7.2 THE REPRESENTATIVENESS OF SKIN TEMPERATURE MEASUREMENTS AT OKLAHOMA MESONET SITES

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1. Introduction

Physical processes that exchange mass and energy between the atmosphere and the land surface involve surface. The relationship between surface conditions and atmospheric processes has been documented across a number of spatial and temporal scales including the diurnal cycle of the planetary boundary layer (PBL; Betts and Ball 1995). The relationships also impact baroclinic disturbances and precipitation patterns (Castelli et al. 1996) and produce anomalies associated with large-scale features such as drought and flood (Koster et al. 2000).

Unfortunately, observations of surface conditions are limited. Yet, the need for such observations has been addressed in recent articles such as Emanuel et al. (1995) and Entekhabi et al. (1999).

Recognizing the need for improved in situ measurements, the Oklahoma Mesonet (Brock et al. 1995), an automated network of 115 remote, meteorological stations across Oklahoma, has integrated additional sensing devices to compliment the standard suite of meteorologic and hydrologic sensors. In addition to providing observations such as air temperature and humidity, station pressure, and wind speed and direction, nearly 100 sites were outfitted with soil thermistors, sensors to measure latent, sensible, and ground heat fluxes, net radiometers, heat dissipation probes to estimate soil moisture, and infrared temperature sensors (IRTs) to measure surface skin temperature.

Skin temperature (T_S), commonly defined as the temperature of the interface between the surface and the atmosphere, is a key variable critical to land-atmosphere interactions. In 1999, infrared temperature sensors (IRTs) manufactured by Apogee Instruments, Inc. (Bugbee et al. 1998) were installed at 89 sites (Fiebrich et al. 2002).

During 2002 a project was designed to investigate the representativeness of skin temperature measurements at Oklahoma Mesonet sites. First, field measurements of skin temperature collected at and near Mesonet sites were compared with Mesonet IRT observations. Second, two Mesonet sites in close proximity (approximately 3 km) were compared to determine the variability of skin temperature on the order of kilometers.

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2. Data

2.1 Oklahoma Mesonet Data

The Oklahoma Mesonet (Brock et al. 1995) is an automated network of 115 meteorological stations evenly spaced across the state (Fig. 1). Each Mesonet site measures solar radiation, air pressure, precipitation, wind speed and direction at 10 m, temperature and relative humidity at 1.5 m, and bare soil and sod temperatures at 10 cm depth. A majority of sites also measure wind speed at 2 m and 9 m, temperature at 9 m, net radiation, soil moisture at 5, 25, 60, and 75 cm depths, and soil temperatures at 5 cm and 30 cm. Observations from Mesonet sites are acquired at intervals of between 5 and 30 minutes and are subjected to rigorous QA procedures (Shafer et al. 2000).

During 1999, infrared temperature sensors (IRTs) manufactured by Apogee Instruments, Inc. (Bugbee et al. 1998) were installed at 89 sites (Fiebrich et al. 2002). The accuracy of the IRT sensor is approximately +/- 0.2 K from 288 to 305 K and +/- 0.3 K from 278 to 318 K (Bugbee et al, 1998). IRT data were collected at 5 minute intervals and Quality Assured using a number of techniques discussed in Shafer et al. 2000. Any data which did not meet these QA parameters were not included in this study.

2.2. Field Measurements

During 2002 skin temperature measurements were collected at Mesonet sites using handheld sensors. Between the dates of 8 May 2002 and 8 August 2002, eighty-four site visits were made to 12 different Mesonet sites (Fig. 1). During each visit, which occurred between 1400 UTC and 0200 UTC (0900 to 2100 LST), seventeen discrete infrared skin temperature measurements were collected at predetermined locations over a 900 square meter area encompassing the Mesonet site (100 square meters) and portions of the adjacent landscape. In addition to the IRT measurements, basic atmospheric observations and site conditions were

