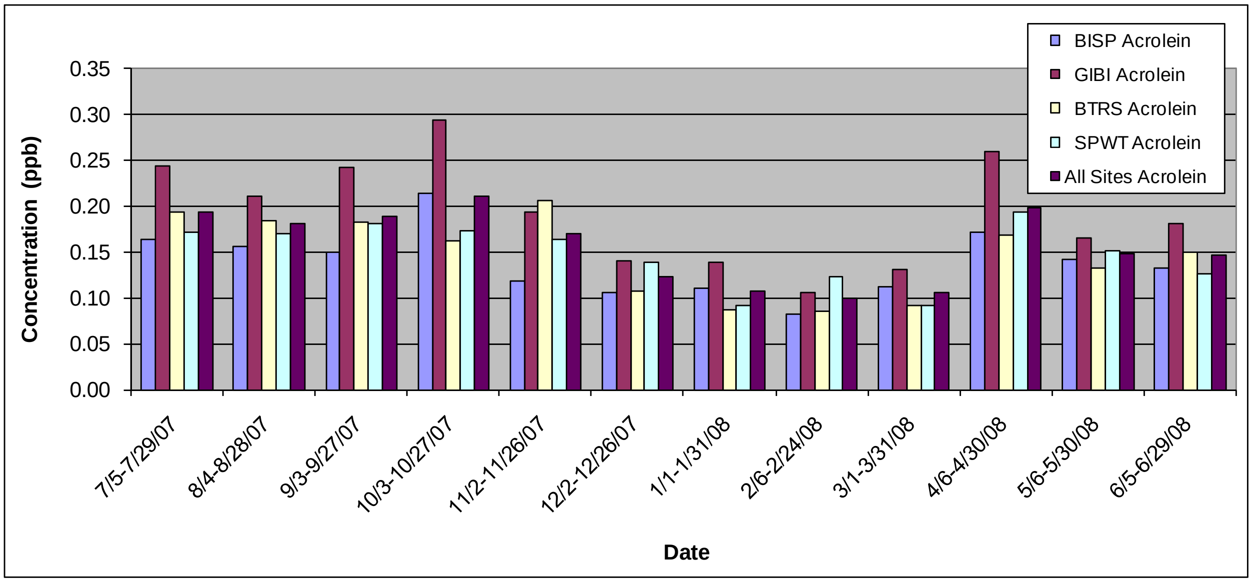



**Figure P.17.** Monthly Trends of Acrolein Concentrations.

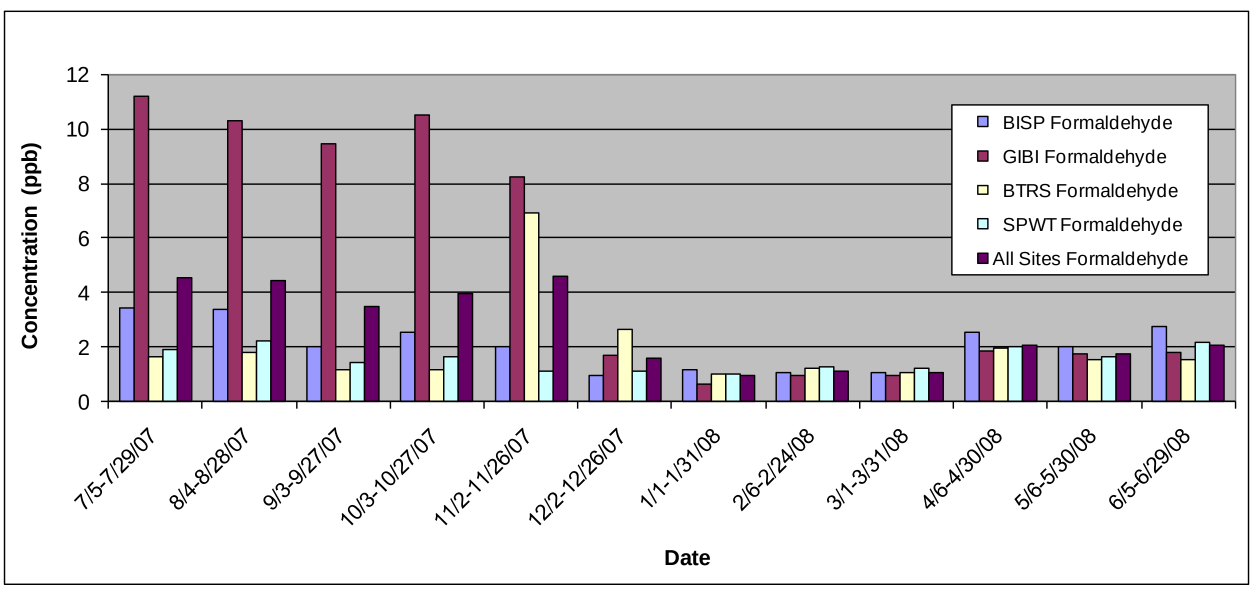



**Figure P.18.** Monthly Trends of Formaldehyde Concentrations.

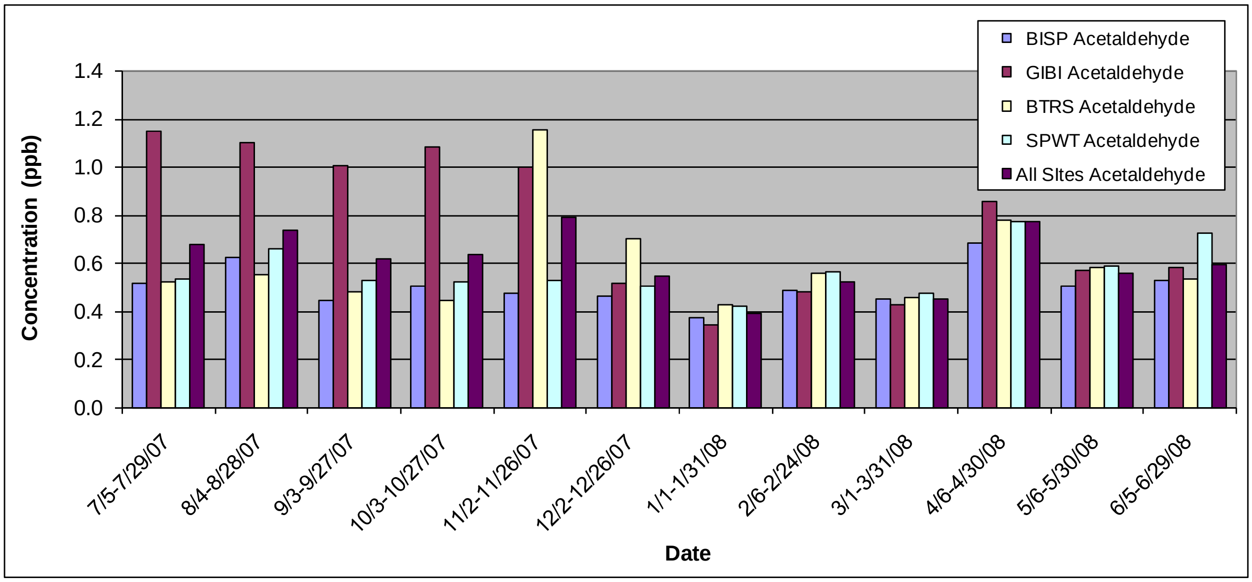



