3.10 AN ANALYSIS OF URBAN SURFACE METEOROLOGY DATA COLLECTED PRIOR TO THE JOINT URBAN 2003 DISPERSION EXPERIMENT

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1. INTRODUCTION

The Joint Urban 2003 dispersion experiment took place in Oklahoma City in July 2003. Joint Urban 2003 experiment objectives included characterizing the airflow within a street canyon, within the central business district (CBD), and in the surrounding suburbs of Oklahoma City (Allwine et al. 2004). For nearly one full year prior to the field experiment, the West Desert Test Center (WDTC) Meteorology Division deployed an array of 15 automated weather stations mounted on light posts and rooftops in and around the CBD. These Portable Weather Information Display System (PWIDS) stations measured wind speed and direction, temperature, and relative humidity with a temporal resolution of 10 s. The primary purpose for the deployment of the PWIDS was to obtain wind flow data that could be used by the Joint Urban 2003 science team to optimize the placement of instrumentation and SF_6 dissemination sites during the July 2003 experiment.

In this paper, we use the PWIDS data to characterize the flow in and around Oklahoma City prior to the Joint Urban 2003 experiment. We examine similarities and differences in wind direction distributions between the 15 PWIDS sites. We also show how the wind varies during a typical day, and how it differs from rural sites with unobstructed flow.

2. INSTRUMENTATION

Each PWIDS is a portable meteorological measurement station that records wind speed, wind direction, temperature, and humidity (Storwold et al. 2002). Wind measurements are made using a R.M. Young model 05103 wind monitor. A Campbell CS500 Temp/RH probe is used to sample temperature and relative humidity. During Joint Urban 2003, data were collected every second, averaged over a 10 s period, and output to a serial port. The data were stored on a Campbell SM16M storage module. Power for each station was supplied using a Campbell PS12LA 12 Volt solar rechargeable power supply.

PWIDS are highly adaptable in terms of mounting configurations. During most field experiments, PWIDS are tripod mounted with measurements available at heights less than 4 m. In Oklahoma City, PWIDS were mounted on rooftop tripods (Figure 1), traffic light poles, street light posts, and on a 50 m tower.

Figure 1. Photo of a tripod-mounted PWIDS located on a roof in Oklahoma City.

Figure 2 shows the locations of the 15 PWIDS in Oklahoma City. PWIDS sites 1 through 10 were initially fielded on 24 June 2002. Sites 11 through 15 were added to the network on 16 November 2002. All stations were located in the CBD. PWIDS placement was based on the need to determine any channeling effects that might occur through street canyons. During the initial deployment, it was discovered that some of the stations within the CBD would not receive enough solar energy to keep the power supply fully charged. This problem resulted in lost data in October 2002, when there were several days of continuous cloudy skies.

The data recorded by PWIDS 1 through 10 quickly revealed the complexity of street-level winds within the Oklahoma City CBD, with significant differences in winds often occurring between different corners of the same intersection. The five additional PWIDS were added to provide wind measurements on all four corners of the intersections at either end of the portion of Park Avenue selected for the street canyon experiment and on two corners of the intersection of Broadway and Sheridan, near several of the SF_6 tracer release sites.

All PWIDS data have been subjected to a quality assurance program to insure high data quality. All sensors were calibrated before and after deployment, and the recorded data were put through various quality control tests, including an

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out-of-range check, an extreme value check, a missing data check, and visual inspection of time series quick look images. Questionable data were flagged to indicate the probable data quality. Only data that passed all quality control tests were used in this paper.

Rural meteorological data were obtained from the Oklahoma Mesonet (Brock et al. 1995). In this paper, we examine wind data from the Mesonet stations surrounding Oklahoma City, which include the El Reno (ELRE), Guthrie (GUTH), and Norman (NRMN) sites. Figure 3 is a photograph of a typical Mesonet station. All Mesonet stations are within 50 km of Oklahoma City, with ELRE located about 30 km to the west, GUTH approximately 40 km to the north-northwest, and NRMN roughly 30 km to the south. According to Brock et al. (1995), rural locations were selected for the Mesonet stations in an effort to avoid anthropogenic factors that can be observed in urban and suburban locations. Oklahoma Mesonet data are put through a rigorous quality assurance program, as described in Shafer et al. (1999).

