JP4.14 REPRESENTATIVENESS OF SOIL MOISTURE CONDITIONS IN CENTRAL OKLAHOMA DURING THE ENHANCED DRYING PHASE

Bradley G. Illston, Oklahoma Climatological Survey/University of Oklahoma, Norman, OK, J. Collin Caldwell, and Stephen G. Bodnar.

1. INTRODUCTION

Soil moisture is an integral part of the surface energy balance. Thus, increased understanding of the spatial representativeness of soil moisture measurements will result in greater understanding of how the atmosphere is impacted by varying soil water conditions. Unfortunately, a limited number of real-time soil moisture observations (Emmanuel et al. 1995; Entekhabi et al. 1999) exists. However, a number of automated soil observation networks have been installed in recent years, such as the Soil Climate Analysis Network (SCAN), Automated Weather Data Network (AWDN), and the Oklahoma Mesonet.

The Oklahoma Mesonet (Brock et al. 1995), a network of 115 automated meteorological stations, instrumented nearly 100 sites with soil moisture sensors at four depths (5, 25, 60 and 75 cm). These sites provide quality assured soil moisture observations every 30 minutes across varying soil, vegetation and climate conditions.

During the summer of 2003, soil core samples were collected at 40 Mesonet stations in Central Oklahoma. The goal of this field study was to determine the representativeness of soil moisture within the topsoil layers during the enhanced drying phase in Oklahoma noted by Illston, 2002. The soil core samples were analyzed to calculate the soil water content and were compared to observations at Mesonet sites.

2. DATA COLLECTION

2.1 Oklahoma Mesonet Data

The Oklahoma Mesonet (Brock et al. 1995) provides real-time data from 115 stations across Oklahoma with at least one station in every county. Standard meteorological data, such as air temperature, wind speed and direction and rainfall, are recorded every 5 minutes. Supplemental data, such as soil moisture, infrared surface temperature, and net radiation, are recorded in various time periods at most of the sites.

Since 1996, Campbell Scientific 229-L (CSI 229-L) soil moisture sensors were installed at over 100 Mesonet sites. These heat dissipation sensors measure a temperature change in the sensor (DeltaT) before and after a heat pulse is introduced (Basara and Crawford 2000). The majority of the over 100 Mesonet sites equipped to measure soil moisture have 229-L sensors at four depths (5 cm, 25 cm, 60 cm, and 75 cm). These depths were strategically placed to enhance agricultural and meteorological modeling aid in drought monitoring, and generate research quality datasets. From the measured DeltaT values, hydrological variables such as soil water content, soil matric potential, and Fractional Water Index (FWI; Schneider et al. 2003) can be calculated. This study compared soil water content (measured in m^3_{water}/m^3_{soil}, or m^3/m^3) with field observations.

2.2 Field Measurements

Figure 1 shows a map of the Oklahoma Mesonet with soil moisture sensors installed. The shaded area represents the 40 sites that were visited at least 3 times between 16 June 2003 and 17 July 2003. Each soil core was weighed, oven dried, and reweighed to determine the mass of the water in the soil. In addition, the calculated soil density was used to determine the water content of the samples. At each site, soil cores at 5 cm and 25 cm were collected near the 229-L sensors. Overall, 237 independent samples were collected. The observation period lies at the beginning of the enhanced drying phase of soil moisture in Oklahoma (Illston, 2002). The transition of near surface soil moisture from moist to dry conditions, as well as the lack of precipitation during the period, results in a time frame most suitable for soil moisture comparison studies with few outside impacts.

This supplemental dataset was used in conjunction with quality assured Oklahoma Mesonet data to determine the representativeness of soil moisture measurements at Mesonet sites. In addition to the soil cores, site photographs, vegetation characteristics and current meteorological conditions were recorded.

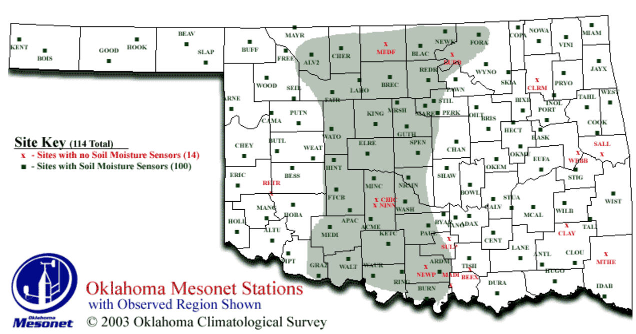

Figure 1. A map of the Oklahoma Mesonet with soil moisture sensors installed and field study area shaded.

