ISOLATING MICROSCALE PHENOMENA FROM MESOSCALE OBSERVATIONS

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1. INTRODUCTION.

A mesoscale observation network, such as the Oklahoma Mesonet (Brock et al. 1995) can be regarded as a network that observes microscale phenomena with mesoscale resolution. Similar "mesonets" have been proliferating across the United States. These networks rely on the assumption that each site is representative of its mesoscale region. Thus, site locations should be carefully selected to minimize the impact of sub-mesoscale land features on the observations.

In reality, no single point can truly be representative of a mesoscale region. All "mesonet" sites are surrounded by microscale land features such as trees, sloped terrain, lakes, and cities. Each has the potential to impact the observations. The purpose of this paper is to isolate microscale anomalies from "mesoscale" observations and estimate their magnitudes.

This paper will focus on wind speed and temperature as measured by the Oklahoma Mesonet. Wind speed anomalies indicate how well a site is exposed to the surrounding flow. Because nighttime temperature is strongly affected by wind speed, nighttime temperature anomalies will be examined as a possible side effect of anomalous site exposure. The temperature anomalies also will be used to detect downwind effects of meso-gamma scale features such as cities and lakes.

2. METHODOLOGY

The Oklahoma Mesonet is a statewide network of 115 automated weather stations. At least one Mesonet site is located in each county of the state, and the average distance between sites is 32 km (Brock et al. 1995). The data used in this study are Mesonet observations averaged over the last five minutes of each hour. Between January 1994 and December 2002, approximately 80,000 observations per Mesonet site were acquired; they serve as the basis for this study.

Observations of wind speed and temperature at each Oklahoma Mesonet site from 1994-2002 were averaged and stratified by wind direction in 5-degree increments. The observed variables at each site also were averaged over the 8-year period and compared with the statewide averages for each 5-degree increment in wind direction. The resulting "anomalies" were plotted as a function of wind direction, in effect, creating a microscale "fingerprint" of each Mesonet site.

Because small obstructions to the wind are not likely to have as direct an impact under unstable stratification, the observations were limited to the nighttime hours, defined in this study as 9:00 PM to 6:00 AM local standard time. To ensure that the observations of wind direction were reliable, the procedure only used observations with a standard deviation in the wind speed of less than 10 degrees during the 5-minute sampling period. To reduce noise and account for routine deviations in the wind direction, the data at each site were smoothed using a simple low pass filter – the final value of variables for each 5-degree increment in wind direction was equal to 50% of the observed value within that wind direction increment, plus 25% of the values measured at the two adjacent 5-degree increments.

The remainder of this manuscript focuses on the results at 4 Oklahoma Mesonet sites: Putnam, Blackwell, Clayton and Bixby, and several adjacent sites (Fig. 1).

Figure 1. Map of Oklahoma Mesonet sites discussed in this paper.

3. RESULTS

The stratification of wind speed by wind direction across Oklahoma revealed the strongest winds were from the south (4.8 m/s) or from the north (4.1 m/s); the weakest winds were from the east (2.4 m/s) or the west (2.8 m/s; Fig. 2).

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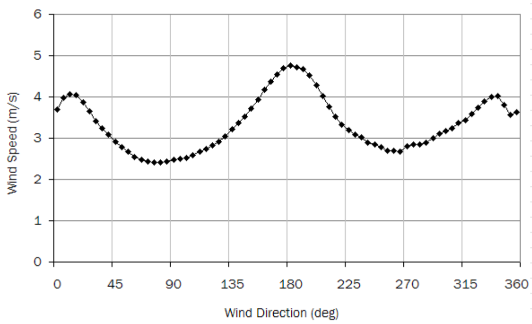

Figure 2. Average nighttime wind speed across Oklahoma as a function of wind direction.

Average statewide nighttime temperatures across Oklahoma ranged from 5.7°C with west-northwest wind to 17.0°C with south-southeast wind (Fig. 3). A sharp decline in nighttime temperature was observed between southerly and westerly wind directions.

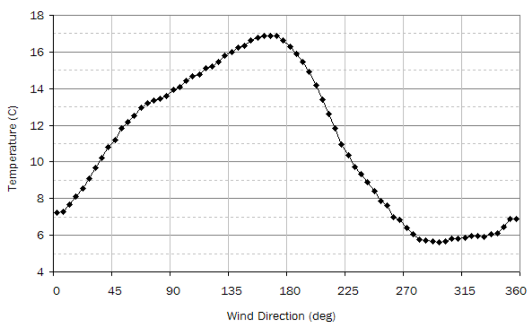

Figure 3. Average nighttime temperature across Oklahoma as a function of wind direction.

Wind speed anomalies (direction-dependent wind speed biases) were 50% or greater than the statewide mean wind speed at approximately 50% of the Oklahoma Mesonet sites. The sites with the smallest wind speed anomalies were generally very flat sites in Western Oklahoma with few trees nearby. One such site was Putnam, located on a flat plateau surrounded by grassland and cropland.