Figure 3. Photograph of a typical Oklahoma Mesonet station.

3. DATA ANALYSIS

We used WDTC's Meteorological and Air Quality Statistical Analysis Program (MAQSAP) (Bjorklund and Geary, 1980) to examine both the urban and rural wind data. MAQSAP provides the joint frequency of occurrence of wind speed and wind direction for four time-of-day categories, as well as vector mean wind directions and speeds. Table 1 defines the time-of-day categories used in our analyses. Percent frequencies of occurrence distributions were then plotted as wind roses to more easily examine the data.

Table 1. Start and end times for the MAQSAP time-of-day categories.

TOD Category	Start Time	End Time
Morning	Sunrise + 1 Hr	Sunrise + 4 Hrs
Afternoon	Sunrise + 4 Hrs	Sunset – 1 Hr
Evening	Sunset – 1 Hr	Sunset + 2Hrs
Night	Sunset + 2 Hr	Sunrise + 1 Hr

3.1 *Urban Wind Analysis*

During instrumentation setup, it was speculated that PWIDS 1, 4, and 5 generally would observe a north-south wind regime. Figure 4 shows that the expected north-south channeled flow was observed at these sites. Similarly, we speculated that PWIDS 2 and 3 generally would observe an east-west channeled flow, which is seen in Figure 5. However, PWIDS 3 and 4 also show effects induced by the open plaza located directly to the east. The wind roses shown in Figure 6 for PWIDS 6, 7, 9, and 10 generally reflect their open surrounding, with prevailing wind flow rather than channeled flow.

To better understand the wind flow through a street intersection in the CBD, we mounted PWIDS on light posts on the four corners of the Robinson and Park intersection. The PWIDS were located roughly 15 m apart with PWIDS 11 on the northwest corner, PWIDS 12 on the northeast, PWIDS 2 on the southeast, and PWIDS 1 on the southwest. A comparison of the data collected at these four stations is shown in Figure 7. An east-west wind distribution is primarily seen at PWIDS 2, 11, and 12, while a southerly flow is most prominent at PWIDS 1. However, roughly 20% of the time an east-west flow was recorded by PWIDS 1. While the wind flow generally appears to be channeled east and west through the intersection, each location experienced subtle variations in the wind. The causes of these variations are unclear, but they could be a result of eddies or the wake of nearby objects. In any case, the wind regime seen at the Robinson and Park intersection is extremely complex.

Examination of wind variations between the four time-of-day categories reveals only minor changes in the wind flow characteristics throughout the day. However, Hall and Basra (2004) noted a diurnal wind variation during the July 2003 Joint Urban experiment. They noticed wind variations at the beginning of the day, when surface heating and mixing occurred, and at the end of the day, when a decoupling of the urban boundary layer from the overlying flow took place. Ultimately, a more in-depth analysis should be conducted to better understand the diurnal wind variability of the Oklahoma City urban environment.

3.2 *Urban/Rural Wind Comparison*

We used the same procedures to analyze the Oklahoma Mesonet as we used to analyze the

PWIDS data. As shown in the wind roses in Figure 8 for ELRE, GUTH, and NRMN, the large-scale flow surrounding Oklahoma City is generally from the southwest to southeast, with a secondary peak frequency for winds from the north.

Figure 8 shows only a small diurnal variation in the Mesonet winds. In the morning, the peak in the wind direction frequency of occurrence is from the south-southwest, while in the evening the peak is from the south-southeast. Further analysis should reveal what, if any, influence these large-scale directional variations have on the winds observed in the urban environment.

Comparison of the PWIDS wind roses in Figures 4 through 6 with the Oklahoma Mesonet wind roses in Figure 8 shows that winds in relatively open areas on the edge of the Oklahoma City CBD (Figure 6) are similar to the rural winds (Figure 8), although the most frequent urban wind directions are spread over a broader sector centered on south than the most frequent rural wind directions. Also, the peak in the frequency of occurrence of northerly winds at the rural locations is absent in the wind roses for PWIDS 6, 7, 9, and 10 (Figure 6). All of these PWIDS are on the south side of the CBD, which places them in the wake of the CBD when the large-scale flow is from a northerly direction. In contrast to the PWIDS at relatively open sites, the wind roses for the PWIDS within street canyons (Figures 4 and 5) show that the street-level flow is mostly parallel to the street.