**Figure P.19.** Monthly Trends of Acetaldehyde Concentrations.

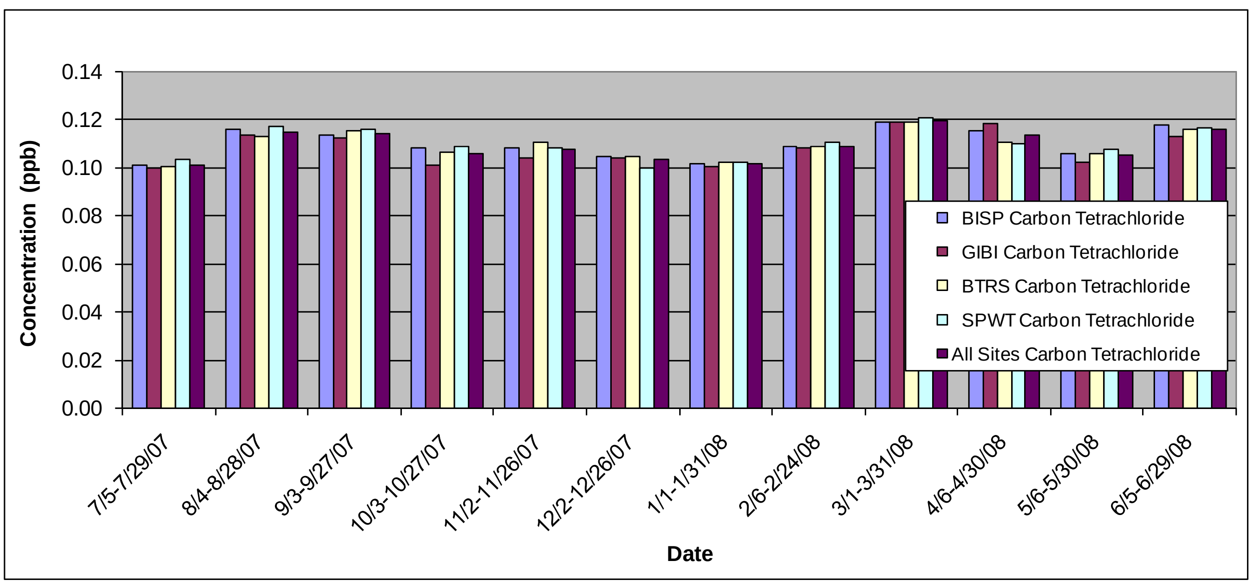



**Figure P.20.** Monthly Trends of Carbon Tetrachloride Concentrations.

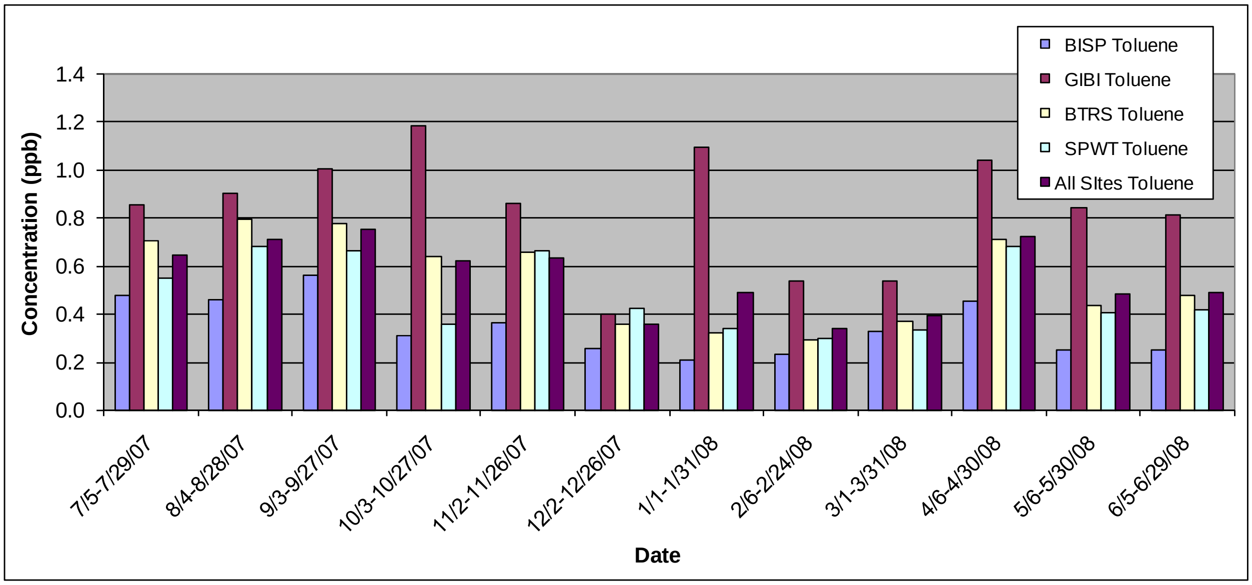



**Figure P.21.** Monthly Trends of Toluene Concentrations.

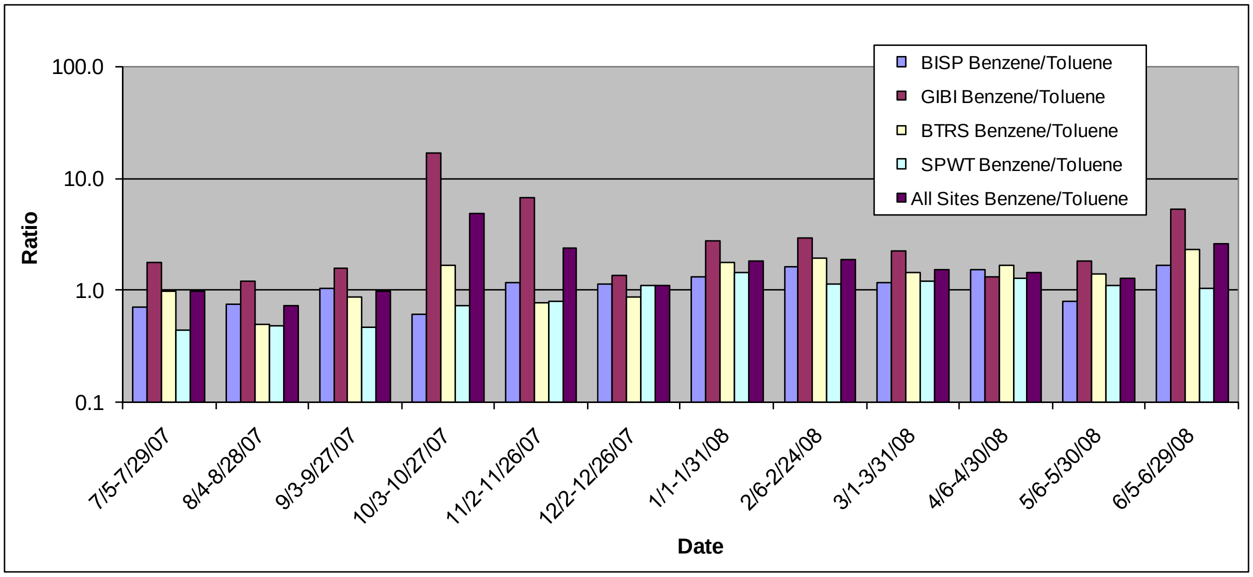



**Figure P.22.** Monthly Trends of Benzene/Toluene Ratios in Log Scale. The concentrations are presented using the logarithmic scale because the high GIBI monitor concentration in October resulted in very small bars for many of the other concentrations presented when the normal scale was used.