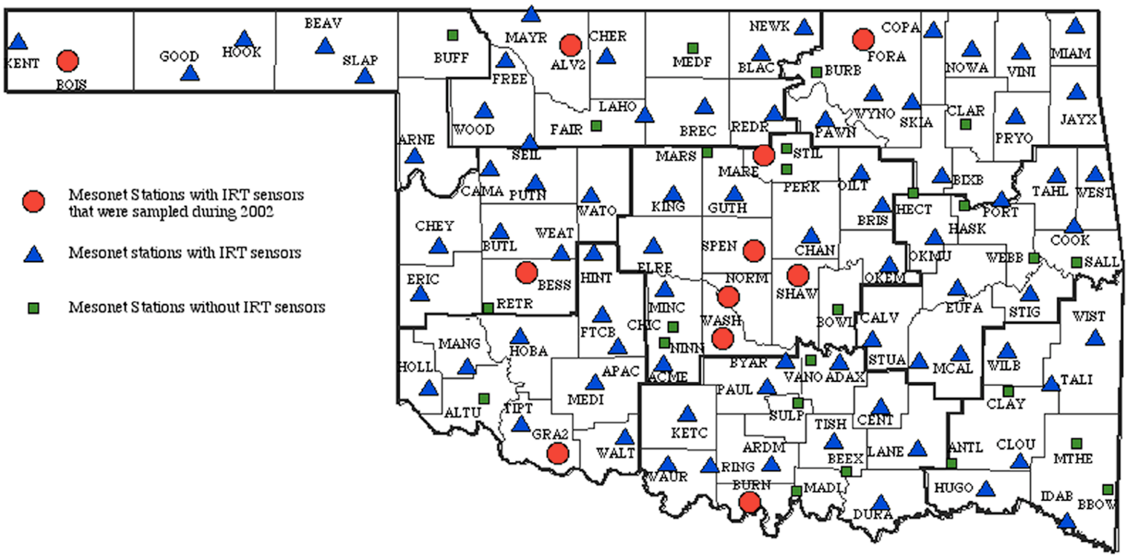

Figure 1. The Oklahoma Mesonet.

observed.

3. Analysis of Field Measurements

The mean range of Ts values including all Mesonet sites sampled during the study was 9.7^{o}C. In addition, the standard deviation was 5.0^{o}C. The frequency of the ranges (Fig. 2) was a quasi-normal distribution, but with a standard deviation of 5.0, there was a significant amount of variance. For a single site visit, the smallest range of skin temperature values was 1^{o}C, while the largest range was 21.6^{o}C.

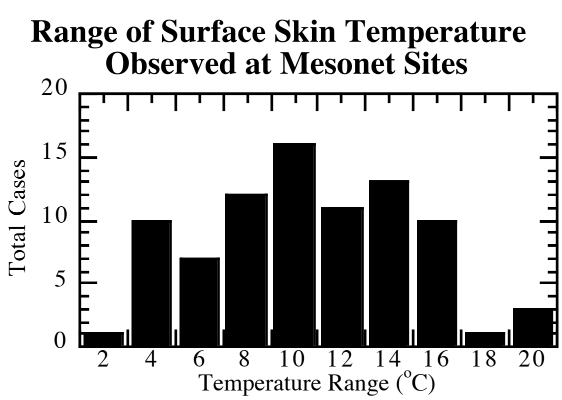

Figure 2. The frequency of the range of T_S observed at Mesonet sites during 2002.

The mean temperature (from all seventeen measurements) for individual site visits was compared to the range of temperatures for the same visit. A positive correlation (R^2 value of 0.788) between the average site temperature and the range of temperatures across the site. Thus, as the average temperature increased at the site, the temperature range across the site also increased.

Finally, field measurements were compared with observations of T_S obtained from the Apogee sensors mounted on the Mesonet tower. Overall the Mesonet T_S values compared well with the field measurements. Field observations collected within the field of view (FOV) of the Apogee sensor had a slight negative bias (-0.46^{o}C), a standard deviation of 2.40^{o}C, and a root mean squared difference (RMSD) of 2.43^{o}C. Furthermore, the overall correlation between the field measurement in the FOV of the Apogee instrument and the Apogee measurement was 0.94. The differences are likely due to a larger FOV of the Apogee sensor compared with the handheld IRT. Thus, the Apogee sensor integrates a larger area (approximately 0.5 m^2) than the handheld instruments (approximately 10 cm^2) which means that the handheld instruments are more likely to measure larger temperature extremes than the Apogee sensor.