* *Corresponding author address*: Bradley G. Illston, Oklahoma Climatological Survey, 100 E. Boyd St., Suite 1210, Norman, Oklahoma, 73019. E-mail: illston@ou.edu

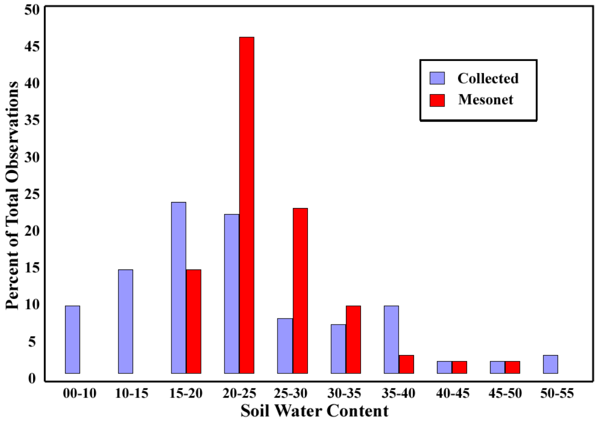

Figure 2. The frequency of the range of collected and observed 5cm soil water content values at Mesonet sites during the sampling period.

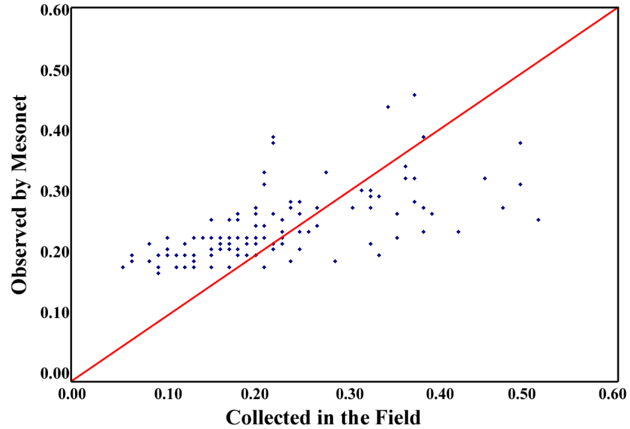

Figure 3. Collected 5cm soil water content values versus 5cm soil water content values observed by the Oklahoma Mesonet during the sampling period.

3. SOIL MOISTURE REPRESENTATIVENESS

3.1 5 cm Depth

The range of observed soil water content values from collected soil cores at 5 cm was from 0.05 m^3/m^3 to 0.52 m^3/m^3, with a mean of 0.22 m^3/m^3 and a standard deviation of 0.11 m^3/m^3. The range of observed soil water content values from Mesonet instruments at 5 cm spanned 0.17 m^3/m^3 to 0.47 m^3/m^3, with a mean of 0.25 m^3/m^3 and a standard deviation of 0.06 m^3/m^3. The frequency of the range of collected and observed 5 cm soil water content (Fig. 2) have a bell shaped distribution. However, the field sample values reveal a curve with a smaller amplitude and a wider distribution.

Despite the differences in the distribution of the 5 cm soil water content between field and in situ values, the average differences between the point measurements (0.07 m^3/m^3) is small. While outliers were present in the analyses, the standard deviation was 0.05 m^3/m^3. Figure 3 shows a comparison of the collected values versus the observed values of soil water content at 5 cm. Overall, the drier values (~0.15 m^3/m^3) demonstrate a stronger intercomparison than the values at the moist end of the spectrum (~0.40 m^3/m^3). Finally, the root mean squared difference between Mesonet observations and field samples was 0.41 m^3/m^3.

3.2 25 cm Depth

The soil water content values collected via soil cores at 25 cm ranged from 0.08 m^3/m^3 to 0.52 m^3/m^3 with a mean of 0.27 m^3/m^3 and a standard deviation of 0.09 m^3/m^3. These values are very similar to the 5 cm values. The soil water content values observed by Mesonet sensors at 25 cm ranged from 0.18 m^3/m^3 to 0.41 m^3/m^3 with a mean of 0.27 m^3/m^3 and a standard deviation of 0.05 m^3/m^3. This range of values was slightly less than those at 5 cm due to the inherently smaller variation of soil moisture at deeper depths. However, the frequency of the range of field samples and in situ observations of soil water content at 25 cm (Fig. 4) have a bell shaped distribution similar to the 5 cm distribution. However, the amplitude is smaller at 25 cm than at 5 cm.

The differences between point measurements of the collected 25 cm soil water content and the observed

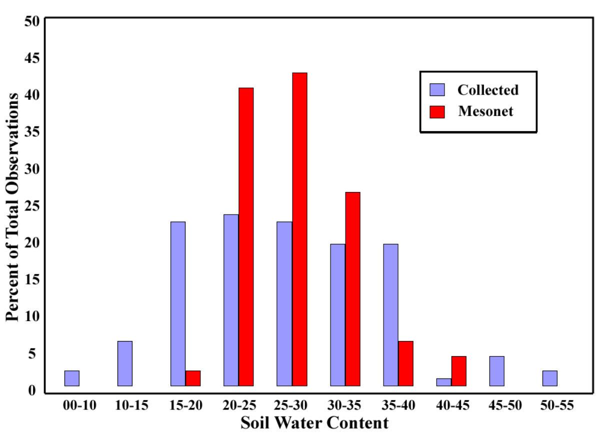

Figure 4. The frequency of the range of collected and observed 25cm soil water content values at Mesonet sites during the sampling period.