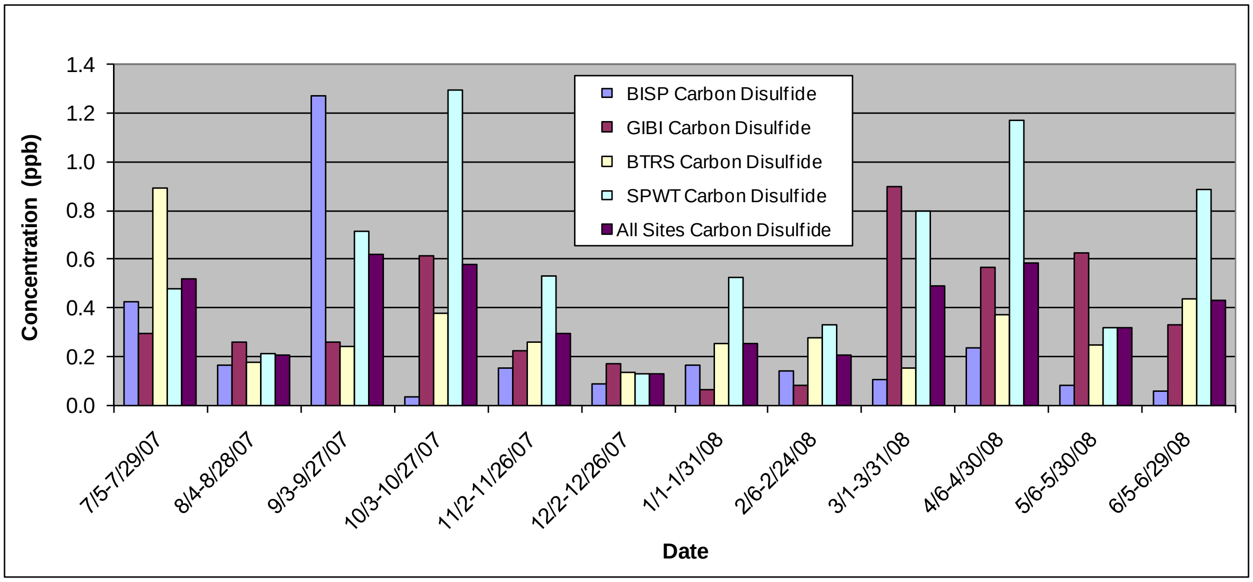
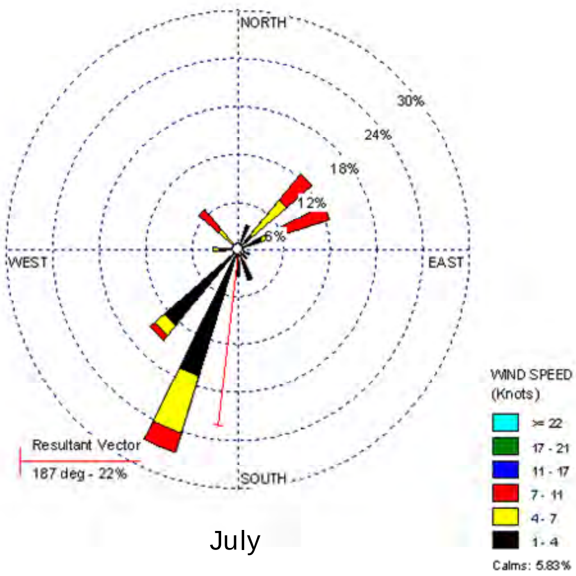
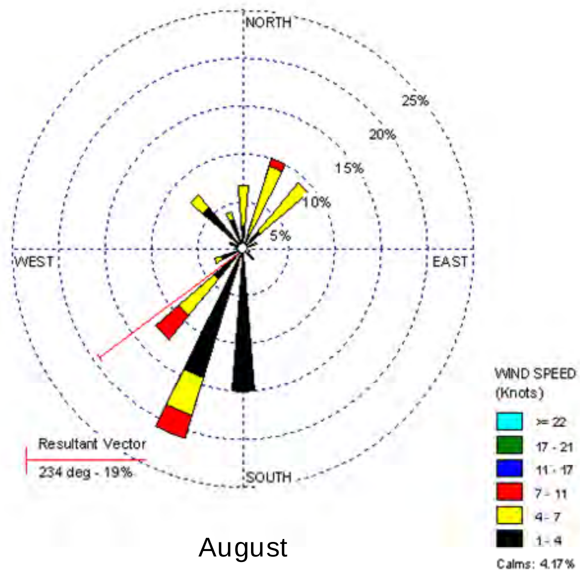