4. SUMMARY

In preparation for the Joint Urban 2003 dispersion experiment, the WDTC Meteorology Division deployed an array of 15 PWIDS for nearly a full year preceding the experiment. The meteorological data gathered by these instruments were used to characterize the flow in and around the city. Analyses of the PWIDS data helped the Joint Urban 2003 science team optimize instrument placement and the locations of dissemination sites. The PWIDS measurements made prior to the Joint Urban 2003 experiment are included in the experiment database.

In this paper, we have briefly discussed the Oklahoma City urban wind flow as was observed by the PWIDS climatology network. As expected, wind flow within the CBD tends to be highly influenced by the surrounding structures. PWIDS located in the street canyons recorded channeled flow. Depending on the placement of the instrument within the CBD, either a north-south or east-west flow was observed. Instruments located in more open settings within the city generally recorded more of the prevailing wind flow and lesser channeling effects. However, when winds from these sites are compared with the rural wind data, it is apparent that these PWIDS also experience urban influences, especially when the large-scale flow is from a northerly direction.

The results presented here are only a first look at the complex wind flow through Oklahoma City. Future work should attempt to better understand how the flow within the city is affected by the large-scale wind characteristics.

5. ACKNOWLEDGEMENTS

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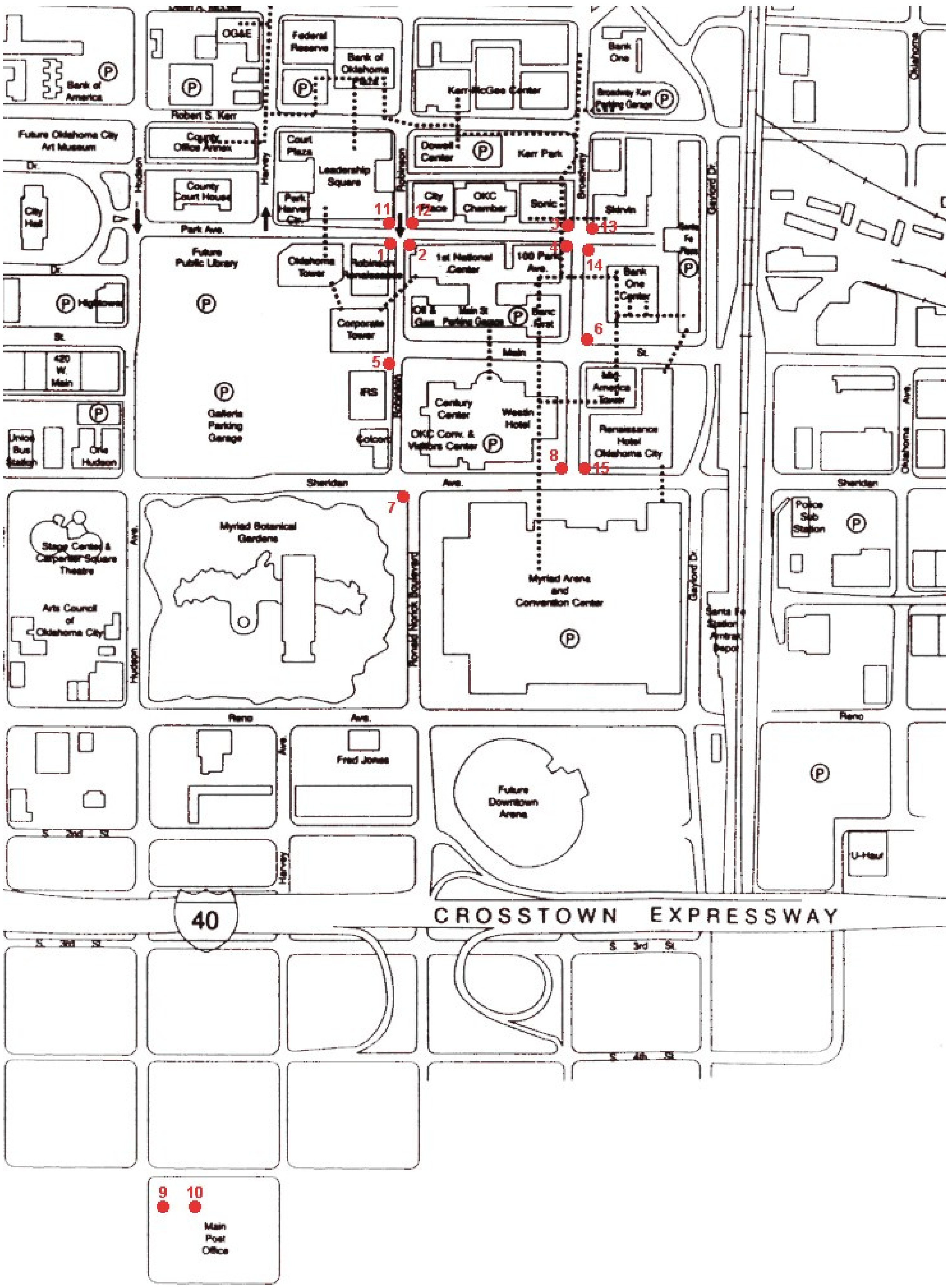