Because of its location in western Oklahoma atop a plateau, average observed wind speeds were greater than the statewide mean (Fig. 4). Because of the flatness and uniformity of vegetation around the site (note the panoramic site photo at the bottom of the figure), wind speed anomalies at Putnam deviated less than 25% with wind direction.

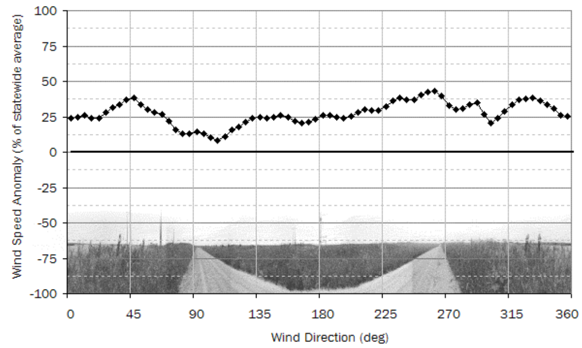

Figure 4. Average nighttime wind speed anomaly at Putnam, OK as a function of wind direction.

The range of wind speed anomalies at Putnam was among the lowest of all Oklahoma Mesonet sites. The analysis of adjacent sites revealed larger anomalies, which suggested that the wind fetch was not as pure as that at Putnam (Fig. 5).

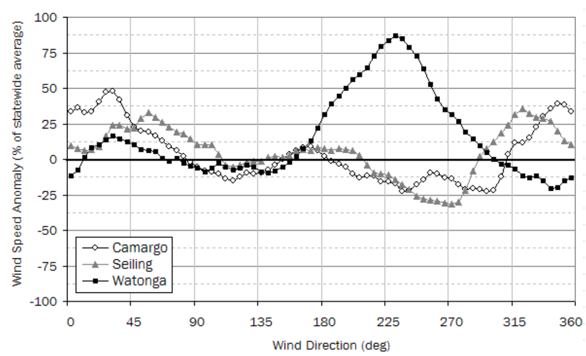

Figure 5. Average nighttime wind speed anomalies at Camargo, Seiling, and Watonga as a function of wind direction.

At Watonga, the eight-year average southwest wind was 87% stronger than the statewide average. The anomaly was apparently created by the downward sloping terrain southwest of the Watonga site. On the other hand, southwest winds at Camargo and Seiling were weaker than the statewide mean, probably because the terrain was higher southwest of the Camargo site and trees were west and southwest of the Seiling site.

Strong wind increases turbulent mixing, which offsets nighttime radiational cooling near the surface. Weak wind allows a stronger inversion to develop, resulting in cooler temperatures near the surface. Thus, microscale wind speed anomalies were hypothesized to produce similar anomalies in nighttime temperatures.

The Blackwell Mesonet site offered an excellent setting to study this hypothesis. Blackwell is located in north-central Oklahoma, a region where wind speeds are close to the statewide average. The terrain around the site is slightly higher south to southeast of the site, and slightly lower northwest to northeast of the site. A small house surrounded by a group of tall trees is located southeast of the site. Scattered trees are located south-southwest and west of the site. The average nighttime wind speed anomalies revealed a pronounced impact of the trees and terrain (Note the panoramic site photo at the bottom of the figure; Fig. 6).

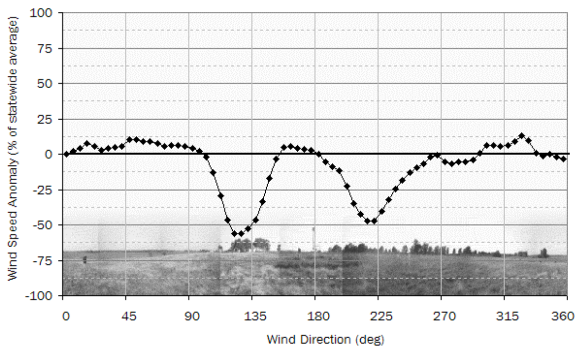

Figure 6. Average nighttime wind speed anomaly at Blackwell, OK as a function of wind direction.

Southeast winds at Blackwell were 56% lower than the statewide average, and southwest winds were 47% lower than the statewide average. The low wind speed anomalies corresponded well with the trees and higher terrain near the site. For all directions, wind speed anomalies were proportional to tree density, except toward the northwest where the trees were farther away such that their impact was offset by lower terrain. Average nighttime (cool) temperature anomalies corresponded well with the (low) wind speed anomalies (Fig. 7).