The representativeness of the Apogee sensor to the surrounding terrain was determined by comparing field measurements with the Mesonet T_S data. Again, the overall comparison was quite strong. In this case the negative (cool) bias of the Apogee compared to the mean of the field measurements was slightly larger (-1.10^{O}C) than those measurements explicitly collected in the Apogee sensor's FOV. However, the standard deviation and the RMSD were quite similar (2.49^{O}C and 2.71^{O}C respectively). Furthermore, the correlation between the Mesonet T_S data and the mean of the field samples was quite strong at 0.96. Thus, even though the range of T_S values measured at the site (Fig. 2) was quite large at times (up to 21.6^{O}C), the Mesonet T_S data was quite representative of the mean T_S in the area surrounding the site at a scale of meters.

4. Mesonet Site Intercomparison

During the summer of 2002, the original Norman Mesonet site (NORM) was decommissioned. However, a new Norman site (NRMN) was installed approximately 3.05 km to the southeast of the original site. For a period of 30 days, both sites were operational. More importantly, both sites simultaneously collected T_S data during the period.

The simultaneous collection of T_S data represented a unique opportunity to determine the representativeness of T_S data at a larger scale than the analysis in Section 3. In addition, the station spacing between NORM and NRMN is an order of magnitude less than the typical station spacing of mesonet sites (approximately 30 km).

The comparison of T_S data between the two sites is shown in Figure 3a. While the relationship between the two sites is strong overall (a correlation of 0.97), a significant degree of scatter is also observed. The mean difference between the sites demonstrates that, on average) NORM was approximately 1.8^{O}C warmer than NRMN. Furthermore, the maximum difference between the sites was 15.9^{O}C (NORM was warmer than NRMN). Conversely the minimum difference between the two sites was 3.6^{O}C (NORM was cooler than NRMN).

Closer inspection of the data yields critical results. Observations from the two sites during the overnight hours are plotted in Figure 3b. This analysis demonstrates that skin temperature measured at the two sites in the absence of solar radiation was very similar (a correlation of 0.98 with a slight warm bias at NORM of 0.11^{O}C). However, when data from the two sites were analyzed for daylight conditions (Fig. 3c), the mean warm bias at NORM increased to 3.05C and the correlation weakened to 0.94). Thus, solar radiation had a significant impact on the the T_S values measured at both sites.

Further analysis clearly addresses the impact of

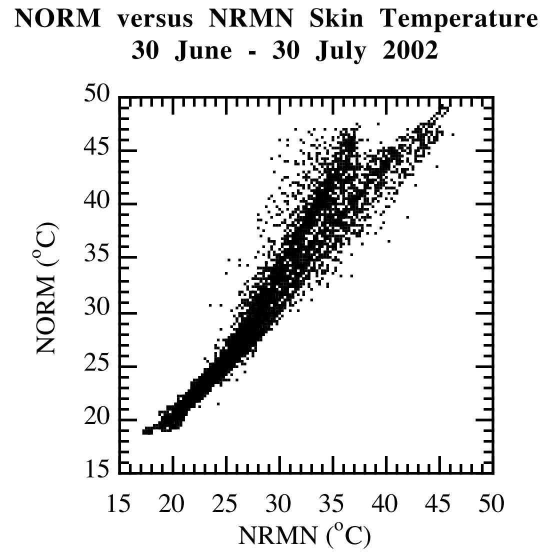

Figure 3a. Skin temperature at NORM versus Skin temperature at NRMN between 30 June and 30 July 2002.

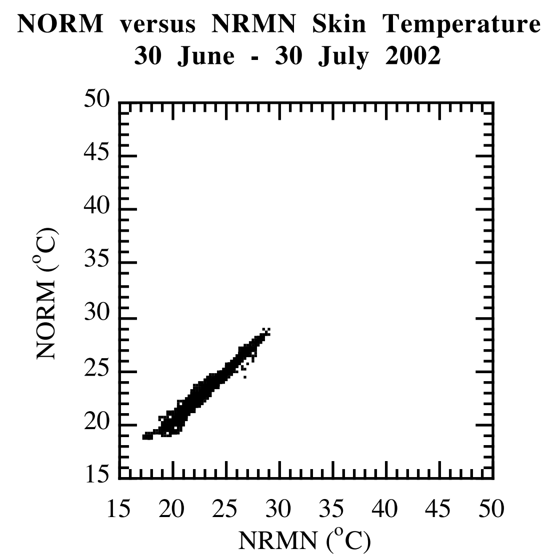

Figure 3b. Skin temperature at NORM versus Skin temperature at NRMN during overnight hours between 30 June and 30 July 2002.

incoming shortwave radiation on skin temperature values. Figure 4 shows the diurnal cylce of the RMSD of skin temperature between NORM and NRMN. During the overnight period, the RSMD values are minimal. However, as solar radiation increases, the RMSD values increase to nearly 7°C at the time of solar noon before decreasing.