Figure 2. A map showing the locations of the 15 PWIDS stations within the Oklahoma City central business district.

PWID #1, PWID # 4, PWID # 5
July 2002 to May 2003
Percent Frequency of Occurrence
for All Wind Speeds

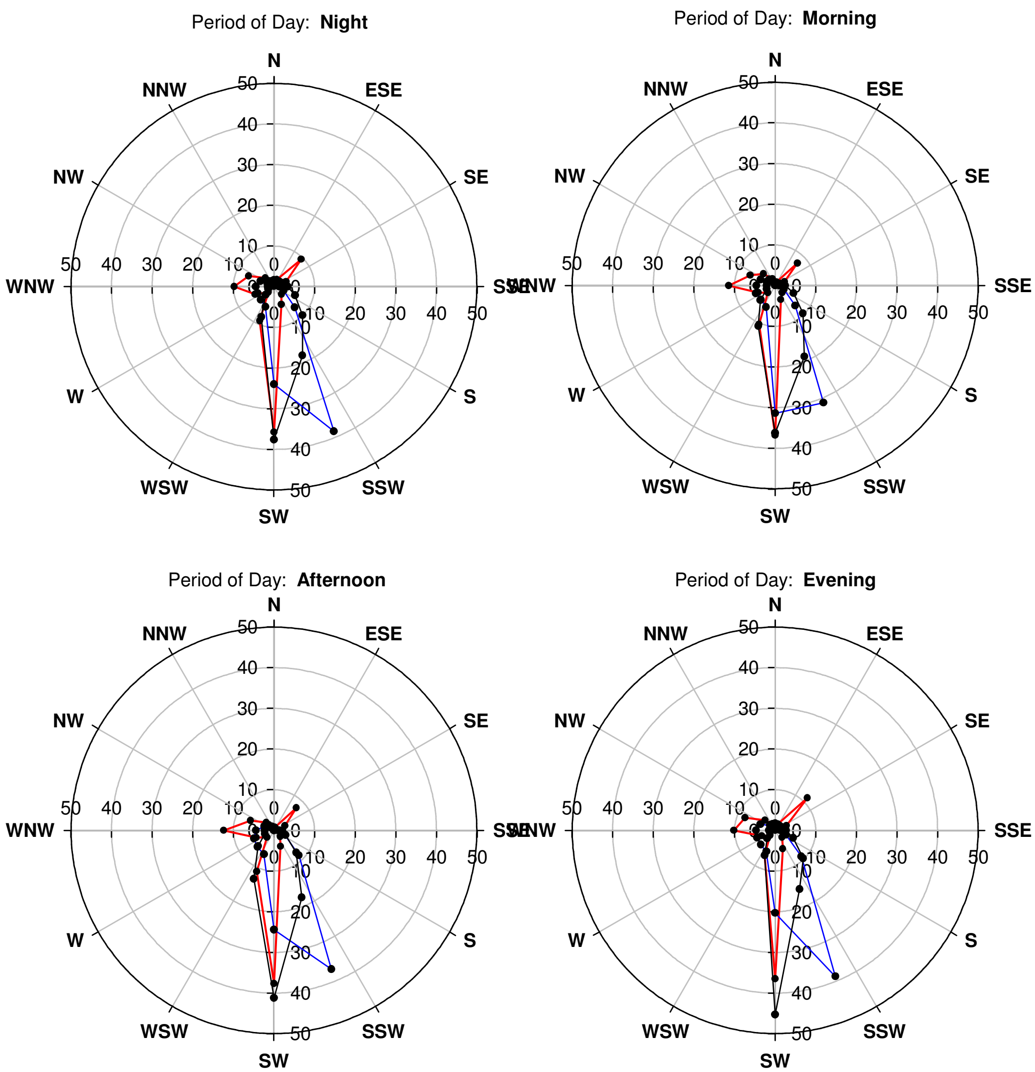

Figure 4. Wind direction frequency of occurrence plots for