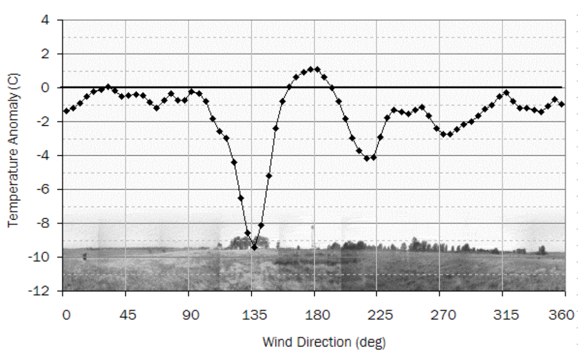

Figure 7. Average nighttime temperature anomaly at Blackwell, OK as a function of wind direction.

The simple correlation between the wind speed and temperature anomalies was 0.773. The two large negative (cool) temperature anomalies coincided with the two large negative wind speed anomalies. With a southeast wind, the average nighttime temperature at Blackwell was an astounding 9.4°C cooler than the statewide average. However, with a southerly wind, the nighttime temperature at Blackwell was 1.1°C higher than the statewide average.

To determine whether the wind speed and temperature anomalies at Blackwell were representative of the mesoscale region, anomalies at the three nearest Mesonet sites (Newkirk, Burbank, and Medford) were investigated (Fig. 8).

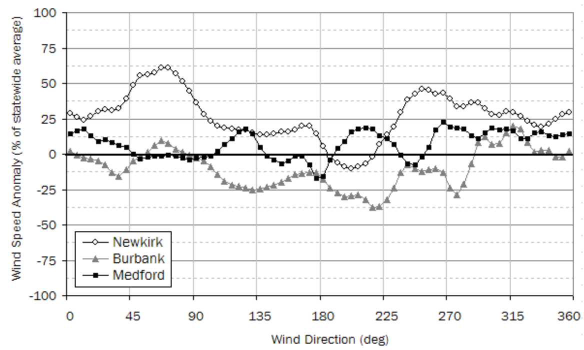

Figure 8. Average nighttime wind speed anomalies at Newkirk, Burbank, and Medford as a function of wind direction.

Wind speed anomalies at the three nearest Mesonet sites were not consistent with the wind speed anomalies detected at Blackwell. Thus, the southeast wind speed anomaly of -56% had to result from a process that occurred on a scale smaller than the distance to the nearest Mesonet sites. The variability between the three nearest sites suggests that each site is subject to significant sub-mesoscale modification of the wind field.

Temperature anomalies at the three nearest sites do not resemble the anomalies observed at Blackwell (Fig. 9). Thus, the processes responsible for the –9.4°C temperature anomaly with southeast winds at Blackwell also occurred on a smaller scale than the distance between sites.

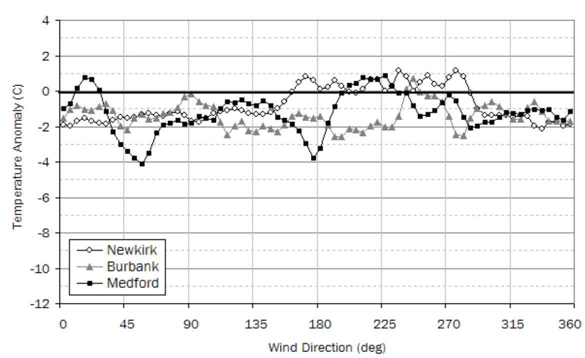

Figure 9. Average nighttime temperature anomalies at Newkirk, Burbank, and Medford as a function of wind direction.

At some sites, it was not clear whether the temperature anomalies were created by microscale land features. For example, the Clayton Mesonet site is located near the eastern edge of Sardis Lake. At Clayton, the average off-lake wind speed was approximately double the magnitude of wind speeds from other directions. Warm nighttime temperature anomalies of 5°C also coincided with wind from the direction of the lake. It cannot be concluded whether the anomalies were caused by enhanced vertical mixing by stronger wind, advection of air that was heated by the lake, or both.

At some sites, nighttime temperature anomalies did not correspond with wind speed anomalies. For example, the Bixby Mesonet site is located near the south-southeast edge of the Tulsa metropolitan area. North to northwest winds at Bixby were 50-75% weaker than the statewide average. However, temperatures with those winds were over 3°C higher than the statewide average. Nighttime temperature anomalies over 3°C at Bixby only occurred with north to northwest winds. Thus, the 3°C temperature anomaly when winds were north to northwest was likely a downwind effect of the large urban area.

4. CONCLUSIONS

The analyses showed that microscale land features near the Mesonet sites, including trees and sloped terrain, create substantial anomalies in the nighttime wind speed observations. These wind speed anomalies created corresponding temperature anomalies in many cases. The wind and temperature anomalies also indicated the magnitude of the impact of microscale surface features and the downwind effects of meso-gamma scale features.

The unique meteorological "fingerprints" at each Mesonet site should be considered when interpreting Mesonet observations and using Mesonet observations in numerical models.

Based on extensive investigations of Mesonet data from 115 sites during an eight-year period, it is the author's strong opinion that all surface data is impacted by microscale landscape features near the observation site. Thus, let the user beware!

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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