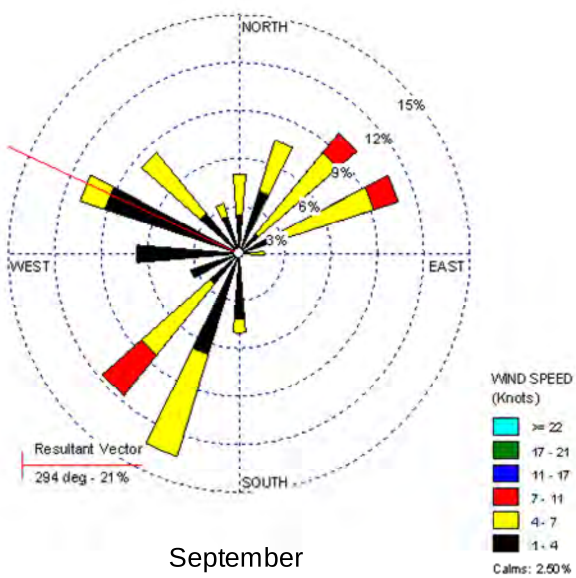

**Figure P.23.** Monthly Trends of Carbon Disulfide Concentrations.



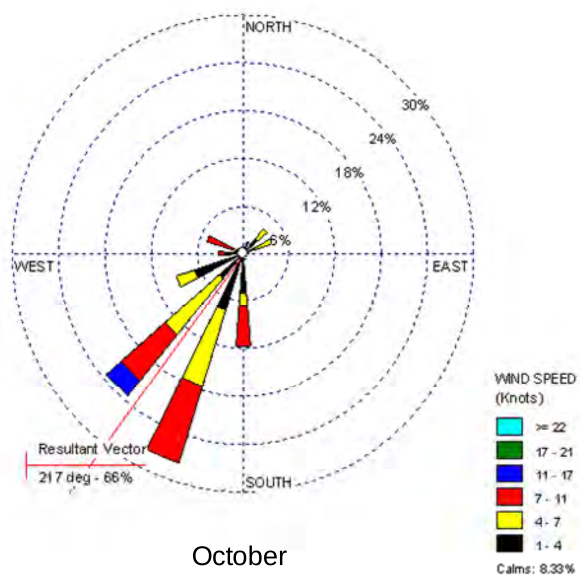

July



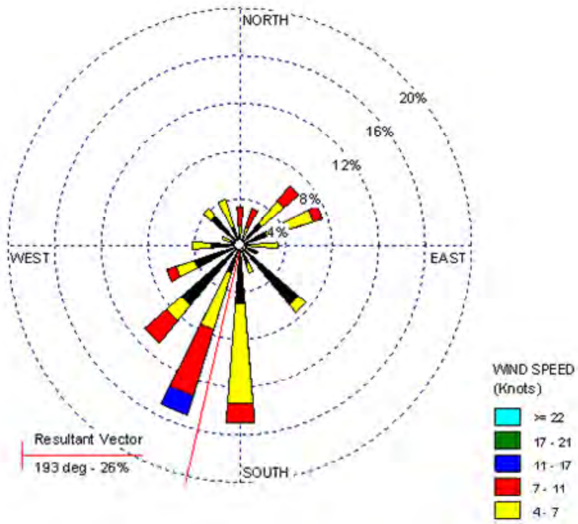