PWIDS 1 (red), 4 (blue), and 5 (black) for the night, morning, afternoon, and evening time-of-day categories.

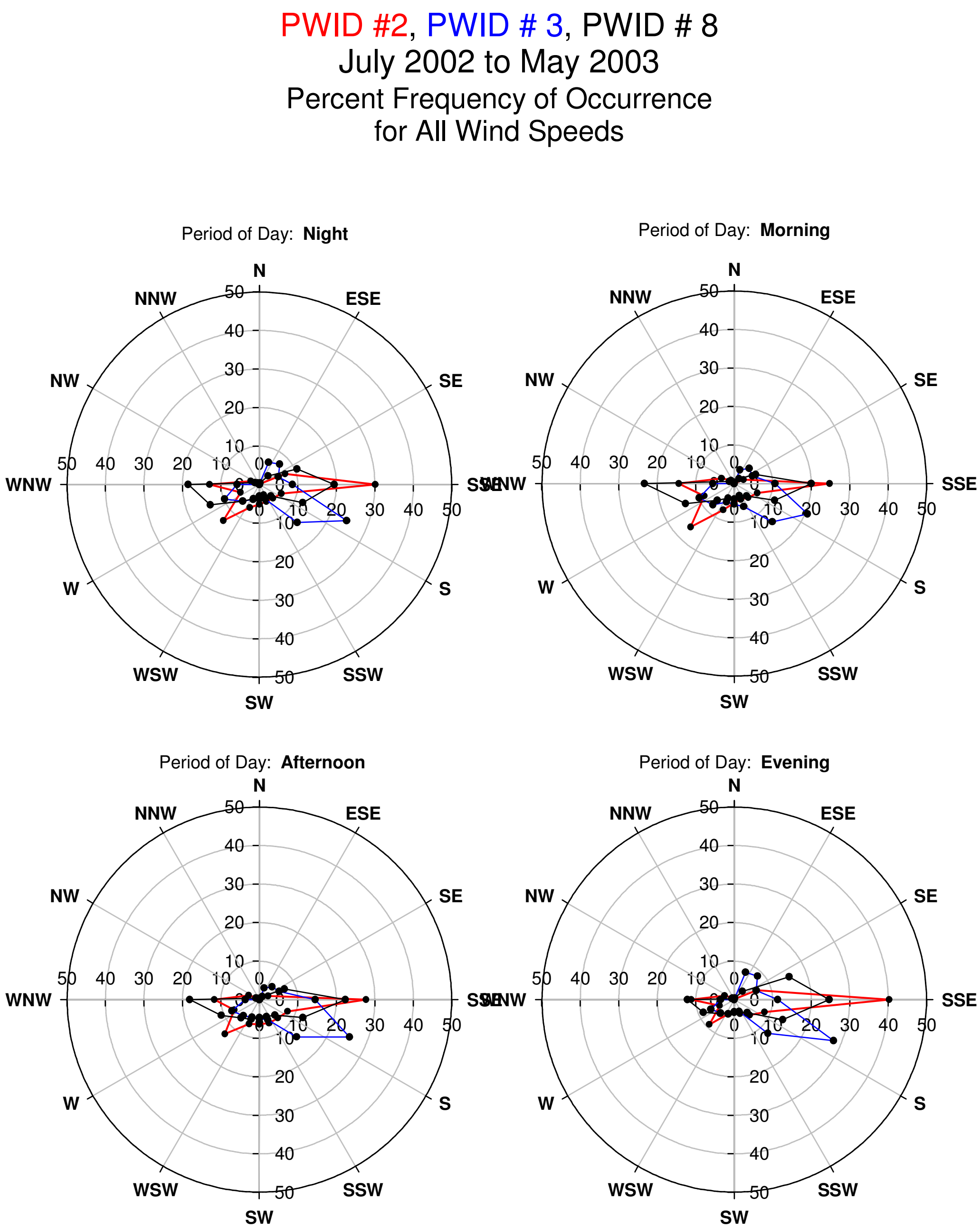

Figure 5. Wind direction frequency of occurrence plots for PWIDS 2 (red), 3 (blue), and 8 (black) for the night, morning, afternoon, and evening time-of-day categories.