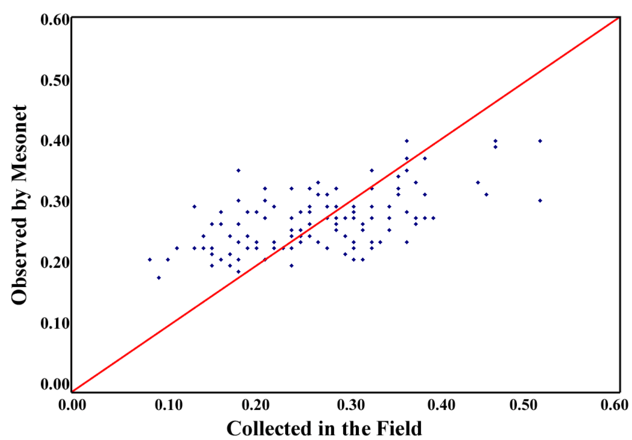

Figure 5. Collected 25cm soil water content values versus 25cm soil water content values observed by the Oklahoma Mesonet during the sampling period.

25 cm soil water content values were also small. The average difference between point measurements was 0.06 m^3/m^3 with fewer outliers. As such the standard deviation was 0.04 m^3/m^3. Figure 5 shows a comparison of the field samples versus the in situ values of soil water content at 25 cm. The overall root mean squared difference of 0.35 m^3/m^3, which is smaller than the 5 cm value.

4. CONCLUSIONS

The results of this study offer an initial insight on the near surface representativeness of the of the Campbell Scientific 229-L sensor used to obtain soil moisture measurements at Oklahoma Mesonet sites. Soil moisture conditions exhibit significant spatial and temporal variability in Oklahoma due to the varying soil textures and vegetation. However, accurate representation of soil moisture conditions is critical information to climatologists.

Overall, the Campbell Scientific 229-L soil moisture sensors installed at the Oklahoma Mesonet performed quite well during the enhanced drying phase of soil moisture in Central Oklahoma. The average difference between the collected and observed measurements of soil water content was ~0.07 m^3/m^3 with a standard deviation of 0.05 m^3/m^3. In addition, the range of soil moisture values from the 229-L sensor matched the range of the field samples fairly well. Finally, the soil moisture values 25 cm depth compared better than the values at the 5 cm depth which was likely due to decreased variability of the soil moisture conditions.

5. REFERENCES

Basara, J. B., and T. M. Crawford, 2000: Improved installation procedures for deep layer soil moisture measurements, *J. Atmos. Oceanic Technology*, **17**, 879-884.

Brock, F. V., and coauthors, 1995: The Oklahoma Mesonet: A technical overview*, J. Atmos. Oceanic Technology,* **12**, 5-19.

Dingman, S.L., 1994: *Physical Hydrology*. Prentice Hall, Upper Saddle River, NJ. 575 pp

Emmanuel, K., D. Raymond, A. Betts, L. Bosart, C. Bretherton, K.K. Droegemeier, B. Farrell, J.M. Fritsch, R. Houze, M. Lemone, D. Lilly, R. Rotunno, M. Shapiro, R. Smith, and A. Thorpe, 1995: Report of the first prospectus development team of the U.S. Weather Research Program to NOAA and the NSF. Bull. Amer. Meteor. Soc., 76, 1194-1208.

Entekhabi, D., G.R. Asrar, A.K. Betts, K.J. Beven, R.L. Bras, C.J. Duffy, T. Dunne, R.D. Koster, D.P. Lettenmaier, D.B. McLaughlin, W.J. Shuttleworth, M.T. van Genuchten, M. Wei, and E.F. Wood, 1999: An agenda for land surface hydrology research and a call for the Second International Hydrological Decade. Bull. Amer. Meteor. Soc., 80, 2043-2058.

Illston, B. G., 2002: Climatological influences on the seasonal variation of soil moisture using the Oklahoma Mesonet. M.S. Thesis, School of Meteorology, University of Oklahoma, 78 pp.

Schneider, J.M., D.K. Fisher, R.L. Elliott, G.O. Brown, and C.P. Bahrmann, 2003: “Spatiotemporal Variations in Soil Water: First Results from the ARM SGP CART Network”, *J. of Hydro.*, **4**, 106-120.

6. ACKNOWLEDGEMENTS

Special thanks to the many people at the Oklahoma Climatological Survey who gave their assistance in numerous ways. This research was made possible, in part, by an NSF-EPSCOR grant (Project Number EPS9550478), which provided funds to add soil moisture sensors to the Oklahoma Mesonet.