August



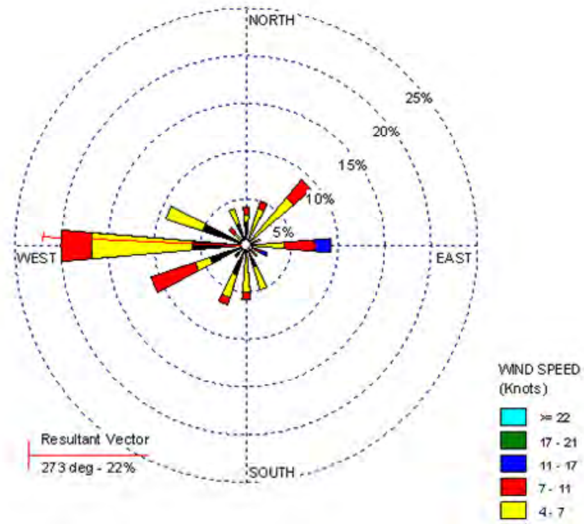

September



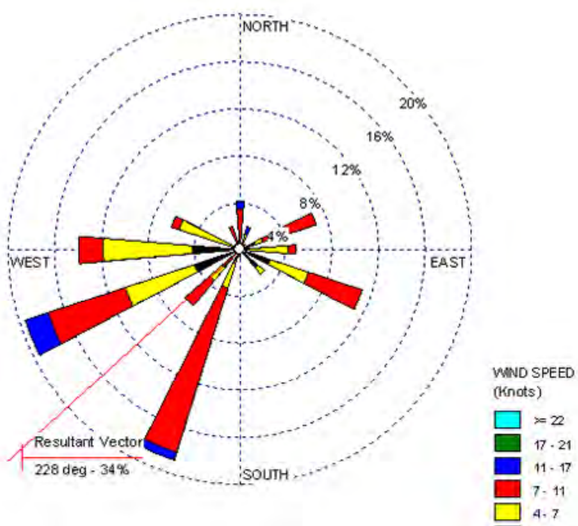

October



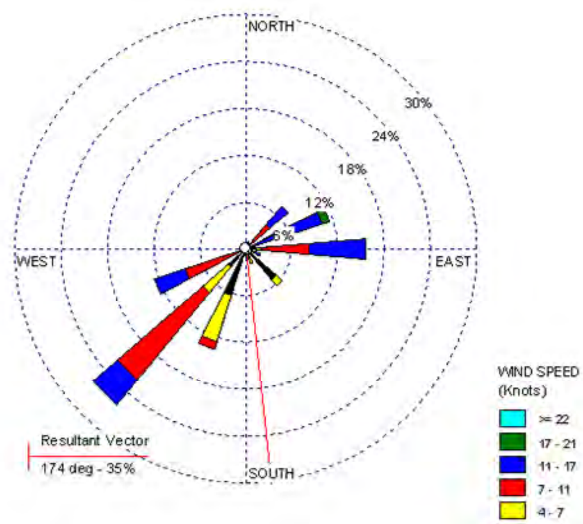
November



December



January



February