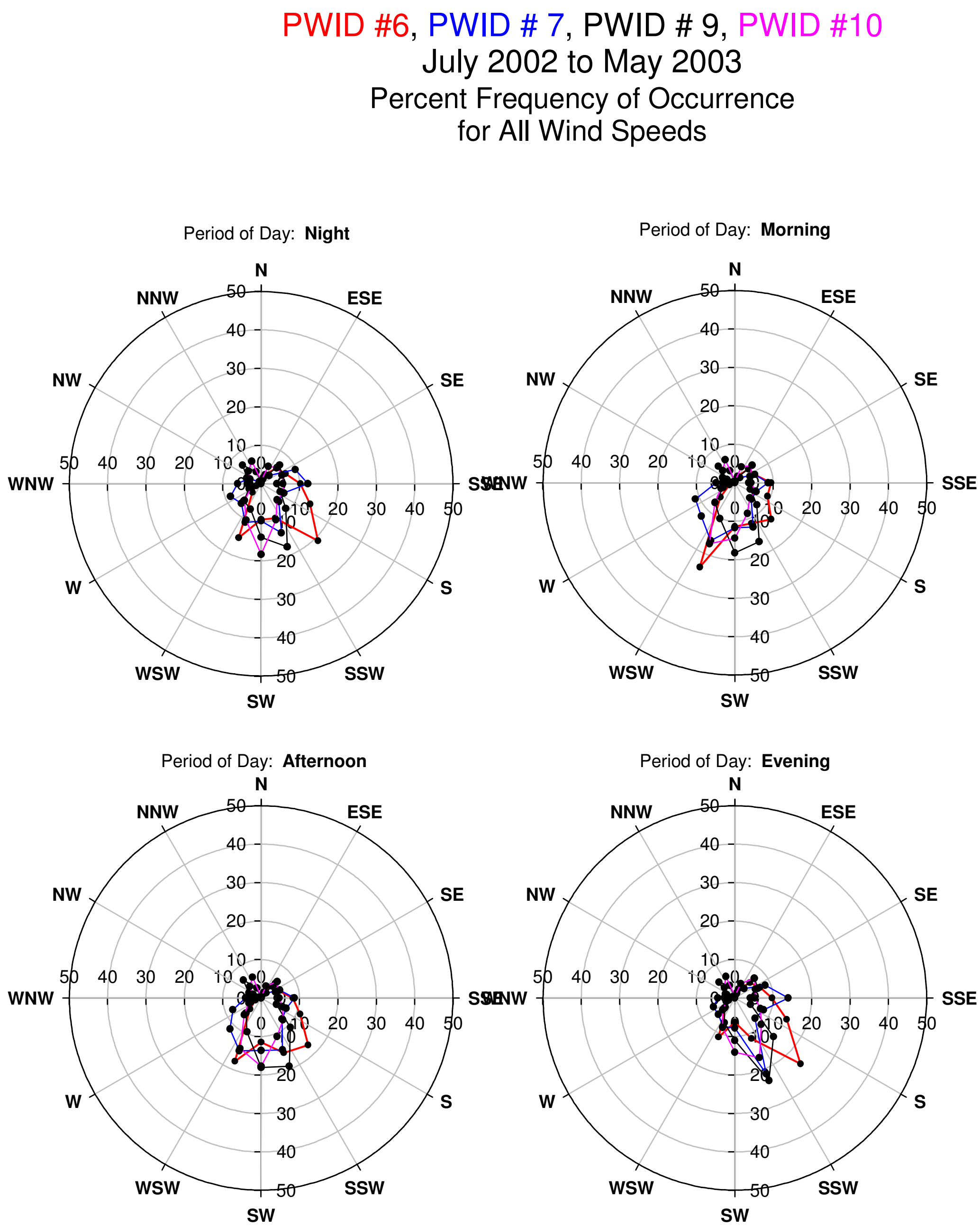

Figure 6. Wind direction frequency of occurrence plots for PWIDS 6 (red), 7 (blue), 9 (black), and 10 (pink) for the night, morning, afternoon, and evening time-of-day categories.