These results are likely due to the heterogeneity of the land surface. Thus, as incoming solar radiation is absorbed by the land surface, varying surface characteristics including albedo, soil type, soil color, vegetation type, and the heat capacity of the soil and vegetation lead to variability in the partitioning of available energy into turbulent heat fluxes. As a result, significant variability in temperature occurred at the interface between the land surface and the atmosphere, thus resulting in the variability observed between the two sites.

5. Conclusions

The results of this study are offer significant insight into the representativeness of the Apogee sensor used to obtain skin temperature measurements at Oklahoma Mesonet Sites. First, field measurements collected during the summer of 2002 compared well the Apogee sensor. More importantly, the mean value of the field measurements correlated well in magnitude and trend with the Apogee sensor. Thus, even though the range of skin temperature at and around Mesonet sites may vary significantly, the Mesonet skin temperature measurements provide a good estimate of a larger area (on the order of meters).

The comparison of skin temperature data from two Mesonet sites also provided some key insights into the variability of T_S at slightly greater spatial scales. Data from the two sites revealed that the sites compared well during times of weak solar forcing. However, during periods when solar forcing was strong, the RMSD in skin temperature measurements between the sites often exceeded 6°C and the overall difference between the sites even exceeded 15°C. The explanation of these large differences due strong solar forcing include the heterogeneity of the land surface, the variability of the heat capacity of the surface, and the associated variability of the partitioning of available energy into turbulent fluxes of heat and moisture.

This study points out that because the Apogee sensor has a large FOV, it can integrate the local scale variability of land surface conditions into Mesonet skin temperature measurements. However, as spatial scales increase, the representativeness of the sensor decreases due to increased heterogeneity of the land surface between sites.

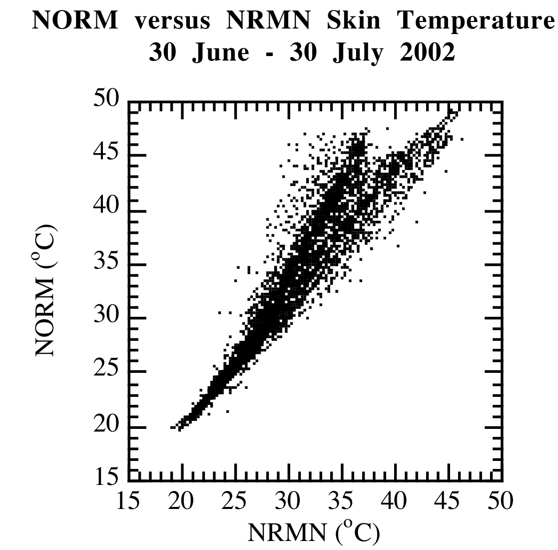

Figure 3c. Skin temperature at NORM versus Skin temperature at NRMN during daylight hours between 30 June and 30 July 2002.

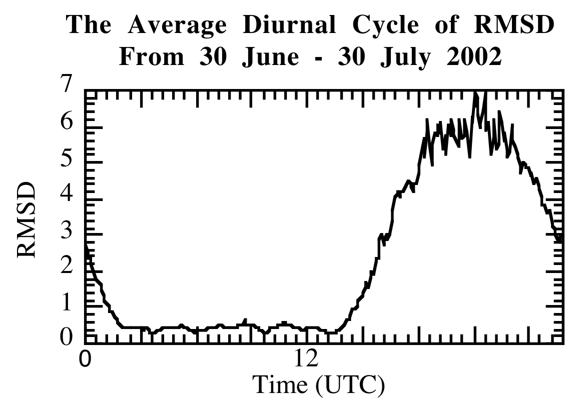

Figure 4. The average diurnal cylce of the root mean squared difference (RMSD) between NORM and NRMN between 30 June and 30 July 2002.

Acknowledgements

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