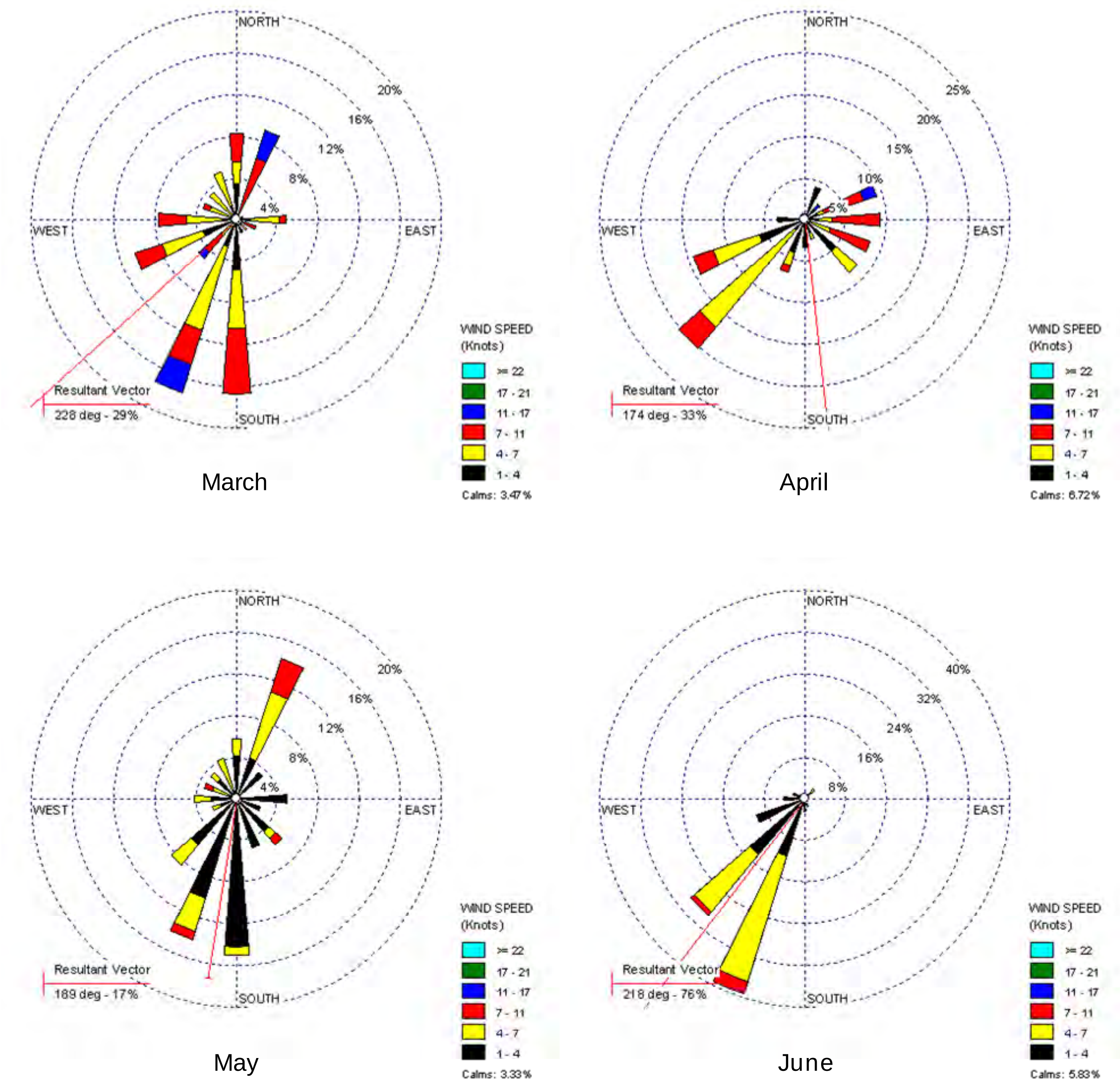



**Figure P.24.** Wind Roses for the Twelve Months of the Study Period.

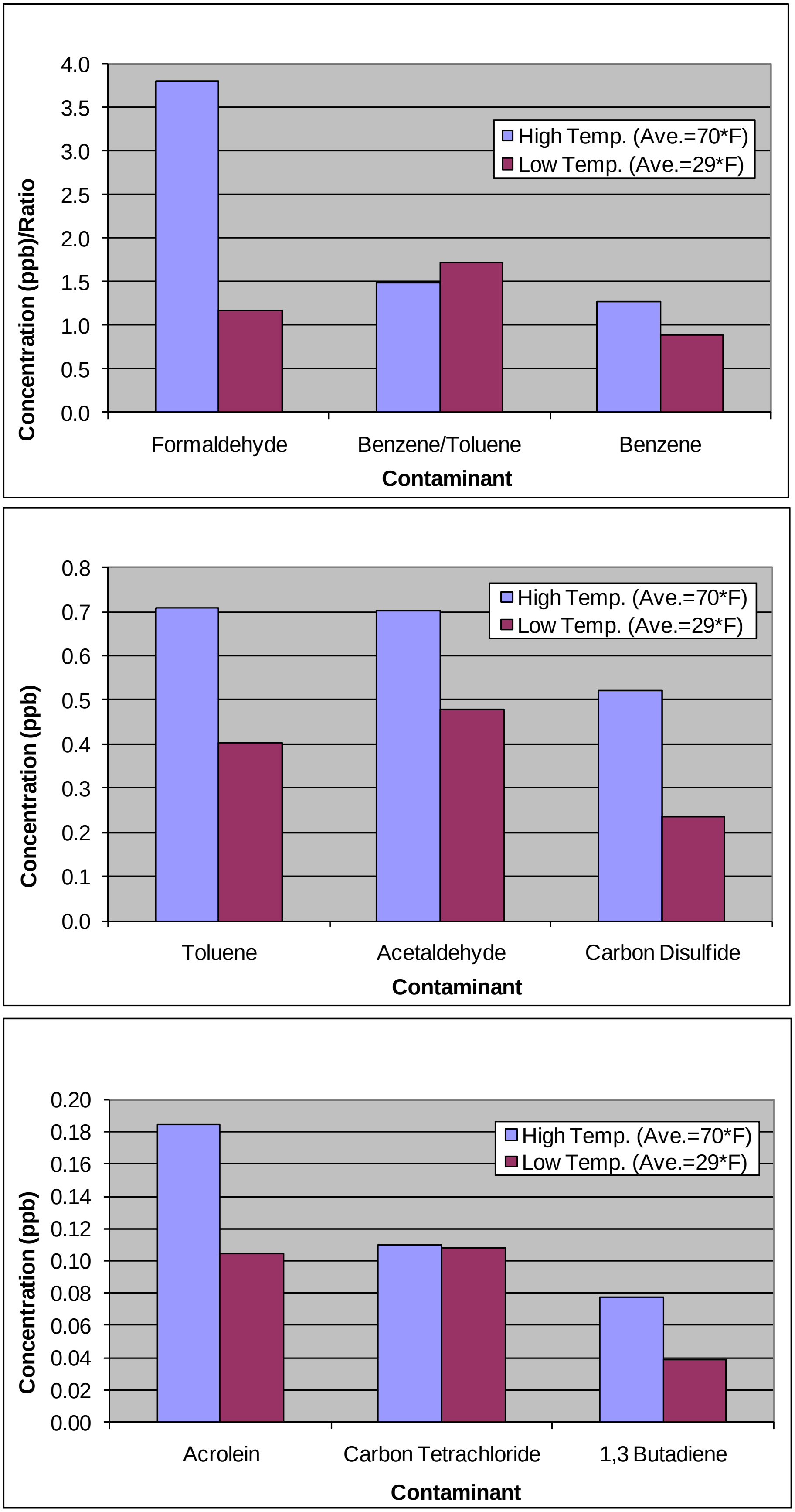
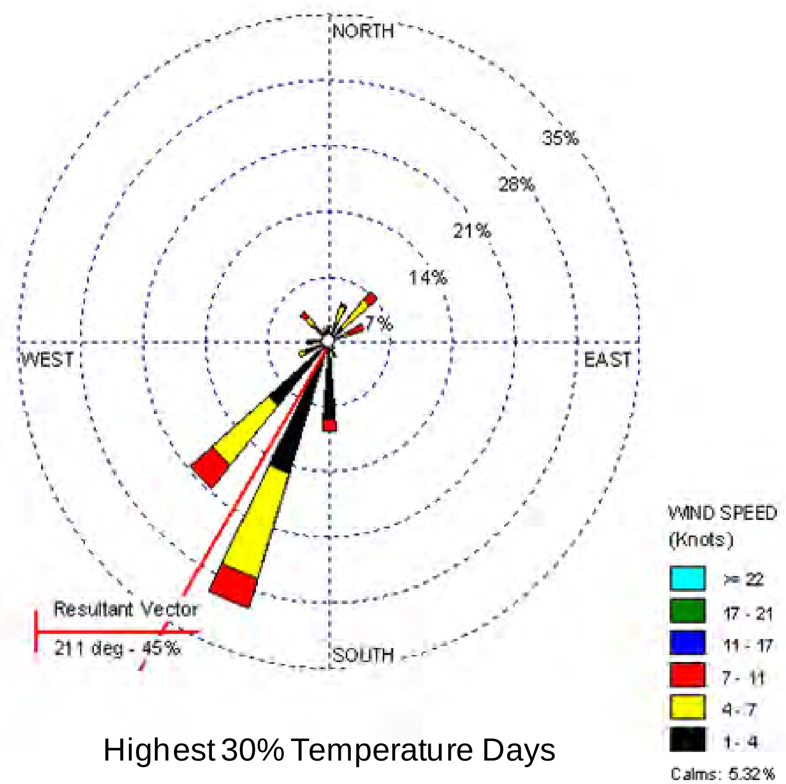