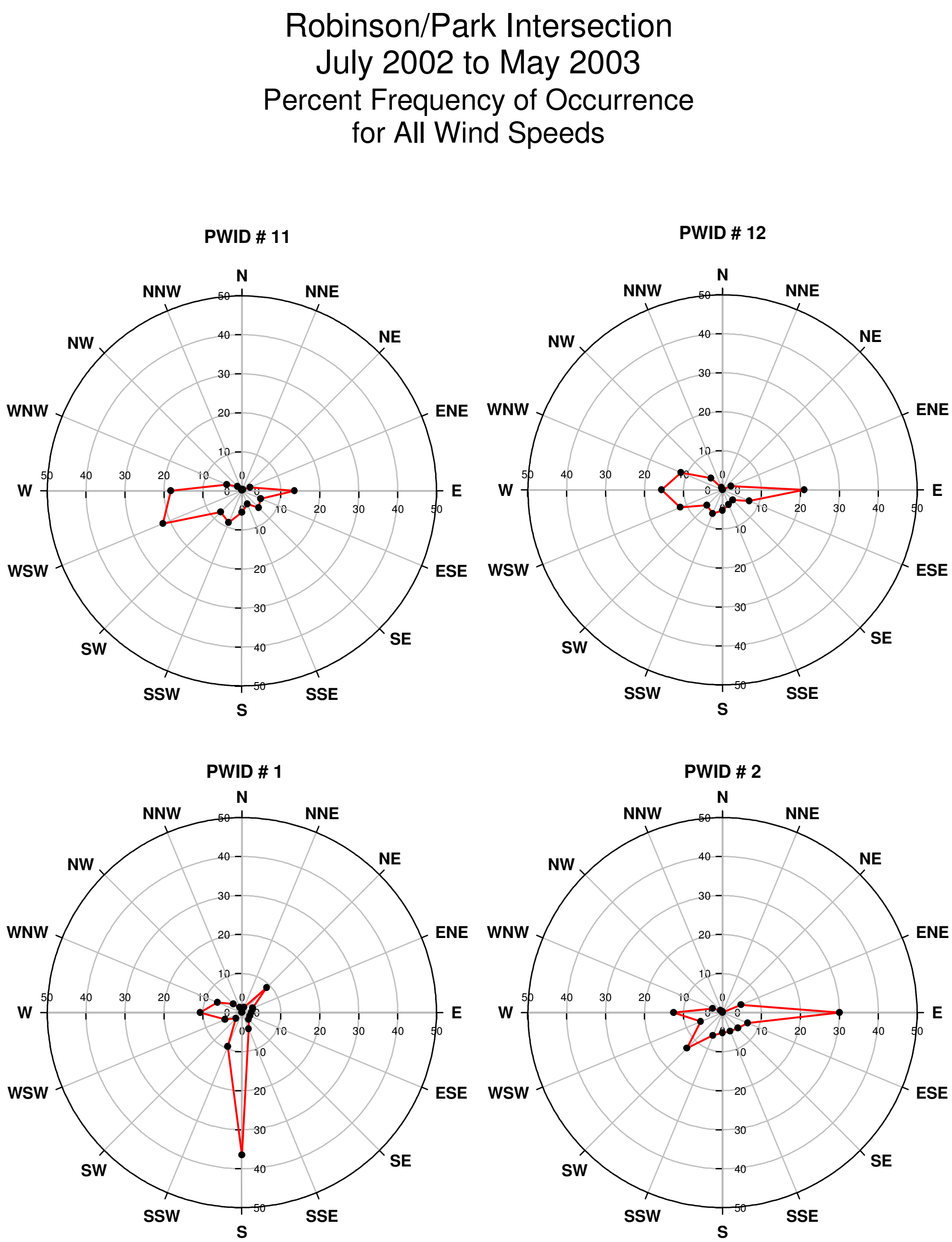

Figure 7. Wind direction percent frequency of occurrence plots for PWIDS 11 (top left), 12 (top right), 1 (bottom left), and 2 (bottom right), which were located at the four corners of the Robinson and Park intersection.