**Figure P.25.** Concentrations of Air Contaminants for the Highest 30% versus the Lowest 30% Temperature Days Combined.



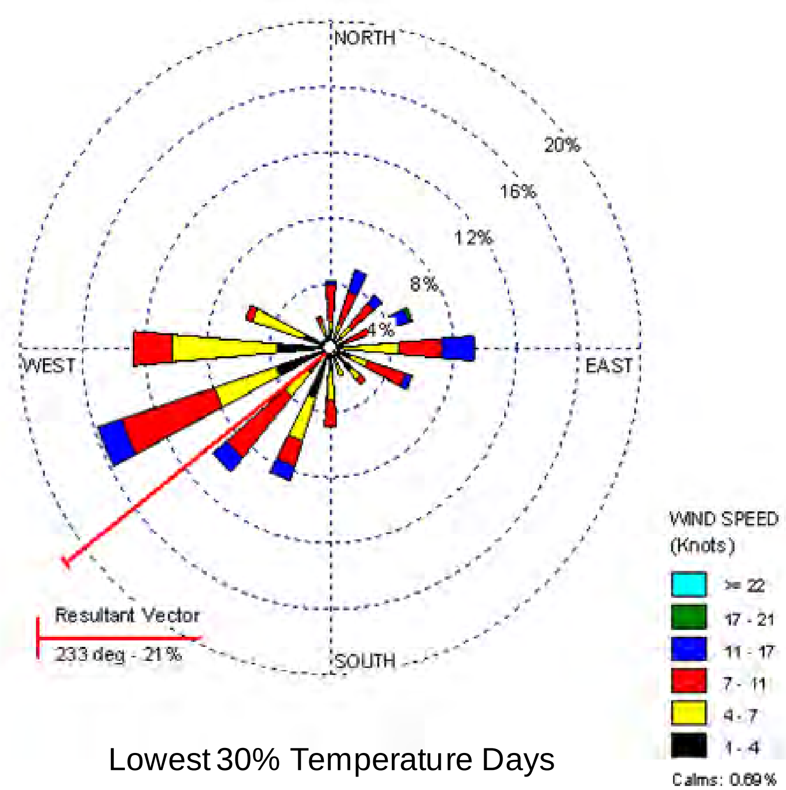




**Figure P.26.** Wind Roses for the Highest 30% versus the Lowest 30% Temperature Days Combined.