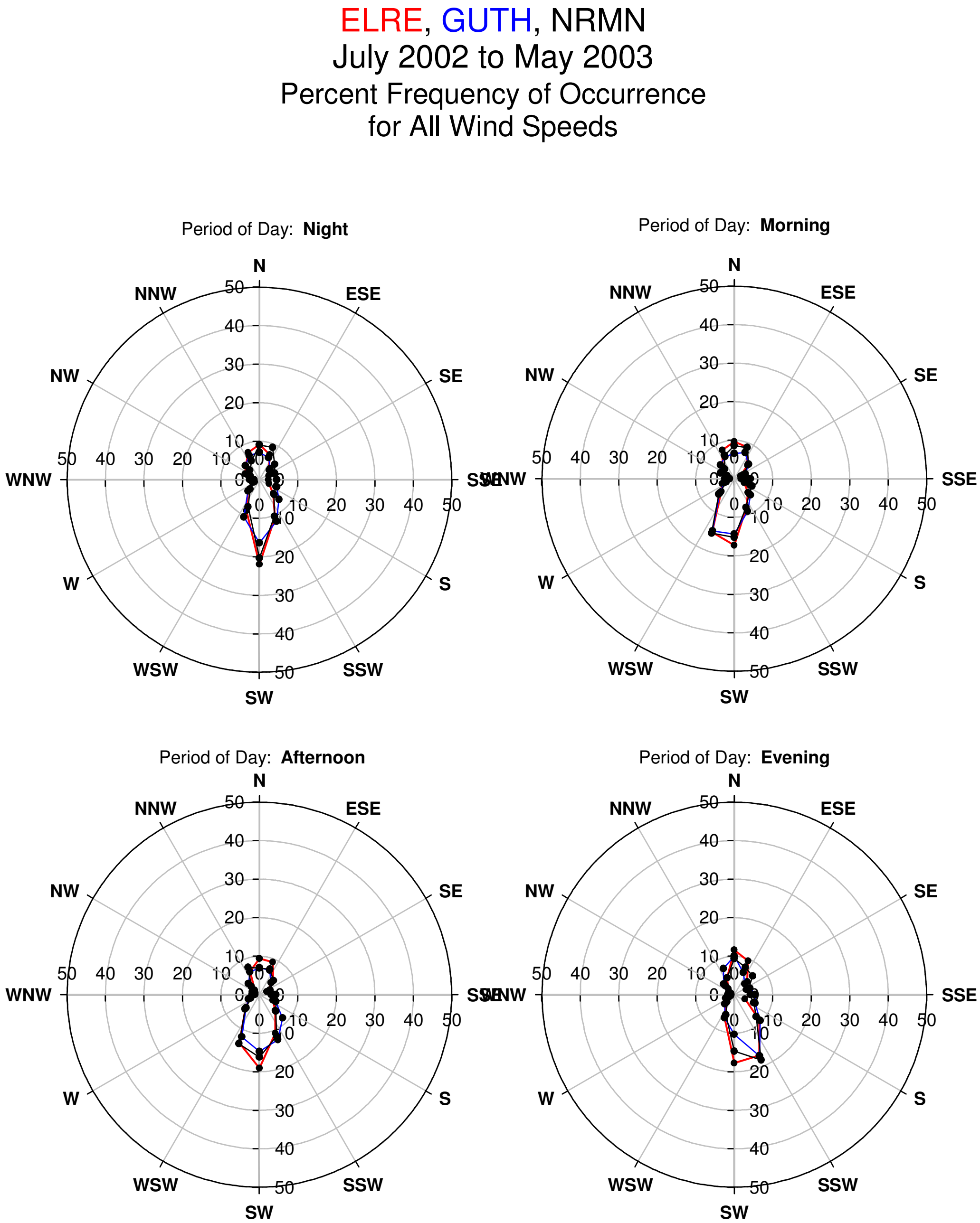

Figure 8. Wind direction frequency of occurrence plots for the Oklahoma Mesonet Stations ELRE (red), GUTH (blue), and NRMN (black) for the night, morning, afternoon, and evening time-of-day categories.